ON SOME
SECONDARY PHYSIOLOGICAL EFFECTS
PRODUCED BY
ATMOSPHERIC ELECTRICITY.

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As artificially excited Electricity produces some very striking effects upon the animal system, so it has been very often supposed that Atmospheric Electricity also exerts a powerful influence on living beings in general, and on the human body in particular.

Although much has been said and written on this supposed influence, yet I am afraid that the best of it will not reach beyond the limits of conjecture; and most of it will fall, not only within the circle of "doubtful truths," but within the larger compass of evident errors.

If a chemist may be allowed to give his opinion on a physiological subject, I should venture to say, that the physiological importance of electricity has, upon the whole, been much exaggerated, that agent, in comparison to heat and light, acting but an inferior part in the economy of organised beings.

For more than one reason, it is not, however, my intention to enter here into the entire details of so difficult a

subject; and I therefore shall confine myself to pointing out some indirect effects of electricity, which, in my opinion, are of peculiar interest both to the physician and to the physiologist.

Philosophers endeavour to distinguish between the immediate and the indirect effects of any cause, and they are assuredly very right in doing so; but, in many cases, it is very difficult, or quite impossible, to make the distinction.

As to electricity, it seems as if it were capable of acting directly upon all the organs of sensation, upon that of smell, &c.

Concerning the cause of the peculiar sensation apparently excited by electricity in the olfactory nerves, it may now be considered as a settled point, that it is not electricity itself that produces, what has often been called, the electrical smell, but that it is the peculiar gaseous matter, which I have named ozone, and shown to be formed out of oxygen, when subjected to electrical influences.

The most striking proof of the correctness of my statement, is the fact, that chemically pure oxygen, or atmospheric air, when enclosed within a tube or small bottle, and exposed to the action of electrical sparks, becomes ozoniferous, *i. e.*, permanently assumes the odour perceived near electrical points, or in the neighbourhood of electrical batteries at the time of their discharge, or at places which happen to be struck by lightning, or near dry glass plates when rubbed in atmospheric air, or at the positive electrodes, when water is electrolysing, or, also, when moist rarified oxygen, or atmospheric air, at the common temperature, is kept in contact with phosphorus. There cannot, therefore, any longer be a question regarding a truly electrical smell, *i. e.*, whether electricity immediately affects the olfactory nerves.

As to the sour taste which is perceived when electrical sparks are caused to pass, either from negatively- or positively-charged conductors, to the tongue, it may also be considered as a matter of certainty, that it is not an immediate effect of electricity, but is due to some nitric acid; which, under electrical influence, is formed out of the con-

stituent parts of the atmospheric air, through which the electrical sparks happen to pass.

The correctness of this statement is proved, in the first place, by Cavendish's experiment, or, what comes to the same, by the fact that litmus paper becomes red, or a band of filtering paper, when impregnated with a solution of potash, becomes nitriferous, if they be for a certain time exposed to the action of electrical sparks passing through atmospheric air.

For these reasons, we may safely assert that electricity would affect neither the nose nor the tongue, if atmospheric air did not happen to contain oxygen and nitrogen; though, to my knowledge, this has not yet been experimentally demonstrated.

As to the phenomena of sound and light, so frequently perceived by our ear and eye during electrical discharges, there can be hardly any doubt that electricity has nothing to do with them directly, and that they are due to the vibrations into which the particles of air, &c., happen to be thrown by the electrical discharges.

Whether the best known and most peculiar sensations called forth in the nerves of touch (the electrical shock in all its various degrees), are to be considered as a primitive effect of electicity, I am not prepared to say; it is, however, very possible that the proximate cause even of that physiological phenomenon, may be something different from electricity, and that this agent, as such, may have no power of acting directly upon any organ of sensation.

Before proceeding farther, I may, perhaps, be allowed to draw the attention of my medical hearers to a fact, which, in relation to the question before us, is worthy of their most attentive consideration.

All the effects called electrical, such as the chemical combination, or the separation of elementary bodies, the generation of heat, light, and magnetism, the contraction of muscles, &c., are not produced by what is called statical electricity. These phenomena are only called forth when the state of electrical antagonism, excited in some way or

other, in ponderable matters, is in the act of disappearing, or, as it is usually expressed, when both the electricities are uniting.

