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ATMOSPHERE:

A

PHILOSOPHICAL WORK.

BY

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PREFACE.

THE design of this work is to explain the causes of certain effects, the discovery of which has baffled the efforts of mankind from the earliest ages to the present time; and to supply true principles for the investigation of the operations of nature, the hidden springs of which have occupied more or less the minds of the Philosophers of ancient Greece and all succeeding ages, and eluded their most careful researches.

The papers, composing the text or body of the book, were published separately, at considerable intervals, and are inserted, with few exceptions, in the order of succession in which they originally appeared. They are not arranged in the form of a treatise on any particular subject, but some of them, such as the papers "on Atmospherical Pressure," "on Evaporation," and others, may be regarded as essays on the subjects to which they refer; and, taken altogether, they constitute the basis of a true Philosophy, which points to the Sun and its Light, the Earth, the Atmosphere, and the Waters, as the instruments with which the Almighty carries on the operations of nature. By the reciprocal action of the Sun, the Earth, the Atmosphere, and the Waters, all the organizations of nature, and all natural modifications and transformations of matter, are effected. For, comparatively, but little effect can be attributed to stellar influence, and the light and influence of the Moon seem to be derived chiefly if not wholly from the Sun.

Among the objects most worthy of the regard and consideration of mankind, are the works of God in his creation; for on them the life, health, material comforts, and much of the temporal happiness of man continually depend. On those operations of the material world, however, the temporal happiness of man does not wholly rest. It is affected in no slight degree by the operations of the human mind. The mind of man controls his actions. Therefore, from the operations of the human mind spring peace and war, violence and wrong, justice and injustice, and (the divine laws excepted) all the laws which regulate the intercourse of nations with nations and of communities and individuals among themselves, and all infractions of all laws, and all the crime and misery thence arising. And seeing how much the wellbeing of man depends upon the operations of his own mind, we also perceive how important it is that the human mind should be instructed and guided by principles the most conducive to human happiness; and those principles we find in the divine ethics of the Bible. For the wisdom of man has given to the world no system of morality to compare at all in goodness with that of the Sacred Scriptures. It is quite evident that, if the actions of men were governed by the doctrines of the New Testament, wars and violence, injustice and wrong, would then wholly cease. And thus we see how largely the Almighty has placed as it were the temporal happiness of man under his own control.

OLD HALL, MOTTRAM,
July 1851.

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The process through which cold water passes to a boiling state, seems to indicate that the boiling or bubbling is caused by a current or currents of air passing through it. After the water is put on the fire to boil, the process commences, by the formation of an immense number of small bubbles on the bottom of the vessel containing the water, which gradually enlarge, run into each other, and begin to ascend to the surface of the water; and still they go on, increasing in size and number and in the rapidity of their ascent, until they form here and there streams from the bottom of the vessel to the surface of the water, whose united action produces the agitation in the water called boiling.

Now, these appearances seem to be caused by air, and not by heat;* for if a

* When this paper was first published, all ignitions, combustions, and explosions, such as the burning of coal or wood, or any other matter solid or fluid, and the explosion of all explosive substances, the boiling of water, and many other remarkable effects, were supposed to be caused by an agent called "heat," the

tin vessel containing water be partly immersed in a vessel of boiling water, the water in the tin vessel may be raised to boiling heat,* but it will not boil.

From this it appears that heat is not the cause of the agitation in boiling water; for here is the requisite heat without the boiling. But the air has not free access to the tin vessel, being excluded by the water which surrounds it; and hence the reason why the water in the tin vessel does not boil.

If a tumbler or common drinking-glass be put into a pan of water sufficiently deep to cover or completely immerse the glass,

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nature of which was unknown. Some supposed heat to be a subtle fluid, whose particles were invisible and imponderable, of extreme tenuity, repulsive of each other, and attractive of the particles of other matter. Others regarded heat as consisting of some motion of matter, or the particles of matter. And some thought that heat was caused, or produced, by the vibrations or undulations of a peculiar elastic fluid or ether universally diffused.

* The degrees of heat are measured by a thermo-

and the glass then be turned upside-down, in such a manner that no air can enter it in the act of turning, and that the water may have full possession of the inside of

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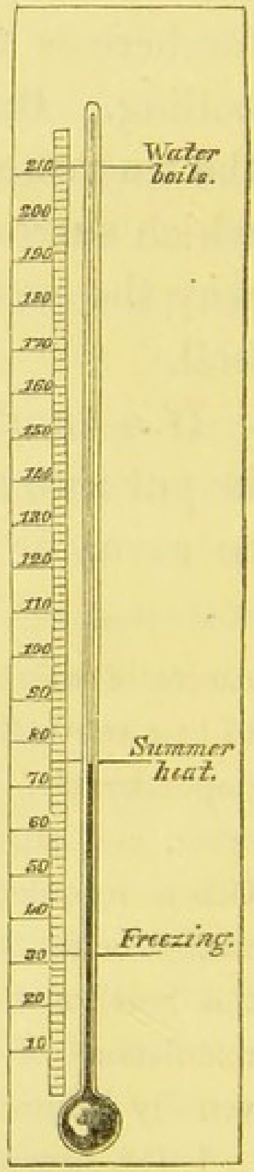
meter, an instrument which usually consists of a glass tube six or eight inches long, and about the twentieth part of an inch in diameter, terminating in a hollow ball at the lower end, which is filled with mercury, extending into the tube, as represented in the annexed drawing, and hermetically sealed, by the blowpipe, at the other end. To fill the ball with mercury and complete the instrument, the air must be extracted or expelled, the mercury introduced through the tube, and the end hermetically sealed. It is then fastened to a frame of metal, wood, or ivory, on which the degrees of heat are marked. The mercury in the tube rises and falls with the strength of the heat which is supposed to act upon it. The accompanying figure shows the form of a thermometer.



the glass when turned, and the pan then be put on the fire to boil, the air will gradually take possession of the glass, and drive the water out. The operation of the air under the glass will be plainly perceived by watching it.

[This paper, with slight variations, and without the notes now appended to it, was published in the *Mechanics' Magazine*, in the month of December, 1836, in the form of a letter addressed to the Editor, signed "W."]

CHAPTER II.

ON HEAT—THE ACTION OF LIGHT AND ATMOSPHERE—AND THE DISTRIBUTION OF THE ATMOSPHERE OVER THE EARTH'S SURFACE.

In this paper an attempt is made to show that the effects usually ascribed to the sun's heat are produced by the combined action of light and air; that the degree of the sun's heat, at any given point, is in proportion to the intensity of the light and the pressure, and consequent density, of the atmosphere at that place; and that the distribution of the atmosphere over the earth's surface is effected and regulated by the earth's rotation on its axis.

To the effects produced by the burning-glass, whether it be the burning of a piece of wood, or the melting of a piece of iron, both light and air contribute. We know that these agents are both present in the operation; and we do not know that any other agent is present; and in the absence of either of them, the burning-glass will not burn. If a light from a lens which sets substances on fire be thrown into the same substances in an exhausted receiver,* it

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* Atmospheric air is a fluid which, like water, can be acted upon by mechanical means. By means of air-pumps, air can be drawn out of or forced into any place or space as effectually as water. To exhaust the air from any particular place or space, it is necessary to surround or enclose it with a case or covering of some solid substance, such as a glass jar or cup, to keep out the surrounding atmosphere; and then to draw out the air by an air-pump. An exhausting air-pump is a hollow cylinder of metal, generally brass, with a well-adapted piston, having two valves, one at the bottom of the cylinder, the other in the piston; and the cylinder is connected by a tube, proceeding from its lower or valve end, with a very smooth brass plate, through which it passes and opens on the upper side; on which, over the orifice, the receiver to be exhausted is

produces, on many of them, no visible effect. This shows that the effects produced by the burning-glass, which are

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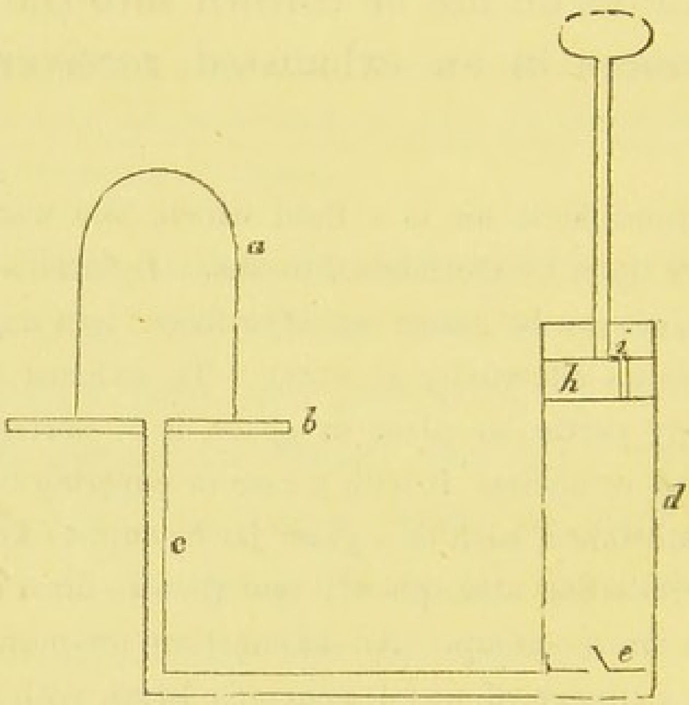
placed. The drawing below shows the form of an air-pump.

AN AIR-PUMP, WITH A RECEIVER ON ITS PLATE, READY FOR EXHAUSTION.



a is the receiver; *b* is the brass plate, which is generally circular; *c* is the tube connecting the cylinder with the brass plate; *d* is the cylinder; *e* is the valve in the cylinder; *h* is the piston; *i* is the valve in the piston.

When the piston is forced down, the valve in the usually ascribed to heat, result from the combined action of light and air. It also tends to show that, in the pure sunbeam, there is no heat; and there are certain natural facts which have the same tendency.

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bottom of the cylinder is closed, and the compressed air opens the valve in the piston and escapes through the aperture. When the piston is drawn up, a vacuum is made in the cylinder under the piston, and the air in the receiver and tube expands, forces up the valve in the bottom of the cylinder, and rushes through the aperture into the cylinder, and is again forced out through the aperture in the piston, until the exhaustion is complete.

In the construction of air-pumps, a variety of mechanical arrangements are used. Some air-pumps are made with two cylinders, and have a barometric tube, or a syphon containing mercury, to indicate the degree of exhaustion. The receiver is of glass, with a broad edge or brim, which is ground flat and smooth; and, to make the connection between the receiver and the plate of the air-pump air-tight, the edge of the receiver is besmeared with lard. Anything to be subjected to experiment is placed within the receiver. If it be a liquid, in a proper vessel.

The summits of the lofty mountains within the tropics, which, while smitten by the sun's intensest rays, are wrapped in everlasting ice, attest that in those rays there is no heat. In the case of the exhausted receiver, the reason why the light does not produce its usual effect, obviously is the want of air. In the other case the reason is analogous, or the same—the want of sufficient air and atmospheric pressure, to assist the action of the light. Ascending from the earth's surface, the density and pressure of the atmosphere are known gradually to decrease;* and it admits of no doubt that the atmosphere about the summits of those mountains is too highly rarefied to enable the sun's light to act with effect. Those summits probably rise to, and perhaps transcend, the surface of the ocean of air which rests upon the earth.†

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* See the paper "On Atmospherical Pressure," page 91.

† Baron Humboldt expresses a similar opinion respect-

Light and air, in producing the effects ascribed to heat, seem to act after this manner:—the light appears to penetrate bodies, and to make way for the admission of air into them; and, when the light is sufficiently concentrated, the matter or particles composing bodies are thereby separated and set at liberty, and the appearances called combustion and melting are produced. It is unnecessary to prove that light penetrates solid bodies, further than to observe that the burning-glass supplies abundant proof of that fact. It is evident that all the convergent rays pass through the glass.

And the expansion of heated bodies is caused by air that has entered them; which, when they cool and contract, they give out, or squeeze out. It is the expressed air issuing out of heated substances which causes the ebullition, repulsion, steam and hissing perceived when

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ing the atmosphere in his "Cosmos," published in 1845. See "Cosmos," vol. i. page 6.

water is thrown upon them. If a piece of red-hot iron, or any other red-hot substance, be plunged into water, the air which it contains, and which is the cause of its redness, will be perceived issuing from it in innumerable bubbles. Hence, atmospheric air appears to be the active agent in the melting of metals. Aided by intense light, it seems to enter into them, and to be the power which ultimately separates the particles composing them, and produces the appearance called melting. Moreover, the currents of air which agitate boiling water enter through the metal or substance of the vessel in which the water boils. This, I think, is evident from the following facts:—the air issues from the metal, or substance of the vessel, as is plainly perceived by observing it. It may be caught before it reaches the surface of the water. And if a tin vessel containing water be partly immersed in a vessel of boiling water, the water in the tin vessel may be raised to boiling heat, but it will not boil, because it is protected from the action of the air by the water which surrounds the vessel in which it is contained.

The distribution of the atmosphere over the earth's surface seems to be effected and regulated by the earth's rotation. The atmosphere being a fluid resting on the face of the earth; and the earth being a sphere, turning with great velocity on its axis; the centrifugal force, thence arising, will necessarily cause an accumulation of air at the equator of the earth, which, under the influence of the same force, will decrease towards the poles;* and the necessary consequence of the accumulation will be an increased density and pressure of the atmosphere at the equator, which will also gradually diminish with the

* The waters of the ocean are known to be under the influence of the same force. The centrifugal force of the earth's rotation seems to be the power which obeyed the Almighty fiat, "Let the waters under the heaven be gathered together." This appears to be the power which at first established and still maintains the level of the sea.

accumulation thence towards the poles. And that such a distribution or arrangement of the atmosphere exists, is proved by the fact that, within the tropics, the barometer does not descend more than half as much for every 200 feet of elevation as it does beyond the tropics.*

The sun's light, also, is most intense at the equator, and within the tropics.

Now this distribution of atmosphere and light (supposing the sun's heat to result from the combined action of light and air, and that it is proportioned to the intensity of the light, and the pressure and density of the atmosphere at any given place) would cause just such a distribution of the sun's heat as is everywhere found. It would be greatest, and ascend highest, within the tropics, where the light is most intense, and the atmospheric accumulation and pressure are greatest; and thence its elevation would decline, and its intensity decrease, towards the poles. And

* See "Bell's Geography," vol. i. page lxx.

that is the order we find in Nature; there is the greatest heat, attaining the highest elevation, within the tropics, which thence gradually declines in elevation, and decreases in intensity, towards the poles.*

Atmospheric air is susceptible of a great variety of modifications, under some of which it seems to become light, or to give light; of which kind are all artificial lights.† And the electric light and the Aurora Borealis probably are but modifications of atmospheric air.

