it may be expected, *à fortiori*, that it can decompose one of its own salts. Instances of this are not wanting.

Magnesium connected with platinum will decompose a magnesium salt, the almost insoluble hydrate of magnesium being found adhering to the negative metal. The deposition of zinc on the plates of an old-fashioned battery, when the battery is pretty well exhausted, is a well-known phenomenon. In our experiments with copper and silver in conjunction in a solution of nitrate of copper, we never succeeded in reducing the galvanic action to *nil* by our utmost efforts to exclude all oxygen: and the whole of the present inquiry originated in an experiment described by us before the Physical Society, that mercury and gold in conjunction would decompose mercuric chloride with the deposition not only of the lower chloride, but also of metallic mercury upon the gold.

[We reserve for further consideration the part played by the water in these decompositions, and the bearing of the experiments on the rival theories of voltaic action.—Nov. 26.]

II. "On the Production of Glycosuria by the Effect of Oxygenated Blood on the Liver." (Supplement to Communication presented June 17th, 1875.) By F. W. Pavy, M.D., F.R.S. Received August 12th, 1875.

In my former communication I showed that the injection of defibrinated arterial blood into the portal system occasioned the immediate production of marked glycosuria. In the present supplement to it I purpose treating of the production of glycosuria by other conditions, leading to the portal blood being surcharged with oxygen. There are also certain collateral considerations which I shall afterwards proceed to refer to.

After noticing the fact which has been mentioned, it occurred to me to try the effect of endeavouring to saturate the blood with oxygen, through the medium of respiration, to an extent beyond the capacity existing in the systemic capillaries for reducing it to its ordinary venous condition.

I first directed my efforts to attain the object desired by causing an animal to breathe oxygen instead of air.

The oxygen employed was obtained from a mixture of chlorate of potash and peroxide of manganese. I constructed a vulcanized india-rubber mouthpiece, to fit tightly over the muzzle of the dog and exclude the entrance of air. This tapered off and was connected with a piece of vulcanized tubing, which passed to a balloon containing the oxygen for use. A valvular arrangement was provided to allow only the oxygen from the balloon to enter the chest during inspiration, and to cause the

expired gas to be expelled without re-entering the balloon. In this way the respiration of oxygen could be easily kept up as desired.

I found that when the gas was breathed without being purified, it acted as a powerful irritant upon the respiratory passages—exciting cough, difficulty of breathing (apparently from spasmodic contraction of the bronchial tubes), and a profuse flow of mucous secretion. The cough and excessive secretion continued for two or three days and showed that bronchitis had been set up. I at first attributed these symptoms to the presence of chlorine, for the gas possessed what appeared to be a chlorinous odour. On testing for chlorine, however, no reaction was procurable. Ozone was then looked for, and a strongly marked indication of its presence obtained. Acting upon this information, the gas was passed over peroxide of manganese in a granulated state, and was found to be completely deprived of both chlorinous odour and irritating effect upon the respiratory passages. It could now be breathed without any inconvenience whatever being noticeable. Passage through water also to some extent diminished its odour and irritant action. While, therefore, ozone acts as a powerful irritant upon the air-passages, oxygen is devoid of any irritating property.

The observations above recorded were made in 1874. In the second supplement to Watt's 'Dictionary of Chemistry' (1875), I find under the article "Ozone" that the chemical part of the question has recently formed the subject of discussion by others. Special properties are spoken of as belonging to the gas evolved from a mixture of chlorate of potash and peroxide of manganese; and while some attribute these to the presence of chlorine, Witt, in harmony with my own observations, affirms that they are due to ozone and not to chlorine.

With these preliminary remarks I come to the description of the results obtained by the respiration of oxygen in relation to the subject of this communication.

Amongst several experiments conducted upon the dog, I have met with the production of saccharine urine upon two occasions, while in the case of the others a negative result was yielded.

