

XXIV. *Physical and Meteorological Observations, Conjectures, and Suppositions*, by Benjamin Franklin, LL. D. and F. R. S. \*

Read June 3, 1756. **T**HE particles of air are kept at a distance from each other by their mutual repulsion.

Every three particles mutually and equally repelling each other, must form an equilateral triangle.

All the particles of air gravitate towards the earth, which gravitation compresses them, and shortens the sides of the triangles, otherwise their mutual repellency would force them to greater distances from each other.

Whatever particles of other matter (not endued with that repellency) are supported in air, must adhere to the particles of air, and be supported by them; for in the vacancies there is nothing they can rest on.

Air and water mutually attract each other. Hence water will dissolve in air, as salt in water.

The specific gravity of matter is not altered by dividing the matter, though the superficies be increased. Sixteen leaden bullets, of an ounce each, weigh as much in water, as one of a pound, whose superficies is less.

\* On reading the preceding paper in the Society, it was recollected that *this* paper, similar in some particulars, had been communicated to the Society about nine years before, though not till now printed.

Therefore

Therefore the supporting of salt in water is not owing to its superficies being encreased.

A lump of salt, though laid at rest at the bottom of a vessel of water, will dissolve therein, and its parts move every way till equally diffused in the water; therefore there is a mutual attraction between water and salt. Every particle of water assumes as many of salt as can adhere to it; when more is added, it precipitates, and will not remain suspended.

Water, in the same manner, will dissolve in air, every particle of air assuming one or more particles of water; when too much is added, it precipitates in rain.

But there not being the same contiguity between the particles of air as of water, the solution of water in air is not carried on without a motion of the air, so as to cause a fresh accession of dry particles.

Part of a fluid, having more of what it dissolves, will communicate to other parts that have less. Thus very salt water coming in contact with fresh, communicates its saltness till all is equal, and the sooner if there is a little motion of the water.

Even earth will dissolve, or mix with air. A stroke of a horse's hoof on the ground in a hot dusty road, will raise a cloud of dust, that shall, if there be a light breeze, expand every way till perhaps near as big as a common house. 'Tis not by mechanical motion communicated to the particles of dust by the hoof, that they fly so far, nor by the wind that they spread so wide. But the air near the ground, more heated by the hot dust struck into it, is rarified and rises, and in rising mixes with the cooler air, and communicates of its dust to it, and it is at length so diffused.

diffused as to become invisible. Quantities of dust are thus carried up in dry seasons. Showers wash it from the air and bring it down again. For water attracting it stronger, it quits the air and adheres to the water.

Air suffering continual changes in the degrees of its heat, from various causes and circumstances, and consequently changes in its specific gravity, must therefore be in continual motion.

A small quantity of fire mixed with water (or degree of heat therein) so weakens the cohesion of its particles, that those on the surface easily quit it, and adhere to the particles of air.

A greater degree of heat is required to break the cohesion between water and air.

Air moderately heated will support a greater quantity of water invisibly than cold air; for its particles being by heat repelled to a greater distance from each other, thereby more easily keep the particles of water, that are annexed to them, from running into cohesions that would obstruct, refract, or reflect the light.

Hence, when we breathe in warm air, though the same quantity of moisture may be taken up from the lungs as when we breathe in cold air, yet that moisture is not so visible.

Water being extremely heated, *i. e.* to the degree of boiling, its particles, in quitting it, so repel each other, as to take up vastly more space than before, and by that repellency support themselves, expelling the air from the space they occupy. That degree of heat being lessened, they again mutually attract, and having no air-particles mixed, to adhere to, by

which they might be supported and kept at a distance, they instantly fall, coalesce, and become water again.

The water commonly diffused in our atmosphere never receives such a degree of heat from the sun, or other cause, as water has when boiling; it is not, therefore, supported by such heat, but by adhering to air.

Water being dissolved in, and adhering to air, that air will not readily take up oil, because of the natural repellency between water and oil.

Hence cold oils evaporate but slowly, the air having generally a quantity of dissolved water.

Oil being heated extremely, the air that approaches its surface will be also heated extremely; the water then quitting it, it will attract and carry off oil, which can now adhere to it. Hence the quick evaporation of oil heated to a great degree.

Oil being dissolved in air, the particles to which it adheres will not take up water.

Hence the suffocating nature of air impregnated with burnt grease, as from snuffs of candles, and the like. A certain quantity of moisture should be every moment discharged and taken away from the lungs. Air that has been frequently breathed is already overloaded, and for that reason can take no more, so will not answer the end. Greasy air refuses to touch it. In both cases suffocation for want of the discharge.

Air will attract and support many other substances.

