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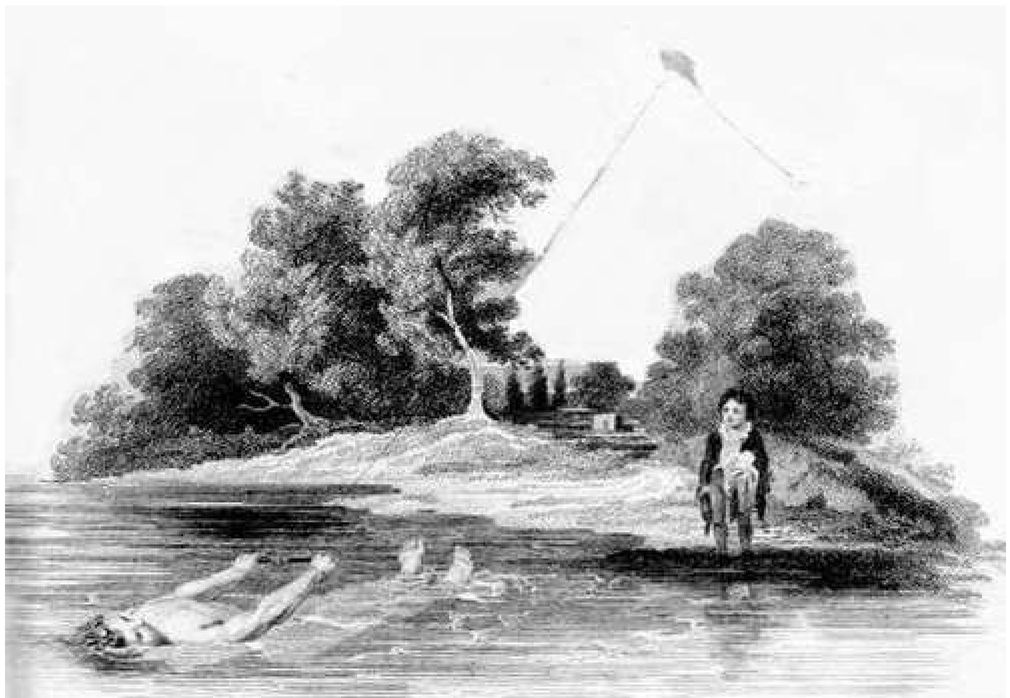
Several pages of the book contain a description and examples of a modified alphabet proposed by B.F. There are six new characters in his alphabet; these, and the example text using them (pages 360-366 in the original book) are shown as images in this ebook.

More detail can be found at the end of the book.

The
WORKS
Of
Benjamin Franklin, L.L.D.

VOL. 2.



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THE

COMPLETE
WORKS,

IN

PHILOSOPHY, POLITICS, AND MORALS,

OF THE LATE

DR. BENJAMIN FRANKLIN,

NOW FIRST COLLECTED AND ARRANGED:
WITH

MEMOIRS OF HIS EARLY LIFE,

WRITTEN BY HIMSELF.

IN THREE VOLUMES.

VOL. II.

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VOL. II.

LETTERS AND PAPERS ON PHILOSOPHICAL SUBJECTS.

PAPERS ON SUBJECTS OF GENERAL POLITICS.

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ERRATA.

Page.	*Line.*	
117	penult.	for preceding day, read the preceding day.
254	17:	for the annexed cut, read Plate VIII.
276	11:	for Plate I, read Plate IX.
293	23:	for Fig. 13, read Fig. 10.
318	9:	for descent, read decent.
326	5:	for Plate XI, read Plate V. Fig. 3.

LETTERS AND PAPERS

ON

PHILOSOPHICAL SUBJECTS.

LETTERS AND PAPERS

ON

PHILOSOPHICAL SUBJECTS.

Physical and Meteorological Observations, Conjectures and Suppositions.

Read at the Royal Society, 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 [2] bullets, of an ounce each, weigh as much in water as one of a pound, whose superficies is less.

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

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. It is 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 rarefied and rises, and in rising [3]
mixes with the cooler air, and communicates of its dust to it, and it is at length so 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 [4]
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 mutual 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.

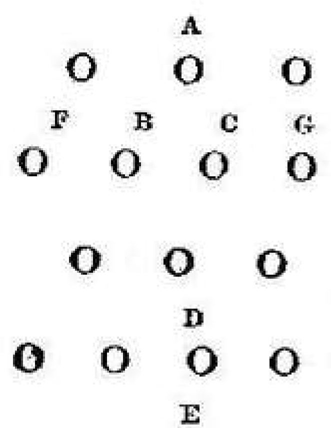
Oil being dissolved in air, the particles to which it adheres will not take up water.

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, [5]
or meets with, sufficient to overcome, in some degree, their mutual repellency, and push them nearer to each other.



Thus, supposing the particles A B C D, and the other 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 sun-shiny 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. [6]

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 heavy cold air over a heated country, becoming by any means unequally supported, or unequal in its weight, [7] 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, increase 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 twenty-four hours, the equatorial parts must move about fifteen 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 [8] motion of the ship.

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 twelve 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 rarefied 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[1].

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 rarefied 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. [9]

Hence our general cold winds are about north west, 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[2], as they are not so much frozen, nor so apt to freeze as the earth, rather moderate [10]
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, may be another cause of our general N. W. 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. [11]
The air entering rises within, and carries up dust, leaves, and even heavier bodies that happen in its way, as the eddy, or whirl, passes over land.

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, water-spouts 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 admit 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 then breaks, sudden, violent, and mischievous torrents are the consequences.

B. FRANKLIN.

FOOTNOTES:

[1] See a paper on this subject, by the late ingenious Mr. Hadley, in the Philosophical Transactions, wherein this hypothesis for explaining the trade-winds first appeared.

[2] In Pensylvania.

DOCTOR ——[3] OF BOSTON, TO BENJAMIN FRANKLIN, ESQ. AT PHILADELPHIA.

On Water-Spouts.

Read at the Royal Society, June 3, 1756.

Boston, October 16, 1752.

Sir,

I find by a word or two in your last[4], that you are willing to be found fault with; which authorises me to let you know what I am at a loss about in your papers, which is only in the article of the water-spout. I am in doubt, whether water in bulk, or even broken into drops, ever ascends into the region of the clouds *per vorticem*; i. e. whether there be, in reality, what I call a direct water-spout. I make no doubt of direct and inverted whirl-winds; your description of them, and the reason of the thing, are sufficient. I am sensible too, that they are very strong, and often move considerable weights. But I have not met with any historical accounts that seem exact enough to remove my scruples concerning the ascent abovesaid. [12]

Descending spouts (as I take them to be) are many times seen, as I take it, in the calms, between the sea and land trade-winds on the coast of Africa. These contrary winds, or diverging, I can conceive may occasion them, as it were by suction, making a breach in a large cloud. But I imagine they have, at the same time, a tendency to hinder any direct or rising spout, by carrying off the lower part of the atmosphere as fast as it begins to rarefy; and yet spouts are frequent here, which strengthens my opinion, that all of them descend.

But however this be, I cannot conceive a force producible by the rarefication and condensation of our atmosphere, in the circumstances of our globe, capable of carrying water, in large portions, into the region of the clouds. Supposing it to be raised, it would be too heavy to continue the ascent beyond a considerable height, unless parted into small drops; and even then, by its centrifugal force, from the manner of conveyance, it would be flung out of the circle, and fall scattered, like rain.

But I need not expatiate on these matters to you. I have mentioned my objections, and, as truth is my pursuit, shall be glad to be informed. I have seen few accounts of these whirl or eddy winds, and as little of the spouts; and these, especially, lame and poor things to obtain any certainty by. If you know any thing determinate that has been observed, I shall hope to hear from you; as also of any mistake in my thoughts. I have nothing to object to any other part of your suppositions: and as to that of the trade-winds, I believe nobody can. [13]

I am, &c.

P. S.. The figures in the *Philosophical Transactions* show, by several circumstances, that they all descended, though the relators seemed to think they took up water.

FOOTNOTES:

[3] Dr. Perkins. *Editor.*

[4] A Letter on Inoculation, which is transferred to a subsequent part of this volume, that the papers on meteorological subjects may not be interrupted. *Editor.*

DR. PERKINS OF BOSTON, TO BENJAMIN FRANKLIN, ESQ. AT PHILADELPHIA.

The same Subject continued.

Read at the Royal Society, June 24, 1756.

Boston, October 23, 1752.

Sir,

In the inclosed, you have all I have to say of that matter[5]. It proved longer than I expected, so that I was forced to add a cover to it. I confess it looks like a dispute; but that is quite contrary to my intentions.

The sincerity of friendship and esteem were my motives; nor do I doubt your scrupling the goodness of the intention. [14]
However, I must confess I cannot tell exactly how far I was acted by hopes of better information, in discovering the whole

foundation of my opinion, which, indeed, is but an opinion, as I am very much at a loss about the validity of the reasons. I have not been able to differ from you in sentiment concerning any thing else in your *Suppositions*. In the present case I lie open to conviction, and shall be the gainer when informed. If I am right, you will know that, without my adding any more. Too much said on a merely speculative matter, is but a robbery committed on practical knowledge. Perhaps I am too much pleased with these dry notions: however, by this you will see that I think it unreasonable to give you more trouble about them, than your leisure and inclination may prompt you to.

I am, &c.

Since my last I considered, that, as I had begun with the reasons of my dissatisfaction about the ascent of water in spouts, you would not be unwilling to hear the whole I have to say, and then you will know what I rely upon.

What occasioned my thinking all spouts descend, is, that I found some did certainly do so. A difficulty appeared concerning the ascent of so heavy a body as water, by any force I was apprised of, as probably sufficient. And, above all, a view of Mr. Stuart's portraits of spouts, in the *Philosophical Transactions*.

Some observations on these last will include the chief part of my difficulties. Mr. Stuart has given us the figures of a number observed by him in the Mediterranean: all with some particulars which make for my opinion, if well drawn. [15]

The great spattering, which relators mention in the water where the spout descends, and which appears in all his draughts, I conceive to be occasioned by drops descending very thick and large into the place.

On the place of this spattering, arises the appearance of a bush, into the centre of which the spout comes down. This bush I take to be formed by a spray, made by the force of these drops, which being uncommonly large, and descending with unusual force by a stream of wind descending from the cloud with them, increases the height of the spray: which wind being repulsed by the surface of the waters rebounds and spreads; by the first raising the spray higher than it otherwise would go; and by the last making the top of the bush appear to bend outwards (*i. e.*) the cloud of spray is forced off from the trunk of the spout, and falls backward.

The bush does the same where there is no appearance of a spout reaching it; and is depressed in the middle, where the spout is expected. This, I imagine, to be from numerous drops of the spout falling into it, together with the wind I mentioned, by their descent, which beat back the rising spray in the centre.

This circumstance, of the bush bending outwards at the top, seems not to agree with what I call a direct whirlwind, but consistent with the reversed; for a direct one would sweep the bush inwards; if, in that case, any thing of a bush would appear.

The pillar of water, as they call it, from its likeness, I suppose to be only the end of the spout immersed in the bush, a little blackened by the additional cloud, and, perhaps, appears to the eye beyond its real bigness, by a refraction in the bush, and which refraction may be the cause of the appearance of separation, betwixt the part in the bush, and that above it. The part in the bush is cylindrical, as it is above (*i. e.*) the bigness the same from the top of the bush to the water. Instead of this shape, in case of a whirlwind, it must have been pyramidical. [16]

Another thing remarkable, is, the curve in some of them: this is easy to conceive, in case of descending parcels of drops through various winds, at least till the cloud condenses so fast as to come down, as it were, *uno rivo*. But it is harder to me to conceive it in the ascent of water, that it should be conveyed along, secure of not leaking or often dropping through the under side, in the prone part: and, should the water be conveyed so swiftly, and with such force, up into the cloud, as to prevent this, it would, by a natural disposition to move on in a present direction, presently straiten the curve, raising the shoulder very swiftly, till lost in the cloud.

Over every one of Stuart's figures, I see a cloud: I suppose his clouds were first, and then the spout; I do not know whether it be so with all spouts, but suppose it is. Now, if whirlwinds carried up the water, I should expect them in fair weather, but not under a cloud; as is observable of whirlwinds; they come in fair weather, not under the shade of a cloud, nor in the night; since shade cools the air: but, on the contrary, violent winds often descend from the clouds; strong gusts which occupy small spaces; and from the higher regions, extensive hurricanes, &c.

Another thing is the appearance of the spout *coming from* the cloud. This I cannot account for on the notion of a direct [17]
spout, but in the real descending one, it is easy. I take it, that the cloud begins first of all to pour out drops at that particular spot, or *foramen*; and, when that current of drops increases, so as to force down wind and vapour, the spout becomes so far as that goes opaque. I take it, that no clouds drop spouts, but such as make very fast, and happen to condense in a particular spot, which perhaps is coldest, and gives a determination downwards, so as to make a passage through the subjacent atmosphere.

If spouts ascend, it is to carry up the warm rarefied air below, to let down all and any that is colder above; and, if so, they must carry it through the cloud they go into (for that is cold and dense, I imagine) perhaps far into the higher region, making a wonderful appearance at a convenient distance to observe it, by the swift rise of a body of vapour, above the region of the clouds. But as this has never been observed in any age, if it be supposeable that is all.

I cannot learn by mariners, that any wind blows towards a spout more than any other way; but it blows towards a whirlwind, for a large distance round.

I suppose there has been no instance of the water of a spout being salt, when coming across any vessel at sea. I suppose too, that there have been no salt rains; these would make the case clear.

I suppose it is from some unhappy effects of these dangerous creatures of nature, that sailors have an universal dread on
them of breaking in their decks, should they come across them. I imagine spouts, in cold seasons, as Gordon's in the [18]
Downs, prove the descent.

Query. Whether there is not always more or less cloud, first, where a spout appears?

Whether they are not, generally, on the borders of trade-winds; and whether this is for, or against me?

Whether there be any credible account of a whirlwind's carrying up all the water in a pool, or small pond: as when shoal, and the banks low, a strong gust might be supposed to blow it all out?

Whether a violent tornado, of a small extent, and other sudden and strong gusts, be not winds from above, descending nearly perpendicular; and, whether many that are called whirlwinds at sea, are any other than these; and so might be called air-spouts, if they were objects of sight?

I overlooked, in its proper place, Stuart's No. 11, which is curious for its inequalities, and, in particular, the approach to breaking, which, if it would not be too tedious, I would have observed a little upon, in my own way, as, I think, this would argue against the ascent, &c. but I must pass it, not only for the reason mentioned, but want of room besides.

As to Mr. Stuart's ocular demonstration of the ascent in his great perpendicular spout, the only one it appears in, I say, as to this, what I have written supposes him mistaken, which, yet, I am far from asserting.

The force of an airy vortex, having less influence on the solid drops of water, than on the interspersed cloudy vapours, makes the last whirl round swifter, though it descend slower: and this might easily deceive, without great care, the most unprejudiced person.

FOOTNOTE:

[5] Water-Spouts.

TO DOCTOR ——[6], OF BOSTON. [19]

Water-Spouts and Whirlwinds compared.

Read at the Royal Society, June 24, 1756.

Philadelphia, Feb. 4, 1753.

Sir,

I ought to have written to you, long since, in answer to yours of October 16, concerning the water-spout; but business partly, and partly a desire of procuring further information, by enquiry among my seafaring acquaintance, induced me to postpone writing, from time to time, till I am now almost ashamed to resume the subject, not knowing but you may have forgot what has been said upon it.

Nothing certainly, can be more improving to a searcher into nature, than objections judiciously made to his opinion, taken up, perhaps, too hastily: for such objections oblige him to re-study the point, consider every circumstance carefully, compare facts, make experiments, weigh arguments, and be slow in drawing conclusions. And hence a sure advantage results; for he either confirms a truth, before too slightly supported; or discovers an error, and receives instruction from the objector.

In this view I consider the objections and remarks you sent me, and thank you for them sincerely: but, how much soever my inclinations lead me to philosophical enquiries, I am so engaged in business, public and private, that those more pleasing pursuits are frequently interrupted, and the chain of thought, necessary to be closely continued in such disquisitions, is so broken and disjointed, that it is with difficulty I satisfy myself in any of them: and I am now not much [20]
nearer a conclusion, in this matter of the spout, than when I first read your letter.

Yet, hoping we may, in time, sift out the truth between us, I will send you my present thoughts, with some observations on your reasons on the accounts in the *Transactions*, and on other relations I have met with. Perhaps, while I am writing, some new light may strike me, for I shall now be obliged to consider the subject with a little more attention.

I agree with you, that, by means of a vacuum in a whirlwind, water cannot be supposed to rise in large masses to the region of the clouds; for the pressure of the surrounding atmosphere could not force it up in a continued body, or column, to a much greater height, than thirty feet. But, if there really is a vacuum in the centre, or near the axis of whirlwinds, then, I think, water may rise in such vacuum to that height, or to a less height, as the vacuum may be less perfect.

I had not read Stuart's account, in the *Transactions*, for many years, before the receipt of your letter, and had quite forgot it; but now, on viewing his draughts, and considering his descriptions, I think they seem to favour *my hypothesis*; for he describes and draws columns of water, of various heights, terminating abruptly at the top, exactly as water would do, when forced up by the pressure of the atmosphere into an exhausted tube.

I must, however, no longer call it *my hypothesis*, since I find Stuart had the same thought, though somewhat obscurely expressed, where he says, "he imagines this phenomenon may be solved by suction (improperly so called) or rather pulsion, as in the application of a cupping glass to the flesh, the air being first voided by the kindled flax." In my paper, I [21] supposed a whirlwind and a spout to be the same thing, and to proceed from the same cause; the only difference between them being, that the one passes over land, the other over water, I find, also, in the *Transactions*, that M. de la Pryme was of the same opinion; for he there describes two spouts, as he calls them, which were seen at different times, at Hatfield, in Yorkshire, whose appearances in the air were the same with those of the spouts at sea, and effects the same with those of real whirlwinds.

Whirlwinds have generally a progressive, as well as a circular motion; so had what is called the spout, at Topsham—(*See the account of it in the Transactions*) which also appears, by its effects described, to have been a real whirlwind. Water-spouts have, also, a progressive motion; this is sometimes greater, and sometimes less; in some violent, in others barely perceivable. The whirlwind at Warrington continued long in Acrement-Close.

Whirlwinds generally arise after calms and great heats: the same is observed of water-spouts, which are, therefore, most frequent in the warm latitudes. The spout that happened in cold weather, in the Downs, described by Mr. Gordon in the *Transactions*, was, for that reason, thought extraordinary; but he remarks withal, that the weather, though cold when the spout appeared, was soon after much colder; as we find it, commonly, less warm after a whirlwind.

You agree, that the wind blows every way towards a whirlwind, from a large space round. An intelligent whaleman of Nantucket, informed me that three of their vessels, which were out in search of whales, happening to be becalmed, lay in sight of each other, at about a league distance, if I remember right, nearly forming a triangle: after some time, a water- [22] spout appeared near the middle of the triangle, when a brisk breeze of wind sprung up, and every vessel made sail; and then it appeared to them all, by the setting of the sails, and the course each vessel stood, that the spout was to the leeward of every one of them; and they all declared it to have been so, when they happened afterwards in company, and came to confer about it. So that in this particular likewise, whirlwinds and water-spouts agree.

But, if that which appears a water-spout at sea, does sometimes, in its progressive motion, meet with and pass over land, and there produce all the phenomena and effects of a whirlwind, it should thence seem still more evident, that a whirlwind and a spout are the same. I send you, herewith, a letter from an ingenious physician of my acquaintance, which gives one instance of this, that fell within his observation.

