Art. I. *Experiments on Absorption.* By John W. Draper, M. D. Christiansville, Mecklenburg, Va.

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1. If we could place a known volume of vapour in the centre of an extensive void, where no disturbance from without could solicit its particles to move in one direction rather than another, it is to be supposed, that, conformably to certain laws that are known to obtain and operate on bodies of an aerial constitution, movement would ensue. To an assignable limit the vapour would expand, by a species of repulsion of its own particles. In the immense vacuum in which the solar system moves, there are orbs that seem to fulfil this condition; these, though they wander through very large paths, and are disturbed by the reaction of bodies they move past, sufficiently approximate the circumstances here laid down, to show that there is an extent, beyond which, bodies, so constituted, are not disposed to expand. Astronomical observations also show, that gases such as our own atmosphere is composed of, do not by their expansion trespass beyond a given point into a void, for then the laws upon which they are formed, react as the firmest barrier from without would do, to prevent their further extension.

2. An orb, so constituted, could not in any length of time, undergo any change of composition, structure, or figure. For, so soon as the first motion was over, which decided its equilibrium, that equilibrium would remain undisturbed, unless forces from without were brought

to bear upon it. In a void, such as we are here supposing, apart from any such derangement, equally a void as to force as well as to matter, the vaporous mass could not be subject to any contingency.

3. Let us extend our supposition, by placing another volume in presence of the former, and differing from it in chemical composition alone. That difference would determine certain motions of penetration, in addition to those resulting from mere mechanical action. Not only would the united mass move, so as to assume a mathematical equilibrium, but its constituent parts would also move, so as to establish a chemical equilibrium at the same time. Wherever an atom of one of the vapours existed, there would be found one of the other also. To bring about this result, a mutual penetration of parts is demanded, a transit of the constituents of one vapour among those of the other. The motions that effect this arrangement, take place without any resistance, just in the way that the light of a distant star comes into our system undeterred by the rays of our sun, and moves freely in every direction; his beams also move in the vacuum, intersecting the paths of other luminous bodies, without any hindrance or shock.

4. In this state of extension, when the component atoms of a gas or vapour, are supposed to be stretched to their utmost limit, which we are prone to suppose can only be done by an increase of the distance usually existing between an atom and its neighbours, it is not difficult to suppose that these different motions can go on, and that a foreign atom may insinuate itself in the interstices between others. But our ideas of space and size being only relative, and as we know nothing of the dimensions of an ultimate atom, nor of the interval that parts it from those around it, it is plain we could not without actual experiment determine when a body had arrived at that state of condensation, or when its particles had become so closely approximated to each other as to refuse the admission of foreign atoms between them.

5. A mass of any kind, in a vacuum, and undisturbed, moves, therefore, only in that manner which the laws of dynamics indicate. Motions of another kind, however, are induced when the vacuum is changed for a substance; a kind of penetration, permeation, or absorption is the result; nor do the mechanical conditions of bodies appear to have any effect on this: with some of these phenomena we are familiar. A gas, a liquid, or a solid, may indiscriminately pass by solution into the pores of water, without any reference to their aggregation. A variety of words have been used to express this action; solution, endosmosis, permeation, &c.; but parting from the simplest

experimental condition, we shall have occasion to see that all these refer to varieties of *one phenomenon only.*

6. Binary arrangements.—If a solitary body has thus no opportunity of exhibiting the conditions of its own arrangement, as to structure or the forces that inhabit the interstices of its atoms, it is very different with a binary arrangement. Chemists are familiar with the phenomena exhibited when gases, solids, or liquids are exposed to each other, under those circumstances where no direct change of composition ensues. Thus, if a cubic inch of carbonic acid gas be exposed to a cubic inch of water, the gas in a short time passes into the liquid mass, or is absorbed by it, with a certain degree of force, and to a certain amount. Also, aqueous gas rises from the water, and diffuses itself into the unabsorbed remainder of the carbonic acid. After a sufficient time, no part of the carbonic acid will be found destitute of aqueous gas, nor will any part of the water be without its equivalent of carbonic acid. The simplest example of these combinations is furnished by the solution of saline bodies in water, where there is no change of chemical composition, but merely a detachment of the solid crystalline particles from the mass of the dissolving substance; these pass among the interstices of the liquid, and remain there, unaffected by gravity, being equally and uniformly diffused. Of the powers by which this is brought about, we are not well informed, but no fact in science is better ascertained than this uniform and equable diffusion. If, by affinity, we mean a power that causes substances to unite with an interchange of elements, or only exerted to bring about an alteration of composition, such a force is obviously insufficient to give rise to these effects.

7. That one particle has the power of attaching itself to another of a dissimilar kind, without any thing like change of composition, numerous facts demonstrate. The most delicate dyes that adhere to cloth-fibre offer an example; they cannot be supposed to be attached by any force affecting either their composition or structure, since the successful operations of the artist proceed upon the supposition that the tint shall remain unimpaired, and the strength and organization of the fibre which is dyed shall remain untouched. Now, in those cases where we know that the dying material acts chemically on the fibre, is there not abundant proof that the elementary changes affect the uniting bodies? is not the hue of the dye changed, and does not the fabric become rotten? Other facts also show that these adhesions, without chemical change, are possible; the foil on the back of a mirror is not retained by the exercise of any force which has brought about a change in its composition. When the dye is washed off, or the foil

scraped away, the cloth-fibre and the looking-glass are both found in their original integrity of structure.

