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ON YEAST.

A LECTURE

BY PROFESSOR HUXLEY, LL.D., F.R.S.

Delivered in the Free Trade Hall, Manchester, 3rd November, 1871.

I HAVE selected to-night the particular subject of Yeast for two reasons—or, rather, I should say for three. In the first place, because it is one of the simplest and the most familiar objects with which we are acquainted. In the second place, because the facts and phenomena which I have to describe are so simple that it is possible to put them before you without the help of any of those pictures or diagrams which are needed when matters are more complicated, and which, if I had to refer to them here, would involve the necessity of my turning away from you now and then, and thereby increasing very largely my difficulty (already sufficiently great) in making myself heard. And thirdly, I have chosen this subject because I know of no familiar substance forming part of our every day knowledge and experience, the examination of which, with a little care, tends to open up such very considerable issues as does this substance—yeast.

In the first place, I should like to call your attention to a fact with which the whole of you are, to begin with, perfectly acquainted, I mean the fact that any liquid containing sugar, any liquid which is formed by pressing out the succulent parts of the fruits of plants, or a mixture of honey and water, if left of itself for a short time, begins to undergo a peculiar change. No matter how clear it might be at starting, yet after a few hours, or at most a few days, if the temperature is high, this liquid begins to be turbid, and by-and-by bubbles make their appearance in it, and a sort of dirty-looking yellowish foam or scum collects at the surface; while at the same time, by degrees, a similar kind of matter, which we call the "lees," sinks to the bottom.

The quantity of this dirty-looking stuff, that we call the scum and the lees, goes on increasing until it reaches a certain amount, and then it stops; and by the time it stops, you find the liquid in which this matter has been formed has become altered in its quality. To begin with it was a mere sweetish substance, having the flavour of whatever might be the plant from which it was expressed, or having merely the taste and the absence of smell of a solution of sugar; but by the time that this change that I have been briefly describing to you is accomplished the liquid has become completely altered, it has acquired a peculiar smell, and, what is still more remarkable, it has gained the property of intoxicating the person who drinks it. Nothing can be more innocent than a solution of sugar; nothing can be less innocent, if taken in excess, as you all know, than those fermented matters which are produced from sugar. Well, again, if you notice that bubbling, or, as it were, seething of the liquid, which has accompanied the whole of this process, you will find that it is produced by the evolution of little bubbles of air-like substance out of the liquid; and I dare say you all know this air-like substance is not like common air; it is not a substance which a man can breathe with impunity. You often hear of accidents which take place in brewers' vats when men go in carelessly, and get suffocated there without knowing that there was anything evil awaiting them. And if you tried the experiment with this liquid I am telling of while it was fermenting, you would find that any small animal let down into the vessel would be similarly stifled; and you would discover that a light lowered down into it would go out. Well, then, lastly, if after this liquid has been thus altered you expose it to that process which is called distillation; that is to say, if you put it into a still, and collect the matters which are sent over, you obtain, when you first heat it, a clear transparent liquid, which, however, is something totally different from water; it is much lighter; it has a strong smell, and it has an acrid taste; and it possesses the same intoxicating power as the original liquid, but in a much more intense degree. If you put a light to it, it burns with a bright flame, and it is that substance which we know as spirits of wine.

Now these facts which I have just put before you—all but the last—have been known from extremely remote antiquity. It is, I hope, one of the best evidences of the antiquity of the human race, that among the earliest records of all kinds of men, you find a time recorded when they got drunk. We may hope that that must have been a very late period in their history. Not only have we the record of what happened to Noah, but if we turn to the traditions of a different people, those forefathers of ours who lived in the high lands of Northern India, we find that they were not less addicted to intoxicating liquids; and I have no doubt that the knowledge of this process extends far beyond the limits of historically recorded time. And it is a very curious thing to observe that all the names we have of this process, and all that belongs to it, are names that have their roots not in our present language, but in those older languages which go back to the times at which this country was peopled. That word "fermentation" for example, which is the title we apply to the whole process, is a Latin term; and a term which is evidently based upon the fact of the effervescence of the liquid. Then the French, who are very fond of calling themselves a Latin race, have a particular word for ferment, which is *levûre.* And, in the same way, we have the word "leaven," those two words having reference to the heaving up, or to the raising of the substance which is fermented. Now those are words which we get from what I may call the Latin side of our parentage; but if we turn to the Saxon side, there are a number of names connected with this process of fermentation. For example, the Germans call fermentation—and the old Germans did so—"*gähren;*" and they call anything which is used as a ferment by such names, such as "*gheist*" and "*geest,*" and finally in low German, "*yest*;" and that word you know is the word our Saxon forefathers used, and is almost the same as the word which is commonly employed in this country to denote the common ferment of which I have been speaking. So they have another name, the word "*hefe,*" which is derived from their verb "*heben,*" which signifies to raise up; and they have yet a third name, which is also one common in this country (I do not know whether it is common in Lancashire, but it is certainly very common in the Midland counties), the word "*barm,*" which is derived from a root which signifies to raise or to bear up. Barm is a something borne up; and thus there is much more real relation than is commonly supposed by those who make puns, between the beer which a man takes down his throat and the bier upon which that process, if carried to excess, generally lands him, for they are both derived from the root signifying bearing up; the one thing is borne upon men's shoulders, and the other is the fermented liquid which was borne up by the fermentation taking place in itself.

Again, I spoke of the produce of fermentation as "spirit of wine." Now what a very curious phrase that is, if you come to think of it. The old alchemists talked of the finest essence of anything as if it had the same sort of relation to the thing itself as a man's spirit is supposed to have to his body; and so they spoke of this fine essence of the fermented liquid as being the spirit of the liquid. Thus came about that extraordinary ambiguity of language, in virtue of which you apply precisely the same substantive name to the soul of man and to a glass of gin! And then there is still yet one other most curious piece of nomenclature connected with this matter, and that is the word "alcohol" itself, which is now so familiar to everybody. Alcohol originally meant a very fine powder. The women of the Arabs and other Eastern people are in the habit of tinging their eyelashes with a very fine black powder which is made of antimony, and they call that "kohol;" and the "al" is simply the article put in front of it, so as to say "the kohol." And up to the 17th century in this country the word alcohol was employed to signify any very fine powder; you find in Robert Boyle's works that he uses "alcohol" for a very fine subtle powder. But then this name of anything very fine and very subtle came to be specially connected with the fine and subtle spirit obtained from the fermentation of sugar; and I believe that the first person who fairly fixed it as the proper name of what we now commonly call spirits of wine, was the great French chemist Lavoisier, so comparatively recent is the use of the word alcohol in this specialised sense.

So much by way of general introduction to the subject on which I have to speak to-night. What I have hitherto stated is simply what we may call common knowledge, which everybody may acquaint himself with. And you know that what we call scientific knowledge is not any kind of conjuration, as people sometimes suppose, but it is simply the application of the same principles of common sense that we apply to common knowledge, carried out, if I may so speak, to knowledge which is uncommon. And all that we know now of this substance, yeast, and all the very strange issues to which that knowledge has led us, have simply come out of the inveterate habit, and a very fortunate habit for the human race it is, which scientific men have of not being content until they have routed out all the different chains and connections of apparently simple phenomena, until they have taken them to pieces and understood the conditions upon which they depend. I will try to point out to you now what has happened in consequence of endeavouring to apply this process of "analysis," as we call it, this teazing out of an apparently simple fact into all the little facts of which it is made up, to the ascertained facts relating to the barm or the yeast; secondly, what has come of the attempt to ascertain distinctly what is the nature of the products which are produced by fermentation; then what has come of the attempt to understand the relation between the yeast and the products; and lastly, what very curious side issues—if I may so call them—have branched out in the course of this inquiry, which has now occupied somewhere about two centuries.

The first thing was to make out precisely and clearly what was the nature of this substance, this apparently mere scum and mud that we call yeast. And that was first commenced seriously by a wonderful old Dutchman of the name of Leeuwenhoek, who lived some two hundred years ago, and who was the first person to invent thoroughly trustworthy microscopes of high powers. Now, Leeuwenhoek went to work upon this yeast mud, and by applying to it high powers of the microscope, he discovered that it was no mere mud such as you might at first suppose, but that it was a substance made up of an enormous multitude of minute grains, each of which had just as definite a form as if it were a grain of corn, although it was vastly smaller, the largest of these not being more than the two-thousandth of an inch in diameter; while, as you know, a grain of corn is a large thing, and the very smallest of these particles were not more than the seven-thousandth of an inch in diameter. Leeuwenhoek saw that this muddy stuff was in reality a liquid, in which there were floating this immense number of definitely shaped particles, all aggregated in heaps and lumps and some of them separate. That discovery remained, so to speak, dormant for fully a century, and then the question was taken up by a French discoverer, who, paying great attention and having the advantage of better instruments than Leeuwenhoek had, watched these things and made the astounding discovery that they were bodies which were constantly being reproduced and growing; that when one of these rounded bodies was once formed and had grown to its full size, it immediately began to give off a little bud from one side, and then that bud grew out until it had attained the full size of the first, and that, in this way, the yeast particle was undergoing a process of multiplication by budding, just as effectual and just as complete as the process of multiplication of a plant by budding; and thus this Frenchman, Cagniard de la Tour, arrived at the conclusion—very creditable to his sagacity, and which has been confirmed by every observation and reasoning since—that this apparently muddy refuse was neither more nor less than a mass of plants, of minute living plants, growing and multiplying in the sugary fluid in which the yeast is formed. And from that time forth we have known this substance which forms the scum and the lees as the yeast plant; and it has received a scientific name—which I may use without thinking of it, and which I will therefore give you—namely, "Torula." Well, this was a capital discovery. The next thing to do was to make out how this torula was related to other plants. I won't weary you with the whole course of investigation, but I may sum up its results, and they are these—that the torula is a particular kind of a fungus, a particular state rather, of a fungus or mould. There are many moulds which under certain condiiions give rise to this torula condition, to a substance which is not distinguishable from yeast, and which has the same properties as yeast—that is to say, which is able to decompose sugar in the curious way that we shall consider by-and-by. So that the yeast plant is a plant belonging to a group of the Fungi, multiplying and growing and living in this very remarkable manner in the sugary fluid which is, so to speak, the nidus or home of the yeast.

That, in a few words, is, as far as investigation—by the help of one's eye and by the help of the microscope—has taken us. But now there is an observer whose methods of observation are more refined than those of men who use their eye, even though it be aided by the microscope; a man who sees indirectly further than we can see directly—that is, the chemist; and the chemist took up this question, and his discovery was not less remarkable than that of the microscopist. The chemist discovered that the yeast plant being composed of a sort of bag, like a bladder, inside which is a peculiar soft, semifluid material—the chemist found that this outer bladder has the same composition as the substance of wood, that material which is called "cellulose," and which consists of the elements carbon and hydrogen and oxygen, without any nitrogen. But then he also found (the first person to discover it was an Italian chemist, named Fabroni, in the end of the last century) that this inner matter which was contained in the bag, which constitutes the yeast plant, was a substance containing the elements carbon and hydrogen and oxygen and nitrogen; that it was what Fabroni called a vegeto-animal substance, and that it had the peculiarities of what are commonly called "animal products."

This again was an exceedingly remarkable discovery. It lay neglected for a time, until it was subsequently taken up by the great chemists of modern times, and they, with their delicate methods of analysis, have finally decided that, in all essential respects, the substance which forms the chief part of the contents of the yeast plant is identical with the material which forms the chief part of our own muscles, which forms the chief part of our own blood, which forms the chief part of the white of the egg; that, in fact, although this little organism is a plant, and nothing but a plant, yet that its active living contents contain a substance which is called "protein," which is of the same nature as the substance which forms the foundation of every animal organism whatever.

Now we come next to the question of the analysis of the products, of that which is produced during the process of fermentation. So far back as the beginning of the 16th century, in the times of transition between the old alchemy and the modern chemistry, there was a remarkable man, Von Helmont, a Dutchman, who saw the difference between the air which comes out of a vat where something is fermenting and common air. He was the man who invented the term "gas," and he called this kind of gas "*gas silvestre*"—so to speak gas that is wild, and lives in out of the way places—having in his mind the identity of this particular kind of air with that which is found in some caves and cellars. Then, the gradual process of investigation going on, it was discovered that this substance, then called "fixed air," was a poisonous gas, and it was finally identified with that kind of gas which is obtained by burning charcoal in the air, which is called "carbonic acid." Then the substance alcohol was subjected to examination, and it was found to be a combination of carbon, and hydrogen, and oxygen. Then the sugar which was contained in the fermenting liquid was examined, and that was found to contain the three elements carbon, hydrogen, and oxygen. So that it was clear there were in sugar the fundamental elements which are contained in the carbonic acid, and in the alcohol. And then came that great chemist Lavoisier, and he examined into the subject carefully, and possessed with that brilliant thought of his which happens to be propounded exactly apropos to this matter of fermentation—that no matter is ever lost, but that matter only changes its form and changes its combinations—he endeavoured to make out what became of the sugar which was subjected to fermentation. He thought he discovered that the whole weight of the sugar was represented by the weight of the alcohol produced, added to the weight of the carbonic acid produced; that in other words, supposing this tumbler to represent the sugar, that the action of fermentation was as it were the splitting of it, the one half going away in the shape of carbonic acid, and the other half going away in the shape of alcohol. Subsequent inquiry, careful research with the refinements of modern chemistry, have been applied to this problem, and they have shown that Lavoisier was not quite correct; that what he says is quite true for about 95 per cent of the sugar, but that the other 5 per cent, or nearly so, is converted into two other things; one of them, matter which is called succinic acid, and the other matter which is called glycerine, which you all know now as one of the commonest of household matters. It may be that we have not got to the end of this refined analysis yet, but at any rate, I suppose I may say—and I speak with some little hesitation for fear my friend Professor Roscoe here may pick me up for trespassing upon his province—but I believe I may say that now we can account for 99 per cent at least of the sugar, and that that 99 per cent is split up into these four things, carbonic acid, alcohol, succinic acid, and glycerine. So that it may be that none of the sugar whatever disappears, and that only its parts, so to speak, are re-arranged, and if any of it disappears, certainly it is a very small portion.

Now these are the facts of the case. There is the fact of the growth of the yeast plant; and there is the fact of the splitting up of the sugar. What relation have these two facts to one another?

For a very long time that was a great matter of dispute. The early French observers, to do them justice, discerned the real state of the case, namely, that there was a very close connection between the actual life of the yeast plant and this operation of the splitting up of the sugar; and that one was in some way or other connected with the other. All investigation subsequently has confirmed this original idea. It has been shown that if you take any measures by which other plants of like kind to the torula would be killed, and by which the yeast plant is killed, then the yeast loses its efficiency. But a capital experiment upon this subject was made by a very distinguished man, Helmholz, who performed an experiment of this kind. He had two vessels—one of them we will suppose full of yeast, but over the bottom of it, as this might be, was tied a thin film of bladder; consequently, through that thin film of bladder all the liquid parts of the yeast would go, but the solid parts would be stopped behind; the torula would be stopped, the liquid parts of the yeast would go. And then he took another vessel containing a fermentable solution of sugar, and he put one inside the other; and in this way you see the fluid parts of the yeast were able to pass through with the utmost ease into the sugar, but the solid parts could not get through at all. And he judged thus: if the fluid parts are those which excite fermentation, then, inasmuch as these are stopped, the sugar will not ferment; and the sugar did not ferment, showing quite clearly that an immediate contact with the solid, living torula was absolutely necessary to excite this process of splitting up of the sugar. This experiment was quite conclusive as to this particular point, and has had very great fruits in other directions.

Well, then, the yeast plant being essential to the production of fermentation, where does the yeast plant come from? Here, again, was another great problem opened up, for, as I said at starting, you have, under ordinary circumstances in warm weather, merely to expose some fluid containing a solution of sugar, or any form of syrup or vegetable juice to the air, in order, after a comparatively short time, to see all these phenomena of fermentation. Of course the first obvious suggestion is, that the torula has been generated within the fluid. In fact, it seems at first quite absurd to entertain any other conviction; but that belief would most assuredly be an erroneous one.

Towards the beginning of this century, in the vigorous times of the old French wars, there was a Monsieur Appert, who had his attention directed to the preservation of things that ordinarily perish, such as meats and vegetables, and in fact he laid the foundation of our modern method of preserving meats; and he found that if he boiled any of these substances and then tied them so as to exclude the air, that they would be preserved for any time. He tried these experiments, particularly with the must of wine and with the wort of beer; and he found that if the wort of beer had been carefully boiled and was stopped in such a way that the air could not get at it, it would never ferment. What was the reason of this? That, again, became the subject of a long string of experiments, with this ultimate result, that if you take precautions to prevent any solid matters from getting into the must of wine or the wort of beer, under these circumstances—that is to say, if the fluid has been boiled and placed in a bottle, and if you stuff the neck of the bottle full of cotton wool, which allows the air to go through, and stops anything of a solid character however fine, then you may let it be for ten years and it will not ferment. But if you take that plug out and give the air free access, then, sooner or later, fermentation will set up. And there is no doubt whatever that fermentation is excited only by the presence of some torula or other, and that that torula proceeds, in our present experience, from pre-existing torulæ. These little bodies are excessively light. You can easily imagine what must be the weight of little particles, but slightly heavier than water, and not more than the two thousandth or perhaps seven thousandth of an inch in diameter. They are capable of floating about and dancing like motes in the sunbeam; they are carried about by all sorts of currents of air; the great majority of them perish; but one or two, which may chance to enter into a sugary solution, immediately enter into active life, find there the conditions of their nourishment, increase and multiply, and may give rise to any quantity whatever of this substance yeast. And, whatever may be true or not be true about this "spontaneous generation," as it is called, in regard to all other kinds of living things, it is perfectly certain, as regards yeast, that it always owes its origin to this process of transportation or inoculation, if you like so to call it, from some other living yeast organism; and so far as yeast is concerned, the doctrine of spontaneous generation is absolutely out of court. And not only so, but the yeast must be alive in order to exert these peculiar properties. If it be crushed, if it be heated so far that its life is destroyed, that peculiar power of fermentation is not excited. Thus we have come to this conclusion, as the result of our inquiry, that the fermentation of sugar, the splitting of the sugar into alcohol and carbonic acid, glycerine, and succinic acid, is the result of nothing but the vital activity of this little fungus, the torula.

And now comes the further exceedingly difficult inquiry—how is it that this plant, the torula, produces this singular operation of the splitting up of the sugar? Fabroni, to whom I referred some time ago, imagined that the effervescence of fermentation was produced in just the same way as the effervescence of a seidlitz powder, that the yeast was a kind of acid, and that the sugar was a combination of carbonic acid and some base to form the alcohol, and that the yeast combined with this substance, and set free the carbonic acid; just as when you add carbonate of soda to acid you turn out the carbonic acid. But of course the discovery of Lavoisier that the carbonic acid and the alcohol taken together are very nearly equal in weight to the sugar, completely upset this hypothesis. Another view was therefore taken by the French chemist, Thénard, and it is still held by a very eminent chemist, M. Pasteur, and their view is this, that the yeast, so to speak, eats a little of the sugar, turns a little of it to its own purposes, and by so doing gives such a shape to the sugar that the rest of it breaks up into carbonic acid and alcohol.

Well, then, there is a third hypothesis, which is maintained by another very distinguished chemist, Liebig, which denies either of the other two, and which declares that the particles of the sugar are, as it were, shaken asunder by the forces at work in the yeast plant. Now I am not going to take you into these refinements of chemical theory, I cannot for a moment pretend to do so, but I may put the case before you by an analogy. Suppose you compare the sugar to a card house, and suppose you compare the yeast to a child coming near the card house, then Fabroni's hypothesis was that the child took half the cards away; Thénard's and Pasteur's hypothesis is that the child pulls out the bottom card and thus makes it tumble to pieces; and Liebig's hypothesis is that the child comes by and shakes the table and tumbles the house down. I appeal to my friend here (Professor Roscoe) whether that is not a fair statement of the case.

Having thus, as far as I can, discussed the general state of the question, it remains only that I should speak of some of those collateral results which have come in a very remarkable way out of the investigation of yeast. I told you that it was very early observed that the yeast plant consisted of a bag made up of the same material as that which composes wood, and of an interior semifluid mass which contains a substance, identical in its composition, in a broad sense, with that which constitutes the flesh of animals. Subsequently, after the structure of the yeast plant had been carefully observed, it was discovered that all plants, high and low, are made up of separate bags or "cells," as they are called; these bags or cells having the composition of the pure matter of wood; having the same composition, broadly speaking, as the sac of the yeast plant, and having in their interior a more or less fluid substance containing a matter of the same nature as the protein substance of the yeast plant. And therefore this remarkable result came out—that however much a plant may differ from an animal, yet that the essential constituent of the contents of these various cells or sacs of which the plant is made up, the nitrogenous protein matter, is the same in the animal as in the plant. And not only was this gradually discovered, but it was found that these semifluid contents of the plant cell had, in many cases, a remarkable power of contractility quite like that of the substance of animals. And about 24 or 25 years ago, namely, about the year 1846, to the best of my recollection, a very eminent German botanist, Hugo Von Mohl, conferred upon this substance which is found in the interior of the plant cell, and which is identical with the matter found in the inside of the yeast cell, and which again contains an animal substance similar to that of which we ourselves are made up—he conferred upon this that title of "protoplasm," which has brought other people a great deal of trouble since! I beg particularly to say that, because I find many people suppose that I was the inventor of that term, whereas it has been in existence for at least twenty-five years. And then other observers, taking the question up, came to this astonishing conclusion (working from this basis of the yeast), that the differences between animals and plants are not so much in the fundamental substances which compose them, not in the protoplasm, but in the manner in which the cells of which their bodies are built up have become modified. There is a sense in which it is true—and the analogy was pointed out very many years ago by some French botanists and chemists—there is a sense in which it is true that every plant is substantially an enormous aggregation of bodies similar to yeast cells, each having to a certain extent its own independent life. And there is a sense in which it is also perfectly true—although it would be impossible for me to give the statement to you with proper qualifications and limitations on an occasion like this—but there is also a sense in which it is true that every animal body is made up of an aggregation of minute particles of protoplasm, comparable each of them to the individual separate yeast plant. And those who are acquainted with the history of the wonderful revolution which has been worked in our whole conception of these matters in the last thirty years, will bear me out in saying that the first germ of them, to a very great extent, was made to grow and fructify by the study of the yeast plant, which presents us with living matter in almost its simplest condition.

Then there is yet one last and most important bearing of this yeast question. There is one direction probably in which the effects of the careful study of the nature of fermentation will yield results more practically valuable to mankind than any other. Let me recall to your minds the fact which I stated at the beginning of this lecture. Suppose that I had here a solution of pure sugar with a little mineral matter in it; and suppose it were possible for me to take upon the point of a needle one single, solitary yeast cell, measuring no more perhaps than the three thousandth of an inch in diameter—not bigger than one of those little coloured specks of matter in my own blood at this moment, the weight of which it would be difficult to express in the fraction of a grain—and put it into this solution. From that single one, if the solution were kept at a fair temperature in a warm summer's day, there would be generated, in the course of a week, enough torulæ to form a scum at the top and to form lees at the bottom, and to change the perfectly tasteless and entirely harmless fluid, syrup, into a solution impregnated with the poisonous gas carbonic acid, impregnated with the poisonous substance alcohol; and that, in virtue of the changes worked upon the sugar by the vital activity of these infinitesimally small plants. Now you see that this is a case of infection. And from the time that the phenomenon of fermentation were first carefully studied, it has constantly been suggested to the minds of thoughtful physicians that there was a something astoundingly similar between this phenomena of the propagation of fermentation by infection and contagion, and the phenomena of the propagation of diseases by infection and contagion. Out of this suggestion has grown that remarkable theory of many diseases which has been called the "germ theory of disease," the idea, in fact, that we owe a great many diseases to particles having a certain life of their own, and which are capable of being transmitted from one living being to another, exactly as the yeast plant is capable of being transmitted from one tumbler of saccharine substance to another. And that is a perfectly tenable hypothesis, one which in the present state of medicine ought to be absolutely exhausted and shown not to be true, until we take to others which have less analogy in their favour. And there are some diseases most assuredly in which it turns out to be perfectly correct. There are some forms of what are called malignant carbuncle which have been shown to be actually effected by a sort of fermentation, if I may use the phrase, by a sort of disturbance and destruction of the fluids of the animal body, set up by minute organisms which are the cause of this destruction and of this disturbance; and only recently the study of the phenomena which accompany vaccination has thrown an immense light in this direction, tending to show by experiments of the same general character as that to which I referred as performed by Helmholz, that there is a most astonishing analogy between the contagion of that healing disease and the contagion of destructive diseases. For it has been made out quite clearly, by investigations carried on in France and in this country, that the only part of the vaccine matter which is contagious, which is capable of carrying on its influence in the organism of the child who is vaccinated, is the solid particles and not the fluid. By experiments of the most ingenious kind, the solid parts have been separated from the fluid parts, and it has then been discovered that you may vaccinate a child as much as you like with the fluid parts, but no effect takes place, though an excessively small portion of the solid particles, the most minute that can be separated, is amply sufficient to give rise to all the phenomena of the cow pock, by a process which we can compare to nothing but the transmission of fermentation from one vessel into another, by the transport to the one of the torula particles which exist in the other. And it has been shown to be true of some of the most destructive diseases which infect animals, such diseases as the sheep pox, such diseases as that most terrible and destructive disorder of horses, glanders, that in these, also, the active power is the living solid particle, and that the inert part is the fluid. However, do not suppose that I am pushing the analogy too far. I do not mean to say that the active, solid parts in these diseased matters are of the same nature as living yeast plants; but, so far as it goes, there is a most surprising analogy between the two; and the value of the analogy is this, that by following it out we may some time or other come to understand how these diseases are propagated, just as we understand, now, about fermentation; and that, in this way, some of the greatest scourges which afflict the human race may be, if not prevented, at least largely alleviated.

This is the conclusion of the statements which I wished to put before you. You see we have not been able to have any accessories. If you will come in such numbers to hear a lecture of this kind, all I can say is, that diagrams cannot be made big enough for you, and that it is not possible to show any experiments illustrative of a lecture on such a subject as I have to deal with. Of course my friends the chemists and physicists are very much better off, because they can not only show you experiments, but you can smell them and hear them! But in my case such aids are not attainable, and therefore I have taken a simple subject and have dealt with it in such a way that I hope you all understand it, at least so far as I have been able to put it before you in words; and having once apprehended such of the ideas and simple facts of the case as it was possible to put before you, you can see for yourselves the great and wonderful issues of such an apparently homely subject.

SCIENCE LECTURES FOR THE PEOPLE.

THIRD SERIES—1871.

ON COAL COLOURS.

A LECTURE,

BY PROFESSOR ROSCOE, F.R.S.,

Delivered in the Hulme Town Hall. November 10th, 1871.

THE subject of coal has naturally attracted much of our attention in these Science Lectures. In the first series, Professor Jevons, than whom no one in the country is more able to speak upon the economic aspects of the question, discoursed of the importance of coal in manufactures and trades; whilst in the last series Mr. Boyd Dawkins and Mr. Green unfolded some of the secrets which lie hidden in a piece of coal. I propose to take up the subject this evening from another point of view, and to endeavour to open out to you still more wonderful, and, if possible, still more interesting fields than they did, inasmuch as I shall attempt to give you an account of the composition of coal, and of one or two of the very large number of derivatives which we can obtain from coal.

You are all aware that from coal we get the magnificent colours which are so much admired, and which are used so much in silk, woollen, and cotton dyeing. You know also, perhaps, that even certain essences and sweet savours can be obtained from this dirty-looking substance—a piece of coal.

To tell you all about the bodies which have been got from coal would take me a very long time, I therefore only propose to give you a short history of the mode in which these bodies are obtained, choosing out one or two for our more special study.

In order to commence the study of our subject, I will, in the first place, take here two tobacco pipes, in each of which I have placed a small quantity of coal. In the one I have placed a small quantity of the kind of coal which is found in South Wales, and which is called anthracite coal; whilst in the other pipe we have placed some coal which is found at Wigan, and is called cannel coal. The difference between the effect of heat upon these two kinds of coal will very soon be visible to you. We shall be able to get from the pipe in which we have placed the cannel coal a quantity of brown vapour, which on bringing a light to it will take fire; whilst from the other pipe we shall not get any such brown vapour at all. Now this shows us at once that coals differ very widely in their properties.

Coal, as you have been told in the previous lectures, is a body made up of several elementary constituents. It contains carbon, hydrogen, nitrogen, and oxygen; and the quantities of these elements which the coals contain varies very much. In this cannel coal there is a much larger quantity or proportion of hydrogen and oxygen than there is in the anthracite coal. There is much more of what we call volatile or bituminous matter; and therefore this cannel coal will yield us a much larger quantity of gas than can be got by the use of anthracite coal. Anthracite coal is almost pure carbon.

[The experiment with the coal in the pipes and all the subsequent experiments were very successful, and were much applauded.]

The quantity of gas or volatile products which can be obtained from different kinds of coal depends in the first place, then, upon the composition of the coal. I have here a small model of a gas making apparatus; in which the same process is going on which occurs in an enormously larger scale in the gas works of the Corporation of Manchester. And for this purpose I have used cannel coal, because the anthracite coal does not yield us any supply of gas. Let us now examine what takes place in the gas works—what is going on when we make this coal gas. We may divide the products of the gas works into four classes:—first, the coke, which is left behind in the retort; secondly, the gas which comes off; thirdly, the watery liquid which is formed; and fourthly, the tarry matter which comes with the gas, but which, together with the watery liquid, is not sent through the mains, but is condensed before it leaves the gas works.

Let us now notice what is the chemical composition, first of the coal gas itself; secondly, of the watery portions, called the ammonia water; and thirdly, of the gas tar. On the side of the room I have suspended a large diagram of the various products of coal, some of them having rather curious names (see Table on page 5). I am afraid that it may frighten some of you if you think that I am going to talk about all these substances. I do not intend to do so; but I wish you to see what a very large number of chemical substances exist as the products of the destructive distillation of coal. Mark the words "destructive distillation," because I shall have to speak of this again. In the destruction of the coal by distillation, all these products can be got, and are found either in the gas or in the coke, or in the ammonia liquor, or in the tar.

Here I have two pounds of cannel coal. I have here a large white cube, each of whose sides is 26 inches in length, which represents the quantity of gas which can be got from these two pounds of cannel coal. I have in this bottle the exact quantity of coke, namely, 19 ounces, which would be left behind in the retort when this quantity of coal is heated. Here is three ounces of watery ammonia liquor which would come away; and this is the $2\frac{3}{4}$ ounces of tar which would be formed by the destructive distillation of two pounds of coal. You will see from the diagram below that 100 tons of cannel coal distilled to yield 10,000 cubic feet of gas, having a specific gravity of 0·6, gives the following products: about 60 tons of coke, $9\frac{1}{2}$ tons of ammonia water, $8\frac{1}{2}$ of tar, and $22\frac{1}{4}$ of gas, by weight. This expresses in numbers what you there see illustrated by the model.

DESTRUCTIVE DISTILLATION OF COAL.

100 tons of cannel and coal distilled to yield 10,000 cubic feet of gas of specific gravity, 0·6 gives the following products:—

	GAS.	TAR.	AMMONIA WATER.	COKE.	SOURCE.
1	22·25	8·5	9·5	59·75	Average (Muspratt)
2	20·01	7·85	7·14	65·00	Manchester
3	20·40	6·40	5·40	67·84	Dukinfield
4	21·70	7·50	5·80	65·00	Macclesfield
5	16·50	10·70	8·00	65·00	

First, then, with regard to the gas. Coal gas—that with which we are supplied and lighted at the present time—is not one definite chemical compound, but is a mixture of several component chemical substances, and the composition of coal gas varies very much. Here in the north of England we get a better gas than those who live in the south, because here we have the command of a better sort of cannel coal. In London the ordinary illuminating power of the gas is about $12\frac{1}{2}$ candles; whilst in Manchester the gas has an illuminating power of about 20 candles; that is, a jet of gas burning at the rate of 5 cubic feet per hour gives a light equal to that given by 20 standard candles. I mention this to show that gas is not the same all the world over, but that it depends both upon the quality of the coal employed, and upon the mode of its manufacture.