A fluid, moving from all points horizontally, towards a centre, must, at that centre, either ascend or descend. Water being in a tub, if a hole be opened in the middle of the bottom, will flow from all sides to the centre, and there descend in a whirl. But, air flowing on and near the surface of land or water, from all sides, towards a centre, must, at that centre ascend; the land or water hindering its descent.

If these concentring currents of air be in the upper region, they may, indeed, descend in the spout or whirlwind; but then, when the united current reached the earth or water, it would spread, and, probably, blow every way from the centre. There may be whirlwinds of both kinds, but from the commonly observed effects, I suspect the rising one to be the most common: when the upper air descends, it is, perhaps, in a greater body, extending wider, as in our thunder-gusts, and [23]
without much whirling; and, when air descends in a spout, or whirlwind, I should rather expect it would press the roof of a house *inwards*, or force *in* the tiles, shingles, or thatch, force a boat down into the water, or a piece of timber into the earth, than that it would lift them up, and carry them away.

It has so happened, that I have not met with any accounts of spouts, that certainly descended; I suspect they are not frequent. Please to communicate those you mention. The apparent dropping of a pipe from the clouds towards the earth or sea, I will endeavour to explain hereafter.

The augmentation of the cloud, which, as I am informed, is generally, if not always the case, during a spout, seems to shew an ascent, rather than a descent of the matter of which such cloud is composed; for a descending spout, one would expect, should diminish a cloud. I own, however, that cold air descending, may, by condensing the vapours in a lower region, form and increase clouds; which, I think, is generally the case in our common thunder-gusts, and, therefore, do not lay great stress on this argument.

Whirlwinds and spouts, are not always, though most commonly, in the day time. The terrible whirlwind which damaged a great part of Rome, June 11, 1749, happened in the night of that day. The same was supposed to have been first a spout, for it is said to be beyond doubt, that it gathered in the neighbouring sea, as it could be tracked from Ostia to Rome. I find this in Pere Boschovich's account of it, as abridged in the Monthly Review for December 1750. In that [24]
account, the whirlwind is said to have appeared as a very black, long, and lofty cloud, discoverable, notwithstanding the darkness of the night, by its continually lightning or emitting flashes on all sides, pushing along with a surprising swiftness, and within three or four feet of the ground. Its general effects on houses, were stripping off the roofs, blowing away chimneys, breaking doors and windows, *forcing up the floors, and unpaving the rooms* (some of these effects seem to agree well with a supposed vacuum in the centre of the whirlwind) and the very rafters of the houses were broken and dispersed, and even hurled against houses at a considerable distance, &c.

It seems, by an expression of Pere Boschovich's, as if the wind blew from all sides towards the whirlwind; for, having carefully observed its effects, he concludes of all whirlwinds, "that their motion is circular, and their action attractive."

He observes, on a number of histories of whirlwinds, &c. "that a common effect of them is, to carry up into the air, tiles, stones, and animals themselves, which happen to be in their course, and all kinds of bodies unexceptionably, throwing them to a considerable distance, with great impetuosity."

Such effects seem to shew a rising current of air.

I will endeavour to explain my conceptions of this matter by figures, representing a plan and an elevation of a spout or whirlwind.

I would only first beg to be allowed two or three positions, mentioned in my former paper.

1. That the lower region of air is often more heated, and so more rarefied, than the upper; consequently, specifically lighter. The coldness of the upper region is manifested by the hail which sometimes falls from it in a hot day. [25]

2. That heated air may be very moist, and yet the moisture so equally diffus'd and rarefied, as not to be visible, till colder air mixes with it, when it condenses, and becomes visible. Thus our breath, invisible in summer, becomes visible in winter.

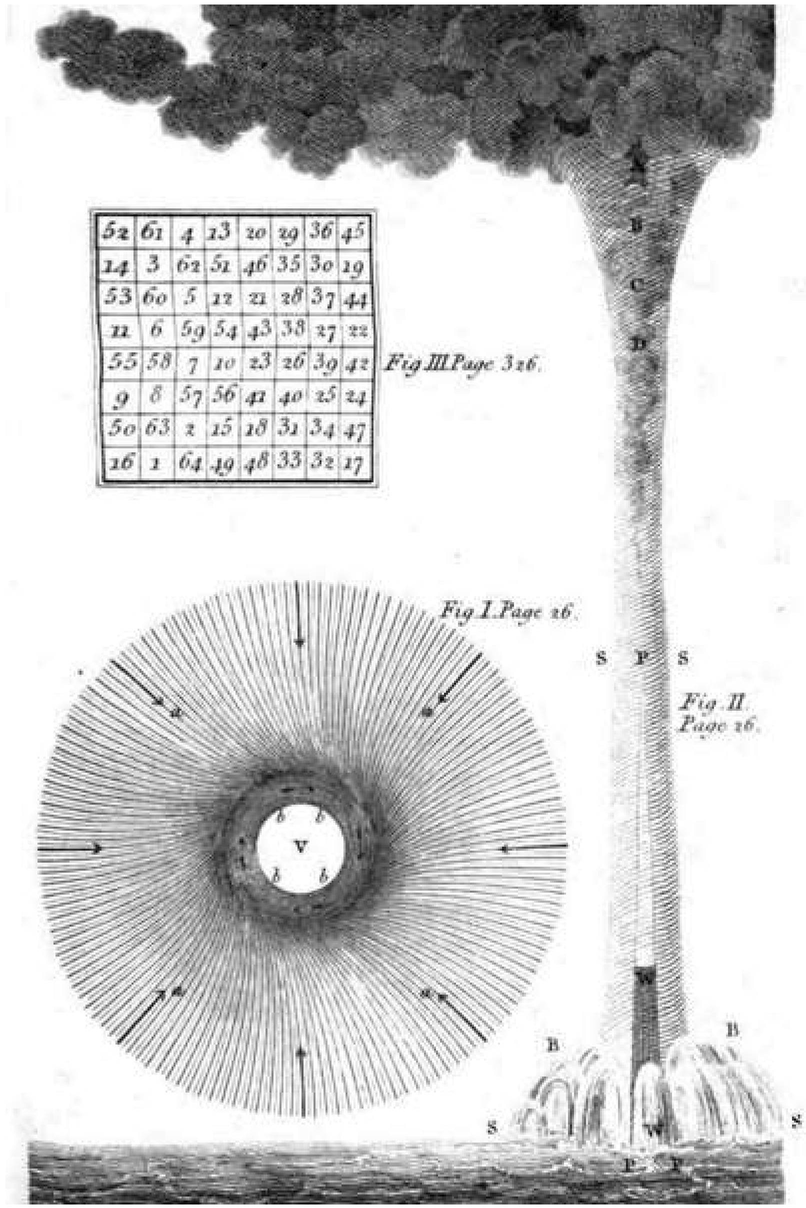
Now let us suppose a tract of land, or sea, of perhaps sixty miles square, unscreened by clouds, and unfanned by winds, during great part of a summer's day, or, it may be, for several days successively, till it is violently heated, together with the lower region of air in contact with it, so that the said lower air becomes specifically lighter than the superincumbent higher region of the atmosphere, in which the clouds commonly float: let us suppose, also, that the air surrounding this tract has not been so much heated during those days, and, therefore, remains heavier. The consequence of this should be, as I conceive, that the heated lighter air, being pressed on all sides, must ascend, and the heavier descend; and, as this rising cannot be in all parts, or the whole area of the tract at once, for that would leave too extensive a vacuum, the rising will begin precisely in that column that happens to be the lightest, or most rarefied; and the warm air will flow horizontally from all points to this column, where the several currents meeting, and joining to rise, a whirl is naturally formed, in the same manner as a whirl is formed in the tub of water, by the descending fluid flowing from all sides of the tub, to the hole in the centre.

And, as the several currents arrive at this central rising column, with a considerable degree of horizontal motion, they cannot suddenly change it to a vertical motion; therefore as they gradually, in approaching the whirl, decline from right to [26]
curve or circular lines, so, having joined the whirl, they *ascend* by a spiral motion, in the same manner as the water *descends* spirally through the hole in the tub before-mentioned.

Lastly, as the lower air, and nearest the surface, is most rarefied by the heat of the sun, that air is most acted on by the pressure of the surrounding cold and heavy air, which is to take its place; consequently, its motion towards the whirl is swiftest, and so the force of the lower part of the whirl, or trump, strongest, and the centrifugal force of its particles greatest; and hence the vacuum round the axis of the whirl should be greatest near the earth or sea, and be gradually diminished as it approaches the region of the clouds, till it ends in a point, as at P in Fig. II. Plate V. forming a long and sharp cone.

In Fig. I. which is a plan or ground-plat of a whirlwind, the circle V. represents the central vacuum.

Between *a a a a* and *b b b b* I suppose a body of air, condensed strongly by the pressure of the currents moving towards it, from all sides without, and by its centrifugal force from within, moving round with prodigious swiftness, (having, as it were, the momenta of all the currents ——> ——> ——> ——> united in itself) and with a power equal to its swiftness and density.



52	61	4	13	20	29	36	45
14	3	62	51	46	35	30	19
53	60	5	12	21	28	37	44
11	6	59	54	43	38	27	22
55	58	7	10	23	26	39	42
9	8	57	56	41	40	25	24
50	63	2	15	18	31	34	47
16	1	64	49	48	33	32	17

View larger image here

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It is this whirling body of air between *a a a a* and *b b b b* that rises spirally; by its force it tears buildings to pieces, twists up great trees by the roots, &c. and, by its spiral motion, raises the fragments so high, till the pressure of the surrounding and approaching currents diminishing, can no longer confine them to the circle, or their own centrifugal force [27] encreasing, grows too strong for such pressure, when they fly off in tangent lines, as stones out of a sling, and fall on all sides, and at great distances.

If it happens at sea, the water under and between *a a a a* and *b b b b* will be violently agitated and driven about, and parts of it raised with the spiral current, and thrown about so as to form a bush-like appearance.

This circle is of various diameters, sometimes very large.

If the vacuum passes over water, the water may rise in it in a body, or column, to near the height of thirty-two feet.

If it passes over houses, it may burst their windows or walls outwards, pluck off the roofs, and pluck up the floors, by the sudden rarefaction of the air contained within such buildings; the outward pressure of the atmosphere being suddenly taken off: so the stopped bottle of air bursts under the exhausted receiver of the air-pump.

Fig. II. is to represent the elevation of a water-spout, wherein I suppose P P P to be the cone, at first a vacuum, till W W, the rising column of water, has filled so much of it. S S S S, the spiral whirl of air, surrounding the vacuum, and continued higher in a close column after the vacuum ends in the point P, till it reaches the cool region of the air. B B, the bush described by Stuart, surrounding the foot of the column of water.

Now, I suppose this whirl of air will, at first, be as invisible as the air itself, though reaching, in reality, from the water, to the region of cool air, in which our low summer thunder-clouds commonly float; but presently it will become visible at [28] its extremities. *At its lower end*, by the agitation of the water, under the whirling part of the circle, between P and S forming Stuart's bush, and by the swelling and rising of the water, in the beginning vacuum, which is, at first, a small, low, broad cone, whose top gradually rises and sharpens, as the force of the whirl encreases. *At its upper end* it becomes visible, by the warm air brought up to the cooler region, where its moisture begins to be condensed into thick vapour, by the cold, and is seen first at A, the highest part, which being now cooled, condenses what rises next at B, which condenses that at C, and that condenses what is rising at D, the cold operating by the contact of the vapours faster in a right line downwards, than the vapours themselves can climb in a spiral line upwards; they climb, however, and as by continual addition they grow denser, and, consequently, their centrifugal force greater, and being risen above the concentrating currents that compose the whirl, fly off, spread, and form a cloud.

It seems easy to conceive, how, by this successive condensation from above, the spout appears to drop or descend from the cloud, though the materials of which it is composed are all the while ascending.

The condensation of the moisture, contained in so great a quantity of warm air as may be supposed to rise in a short time in this prodigiously rapid whirl, is, perhaps, sufficient to form a great extent of cloud, though the spout should be over land, as those at Hatfield; and if the land happens not to be very dusty, perhaps the lower part of the spout will scarce become visible at all; though the upper, or what is commonly called the descending part, be very distinctly seen. [29]

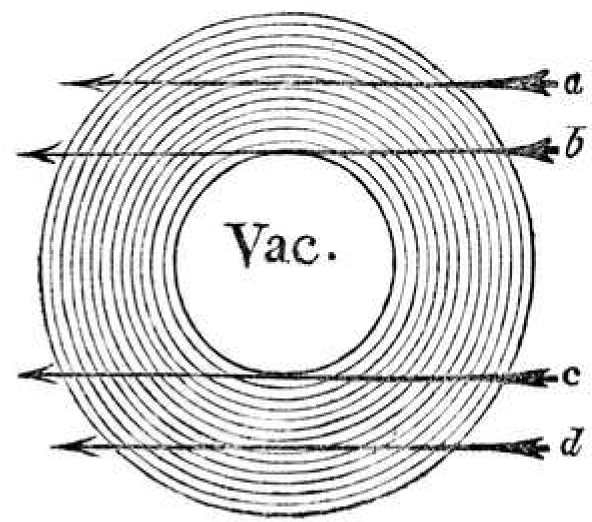
The same may happen at sea, in case the whirl is not violent enough to make a high vacuum, and raise the column, &c. In such case, the upper part A B C D only will be visible, and the bush, perhaps, below.

But if the whirl be strong, and there be much dust on the land, and the column W W be raised from the water, then the lower part becomes visible, and sometimes even united to the upper part. For the dust may be carried up in the spiral whirl, till it reach the region where the vapour is condensed, and rise with that even to the clouds: and the friction of the whirling air, on the sides of the column W W, may detach great quantities of its water, break it into drops, and carry them up in the spiral whirl mixed with the air; the heavier drops may, indeed, fly off, and fall, in a shower, round the spout; but much of it will be broken into vapour, yet visible; and thus, in both cases, by dust at land, and, by water at sea, the whole tube may be darkened and rendered visible.

As the whirl weakens, the tube may (in appearance) separate in the middle; the column of water subsiding, and the superior condensed part drawing up to the cloud. Yet still the tube, or whirl of air, may remain entire, the middle only becoming invisible, as not containing visible matter.

Dr. Stuart says, "It was observable of all the spouts he saw, but more perceptible of the great one; that; towards the end, it began to appear like a hollow canal, only black in the borders, but white in the middle; and though at first it was altogether black and opaque, yet, now, one could very distinctly perceive the sea-water to fly up along the middle of this [30] canal, as smoak up a chimney."

And Dr. Mather, describing a whirlwind, says, "a thick dark small cloud arose, with a pillar of light in it, of about eight or ten feet diameter, and passed along the ground in a tract not wider than a street, horribly tearing up trees by the roots, blowing them up in the air like feathers, and throwing up stones of great weight to a considerable height in the air, &c."



These accounts, the one of water-spouts, the other of a whirlwind, seem, in this particular, to agree; what one gentleman describes as a tube, black in the borders, and white in the middle, the other calls a black cloud, with a pillar of light in it; the latter expression has only a little more of the *marvellous*, but the thing is the same; and it seems not very difficult to understand. When Dr. Stuart's spouts were full charged, that is, when the whirling pipe of air was filled between *a a a a* and *b b b b*, Fig. I., with quantities of drops, and vapour torn off from the column W W, Fig. II., the whole was rendered so dark, as that it could not be seen thro', nor the spiral ascending motion discovered; but when the quantity ascending lessened, the pipe became more transparent, and the [31] ascending motion visible. For, by inspection of the figure in the opposite page, representing a section of our spout, with the vacuum in the middle, it is plain that if we look at such a hollow pipe in the direction of the arrows, and suppose opaque particles to be equally mixed in the space between the two circular lines, both the part between the arrows *a* and *b*, and that between the arrows *c* and *d*, will appear much darker than that between *b* and *c*, as there must be many more of those opaque particles in the line of vision across the sides, than across the middle. It is thus that a hair in a microscope evidently appears to be a pipe, the sides shewing darker than the middle. Dr. Mather's whirl was probably filled with dust, the sides were very dark, but the vacuum within rendering the middle more transparent, he calls it a pillar of light.

It was in this more transparent part, between *b* and *c*, that Stuart could see the spiral motion of the vapours, whose lines on the nearest and farthest side of the transparent part crossing each other, represented smoak ascending in a chimney; for the quantity being still too great in the line of sight through the sides of the tube, the motion could not be discovered there, and so they represented the solid sides of the chimney.

When the vapours reach in the pipe from the clouds near to the earth, it is no wonder now to those who understand electricity, that flashes of lightning should descend by the spout, as in that of Rome.

But you object, if water may be thus carried into the clouds, why have we not salt rains? The objection is strong and [32] reasonable, and I know not whether I can answer it to your satisfaction. I never heard but of one salt rain, and that was where a spout passed pretty near a ship, so I suppose it to be only the drops thrown off from the spout, by the centrifugal force (as the birds were at Hatfield) when they had been carried so high as to be above, or to be too strongly centrifugal for, the pressure of the concurring winds surrounding it: and, indeed, I believe there can be no other kind of salt rain; for it has pleased the goodness of God so to order it, that the particles of air will not attract the particles of salt, though they strongly attract water.

Hence, though all metals, even gold, may be united with air, and rendered volatile, salt remains fixt in the fire, and no heat can force it up to any considerable height, or oblige the air to hold it. Hence, when salt rises, as it will a little way, into air with water, there is instantly a separation made; the particles of water adhere to the air, and the particles of salt fall down again, as if repelled and forced off from the water by some power in the air; or, as some metals, dissolved in a proper menstruum, will quit the solvent when other matter approaches, and adhere to that, so the water quits the salt, and embraces the air; but air will not embrace the salt, and quit the water, otherwise our rains would indeed be salt, and every tree and plant on the face of the earth be destroyed, with all the animals that depend on them for subsistence.——He who hath proportioned and given proper qualities to all things, was not unmindful of this. Let us adore Him with praise and thanksgiving! By some accounts of seamen, it seems the column of water W W, sometimes falls suddenly; and if it be, as [33] some say, fifteen or twenty yards diameter, it must fall with great force, and they may well fear for their ships. By one account, in the *Transactions*, of a spout that fell at Colne in Lancashire, one would think the column is sometimes lifted off from the water, and carried over land, and there let fall in a body; but this, I suppose, happens rarely.

Stuart describes his spouts as appearing no bigger than a mast, and sometimes less; but they were seen at a league and a half distance.

I think I formerly read in Dampier, or some other voyager, that a spout, in its progressive motion, went over a ship becalmed, on the coast of Guinea, and first threw her down on one side, carrying away her foremast, then suddenly whipped her up, and threw her down on the other side, carrying away her mizen-mast, and the whole was over in an instant. I suppose the first mischief was done by the fore-side of the whirl, the latter by the hinder-side, their motion being contrary.

I suppose a whirlwind, or spout, may be stationary, when the concurring winds are equal; but if unequal, the whirl acquires a progressive motion, in the direction of the strongest pressure.

When the wind that gives the progressive motion becomes stronger below than above, or above than below, the spout will be bent, and, the cause ceasing, straiten again.

Your queries, towards the end of your paper, appear judicious, and worth considering. At present I am not furnished with facts sufficient to make any pertinent answer to them; and this paper has already a sufficient quantity of conjecture. [34]

Your manner of accommodating the accounts to your hypothesis of descending spouts, is, I own, ingenious, and perhaps that hypothesis may be true. I will consider it farther, but, as yet, I am not satisfied with it, though hereafter I may be.