8. The cases here cited furnish examples of one solid uniting to another in a manner that involves something different from the action of chemical affinity. There is a whole range or class of similar combinations; a solid may unite thus with a liquid, as sugar and water; a liquid with a liquid, as alcohol and water; a liquid with a gas, as carbonic acid and water; or a gas with a gas, as oxygen and nitrogen, or the atmosphere. All these are cases where there is no interchange of chemical elements, and which we cannot therefore suppose to ensue in virtue of chemical force.

9. Although these actions are the result of a kind of adhesion of particle to particle, and might therefore be supposed to take place in an indiscriminate or irregular manner, there are some remarkable circumstances attending them, which go to show the contrary; thus water will dissolve a certain quantity of sulphuric ether and no more; it will take up its own volume of carbonic acid and no more; it will hold in solution of bisulphate of potash, sulphate of ammonia, protosulphate of iron, bicarbonate of potash, chromate of potash, muriate of strontian, &c. half its weight, at 60 F. At the same temperature it dissolves its own weight of sulphate of magnesia, and this comparison might be extended much farther. The same kind of predilection for definite quantities obtains also in gases, as is the case with atmospheric air where the proportions of oxygen dissolved in nitrogen, is as one to four.

10. All these things go to prove that the passage of the particles of one body among the particles of another, proceeds upon certain and definite laws. Whether the residence of saline atoms among the interstices of a liquid is a phenomenon of the same sort as the adherence of dye to a fibre, it is not material to inquire. We know, by experiment, that a solitary gas has a tendency to expand itself to a certain extent, but not further; and we are equally assured, that bodies, whether of the same or of different kinds, have an inclination to penetrate into each other. Where there is an apparent indisposition to do this, we are not without plausible reasons for supposing it through the intervention of disturbing causes. If oil and water do not commingle, it is a result determined by the action of their cohesion, as compared with the force of attraction between them. An interesting example of this nature is afforded by the action of mercury on glass; under ordinary circumstances they show no disposition to unite, not even so much as water and oil; but, by a suitable application of heat, the cohesion of the mercury may be so lessened, and its force of attrac-

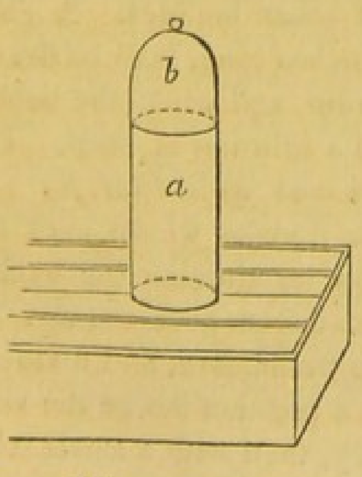
tion for glass at the same time so exalted, that it can be brought to *wet* it; an experiment first successfully performed by Laplace.

11. This *nisus*, or endeavour of one body to diffuse itself into the interstices of another has, under a variety of forms, been long recognised. The solution of salts, the absorption of gas by liquids, the passage of liquids through crystals, the permeation of porous textures, the diffusion of gases, the languid movement occurring in solids, were known long ago. Of late years, some extension of these facts has been obtained, and the new phenomenon, though explicable on the same principles, is dignified by the title ENDOSMOSIS.

12. For the explanation of the whole of this most interesting series of results, one postulate alone is demanded. That *all bodies have a tendency to diffuse themselves into the interstices of all others, with more or less intensity.* Nor is it difficult to admit this principle in its fullest extent, when we consider the numerous examples philosophy affords of it. All kinds of chemical absorptions and solutions are cases of it. The disturbing causes which sometimes change or even entirely hinder these actions, we shall consider hereafter.

13. BINARY ARRANGEMENTS, or those in which *two* bodies are engaged, whether solid, liquid, or gaseous, exhibit some circumstances which it is here necessary to point out. Let us suppose the couple under consideration, as oxygen gas exposed to an equal volume of water. No remarkable phenomena attend the passage of the gas into the liquid, there is no rise of temperature, and the whole amount absorbed is greatly less than the bulk of the water. If another gas be substituted, as carbonic acid, though much more soluble, there is still no indication of change of temperature, but ammonia and chlorohydric acid condensing to a much greater amount, disengage much heat. Another couple might be assumed, as charcoal or porous masses, with oxygen or other gases, and similar indications be obtained.

14. If, after a liquid has absorbed as much of any given gas as it is capable, we remove the remnant of unabsorbed gas, and in its place substitute some other of a different kind, complex reaction ensues. The gas, already absorbed by the water, has its condition of equilibrium disturbed, and in conformity with the general principle, (12,) it has a tendency to diffuse itself out of the water into the newly introduced gas. This, in its turn, has also a tendency to pass into the water. Thus, if over a volume of water,



a, impregnated with carbonic acid, and confined in a jar over mercury, we placed a volume of oxygen, *b*, equilibrium would not be obtained until a certain amount of carbonic acid was found in the gas, *b*, and a certain amount of oxygen in the water, *a*. And the same would hold in the case of any other gases, or any other liquid. In the course of experiment, examples of this case are often met with. The water commonly used in pneumatic troughs, contains both oxygen gas and nitrogen. If, into a jar containing such water, we pass pure nitrogen gas, in the course of a few minutes the oxygen will leave the water to diffuse itself into the nitrogen. Had we thrown in pure oxygen, the nitrogen, on the contrary, would have deserted the water and mingled with the oxygen gas. In gaseous analysis, this action, which obtains to a greater or less extent with every gas, often gives rise to the greatest perplexity.