[This paper, with slight variations, and without any notes except those at pages

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* It is evident that a distribution of solar heat, analogous to the distribution mentioned in the text, might exist on the hypothesis that the atmosphere is equally or evenly spread over the earth, that the sun's light is most intense at the equator and within the tropics, and that its intensity gradually decreases, thence, towards the poles.

† See note, page 82.

13 and 14, was published in the *Mechanics' Magazine*, in April, 1837, in the form of a letter addressed to the Editor, signed "W."]

CHAPTER III.

ON THE ACTION OF LIGHT AND AIR—AND THE DISTRIBUTION OF THE ATMOSPHERE OVER THE EARTH'S SURFACE.

The object of this paper is to show that the effects attributed to the sun's heat are produced by the combined action of light and air; that the degree of the sun's heat, at any given point, is in proportion to the intensity of the light, and the pressure and density of the atmosphere, at that place; and that the distribution of the atmosphere over the earth's surface is effected and regulated by the earth's rotation on its axis. And some observations are added on the nature of light and heat from the compression of air.

To the effects produced by the burning-glass, whether it be the burning of a piece of wood, or the melting of a piece of iron, both light and air contribute. It is certain that both those agents are present in the operation; and we do not know that any other agent is present; and, in the absence of either of them, the burning-glass will not burn. If a light from a lens, which sets substances on fire, be thrown into the same substances in an exhausted receiver, it will produce no perceptible effect on some of them. It will not ignite gunpowder. If a burning light be thrown upon gunpowder in a glass receiver well exhausted, it produces no perceptible effect so long as the vacuum is tolerably good. As the air returns into the receiver, and is accumulated in the grains of powder by the light which enters them, they begin to smoke and jump about; but the light will not inflame them until the receiver is replenished with air. Gunpowder cannot by any means be made to explode in vacuo. I have seen the finest gunpowder lie on a red-hot wire, in vacuo, until the wire melted, without either exploding or igniting, or being in any way perceptibly affected; and I have seen the same gunpowder taken out of the receiver and exploded in air by the remnant of the same wire, heated by the same galvanic battery;* for that was the source whence the fire was derived. If the vacuum be defective, the gunpowder, after being in contact with the connecting wire some time, begins to smoke and burn; which

* There are many methods of constructing the galvanic battery. Two plates, one of copper or iron, the other of zinc, each five or six inches square, dipped in a mixture of sulphuric acid and water, consisting of one part, by measure, of sulphuric acid and eight or ten of water (for instance, a pint of sulphuric acid to 8 or 10 pints of water), make a battery sufficient for some experiments. To a ring, in each plate, is attached a copper wire, through which the fluids pass; and if the two wires are connected at the ends, or any other part of them, by a piece of fine wire of platinum, steel, or iron, laid firmly across them, the portion of the connecting wire between the two conducting wires becomes warm, and, if the battery be strong enough, red-hot,

effects are caused partly by the air in the receiver, and partly by air which issues out of the wire. An explosion may be

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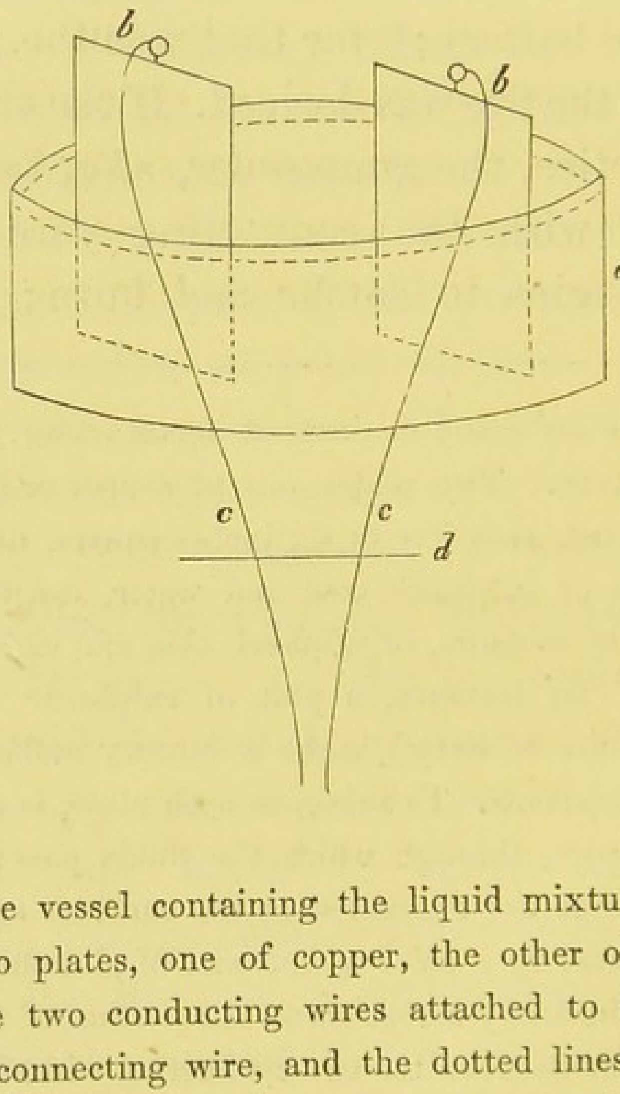
and melts. The following figure shows a battery with two plates :



a is the vessel containing the liquid mixture, *b b* are the two plates, one of copper, the other of zinc, *c c* are the two conducting wires attached to the plates, *d* is a connecting wire, and the dotted lines represent the liquid mixture and the plates dipped in it.

obtained from gunpowder under water, if a sufficient quantity of atmospheric air be put down with it; but no explosion can be had without air. If a little gunpowder be put in a glass bottle, and the bottle be then corked and sunk in water, the powder may be exploded by light, that is, by a lens. But if the powder be put into the bottle, and the bottle be then filled up with flour or fine sand, firmly rammed down, so as to exclude all air from the powder, and then corked and sunk, the powder will not explode, nor can it be ignited. Now these facts clearly prove that the fire and light, the noise, the concussion, and the dispersion of matter, which accompany, and in fact constitute the explosion of gunpowder, are caused by an action or operation of the atmosphere.

To increase the strength and effect of the battery, the number of plates must be multiplied, and they must be soldered or joined together in pairs, one copper or iron plate to one of zinc, with a space of an inch or two between the plates, and a like space between each pair of plates.

It may be asked, if fire is air in a state of radiation, whence comes the fire which appears in the connecting wire of the galvanic battery, in the exhausted receiver, where, it may be said, there is no air? The answer is, that it is caused by the two streams of aëriform fluid which come from the battery, pass through the conducting wires, meet in the connecting wire, and there, by their confluence and the pressure arising from it, produce the fire perceived. If the ends of the two conducting wires are dipped in water, aëriform, elastic fluids or gases, called oxygen and hydrogen,*

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* Oxygen and hydrogen are obtained in various ways. Oxygen, by exposing the binoxide of mercury or the nitrate of potassa, in closed vessels, to the action of fire, and collecting the vapour or effluvium, which is oxygen. It is also procured from other substances by different processes.

Hydrogen is obtained by putting zinc into a mixture of sulphuric acid and water, in a glass bottle or other closed vessel, and collecting the vapour or effluvium, which is hydrogen. Hydrogen is also procured from other substances by other means.

come from them; the oxygen coming from one wire, the hydrogen from the other; which gases, according to many opinions, are somehow formed from the water; but in this opinion I do not concur. It seems to me that these gases or fluids are derived from the atmosphere; that they are but modifications of atmospheric air; and that they come from the battery through the conducting wires. I think so because the

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If a light be applied to hydrogen, which is usually retained in vessels inverted (for, being specifically lighter than atmospheric air, it immediately ascends on the mouth of the vessel being turned upwards), it burns; but advance the light, a candle for instance, into it, and the light is immediately extinguished.

Apply a light to oxygen, and the gas does not burn; but put the light into it, and the light burns with greater brilliancy.

If these gases be mixed in the proportions of about two parts of hydrogen to one of oxygen, in an elastic receiver, such as a bladder, and then suddenly compressed, they ignite and explode. And this fact throws light on the nature of atmospheric lightning; for a jet of atmospheric air burns brightly in hydrogen. And see the paper " On the Action of Air," page 57.

fluids issue from the wires, and may be diverted at any part of them; because atmospheric air can be forced copiously through many kinds of wood and stone (a vacuum being made under them) by atmospheric pressure alone;* and because all metals are and necessarily must be saturated with air in the process of their smelting, formation, and manufacture.

A burning light thrown upon paper immersed in water will not burn it; and why? because the water excludes the action of the atmosphere; and not, as is commonly said, because the water absorbs the heat before it can act on the paper. This is evident, from the fact that the light will burn the paper when passed through the water to it. Thus, take a flat transparent glass phial, an inch or two thick, and two or three inches square; fill it with clear water, and place it between the lens and the paper, so that the light must pass through the bottle of water before it

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* See note, page 61.

reaches the paper, and it will then burn the paper. In this case, allowing for a little dispersion which takes place in its passage through the water, the light acts with undiminished force. If the water absorbed the heat, it would absorb it in both cases; and the ray of light in each case would be unable to burn; but it is not so; and the reason why it is not so is, that, in the former case, the paper is protected from the action of the air; and in the latter case it is not. If a burning light from a lens be thrown upon the hand immersed in water, it causes a pricking sensation; if it be thrown upon sealing-wax so immersed, it makes a crackling noise; and globules of air arise from the part of the wax under the focus, which is pitted and made rough by the bursting forth of the fluid. If such a light be thrown upon a piece of wood, unpolished iron, dark-coloured flint, or dark-coloured cloth, immersed in water, globules of air also rise from the parts touched by the focus. This is the incipient process of burning; which, when exposed to the action of the atmosphere, that element completes.

That the globules, in all these cases, are air, may be easily ascertained in the following manner:—take a glass shade, such as is used to cover artificial flowers, four or five inches deep, and three or four inches in diameter at the mouth, immerse it in a vessel of clear water, deep enough to cover it, and then invert it, taking care to turn it under water, so as to exclude the air and leave the interior of the glass wholly occupied by the water. Then put the wax or other substance to be operated on under the glass, and apply the focus of the lens to it, and globules of air will issue from the substance, ascend to the top of the glass shade, and be retained there. With this apparatus I have obtained air globules in abundance from black sealing-wax, rusty iron, dark coloured cloth, dark flint, and wood, and from lead and white pebbles a few minute globules; but from gold, silver, copper and glass I could get none, because the gold, silver, and copper reflect a large portion of the light thrown upon them, and the glass also reflects a part of the light thrown upon it while another part passes through it. The lens used in these experiments was nearly six inches in diameter. With a more powerful lens I think air would be obtained from gold, silver, and copper, or any other substance, except transparent substances, and perhaps from them. The focus made deep pits in the wax, which was rent and torn by the escape of the fluid. The air obtained from all these substances was permanent; it might be retained for any length of time. The nearer the object is to the surface of the water, that is, the less it is submerged, the greater is the effect produced by the focus. In most of these experiments a portion of the water was poured out of the vessel containing the apparatus, so as to expose the top of the glass shade, and the light had then only to pass through the glass and the water under it to the object which was elevated or depressed at pleasure. The effect was the same whether the water had been previously boiled or not; but it was somewhat less in sea water than in fresh water. This is not air liberated from the substances by the action of the light, because air, without diminution, may be obtained from the same substance so long as there is light enough to make a powerful focus. Nor is it air from the water, for it evidently issues out of the substances; and if it were from the water, it would come from the gold and silver as well as from the iron and wax. It is from the light. These facts show that solar light is air in that peculiar state of action called radiation. They show with what facility air, in that state of action, passes through transparent bodies, and how it penetrates and is arrested by dark-coloured substances; and they also show that the effects of the burning glass, operating in air, are produced by the combined action of light and air. These conclusions inevitably result from the preceding facts: it seems impossible to resist them. And the summits of the tropical mountains, which, while smitten by the sun's intensest rays, are wrapped in everlasting ice, also prove irresistibly that the sun's rays, unaided, and by their own force, can produce no effect of heat. In all these cases it is the deficiency of air at the point of action that deprives the sun's ray of its full effect.

Solar light and atmospheric air, in producing the effects ascribed to solar heat, evidently act in the following manner:—the light penetrates the substances, and makes way for the admission of the air into them; and when the light is sufficiently concentrated, the particles composing bodies are, by the power of these agents, separated, and the appearances, called combustion and melting, are produced, an operation which is more easily understood when we consider that the atmosphere is an immense ocean of extremely subtile fluid, resting on the face of the earth, in the bottom of which ocean man lives, and all his works are carried on; that it presses with a force of more than fourteen pounds to the square inch on all objects at the earth's surface; and that it penetrates, permeates, and saturates all bodies and solid substances, animate and inanimate, living or being therein.* Such indeed are the solvent

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* The reality of the atmosphere is shown by the suspension and floating of the clouds, the flight of birds, the rise of balloons, and especially by that modern wonder the atmospheric railway, and by the ability of air to displace, and, where it has a stay, to keep out liquids; as in the case of the diving-bell, or of an inverted wine-glass put down into a vessel of water. That the atmosphere has an upper limit or surface not very many miles above the surface of the earth, is shown by the decrease of its pressure with the distance from the earth's surface, as indicated by the descent of the quicksilver in the barometer on occasions of ascent in the atmosphere. And the great force with which the atmosphere presses on all objects on the earth's surface is shown by the difficulty with which an exhausted receiver is removed from the plate of the air-pump to which it is held by the pressure of the

powers of solar light and atmospheric air when their action is combined and sufficiently concentrated, that few things, if any, can resist them.

That light penetrates solid substances is a truth sufficiently apparent from the foregoing facts; but, if further proof were wanted, it would be furnished by the burning-glass. It is evident that all the convergent rays pass through the glass; and if the concentrated light from a lens be passed through a transparent bottle of water, the cone of light will be seen in the water as it passes through, and a beautiful sight it is.