Here you have my method of accounting for the principal phenomena, which I submit to your candid examination.

And as I now seem to have almost written a book, instead of a letter, you will think it high time I should conclude; which I beg leave to do, with assuring you, that

I am, Sir, &c.

B. FRANKLIN.

FOOTNOTE:

[6] Perkins. *Editor*.

DOCTOR M——[7], TO BENJAMIN FRANKLIN, ESQ. AT PHILADELPHIA.

Description of a Water-Spout at Antigua.

Read at the Royal Society, June 24, 1756.

New-Brunswick, November 11, 1752.

Sir,

I am favoured with your letter of the 2d instant, and shall, with pleasure, comply with your request, in describing (as well as my memory serves me) the water-spout I saw at Antigua; and shall think this, or any other service I can do, well [35] repaid, if it contributes to your satisfaction in so curious a disquisition.

I had often seen water-spouts at a distance, and heard many strange stories of them, but never knew any thing satisfactory of their nature or cause, until that which I saw at Antigua; which convinced me that a water-spout is a whirlwind, which becomes visible in all its dimensions by the water it carries up with it.

There appeared, not far from the mouth of the harbour of St. John's, two or three water-spouts, one of which took its course up the harbour. Its progressive motion was slow and unequal, not in a strait line, but, as it were, by jerks or starts. When just by the wharf, I stood about one hundred yards from it. There appeared in the water a circle of about twenty yards diameter, which, to me, had a dreadful, though pleasing appearance. The water in this circle was violently agitated, being whisked about, and carried up into the air with great rapidity and noise, and reflected a lustre, as if the sun shined bright on that spot, which was more conspicuous, as there appeared a dark circle around it. When it made the shore, it carried up with the same violence shingles, staves[8], large pieces of the roofs of houses, &c. and one small wooden house it lifted entire from the foundation on which it stood, and carried it to the distance of fourteen feet, where it settled without breaking or oversetting; and, what is remarkable, though the whirlwind moved from west to east, the house moved from [36] east to west. Two or three negroes and a white woman, were killed by the fall of timber, which it carried up into the air and dropped again. After passing through the town, I believe it was soon dissipated; for, except tearing a large limb from a tree, and part of the cover of a sugar-work near the town, I do not remember any farther damage done by it. I conclude, wishing you success in your enquiry,

And am, &c.

W. M.

FOOTNOTES:

[7] Dr. Mercer. *Editor.*

[8] I suppose shingles, staves, timber, and other lumber, might be lying in quantities on the wharf, for sale, as brought from the northern colonies. B. F.

DOCTOR ——[9], OF BOSTON, TO BENJAMIN FRANKLIN, ESQ. AT PHILADELPHIA.

Shooting Stars.

Read at the Royal Society, July 8, 1756.

Boston, May 14, 1753.

Sir,

I received your letter of April last, and thank you for it. Several things in it make me at a loss which side the truth lies on, and determine me to wait for farther evidence.

As to shooting-stars, as they are called, I know very little, and hardly know what to say. I imagine them to be passes of electric fire from place to place in the atmosphere, perhaps occasioned by accidental pressures of a non-electric circumambient fluid, and so by propulsion, or allicited by the circumstance of a distant quantity *minus* electrified, which it shoots to supply, and becomes apparent by its contracted passage through a non-electric medium. Electric fire in our globe [37] is always in action, sometimes ascending, descending, or passing from region to region. I suppose it avoids too dry air, and therefore we never see these shoots ascend. It always has freedom enough to pass down unobserved, but, I imagine, not always so, to pass to distant climes and meridians less stored with it.

The shoots are sometimes all one way, which, in the last case, they should be.

Possibly there may be collections of particles in our atmosphere, which gradually form, by attraction, either similar ones *per se*, or dissimilar particles, by the intervention of others. But then, whether they shoot or explode of themselves, or by the approach of some suitable foreign collection, accidentally brought near by the usual commotions and interchanges of our atmosphere, especially when the higher and lower regions intermix, before change of winds and weather, I leave.

I believe I have now said enough of what I know nothing about. If it should serve for your amusement, or any way oblige you, it is all I aim at, and shall, at your desire, be always ready to say what I think, as I am sure of your candour.

I am, &c.

FOOTNOTE:

[9] Dr. Perkins. *Editor.*

A subsequent Paper from the same.

Water-Spouts and Whirlwinds.

Read at the Royal Society, July 8, 1756.

Spouts have been generally believed ascents of water from below, to the region of the clouds, and whirlwinds the [38] means of conveyance. The world has been very well satisfied with these opinions, and prejudiced with respect to any observations about them. Men of learning and capacity have had many opportunities in passing those regions where these phenomena were most frequent, but seem industriously to have declined any notice of them, unless to escape danger, as a matter of mere impertinence in a case so clear and certain as their nature and manner of operation are taken to be. Hence it has been very difficult to get any tolerable accounts of them. None but those they fell near can inform us any thing to be depended on; three or four such instances follow, where the vessels were so near, that their crews could not avoid knowing something remarkable with respect to the matters in question.

Capt. John Wakefield, junior, passing the Straits of Gibraltar, had one fall by the side of his ship; it came down of a sudden, as they think, and all agree the descent was certain.

Captain Langstaff, on a voyage to the West Indies, had one come across the stern of his vessel, and passed away from him. The water came down in such quantity that the present Captain Melling, who was then a common sailor at helm, says it almost drowned him, running into his mouth, nose, ears, &c. and adds, that it tasted perfectly fresh.

One passed by the side of Captain Howland's ship, so near that it appeared pretty plain that the water descended from first to last.

Mr. Robert Spring was so near one in the Straits of Malacca, that he could perceive it to be a small very thick rain.

All these assure me, that there was no wind drawing towards them, nor have I found any others that have observed such [39] a wind.

It seems plain, by these few instances, that whirlwinds do not always attend spouts; and that the water really descends in some of them. But the following consideration, in confirmation of this opinion, may, perhaps, render it probable that all the spouts are descents.

It seems unlikely that there should be two sorts of spouts, one ascending and the other descending.

It has not yet been proved that any one spout ever ascended. A specious appearance is all that can be produced in favour of this; and those who have been most positive about it, were at more than a league's distance when they observed, as Stuart and others, if I am not mistaken. However, I believe it impossible to be certain whether water ascends or descends at half the distance.

It may not be amiss to consider the places where they happen most. These are such as are liable to calms from departing winds on both sides, as on the borders of the equinoctial trade, calms on the coast of Guinea, in the Straits of Malacca, &c. places where the under region of the atmosphere is drawn off horizontally. I think they do not come where the calms are without departing winds; and I take the reason to be, that such places, and places where winds blow towards one another, are liable to whirlwinds, or other ascents of the lower region, which I suppose contrary to spouts. But the former are liable to descents, which I take to be necessary to their production. Agreeable to this, it seems reasonable to believe, that any Mediterranean sea should be more subject to spouts than others. The sea usually so called is so. The [40] Straits of Malacca is. Some large gulphs may probably be so, in suitable latitudes; so the Red Sea, &c. and all for this reason, that the heated lands on each side draw off the under region of the air, and make the upper descend, whence sudden and wonderful condensations may take place, and make these descents.

It seems to me, that the manner of their appearance and procedure, favour the notion of a descent.

More or less of a cloud, as I am informed, always appears over the place first; then a spattering on the surface of the water below; and when this is advanced to a considerable degree, the spout emerges from the cloud, and descends, and that, if the causes are sufficient, down to the places of spattering, with a roaring in proportion to the quantity of the discharge; then it abates, or stops, sometimes more gradually, sometimes more suddenly.

I must observe a few things on these particulars, to shew how I think they agree with my hypothesis.

The preceding cloud over the place shews condensation, and, consequently, tendency downwards, which therefore must naturally prevent any ascent. Besides that, so far as I can learn, a whirlwind never comes under a cloud, but in a clear sky.

The spattering may be easily conceived to be caused by a stream of drops, falling with great force on the place, imagining the spout to begin so, when a sudden and great condensation happens in a contracted space, as the Ox-Eye on the coast of Guinea.

The spout appearing to descend from the cloud seems to be, by the stream of nearly contiguous drops bringing the air [41]
into consent, so as to carry down a quantity of the vapour of the cloud; and the pointed appearance it makes may be from the descending course being swiftest in the middle, or centre of the spout: this naturally drawing the outer parts inward, and the centre to a point; and that will appear foremost that moves swiftest. The phenomenon of retiring and advancing, I think may be accounted for, by supposing the progressive motion to exceed or not equal the consumption of the vapour by condensation. Or more plainly thus: the descending vapour which forms the apparent spout, if it be slow in its progress downwards, is condensed as fast as it advances, and so appears at a stand; when it is condensed faster than it advances, it appears to retire; and *vice versa*.

Its duration, and manner of ending, are as the causes, and may vary by several accidents.

The cloud itself may be so circumstanced as to stop it; as when, extending wide, it weighs down at a distance round about, while a small circle at the spout being exonerated by the discharge ascends and shuts up the passage. A new determination of wind may, perhaps, stop it too. Places liable to these appearances are very liable to frequent and sudden alterations of it.

Such accidents as a clap of thunder, firing cannon, &c. may stop them, and the reason may be, that any shock of this kind may occasion the particles that are near cohering, immediately to do so; and then the whole, thus condensed, falls at once (which is what I suppose is vulgarly called the breaking of the spout) and in the interval, between this period and that of the next set of particles being ready to unite, the spout shuts up. So that if this reasoning is just, these phenomena [42]
agree with my hypothesis.

The usual temper of the air, at the time of their appearance, if I have a right information, is for me to; it being then pretty cool for the season and climate; and this is worth remark, because cool air is weighty, and will not ascend; besides, when the air grows cool, it shews that the upper region descends, and conveys this temper down; and when the tempers are equal, no whirlwind can take place. But spouts have been known, when the lower region has been really cold. Gordon's spout in the Downs is an instance of this—(*Vide Philosophical Transactions*)—where the upper region was probably not at all cooler, if so cold as the lower: it was a cold day in the month of March, hail followed, but not snow, and it is observable, that not so much as hail follows or accompanies them in moderate seasons or climes, when and where they are most frequent. However, it is not improbable, that just about the place of descent may be cooler than the neighbouring parts, and so favour the wonderful celerity of condensation. But, after all, should we allow the under region to be ever so much the hottest, and a whirlwind to take place in it: suppose then the sea-water to ascend, it would certainly cool the spout, and then, query, whether it would not very much, if not wholly, obstruct its progress.

It commonly rains when spouts disappear, if it did not before, which it frequently does not, by the best accounts I have had; but the cloud encreases much faster after they disappear, and it soon rains. The first shews the spout to be a contracted rain, instead of the diffused one that follows; and the latter that the cloud was not formed by ascending water, [43]
for then it would have ceased growing when the spout vanished.

However, it seems that spouts have sometimes appeared after it began to rain; but this is one way a proof of my hypothesis, viz. as whirlwinds do not come under a cloud.

I forgot to mention, that the increase of cloud, while the spout subsists, is no argument of an ascent of water, by the spout. Since thunder-clouds sometimes encrease greatly while it rains very hard.

Divers effects of spouts seem not so well accounted for any other way as by descent.

The bush round the feet of them seems to be a great spray of water made by the violence of descent, like that in great falls of water from high precipices.

The great roar, like some vast inland falls, is so different from the roar of whirlwinds, by all acounts, as to be no ways compatible.

The throwing things from it with great force, instead of carrying them up into the air, is another difference.

There seems some probability that the sailors traditionary belief, that spouts may break in their decks, and so destroy vessels, might originate from some facts of that sort in former times. This danger is apparent on my hypothesis, but it seems not so on the other: and my reason for it is, that the whole column of a spout from the sea to the clouds, cannot, in a natural way, even upon the largest supposition, support more than about three feet water, and from truly supposeable causes, not above one foot, as may appear more plainly by and by. Supposing now the largest of these quantities to rise, it must be disseminated into drops, from the surface of the sea to the region of the clouds, or higher; for this reason it is [44]
quite unlikely to be collected into masses, or a body, upon its falling; but would descend in progression according to the several degrees of altitude the different portions had arrived at when it received this new determination.

Now that there cannot more rise upon the common hypothesis than I have mentioned, may appear probable, if we attend to the only efficient cause in supposed ascending spouts, viz. whirlwinds.

We know that the rarefaction of the lower, and the condensation of the upper region of air, are the only natural causes of whirlwinds. Let us then suppose the former as hot as their greatest summer heat in England, and the latter as cold as the extent of their winter. These extremes have been found there to alter the weight of the air one-tenth, which is equal to a little more than three feet water. Were this case possible, and a whirlwind take place in it, it might act with a force equal to the mentioned difference. But as this is the whole strength, so much water could not rise; therefore to allow it due motion upwards, we must abate, at least, one-fourth part, perhaps more, to give it such a swift ascension as some think usual. But here several difficulties occur, at least they are so to me. As, whether this quantity would render the spout opaque? since it is plain that in drops it could not do so. How, or by what means it may be reduced small enough? or, if the water be not reduced into vapour, what will suspend it in the region of the clouds when exonerated there? And, if vapourized while ascending, how can it be dangerous by what they call the breaking? For it is difficult to conceive how a condensative power should instantaneously take place of a rarefying and disseminating one. [45]

The sudden fall of the spout, or rather, the sudden ceasing of it, I accounted for, in my way, before. But it seems necessary to mention something I then forgot. Should it be said to do so (*i. e.*) to fall, because all the lower rarefied air is ascended, whence the whirlwind must cease, and its burden drop; I cannot agree to this, unless the air be observed on a sudden to have grown much colder, which I cannot learn has been the case. Or should it be supposed that the spout was, on a sudden, obstructed at the top, and this the cause of the fall, however plausible this might appear, yet no more water would fall than what was at the same time contained in the column, which is often, by many and satisfactory accounts to me, again far from being the case.

We are, I think, sufficiently assured, that not only tons, but scores or hundreds of tons descend in one spout. Scores of tons more than can be contained in the trunk of it, should we suppose water to ascend.

But, after all, it does not appear that the above-mentioned different degrees of heat and cold concur in any region where spouts usually happen, nor, indeed, in any other.

Observations on the Meteorological Paper; by a Gentleman in Connecticut.

Read at the Royal Society, Nov. 4, 1756.

"Air and water mutually attract each other, (saith Mr. F.) hence water will dissolve in air, as salt in water." I think that he hath demonstrated, that the supporting of salt in water is not owing to its superficies being increased, because "the specific gravity of salt is not altered by dividing of it, any more than that of lead, sixteen bullets of which, of an ounce each, weigh as much in water as one of a pound." But yet, when this came to be applied to the supporting of water in air, I found an objection rising in my mind. [46]

In the first place, I have always been loth to seek for any new hypothesis, or particular law of nature, to account for any thing that may be accounted for from the known, general, and universal law of nature; it being an argument of the infinite wisdom of the author of the world, to effect so many things by one general law. Now I had thought that the rising and support of water in air, might be accounted for from the general law of gravitation, by only supposing the spaces occupied by the same quantity of water increased.

And, with respect to the lead, I queried thus in my own mind; whether if the superficies of a bullet of lead should be increased four or five fold by an internal vacuity, it would weigh the same in water as before. I mean, if a pound of lead should be formed into a hollow globe, empty within, whose superficies should be four or five times as big as that of the same lead when a solid lump, it would weigh as much in water as before. I supposed it would not. If this concavity was filled with water, perhaps it might; if with air, it would weigh at least as much less, as this difference between the weight of that included air, and that of water.

Now although this would do nothing to account for the dissolution of salt in water, the smallest lumps of salt being no more hollow spheres, or any thing of the like nature than the greatest; yet, perhaps, it might account for water's rising and [47] being supported in air. For you know that such hollow globules, or bubbles, abound upon the surface of the water, which even by the breath of our mouths, we can cause to quit the water, and rise in the air.

These bubbles I used to suppose to be coats of water, containing within them air rarefied and expanded with fire, and that, therefore, the more friction and dashing there is upon the surface of the waters, and the more heat and fire, the more they abound.

And I used to think, that although water be specifically heavier than air, yet such a bubble, filled only with fire and very rarefied air, may be lighter than a quantity of common air, of the same cubical dimensions, and, therefore, ascend; for the rarefied air inclosed, may more fall short of the same bulk of common air, in weight, than the watery coat exceeds a like bulk of common air in gravity.

This was the objection in my mind, though, I must confess, I know not how to account for the watery coat's encompassing the air, as above-mentioned, without allowing the attraction between air and water, which the gentleman supposes; so that I do not know but that this objection, examined by that sagacious genius, will be an additional confirmation of the hypothesis.

The gentleman observes, "that a certain quantity of moisture should be every moment discharged and taken away from the lungs; and hence accounts for the suffocating nature of snuffs of candles, as impregnating the air with grease, between which and water there is a natural repellency; and of air that hath been frequently breathed in, which is overloaded with water, and, for that reason, can take no more air. Perhaps the same observation will account for the suffocating nature of [48] damps in wells."

But then if the air can support and take off but such a proportion of water, and it is necessary that water be so taken off from the lungs, I queried with myself how it is we can breathe in an air full of vapours, so full as that they continually precipitated. Do not we see the air overloaded, and casting forth water plentifully when there is no suffocation?

The gentleman again observes, "That the air under the equator, and between the tropics, being constantly heated and rarefied by the sun, rises; its place is supplied by air from northern and southern latitudes, which, coming from parts where the air and earth 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."

In reading this, two objections occurred to my mind:

First, that it is said, the trade-wind doth not blow in the forenoon, but only in the afternoon.

Secondly, that either the motion of the northern and southern air towards the equator is so slow, as to acquire almost the same motion as the equatorial air when it arrives there, so that there will be no sensible difference; or else the motion of the northern and southern air towards the equator, is quicker, and must be sensible; and then the trade-wind must appear either as a south-east or north-east wind: south of the equator, a south-east wind; north of the equator, a north-east. For the apparent wind must be compounded of this motion from north to south, or *vice versa*; and of the difference between its [49] motion from west to east, and that of the equatorial air.

Observations in Answer to the foregoing, by B. Franklin.

Read at the Royal Society, Nov. 4, 1756.

1st. The supposing a mutual attraction between the particles of water and air is not introducing a new law of nature; such attractions taking place in many other known instances.

2dly. Water is specifically 850 times heavier than air. To render a bubble of water, then, specifically lighter than air, it seems to me that it must take up more than 850 times the space it did before it formed the bubble; and within the bubble should be either a vacuum or air rarefied more than 850 times. If a vacuum, would not the bubble be immediately crushed by the weight of the atmosphere? And no heat, we know of, will rarefy air any thing near so much; much less the common heat of the sun, or that of friction by the dashing on the surface of the water. Besides, water agitated ever so violently produces no heat, as has been found by accurate experiments.

3dly. A hollow sphere of lead has a firmness and consistency in it, that a hollow sphere or bubble of fluid unfrozen water cannot be supposed to have. The lead may support the pressure of the water it is immersed in, but the bubble could not support the pressure of the air, if empty within.

4thly. Was ever a visible bubble seen to rise in air? I have made many, when a boy, with soap-suds and a tobacco-pipe; [50] but they all descended when loose from the pipe, though slowly, the air impeding their motion. They may, indeed, be forced up by a wind from below, but do not rise of themselves, though filled with warm breath.

