females after an ordinary accouchement; her sufferings after the operation, were slight indeed; in twenty days from the day of its performance, she sat up; and for some days previous, constantly nursed her infant. The adhesions connecting the uterus and abdominal parietes in front, were so extensive, as almost to have permitted the performance of the operation, without necessarily opening the peritoneal sac; very much diminishing its dangers. It may be worthy of notice, that nine months subsequent to the former operation, during lactation, the menstrual discharge returned, healthy and natural in every respect. During the progress of the case, the patient was visited by many of our medical friends.

The infant has grown finely, not having had an hour's sickness since birth.

Philadelphia, February 22nd, 1838.

ART. II. *On some Mechanical Functions of Areolar Tissues. Containing the co-ordination of the Diffusion Laws of Professor Graham and the Experiments of Dr. J. K. Mitchell; and the General Law of Equilibrium.* By JOHN W. DRAPER, M. D., Professor of Chemistry and Physiology in Hampden Sydney College, Virginia.

1. Of all bodies, those alone are capable of exhibiting the phenomena of life, which consist of an areolar structure. Identity of chemical constitution does not appear to be essential, yet it is only a limited number out of the long list of chemical elements, that are capable of organization; these, if left alone to satisfy the conditions of their affinities undisturbed, would most commonly give rise to the production of water, ammonia, and carbonic acid. Life, therefore, in this point of view, has no other action than to disturb the play of these affinities, and force the elementary atoms into other forms of combination; it depends upon the success of this action, whether a living or inorganic mass shall result. A living body is endued with a peculiarity of form, and does not require an identity of composition; an inorganic body depends for its nature on certain and definite composition, without any relation to structure. It is true that most bodies, whether elementary or composite, exhibit a marked tendency to geometrical arrangements, and all crystallizations are brought about by the operation of polar forces, but an inorganic compound body does not of necessity require any peculiar crystalline shape, or other form for existence.

2. Life, then, is a state of force; the system of nature presents us

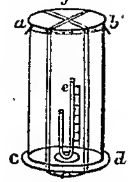
with but four of the chemical elements subject to it, for we are taught to make a distinction between crystalline arrangement and living structure. We have not any direct evidence to show, that all simple substances are in any wise obedient to the laws of vitality; or that when they assume symmetrical arrangements round an axis, that it is an approach to organization; an imperfect organizatiun, depending on the sluggishness of their character, or the incompetency of the vital forces to control the range of their affinities; nnr is there any real proof, that the laws directing the atomic arrangement of macled and tri-macled crystals, bear any sort of analngy with those that direct the structural deposit of the radiated class of animals. It is true, that the passage of a polarized ray of light through transparent crystals, has disclosed to us the fact, that their atomic constituents are held tngether in a state of force, and we judge from the phenomena of their nodal lines, when they are thrown into vibratinn, that their elasticity varies in different parts; yet the mere fact of their permanence assures us, that they are in a state of stable equilibrium. On the other hand, organized structures are in a condition of instable equilibrium, and require a continued series of adjustments for the perpetuatinn of their existence. In the crystal, the electrical or polar forces have compensated one another, and its particles being brought into a state of rest, continue so without change; whilst in the living being their situation is only momentary, they are subject to incessant vicissitude and change, their place has to be supplied by new materiel; and to accomplish this end, electrical currents traverse the body in all directions, and machinery more or less complex is employed to bring new matter and carry the effete away.

3. Does this cellular or areolar structure, which appears to be the essential habitat of vitality, owe its properties to the residence of a peculiar force, or are they derived from its organization? If the latter, we ought to find it possessed of remarkable characteristics; of forces arising from the aggregation of particles.

4. It has been known for some years, that gases and liquids pass through porous structures with a considerable force. If over the mouth of a cylindrical jar a thin sheet of India rubber is tied, and the jar exposed to an atmnsphere of ammonia, or protoxide of nitrogen, in the course of a short time, by the ingress nf a portion of the external atmosphere, a pressure is created, tending to rupture the membrane outwards.

5. That the force exerted in this case is very great, appears from the following experiment. In a cylindrical jar, *a b c d*, Fig. 1, four inches long, and one and a quarter in diameter, a syphon gage *c* was placed, and over the mouth of the jar a piece of India rubber, fortified

Fig. 1



by a layer of stout cloth, was tied. Two pieces of tape, crossing each other at the top, and passing down the sides of the jar, were knotted as tightly as possible at its bottom, and the arrangement was then exposed to an atmosphere of ammonia. In the course of six hours, the India rubber, notwithstanding it was forcibly held down by the cloth and tapes, began to stretch upwards, and the gage had risen thirteen divisions of an arbitrary scale attached to it. In twenty-four hours, it had risen to nineteen and a half, and finally to twenty, after which it remained stationary. On estimating the divisions of the scale, after the experiment was over, it was found that the maximum pressure in this case was about two-thirds of an atmosphere, or ten pounds on the square inch.

6. This effect is not confined to gases, but takes place with equal energy when liquids only are used. In a jar, containing alcohol, a gage was placed, and a piece of human peritoneum was stretched over the mouth, fortified by silk. The whole was then sunk into a vessel of water. In twelve hours it was found that the level of the fluid in the gage had risen the whole length of the scale, and that when the maximum pressure took effect, the gage was exhibiting a condensation of one atmosphere, exactly.

7. Here, then, we have proof that the passage through tissues is accomplished with a degree of energy indicating that the forces which produce it are of a very high intensity. To measure these forces, or to obtain some approximation of their value, the following researches were made.

8. Before, however, proceeding to the detail of these experiments, it is necessary to allude to certain disturbing circumstances which take place, arising from extraneous mechanical action, and vitiating the result. One of the most prominent of these is due to the general leakage which takes place through the open pores of all tissues; a leakage which is to be distinguished from the proper capillary transit. If, for example, a barrier of peritoneum be placed over the mouth of a vessel of water, under ordinary circumstances the escape of the water will be prevented, but if a pressure gradually increasing be exerted on the water, it will rapidly ooze through every pore, and finally if the membrane stand the strain without rupture, will spirt through those of a large diameter. This effect, to a greater or lesser extent, takes place wherever tissues have to resist mechanical pressure; the amount of disturbance arising from it, depends mainly on the diameter of the pores of the structure.

