

*June 15, 1854.*

The EARL of ROSSE, President, in the Chair.

The following gentlemen having paid their Fees, were admitted into the Society :—

James Apjohn, M.D.	Charles May, Esq.
Edward William Brayley, Esq.	Captain Richard Strachey.
Alexander Bryson, M.D.	Robert Dundas Thomson, M.D.
John Bennet Lawes, Esq.	Samuel Charles Whitbread, Esq.

The following gentlemen were elected Foreign Members of the Society :—

Karl Ernst von Baer.  
Michel Chasles.  
Friedrich Wöhler.

The following papers were read :—

I. THE BAKERIAN LECTURE.—“On Osmotic Force.” By  
Professor GRAHAM, V.P.R.S.

This name was applied to the power by which liquids are impelled through moist membrane and other porous septa in experiments of endosmose and exosmose. It was shown that with a solution of salt on one side of the porous septum and pure water on the other side (the condition of the osmometer of Dutrochet when filled with a saline solution and immersed in water), the passage of the salt outward is entirely by diffusion, and that a thin membrane does not sensibly impede that molecular process. The movement is confined to the liquid salt particles, and does not influence the water holding them in solution, which is entirely passive: it requires no further explanation. The flow of water inwards, on the other hand,

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affects sensible masses of fluid, and is the only one of the movements which can be correctly described as a current. It is osmose, and the work of the osmotic force to be discussed.

As diffusion is always a double movement—while salt diffuses out, a certain quantity of water necessarily diffusing in at the same time in exchange—diffusibility might be imagined to be the osmotic force. But the water introduced into the osmometer in this way has always a definite relation to the quantity of salt which escapes, and can scarcely rise in any case above four or six times the weight of salt, while the water entering the osmometer often exceeds the salt leaving it, at least one hundred times. Diffusion is therefore quite insufficient to account for the water current.

The theory which refers osmose to capillarity appears to have no better foundation. The great inequality of ascension assumed among aqueous fluids is found not to exist, when their capillarity is correctly observed: and many of the saline solutions which give rise to the greatest osmose are undistinguishable in ascension from pure water itself.

Two series of experiments on osmose were described, the first series made with the use of porous mineral septa, and the second series with animal membrane. The earthenware osmometer consisted of the porous cylinder employed in voltaic batteries, about 5 inches in depth, surmounted by an open glass tube 0·6 inch in diameter, attached to the mouth of the cylinder by means of a cap of gutta percha. In conducting an experiment the cylinder was filled with any saline solution to the base of the glass tube, and immediately placed in a large jar of distilled water; and as the fluid within the instrument rose in the tube, during the experiment, water was added to the jar so as to prevent inequality of hydrostatic pressure. The rise (or fall) of liquid in the tube was highly uniform, as observed from hour to hour, and the experiment was generally terminated in five hours. From experiments made on solutions of every variety of soluble substance, it appeared that the rise or osmose is quite insignificant with neutral organic substances in general, such as sugar, alcohol, urea, tannin, &c.; so also with neutral salts of the earths and ordinary metals, and with chlorides of sodium and potassium, nitrates of potash and soda and chloride of mercury. A more sensible but still very moderate osmose is exhibited by hydrochloric,

nitric, acetic, sulphurous, citric and tartaric acids. These are surpassed by the stronger mineral acids, such as sulphuric and phosphoric acid and sulphate of potash, which are again exceeded by salts of potash and soda possessing either a decided acid or alkaline reaction, such as binoxalate of potash, phosphate of soda and carbonates of potash and soda. The highly osmotic substances were also found to act with most advantage in small proportions, producing in general the largest osmose in the proportion of one-quarter per cent. of salt dissolved. Osmose is eminently the phenomenon of weak solutions. The same substances are likewise always chemically active bodies, and possess affinities which enable them to act upon the material of the earthenware septum. Lime and alumina were accordingly always found in solution after osmose, and the corrosion of the septum appeared to be a necessary condition of the flow. Septa of other materials, such as pure carbonate of lime, gypsum, compressed charcoal and tanned sole-leather, although not deficient in porosity, gave no osmose, apparently because they are not acted upon chemically by the saline solutions. Capillarity alone was manifestly insufficient to produce the liquid movement, while the *vis motrix* appeared to be chemical action.