And the expansion of heated substances undoubtedly is caused by air which has entered them, which, when they cool and contract, they give out or squeeze out; and it is the air, so pressed out of cooling bodies, that causes the ebullition, repul-

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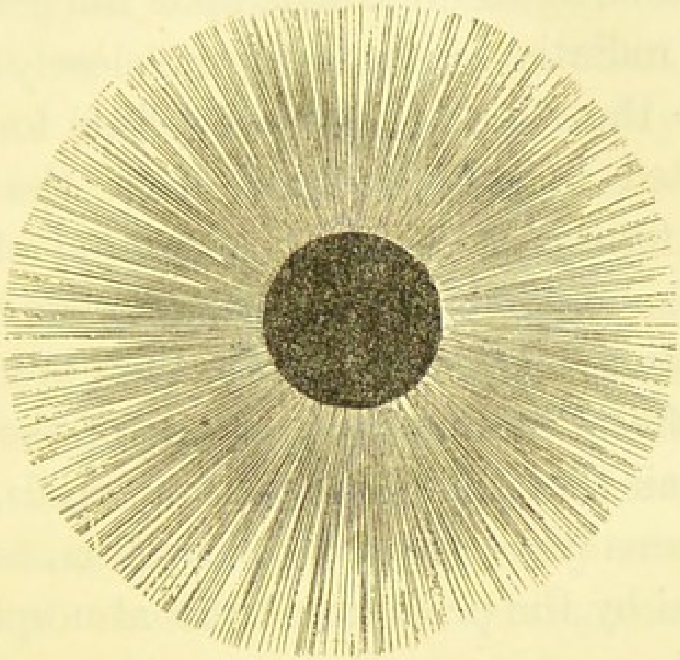
atmosphere, and by the speed and power with which it propels trains on the atmospheric railway. And see Chapter VIII. "On Atmospherical Pressure."

sion, and hissing perceived when water, oil, and other liquids are thrown upon them. If a piece of red-hot iron, or any other red-hot substance is plunged into water, the air it contains, and which is the cause of its redness, will be seen issuing from it in innumerable bubbles, which may be caught and retained in the following manner:—Take a vessel of cold water, either from the spring or of water which has been previously boiled, deep enough to allow a common drinking-glass to be inverted under water in it, and invert such a glass therein without admitting air into the glass; then raise the inverted glass a few inches from the bottom of the vessel, and thrust a piece of red-hot stone, iron, cinder, or any other red-hot substance under the inverted glass, the interior of the glass being free from air and full of water, and the air from the heated substance will rise into the glass and be retained. These experiments prove, beyond all doubt, that air issues copiously out of highly heated substances. They also account for the expansion of heated substances, and show the cause of their repulsion of liquids. Hence it is clear that atmospheric air, aided by light, and in the form of light, enters into substances and separates the particles composing them, and is the agent which effects the dissolution of the substances in all cases of combustion and melting, whether it be of metals or other things. They also show that the agitation of boiling water is caused by air which comes through the substance of the vessel in which it boils, and not by any conversion of the water into gas, or vapour, or steam, of which truth the following facts afford further proof. The boiling of water commences by the formation of numerous small bubbles on the bottom and sides of the vessel exposed to the action of the fire, which gradually enlarge and rise to the surface, and others are again formed in their stead, and rise, with continually increasing celerity, until they produce the ebullition called boiling. These bubbles are air which comes through the substance of the vessel. If a common drinking-glass be put into a vessel of water sufficiently deep to cover it, and turned with the mouth downwards, care being taken to turn it under water, so as not to admit any air in the act of turning, and the vessel then be put on the fire to boil, the air will gradually take possession of the glass and drive the water out. The operation will be plainly seen by watching the glass. If, when the glass is full of air, the vessel be taken off the fire and allowed to stand, the air will escape through the expanded substances enclosing it, rapidly at first, while the expansion is greatest, but more slowly afterwards as the substances cool and contract, and in half an hour, or an hour, it will wholly disappear. If, however, a portion of the hot water be poured out of the vessel, and the remainder cooled by adding cold water to it, or if the whole of the water in the vessel, when taken off the fire, be cooled by adding cold water to it as quickly as may be, without breaking the glass, a portion of the air inside the glass will be retained. The result is the same if milk or oil be used instead of water. The glass fills with air, which escapes in the same manner as when water is used, except that, with oil, the glass fills with air sooner, which escapes more slowly than with water or milk, and a portion of the air always remains in the glass. And, I apprehend, the result will be the same, or similar, with any other liquid that will boil. Again; if a tin vessel containing water be partially immersed in a vessel of boiling water, the water in the tin vessel may be raised to boiling heat, but it will not boil, because the water in which the tin vessel is immersed interrupts the action of the air. The air penetrates and impregnates the tin vessel and the water it contains, but the surrounding water prevents it passing through in such force as to produce continued ebullition. It is clear, beyond question, that the ebullition of boiling water is caused by air which penetrates and comes through the substance of the vessel in which the water boils.

And further to illustrate these views, to show the sort of action which is continually going on about all fires, and how they produce the effects attributed to heat, and that those effects are produced by an aëriform fluid, of which the atmosphere is the source, I may mention an occurrence which came under my observation on the 20th of January, 1838. At noon on that day, the ground being covered with snow about one inch deep, there being a keen frost, a brilliant sun, which made no impression on the frost, a calm atmosphere, or, if disturbed at all, it was by breathings from the north-east, and the thermometer standing at 14° Fahrenheit, a brasier of burning coke was placed upon the snow in the open air, which made upon the ground a radiated figure of the form given on the following page; the dark parts being thawed. The brasier was a circular one, and occupied the centre of the figure. In



order to ascertain if the radiation resulted from any local cause, the brasier was removed into different places, but it produced, in all of them, the same figure. On the 28th of January, 1839, the experiment was tried again with coal instead of coke, the ground being covered with snow about half an inch deep,—there being a keen frost, with a sky perfectly overcast, and a gentle breeze from the north-west, the thermometer standing at 31° Fahrenheit, when the same figure was made upon the ground. The radiation in this figure clearly indicates the action of an aërial fluid forcibly emitted in all directions from the fire. The figure is made by an action of the atmosphere, which may properly be called radiation. It is this action that produces the effects ascribed to the heat of the fire. The air that enters burning materials, and performs the office of combustion, is displaced by the pressure of the atmosphere, which appears to be the cause of the action indicated by the figure.

Solid substances may be impregnated with air by friction and compression, and both solids and liquids by the radiation described by this figure; and a substance, so impregnated, immediately begins to radiate and impregnate all other substances within the sphere of its action. This is the kind of action by which fires burn. The radiation is the subtile action of a subtile fluid in a homogeneous fluid, of air in air, which is the reason why it is invisible. From this it is evident that all metals which have been melted or made red hot by fire must, when cool, remain saturated with air, probably with hydrogen gas; hence we may understand why iron and steel burn in oxygen. It is by the union and ignition of the gases.

The distribution of the atmosphere over the earth's surface appears to be effected and regulated by the earth's rotation. This seems to be the necessary result of natural causes and the arrangement of matter. The atmosphere being a fluid resting on the face of the earth, and the earth being a sphere turning with great velocity on its axis, the centrifugal force arising from the earth's rotation must cause an accumulation of air or atmosphere at the equator; which, under the influence of the same force, will gradually decline towards the poles. And the result of the accumulation will be an increased density at the equator, which, likewise, will gradually diminish with the accumulation thence towards the poles. And that such an atmospheric accumulation and density at the equator do exist, is proved by the fact, that, within the tropics, the barometer does not descend more than half as much for every 200 feet of elevation as it does beyond the tropics. And the height of the barometer, at the level of the sea within the tropics, affords, I think, corroborative evidence of the truth of this proposition. The retardation of the pendulum,* and the decrease in the intensity

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* A pendulum that vibrates seconds in England loses from two minutes to two minutes and a half a day at the equator; or, in other words, makes from 130 to 150 vibrations less in the twenty-four hours. The effect may be, and probably is, partly due to the expansion of the metal.

Some experiments have been made with pendulums, in vacuo, which show that the vibration of the pendulum is impeded by the atmosphere; but to what extent its vibration is accelerated in vacuo, those experiments do not satisfactorily show. The pendulum may expand or contract in vacuo, and the action of the machinery which impels it may be relaxed and weakened.

Nothing, perhaps, gives a clearer conception of the resistance offered by the atmosphere to bodies moving of gravity in the equatorial regions, appear also to be attributable to the increased density of the atmosphere in those regions, and not to the centrifugal force of the earth's rotation, further than that force increases the atmospheric density there. Bodies fall or move with more facility and speed in vacuo than in air, because all resistance to the moving body is withdrawn; through air than through water, because the air offers less resistance than the water; and it follows as a necessary consequence, that they move with greater facility in rare than in dense air; and that the resistance to the motion of bodies increases with the density of the atmosphere in which they move. I refer, therefore, to the equatorial retardation of the pendulum, and decrease of gravity, as addi-

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in it than the experiment of dropping a shilling and a feather, in vacuo, in which the feather falls as fast, and reaches the bottom as soon as the shilling, because the resistance which the atmosphere, at other times, opposes to the descent of the feather is withdrawn.

tional proofs of an accumulation and increased density of atmosphere at the equator. But to my mind the dip of the magnetic needle* affords still stronger and

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* If a steel bar or needle, such as the mariner's compass needle, be suspended by a fibre of silk, or be nicely balanced on a pivot, so as to rest horizontally and point freely in any direction, and then be magnetised, it will, after being magnetised, cease to point freely, or to rest horizontally; and, in the extra-tropical portions of the northern hemisphere, it will point towards the north, and dip or incline downwards; and, in the extra-tropical portions of the southern hemisphere, it points and dips southwards. In the northern hemisphere, the northern end of the needle inclines downwards towards the earth; and in the southern hemisphere, the southern end of the needle inclines downwards; and this downward inclination of the needle is called the dip of the needle; and a magnetic needle so balanced is a dipping-needle.

The mariner's compass is prevented from dipping by loading one end of the compass-needle with a small weight.

The dipping-needle is horizontal, or dips but little near the equator; but receding from the equator, either to the north or south, the dip gradually increases until more striking evidence of this arrangement of the atmosphere. From the equator towards the poles, to about the seventieth degree of latitude, the dip gradually increases. Suppose, then, that the density of the atmosphere at every step in the same progress, decreases; and we have the reason for the increased dip in the diminished density of the atmosphere, and the diminished resistance consequent thereon. The dip increases as the resistance to it diminishes. And further, the attractive power which causes the needle to dip (and which seems to be seated in the earth, and to be an induced attraction) combined with this distribution of the atmosphere, will give to the needle a general polarity. It necessarily must point in the direction where it meets the least resist-

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the seventieth degree of latitude is attained, when the needle points nearly straight down to the earth.

For an account of the various modes of magnetising bars or needles of steel, and of making artificial magnets, see the treatises on magnetism.

ance. And, moreover, according to these views, there ought to be a complete terrestrial circle in each hemisphere, somewhere short of the terrestrial axis or pole, namely, in that latitude at which the centrifugal force of the earth's rotation ceases to produce an accumulative effect on the atmosphere; throughout which circle, allowance being made for local influences, the magnetic needle will attain its greatest dip, and not be confined to any point or pole, or small locality. And I think I may be allowed to say there is reason to suppose that such a circle, in each hemisphere, does exist.

The preceding facts are submitted as evidence of an atmospherical accumulation and density at the equator; and proof of the extreme intensity of the solar light in the equatorial regions is unnecessary, that fact being well known and universally admitted. We have, then, such an arrangement of atmosphere and solar light as proportions the degree of solar heat, at any given point, to the intensity of the light, and the pressure and density of the atmosphere at that place, and as gives just such a distribution of natural heat as is found to exist. According to this system, the heat would be greatest and ascend highest within the tropics, where the light is most intense, and the atmospheric accumulation, pressure, and density are greatest and most constant; and thence its elevation would decline, and its intensity decrease towards the poles. And that is the order we find in nature. We have the greatest heat, attaining the highest elevation, within the tropics; which thence gradually declines and decreases in intensity towards the poles.

The anomalies of the Himmalayas, a chain of lofty mountains on the north of Hindostan, in Asia, perhaps may be adduced against these views. Those anomalies, however, appear rather to confirm than to weaken them. They are of that class of exceptions which prove the rule. That range of mountains situate between 28° and 36° north latitude, extends in one continued chain from 67° to 97° east longitude; a distance, including sinuosities, of about two thousand miles; presenting throughout that immense range a barrier towards the north of the mean height of 17,000 feet. And that is but the average elevation of the ridge, from which rise numerous lofty peaks, some of which attain the height of more than 26,000 feet, and but few of them rise less than 20,000 feet above the level of the sea. On some parts of those mountains the inferior line of perpetual congelation does not descend lower than 17,000 feet above the level of the sea; whereas the inferior line of perpetual congelation on the Andes, at the equator, is only 15,700 feet above that level. But the most remarkable of those anomalies is, that the heat and the inferior line of perpetual congelation appear to attain a higher elevation on the northern than on the southern side of those mountains. At least that inference fairly may be drawn from the facts which seem to be well established, that the extreme height of cultivation on the southern slope of those mountains is 10,000 feet; the height of habitation 9,500; while, on the northern slope, villages are found at 13,000 feet, and cultivation at 13,600 feet. The centrifugal force arising from the earth's rotation will necessarily cause, and at all times keep up, a strong bearing or pressure of the atmosphere from the direction of the poles towards the equator; which, coming in contact with, and being resisted by, the immense barrier presented to it by those mountains, will force up and compress and condense itself by its own momentum, against its northern side; and thus may be produced the existing anomalies.

With regard to heat from the compression of air, it is well ascertained that the temperature or action of atmospheric air is proportioned to its pressure and density, increasing where the density increases, and diminishing where it diminishes; and that its density is increased by compression, whether the compression be effected by mechanical means, or by its own superincumbent weight. Hence the reason why a piece of tinder is ignited by putting it in a small tube or cylinder with a close-fitting piston, and suddenly forcing the piston down to the bottom. Hence, too, the reason why the temperature or action of the atmosphere diminishes as we ascend from the earth's surface,* and increases as we descend into the earth. The temperature at the bottom of deep mines is greater than at the surface of the earth. The deeper the pit, the greater the heat, which gradually increases with the depth. This is caused by the superincumbent pressure of the column of air which descends the pit. Proceeding from the poles to the equator, the temperature of the atmosphere increases. Ascending from the earth's surface, it decreases. We know that the pressure and density of the atmosphere decrease as we ascend from the

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* See Chapter VIII. "On Atmospherical Pressure."

earth's surface; and we have seen that they increase as we approach the equator.*

By compression, air also gives light or becomes light; that is, it produces the effects ascribed to light, and becomes the medium whereby things appear. The heat and light arising from percussion are caused by the compression of air in the substances coming into contact. All solid substances, immersed in air, become thoroughly saturated with air. The subtilty of atmospheric air, aided by the pressure of the atmosphere alone, would enable it to penetrate and permeate all solid substances at the earth's surface; but, in that operation, it is also assisted by the action of solar light, as the preceding experiments on light clearly show. Solid substances immersed in water, which is a less subtile fluid than air, soon become saturated. Water will saturate

* See Chapter VII. "On Barometrical Pressure."

wood and stone, and many other substances, when permanently immersed in it. It is evident, therefore, that the violent collision of substances causes a sudden compression of air in the parts coming into contact; and that the compression is greater or less according to the hardness or softness of the substances used. Stone and iron in collision, being hard and rigid substances, give out sparks. The common kinds of wood, being softer, do not. From flint and steel, which produce an abundance of brilliant sparks when struck in air, no spark or light whatever can be obtained when struck in vacuo. This is shown by screwing the lock of a gun to the plate of an air-pump, exhausting the air, and drawing the trigger. Nor can any light or spark be obtained from the percussion of flint and steel under water. But two pieces of agate or quartz rubbed together under water give out light by a sort of coruscation, caused by the compression of the air in the parts of the agates or quartz which come into contact.