9. In the experiment related in section 5, we have a well marked instance of this disturbance. It might be inferred from that experiment, that the force with which water passed through a piece of peritoneum into alcohol, was not greater than one atmosphere; whereas, in truth, it was much more; but, as soon as the pressure within the vessel by the infiltration of water had amounted to about one atmosphere, the alcohol escaped from the vessel as rapidly as the water entered, by general leakage from the whole surface of the membrane, and the gage therefore gave no evidence of the passage of the liquid. Nor are very porous structures alone liable to this accident; the experiment of the old Florentine academicians shows, that even through the pores of gold, one of the densest of the metals, fluids under a severe pressure will find their way, as appeared when they attempted to compress water in a globe of that metal.

10. This accidental passage through pores, may be made visible to the eye, by condensing about one atmosphere of air into a vessel whose mouth is closed by a sheet of India rubber, and then placing it in a jar filled with water; small bubbles of air will be seen escaping from every part of the India rubber, and passing in great numbers through the water.

11. It has just been stated, that the force with which water passes through a membrane into alcohol, is much more than one atmosphere; this may be proved, by making use of a barrier of a stouter fabric than the peritoneum here mentioned. A piece of bladder being used in lieu of it, the gage indicated when the pressure was a maximum, a force of 1.8 atmospheres; but even this cannot be taken as the true value of the force, for a certain period of time elapses, amounting in this instance to almost two days, before the gage reaches its highest point; and when that is gained, the alcohol has become considerably diluted, and agreeable to a law which will hereafter be pointed out, the amount of force rapidly diminishes as this takes effect. For, as soon as the composition of the fluids on both sides of the bladder is the same, provided the temperature of both is alike, and no mechanical disturbance arises from unequal pressure, all motion either way ceases, and this may happen long before the column of fluid in the gage has reached its highest point.

12. The air gage, however, at the best, is a very imperfect indicator of the force with which gases or liquids mingle, for it will remain stationary, even when the passage is taking place with very great force, provided the rate of the bodies on both sides of the barrier is the same. It gives erroneous results in all those cases where the mechanical leakage exceeds the true percolation, and hence has a

very limited application in all these experiments. Other means are therefore required to test the passage of fluids, and for this purpose there is no arrangement more convenient than that represented in Fig. 2. It consists of a tube, three-eighths of an inch in diameter, and several feet long, bent at the point *b* upwards, and expanded at *c c′* into a funnel termination. When the instrument is in action, the longer limb *d b* is filled to some determinate height with mercury, which also rises to a certain distance in the shorter leg, above this, and to the height *a a′*, some fluid is placed acting as a chemical test of the presence of the gas, intended to be passes through the barrier *c c′*, which is tied air tight over the funnel mouth. The following experiment will indicate its use. Having placed the syphon on the mercurial trough, a quantity of mercury was poured into it, sufficient to cut off communication between the two limbs, then in the shorter limb a column of litmus water reddened by muriatic acid and occupying a depth of one-eighth of an inch was introduced; over the funnel mouth a thin lamina of India rubber was tied, and upon that a piece of stout silk, for the purpose of strengthening the barrier. A column of mercury, forty-three inches in height, was next placed in the long limb, and a jar of ammoniacal gas over the short one. In the course of one minute, a cloud of dark blue particles was seen descending through the litmus, and in six minutes it had become uniformly blue; thus proving the passage of ammonia through a tissue of India rubber, against a pressure of almost one atmosphere and a half.

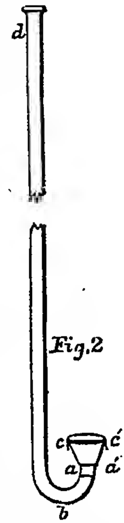


Fig. 2

13. There were considerable difficulties encountered in the outset of these experiments in tying on the India rubber barriers, so as to withstand the high pressures to which they were exposed without leakage; an insidious leakage, which took place between the sides of the glass and that part of the India rubber compressed by the string against it. This, however, was effectually prevented by setting fire to a piece of India rubber, and daubing the semi-fluid material on that part of the glass around which the string was to pass; then, on tightly binding on the barrier, it came into perfect contact with the glass, and was retained there by the sticky material, no leakage whatever taking place, unless some part of the arrangement burst.

14. The experiment just related, leads to some important conclu-

sions; we see that the force of impulsion driving ammonia into atmospheric air, exceeds a pressure equivalent to forty-three inches of mercury, the barometric pressure at the time being 29.73, that is to say, exceeding by very near half an atmosphere the force which theory would indicate. The hypothesis of Mr. Dalton, which seems to me to be fully confirmed by the observations of Mr. Thomson, founded on the experiments of Mr. Graham, assumes that gases act towards each other as a vacuum, or in other words, the force impelling the particles of one gas into the interstices of another, does not exceed the barometric pressure; but here we find that the result apparently leads to a very different conclusion. It was from an experiment of this kind that Dr. J. K. Mitchell was led to doubt the truth of Dalton's theory, inferring from his results that gases penetrated each other with much greater force. Such a conclusion however, does not legitimately follow, for it is highly probable that the nature of the barrier itself is very much concerned in the final action. A gas may penetrate into another with a force not greater than one atmosphere, and yet, because of the disturbing agency of the medium through which it must go, it may succeed in lifting a column of mercury equivalent to a pressure of many atmospheres.