The electrical endosmose of Porrett, which has lately been defined with great clearness by Wiedemann, was believed to indicate the possession of a peculiar chemical constitution by water, while liquid, or at least the capacity to assume that constitution when polarized and acting chemically upon other substances. A large but variable number of atoms of water are associated together to form a liquid molecule of water, of which an individual atom of oxygen stands apart forming a negative or chlorous radical, while the whole remaining atoms together are constituted into a positive or basylous radical, which last will contain an unbalanced equivalent of hydrogen giving the molecule basicity, as in the great proportion of organic radicals. Now it is this voluminous basylous radical that travels in the electrical decomposition of pure water, and resolves itself into hydrogen gas and water at the negative pole, causing the accumulation of water observed there, while the oxygen alone proceeds in the opposite direction to the positive pole. Attention was also called to the fact that acids, and alkalies, when in solution, are chemically combined with much water of hydration, sulphuric acid for instance evolving heat

when the fiftieth equivalent of water is added to it. In the combination of such bodies, the disposal of the water is generally overlooked. Osmose was considered as depending upon such secondary results of combination, that is, upon the large number or voluminous proportions of the water molecules involved in such combinations. The porous septum is the means of bringing out and rendering visible, both in electrical and ordinary osmose, this liquid movement attending chemical combinations and decompositions.

Although the nature and *modus operandi* of chemical action producing osmose remains still very obscure, considerable light is thrown upon it in the application of septa of animal membrane. Ox-bladder was found to acquire greatly increased activity, and also to act with much greater regularity when first divested of its outer muscular coat. Cotton calico also impregnated with liquid albumen and afterwards exposed to heat so as to coagulate that substance, was sufficiently impervious, and formed an excellent septum, resembling membrane in every respect. The osmometer was of the usual bulb-form, but the membrane was supported by a plate of perforated zinc, and the instrument provided with a tube of considerable diameter. The diameter of the tube being one-tenth of that of the mouth of the bulb or the disc of membrane exposed to the fluids, a rise of liquid in the tube, amounting to 100 millimeters, indicated that as much water had permeated the membrane and entered the osmometer, as would cover the whole surface of the membrane to a depth of one millimeter, or one twenty-fifth part of an inch. Such millimeter divisions of the tube become degrees of osmose, which are of the same value in all instruments.

Osmose in membrane presented many points of similarity to that in earthenware. The membrane is constantly undergoing decomposition and its osmotic action is exhaustible. Salts and other substances, also capable of determining a large osmose, are all chemically active substances, while the great mass of neutral organic substances and perfectly neutral monobasic salts of the metals, such as chloride of sodium, possess only a low degree of action or are wholly inert. The active substances are also relatively most efficient in small proportions. When a solution of the proper kind is used, the osmose or passage of fluid proceeds with a velocity wholly unprecedented in such experiments. The rise of liquid in the tube with a

solution containing one-tenth of a per cent. carbonate of potash in the osmometer, was 167 degrees, and with 1 per cent. of the same salt 206 degrees, in five hours. With another membrane and stronger solution, the rise was 863 millimeters, or upwards of 38 inches, in the same time, and as much water was therefore impelled through the membrane as would cover its whole surface to a depth of 8.6 millimeters or one-third of an inch. The chemical action must be different on the substance of the membrane, at its inner and outer surfaces, to induce osmose; and according to the hypothetic view which accords best with the phenomena, the action on the two sides is not unequal in degree only, but also different in kind. It appears as an alkaline action on the albuminous substance of the membrane, at the inner surface, and as an acid action on the albumen at the outer surface. The most general empirical conclusion that can be drawn is, that the water always accumulates on the alkaline or basic side of the membrane. Hence, with an alkaline salt, such as carbonate or phosphate of soda in the osmometer, and water outside, the flow is inwards. With an acid in the osmometer, on the contrary, the flow is outwards, or there is negative osmose, the liquid then falling in the tube. In the last case the water outside is basic when compared with the acid within, and the flow is therefore still towards the base. The chloride of sodium, chloride of barium, chloride of magnesium, and similar neutral salts, are wholly indifferent, or appear only to act in a subordinate manner to some other active acid or basic substance, which last may be present in the solution or membrane only in the most minute quantity. Salts which admit of dividing into a basic subsalt and free acid exhibit an osmotic activity of the highest order. Such are the acetate and various other salts of alumina, iron and chromium, the protochloride of copper and tin, chloride of copper, nitrate of lead, &c. The acid travels outwards by diffusion, superinducing a basic condition of the inner surface of the membrane and an acid condition of the outer surface, the favourable condition for a high positive osmose. The bibasic salts of potash and soda, again, although strictly neutral in properties, such as the sulphate and tartrate of potash, begin to exhibit a positive osmose, in consequence, it may be presumed, of their possible resolution into an acid supersalt and free alkaline base.