Of the effects produced, either by positive or negative electricity, when in their tensional condition, we know nothing, if we except their inductive actions.

After having made these introductory remarks, I think we are fully prepared to enter into the details of our principal subject. My own experiments, and those of De la Rive, Marignac, Berzelius, Erdmann, and Marchand, have, I think, satisfactorily demonstrated, that pure or atmospheric oxygen, on being exposed to the action of electrical sparks, is transformed into that odoriferous matter which the eminent philosophers mentioned, have declared to be nothing but an allotropic modification of common oxygen; whilst I have hitherto been inclined to consider it as a peculiar peroxide of hydrogen, being, in many respects, similar to Thenard's oxygenated water. But I will not conceal from my hearers, that the results of the researches I have of late instituted, with a view of settling the question of the chemical nature of ozone, are rather in favour of De la Rive's and Berzelius' views than of my own opinion; but, notwithstanding, I do not yet venture to pronounce my final judgment upon the subject. As to the point, however, with which we are now occupied, it luckily matters very little which of those divergent opinions may be correct, for we have, at present, to deal with the effects only, and not with the nature of ozone.

As for the chemical character of this enigmatical body, we may say that it is the most powerful oxidising agent we as yet know of, transforming, in the cold, even silver into the peroxide of that metal, iodine into iodic acid, nitrogen (a strong base being present) into nitric acid, the "-ous" acids into "-ic" acids, the "-ites" salts into "-ates" salts, the metallic sulphurets into sulphates. Ozone destroys, instantaneously, sulphuretted, seleniuretted, phosphoretted, iodu-retted, arseniuretted, and stibiuretted hydrogen, oxidising their constituent parts; it eliminates iodine from a number

of iodides; it changes the yellow prussiate of potash into the red cyanide, precipitates from the salts of the protoxide of manganese their base, in the shape of wad or hydrate of peroxide of manganese, &c.

Ozone also acts powerfully upon most organic matters, in consequence of which, like chlorine, it discharges the colour of the organic pigments, and is rapidly taken up by a variety of vegetable and animal substances, such as albumen, casein, fibrin, glue, blood, starch, vegetable fibrous matters, &c. Ozone possesses an eminent electro-motive power, being similar to that enjoyed by chlorine, bromine, iodine, and a number of metallic peroxides. But what must make ozone most interesting both to the physician and physiologist, are the physiological effects produced by this subtle agent upon the animal system. These effects are, as we shall presently see, very similar to those of chlorine and bromine.

When I began my researches on the chemical generation of ozone about ten years ago, I frequently inhaled strongly ozonised air, and the consequence was a really painful affection of the chest, a sort of asthma, connected with a violent cough, which forced me to discontinue, for a time, my investigations.

I do not doubt, therefore, for an instant, but that pure ozone, in spite of its being (according to De la Rive and Berzelius) nothing but allotropised oxygen, would act as a most powerful poison, and would quickly destroy the strongest animal life, if exposed to its action. At least, I saw that mice, when placed in strongly ozonised air, died in a very short time.

The facts just mentioned render it, I think, quite certain that ozone (perhaps on account of its exalted oxidising powers) is a poisonous substance capable of producing, even in minute doses, deleterious effects upon the system when introduced into the lungs,—effects very like those caused by chlorine or bromine.

If by some natural cause, chlorine, for instance, should happen to be thrown into, or be formed within, the atmosphere, at different times in different quantities, what chemist

or physiologist could, for a moment, doubt that such atmospheric chlorine would produce chemical and physiological effects proportional, as to their amount, to the quantity of the chlorine happening to exist in the atmospheric air at those times?

As a fact, certainly, no such chlorification of the atmosphere takes place; but, in consequence of electrical discharges continually going on in the atmosphere, ozone, a chlorine-like substance, is incessantly formed there out of atmospheric oxygen. My ozonometric observations show that the quantity of ozone present in the atmosphere at the same place, varies at different times, bearing, very likely, some ratio to the amount of the electrical discharges taking place at a given time, and also depending, in some measure, upon the direction of the currents of air.