15. The evidence, proving that gases do not infiltrate each other with a pressure greater than one atmosphere, is very cogent. Much of its weight is derived from the identity of the resulting volumes of commingled gases; but the most important fact relates to the passage of these substances into each other, when the barrier separating them is very porous, and has no condensing action, as in the case with a stucco plug, which opposes simply a mechanical impediment to their motion, acting, as will be hereafter proved, merely as a temporary valve; a mode of action totally different to that of closer textures. The final volumes exchanged, being inversely proportional to the square root of the densities, and these final volumes representing the true initial velocities, we have a striking illustration of that law of gaseous mechanics, that the velocities of different gases, rushing into a vacuum, are inversely proportional to the square root of their densities. Consequently, we are constrained to infer, that one gas acts towards another equally in the same manner as if it were a vacuum; and, therefore, that the force impelling the particles of one gas into the interstices of another, never exceeds the pressure of one atmosphere.

16. In an experiment made on the passage of ammonia into atmospheric air, it was found, that though the passage of the gas was resisted by a pressure of seventy-five inches of mercury, or upwards of

two atmospheres and a half, it took place apparently as readily as if no such resistance had been opposed to it. The question at once arises, whence is this powerful impulsive force derived? clearly not from the action of one gas upon the other, for there is great probability, as we have already seen, that that force would not be able to lift more than thirty inches of mercury. The porous tissue or barrier *alone*, can be regarded as the seat of this power. This fact, that systems of capillary tubes, or thin tissues, have in themselves certain powers, capable of producing high mechanical action, and operating successfully against the severest pressures that can be brought to bear against them, is worthy of the serious contemplation of physiologists; it is a great error to impute the forces producing these phenomena to the gaseous media. In the tissue itself, we must admit a source of power, a source far transcending that which solicits the gases to penetrate each other. Let us next inquire into the nature of this power.

17. It is well known that porous substances of all kinds and fluids absorb gaseous matter very readily, in volumes varying according to circumstances. Water, for example, absorbs its own volume of carbonic acid, and 480 times its volume of hydrochloric acid gas. In the latter case, therefore, an extremely great condensation takes place. So too, a fragment of porous charcoal, absorbs nearly ten times its volume of oxygen, and ninety times its volume of ammonia; these gases, therefore, exist on the surface of the particles of the absorbing medium, in a state of very high compression. And the reasoning which here applies, applies also in the case where the two gases are separated by a tissue. If, for example, we separated by a medium of this kind, a certain volume of ammonia, from a like volume of nitrogen gas, though at the outset of the experiment both the gases might be existing under the same pressure, yet this equality would very rapidly be lost. The absorption of the ammonia, taking place with much more rapidity than the nitrogen, it would be presented to this latter gas; not under an equivalent pressure, but in a state of great condensation. Under such circumstances, the transit of a gas is not, as will be shortly shown, analogous to the case where it flows under common pressure into a vacuum, or into another gas, but the tissue, continually acting as a perpetual condensing engine, brings the two media in contact with each other, under extremely different conditions; the one in a compressed state, but ready to exert the whole of its elastic force, the other in a state perhaps little varying from its normal condition.

18. If tissues really exert a power of this kind, some might inquire how it is, that when a tube closed at one end with such a structure,

and filled with mercury, is sunk in the trough to its hydrostatic level, that atmospheric air, or any gas to which it is exposed, does not pass through and expel the mercury from the tube. If, it might be said, the gas is existing in such a condensed state in the tissue, what is the reason it does not expand, and drive the mercury down? Experiment proves that this is not the case, but no argument can be drawn from it at all effecting the position here taken. For, as soon as the gas has gained the under-side of the tissue, there is no cause soliciting it to escape any more this way than backwards into its own atmosphere; the pressures each way are equal, and therefore counteract each other's effects. Or, rather, the pressures are unequal, for that tending to expel the mercury is resisted by the hydrostatic action of that fluid, and hence no gas can pass into the tube.

19. We can now understand the rationale of action in Graham's experiment, with plugs of stucco. He found that this material exerted a very slight absorbent power over the gases. Oxygen, hydrogen, nitrogen, &c. not being absorbed in any sensible quantity. When, therefore, he diffused hydrogen into atmospheric air, the stucco not acting mechanically on either of those substances, they were presented to each other under equal and ordinary pressures; and they therefore began to flow into each other, just in the same way that they would have flowed into a vacuum; but very different is the result when we make use of sheets of India rubber, or moistened animal membranes. The stucco plug serves only to make the experiment manageable by opposing a slight resistance to the escape of the gases, and acting, as I have said before, as a temporary valve; so that if a diffusion tube be fitted up in Graham's manner, at the end of the arm of a balance, the gas does not escape so rapidly but that there is time for a very accurate self-adjustment of the apparatus, and the volume of re-entered air can be measured with precision.

20. It might, perhaps, be objected to the view here taken, that the condensation which some gases experience, is more than sufficient to liquefy them; and that, therefore, they do not act simply as gaseous bodies would do towards each other. This condition, however, when it does take place, appears not to change the resulting phenomena, as the following experiment shows. The thermometer being at 38° F., and the barometer at 29.88, atmospheric air, under a pressure of two atmospheres and a half, was exposed under a sheet of India rubber to sulphurous acid gas; care being taken that the temperature of the mercurial trough, and all parts of the arrangement should be as above. The passage of the gas took place with great promptness, the litmus water, used to detect its presence, reddening rapidly. Now, sulphur-

ous acid, according to the experiments of Sir M. Faraday, condenses into a liquid at 45° F., under a pressure of thirty inches of mercury; we know, therefore, that in this trial the gas must have existed in a liquid condition in the barrier, and yet it passed through into atmospheric air, under a resistance almost two and a quarter times sufficient to condense it, and at a temperature eight degrees lower.