The following Table exhibits the osmose of substances of all classes :—

*Osmose of 1 per cent. solutions in Membrane.*

	Degrees.		Degrees.
Oxalic acid .....	— 148	Chloride of zinc .....	54
Hydrochloric acid (0·1 per c.) .....	— 92	Chloride of nickel .....	88
Terchloride of gold .....	— 54	Nitrate of lead .....	125 to 211
Bichloride of tin .....	— 46	Nitrate of cadmium .....	137
Bichloride of platinum... ..	— 30	Nitrate of uranium.....	234 to 458
Chloride of magnesium... ..	— 3	Nitrate of copper.....	204
Chloride of sodium .....	+ 2	Chloride of copper .....	351
Chloride of potassium ...	18	Protochloride of tin .....	289
Nitrate of soda .....	2	Protochloride of iron .....	435
Nitrate of silver .....	34	Chloride of mercury .....	121
Sulphate of potash .....	21 to 60	Protonitrate of mercury... ..	356
Sulphate of magnesia ...	14	Pernitrate of mercury.....	476
Chloride of calcium .....	20	Acetate of sesquioxide of iron .....	194
Chloride of barium .....	21	Acetate of alumina.....	280 to 393
Chloride of strontium ...	26	Chloride of aluminium ...	540
Chloride of cobalt .....	26	Phosphate of soda .....	311
Chloride of manganese... ..	34	Carbonate of potash .....	439

The osmotic action of carbonate of potash and other alkaline salts is interfered with in an extraordinary manner by the presence of chloride of sodium, being reduced almost to nothing by an equal proportion of that salt. The moderate positive osmose of sulphate of potash is converted into a very sensible negative osmose by the presence of the merest trace of a strong acid, while the positive osmose of the first-mentioned salt is singularly promoted by a small proportion of an alkaline carbonate. The last statement is illustrated by the following observations :—

*Osmose in same membrane.*

	Degrees.
1 per cent. sulphate of potash .....	21
Same + 0·1 per c. carb. potash ..	254
Same + Same .....	264
0·1 per cent. carbonate of potash alone .....	92
Same .....	95

It may appear to some that the chemical character which has been assigned to osmose takes away from the physiological interest of the subject, in so far as the decomposition of the membrane may appear to them to be incompatible with vital conditions, and that osmotic movement must therefore be confined to dead matter. But such apprehensions are, it is believed, groundless, or at all events premature. All parts of living structures are allowed to be in a state of incessant change, of decomposition and renewal. The decomposition occurring in a living membrane, while effecting osmotic propulsion, may possibly therefore be of a reparable kind. In other respects chemical osmose appears to be an agency particularly adapted to take part in the animal œconomy. It is seen that osmose is peculiarly excited by dilute saline solutions, such as the animal juices really are, and that the alkaline or acid property which these juices always possess is another most favourable condition for their action on membrane. The natural excitation of osmose in the substance of the membranes or cell-walls dividing such solutions seems therefore almost inevitable.

In osmose there is further a remarkably direct substitution of one of the great forces of nature by its equivalent in another force—the conversion, as it may be said, of chemical affinity into mechanical power. Now what is more wanted in the theory of animal functions than a mechanism for obtaining motive power from chemical decomposition as it occurs in the tissues? In minute microscopic cells, the osmotic movements should attain the highest velocity, being entirely dependent upon extent of surface. May it not be hoped, therefore, to find in the osmotic injection of fluids the deficient link, which certainly intervenes between muscular movement and chemical decomposition?

II. “Examination of the Cerebro-spinal Fluid.” By WILLIAM TURNER, Esq., Scholar of St. Bartholomew’s Hospital. Communicated by JAMES PAGET, F.R.S. Received May 18, 1854.

In the Bulletin de l’Académie de Médecine for December 1852, a paper is published by M. Bussy, containing an analysis by M. Des-