Now the substances which coal gas contains may be divided into three classes; first, those parts of the gas which give off light, or the illuminating constituents; secondly, those parts of the gas which burn, but which do not give off light, and which may be termed heating constituents; and thirdly, those portions of the gas which neither give off light nor heat, that is to say, which do not burn at all, and these may be termed the impurities contained in the gas, which require to be removed, or ought to be removed completely in the process of gas making, and before the gas is distributed to the town. Here we have one of the luminous constituents of coal gas. This is termed ethylene or olefiant gas. You see it burns with a very bright and brilliant light. This is the chief illuminating constituent of coal gas. Here we have another constituent of coal gas, termed carbonic oxide gas, which burns with a very pale blue flame, as you will observe, but which scarcely gives off any light. This is one of the heating constituents of the coal gas or diluents, as they have been termed, because they dilute the illuminating constituents. Here we have another constituent which requires removal from the coal gas, namely, carbonic acid gas; and this you see extinguishes the taper the moment I place it in the gas. This, together with sulphuretted hydrogen and the vapour of bisulphide of carbon, ought to be removed in the process of gas making, and this is more or less completely done by the scrubbers and the lime—or oxide of iron—purifiers. In the following table you will see first the names of the three illuminating constituents; the next four are the heating constituents; and the next three are the impurities which have to be removed.

We have here an arrangement for making gas: the fire is burning and heating the cannel coal contained in this iron retort; here is what is termed the tar well, for the first thing that is deposited from the heated gas when it cools is the tar. These tubes are termed atmospheric condensers, where the gas is cooled and more of the tar deposited; and here we have the purifiers for the purpose of ridding the gas of the three impurities to which I have referred; and here we have the gas holder, into which the gas is now passing, and from which we can now pass it through our system of mains and light it, as you see here. [Gas made in the room was then ignited.]

Now, passing down the list, the next material we reach is the ammonia water.

PRODUCTS FOUND IN THE DESTRUCTIVE DISTILLATION OF COAL.

COAL GAS.

Ethylene, Tritylene, Tetralene, — Illuminating constituents.

Marshgas, Acetylene, Carbonic oxide, Hydrogen, — Diluents or heating constituents.

Carbonic acid, Sulphuretted hydrogen, Carbon dishulphide, — Impurities.

AMMONIA WATER.

TAR-PITCH.

COAL-TAR.

Paraffines.

Amyl hydride.
Hexyl hydride.
Heptyl hydride.
Octyl hydride.
Nonyl hydride.
Decatyl hydride.

Olefines.

Amylene.
Hexylene.
Heptylene.
Octylene.
Nonylene.
Decatylene.

Acetylene Series.

Terpenes.

Benzene Series.

Benzene.
Toluene.
Xylene.
Isoxylene.
Pseudo-cumene.
Mesitylene.

Napthaline.

Anthracene.

Pyrene.

Chrysene.

Phenols.

Phenol, or Carbolic Acid.
Cresol.
Xylenol.

Bases.

Aniline.
Tolindine, &c.
Pyridin.
Picolin.
Lutidin.
Collidin.
Parvolin.
Coridin.
Rubidin.
Viridin.

Leucolin.
Iridolin.
Cryptidin.

This ammonia water is a very important part of the gas products, because from this a number of very interesting substances are obtained. Now what is the ammonia water? The ammonia water is a liquid coming from the coal, for a good deal of moisture, which the coal contains, comes over with the products, and this moisture condenses or absorbs the gas called ammonia, forming what I dare say most of you know as spirits of hartshorn. Now this gas-ammonia is a compound body, and contains nitrogen and hydrogen. The nitrogenous portion of the coal is converted in the process of distillation into this ammoniacal gas, which is taken hold of by the water, and the solution flows down as a brownish coloured, strongly smelling liquid, known as "gas water," which is pumped off and sold for purposes of manufacturing the ammoniacal salts and alum. We have here specimens of sal-ammoniac and of carbonate of ammoniac and also a large lump of alum, which I have to thank Mr. Spence for sending. All these substances are made from the ammonia liquor. Now I wish to show you that this ammonia gas which is given off will dissolve in water, and that is the reason why it does not come off with the rest of the gas, but is kept back as a liquid; in order to show that I will make a simple experiment: we have got here a large globe, filled with this gas ammonia, which as you see is a colourless, invisible gas, but possesses a very pungent smell, aud has the power of dissolving very rapidly in water. Now in the lower vessel I have got some water, and I am going to blow a little of this reddened water up into this upper globe, filled with the ammoniacal gas, and you will see that the whole of this water will rush up into the upper globe, because the ammonia dissolves in the water, and the water therefore takes the place of the gas, and we shall have a very beautiful fountain produced. [Experiment very interesting and successful.] There now you see that the ammonia has been absorbed by the water, and the effect of the alkaline nature of this substance is seen, inasmuch as the red liquid has turned blue.

Now we get to the next part of our subject—the COAL-TAR, and the greater part of what I have to say will be with regard to the tar contained in the products of the distillation of coal. In the first place, with regard to the tar, let me say this, that we can obtain from tar a great variety of very beautiful white colourless substances. For instance, this white crystalline body here is carbolic acid, so largely used for disinfecting purposes; this beautiful white crystalline substance napthaline; this beautiful clear, colourless liquid benzole, all come from that dirty substance—coal tar—which you see, and which you rather avoid when you do see it, going along the streets in those very black, dirty-looking barrels. Nay, even from similar products of coal tar this beautiful white body—paraffin—can be got. It was the great chemist Liebig who some years ago said that the man who should be able to liquify coal gas, so that it could be carried about readily from place to place, would be a great benefactor to his species. This has now been done, mainly through the labours of one man, Mr. James Young, who first began this conversion of coal into oil. These products of the distillation of coal are not obtained in gas making, it is true, but they are obtained by quite a similar process—the destructive distillation of a coal-like substance, at a lower temperature than that used for making coal-gas.

It seems, I dare say, hard for you to understand how such a beautiful white body as this paraffin can be got from black coal. But I will show you a few experiments which I think will render this subject clearer to you. We have here a very well-known substance—sugar. This white sugar I will now dissolve in a little hot water, and I think in a few moments I can show you that this white sugar contains carbon. I am now going through the opposite process to that which is done by Mr. Young in distilling his shale. I am going to convert a white substance into carbon. The point I wish to illustrate is, that it is possible to get a white substance like paraffin from a black one as coal, inasmuch as the white substance contains carbon, only in a different state of combination. I have only got now to pour into this some strong sulphuric acid, when you will see that this sugar will be converted into charcoal. (The conversion into a seething, black, frothy substance was instantaneous.] Here you see that the whole of this white substance has been converted into charcoal. So much, then, for the fact that a white solid body contains carbon. I have in this bottle another colourless substance, liquid turpentine, and I wish to show you that turpentine also contains carbon. I will pour a little of this turpentine on to a bit of paper, and then plunge it into this cylinder of chlorine gas, when I think you will see that the carbon of the turpentine will become visible. [A cloud of black vapour is instantly produced.] In the same way I have got here a colourless olefiant gas, which also contains carbon, and when I mix this gas together with chlorine gas, and bring a light to the mixture, I get a large quantity of carbon set free, and thus we learn that white solids, colourless liquids, and colourless gases all may contain black carbon; and it must, therefore, not surprise you to find that from black coal we can get these beautiful white bodies.

What I have as yet said has reference to the destructive distillation of coal. I have had to destroy the coal in order to get these various new and interesting products. Let us now turn to another question, and let us ask ourselves, can we by any other process than this destructive action get hold of new bodies? The first era in chemical science has been what we term the analytical era. By analysis we mean destruction, breaking up, pulling asunder. The first object that the chemist had to achieve was to find what he could get by destroying bodies. We have destroyed the coal, and we have got this variety of substances whose names you find on the list. The second era in chemical science is what we term the synthetic or constructive era, the era in which we begin to build up. We all know it is very much more easy to destroy than it is to construct. And as it is in every-day life, so it is with chemical compounds, as proved by the history of chemical science. It is very much more easy to find out what we can get by destroying the coal than it is to find out what we can make by building up the various substances which are obtained from coal. Hence it is, as you will easily understand, that analytical chemistry or destructive chemistry came first in the history of science, and then came synthetic chemistry.

Within the last forty years very great progress has been made in this constructive chemistry. Before the year 1828, it was generally supposed that any chemical substance which was found in animal or vegetable bodies (which substances you will understand are very numerous) was constructed in the body of the animal or plant, according to laws altogether different from the laws by which the chemist was able to build up what are termed his inorganic compounds. He could bring together oxygen and hydrogen, and form water; he could bring together sulphur and copper, and get a black sulphide; but could he obtain such a substance as urea, which was only found in the products of animal life? This was the great question. And this has, by dint of laborious experimental investigations, been answered most completely in the affirmative. He can construct the substances which are found in the bodies of animals and plants. He has not succeeded in constructing all these substances, but he has succeeded in constructing a great number. I might give you instances of hundreds of substances which were first known as products solely found in animal or vegetable bodies, but which have since been built up from their constituent elements. Thus, for instance, that curious acid has been produced which is found in the bodies of ants, and which we term formic acid, and which is also found in the sting of the nettle, the sting being due to the peculiar effect of this acrid liquid. This formic acid was originally found only in these two sources, but formic acid can now be procured from its organic constituents, from carbon, hydrogen, and oxygen. So too with alcohol, about which Professor

Huxley discoursed in his lecture on yeast, last week. He showed you that the process by which alcohol is ordinarily formed is a very complicated one, and one which it is altogether beyond the power of the chemist to follow. The chemist cannot tell you the exact process by which the yeast particles decompose the sugar and liberate the alcohol, carbonic acid, glycerine, succinic acid, and other products. That is a process not perhaps so completely dark to us as the processes which go on in the animal and vegetable bodies, but it is a process about which chemists know very little, and is doubtless a process analogous to those which go on in the living body. But this alcohol can now be built up from its elements, or from mineral constituents, from charcoal, hydrogen, and oxygen. And so I might go on with illustrations of substances which were supposed originally to be only the sole products of that action which is termed vital action, but which now we find can be formed in the ordinary way of chemical synthesis. For instance, only the other day the beautiful and singular substance known as essential essence of the Tonka bean was prepared artificially. Those persons who take snuff are very fond of carrying this bean in their snuff boxes, because it imparts to the snuff a still more pungent and agreeable odour. It is a white crystalline body, termed coumarine, and this has been quite recently prepared artificially, and found to possess all the properties of that contained in this peculiar bean. In short, as far as regards the artificial construction of liquid or crystalline products produced in vital processes, the chemist's power seems boundless, though, when we come to organised bodies—such as the yeast globule or the starch grain, our domain seems to end, for the chemist knows nothing about the artificial formation of the simplest organised structure.

Well, then, let us see what we can learn with regard to constructive chemistry as applied to the coal products. We shall find that the substances which can be artificially built up from the bodies contained in coal-tar possess most interesting properties; thus, for instance, they exhibit the most remarkable colouring powers.

In the year 1825, our great English philosopher Faraday discovered benzole. This benzole was then a chemical rarity; now it is prepared by thousands of tons for the production of the beautiful aniline colours which you know so well. From the crude benzole contained in the tar we can build up, by a process of addition, the details of which I have not time to describe to-night, this heavy liquid aniline; and this has the power, after it has been subjected to another additive process, of producing the most beautiful colours. I have in this jar a small quantity of aniline; I will add a drop or two to the water in this large glass globe; and now I will add some of this colourless liquid, hypochlorite of sodium, and after a while you will see that the colour of this water will be changed, and that we shall have a splendidly violet-coloured liquid, containing the well-known colour, mauve, which was discovered by Mr. Perkin, in 1856, and this will give you an idea of the beauty of the colours which are got from coal. By a modification of the constructive processes to which the crude aniline is subjected a great variety of differently-coloured substances can be got thus. There we have the beautiful aniline blue colour. Here we have got the celebrated aniline red, known as magenta, and a bloody red it is. Here we have another coloured derivative—the aniline violet. In these compounds which we can thus build up we have not only a mine of interest, but also a mine of wealth, for the money value of these aniline colours is enormous. And how interesting it is to think that this body, aniline, which a few years ago was a curiosity, and only found in the laboratories of the chemists, is now a substance which is manufactured by tons, and thousands of tons, and which can be thus made to minister to our gratification, and appeal to our sense of beauty!

Another interesting point I must not forget to mention, and that is, that these beautiful colours are compounds of bodies which are perfectly colourless! Through the kindness of my friends, Messrs. Roberts, Dale, and Co., who are one of the largest manufacturers of these beautiful colours in England, I have here some of these bodies in their colourless state. Let me show you how these colourless bodies can be made to become brightly coloured. It is on combining these colourless bodies with acids that their colouring power first becomes evident. Here is a colourless liquid. I pour a little of it on to this piece of white blotting paper, and on warming the paper over a lamp a bright green colour becomes at once apparent. This is because the base of the green-coloured compound does not possess any colour whatever, and it is only when this base is by drying converted into a salt that the colour appears. Again, I take a colourless solution—rosaniline, and I have only to heat it to convert it into salt, and the beautiful bright red colour at once is seen. A very small quantity of this, placed on a piece of white paper, will, in a moment or two, when dried, turn the colourless paper into a bright crimson. This, then, is a very interesting and singular property of these colours. I may show it to you in another way. I will write on this large sheet of white calico, stretched on a frame, the three words "blue," and "red," and "green," in large letters, with the colourless solutions of the bases, and then if I rub a little acid on the back of the paper you see that it instantly brings out these three colours. This illustrates the fact that the colour of a chemical substance, is not, as it were, an essential or necessary characteristic of it, the colour in this case depends upon an acid being present, for the pure bases of these colours are colourless.

Now, I might, if I had time, tell you much more respecting these splendid blue, red, and violet colours which are derived from the aniline. I will, however, now describe to you another and perhaps a still more interesting colouring matter, which has been more recently obtained from coal tar. I suppose you all know what madder roots are. Madder is the root of a plant termed the rubia tinctorum. It grows in Turkey, France, Russia, and various other countries, and is imported into England in large quantities for the sake of the beautiful and valuable dye which can be got from it. Everybody in Manchester, I suppose, knows what madder pinks and madder purples are. Now, what is it in the madder which gives these peculiar and beautiful colours? It is a red crystalline substance which has been prepared from madder, and to which the name of alizarine has been given; but we knew nothing of the mode of action of this colour until the year 1848, when Dr. Schunck, of Manchester, showed that all the finest madder colours contain this alizarine as their colouring principle. Dr. Schunck and Mr. Higgin next showed that this alizarine was not contained in the fresh madder root, but that the colour was only got when the substance of the madder root had undergone a peculiar kind of change—a sort of fermentation, in which a kind of madder-sugar or glucoside yielded, amongst other products, alizarine. And Dr. Schunck showed that it is to this alizarine that is to be ascribed the power which madder possesses of producing these distinct and beautiful tints which we know either as madder pinks or madder purples, as well as the brighter colour which we all know as Turkey red. Now the mode in which the colouring matter of madder, this alizarine, is brought on to cotton goods, is the point to which I wish to draw your attention. The colouring matter itself will not fasten on the cotton; it is not "fast;" that is to say, it will wash out; and therefore it is necessary, in order that we should get the colour fixed in the cloth, that it should be held down by something in the cloth, in a similar way to that in which the ammonia was held by the water. And this is done by what the dyers and calico printers term mordants. A mordant is a body which enables the colouring matter to be fixed upon the cloth, to be laid hold of, as it were. And this is because the colouring matter forms with the mordant a solid substance, which is thereby fixed in the little pores and tubes of the cotton fibre. Thus the colour does not escape when the goods are washed, because it is held fast in the tubes as a coloured solid body, which is generally termed a "lake." These mordants are "printed" on the cloth in various patterns; where a red or pink colour is required, there the alumina mordant is impressed on the cloth; where a purple colour is needed there the iron mordant is printed, and this explains the fact that by dyeing the cloth thus prepared, in one dye beck with one colouring substance, madder, such different tints are obtained.

But now to get to our point with regard to the other example from the coal tar series of constructive chemistry. You will easily understand how desirable it would be to get these madder colours from the coal tar, for although not so beautiful and bright as the aniline colours, yet they possess properties which render them still more valuable; for we in this country prefer, as a rule, colours which are not so bright or glaring as the aniline colours; and, therefore, the reds and purples of madder will always be in large demand in this country as well as elsewhere. If now we could obtain from the coal oil this beautiful and valuable colour which is found in madder, the advantage would be of course very great. The truth of this will at once be evident when we learn that the total growth of madder in the world is estimated at 47,500 tons per annum, worth about £45 per ton, and having therefore a value of £2,150,000. Of this nearly one half is used in this country, so that no less than £1,000,000 is now paid each year by us for madder grown in foreign countries. Now two young German chemists, Messrs. Graebe & Liebermann, set to work to endeavour to perform this chemical synthesis; they began in a very workmanlike and a very scientific way; for instead of trying all the various bodies which are found in the coal tar to see which of them would yield this colouring matter, they began the other way about, and first took some of the natural colouring matter itself and tried to decompose it or split it up, in order that they might see what sort of a body this colouring matter would yield them; and they found that in reality this body when it was decomposed gave rise to a white substance, which, on analysis, they found to be identical in composition with one of these bodies which had been formerly found in coal tar, which had been named anthracene, a specimen of which you see in that bottle. Here, then, was the first step; for they had proved that anthracene could be got from the colouring matter of the madder plant. Next, these two German chemists set themselves the opposite problem, which now had become much easier, inasmuch as they now knew the kind of skeleton, as it were, from which they had got to work to build up their wished-for structure; they set to work, I say, to endeavour by bringing together other compounds with this anthracene, to build up the colouring matter, of which, remember, they knew the composition, from the coal-tar product. And this they succeeded in doing. They actually obtained this beautiful red crystalline body from coal tar; which body possesses every property of that got from the madder plant, that essential which gives to madder its peculiar and its valuable qualities. Here, then, we have indeed a triumph of synthesis, and another proof, if one were needed, of the value of the results of constructive chemistry. This is the first case of a colouring matter contained in a plant having been artificially made. The beautiful colours derived from crude aniline do not exist in nature; they are altogether new, and are not found in any plant. But many other colours, besides alizarine, which are used largely in dyeing, occur only in plants. Thus indigo is another well-known colour, but indigo has not yet been artificially prepared, though there is very little doubt that before long we shall be able to do so. Indigo is as yet only produced as the result of the life of a plant, and the artificial production of this valuable dye is a problem which yet remains to be solved.

Now this anthracene, although it is contained in comparatively small quantities in coal tar (100 tons of tar yielding only about half a ton of anthracene, or one ton of anthracene being got from the distillation of 2,000 tons of coal), yet still it can be got in absolutely large quantities, because such an enormous quantity of coal is distilled for gas making all the world over; and therefore if the processes of building up the alizarine from this anthracene be not too costly, there is little doubt that the artificial colour will be made in quantity, and a part at least of the money which we now send out of the country to buy madder roots will go to benefit our own population, as we can now transform our coal into this invaluable colouring matter.

Well, now, let me try to show you that the artificial alizarine which is got from coal tar possesses similar, or rather identical, colouring properties with the alizarine got from madder. It is impossible for me to enter into the minutiæ of the mode in which anthracene can be converted into alizarine, for I should have to use formulæ, which I am afraid many of you would not understand, and I must be content with referring those who wish for information on this subject to the annexed diagram, or to treatises on organic chemistry.

In the following Table we have a statement of the synthetic production of alizarine from its constituent elements.

Synthesis of Alizarine.

1. Acetylene by direct union of Carbon and Hydrogen in Electric Arc.
   $C_2 + H_2 = C_2 H_2$ (Berthelot, 1862.)
2. Benzol (Tri-acetylene) from Acetylene by Heat.
   $3 C_2 H_2 = C_6 H_6$ (Berthelot, 1866.)
3. Anthracene from Benzol and Ethylene.
   $2 C_6 H_6 + C_2 H_4 = C_{14} H_{10} + 3 H_2$ (Berthelot, 1866.)
4. Alizarine from Anthracene. (Process No. 1.)
   (Graebe and Liebermann, 1869.)
   (A) Oxyanthracene or Anthraquinone by Nitric Acid.
   $C_{14} H_6 (O H)_2$ (Anderson, 1861.)
   (B) Bibromanthraquinone by action of Bromine.
   $C_{14} H_8 O_2 + 2 Br_2 = C_{14} H_6 Br_2 O_2 + 2 Br H$
   (C) Alizarine by action of Caustic Potash.
   $C_{14} H_6 Br_2 O_2 + 4 K H O = C_{14} H_6 (O K)_2 O_2 + 2 K Br + 2 H_2 O$
   Potassium alizarate.
5. Alizarine from Anthracene. (Process No. 2.)
   (Graebe and Caro, Perkin, Schorlemmer and Dale.)
   (A) Disulphoanthraquinonic Acid from Anthraquinone.
   $$C_{14} H_6 (O H)_2 + 2 H_2 S O_4 = C_{14} H_6 O_2 \left\{ \begin{matrix} S O_3 H \\ S O_3 H \end{matrix} \right\} + 2 H_2 O$$
   (B) Alizarine from the above by the action of Potash.
   $$C_{14} H_6 O_2 \left\{ \begin{matrix} S O_3 H \\ S O_3 H \end{matrix} \right\} + 4 K H O = C_{14} H_6 O_2 \left\{ \begin{matrix} O H \\ O H \end{matrix} \right\} + 2 K_2 S O_3 + 2 H_2 O$$
   Alizarine.

Contributions to the History of Alizarine. $C_{14} H_8 O_4$

1825. Faraday discovered Benzol in Coal-gas Oil. $C_6 H_6$
1831. Robiquet and Colin discovered Alizarine in Madder Root
1832. Dumas and Laurent discovered Anthracene in Coal Oils
1848. Schunck gave the Composition of Alizarine. $C_{14} H_{10} O_4$
1850. Strecker ,, ,, ,, $C_{10} H_6 O_3$;
1862. Anderson examined Anthracene Compounds. $C_{14} H_{10}$
1865. Kekulé explained the constitution of the Aromatic Compounds
1866. Baeyer obtained Benzol from Phenol
1868. Graebe investigated the Quinones.
1868. Graebe and Liebermann obtained Anthracene from Alizarine.
1869. ,, ,, ,, Alizarine from Anthracene

The point, however, which all of you can understand is that we are now using this method of constructive chemistry for the purpose of building up substances which up to this time have only been found in the bodies of plants or animals.

One of the most remarkable properties of the alizarine got from madder is its power of forming an insoluble compound with a mordant. I have here the alumina mordant, or red liquor, which forms, with alizarine, a pink insoluble lake; and here I have the iron liquor, or iron mordant, a solution of a salt of iron, which forms, with alizarine a purple insoluble lake. I pour some of these mordants into both these bottles of water; next I bring into one some extract of madder root, some of the natural alizarine got from the plant. You will observe we get here a bright red precipitate. Next I take the artificial alizarine made from coal tar, and I pour this into the other globe of water to which I added some alumina mordant. You will see that I get exactly the same sort of red coloured precipitate. One is the natural, the other the artificial, and both give exactly the same kind of colour. In the same way, if I take and compare the effect of the iron mordant, I shall find that both the natural and the artificial colour give exactly the same purple precipitate.

Now in order to show you in another way the identity of these two things, we have written here on this screen the words "natural alizarine" and "artificial alizarine," and when these are sponged at the back with alkali you will see that we get the same colour exactly produced by the two kinds of alizarine. By burning a bit of magnesium wire the purple colour of the alkaline alizarine will be better seen, and you will observe that we have got exactly the same tint in both cases. I will show you the same thing by dyeing some cloth with the artificial and with the natural alizarine. Here we throw a very small quantity of the madder alizarine into a basin-full of boiling water, and here do the same with the artificial colouring matter, then I bring into each basin a little bit of mordanted cloth. I won't say that we can get a very fine colour, but you will see that the colour we get is equal in the two cases, that the artificial alizarine produces the same colour as the natural. We will allow these cloths to remain a little while in the boiling liquor, and now on taking them out you see that the alumina pinks are in both cases equally bright and the iron purples also exactly of the same shade and tint. Thus, then, we see that the artificial alizarine is exactly identical in its dyeing and colouring power with the colouring matter contained in and derived from the madder root. How far the artificial alizarine will in time displace the madder it is not for me to say; this is a question which I will leave to the calico printers and dyers of this great district; but certain it is, that the two are chemically the same substance, and that this production of alizarine from coal tar is one of the greatest triumphs of modern synthetical chemistry. This new dyeing substance is now being largely used on all hands, especially for what is called topical printing and for Turkey red dyeing, and I am told that the colours which can be obtained from the artificial alizarine are quite equal, if not superior, to those which can be obtained from the natural madder.

And now if we are to draw a moral from all this, I think that we shall have little difficulty in doing so. These facts show us the truth of the old saying that great results come from small beginnings; they teach us that nothing in science is unimportant; that no one can foresee the benefits which to-morrow may spring from our apparently abstruse discoveries of to-day. Science is advancing, and its progress, unlike that of so many human institutions, is without the possibility of retrogression. Boldly, then, may the least of its votaries step forward, in the firm conviction that the degree, however insignificant, by which he may be able to advance the boundaries of science is a certain progress, and one which must add its share towards the enlightenment and benefit of mankind.

THE ORIGIN OF THE ENGLISH PEOPLE.

A LECTURE

BY PROFESSOR A. S. WILKINS, M.A.

Delivered in the Hulme Town Hall, Manchester, November 16th, 1871.

I HAVE undertaken to speak to you this evening on a branch of science which I think has not before been brought under your notice. This course of lectures has hitherto been confined to those branches of science which deal especially with the things which we see around us. To-night I am going to confine your attention almost entirely to things which you *hear* round about you. And I want to discuss these things that you hear—the words that we are using in daily life—somewhat after the manner in which other scientific men deal with things which we see, the objects of sight. You know that chemists such as Dr. Roscoe, and the distinguished chemist whom we are to have next Friday evening, Dr. Odling, make it their business to examine into everything which they can find in the heavens above, in the earth beneath, and in the waters under the earth. They will tell you what these things are composed of; they will split them up, analyse them, as they call it, into their remotest and most ultimate constituents. Now, the geologists, on the other hand, may be said not to trouble themselves quite so much with the composition of the substances they deal with; but they are concerned perhaps more with the manner in which they got into their present position.

I want to try this evening to show you, as far as I may be able in the short time during which I can hope to have your attention—

for the lecture is necessarily not illustrated by any experiments—both how those words which we are using are made up; and also how they came to be in their present position. I have said that I am not able to show you anything to see. I had hoped that I should have had a map which would have enabled me to explain at least some of the facts which I wish to bring before you a little more clearly than I shall now be able to do; but in this I have been disappointed, so I must, I suppose, ask for your special indulgence, on the ground that you will have to listen and not to see during almost the whole of the time allotted to us.

Now if we begin to split up, or to analyse, or to examine closely, the words which we are using in daily life, we shall find that a fair proportion of them, quite a considerable proportion, are very closely akin to the words which Welshmen would use. I do not mean to say that we use them in exactly the same form in which Welshmen would use them; but at all events the words are very strikingly like Welsh words. This is the case with the English that is spoken all over this country of ours. For instance, when you want to speak of an article of dress, you may talk about a *coat;* you may talk about a *gown;* you may talk about *frieze*, from which you would make the coat; and to come to smaller points, you may talk about a *button*, a *tassel*, of the *gussets* in shirts, of *welts* on shoes, and of *clouts* and *dishclouts*. In all these cases we are using words which are almost exactly like words which Welshmen would use in such cases. If we come to our household things, if we talk about a *basket*, a *barrow*, a *funnel*, a *pitcher*, or if we talk about *crockery*—in all these cases we are still using the same class of words. And here in Lancashire we use a good many of these Welsh-like words, which scientific scholars call Keltic words, which are not known or understood in the rest of England. If I were talking to people in the south, I dare say they would not understand what I mean by *bamming*. You may know, perhaps. So in the same way they do not know what *boggarts* are. They would not understand what I meant if I talked about a man being a *farrant* or a *gradely* man; if we talked about setting *craddies;* if we talked about *cobbing*, or *wapping*, or *punsing*—all these words would be unknown in the south; and I think I may suppose they are pretty well known here. If we hear that a man is a cunning *file*, it has nothing whatever to do with the file that a blacksmith would use. That again is only another form of a Welsh word, meaning a *twisty* fellow. In the same way, if you talk about going out for a *spree*, and of playing fine *pranks*, in all these instances you are talking Welsh or Keltic words. The same thing would be true, if in your business you talked about a cotton *gin*, or a weaver spoke about his *picking stick*. Here again we still keep to the Keltic element of our language.

Now, one of the first questions that men ask who wish to go into a subject of this kind scientifically is—How did these words get into our language? Of course there are several ways in which words not belonging to a language originally may come into it. We may borrow them. For instance, we use the word *gutta percha* to describe a substance well known to all of us. That is not an old English word, we get the name from the country where we get the thing from. Just in the same way with *coffee;* where we get the coffee berry we also get its name. There is another way in which words may be borrowed, that is, from fashion. For instance, we have borrowed a great many French words, and many people now-a-days very foolishly, I think we may say, prefer to use French words where good English words would do as well. Nobody, I suppose, imagines that *coats* were never known in England until Welshmen came here and brought them, or *gowns* or *buttons*; that *cobbing* or *wapping* was unknown until Welshmen taught it us. We must try to find some other method of explaining the presence of these words in our language. That is one of the questions that we shall have to try to answer to-night.

But now, when we go on and try to analyse or to account for other words in the language that we are talking about, we find a good many of them come from the Latin. Some of them come straight away, very little changed in their passage, so that the man who knows Latin, whatever country he belongs to, would be able to understand this sort of English words. A good number of them are words that everybody knows now, words like *science*, or *student*, or *origin*, or *admit*, or *adopt*—plenty of words of that kind which have become part and parcel of our everyday English talk. And there are a great number of other Latin words which are used perhaps solely in sermons or solely in scientific treatises, which are not known to us usually in everyday talk, but which we have to learn specially, and which have come directly from the Latin to us. But besides this kind of Latin words, we have another set of words which scholars are able to derive from the Latin, but not directly; they have got so much changed on their way, that they seem to have gone through a different kind of process, have been sifted or moulded in some way, generally cut shorter at the head or the tail, or at both. Such words, for instance, as *cover*, or *obtain*, *complain*, *hour*, *flower*—words of that kind are abundant, and certainly they are not old-fashioned English words; they are the children, perhaps in this case I ought rather to say the grandchildren, of Latin words; but they have taken such a changed form in their passage from Latin into English, that we cannot suppose they were borrowed straight from the one language for the use of the other. When we examine these words further we find that they are not exactly like Latin words, but they are almost exactly like French words. I can give you some instances of words which we have got straight from the Latin, and words which originally come from Latin have come to us through French. For instance, we may talk about food being *nutritious*, or we may talk about food being *nourishing*. These words have precisely the same origin, and have precisely the same meaning; but one of them has come to us through the French, and so it has got a little bit changed on its way. In the same way, to give you a more striking instance of the same kind, we have the word *preach*. We have another word which has come directly from the Latin, not through the French, and therefore is longer and fuller,—a word which is not commonly used, but may be found sometimes in the leading articles in newspapers, and other writings of that kind—the word *predicate*. These words are the same in origin, but have got a good deal changed one from the other. So, again, the *poor* man is not always a *pauper*, but the word *poor* is only a shortened form of the word *pauper*, that has come to us through the French. *Story* is not quite the same thing now-a-days as *history*, and the shortening is to be explained in the same way. So a *mayor*, the chief magistrate of a borough, is a different person from a *major* now-a-days, but originally they were the same. So, to give a more striking instance—one which might not have struck you at first when you saw it—the word *spice*, which we now apply to fragrant things like nutmeg and pepper, &c., is exactly the same word as the word *species*—of which we have heard a great deal lately—modified both in form and in meaning on its way to us.

Well, now, you see we have two more questions to solve, if we can. Not only are there these Keltic or Welsh-like words in our language, but there are Latin words very little changed, and Latin words a great deal changed—so that they are very much more like French words than Latin words.