21. Having progressed thus far in this part of the inquiry, on the action of tissues, it became important to find if any pressure which could conveniently be brought into action, would restrain the passage of gaseous matter. Resort was first had to the usual mechanical condensing apparatus; but although the college possesses some very good engines of this class, they were found to be ill adapted to the purpose in hand. The necessary motions were always productive of inconvenience, and it was not found possible to carry the condensation to the degree required, or to avoid leakage from some of the numerous joints. After some trouble, the following contrivance was fallen upon, which answers the end perfectly, is not open to the serious objections of the former, and requiring no cock or valve, can be readily made without leakage. A tube of glass about one-third of an inch in bore, of stout substance, and about ten inches long, is bent into a kind of syphon, so that one leg shall be about six, and the other two inches long. The extremity *a a*, Fig. 3, has a lip or rim turned round it, at the lamp; whilst in the longer leg, a thin glass tube *c c*, about one-eighth of an inch in bore, and closed at one end, is included, to serve, as will be hereafter shown, as a gage. Next, the extremity *b* of the syphon is closed, there being inserted through it two platinum wires *d d*, *e e*, parallel to each other, but not touching. The arrangement is then ready for use. Suppose, for example, it was required to pass through India rubber, sulphurous acid gas, into atmospheric air, condensed by a pressure of five or six atmospheres; the long leg of the syphon is to be filled with water, which is excluded from the gage-tube *c c*, owing to the narrowness of its bore; next, a strong decoction of litmus is to be poured into the short leg, until it is about half filled.

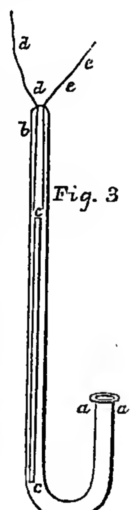


Fig. 3

The rim round the extremity *a a*, is then daubed with a piece of burning caoutchouc, and upon it is tied a thin piece of that substance, with a fine but strong waxed thread. Over this is tied a piece of stout silk or cotton cloth, for the purpose of fortifying the barrier: the wires *d d*, *e e*, are then made to communicate with the poles of an active voltaic battery, and the condensation commences; for the gas which is evolved from these electrodes rising to the top of the tube accumulates there, causing the column of water in the short leg to rise and condense the atmospheric air above it. The membrane, though fortified, gives way to a certain extent, becoming convex outwards, and as the accumulation of gas in the long leg continues, the condensation of that in the short leg increases, as is indicated by the gage *c c*. A very thin India rubber, of the diameter here used, will stand a pressure from six to twenty atmospheres without rupture, if its silk support is good; and I have found that anointing the edges of the rim with the burnt substance, enables the operator to tie it on so that no leakage shall occur between the India rubber and the glass, even under the severest pressures. When the gage shows that the required degree of condensation is arrived at, the connexion with the battery is broken, and the condensation, of course, stops; the syphon being carried to the mercurial trough, taking care to keep its position erect, its short limb is depressed under the mercury, and carried into a jar containing the sulphurous acid. If, under these pressures, any of the acid gas finds its way into the condensed air, its presence is detected by the reddening of the blue litmus water. It is necessary here to observe, that the indications of the air gage do not give a correct estimate of the amount of condensation, but always represent them higher than they are according to Marriotte's law: it has long been known, that the volume of gas dissolved by water, depends in a great measure on the pressure exerted on it; now it will be found, when the operation is conducted in an instrument arranged as this, that a very large proportion of the air in the gage disappears in this manner; its zero point is therefore altered, and the condensation appears higher than it really is. It may be remarked, in passing, that it is surprising to what an extent the absorption of oxygen and hydrogen is carried in the longer leg, owing to their making their appearance in a nascent form. To ascertain the true condensation, so soon as the passage of the sulphurous acid or other gas has taken place satisfactorily, the membrane is to be punctured with a pin, and when a pneumatic equilibrium is obtained, the height of the liquid in the gage will mark the point, where the zero of the scale should be placed.

22. Some chemists might suppose that there is danger in making use of an apparatus like this, where a high pressure is produced, owing to the risk of an explosion of the compound gases in the long limb, since it is stated in most works on chemistry, that a mixture of

oxygen and hydrogen when compressed, will explode. To ascertain if there was any danger arising from this, as also to know to what extent the condensation could be pushed, by the aid of a voltaic battery, I took a tube *a b*, Fig. 4, and into the closed extremity having fused a pair of platinum wires, and drawn the other into a long capillary tube, bending it at the same time at right angles to the former, I filled it with water, (boiled until all the air mechanically enclosed in it was expelled), except a portion of the narrow capillary part from *d* to *c*, which contained atmospheric air to act as a gage; the extremity *c* was closed. Next, the platina wires were made to communicate with the poles of an active voltaic battery of 120 pairs, and gas slowly accumulated, the current of electricity steadily passing all the time, as was indicated by the deviations of a galvanometer, through which it was made to circulate. Observations were made every few minutes, on the progress of the experiment, the last of which, indicated a pressure of slightly upwards of forty-three atmospheres, and shortly after it was taken, the tube burst; not, however, on account of the explosion of the gaseous materials in it, but because it could not sustain so excessive a pressure tending to burst it, a pressure equivalent to that of a column of mercury, nearly thirteen hundred inches high.

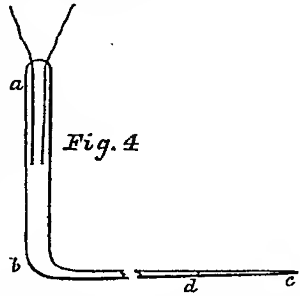


Fig. 4

23. These results lead us to some remarkable conclusions, in relation to the passage of voltaic currents. Sir M. Faraday found, that they cannot pass along such media as water, without effecting its decomposition; in fact, that the transfer of elements seemed to be absolutely essential to the transit of the electricity. Now it might be supposed, that if some powerful force were brought to bear against and antagonize this,—as where by a severe pressure the oxygen and hydrogen are prevented from being evolved—one of four things must happen: 1st, That the water would become a non-conductor. 2nd, That the vessel, no matter how strong it might be, would burst. 3d, That the current would pass without any decomposition happening; or lastly, that the current would pass and gas be evolved, but as fast as evolved, it would be dissolved in the water. A quantity of boiled water was hermetically sealed up in a glass tube, which it filled entirely, except a small space occupied by a bubble of air, probably not more than one-fiftieth part of an inch in diameter. A pair of

platinum wires had been fixed into the tube, so as to transmit the voltaic current. The current passing freely as was indicated by a galvanometer, decomposition of the water ensued; extremely minute bubbles making their appearance, the water absorbing the greatest part of them; its temperature rising very much, so that the tube communicated a sensation of warmth, when touched by the finger. When the pressure was estimated to have risen to about fifty atmospheres, the tube burst; and in an instant, all the gas that had been imprisoned in the water, made its escape, throwing it into a violent effervescence. Hence, we find, that when water is enclosed hermetically in a vessel, and a galvanic current passes through it, decomposition ensues, a portion of the gases making their appearance in the gaseous form, replacing the small space occupied by the decomposed water, the whole of the remainder being absorbed by that fluid, as fast as it is given off. When the pressure is high, it is probable that the dimensions of the vessel become greater, and hence the little bubble of air accumulated, exceeds in bulk the volume of decomposed water. It is also found, that any pressure up to forty or fifty atmospheres, may be commanded in this way.