In one of the successful instances the animal was breathing the gas for 55 minutes. It took deep inspirations, and no irritation was excited, nor did any subsequent ill-effect arise. Indeed all that was specially noticeable, besides the deep breathing, was that at the end of the 55 minutes a state of apnœa was induced, such as is known to be occasioned by increased respiratory action. It was from this occurrence that the inhalation of oxygen was discontinued, as I felt apprehensive about the issue. In the course of a short time, however, the animal began to breathe in a natural way, and showed no signs of disturbance. The urine was examined at the commencement of the experiment, and gave no reaction of sugar. At the end of the 55 minutes there was also no decided indication of the presence of sugar; but half an hour later it contained 9·6 grains of sugar

to the fluid ounce; half an hour later still, 10·48 grains; and again 40 minutes after this, 6·31 grains to the fluid ounce. At the completion of the inhalation some blood was collected from the jugular vein, and found to possess an intermediate colour between arterial and venous. On examination for sugar a strong reaction was obtainable; and through observing this, although no decided indication of the presence of sugar existed in the urine at the time, I was led to anticipate that it would be found, as proved to be the case, later on.

In the other successful experiment the inhalation was carried on in a deep and active manner for half an hour without any irritation of the air-passages being produced. When discontinued, the urine was found to contain a trace of sugar; and half an hour later sugar was present to the extent of 5·71 grains to the fluid ounce.

From observation I have been led to believe that the issue in these experiments with oxygen depends upon the manner in which the process of respiration happens to be carried on. I have frequently noticed that the movements of the chest have been performed in a signally sluggish way. In each of the experiments, on the other hand, where the production of glycosuria occurred, the breathing was carried on in a strikingly deep and active manner. It is known that the muscular operation of respiration is ordinarily conducted with an inverse degree of activity to its effect upon the blood. Through the accommodating relation existing, the more effective the oxygenation of the blood, the less actively are the movements of respiration performed; and thus, although the animal may be supplied with oxygen instead of air, it does not follow that any altered result should occur. In illustration of this I may state that upon one occasion I placed a guinea-pig in a sealed glass jar and kept a free current of purified oxygen passing through for the space of seven hours, without producing the slightest perceptible effect either at the time or afterwards upon the animal.

Some of my experiments with oxygen have been conducted upon frogs; and the plan adopted has been to place the animal in a glass jar sealed at the bottom with water, and to pass a current of the gas continuously through it for varying lengths of time. The urine is readily obtained by pressure over the bladder; and by using a small test-tube the amount collected from one animal may be quite sufficient for testing. Many of the experiments have been attended with a negative result; but in some a faint though distinctly appreciable and in others a fairly strong reaction of sugar has been obtained. Three or four hours' time has sufficed for this effect to be noticed.

Finding that I was dependent in the above mode of experimenting upon the chance manner, as it seemed, in which the process of respiration was carried on, I determined to resort to the performance of artificial respiration for the purpose of removing the uncertainty that existed. The artificial-respiration apparatus which for many years past I have been in the habit of using in my laboratory was constructed after my own

design, and consists of two bellows so arranged and adapted with vulcanized tubing connected with a canula for ligaturing into the trachea, that in working the one inflates and the other exhausts the lungs. Valves are provided so as to determine this result; and with these in good order I have found, in common with what has been noticed by others, that respiration can be so effectively performed as to sufficiently surcharge the blood with oxygen to induce a state of apnœa.

Now by means of the performance of artificial respiration with the artificial-respiration apparatus referred to, I have succeeded in producing strongly saccharine urine, and this with the employment of atmospheric air. In one experiment upon a dog, where the artificial respiration was carried on for an hour, the urine, ten minutes after its cessation, gave a strong reaction of sugar. In another experiment with the artificial respiration continued an hour and twenty minutes, the urine, which was collected ten minutes after its cessation, was also strongly charged with sugar, and thirty five minutes later showed on analysis the presence of 11 grains to the fluid ounce. In each case, for the sake of precision, urine was collected and tested at the commencement of the experiment, and found to be free from sugar.

I am indebted to Dr. Lauder Brunton for directing my attention to a recorded existence of the production of glycosuria by the performance of artificial respiration. Tieffenbach (Centralblatt für die medicinischen Wissenschaften, 1869, p. 181), in referring to the production of glycosuria in curarized rabbits subjected to artificial respiration, says that he also once obtained the same result without the previous poisoning. This seems to have been a mere passing observation, while my own experiments were elicited by a train of reasoning and without the knowledge of any previously published result existing. I am not disconcerted, however, to find that I have been thus anticipated; for it is only with the question of fact that I feel concerned; and it is a satisfaction to learn that the result I have obtained is confirmed by the independent observation of another.