5thly. The objection relating to our breathing moist air seems weighty, and must be farther considered. The air that has been breathed has, doubtless, acquired an addition of the perspirable matter which nature intends to free the body from, and which would be pernicious if retained and returned into the blood; such air then may become unfit for respiration, as well for that reason, as on account of its moisture. Yet I should be glad to learn, by some accurate experiment, whether a draft of air, two or three times inspired, and expired, perhaps in a bladder, has, or has not, acquired more moisture than our common air in the dampest weather. As to the precipitation of water in the air we breathe, perhaps it is not always a mark of that air's being overloaded. In the region of the clouds, indeed, the air must be overloaded if it lets fall its water in drops, which we call rain; but those drops may fall through a drier air near the earth; and accordingly we find that the hygroscope sometimes shews a less degree of moisture, during a shower, than at other times when it does not rain at all. The dewy dampness, that settles on the insides of our walls and wainscots, seems more certainly to denote an air overloaded with moisture; and yet this is no sure sign: for, after a long continued cold season, if the air grows suddenly warm, the walls, &c. continuing longer their coldness, will, for some time, condense the moisture of such air, till they grow equally warm, and then they condense no more, though the air is not become drier. And, on the other hand, after a [51] warm season, if the air grows cold, though moister than before, the dew is not so apt to gather on the walls. A tankard of cold water will, in a hot and dry summer's day, collect a dew on its outside; a tankard of hot water will collect none in the moistest weather.

6thly. It is, I think, a mistake that the trade-winds blow only in the afternoon. They blow all day and all night, and all the year round, except in some particular places. The southerly sea-breezes on your coasts, indeed, blow chiefly in the afternoon. In the very long run from the west side of America to Guam, among the Philippine Islands, ships seldom have occasion to hand their sails, so equal and steady is the gale, and yet they make it in about 60 days, which could not be if the wind blew only in the afternoon.

7thly. That really is, which the gentleman justly supposes ought to be on my hypothesis. In sailing southward, when you first enter the trade-wind, you find it north-east, or thereabouts, and it gradually grows more east as you approach the line. The same observation is made of its changing from south-east to east gradually, as you come from the southern latitudes to the equator.

Observations on the Meteorological Paper; sent by a Gentleman[10] *in New-York to B. Franklin.*

Read at the Royal Society, Nov. 4, 1756.

That power by which the air expands itself, you attribute to a mutual repelling power in the particles which compose the air, by which they are separated from each other with some degree of force: now this force, on this supposition, must not only act when the particles are in mutual contact, but likewise when they are at some distance from each other. How can two bodies, whether they be great or small, act at any distance, whether that distance be small or great, without something intermediate on which they act? For if any body act on another, at any distance from it, however small that distance be, without some medium to continue the action, it must act where it is not, which to me seems absurd. [52]

It seems to me, for the same reason, equally absurd to give a mutual attractive power between any other particles supposed to be at a distance from each other, without any thing intermediate to continue their mutual action. I can neither attract nor repel any thing at a distance, without something between my hand and that thing, like a string, or a stick; nor can I conceive any mutual action without some middle thing, when the action is continued to some distance.

The encrease of the surface of any body lessens its weight, both in air, and water, or any other fluid, as appears by the slow descent of leaf-gold in the air.

The observation of the different density of the upper and lower air, from heat and cold, is good, and I do not remember it is taken notice of by others; the consequences also are well drawn; but as to winds, they seem principally to arise from some other cause. Winds generally blow from some large tracts of land, and from mountains. Where I live, on the north side of the mountains, we frequently have a strong southerly wind, when they have as strong a northerly wind, or calm, on [53] the other side of these mountains. The continual passing of vessels on Hudson's River, through these mountains, give frequent opportunities of observing this.

In the spring of the year the sea-wind (by a piercing cold) is always more uneasy to me, accustomed to winds which pass over a tract of land, than the north-west wind.

You have received the common notion of water-spouts, which, from my own ocular observation, I am persuaded is a false conception. In a voyage to the West-Indies, I had an opportunity of observing many water-spouts. One of them passed nearer than thirty or forty yards to the vessel I was in, which I viewed with a good deal of attention; and though it be now forty years since I saw it, it made so strong an impression on me, that I very distinctly remember it. These water-spouts were in the calm latitudes, that is, between the trade and the variable winds, in the month of July. That spout which passed so near us was an inverted cone, with the *tip* or *apex* towards the sea, and reached within about eight feet of the surface of the sea, its basis in a large black cloud. We were entirely becalmed. It passed slowly by the vessel. I could plainly observe, that a violent stream of wind issued from the spout, which made a hollow of about six feet diameter in the surface of the water, and raised the water in a circular uneven ring round the hollow, in the same manner that a strong blast from a pair of bellows would do when the pipe is placed perpendicular to the surface of the water; and we plainly heard the same hissing noise which such a blast of wind must produce on the water. I am very sure there was nothing like the sucking of water from the sea into the spout, unless the spray, which was raised in a ring to a small height, could be [54] mistaken for a raising of water. I could plainly distinguish a distance of about eight feet between the sea and the tip of the cone, in which nothing interrupted the sight, which must have been, had the water been raised from the sea.

In the same voyage I saw several other spouts at a greater distance, but none of them whose tip of the cone came so near the surface of the water. In some of them the axis of the cone was considerably inclined from the perpendicular, but in none of them was there the least appearance of sucking up of water. Others of them were bent or arched. I believe that a stream of wind issued from all of them, and it is from this stream of wind that vessels are often overset, or founder at sea suddenly. I have heard of vessels being overset when it was perfectly calm, the instant before the stream of wind struck them, and immediately after they were overset; which could not otherwise be but by such a stream of wind from a cloud.

That wind is generated in clouds will not admit of a dispute. Now if such wind be generated within the body of the cloud, and issue in one particular place, while it finds no passage in the other parts of the cloud, I think it may not be difficult to account for all the appearances in water-spouts; and from hence the reason of breaking those spouts, by firing a cannon-ball through them, as thereby a horizontal vent is given to the wind. When the wind is spent, which dilated the cloud, or the fermentation ceases, which generates the air and wind, the clouds may descend in a prodigious fall of water or rain. A remarkable intestine motion, like a violent fermentation, is very observable in the cloud from whence the spout [55] issues. No salt-water, I am persuaded, was ever observed to fall from the clouds, which must certainly have happened if sea-water had been raised by a spout.

FOOTNOTE:

[10] Mr. Cadwallader Colden. *Editor.*

Answer to the foregoing Observations, by B. Franklin.

Read at the Royal Society, Nov. 4, 1756.

I agree with you, that it seems absurd to suppose that a body can act where it is not. I have no idea of bodies at a distance attracting or repelling one another without the assistance of some medium, though I know not what that medium is, or how it operates. When I speak of attraction or repulsion, I make use of those words for want of others more proper, and intend only to express *effects* which I see, and not *causes* of which I am ignorant. When I press a blown bladder between my knees, and find I cannot bring its sides together, but my knees feel a springy matter, pushing them back to a greater distance, or repelling them, I conclude that the air it contains is the cause. And when I operate on the air, and find I cannot by pressure force its particles into contact, but they still spring back against the pressure, I conceive there must be some medium between its particles that prevents their closing, though I cannot tell what it is. And if I were acquainted with that medium, and found its particles to approach and recede from each other, according to the pressure they suffered, I should imagine there must be some finer medium between them, by which these operations were performed.

I allow that increase of the surface of a body may occasion it to descend slower in air, water, or any other fluid; but do [56] not conceive, therefore, that it lessens its weight. Where the increased surface is so disposed as that in its falling a greater quantity of the fluid it sinks in must be moved out of its way, a greater time is required for such removal. Four square feet of sheet-lead sinking in water *broadways*, cannot descend near so fast as it would *edgeways*, yet its weight in the hydrostatic balance would, I imagine, be the same, whether suspended by the middle or by the corner.

I make no doubt but that ridges of high mountains do often interrupt, stop, reverberate, or turn the winds that blow against them, according to the different degrees of strength of the winds, and angles of incidence. I suppose, too, that the cold upper parts of mountains may condense the warmer air that comes near them, and so by making it specifically heavier, cause it to descend on one or both sides of the ridge into the warmer valleys, which will seem a wind blowing from the mountain.

Damp winds, though not colder by the thermometer, give a more uneasy sensation of cold than dry ones; because (to speak like an electrician) they *conduct* better; that is, are better fitted to convey away the heat from our bodies. The body cannot feel *without* itself; our sensation of cold is not in the air *without* the body, but in those parts of the body which have been deprived of their heat by the air. My desk, and its lock, are, I suppose, of the same temperament when they have been long exposed to the same air; but now if I lay my hand on the wood, it does not seem so cold to me as the lock; because (as I imagine) wood is not so good a conductor, to receive and convey away the heat from my skin, and the [57] adjacent flesh, as metal is. Take a piece of wood, of the size and shape of a dollar, between the thumb and finger of one hand, and a dollar, in like manner, with the other hand; place the edges of both, at the same time, in the flame of a candle; and though the edge of the wooden piece takes flame, and the metal piece does not, yet you will be obliged to drop the latter before the former, it conducting the heat more suddenly to your fingers. Thus we can, without pain, handle glass and china cups filled with hot liquors, as tea, &c. but not silver ones. A silver tea-pot must have a wooden handle. Perhaps it is for the same reason that woollen garments keep the body warmer than linen ones equally thick; woollen keeping the natural heat in, or, in other words, not conducting it out to air.

In regard to water-spouts, having, in a long letter to a gentleman of the same sentiment with you as to their direction, said all that I have to say in support of my opinion; I need not repeat the arguments therein contained, as I intend to send you a copy of it by some other opportunity, for your perusal. I imagine you will find all the appearances you saw, accounted for by my hypothesis. I thank you for communicating the account of them. At present I would only say, that the opinion of winds being generated in clouds by fermentation, is new to me, and I am unacquainted with the facts on which it is founded. I likewise find it difficult to conceive of winds confined in the body of clouds, which I imagine have little more solidity than the fogs on the earth's surface. The objection from the freshness of rain-water is a strong one, but I [58] think I have answered it in the letter above-mentioned, to which I must beg leave, at present, to refer you.

[In Mr. Collinson's edition, there followed here, several extracts, on water-spouts, from Dampier's Voyages, which, as Dampier's book is by no means scarce, and is consequently accessible to the reader, we have omitted, and shall content ourselves with giving the references. The extracts are three. The first is from Vol. I. p. 451. The second and third from Vol. III. p. 182 and 223.]

Gentleman of New York in Reply.

Read at the Royal Society, December 6, 1756.

April 2, 1754.

Any knowledge I have of the winds, and other changes which happen in the atmosphere, is so very defective, that it does not deserve the name; neither have I received any satisfaction from the attempts of others on this subject. It deserves then your thoughts, as a subject in which you may distinguish yourself, and be useful.

Your notion of some things conducting heat or cold better than others pleases me, and I wish you may pursue the scent. If I remember right, Dr. Boerhaave, in his chymistry, thinks that heat is propagated by the vibration of a subtle elastic fluid, dispersed through the atmosphere and through all bodies. Sir Isaac Newton says, there are many phenomena to prove the existence of such a fluid; and this opinion has my assent to it. I shall only observe that it is essentially different [59] from that which I call ether; for ether, properly speaking, is neither a fluid nor elastic; its power consists in re-acting any action communicated to it, with the same force it receives the action.

I long to see your explication of water-spouts, but I must tell you before-hand, that it will not be easy for you to convince me that the principal phenomena were not occasioned by a stream of wind issuing with great force, my eyes and ears both concurring to give me this sentiment, I could have no more evidence than to feel the effects, which I had no inclination to do.

It surprises me a little, that wind, generated by fermentation, is new to you, since it may be every day observed in fermenting liquor. You know with what force fermenting liquors will burst the vessels which contain them, if the generated wind have not vent; and with what force it issues on giving it a small vent, or by drawing the cork of a bottle. Dr. Boerhaave says, that the steam issuing from fermenting liquors received through a very small vent-hole, into the nose, will kill as suddenly and certainly as lightning. That air is generated by fermentation, I think you will find fully proved in Dr. Hales's Analysis of the Air, in his Vegetable Statics. If you have not read the book, you have a new pleasure to come.

The solution you give to the objection I made from the contrary winds blowing from the opposite sides of the mountains, from their being eddies, does not please me, because the extent of these winds is by far too large to be occasioned by any eddy. It is forty miles from New York to our mountains, through which Hudson's River passes. The river runs twelve miles in the mountains, and from the north side of the mountains it is about ninety miles to Albany. I [60] have myself been on board a vessel more than once, when we have had a strong northerly wind against us, all the way from New York, for two or three days. We have met vessels from Albany, who assured us, that, on the other side of the mountains, they had, at the same time, a strong continued southerly wind against them; and this frequently happens.

I have frequently seen, both on the river, in places where there could be no eddy-weeds, and on the open sea, two vessels sailing with contrary winds, within half a mile of each other; but this happens only in easy winds, and generally calm in other places near these winds.

You have, no doubt, frequently observed a single cloud pass, from which a violent gust of wind issues, but of no great extent. I have observed such a gust make a lane through the woods, of some miles in length, by laying the trees flat to the ground, and not above eight or ten chains in breadth. Though the violence of the wind be in the same direction in which the cloud moves and precedes it, yet wind issues from all sides of it; so that supposing the cloud moves south-easterly, those on the north-east side of it feel a south-west wind, and others on the south-west side, a north-east. And where the cloud passes over, we frequently have a south-east wind from the hinder part of it, but none violent, except the wind in the direction in which the cloud moves. To shew what it is which prevents the wind from issuing out equally on all sides, is not an easy problem to me, and I shall not attempt to solve it; but when you shall show what it is which restrains the electrical fluid from spreading itself into the air surrounding it, when it rushes with great violence through the air along, or [61] in the conductor, for a great extent in length, then I may hope to explain the other problem, and remove the difficulty we have in conceiving it.

TO PETER COLLINSON, ESQ. LONDON.

Account of a Whirlwind at Maryland.

Philadelphia, Aug. 25, 1755.

Dear Sir,

As you have my former papers on whirlwinds, &c. I now send you an account of one which I had lately an opportunity of seeing and examining myself.

Being in Maryland, riding with Colonel Tasker, and some other gentlemen, to his country seat, where I and my son were entertained by that amiable and worthy man with great hospitality and kindness, we saw, in the vale below us, a small whirlwind beginning in the road, and shewing itself by the dust it raised and contained. It appeared in the form of a sugar-loaf, spinning on its point, moving up the hill towards us, and enlarging as it came forward. When it passed by us, its smaller part near the ground appeared no bigger than a common barrel, but widening upwards, it seemed, at forty or fifty feet high, to be twenty or thirty feet in diameter. The rest of the company stood looking after it, but my curiosity being stronger, I followed it, riding close by its side, and observed its licking up, in its progress, all the dust that was under its smaller part. As it is a common opinion that a shot, fired through a water-spout, will break it, I tried to break this [62] little whirlwind, by striking my whip frequently through it, but without any effect. Soon after, it quitted the road and took into the woods, growing every moment larger and stronger, raising, instead of dust, the old dry leaves with which the ground was thick covered, and making a great noise with them and the branches of the trees, bending some tall trees round in a circle swiftly and very surprisingly, though the progressive motion of the whirl was not so swift but that a man on foot might have kept pace with it, but the circular motion was amazingly rapid. By the leaves it was now filled with, I could plainly perceive that the current of air they were driven by moved upwards in a spiral line; and when I saw the passing whirl continue entire, after leaving the trunks and bodies of large trees which it had enveloped, I no longer wondered that my whip had no effect on it in its smaller state. I accompanied it about three quarters of a mile, till some limbs of dead trees, broken off by the whirl, flying about, and falling near me, made me more apprehensive of danger; and then I stopped, looking at the top of it as it went on, which was visible, by means of the leaves contained in it, for a very great height above the trees. Many of the leaves, as they got loose from the upper and widest part, were scattered in the wind; but so great was their height in the air, that they appeared no bigger than flies. My son, who was, by this time, come up with me, followed the whirlwind till it left the woods, and crossed an old tobacco-field, where, finding neither dust nor leaves to take up, it gradually became invisible below as it went away over that field. The course of the general wind then blowing was along with us as we travelled, and the progressive motion of the whirlwind was in a direction nearly opposite, though it did not keep a strait line, nor was its progressive motion uniform, it making little sallies on either hand as it went, proceeding sometimes faster, and sometimes slower, and seeming sometimes for a few seconds almost stationary, then starting forwards pretty fast again. When we rejoined the company, they were admiring the vast height of the leaves now brought by the common wind, over our heads. These leaves accompanied us as we travelled, some falling now and then round about us, and some not reaching the ground till we had gone near three miles from the place where we first saw the whirlwind begin. Upon my asking Colonel Tasker if such whirlwinds were common in Maryland, he answered pleasantly, No, not at all common, but we got this on purpose to treat Mr. Franklin. And a very high treat it was to, [63]

Dear Sir,

Your affectionate friend and humble servant,

B. FRANKLIN.

TO MR. ALEXANDER SMALL, LONDON.

On the North-East Storms in North America.

May 12, 1760.

Dear Sir,

Agreeable to your request, I send you my reasons for thinking that our north-east storms in North America begin first, in point of time, in the south-west parts: that is to say, the air in Georgia, the farthest of our colonies to the south-west, [64] begins to move south-westerly before the air of Carolina, which is the next colony north-eastward; the air of Carolina has the same motion before the air of Virginia, which lies still more north-eastward; and so on north-easterly through Pensylvania, New-York, New-England, &c. quite to Newfoundland.

These north-east storms are generally very violent, continue sometimes two or three days, and often do considerable damage in the harbours along the coast. They are attended with thick clouds and rain.

What first gave me this idea, was the following circumstance. About twenty years ago, a few more or less, I cannot from my memory be certain, we were to have an eclipse of the moon at Philadelphia, on a Friday evening, about nine o'clock. I intended to observe it, but was prevented by a north-east storm, which came on about seven, with thick clouds as usual, that quite obscured the whole hemisphere. Yet when the post brought us the Boston news-paper, giving an account of the effects of the same storm in those parts, I found the beginning of the eclipse had been well observed there, though Boston lies N. E. of Philadelphia about four hundred miles. This puzzled me, because the storm began with us so soon as to prevent any observation, and being a north-east storm, I imagined it must have begun rather sooner in places farther to the north-east-ward than it did at Philadelphia. I therefore mentioned it in a letter to my brother, who lived at Boston; and he informed me the storm did not begin with them till near eleven o'clock, so that they had a good observation of the eclipse: and upon comparing all the other accounts I received from the several colonies, of the time of [65] beginning of the same storm, and since that of other storms of the same kind, I found the beginning to be always later the farther north-eastward. I have not my notes with me here in England, and cannot, from memory, say the proportion of time to distance, but I think it is about an hour to every hundred miles.

From thence I formed an idea of the cause of these storms, which I would explain by a familiar instance or two.—Suppose a long canal of water stopped at the end by a gate. The water is quite at rest till the gate is open, then it begins to move out through the gate; the water next the gate is first in motion, and moves towards the gate; the water next to that first water moves next, and so on successively, till the water at the head of the canal is in motion, which is last of all. In this case all the water moves indeed towards the gate, but the successive times of beginning motion are the contrary way, viz. from the gate backwards to the head of the canal. Again, suppose the air in a chamber at rest, no current through the room till you make a fire in the chimney. Immediately the air in the chimney being rarefied by the fire rises; the air next the chimney flows in to supply its place, moving towards the chimney; and, in consequence, the rest of the air successively, quite back to the door. Thus to produce our north-east storms, I suppose some great heat and rarefaction of the air in or about the Gulph of Mexico; the air thence rising has its place supplied by the next more northern, cooler, and therefore denser and heavier, air; that, being in motion, is followed by the next more northern air, &c. &c. in a successive current, to which current our coast and inland ridge of mountains give the direction of north-east, as they lie N. E. and S. [66] W.