If, at given periods and places, comparatively large quantities of ozone happen to be formed, and, for some time, inhaled, I think we have as little reason to wonder at the sensitive mucous membranes becoming then irritated or inflamed, as we have to be surprised at seeing paste of starch containing some iodide of potassium turned blue, after having been exposed, for some time, to the action of that ozoniferous air. After ascertaining the identity of the ozone produced, by means of phosphorus, out of common or atmospheric oxygen, with that produced by electrical sparks passing through the same sort of oxygen; and, farther, after finding out that the ozone, which was chemically produced, acted powerfully and injuriously upon the system, and after convincing myself, at last, that there are always appreciable, though varying, quantities of ozone to be met with in the atmosphere, I could not help conjecturing that that ozoniferous atmosphere would produce, upon the animal constitution, effects, lesser or greater, according to the quantity of ozone existing in the air for the time being. I hardly need say that I suspected certain catarrhal affections to be the principal physiological effects brought about by atmospheric ozone. To test, as far as my limited means enabled me, the correctness of this view, I induced, some years ago,

several physicians of Bâsle to compare with me the lists of their catarrhal patients with the tables of my atmospheroozonometric observations, and we could not help being struck at the coincidence of what I called my blue days, with an unusual number of catarrhal cases. I am, of course, very far from thinking that the matter is decided by those insulated observations, for we cannot arrive at certainty, unless we multiply these comparative observations. It seems, therefore, to me to be highly desirable that physicians and physiologists should, in many different places, and under a variety of circumstances, make comparable atmospheroozonometric observations,[1] making them simultaneously, with the observations on the frequency of catarrhal affections, &c. I hardly need remark, that the temperature and moisture of the atmosphere, the winds and their directions, &c., should not be left unnoticed.

That very minute quantities of certain substances have the power of acting most energetically upon the system, is a well-known fact, and we have good reason to suspect that, now and then, poisonous matters are spread through our atmosphere; but, to my knowledge, no such matter has as yet been found there with satisfactory certainty. Now, as I cannot entertain any doubt that ozone is a regular constituent part of free atmospheric air, it seems to me that this substance yields, as it were, a handle, which ought to be laid hold of for instituting researches on the terra incognita of miasmatic bodies. I therefore recommend the subject to the attention of physicians and physiologists.

I shall proceed in my attempt to show that the electrical condition of the atmosphere is most likely intimately con-

[1] Mr. Bürgy, bookbinder, of Bâsle, makes ozonometers according to my directions, for a few shillings a piece. Such an ozonometer consists of a box holding bands of ozone test-paper, bound up into thirteen packets; twelve of these packets contain sixty bands each, and one thirty only; these are calculated for making two observations a day, during twelve months. A chromatic scale and instructions for using the ozonometer are added. Mr. Newman, the instrument maker in Regent-street, will prepare the same test-paper.

nected with another subject, also highly important in a physiological point of view.

ON MIASMATIC SUBSTANCES.

By miasmatic substances I understand gaseous or vapourous matters which prove deleterious to the system, if inhaled even with large volumes of air; such poisons are produced and thrown into the atmosphere either by purely chemical, or physical, or physiologically chemical actions, taking place within the earth, or upon its surface, in stagnant or moving waters, or in the atmosphere itself.

It is well known that we may artificially produce a number of gaseous inorganic substances, minute quantities of which have the power of poisoning atmospheric air and of making it entirely unfit to sustain animal life. Sulphuretted, seleniuretted, phosphoretted, arseniuretted, and stibiuretted hydrogen are examples. Those gases, being distinguished by a high degree of oxidability, owe, perhaps, their poisonous character to that chemical property. There is another set of gaseous or vaporous bodies, minute quantities of which also act energetically upon the animal system, and which may, in some respects, be considered as the chemical antipodes and antidotes to the gases before mentioned, instantaneously destroying the latter and being highly oxidising agents. Such substances are—ozone, chlorine, bromine, and iodine, the chemical, voltaic, and physiological properties of which, in many respects, closely resemble each other.

As to the first set of the gaseous matters named, none of them, sulphuretted and perhaps phosphoretted hydrogen excepted, are produced by a natural cause and thrown into the atmosphere. And even those two gases are engendered in such very minute quantities, that with the exception of a few localities, they cannot exert any general influence upon animal life.