24. Being thus furnished with a very convenient and very portable method of condensation, I proceeded to examine the force of passage of gaseous matter into atmospheric air. Sulphurous acid, passed instantaneously into atmosphere air, against a pressure equivalent to two hundred and twenty inches of mercury, or seven atmospheres and a third. Some experiments were made on the absorbing action of the sample of India rubber here used, which had been softened in ether for the purpose of procuring it in thin sheets. Of the gas here spoken of, it was found to absorb sixteen times its own volume. It is to be expected, that even had a much more powerful pressure been applied, the gas would nevertheless have gone through.

25. The curved form of the instrument, described in 20, was found to present certain inconveniences, when pressures upwards of six or seven atmospheres were made use of; the volume of air, which at the beginning of the experiment, occupied the greater part of the extent of the shorter limb, had now collapsed much in its dimensions, and owing to the unavoidable giving way of the India rubber and its silk, had retreated out of sight, beneath it. It was not found convenient to lengthen this limb, for that entailed a corresponding increase in the dimensions of the battery, in order to produce a given condensation in a given time; an objection also applying, in a measure, to the apparatus even at lower pressures. Though I had the command of batteries, consisting of 600 pairs of four inch plates, I preferred a

modification in the instrument itself, than a resort to such an energetic, but unwieldy apparatus. A straight tube was therefore taken, about three-sevenths of an inch in bore, Fig. 5, and a rim turned on it at *a a*, at the closed extremity the platina wires *b c* entered, a gage tube *d d* was dropped in between them, water was then poured in to the height *e e*, and lastly, a tube *f* containing the appropriate chemical test, was inserted, its bottom resting on the top of the gage tube. Nothing then remained but to tie on the India rubber with its silken support, and by the voltaic battery to proceed to condense. In this instrument, the test fluid was never out of sight, nor did the volume of the gas suffer any inconvenient change, the gage too was well located for observation, and a given condensation could be produced in less time, and by a less amount of electricity, than with the syphon tube; for the space contained between *a a* and *e e*, was less in volume. As an auxiliary arrangement, a glass tube *a a a a*, Fig. 6, one inch in diameter, and ten long, with a support *b* was taken, and its mouth ground true, so that a piece of plate glass *c c* would close it, when placed over it; this tube served in many cases as a gas generator, and also as a receiver for the tube, Fig. 5, which was dropped into it. It is to be observed, that in the arrangement here adopted, the gaseous matter evolved from water, mingles with the atmospheric air in the upper part around the tube *f*, and therefore the passage of the gases tried, does not take place into atmospheric air, but into a mixture of oxygen, hydrogen and nitrogen gases.

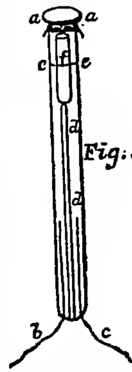


Fig. 5

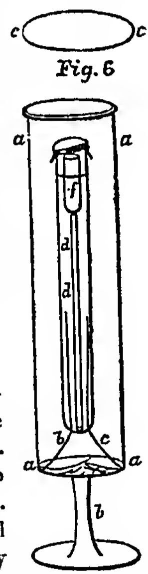


Fig. 6

26. The tube *f* being filled with lime water, and a pressure amounting to ten atmospheres being produced in the vessel, it was exposed to an atmosphere of carbonic acid, generated in the tube *a a a a*, Fig. 6; procured by dropping a few pieces of marble into the tube, and pouring thereon dilute muriatic acid. When the vessel was full, the plate *c c* was laid upon it, and any surplus gas generated, escaped by lifting it up. In the course of a few minutes, the upper part of the

tube containing lime water, began to look milky, and in an hour, a cloud of particles of carbonate of lime had fallen to the bottom.

27. Again, having filled the tube *f* with a solution of acetate of lead, and produced a pressure amounting to twelve atmospheres, it was exposed to sulphuretted hydrogen, generated in the vessel, Fig. 6, from protosulphuret of iron, and dilute sulphuric acid. In a very short time, the black sulphuret of lead appeared, giving tokens of the rapid passage of this gas through the barrier. A comparative experiment was made, in order to discover whether the transmission took place more slowly than when it was not resisted by such a severe pressure. It appeared, however, so far as the experiment could be tried under similar circumstances, as regards the thickness of the barrier, &c., that sulphuretted hydrogen went through the barrier against a pressure of three hundred and sixty inches of mercury, as readily as if no such force were exerted against it.

28. As numerous experiments, which had been tried on various gases, had hitherto failed to indicate any obstacle to their passage, it became necessary to know, whether at the extremest pressures that could be commanded, they would pass through a barrier. To accomplish this I took a strong and narrow tube, and having turned a rim at one end, and sealed fine platina wires in the other, I filled it with distilled water, and enclosed a narrow capillary tube in it, the gaseous contents of which were small. As a test, in the upper part of the arrangement, and in lieu of the tube *f*, I placed a slip of paper, which had been alternately soaked in acetate of lead and carbonate of soda; the India rubber was fortified by a piece of very strong silk, which was carefully tied on, there was not, therefore, any gaseous matter present except the small quantity of atmospheric air in the gage-tube. The condensation, therefore, went on with great rapidity, a mixture of oxygen and hydrogen gradually accumulating in the top of the vessel, bulging out the India rubber and silk barrier until it was almost hemispherical. It was my intention to try a pressure of twenty-five atmospheres, and when that was supposed to be reached, the instrument was placed in an atmosphere of sulphuretted hydrogen. Very soon the test paper became of a tawny appearance, and finally it was quite black. The pressure, when the experiment was over, was found to be twenty-four and a quarter atmospheres.