They will, however, cease to produce light under water after having lain in water until they are saturated, until, in fact, the water has expelled the air out of them. To effect this, the agates must be put in a vessel of water, twelve or eighteen inches deep, placed in a dark room, and covered with a lid, so as to exclude every ray of light, and kept in that state four or five months; and no light will then be obtained from them under water. But if light be admitted to them while in the water, they will continue to give light. Hence we have convincing proof that neither light nor heat can be obtained by percussion in the absence of air.

Heat from friction, also, is caused by the compression of air in the pores or interstices, and the mass of solid substances; the compression being effected by the action of the substances in air.

The axles of machinery would not heat if the air could be excluded from them. By friction in air, substances may be heated red-hot; but they can neither be heated red-hot, nor in any considerable degree; nor, I think, heated at all by friction in water, because the air or atmosphere is excluded from them. In the case of friction, the compression of the air commences in the superficial pores or interstices of the substances, and gradually extends throughout the mass. But there is a case of heat from compression of air, in which the compression commences in the interior of the substance; and the heat comes principally, if not wholly, from the inside, or out of the mass of the substance. That is the case when a piece of iron is hammered until it is hot. The iron being saturated with air, the air in the iron is compressed by the compression of the iron effected by the hammering, and thence the heat. Of this kind was the heat Count Romford obtained by boring cannon in water; if, indeed, the heat he obtained did come from the boring; but from the length of time occupied in that experiment (two hours and a half), and the degree of heat obtained (boiling heat), it is possible that some portion of the heat might be caused by the action of that part of the machinery which was out of the water, and communicated thence to the water. The boring of cannon, however, is an operation requiring great force; being effected by shaving or cutting the iron; and possibly the heat might arise wholly from the compression of the air caused by cutting the iron. From this kind of heat, that eminent philosopher, Dr. Black, might conceive his theory of latent heat. He supposed the existence of something in bodies which, under some circumstances, was evolved or set free, and produced the effects ascribed to heat, which he called latent heat.

The heat in many, if not in all cases of spontaneous combustion, seems to arise from the compression of air; the compression being effected by subsidence, and the contractile and accretive properties of the substances.

And animal heat appears to be caused by the compression of air in the lungs.*

The light arising from percussion and friction also affords evidence that atmospheric air, under some of the many modifications of which it is susceptible, gives light or becomes light, and causes things to appear by becoming the medium whereby they appear. All objects appear by the reflection and radiation of light; some by reflection, others by radiation. The sun, a candle, a jet of burning gas, and all luminous objects, appear by radiation. The letters of a book, the book itself, and all

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* By the operation of the ribs and their muscles, the diaphragm, and the lungs, in the act of respiration, atmospheric air appears to be mixed with the blood and forced copiously into the body; and the air so forced into the body pervades all its members and becomes the cause and source of insensible perspiration, and of what is called animal heat. The warmth of a body, so saturated with air, must be increased by every motion of its muscles and members; because such motion tends to compress the air in the parts moved, to force it out of them, and so to cause perspiration.

opaque objects, appear by reflected light. And transparent objects appear both by radiation and reflection.*

The electrical light, and all artificial lights, are but modifications of atmospheric air; and all electrical effects appear to be produced, principally, if not wholly, by an action of the atmosphere.

I may also state that the sea and land breezes which in these latitudes prevail in summer, the east passage winds, and the monsoons, may be accounted for, and I think satisfactorily explained, on the principles laid down in the paper.

[The preceding paper " On the Action of Light and Air, and the Distribution of the Atmosphere over the Earth's Surface," with slight variations, and without any of the notes now appended to it, was published in the *Mechanics' Magazine*, in the month of April, 1841, in the form of a letter addressed to the Editor, signed

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* See Chapter VI. " On Light and Vision."

W., having been previously published in the same Magazine, in December, 1838, in the same form, and with the same signature.]

CHAPTER IV.

ON THE ACTION OF AIR.

ALTHOUGH this subject has in some degree engaged the attention of philosophers, yet it has not had so large a share of their consideration as it merits. To the action of air in its various conditions, I am persuaded, all the phenomena of heat, electricity, and magnetism are referable. It is not necessary to have recourse to the imaginary agent called heat, to explain the effects produced by fire; for they evidently are caused by the action of atmospheric air and its several modifications coming under the denominations of combustible gas and gas which supports combustion. It is as clear as two and two make four, that the effects of the burning-glass are produced by the joint action of solar light and atmospheric air; and that the combustion originated by the lens will proceed without the aid of solar light, and by the action of the atmosphere alone. No combustible thing can be ignited in the absence of air. Gunpowder cannot by any means be exploded in vacuo. I have seen the finest gunpowder lie on a red-hot wire, in vacuo, until the wire melted, without either exploding or igniting, or being in any way perceptibly affected. And I have seen the same gunpowder taken out of the receiver and exploded in air, by the remnant of the same wire, ignited by the same galvanic battery; for that was the source whence the fire was derived. If the vacuum be imperfect, that is, less complete than it might be (for a perfect vacuum is unfeasible), the gunpowder, after being in contact with the connecting wire for a while, begins to smoke and burn; effects which are caused partly by the air in the receiver, and partly by air which issues out of the wires. Gunpowder may be exploded under water if a sufficient quantity of atmospheric air be put down with it; but no explosion, under water, can be had without air. If a little gunpowder be put in a glass bottle, and the bottle be then corked and sunk in water, the powder may, by means of a lens, be exploded by solar light. But, if the powder is put in the bottle, and the bottle is afterwards filled up with flour or fine sand, firmly rammed down so as to exclude all air from the powder, and then corked and sunk, the powder will not explode, nor can it be ignited. Now these facts clearly prove that the noise, the concussion, the fire and light, and the dispersion of matter which accompany, and, in fact, constitute the explosion of gunpowder, are produced by an action or operation of the atmosphere. All explosions of this kind are but rapid combustions, and differ only from the burning of a candle in the quickness of the operation. Both are caused or effected by the atmosphere; and the atmosphere is enabled to effect these combustions by its subtilty, elasticity or expansibility, and pressure, which gradually diminishes from the earth upwards; and so, both allows and causes a free passage upwards for the air which issues out of burning substances and effects their combustion. Whenever air is forced into substances by radiation or friction, the pressure of the atmosphere forces it out again; and, from their nature, it can only issue out of solids in rays or streams which, when the solids are in a state of great repletion with air, issue with such force as gradually to dissolve and dissipate such of the solids as are combustible; and that operation is combustion. It may be asked, if air be necessary to ignition, and fire be air in a state of radiation, whence comes the fire in the connecting wire of the galvanic battery in the exhausted receiver, where, it will be said, there is no air? The answer is, that it arises from the confluence of the two columns of aëriform fluid which come from the battery, pass through the conducting wires, meet in the connecting wire, and there, by their confluence and the pressure arising from it, produce the fire perceived. If the ends of the conducting wires be dipped in water, aëriform fluids or gases, called oxygen and hydrogen, come from them, which are supposed to be somehow formed from the water. With this opinion, however, I do not agree. I think these gases are derived from the atmosphere; that they are but modifications of that element; and that they come from the battery through the conducting wires. I think so, because the air or fluid appears to issue from the wires, and is susceptible of diversion at any part of them; because atmospheric air can be sent through many kinds of wood and stone by atmospheric pressure alone; and because all metals prepared by fire, such as copper, steel, and iron, necessarily are saturated with air.*

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* The following experiments show that copper, brass, cast and beaten iron, and glass, are pervious, and that

The ebullition of boiling liquids is caused by air which comes through the substance of the vessel in which the liquid boils. If

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atmospheric air may be forced through them by atmospheric pressure. Get a glass receiver with a loose brass top, having one or two holes, three quarters of an inch in diameter, in its surface; and if there are two holes, they should be about an inch apart. Get also a hollow cylinder or tube of each of the materials or metals above mentioned (copper, brass, cast and beaten iron, and glass) three or four inches long, and three-eighths or half an inch in diameter, closed at one end, and having fitted to the other end, which is left open, a brass collar with a worm upon it, adapted to the perforations in the top of the receiver, into which they may be firmly screwed as occasion may require. Place upon the plate of an air-pump a glass of cold water, then put over it the receiver, properly prepared for exhaustion, and in such a manner that the tube or tubes (if more than one be used), screwed into the top of the receiver, may descend into the glass of water placed on the plate of the air-pump; and when the air is exhausted from the receiver, that portion of the tube or tubes which descends into the water will be covered with bubbles, which occasionally spring off into the water, and are succeeded by others in such a manner as to show plainly that the metals and glass are pervious;

a common drinking-glass be immersed in a vessel of oil, and the mouth turned downwards in such a manner as to exclude all air from the interior of the glass when turned, and the vessel be then put on the fire to boil, the air will gradually drive out the oil and take possession of the glass. The result will be the same if milk, or water, or, I apprehend, any other liquid that will boil, be used instead of oil.

By compression, air produces light and heat. For instance, sparks from percussion arise from the compression of atmospheric air in the parts of the substances brought into contact by the percussion. The radiation of the spark is an action whereby the condensed and compressed air recovers its equilibrium; and the effects which the spark is capable of producing are caused by that radiation. This is proved by the

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and that the air forming the bubbles on the tubes comes through the metals or materials of which they are made.

fact that sparks can be obtained only from percussion in air, or from substances saturated with air. From flint and steel, which produce an abundance of brilliant sparks when struck in air, no spark whatever can be obtained in vacuo. This is shown by screwing the flint-lock of a gun to the plate of an air-pump, exhausting the air, and drawing the trigger.

All substances, at the earth's surface, are saturated with air; and some of them, such as agate and quartz, are extremely tenacious of it, but it may be extracted from them. Two pieces of agate or quartz rubbed together under water give out light by a sort of coruscation, which arises from the compression of air in the parts of the substances brought into collision or contact by the operation; for if the substances are put into a vessel of water about eighteen inches deep, covered with a lid, and placed in a dark room so as to exclude every ray of light, and kept in that state for four or five months, the water will saturate them and expel the air out of them, and they will then give no light under water. If, however, the light be admitted to them while in the water, they will continue to give light. Iron and steel, from the method of preparing them, seem to be saturated with a species of hydrogen; hence we may understand how they burn in oxygen, namely, by the union and ignition of the two gases.

Animal radiation, or animal heat, as it is called, seems to arise from the compression of air in the lungs in the act or operation of breathing.

The sun revolves on its axis, and solar light appears to be the power which moves the earth, both on its axis and in its orbit. And the power which moves the earth seems also to regulate the motions of the planets.

More solar light appears to impinge upon the earth at the solstices than at the equinoxes, and to strike it on the poles, and more against its equatorial or greater diameter, which perhaps may account for the variation of the earth's distance from the sun.

In support of these views, allow me also to refer to the following papers in the *Mechanics' Magazine;* viz., A paper "On the Action of the Atmosphere," signed W. in No. 698, vol. xxvi.; a paper "On Heat, the Action of Light and Atmosphere, and the Distribution of the Atmosphere over the Earth's Surface," signed W. in No. 716, vol. xxvii.; a paper "On the Action of Light and Air, and the Distribution of the Atmosphere over the Earth's Surface," signed W. in No. 800, vol. xxx.; a paper "On Vaporization," signed W., in No. 821, vol. xxxi.; a paper "On the Action of Light and Air, and the Distribution of the Atmosphere over the Earth's Surface," signed W. in No. 921, vol. xxxiv.; and especially to the last of them, and to say that they are my papers.

[The preceding paper, "On the Action of Air," with slight variations, and without notes, was published in the *Mechanics' Magazine* in the month of October, 1842.]

CHAPTER V.

ON EVAPORATION.

Whenever air enters liquids, or oleaginous or bituminous matter, the pressure on all sides is so nearly equal, that, from necessity, it assumes a globular form. The pressure gives it that form. The globule is the impress of a law of Nature. Whoever will be at the trouble to observe the state of air in water, oil, or any other liquid, whether the air be in large masses or small ones, will perceive that they are always globular; and when the globule emerges, it always comes out enveloped in a film of the matter from which it emerges. Of such globules are vapours composed. All vapours consist of globules of air enveloped in films of liquid, unctuous or bituminous matter; for the evaporation of liquids and other substances is effected by the issuing of air out of them, which has previously entered either by radiation or by pressure from accession, which is called conduction. And the rate of evaporation is proportioned to the accession of air, by the agencies before mentioned, to the evaporating matter, increasing and diminishing with the rate of accession. Such is steam, or the vapour of water. Such also is smoke, or the vapour of burning matter; so that the end to be attained in the burning of smoke is to ignite the spherules of air or gas as soon as they emerge from the burning matter; for the instant the gas is ignited, the film of bituminous matter which envelopes it bursts and falls back, and the gas reunites with the atmosphere, the source whence it came.

When the smoke is collected for the purpose of lumination, another mode of separating the gas from the bituminous matter is adopted, which is minutely described in the treatises on gas-light. In that case, the separated films produce the sediment termed coal-tar.* And the process of artificial evaporation is further

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* Coal-gas, the gas used to light the streets and houses of towns, is obtained by collecting the vapour or smoke of burning coals, and separating and purifying it from its films. The apparatus employed for the production, collection, and purification of the smoke, and making it fit for use as gas, consists, in most cases, of a large cast-iron vessel of a cylindrical shape, called a retort, having an opening covered with a lid. This retort is placed in brick-work over a furnace; and the coals, by means whereof the gas is to be obtained, are put into the retort at the lid, which is then closed, luted to exclude the air, and the furnace lighted, when a thick black smoke ascends through a pipe fixed on the upper side of the retort, called the dip-pipe, whereby it is conducted into a large cast-iron pipe, called the condensing main, whence it passes into other pipes and contrivances for the purpose of freeing it from the films of water and tar in which it is enclosed when it ascends from the retort; and from which pipes and contrivances it ultimately issues into the gasometer a

elucidated by a paper "On Vaporization," subsequently inserted at page 127.