You may naturally ask here what proportion of words in our language can thus be traced back to the Latin. That depends to a certain extent upon the way in which you count words. Suppose you put all the different words you find in any writer into a dictionary or an index, not repeating the same word more than once, you will find perhaps one word in four Latin. The proportion varies very much, the simpler and plainer and the more straightforward the style of the writer, the fewer of these Latinised words he will use; the more involved and pompous and formal and generally unintelligible his writing is, the more of these Latin words he will use: so that in our old English Bible—which is among other things just the very finest specimen of the English language that we have—sometimes out of a hundred words you will only find four that are not good plain English; and in the hardest places, where Latin words seem almost necessary, you will not find more than ten in a hundred. Shakspere, too, who usually says what he means in a way which most of us can understand easily, will only use perhaps from nine to a dozen out of a hundred words. Milton, who was more stately and formal in his style than Shakspere, will use generally about twenty. Dr. Johnson twenty-five, and the great historian who wrote about a hundred years ago, Gibbon, will use sometimes thirty. But this is when you arrange the words in a sort of index, counting each word only once. But suppose, on the other hand, you take a piece of English just as it is written, then plain, simple English words will come over a good deal oftener than that. To get a fair specimen of the English that is talked now-a-days, when a man wishes to make his meaning as plain as he can, I took a speech which was delivered a little while ago by the Bishop of this diocese. You know that he always tries to make himself understood as plainly as he can; and out of some three hundred words that he used, I find there are about fifty belonging to this class which we are now discussing. What are we to say of the rest? Well, of course, we have here and there a word got from almost every language under heaven; because, generally, wherever we have got anything new, there we get the name for it; but almost the whole of the rest of our language, that is to say, perhaps two words out of every three, belong to what is called the German class of languages—not quite the German that is spoken now-a-days by the educated people in Germany, for our language is based upon what is called the Low German. No disrespect is intended to it by that phrase; it simply means the sort of German that is talked in the low region near the sea, and not in the more hilly region inland. The High German, as it is called, differs from the Low German in several ways, some of which it would take me perhaps too long to explain now; but I think I can give you with very little trouble an idea of one of the main differences between the Low German on which our language is based, and which our English really is, and the High German which Germans now-a-days speak. Suppose you pronounce any vowel sound, say *a*; as long as you pronounce that vowel sound you are letting one uninterrupted stream of breath come out of your lungs, play on a little instrument at the top of your throat which determines the sound you produce, and then pass into the air unchecked. So if you simply content yourself with pronouncing a vowel, you can go on as long as you please with it—*ā-ā-ā*—as long as you have breath. But you can check that stream of air, producing sound, in three different ways. You may check it in your throat, and then let it go on again, and then you will pronounce a consonant like *k*. Or you may check it at the top of your tongue, and then you will pronounce the consonant *t*. Or you may check it with your lips and then you will pronounce the consonant *p*. You can say *kay*, *tay*, *pay*. But then checking it in just the same place you can produce sounds that are a little different from those. I can say in my throat not only *kay* but also *gay*; not only *pay* but also *bay*. Well, those who are concerned with the scientific examination of sounds have given names to these different letters. Those which I gave at first they call properly *surds*; those which I gave in the second instance they call *sonants*; for this reason, when you pronounce *b* or *g* or *d* you make a vocal sound in your throat at the actual time you are pronouncing that letter; but when you say *p*, *t*, or *k*, you do not. Now it is a little more trouble to pronounce those which make a sound in your throat, which we call *sonants*, than those which do not produce a sound in your throat, which we call *surds*. You can easily test that for yourselves. It is a little more trouble to say *bad* than it is to say *pat*, and the people who talk the High German language have got into this lazier or more slovenly way of pronouncing, using the surd instead of the sonant letters. And you will find that that is really the main difference between the High German the Germans talk and the Low German that we English still talk. For instance, when we talk about a *dale* they will talk about a *tal*; if we say *door* they will say *tor*; if we talk about *daughter* they will say *tochter*; if we say *drink* they will say *trink*, and so on. Then further, when we get the *t* sounds they will soften them down still more into *th* or *z*, not completely cutting off the stream. For instance, our *ten* is their *zehn*; our *tongue* is their *zunge*; our *tear* is their *zerren*. When the *t*, instead of beginning a word, comes in the middle or at the end, they make a further change. You know now-a-days instead of saying he hath, or he loveth, we generally say he has, or he loves. The Germans have adopted just the same change, changing our *t's* into *s's;* so that when we say *white* they will say *weiss;* for *water* they will say *wasser*, and so on. But with these exceptions, we are talking in the basis of our language, that is to say, in simple, every-day words, mainly the same sort of language as our German cousins.

Now we have to consider how to explain these facts. We have got a fourth one now in addition to our three problems before. How is it we use Welsh words? How is it we use Latin words? How is it we use Latin words that seem to have come to us through the French? And how is it, finally, that the basis of our language is just the same as the German which is spoken on the coast of Germany? History has to help us to explain these facts. If we go back as far as ever we can in the history of man—I do not mean as far as Mr. Darwin would take us back, but as far as we can go back with the men with whom we have any sort of concern as our fellow men—we find that there must have been some great hive somewhere about the middle of Western Asia, which was constantly sending forth swarms of people, for the most part always westward. Then when one swarm—if I may use the language they would use of bees—had come out, they would settle down in some territory which they liked, until another swarm came from behind, and finding this territory suited them also, they would drive those who had gone before them a little further to the west; and so on, until we are able to trace at least five distinct waves of people coming one after the other from this part of Asia that I speak of—very much that same part where the Bible tells us Noah landed out of his ark—and always pushing before them those who had gone first. Now you know that those who live furthest to the west of all the people of Europe are the people of Ireland; therefore we think we are justified in assuming that the Irish were probably the first to leave, and then they got pushed further and further on towards the west always, till they got pushed so far that they could not go any farther without being pushed into the sea. Then, of course, they had not discovered the way to America; now they are pushed right beyond the sea into America. We know this principally because we find them at the extreme west. We know they could not have come over the water from America; we know that they did not grow as a nation where they are now; therefore they must have come the other way. We have additional proof of this in the fact that all about the continent of Europe there are names which we can show to be properly Irish names. I shall come back to this question if I have time this evening—this question of the meaning of local names. The Irish have left very few traces of their passage through England; but I think we may find one or two traces of the time when England was peopled principally by those who are now living in Ireland, but they are not at all certain, and I should not like to give them to you as facts. But we do know that there are plenty of traces of the next great wave, and those are the people who are now the Welsh. They live the next towards the west. The people at the top of Scotland were probably originally the same as the people of Wales. We judge of that also by the evidence of local names, the names of places. About 1,400 or 1,500 years ago, some tribes of Irishmen who called themselves Scots—because you must remember that the Scotch came first from Ireland—came back into Scotland, and practically absorbed or exterminated the Welsh folk who lived in Scotland then, and took the country for themselves; so that now-a-days the people in the north of Scotland, the Highlands, and the people in Ireland speak languages which are very closely akin to each other, but not so closely akin to the Welsh as the language of the Highlands used to be. Then, just about 1,800 years ago, the Romans came—they had been here a hundred years before that, but their expedition failed—and they conquered all those Welshmen, or Kelts, as we call them sometimes, who dwelt in England and Wales—it was not England then, it was Britain—and subdued them entirely under their dominion. They remained about 400 years, and then they withdrew. And before they had gone long, swarms of these Low Germans came over. I use the word Low, you must remember, always in its technical sense, meaning the Germans living by the sea coast, not in the way of disparagement. They lived in that part of Germany which is just at the bottom of Denmark, where Denmark joins on to the main land, just about Schleswig Holstein, of which we heard so much six or eight years ago. They came over in their families and tribes, as I shall be able to show you by this same evidence of names of places, and conquered England by degrees. There were two tribes; one called themselves Saxons, and the other called themselves Angles, from which we get our name of England. They did not come over all together; they kept coming over for nearly a hundred years, one swarm after another, moving with their wives and their children, and perhaps their cattle also, and settling here, driving the old Welsh people, who lived all about the country then, before them, till they cooped them up into the western parts, *i.e.*, Cornwall, Wales, Cumberland, and Westmorland. They left a good many of them in Lancashire. To speak very roughly, if you draw a line from Chester to London, you will find that the Saxons lived to the south-west of this line, and the Angles, or the English, lived in the north-eastern part, right away up as far as Edinburgh. I will show you one means by which you can tell that at once. Look at those places which end in *sex;* Sussex, South Saxons lived there; Essex, East Saxons lived there; Middlesex, the Middle Saxons lived there. And in the old days, before these counties were so split up, all this part was called Wessex, that is to say, where the West Saxons lived. On the other hand, as you may know still from the name of one of our railways, all this part was called East Anglia, and by degrees the name Anglia in Latin, or in English Angle Land, spread over the country.

There is a subject which has been much discussed by scholars as to how it was that we came to be called English and not Saxons. If you are going about in Wales and you meet one of the rough peasantry and you ask him the way to any place, the answer you will probably get will be *Dim Sassenach*—I know no English; in other fashion, I know no Saxon—another proof, as I have shown you, that the people with whom the Welsh came into contact were the Saxon people.

Two theories have been started to explain this; there may be something in both of them. In the first place there were a good many more Angles than there were Saxons. In the second place those people who first came into contact with the missionaries who came over from Rome to convert the German invaders to Christianity (for when they came over they were pagans) were the Angles, and so the missionaries called the whole people Angles, and the name came to be gradually accepted; it got used in books, and then by degrees it was used generally. The Angles and Saxons founded several small kingdoms: one of them, the kingdom of Northumberland, stretched to the south and west beyond Manchester; and in an old book I have read of Manchester in Northumberland, not because they thought it was up there, but because in that time Northumberland stretched from here right away to Edinburgh. And just about the time when these various kingdoms were first brought under one king, other swarms, very much resembling those Saxons and Angles which had first come over, came from Denmark and Norway; and they pillaged the coasts when they came in small numbers, and when they came in large numbers they formed armies which conquered large portions of the country for themselves; so that after nearly a hundred years' hard fighting between them and the English people they succeeded in getting a firm footing on the ground. And almost the same part of the country which I said was held by the Angles was given up to the Danes, under the name of the Danelagh. At the same time the Norwegians came sailing round Scotland and conquered the Isle of Man, and settled in large numbers in Cumberland and Westmorland and North Lancashire, and all along this part of the coast, in fact; and I shall be able in a minute or two, I hope, to show you what tokens we have still of their presence.

Our English kings—the old English race of kings—reigned for nearly 300 years after England had been made a united monarchy, and then the last of them, Edward the Confessor, died without leaving any children. The English people in those days had the right of choosing their kings freely. They always exercised it by choosing one of the royal family, but they chose not always the eldest son, but the man whom they thought fittest to rule, the bravest, the wisest, and strongest. But now all the old English royal family was extinct, except one distant relation, who was a mere boy, and whom the English people did not think worthy to rule over them. So they chose a great earl of the time, Earl Harold, whose father had been the son of a swineherd, and had raised himself by his valour and ability to the rank of the first man in the kingdom. But there was some sort of claim upon the crown—not a very good one—on the part of the Duke of Normandy, and he put forth his claim. He said that as there was no nearer heir to the crown, it fell by right to him. The English people held firmly to the king they had chosen; but William, the Duke of Normandy, gathered a large body of French troops, and came over, and, as most of you know, defeated the English king, Harold, at the great battle of Hastings, and killed him, and succeeded in compelling the English to choose him as their king. This is what is meant by the Norman Conquest. The word has often been misunderstood; it is not very happily chosen perhaps, because it was not that the English people were conquered by a foreign people, but rather that the foreign king was strong enough to make the English people choose him as their king. However, the result was at first sight very injurious to the English language and laws, because the foreign king was surrounded by a large body of French nobles and captains, to whom were given large estates, and French and not English was made the prevailing language for something like two centuries. This Duke of Normandy had also large possessions in France, and the first six of these Norman kings were much more Frenchmen than Englishmen. We read in our history books about Richard the Lion Hearted, and think him a fine specimen of an English king, but it is extremely doubtful whether he could ever speak a word of English in his life; and it is very certain that he only spent two or three months in England, and that was when he came over here to get money out of the people. However, his brother, the bad John, lost all his dominions in France, and was driven out of them by the French king, and so England became again an independent kingdom, without any possessions other than those within her own boundaries. The result of this was that there was no longer any occasion for French to be the language of the court and of the nobles. It continued to be so for a short time, because they were accustomed to speak it; but it was not very long before the English language raised its head again. It had never been disused; it had always held its own among the common people. Their songs were written in English—we have many of them remaining to us—and they had always talked it among themselves, but it had been looked down upon. Now that the English noblemen were shut out from their foreign possessions they began to be proud of the name of Englishmen, and they began to learn by degrees to talk the English language. But they mixed it up with a great many of the French words which they had been accustomed to use. And now I think you will be able to see how it is that we have got these four elements in our language which I was speaking about. I do not know whether you noticed when I was talking about the Keltic words, that they were either words relating to home affairs, or else familiar and somewhat vulgar phrases. A large number of the coarse and bad words that we use now-a-days are Keltic words. That points to the fact, which you would naturally expect, that when the Saxons and English people who came over (after the Romans had left this country) and conquered the Welsh people, those whom they left in the land they made their slaves; and so they would naturally get from them just those words which were necessary to explain to their slaves what they wanted. The words which I named before, like coat, or gown, or basket, or barrow, are the words which would be common among the household slaves, and they would be used by the Keltic or Welsh slaves who were made so by the Anglo-Saxons. You see also how it is we have so many German words, because these people, when they came from North Germany and crossed over to conquer England (Britain as it then was), would naturally bring their own language with them.

The French words came in from the Norman Conquest; and though it is not true to speak of English as a mixture of this Low German and French, yet it has borrowed a good many French words which are incorporated with its own, and are made one with its own substance. And then the Latin words are to be explained from this fact, that for many hundred years Latin was the only language that was written and used by learned men in all the countries of Europe; and whenever they wanted a word for something which they did not know how to express in the plain English of the common folk, they would borrow it from the Latin with which they were familiar. That is the way in which we explain the four elements which we get in our language.

Now I want to show you another side of this question, and that is, the light which the names of places throw upon the origin of the English people. The first population of this country, you will remember (supposing we put aside for a moment the possibility, or I should rather say the probability, that the Irish people lived here before they were driven across to their own country), was the Welsh division of the Keltic stock. Now the first places which would require names, of course, would be the rivers and mountains. When the Welsh came to the country they would want a name of course for a river, and a name for a mountain, for there were no towns as yet; and so we find that almost all the names of rivers and mountains in England are nearly Keltic. Take for instance a few of the Keltic words that we find in proper names. One of the Welsh words now-a-days for a river is *avon*. Well, however little you know about the rivers of our English country, you must remember several of them that are called Avon. There is the Avon on which is Stratford, Shakspere's birthplace; there is the Avon in Somersetshire, where Bristol is; and there are several others. This word avon simply means river, and we call the river by Bristol Avon simply because the Welshmen who lived in our country 2,000 or 2,500 years ago called the river by a name which in their language meant river. There is another word, *dwr*, which means water. We get that in plenty of our words. In the Lake country we have the Derwent and Derwentwater. Derwent simply means *clear water*. In the same way that other beautiful lake is named Windermere, which is simply *beautiful water*. *Wyn* is beautiful, *dwr* is water in the language of old Welsh, and *mere*,—you know that from Rostherne Mere, and so on. We get the same in the names of many rivers. You know the Calder here, it flows along by Todmorden; that is again a crooked or winding water. And wherever we have a word with a meaning of this kind in Welsh, we may be quite sure that it was Welsh people who gave it that name. Therefore, if we find a river called the Calder, we may be quite sure that the first people who came to that river were Welshmen. There is another name which has got a good deal changed, but perhaps it is the most widely-spread of all, and that is *Wysg*—which also means "water." If I should have any Irish people here to-night, they will pretty well understand, I think, what is meant by usquebagh; that has the same root—water. Well, this occurs in many of the names of rivers in England, only a little modified. There are two or three rivers called Ouse; other rivers called Exe, Axe, Esk, or Usk. All these names of rivers simply show that Welsh or Keltic people came there, and when they found a stream of water they called it in their language river, or water. The Ribble, which flows by Preston, is again another Welsh word, which means simply "fast river." Then the same word Avon, which I spoke to you about before, comes in in a good many compound names. Take, for instance, this county in which we are in now. It is called Lancashire because it is the shire of Lancaster. I will talk about the second part of it afterwards. Lancaster is called so because it is on the Lune, which, in old days, used to be called Alauna. Words always have a tendency to grow shorter the longer they live. A distinguished English scholar said once that letters were like soldiers, they had a great tendency to drop off on a long march. And I could find dozens, hundreds, thousands, literally, of instances in our English language in which words have got shorter. To give you just one example. Our word "ma'am," which some persons would use in addressing a lady, is cut short from a phrase which originally had five syllables at least. So the name of the Lune was Alauna, and that in the language of the Welsh people simply means "white water." So we call the county town Lancaster—that is, the camp or castle that is on the white water river. Then there is the opposite word in Welsh, *dhu*, which means black. Thus we get Douglas, or in the shorter form, Diggles, meaning "black water." There is a word which you have still in Lancashire, *cam*, which means crooked. It is a word that Shakespere uses. We get that in several forms, Camden, for instance. Another instance which most of you remember is Morecambe Bay, that is, the crooked sea. You remember how the sea goes in and out there, and Morecambe must have been called the crooked sea at the time when Welsh people lived there, to whom this word Morecambe would mean crooked sea. If time would allow me, I could show you in the same way that Irwell (the quick, winding stream), Irk (the leaper), Med-lock (the full pool), all preserve in their names signs that the Welsh were here before us. But to pass on from rivers to hills, we have *pen* the Welsh word for hill; which of course we get in Pendleton, which is simply hill town; Pendlebury, another form of the same name; and the hill which is above Clitheroe, Pendle Hill. In Wales and Cornwall it is a very common name—Penrhyn, Penmaenmaur, Pendennis: in all cases *pen* meaning hill. And wherever we find this word *pen* it means simply that the Welshman was there before us and talked about the "hill." Coniston Old Man is called so simply from the Welsh Alt Maen (high mountain), and has nothing to do with any old gentleman.

Of town names we have very few that are Keltic, for the natural reason that the Welsh folk who lived here in Lancashire once had very few towns to give any names to. In Doomsday Book, which gives us a very complete account of the country a few years after the Normans came here, I find that only 16 villages are mentioned as existing then in the whole of Lancashire. So that it need not surprise us if we find that Wigan is about the only instance of a Keltic name for a town: this means "battles," and the place is so called because of some battles that were fought there in very early times.

Now, let us pass on. We have seen that the Kelts were here; the Romans came after them. They have left us very few names. One or two will be of interest here. Their word for camp was *castra*, which we get in Lancaster. We know that Lancaster must have been at least as old as the Roman times, because no other people but Romans would have talked about "castra" for camp, therefore it must have been Romans who gave the name of Lancaster to the city or town which was built on the river which before then the Welsh people had called the Lune or the Alauna—the "white water." So with the name of this city, Manchester. "Chester" is only the softened form of this same "castra." In all languages that I know anything about there are instances of this changing of sounds. The *k* sound gets softened by degrees either into *s* or *ts* or *ch*. So Manchester means a camp or fortified place. But what does the "man" mean? If you believe that the Welsh word *man* means a plain, and if you will just ride from Cheetham Hill down to here, you will, I think, easily see why Manchester was called "the camp at the edge of the plain." If you go to the north of Manchester, you get into the hill country at once; if you go south—as those know who live on this side, you get very little hill, but just a broad, flat plain.

Manchester means a camp, or a fortified place which was built by these Romans, just at the place where the great flat plain of South Lancashire and Cheshire begins.

We have only one other instance perhaps worth troubling you about, and that because of its local interest. We have another Roman word remaining to us, in *street*. "Street" is an old Roman word for road. Some of you may know High Street, in Westmorland, the high mountain over which the Roman road runs at the top; and an old Roman road runs down to Stretford, that is, where the "street" went over the river. Camp Field is a later name; it has nothing to do with the Romans; here we get the English again. Now we have plenty of local names which are English. And here is one thing to be noticed at once—we do not talk now-a-days about Avon, but rather the River Avon, the River Usk, and so on. That points us to this fact, that when the English people came here, if they saw a river they asked what it was called. The Welsh people would say "avon," that is "river," Now the English did not know that avon meant river; they thought that was the proper name of it, just as we say Irwell, or Irk; and they would put their word "river" on to this word, whatever it might be—Ouse, or Avon, or so on. So we get River Ouse, River Avon. In just the same way we get Pendle Hill. The English people on coming would ask what that hill was called. The people there would say it was *pen*. Then the English coming would call it Pen Hill, and that would soon get changed into Pendle, and the hill which is near Clitheroe is still often called Pendle, and when hill gets mixed up with pen, the people forget that there is the word hill in the name; and so they put another hill, and talk of Pendle Hill, which simply means Hill, Hill, Hill! Just the same with Pendleton; that is Hill, Hill Town; Pendlebury, Hill, Hill Borough. We have a curious instance of this, which may have escaped many of you, here in Cornbrook. Brook is intelligible enough, but what is the "corn?" Of course, we suppose at first sight that it is a brook that ran through cornfields; it must have been a long time ago if it did! But we should be going quite wrong if we judged so hastily. Corn is simply our old word avon cut short, with the Welsh prefix *cor*, which means narrow. Now there is the Irwell, a comparatively broad stream, and the *cor-an*, narrow stream flowing into it. The old Welsh people called it the *Corn*, that is, the narrow stream. The people coming afterwards asked what stream that was, and were told the Corn, or narrow stream. The English put on "brook," and so we get Cornbrook, narrow stream brook

We can tell very well wherever the English people proper have been by the terminations. There is an old rhyme that runs—

In Ford, in Ham, in Ley, in Ton,
The most of English surnames run.

And whenever we find any words with these endings, you may be sure that there the English people settled, not Welsh people, not Danish people, not French people, but simply the English, either Angles or Saxons. Wherever we have a word ending in *ton*, as we have abundantly here, Pendleton, Bolton, Middleton; where-ever we have them ending in *ley*, as in Alderley and Timperley, and so many places in Cheshire; wherever we have *ham*, and in most cases where we have *ford**—in these instances you may be sure that the words are of English origin. I am not sure whether I shall have time to explain all these terminations. *Ton* simply means a sort of enclosure, more like a farmyard than a town. We have Barton-on-Irwell. *Bar*, the first part of it, is simply *bear*, and *ton* is the enclosure; and so Barton means the enclosure for what was borne by the ground, that is to say, for the harvest or the crop. Barton means a sort of farm yard or rick yard. That accounts for the fact that we have so many Bartons all over England, because there are so many enclosures where people put up their harvest produce. In "Broughton," near here, we have the same ending; and if any of you had the misfortune to live in Lower Broughton during the floods, you will understand why it was called Broughton, when I tell you that the first part of it means marshy ground.

In one name that we have near here, we get an instance of what is extremely important and interesting in its way—that is, Withington. Now here we have not so many of them, but in some parts of England there are a great many names ending in this *ington*. We have a fair number of them about here. You know we have Bollington, Carrington, Doddington, Rivington, Warrington. And then we have some in *ham*—Altringham, Aldingham, and Birmingham. And besides these, we have some words which end simply in *ing*—Melling, Pilling, and Billing, all just about this part of Lancashire. But as I have said, there are nothing like so many in Lancashire as in some other parts of England. In all Lancashire we have only 19 names with this *ing* in them, but in the little county of Bedfordshire we have 63; in Huntingdon-

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* Fords by the sea are of Danish origin, and contain their word *fiord*, our *frith*.

shire we have 57; and in Kent 51 names having this *ing* in them. Well, of course, just as the chemist as soon as he gets hold of any substance whatever, no matter whether animal, vegetable, or mineral, wants to find out what its composition is, so we want to find out what this *ing* means. And we go back as far as we can, and we find that our old English forefathers used this termination *ing* to denote the son of a person. Suppose a man was named Eoppa, his son would be named Eopping, and all his sons would be named Eoppings. Suppose it was Boll, his family would be named Bollings. For instance, in our oldest version of the list of fathers and sons at the beginning of our New Testament, we have just the same form used; they would put *ing* on to the name of the father to denote the son. Wherever we have this *ing* we have an intimation and a proof, we may say, that the people who founded the town were all of one family, one little tribe, the children of a man called *Boll*, or something of the kind. Warrington is the *ton*, the enclosure, the village, we may say, of the children of *Wara*; and that is a proof of the fact which I told you on other authorities, that when our English forefathers came over from Germany, they did not come separately, like the Danes, but they came in families, altogether, "clans," as the Scotchmen call them. *Ing* means just the same thing as the Scotch "Mac," or the Irish "O'."

The Danes, I told you, lived in this part (north and east), and the Saxons in this (south and west). I will just mention the fact, though I cannot bring out the full meaning of it now, that here (north) you will find lots of *bys*, and in this part (south) lots of *tons*. Wherever you find places ending in *by*, as Whitby, Derby, Rugby, there you find Danes have been. *By* is the old Danish form for town or borough; and when you talk about "by laws" you simply mean the borough laws as distinguished from the laws of the country. Of course now we use the phrase for the laws of a railway or a club; but originally *by-law* meant borough law, as distinguishing it from the national law of the great Parliament. Here you find lots of *bys*, and here lived the Danes; here you will find *tons*, and English folk settled there. In Lancashire you will find *bys*, as Crosby, Formby, in the West Derby Hundred, and so on; that means that the Danes, sailing round the country with their ships, came and settled just on the sea coast, but could not get any further inland, because the English people drove them away. Hence you find them chiefly on the coast.

I meant to tell you much more about these Danish settlements, and also about the manner in which local names bear witness to the presence of Norwegians rather than Danes in Cumberland and Westmorland. I should like also to show you how we know from names where the Angles settled and where the Saxons, but I cannot allow myself to try your very great patience any longer. I will simply assure you I have only given you this evening a very slight sample of the interest you may find in the scientific study of language.

THE FOOD OF PLANTS.

A LECTURE

BY PROFESSOR ODLING, F.R.S.,

Delivered in the Hulme Town Hall, Manchester, 24th November, 1871.

YOU all know that a piece of wood, or any quantity of wood, when set fire to, is capable of being burned entirely away, with the exception of a small—almost insignificant—residue of white ash which is left. [Holding up a piece of burning wood.] This white ash is spoken of as the mineral matter of the wood, from the circumstance of its being of the same nature as the matter of which our most common rocks and minerals are composed; whereas that portion of the wood which burns away is called the organic matter of the wood, from its being the matter of which the living, growing plant, with its different parts or organs, is mainly constituted. Now, when a piece of wood is exposed to the action of heat—by being thrust into the fire, for example—it gives off gases, and these gases, taking fire, burn with flame. A short time back Professor Roscoe showed you that when coal was heated in the bowl of a tobacco pipe, it gave off inflammable gases which might be burnt at the other end of the pipe; and, in the same manner that the coal when heated gave off inflammable gases, so also this wood, when heated, gives off inflammable gases; and when we say, in ordinary language, that a piece of wood is burning with flame, our language is not strictly correct; we should rather say that the heated wood gives off gases, and that those gases burn with flame,—and they burn with flame you perceive on the surface of the wood where they are discharged into the air, much in the same manner that the gas of the coal heated in the tobacco pipe burnt at the other end of the pipe where it was discharged into the air. Now you will observe that where the piece of wood is subjected to heat, and more particularly where it is subjected to the hot flame of the burning gases surrounding it, it becomes blackened, or charred, or converted into charcoal. And the point of interest in connection with this charring process is that it does not take place where the wood itself, or the partly burnt wood, comes into contact freely with the air; but that it takes place where the wood is separated from the air by these burning gases. Where the wood is subjected to the heat of the burning gases, or to heat of any kind, and is kept out of contact with the air by the burning gases, or by some other means, there it becomes charred or converted into charcoal. But where the gases are burnt out, the charred residue, now left in contact with the air, quickly disappears, leaving only the white ash of which we spoke a moment ago. The same principle is made use of in the production of charcoal for manufacturing purposes. When manufacturers want to produce charcoal, they resort to one or other of two principal methods. One of these methods is to heat the wood to redness in an iron box or oven, entirely excluded from the air, with the exception of a pipe allowing the gases to escape; and after these gases have been driven off through the pipe, nothing is found left in the iron box or oven but a quantity of charcoal. Another way of making charcoal consists in piling the wood up into a large heap, and setting fire to it. By this means the outside wood, in contact with the air, gets burnt away to a greater or less extent; but the inside wood, being simply heated by the burning which is taking place upon the outside of the heap, does not get burnt away, but gives off its gases which burn on the outside; and what is left in the inside is this substance—charcoal, produced by the action of heat upon wood out of the access of air. Now if you examine a piece of charcoal obtained in one or other of these ways, and compare it with the wood out of which it was produced, you will observe that in the conversion of a particular piece of wood into a corresponding piece of charcoal, there has been an appreciable shrinking or loss of bulk; so that the resulting charcoal is considerably less in size than the original wood. It is also very much less in weight than the original wood; or, in the course of the process of its manufacture, there has been a certain shrinking in bulk, and a very much greater diminution of weight. But you will observe that the resulting charcoal presents exactly the form of the original piece of wood; so that yuo can recognise in it the stem and branches and knots of the wood, the bark, and the pith, and even the longitudinal fibres and concentric laminæ of which the wood was constituted. From the circumstance, then, of charcoal, having these characters, being produced from wood by the driving away of certain of its component parts, so as to leave the charcoal behind, we come to the conclusion that wood is a substance partly composed of charcoal; or in other words, that charcoal is one of the constituents of wood.

But the charcoal obtained from wood is not itself a pure substance; it is contaminated, for instance, with the ashes of the wood; and, accordingly, when we burn the charcoal away these ashes are left as a white residue. In its pure state the black combustible matter of the charcoal is known by the name of "carbon," and we say accordingly that charcoal is an impure form of carbon. Now this substance, "carbon," in its pure state, is what chemists call a "simple substance," that is to say, a substance which they have not yet succeeded in breaking up, or resolving into two or more different kinds of substance. Wood, on the contrary, is a compound substance; and, when subjected to the action of heat, breaks up into charcoal, which remains behind, and certain gaseous products which are driven off. We take away something from the wood which is not wood, and thereby leave charcoal. But with regard to this substance—charcoal, or rather with regard to carbon in its pure state,—we cannot take anything away from it but carbon, and we cannot alter it in any way by the taking away of something from it, so as to leave anything but carbon. It is a substance which we may alter by adding something else to it—by combining something else with it—but which we cannot alter by taking anything else away from it. Therefore, in practical effect, if not in actual fact, carbon is a simple substance. It is a substance which has not yet been decomposed, and is not, so far as our present knowledge goes, decomposable into two or more different kinds of substance.

Now charcoal is not only a constituent of wood, but also of hay and corn, and indeed of vegetable produce generally. [A bundle of hay and a glass jar of corn were exhibited on the platform.] You know that hay has the property of undergoing by itself, under certain conditions, a process of heating, which sometimes results in its actually taking fire; and on cutting into a haystack, it is not an uncommon occurrence to find the interior portion of the stack completely charred by the heating which has taken place. Much in the same manner, then, that wood charcoal is produced by the heating of wood in heaps, purposely set fire to—so is hay charcoal produced by the spontaneous heating of hay in haystacks; access of air to the interior being, in both cases, more or less completely prevented. And in the same way, if we take wheat grain and expose it to the action of heat, out of access of air, we get the grains completely charred or converted into charcoal. Here we have some wheat charcoal, presenting the form of the original grains of wheat—just as wood charcoal and hay charcoal present the forms of the original wood and hay respectively.

But it is important, in reference to the rest of the story I have to tell you this evening, that we should know, not only that vegetable produce—wood, and hay and corn—contain charcoal, but that we should be able also to form some notion of the amount of charcoal or carbon which they contain.