15. Ternary arrangements.—It is plain that the conditions of the action considered in the last paragraph, may be obtained *at once* by suitable arrangements; and, as it is important that these should be well understood, I shall dwell upon them minutely.

16. In paragraph 14, we considered the reaction ensuing, first, of a single couple, or binary arrangement, and then the disturbance effected by the introduction of another element. Could we then, *at once*, have exposed the volume of water by one surface to oxygen gas, and by another to carbonic acid, the changes that were consecutive, would have been simultaneous. Let *a* be a sheet of water, on which, at its upper surface, a volume, *b*, of carbonic acid reposes, and, beneath its under surface, *c*, a volume of oxygen; both gases pass *at once* through the water in opposite directions, into each other. It is evident that the thinner we make the barrier of water, the more rapidly will equilibrium be obtained. This I have accomplished in the following manner, by using mere liquid films, and for that purpose have taken advantage of soap and other bubbles. A glass tube $\frac{1}{8}$ inch in the bore, and seven or eight inches long, is to be drawn out at one extremity to a capillary termination, and when the bubble is to be blown, the other end is dipped into a solution of soap. The tube having been previously passed through a cork, as in *Pl. I. fig.* 1, is now to be introduced into a clear vial or bell glass, whose neck the cork fits loosely; on blowing at the capillary termination the bubble slowly expands in the vial, where it is protected from access of air. To measure its diameter, I take a strip of white pasteboard, and divide it into inches and decimals, placing it in such a position before the vial, that it should cross the bubble diametrically, then with a small tele-

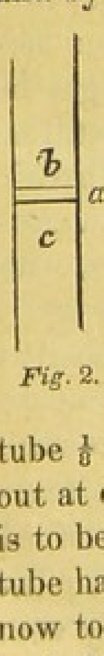


Fig. 2.

scope that magnifies twelve or twenty times, and at the distance of about eight feet, I observe the bubble much magnified, the micrometrical pasteboard apparently passing through its very substance, as is shown in *Pl. I. fig.* 2.

17. Through a soap bubble 1·53 inch in diameter, whose substance, previous to expansion, was contained in a cylinder $\frac{1}{8}$ inch in diameter and $\frac{1}{4}$ in height, ammonia, either pure or diluted with atmospheric air, passes instantaneously, when air from the lungs is on the other side. Into the bottle in which the bubble is to be blown, a little strong solution of ammonia is to be poured, the bubble is then expanded, at a particular point it becomes dyed with the richest hues, and that moment the phenomenon of endosmosis is complete—care must be had to suffer no moisture from the mouth to close the capillary termination of the glass tube—and now a rod, *a*, (*Pl. I. fig.* 2,) dipped in muriatic acid, is to be brought over the opening; as the bubble is collapsing by the attraction of its own parts, dense fumes of muriate of ammonia make their appearance, which continue until the substance of the bubble has entirely returned into the tube. The extraordinary rapidity of this action is remarkable. The bubble is scarcely blown before it is full of ammonia; and it is not less interesting to observe how the colours play with change of atmosphere. A little cylinder expanded to the size of a pea, which, in common air, is opaque white, and which would not be coloured until expanded to six or eight times that diameter, becomes deeply tinged as soon as it is penetrated by ammonia. If restored to the free atmosphere it loses all its beauty, and these alterations may be kept up at pleasure by merely changing it from one medium to another.

18. When, for the purposes of experiment, it is desirable to have a permanent bubble, a small column of moisture from the tongue must be allowed to close the capillary termination of the tube.

19. In the same manner sulphydrate of ammonia is found to pass with instantaneous rapidity through the film, and is to be detected by a paper dipped in acetate of lead. The colours in this case become very quickly stable, as with ammonia, and do not produce that iridescent play which the passage of certain other substances affords. It is, however, essential to the success of these experiments that the substances about to be passed through the film shall not have any chemical action upon it. Thus, it is not possible to use muriatic acid, which decomposes the soap, but there is no difficulty in the management of such as oxygen, hydrogen, nitrogen, &c. The passage of hydrogen through these films, is exemplified in the following table.

Diameter of a bubble of hydrogen gas exposed to atmospheric air.

	When Blown.	In two Minutes.	×
Exp. 1,	·460	·430	·430
2,	·415	·390	·390
3,	·425	·400	·400

Diameter of a bubble of atmospheric air exposed to hydrogen gas.

	When Blown.	In two Minutes.	×
Exp. 1,	·470	·485	·495
2,	·360	·375	·380
3,	·420	·435	·445

20. The third column, marked × in these tables, was taken when the black spot on the top of the bubble was about half an inch in diameter, for, as the coloured rings were the same in each experiment, and the surface incapable of reflecting light of equal extent, it is presumable that the measures were obtained under like circumstances, as far as the thickness of the film was concerned. In all cases the bubbles were blown by pressure on a gum elastic bag. This method of measuring the expansion, though suitable for general purposes, cannot, however, be extensively relied on, owing to thermal disturbance and the earth's action changing the figure from a true sphere to a prolate spheroid.