A particle of air loaded with adhering water, or any other matter, is heavier than before, and would descend.

The atmosphere supposed at rest, a loaded descending particle must act with a force on the particles it passes between, or meets with, sufficient to overcome in some degree their mutual repellency, and push them nearer to each other.

A

○ ○ ○

F ○ B ○ C ○ G ○

○ D ○

○ ○ ○ ○

E

Thus, supposing the particles ABCD, and the others near them, to be at the distance caused by their mutual repellency (confined by their common gravity) if A would descend to E, it must pass between B and C. When it comes between B and C, it will be nearer to them than before, and must either have pushed them nearer to F and G, contrary to their mutual repellency, or pass through by a force exceeding its repellency with them. It then approaches D, and, to move it out of the way, must act on it with a force sufficient to overcome its repellency with the two next lower particles, by which it is kept in its present situation.

Every particle of air, therefore, will bear any load inferior to the force of these repulsions.

Hence the support of fogs, mists, clouds.

Very warm air, clear, though supporting a very great quantity of moisture, will grow turbid and cloudy on the mixture of a colder air : as foggy turbid air will grow clear by warming.

Thus the sun shining on a morning fog, dissipates it. Clouds are seen to waste in a sunshiny day.

But cold condenses and renders visible the vapour. A tankard, or decanter, filled with cold water, will condense the moisture of warm clear air, on its outside, where it becomes visible as dew, coalesces into drops, descends in little streams.

The sun heats the air of our atmosphere most near the surface of the earth; for there, besides the direct rays, there are many reflections. Moreover, the earth itself being heated, communicates of its heat to the neighbouring air.

The higher regions having only the direct rays of the sun passing through them, are comparatively very cold. Hence the cold air on the tops of mountains, and snow on some of them all the year, even in the torrid zone. Hence hail in summer.

If the atmosphere were, all of it (both above and below) always of the same temper as to cold or heat, then the upper air would always be rarer than the lower, because the pressure on it is less; consequently lighter, and therefore would keep its place.

But the upper air may be more condensed by cold, than the lower air by pressure. The lower more expanded by heat, than the upper for want of pressure. In such case, the upper air will become the heavier, the lower the lighter.

The lower region of air being heated and expanded, heaves up and supports, for some time, the colder heavier air above, and will continue to support it while the equilibrium is kept. Thus water is supported in an inverted open glass, while the equilibrium is maintained by the equal pressure upwards of the air below; but the equilibrium by any means breaking, the water descends on the heavier side, and the air rises into its place.

The lifted cold heavy air over a heated country, becoming by any means unequally supported, or unequal in its weights, the heaviest part descends first, and the rest follows impetuously. Hence gusts after heats, and hurricanes in hot climates. Hence the

air of gusts, and hurricanes cold, though in hot climes and seasons; it coming from above.

The cold air descending from above, as it penetrates our warm region full of watry particles, condenses them, renders them visible, forms a cloud thick and dark, overcasting sometimes at once, large and extensive; sometimes, when seen at a distance, small at first, gradually increasing; the cold edge, or surface, of the cloud, condensing the vapours next it, which form smaller clouds, that join it, encrease its bulk, it descends with the wind and its acquired weight, draws nearer the earth, grows denser with continual additions of water, and discharges heavy showers.

Small black clouds thus appearing in a clear sky, in hot climates, portend storms, and warn seamen to hand their sails.

The earth turning on its axis in about 24 hours, the equatorial parts must move about 15 miles in each minute. In northern and southern latitudes this motion is gradually less to the poles, and there nothing.

If there was a general calm over the face of the globe, it must be by the air's moving in every part, as fast as the earth, or sea, it covers.

He that sails, or rides, has insensibly the same degree of motion, as the ship, or coach, with which he is connected. If the ship strikes the shore, or the coach stops suddenly, the motion continuing in the man, he is thrown forward. If a man were to jump from the land into a swift sailing ship, he would be thrown backward (or towards the stern) not having at first the motion of the ship.

He

He that travels, by sea or land, towards the equinoctial, gradually acquires motion ; from it, loses.

But if a man were taken up from latitude 40 (where suppose the earth's surface to move 12 miles *per* minute) and immediately set down at the equinoctial, without changing the motion he had, his heels would be struck up, he would fall westward. If taken up from the equinoctial, and set down in latitude 40, he would fall eastward.

The air under the equator, and between the tropics, being constantly heated and rarified by the sun, rises. Its place is supplied by air from northern and southern latitudes, which coming from parts where the earth and air had less motion, and not suddenly acquiring the quicker motion of the equatorial earth, appears an east wind blowing westward, the earth moving from west to east, and slipping under the air.