This I offer only as an hypothesis to account for this particular fact; and perhaps, on farther examination, a better and truer may be found. I do not suppose all storms generated in the same manner. Our north-west thunder-gusts in America, I know are not; but of them I have written my opinion fully in a paper which you have seen.

I am, &c.

B. FRANKLIN.

Meteorological Imaginations and Conjectures[11].

There seems to be a region higher in the air over all countries, where it is always winter, where frost exists continually, since in the midst of summer, on the surface of the earth, ice falls often from above in the form of hail.

Hailstones, of the great weight we sometimes find them, did not probably acquire their magnitude before they began to descend. The air, being eight hundred times rarer than water, is unable to support it but in the shape of vapour, a state in which its particles are separated. As soon as they are condensed by the cold of the upper region, so as to form a drop, that drop begins to fall. If it freezes into a grain of ice, that ice descends. In descending, both the drop of water and the grain of [67] ice are augmented by particles of the vapour they pass through in falling, and which they condense by coldness, and attach to themselves.

It is possible that, in summer, much of what is rain, when it arrives at the surface of the earth, might have been snow when it began its descent; but being thawed, in passing through the warm air near the surface, it is changed from snow into rain.

How immensely cold must be the original particle of hail, which forms the centre of the future hailstone, since it is capable of communicating sufficient cold, if I may so speak, to freeze all the mass of vapour condensed round it, and form a lump of perhaps six or eight ounces in weight!

When, in summer time, the sun is high, and continues long every day above the horizon, his rays strike the earth more directly, and with longer continuance, than in the winter; hence the surface is more heated, and to a greater depth, by the effect of those rays.

When rain falls on the heated earth, and soaks down into it, it carries down with it a great part of the heat, which by that means descends still deeper.

The mass of earth, to the depth perhaps of thirty feet, being thus heated to a certain degree, continues to retain its heat for some time. Thus the first snows that fall in the beginning of winter, seldom lie long on the surface, but are soon melted, and soon absorbed. After which, the winds, that blow over the country on which the snows had fallen, are not rendered so cold as they would have been, by those snows, if they had remained, and thus the approach of the severity of winter is retarded; and the extreme degree of its cold is not always at the time we might expect it, viz. when the sun is at [68] its greatest distance, and the day shortest, but some time after that period, according to the English proverb, which says, "as the day lengthens, the cold strengthens;" the causes of refrigeration continuing to operate, while the sun returns too slowly, and his force continues too weak to counteract them.

During several of the summer months of the year 1783, when the effects of the sun's rays to heat the earth in these northern regions should have been the greatest, there existed a constant fog over all Europe, and great part of North America. This fog was of a permanent nature: it was dry, and the rays of the sun seemed to have little effect towards dissipating it, as they easily do a moist fog, arising from water. They were indeed rendered so faint in passing through it, that when collected in the focus of a burning glass, they would scarce kindle brown paper. Of course, their summer effect in heating the earth was exceedingly diminished.

Hence the surface was early frozen.

Hence the first snows remained on it unmelted, and received continual additions.

Hence perhaps the winter of 1783-4, was more severe than any that had happened for many years.

The cause of this universal fog is not yet ascertained. Whether it was adventitious to this earth, and merely a smoke proceeding from the consumption by fire of some of those great burning balls or globes which we happen to meet with in our rapid course round the sun, and which are sometimes seen to kindle and be destroyed in passing our atmosphere, and whose smoke might be attracted and retained by our earth; or whether it was the vast quantity of smoke, long continuing [69]
to issue during the summer from Hecla, in Iceland, and that other volcano which arose out of the sea near that island, which smoke might be spread by various winds, over the northern part of the world, is yet uncertain.

It seems however worth the enquiry, whether other hard winters, recorded in history, were preceded by similar permanent and widely extended summer fogs. Because, if found to be so, men might from such fogs conjecture the probability of a succeeding hard winter, and of the damage to be expected by the breaking up of frozen rivers in the spring; and take such measures as are possible and practicable, to secure themselves and effects from the mischiefs that attended the last.

Passy, May 1784.

FOOTNOTE:

[11] This paper is taken from the Memoirs of the Literary and Philosophical Society of Manchester, Vol. II. page 373. It was communicated by Dr. Percival, and read December 22, 1784. *Editor.*

Suppositions and Conjectures towards forming an Hypothesis, for the Explanation of the Aurora Borealis[12].

1. Air heated by any means, becomes rarefied, and specifically lighter than other air in the same situation not heated.

2. Air being made thus lighter rises, and the neighbouring cooler heavier air takes its place.

3. If in the middle of a room you heat the air by a stove, or pot of burning coals near the floor, the heated air will rise to the ceiling, spread over the cooler air till it comes to the cold walls; there, being condensed and made heavier, it descends [70] to supply the place of that cool air, which had moved towards the stove or fire, in order to supply the place of the heated air, which had ascended from the space around the stove or fire.

4. Thus there will be a continual circulation of air in the room; which may be rendered visible by making a little smoke, for that smoke will rise and circulate with the air.

5. A similar operation is performed by nature on the air of this globe. Our atmosphere is of a certain height, perhaps at a medium [   ] miles: above that height it is so rare as to be almost a vacuum. The air heated between the tropics is continually rising; its place is supplied by northerly and southerly winds, which come from the cooler regions.

6. The light heated air, floating above the cooler and denser, must spread northward and southward; and descend near the two poles, to supply the place of the cool air, which had moved towards the equator.

7. Thus a circulation of air is kept up in our atmosphere, as in the room above-mentioned.

8. That heavier and lighter air may move in currents of different and even opposite direction, appears sometimes by the clouds that happen to be in those currents, as plainly as by the smoke in the experiment above-mentioned. Also in opening a *door* between two chambers, one of which has been warmed, by holding a candle near the top, near the bottom, and near the middle, you will find a strong current of warm air passing out of the warmed room above, and another of cool air entering below; while in the middle there is little or no motion.

9. The great quantity of vapour rising between the tropics forms clouds, which contain much electricity. [71]

Some of them fall in rain, before they come to the polar regions.

10. If the rain be received in an isolated vessel, the vessel will be electrified; for every drop brings down some electricity with it.

11. The same is done by snow or hail.

12. The electricity so descending, in temperate climates, is received and imbibed by the earth.

13. If the clouds are not sufficiently discharged by this gradual operation, they sometimes discharge themselves suddenly by striking into the earth, where the earth is fit to receive their electricity.

14. The earth in temperate and warm climates is generally fit to receive it, being a good conductor.

15. A certain quantity of heat will make some bodies good conductors, that will not otherwise conduct.

16. Thus wax rendered fluid, and glass softened by heat, will both of them conduct.

17. And water, though naturally a good conductor, will not conduct well, when frozen into ice by a common degree of cold; not at all, where the cold is extreme.

18. Snow falling upon frozen ground has been found to retain its electricity; and to communicate it to an isolated body, when after falling, it has been driven about by the wind.

19. The humidity, contained in all the equatorial clouds that reach the polar regions, must there be condensed and fall in snow.

20. The great cake of ice that eternally covers those regions may be too hard frozen to permit the electricity, descending [72]
with that snow, to enter the earth.

21. It may therefore be *accumulated upon that ice*.

22. The atmosphere being heavier in the polar regions than in the equatorial, will there be lower; as well from that cause, as from the smaller effect of the centrifugal force: consequently the distance of the vacuum above the atmosphere will be less at the poles, than elsewhere; and probably much less than the distance (upon the surface of the globe) extending from the pole to those latitudes in which the earth is so thawed as to receive and imbibe electricity; (the frost continuing to lat. 80, which is ten degrees, or six hundred miles from the pole; while the height of the atmosphere there of such density as to obstruct the motion of the electric fluid, can scarce be esteemed above [ ] miles).

23. The *vacuum* above is a good conductor.

24. May not then the great quantity of electricity, brought into the polar regions by the clouds, which are condensed there, and fall in snow, which electricity would enter the, earth, but cannot penetrate the ice; may it not, I say, (*as a bottle overcharged*) break through that low atmosphere, and run along in the vacuum over the air towards the equator; diverging as the degrees of longitude enlarge; strongly visible where densest, and becoming less visible as it more diverges; till it finds a passage to the earth in more temperate climates, or is mingled with their upper air?

25. If such an operation of nature were really performed, would it not give all the appearances of an aurora borealis?

26. And would not the auroras become more frequent *after the approach of winter*: not only because more visible in [73]
longer nights; but also because in summer the long presence of the sun may soften the surface of the great ice cake, and render it a conductor, by which the accumulation of electricity in the polar regions will be prevented?

27. The *atmosphere of the polar regions* being made more dense by the extreme cold, and all the moisture in that air being frozen; may not any great light arising therein, and passing, through it, render its density in some degree visible, during the night time, to those who live in the rarer air of more southern latitudes; and would it not in that case, although in itself a complete and full circle, extending perhaps ten degrees from the pole, appear to spectators so placed (who could see only a part of it) *in the form of a segment*; its chord resting on the horizon, and its arch elevated more or less above it as seen from latitudes more or less distant; *darkish in colour*, but yet *sufficiently transparent* to permit some stars to be seen through it.

28. The *rays* of electric matter issuing out of a body, diverge by mutually repelling each other, unless there be some conducting body near, to receive them: and if that conducting body be at a greater distance, they will *first diverge*, and then *converge* in order to enter it. May not this account for some of the varieties of figure seen at times in the *motions* of the luminous matter of the auroras: since it is possible, that in passing over the atmosphere, from the north in all directions or meridians, towards the equator, the rays of that matter may find, in many places, portions of cloudy region, or moist atmosphere under them, which (being in the natural or negative state) may be fit to receive them, and towards which they [74]
may therefore converge: and when one of those receiving bodies is more than saturated, they may *again* diverge from it, towards other surrounding masses of such humid atmosphere, and thus form the *crowns*, as they are called, and other figures mentioned in the histories of this meteor?

29. If it be true that the clouds which go to the polar regions, and carry thither the vapours of the equatorial and temperate regions, [have their] vapours condensed by the extreme cold of the polar regions, and fall in snow or hail; the winds which come from those regions ought to be generally dry, unless they gain some humidity by sweeping the ocean in their way. And if I mistake not, the winds between the north east and the north west, are for the most part dry, when they have continued for some time.

[In the Philosophical Transactions for 1774, p. 122, is a letter from Mr. I. S. Winn to Dr. Franklin, stating, that since he had first made the observation concerning the south or south west winds succeeding an aurora, he had found it invariably obtaining in twenty-three instances; and he adds in a note a fresh confirming instance. In reply, Dr. Franklin makes the following conjecture.]

The *Auroræ Boreales*, though visible almost every night of clear weather in the more northern regions and very high in the atmosphere, can scarce be visible in England, but when the atmosphere is pretty clear of clouds for the whole space between us and those regions; and therefore are seldom visible here. This extensive clearness may have been produced by a long continuance of northerly winds. When the winds have long continued in one quarter, the return is often violent. [75] Allowing the fact so repeatedly observed by Mr. Winn, perhaps this may account for the violence of the southerly winds, that soon follow the appearance of the aurora on our coasts.

FOOTNOTES:

[12] If I mistake not, this paper was read to the Royal Academy of Sciences, at Paris, at the meeting held immediately after Easter, 1779. B. V[13].

[13] For an explanation of the signature B. V. see the note in page 399 of Vol. I. *Editor.*

TO DR. L.[14] AT CHARLES-TOWN, SOUTH-CAROLINA.

On Cold produced by Evaporation.

New-York, April 14, 1757.

Sir,

It is a long time since I had the pleasure of a line from you; and, indeed, the troubles of our country, with the hurry of business I have been engaged in on that account, have made me so bad a correspondent, that I ought not to expect punctuality in others.

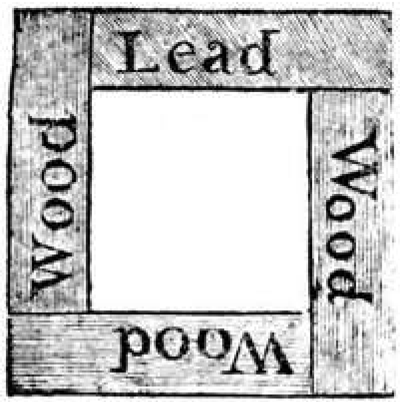
But being about to embark for England, I could not quit the continent without paying my respects to you, and, at the same time, taking leave to introduce to your acquaintance a gentleman of learning and merit, colonel Henry Bouquet, who does me the favour to present you this letter, and with whom I am sure you will be much pleased.

Professor Simpson, of Glasgow, lately communicated to me some curious experiments of a physician of his acquaintance, by which it appeared, that an extraordinary degree of cold, even to freezing, might be produced by evaporation. I have not had leisure to repeat and examine more than the first and easiest of them, *viz.*—Wet the ball of a [76] thermometer by a feather dipt in spirit of wine, which has been kept in the same room, and has, of course, the same degree of heat or cold. The mercury sinks presently three or four degrees, and the quicker, if, during the evaporation, you blow on the ball with bellows; a second wetting and blowing, when the mercury is down, carries it yet lower. I think I did not get it lower than five or six degrees from where it naturally stood, which was, at that time, sixty. But it is said, that a vessel of water being placed in another somewhat larger, containing spirit, in such a manner that the vessel of water is surrounded with the spirit, and both placed under the receiver of an air-pump; on exhausting the air, the spirit, evaporating, leaves such a degree of cold as to freeze the water, though the thermometer, in the open air, stands many degrees above the freezing point.

I know not how this phenomenon is to be accounted for, but it gives me occasion to mention some loose notions relating to heat and cold, which I have for some time entertained, but not yet reduced into any form. Allowing common fire, as well as electrical, to be a fluid capable of permeating other bodies, and seeking an equilibrium, I imagine some bodies are better fitted by nature to be conductors of that fluid than others; and that, generally, those which are the best conductors of the electrical fluid, are also the best conductors of this; and *e contra*.

Thus a body which is a good conductor of fire readily receives it into its substance, and conducts it through the whole to all the parts, as metals and water do; and if two bodies, both good conductors, one heated, the other in its common [77] state, are brought into contact with each other, the body which has most fire readily communicates of it to that which had least, and that which had least readily receives it, till an equilibrium is produced. Thus, if you take a dollar between your fingers with one hand, and a piece of wood, of the same dimensions, with the other, and bring both at the same time to the flame of a candle, you will find yourself obliged to drop the dollar before you drop the wood, because it conducts the heat of the candle sooner to your flesh. Thus, if a silver tea-pot had a handle of the same metal, it would conduct the heat from the water to the hand, and become too hot to be used; we therefore give to a metal tea-pot a handle of wood, which is not so good a conductor as metal. But a china or stone tea-pot being in some degree of the nature of glass, which is not a good conductor of heat, may have a handle of the same stuff. Thus, also, a damp moist air shall make a man more sensible of cold, or chill him more, than a dry air that is colder, because a moist air is fitter to receive and conduct away the heat of his body. This fluid, entering bodies in great quantity, first expands them, by separating their parts a little, afterwards, by farther separating their parts, it renders solids fluid, and at length dissipates their parts in air. Take this fluid from melted lead, or from water, the parts cohere again, the first grows solid, the latter becomes ice: and this is sooner done by the means of good conductors.

Thus, if you take, as I have done, a square bar of lead, four inches long, and one inch thick, together with three pieces of wood planed to the same dimensions, and lay them, as in the margin, on a smooth board, fixt so as not to be easily [78] separated or moved, and pour into the cavity they form, as much melted lead as will fill it, you will see the melted lead chill, and become firm, on the side next the leaden bar, some time before it chills on the other three sides in contact with the wooden bars, though before the lead was poured in, they might all be supposed to have the same degree of heat or



coldness, as they had been exposed in the same room to the same air. You will likewise observe, that the leaden bar, as it has cooled the melted lead more than the wooden bars have done, so it is itself more heated by the melted lead. There is a certain quantity of this fluid called fire, in every living human body, which fluid, being in due proportion, keeps the parts of the flesh and blood at such a just distance from each other, as that the flesh and nerves are supple, and the blood fit for circulation. If part of this due proportion of fire be conducted away, by means of a contact with other bodies, as air, water, or metals, the parts of our skin and flesh that come into such contact first draw more near together than is agreeable, and give that sensation which we call cold; and if too much be conveyed away, the body stiffens, the blood ceases to flow, and death ensues. On the other hand, if too much of this fluid be communicated to the flesh, the parts are separated too far, and pain ensues, as when they are separated by a pin or lancet. The sensation that the separation by fire occasions, we call heat, or burning. My [79]
desk on which I now write, and the lock of my desk, are both exposed to the same temperature of the air, and have therefore the same degree of heat or cold; yet if I lay my hand successively on the wood and on the metal, the latter feels much the coldest, not that it is really so, but being a better conductor, it more readily than the wood takes away and draws into itself the fire that was in my skin. Accordingly if I lay one hand, part on the lock, and part on the wood, and after it had lain so some time, I feel both parts with my other hand, I find the part that has been in contact with the lock, very sensibly colder to the touch, than the part that lay on the wood. How a living animal obtains its quantity of this fluid called fire, is a curious question. I have shown, that some bodies (as metals) have a power of attracting it stronger than others; and I have sometimes suspected, that a living body had some power of attracting out of the air, or other bodies, the heat it wanted. Thus metals hammered, or repeatedly bent, grow hot in the bent or hammered part. But when I consider that air, in contact with the body, cools it; that the surrounding air is rather heated by its contact with the body; that every breath of cooler air drawn in, carries off part of the body's heat when it passes out again; that therefore there must be in the body a fund for producing it, or otherwise the animal would soon grow cold; I have been rather inclined to think, that the fluid *fire*, as well as the fluid *air*, is attracted by plants in their growth, and becomes consolidated with the other materials of which they are formed, and makes a great part of their substance: that when they come to be digested, and to suffer in the vessels a kind of fermentation, part of the fire, as well as part of the air, recovers its fluid active state again, [80]
and diffuses itself in the body digesting and separating it: that the fire so reproduced, by digestion and separation continually leaving the body, its place is supplied by fresh quantities, arising from the continual separation. That whatever quickens the motion of the fluids in an animal quickens the separation, and reproduces more of the fire; as exercise. That all the fire emitted by wood, and other combustibles, when burning, existed in them before, in a solid state, being only discovered when separating. That some fossils, as sulphur, sea-coal, &c. contain a great deal of solid fire; and that, in short, what escapes and is dissipated in the burning of bodies, besides water and earth, is generally the air and fire that before made parts of the solid. Thus I imagine that animal heat arises by or from a kind of fermentation in the juices of the body, in the same manner as heat arises in the liquors preparing for distillation, wherein there is a separation of the spirituous, from the watry and earthy parts. And it is remarkable, that the liquor in a distiller's vat, when in its highest and best state of fermentation, as I have been informed, has the same degree of heat with the human body; that is, about 94 or 96.