21. It is interesting to remark with what extraordinary rapidity these permeations take place. If we expand a small bubble in a vessel of ammonia, hydrogen, sulphuretted hydrogen, &c. by means of the mouth, and without removing the lips from the capillary opening of the tube, inhale *immediately* the contents of the bubble, the gaseous matter will impress the organs of taste with a very distinct savour, peculiar to the gas, on which the experiment is tried. There is a class of vapours which appear to possess little or no affinity for water, such as ether and the essential oils; these, however, percolate through tissues of water with rapidity. On covering the bottom of a vial with oil of peppermint, and then expanding a bubble, the taste of the essential oil will be perceived, when a portion of the air is drawn back out of the bubble into the mouth. With other oils, as cajeput, and with ethers the effect is the same; and it is to be observed that during the transit they work the surface of the bubble into a kind of microscopic waves and an iridescent play of colours.

To obviate any exception that might be taken to the use of soapy matter in these films, or to their excessive thinness, I have employed the following arrangement, which establishes the same truth. A tube,

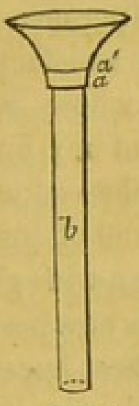


Fig. 3.

b, open at both ends, and whose upper extremity is shaped into a trumpet-like expansion, has at *a* a disc of common writing paper, cemented water tight. The part, *b*, which is under *a*, being filled with hydrogen gas, and a thickness of water being placed on the disc, as *á a*, the lower end of the tube is closed by placing it on the shelf of the pneumatic trough.

23. Into such a tube I threw 200 measures of hydrogen gas, and the same quantity into one whose upper extremity was hermetically sealed, by way of affording a comparison. In the former the thickness of the roof of water was about ⅛ inch, and, in 24 hours, the level of the water in it rose half an inch, whilst in the latter it remained undisturbed, thus incontestibly proving that hydrogen gas passes with great freedom through masses of water. Nor is this permeability confined to that liquid alone: a tube which was thus covered with a tissue of lamp oil, in five days raised the level of the water in it more than two inches; and one whose roof was of copaiba balsam threw out all the gas to within ⅛ of an inch of its top; whilst a tube of the same size, but sealed at the other end, that stood by them, kept its level.

24. It appears to me, the reason that we have not hitherto understood the phenomena of endosmosis, or the action of these ternary arrangements, as I have called them, has arisen chiefly from the employment of substances as barriers, which were possessed of pores of sensible size. A moment's consideration will place this in its true light; suppose two gases were kept apart by the intervention of a plug of charcoal in their diffusion into each other, not only would those portions pass the barrier which were brought along by a direct action, but a much larger quantity would *slip through by mere leakage* among the pores. Bladder, tissues, stucco plugs, &c. which we know to possess pores of sensible size, lay open to this objection; but the case is very different with liquids, which, from their uniform condition and the close proximity of their atoms, admit of no such action. A mass of stucco, a foot thick, would be subject to this kind of mechanical derangement, but a sheet of water reduced to that *excessive degree of thinness that it is invisible*, allows no gas to go through it by leakage, but all passes by absorption.

25. The original experiment of Dutrochet on Endosmosis, and those of Dr. Mitchell, were examples of this class of *ternary arrangements*. In these cases, membranes or gum elastic were tied over the

mouths of vessels, and the result was shown by the swelling or sinking of the barrier. These can be repeated, in a more satisfactory manner, with liquids. I took a vial, or glass tube, whose neck might be half an inch in diameter, and dipping the end of my finger into a solution of soap, I so passed it over the mouth of the vial as to leave a very thin filmy sheet there. The vial so situated, and of course filled with atmospheric air, was placed under a jar, covering a wine glass containing strong ammonia, as at *c*, *Pl. I.* fig. 3. The ammonia now passed instantly through the aqueous tissue, tinging it of the richest hues; at the same time I saw the bubble, which before was horizontal, raise itself up, *Pl. I.* fig. 4, its tints each moment varying, *Pl. I.* fig. 5. When it had risen so as to be considerably more than a hemisphere, as in *Pl. I.* fig. 6, a black spot appeared at its summit, and, as the bubble still expanded, the spot enlarged, until at length it appeared spread over the whole surface, *Pl. I.* fig. 7. The film of water was then perfectly invisible, except from certain positions, where the eye might catch its contour. Sometimes it would continue at this excessive thinness for a short period; a thinness so great that it was utterly unable to reflect light; but, at last, its cohesion yielding to the action forcing it out, it burst, closing one of the most beautiful experiments that the eye can behold.

26. In this experiment we also recognise an identity of results, with those which have heretofore excited so much attention, under the title *Endosmose;* but, understanding in this case, as we do thoroughly, the conditions under which the result is obtained, there is no difficulty in extending the explanation of one experiment to the other. ENDOSMOSE IS ONLY A COMPLEX CASE OF SIMPLE ABSORPTION. The mechanical results here obtained, the swelling or sinking of the barrier depends on the more rapid absorption of *one gas* by that barrier. The condition under which we obtain the mechanical result, will, by being duly varied, also furnish chemical results, an investigation of which forms our next object.

27. CHEMICAL DECOMPOSITION, *and first, by* BINARY ARRANGEMENT.— A solitary arrangement of any kind has no power of change in itself, whether it be of a simple or of a compound nature; but it is conceivable, that one of the latter kind—compound—on forming part of a binary arrangement, may be differently affected; as an illustration, let us take atmospheric air and water, appropriately situated, to form such an arrangement. In this case, were the nitrogen and oxygen equally absorbable by the liquid, no remarkable result would ensue; but such is not the fact; the oxygen gas passes much more quickly into the water than the nitrogen, and decomposition takes place. An excess of oxygen being in the liquid, and an excess of nitrogen being left.