Of the second set there is certainly one, which in appreciable quantities is met with in the atmosphere, namely, ozone. But there exists an inexhaustible source from which mias-

matic substances are abundantly and unremittingly flowing into the atmosphere, and that source is the infinite number of plants and animals daily and hourly dying away within and upon the earth, in the seas and other waters, and even in the atmosphere. An immense quantity of organic matter constituting those vegetable and animal substances, so soon as life has departed from them, undergoes a variety of chemical changes, in consequence of which carbonic acid, ammonia, in many instances carburetted, sulphuretted, and phosphoretted hydrogen, are produced. But besides these compounds which are sent into the atmosphere, a number of gaseous substances are formed whose chemical nature is, as yet, entirely unknown. Of these matters we have, however, some reason to admit that if mixed up even with large quantities of atmospheric air and introduced into the lungs, they produce very deleterious effects upon the system.

If we are allowed to admit that such deleterious gases are disengaged from putrefying organic matters, we shall also, I think, be permitted to consider putrefaction as one of the principal causes of the pollution of the atmosphere by miasmatic substances.

If we consider that the putrefaction of organic matters is constantly going on, on almost every point of our globe, it can hardly fail that in the process of time, the miasmatic gases, small as their absolute quantity may be with reference to the immense bulk of the atmosphere, would accumulate so much, as to render the latter poisonous and unfit for sustaining animal life, if nature had not contrived some general arrangement for destroying those miasmatic substances again.

The question now arises, what means nature employs for arriving at that end.

I am inclined to believe that the ozone, which is formed under the influence of atmospheric electricity, amongst other functions, performs that work of destruction, so important to animal life: and the reasons that make me entertain such a notion are the following:—

Ozone, as already mentioned, is an agent of high oxidising

power, acting even in the cold not only upon most of the inorganic oxidable matters, but also upon almost all organic substances, and changing their chemical constitution, conjointly with their physiological properties.

With the view of testing the destructive power of artificially prepared ozone upon the miasmatic gases, disengaged from putrefying animal matters, I suspended, within a bottle holding about sixty litres, a piece of flesh, which was in a high state of putrefaction, and weighing about four ounces. After the flesh had remained for one minute only in the vessel, its atmospheric air was so strongly charged with the flesh miasma as to exhibit a most fetid and nauseous odour.

To produce ozone, I put into the bottom of the miasmatised bottle a piece of phosphorus, about one inch long, covering half its bulk with water, and exposing the whole to a temperature of 18—20° C. For comparison's sake, another bottle holding pure atmospheric air was provided with phosphorus and water to generate ozone. After a few minutes, I could detect, by means of my test-paper, the presence of ozone in the last vessel, whilst in the miasmatic bottle, no ozone could be observed, but still the fetid odour was perceived. After the lapse of about twelve minutes, however, the fetid smell had entirely been destroyed; free ozone then made its appearance.

From these facts I draw the conclusion, that the first portions of the ozone which was produced in the miasmatic bottle, were employed for destroying the miasma, *i. e.* oxidising its constituent parts, free ozone only making its appearance when the last particle of the miasmatic gas had been destroyed.

The power of ozone to destroy the miasma disengaged from putrid flesh, was exhibited in a still more striking manner by the following means:—The air of a bottle holding sixty litres was so strongly ozonised, as almost instantaneously to colour dark blue the moist test-paper, on its being introduced into the vessel. The phosphorus was then removed, and the bottle cleaned with water; a piece of

strongly putrid flesh, weighing about four ounces, was introduced into the ozoniferous vessel, and it could remain therein for fully nine hours before the ambient air assumed the slightest fetid odour. During that space of time, from half-hour to half-hour, I tested the air of the bottle, and found, indeed, its ozone continually diminishing; but as long as the test paper indicated the presence of free ozone, the most delicate nose could not perceive the slightest fetid smell within the bottle. So soon, however, as the test-paper was no longer acted upon, the nauseous odour began to make its appearance.

From these experiments we learn that all the miasmatic substances which were produced by the putrid flesh, in the course of nine hours, were completely destroyed by the ozone contained in the bottle of sixty litres' capacity.

Now, if we admit that the disengagement of the miasmatic matters were uniform during the course of the nine hours, we are allowed to conclude that those four ounces of putrid flesh would have miasmatised $9+60=540$ bottles, or 32,400 litres of air just as strongly as 60 litres of air were impregnated with miasma, within a minute, by the same four ounces of flesh.