[The preceding paper "On Evaporation," without the Note now appended to it, was published in the *Mechanics' Magazine*, in the month of March, 1843.]

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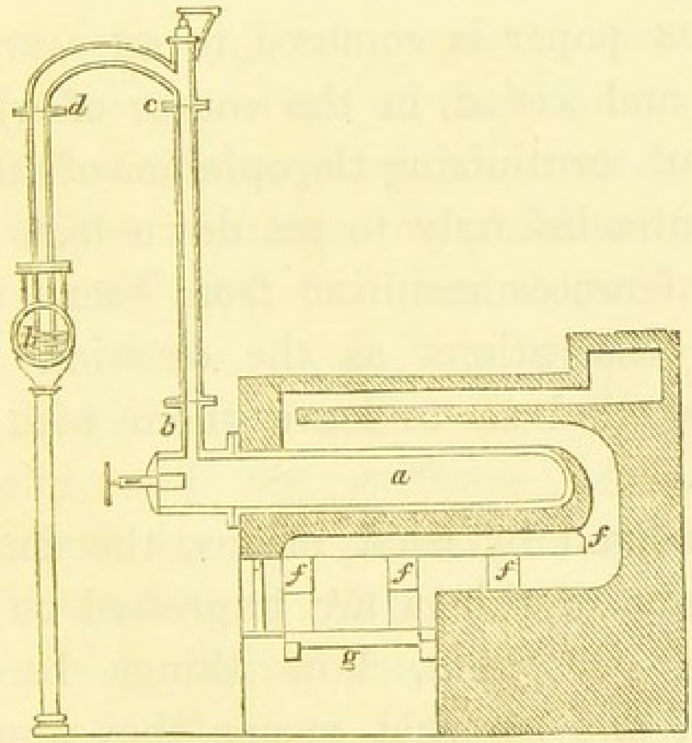
clear, transparent, aërial fluid, which burns and gives light. Below is the figure of a Gas apparatus.



a is the retort; *g* the grate of the furnace; *f f* the flues; *b c d* the dip-pipe; *h* the condensing main.

CHAPTER VI.

ON LIGHT AND VISION.

THIS paper is confined to an essay on light and vision, in the course of which, without scrutinizing the opinions of others, it is intended only to set down facts and the inferences resulting from them, with such observations as the occasion may require, and so to leave them with the world.

How, and by what means, the images or forms of things are impressed on the organs of vision, how things become visible, and by what means they appear, are important and interesting questions. We say it is by light we see objects;

but, what is light ?—and how does it enable us to see objects? In answer to these questions it may confidently be asserted, that light is air in a state of radiation; that is, air issuing in rays or streams from a common source, as from the sun, or from a jet of burning gas, and that the appearance of things is caused by air in that state of action.

When the rays proceed from the source of radiation to the object, and thence to the eye, the object appears by reflected light; for a portion of the light which strikes bodies always rebounds or glances off, obvious instances of which occur in the light reflected from water, glass, and polished metals; and this property of light, which seems to arise from its elasticity, and the swiftness and force with which its rays proceed, is called the reflection of light. But the quantity of light which glances from objects is not the same in all cases. It differs with the texture, smoothness, and colour of the substances, and the degree of obliquity at which the light strikes them. More light rebounds or glances from bright white substances than from dark or coloured ones; and more when the light strikes the substance obliquely than when it strikes it directly.

By reflected light all opaque objects, and all solids and liquids appear.

When the rays of light proceed directly from their source to the eye, the object seen is luminous, and appears by direct radiation.

In both cases, a communication between the eye and the object is effected by the rays of the fluid which pass from the object to the eye, and impress its form or image on the organs of vision, the convexity of the eye concentrating the rays of light and increasing their effect. This elucidates the nature and mode of operation of photographic apparatus,* and

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* Photography is a term used to express a mode of taking pictures or drawings, in which the delineations or pictures are made by the action of light, either

those apparatus and their effects contribute to the truth of these views. But how the impressions so made on the organs of vision are communicated to the mind, I do not here intend to inquire, my present purpose being to deal only with matter and material things.

Light, therefore, is matter in a state of

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directly radiating or reflected, on paper or other substances charged with a chemical preparation extremely sensitive of the effects of light. Different methods are used. Of one proposed by Mr. Talbot, the general arrangements are stated by Dr. Reid, in his "Elements of Chemistry," to be as follows : — Take paper, and steep it in a dilute solution of salt, dry it, and steep it again in a dilute solution of nitrate of silver so as to impregnate the paper with chloride of silver, which is formed upon it by the mutual action of the common salt and nitrate of silver. By repeating this in diluted solutions with much care, excluding the light as the paper is dried, a surface is at last obtained fit for use. When a drawing is to be made with this paper, an outline, or engraving, or a leaf, a flower, or any similar object, is properly arranged on one side of a thin glass plate and the prepared paper on the other, and on exposing the first to a brilliant light, the prepared action. It is air in a state of radiation, in which sense the word "light" is used in this paper. Hence, some new term may be deemed necessary to represent

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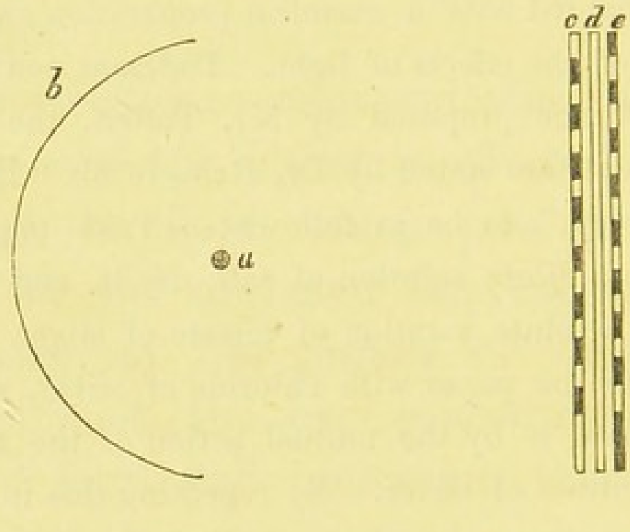
paper is darkened wherever the light is not intercepted by the leaf, the engraving, or other object to be delineated.



The lime-ball light at *a*, with a reflector *b*, admits of this process being conducted easily with artificial light; *c* represents paper with a series of lines, *d* the interposed glass, *e* the photogenic paper, presenting, after having been acted upon, the reverse of the pattern.

the state of things, to express the truth, but to me it appears to be more conducive to the advancement of science that the meaning of words in use should be well defined, than that new ones should be introduced.

Light may be caught and examined, when it is found to be air. Thus, if a burning light from a lens of five or six inches diameter be thrown upon sealing-wax immersed in cold water, the light enters the wax and issues out again in globules of air, which arise from the part touched by the focus, accompanied by a crackling noise, caused by the bursting forth of the fluid, and by the action of the light, deep pits are made in the wax. If such a light be thrown upon a piece of stone, wood, rusty iron, flint, brown cloth, or any dark-coloured

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It is evident that such drawings would be destroyed by exposure to solar light; but the methods now in general use produce permanent pictures by the agency of solar light.

substance so immersed, globules of air in abundance arise from the parts touched by the focus; and the path or passage of the light from the lens through the water to the object on which it acts is visible. That the globules in all these cases are air, may easily be ascertained in the following manner:—Take a glass shade, such as is commonly used for covering artificial flowers, four or five inches deep, and three or four inches across at the mouth, immerse it in a vessel of clear water, and turn the mouth downwards, taking care to turn the glass under water, so as to exclude the air, and leave the glass wholly occupied by the water, then put the wax or other substance to be operated on under the glass, and apply the focus of the lens to it, and as the globules of air arise from the substance, they are stopped and retained by the glass. With this apparatus I have obtained air globules in abundance from sealing-wax, rusty iron, wood, brown cloth, and flint; from lead and white pebbles a few minute globules, and, I think, a few from copper. But from gold, silver, and glass none can be obtained by a lens of five inches diameter, because the gold and silver reflect a large portion of the light thrown upon them, and the glass transmits it, or rather a portion of the light passes through the glass, and another portion is reflected by it. With a more powerful lens I have no doubt air would be obtained from copper, and I think from gold and silver, and, perhaps, from transparent substances, for they arrest and retain a portion of the light which penetrates them. The air obtained is permanent. It may be retained for any length of time. In some of these experiments part of the water was poured out of the vessel containing the apparatus, so as to expose the top of the glass shade, and the light had only to pass through the glass and the water under it to the object, which was elevated or depressed at pleasure; and the more the object was raised towards the top of the shade, the greater was the effect produced by the focus. The effect is the same, whether the water has been previously boiled or not, but it is somewhat less in sea water than in fresh water.

This is not air liberated from the substances by the action of light, because air, without diminution, may be obtained from the same substance so long as there is light enough to make a strong focus. Nor is it air from the water, for it evidently issues out of the substances. And if it were from the water, it would come from the gold and silver as well as from the iron and wax. It is from the light. These facts show that solar light is air in a state of radiation. They also show with what facility air, in that state of action, passes through transparent substances, and how it penetrates and is arrested by opaque ones. These conclusions inevitably result from the preceding facts; it seems impossible to resist them.

These facts also illustrate the effects of the burning glass operating on substances in air. In that case, the light evidently penetrates the substances, and makes way for the air to enter them; and when the light is sufficiently concentrated, the particles composing bodies are, by the power of those agents, separated, and the appearances called burning and melting are produced; the nature of which operation is more easily comprehended when we consider that the atmosphere is an immense ocean of extremely subtile fluid resting on the face of the earth, in the bottom of which man lives, and all his works are carried on; that it presses with a force of more than fourteen pounds to the square inch on all objects at the earth's surface* (except on the upper parts and summits of high moun-

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* Air, under ordinary circumstances, is not visible, because it is in contact with the eye; and to be seen, things must be at a distance from it, in order to allow the light proceeding from the object to act upon the eye. But air becomes visible by separation and contrast, as when a bubble is seen in water. The bubble is a lump or mass of air. It is not a vacuity, but space occupied by air which has displaced the water.

tains), and that it penetrates, permeates, and saturates all solid substances, animate and inanimate, living or being therein. Such, indeed, are the solvent powers of solar light and atmospheric air, when their action is combined and sufficiently concentrated, that few things, if any, can resist them.

And quiescent air may be put into a state of radiation, when it becomes light and causes objects to appear. This truth is proved by every jet of burning gas, for the gas is air; and atmospheric air also, under some circumstances, burns and becomes light.* If common coal-gas

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* It is quite certain that under some circumstances atmospheric air burns, gives light, and becomes the medium of vision. By means of the apparatus after mentioned, Mr. David Waldie caused oxygen to burn in atmospheres of hydrogen, olefiant-gas, coal-gas, sulphuretted hydrogen and carbonic oxide, nitrous oxide in hydrogen and coal-gas, nitrous acid vapour in hydrogen, chlorine in hydrogen, and mixtures of these with nitrogen or carbonic acid, and common air in the same gases.

be allowed to flow through the pipe or tube which conducts it into an apartment, it will soon fill the room, render

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The following is Mr. Waldie's account of the apparatus and experiments whereby he obtained these results:—" The apparatus employed for these experiments consisted of a wide-mouthed flask, about eight or nine inches long, having cemented to it a cap of tinned iron, pierced with four holes; to two of these, two brass sockets were soldered, made to fit the ends of two flexible tubes proceeding from two gas-holders; to the two other holes were attached small pieces of tube, over one of which a piece of sheet caoutchouc was tied, through which a slender platinum, or iron wire, could be passed, to try the temperature of different parts of the flame; and to the other was fixed a bladder, in order to allow of expansion. The flask was filled by being immersed in a trough of water; the water was then displaced by inserting one of the flexible tubes into one of the sockets, and causing gas to flow into it from a connected gas-holder, the water escaping by the other socket; the tube was then removed, corks inserted in the sockets, and the flask placed on a retort-stand, with its mouth downwards, and the bladder hanging flaccid; the tube was then replaced in the socket so as to supply more gas, if necessary. Now when the flask was filled with one of it uninhabitable, and, if ignited, will explode. But if, when the gas begins to flow, a light be applied to the jet, the

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the common supporters, such as oxygen, and one of the common combustible gases was to be burnt in it, the method requires no explanation. When again the oxygen was to be burnt in hydrogen, the cork was removed from the socket, and the gas set fire to, being made to flow gently from the flask, in order to prevent the combustion from getting inwards; the oxygen then being made to flow with a proper degree of force from a small brass jet fixed on the end of another flexible tube, communicating with another gas-holder containing oxygen, was passed steadily through the burning hydrogen into the flask, and the end of the flexible tube pushed home into the socket; the hydrogen burning outside the flask was now extinguished, and the oxygen found burning within.

"When again the gas was not confinable in a common gas-holder with water, such as nitrous acid vapour, it was prepared in a wide-mouthed flask; and when this was believed to be full, a jet of hydrogen burning from a brass nozzle fixed to the turned-up extremity of a glass tube connected with a flexible tube was let down into it; or, for instance, with chlorine, a jar was filled with this gas over the water-trough, and a jet let down as before, a tin plate being issuing air is thrown into a state of radiant action, a flame appears, and the air, as it issues from the tube, reunites with the atmosphere. During all the time the air or gas burns, it is flowing rapidly into the room without very materially vitiating the air of the apartment as it would do if unlighted, because it reunites with the atmosphere as it issues from the tube. It unites with a radiant action, which causes things to appear, and, if they are brought near to the source of

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fixed to the tube so as to cover the jar, and allow the jet to descend to near the bottom. If, again, these gases were to be burnt, the materials were placed in a small flask, to which was fixed a tube having a brass piece to fit the socket of the flask, and a jet placed on its extremity.

"By these experiments, oxygen, *atmospheric air*, nitrous oxide, nitrous acid, and chlorine, are shown to be not only really, but also apparently, as much combustibles as hydrogen or coal-gas; and these, again, are exhibited in the form of supporters of combustion." —*Experimental Researches on Combustion and Flame, by David Waldie. Phil. Mag.*, *S.* 3, *Vol.* 13, *No.* 80. *August*, 1838.

action, will burn such of them as are combustible and reduce them to ashes.