We should, therefore, expect that rain and dew, and springs, and rivers which have been exposed in the most divided state to the air, ought to contain a gas richer in oxygen than that of the atmosphere; and such, in fact, is the case, the atmosphere containing one volume of oxygen and four of nitrogen, the gas of water containing one of oxygen and two of nitrogen, as we shall shortly find.

28. Instead of a gas and a liquid, to form these binary arrangements, a solid and a gas may be used. Into 500 measures of atmospheric air, a piece of charcoal, that had been made red hot and quenched under mercury, was placed. The volume of the air experienced a rapid diminution, and, after the absorption had gone on for several hours, there remained 205 measures, 100 of which contained only eight of oxygen. The charcoal was now introduced into water, over mercury, and commenced very actively evolving gas, which contained only 3·75 per cent. of oxygen, and the last portions of it that were given off, only 28. Solution of lime was not capable of detecting the presence of carbonic acid in the water.

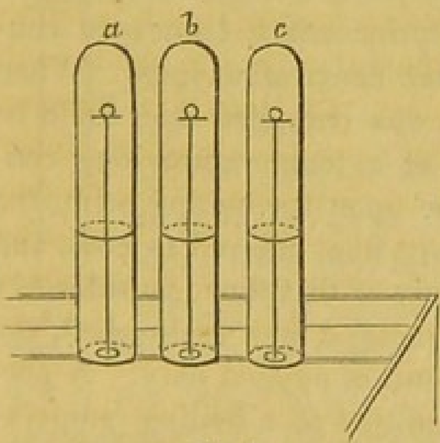


Fig. 4.

29. In the place of charcoal other porous solids might be substituted; into the jar, *a*, which contained atmospheric air, there was introduced a piece of red hot pumice stone; into *b*, a piece of clay, that had been made red hot; and into *c*, a piece of charcoal quenched under water. Absorption took place in them all, and, in a quarter of an hour, *a* was found to contain 19 per cent. of oxygen, shortly after *b* was found to contain 19 per cent. of oxygen, and *c*, in half an hour, only 18 per cent. Also, in five hours, *c* only contained 17·25 of oxygen, and in seven days, only seven per cent.; but, at the same time, *a* and *b* contained 14·50 per cent. Four days after *c* contained only five per cent.

30. By long boiling, I extricated all the air possible by such a process, from a quantity of water, and pouring it into a glass cup, left it exposed to the atmosphere for some days; at the end of that period the water was again boiled in a close vessel, and the gaseous matter it had absorbed submitted to analysis. After the carbonic acid had been carefully washed off, its amount being about 29 per cent., it was found that the residue contained 32½ per cent. of oxygen gas. It is a singular fact, that an aqueous tissue, in thus decomposing atmospheric air, appears to follow a very simple law; pure spring water and

distilled water, after a competent exposure to the atmosphere, are found to contain a gas whose elements are not in the proportion of *one* to *four*, as in the case with the atmosphere, but in the proportion of *one* to *two*. In several analyses of the air extricated by boiling from the water of my spring, which flows from a sandy bottom, and also from the dews which fall on a neighbouring hill, but too remote to be affected by the exhalations of dwellings, I found the proportion, when care was taken in the analysis, to be uniformly 33⅓ per cent., or as 1 to 2 by volume. This gas, thus extricated, is isomeric with protoxide of nitrogen, with the particular exception that, in the protoxide, the two volumes of nitrogen are compressed into half their bulk.

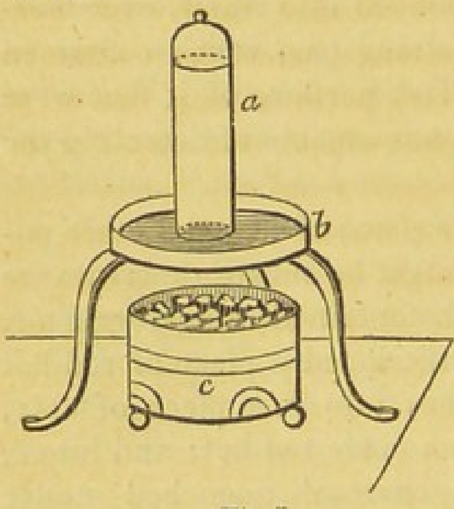


Fig. 5.

31. In a quart jar *a*, which was filled with spring water and inserted into a tin capsule *b*, I collected all the aeriform matter that could be disengaged from the water by means of a fire *c*, placed beneath the jar and its tin. This gas, from many prior trials, I knew to contain 33⅓ per cent. of oxygen. When all the gas was collected that could be extracted, at a temperature long continued close upon the boiling point, the arrangement was suffered to cool, and kept undisturbed for four days; at the close of that time, considerably more than three-fourths of the gas disengaged was reabsorbed, the residue on analysis contained 5.25 per cent. of oxygen only. A portion of the water in the jar was now submitted to a boiling temperature in a small close vessel, and the gas collected was analysed. It contained, instead of 33⅓, rather more than 47 per cent. of oxygen. There cannot, therefore, be any doubt, that oxygen may be obtained from the atmosphere, in a pure and undiluted state, by the action of a tissue, or a binary, and also a ternary arrangement.