But what was the weight of the ozone that disinfected 32,400 litres of such fetid air, or destroyed the miasma, which was emitted during nine hours by the four ounces of the putrid flesh? According to my former experiments, 60 litres of air being as strongly as possible ozonised, are capable of transforming about 87 milligrammes of silver into the peroxide of that metal, which requires 13 milligrammes of oxygen. Whether ozone be an allotropic modification of common oxygen, or whether it be a peroxide of hydrogen, it is certain that the 13 milligrammes of chemically-excited oxygen which was contained in the ozonised air of the bottle, and was capable of transforming 87 milligrammes of silver into the peroxide, destroyed by oxydation the miasma, which in nine hours was disengaged from the putrid flesh.

Whatever the chemical nature of that miasma may have

been, we are, at any rate, allowed to assume that its weight must have been proportional to the quantity of ozone by which it was destroyed. Now, the quantity of ozone which did that work having been so very minute, the weight of the miasmatic substance destroyed by it cannot have been much larger.

To convey to my hearers a still more distinct idea of the extreme minuteness of the quantities which are concerned in the miasmatic experiments mentioned, I will give some further data.

Sixty litres of atmospheric air weigh about 78,000 milligrammes, and contain, if strongly ozonised, (by means of phosphorus) about 13 milligrammes of active oxygen, *i. e.*, $\frac{1}{6000}$ of ozone; from whence, and from the experiments before mentioned, it follows that atmospheric air, containing but $\frac{1}{6000}$ of ozone, has the power of disinfecting 540 times its own volume of air, which is as strongly loaded with miasma as 60 litres of air become by four ounces of highly putrid flesh within a minute: or what comes to the same, atmospheric air, containing but $\frac{1}{3240000}$ of ozone, is able to disinfect its own volume of such miasmatic air.

From these statements it appears, that in miasmatic substances, though still affecting very strongly the sense of smell, we have to deal with infinitesimal quantities of matter; and it follows farther, that extremely minute quantities of ozone are required to be formed in the atmosphere, in order to destroy the oxidable miasmatic bodies thrown into it by putrefying organic matters, those miasmata making up (as to quantity) but a very small portion of the rest of the product of spontaneous putrefaction.

That ozone occurs in atmospheric air, is a natural consequence of the formation of that principle by electrical discharges, acting on atmospheric oxygen; and that ozone is present in the atmosphere, can directly be proved by means of my test-paper.

We may therefore conclude, that the electrical discharges, constantly taking place in different parts of the atmosphere, and engendering ozone, indirectly purify it from the oxidable

miasmatic gaseous matters with which it happens to be continually contaminated, and maintain it in that condition which is compatible with the sustenance of animal life.

By means of atmospheric electricity, nature has, as I think, established a process, through which she arrives on a large scale at the same end, which we try to get at in a small way by chlorine fumigations; or to express myself more distinctly, atmospheric ozone is continually produced for the purification of the atmospheric ocean, which is incessantly infected by miasmatic gases, just as chlorine may be produced for the disinfection of small volumes of air containing miasmata.

And as nature so well knows how to arrive by simple means at a variety of ends, so in this instance. For if the oxidable miasmata be destroyed by atmospheric ozone, which itself is a miasmatic principle, that ozone, *vice versâ*, also suffers destruction by those miasmatic matters; this is one of the reasons why atmospheric ozone, although it is continually engendered, cannot, in general at least, accumulate in the atmosphere to an extent which is dangerous to animal life.

It is a very old popular opinion, that thunderstorms are capable of purifying the atmosphere; and I think there are some grounds for entertaining that notion.

As we now know, that during a thunderstorm comparatively large quantities of ozone are formed, we can easily conceive in what manner such a purification may be brought about. The deterioration of atmospheric air which is supposed to take place in the hot season, may possibly consist only in an accumulation of miasmatic gases (principally resulting from the putrefaction of organic matters) in the lower regions of the atmosphere; and the purification of the air can be effected only by the destruction of those miasmatic gases. Now, as ozone is abundantly produced by thunderstorms[1] that principle will act like chlorine, and will

[1] I must not omit to mention here an interesting observation made by the excellent Swiss engineer, Mr. Buchwalder, who communicated it to me. This gentleman, having for years been engaged in surveying our Alps, had

purify the air in which those electrical phenomena take place.