In the course of experimenting upon this subject, I discovered that the inhalation of the fumes of burning puff-ball (*Lycoperdon giganteum*) is rapidly productive of strongly marked glycosuria; and from certain phenomena which I observed, I at first attributed the result to an imperfect dearterialization of the blood. I noticed, for instance, when a dog was brought under the anæsthetic influence of puff-ball smoke that there was fulness and throbbing of the arteries, that the tongue became intensely red, and that the veins underneath were in a turgid state and filled with red instead of dark-coloured blood. I thought I saw in these phenomena the effects of a general vaso-motor paralysis, resulting in the blood being allowed to flow through the capillaries without becoming properly dearterialized, in the same manner as it is known to do locally after section of certain parts of the sympathetic.

Through Dr. Richardson, I have since learnt that the active agent of puff-ball smoke was some time back shown, by Thornton Herepath and Snow, to consist of carbonic oxide, a gas which reddens blood in the same manner as oxygen, but which, unlike oxygen, is not easily displaced by the agency of other gases. Now, Dr. Richardson having noticed* that the inhalation of carbonic oxide is followed by glycosuria, our respective observations coincide, and I have no reason to doubt that the circumstances are otherwise than identical; indeed a comparison of the effects of puff-ball smoke and carbonic oxide enables me to support the conclusion that the action of the former is dependent on the presence of the latter. There is the same kind of anæsthesia, the same red state of the blood contained in the venous system, and the same rapid occurrence of strongly marked glycosuria. No matter whether puff-ball smoke or artificially procured carbonic oxide may be used, within ten minutes or a quarter of an hour after the production of anæsthesia, sugar may be recognizable to a notable extent in the urine; and a little later I have upon some occasions found that my analyses have indicated the presence of as much as upwards of 30 grains to the fluid ounce.

Such is the result to which I desire to direct attention; and I will proceed to explain in what way it appears to me to stand connected with the subject under consideration.

It is seen that a gas which produces the same physical effect on the blood as oxygen likewise determines the production of glycosuria. The bright scarlet colour belonging to arterial blood is also the colour which is given to blood by the presence of carbonic oxide; and, furthermore, Dr. Gamgee has shown that the spectral properties of the compound of colouring-matter and carbonic oxide are identical with those of oxidized blood. There is this difference, however, noticeable, which seems to tell in a striking way in relation to glycosuria. The combination of colouring-matter and oxygen (oxy-hæmoglobin) is so feebly maintained that a reducing action is readily exerted by the influence of carbonic acid, and hence the facility with which oxidized is converted into deoxidized blood. In the case of carbonic oxide, however, the gas is so much more strongly held, that it is not similarly susceptible of being readily displaced by other gases. As a result of its inhalation the blood becomes charged with it, and, by virtue of the property alluded to, retains it while traversing the systemic capillaries. In consequence of this retention it is allowed to reach the liver, and there produce the effect which results in glycosuria. It is to the capacity of retention that I assume may be ascribed the speedy occurrence of glycosuria which follows its inhalation; and I think it may be surmised, seeing that oxygenated blood acts in a similar way upon the liver, that if it were not for the easy manner in which oxygen is withdrawn from the blood in its passage through the systemic capillaries, the result of its inhalation, even under the form of

* Medical Times and Gazette, March 8th, 1862.

atmospheric air, would be the same, as far as the urine is concerned, as that of carbonic oxide. On account of the facility with which the abstraction of oxygen is effected, we obtain our escape from being glycosuric under the process of oxygen inhalation naturally carried on. The capacity of abstraction, however, is not unlimited, and, as has been shown in this communication, glycosuria may be induced by artificially surcharging the blood with inhaled oxygen.

As yet I have only assumed, without adducing any experimental evidence upon the point, that the production of glycosuria by the inhalation of carbonic oxide is due to the direct action of the blood impregnated with the gas upon the liver. It might be urged that the effect is attributable to hyperæmia of the liver, the hyperæmia being brought about either through the state of the arteries of the organ, or that of the chylo-poietic vessels in general leading to increased pressure in the portal system. An appeal to experiment has afforded a decided answer to these suggestions.