32. Decompositions by ternary arrangements.—After this consideration of the case, in which two elements are employed, we are prepared to understand how ternary arrangements effect decompositions. Let *a* be a compound gas, which is placed above a barrier *b*, of such a nature, that one of the elements of *a* shall pass more rapidly through it, or, in other words, be more readily absorbed by it than the other. Also, let the other substance *c*, which is on the opposite side of the barrier, be of a kind capable of removing the quicker passing ele-

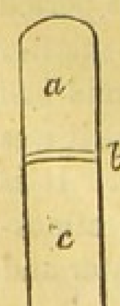


Fig. 6.

ment of *a* from the under surface of *b*, as fast as it arrives there. It is immaterial how this removal be accomplished, whether by chemically uniting with it, or by mechanical action; the quick passing element, finding in its approach to the under surface of the barrier, a ready exit, continually passes off, and its place is supplied by fresh portions from above, so that in the lapse of time only the less absorbable element will be found in *a*.

33. The general conditions, therefore, of chemical decomposition by ternary arrangements, are: that one element of the compound to be decomposed, shall pass more easily through the barrier or bounding tissue, than the others, and, on its arrival at the opposite side of the barrier, it shall be rapidly removed.

34. Reasoning upon this principle, I succeeded, nearly two years ago, in effecting decompositions in this manner, which have some important physiological applications. Having taken a tube, one of the ends of which was expanded into a trumpet-shape, and closed with a thin serous membrane—peritoneum stripped from the liver—which was tightly tied on with a waxed thread, while it was wet, I poured through the orifice, which was open, a strong *but clear* solution of litmus in water, to the height *a*. The tube thus situated, was placed in a wine-glass containing strong alcohol, and the level of the liquid, inside and outside, made to coincide, as in *Pl. I. fig.* 8. The conditions for decomposition were thus fulfilled, the water could find a ready passage through the serous membrane, but the colouring matter could not. Now, on arriving at the under side of the membrane, the water either was removed by uniting chemically with the alcohol, or by sinking mechanically through it to the bottom of the glass. Complete decomposition was effected, all the colouring matter being retained above the membrane, and, on placing a candle on one side of the glass and the eye on the other, dense striæ of colourless water were seen passing through the alcohol, but not a particle of the litmus escaped.

Fig. 7.

35. Under this condition those experiments which have been instituted to demonstrate the passage of colouring matter through the lacteals have been made. The lacteals do not open into an intestine with patulous mouths, but their lining membrane of serous tissue ends bluntly in a kind of cul de sac. Through such a membrane, litmus, indigo, &c. cannot penetrate, though water may find a ready passage. Hence, because we cannot colour the chyle by an injection of litmus or indigo water, it is not to be inferred that no medicine can pass from an intestine into the lymphatic system, the experiment, now detailed,

goes to prove directly the reverse, and furnishes us with an explanation of the uniformity of colour of the fluid in the chyliferous vessels.

36. An important circumstance in gaseous analysis, may here be noticed. If a tissue, in the act of transmitting gas, or ready to do so, be placed in contact with another gas, of a different nature, disturbance immediately ensues. A cubic inch of nitrogen gas, made with phosphorus, but which was found to be contaminated with 4½ per cent. of oxygen, was agitated briskly in a vial containing about an ounce of spring water, such as has been mentioned to contain a gas ⅓ oxygen. In *one minute* the nitrogen gained one per cent. by the agitation. The same quantity of nitrogen gas, agitated in a pint of water, gained no less than *eleven* per cent. of oxygen, which it had taken from the rich gas of the water. Nor is agitation or mechanical violence necessary to produce this important result. Into a bell, filled with water, and inverted into another vessel, so as not to touch it in any point, I threw 100 measures of a gas, 85 of which were oxygen. After four weeks an analysis was made, and the gas in the bell found to contain only 72 per cent. of oxygen, the remainder being nitrogen. In this way, too, in the lapse of time, from an inverted vessel, partially filled with atmospheric air, the oxygen will escape into the water, and thence into the atmosphere; and I have twice known this event to take place, so that the residue did not contain more than three or four per cent. of oxygen. In many of the most delicate researches of chemistry, we have this disturbing cause in operation, which has for the most part been overlooked. Water is universally employed in our laboratories as a means of confining gases; it enters largely into our processes of pneumatic manipulation; and though we have hitherto neglected its action, it silently disturbs all our results. An air bell cannot pass to the top of a jar without instant contamination: during its residence there it is subject to a continued succession of changes—at no two moments is it the same in composition—a perfect freedom of communication existing between it and the atmosphere.

37. As an instrument of rigid analysis, the pneumatic apparatus, so arranged, requires to be used with circumspection. It is impossible to keep oxygen, nitrogen, or any other gas in its original purity, if confined by water. This fluid, which, when reduced to a thin, imperceptible film, is instantaneously permeated by almost every substance, undergoes the like action in course of time, even in deep masses. Gases are absorbed by it, and thrown off by it in its purest state; how much more complicated then must its action be in that impure condition in which it is commonly used. Connected with this point there is another:—if a series of bells stand on a pneumatic

trough, each will affect all the others, communicating a part of its contents and receiving from them in return. A jar, containing bin-oxide of nitrogen, standing by the side of one containing common air, seriously affects it. I have noticed two common tumblers, filled with these gases, and so placed, communicate with each other so freely, that, in 17 hours, the tumbler, originally filled with atmospheric air, contained only 9¾ per cent. of oxygen. The habit of collecting gases at the same trough, that is destined to preserve others, is very exceptionable; we place the disturbing agency in circumstances the most favourable for its action. All operations of washing are liable to the same strictures.