[The preceding paper "On Light and Vision," with slight variations, was published as an essay "On Light" in the *Mechanics' Magazine*, in June, 1844, without the Note on page 74, and the Note on page 82.]

CHAPTER VII.

BAROMETRICAL PRESSURE.

It was with much satisfaction I perceived, from the report of Sir John Herschell's address, at the last meeting of the British Association, that the Antarctic voyage of Sir James Ross had ascertained that a permanently low barometric pressure exists in high south latitudes,—a pressure less by considerably more than an inch of mercury than what is found between the tropics, because it supplies additional evidence of the truth of the principles laid down in my papers "On the Action of the Atmosphere;" "On Heat; the Action of Light and Atmosphere, and the Distribution of the Atmosphere over the Earth's Surface;" "On the Action of Light and Air, and the Distribution of the Atmosphere over the Earth's Surface;" "On the Action of Air," and "On Light," inserted in the *Mechanics' Magazine*, at page 239, vol. xxvi.; page 59, vol. xxvii.; page 171, vol. xxx.; page 277, vol. xxxiv.; page 405, vol. xxxvii.; and page 354, vol. xl.; and establishes the truth of what, before the sailing of the antarctic expedition, I had maintained on principle. In those papers, some of which were published a year or two before the antarctic expedition under Sir James Ross sailed from England,* it is shown

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* The antarctic expedition, under Sir James Ross, which sailed from England in September, 1839, was sent out by Her Majesty's Government, on the recommendation of the British Association for the Advancement of Science and the President and Council of the Royal Society, to establish magnetic observatories at several places in the southern hemisphere, to make magnetic and meteorological observations; to collect

that the distribution of the atmosphere over the earth's surface is effected and regulated by the earth's rotation; that the atmosphere is accumulated at the equator, and within the tropics by that rotation, where, in consequence of the accumulation, its density and pressure are greatest, and that they gradually diminish thence towards the poles.

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geological, zoological, and botanical specimens; and for other scientific purposes.

Sir James Ross, speaking of a remarkable fall of the barometer, which occurred at noon on the 14th of March, 1841, in lat. 62° 42′ S., says—"The mercury in the barometer at that time had attained the unusual height, for these latitudes, of 29·5 inches, at which it stood until midnight (the wind then shifting to the north, accompanied by a very thick fog), when it again fell as rapidly as it had risen, until, at noon the following day, it had reached 28·8 inches."—Sir James Ross's "Voyage to the Southern Seas," vol. i., p. 303.

From barometrical observations, made during this voyage, it appears that the mean atmospheric pressure, which is 30·085 at the tropic of Capricorn, thence gradually diminishes southwards; and that, in lat. 74° S., it is 28·928.

And here perhaps I may be allowed to state, that the papers above mentioned develop a new, and I am sure a true, philosophy, which is exercising, and will exercise, on the destinies of man, influences greater and more beneficial than any which have hitherto affected them,—the influences of the sacred Scriptures alone excepted.

[This paper was published in the *Mechanics' Magazine*, in November, 1845, in the form of a letter addressed to the Editor.]

CHAPTER VIII.

ON ATMOSPHERICAL PRESSURE.

In a paper "On some Points in the Meteorology of Bombay," lately published in the *London and Edinburgh Philosophical Magazine*, an attempt is made to account for the increased pressure on the barometer at the equator, and its gradual diminution thence towards the poles, on the hypothesis that the increase is due to an elastic fluid generated by evaporation, the presence of which is indicated by the hygrometer. But that attempt cannot, I think, succeed, because the hygrometer is not a trustworthy instrument; its indications are not at one with themselves; and it would be odd if they were, for it is used to measure something which does not exist,—namely, an elastic fluid generated from liquids by evaporation. All vapours, indeed, are elastic, but then they are compound substances or matters, consisting partly of elastic fluid, and partly of the evaporated matter. The elastic fluid, however, is no part of the evaporated matter. On the contrary, it is the agent which has effected the evaporation. All liquids are evaporated by the issuing of air out of them, which has previously entered, either by radiation or by pressure from accession, which is called conduction.

The cause of the equatorial accumulation, density, and pressure of the atmosphere, and their diminution from the equator towards the poles, appears to be the earth's rotation on its axis. This cause is sufficient to produce those effects.

And in connection with this subject it may be observed, that to this cause, the pressure of the atmosphere, all the varieties of climate on the earth's surface, and also all those variations in the seasons called mild and cold winters, and warm and cold summers, are chiefly owing, as the facts after mentioned, and a close attention to the changes of the barometer will show. While observing the barometer, however, it should be remembered that its changes are not always immediately followed by corresponding changes in the thermometer; because, after a long continuance of high atmospheric pressure and bright solar action, an allowance should be made for the effect produced on the thermometer by the earth's radiation or emission of air, which continues for some time after the atmospherical pressure has abated, and which affects the thermometer somewhat as a piece of iron taken out of the fire would affect it when brought near to it. In such cases the thermometer may, for a time, keep its position, or even rise, while the barometer is going down; but if a good barometer maintain an average range of 30 inches for ten days or a fortnight, it will be attended by comparatively warm weather, and a corresponding state of the thermometer at any season of the year. And, on the other hand, if the barometer should, during ten days or a fortnight, maintain an average range of 29 inches or under, it will be attended by cold weather at any time of the year,*

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* At whatever height the quicksilver in the thermometer may stand, it will fall if the quicksilver in the barometer falls, and the wind continues in the same quarter, and the degree of solar action remains the same, after the effect of the earth's radiation has ceased, if any should at the time exist. For instance, if the barometer stands at 30°, and the thermometer at 50°, the wind blowing from the north; and the barometer then falls to 29·5, the wind continuing in the north, the thermometer will also fall; but the fall will be more or less, according to the clearness or cloudiness of the weather, and the degree of solar action at the time and place of observation. With the barometer standing at 30°, in the month of January, and the wind in the south, the thermometer will stand higher than if the wind came from the north; but this arises from the

and the clouds which float in such a state of atmosphere, not being sufficiently sustained, will generally collapse and come down in rain, hail, or snow. A piece of iron in the fire is gradually filled with air, and so becomes red; and, when taken out of the fire, the air gradually issues out of it, being forced out of it by the pressure of the atmosphere until it is cool, when it resumes its former colour, a length of time being necessary either to warm it or cool it in the atmosphere. And so it is with the earth, it gradually warms and gradually cools. And I see no reason to think, as some eminent persons have supposed, that the seasons are affected by the ice that floats in the Atlantic or any other ocean, or by any oceanic stream.

The sun governs the seasons, influenced only by the changes which take place in

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earth's radiation. The land over which the wind comes from the south is warmer than the land to the northward, and that is the cause of the difference.

the state of the atmosphere; and the atmosphere by its pressure regulates the climates.

Between the summits and the base of the Andes, within the tropics, and almost under the equator, may be found at all times every variety of climate, from everlasting winter, frost and snow, to the perpetual scorchings of the Torrid Zone; all which varieties clearly are caused by the different degrees of atmospherical pressure on the summits and sides of those mountains; for the barometer* shows, that in the ascent of lofty mountains, the pressure of the atmosphere gradually decreases with the increase of elevation. And the truth of these views is confirmed by the effects produced on

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* The barometer, an instrument used for the purpose of measuring or indicating the weight or pressure of the atmosphere, consists of a glass tube about 32 or 33 inches long, and about a quarter of an inch in diameter, closed at one end, and open at the other, which being filled with quicksilver, and the finger being placed on the open end, to prevent the quicksilver from running

the barometer and thermometer during balloon ascents. As the balloon ascends in the atmosphere, the quicksilver in both instruments always descends, because the pressure of the atmosphere gradually decreases as the balloon rises in the air; a fine proof of which is afforded by an experimental ascent made by Mr. Rush, of Elsenham Hall, Essex, and the celebrated aëronaut, Mr. Charles Green, on the 8th of September, 1838, in the Nassau Balloon. On that occasion they attained an elevation of 27,146 feet, or more than five miles. They ascended from the Royal Gardens, Vauxhall, London. When they left the earth, the barometer stood at 30·5 inches, and the thermometer at 61° Fahrenheit. When they reached the altitude above mentioned the barometer had fallen to 11 inches, and the thermometer to 5°. They

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out, and the tube being then inverted, and the open end dipped in a cup of quicksilver, the quicksilver in left the ground at half-past six o'clock in the evening, and descended, or landed, again at Lewes, near Brighton, a dis-

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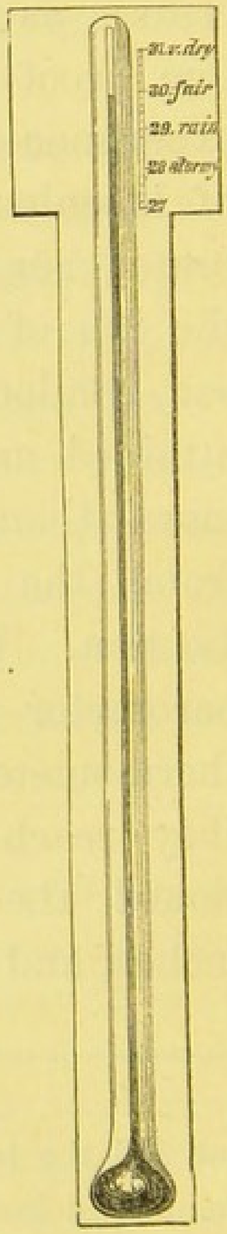
the tube, on the finger being withdrawn from the open end, descends until the column becomes 29 or 30 inches high, or more or less, according to the pressure of the atmosphere at the time; and it afterwards continues to rise and fall in the tube as the pressure of the atmosphere on the surface of the cup of quicksilver varies. The tube is usually fixed to a frame of wood or metal, on which is a scale to show the rising and falling of the quicksilver therein. The annexed figure shows the form of a barometer, in which the cup containing the quicksilver is joined to and forms part of the tube.



tance of about fifty miles from the Royal Gardens, at a quarter before eight o'clock the same evening,—having travelled that distance in the atmosphere in seventy-five minutes, or one hour and a quarter. The weight of the balloon, with its freight and appendages, when it left the earth, was 2,544 pounds, consisting of the following particulars, viz.:

	lb.
Balloon, netting, and car . .	702
Ballast	1,500
Mr. Rush	145
Mr. Green	145
Grapnel	32
Elastic rope attached to grapnel	20
Total . .	2,544

The following observations, made during the ascent, show the gradual descent of the quicksilver in both instruments as they rose in the atmosphere:

BAROMETER. Inches.	THERMOMETER. Degrees.
30·5	61
29	60
27	58
26	55
25	52
24	48
23	46
22	43
21	40
20	36
19	35
18	30
17	25
16	20
15	18
13	11
12	8
11	5

And if the aëronauts had kept their highest elevation for half an hour or an hour, the quicksilver in the thermometer probably would have frozen and sunk into the bulb.*

* By the ascent of Monday, the 8th of September,

And such effects are always produced on the barometer and thermometer

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1838, a greater altitude was attained than by any balloon ascent heretofore made; and perhaps the greatest height was reached to which mortal man has hitherto ascended by natural or artificial means; of which ascent the following is Mr. Green's own account, somewhat abridged:—"The success which attended my trip on Tuesday week, when, with the Nassau Balloon inflated with carburetted hydrogen gas, accompanied by Mr. Rush and Mr. Edward Spencer, we attained an altitude of 19,335 feet, or $3\frac{3}{4}$ miles, minus 465 feet, created a desire in Mr. Rush and myself to make another ascent, with two persons only in the car. Accordingly, on Monday last, Mr. Rush made arrangements with the proprietors of Vauxhall Gardens, for the ascent to take place on that afternoon, that gentleman engaging the car for the occasion. Preparatory to the ascent, the first object to be gained was that of diminishing the weight of the apparatus to as low a point as a due regard to our own personal safety would admit. A small car was substituted for that usually used, and the light grapnel belonging to my own balloon, as well as an elastic rope attached to it, replaced those of the Monster.

"The work of inflation having terminated, I, at five o'clock in the afternoon, proceeded to ascertain the power of the gas with which the balloon was charged.

during balloon ascents, hundreds of which have been made during the last

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This the tranquil state of the weather rendered an operation of the greatest ease, and I was consequently enabled to effect my inquiry with the nicest accuracy.

"On examination, I found that the whole weight of the balloon and its appendages at that moment was 4,056 pounds, thus constituted:

	lbs.
Balloon, netting, and car	702
Ballast	1,500
Mr. Rush..................	145
Myself	145
Grapnel	32
Elastic rope to grapnel	20
27 half-hundred weights slung round the hoop	1,512
Total....	4,056

"As soon as this trial had been completed, Mr. Rush once more took his seat in the car, and adjusted the barometers. I then opened the upper valve, and discharged a quantity of gas equal to the power of the 27 half-hundred weights, which were then removed from the hoop; and everything in the shape of preliminary having been effected, I released the balloon from its moorings at half-past six o'clock, by means of the liberating iron, and rose from earth with an ascending power of 112 lbs.

half-century, more than four hundred and fifty such ascents having been made

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"At the moment of our quitting the earth, the barometer stood at 30·50, and the thermometer at 61. Before, however, seven minutes had elapsed, the instruments had fallen, the former to 20 and the latter to 36, equal to 11,000 feet, thereby giving us an altitude from the earth of upwards of two miles.

"The direction we took on leaving the gardens was N.E., and so continued during the early part of our upward course; but on reaching the elevation of 11,000 feet, we became totally stationary for a minute or two, as regarded any forward progress. I then threw out two bags of ballast, which gave us an astonishingly increased rising power. Another current now took us, and we were driven backwards nearly due south. We continued to rise with great rapidity, and in a few minutes a different current drove us from west to east. The whole of this time I was throwing out ballast as fast as I could. When we attained an elevation of 16,000 feet (about 3 miles), we got into a current which was blowing with considerable violence, at the rate of about sixty miles an hour. The course of this current was north by west, and it was under the influence of that wind that we were carried to our ultimate destination.

"During our ascent, particularly above the elevation of 16,000 feet, we forced our way upwards with by Mr. Green himself during that period, and many hundreds by other aëronauts.

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great velocity, through a range of currents running horizontally, at the rate of about 60 miles an hour. At this period, the roaring of the winds strongly resembled the noise produced at the time of a hurricane, as heard on the top of a high hill, and the temperature was at the same moment piercingly cold. At this altitude I suffered severely from the effect of cold in my hands and feet. We were now exposed to the influence of the winds to which I have referred, which, combined with the extraordinary exertion I was compelled to undergo, frequently rendered it a matter of the utmost difficulty for me to fetch breath.