Now it is found that pure dry woody matter contains very nearly half its weight of carbon. It contains in reality 45 parts in 100, or, as we say, 45 per cent. If it contained 50 parts in 100, that would be exactly half its weight; but it does not contain quite this, but only 45 instead of 50 parts in 100. Now, if we pass from the consideration of pure woody matter to the consideration of other forms of vegetable produce, such for instance, as starch, of which here is a specimen, we find that starch contains exactly the same proportion of charcoal as woody matter; and that sugar, of which here is a specimen, contains very nearly the same proportion. Only a few lectures back, Professor Roscoe showed you that when sugar was acted upon by a certain chemical agent, it underwent a great swelling up, and became changed into a black spongy mass of charcoal, one of the constituent parts of the original sugar. And the proportion of charcoal, I repeat, in starch and sugar, is the same or very nearly the same as the proportion in pure woody matter. But we are acquainted with other vegetable substances which contain a much larger proportion of charcoal; such substances, for instance, as rosin and turpentine, and the oils expressed from seeds and fruits, as linseed oil, cabbage seed oil, and olive oil, &c. All these substances contain a much larger proportion of carbon than is contained in wood; and when they are set on fire, the smoke or soot they evolve in burning is some evidence to you of the large proportion of carbon which they originally contained. Now, just as certain vegetable products contain more carbon than wood, so there are other products which contain less; and among these I may refer to the different acids, or sour substances, which are found more particularly in the juices of unripe fruit. There, for example, is a fine specimen of tartaric acid—an acid which exists in the juice of the grape, and is produced on a large scale, in wine-growing countries, in the process of converting the juice of the grape into wine. In the same way we meet with citric acid in the juice of lemons, and other vegetable acids in other vegetable juices. Now all these vegetable acids contain a smaller proportion of carbon than is contained in wood. But having regard to the fact that the great mass of vegetable produce is composed of woody matter, or of substances such as starch and sugar, having substantially the same composition as wood; and having regard further to the circumstance that, of other vegetable products, some of them contain a larger and some of them a smaller proportion of carbon than is contained in wood, it results that the amount of carbon contained in woody matter may be taken as a fair representative of the amount of carbon contained in vegetable produce generally, viewed as a whole. We may say, then, that the dry organic substance of a growing plant contains on an average about 45 parts in 100, or rather less than half of its weight of charcoal.

Now it is found that on an acre of meadow land, or arable land, or wood land, there are produced in the course of a single season several thousand pounds weight of vegetable produce, containing not unfrequently as much as two thousand pounds weight of charcoal; while the charcoal of an average crop may be taken at over 1,600 pounds, or nearly three-quarters of a ton per acre. In illustration of the large quantities of vegetable matter, and of its constituent carbon, produced annually on an acre of land, let me call your attention to the table before you, which shows the numbers deduced by Messrs. Lawes & Gilbert, from their many determinations of the quantities and compositions of actual crops of wheat, barley, and oats, as representing the average weights of produce obtained under the ordinary system of rotation of crops and moderately good farming.

	Wheat.	*Barley.*	*Oats.*	
Gross produce	4,800	4,580	4,172	Pounds per acre.
Dry organic matter	3,869	3,714	3,328	
Carbon	1,734	1,663	1,495	

From results obtained then, on Mr. Lawes' experimental farm at Rothamstead—a farm conducted for the purpose of knowledge and not for the purpose of profit—Mr. Lawes and Dr. Gilbert have arrived at the conclusion that, taking one year with another, the average weight of wheat, including grain and straw, produced from an acre of land in a single season, amounts to 4,800 pounds. But the gross produce, as it is removed from the land, still contains, although seemingly dry, a considerable proportion of water; and if from the weight of gross produce there be deducted the weight of water which it contains, and if from the resulting weight of perfectly dry substance there be further deducted the weight of mineral matter or ash which it yields when burnt, there will be left 3,869 pounds as the weight of dry organic matter, and 1,734 pounds as weight of carbon contained in this organic matter. Similarly with regard to barley, the average weight of dry organic matter is 3,714 pounds per acre, including 1,663 pounds of carbon; while with regard to oats, the average weight of dry organic matter is 3,328 pounds per acre, including 1,495 of carbon. From results of this kind then, obtained in the cultivation of ordinary crops grown in a single season, you may form some notion of the large amounts of charcoal or carbon accumulated somehow in vegetable produce. And when we pass to the consideration of vegetation, not as we see it here, but as it manifests itself in the luxurious growth of tropical climates, the amounts of produce, and consequently of carbon contained in the produce, become yet more astounding. The celebrated naturalist and traveller, Humboldt, among his experiences in South America, records the existence there of forests so huge and so thick that monkeys might run on the tops of the trees for a hundred miles in a straight line, without a single break. And the millions of tons of dry wood, capable of being furnished by these forests, are composed, we know, to the extent of nearly half their weight, of charcoal! You perceive, then, that the growing plant, whether large or small, tree of the forest or grass of the field, may be regarded by us simply as a contrivance for producing carbon.

Reverting once more to the case of crops that are grown in a single season, it is evident that we remove from the land at the end of the season, several thousand pounds weight of vegetable produce which did not exist in the form of vegetable produce a few short months previously. Nevertheless the actual substance, or weight of matter, constituting this produce must have existed before the growth of the crop, although in a very different form. The several thousand pounds weight of wheat and barley and oats, grown on an acre of land in a single season, were not produced out of nothing; but were produced out of many thousand pounds weight of something pre-existing at the beginning of the season in the form of certain very different kinds of matter, out of which this matter of wheat and barley and oats was somehow constituted.

In the same manner, when, in course of time, the acorn grows into a tall oak tree, the several tons of matter, which go to compose the woody tissue of the full-grown oak, were not produced out of nothing, but out of many tons of matter which existed, though in a different form, before the acorn was even planted; and which have been accumulated, and transformed into woody matter, by the plant or tree, during the period of its many years growth. For the matter or substance of which the grown oak is finally composed, was not furnished by the acorn, but was furnished to the acorn, or young plant springing from the acorn, by external and very different forms of pre-existing matter. The problem then which I wish to put to you is this—what is the external matter or substance out of which the matter of wheat and barley and oats and hay and wood is ultimately produced? And more particularly, what is the sufficiently abundant substance containing carbon, out of which the carbon of all this vegetable produce is accumulated? for I need scarcely tell you that this carbon can only be got from some substance already containing carbon. Iron, you know, can only be produced from iron stone, or matter containing iron; copper can only be produced from copper ore, or matter containing copper; and in the same way, it is evident that the carbon of vegetable produce can only be obtained from matter containing carbon. What, then, is the primitive matter, containing carbon, out of which, in the course of the growth of the plant, this carbon of vegetable matter is ultimately produced?

It is well known that in forest lands, there exists a large amount of rich vegetable mould, the produce mainly of the decay of leaves; and this vegetable mould, which has received the name of *humus*, is found to be exceedingly rich in carbon. Further, richly carbonaceous vegetable matter of much the same kind is found in a sod of grass turf; and again matter of a not dissimilar kind is commonly added to arable land in the form of farmyard manure. Now, until about thirty years ago, the prevalent notion was that the carbon of vegetable produce was furnished to the plant by the carbonaceous matter of the soil called *humus*, or by matter of a similar nature. The vegetable matter of the growing plant was conceived to be formed out of pre-existing vegetable matter; and plants, like animals, were thus supposed to live upon food more or less resembling in composition the tissues or parts of the plants and animals respectively nourished. Now, notwithstanding the inadequacy of this notion, and notwithstanding its discordance with well-known facts, and with facts that had been for a long time well-known, it prevailed for very many years almost without question. About thirty or more years ago, however, the consideration of eminent agricultural chemists both in England and in France was directed to this view of the subject, and very serious doubts of its truthfulness began to be entertained. But the notion was not ultimately exploded until the year 1840, by the celebrated German chemist, Liebig. Now I do not propose to take you over all the arguments which may be employed to show the inadequacy of this *humus* theory to account for the accumulation of carbon in plants; but I will direct your attention for a short time to some of the most prominent reasons only. First of all it is probable that in certain rich soils there does exist an amount of humus, or such like vegetable matter containing a quantity of carbon sufficient to furnish the crop grown upon the soil, with the carbon which it ultimately contains. But this vegetable humus is exceedingly insoluble in water; and Liebig made the curious calculation that if all the rain, that falls upon the land during the period of the growth of the crop, were to remain upon the land and to dissolve as much of this humus matter as it is capable of dissolving, so as to become thoroughly saturated with humus; and then, if all this water, so saturated with humus, instead of draining away, as we know that most of it does, and evaporating from the surface, as we know that much of it does,—it all of this so saturated water were absorbed into the tissues of the plants, nevertheless there could not be dissolved in this water, and so supplied to the plant, a sufficient quantity of humus to furnish the quantity of carbon ultimately found in the crop. This of course does not amount to a demonstration that the plant cannot get its carbon from the humus of the soil; it is only a demonstration that the plant cannot get its carbon from this humus by the only process of absorption of which we have any knowledge; and accordingly it comes to this, that if plants do acquire their carbon from humus, they must get it therefrom in a manner with which we are totally unacquainted. But another argument, and a much more striking one, has reference to the fact, that the carbon of the crop may be increased two-fold, and even three-fold, by adding to the soil matters which contain no carbon whatever. And this is very well shown in the table before you, which records some more of the results of Messrs. Lawes and Gilbert's work at Rothamstead. This table gives an account of experiments made on a tolerably large scale of experimental farming during the year 1868 and the 16 years preceding, in the case of wheat, making 17 years altogether; for 1868 and the 16 years preceding, in the case of barley; and for 1868 and the 12 years preceding, in the case of hay:—

Rothamstead Field Experiments, 1868.

Results in Pounds per Acre.

Gross Produce.

	Wheat. 17 years.	Barley. 17 years.	Hay. 13 years.
Unmanured	2,434	2,532	2,558
Mineral Salts	2,912	3,260	3,914
Do. + Ammonia	6,394	5,821	5,921
Farmyard Manure......	6,059	5,903	4,804
Dry Organic Matter.			
Unmanured	1,963	2,054	1,995
Mineral Salts...........	2,347	2,645	3,053
Do. + Ammonia	5,149	4,720	4,618
Farmyard Manure......	4,883	4,788	——
Carbon.			
Unmanured	880	920	902
Mineral Salts...........	1,052	1,186	1,380
Do. + Ammonia	2,308	2,115	2,088
Farmyard Manure......	2,183	2,341	——

For the purpose of these experiments, considerable strips of land have been treated every year, each strip in exactly the same way, for 17 years continuously, up to and including the year 1868; and indeed the experiments have been similarly carried on, and with similar results, up to the present year, 1871; and are likely to be similarly carried, on with similar results, for a good many years yet to come. And I would call your attention simply, as time is getting on so rapidly, to the case of wheat. You will then be able to make out for yourselves what were the results of the similar experiments made with the crops of barley and hay. Messrs. Lawes and Gilbert have found that, taking the average of these 17 years, the gross amount of produce removed from an acre of continuously unmanured land, in the case of wheat, was 2,434 lbs., and that when from this gross produce they subtracted the amounts of water it contained, and of ash which it yielded, there remained 1,963 pounds of dry organic matter; and when they came to analyse these 1,963 pounds of dry organic matter, they found them to contain 880 pounds of carbon. And this, mind, is the average produce of 17 years continuous growth of wheat, on land to which nothing whatever was added. Now to a similar strip of land Messrs. Lawes & Gilbert added every year a certain quantity of mineral matter, corresponding to the ashes yielded by each successive crop removed; and on the strip so treated, the amount of gross produce was found to be increased from 2,434 pounds to 2,912 pounds, the amount of dry organic matter to be increased from 1,963 pounds to 2,347 pounds; and the amount of carbon to be increased from 880 pounds to 1,052 pounds. Now to another slip of land they added year by year exactly the same quantity of mineral matter, and in addition, a considerable quantity of ammonia salts,—the ammonia salts and mineral matter being alike absolutely free from carbonaceous organic matter. And in the case of this strip, they found that the amount of gross produce was increased to the surprising extent of 6,394 pounds, while the amount of dry organic matter was increased to 5,149 pounds, and the amount of carbon to 2,308 pounds. These results, you will observe, are fully as high—in most cases indeed somewhat higher—than are results obtained on a fourth strip of land, supplied year by year with an abundance of farm-yard manure, containing not only the mineral matter and ammonia added to the third strip, but rich also, as you know, in carbonaceous organic matter. It is inconceivable then that the plant should acquire its carbon from these organic matters of the soil, seeing that the amount of carbon in the crop may be increased twofold and in some cases nearly threefold, by adding to the soil substances such as mineral salts and ammonia which are entirely free from organic matter.

And this table further illustrates another point. We have admitted that the amount of humus or carbonaceous vegetable matter existing in the soil, might in some cases be sufficient to furnish the organic matter and the carbon for a single year's crop; but you observe that these 880 lbs. represent the average amount of carbon which has been produced for 17 years, and up to the present time, 21 years in succession; and which now seems to undergo from year to year no appreciable decrease. So that, although it is conceivable that the amount of humus in the soil might furnish the amount of carbon contained in a single crop, it is quite inconceivable that the original humus in the soil could furnish the carbon contained in a succession of crops for 17 years consecutively, and for the several years beyond that to which the experiment has now been carried, and for the indefinite number of years to which it will continue to be carried.

A still more cogent argument against this notion of the origin of the carbon of vegetation directly from organic matter in the soil, is afforded by the fact, established both by experiments specially made, and by the observation of nature, that plants and crops have been, and in many cases habitually are, grown upon soils which are either absolutely free, or which are practically, and to all intents and purposes, free from organic vegetable matter. Very many such experiments have been made by the French chemist, Boussingault, who has grown plants from seeds in artificially prepared soils, which had been subjected to a red heat, and from which the whole of the organic carbonaceous vegetable matter had been so removed and burned away; and yet the plants have not only grown in these soils, but have thriven and arrived at maturity. It is found, moreover, that many plants flourish best, in a state of nature, upon soils which, if not like the experimental soils of Boussingault, absolutely free from organic matter, are yet to all intents and purposes free. Thus, according to Darwin, rich harvests of maize are yielded in the interior of Chili and Peru by soils consisting of the merest quicksand, never enriched by manure. According to Colonel Campbell, the soil of the cinnamon gardens at Colombo, and where else the tree is cultivated, is pure quartz sand, as white as snow. Dr. Schleiden, again, observes that the oil palms of the western coast of Africa are grown in moist sea-sand; and that from the year 1821 to the year 1830, there were exported, as produce of these palm-trees, into England alone, 107,118,000 lbs. of palm oil, containing 76 million lbs. or 32 thousand tons of carbon; these thousands of tons of carbon being furnished by trees grown in a soil that was practically free from organic or carbonaceous matter of any kind whatever.

The only further argument with which I will trouble you is based on the observation that when plants are grown upon soils actually containing organic vegetable matter, so far from this vegetable matter in the soil being used up or decreased by any feeding of plants upon it, it is very much increased; so that the more vegetation we get from the surface the more humus we get accumulated in the soil; and we say, therefore, that so far from humus being the cause of vegetation, vegetation, on the contrary, is the cause of humus—the humus being produced chiefly by the decay of matter formed by vegetation.

I think, then, I have now brought before you, not all the arguments which might be adduced, but a sufficient number of them to satisfy you that the quantities of carbon accumulated in the crop or tree are not derived from carbonaceous matter existing in the soil; and seeing, in this way, that the solid substance of the earth does not suffice to furnish the carbon required, our attention is next directed to the liquid water which falls upon the earth, as a possible source of all this carbon. Now water—pure water, that is to say—is a substance which itself contains no carbon, and therefore cannot furnish any carbon to the plant. But certain natural waters are found to contain carbon in small quantity. For instance, the drainage water of peat bogs, and land-drainage water in general, contains a certain amount of carbonaceous organic matter derived from the land; but we have already seen that the land does not contain enough of this organic matter to furnish the carbon of vegetation directly, and cannot therefore furnish it indirectly through the intervention of water, taking up organic matter from the land.

But we find that rain water does contain carbon derived from another source. The rain, in falling through the air, acquires different impurities or additions from the air; and more especially it takes up a certain carbonaceous constituent of the air, on which I shall have to dwell more particularly in a minute or two's time. And I am not merely speaking of the rain which has fallen in great cities like this, and has so become contaminated with the carbonaceous soot and smoke of imperfectly burnt coal; but I am speaking of rain wherever it falls, whether on land or ocean, in town or country, at the end of a period of drought when the air is foul, as at the end of a period of wet, when it has been washed clean by continuous showers. Pure water I have said, is quite free from carbon in any form whatever. But all water that has been left in contact with the air, and especially water that has been condensed from and fallen through the air, contains, in small proportion, a particular definite compound of carbon, namely, carbonic acid, very different indeed in its nature from the indefinite compounds of carbon we have hitherto spoken of under the name of humus and vegetable organic matter.

In this way our attention is necessarily directed to the air as a possible source of all the millions of tons of carbon that are accumulated in forest trees and annual crops, growing on extensive areas of land. And although at first sight it must strike us all as being improbable — scarcely, we should think, possible — that any such quantity of solid carbon could be got from the fresh, transparent, intangible, fleeting air, yet, when we consider that upon setting fire to a heap of wood, or of the charcoal produced from wood, and letting it go on burning, it is mainly resolved into matters which are dispersed into the air, and are themselves aerial, we begin to perceive that the improbability is not in reality so great as at first it appears. When we burn, however large a quantity of wood, or of the charcoal produced from wood, there is nothing, you know, left behind but an insignificant quantity of ashes; there is no solid body formed; there is no liquid body formed; there is nothing but an aerial body formed, which is discharged into the air. Now this aerial body used actually to be called air—fixed air, to distinguish it from ordinary atmospheric air — but is now-a-days called carbonic acid gas. This carbonic acid gas is possessed of many very curious properties, and is more especially characterised by two properties, to which I am desirous of calling your attention. The first of these is the property which it has of extinguishing the flame of any burning body. On introducing a lighted gas jet into this bottle of carbonic acid gas, the flame, you observe, is at once extinguished. [An experiment illustrated this fact.] Another property of carbonic acid gas is the property it has of combining with lime, to produce carbonate of lime, or chalk. Now lime is a substance which dissolves in water to form a clear transparent liquid; but chalk is a substance that will not dissolve in water. You may observe, when you go to the sea-side, that the sea-salt remains dissolved in the water, while the sea-sand remains undissolved upon the shore. Now lime, like salt, dissolves in water, though, indeed, to a much less extent than salt, to furnish a perfectly bright solution known as lime-water. Chalk, on the other hand, like sand, is a substance which does not dissolve in water, but remains simply mixed up with it for a time, in the form of a white milky opaque liquid. The property, then, which carbonic acid has of combining with lime to produce chalk, is manifested to you in this way—that upon adding our clear lime water to the carbonic acid in the bottle, carbonate of lime or chalk is formed, and this chalk, not being soluble in water, is deposited so as to form the milky liquid which you see we have now produced. [Experiment made.] This other bottle also contains carbonic acid, but mixed with a considerable excess of air; so that in this case, there is not a sufficient amount of carbonic acid present to cause the extinction of flame. When I put in the gas-flame you see that it continues burning. But that the bottle really does contain some carbonic acid, I can show you by adding in this case also our lime water; and now, on shaking up the bottle, the lime water is at once rendered milky. You see in this way, we have two tests for carbonic acid. When the carbonic acid exists in a large proportion, it has the property of rendering lime water milky and also of extinguishing the flame; but when the proportion of carbonic acid is not sufficient to extinguish flame, we are able, nevertheless, to recognise its presence by the property it has of converting our clear lime water into an opaque white mixture of chalk and water.

Now I told you a few moments ago that the aerial substance into which solid charcoal was converted, when it underwent the process of being burnt in air, was carbonic acid gas. And, accordingly, when I put some pieces of red hot charcoal into this upright glass tube, through which a gentle current of air is being blown, so as to keep the charcoal burning, and when I cause this same air, now charged with the aerial matter furnished by the burning charcoal, to bubble up through lime water, you perceive the lime water is quickly rendered milky, showing you the formation of carbonate of lime or chalk, a substance producible only from lime by the addition of carbonic acid to it. [Experiment made.]

I want next to call your attention for a moment to what takes place in the act of burning. Ordinary atmospheric air consists substantially of two distinct kinds of air or gas—one is called nitrogen and the other oxygen. Now when our charcoal or carbon burns in the open air, or in the tube through which we are blowing a current of air, that carbon enters into combination with the oxygen of the air, and forms a compound of oxygen and carbon, which is, indeed, sometimes called oxide of carbon, but more commonly, as I have said, carbonic acid. If, instead of burning our carbon in the air, which contains only one-fifth of its bulk of oxygen, we burn it in pure oxygen, it burns with greatly increased brilliancy, but furnishes exactly the same product, namely, carbonic acid. Here we have the chalk, which we produced a moment ago, by taking lime water and adding to it the carbonic acid we made by combining our carbon or charcoal with the oxygen of the air; and here we have some charcoal that is already ignited; and on passing the pure oxygen gas over it, you observe the very greatly increased brilliancy with which, under these circumstances, it burns. We next cause the air which is left by this burning of the charcoal in oxygen, to bubble up through lime water; and the abundant presence in it of oxide of carbon, or carbonic acid gas, is at once manifested to you by the immediate deposition of carbonate of lime or chalk. [Experiment made.] I venture to impress upon your attention the fact that carbonic acid gas is a compound of the solid substance carbon with the aerial or gaseous substance oxygen; and that when carbon or charcoal burns in ordinary air, it unites with the oxygen of the air to form the aerial substance, carbonic acid gas, which is discharged into the air.

Now, if we reflect for a minute or two, we shall see that inasmuch as wood and charcoal, and I may add coal (although we are not talking about coal on the present occasion), when they are burned, produce the aerial substance, oxide of carbon, or carbonic acid; and inasmuch as they discharge this carbonic acid into the air; it is a matter of necessity that the air itself should contain some carbon in this particular form. And not only is it a matter of necessity that it must contain, but it is also a matter of easy experimental demonstration that it actually does contain this aerial compound of carbon, namely, carbonic acid. One rough way of establishing the fact is this:—If we take some clear, transparent, colourless lime water, and pour it into a dish, and expose it to the air for several hours, the top layer of the lime water in contact with the air, gradually becomes converted into an opaque white scum of chalk; and chalk, we know, is producible only from lime, by the acquisition of carbonic acid, which can in this case have been acquired from no other source than from the air with which the surface of lime water was in contact. That the air, then, must contain some carbonic acid is a matter of argument; and that it does contain some is a matter of experimental fact.

But although the air does, beyond question, contain carbon in the form of carbonic acid, the proportion that it contains is exceedingly small; as you may infer from the length of time we require to keep lime water exposed to the air, in order for it to acquire a thick scum; and from the circumstances that we may even blow a current of air through lime water for a considerable time, without producing any sensible effect. [Further experiments.] We are now blowing ordinary air through this lime water; and I might go on blowing for a great length of time, before I should get any appreciable turbidity. This shows you that although the air does contain carbonic acid, it must contain it in an exceedingly small proportion. We require, then, to know what this proportion is. Now it is found that the amount of carbonic acid gas in the open air varies within a certain range, but that it amounts on the average to somewhat less than one-half part in a thousand parts by volume: or we may say more accurately that it constitutes four parts in ten thousand. Here the composition of the air is written up:—

COMPOSITION OF AIR.

$\frac{1}{5}$	Oxygen........................	210	Parts per 1000.
$\frac{4}{5}$	Nitrogen	790	
	Carbonic acid ....nearly	$\frac{1}{2}$	

Nitrogen gas 790 parts, or about four-fifths; oxygen 210 parts, or about one-fifth; and carbonic acid gas not quite one-half part. If it contained exactly one-half part, that would of course be five parts, instead of only four parts, in 10,000. Now the expression of four parts in 10,000 does not convey a very definite idea to the mind, but I may perhaps render it more definite to you in this way. Imagine four farthings among ten thousand farthings, or, what comes to the same thing, imagine one penny piece among two thousand five hundred penny pieces. If you were to take 2,500 penny pieces and pile them on the top of each other you would produce a column of pence some 15 or 16 feet high—about as high as this rod, and considerably more than twice the height of the tallest man in the room—and if from such a pile of 2,500 pence you were to remove one penny, that would represent to you the bulk of carbonic acid gas contained in a similar column of air: that is, the one part of carbonic acid in 2,500 parts of air, or, of course, four parts of carbonic acid in 10,000 of air. But although the proportion is exceedingly small, a little consideration will suffice to show us that the absolute quantity is exceedingly great. I have said that the proportion is four parts of carbonic acid in 10,000. Now, consider for a moment what is the quantity existing in the air of a moderately sized room. A room 25 feet long, 25 feet broad, and 16 feet high, would hold 10,000 cubic feet of air, containing, of course, four cubic feet of carbonic acid gas. And these four cubic feet of carbonic acid gas would weigh 2,465 grains, and contain 607 grains of charcoal—that is to say, the quantity of charcoal I now hold in my hand (about the size of an egg). This Town Hall holds, in round numbers, about 150,000 cubic feet of air, and, consequently, the amount of carbonic acid contained in it will be fifteen times four, or 60 cubic feet; and the amount of charcoal contained in this carbonic acid will be fifteen times 607 grains, or the weight of the bundle of charcoal, considerably more than a pound and a quarter, I now hold in my hand. And when we pass from the consideration of the air in rooms, small or large, to the consideration of the air pressing everywhere upon the surface of the earth, we shall get to results great almost beyond conception. You know that the weight of air overlying every square inch of the earth's surface is 15 lbs., and that this is what we mean by saying, as we commonly do, that the atmospheric pressure is 15 lbs. on the square inch. Now, 15 lbs. on the square inch is 2,160 lbs. on the square foot; so that every square foot of the earth's surface has overlying it 2,160 lbs. of air, and these

2,160 lbs. of air contain about 1½ lbs. of carbonic acid gas, equivalent to very nearly half a pound of carbon. I showed you a few minutes ago that there are produced, in many cases, from an acre of land, some 2,000 lbs. of carbon in a single season. Now, reckoning from feet to acres, we find that not merely at the first instant of the growth of the crop, but that during every instant of the period of its growth—at the end no less than at the beginning—there is overlying the acre of land furnishing those 2,000 lbs. of carbon some 20,000 lbs. of carbon in the form of carbonic acid, existing, though in such small proportion, in the air. Calculating in this way, we find that the amount of carbon existing in the atmosphere, in the form of carbonic acid gas, is not only enormous in its absolute quantity, but that it is far in excess of the wants of vegetation, and far in excess, moreover, of the quantities of carbon contained in all living beings, both plants and animals, existing on the surface of the earth, and in inflammable carbonaceous minerals, such as coal, which exist buried beneath the surface.

In this way, then, we come to the conclusion that by their contact with the air, plants are at any rate afforded the opportunity of getting that carbon, which constitutes so large a proportion of their structure. The question now is, do they avail themselves of the opportunity afforded them—do they actually absorb carbonic acid gas from the atmosphere, and extract the carbon of the gas which they absorb. Now, the evidence on this point dates from the latter end of the last century; when it was ascertained by the older chemical philosophers, and more particularly Dr. Priestley, and by Saussure and Sennebier, that when growing plants are exposed, under the influence of sunlight, to air containing carbonic acid, they do as a matter of fact absorb some of this carbonic acid; and, that having absorbed it, they do not discharge it again into the air, but instead discharge only its one constituent oxygen; the necessary inference being that its other constituent, carbon, is retained in their tissues. Here you have an imitation of one of these early experiments, showing the removal of carbonic acid from, and the restoration of oxygen to, a confined amount of air, by means of a fresh sprig of mint or parsley. [Experiment.] Of late years, the subject has been investigated with great care and elaboration by the French chemist Boussingault, who has shown not merely that plants have this property of absorbing carbonic acid from the air, and of discharging the constituent oxygen of the gas into the air and retaining the constituent carbon of the gas in their tissues, but that they do this with extreme rapidity. The mode of experimenting which he adopted is illustrated to you here. Taking a growing plant, such as this, he enclosed one or more branches of the plant in a glass vessel, and through that glass vessel passed a current of air, which was subjected to analysis both before and after its passage through the vessel. [Experiment to show the process of sucking air through a globe holding the branch of a growing plant.]

I cannot trouble you at this late hour with the details of his experiments, but will call your attention only to one or two of the results. In the case of some oleander leaves, enclosed in a glass globe of this kind, he found, by measuring the leaves and analyzing the air passing over them, that under exposure to sunlight, there was an absorption of carbonic acid from the air at the rate of $56\frac{1}{2}$ cubic inches, or a fixation of carbon at the rate of $11\frac{1}{2}$ grains per hour, per square yard of leaf surface exposed, showing the extreme rapidity with which the absorption of carbonic acid from the air and the retention of its carbon actually took place. Moreover, he made a great number of other experiments, that I cannot refer to in detail, which established not merely the general fact that plants can absorb carbonic acid gas from the air, and can discharge the oxygen and retain the carbon of the gas so absorbed; but, operating with seeds, and more particularly with peas and vetches, and growing them in artificial soils quite free from carbon, he found that the entire weight of the carbon ultimately accumulated in the grown plant was identical with the weight of carbon contained in the carbonic acid gas which the growing plant had absorbed from, and the oxygen of which alone it had discharged back into the atmosphere. In this way, then, Boussingault established the important fact that plants acquire their carbon from the carbonic acid of the abundant ever-changing air, in which they are grown.

We have thus considered the source from which the carbon of vegetation is obtained. But we have yet another point to consider, and that is—what becomes of it? Now, a little consideration, I think, will show you, that just as the carbon of vegetation is produced from the aerial substance, carbonic acid gas, so the destiny, if I may so say, of the carbon of vegetation is to be reconverted into this same aerial substance. First of all, let us see what becomes of the most abundant of vegetable products, namely, wood. You know that a great deal of fresh wood is put to no intermediate use, but is at once chopped up for the fire; and when this wood is burned, its carbon combines with the oxygen of the

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from the lungs in the act of respiration. Another portion gets accumulated in his body, whereby it is fattened and rendered fit to become the food of the flesh feeder. And when the flesh-feeding animal eats up the bodies of the vegetable feeders, their vegetable-derived fat and lean that becomes assimilated in his body is found to suffer there a speedy oxidation. Store animals, intended for food, increase gradually in weight; but hard-working animals, whether vegetable feeders like the horse, or mixed feeders like ourselves, or animal feeders like the hound, go on eating day after day, year after year, without any sensible increase of bodily weight—the carbonaceous matter of the food continually eaten, sufficing only to replace that continually destroyed in the process of gradual oxidation or burning away to which the substance of our blood and tissues is ever subjected, in order that the temperature and activity of our bodies may be maintained. Accordingly, we find the air expired from the lungs of both vegetable and animal feeders, to be charged with carbonic acid, produced by the oxidation of carbonaceous organic matter—furnished directly or indirectly by the vegetable kingdom, out of aerial carbonic acid, and restored by the animal back into the same carbonic acid. On breathing into this lime water for a little time [Experiment made] we have shortly a dense milky deposit of carbonate of lime, or chalk, produced—the carbonic acid, thus serving to convert the lime into chalk, being supplied by the oxidation within our bodies of carbonaceous organic matter, accumulated in the first instance by the growing vegetable. So that in the case of food consumed in our bodies, as in the case of wood consumed on our fires, the carbon of vegetable produce is directly or indirectly converted back into the aerial carbonic acid from which it was originally formed. I need only detain you a few minutes longer. When we burn charcoal in the fire, it evolves in the act of burning a considerable amount of heat. The temperature produced in this way varies considerably, accordingly to circumstances. We may have a fire in which the charcoal is just glowing, and the temperature comparatively low—hardly sufficient to raise a piece of metal to a visible red heat; and with another quantity of charcoal on the fire, urged by the blast of powerful bellows, we may obtain an intense degree of temperature, capable of melting that most difficultly fusible metal—wrought iron. Now, whether we obtain a high or a low degree of temperature depends mainly upon the rapidity with which we burn the charcoal. If we take a quantity of charcoal and burn it away slowly, it gives out its air, and is so re-converted into carbonic acid. Again, a considerable quantity of wood is manufactured into charcoal, and this charcoal is then burned and so converted into carbonic acid. And with regard to the diverse applications of wood, we know that much of it is made into furniture, and that this furniture does not last for ever, but finds its way from the best rooms to the attics, and at last to the fireplace. Wood is also used for the building of ships, and in the construction of houses; but in course of time, the ships get broken up, and the houses get pulled down, and the wood of both ships and houses becomes ultimately sold for firewood, and then the carbon of this wood gets burnt into the very carbonic acid from which it was long years before produced. In other cases, the wood or woody matter, although it never undergoes a process of actual burning, nevertheless undergoes an equivalent process of oxidation. At the present season, or but very recently, we had large falls of autumn leaves, and those leaves are still accumulated in many places, and undergoing not burning but decay. Now the process of decay consists really in a slow combination of the carbon of the leaves with the oxygen of the air, whereby carbonic acid is produced. Here we have some fallen leaves in a flask; the air of which you will find is now sufficiently charged with carbonic acid gas, produced by the union of the carbon of the decaying leaves with the oxygen of the original air, as to be no longer capable of maintaining the flame of a taper or gas jet. [Experiment.] The moment I introduce the taper you see that its flame is at once extinguished. Here again we have some sawdust which is undergoing the same process. The moist sawdust gradually undergoes decay; whereby the oxygen of the air is gradually absorbed and the carbon of the sawdust gradually converted into carbonic acid, so that the flame of the taper is in this case also at once extinguished. [Experiment.] And, indeed, woody matter of all kinds exposed to the weather, to the action, that is, of air and water, gradually undergoes decay or oxidation, and, if left to itself, crumbles away, and in course of time, disappears altogether, being converted into the invisible aerial matter carbonic acid.