38. We have assumed it as a LAW OF NATURE, that every or any substance, when placed in opposition with another, has a tendency to diffuse into it.

39. It is to be remarked, in reference to this, that no hypothetical cause is assumed, it is merely taken as one of those ultimate facts, which the progress of knowledge has not explained. We do not consider whether it involves the position that two bodies can exist in one place at one time, nor do we deny the impenetrability of matter. But it is required of us by a crowd of facts to admit this law, as the only legitimate position on which they can be explained. We know nothing of the size, or figure, or condition of the ultimate atoms of bodies; there are, indeed, some circumstances which would lead us to suppose that, even in the densest structures, each particle is at an immeasurable distance from those that are next around it, in comparison with its own diameter. In those interstices, which must necessarily exist, these phenomena of absorption may take place, in accordance with laws which obtain among the molecules of bodies. In the same way that a comet comes down from the regions of space, and traverses a planetary system, receiving impressions, greater or less, from each star that it passes, and emerges back again, untouched and unimpaired, so a gaseous particle may pass through the system of atoms that constitute a solid mass, and moving therein unimpeded and without contact with any of them, may emerge without change of physical condition, or only a mark, that its motion has been subject to those laws which obtain in the system through which it has gone.

40. All these observations go to establish the point, that pores of a sensible size have nothing to do with endosmosis—that it is a phenomenon depending simply on absorption. No one would aver that water possessed any apertures, or vessels, or tubular arrangement.

41. The experiment of (17) does not alone prove that endosmosis takes place through liquids and tissues whose pores have no sensible

size, it has a much more interesting application. Physiologists know that the primitive form of all organic bodies is an imperforate vesicle or globule, having the power of absorbing those substances which are around it, and decomposing them. The ultimate vesicle yields to analysis the elements of water and a few salts. It is a centre of vital activity, a laboratory assimilating things for its own substance. The simplest plants, confervæ, tremellæ, and the simplest animals, consist alone of this structure. Let us observe how nearly this vesicle agrees both in its constitution and mode of action with the vesicle of (17.) Like that, it is not only an imperforate, but also consists of the very same elements. The properties which the organized vesicle is supposed to enjoy, are met with in the fullest extent in that which is not organized. Both have powers of endosmosis and a species of assimilation of things exterior to their own substance. What property have the lowest order of animal and vegetable life which that bubble does not possess? A thing thus endowed with vitality may well excite our interest—it breathes, it is nourished, it exhales.

42. We may further remark, the vesicle of physiology is supposed to be organized, and, therefore, endowed with *life*, but what power or property does it possess which its inorganic and *dead* representative has not. The phenomena of life and vital force, which are only the aggregate of the actions of these organic elements, have obviously here no place, and it becomes an object for us to determine whether those occult and unknown and undefinable principles are really the cause of all the phenomena of this animal frame; or, whether such principles, having no existence, we are not rather to refer these phenomena to the direct agency of simple dynamic force. Is the growth of an animal or a vegetable that is referred to a principle of life, more mysterious than the growth of a crystal or the filling of a metalliferous vein? Are we, with the ancients, to suppose that the blood turns red because the lung is alive, or are we not rather to seek in the multiplied actions of the molecular force for a key to all the mystery?

43. These powers of life are only transient; beginning, however, at an unknown period, their operation continues through a vicissitude of change. In some structures it endures only for a day, in others it lasts for ages; but whether ultimately worn down and spent by a long continuance of exertion, or overcome by the action of molecular force, a period at last arrives when the whole fabric, animal or vegetable, sinks into decay. Is it only the aggregate of functions that ceases, or do the force giving atoms themselves die? Is that immortality that God has given to the chemical elements extended also to their modes of action, when in union with one another? The duration of the im-

perishable atom has not a limit, and time and circumstance leave it unchanged; at one moment it puts on the organic, at another the unorganized form; whilst its essence continues the same, all things proclaim that its functions are mortal.

44. The fabric of a membrane which shall last in a healthy condition for an unlimited period of years, is, however, of a more complex character than that here pointed out. Subject, from the state of force in which it is placed, to hourly decay, it would soon be unable to perform its appointed task, were it not continually renewed. A dead membrane, in a very short time, becomes disorganized by the passage of liquids through it, and a living one must slowly but surely decay, by the unremitting action of the same force. To accomplish this end, a complicated vascular arrangement is bestowed upon it; veins, arteries, and lymphatics freely traverse it, and to give it that sensibility which distinguishes an animal from a vegetable, a nervous net is spent upon it.

45. As yet, we do not know under what circumstances vesicles are formed. Whether or not they result from laws analogous to those which determine crystallizations. The misty vapour that rises from water, in the form which is vulgarly called steam, is perhaps the most common instance of this kind of formation. If we observe this vapour through a lens, we find that each particle is a little aqueous sac, which, by its collapse, produces a drop—perhaps, in this case, the chilling of the exterior surface of a little volume of steam, forms, by agglutination, a shell, which, by its nonconducting power, temporarily preserves the included vapour from being condensed. This shell of water, could it be secure from mechanical violence, would, without doubt, expand on exposure to certain substances, assimilate a part of them to its own structure, secrete another part into its own interior, and reject the residue; such at least is the action of a soap bubble, which is a type of all these vesicular actions. On this principle, also, we explain the formation of starch, and a variety of vegetable and animal substances. By unknown means, a little sac is formed, whose texture is of a definite kind. From the fluids to which it is exposed, this sac has the power of absorbing, and from its inner surface secreting fecula alone. These vesicular actions have a faithful representative in the action of a soap bubble.