Thus, as by a constant supply of fuel in a chimney, you keep a warm room, so, by a constant supply of food in the stomach, you keep a warm body; only where little exercise is used, the heat may possibly be conducted away too fast; in which case such materials are to be used for cloathing and bedding, against the effects of an immediate contact of the air, as are, in themselves, bad conductors of heat, and, consequently, prevent its being communicated through their substance [81] to the air. Hence what is called *warmth* in wool, and its preference on that account, to linen; wool not being so good a conductor: and hence all the natural coverings of animals, to keep them warm, are such as retain and confine the natural heat in the body, by being bad conductors, such as wool, hair, feathers, and the silk by which the silk-worm, in its tender embrio state, is first cloathed. Cloathing, thus considered, does not make a man warm by *giving* warmth, but by *preventing* the too quick dissipation of the heat produced in his body, and so occasioning an accumulation.

There is another curious question I will just venture to touch upon, viz. Whence arises the sudden extraordinary degree of cold, perceptible on mixing some chemical liquors, and even on mixing salt and snow, where the composition appears colder than the coldest of the ingredients? I have never seen the chemical mixtures made, but salt and snow I have often mixed myself, and am fully satisfied that the composition feels much colder to the touch, and lowers the mercury in the thermometer more than either ingredient would do separately. I suppose, with others, that cold is nothing more than the absence of heat or fire. Now if the quantity of fire before contained or diffused in the snow and salt was expelled in the uniting of the two matters, it must be driven away either through the air or the vessel containing them. If it is driven off thro' the air, it must warm the air, and a thermometer held over the mixture, without touching it, would discover the heat, by the rising of the mercury, as it must, and always does in warm air.

This, indeed, I have not tried, but I should guess it would rather be driven off through the vessel, especially if the vessel [82] be metal, as being a better conductor than air; and so one should find the bason warmer after such mixture. But, on the contrary, the vessel grows cold, and even water, in which the vessel is sometimes placed for the experiment, freezes into hard ice on the bason. Now I know not how to account for this, otherwise than by supposing, that the composition is a better conductor of fire than the ingredients separately, and, like the lock compared with the wood, has a stronger power of attracting fire, and does accordingly attract it suddenly from the fingers, or a thermometer put into it, from the bason that contains it, and from the water in contact with the outside of the bason; so that the fingers have the sensation of extreme cold, by being deprived of much of their natural fire; the thermometer sinks, by having part of its fire drawn out of the mercury; the bason grows colder to the touch, as, by having its fire drawn into the mixture, it is become more capable of drawing and receiving it from the hand; and through the bason, the water loses its fire that kept it fluid; so it becomes ice. One would expect, that from all this attracted acquisition of fire to the composition, it should become warmer; and, in fact, the snow and salt dissolve at the same time into water, without freezing.

I am, Sir, &c.

B. FRANKLIN.

FOOTNOTE:

[14] Dr. Lining. *Editor*.

TO THE SAME ON THE SAME SUBJECT. [83]

London, June 17, 1758.

Dear Sir,

In a former letter I mentioned the experiment for cooling bodies by evaporation, and that I had, by repeatedly wetting the thermometer with common spirits, brought the mercury down five or six degrees. Being lately at Cambridge, and mentioning this in conversation with Dr. Hadley, professor of chemistry there, he proposed repeating the experiments with ether, instead of common spirits, as the ether is much quicker in evaporation. We accordingly went to his chamber, where he had both ether and a thermometer. By dipping first the ball of the thermometer into the ether, it appeared that the ether was precisely of the same temperament with the thermometer, which stood then at 65; for it made no alteration in the height of the little column of mercury. But when the thermometer was taken out of the ether, and the ether, with which the ball was wet, began to evaporate, the mercury sunk several degrees. The wetting was then repeated by a feather that had been dipped into the ether, when the mercury sunk still lower. We continued this operation, one of us wetting the ball, and another of the company blowing on it with the bellows, to quicken the evaporation, the mercury sinking all the time, till it came down to 7, which is 25 degrees below the freezing point, when we left off. Soon after it passed the freezing point, a thin coat of ice began to cover the ball. Whether this was water collected and condensed by the coldness of the ball, from the moisture in the air, or from our breath; or whether the feather, when dipped into the ether, might not sometimes go [84]
through it, and bring up some of the water that was under it, I am not certain; perhaps all might contribute. The ice continued increasing till we ended the experiment, when it appeared near a quarter of an inch thick all over the ball, with a number of small spicula, pointing outwards. From this experiment one may see the possibility of freezing a man to death on a warm summer's day, if he were to stand in a passage through which the wind blew briskly, and to be wet frequently with ether, a spirit that is more inflammable than brandy, or common spirits of wine.

It is but within these few years, that the European philosophers seem to have known this power in nature, of cooling bodies by evaporation. But in the east they have long been acquainted with it. A friend tells me, there is a passage in Bernier's Travels through Indostan, written near one hundred years ago, that mentions it as a practice (in travelling over dry deserts in that hot climate) to carry water in flasks wrapt in wet woollen cloths, and hung on the shady side of the camel, or carriage, but in the free air; whereby, as the cloths gradually grow drier, the water contained in the flasks is made cool. They have likewise a kind of earthen pots, unglazed, which let the water gradually and slowly ooze through their pores, so as to keep the outside a little wet, notwithstanding the continual evaporation, which gives great coldness to the vessel, and the water contained in it. Even our common sailors seem to have had some notion of this property; for I remember, that being at sea, when I was a youth, I observed one of the sailors, during a calm in the night, often wetting [85]
his finger in his mouth, and then holding it up in the air, to discover, as he said, if the air had any motion, and from which side it came; and this he expected to do, by finding one side of his finger grow suddenly cold, and from that side he should look for the next wind; which I then laughed at as a fancy.

May not several phenomena, hitherto unconsidered, or unaccounted for, be explained by this property? During the hot Sunday at Philadelphia, in June 1750, when the thermometer was up at 100 in the shade, I sat in my chamber without exercise, only reading or writing, with no other cloaths on than a shirt, and a pair of long linen drawers, the windows all open, and a brisk wind blowing through the house, the sweat ran off the backs of my hands, and my shirt was often so wet, as to induce me to call for dry ones to put on; in this situation, one might have expected, that the natural heat of the

body 96, added to the heat of the air 100, should jointly have created or produced a much greater degree of heat in the body; but the fact was, that my body never grew so hot as the air that surrounded it, or the inanimate bodies immersed in the same air. For I remember well, that the desk, when I laid my arm upon it; a chair, when I sat down in it; and a dry shirt out of the drawer, when I put it on, all felt exceeding warm to me, as if they had been warmed before a fire. And I suppose a dead body would have acquired the temperature of the air, though a living one, by continual sweating, and by the evaporation of that sweat, was kept cold. May not this be a reason why our reapers in Pensylvania, working in the open field, in the clear hot sun-shine common in our harvest-time[15], find themselves well able to go through that labour, [86]
without being much incommoded by the heat, while they continue to sweat, and while they supply matter for keeping up that sweat, by drinking frequently of a thin evaporable liquor, water mixed with rum; but if the sweat stops, they drop, and sometimes die suddenly, if a sweating is not again brought on by drinking that liquor, or, as some rather chuse in that case, a kind of hot punch, made with water, mixed with honey, and a considerable proportion of vinegar? May there not be in negroes a quicker evaporation of the perspirable matter from their skins and lungs, which, by cooling them more, enables them to bear the sun's heat better than whites do? (if that is a fact, as it is said to be; for the alledged necessity of having negroes rather than whites, to work in the West-India fields, is founded upon it) though the colour of their skins would otherwise make them more sensible of the sun's heat, since black cloth heats much sooner, and more, in the sun, than white cloth. I am persuaded, from several instances happening within my knowledge, that they do not bear cold weather so well as the whites; they will perish when exposed to a less degree of it, and are more apt to have their limbs frostbitten; and may not this be from the same cause? Would not the earth grow much hotter under the summer-sun, if a constant evaporation from its surface, greater as the sun shines stronger, did not, by tending to cool it; balance, in some degree, the warmer effects of the sun's rays? Is it not owing to the constant evaporation from the surface of every leaf, that trees, [87]
though shone on by the sun, are always, even the leaves themselves, cool to our sense? at least much cooler than they would otherwise be? May it not be owing to this, that fanning ourselves when warm, does really cool us, though the air is itself warm that we drive with the fan upon our faces; for the atmosphere round, and next to our bodies, having imbibed as much of the perspired vapour as it can well contain, receives no more, and the evaporation is therefore checked and retarded, till we drive away that atmosphere, and bring drier air in its place, that will receive the vapour, and thereby facilitate and increase the evaporation? Certain it is, that mere blowing of air on a dry body does not cool it, as any one may satisfy himself, by blowing with a bellows on the dry ball of a thermometer; the mercury will not fall; if it moves at all, it rather rises, as being warmed by the friction of the air on its surface? To these queries of imagination, I will only add one practical observation; that wherever it is thought proper to give ease, in cases of painful inflammation in the flesh (as from burnings, or the like) by cooling the part; linen cloths, wet with spirit, and applied to the part inflamed, will produce the coolness required, better than if wet with water, and will continue it longer. For water, though cold when first applied, will soon acquire warmth from the flesh, as it does not evaporate fast enough; but the cloths wet with spirit, will continue cold as long as any spirit is left to keep up the evaporation, the parts warmed escaping as soon as they are warmed, and carrying off the heat with them.

I am, Sir, &c.

B FRANKLIN.

FOOTNOTE:

[15] Pensylvania is in about lat. 40, and the sun, of course, about 12 degrees higher, and therefore much hotter than in England. Their harvest is about the end of June, or beginning of July, when the sun is nearly at the highest.

Concerning the Light in Sea-Water.

Read at the Royal Society, December 6, 1756.

November 12, 1753.

**** When I was at the eastward, I had an opportunity of observing the luminous appearance of the sea when disturbed: at the head and stern of the vessel, when under way, it appeared very bright. The best opportunity I had to observe it was in a boat, in company with several gentlemen going from Portsmouth, about three miles, to our vessel lying at the mouth of Piscataqua River. Soon after we set off (it being in the evening) we observed a luminous appearance, where the oars dashed the water. Sometimes it was very bright, and afterwards, as we rowed along, gradually lessened, till almost imperceptible, and then re-illumined. This we took notice of several times in the passage. When I got on board the vessel, I ordered a pail to be dipped up, full of sea-water, in which, on the water's being moved, a sparkling light appeared. I took a linen cloth, and strained some of the water through it, and there was a like appearance on the cloth, which soon went off; but on rubbing the cloth with my finger, it was renewed. I then carried the cloth to the light, but could not perceive any thing upon it which should cause that appearance.

Several gentlemen were of opinion, that the separated particles of putrid, animal, and other bodies, floating on the surface of the sea, might cause that appearance; for putrid fish, &c. they said, will cause it: and the sea-animals which [89] have died, and other bodies putrified therein since the creation, might afford a sufficient quantity of these particles to cover a considerable portion of the surface of the sea; which particles being differently dispersed, might account for the different degrees of light in the appearance above-mentioned. But this account seems liable to this obvious objection, that as putrid fish, &c. make a luminous appearance without being moved or disturbed, it might be expected that the supposed putrid particles on the surface of the sea, should always appear luminous, where there is not a greater light; and, consequently, that the whole surface of the sea, covered with those particles, should always, in dark nights, appear luminous, without being disturbed. But this is not fact.

Among the rest, I threw out my conjecture, that the said appearance might be caused by a great number of little animals, floating on the surface of the sea, which, on being disturbed, might, by expanding their finns, or otherwise moving themselves, expose such a part of their bodies as exhibits a luminous appearance, somewhat in the manner of a glow-worm, or fire-fly: that these animals may be more numerous in some places than others; and, therefore, that the appearance above-mentioned being fainter and stronger in different places, might be owing to that: that certain circumstances of weather, &c. might invite them to the surface, on which, in a calm, they might sport themselves and glow; or in storms, being forced up, make the same appearance.

There is no difficulty in conceiving that the sea may be stocked with animalcula for this purpose, as we find all nature [90] crowded with life. But it seems difficult to conceive that such small portions of matter, even if they were wholly luminous, should affect our sight; much more so, when it is supposed that only a part of them is luminous. But, if we consider some other appearances, we may find the same difficulty to conceive of them; and yet we know they take place. For instance, the flame of a candle, which, it is said, may be seen four miles round. The light which fills this circle of eight miles diameter, was contained, when it first left the candle, within a circle of half an inch diameter. If the density of light, in these circumstances, be as those circles to each other, that is, as the squares of their diameters, the candle-light, when come to the eye, will be 1027709337600 times rarer than when it quitted the half inch circle. Now the aperture of the eye, through which the light passes, does not exceed one-tenth of an inch diameter, and the portion of the lesser circle, which corresponds to this small portion of the greater circle, must be proportionably, that is, 1027709337600 times less than one-tenth of an inch; and yet this infinitely small point (if you will allow the expression) affords light enough to make it visible four miles; or, rather, affords light sufficient to affect the sight at that distance.

The smallness of the animalcula is no objection then to this conjecture; for supposing them to be ten thousand times less than the *minimum visibile*, they may, notwithstanding, emit light enough to affect the eyes, and so to cause the luminous appearance aforesaid. This conjecture I send you for want of something better ****.

FOOTNOTE:

[16] I. Badoin. *Editor.*

TO MR. P. F.[17] IN NEWPORT. [91]

On the Saltness of Sea-Water.

London, May 7, 1760.

Sir,

**** It has, indeed, as you observe, been the opinion of some very great naturalists, that the sea is salt only from the dissolution of mineral or rock-salt, which its waters happened to meet with. But this opinion takes it for granted that all water was originally fresh, of which we can have no proof. I own I am inclined to a different opinion, and rather think all the water on this globe was originally salt, and that the fresh water we find in springs and rivers, is the produce of distillation. The sun raises the vapours from the sea, which form clouds, and fall in rain upon the land, and springs and rivers are formed of that rain. As to the rock-salt found in mines, I conceive, that instead of communicating its saltness to the sea, it is itself drawn from the sea, and that of course the sea is now fresher than it was originally. This is only another effect of nature's distillery, and might be performed various ways.

It is evident from the quantities of sea-shells, and the bones and teeth of fishes found in high lands, that the sea has formerly covered them. Then, either the sea has been higher than it now is, and has fallen away from those high lands, or they have been lower than they are, and were lifted up out of the water to their present height, by some internal mighty force, such as we still feel some remains of, when whole continents are moved by earthquakes. In either case it may be [92] supposed that large hollows or valleys among hills, might be left filled with sea-water, which evaporating, and the fluid part drying away in a course of years, would leave the salt covering the bottom; and that salt coming afterwards to be covered with earth, from the neighbouring hills, could only be found by digging through that earth. Or, as we know from their effects, that there are deep fiery caverns under the earth, and even under the sea, if at any time the sea leaks into any of them, the fluid parts of the water must evaporate from that heat, and pass off through some volcano, while the salt remains, and by degrees, and continual acretion, becomes a great mass. Thus the cavern may at length be filled, and the volcano connected with it cease burning, as many it is said have done; and future miners, penetrating such cavern, find what we call a salt-mine. This is a fancy I had on visiting the salt-mines at Northwich, with my son. I send you a piece of the rock-salt which he brought up with him out of the mine. ****

I am, Sir, &c.

B. FRANKLIN.

FOOTNOTE:

[17] Peter Franklin. *Editor.*

TO MISS STEPHENSON.

On the Effect of Air on the Barometer, and the Benefits derived from the Study of Insects.

Craven Street, June 11, 1760.

'Tis a very sensible question you ask, how the air can affect the barometer, when its opening appears covered with wood? If indeed it was so closely covered as to admit of no communication of the outward air to the surface of the mercury, the change of weight in the air could not possibly affect it. But the least crevice is sufficient for the purpose; a pinhole will do the business. And if you could look behind the frame to which your barometer is fixed, you would certainly find some small opening. [93]

There are indeed some barometers in which the body of mercury at the lower end is contained in a close leather bag, and so the air cannot come into immediate contact with the mercury; yet the same effect is produced. For the leather being flexible, when the bag is pressed by any additional weight of air it contracts, and the mercury is forced up into the tube; when the air becomes lighter, and its pressure less, the weight of the mercury prevails, and it descends again into the bag.

Your observation on what you have lately read concerning insects is very just and solid. Superficial minds are apt to despise those who make that part of the creation their study, as mere triflers; but certainly the world has been much obliged to them. Under the care and management of man, the labours of the little silkworm afford employment and subsistence to thousands of families, and become an immense article of commerce. The bee, too, yields us its delicious honey, and its wax useful to a multitude of purposes. Another insect, it is said, produces the cochineal, from whence we have our rich scarlet dye. The usefulness of the cantharides or Spanish flies, in medicine, is known to all, and thousands owe their lives to that knowledge. By human industry and observation, other properties of other insects may possibly be [94] hereafter discovered, and of equal utility. A thorough acquaintance with the nature of these little creatures may also enable mankind to prevent the increase of such as are noxious, or secure us against the mischiefs they occasion. These things doubtless your books make mention of: I can only add a particular late instance which I had from a Swedish gentleman of good credit. In the green timber, intended for ship-building at the king's yards in that country, a kind of worms were found, which every year became more numerous and more pernicious, so that the ships were greatly damaged before they came into use. The king sent Linnæus, the great naturalist, from Stockholm, to enquire into the affair, and see if the mischief was capable of any remedy. He found, on examination, that the worm was produced from a small egg, deposited in the little roughnesses on the surface of the wood, by a particular kind of fly or beetle; from whence the worm, as soon as it was hatched, began to eat into the substance of the wood, and after some time came out again a fly of the parent kind, and so the species increased. The season in which the fly laid its eggs, Linnæus knew to be about a fortnight (I think) in the month of May, and at no other time in the year. He therefore advised, that some days before that season, all the green timber should be thrown into the water, and kept under water till the season was over. Which being done by the king's order, the flies missing their usual nests, could not increase; and the species was either destroyed or went elsewhere; and the wood was effectually preserved, for after the first year, it became too dry and hard for their purpose.

There is, however, a prudent moderation to be used in studies of this kind. The knowledge of nature may be ornamental, and it may be useful, but if to attain an eminence in that, we neglect the knowledge and practice of essential duties, we deserve reprehension. For there is no rank in natural knowledge of equal dignity and importance with that of being a good parent, a good child, a good husband, or wife, a good neighbour or friend, a good subject or citizen, that is, in short, a good christian. Nicholas Gimcrack, therefore, who neglected the care of his family, to pursue butterflies, was a just object of ridicule, and we must give him up as fair game to the satyrist. [95]

Adieu, my dear friend, and believe me ever

Yours affectionately,

B. FRANKLIN.

TO THE SAME.

On the Bristol Waters, and the Tide in Rivers.

London, Sept. 13, 1760.

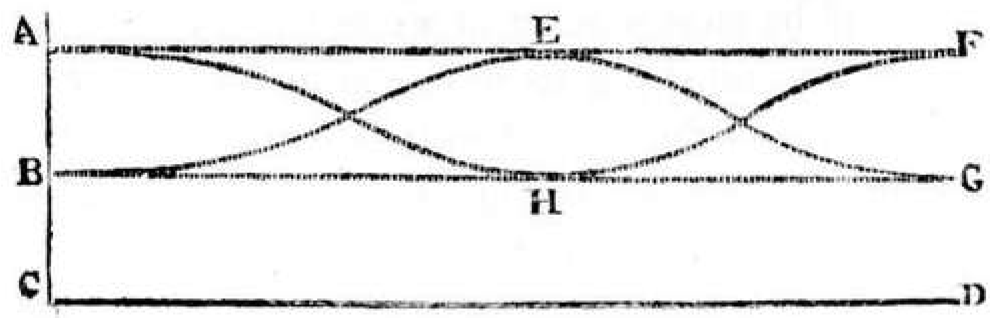
MY DEAR FRIEND,

I have your agreeable letter from Bristol, which I take this first leisure hour to answer, having for some time been much engaged in business.