It is possible and even probable, that sometimes (under given circumstances and in certain localities) a disproportion will occur as to the quantities of ozone and oxidable miasmatic gases which are engendered at the same time, so that the quantity of atmospheric ozone may not be sufficient to destroy all the miasmatic matter arriving in the atmosphere. Now, according to the chemical quality (physiological properties) and the quantity of that surplus of miasmatic matters, more or less perceptible effects will be produced upon animal life, that is, some kind of epidemic will, to a greater or lesser degree, prevail.

As indicated by my test-paper, the atmosphere is usually more or less ozoniferous; hence it follows that oxidable miasmatic matters, such as sulphuretted hydrogen, the fetid gases emitted by putrefying flesh, &c., can no more exist in that ozoniferous air, than they could exist in air containing the slightest traces of free chlorine.

I do not know whether the assertion be true, that during the prevalence of certain diseases, such as cholera, the atmosphere is deficient of ozone; but nothing can be easier than testing that assertion.

I have still to speak of some facts which, in my opinion, are worthy of the attention of physicians and physiologists.

many opportunities of observing, in the immediate neighbourhood, and even in the very midst of thunderstorms, the grand and awful effects produced by the electricity of the clouds.

One day, when Mr. Buchwalder was on the summit of the Senlis (near Appenzell), and was couched with his servant under a little tent, which was pitched upon a field of snow, on a sudden he was enveloped by a thick electrical cloud, from which lightning proceeded in all directions. One flash struck the master and the servant; it instantaneously killed the latter, and immediately afterwards the tent was filled with a very strong and peculiar odour. When Mr. Buchwalder visited me in my laboratory, he happened to smell strongly ozonised air, with which I was just then experimenting; and without any hesitation the engineer declared that the odour of that air was perfectly identical with the smell perceived by him in his tent upon the heights of the Senlis.

As far as my own observations go, above all other seasons winter is most distinguished by the abundance of atmospheric ozone; from which fact we may conclude, that in winter time the atmosphere must be freest from oxidable miasmatic matters.

I have also ascertained the remarkable fact, that the higher strata of the atmosphere are more ozoniferous than the lower ones. Having made experiments on different heights of the Jura mountains, 12—1800 feet above the level of Bâsle, I invariably found that my ozonometer exhibited there higher ozonometric degrees than it did at the same time in Bâsle. Hence we may infer, that the higher regions of the atmosphere contain less oxidable miasmatic matter than those which are nearer the surface of the earth. Now, as the generation of some diseases, such as the yellow fever, &c., seems to be connected with certain seasons and geographical positions, it would, I think, be worth while to ascertain, by comparative ozonometric observations, whether certain diseases bear any relation to the ozoniferous state of that portion of the atmosphere within which they happen to occur.

Considering the great obscurity in which the causes of most diseases are as yet enveloped, and as it is, nevertheless, highly probable that some at least, if not many of them, are the effects of chemical agents which exist in the atmosphere, and have a great physiological effect, *i. e.*, act in most minute quantities with great energy upon the animal constitution, scientific physicians and physiologists should earnestly follow out any train of research which promises to increase our insight into the connection between abnormal physiological phenomena, and physical or chemical agents.

One remark more and I have done.

By a series of experiments, I think, I have satisfactorily proved that the ozone, which is produced out of pure or atmospheric oxygen by electrical sparks, is, in every respect, identical with that ozone which is engendered out of pure or atmospheric oxygen by the means of phosphorus, or with

the ozone which is disengaged at the positive electrode during the electrolysis of water. On this account, we cannot entertain the slightest doubt, that electric and voltaic, as well as chemical ozone, has the power of destroying oxidable miasmatic gases; but to remove even the slightest shade of doubt on the subject, I have experimentally convinced myself that they have the same action.

If a small inclosed volume of pure oxygen or atmospheric air, which has previously been strongly charged with miasmata by putrid meat, be subject to the action of electrical sparks, it will soon become disinfected; and on mixing up miasmatised oxygen or atmospheric air with a sufficient quantity of ozoniferous oxygen, obtained from water which has been electrolysed, the same effects will be produced.