In the first place I ligatured the hepatic artery of an animal while under the effects of chloroform, and afterwards subjected it to the influence of puff-ball smoke. Before exposure to the inhalation of the puff-ball smoke, the urine was ascertained to be free from sugar. Twenty minutes after the cessation of the inhalation the urine contained $11\frac{1}{4}$ grains of sugar to the fluid ounce. The hepatic artery being tied, direct arterial hyperæmia of the liver was out of the question as a cause of the glycosuria.

In the next place I directed my attention to the question of the possibility of the effect being due to hyperæmia of the liver occurring as a result of an increased activity of the circulation through the chylo-poietic viscera, and thence an increased flow of blood through the portal vein. It was difficult certainly to realize that any thing like the hyperæmic state producible through the arterial system could be induced through the medium of the portal vein, looking at the position of the vessel with its delicate walled radicles and a capillary circulation behind. But however this might be, I determined to submit the point to experimental inquiry.

If hyperæmia of the liver from an increased afflux of portal blood constituted the cause of the glycosuria, it ought to be averted on cutting off a considerable portion of the flow through the chylo-poietic viscera.

In one experiment to accomplish this I tied the superior mesenteric artery of a dog, while the animal was under the influence of chloroform, and half an hour afterwards caused it to inhale a mixture of carbonic oxide and air, in the proportion of one part of the former to nineteen of the latter. Notwithstanding this extent of dilution it was found necessary to allow the animal to breathe pure air from time to time, to prevent a fatal result occurring. The inhalation was carried on in the manner stated for half an hour. Some urine was collected at the commencement,

and found to give no reaction with the copper test, while that collected at its termination was freely charged with sugar. Urine was again collected half an hour later, and sufficient having been obtained for a quantitative analysis, sugar was found to be present to the extent of 20 grains to the fluid ounce.

In another experiment, conducted in a similar manner, I tied the cœliac axis and obtained a similar result. The urine collected a quarter of an hour after the process of inhalation was highly charged with sugar.

In each of the above experiments the perfect deligation of the arteries was verified by dissection after death; and with the amount of blood allowed to reach the portal vein so diminished, the liver must have received very much less than its ordinary supply. I consider the conclusion to be warranted that it is by virtue of its presence in the blood (and probably through the combination which possesses the same physical properties as oxy-hæmoglobin) that carbonic oxide determines the escape of sugar from the liver and thence the production of glycosuria.

The fundamental point of physiological interest brought forward in this communication is that the passage of oxygenated blood through the liver excites the transformation of its amyloid substance into sugar. Although I abstain at present from committing myself to any settled conclusion regarding the precise *modus operandi*, yet the evidence before me leads me to think that the effect is due to the action of the oxidized blood as a ferment, and not to the direct influence of oxygen; and under this view the inhalation of carbonic oxide may lead to the result observed, by the compound with hæmoglobin, which possesses corresponding physical properties to oxy-hæmoglobin, acting in a similar way. I am inclined also to think that the production of sugar is only one part of the event occurring.

It is a noteworthy fact that in the puff-ball and carbonic oxide experiments there was a strikingly rapid disappearance of amyloid substance from the liver. Under ordinary circumstances the decoction of the liver is milky, from the presence of amyloid substance, but under the conditions referred to the decoction was found nearly or quite clear. Even in the space of about an hour I have in some instances observed the decoction yielded to possess no sign of milkiness; and there was other evidence to show that the amyloid substance had disappeared.

On giving attention to the position where amyloid substance is discoverable, it appears to be especially where a limited amount of oxygen exists that it is present. There is no organ in the body supplied with venous blood like the liver, and in correspondence there is no structure which is charged to a similar extent with amyloid substance. During the first portion of intra-uterine life the liver is free from amyloid substance, while the *liquor amnii* and the fluid of the allantois contain sugar. May this not arise from the oxygenated blood of the umbilical vein causing the amyloid substance, which might otherwise accumulate in the liver,