Your first question, *What is the reason the water at this place, though cold at the spring, becomes warm by pumping?* It will be most prudent in me to forbear attempting to answer, till, by a more circumstantial account, you assure me of the fact. I own I should expect that operation to warm, not so much the water pumped, as the person pumping.—The rubbing of dry solids together has been long observed to produce heat; but the like effect has never yet, that I have heard, been [96] produced by the mere agitation of fluids, or friction of fluids with solids. Water in a bottle shook for hours by a mill-hopper, it is said, discovered no sensible addition of heat. The production of animal heat by exercise is therefore to be accounted for in another manner, which I may hereafter endeavour to make you acquainted with.

This prudence of not attempting to give reasons before one is sure of facts, I learnt from one of your sex, who, as Selden tells us, being in company with some gentlemen that were viewing, and considering something which they called a Chinese shoe, and disputing earnestly about the manner of wearing it, and how it could possibly be put on; put in her word, and said modestly, *Gentlemen, are you sure it is a shoe?—Should not that be settled first?*

But I shall now endeavour to explain what I said to you about the tide in rivers, and to that end shall make a figure, which though not very like a river, may serve to convey my meaning.—Suppose a canal one hundred and forty miles long, communicating at one end with the sea, and filled therefore with sea water. I chuse a canal at first, rather than a river, to throw out of consideration the effects produced by the streams of fresh water from the land, the inequality in breadth, and the crookedness of courses.



Let A, C, be the head of the canal; C, D, the bottom of it; D, F, the open mouth of it next the sea. Let the strait pricked line, B, G, represent low water mark the whole length of the canal, A, F, high water mark:—Now if a person standing at E, and observing at the time of high water there, that the canal is quite full at that place up to the line E, should conclude that the canal is equally full to the same height from end to end, and therefore there was as much more water come into the canal since it was down at low water mark, as would be included in the oblong space A, B, G, F, he would be greatly mistaken. For the tide is *a wave*, and the top of the wave, which makes high water, as well as every other lower part, is progressive; and it is high water successively, but not at the same time, in all the several points between G, F, and A, B.—And in such a length as I have mentioned it is low water at F, G, and also at A, B, at or near the same time with its being high water at E; so that the surface of the water in the canal, during that situation, is properly represented by the curve pricked line B, E, G. And on the other hand, when it is low water at E, H, it is high water both at F, G, and at A, B, at or near the same time: and the surface would then be described by the inverted curve line, A, H, F.

In this view of the case, you will easily see, that there must be very little more water in the canal at what we call high water, than there is at low water, those terms not relating to the whole canal at the same time, but successively to its parts. And if you suppose the canal six times as long, the case would not vary as to the quantity of water at different times of the tide; there would only be six waves in the canal at the same time, instead of one, and the hollows in the water would be [98] equal to the hills.

That this is not mere theory, but conformable to fact, we know by our long rivers in America. The Delaware, on which Philadelphia stands, is in this particular similar to the canal I have supposed of one wave: for when it is high water at the Capes or mouth of the river, it is also high water at Philadelphia, which stands about one hundred and forty miles from the sea; and there is at the same time a low water in the middle between the two high waters; where, when it comes to be high water, it is at the same time low water at the Capes and at Philadelphia. And the longer rivers have some a wave and half, some two, three, or four waves, according to their length. In the shorter rivers of this island, one may see the same thing in part: for instance, it is high water at Gravesend an hour before it is high water at London Bridge; and twenty miles below Gravesend an hour before it is high water at Gravesend. Therefore at the time of high water at Gravesend the top of the wave is there, and the water is then not so high by some feet where the top of the wave was an hour before, or where it will be an hour after, as it is just then at Gravesend.

Now we are not to suppose, that because the swell or top of the wave runs at the rate of twenty miles an hour, that therefore the current, or water itself of which the wave is composed, runs at that rate. Far from it. To conceive this motion of a wave, make a small experiment or two. Fasten one end of a cord in a window near the top of a house, and let the other end come down to the ground; take this end in your hand, and you may, by a sudden motion, occasion a wave in the [99] cord that will run quite up to the window; but though the wave is progressive from your hand to the window, the parts of the rope do not proceed with the wave, but remain where they were, except only that kind of motion that produces the wave. So if you throw a stone into a pond of water when the surface is still and smooth, you will see a circular wave proceed from the stone as its centre, quite to the sides of the pond; but the water does not proceed with the wave, it only rises and falls to form it in the different parts of its course; and the waves that follow the first, all make use of the same water with their predecessors.

But a wave in water is not indeed in all circumstances exactly like that in a cord; for water being a fluid, and gravitating to the earth, it naturally runs from a higher place to a lower; therefore the parts of the wave in water do actually run a little both ways from its top towards its lower sides, which the parts of the wave in the cord cannot do. Thus, when it is high and standing water at Gravesend, the water twenty miles below has been running ebb, or towards the sea for an hour, or ever since it was high water there; but the water at London Bridge will run flood, or from the sea yet another hour, till it is high water, or the top of the wave arrives at that bridge, and then it will have run ebb an hour at Gravesend, &c. &c. Now this motion of the water, occasioned only by its gravity, or tendency to run from a higher place to a lower, is by no means so swift as the motion of the wave. It scarce exceeds perhaps two miles in an hour.

If it went as the wave does twenty miles an hour, no ships could ride at anchor in such a stream, nor boats row against [100] it.

In common speech, indeed, this current of the water both ways from the top of the wave is called *the tide*; thus we say, *the tide runs strong*, *the tide runs at the rate of one, two, or three miles an hour, &c.* and when we are at a part of the river behind the top of the wave, and find the water lower than high-water mark, and running towards the sea, we say, *the tide runs ebb*; and when we are before the top of the wave, and find the water higher than low-water mark, and running from the sea, we say, *the tide runs flood*; but these expressions are only locally proper; for a tide, strictly speaking, is *one whole wave*, including all its parts higher and lower, and these waves succeed one another about twice in twenty-four hours.

This motion of the water, occasioned by its gravity, will explain to you why the water near the mouths of rivers may be salter at high water than at low. Some of the salt-water, as the tide wave enters the river, runs from its top and fore side, and mixes with the fresh, and also pushes it back up the river.

Supposing that the water commonly runs during the flood at the rate of two miles in an hour, and that the flood runs five hours, you see that it can bring at most into our canal only a quantity of water equal to the space included in the breadth of the canal, ten miles of its length, and the depth between low and high-water mark; which is but a fourteenth part of what would be necessary to fill all the space between low and high-water mark, for one hundred and forty miles, the whole length of the canal.

And indeed such a quantity of water as would fill that whole space, to run in and out every tide, must create so [101] outrageous a current, as would do infinite damage to the shores, shipping, &c. and make the navigation of a river almost impracticable.

I have made this letter longer than I intended, and therefore reserve for another what I have further to say on the subject of tides and rivers. I shall now only add, that I have not been exact in the numbers, because I would avoid perplexing you with minute calculations, my design at present being chiefly to give you distinct and clear ideas of the first principles.

After writing six folio pages of philosophy to a young girl, is it necessary to finish such a letter with a compliment?—Is not such a letter of itself a compliment?—Does it not say, she has a mind thirsty after knowledge, and capable of receiving it; and that the most agreeable things one can write to her are those that tend to the improvement of her understanding?—It does indeed say all this, but then it is still no compliment; it is no more than plain honest truth, which is not the character of a compliment. So if I would finish my letter in the *mode*, I should yet add some thing that means nothing, and is *merely* civil and polite. But being naturally aukward at every circumstance of ceremony, I shall not attempt it. I had rather conclude abruptly with what pleases me more than any compliment can please you, that I am allowed to subscribe myself

Your affectionate friend,

B. FRANKLIN.

TO THE SAME. [102]

On the same Subject.

Craven-street, Monday, March 30, 1761.

MY DEAR FRIEND,

Supposing the fact, that the water of the well at Bristol is warmer after sometime pumping, I think your manner of accounting for that increased warmth very ingenious and probable. It did not occur to me, and therefore I doubted of the fact.

You are, I think quite right in your opinion, that the rising of the tides in rivers is not owing to the immediate influence of the moon on the rivers. It is rather a subsequent effect of the influence of the moon on the sea, and does not make its appearance in some rivers till the moon has long passed by. I have not expressed myself clearly if you have understood me to mean otherwise. You know I have mentioned it as a fact, that there are in some rivers several tides all existing at the same time; that is, two, three, or more, high-waters, and as many low-waters, in different parts of the same river, which cannot possibly be all effects of the moon's immediate action on that river; but they may be subsequent effects of her action on the sea.

In the enclosed paper you will find my sentiments on several points relating to the air, and the evaporation of water. It is Mr. Collinson's copy, who took it from one I sent through his hands to a correspondent in France some years since; I have, as he desired me, corrected the mistakes he made in transcribing, and must return it to him; but if you think it worth while, you may take a copy of it: I would have saved you any trouble of that kind, but had not time. [103]

Some day in the next or the following week, I purpose to have the pleasure of seeing you at Wanstead: I shall accompany your good mamma thither, and stay till the next morning, if it may be done without incommoding your family too much.—We may then discourse any points in that paper that do not seem clear to you; and taking a walk to lord Tilney's ponds, make a few experiments there to explain the nature of the tides more fully. In the mean time, believe me to be, with the highest esteem and regard, your sincerely affectionate friend,

B. FRANKLIN.

TO THE SAME.

Salt-Water rendered fresh by Distillation.—Method of relieving Thirst by Sea-Water.

Craven-street, August 10, 1761.

We are to set out this week for Holland, where we may possibly spend a month, but purpose to be at home again before the coronation. I could not go without taking leave of you by a line at least, when I am so many letters in your debt.

In yours of May 19, which I have before me, you speak of the ease with which salt water may be made fresh by distillation, supposing it to be, as I had said, that in evaporation the air would take up water but not the salt that was mixed with it. It is true that distilled sea water will not be salt, but there are other disagreeable qualities that rise with the water in [104] distillation; which indeed several besides Dr. Hales have endeavoured by some means to prevent; but as yet their methods have not been brought much into use.

I have a singular opinion on this subject, which I will venture to communicate to you, though I doubt you will rank it among my whims. It is certain that the skin has *imbibing* as well as *discharging* pores; witness the effects of a blistering plaister, &c. I have read that a man, hired by a physician to stand by way of experiment in the open air naked during a moist night, weighed near three pounds heavier in the morning. I have often observed myself, that however thirsty I may have been before going into the water to swim, I am never long so in the water. These imbibing pores, however, are very fine, perhaps fine enough in filtering to separate salt from water; for though I have soaked (by swimming, when a boy) several hours in the day for several days successively in salt-water, I never found my blood and juices salted by that means, so as to make me thirsty or feel a salt taste in my mouth: and it is remarkable, that the flesh of sea fish, though bred in salt-water, is not salt.—Hence I imagine, that if people at sea, distressed by thirst when their fresh water is unfortunately spent, would make bathing-tubs of their empty water-casks, and, filling them with sea-water, sit in them an hour or two each day, they might be greatly relieved. Perhaps keeping their clothes constantly wet might have an almost equal effect; and this without danger of catching cold. Men do not catch cold by wet cloaths at sea. Damp, but not wet linen may possibly give colds; but no one catches cold by bathing, and no clothes can be wetter than water itself. Why [105] damp clothes should then occasion colds, is a curious question, the discussion of which I reserve for a future letter, or some future conversation.

Adieu, my little philosopher. Present my respectful compliments to the good ladies your aunts, and to miss Pitt; and believe me ever

Your affectionate friend,

And humble Servant,

B. FRANKLIN.

TO THE SAME.

Tendency of Rivers to the Sea.—Effect of the Sun's Rays on Cloths of different Colours.

Sept. 20, 1761.

My dear Friend,

It is, as you observed in our late conversation, a very general opinion, that *all rivers run into the sea*, or deposite their waters there. 'Tis a kind of audacity to call such general opinions in question, and may subject one to censure. But we must hazard something in what we think the cause of truth: and if we propose our objections modestly, we shall, though mistaken, deserve a censure less severe, than when we are both mistaken and insolent.

That some rivers run into the sea is beyond a doubt: such, for instance, are the Amazons, and I think the Oronoko and the Mississippi. The proof is, that their waters are fresh quite to the sea, and out to some distance from the land. Our question is, whether the fresh waters of those rivers whose beds are filled with salt water to a considerable distance up [106]
from the sea (as the Thames, the Delaware, and the rivers that communicate with Chesapeak-bay in Virginia) do ever arrive at the sea? And as I suspect they do not, I am now to acquaint you with my reasons; or, if they are not allowed to be reasons, my conceptions at least, of this matter.

The common supply of rivers is from springs, which draw their origin from rain that has soaked into the earth. The union of a number of springs forms a river. The waters as they run, exposed to the sun, air, and wind, are continually evaporating. Hence in travelling one may often see where a river runs, by a long blueish mist over it, though we are at such a distance as not to see the river itself. The quantity of this evaporation is greater or less, in proportion to the surface exposed by the same quantity of water to those causes of evaporation. While the river runs in a narrow confined channel in the upper hilly country, only a small surface is exposed; a greater as the river widens. Now if a river ends in a lake, as some do, whereby its waters are spread so wide as that the evaporation is equal to the sum of all its springs, that lake will never overflow:—And if instead of ending in a lake, it was drawn into greater length as a river, so as to expose a surface equal in the whole to that lake, the evaporation would be equal, and such river would end as a canal; when the ignorant might suppose, as they actually do in such cases, that the river loses itself by running under ground, whereas in truth it has run up into the air.

Now, many rivers that are open to the sea widen much before they arrive at it, not merely by the additional waters they receive, but by having their course stopped by the opposing flood-tide; by being turned back twice in twenty-four hours, [107]
and by finding broader beds in the low flat countries to dilate themselves in; hence the evaporation of the fresh water is proportionably increased; so that in some rivers it may equal the springs of supply. In such cases, the salt water comes up the river, and meets the fresh in that part where, if there were a wall or bank of earth across from side to side, the river would form a lake, fuller indeed at some times than at others, according to the seasons, but whose evaporation would, one time with another, be equal to its supply.

When the communication between the two kinds of water is open, this supposed wall of separation may be conceived as a moveable one, which is not only pushed some miles higher up the river by every flood tide from the sea, and carried down again as far by every tide of ebb, but which has even this space of vibration removed nearer to the sea in wet seasons, when the springs and brooks in the upper country are augmented by the falling rains, so as to swell the river, and farther from the sea in dry seasons.

Within a few miles above and below this moveable line of separation, the different waters mix a little, partly by their motion to and fro, and partly from the greater specific gravity of the salt water, which inclines it to run under the fresh, while the fresh water, being lighter, runs over the salt.

Cast your eye on the map of North America, and observe the bay of Chesapeak in Virginia, mentioned above; you will see, communicating with it by their mouths, the great rivers Sasquehanah, Potowmack, Rappahanock, York, and James, besides a number of smaller streams, each as big as the Thames. It has been proposed by philosophical writers, that to [108] compute how much water any river discharges into the sea in a given time, we should measure its depth and swiftness at any part above the tide; as, for the Thames, at Kingston or Windsor. But can one imagine, that if all the water of those vast rivers went to the sea, it would not first have pushed the salt water out of that narrow-mouthed bay, and filled it with fresh?—The Sasquehanah alone would seem to be sufficient for this, if it were not for the loss by evaporation. And yet that bay is salt quite up to Annapolis.

As to our other subject, the different degrees of heat imbibed from the sun's rays by cloths of different colours, since I cannot find the notes of my experiment to send you, I must give it as well as I can from memory.

But first let me mention an experiment you may easily make yourself. Walk but a quarter of an hour in your garden when the sun shines, with a part of your dress white, and a part black; then apply your hand to them alternately, and you will find a very great difference in their warmth. The black will be quite hot to the touch, the white still cool.

Another. Try to fire the paper with a burning glass. If it is white, you will not easily burn it;—but if you bring the focus to a black spot, or upon letters, written or printed, the paper will immediately be on fire under the letters.

Thus fullers and dyers find black cloths, of equal thickness with white ones, and hung out equally wet, dry in the sun much sooner than the white, being more readily heated by the sun's rays. It is the same before a fire; the heat of which [109] sooner penetrates black stockings than white ones, and so is apt sooner to burn a man's shins. Also beer much sooner warms in a black mug set before the fire, than in a white one, or in a bright silver tankard.

My experiment was this. I took a number of little square pieces of broad cloth from a taylor's pattern-card, of various colours. There were black, deep blue, lighter blue, green, purple, red, yellow, white, and other colours, or shades of colours. I laid them all out upon the snow in a bright sun-shiny morning. In a few hours (I cannot now be exact as to the time) the black, being warmed most by the sun, was sunk so low as to be below the stroke of the sun's rays; the dark blue almost as low, the lighter blue not quite so much as the dark, the other colours less as they were lighter; and the quite white remained on the surface of the snow, not having entered it at all.

What signifies philosophy that does not apply to some use?—-May we not learn from hence, that black clothes are not so fit to wear in a hot sunny climate or season, as white ones; because in such clothes the body is more heated by the sun when we walk abroad, and are at the same time heated by the exercise, which double heat is apt to bring on putrid dangerous fevers? That soldiers and seamen, who must march and labour in the sun, should in the East or West Indies have an uniform of white? That summer hats, for men or women, should be white, as repelling that heat which gives head-achs to many, and to some the fatal stroke that the French call the *coup de soleil?* That the ladies summer hats, however, should be lined with black, as not reverberating on their faces those rays which are reflected upwards from the [110] earth or water? That the putting a white cap of paper or linen *within* the crown of a black hat, as some do, will not keep out the heat, though it would if placed *without*. That fruit-walls being blacked may receive so much heat from the sun in the day-time, as to continue warm in some degree through the night, and thereby preserve the fruit from frosts, or forward its growth?—with sundry other particulars of less or greater importance, that will occur from time to time to attentive minds?—I am,

Yours affectionately,

B. FRANKLIN.

TO MR. HOPKINSON.

On the Vis Inertiæ of Matter.

Philadelphia, 1748.

Sir,

According to my promise, I send you *in writing* my observations on your book[18]: you will be the better able to consider them; which I desire you to do at your leisure, and to set me right where I am wrong.

I stumble at the threshold of the building, and therefore have not read farther. The author's *vis inertiæ essential to matter*, upon which the whole work is founded, I have not been able to comprehend. And I do not think he demonstrates at all clearly (at least to me he does not) that there is really *such a property in matter*.