46. The condition of chemical decomposition by ternary arrangements are such as to allow of a vast variety of results; these may depend not only on the nature of the substance exposed to decomposition, but also on the nature and structure of the barrier or bounding tissue, and likewise on the mode of the removal of the element most

disposed to pass. The animal mechanism furnishes abundant instances for illustration. Blood, which is a mixture of several substances, to supply the demands of the economy, is compelled to undergo a variety of changes. Coming along the pulmonary artery loaded with carbonic acid, it moves successively past cells inflated with atmospheric air. The structure of those cells is so arranged, that whilst carbonic acid finds no difficulty in passing in one direction, at the time that oxygen moves in the other, the nitrogen is almost entirely excluded. It only remains, therefore, to provide for the expulsion or removal of the gases accumulated in the cells; this affords an instance, where a mechanical operation is resorted to. Now, it is conceivable that the air cells might have had such a texture, as to have allowed nitrogen to pass through, and rejected oxygen. Or, other means than those merely mechanical, might have been resorted to, to effect the removal of the effete gaseous matter filling the cells. In the kidneys there is an arrangement of this kind, the urine being thrown into the ureter by the direct action of the walls of the tubuli uriniferi, the mechanical force of muscular contraction being afterwards exerted to remove it from the bladder, where it collects. The motion also of the bile, in the ramifications of the biliary ducts, (pori biliarii,) and probably the phenomena of the portal circulation depend on this tissue action. Nor is it a force incompetent to perform all that the animal mechanism demands, the action of a similar membrane is able in the case of vegetable life, to throw up sap under a pressure of not less than three atmospheres.

47. Haller remarked, that if ever the secret of glandular action was discovered it would probably first occur in the case of the kidneys. The specific action which he assumed, as a property of every secreting organ, has much light thrown upon it by what we now know to be effected when change of structure takes place in an acting tissue. Thus, the leading experiment of Dutrochet, of the endosmosis of water into alcohol, will take place through almost any animal membrane, but a thin lamina of gum elastic, though not one-tenth the thickness of such membranes, and even more transparent, entirely prevents the occurrence of any such phenomenon. Now, it has happened, in the case of the lungs, that the general progress of science has taught us, under what condition venous blood was brought into their structure, what it gave off, and what it received in passing the air cells, and what is the constitutional difference between it and arterial blood. We know that carbonic acid is contained in the venous blood, and oxygen in the arterial; we also know how this change is brought about; but not so with the liver or the kidneys. Would the

mixture of the blood of the emulgent veins, with a due quantity of urine, produce aortic blood, or blood like that of the emulgent arteries? Certainly, it should follow, if glandular action is explicable on these principles of absorption.

48. To determine the condition of the blood, in all the great venous trunks, is a problem of the utmost importance, in giving an explanation of secerning action. The blood of the splenic veins cannot be the same as that coming from the extremity in the saphena; the same applies to emulgent and mesenteric blood; yet, after this visceral blood has gone through the liver, and got into the ascending cava, we have no reason to suppose it is different from that in the descending cava; this remarkable change has, therefore, been impressed upon it during its portal circulation. There are many facts which would tend to show that the primary action of the liver is to accomplish this end, to bring the visceral blood to the same chemical constitution as that coming from the extremities, and, therefore, fit it for the subsequent arterializing action of the lungs.

49. There are some curious physical phenomena which will occur in repeating these experiments, on the action of thin films, in relation to the colours they assume, especially when acted on by ammoniacal gas. It has been remarked, that a very minute soap bubble, the diameter of which does not exceed a quarter of an inch, as soon as it is immersed in an atmosphere of ammonia, becomes dyed with the richest colours; on taking it out from that atmosphere and exposing it to the free air it loses its colour and again becomes white. Bubbles of a larger class, as those of more than two inches in diameter, exhibit also a surprising permanency of tint; above there may be a blush of pink, and on the under part a fair green; and this will continue for a long time without any kind of change. It may be proper to add, that, during the action of absorption, these bubbles exert no action on a beam of polarized light.

50. By referring the phenomenon of endosmosis to absorption, such as has been recognised by chemists, we advance one point in the simplification of our knowledge. It gives us also a better idea of the specific action of tissues, as depending on structural arrangement, and presents an intricate problem in its easiest form for solution; moreover, it is, as I know by experience, a safe guide in experimental research. We can hardly doubt that the forces bringing about the result indicated in (25) are the same as those which operate in Dr. Mitchell's experiment, where India rubber is used as a barrier; and if that result receives so ample and so easy an explanation upon this doctrine, why should we hesitate to apply it to the other. But the

composition, structure, and habitudes of a thin, watery film, are much better known than those of a lamina of India rubber,—we can reason with certainty respecting the one, and vary its composition to suit the purposes of experiment; the other affords no such advantage. If, however, it should eventually be found that the simple doctrine of absorption is not sufficient to explain all the phenomena of endosmosis that may hereafter be discovered, this paper will at least prove, that the cause of those phenomena are not alone enjoyed by *organic* and *solid* tissues, but also by *liquids* and *substances without organization.*