29. At a temperature of 48° F., and pressure of 29.74 B. sulphuretted hydrogen gas passes into a mixture of oxygen and hydrogen, though it may be resisted by a pressure of twenty-four and a quarter atmospheres, or nearly seven hundred and thirty inches of mercury. Like sulphurous acid, it penetrates through a barrier, and

then diffuses into an atmosphere beyond it, at pressures greater than that which is necessary to condense it into a liquid.

30. If, as it thus appears, no pressure which we can command is sufficient to restrain one gas from passing into another, we next inquire what obstacle the condensed gas exhibits. There is abundant and conclusive evidence, that under ordinary circumstances of temperature and pressure, this medium bears the same relation to the percolating gas that a vacuum would do; inasmuch as the rate of discharge into it is identically the same as it is intu a vacuum. For the purpose of illustration we may, therefore, regard it to all intents as a vacuum, and reason accordingly. If the particles of heterngeneous gases possess no repulsive tendency, as respects each other, but are perfectly quiescent and neutral, if the presence or absence of one makes no difference nor produces any retardation on the motions of the particles of the other, then it is apparent that it is immaterial how many of such particles are condensed together into a given space, owing to the want of repulsive actiun in those particles, that space will be as much a vacuum to any other gas, as it ever was. Now it has been shown by the experiment above cited, that certain gases will diffuse into others, even though the latter may be condensed into a space twenty-four times less than that which they would ordinarily occupy. The vacuum is not less a vacuum because it is contained under smaller dimensions, any more than a torricilian vacuum is less perfect when the mercury is made to rise nearly to the top of the barometric tube, than it was when there was a vacant space many inches in length. Theory would therefore indicate that these diffusions will take place under all pressures, provided the gaseous condition subsists; and this conclusion is abundantly borne out by the experiments herein detailed.

31. Having thus shown how it is that when gaseous matter is on one side of a barrier, the space so occupied may be regarded as a vacuum, even though the gas should be highly condensed, I come next to the consideration of a much more intricate part uf the subject, the action of the barrier itself as an areolar tissue, which is the more immediate object of this paper. I have already stated that the results of Dr. Mitchell and Professor Graham apparently exhibit a striking discordance; it will here be seen that the facts reported by those chemists can be readily co-ordinated.

32. Both of them appear to have made trials of the absorbent power of the barriers they respectively employed; Prof. Graham having operated on a mass of stucco of certain dimensions, and found its absorbing power, in relation to most gases, very low; Dr. Mitchell on a thick cylin-

der of gum elastic; but neither of them appear to have had any idea of the importance of this element in the production of the final result. In the case of the action of stucco, this indeed is a remarkable circumstance, for in all those instances where the absorbing power of the stucco was great, the equivalent volumes of diffusion, as obtained, were without exception erroneous. Dr. Mitchell, on seeing certain gases pass into each other, with a force that was greater than the pressure of sixty-three inches of mercury, and inferring that there was no *vis a tergo* in play, was obliged to impute his result to the inherent power of gaseous penetration, hence he came into direct collision with the Daltonian hypothesis. On the other hand, Prof. Graham, supposing that in all his erroneous cases, the deficit was to be imputed to the porous mass, which in some manner detained and absorbed the gases, found in every other instance a full confirmation of the doctrine of a vacuum.

33. The whole phenomenon depends, however, upon the action or inactivity of the areolar tissue itself: it will be convenient for the better understanding of it, to consider it under two heads. First, where the tissue exerts no absorbent action on the media, or absorbs both to the same extent; and secondly, where one is absorbed to a much greater extent than the other.

34. In the first case,—the velocities with which any two gases pass into a vacuum are inversely proportional to the square roots of their densities respectively; moreover the volumes that so pass vary directly as the velocities, and therefore may be taken as an index and measure of them; but, as the mass of each gas is expressed by the product of its density into its volume, it may be also represented by the velocity multiplied into the density; and, as the square of the velocity of the one, multiplied into its density, is equal to the square of the velocity of the other, multiplied into its density, whatever may be the difference of the specific gravity of the two gases, their mechanical momentum will always be the same; the resistance they meet with in passing through the tissue is common to both, and equal in both cases; and hence the initial velocities of diffusion ought to be inversely proportional to the square roots of the densities; and as during the progress of the experiment the impelling force of the one gas is equal to the expelling force of the other, the resulting momenta of the two currents is still equal, and the final volumes are such as are found by direct experiment.

35. We now come to consider the second case,—where the areolar tissue presents one of the gases in a condensed form to the other, or in other words absorbs it; and here we have to refer to a fundamental pro-

position of dynamics, that when the moving force and the matter to be moved vary in the same proportion, the resulting velocity will always be the same. An illustration will show the application of this principle to the case in hand. If a cylinder of air, fitted appropriately with a piston, communicates with a vacuum by means of an aperture, it is immaterial whether the air be allowed tn flow into the void withnut any pressure, nr whether it be urged by a direct action nn the piston, its velocity as it goes into the void will be in both cases the same; fnr, if it be compressed, the immediate action of the force exerted on the piston is to reduce the air in the cylinder to such a density that its elasticity shall be equal to the compressing force, and because the elasticity varies directly as the density, the density of the air increases with the impelling force. The matter to be moved is increased, therefore, in the same proportion with the pressure, and therefore the final velocity is the same. Now, what is here said of a cylinder of compressed air, applies evidently to the action of an areolar tissue, which is nothing more than a perpetual and equable condensing engine. If it increases the elastic force of one of the gases by compressing it, at the same time it increases its density; and, therefore, its velocity of transit is the same as though it had not suffered any action of compression.