When we pass from the consideration of wood to that of the hay and grain eaten by different classes of animals, and mark what becomes of all this food, we shall find that so much of it as is both eaten and made part of the blood and substance of the vegetable feeding animal, undergoes one or other of two principal changes. A large portion of it gets oxidised in the body of the vegetable-feeder, with production of carbonic acid, discharged principally

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heat over a length of time, and at no one instant is there a very high degree of temperature; but if we take that same quantity of charcoal and, setting it on fire, burn it rapidly away, we get a very high degree of temperature; so that the degree of temperature produced by the burning of charcoal depends upon the quantity of charcoal that is burned within a limited space and time. But if we take any quantity of charcoal, say an ounce, and burn it in one case very slowly, and in another case very quickly, and do this in a vessel surrounded on all sides by water, so that all the heat produced in the hour say, or in the few minutes, shall be taken up and retained in the water, we shall find that the quantity of heat imparted to the water is exactly the same in both cases. So that whether we burn the charcoal quickly, so as to get a high temperature, or burn it slowly, so as to get a low temperature, the quantity of heat which that charcoal produces in burning, as measured by the quantity of water it is capable of heating through a given rise of temperature is exacty the same in both cases. And this is true, not only when we actually burn charcoal upon a fire, but in all cases of the conversion of carbon or charcoal into carbonic acid, by the act of oxidation. And indeed the temperature of our own bodies is maintained in a great measure by the slow oxidation, or quasi-combustion of carbonaceous matter going on within us. Whether, then, we burn our charcoal in an open fire rapidly, so as to produce a high temperature, or whether we burn it in our bodies slowly, so as to produce a low temperature, we find that for so much carbon converted into carbonic acid, there is exactly the same quantity of heat produced. For example—In burning one ounce of charcoal into about 3½ ounces of carbonic acid, a quantity of heat is evolved, sufficient to raise the temperature of 100 pounds, or 10 gallons of water ten degrees; and this, whether the act of burning takes place quickly or slowly, with production of a high or of a low degree of temperature. Now it is a well-established law in chemistry, established, I mean, by the careful examination of a great number of instances, that whenever heat is given out by the act of combination, as of charcoal and oxygen to produce carbonic acid, exactly the same quantity of heat is absorbed in the corresponding act of separation, as of charcoal and oxygen, out of carbonic acid. The conversion of carbon into carbonic acid, on the fire, is a burning process, attended with the evolution of heat. The conversion of carbonic acid into carbon and oxygen, in the tissues of a growing plant under the influence of the sun's rays, is an unburning process attended, not with an evolution of heat, but with an absorption of heat from the solar rays: and it follows that there is just as much disappearance of solar heat in the production of the charcoal, as there is evolution of heat in the ultimate combustion of the charcoal produced. So that, you see, the quantity of heat which the charcoal eventually gives out in burning on the fire, is the exact equivalent of the quantity of solar heat which disappeared in the act of growth of the wood, from which the charcoal furnishing our fire was obtained.

SCIENCE LECTURES FOR THE PEOPLE.

THIRD SERIES—1871.

THE UNCONSCIOUS ACTION OF THE BRAIN.

A LECTURE

BY DR. CARPENTER, F.R.S.,

REGISTRAR OF THE UNIVERSITY OF LONDON.

Delivered in the Hulme Town Hall, Manchester, December 1st, 1871.

MANY of you, I doubt not, will remember that I had the pleasure of addressing you in this hall some months ago, with reference to researches which I had a share in carrying on into the Depths of the Ocean; when I endeavoured to give you some insight into the conditions of the sea bottom as regards temperature, pressure, animal life, and the deposits now in process of formation upon it.

Now I am going this evening to carry you into quite a different field of inquiry, an inquiry which I venture to think I have had some share in myself promoting, into what goes on in the Depths of our own Minds. And I think I shall be able to show you that some practical results of great value in our own mental culture, as training and as discipline, may be deduced from this inquiry. I shall begin with an anecdote that was related to me after a lecture which I gave upon this subject about five years ago, at the Royal Institution, in London. As I was coming out from the lecture-room, a gentleman stopped me and said, "A circumstance occured recently in the North of England, which I think will interest you, from its affording an exact illustration of the doctrine which you have been setting forth to-night." The illustration was so apposite, and leads us so directly into the very heart of the inquiry, that I shall make it, as it were, the text for the commencement of this evening's lecture. The Manager of a bank in a certain large town in Yorkshire could not find a key which gave access to all the safes and desks in the bank. This key was a duplicate key, and ought to have been found in a place accessible only to himself and to the assistant-manager. The assistant manager was absent on a holiday in Wales, and the manager's first impression was that the key had probably been taken away by his assistant in mistake. He wrote to him, and learned to his own great surprise and distress that he had not got the key, and knew nothing of it. Of course, the idea that the key, which gave access to every valuable in the bank, was in the hands of any wrong person, having been taken with a felonious intention, was to him most distressing. He made search everywhere, thought of every place in which the key might possibly be, and could not find it. The assistant-manager was recalled, both he and every person in the bank were questioned, but no one could give any idea of where the key could be. Of course, although no robbery had taken place up to this point, there was the apprehension that a robbery might be committed after the storm, so to speak, had blown over, when a better opportunity would be afforded by the absence of the same degree of watchfulness. A first-class detective was then brought down from London, and this man had every opportunity given him of making inquiries; every person in the bank was brought up before him; he applied all those means of investigation which a very able man of this class know how to employ; and at last he came to the manager and said, "I am perfectly satisfied that no one in the bank knows anything about this lost key. You may rest assured that you have put it somewhere yourself, and you have been worrying yourself so much about it that you have forgotten where you put it away. As long as you worry yourself in this manner, you will not remember it; but go to bed to-night with the assurance that it will be all right; get a good night's sleep; and in the morning I think it is very likely you will remember where you have put the key." This turned out exactly as it was predicted. The key was found the next morning in some extraordinarily secure place which the Manager had not previously thought of, but in which he then felt sure he must have put it himself.

Now, then, ladies and gentlemen, this you may say is merely a remarkable case of that which we all of us are continually experiencing; and so I say it is. Who is there among you who has not had occasion some time or other to try to recall something to his (or her) mind which he has not been able to bring to it? He has seen some one in the street, for instance, whose face he recognises and says, "I ought to know that person;" and thinks who it can be, going over (it may be) his whole list of friends and acquaintances in his mind, without being able to recall who it is; and yet, some hours afterwards, or it may be the next day, it flashes into his mind who this unknown person is. Or you may want to remember some particular and recent event; or it may be, as I have heard classical scholars say, to recall the source of a classical quotation. They "cudgel their brains," to use a common expression, and are unsuccessful; they give their minds to something entirely different; and some hours afterwards, when their thoughts are far away from the subject on which they had been concentrating them with the idea of recovering this lost clue, the thing flashes into the mind. Now this is so common an occurrence, that we pass it by without taking particular note of it; and yet I believe that the inquiry into the real nature of this occurrence may lead us to understand something of the inner mechanism of our own minds which we shall find to be very useful to us.

There is another point, however, arising out of the story which I have just told you, upon which again I would fix your attention:—Why and how did the detective arrive at this assurance from the result of his inquiries? It was a matter of judgment based upon long practice and experience, which had given him that kind of insight into the characters, dispositions, and nature of the persons who were brought before him, which only those who have got that faculty as an original gift, or have acquired it by very long experience, can possess with anything like that degree of assurance which he was able to entertain. I believe that this particular power of the detective is, so to speak, an exaltation in a particular direction of what we call "common sense." We are continually bringing to the test of this common sense a great number of matters which we cannot decide by reason; a number of matters as to which, if we were to begin to argue, there may be so much to be said on both sides, that we may be unable to come to a conclusion. And yet, with regard to a great many of these subjects—some of which I shall have to discuss in my next lecture—we consider that common sense gives us a much better result than any elaborate discussion. Now I will give you an illustration of this which you will all readily comprehend. Why do we believe in an external world? Why do I believe that I have at present before me many hundreds of intelligent auditors, looking up and listening to every word that I say? Why do you believe that you are hearing me lecture? You will say at once that your common sense tells you. I see you; you see and hear me; and I know that I am addressing you. But if once this subject is logically discussed, if once we go into it on the basis of a pure reasoning process, it is found really impossible to construct such a proof as shall satisfy every logician. As far as my knowledge extends, every logician is able to pick a hole in every other logician's proof. Now here we have then a case obvious to you all, in which common sense decides for us without any doubt or hesitation at all. And I venture to use an expression upon this point which has been quoted with approval by one of the best logicians and metaphysicians of our time, Archbishop Manning; who cited the words that I have used, and entirely concurred in them, namely, that "in regard to the existence of the external world the common-sense decision of mankind is practically worth more than all the arguments of all the logicians who have discussed the basis of our belief in it." And so, again, with regard to another point which more nearly touches our subject to-night—the fact that we have a Will which dominates over our actions; that we are not merely the slaves of automatic impulse which some philosophers would make us—"the decision of mankind (as Archbishop Manning, applying my words, has most truly said) derived from consciousness of the existence of our living self or personality, whereby we think, will, or act, is practically worth more than all the arguments of all the logicians who have discussed the basis of our belief in it."

Now, then, my two points are these—What is the nature of this process which evolves, as it were, this result unconsciously to ourselves, when we have been either asleep, as in the case of the banker, or, as in the other familiar case I have cited, when we have been giving our minds to some other train of thought in the interval? What is it that brings up spontaneously to our consciousness a fact which we endeavoured to recall with all the force of our will, and yet could not succeed?

And then again:—What is the nature of this Common Sense, to which we defer so implicitly and immediately in all the ordinary judgments of our lives?

Now, in order that we may have a really scientific conception of the doctrine I would present to you, I must take you into an inquiry with regard to some of the simpler functions of our bodies, from which we shall rise to the simpler actions of our minds. You all know that the Brain, using the term in its general sense, is the organ of our Mind. That every one will admit. We shall not go into any of the disputed questions as to the relations of Mind and Matter; for the fact is that these are now coming to take quite a new aspect, from Physical philosophers dwelling so much more upon Force than they do upon Matter, and on the relations of Mind and Force, which every one is coming to recognise. Thus when we speak of nerve-force and mind as having a most intimate relation, no one is found to dispute it; whereas when we talk about Brain and Mind having this intimate relation, and Mind being the function of the brain, there are a great many who will rise up against us and charge us with materialism, and atheism, and all the other deadly sins of that kind. I merely speak of the relation of the brain to the mind, as the instrument through which the mind operates and expresses itself. We all know that it is in virtue of the impressions carried to the brain through the nerves proceeding from the different sensory organs in various parts of the body, that we become conscious of what is taking place around us. And, again, that it is through the nerves proceeding from the brain that we are able to execute those movements which the Will prompts and dictates, or which arise from the play of the Emotions. But I have first to speak of a set of lower centres, those which the Will can to a certain extent control, but which are not in such immediate relation to it as is the brain. You all know that there passes down our backbone a cord which is commonly called the "Spinal Marrow." Now this spinal marrow gives off a pair of nerves at every division of the backbone; and these nerves are double in function—one set of fibres conveying impressions from the surface to the spinal cord, the other motor impulses from the spinal cord to the muscles. Now it used to be considered that this Spinal Cord (I use the term spinal cord, which is the same as spinal marrow, because it is just as intelligible and more correct) was a mere bundle of nerves proceeding from the brain; but we have long known that that is not the case, that the spinal cord is really a nervous centre in itself, and that if there were no brain at all the spinal cord would still do a great deal. For example, there have been infants born without a brain, yet these infants have breathed, have cried, have sucked, and this in virtue of the separate existence and the independent action of this spinal cord. Let us analyse one or two of these actions. We will take the act of Sucking as the best example, because experiments have been made upon young puppies, by taking out the brain, and then trying whether they would suck; and it was found that putting between the lips the finger moistened with milk or with sugar and water, produced a distinct act of suction, just as when an infant is nursed. Now how is this? It is what we call a "reflex action." I shall have a good deal to say of reflex action higher up in the nervous system, and therefore I must explain precisely what we mean by that term. It is just this. There is a certain part of the spinal cord, at the top of the neck, which is what we call a ganglion, that is, a centre of nervous power: in fact the whole of the spinal cord is a series of such ganglia; but this ganglion at the top of the neck is the one which is the centre of the actions which are concerned in the act of sucking. Now this act of sucking is rather a complicated one, it involves the action of a great many muscles put into conjoint and harmonious contraction. We will say then that here is a nervous centre. [Dr. Carpenter made a sketch upon the black board.] These are nerves coming to it, branches from the lips; and these another set going to the muscles concerned in the movement of sucking from it. Thus, by the conveyance to the ganglionic centre of the impression made on the lips, a complicated action is excited, requiring the combination of a number of separate muscular movements. We will take another example—the act of Coughing. You feel a tickling in your throat, and you feel an impulse to cough which you cannot resist; and this may take place not only when you are awake and feel the impulse, but when you are asleep and do not feel it. You will often find persons coughing violently in sleep, without waking or showing any sign of consciousness. Here, again, the stimulus, as we call it, produced by some irritation in the throat, gives rise to a change in the nerves going towards the ganglionic centre, which produces the excitement of an action in that centre that issues the mandate, so to speak, through the motor nerves to the muscles concerned in coughing, which actions have to be united in a very remarkable manner, which I cannot stop to analyse; but the whole action of coughing has for its effect the driving out a violent blast of air, which tends to expel the offending substance. Thus when anything "goes the wrong way," as we term it,—a crumb of bread, or a drop of water finding its way into the windpipe, then this sudden and violent blast of air tends to expel it.

Now these are examples of what we call "reflex action"; and this is the character of most of the movements that are immediately concerned with the maintenance of the vital functions. I might analyse other cases. The act of breathing is a purely reflex action, and goes on when we are perfectly unconscious of exerting any effort, and when our attention is entirely given up to some act or thought; and even when asleep the act of breathing goes on with perfect regularity, and if it were to stop, of course the stoppage would have a fatal effect upon our lives. But most of these reflex actions are to a certain degree placed under the control of our Will. If it were not for this controlling power of will, I could not be addressing you at this moment. I am able so to regulate my breath as to make it subservient to the act of speech; but that is the case only to a certain point. I could not go on through a long sentence without taking my breath. I am obliged to renew the breath frequently, in order to be able to sustain the circulation and other functions of life. But still I have that degree of control over the act of respiration, that I can regulate this drawing in and expulsion of the breath for the purposes of speech. This may give you an idea of the way in which Mental operations may be independent of the Will, and yet be under its direction. To this we shall presently come.

Now those reflex actions of the spinal cord, which are immediately and essentially necessary to the maintenance of our lives, take place from the commencement without any training, without any education; they are what we call "instinctive actions;" the tendency to them is part of our nature; it is born with us. But, on the other hand, there are a great many actions which we learn, to which we are trained in the process of bodily education, so to speak, and which, when we have learned them, come to be performed as frequently, regularly, methodically, and unconsciously as those of which I have spoken. This is the case particularly with the act of walking. You all know with how much difficulty a child is trained to that action. It has to be learned by a long and painful experience, for the child usually gets a good many tumbles in the course of that part of its education; but when once acquired it is as natural as the act of breathing, only it is more directly under the control of the will; yet so completely automatic does it become, that we frequently execute a long series of these movements without any consciousness whatever. You start in the morning, for instance, to go from your home to your place of employment; your mind is occupied by a train of thought, something has happened which has interested you, or you are walking with a friend and in earnest conversation with him; and your legs carry you on without any consciousness on your part that you are moving them. You stop at a certain point, the point at which you are accustomed to stop, and very often you will be surprised to find that you are there. While your mind has been intent upon something else, either the train of thought which you were following out in your own mind, or upon what your friend has been saying, your legs move on of themselves, just as your heart beats, or as your muscles of breathing continue to act. But this is an acquired habit;

this is what we call a "secondarily automatic" action. Now that phrase is not very difficult when you understand it. By automatic we mean an action taking place of itself. I daresay most of you have seen automata of one kind or another, such as children's toys and more elaborate pieces of mechanism, which, being wound up with a spring, and containing a complicated series of wheels and levers, execute a variety of movements. In each of the Great Exhibitions there have been very curious automata of this kind. We speak then of the actions being "automatic," when we mean that they take place of themselves, without any direction on our own parts; such as the act of sucking in the infant, the acts of respiration and swallowing, and others which are entirely involuntary, and are of this purely reflex character. Now those are "primarily automatic," that is originally automatic; we are born with a tendency to execute them; but the actions of the class I am now speaking of are executed by the same portion of the nervous system—the spinal cord—and are "secondarily automatic," that is to say, we have to learn them, but when once learned, they come very much into the condition of the others, only we have some power of will over them. We start ourselves in the morning by an act of the will; we are determined to go to a particular place; and it may be that we are conscious of these movements over the whole of our walk; but, on the other hand, we may be utterly unconscious of them, and continue to be so until either we have arrived at our journey's end or begin to feel fatigued. Now when we begin to feel fatigued, we are obliged to maintain the action by an effort of the will; we are no longer unconscious, and we are obliged to struggle against the feeling of fatigue, to exert our muscles in order to continue the action.

Now, having set before you this reflex action of the Spinal Cord, you will ask me perhaps what is the exciting cause of this succession of actions in walking. I believe it is the contact of the ground with the foot at each movement. We put down the foot, that suggests as it were to the spinal cord the next movement of the leg in advance, and that foot comes down in its turn, and so we follow with this regular rhythmical succession of movements.

We next pass to a set of centres somewhat higher, those which form the summit, as it were, of this spinal cord, which are really imbedded in the brain, but which do not form a part of that higher organ, which is in fact the organ of the higher part of our mental nature, yet which are commonly included in that which we designate the brain. In fact, the anatomist who only studies the human brain is very liable to be misled in regard to the character of these different parts, by the fact that the higher part—that which we call the Cerebrum—is so immensely developed in Man, in proportion to the rest of the animal creation, that it envelopes, as it were, the portion of which I am about to speak, concealing it and reducing it apparently to the condition of a very subordinate part; and yet that subordinate part is, as I shall show you, the foundation or basis of the higher portion—the Cerebrum itself. The brain of a Fish consists of very little else than a series of these ganglia, these little knots—the word "ganglion" means "knot," and the ganglia in many instances, when separated, are little knots, as it were, upon the nerves. The brain of a fish consists of a series of these ganglia, one pair belonging to each principal organ of sense. Thus we have in front the ganglia of smell, then the ganglia of sight, the ganglia of hearing, and the ganglia of general sensation. These constitute almost entirely the brain of the fish. There is scarcely anything in the brain of the fish which answers to the Cerebrum or higher part of the brain of man. I will give you an idea of the relative development of these parts. [Dr. Carpenter made other sketches on the black board to represent these ganglia of sense in man and the lower animals.] Now, the Cerebrum in most fishes is a mere little film, overlaying the sensory tract, but in the higher fish we have it larger; in the reptiles we have it larger still; and in birds we have it still larger; in the lower mammalia it is larger still; and then as we ascend to man this part becomes so large in proportion that my board will not take it in. This Cerebrum, this great mass of the brain, at the bottom of which these Ganglia of Sense are buried, as it were, so overlies and conceals them that their essential functions for a long time remained unknown. Now, in the Cerebrum, the position of the active portion, what we call the ganglionic matter, that which gives activity and power to these nervous centres, is peculiar. In all ganglia this "grey" matter, as it is called, is distinct from the white matter. In ordinary ganglia, this grey matter lies in the interior as a sort of little kernel; but in the Cerebrum it is spread out over the surface, and forms a film or layer. If any of you have the curiosity to see what it is like, you have only to get a sheep's brain and examine it, and you will see this film of a reddish substance covering the surface of the Cerebrum. In the higher animals and in man this film is deeply folded upon itself, with the effect of giving it a very much more extended surface, and in this manner the blood vessels come into relation with it; and it is by the changes which take place between this nervous matter and the blood that all our nervous power is produced. You might liken it roughly to the galvanic battery by which the electric telegraph acts, the white or fibrous portion of the brain and nerves being like the conducting wires of the telegraph. Just as the fibres of the nerves establish a communication between the organs of sensation and the ganglionic centres, and again between the ganglionic centres and the muscles, so do the white fibres which form a great part of the brain, establish a communication between the grey matter of the convoluted or folded surface of the Cerebrum and the Sensory Ganglia at its base. Now I believe that this sensory tract which lies at the base of the skull is the real *Sensorium*, that is, the centre of sensation; that the brain at large, the cerebrum, the great mass of which I have been speaking, is not in itself the centre of sensation; that, in fact, the changes which take place in this grey matter only rise to our consciousness—only call forth our conscious mental activity—when the effect of those changes is transmitted downwards to this Sensorium. Now this Sensorium receives the nerves from the organs of sense. Here, for instance, is the nerve from the organ of smell, here from the eye, and here from the body generally (the nerves of touch), and here the nerves of hearing—every one of these has its own particular function. Now these Sensory ganglia have in like matter reflex actions. I will give you a very curious illustration of one of these reflex actions. You all know the start we make at a loud sound or a flash of light; the stimulus conveyed through our eyes from the optic nerve to the central ganglion, causing it to send through the motor nerves a mandate that calls our muscles into action. Now this may act sometimes in a very important manner for our protection, or for the protection of some of our delicate organs. A very eminent chemist a few years ago was making an experiment upon some extremely explosive compound which he had discovered. He had a small quantity of this compound in a bottle, and was holding it up to the light, looking at it intently; and whether it was a shake of the bottle or the warmth of his hand, I do not know, but it exploded in his hand, the bottle was shivered into a million of minute fragments, and those fragments were driven in every direction. His first impression was that they had penetrated his eyes, but to his intense relief he found presently that they had only penetrated the outside of his eyelids. You may conceive how infinitesimally short the interval was between the explosion of the bottle and the particles reaching his eyes; and yet in that interval the impression had been made upon his sight, the mandate of the reflex action, so to speak, had gone forth, the muscles of his eyelids had been called into action, and he had closed his eyelids before the particles reached them, and in this manner his eyes were saved. You see what a wonderful proof this is of the way in which the automatic action of our nervous apparatus enters into the sustenance of our lives, and the protection of our most important organs from injury.

Now I have to speak of the way in which this Automatic action of the Sensory nerves and of the motor nerves which answer to them, grows up as it were in ourselves. We will take this illustration. Certain things are originally instinctive, the tendency to them is born with us; but in a very large number of things we educate ourselves, or we are educated. Take, for instance, the guidance of the class of movements I was speaking of just now—our movements of locomotion. We find that when we set off in the morning with the intention of going to our place of employment, not only do our legs move without our consciousness, if we are attending to something entirely different, but we guide ourselves in our walk through the streets; we do not run up against anybody we meet; we do not strike ourselves against the lamp posts; and we take the appropiate turns which are habitual to us. It has often happened to myself, and I dare say it has happened to every one of you, that you have intended to go somewhere else—that when you started you intended instead of going in the direct line to which you were daily accustomed, to go a little out of your way to perform some little commission; but you have got into a train of thought and forgotten yourself, and you find that you are half way along your accustomed track before you become aware of it. Now there you see is the same automatic action of these sensory ganglia—we see, we hear—for instance, we hear the rumbling of the carriages, and we avoid them without thinking of it—our muscles act in respondence to these sights and sounds—and yet all this is done without our intentional direction—they do it for us. Here again, then, we have the "secondarily automatic" action of this power, that of a higher nervous apparatus which has grown, so to speak, to the mode in which it is habitually exercised. Now that is a most important consideration. It has grown to the mode in which it is habitually exercised; and that principle, as we shall see, we shall carry into the higher class of Mental operations.

But there is one particular kind of this action of the Sensory nerves to which I would direct your attention, because it leads us to another very important principle. You are all of you, I suppose, acquainted with the action of the Stereoscope; though you may not all know that its peculiar action, the perception of solidity it conveys to us, depends upon the combination of two dissimilar pictures—the two dissimilar pictures which we should receive by our two eyes of an object if it were actually placed before us. If I hold up this jug for instance before my eyes, straight before the centre of my face, my two eyes receive pictures which are really dissimilar. If I made two drawings of the jug, first as I see it with one eye and, then with the other, I should represent this object differently. For instance, as seen with the right eye I see no space between the handle and the body of the jug; as I see it with the left eye I see a space there. If I were to make two drawings of that jug as I now see it with my two eyes, and put them into a stereoscope, they would bring out, even if only in outline, the conception of the solid figure of that jug in a way that no single drawing could do. Now that conception is the result of our early acquired habit of combining with that which we *see* that which we *feel*. That habit is acquired during the first twelve or eighteen months of infancy. When your little children are lying in their cradles and are handling a solid object, a block of wood, or a simple toy, and are holding it at a distance from their eyes, bringing it to their mouth and then carrying it to arm's length, they are going through a most important part of their education; that part of their education which consists in the harmonization of the mental impressions derived from sight and those derived from the touch; and it is by that harmonization that we get that conception of solidity or projection, which, when we have once acquired it we receive from the combination of these two dissimilar pictures alone, or even, in the case of objects familiar to us, without two dissimilar pictures at all—the sight of the object suggesting to us the conception of its solidity and of its projection.

Now this is a thing so familiar to you, that few of you have probably ever thought of reasoning it out; and in fact it has only been by the occurrence of cases in which persons have grown to adult age without having acquired this power, from having been born blind and having only received sight by a surgical operation at a comparatively late period, when they could describe things as they saw them—I say it is only by such cases that we have come to know how completely dissimilar and separate these two classes of impressions really are, and how important is this process of early infantile education of which I have spoken. A case occurred a few years ago in London where a friend of my own performed an operation upon a young woman who had been born blind, and though an attempt had been made in early years to cure her, that attempt had failed. She was able just to distinguish large objects, the general shadow as it were of large objects without any distinct perception of form, and to distinguish light from darkness. She could work well with her needle by the touch, and could use her scissors and bodkin and other implements by the training of her hand, so to speak, alone. Well, my friend happened to see her, and he examined her eyes, and told her that he thought he could get her sight restored; at any rate, it was worth a trial. The operation succeeded; and being a man of intelligence and quite aware of the interest of such a case, he carefully studied and observed it; and he completely confirmed all that had been previously laid down by the experience of similar cases. There was one little incident which will give you an idea of the education which is required for what you would suppose is a thing perfectly simple and obvious. She could not distinguish by sight the things that she was perfectly familiar with by the touch, at least, when they were first presented to her eyes. She could not recognise even a pair of scissors. Now you would have supposed that a pair of scissors, of all things in the world, having been continually used by her, and their form having become perfectly familiar to her hands, would have been most readily recognised by her sight; and yet she did not know what they were; she had not an idea until she was told, and then she laughed, as she said, at her own stupidity. No stupidity at all; she had never learned it, and it was one of those things which she could not know without learning. One of the earliest cases of this kind was related by the celebrated Cheselden, a surgeon of the early part of last century. Cheselden relates how a youth just in this condition had been accustomed to play with a cat and a dog; but for some time after he attained his sight he never could tell which was which, and used to be continually making mistakes. One day being rather ashamed of himself for having called the cat the dog, he took up the cat in his arms and looked at her very attentively for some time, stroking her all the while; and in this way he associated the impression derived from the sight of the cat with the impression derived from the touch, and made himself master (so to speak) of the whole idea of the animal. He then put the cat down, saying, "Now puss, I shall know you another time."

Now, the reason why I have specially directed your attention to this is because it leads to one of the most important principles that I desire to expound to you this evening—what I call in Mental Physiology the doctrine of *resultants*. All of you who have studied merchanics know very well what a "resultant" means. You know that when a body is acted on by two forces at the same time, one force carrying it in this direction, and another force in that direction, we want to know in what direction it will go, and how far it will go. To arrive at this we simply complete what is called the parallelogram of forces. In fact it is just as if a body was acted on at two different times, by a force driving it in one direction, and then by a force driving it in the other direction. [Dr. Carpenter illustrated this point by the aid of the blackboard.] We draw two lines parallel to this, and we draw a diagonal—that diagonal is what is called the resultant; that is, it expresses the direction, and it expresses the distance—the length of the motion which that body will go when acted upon by these two forces. Now I use this term as a very convenient one to express this—that when we have once got the conception that is derived from the harmonisation of these two distinct sets of impressions on our nerves of sense, we do not fall back on the original impressions, but we fall back on the resultant, so to speak. The thing has been done for us; it is settled for us; we have got the resultant; and the combination giving that resultant is that which governs the impression made upon our minds by all similar and future operations of the same kind. We do not need to go over the processes of judgment by which the two sets of impressions are combined in every individual case; but we fall back, as it were, upon the resultant. Now what is the case in the harmonisation of the two classes of impressions of sight and touch, I believe to be true of the far more complicated operations of the mind of which the higher portion of the brain, the Cerebrum, is the instrument. Now this Cerebrum we regard as furnishing, so to speak, the mechanism of our thoughts. I do not say that the Cerebrum is that which does the whole work of thinking, but it furnishes the mechanism of our thought. It is not the steam engine that does the work; the steam engine is the mere mechanism; the work is done, as my friend Professor Roscoe would tell you, by the heat supplied; and if we go back to the source of that heat, we find it originally in the heat and light of the sun that made the trees grow by which the coal was produced, in which the heat of the sun is stored up, as it were, and which we are now using, I am afraid, in rather wasteful profusion. The steam engine furnishes the mechanism; the work is done by the force. Now in the same manner the brain serves as the mechanism of our thought; and it is only in that sense that I speak of the work of the brain. But there can be no question at all that it works of itself, as it were,—that it has an automatic power, just in the same manner as the sensory centres and the spinal cord have automatic power of their own. And that a very large part of our mental activity consists of this automatic action of the brain, according to the mode in which we have trained it to action, I think there can be no doubt whatever. And the illustration with which I started in this lecture gives you, I believe, a very good example of it. However, there are other examples which are in some respects still better illustrations of the automatic work that is done by the brain, in the state which is sometimes called Second Consciousness, or Somnambulism—to which some persons are peculiarly subject. I heard only a few weeks ago of an extremely remarkable example of a young man who had overworked himself in studying for an examination, and who had two distinct lives, as it were, in each of which his mind worked quite separately and distinct from the other. One of these states, however,—the ordinary one—is under the control of the will to a much greater extent than the other; while the secondary state is purely, I suppose, automatic. There are a great many instances on record of very curious mental work, so to speak, done in this automatic condition—a state of active dreaming in fact. For instance, Dr. Abercrombie mentions, in his very useful work on the Intellectual Powers, an example of a lawyer who had been excessively perplexed about a very complicated question. An opinion was required from him, but the question was one of such difficulty that he felt very uncertain how his opinion should be given. The opinion had to be given on a certain day, and he awoke in the morning of that day with a feeling of great distress. He said to his wife, "I had a dream, and the whole thing in that dream has been clear before my mind, and I would give anything to recover that train of thought." His wife said to him, "Go and look on your table." She had seen him get up in the night and go to his table and sit down and write. He went to his table, and found there the very opinion which he had been most earnestly endeavouring to recover, lying in his own handwriting. There was no doubt about it whatever, and this opinion he at once saw was the very thing which he had been anxious to be able to give. A case was put on record of a very similar kind only a few years ago by a gentleman well known in

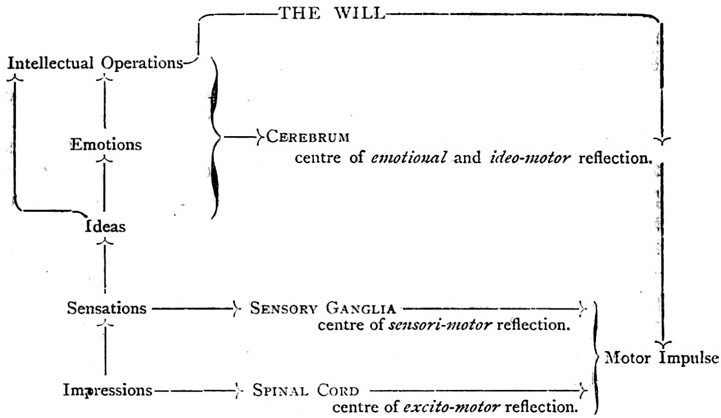
London, the Rev. John De Liefde, a Dutch clergyman. This gentleman mentioned it on the authority of a fellow student who had been at the college at which he studied in early life. He had been attending a class in mathematics, and the professor said to his class one day—"A question of great difficulty has been referred to me by a banker, a very complicated question of accounts—which they have not themselves been able to bring to a satisfactory issue, and they have asked my assistance. I have been trying, and I cannot resolve it. I have covered whole sheets of paper with calculations, and have not been able to make it out. Will you try?" He gave it as a sort of problem to his class, and said he should be extremely obliged to any one who would bring him the solution by a certain day. This gentleman tried it over and over again; he covered many slates with figures, but could not succeed in resolving it. He was a little put on his mettle, and very much desired to attain the solution; but he went to bed on the night before the solution, if attained, was to be given in, without having succeeded. In the morning, when he went to his desk, he found the whole problem worked out in his own hand. He was perfectly satisfied that it was his own hand; and this was a very curious part of it—that the result was correctly obtained by a process very much shorter than any he had tried. He had covered three or four sheets of paper in his attempts, and this was all worked out upon one page, and correctly worked, as the result proved. He inquired of his "hospita," as she was called—I believe our English equivalent is bedmaker, the woman who attended to his rooms—and she said she was certain that no one had entered his room during the night. It was perfectly clear that this had been worked out by himself.