" The greatest altitude we reached was 27,146 feet, indicating an elevation from the earth of 5 miles and 746 feet; the barometer at this period having fallen from 30·50 to 11, and the thermometer from 61 to 5, or 27 degrees below the freezing-point.

" I now subjoin a copy of the operations of the instruments we took up with us; those of the barometer being taken from that made by Mr. Jones, of Charing-cross, for Mr. Rush, especially for the two ascents. This barometer acted with the nicest accuracy, and enabled us to carry our observations to a far greater extent than any which I had ever before had with me; for whilst on the former ascent Mr. Spencer's barometer ceased to act at 20, and Mr.

In addition to these remarks, it should be observed, that there is abundant evi-

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Rush's marked at 14·70; on this occasion, when the action of my glass stopped at 17, Mr. Rush's went on until the mercury had sunk to 11, our highest elevation.

"The following is an extract from Mr. Rush's memorandum, showing the variations in the ascent:

BAROMETER. Inches.	THERMOMETER. Degrees.
30·5	61
29	60
27	58
26	55
25	52
24	48
23	46
22	43
21	40
20	36
19	35
18	30
17	25
16	20
15	18

"Here Mr. Rush suffered such inconvenience from the escape of the gas at the lower valve, that he was dence to show that the atmosphere is capable of producing all the effects which

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obliged to ask me to continue the observations. They thus proceeded :

BAROMETER. Inches.	THERMOMETER. Degrees.
13	11
12	8
11	5

" By the time we had attained this elevation, I had reduced the ballast, which at our starting was 1,500 lbs. to something under 70 lbs., which I resolved on preserving, because I felt that, being ignorant of the character of the country which, from all appearances, we should have to descend in, and it being dark, it would be but an act of prudence to have at command a 'playing' or available moveable power, and the result fully proved the propriety of the reservation.

" Shortly after we had commenced our downward course, we discovered that there was something falling which very much bore the appearance and consistency of snow. To this circumstance I directed the attention of Mr. Rush ; whereupon we looked aloft, when we found the sky to be more than usually thickly studded with stars, and perfectly free from any mass in the shape of cloud. This result, at the moment, gave rise to no inconsiderable feeling of astonishment in our minds ; especially as the snow continued to descend in large quantities. Upon an after consideration, how-are usually ascribed to the imaginary agent called heat.

[This paper, without the Notes, and also

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ever, I am inclined to think the substance which fell was not snow, but the dew and moisture collected on the balloon, which had become congealed or frozen by the coldness of the temperature to which it had been subjected in our passage upwards. The particles adhered to the netting and balloon until an increased collapse was caused by the intentional voidance of gas; and when that operation took effect, they were removed by the motion of the netting, and fell in flakes like a shower of snow. This falling of flakes continued for a considerable time, and from its appearance fully justified our original notion, that it really was a snow-shower.

"We left the Royal gardens at half-past six, and landed again at Lewes, a distance of about fifty miles, at a quarter before eight o'clock, having performed the trip in an hour and a quarter.

"In this ascent we had a double advantage, with respect to witnessing a setting sun; for prior to our quitting the earth that operation had taken place, and on our reaching an altitude of about 12,500 feet, we were once more within the action of the rays of that orb, whose setting we a second time observed in the course of a quarter of an hour."

without some slight additions now made to it, was published in the *Mechanics' Magazine*, in August, 1826.]

A balloon consists of a large bag of silk, or cloth of fine texture, enclosed in a network of cord, inflated with hydrogen or carburetted hydrogen gas, to which a car for the aëronauts is attached by cords, as represented in the figure below; the silk or cloth of which the balloon is made having been previously prepared, so as to prevent the escape of the gas through the material.

CHAPTER IX.

ON COAL-PIT EXPLOSIONS.

A THOROUGH ventilation of the mine, no doubt, is the best method of obviating these explosions; but there is the difficulty of effecting such a ventilation, which, to say the least, is great. If, therefore, a plan could be devised whereby the foul air could be ignited and exploded when the people are out of the pit, such a mode of dealing with it, though attended with inconvenient consequences, would be preferable to allowing the explosions to occur as they do now, bringing with them ruin, and death, and endless misery. And this end, I think, may be attained by a judicious application of the galvanic battery. The wires from the battery might be carried down the shaft to the works; and from these, other wires might be carried along the roof or sides of the drifts, and connected, at intervals of a few yards, by a piece of fine steel wire; all of which connecting wires perhaps would, by a powerful battery, be ignited when the connection with the battery took place, to such a degree as to ignite the foul air. But if the fire of the connecting wires should be insufficient for that purpose, explosive or inflammable substances might be attached to them, the ignition of which would effect the purpose.

By such an apparatus all the drifts in the pit might, perhaps, be operated on at once; or, by detaching the wires which run along the drifts from the wires which descend the shaft, part only of the drifts, or any one of them in particular, might be operated on and tried. Since the place occupied by the foul air can be exactly ascertained, surely it may be dealt with and made less mischievous by these or some such means. And I apprehend that a coal-mine might be fitted with an apparatus like the one above mentioned, at the expense of a few pounds.

I have also a plan for ventilating mines, which I wish to submit for consideration; namely: if a pipe or tube of sheet-iron or tin, a foot or eighteen inches in diameter, were let into the side of the shaft, and carried down to the works, and there carried round the shaft, and from this circle pipes or tubes of smaller diameter were carried along the roofs of the drifts, having proper holes or openings in them, at which the vitiated air might enter, through this apparatus I think the foul air would rise, and cause a current that would ventilate the mine, especially if the pipe or tube which descends the shaft were carried up eight or ten yards higher than the mouth of the pit. And if the apparatus itself should not bring about a current, and so ventilate the mine, it would be an easy matter to connect the tube or pipe at the top of the shaft with an exhausting air-pump, to be worked continually, or occasionally, as might be found necessary; and that, I am persuaded, would effectually ventilate the mine, at, all things considered, a moderate expense.

[This paper, "On Coal-pit Explosions," was published in the *Mechanics' Magazine*, in March, 1847, in the form of a letter to the Editor, signed "G."]

CHAPTER X.

ON THE GROWTH OF PLANTS.

This paper treats principally of the rise of the sap in plants; the expansion and elongation of the roots, trunk, and branches; the germination of seeds; and the consolidation and conversion of the sap into the substance of the plant.

Plants, both in air and in water, rise or are forced upwards, and their roots and branches are ramified and elongated by the pressure of the element in which they grow; for the contractions of the plant, which also contribute to its growth, originate in the pressure of the fluid in which it grows.*

The pressure of the atmosphere diminishes from its base, the earth, upwards to

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* The force and vigour of vegetation decline as the pressure of the atmosphere diminishes. The ascent of lofty mountains in the torrid zone presents the flora of a vast variety of climates. This is beautifully illustrated in Humboldt's "*Geographie des Plantes Equinoxiales*," who divides equinoctial America into eight regions.

1. The region of Palms, &c., which extends from the level of the sea, under the equator, to the elevation of 5,700 feet.

2. The region of arborescent Ferns. Gigantic Ferns disappear at an elevation of 4,900 feet.

3. The region of Oaks commences at 5,200 feet, and reaches to

4. The region of Shrubs. Trees disappear entirely at a height of 10,800 feet, and are succeeded by shrubby plants.

5. The region of Shrubby Plants, which continues to the height of 12,600 feet, or to

6. The region of Grasses, which continues to the elevation of 14,200 feet. Here the Graminæ are the sole vegetable produce.

7. The region of Lichens, &c. These lowly and

its surface. And in like manner, the pressure of the ocean diminishes from its bed to its surface. The pressure of the atmosphere on all objects on the earth, at the level of the sea, exceeds 14lbs. on each square inch of surface; and, as before observed, this pressure gradually diminishes upwards with the distance from the earth. The pressure of the ocean, on things immersed in it, is still greater, and is regulated by a like gradation. So then, the pressure of the air or water in which a plant grows, is greatest on the roots, and on that part of the trunk which is nearest to the ground, and gradually diminishes upwards. It is this arrangement of those elements that not only permits plants to rise, but which gives to them a general tendency upwards; the resistance in that direction being least, and gradually dimi-

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hardy forms of vegetable life continue to the very verge of perpetual winter, which in the

8. Region covers the equinoctial Andes, from the height of 15,700 feet to their towering summits.

nishing as the plant rises. It is this structure of those elements which enables, or rather causes, some substances, when immersed in them, to rise to or towards the surface, as a piece of wood in water, or a balloon in the atmosphere.

The entrance of the sap into the roots of plants is effected by the action of solar light and the atmosphere; for solar light is air in a state of radiation, as is shown by the experiments referred to in the note below.* These agents fill the roots, trunk,

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* Light may be caught and examined, when it is found to be air. Thus if a burning light from a lens, of five or six inches in diameter, be thrown upon black sealing-wax immersed in cold water, the light enters the wax and issues out again in globules of air which arise from the parts touched by the focus, accompanied by a crackling noise caused by the bursting forth of the fluid; and, by the operation of the light, deep pits are made in the wax. If such a light be thrown upon a piece of stone, wood, rusty iron, black flint, black cloth, or any dark substance so immersed, globules of air in abundance will arise from the parts touched by the focus. If a piece of mould-candle be used, it shows how the air diffuses itself in the substance; and,

and branches of the tree with air, which expands them, and opens the texture of the roots, so as to admit the mixture of

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in all these cases, the path or passage of the light from the lens, through the water to the object on which it acts, is visible. This is the commencement of the process of burning which, when exposed to the action of the atmosphere, that element completes. These experiments show the effect produced by light upon substances in water; and its effect on substances in other liquids is worthy of trial. That the globules in all these cases are air, may easily be ascertained in the following manner; viz., take a glass shade, such as is commonly used for covering artificial flowers, four or five inches deep, and three or four inches across at the mouth; immerse it in a vessel of clear cold water, and turn the mouth downwards, taking care to turn the glass under water, so as to keep out the air, and leave the glass wholly occupied by the water; then put the wax or other substance to be operated on under, and leave it inside the glass, and apply the focus of the lens to it; and as the globules of air arise from the substance, they are stopped and retained by the shade. With this apparatus I have obtained air globules in abundance, from sealing-wax, rusty iron, wood, brown cloth, and black flint; from lead and white pebbles, a few minute globules; but from gold, silver, and glass, aqueous and earthy matter that forms the sap, which is then forced into them, as into a partly formed vacuum, by the pres-

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no air globules can be obtained with a lens of five inches diameter, because the gold and silver reflect a large portion of the light thrown upon them, and the glass transmits it, or rather it passes through the glass. With a more powerful lens, I think air would be obtained from gold and silver, and perhaps from transparent substances; for they arrest and retain a portion of the light which penetrates them. The air obtained is permanent. It may be retained for any length of time. In some of these experiments, part of the water was poured out of the vessel containing the apparatus, so as to lay bare the top of the glass shade; the light had then only to pass through the glass, and the water under it to the object, which was elevated or depressed at pleasure; and the more the object was raised towards the surface of the water, the greater was the effect produced by the focus. The effect is the same whether the water has been previously boiled or not; but it is somewhat less in sea-water than in fresh-water.

This is not air liberated from the substances by the action of the light; because air, without diminution, may be obtained from the same substance, so long as there is light enough to make a strong focus. Nor is sure of the atmosphere; which, be it remembered, is greatest on the roots, and gradually diminishes upwards. And by the same pressure the sap is forced up through the expanded trunk and branches to their extremities, and into the buds, leaves, flowers, and fruits. And when the action of the solar rays is interrupted by the intervention of clouds, or the setting of the sun, the expansion of the plant

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it air from the water; for it evidently issues out of the substances. And if it were from the water, it would come from the gold and silver as well as from the iron and wax. It is from the light. These facts show that solar light is air in a state of radiation; that is, air issuing in rays or streams from a common source, as from the sun, or from a jet of burning gas. They also show with what facility air, in that state of action, passes through transparent substances, and how it penetrates and is arrested by opaque ones. These conclusions inevitably result from the preceding facts; it seems impossible to resist them. These facts also illustrate the effects of the burning-glass operating on substances in air. They make it evident that the light penetrates the substances, and makes way for the air to enter them.

ceases, and the pressure of the atmosphere acts upon it without resistance, and with such energy, as to cause contraction of the roots, trunk, and branches; which contractions, in connection with the pressure of the atmosphere, effect a lodgment of sap between the bark and the wood of the tree, whereby the trunk is enlarged laterally, and its girth and diameter increased; and they force that portion of the sap through the bark which forms buds; and they also force back the sap in the roots, which elongates and ramifies them.

In the motions of the sap, however, there seems to be nothing resembling the circulation of the blood in animate bodies, or a circulation of any kind. The sap rises gradually from the roots through the trunk and branches into the buds, leaves, and fruit. No part of it ever returns or recedes in its passage, except the sap in the roots, which, when the contractions of the plant take place, is thereby forced back in its channels to the extremities of the roots, and through the bark or skin, and so the roots are elongated and ramified.

And the experiments before mentioned not only show that solar light, when in a quiescent state, is air, but they also show how it enters plants, and expands them, and becomes an agent in their growth in water. Those experiments also show how solar light enters plants growing in air—in the atmosphere. And the great pressure and extreme subtilty of the atmosphere enable it to penetrate plants with the light, and so to aid its action in their growth. Hence we have the reason why the growth of plants in water is less vigorous than in air.

The agents which expand the roots, trunk, and branches of the tree, and cause the sap to enter and ascend, also expand seeds in the earth, and cause them to germinate; the path or way of the germ out of the seed being, in most if not in all cases, the way or passage into the seed by which the sap entered, which nourished and produced the seed. And it seems that the germ of the seed is partly, or wholly, formed by the growth which produced the seed; and its way out of the seed is previously prepared for it in the manner before mentioned. For the channels through which the sap passes admit its passage either way, provided it ascends: for instance, if, in February or March, when, from the winter's accession, the tree is full of sap; and when, from the effect of the increasing light, the sap begins to rise with increased force, a branch be cut from a willow, or almost any other tree, and planted with the cut end up, the bud-end being in the ground, the buds which are in the ground will put forth roots instead of the leaves which they would have put forth if the branch had remained on the tree on which it grew; the sap will ascend the branch in the direction opposite to that by which it entered and ascended it when on the tree; and the other buds on the branch, which are out of the ground, will put forth leaves and branches. It also appears that the germ of the seed, in many, if not in all, cases, becomes the root of the plant; and the remaining substance of the seed forms the first leaves. All which is clearly shown by sowing mustard, cress, peas, beans, or any other small seeds, on wet flannel, and keeping the flannel moist or wet until the seeds germinate. In this way the germination of seeds may be closely and accurately observed. In some beans the germ is visible before the bean is sown or set. There also appears to be a viscous or glutinous matter in seeds, which gives to them that degree of elasticity or pliability which is essential to their growth.

