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

Read June 3, 1756. THE 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

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 extreamly, 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.

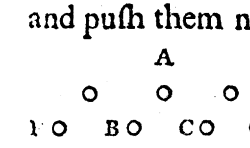
Oil being diſſolved in air, the particles to which it adheres will not take up water.

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.



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 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

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.