Thus, when we ride in a calm, it seems a wind against us. If we ride with the wind, and faster, even that will seem a small wind against us.

The air rarified between the tropics, and rising, must flow in the higher region north and south. Before it rose, it had acquired the greatest motion the earth's rotation could give it. It retains some degree of this motion, and descending in higher latitudes, where the earth's motion is less, will appear a westerly wind, yet tending towards the equatorial parts, to supply the vacancy occasioned by the air of the lower regions flowing thitherwards.

Hence our general cold winds are about northwest, our summer cold gusts the same.

The



The air in sultry weather, though not cloudy, has a kind of haziness in it, which makes objects at a distance appear dull and indistinct. This haziness is occasioned by the great quantity of moisture equally diffused in that air. When, by the cold wind blowing down among it, it is condensed into clouds, and falls in rain, the air becomes purer and clearer. Hence, after gusts, distant objects appear distinct, their figures sharply terminated.

Extreme cold winds congeal the surface of the earth, by carrying off its fire. Warm winds afterwards blowing over that frozen surface will be chilled by it. Could that frozen surface be turned under, and a warmer turned up from beneath it, those warm winds would not be chilled so much.

The surface of the earth is also sometimes much heated by the sun; and such heated surface not being changed, heats the air that moves over it.

Seas, lakes, and great bodies of water, agitated by the winds, continually change surfaces; the cold surface in winter is turned under, by the rolling of the waves, and a warmer turned up; in summer, the warm is turned under, and colder turned up. Hence the more equal temper of sea-water, and the air over it. Hence in winter, winds from the sea seem warm, winds from the land cold. In summer the contrary.

Therefore the lakes north-west of us\*, as they are not so much frozen, nor so apt to freeze as the earth, rather moderate than increase the coldness of our winter winds.

The air over the sea being warmer, and therefore lighter in winter than the air over the frozen land,

\* In Pensilvania.

may be another cause of our general north-west winds, which blow off to sea at right angles from our North American coast; the warm light sea air rising, the heavy cold land air pressing into its place.

Heavy fluids descending frequently form eddies, or whirlpools, as is seen in a funnel, where the water acquires a circular motion receding every way from a centre, and leaving a vacancy in the middle, greatest above, and lessening downwards, like a speaking trumpet, its big end upwards.

Air descending, or ascending, may form the same kind of eddies, or whirlings, the parts of air acquiring a circular motion, and receding from the middle of the circle by a centrifugal force, and leaving there a vacancy, if descending, greatest above, and lessening downwards; if ascending, greatest below, and lessening upwards, like a speaking trumpet, standing its big end on the ground.

When the air descends with violence in some places, it may rise with equal violence in others, and form both kinds of whirlwinds.

The air in its whirling motion receding every way from the centre, or axis, of the trumpet, leaves there a vacuum, which cannot be filled through the sides, the whirling air as an arch preventing; it must then press in at the open ends.

The greatest pressure inwards must be at the lower end, the greatest weight of the surrounding atmosphere being there. The air entering rises within, and carries up dust, leaves, and even heavier bodies that happen in its way, as the eddy or whirlpool passes over land.

If

If it passes over water, the weight of the surrounding atmosphere forces up the water into the vacuity, part of which, by degrees joins with the whirling air, and adding weight, and receiving accelerated motion, recedes still farther from the centre, or axis, of the trump, as the pressure lessens, and at last, as the trump widens, is broken into small particles, and so united with air, as to be supported by it, and become black clouds at the top of the trump.

Thus these eddies may be whirlwinds at land, waterspouts at sea. A body of water so raised may be suddenly let fall, when the motion, &c. has not strength to support it, or the whirling arch is broken so as to let in the air; falling in the sea, it is harmless, unless ships happen under it. But if in the progressive motion of the whirl it has moved from the sea over the land, and there breaks, sudden, violent, and mischievous torrents are the consequence.

A. D. 1770, and at the present time, 1784, and  
 where the water stands; incontinently after  
 much of the water, and continues to rise the  
 time also different, because incontinently evident  
 in the province of New York, New Jersey, and  
 Pennsylvania, the like operations have not been taken,  
 and the result has been provided in those provinces,  
 but more especially in the capital towns, and other  
 adjacent towns, in about six or seven years, where  
 incontinently has been practised with surprising suc-  
 cess, as the inhabitants of the lives of many  
 of the town of Boston, the inhabitants of the town of  
 Boston were 570 souls at the time that died  
 of the small-pox, A. D. 1721, the number of  
 the inhabitants were 10,207, besides those moved out  
 in 1721, the deaths; the deaths were 2,089,  
 whereof  
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