Now there are many cases of this kind, in which the mind has obviously worked more clearly and more successfully in this automatic condition, when left entirely to itself, than when we have been cudgelling our brains, so to speak, to get the solution. I have paid a good deal of attention to this subject, in this way:—I have taken every opportunity that occurred to me of asking inventors and artists—creators in various departments of art—musicians, poets, and painters, what their experience has been in regard to difficulties which they have felt, and which they have after a time overcome. And the experience has been almost always the same, that they have set the result which they have wished to obtain strongly before their minds, just as we do when we try to recollect something we have forgotten; they think of everything that can lead to it; but if they do not succeed, they put it by for a time, and give their minds to something else, and endeavour to obtain as complete a repose or refreshment of the mind upon some other occupation as they can; and they find that either after sleep, or after some period of recreation by a variety of employment, just what they want comes into their heads. A very curious example of this was mentioned to me a few years ago by Mr. Wenham, a gentleman who has devoted a great deal of time and attention to the improvement of the microscope, and who is the inventor of that form of binocular microscope (by which we look with two eyes and obtain a stereoscopic picture), which is in general use in this country. The original binocular microscope was made upon a plan which would suggest itself to any optician. I shall not attempt to describe it to you, but it involved the use of three prisms, giving a number of reflections; and every one of these reflections was attended with a certain loss of light and a certain liability to error. And beside that, the instrument could only be used as a binocular microscope. Now Mr. Wenham thought it might be possible to construct an instrument which would work with only one prism, and that this prism could be withdrawn, and then we could use the microscope for purposes to which the binocular microscope could not be applied. He thought of this a great deal, but he could not think of the form of prism which would do what was required. He was going into business as an engineer, and he put his microscopic studies aside for more than a fortnight, attending only to his other work, and thinking nothing of his microscope. One evening after his day's work was done, and while he was reading a stupid novel, as he assured me, and was thinking nothing whatever of his microscope, the form of the prism that should do this work flashed into his mind. He fetched his mathematical instruments, drew a diagram of it, worked out the angles which would be required, and the next morning he made his prism, and found it answered perfectly well; and upon that invention nearly all the binocular microscopes made in this country have since been constructed.

I could tell you a mumber of anecdotes of this kind which would show you how very important is this automatic working of our minds—this work which goes on without any more control or direction of the Will, than when we are walking and engaged in a train of thought which makes us unconscious of the movements of our legs. And I believe that in all these instances—such as those I have named, and a long series of others—the result is owing to the mind being left to itself without the disturbance of any emotion. It was the worry which the bank manager had been going through, that really prevented the mind from working with the steadiness and evenness that produced the result. So in the case of the lawyer; so in the case of the mathematician; they were all worrying themselves, and did not let their minds have fair play. You have heard, I dare say, and those of you who are horsemen may have had experience, that it is a very good thing sometimes, if you lose your way on horseback, to drop the reins on the horse's back and let him find his way home. You have been guiding the horse into one path and into another, and following this and that path, and you find that it does not lead you in the right direction; just let the horse go by himself, and he will find his way better than you can. In the same manner, I believe, that our minds, under the circumstances I have mentioned, really do the work better than our wills can direct. The will gives the impulse in the first instance, just as when you start on your walk; and not only this, but the will keeps before the mind all the thoughts which it can immediately lay hold of, or which association suggests, that bear upon the subject. But then these thoughts do not conduct immediately to an issue, they require to work themselves out; and I believe that they work themselves out very often a great deal better by being left to themselves. But then we must recollect that such results as these are only produced in the mind which has been trained and disciplined; and that training and discipline are the result of the control of the Will over the mental processes, just as in the early part of the lecture I spoke to you of the act of speech as made possible by the control which the will has over the muscles of breathing. We cannot stop these movements—we must breathe—but we can regulate them, and modify them, and intensify them, or we can check them for a moment, in accordance with the necessities of speech. Well, so it is, I think, with regard to the action of our will upon our mental processes. I believe that this control, this discipline of the will, should be learned very early; and I will give to the mothers amongst you, especially, one hint in regard to a most valuable mode of training it even in early childhood. I learned this, I may say, from a nurse whom I was fortunate enough to have, and whose training of my own sons in early childhood I regard as one of the most valuable parts of their education. She was a sensible country girl, who could not have told her reasons, but whose instincts guided her in the right direction. I studied her mode of dealing with the children, and learned from that the principle. Now the principle is this :—A child falls down and hurts itself. (I take the most common of nursery incidents. You know that Sir Robert Peel used to say that there were three ways of looking at this question; and there are three modes of dealing with this commonest of nursery incidents.) One nurse will scold the child for crying. The child feels the injustice of this; it feels the hurt, and it feels the injustice of being scolded. I believe that is the most pernicious of all the modes of dealing with it. Another coddles the child, takes it up and rubs its head, and says, "O naughty chair, for hurting my dear child!" I remember learning that one of the royal children fell against a table in the Queen's presence, and the nurse said, "O naughty table," when the Queen very sensibly said, "I will not have that expression used; it was not the table that was naughty; it was the child's fault that he fell against the table." I believe that this method is extremely injurious; the result of it being that it fixes the child's attention upon its hurt, and causes it to attain that habit of self-consciousness which is in after life found to have most pernicious effects. Now, what does the sensible and judicious nurse do? She distracts the child's attention, holding it up to the window to look at the pretty horses, or gets it a toy to look at. This excites the child's attention, and the child forgets its hurt, and in a few moments is itself again, unless the hurt has been severe. When I speak of coddling, I mean about a trifling hurt such as is forgotten in a few moments; a severe injury is a different matter. But I believe that the coddling is only next in its evil results (when followed out as a system) to the evil effects of the system of scolding; the distraction of the attention is the object to be aimed at. Well, after a time the child comes to be able to distract its own attention. It feels that it can withdraw its own mind from the sense of its pain, and can give its mind to some other object, to a picture-book or to some toy, or whatever the child feels an interest in; and that is the great secret of self-government in later life. We should not say, "I wont think of of this"—some temptation, for instance; *that* simply fixes the attention upon the very thought that we wish to escape from; but the true method is—"I will think of something else;" *that*, I believe, is the great secret of self-government, the knowledge of which is laid in the earliest periods of nursery life.

Now just direct your attention to this diagram, as a sort of summary of the whole :—

[Diagram.]



You see I put at the top the Will. The will dominates everything else. I do not pretend to explain it, but I simply say, as Archbishop Manning said, in applying my own language to this case, that our common sense teaches us that we have a will, that we have the power of self-government and self-direction, and that we have the power of regulating and dominating all these lower tendencies to a certain extent, not to an unlimited extent. We cannot prevent those thoughts and feelings rising in our minds that we know to be undesirable; but we can escape from them, we can repress them; but as I said the effort to escape from them is much more effectual than the effort to repress them, excepting when they arise with great power, and then we have immediately, as it were, to crush them out; but when they tend to return over and over again, the real mode of subduing them is to determine to give our attention to something else. It is by this exercise of the will, therefore, in training and disciplining the mind, that it acquires that method by which it will work of itself. The mathematician could never have worked out that difficult problem, nor the lawyer have given his opinion, nor the artist have developed those conceptions of beauty which he endeavours to shape either in music, or poetry, or painting, but for the training and disciplining which his mind has undergone. The most wonderfully creative of all musicians, Mozart, whose music flowed from him with a spontaneousness that no musician, I think, has ever equalled —Mozart went through, in early life, a most elaborate course of study, imposed upon him, in the first instance, by his father, and afterwards maintained by himself. When his cotemporaries remarked how easily his compositions flowed from him, he replied, "I gained the power by nothing but hard work." Mozart had a most extraordinary combination of this intuitive musical power, with the knowledge derived from patient and careful study, that probably any man ever attained. Now in the same manner we have persons of extraordinary natural gifts, and see these gifts frequently running to waste, as it were, because they have not received this culture and discipline. And it is this discipline which gives us the power of performing, unconsciously to ourselves, these elaborate mental operations; because I hold that a very large part of our mental life thus goes on, not only automatically, but even below the sphere of our consciousness. And you may easily understand this if you refer to the diagram which I drew just now on the blackboard. You saw that the Cerebrum, the part that does the work, what is called the convoluted surface of the brain, lies just immediately under the skull cap; that it is connected with the sensorium at the base of the brain by a series of fibres which are merely, I believe, conducting fibres. Now I think that it is just as possible that the Cerebrum should work by itself when the sensorium is otherwise engaged or in a state of unconsciousness, as that impressions should be made on the eye of which we are unconscious. A person may be sleeping profoundly, and you may go and raise the lid and bring a candle near, and you will see the pupil contract; and yet that individual shall see nothing, for he is in a state of perfect unconsciousness. His eye sees it, so to speak, but his mind does not; and you know that his eye sees it by the contraction of the pupil, which is a reflex action; but his mind does not see it, because the sensorium is in a state of inaction. In the same manner during sleep the Cerebrum may be awake and working, and yet the Sensorium shall be asleep, and we may know nothing of what the cerebrum is doing except by the results. And it is in this manner, I believe, that, having been once set going, and the cerebrum having been shaped, so to speak, in accordance with our ordinary processes of mental activity, having grown to the kind of work we are accustomed to set it to execute, the cerebrum can go on and do its work for itself. The work of invention, I am certain, is so mainly produced, from concurrent testimony I have received from a great number of inventors, or what the old English called "makers"—what the Greeks called poets, because the word poet means a maker.

Every inventor must have a certain amount of imagination, which may be exercised in mechanical contrivance or in the creations of art; these are *inventions*—they are made, they are produced, we don't know how; the conception comes into the mind we cannot tell whence; but these inventions are the result of the original capacity for that particular kind of work, trained and disciplined by the culture we have gone through. It is not given to every one of us to be an inventor. We may love art thoroughly, and yet we may never be able to evolve it for ourselves. So in regard to humour. For instance, there are some men who throw out flashes of wit and humour in their conversation, who cannot help it—it flows from them spontaneously. There are other men who enjoy this amazingly, whose nature it is to relish such expressions keenly, but who cannot make them themselves. The power of invention is something quite distinct from the intellectual capacity or the emotional capacity for enjoying and appreciating; but although we may not have these powers of invention, we can all train and discipline our minds to utilise that which we do possess to its utmost extent. And here is the conclusion to which I would lead you in regard to Common Sense. We fall back upon this, that common sense is, so to speak, the **general resultant of the whole previous action of our minds.** We submit to common sense any questions—such questions as I shall have to bring before you in my next lecture; and the judgment of that common sense is the judgment elaborated as it were by the whole of our mental life. It is just according as our mental life has been good and true and pure, that the value of this acquired and this higher common sense is reached. We may in proportion I believe to our honesty in the search for truth—in proportion as we discard all selfish considerations and look merely at this grand image of truth, so to speak, set before us, with the purpose of steadily pursuing our way toward it—in proportion as we discard all low and sensual feelings in our love of beauty, and especially in proportion to the earnestness of the desire by which our minds are pervaded always to keep the right before us in all our judgments—so I believe will our minds be cleared in their perception of what are merely prudential considerations. It has on several occasions occurred to me to form a decision as to some important change either in my own life, or in the life of members of my family, which involved a great many of what we are accustomed to call *pros* and *cons*—that is, there was a great deal to be said on both sides. I heard the expression once used by a naturalist, with regard to difficulties in classification,—"It is very easy to deal with the white and the black; but the difficulty is to deal with the grey." And so it is in life. It is perfectly easy to deal with the white and the black,—there are things which are clearly right, and things which are clearly wrong; there are things which are clearly prudent, and things which are clearly imprudent; but a great many cases arise in which even right and wrong may seem balanced, or the motives may be so balanced that it is difficult to say what is right; and again there are cases in which it is difficult to say what is prudent; and I believe in these cases where we are not hurried and pressed for a decision, the best plan is to do exactly that which I spoke of in the earlier part of the lecture—to set before us as much as possible everything that is to be said on both sides. Let us consider this well; let us go to our friends; let us ask what they think about it. They will suggest considerations which may not occur to ourselves. It has happened to me within the last three or four months to have to make a very important decision of this kind for myself; and I took this method—I heard everything that was to be said on both sides, I considered it well, and then I determined to put it aside as completely as possible for a month, or longer, if time should be given, and then to take it up again, and simply just to see how my mind gravitated—how the balance then turned. And I assure you that I believe that in those who have disciplined their minds in the manner I have mentioned, that act of "Unconscious Cerebration," for so I call it, this unconscious operation of the brain in balancing for itself all these considerations, in putting all in order, so to speak, in working out the result—I believe that that process is far more likely to lead us to good and true results than any continual discussion and argumentation, in which one thing is pressed with undue force and then that leads us to bring up something on the other side, so that we are just driven into antagonism, so to speak, by the undue pressure of the force which we think is being exerted. I believe that to hear everything that is to be said, and then not to ruminate upon it too long, not to be continually thinking about it, but to put it aside entirely from our minds as far as we possibly can, is the very best mode of arriving at a correct conclusion. And this conclusion will be the *resultant* of the whole previous training and discipline of our minds. If that training and discipline has all been in the direction of the true and the good, I believe that we are more likely to obtain a valuable result from such a process than from any conscious discussion of it in our minds, anything like continually bringing it up and thinking of it, and going over the whole subject again in our thoughts. The unconscious settling down, as it were, of all these respective motives, will I think incline the mind ultimately to that which is the just and true decision.

There is just one other point I could mention in connection with this subject: the manner in which the *conscious* direction and discipline of the mind will tend to remove those *unconscious* prejudices that we all have more or less from education, from the circumstances in which we were brought up; and from which it is excessively difficult for us to free ourselves entirely. I have known a great many instances in public and in private life, in which the most right-minded men have every now and then shown the trammelling, as it were, of their early education and early associations, and were not able to think clearly upon the subject in consequence of this. These early prejudices and associations cling around us and influence the thoughts and feelings of the honestest men in the world unconsciously; and it is sometimes surprising to those who do not know the force of these early associations, to see how differently matters which are to them perfectly plain and obvious are viewed by men whom we feel we must respect and esteem. Now I believe that it is the earnest habit of looking at a subject from first principles, and, as I have said over and over again, looking honestly and steadily at the true and the right, which gives the mind that direction that ultimately overcomes the force of these early prejudices and these early associations, and brings us into that condition which approaches the nearest of anything that I think we have the opportunity of witnessing in our earthly life, to that *direct insight*, which many of us believe will be the condition of our minds in that future state in which they are released from all the trammels of our corporeal existence.

EPIDEMIC DELUSIONS.

A LECTURE

By Dr. CARPENTER, F.R.S.,

Delivered in the Hulme Town Hall, Manchester, December 8th, 1871.

Our subject to-night links itself in such a very decided manner to the subject in which we were engaged last week, and the illustrations which I shall give you are so satisfactorily explained on the scientific principle which I endeavoured then to expound to you, that I would spend a very few minutes in just going over some of the points to which I then particularly directed your attention. My object was to show you that between our Mental operations and our Will there is something of that kind of relation which exists between a well-trained horse and his rider; that the will,—if rightly exercised in early infancy in directing and controlling the mental operations; in directing the attention to the objects to which the intellect should be applied; in controlling and repressing emotional disturbance; restraining the feelings when unduly excited, and putting a check upon the passions—that the will in that respect has the same kind of influence over the mind, or ought to have, as the rider has upon his horse; that the powers and activities of the mind are to a very great degree independent of the will; that the mind will go on of itself without any more than just the starting of the will, in the same manner as a horse will go on in the direction that it has been accustomed to go with merely the smallest impulse given by the voice, or the hand, or the heel of the rider, and every now and then a very slight check (if it is a well-trained horse) or guidance from the bridle or from a touch of the spur, and will follow exactly the course that the rider desires, but by its own independent power. And, again, I showed you that as there are occasions on which a horse is best left to itself, so there are occasions when the mind is best left to itself, without the direction and control of the will; in fact in which the operations of the mind are really disturbed by being continually checked and guided and pulled up by the action of the will, the result being really less satisfactory than when the mind, previously trained and disciplined in that particular course of activity, is left to itself. I gave you some curious illustrations of this from occurrences which have taken place in Dreaming, or in that form of dreaming which we call Somnambulism: where a legal opinion had been given, or a mathematical problem had been resolved, in the state of sleep waking; that is to say the mind being very much in the condition of that of the dreamer, its action being altogether automatic, going on of itself without any direction or control from the will—but the bodily activity obeying the direction of the mind. And then I went on to show you that this activity very often takes place, and works out most important results, even without our being conscious of any operations going on; and that some of these results are the best and most valuable to us in bringing at last to our consciousness ideas which we have been vainly searching for,—as in the case where we have endeavoured to remember something that we have not at first been able to retrace, and which has flashed into our minds in a few hours, or it may be a day or two afterwards; or, again, when we have been directing our minds to the solution of some problem which we have put aside in a sort of despair, and yet in the course of a little time that solution has presented itself while our minds have either been entirely inactive, as in sleep, or have been directed into some entirely different channel of action.

Now, like the well-trained horse which will go on of itself with the smallest possible guidance, yet still under the complete domination of the rider, and will even find its way home when the rider cannot direct it thither, we find that the human mind sometimes does that which even a well-trained horse will do—that it runs away from the guidance of its directing will. Something startles the horse, something gives it alarm; and it makes a sudden bound, and then, perhaps, sets off at a gallop, and the rider cannot pull it up. This alarm often spreads contagiously, as it were, from one horse to another; as we lately saw in the "stampede" at Aldershot. Or, again, a horse, even if well trained, when he gets a new rider, sometimes, as we say, "tries it on," to see whether the horse or the rider is really the master. I have heard many horsemen say that that is a very familiar experience. When you first go out with a new horse, it may be to a certain degree restive; but if the horse finds that you keep a tight hand upon him, and that his master knows well how to keep him under control, a little struggling may have to be gone through, and the horse from that time becomes perfectly docile and obedient. But if, on the other hand, the horse finds that *he* is the master, even for a short time, no end of trouble is given afterwards to the rider in acquiring that power which he desires to possess. Now that is just the case with our minds; we may follow out the parallel very closely indeed. We find that if our minds once acquire habits—habits of thought, habits of feeling—which are independent of the will, which the will has not kept under adequate regulation, these habits get the better of us; and then we find that it is very difficult indeed to recover that power of self direction which we have been aiming at, and which the well-trained and well-disciplined mind will make its highest object. So, again, we find that there are states in which, from some defect in the physical condition of the body, or it may be from some great shock which has affected the mind and weakened for a time the power of the will, very slight impulses—just like the slight things that will make a horse shy—will disturb us unduly; and we feel that our emotions are excited in a way that we cannot account for, and we wonder why such a little thing should worry and vex us in the way that it does. Even the best of us know, within our own personal experience, that when we are excessively fatigued in body, or overstrained in mind, our power of self-control is very much weakened; so that particular ideas will take possession of us, and for a time will guide our whole course of thought, in a manner which our sober judgment makes us feel to be very undesirable. What, for instance, is more common than for a person to take offence at something that has been said or done by his most intimate friend, or by some member of his family; merely because he has been jaded or overtasked, and has not the power of bringing to the fair judgment of his common sense the question whether that offence was really intended, or whether it was a thing he ought not to take any notice of? He broods over this notion, and allows it to influence his judgment; and if he does not in a day or two rouse himself and master his feelings by throwing it off, it may give rise to a permanent estrangement. We are all of us conscious of states of mind of that kind.

But there are states of mind which lead to very much more serious disorder, arising from the neglect of that primary dis cipline and culture on which I have laid so much stress. We find that ignorance, and that want of the habit of self-control which very commonly accompanies it, predispose very greatly indeed to the violent excitement of the feelings, and to the possession of the mind by ideas which we regard as essentially absurd; and under these states of excitement of feeling, and the tendency of these dominant ideas to acquire possession of the intellect, the strangest aberrations take place, not only in individuals but in communities; and it is of such that I have especially to speak to-night. We know perfectly well, in our individual experience, that these states tend to produce Insanity if they are indulged in, and if the individual does not make an earnest effort to free himself from their influence. But, looking back at the history of the earlier ages, and carrying that survey down to the present time, we have experience in all ages of great masses of people being seized upon by these dominant ideas, accompanied with the excitement of some passion or strong impulse which leads to the most absurd results; and it is of these Epidemic Delusions I have to now speak. The word "epidemic" simply means something that falls upon, as it were, the great mass of the people—a delusion which affects the popular mind. And I believe that I can best introduce the subject to you by showing you how, in certain merely physical conditions, mere bodily states, there is a tendency to the propagation, by what is commonly called imitation, of very strange actions of the nervous system. I suppose there is no one of you who does not know what an hysteric fit means; a kind of fit to which young women are especially subject, but which affects the male sex also. One reason why young women are particularly subject to it is that in the female the feelings are more easily excited, while the male generally has a less mobile nervous system, his feelings being less easily moved, while he is more influenced by the intellect. These hysteric fits are generally brought on by something that strongly affects the feelings. Now, it often happens that a case of this sort presents itself in a school or nunnery, sometimes in a factory where a number of young women are collected together; one being seized with a fit, others will go off in a fit of a very similar kind. There was an instancc a good many years ago in a factory in a country town in Lancashire, in which a young girl was attacked with a violent convulsive fit, brought on by alarm, consequent upon one of her companions, a factory operative, putting a mouse down inside her dress. The girl had a particular antipathy to mice, and the sudden shock threw her into a violent fit. Some of the other girls who were near very soon passed off into a similar fit; and then there got to be a notion that these fits were produced by some emanations from a bale of cotton; and the consequence was that they spread, till scores of the young women were attacked day after day with these violent fits. The medical man who was called in saw at once what the state of things was; he assured them in the first place that this was all nonsense about the cotton; and he brought a remedy, in the second place, which was a very appropriate one under the circumstances—namely, an electrical machine; and he gave them some good violent shocks, which would do them no harm, assuring them that this would cure them. And cure them it did. There was not another attack afterwards.—I remember very well that when I was a student at Bristol, there was a ward in the hospital to which it was usual to send young servant girls; for it was thought undesirable that these girls should be placed in the ward with women of a much lower class, especially the lower class of Irish women who inhabited one quarter of Bristol, as I believe there is an Irish quarter in Manchester. These girls were mostly respectable, well-conducted girls, and it was thought better that they should be kept together. Now the result of this was that if an hysteric fit took any one of them, the others would follow suit; and I remember perfectly well, when I happened to be a resident pupil, having to go and scold these girls well, threatening them with some very severe infliction. I forget what was threatened; perhaps it would be a shower bath, for anyone who went off into one of these fits. Now here the cure is effected by a stronger emotion, the emotion of the dread of—we will not call it punishment—but of a curative measure; and this emotion overcame the tendency to what we commonly call imitation. It is the suggestion produced by the sight of one, that brings on the fit in another, where there is the pre-disposition to it.—Now I believe that in all these cases there is something wrong in the general health or in the nervous system; or the suggestion would not produce such results. Take the common teething fits of children. We there see an exciting cause in the cutting of the teeth; the pressure of the tooth against the gum being the immediate cause of the production of convulsive action. But it will not do so in the healthy child. I feel sure that in every case where there is a teething fit, of whatever kind, there is always some unhealthy condition of the nervous system—sometimes from bad food; more commonly from bad air. I have known many instances in which children had fits with every tooth that they cut, yet when sent into the country they had no recurrence of the fit. There must have been some predisposition, some unhealthy condition of the nervous system, to favour the exciting cause, which, acting upon this predisposition, brings out such very unpleasant results.

There are plenty of stories of this kind that I might relate to you. For instance, in nunneries it is not at all uncommon, from the secluded life, and the attention being fixed upon one subject, one particular set of ideas and feelings—the want of a healthy vent, so to speak, for the mental activity—that some particular odd propensity has developed itself. For instance, in one nunnery abroad, many years ago, one of the youngest nuns began to mew like a cat; and all the others, after a time, did the same. In another nunnery one began to bite, and the others were all affected with the propensity to bite. In one of these instances the mania was spreading like wildfire through Germany, extending from one nunnery to another; and they were obliged to resort to some such severe measures as I have mentioned to drive it out. It was set down in some instances to demoniacal possession, but the devil was very easily exorcised by some pretty strong threat on the part of the medical man. The celebrated physician, Boerhaave, was called in to a case of that kind in an orphan asylum in Holland, and I think his remedy was a red-hot iron. He heated the poker in the fire, and said that the next girl who fell into one of these fits should be burnt in the arm; this was quite sufficient to stop it. In Scotland at one time there was a great tendency to breaking out into fits of this kind in the churches. This was particularly the case in Shetland; and a very wise minister there told them that the thing could not be permitted, and that the next person who gave way in this manner—as he was quite sure they could control themselves if they pleased—should be taken out and ducked in a pond near. There was no necessity at all to put his threat into execution. Here, you see, the stronger motive is substituted for the weaker one, and the stronger motive is sufficient to induce the individual to put a check upon herself. I have said that it usually happens with the female sex, though sometimes it occurs with young men who have more or less of the same constitutional tendency. What is necessary is to induce a stronger motive, which will call forth the power of self-control which has been previously abandoned.

Now this tendency which here shows itself in convulsive movements of the body, will also show itself in what we may call convulsive action of the Mind; that is, in the excitement of violent feelings and even passions, leading to the most extraordinary manifestations of different kinds. The early Christians, you know, practised self-mortification to a very great degree; and considered that these penances were so much scored up to the credit side of their account in heaven,—that, in fact, they were earning a title to future salvation by self-mortification. Among other means of self-mortification, they scourged themselves. That was practised by individuals. But in the middle ages this disposition to self-mortification would attack whole communities, especially under the dominant idea that the world was coming to an end. In the middle of the 13th century, about 1250, there was this prevalent idea that the world was coming to an end; and whole communities gave themselves up to this self-mortification by whipping themselves. These Flagellants went about in bands with banners, and even music, carrying scourges; and then, at a given signal, every one would strip off the upper garment (men, women, and children joined these bands), and proceed to flog themselves very severely indeed, or to flog each other. This subsided for a time, but it broke out again during and immediately after that terrible plague which is known as the "black death," which devastated Europe in the reign of Edward III., about the year 1340. This black death seems to have been the Eastern Plague in a very severe form, which we have not known in this country since the great plague of London in Charles II.'s time, and one or two smaller outbreaks since, but which has now entirely left us. The severity of this plague in Europe was so great that upon a very moderate calculation one in four of the entire population were carried off by it; and in some instances it is said that nine-tenths of the people died of it. You may imagine, therefore, what a terrible infliction it was. And you would have supposed that it would have called forth the better feelings of men and women generally; but it did not. One of the worst features, morally, of that terrible affliction, was the lamentable suspension of all natural feelings which it seemed to induce. When any member of a family was attacked by this plague, every one seemed to desert him, or desert her; the sick were left to die alone, or merely under the charge of any persons who thought that they would be paid for rendering this service; and the funerals were carried on merely by these paid hirelings in a manner most repulsive to the feelings: and yet the very people who so deserted their relatives would join the bands of flagellants, who paraded about from place to place, and even from country to country,—mortifying their flesh in this manner for the purpose of saving their own souls, and, as they said, also making expiation for the great sins which had brought down this terrible visitation. This system of flagellation never gained the same head in this country that it did on the Continent. A band of about 100 came to London about the middle of the reign of Edward III., in the year 1350. They came in the usual style, with banners and even instruments of music, and they paraded the streets of London. At a given signal every one lay down and uncovered the shoulders, excepting the last person, who then flogged every one till he got to the front, where he lay down; and the person last in the rear stood up, and in his turn flogged every one in front of him. Then he went to the front and lay down; and so it went on until the whole number had thus been flogged, each by every one of his fellows. This discipline, however, did not approve itself to the good citizens of London, and it is recorded that the band of flagellants returned without having made any converts. Whether the skins of the London citizens were too tender, or whether their good sense prevailed over this religious enthusiasm, we are not informed; but at any rate the flagellants went back very much as they came, and the system never took root in this country; yet for many years it was carried on elsewhere. One very curious instance is given of the manner in which it fastened on the mind—that mothers actually scourged their new-born infants before they were baptised, believing that in so doing they were making an offering acceptable to God. Now all this appears to us perfectly absurd. We can scarcely imagine the state of mind that should make any sober, rational persons suppose that this could be an offering acceptable to Almighty God; but it was in accordance with the religious ideas of the time; and for a good while even the Church sanctioned and encouraged it, until at last various moral irregularities grew up, of a kind that made the Pope think it a very undesirable thing, and it was then put down by ecclesiastical authority; yet it was still practised in secret for some time longer, so that it is said that even until the beginning of the last century there were small bands of flagellants in Italy, who used to meet for this self-mortification.

That was one form in which a dominant idea took possession of the mind and led to actions which might be called voluntary, for they were done under this impression, that such self-mortification was an acceptable offering. But there were other cases in which the action of the body seemed to be in a very great degree involuntary, just about as involuntary as an hysteric fit, and yet in which it was performed under a very distinct idea; such was what was called the "Dancing Mania," which followed upon this great plague. This dancing mania seemed in the first instance to seize upon persons who had a tendency to that complaint which we now know as St. Vitus's dance—St. Vitus was in fact the patron saint of these dancers. St. Vitus's dance, or chorea, in the moderate form in which we now know it, is simply this, that there is a tendency to jerking movements of the body, these movements sometimes going on independently of all voluntary action, and sometimes accompanying any attempt at voluntary movement; so that the body of a person may be entirely at rest until he desires to execute some ordinary movement, such as lifting his hand to his head to feed himself, or getting up to walk; then, when the impulse is given to execute a voluntary movement, instead of the muscles obeying the will, the movement is complicated as (it were) with violent jerking actions, which show that there is quite an independent activity. The fact is that stammering is a sort of chorea. We give the name of chorea to this kind of disturbance of the nervous system, and the action of stammering is a limited chorea—chorea limited to the muscles concerned in speech, when the person cannot regulate the muscles so as to bring out the words desired; the very strongest effort of his will cannot make the muscles obey him, but there is a jerking irregular action every time he attempts to pronounce particular syllables. And the discipline that the stammerer has to undergo in order to cure or alleviate his complaint is just the kind of discipline I have spoken of so frequently—the fixing the attention on the object to be gained, and regularly exercising the nerves and muscles in proceeding from that which they *can* do to that which they find a difficulty in doing. That is an illustration of the simpler form of this want of definite control over the muscular apparatus, connected with a certain mental excitement; because everyone knows that a stammerer is very much affected by the condition of his feelings at the time. If, for example, he is at all excited, or if he apprehends that he shall stammer, that is enough to produce it. I have known persons who never stammered in ordinary conversation. yet when in company with stammerers they could scarcely avoid giving way to it; and even when the subject of stammering was talked about, when the idea was conveyed to their minds, they would begin to hesitate and stutter, unless they put a very strong control upon themselves. It is just in this way, then, only in the most exaggerated form, that these persons were afflicted with what was called the dancing mania.