36. Such is the case whilst the gases are engaged with each other in the tissue, but as soon as they are passed from it, and are beyond the reach of its attractive force, a new condition of things takes place—the condensed gas being no longer under restraint, expands freely into a void, and when there measured, gives a resulting volume totally different to what it would have been, had not the tissue compressed it. Suppnse, for example, we placed on one side of a tissue, carbonic acid, of which it would condense its own volume, and on the other atmospheric air, on which it exerted no action. Whilst the two gases were engaged together in the tissue, one would be presented to the other under an elasticity double of that which it would have had had no absorption gone on; but since its density is directly proportional to its elastic force, the continual velocity with which it would rush intn the other gas, is the same as though no compression had occurred; the rate of exchange in the areolar tissue is the same as under normal circumstances; that is to say, every volume of air replaces 0.8091 of compressed carbonic acid, but so soon as this gas has reached the opposite side of the barrier, and there escapes, its elastic force being restrained by no compression, causes it to assume its original dimensions.

37. It will be readily perceived, that the theory here given, depends

on the principle, that however much a gas is condensed, it will at all pressures rush into a vacuum with the same velocity. The elasticity of a gas in any state, is measured by the force under which it exists, and this is ordinarily the pressure or weight of the atmosphere; it follows therefore, that though the density of gases may vary, yet they have all the same elastic force; but, when pressure is exerted upon them, the density and elasticity increasing together, their velocity in rushing into a void is always, and under all pressures, a constant quantity.

38. We may now apply this reasoning to certain practical cases. Mr. Graham found, that the absorption of carbonic acid by a porous plug of stucco, was very small in amount, and the absorption of atmospheric air is equally minute. Accordingly, when these two gases are separated from each other by a screen of that substance, they diffuse according to the law of the square roots of their density. One volume of air, replacing 0.8091 of carbonic acid, the gas therefore, on that side of the screen where the carbonic acid was, increases in quantity. Now, when instead of a screen of stucco, a thin lamina of India rubber is used, which is found upon trial to condense one atmosphere of carbonic acid, whilst it does not act upon air, the same rate of exchange ensues; but there is a diminution of gaseous matter on the side containing the acid, and because the screen condenses one atmosphere, there should be found only half as much gas as would represent the equivalent volume of diffusion, had the screen possessed no condensing power.

39. One hundred and sixty-one measures of carbonic acid gas, were confined in a tube under a thin sheet of India rubber, and suffered to diffuse for thirty-six hours. To prevent as much as possible any disturbing action of the fluid, over which the experiment was tried, a saturated solution of common salt, which absorbs carbonic acid slowly, was made use of. The gaseous contents of the tube decreased in their dimensions very rapidly, and when measured, were found to consist of 98 volumes only. In the mean time, a tube closed at one end filled with the same quantity of carbonic acid, and placed by the side of the former, had decreased about five measures; we may therefore assume, that the quantity of gas that should have been found in the diffusion tube, ought to have amounted to 100 measures nearly. Now the specific gravity of carbonic acid gas is 1.527, the reciprocal of the square root of which is 0.8091. Hence, under ordinary circumstances, one volume of air should replace 0.8091 of carbonic acid gas; but, as in the experiment here tried, the barrier produced

a compression, one volume of air should displace 1.6182 of carbonic acid, the amount observed very nearly.

40. I would not here be understood to say, that there are no other disturbing actions going on in areolar tissues, except those which result from their absorbent power. A great many facts show, that under peculiar conditions, they are able to produce decompositions of a certain sort. Often, their regular action as indicated by theory, seems to be entirely departed from; great disturbance arising from the fact, that when two gases are absorbed together by any areolar tissue, they experience a greater condensation than each would in a separate state. The presence of nitrogen or carbonic acid, in any porous mass, increases the action of that mass on oxygen, more of the latter being condensed. A piece of charcoal, impregnated with oxygen, condenses more hydrogen than it should do, and the presence of hydrogen facilitates the condensation of nitrogen. It is therefore impossible to foretell what the result of diffusing one gas into another will be, by simply ascertaining how many volumes of either alone will be absorbed by the tissue, inasmuch as a greater or lesser condensation may happen, when both are employed together.

41. Variations of temperature, which probably affect the power of absorption, and thereby the diffusion volumes, are experienced by all tissues. When charcoal, or any other porous mass is placed in an atmosphere of gas, which it can condense rapidly, its temperature rises, the effect apparently depending more on the velocity of absorption than on the final amount. In the case of ammonia, it does not even require a thermometer to discover this increase of temperature, for it is very sensible to the touch. On the other hand, when this condensed gas makes its escape, a corresponding diminution of temperature happens, it is immaterial by what means the liberation of the gas is effected, the same result uniformly follows; if, for example, a porous mass saturated with carbonic acid, be exposed to an air pump vacuum, in connexion with a thermometric arrangement, the gas as it is liberated from the pores of the structure, by the action of the pneumatic machine, gives rise by its expansion to the production of cold. Or, if the same porous mass, saturated in like manner with carbonic acid, be exposed to an atmosphere of hydrogen, it absorbs but a small quantity of this latter substance, whilst a very large amount of the former is liberated from its condensed state, and the thermometer indicates a fall of temperature; the resulting volume of the mixed gases being much larger than the original volume of hydrogen. Again, if a porous mass, which has absorbed its due volume of hydrogen, be immersed in an atmosphere of ammonia, the

resulting volume of the mixed gases is much smaller than the original amount, and the porous mass becomes hot.