The sap or matter which ultimately constitutes the wood, leaves, flowers, and fruit of the tree, ascends the trunk and branches in a liquid state. It is, however, a mixture of earthy matter and water, which, after passing through appropriate channels, is moulded or formed into the wood, leaves, flowers, and fruit of the tree, by the atmospheric pressure, and the contractions of the plant before mentioned; and being so formed, it is consolidated and hardened by evaporation,* caused by the joint action of solar light and the atmosphere. And when the sap ceases to rise

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* The sense in which the word "evaporation" is used in this paper should here be stated. It is used to signify the issuing of air out of any substance animate, organic, solid, or liquid, which brings with it a portion of the liquid matter contained in the mass out of which it issues ; for all evaporation is effected by the issuing of air out of substances into which it has previously entered, either by radiation or by pressure from accession, which is called conduction. It will, therefore, be perceived that this definition comprehends the insensible perspiration of animate bodies, as well as the exhalations of trees and plants, and the vapour of liquids ; for all vaporous exhalations are effected by the issuing of air out of solids or liquids, which brings with it a portion of the moisture contained in them. By a natural operation, resulting from the arrangement of matter, air, in liquids, assumes a globular form, and when it emerges, it always comes out enveloped in a film of the liquid from which it emerges. And whenever air issues from moist substances, it brings with it a film of the moisture therein.

Thus it is that air evaporates liquids, and desiccates, consolidates, and hardens moist substances, such as clay when formed into bricks, the sap in the trunk, in the plant with force sufficient to supply the leaves with the requisite moisture, the evaporation dries them, and the contrac-

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fruit, leaves and flowers of trees, and the liquid gum of trees, which it converts into hard and solid lumps. It seems to be an operation of air similar to this which causes all ossifications, and the petrifaction and concretion of rocks and stones. If on a bright day in summer, when the earth's evaporation is most vigorous, a sunbeam, entering your room about noon, be caught on a white piece of paper, the shadow of an ascending vapour will appear on the paper, though the action in the atmosphere cannot be discerned by the eye, or be detected by any other means with which I am acquainted. At those times and in those places the atmosphere must be, and perhaps at all times and in all places (except such places as are locked up in ice and covered with snow) the atmosphere is, to some extent, in an ascending and descending state ; for the space in the earth which the ascending vapour or matter has left vacant, will instantly be occupied by the atmosphere above it. The earth's evaporation seems to indicate that such an action or operation of the atmosphere is always going on ; and that operation of the atmosphere probably is the cause of natural magnetism and of the earth's magnetic attraction. And the vapours which ascend from the earth, floating in the atmosphere tion resulting from the desiccation separates them from the tree; and, with few exceptions, they fall off. This takes place in autumn, when the diminished action of the sun's rays has ceased to expand the plant sufficiently to allow the sap to rise in force and quantity enough to supply the demand of the leaves.

The fruit of trees appears to derive both its colour and flavour from the atmosphere and solar light.

[This paper, "On the Growth of Plants," without the first Note and some slight additions now made to it, was published in the *Mechanics' Magazine*, on the 29th of January, 1848, under the title of "Mechanics of Vegetation—Growth of Plants."

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and mixing with it, seem to be ignited by its agitations and the pressure thence arising, and thus to become the source of the lightning and thunder.

CHAPTER XI.

ON VAPORIZATION.

The expansion of heated substances is caused by an aërial fluid which has entered them, which, when they cool and contract, they give out or squeeze out; and it is the air, so pressed out of cooling bodies, that causes the ebullition and repulsion perceived when water or oil is thrown upon them. If a piece of red-hot iron, stone, brick, cinder, or any other red-hot substance be plunged into water, the air will be seen issuing out of it in innumerable bubbles, which, in the following manner, may be caught and retained for any length of time. Take a vessel of cold water, either from the spring, or of water which has been previously boiled, deep enough to allow a common drinking-glass to be inverted in it without admitting air into the interior of the glass, then raise the inverted glass a little from the bottom of the vessel and thrust a piece of red-hot iron, brick, or cinder under it, and the air from the heated substance will rise into the glass and be retained. It is not evanescent vapour. It may be retained for any length of time.

These experiments are made without either trouble or expense; and they prove, beyond all doubt, that an aërial fluid issues copiously out of highly heated substances, which sufficiently accounts for their expansion, and is, no doubt, the cause of their repulsion. It is impossible such a fluid should be squeezed out of them without causing more or less of repulsion. And it is submitted that these experiments are equally decisive as to the nature of the vapour of water, and prove that it is not water converted into air, as is commonly supposed; but that it is an aërial fluid which penetrates and comes through the substance of the vessel in which the water boils, and, rising through the water carries up a film of the water with it.

[This paper was published in the *Mechanics' Magazine* in May, 1839, in the form of a letter to the Editor, signed "W."]

CHAPTER XII.

STEAM-BOILER EXPLOSIONS.

These explosions, in every instance, appear to be caused by the pressure of the elastic fluid within the boiler. This is so evident, as to induce me to say that it admits of no question. Sometimes the boiler yields to an even application of the force within; and then the weakest part is found, and is the first to give way. The fatal explosion which occurred in Manchester last week seems to have been one of this kind; but there are other explosions which arise from some disturbance of the equilibrium of the pressure within the boiler; such, for instance, as those which happen at the moment when the engine starts. Suppose the metal of the boiler to be stretched by the pressure within to the last degree of its cohesion, it is evident that any occurrence which at such a time disturbed the equality of the internal pressure so as to increase it on any particular point, might cause a disruption of the boiler, and consequently an explosion. A smart blow on the outside of the boiler with a hammer, or any other heavy instrument, the starting of the engine, letting off the steam, and the sudden and unequal contraction of the boiler consequent thereon, or any motion, such as the motion of a ship, which disturbs the water within the boiler, are all of them occurrences which, by disturbing the equilibrium of the pressure within, might burst the boiler.

The calamitous consequences attending these explosions call loudly for a preventive. The case is indeed one of much difficulty; but if the intelligent men connected with the construction of steam-boilers were to bring their minds to the subject, I think a remedy would soon be found.

[This paper was published in October, 1841.]

CHAPTER XIII.

ON THE CONSTRUCTION OF STEAM-BOILERS.

CONVINCED that the explosions incident to steam-boilers are caused by the pressure of the elastic fluid within the boiler, and that such of them as happen at the starting of the engine, and letting off the steam, originate in the sudden and unequal contraction of the boiler, consequent on the issue of steam from it at a time when it is in a state of extreme tension, allow me to suggest, in the pages of your valuable Magazine, that the pipes or tubes through which the steam passes to the piston of the engine, and to the safety valve, should be carried eight or ten inches into the interior of the boiler, so that when the steam is put on the engine, or let off at the safety-valve, the draught may be from the centre, or at all events from the interior of the mass of elastic fluid in the boiler, instead of from the side; and then the contraction, resulting from the issue of steam, will be distributed more equally throughout the boiler, instead of being confined, as at present, to one place.

A boiler on this construction would, I think, be secure from those explosions to which boilers are liable at the starting of the engine, and the sudden letting off of the steam, without having its efficiency impaired.

[This paper "On the Construction of Steam-boilers," was published in the *Mechanics' Magazine* in December, 1841, in the form of a letter to the Editor, signed "K."]

CHAPTER XIV.

OF CONGELATION AND CONSOLIDATION.

There appears to be a natural cohesiveness in water which, under some circumstances, converts it into a solid body, as when it becomes ice. So there is a cohesiveness in wax, butter, lead, glass, iron, and many other substances, which causes them, under ordinary circumstances, to be solid bodies. But all these solids can be converted into fluids by the power and force of the atmosphere and solar light acting naturally, or through the medium of a lens, or by the force and action of the atmosphere alone; that is, by fire. If the action of solar light be diminished, though the ordinary action of the atmosphere continues, yet, in some such cases, the water congeals, as in the Polar regions; and in this latitude (53° north) in winter. If the pressure and action of the atmosphere upon water be greatly diminished, though the action of solar light in its fullest natural force continues to operate upon it, still the water remains perpetually congealed, as on the tropical summit of the Andes, or in vacuo. So then if the action of the atmosphere be sufficiently removed or withdrawn from water or any of the substances before mentioned, when in a fluid state, it becomes a solid body by virtue of a principle of cohesion in itself, and not by the power or action of the agent cold.

CHAPTER XV.

OF TOUCH, SMELL, TASTE, AND HEARING.

THE feelings or sensations of warmth and cold, and hardness and softness, or pressure arising from touch, seem to be caused in the following manner:—If the hand be applied to a substance impregnated with air in a greater degree than the hand itself, the air in the substance being subject to the pressure of the atmosphere, begins immediately to flow into the hand, and so the sensation of warmth is caused; as if the hand be put upon the bar of the fire-grate when the fire is burning. That, under such circumstances, the air would dart out of the iron into the hand and cause pain, is clear beyond doubt. On the contrary, if the hand be applied to a substance impregnated with air in a less degree than the hand itself, the air in the hand begins to flow into the substance, and thus the sensation of cold is caused; as when the hand is applied to the bars of the fire-grate when the fire is out.

When the hand is applied to a solid body, the perception or sensation of hardness seems to be caused by the compression and disturbance of the air in the hand, arising from the resistance offered by the solid body; and the sensation or perception of the degree of hardness or softness of the substance touched seems to be caused by the degree of resistance, and consequently of compression and disturbance of the air in the hand, which the substance touched is capable of causing. It is obvious that all solid substances, permanently in the atmosphere, must be saturated with air according to their capacities, and that air can be forced into them to repletion by radiation and friction.

The sensation of smell seems to be caused by the radiation and evaporation of the substances smelled; and perhaps by minute particles of dust which enter the nostrils and are deposited on the membrane of smell, such as snuff and pepper.

The sensation of taste appears to be caused partly by the evaporation of the substances, and partly by the evaporation of the tongue and palate, as well as by the contact of the substances with the tongue. It is probable that all the sensations of smell and taste are caused by impressions made on the same organ or organs.

And the sensation of hearing seems to be caused by the action of the atmosphere on the tympanum or drum of the ear; the impressions thereon being communicated to the sensorium apparently by means of fluids; not the "animal spirits" of which some philosophers have spoken, but aëriform and aqueous fluids. Though the tympanum appears to be indispensably necessary only to a good and healthy state of hearing; for the sense of hearing exists imperfectly, I believe, without the tympanum, and appears to arise from the disturbance of the last-mentioned fluids, caused by impressions on the body or some of its members.

CHAPTER XVI.

OF WINDS.

It is evident that the sun's rays penetrate all solid substances and all liquids exposed to their action; that, in so doing, they make way for the air of the atmosphere which enters with them; that water reflects light in a greater degree than dark solid bodies; that the ocean reflects light in a greater degree than the land; and that, in sunny weather, more light, and more of the air of the atmosphere, during the same time, enter any given surface of land, than any equal surface of contiguous water; so that, in this way, the water and land may be said to absorb air, and the water to absorb it more slowly, and in a less degree, than the land. For while water cannot by any ordinary means be raised to more than 212° Fah., solid bodies may easily be raised to a much higher degree. Witness the difference between boiling water and red-hot iron. And the earth's radiation must cause an ascending current from the land analogous to that from heated iron, or any other hot substance. The result of which is, that on bright summer-days, a flow or current of air, caused by the action of a brilliant sun upon the earth, sets in from the water to the land to supply the greater demand for air there, arising from the land's quicker absorption or inhalation and greater radiation of it; and this current or breeze, which is called the sea-breeze, continues so long as the bright sun remains above the horizon; but with the setting sun that solar action wanes and ultimately ceases. Soon after which the earth, under the pressure of the atmosphere, begins to exhale and give out the surcharged air, which flows back from the land to the ocean, whence it came during the day, and so becomes the land-breeze. And thus, it seems, are caused the sea and land-breezes which so constantly prevail on tropical sea-coasts, and are sometimes perceived in these northern latitudes in summer. If any doubt that air, issuing from substances surcharged therewith, can cause a breeze, let them observe a tea-urn after the red heater is put in it, and perhaps they will cease to doubt.

To the same, or similar, causes must be attributed the Trade-winds of the Tropics, and the Monsoons of the Indian Ocean. Between the tropics, the east passage winds or trade-winds (allowance being made for the sea and land-breezes where land occurs) may be said to blow constantly from the east, and to follow the sun. These winds are caused by the parts of the earth's surface immediately under the action of the sun's rays absorbing or inhaling and radiating air, while the parts behind, from which the sun's rays have recently been withdrawn, exhale their surcharged air which flows in to supply the demand of the parts before, then under the action of the solar rays, and so causes a constant flow or current after the sun.

The monsoons appear to be the flow or rush of air to supply, on the one hand, the draught or inhalation of the island of Sumatra, the peninsula of Malacca, and the immense tracts of land on the north of the Indian Ocean, and on the north-east of the Bay of Bengal, caused by the action of the solar rays upon them as the sun proceeds from the equator to the Tropic of Cancer and back; and, on the other hand, to supply the weaker draught or inhalation of the Indian Ocean, partly or wholly caused by the action of the solar rays upon it while the sun is southward of the Equator. In the Indian Ocean, from the tenth degree of south latitude north-wards, a *strong* south-west wind blows from April to October; and, during the remainder of the year, a *gentle* wind from the north-east prevails. These winds are called Monsoons, from a Malayan word signifying "season."

Sudden and extreme depressions of the barometer are frequently, if not always, accompanied or quickly followed by winds and storms, which seem to be partly or wholly caused by air issuing out of the earth and ocean on the sudden removal of the atmospheric pressure indicated by the fall of the barometer. It is obvious that the atmosphere, by its subtilty and pressure, must penetrate and saturate the earth to a considerable depth; and that, on the removal or alleviation of that pressure, the air in the earth must issue out in quantities and with force greater or less, according to the amount of pressure withdrawn or removed; and that, in so doing, it must produce atmospheric disturbances, and winds and storms. And the earth's radiation, when the saturation of any particular portion of its surface, from intense solar action, has reached an extreme point, by forcing off the atmosphere above, perhaps becomes the primary and chief cause of that alleviation of atmospheric pressure which causes the fall of the barometer. Those who have observed the air issue out of warm or cold water, in an exhausted receiver, will be better able to appreciate these observations than those who have not.

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