They would allow themselves to be possessed with the idea that they *must* dance; and this dancing went on, bands going from town to town, and taking in any who would join them. Instances are recorded in which they would go on for twenty-four or thirty-six hours, continually jumping and dancing and exerting themselves in the most violent manner, taking no food all this time, until at last they dropped on the ground almost lifeless; and in fact several persons, it is said, did die from pure exhaustion, and this just because they were possessed with the idea that they *must* dance. They were drawn in, as it were, by the contagion of example; and when once they had given way to it, they did not seem to know when to stop. This was kept up by music and by the encouragement and excitement of the crowd around; and it spread amongst classes of persons who (it might be supposed) would have had more power of self-restraint, and would not have joined such unseemly exhibitions. The extraordinary capacity, as it were, for enduring physical pain, was one of the most curious parts of this condition. They would frequently ask to be struck violently; would sometimes lie down and beg persons to come and thump and beat them with great force. They seemed to enjoy this.—In another case that I might mention this was shown still more. The case was of a similar type, but was connected more distinctly with the religious idea, and it occurred much more recently. The case was that known in medical history as the Convulsionnaires of St. Mêdard. There was a cemetery in Paris in which a great saint had been interred, and some young women visiting his tomb had been thrown into a convulsive attack which propagated itself extensively; and these convulsionnaires spreading the contagion, as it were, into different classes of French society, one being seized after another till the number became very great in all grades. Here, again, one of the most curious things was the delight they seemed to take in what would induce in other persons the most violent physical suffering. There was an organised band of attendants, who went about with clubs, and violently beat them. This was called the *grand secours*, which was administered to those who were subject to these convulsive attacks. You would suppose that these violent blows with the clubs would do great mischief to the bodies of these people; but they only seemed to allay their suffering.

This, then, is another instance of the mode in which this tendency to strange actions under the dominance of a particular idea will spread through a community. Here you have the direct operation of the perverted mind upon the body. But there are a great many cases in which the perversion shows itself more in the mental state alone, leading to strange aberrations of Mind, and ultimately to very sad results in the condition of society where these things have spread, but not leading to anything like these convulsive paroxysms. I particularly allude now to the epidemic belief in Witchcraft, which, more or less, formerly prevailed constantly amongst the mass of the population, but every now and then broke out with great vehemence. This belief in witchcraft comes down to us from very ancient periods; and at the present time it is entertained by the lowest and most ignorant of the population in all parts of the world. We have abundant instances of it still, I am sorry to say, in our own community. We have poor ignorant servant girls allowing themselves to be—if I may use such a word—"humbugged" by some designing old woman, who persuades them that she can predict the husbands they are to have, or tell where some article that they have lost is to be found, and who extracts money from them merely as a means of obtaining a living in this irregular way, and I believe at the bottom rather enjoying the cheat. Every now and then we hear of some brutal young farmer who has pretty nearly beaten to death a poor old woman, whom he suspected of causing a murrain amongst his cattle. This is what we know to exist amongst the least cultivated of the savage nations at the present time, and always to have existed. But we hope that the progress of rationalism in our own community, will, in time, put an end to this, as it has in the middle and upper ranks of society during the last century or century and a half. It is not very long since almost everyone believed in the possession of these occult powers by men and women, but especially by old women. This belief has prevailed generally in countries which have been overridden by a gloomy fanaticism in religious matters. I speak simply as a matter of history. There is no question at all that this prevailed where the Romish Church was most intolerant, especially in countries where the Inquisition was dominant, and its powers were exerted in such a manner as to repress free thought and the free exercise of feeling; and, again, where strong Calvinism has exercised an influence of exactly the same kind—as in Scotland, a century and a half ago, and in New England, where there was the same kind of religious fanaticism. It is in these communities that belief in witchcraft has been most rife, has extended itself most generally, and has taken possession of the public mind most strongly; and the most terrible results have happened. Now I will only cite one particular instance, that of New England, in the early part of the last century and the end of the century before. Not very long after the settlement of New England, there was a terrible outbreak of this belief in witchcraft. It began in a family, the children of which were out of health; and certain persons whom they disliked were accused of having bewitched them. Against these persons a great deal of evidence that we should now consider most absurd was brought forward, and they were actually executed: and some of them under torture, or under moral torture,—for it was not merely physical torture that was applied; in many cases it was the distress and moral torture of being so accused, the dread, even if found not guilty, of being considered outcasts all their lives, or of being a burden to their friends,—made confessions which any sober person would have considered perfectly ridiculous; but under the dominant idea of the reality of this witchcraft, no one interfered to point out how utterly repugnant to common sense these confessions were, as well as the testimony that was brought forward. And this spread to such a degree in New England, one person being accused after another, that at last, even those who considered themselves God's chosen people began to feel, "our turn may come next;" they then began to think better of it, and so put an end to these accusations, even some who were under sentence being allowed to go free; and to the great surprise of those who were entirely convinced of the truth of these accusations, this epidemic subsided, and witchcraft was not heard of for a long time afterwards; so that the belief has never prevailed in New England from that time to the present, excepting amongst the lowest and most ignorant class. In Scotland, these witch persecutions attained to a most fearful extent during the seventeenth century. They were introduced into England very much by James I., who came to England possessed by these ideas, and he communicated them to others, and there were a good many witch persecutions during his reign. After the execution of Charles I., and during the time of the Commonwealth and the Puritans, there were a good many witch persecutions; but I think after that, very little more was heard of them. And yet the belief in witchcraft lingered for a considerable time longer. It is said that even Dr. Johnson was accustomed to remark, that he did not see that there was any proof of the non-existence of witches; that though their existence could not be proved, he was not at all satisfied that they did not exist. John Wesley was a most devout believer in witchcraft, and said on one occasion that if witchcraft was not to be believed, we could not believe in the Bible. So you see that this belief had a very extraordinary hold over the public mind. It was only the most intelligent class, whose minds had been freed from prejudice by general culture, who were really free from it; and that cultivation happily permeated downwards, as it were; so that now I should hope there are very few amongst our intelligent working class in our great towns—where the general culture is much higher than it is in the agricultural districts—who retain anything more than the lingering superstition which is to be found even in the very highest circles—as, for instance, not liking to be married on a Friday, or not liking to sit down thirteen at the dinner table. These are things which even those who consider themselves the very aristocracy of intellect will sometimes confess to, laughing at it all the time, but saying, "It goes against the grain, and I would rather not do it." These, I believe, are only lingering superstitions that will probably pass away in another half century, and we shall hear nothing more of them; the fact being that the tendency to these delusions is being gradually grown out of.

Now this is the point I would especially dwell upon. To the child-mind nothing is too strange to be believed. The young child knows nothing about the Laws of Nature; it knows no difference between what is conformable to principles, and what, on the other hand, is so strange that an educated man cannot believe it. To the child every new thing that it sees is equally strange; there is none of that power of discrimination that we acquire in the course of our education—the education given to us, and the education that we give ourselves. We gradually, in rising to adult years, grow out of this incapacity to distinguish what is strange from what is normal or ordinary. We gradually come to feel—"Well, I can readily believe that, because it fits in with my general habit of thought; I do not see anything strange in this, although it is a little unusual." But, on the other hand, there are certain things we feel to be too strange and absurd to be believed; and that feeling we come to especially, when we have endeavoured to cultivate our Common Sense in the manner which I described to you in my last lecture. The higher our common sense—that is, the general resultant of the whole character and discipline of our minds—the more valuable is the direct judgment that we form by the use of it. And it is the growth of that common sense, which is the most remarkable feature in the progress of thought during the last century. The discoveries of science; the greater tendency to take rational and sober views of religion; the general habit of referring things to principles; and a number of influences which I cannot stop particularly to describe, have so operated on the public mind, that every generation is raised, I believe, not merely by its own culture, but by the acquired result of the experience of past ages; for I believe that every generation is born, I will not say wiser, but with a greater tendency to wisdom. I feel perfectly satisfied of this, that the child of an educated stock has a much greater power of acquiring knowledge than the child of an uneducated stock; that the child that is the descendant of a race in which high moral ideas have been always kept before the mind, has a much greater tendency to act uprightly than the child that has grown up from a breed that has been living in the gutter for generations past. I do not say that these activities are born with us; but the tendency to them,—that is the aptitude of mind for the acquirement of knowledge, the facility of learning, the disposition to act upon right principles,—I believe is, to a very great degree, hereditary. Of course we have lamentable examples to the contrary, but I am speaking of the general average. I am old enough now to look back with some capacity of observation for 40 years; and I can see in the progress of society a most marked evidence of the higher general intelligence, the greater aptitude for looking at things as they are, and for not allowing strange absurd notions to take possession of the mind; while, again, I can trace, even within the last ten years, in a most remarkable manner, the prevalence of a desire to do right things for the right's sake, and not merely because they are politic. And I am quite sure that there is a gradual progress in this respect, which has a most important influence in checking aberrations of the class of which I have spoken.

Still we see these aberrations; and there is one just now which is exciting a good deal of attention,—that which you have heard of under the name of "Spiritualism." Now I look upon the root of this spiritualism to lie in that which is a very natural, and in some respects, a wholesome disposition of the kind—a desire to connect ourselves in thought with those whom we have loved and who are gone from us. Nothing is more admirable, more beautiful, in our nature than this longing for the continuance of intercourse with those whom we have loved on earth. It has been felt in all nations and at all times, and we all of us experience it in regard to those to whom we have been most especially attached. But this manifestation of it is one which those who experience this feeling in its greatest purity and its greatest intensity feel to be absurd and contrary to common sense—that the spirits of their departed friends should come and rap upon tables and make chairs dance in the air, and indicate their presence in grotesque methods of this kind. The most curious part of it is that the spirits should obey the directions of the persons with whom they profess to be in communication,—that when they say "rap once if you mean yes, and rap twice if you mean no," and so on, they should just follow any orders they receive as to the mode in which they will telegraph replies to their questions. It seems to me repugnant to one's common sense; but the higher manifestations of these spiritual agencies seem to me far more repugnant to common sense; and that is when persons profess to be able to set all the laws of nature at defiance; when it is said, for instance, that a human being is lifted bodily up into the air and carried, it may be, two or three miles, and descends through the ceiling of a room. One of the recent statements of this kind, you know, is that a certain very stout and heavy lady was carried a distance of about two miles from her own house, and dropped plump down upon the table round which eleven persons were sitting; she came down through the ceiling, they could not state how, because they were sitting in the dark; and that darkness has a good deal to do with most of these manifestations. Now let us analyse them a little. I am speaking now of what I will call the genuine phenomena—those which happen to persons who really are honest in their belief. I exclude altogether, and put aside the cases, of which I have seen numbers, in which there is the most transparent trickery, and in which the only wonder is that any rational persons should allow themselves to be deceived by it.

I have paid a great deal of attention during the last twenty years to this subject, and I can assure you that I have, in many instances, known things most absurd in themselves, and most inconsistent with the facts of the case as seen by myself and other sober-minded witnesses, believed in by persons of very great ability, and, upon all ordinary subjects, of great discrimination. But I account for it by the previous possession of their minds by this dominant idea—the expectation they have been led to form, either by their own earnest desire for this kind of communication, or by the sort of contagious influence to which some minds are especially subject. I say "the earnest desire," for it is a very curious thing that many of those who are the most devout spiritualists are persons who have been themselves previously rather sceptical upon religious matters; and many have said to me that this communication is really the only basis of their belief in the unseen world. Such being the case, I cannot wonder that they cling to it with very strong and earnest feeling. A lady, not undistinguished in the literary world, assured me several years ago that she had been converted by this spiritualism from a state of absolute unbelief in religion; and she assured me, also, that she regarded medical men and scientific men, who endeavoured to explain these phenomena upon rational principles, and to expose deception, where deception did occur, as the emissaries of Satan, who so feared that the spread of spiritualism would destroy his power upon earth, that he put it into the minds of medical and scientific men to do all that they could to prevent it. Now that, I assure you, is a fact. That was said to me by a lady of considerable literary ability, and I believe it represents, though rather extravagantly, a state of mind which is very prevalent; the great spread of the intense materialism of our age tending to weaken, and in some instances to destroy, that healthful longing which we all have, I believe, in our innermost nature, for a higher future existence, and which is to my mind one of the most important foundations of our belief in it. We live too much in the present; we think too much of the things of the world as regards our material comfort and enjoyment, instead of thinking of them as they bear upon our own higher nature. I believe that this tendency, which I think is especially noticeable in America—or at least it was a few years ago—from all that I was able to learn, had a great deal to do with the spread of this belief in what is called Spiritualism. The spiritualists assert that in America they are numbered by millions, that there are very few people of any kind of intellectual culture who have not either openly or secretly given in their adhesion to it. I believe that is a gross exaggeration; still there can be no doubt from the number of periodicals they maintain, and the advertisements in them of all kinds of strange things that are done—spirit drawings made, drawings of deceased friends, and spiritual instruction given of various kinds—that there must be a very extended belief in this notion of communication with the unseen world through these "media."

I can only assure you for myself that having, as I have said, devoted considerable attention to this subject, I have come to the conclusion most decidedly, with, I believe I may say, as little prepossession as most persons, and with every disposition to seek for truth simply—to allow for our knowledge, or I would rather say for our ignorance, a very large margin of many things that are beyond our philosophy—with every disposition to accept facts when I could once clearly satisfy myself that they were facts—I have had to come to the conclusion that whenever I have been permitted to employ such tests as I should employ in any scientific investigation, there was either intentional deception on the part of interested persons, or else self-deception on the part of persons who were very sober-minded and rational upon all ordinary affairs of life. Of that self-deception I could give you many very curious illustrations, but the limits of our time will prevent my giving you more than one or two. On one occasion I was assured that on the evening before, a long dining table had risen up and stood a foot high in the air, in the house in which I was, and to which I was then admitted for the purpose of seeing some of these manifestations by persons about whose good faith there could be no doubt whatever. I was assured by them—"It was a great pity you were not here last night, for unfortunately our principal medium is so exhausted by the efforts she put forth last night that she cannot repeat it." But I was assured upon the word of three or four who were present, that this table had stood a foot high in the air, and remained suspended for some time, without any hands being near it, or at any rate with nothing supporting it; the hands might be over it. But I came to find from experiments performed in my presence, that they considered it evidence of the table rising into the air, that it pressed upward against their hands; —that they did not rest upon their sense of sight; for I was looking in this instance at the feet of the table, and I saw that the table upon which the hands of the performers were placed, and which was rocking about upon its spreading feet, really never rose into the air at all. It would tilt to one side or to the other side, but one foot was always resting on the ground. And when they declared to me that this table had risen in the air, I said, "I am very sorry to have to contradict you, but I was looking at the feet of the table all the time, and you were not; and I can assert most positively that one of the feet never left the ground. Will you allow me to ask what is *your* evidence that the table rose into the air?" "Because we felt it pressing upwards against our hands." I assure you that was the answer I received; their conclusion that the table rose in the air being grounded on this, that their hands being placed upon the table, they felt, or they believed, that the table was pressing upwards against their hands, though I saw all the time that one foot of the table had never left the ground. Now that is what we call a "subjective sensation;" one of those sensations which arise in our own minds under the influence of an idea. Take for instance the very common case—when we sleep in a strange bed, it may be in an inn that is not very clean, and we begin to be a little suspicious of what other inhabitants there may be in that bed; and then we begin to feel a "creepy, crawly" sensation about us, which that idea will at once suggest. Now those are subjective sensations; those sensations are produced by the mental idea. And so in this case I am perfectly satisfied that a very large number of these spiritual phenomena are simply subjective sensations; that is, that they are the result of expectation on the part of the individual. The sensations are real to them. You know that when a man has suffered amputation of his leg, he will tell you at first that he feels his toes, that he feels his limb; and, perhaps to the end of his life, every now and then he will have this feeling of the limb moving, or of a pain in it; and yet we know perfectly well that that is simply the result of certain changes in the nerve, to which, of course, there is nothing answering in the limb that was removed. These subjective sensations, then, will be felt by the individuals as realities, and will be presented to others as realities, when, really, they are simply the creation of their own minds, that creation arising out of the expectation which they have themselves formed. These parties believed that the table would rise; and when they felt the pressure against their hands, they fully believed that the table was rising.

Take the case of Table-turning, which occurred earlier. I dare say many of you remember that epidemic which preceded the spiritualism; in fact, the spiritualism, in some degree, arose out of table-turning. My friend, the chairman (Dr. Noble), and I hunted in couples, a good many years ago, with a third friend, the late Sir John Forbes, and we went a great deal into these inquiries; and I very well remember sitting at a table with him, I suppose 25 years ago, waiting in solemn expectation for the turning of the table; and the table went round. This was simply the result of one of the party, who was not influenced by the philosophical scepticism that we had on the subject, having a strong belief that the phenomenon would occur; and when he had sat for some time with his hands pressed down upon the table, an involuntary muscular motion, of the kind I mentioned in my last lecture, took place, which sent the table turning. There was nothing to the Physiologist at all difficult in the understanding of this. Professor Faraday was called upon to explain the table-turning, which many persons set down to electricity; but he was perfectly satisfied that this was a most untrue account of it, and that the explanation was (as, in fact, I had previously myself stated in a lecture at the Royal Institution) that the movements took place in obedience to ideas. Movements of this class are what I call "ideo-motor," or reflex actions of the brain; and the occurrence of these movements in obedience to the idea entertained is the explanation of all the phenomena of table-turning. Professor Faraday constructed a very simple testing apparatus, merely two boards, one over the other, and confined by elastic bands, but the upper board rolling readily upon a couple of pencils or small rollers; and resting on the lower board was an index, so arranged that a very small motion of this upper board would manifest itself in the movement of the index through a large arc. He went about this investigation in a thoroughly scientific spirit. He first tied together the boards so that they could not move one upon the other, the object being to test whether the mere interposition of the instrument would prevent the action. He had three or four of these indicators prepared, and he put them down on the table so fixed that they would not move. He then put the hands of the table turners on these; and it was found, as he fully expected, that the interposition of this indicator under their hands did not at all prevent the movement of the table. The hands were resting on the indicator; and when their involuntary pressure was exerted, the friction of the hands upon the indicators, and of the indicators upon the table, carried round the table just as it had done before. Now if there had been anything in the construction of the instrument to prevent it, that would not have happened. Then he loosened the upper board and put the index on, so that the smallest motion of the hands upon the board would manifest itself, before it would act on the table, in the movement of the index; and it was found that when the parties looked at the index and watched its indications, they were pulled up as it were, at the very first involuntary action of their hands, by the knowledge that they were exerting this power, and the table then never went round. One of the strangest parts of this popular delusion was, that even after this complete exposure of it by Faraday, there were a great many persons, including many who were eminently sensible and rational in all the ordinary affairs of life, who said—"O, but this has nothing at all to do with it. It is all very well for Professor Faraday to talk in this manner, but it has nothing at all to do with it. We *know* that we are not exerting any pressure. His explanation does not at all apply to *our* case." But then Professor Faraday's table-turners were equally satisfied that *they* did not move the table, until the infallible index proved that they did. And if any one of these persons who *know* that they did not move the table, were to sit down in the same manner with those indicators, it would have been at once shown that they did move the table. Nothing was more curious than the possession of the minds of sensible men and women by this idea that the tables went round by an action quite independent of their own hands; and not only that, but that really, like the people in the dancing mania, they *must* follow the table. I have seen sober and sensible people running round with a table, and with their hands placed on it, and asserting that they could not help themselves—that they were obliged to go with the table. Now this is just simply the same kind of possession by a dominant idea, that possessed the dancing maniacs of the middle ages.

Then the Table-talking came up. It was found that the table would tilt in obedience to the directions of some spirit, who was in the first instance (I speak now of about 20 years ago) always believed to be an evil spirit. The table talking first developed itself in Bath, under the guidance of some clergymen there, who were quite satisfied that the tiltings of the table were due to the presence of evil spirits. And one of these clergymen went further, and said that it was Satan himself. But it was very curious that the answers obtained by the rappings and tiltings of the tables always followed the notions of the persons who put the questions. These clergymen always got these answers as from evil spirits, or satisfied themselves that they were evil spirits by the answers they got. But, on the other hand, other persons got answers of a very different kind; an innocent girl for instance, asked the table if it loved her, and the table jumped up and kissed her. A gentleman who put a question to one of these tables got an extremely curious answer, which affords a very remarkable illustration of the principle I was developing to you in the last lecture—the unconscious action of the brain. He had been studying the life of Edward Young the poet, or at least had been thinking of writing it; and the spirit of Edward Young announced himself one evening, as he was sitting with his sister-in-law,—the young lady who asked the table if it loved her. Edward Young announced himself by the raps, spelling out the words in accordance with the directions that the table received. He asked, "Are you Young the poet?" "Yes." "The author of the 'Night Thoughts?'" "Yes." "If you are, repeat a line of his poetry." And the table spelt out, according to the system of telegraphy which had been agreed upon, this line:—

"Man is not formed to question but adore."

He said, "Is this in the 'Night Thoughts?'" "No." "Where is it?" "J O B." He could not tell what this meant. He went home, bought a copy of Young's works, and found that in the volume containing Young's poems there was a poetical commentary on Job which ended with that line. He was extremely puzzled at this; but two or three weeks afterwards he found he had a copy of Young's works in his own library, and was satisfied from marks in it that he had read that poem before. I have no doubt whatever that that line had remained in his mind, that is in the lower stratum of it; that it had been entirely forgotten by him, as even the possession of Young's poems had been forgotten; but that it had been treasured up as it were in some dark corner of his memory, and had come up in this manner, expressing itself in the action of the table, just as it might have come up in a dream.

These are curious illustrations, then, of the mode in which the minds of individuals act when there is no cheating at all,—this action of what we call the subjective state of the individual dominating these movements; and I believe that that is really the clue to the interpretation of the genuine phenomena. On the other hand, there are a great many which we are assured of—for instance, this descent of a lady through the ceiling,—which are self-delusions, pure mental delusions, resulting from the preconceived idea and the state of expectant attention in which these individuals are. Here are a dozen persons sitting round a table in the dark, with the anticipation of some extraordinary event happening. In another dark seance one young lady thought she would like to have a live lobster brought in, and presently she began to feel some uncomfortable sensations, which she attributed to the presence of this live lobster; and the fact is recorded that two live lobsters were brought in; that is, they appeared in this dark séance—making their presence known, I suppose, by crawling over the persons of the sitters. But that is all we know about it—that they felt something—they say they were two live lobsters, but what evidence is there of that?—the séance was a dark one. We are merely told that the young lady thought of a live lobster; she said they had received so many flowers and fruits that she was tired of them, and she thought of two live lobsters; and forthwith it was declared that the live lobsters were present. I certainly should be much more satisfied with the narration, if we were told that they had made a supper off these lobsters after the séance was ended.

Now it has been my business lately to go rather carefully into the analysis of several of these cases, and to inquire into the mental condition of some of the individuals who have reported the most remarkable occurrences. I cannot—it would not be fair—say all I could say with regard to that mental condition; but I can only say this, that it all fits in perfectly well with the result of my previous studies upon the subject, viz., that there is nothing too strange to be believed by those who have once surrendered their judgment to the extent of accepting as credible things which common sense tells us are entirely incredible. One gentleman says he glories in not having that scientific incredulity which should lead him to reject anything incredible merely because it seems incredible. I can only say this, that we might as well go back to the state of childhood at once, the state in which we are utterly incapable of distinguishing the strange from the true. That is a low and imperfect condition of mental development; and all that we call education tends to produce the habit of mind that shall enable us to distinguish the true from the false—actual facts from the creations of our imagination. I do not say that we ought to reject everything that to us, in the first instance, may seem strange. I could tell you of a number of such things in science within your own experience. How many things there are in the present day that we are perfectly familiar with—the electric telegraph, for instance—which fifty years ago would have been considered perfectly monstrous and incredible. But there we have the rationale. Any person who chooses to study the facts may at once obtain the definite scientific rationale; and these things can all be openly produced and experimented upon, expounded and explained. There is not a single thing we are asked to believe of this kind, that cannot be publicly exhibited. For instance, in this town, last week, I saw a stream of molten iron coming out from a foundry; I did not see on this occasion,—but the thing has been done over and over again,—that a man has gone and held his naked hand in such a stream of molten iron, and has done it without the least injury; all that is required being to have his hand moist, and if his hand is dry he has merely to dip it in water, and he may hold his hand for a certain time in that stream of molten iron without receiving any injury whatever. This was exhibited publicly at a meeting of the British Association at Ipswich many years ago, at the foundry of Messrs. Ransome, the well known agricultural implement makers. It is one of the miracles of science, so to speak; they are perfectly credible to scientific men, because they know the principle upon which it happens, and that principle is familiar to you all—that if you throw a drop of water upon hot iron, the water retains its spherical form, and does not spread upon it and wet it. Vapour is brought to that condition by intense heat, that it forms a sort of film, or atmosphere, between the hand and the hot iron, and for a time that atmosphere is not too hot to be perfectly bearable. There are a number of these miracles of science, then, which we believe, however incredible at first sight they may appear, because they can all be brought to the test of experience, and can be at any time reproduced under the necessary conditions. Houdin, the conjurer, in his very interesting autobiography—a little book I would really recommend to any of you who are interested in the study of the workings of the mind, and it may be had for 2s.—Houdin tells you that he himself tried this experiment, after a good deal of persuasion; and he says that the sensation of immersing his hand in this molten metal was like handling liquid velvet. These things, I say, can be exhibited openly—above board; but these Spiritual phenomena will only come just when certain favourable conditions are present—conditions of this kind, that there is to be no scrutiny—no careful examination by sceptics; that there is to be every disposition to believe, and no manifestation of any incredulity, but the most ready reception of what we are told. I was asked some years ago to go into an investigation of the Davenport Brothers; but then I was told that the whole thing was to be done in the dark, and that I was to join hands and form part of a circle; and I responded to the invitation by saying that in all scientific inquiries I considered the hands and the eyes essential instruments of investigation, and that I could not enter into any inquiry, and give whatever name I possess in science to the result of it, in which I was not allowed freely to use my hands and my eyes. And wherever I have gone to any of these Spiritual manifestations, and have been bound over not to interfere, I have seen things which, I feel perfectly certain, I could have explained, if I had only been allowed to look under the table, for instance, or to place my leg in contact with the leg of the medium. And it has been publicly stated within the last month, that the very medium whom I suspected strongly of cheating on an occasion of this kind, was detected in the very acts which I suspected, but which I was not allowed to examine. I cannot then go further into this inquiry at the present time; but I can only ask you to receive my assurance as that of a scientific man, who has for a long course of years been accustomed to investigate the curious class of actions to which I have alluded, and which disguise themselves under different names. A great number of the very things now done by persons professing to call themselves Spiritualists, were done 30 years ago, or professed to be done, by those who call themselves "Mesmerists;" thus the lifting of the whole body in the air was a thing that was asserted as possible by mesmerists, as is now done by Mr. Home and his followers. These things I say, crop up now and then, sometimes in one form, sometimes in another; and it is the same general tendency to credulity, to the abnegation of one's Common Sense, that marks itself in every one of these epidemics.

Thus, then, we come back to the principle from which we started—that the great object of all education should be to give to the mind that rational direction which shall enable it to form an intelligent and definite judgment upon subjects of this kind, without having to go into any question of formal reasoning upon them. Thus, for example, is it more probable that Mr. Home floated out of one window and in at another, or that Lord Lindsay should have allowed himself to be deceived as to a matter which he admits only occurred *by moonlight?* That is the question for common sense. I believe, as I stated just now, that the tendency to the higher culture of the present age will manifest itself in the improvement of the next generation, as well as of our own; and it is in that hope that I have been encouraged on this and other occasions to do what I could for the promotion of that desire for self-culture, of which I see so many hopeful manifestations at the present day. When once a good basis is laid by primary education, I do not see what limit there need be to—I will not say the *learning* of future generations—but to their *wisdom*, for wisdom and learning are two very different things. I have known some people of the greatest learning, who had the least amount of wisdom of any persons who have come in my way. Learning, and the use that is made of it, are two very different things. It is the effort to acquire a distinct and definite knowledge of any subject that is worth learning, which has its ultimate effect, as I have said, upon the race, as well as upon the individual.

But there are great differences, as to their effects upon the mind, among different subjects of study; and I have long been of opinion that those studies afford the best discipline, in which the mind is brought into contact with outward realities,— a view which has lately been put forth with new force by my friend Canon Kingsley. You know that Canon Kingsley has acquired great reputation as an historian. He held the Professorship of History at the University of Cambridge for many years, and, in fact, has only recently withdrawn from it. Canon Kingsley also early acquired a considerable amount of scientific culture, and he has always been particularly fond of Natural History. Now he lately said to the working men of Bristol that he strongly recommended them to cultivate Science, rather than study History; having himself almost withdrawn from the study of history, for this reason, that he found it more and more difficult to satisfy himself about the truth of any past event; whilst, on the other hand, in the study of science, he felt that we were always approaching nearer to the truth. A few days ago I was looking through a magazine article on the old and disputed question of Mary Queen of Scots, which crops up every now and then. She is once more put upon her trial. Was Mary Queen of Scots a vicious or a virtuous woman? The question will be variously answered by her enemies and by her advocates; and I believe it will crop up to the day of doom, without ever being settled. Now, on the other hand, as we study scientific truth, we gain a certain point, and may feel satisfied we are right up to that point, though there may be something beyond; while the elevation we have gained enables us to look higher still. It is like ascending a mountain; the nearer we get to the top, the clearer and more extensive is the view. I think this is a far better discipline to the mind than that of digging down into the dark depths of the past, in the search for that which we cannot hope ever thoroughly to bring to light. It so happened that only a fortnight ago I had the opportunity of asking another of our great historians, Mr. Froude, what he thought of Canon Kingsley's remark. He said, "I entirely agree with it;" and in some further conversation I had with him on the subject, I was very much struck with finding how thoroughly his own mind had been led, by the very important and profound researches he has made into our history, to the same conclusion—the difficulty of arriving at absolute truth upon any Historical subject. Now we do hope and believe that there is absolute truth in Science, which, if not at present in our possession, is within our reach; and that the nearer we are able to approach to it, the clearer will be our habitual perception of the difference between the real and the unreal, the firmer will be our grasp of all the questions that rise in the ordinary course of our lives, and the sounder will be the judgment we form as to great political events and great social changes. Especially will this gain be apparent in our power of resisting the contagious influence of "Mental Epidemics."

THE PROGRESS OF SANITARY SCIENCE.

A LECTURE,

BY PROFESSOR ROSCOE, F.R.S.,

Delivered in the Town Hall, Salford, December 19th, 1871.

UNDER THE AUSPICES OF THE MANCHESTER AND SALFORD SANITARY ASSOCIATION.

THE recent illness of the Prince of Wales may be said for several reasons to have been a good thing for the country; and, especially, because it has called attention, and that in a most marked manner, to sanitary matters. We cannot take up a newspaper now but we see it filled with letters on sewers and sewer gases. One suggests that every bad smell may bring to us typhoid fever, or some other disorder; whilst in another we read that these fears are mere illusions, and that in towns where there is a great deal of dirt, and where the ordinary rules of health are universally disobeyed, none of those dreadful ills occur which are painted so gloomily. Now, it is important that we should get to know as much as we can respecting the truth of these two assertions, so that on the one hand we may not be frightened with the idea that whenever we smell a bad odour we are sure to take typhoid fever; nor yet, on the other hand, be lulled into a false repose with regard to these matters, and think that sanitary laws can be broken with impunity. Equally false are both these points of view; and it is with the intention of pointing out some few of the distinct facts which science has been able to accumulate respecting the laws of health that I now address you.