to pass into sugar, and thence determine a saccharine condition of these liquids? At a later period of fœtal life the liver becomes charged with amyloid substance, and sugar is no longer discoverable in the liquids named. But now the chylo-poietic viscera have attained considerable development, and would send venous blood through the portal vein to the liver. It is a specially notable fact, in relation to this point, that the liver and chylo-poietic viscera do not correspond in their state of development at different periods of fœtal life. If they did there would be no alteration in the relative supply of portal and umbilical blood to the former as time advanced. The liver, on the contrary, at an early stage is vastly out of proportion in size to even every other part of the organism. In the human fœtus, at the third or fourth week of embryonic life, it is said to constitute one half of the weight of the whole body*. At the commencement, then, the chief supply of blood to the liver must be from the umbilical vein. Subsequently, as the developmental relation becomes altered and the chylo-poietic viscera attain significant dimensions, the supply of venous blood must correspondingly increase. This may be accepted as a necessary deduction without reference to the precise anatomical disposal of the umbilical vein in relation to the liver. Under the view propounded, what before stood as an incomprehensible phenomenon becomes susceptible of rational explanation.

While the presence of amyloid substance is confined, or almost entirely confined, in the adult to the liver, it is known to have a somewhat wide extent of distribution amongst fœtal structures. Now in harmony with this the tissues of the fœtus, unlike those of the adult, are supplied with a mixture of venous and arterial blood.

The lungs and muscles are found to represent two structures besides the liver in which amyloid substance has been encountered in the adult; but examination shows that when it happens to be here physiologically recognizable it is only so to a comparatively inconsiderable extent, and this under circumstances involving a reduced supply of arterial blood. For instance, it is especially in muscles that have been kept in a state of rest, and in those of the hybernating animal during hybernation, that the substance has been noticed to be discoverable, and it has been observed to disappear under a state of activity. The lung-tissue during hybernation has been found to yield it, but fails to do so when activity is resumed.

It is an interesting and apparently a significant fact that amyloid substance is present to a notable extent in the solidified lung of pneumonia. I have myself obtained it in considerable quantity from lung-tissue in this state. Now it happens that we have here a condition, as regards the relation to blood-supply, which closely resembles that of the liver, for the tissue being solidified and impervious to air will not admit of oxygenation going on, and the blood which reaches it through the pulmonary artery, like the main supply to the liver, is of a venous character.

* Quain's 'Anatomy,' 7th ed. p. 879.

Dr. Michael Foster has shown that amyloid substance exists largely in the bodies of certain Entozoa, as, for instance, the round worm and the tapeworm. Again we have a condition which harmonizes with the other conditions under which its accumulation is observed to take place; for situated as these animals are in the intestinal canal, their position is one which is peculiarly restrictive of a supply of oxygen. My own observations have revealed its extensive existence in the mantle of the mussel, and Bernard has recognized it in the larvæ of flies. These instances, if not specially illustrative of the point under consideration, nevertheless appear to me to stand in conformity with the previous evidence.

Looking at all the considerations which have been here brought forward, I think we may generalize and say that the amyloid substance is a body which tends to accumulate in certain animal structures under the existence of a limited supply of oxygen, and that it is in consequence of the liver exceptionally receiving the supply of venous blood it does, that the special condition belonging to it is attributable. I have shown that the undue transmission of oxygenated blood to the organ at once induces an altered state, which is rendered evident by the production of glycosuria.

I consider that another link has been added to the chain of evidence against the glycogenic theory, which I have never wavered in regarding as untenable since the communication of my former researches to the Royal Society.

III. "On the Structure and Relations of the Alcyonarian *Heliopora cærulea*, with some Account of the Anatomy of a Species of *Sarcophyton*; Notes on the Structure of Species of the Genera *Millepora*, *Pocillopora*, and *Stylaster*; and Remarks on the Affinities of certain Palæozoic Corals." By H. N. Moseley, M.A. (Oxon.), Naturalist to the 'Challenger' Expedition. Communicated by Professor Wyville Thomson, F.R.S., Director of the Civilian Scientific Staff of H.M.S. 'Challenger.' Received September 28, 1875.

(Abstract.)

Introduction.—The author having undertaken the examination of the Deep-sea Corals dredged during the voyage of H.M.S. 'Challenger,' was led to the study of the structure of corals generally, and especially to the examination of the Milleporidæ, which seemed of peculiar interest, since they had been determined by Professor Agassiz to be Hydroids, and had been regarded by him as living representatives of the Palæozoic Rugosa. *Millepora alcicornis* was obtained and examined at Bermuda, and another species of *Millepora* at Zamboangan, Mindanas, Philippine Islands. The examination of these Millepores was found to be beset with great diffi-