42. The observations here made on the vicissitudes of temperature, which an areolar mass experiences, when successively immersed in an atmosphere of different kinds, obviously apply when the exposures instead of being consecutive, are simultaneoos. If, for example, a barrier separates carbonic acid and hydrogen gas, and absorbs the former to a large amount, bot exerts little or no action on the latter, then the opposite sides of that barrier will be uneqoally heated. Suppose, for illostration, we call that surface of the barrier which looks toward the carbonic acid C, and the surface looking toward the hydrogen H, then because of the condensing action of the barrier on the acid gas, the surface C will become hot, but because the gas so soon as it has passed the barrier expands, as into a void, when it reaches the surface H, that surface will become cold. We see, therefore, that immediately after the action of the membrane or barrier is first set up, the absorption of the carbonic acid takes places on a hot surface, and its evolution from a cold one. Whereas, the absorption of the hydrogen takes place on a cold surface, and its liberation from a hot one. A modified result of course happens, when both gases are absorbed in different degrees, and any prediction of the resulting action becomes a matter of much difficulty. Where the barrier is very thin, or has a high conducting power, as respects caloric, this distinct surface action may not rigidly occur, but the whole of the structure experiences some determinate rise or diminution; a mean of the condition of the two surfaces respectively.

43. I proceed lastly, to the developement of the general law of equilibrium, the fundamental statical law of the phenomena here under consideration. We have been considering the relations of an absorbing medium with two others, situated on opposite sides of it, and the particulars of their mutoal transit into each other; it is plain, however, that sooner or later all motion of the media must cease, and that before every thing can obtain that state of repose, certain conditions have to be folfilled.

44. The most eligible method in practice to determine this, is to expand a soap bobble of determinate dimensions, with one of the gases, in a jar whose capacity is known, filled with the other. The extreme degree of thinness to which soap bobbles may be blown, reduces the duration of the experiment within reasonable limits, and by taking care to prevent evaporation from the surface of the bobble, there is little risk that when once well formed, it will burst before the end of the trial. A few experiments will show the degree of viscosity which

it is proper the solution should have. In an interval, varying according to circumstances from five minutes to half an hour, the process will have been completed, and a state of equilibrium gained. All that then remains to be done, is to measure and determine by analysis, the constitution of the gas within the bubble, and also that of the atmosphere in which it was blown.

(*a*) A soap bubble, containing 200 volumes of atmospheric air, was placed in an atmosphere containing 707 of the same gas. In ten minutes, the contents of the bubble being measured, were found to consist of 200 volumes, containing 20.5 per cent. of oxygen. The outer atmosphere consisted of 704 volumes, containing 20.5 per cent. oxygen.

(*b*) Two hundred measures of nitrogen were exposed to an atmosphere of atmospheric air for thirty minutes in a soap bubble; at the close of that time, there was found in the bubble 216 measures, 15.50 per cent. of which were oxygen, and 100 measures of the gas on the outside contained also 15.50 per cent. oxygen.

(*c*) Two hundred measures of nitrogen were exposed in a soap bubble to an atmosphere of oxygen, the increase of size was very well marked; in thirty minutes, there was found in the bubble 361¼ measures, of which 62 per cent. were oxygen, and the atmosphere outside contained 62⅔ per cent. of oxygen.

(*d*) Two hundred measures of oxygen were exposed in a soap bubble to an atmosphere of hydrogen for fifteen minutes; an expansion took place, the result measuring 207¾ volumes, of these, 16¾ per cent. were oxygen, the remainder hydrogen; and the gas outside of the bubble had identically the same constitution.

(*e*) Two hundred measures of hydrogen were exposed in a bubble to an atmosphere of oxygen for thirty minutes; 119 were found in the bubble, of which 47.75 were oxygen, but the atmosphere outside contained 50.50 per cent., and this was the greatest deviation from identity of composition inside and outside the bubble, that occurred in a number of trials.

45. From the foregoing paragraph, we deduce, that the general law of equilibrium asserts the identity in composition of the gaseous media, on both sides of the barrier.

46. It follows from this, that when any quantity of gas is enclosed under a barrier, in a vessel which is freely exposed to the atmosphere, the whole of that gas will pass out, and a certain portion of atmospheric air gain entrance. In this way alone, can the condition of the law of equilibrium be fulfilled.

47. The obvious application of these results, in a physiological

point of view, is to the function of respiration. In no order of life, however, does the respiratory mechanism coincide with these arrangements of two gaseous media, separated from each other by a barrier. In those tribes which breathe by lungs, the pulmonary vessels present themselves on the remote bronchial cells, and the arrangement is in effect, a liquid and a gas, parted from each other by a membrane. Chemical physiologists have hastened to apply the discovery of Dr. Mitchell in this case, and have done right. But still, the chain of evidence is incomplete, for we have not yet seen it proved, that gaseous matter in union with a liquid, will leave it and pass through a barrier to join a gas on the other side. The following experiment will supply this defect. A small jar, the mouth of which was closed with India rubber, and its opposite end made to terminate in a tube one-eighth of an inch in diameter, whilst full of atmospheric air, was sunk in a vessel containing water impregnated with carbonic acid. In a very short time, the acid gas leaving the water, went through the barrier, and as it accumulated in the jar, was delivered by the short tube at the other end, and passed up in bubbles through the water.

48. Branchial respiration deviates still more from the simple type, for we have here two fluids, presenting gaseous matter to each other for interchargé through a membranous screen. In one of them the gas is in a state of solution only, but as to what its condition in the other may be, we can scarcely say. The phenomenon, however, becomes obviously much more complex. In bronchial respiration, the account which Mr. Graham gives of the process by which the little cells empty themselves into the trachea, is probably correct; and the same observation undoubtedly applies to the case of the respiration of insects; but the function of respiration itself is quite another thing, and depends upon very different laws than those of gaseous diffusion.

49. The issue of these investigations, besides co-ordinating the observations of Dr. Mitchell and Professor Graham, has a far more important application. It shews us indisputably that membranes have special mechanical functions, depending on the conditions of their texture; and that often they are, *in appearance*, the generators of power equal to the pressure of many atmospheres. It is not pretended, however, that the foregoing paragraphs contain the whole theory of areolar action, the object of this communication being limited to a discussion of some of those mechanical functions, which have led chemists to conflicting results. Writers on physiology have suspected that membranes were springs of power, both mechanical and chemical, but the direct proof, from actual experiment, has never until now been furnished.

Hampden Sydney College, Feb. 12th, 1838.