In the first place, of the importance of the science of health there can be no doubt. Everybody wishes to be healthy, and everybody, when he thinks of it at any rate, wishes to avoid such things as might bring him disease and suffering. How to preserve the health is not, however, so clear. For the most part men live in ignorance of those laws of health by which their action should be guided; and if we are asked how we should act under certain conditions, or whether such and such a state of things is an unhealthy one, many of us are unable to answer the question. One reason of this is the complicated and changing nature of the requirements. For instance, a man who lives under one set of physical circumstances will have to obey one set of laws of health; whilst men living under different circumstances will have to observe quite other laws in order to be healthy. The red Indian, roaming over the prairies, has to look out for altogether different dangers from those which surround us who live in crowded cities, where, perhaps, one thousand persons in some districts live on an acre. That the science of health is really less developed and less known than many other sciences lies, then, in the fact that it is more complicated than these other sciences, and a little reflection will show you why this is so. Thus, we find that enormous effects are produced by very minute causes; and this is the case not only when we catch a fever or a particular disease, without really being able to tell how we have caught it, or being able to assign to it any origin whatever; but we also find that this often holds good when we know that we are introducing a disease, as, for example, by the vaccine lymph, which, when introduced into the blood, though it be but the smallest particle on the point of a needle, produces a very extraordinary and valuable change on the human body. This, I say, shows us that the effect which is produced is enormously larger than the cause—larger not only than the apparent cause, but larger than the real cause. Hence, then, one great difficulty of determining these questions; and hence it is that men have lived for so many generations, and for so many hundreds and thousands of years, without having obtained even an imperfect knowledge of these subjects; for it is evident that we are only just at the threshold of knowledge as regards these matters; we are merely groping in the dark, and gradually getting hold of facts here and facts there and putting them together, in order to lay the foundation of this science of health of which we all stand so much in need.

If we look back we find that in the olden time, we see that whenever disease and epidemics broke out and spread over the country without apparent cause, the people attributed these afflictions to the visitation of God, or in heathen countries to the work of some offended deity; and even now, in our times and in civilised countries, we find people who ought to know better wearing charms against certain evils, fancying that they will keep away disease. The first idea, then, we must get rid of in our investigation as to matters of health is this notion that disease is brought about by something indefinite and intangible, something which we must call upon the spirits of darkness or the spirits of light to deliver us from. We must first admit that there is a tangible cause for disease, a cause which we shall probably be able to find if we seek for it properly; but, at any rate, whether we find it or not, that a cause exists. It would be useless to attempt investigation unless we believed that there is a cause for every disease, and for every changing condition of the body which may occur. Very well, then, the first question is: can we arrive at such cause; can we put our fingers upon any cause or causes which do affect the general health of the community?

There is no doubt that if we look back at the history of disease, of epidemic disease especially, we shall find that the older epidemics, such as the plague, the sweating-sickness, and a number of these diseases, have, with the progress of time, gradually disappeared. We no longer hear of the plague in our cities. You have all read of the great plague of London in 1665, which was followed by the great fire of London; and it is said that London never would have been purified had it not been almost burnt down to the ground after this visitation. But now a-days we do not hear of these outbreaks of plague, at least in this country, and this is, doubtless, mainly to be attributed to general improvement in the style of living, and to care and cleanliness in getting rid of the impurities which the body throws off. I mention this to show that these epidemic diseases are in some way or other connected with causes which are removable, or, at any rate, which may be mitigated. Now, another fact that we have learned with regard to these epidemics of olden time is that they were most felt, and the mortality was always the greatest, amongst the poor, the dirty and the degraded portion of the population; as a rule these people suffered more than did those whose circumstances enabled them to live in a better way. The general conclusion is therefore that these epidemics are in some way assisted and abetted by dirt and degradation, and that improvement in the condition and habits of life of the people does either avert or lessen the virulence of these outbreaks of epidemic disease. This is shown by a vast number of facts; and the first that occurs to me is the case of the city of Buenos Ayres. You are aware that the year before last a most severe outbreak of yellow fever occurred in the large city of Buenos

Ayres, in the Brazils; and on investigation it was found that the sanitary arrangements of that city were of the very lowest and crudest character; that they had no drains, but only enormous cesspools which were never emptied, and under their tropical sun became festering masses of pollution and impurity. So strong was the conviction that this outbreak was due to the unhealthy arrangements of their city, that the authorities resolved to spend an enormous sum, I believe something like four millions sterling, on a complete system of drainage and water supply for the city. They are going to remodel their whole arrangements, and do away with these festering nuisances, in the belief, which I have no doubt will be justified by the result, that they will thereby prevent such an outbreak in the future.

The question as to the mode in which an individual or a community becomes infected divides itself into two distinct branches of epidemic diseases. First we have to consider why the epidemic comes at certain intervals; why, for instance, the cholera never visited us before 1831, why it then disappeared and after a lapse of years again breaks out? Next we have to ask how is the disease propagated when it has once broken out. As regards the first question I think we have as yet very little safe ground from which to draw conclusions. That the march of the cholera in a westerly direction can generally be traced and its probable occurrence foretold is quite true, and that plausible theories have been proposed to account for the possibility of the existence of cholera in certain countries at certain times is also true. Still on the whole our knowledge on this question is of the most incomplete character. Not so with regard to the second part of our inquiry as to how this particular epidemic disease is propagated. In an inquiry as to the cause of production of any disease, we may take it for granted that the material causing the disease must be brought to the individual either in the water we drink, or in the air we breathe, or in the food we eat. I am not speaking now of what are termed "hereditary diseases," which are of a totally different character, and do not come into the class of those which can be removed by sanitary improvements. Applying this principle to the case of cholera, as being one of the best investigated of epidemics, we find that the poisonous matter which is the cause of this disease is very frequently, at any rate, taken with the water that is drank. In order to make this matter clear to you I will only call your attention to two or three cases of evidence as to the truth of the statement. The first is from that given before the Royal

Commission on the water supply of the metropolis, by Mr. Simon, the medical officer of the Privy Council. Mr. Simon says :—

"It is, I believe, a matter of absolute demonstration that in the old epidemics, when the south side of London suffered so dreadfully from cholera, the great cause of the immense mortality there was the badness of the water then distributed in those districts of London. In the interval between the 1849 epidemic and the 1854 epidemic one of the two companies which supply the south side of London had amended its source of supply; it had gone higher up the river, and we at once lost a great part of the mortality on that side of the river. But it was found that this great difference did not prevail uniformly through the south side of London, but was confined to those houses which were supplied from the amended source. There was still a great mortality on the south side of the river, but this belonged exclusively to the houses which were still supplied with impure water."

From a table given in the report from which I quote it is seen that the number of deaths per thousand from cholera in the visitation of 1848, in the houses supplied by the Lambeth Company, was 12·5; at the next visitation the same houses lost only 3·7; that is to say, that the rate had diminished by three-fourths; whilst in the houses supplied by the Vauxhall Company the death rate at the first visitation was 11·8, and in the second visitation 13; so that the death-rate had actually increased in the houses which were supplied with water from the company which had not mended its ways.

Another epidemic, that of 1866, only confirmed the conclusions drawn from previous experience, for Mr. Simon clearly shows that the heavy mortality in this year fell in the east of London, and was distinctly confined to a district supplied by water drawn from a foul part of the river Lea and containing sewage impurity.

A third instance is that singular case known as the Golden Square case. In the course of five or six days, from the 30th August, 1854, not less than about 500 persons died of cholera in a district in London, round Golden Square, containing about 5,000 inhabitants. Upon investigation it was found that nearly all the people who died had been drinking water from a pump in Broad Street, which was thought to yield very excellent water, but was afterwards found to communicate with a cesspool in an adjoining house. These cases clearly prove that contaminated water may produce cholera.

We will next take the disease from which the Prince of Wales has suffered, and which is known as typhoid or enteric fever. This disease is generally supposed to be caused either by drinking impure water, or by breathing the foul gases generated in sewers; and it is said that 20,000 persons die annually from this preventable disease. The preventable nature of this disease is so generally acknowledged, that when an outbreak of typhoid fever occurs in a district, the medical department of the Privy Council—a most important department, and one which will become of greater influence still, from the act of Parliament passed last session—sends down a duly qualified medical man to inquire into the causes of the origin and spread of such an epidemic outbreak. Dr. Buchanan was sent down in September, 1867, to investigate the cause of the outbreak of typhoid fever at Guildford. He reported that a new well had been sunk to supply the higher part of the town, and that water from this well was supplied to about 330 houses for one day only, the 17th August. On the 28th of August there were several cases of typhoid fever in these houses, although they are all situated in the highest and healthiest district in the town. The number daily increased, and there were in all about 500 cases and 21 deaths. With three exceptions, all the persons attacked in August and September had drank the water exceptionally supplied for one day only—as just stated. It was subsequently found that a sewer ran within ten feet of the well, and that the sewage leaked through the joints of the brickwork and saturated the soil just above the spring which supplied the well.

I might give you a great number of other instances of a similar character. I will content myself by stating that Dr. Parkes, the well known Professor of Sanitary Science in the medical school at Netley, has collected a good deal of evidence as to diseases which may be communicated by water, not only to the troops, but among the civil population; and he has made a list of diseases, all of which may be communicated by means of water, and amongst these he has collected many instances of local outbreaks of typhoid fever arising from water impregnated with typhoid sewage or possibly simple sewage. One case quoted by Dr. Parkes is that of a young ladies' school, where infiltration of sewage into the well supplying the house with water was shown to be the cause of a severe outbreak of typhoid fever.

These cases prove to us that epidemic diseases may be produced and have been produced by drinking impure water. Having assured ourselves of this, let us next see what chemistry can tell us respecting our means of detecting whether the water used for drinking is pure or impure. You will understand that the danger lies in the water being impregnated with animal decomposing matter, and with sewage matters generally. Now, although, chemists, like other men, cannot do all that they would like to do in these investigations, still they can do something; and I wish to point out to you what chemistry can tell us respecting the purity or the impurity of such water. In the first place let us clearly understand that neither the chemist, nor the physician, nor the microscopist, nor the physiologist, can tell us whether the water contains typhoid poison, or whether the water contains cholera poison or whether the water contains the poison of any other particular disease. There are no means of ascertaining this, even with the most poisonous exhalations from the cholera patient, except it be the actual test of the action of the poison on a human subject. The microscopist cannot detect, for instance, in the rice water from a cholera patient, that there are any particular germs of cholera poison in that offensive liquid; and yet if the smallest quantity of it got into the digestive organs of a man it would produce cholera. But although the chemist is unable to do this, he is able to tell the difference between a pure water and a water which contains animal impurity; and if the water contains cholera poison, or the germs of typhoid, or of some other disease, or simply animal excrementitious matter, it is, I need scarcely tell you, unfit to drink; and the chemist can help us to detect such matters.

Now what is it that the chemist can do in this respect? You know that all animal matter makes a disagreeable smell when it is burnt. The difference between burning a feather and burning a piece of wood is evident to your senses. Now, this burnt feather smell is caused by the presence of a body which the chemists call Nitrogen, which exists in the air, but which also enters as a characteristic ingredient into all animal matter. In this respect animal bodies differ from the bodies of vegetables. Now, when the decomposition of an animal body occurs, the nitrogenous portions which are thrown off, that is the liquid and the solid products, get into the sewers; and if we can find in water a large quantity of this nitrogenous animal matter, we may be certain that that water is not fit to drink. I cannot explain to you to-night how the amount of nitrogenous matter contained in water is ascertained; but if you will look at these analyses taken from Professor Frankland's report on the Chemical Composition of the Lancashire rivers, you will see what I mean.

Composition of Lancashire Rivers.

Parts in 100,000.

	Irwell.		*Mersey.*	
	*1	2	3	4
Total solid soluble...............	7·8	55·80	7·62	39·50
Organic carbon	0·187	1·173	0·222	1·231
Organic nitrogen	0·025	0·332	0	0·601
Ammonia	0·004	0·740	0·002	0·622
Nitrogen as nitrates and nitrites	0·021	0·707	0·021	0
Total combined nitrogen	0·049	1·648	0·023	1·113
Chlorine	1·15	9·63	0·94	—
Hardness temporary	3·72	15·04	4·61	10·18
Total hardness	3·72	15·04	4·61	10·18
Suspended Matter.				
Organic	0	2·71	0	—
Mineral	0	2·71	0	—
Total	0	5·42	0	—

*1. The Irwell near its source.
2. The Irwell below Manchester.
3. The Mersey, one of its sources.
4. The Mersey below Stockport.

We have here the composition of Lancashire rivers taken from the admirable report of the Rivers Pollution Commission. In the first column you have the analysis of the river Irwell, that is of the water taken at its source, where it is as pure as we could wish water to be, being, in fact, very much like the pure water which the Manchester corporation supply to us from the Derbyshire hills. In the second column you have the composition of the Irwell below Manchester. In the same way you will see the composition of the Mersey at its source, and its composition below Stockport. Let us confine ourselves to the Irwell. Now, in the first place, you will notice that the total soluble matter, or that which is dissolved in the water, is very much more, as you may imagine, when the Irwell gets below Manchester than it is at its source. But this total soluble matter might be perfectly innocuous; it might, for instance, be common salt, or carbonate of lime, or gypsum, or any other substance which might not be hurtful. But the next constituents which we find on this list are most hurtful; these are the organic carbon and the organic nitrogen, and these are hurtful because they serve as a measure of the vegetable or animal matter which the water contains. Observe the difference in the two kinds of water. You see that in the Irwell below Manchester there is nearly ten times as much organic carbon as there is in the water when taken at its source; and that there is more than ten times as much organic nitrogen (derived solely from animal sources) below Manchester as there is at its source. The next two substances we have to notice are the ammonia and the nitrogen, as nitrates and nitrites, both of which, although harmless in themselves, are products of the oxidation of animal matter, and therefore signs of previous pollution. The quantities of ammonia and nitric acid in the pure Irwell water are almost nothing, whilst below Manchester they are increased, you see, 300 or 400 times. If we next look at the total combined nitrogen contained in the water, we find for 49 parts in the pure Irwell water we have 1,648 parts in the impure water below Manchester! Thus we see that by a chemical analysis of water, we can at once detect by the organic, or albumenous nitrogen, whether it still contains animal impurity, and by the ammonia and nitric acid whether the water has been polluted by animal matter which has since been destroyed, or, by the absence of excessive quantities of these nitrogenous bodies, whether the water has never been in contact with animal matter. It is thus possible to calculate by a very simple process how much sewage has come into such a water. Let us, for instance, take this one case. It is found that in 100,000 parts of average London sewage there are 10 parts of nitrogen existing, as ammonia and nitrates, derived from the oxidation of animal matter. Now, supposing 100,000 parts of Irwell water was found to contain 10 parts of nitrogen, we should say that the Irwell water is just as strong as London sewage, that is, equal to the average composition of the water taken out of London sewers. If it contained five parts in 100,000, we should say that it was just half as strong; or we might then say there are just equal parts of pure water and London sewage in the river Irwell. Now what is the amount we find in the Irwell? We find that the nitrogen, as ammonia and nitrates, as you see in that table, is 1·447 (0·740 + 0·707). Very well; now there is also a small quantity of nitrogen, as ammonia and nitric acid, contained in rain water, but the quantity is exceedingly small. If we therefore subtract the quantity which is found in rain (viz., 0·032 part in 100,000) from the quantity which is found in the Irwell (viz., 1·447), we shall have the quantity (1·415) which is due to the sewage impurity in the

Irwell, and we can then easily calculate how much London sewage this corresponds to. It evidently corresponds to 14,150 parts of London sewage. Thus you see that 100,000 parts of the Irwell water below Manchester contain the quantity of nitrogenous animal impurity which is contained in 14,150 parts of London sewage; in other words—so far as regards the animal impurity—if you were to take 86 gallons of pure water and mix with them 14 gallons of London sewage, you would have the composition—so far as animal impurity goes—of 100 gallons of Irwell water. What I want to prove is that we have in this way a measure of the impurity of water, so that when we have made our analysis we can calculate how much previous sewage contamination the water has undergone.

In diagram No. 2 you see the composition of the Manchester Corporation water:—

MANCHESTER CORPORATION WATER, 1868,

Contains in 100,000 *parts*—

Total solid impurity	6·20
Organic carbon	0·183
Organic nitrogen	0·009
Ammonia	0·006
Nitrogen, as nitrates and nitrites	0·025
Total combined nitrogen	0·039
Previous sewage contamination	0·000
Chlorine	1·120
Temporary hardness	0·14
Permanent hardness	3·59
Total hardness	3·73

You see that there is no previous sewage contamination; but in all river water we find from the drainage of houses or towns previous sewage contamination; and it is therefore possible for us to make the prediction that in the visitation of cholera which this country is almost sure to undergo next summer, Manchester will pass nearly unscathed, while London, being still supplied by river water, will suffer from the epidemic. The point I want you to understand is that the chemist—thanks chiefly to the labours of Professor Frankland—is now able to estimate this previous sewage contamination.

Now, although I cannot show you how the amount of the nitrogen is ascertained, I can show you in another way the difference between Irwell water and our drinking water. In this glass jar we have some pure water, as supplied to us by the Corporation of Manchester. Here we have another clear-looking water, not quite so nice and clear as the drinking water, but still a very respectable water, which you might wish to drink and fancy that it would not be so bad, though the taste might not be so nice as the pure water. This is filtered water taken from the black stream which flows past our doors—the river Irwell. I have here a red liquid which will oxidise animal impurities and destroy them, and thereby lose its own colour. You will find that one drop of this coloured solution—permanganate of potash—will be sufficient to colour this pure water, because there is no impurity in it which requires oxidation. I will put in three drops, which will render the water pink. Now I will take the Irwell water and add many drops of the permanganate. Let us see what happens here. This Irwell water, you see, soon becomes colourless, showing that it contains organic matter capable of undergoing oxidation, and therefore in a condition of decomposition or putrefaction, and you see I have to add a considerable quantity yet until I get a permanent pink colour. And, therefore, although this method of testing water is not so accurate a one, or to be relied on so implicitly as the determination of the nitrogenous impurity, yet it is one which is of value, and which I have no difficulty in making visible to you, thus demonstrating to the sight that the clear Irwell water is impure.

There is still another means which chemists have of telling whether water is pure, and that is by the presence of common salt. Pure spring water ought to contain very little common salt; but water which contains the infiltrations of sewage brings in with it a large quantity of common salt derived from the urine. Any water which contains more than one part of common salt in 100,000 is almost sure to have that salt brought in by sewage, and will therefore be impure. This does not apply, of course, to water flowing through salt districts. The springs and rivers of Cheshire in some places contain large quantities of salt which does not come from sewage; but I am speaking of places in which there is no occurrence of rock salt. Thus you see that we have three means of detecting and determining the amount of organic impurity in water—first, the nitrogen; second, this test with the red permanganate; and, thirdly, the presence of common salt; and it is clear that the chemist is able to detect organic impurity in water, and to tell positively that such and such a water is a pure one, and that such and such a water is an impure one and unfit and dangerous or even fatal to drink; so that although he is not able to say that a certain water contains cholera poison, he is able to say that the water is poisonous.

Next about the air we breathe. You know that the air contains oxygen, nitrogen, and carbonic acid. Oxygen is the vital air. I can show you very easily that air consists of two different things. I take this glass cylinder, which is filled with air. This cylinder contains five volumes of air. I will burn a bit of phosphorus in it, and you will very soon see that the phosphorus will go out. After a little while these white fumes will disappear, and we shall see that we have not got as much air as we had before—about four volumes will be left; we shall also see that the gas which is left, called nitrogen, has different properties from common air, inasmuch as a light will go out in the gas which is left. The oxygen gas, which we use in breathing, is a colourless invisible gas, in which bodies burn with far greater brilliancy than they do in the air. If we take a little bit of charcoal, for instance, and burn it in this oxygen, you will see that it will burn much more brilliantly than it does in ordinary air. Now besides these two gases—oxygen and nitrogen—we have a third gas in the air, called carbonic acid gas. This gas is given off whenever bodies such as charcoal, coal, or candles burn in the air; it is also given off by our breathing, as you know. This will be made evident if I blow into this lime water, which will become turbid from the presence of this carbonic acid coming from the lungs. Well, then, we have in the air the oxygen, or the vital air; the nitrogen, or the non-vital air; and the carbonic acid, which we may call the choke damp. The carbonic acid plays a very important part as regards plants, because it serves as their food; but it renders the air impure for the use of animals, and it is produced by the combustion of bodies. That this is the case I can show you by a very simple experiment. We have here a lamp burning under a jar, and the products of the combustion come out through this chimney. If I hold a clean plate of glass above this aperture, you will see that a large quantity of vapour of water comes out, the result of this burning of the gas. There you see the glass is bedewed with moisture. Now let us stop the door of our glass house with a piece of putty, and observe what takes place. The flame, you see, becomes longer and more smoky, and in a very short time it will go out, because there is not a sufficient supply of oxygen to keep up the combustion; and if we hold this glass plate over it now the plate does not become bedewed with moisture, because there is no draught through the pipe, and no mode by which the vitiated air can escape. This illustrates to you the principle of ventilation. Wherever a candle can burn, there an animal can live; but where the candle goes out, there as a rule the animal also goes out and cannot live. Here you see the gas flame is very nearly gone out. I will now open the door again and let some fresh air in, and I think in a short time that the flame will revive, and the combustion go on much as before. Now the air that we give off from our lungs is impure, because it contains carbonic air; a candle cannot burn in it. You have all heard the story of the Black Hole of Calcutta, and you know that when men are shut up in a close room in which they cannot get any supply of fresh vital air or oxygen, they cannot live, they are suffocated. I have shown you that if we vitiate the air in this bell jar by contaminating it with carbonic acid gas, through the withdrawal of the oxygen from it, the candle will not burn. The candle burns in this jar which contains air, but if we now breathe this air once or twice, you will observe the effect upon the combustion of the candle. There, it has been breathed once; now we will breathe it once again. The candle now burns very dimly. With one further breathing of the air we shall so diminish the quantity of oxygen, and increase that of the carbonic acid, that the candle will go out. Here, then, you see at once the necessity for the ventilation of your rooms. All this has been long well known, and I only introduce these facts because they help to give you a general notion of what chemistry tells us about the composition of the air.

There is, however, still another constituent of the air of still greater importance, as regards our health, even than this carbonic acid, about which our knowledge is newer and less perfect, and that is Organic Matter. You all know what we mean by a "close room;" you all know that if you do not sleep with your windows open, as you ought to do—if you sleep with your windows shut, and especially if you have no fire-place in your room, when you come back to the room from the fresh air, before opening the window, you notice a disagreeable close smell. That smell ought never to exist in the room; for it shows that you have something there which is neither oxygen, nor nitrogen, nor carbonic acid, inasmuch as all these gases have no smell; but it is organic matter—emanations from the bodies of those who have slept in that room. These organic emanations or substances existing in the air are most dangerous, and do much towards spreading epidemic diseases, as far as the air is concerned. What does science teach us with regard to this organic matter in the air? This, again, like the organic matter in water, is not an easy matter to investigate, and in many cases we are as yet quite in the dark concerning its mode of action or constitution. Still it is not difficult to show that organic matter is contained in the air, and that some of these organic substances are gases and some of them solid bodies. Thus if we look at the air of our rooms when the sun is shining in upon it, what do we see? We see what we call "motes" dancing in the sunbeam. What are those motes? They are finely divided bits of all sorts of things—bits of skin, of the epidermis; bits of clothing; dust from the street; bits of stones and bits of iron—a thousand different things, and all so small that they do not settle down in the air—at any rate not for a long time—but continually dance up and down as we see them in the sunbeam, and are as continually being breathed in to our lungs. We do not see these motes when the sun is not shining, not because they are not there, but because they are too small to be seen except when the sunlight strikes upon them and reflects the light back into our eye. That a number of these little things are germs, seeds, or spores of various kinds, has been proved by a great number of experiments. If we wish to prove the organic nature of these particles, we may collect this fine aerial dust by drawing air through something upon which the dust can be filtered out, as upon a piece of cotton wool; and if we then put this cotton wool with the dust upon it into a solution of sugar, we find that that dusty cotton wool can produce all sorts of changes in the sugar—changes which do not occur if we keep out this dust, as we can do—and thus we can show the production from the dust not only of living vegetables but also of living animals. This experiment has been made by our townsman, Dr. Angus Smith, than whom nobody has done more to advance our knowledge concerning the organic matter in the air. Dr. Angus Smith, as long ago as 1848, made the following experiment: he placed a little pure water in a glass bottle and took it into a room where a number of people were present, and very often shook this water up with the air in the bottle, pumping in a fresh supply of air and shaking it up again many hundred times. He then, with his friend Mr. Dancer, examined the nature of the water which was in the bottle, and they found that this water, after a little time, contained living animal organisms—little vibrios, as they are termed—very minute, but still distinct animal forms, which are well known to those who occupy themselves, as Mr. Dancer has done, with the study of the very smallest and lowest creatures, both animal and vegetable, which can only be seen under the microscope. So that of the existence floating in the air of these germs or eggs—if you like to call them so—of the animals there can be no doubt. Now, then, comes the other question how far these little germs which exist in the air, can produce disease? About this, satisfactory evidence is, of course, more difficult to obtain. It has not, so far as I know, been positively proved that these little germs are always the cause of disease, for in many cases the general dissemination of these germs has proved compatible with a healthy condition of the people; but that they may, and sometimes do, produce disease we have abundant evidence to prove. Now the question to which I wish again to direct your attention is, can the chemist determine whether the air is pure or whether it is impure as regards these organic matters? You will say, "we do not want the chemist to do this, because we can smell when the air is impure." But the answer to this is, you cannot always smell when air is impure any more than you can taste when water is impure; thus the fever and ague-producing air of the marshes is quite free from smell, and yet capable of giving rise to most serious diseases. You therefore require something more than your unaided senses, and the chemist can help in this matter; for although he cannot tell whether there are germs present which will produce certain diseases, he can tell whether there is or is not organic matter in the air, and whether it exists in such quantity as to make the air not fit to be breathed for any length of time. In this diagram you see the amount of organic matter contained in the air, according to the experiments of Dr. Angus Smith:—

Relative Amount of Organic and Oxidizable Matter in the Air.

(Angus Smith.)

St. Bernard's Hospice	2·8
Hill in Lancashire	2·8
Lake in Lucerne	1·4
At sea, 60 miles from land	3·5
Kew Gardens	10·0
Finchley	15·0
London, Waterloo steps	42·0
London, Southwark Bridge	55·0

Dr. Angus Smith found in pure air—obtained from St. Bernard's Hospice, on one of the passes over the Alps—a very small quantity (2·8 parts) of this organic matter; but in Manchester, in the air of his own laboratory, he found 48 parts; in the air over the Lake of Lucerne 1·4; in the air of a pigstye 70; he goes away to sea, and at 60 miles distance, finds $3\frac{1}{2}$ parts; in the Greenheys fields, with the wind blowing from Manchester, 40 parts In the neighbourhood of towns he finds less impurity than in towns themselves. Kew and Finchley air shows much less than that taken from near London, Waterloo or Southwark bridges, or from Lambeth. In Manchester, near one of the sweet streams I have referred to, with its strong smell of putrefaction, he got as much as 73 parts of organic matter. These numbers, you will understand, do not give absolute quantities, but they show the difference of pure and impure air as regards this organic matter.

We have heard a great deal lately about sewer gases, and there is no doubt that not only is a general lowering of the tone of the body produced by breathing air vitiated by the entry of sewer gases into houses, but that actual danger to life ensues from the bringing these impure gases, which may contain the germs of specific disease, into our dwelling-houses. But I think we ought to be careful, especially at the present moment, from letting the impression get abroad, that wherever there is a bad smell we are in danger of our lives. The public are very apt to run into extremes. At one time they don't think at all about the matter, but when attention is called to the subject by such an event as the illness of the Prince of Wales, they are apt to fancy that whenever they perceive a bad smell they are sure to be dreadfully ill. Still, as I have shown you, there is no doubt that organic germs exist in the air, and that air coming into houses from sewers, by bringing in these floating germs, must be a constant source of danger, and may become a source of fatal disease. But that effluvia and evil smells from decomposing animal matter are not invariably, or even generally, accompanied by epidemic outbreaks is a fact which common experience proves, though in localities where such effluvia exists the epidemic poison, when it comes, appears to find favourable ground for its growth, and the place at once becomes a hotbed of disease. This view is confirmed by the recent report issued by two very distinguished physicians, Drs. Burdon Saunderson and Parkes, on the sanitary condition of Liverpool. They distinctly say, considering the high death rate in the lowest parts of that town and finding that there has been no outbreak of typhoid fever, that they see no reason to attribute that high death rate chiefly, if at all, to the escape of these sewer gases into the houses: so that as far as Liverpool is concerned, the blame of the high death rate does not seem to lie at the door of the sewer gases.

I should wish next to bring before you a very remarkable example of what exact scientific investigation can do to help us to a knowledge of these most complicated and difficult questions as to the causes of the propagation of epidemic disease. You know that France is one of the great silk-producing countries; and you know that the silk is spun by a small caterpillar or worm that lives on mulberry leaves, and that it is reared largely in the south of France. You are all, I dare say, also aware of the changes which this silkworm undergoes—that the worm changes its skin several times, and that, having attained a certain growth, a peculiar secretion, which forms the silk, is produced inside the animal, which then spins its cocoon and retires into the inside—forming what we know as the chrysalis. After some time this chrysalis appears as a moth, which lays its eggs and dies, and a fresh generation of worms make their appearance from the eggs. Now the value of the productions of the silk trade in France is something enormous. In 1853 the silk produced in France was worth 130 millions of francs. Unfortunately, soon after that year a fatal epidemic, called pébrine, broke out amongst the silkworms. Everything was done and every nostrum and contrivance tried to stop this epidemic, but nothing succeeded, and the silkworms continued to die. The peculiar symptoms of the disease were that black spots came out all over the caterpillars, and their silk secreting power was altogether lost. This went on until, in 1864, the value of the silk made in France amounted to only four millions of francs; so that the disease caused a loss of about 100 millions of francs per annum. The worms—both the healthy and stricken ones—had been carefully examined, and it was found that when they died of this disease they were almost filled with masses of little globular corpuscles, so that the place where the silk ought to have been contained nothing but these disease-bringing globules. Nobody, however, could tell how to stop the epidemic. It was found that sometimes, when the disease could not be detected either in the egg or in the caterpillar (which spun silk), the next generation of apparently healthy caterpillars which came from apparently healthy moths became diseased, and produced no silk. In short, the disease baffled all investigation. But some time after this dreadful state of things, the celebrated

French chemist, Pasteur, was asked to try what he could make of it. Now Pasteur had previously paid great attention to this particular subject of organic germinal matter in the air, and he succeeded in fathoming the whole difficulty. He proved what the disease was occasioned by, and showed how it might be prevented. I will give you an idea how Pasteur found this out. In the first place, I told you that the healthy caterpillar might produce unhealthy moths, or moths that laid bad eggs; but Pasteur found that this was because the particles of diseased matter existing in the caterpillar supposed to be healthy were so small that they could not be seen by the best microscopes. He investigated the matter step by step with scientific precision, and he found that by examining the moth instead of the caterpillar he could invariably tell whether the moth was a sound moth and would lay sound eggs, or whether it was an unsound moth and would lay unhealthy eggs, which afterwards would give birth to a stricken or diseased caterpillar. He proved this completely; and moreover he showed that not only could he tell by examining the moth that these little globules existed in the moth, although not apparent in the caterpillar, but that the caterpillar could become infected, although it did not receive the disease by transmission, by contact with another unhealthy caterpillar. And in this way, by most carefully guarding against a caterpillar becoming infected by a neighbouring one, and by most jealously taking care that all the moths which laid eggs, or whose eggs were kept, were healthy moths, he entirely got the disease under his control, and the result is that the disease is now almost passing away. I will not take up your time now by reading, as I intended, a passage from his paper, but I will simply say that in this way he was able to point out the cause of the disease, and thus to prevent the great pecuniary loss which France had been suffering. Here, then, you have a clear case in which careful scientific examination was successful in explaining a complicated and apparently insoluble difficulty; and there can be little doubt that the application of similar methods of exact investigation to the cases of other epidemic diseases will in the end show that every such disease is capable of being, if not altogether prevented, at any rate greatly lessened.

In conclusion I wish you to understand that, whatever progress men of science may make in the discovery of the cause of epidemic disease, and however completely our imperial or municipal authorities may carry out preventive and curative measures founded upon such discoveries, it rests in the end with the people to say whether such measures shall be productive of good or whether they shall remain a dead letter without influence on the mass of the population. All the discoveries of science, all the care of our authorities can avail nothing, when the people themselves are dirty, dissolute, drunken, and degraded. This debased condition of the population is the most powerful cause of the high death rate of our towns, and this at present far outweighs the evil effects produced by drinking water contaminated with sewage, or by breathing air rendered impure by sewer gases.

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