He says, No. 2. "Let a given body or mass of matter be called *a*, and let any given celerity be called c. That *celerity* doubled, tripled, &c. or halved, thirded, &c. will be 2 *c*, 3 *c*, &c. or ½ *c*, ⅓ *c*, &c. respectively: also the *body* doubled, tripled, or halved, thirded, will be 2 *a*, 3 *a*, or ½ *a*, ⅓ *a*, respectively." Thus far is clear.—But he adds, "Now to move the body *a* with the celerity *c*, requires a certain force to be impressed upon it; and to move it with a celerity as 2 *c*, requires *twice that force* to be impressed upon it, &c." Here I suspect some mistake creeps in by the author's not distinguishing between a great force applied at once, or a small one continually applied, to a mass of matter, in order to move it. I think it is generally allowed by the philosophers, and, for aught we know, is certainly true, that there is no mass of matter, how great soever, but may be moved by any force how small soever (taking friction out of the question) and this small force continued, will in time bring the mass to move with any velocity whatsoever.—Our author himself seems to allow this towards the end of the same No. 2. when he is subdividing his celerities and forces: for as in continuing the division to eternity by his method of ½ *c*, ⅓ *c*, ¼ *c*, ⅕ *c*, &c. you can never come to a fraction of velocity that is equal to 0 *c*, or no celerity at all; so dividing the force in the same manner, you can never come to a fraction of force that will not produce an equal fraction of celerity.—Where then is the mighty vis inertiæ, and what is its strength; when the greatest assignable mass of matter will give way to, or be moved by the *least* assignable force? Suppose two globes, equal to the sun and to one another, exactly equipoised in Jove's balance; suppose no friction in the centre of motion, in the beam or elsewhere: if a musketo then were to light on one of them, would he not give motion to them both, causing one to descend and the other to rise? If it is objected, that the force of gravity helps one globe to descend, I answer, the same force opposes the other's rising: here is an equality that leaves the whole motion to be produced by the musketo, without whom those globes would not be moved at all.—What then does vis inertiæ do in this case? and what other effect could we expect *if there were no* *such thing*? Surely if it were any thing more than a phantom, there might be enough of it in such *vast* bodies to annihilate, by its opposition to motion, so trifling a force?

Our author would have reasoned more clearly, I think, if, as he has used the letter *a* for a certain quantity of matter, and *c* for a certain quantity of celerity, he had employed one letter more, and put *f* perhaps, for a certain quantity of force. This let us suppose to be done; and then as it is a maxim that the force of bodies in motion is equal to the quantity of matter multiplied by the celerity, (or $f = c \times a$); and as the force received by and subsisting in matter, when it is put in motion, can never exceed the force given; so if, *f* moves *a* with *c*, there must needs be required 2 *f* to move *a* with 2 *c*; for *a* moving with 2 *c* would have a force equal to 2 *f*, which it could not receive from 1 *f*; and this, not because there is such a thing as vis inertiæ, for the case would be the same *if that had no existence*; but because nothing *can* give more than it has, if 1 *f* can to 1 *a* give 1 *c*, which is the same thing as giving it 1 *f*; (i. e. if force applied to matter at rest, can put it in motion, and give it *equal* force) where then is vis inertiæ? If it existed at all in matter, should we not find the quantity of its resistance subtracted from the force given?

In No. 4. our author goes on and says, "the body *a* requires a certain force to be impressed on it to be moved with a celerity as *c*, or such a force is necessary; and therefore makes a certain resistance, &c. A body as 2 *a* requires *twice* that force to be moved with the *same celerity*, or it makes twice that resistance; and so on."—This I think is not true; but that the body 2 *a* moved by the force 1 *f* (though the eye may judge otherwise of it) does really move with the same celerity as it did when impelled by the same force; for 2 *a* is compounded of 1 *a*+1 *a*: and if each of the 1 *a*'s or each part of the compound were made to move with 1 *c* (as they might be by 2 *f*) then the whole would move with 2 *c*, and not with 1 *c*, as our author supposes. But 1 *f* applied to 2 *a*, makes each *a* move with ½ *c*; and so the whole moves with 1 *c*; exactly the same as 1 *a* was made to do by 1 *f* before. What is equal celerity but a *measuring the same space by moving bodies in the same time*?—Now if 1 *a* impelled by 1 *f* measures 100 yards in a minute; and in 2 *a* impelled by 1 *f*, each *a* measures 50 yards in a minute, which added make 100; are not the celerities as the forces equal? and since force and celerity in the same quantity of matter are always in *proportion* to each other, why should we, when the quantity of matter is doubled, allow the force to continue unimpaired, and yet suppose one half of the celerity to be lost?—I wonder the more at our author's mistake in this point, since in the same number I find him observing: "We may easily conceive that a body as 3 *a*, 4 *a*, &c. would make 3 or 4 bodies equal to once *a*, each of which would require once the first force to be moved with the celerity *c*." If then in 3 *a*, each *a* requires once the first force *f* to be moved with the celerity *c*, would not each move with the force *f* and celerity *c*; and consequently the whole be 3 *a* moving with 3 *f* and 3 *c?* After so distinct an observation, how could he miss of the consequence, and imagine that 1 *c* and 3 *c* were the same? Thus as our author's abatement of celerity in the case of 2 *a* moved by 1 *f* is imaginary, so must be his additional resistance.—And here again, I am at a loss to discover any effect of the vis inertiæ.

In No. 6, he tells us, "that all this is likewise certain when taken the contrary way, viz. *from motion to rest*; for the body *a* moving with a certain velocity, as *c*, requires a certain degree of force or resistance to stop that motion, &c. &c." that is, in other words, equal force is necessary to destroy force. It may be so. But how does that discover a vis inertiæ? would not the effect be the same *if there were no such thing*? A force 1 *f* strikes a body 1 *a*, and moves it with the celerity 1 *c*, i. e. with the force 1 *f*: It requires, even according to our author, only an opposing 1 *f* to stop it. But ought it not (if there were a vis inertiæ) to have not only the force 1 *f*, but an additional force equal to the force of vis inertiæ, that *obstinate power by which a body endeavours with* all its might *to continue in its present state, whether of motion or rest*? I say, ought there not to be an opposing force equal to the sum of these?—The truth however is, that there is no body, how large soever, moving with any velocity, how great soever, but may be stopped by any opposing force, how small soever, continually applied. At least all our modern philosophers agree to tell us so.

Let me turn the thing in what light I please, I cannot discover the vis inertiæ, nor any effect of it. It is allowed by all, that a body 1 *a* moving with a velocity 1 *c*, and a force 1 *f striking another* body 1 *a* at rest, they will afterwards *move on together*, each with ½ *c* and ½ *f*; which, as I said before, is equal in the whole to 1 *c* and 1 *f*. If vis inertiæ, as in this case, neither abates the force nor the velocity of bodies, what does it, or how does it discover itself? [115]

I imagine I may venture to conclude my observations on this piece, almost in the words of the author; that if the doctrines of the immateriality of the soul and the existence of God and of divine providence are demonstrable from no plainer principles, the *deist* [i.e. *theist*] has a desperate cause in hand. I oppose *my theist* to his atheist, because I think they are diametrically opposite; and not near of kin, as Mr. Whitfield seems to suppose; where (in his journal) he tells us, "*M. B. was a deist, I had almost said an atheist*;" that is, *chalk*, I had almost said *charcoal*.

The din of the market[19] increases upon me; and that, with frequent interruptions, has, I find, made me say some things twice over; and, I suppose, forget some others I intended to say. It has, however, one good effect, as it obliges me to come to the relief of your patience with

Your humble servant,

B. FRANKLIN.

FOOTNOTES:

[18] Baxter's Inquiry into the Nature of the Human Soul. B. V.

[19] Philadelphia market, in which Dr. Franklin lived. B. V.

TO JOHN PRINGLE, M. D. AND F. R. S. [116]

On the different Strata of the Earth.

Craven-Street, Jan. 6, 1758.

Sir,

I return you Mr. Mitchell's paper on the strata of the earth[20] with thanks. The reading of it, and perusal of the draft that accompanies it, have reconciled me to those convulsions which all naturalists agree this globe has suffered. Had the different strata of clay, gravel, marble, coals, lime-stone, sand, minerals, &c. continued to lie level, one under the other, as they may be supposed to have done before those convulsions, we should have had the use only of a few of the uppermost of the strata, the others lying too deep and too difficult to be come at; but the shell of the earth being broke, and the fragments thrown into this oblique position, the disjointed ends of a great number of strata of different kinds are brought up to day, and a great variety of useful materials put into our power, which would otherwise have remained eternally concealed from us. So that what has been usually looked upon as a *ruin* suffered by this part of the universe, was, in reality, only a preparation, or means of rendering the earth more fit for use, more capable of being to mankind a convenient and comfortable habitation.

I am, Sir, with great esteem, yours, &c.

B. FRANKLIN.

FOOTNOTE:

[20] See this paper afterwards printed in the *Philosophical Transactions*.

TO THE ABBE SOULAVIE. [117]

Occasioned by his sending me some notes he had taken of what I had said to him in conversation on the Theory of the Earth. I wrote it to set him right in some points wherein he had mistaken my meaning.[21]

Passy, September 22, 1782.

Sir,

I return the papers with some corrections. I did not find coal mines under the calcareous rock in Derbyshire. I only remarked, that at the lowest part of that rocky mountain which was in sight, there were oyster shells mixed in the stone; and part of the high county of Derby being probably as much above the level of the sea, as the coal mines of Whitehaven were below it, seemed a proof, that there had been a great *bouleversement* in the surface of that island, some part of it having been depressed under the sea, and other parts, which had been under it, being raised above it. Such changes in the superficial parts of the globe, seemed to me unlikely to happen, if the earth were solid to the centre. I therefore imagined, that the internal parts might be a fluid more dense, and of greater specific gravity than any of the solids we are acquainted with, which therefore might swim in or upon that fluid. Thus the surface of the globe would be a shell, capable of being broken and disordered by the violent movements of the fluid on which it rested. And as air has been compressed by art so as to be twice as dense as water, in which case, if such air and water could be contained in a strong glass vessel, the air [118] would be seen to take the lowest place, and the water to float above and upon it; and as we know not yet the degree of density to which air may be compressed, and M. Amontons calculated, that its density increasing as it approached the centre, in the same proportion as above the surface, it would at the depth of [ ] leagues, be heavier than gold, possibly the dense fluid occupying the internal parts of the globe might be air compressed. And as the force of expansion in dense air when heated is in proportion to its density, this central air might afford another agent to move the surface, as well as be of use in keeping alive the subterraneous fires; though, as you observe, the sudden rarefaction of water coming into contact without those fires, may also be an agent sufficiently strong for that purpose, when acting between the incumbent earth and the fluid on which it rests.

If one might indulge imagination in supposing how such a globe was formed, I should conceive, that all the elements in separate particles being originally mixed in confusion, and occupying a great space, they would (as soon as the almighty fiat ordained gravity, or the mutual attraction of certain parts, and the mutual repulsion of others, to exist) all move to their common centre: that the air being a fluid whose parts repel each other, though drawn to the common centre by their gravity, would be densest towards the centre, and rarer as more remote; consequently all matters lighter than the central parts of that air, and immersed in it, would recede from the centre, and rise till they arrived at that region of the air which was of the same specific gravity with themselves, where they would rest; while other matter, mixed with the lighter air, [119]
would descend, and the two meeting would form the shell of the first earth, leaving the upper atmosphere nearly clear. The original movement of the parts towards their common centre would naturally form a whirl there; which would continue upon the turning of the new-formed globe upon its axis, and the greatest diameter of the shell would be in its equator. If by any accident afterwards the axis should be changed, the dense internal fluid, by altering its form, must burst the shell, and throw all its substance into the confusion in which we find it. I will not trouble you at present with my fancies concerning the manner of forming the rest of our system. Superior beings smile at our theories, and at our presumption in making them. I will just mention, that your observation of the ferruginous nature of the lava which is thrown out from the depths of our volcanoes, gave me great pleasure. It has long been a supposition of mine, that the iron contained in the surface of the globe has made it capable of becoming, as it is, a great magnet; that the fluid of magnetism perhaps exists in all space; so that there is a magnetical north and south of the universe, as well as of this globe, and that if it were possible for a man to fly from star to star, he might govern his course by the compass; that it was by the power of this general magnetism this globe became a particular magnet. In soft or hot iron the fluid of magnetism is naturally diffused equally; when within the influence of the magnet it is drawn to one end of the iron, made denser there and rarer at the other. While the iron continues soft and hot, it is only a temporary magnet; if it cools or grows hard in that situation, it becomes a permanent one, the magnetic fluid not easily resuming its equilibrium. Perhaps it may be owing to the [120]
permanent magnetism of this globe, which it had not at first, that its axis is at present kept parallel to itself, and not liable to the changes it formerly suffered, which occasioned the rupture of its shell, the submersions and emersions of its lands and the confusion of its seasons. The present polar and equatorial diameters differing from each other near ten leagues, it is easy to conceive, in case some power should shift the axis gradually, and place it in the present equator, and make the new equator pass through the present poles, what a sinking of the waters would happen in the present equatorial regions, and what a rising in the present polar regions; so that vast tracts would be discovered, that now are under water, and others covered, that are now dry, the water rising and sinking in the different extremes near five leagues. Such an operation as this possibly occasioned much of Europe, and among the rest this Mountain of Passy on which I live, and which is composed of limestone, rock and sea-shells, to be abandoned by the sea, and to change its ancient climate, which seems to have been a hot one. The globe being now become a perfect magnet, we are, perhaps, safe from any change of its axis. But we are still subject to the accidents on the surface, which are occasioned by a wave in the internal ponderous fluid; and such a wave is producible by the sudden violent explosion you mention, happening from the junction of water and fire under the earth, which not only lifts the incumbent earth that is over the explosion, but impressing with the same force

the fluid under it, creates a wave, that may run a thousand leagues, lifting, and thereby shaking, successively, all the countries under which it passes. I know not, whether I have expressed myself so clearly, as not to get out of your sight in these reveries. It they occasion any new enquiries, and produce a better hypothesis, they will not be quite useless. You see I have given a loose to imagination; but I approve much more your method of philosophising, which proceeds upon actual observation, makes a collection of facts, and concludes no farther than those facts will warrant. In my present circumstances, that mode of studying the nature of the globe is out of my power, and therefore I have permitted myself to wander a little in the wilds of fancy. With great esteem, [121]

I have the honour to be, Sir, &c.

BENJ. FRANKLIN.

P. S. I have heard, that chymists can by their art decompose stone and wood, extracting a considerable quantity of water from the one, and air from the other. It seems natural to conclude from this, that water and air were ingredients in their original composition: for men cannot make new matter of any kind. In the same manner may we not suppose, that when we consume combustibles of all kinds, and produce heat or light, we do not create that heat or light; but only decompose a substance, which received it originally as a part of its composition? Heat may be thus considered as originally in a fluid state; but, attracted by organized bodies in their growth, becomes a part of the solid. Besides this, I can conceive, that in the first assemblage of the particles of which this earth is composed, each brought its portion of the loose heat that had [122] been connected with it, and the whole, when pressed together, produced the internal fire that still subsists.

FOOTNOTE:

[21] In an American periodical publication, this paper is said to have been so endorsed in Dr. Franklin's hand. We extract the paper itself, from the Transactions of the American Philosophical Society, where it was read Nov. 21, 1788. The two papers that follow it are from the same work, and were read in the Society the preceding day, and the other Jan. 15, 1790. *Editor.*

New and curious Theory of Light and Heat.

[No date.]

Universal space, as far as we know of it, seems to be filled with a subtle fluid, whose motion, or vibration, is called light.

This fluid may possibly be the same with that, which, being attracted by, and entering into other more solid matter, dilates the substance by separating the constituent particles, and so rendering some solids fluid, and maintaining the fluidity of others; of which fluid, when our bodies are totally deprived, they are said to be frozen; when they have a proper quantity, they are in health, and fit to perform all their functions; it is then called natural heat; when too much, it is called fever; and when forced into the body in too great a quantity from without, it gives pain, by separating and destroying the flesh, and is then called burning, and the fluid so entering and acting is called fire.

While organised bodies, animal or vegetable, are augmenting in growth, or are supplying their continual waste, is not this done by attracting and consolidating this fluid called fire, so as to form of it a part of their substance? And is it not a separation of the parts of such substance, which, dissolving its solid state, sets that subtle fluid at liberty, when it again makes its appearance as fire?

For the power of man relative to matter, seems limited to the separating or mixing the various kinds of it, or changing [123] its form and appearance by different compositions of it; but does not extend to the making or creating new matter, or annihilating the old. Thus, if fire be an original element or kind of matter, its quantity is fixed and permanent in the universe. We cannot destroy any part of it, or make addition to it; we can only separate it from that which confines it, and so set it at liberty; as when we put wood in a situation to be burnt, or transfer it from one solid to another, as when we make lime by burning stone, a part of the fire dislodged in the fuel being left in the stone. May not this fluid, when at liberty, be capable of penetrating and entering into all bodies, organised or not, quitting easily in totality those not organised, and quitting easily in part those which are; the part assumed and fixed remaining till the body is dissolved?

Is it not this fluid which keeps asunder the particles of air, permitting them to approach, or separating them more, in proportion as its quantity is diminished or augmented?

Is it not the greater gravity of the particles of air, which forces the particles of this fluid to mount with the matters to which it is attached, as smoke or vapour?

Does it not seem to have a greater affinity with water, since it will quit a solid to unite with that fluid, and go off with it in vapour, leaving the solid cold to the touch, and the degree measurable by the thermometer?

The vapour rises attached to this fluid, but at a certain height they separate, and the vapour descends in rain, retaining [124] but little of it, in snow or hail less. What becomes of that fluid? Does it rise above our atmosphere, and mix with the universal mass of the same kind?

Or does a spherical stratum of it, denser, as less mixed with air, attracted by this globe, and repelled or pushed up only to a certain height from its surface, by the greater weight of air, remain there surrounding the globe, and proceeding with it round the sun?

In such case, as there may be a continuity or communication of this fluid through the air quite down to the earth, is it not by the vibrations given to it, by the sun, that light appears to us? And may it not be, that every one of the infinitely small vibrations, striking common matter with a certain force, enters its substance, is held there by attraction, and augmented by succeeding vibrations, till the matter has received as much as their force can drive into it?

Is it not thus, that the surface of this globe is continually heated by such repeated vibrations in the day, and cooled by the escape of the heat when those vibrations are discontinued in the night, or intercepted and reflected by clouds?

Is it not thus, that fire is amassed and makes the greatest part of the substance of combustible bodies?

Perhaps, when this globe was first formed, and its original particles took their place at certain distances from the centre, in proportion to their greater or less gravity, the fluid fire, attracted towards that centre, might in great part be obliged, as lightest, to take place above the rest, and thus form the sphere of fire above supposed, which would afterwards be continually diminishing by the substance it afforded to organised bodies, and the quantity restored to it again, by the [125]
burning or other separating of the parts of those bodies.

Is not the natural heat of animals thus produced, by separating in digestion the parts of food, and setting their fire at liberty?

Is it not this sphere of fire which kindles the wandering globes that sometimes pass through it in our course round the sun, have their surface kindled by it, and burst when their included air is greatly rarefied by the heat on their burning surfaces?

May it not have been from such considerations that the ancient philosophers supposed a sphere of fire to exist above the air of our atmosphere?

B. FRANKLIN.

TO MR. BODOIN.

Queries and Conjectures relating to Magnetism and the Theory of the Earth.

[No date.]

Dear Sir,

I received your favours by Messrs. Gore, Hilliard, and Lee, with whose conversation I was much pleased, and wished for more of it; but their stay with us was too short. Whenever you recommend any of your friends to me, you oblige me.

I want to know whether your Philosophical Society received the second volume of our Transactions. I sent it, but never heard of its arriving. If it miscarried, I will send another. Has your Society among its books the French work *Sur les Arts, et les Metiers*? It is voluminous, well executed, and may be useful in our country. I have bequeathed it them in my will; [126]
but if they have it already, I will substitute something else.

Our ancient correspondence used to have something philosophical in it. As you are now more free from public cares, and I expect to be so in a few months, why may we not resume that kind of correspondence? Our much regretted friend Winthrop once made me the compliment, that I was good at starting game for philosophers, let me try if I can start a little for you.

Has the question, how came the earth by its magnetism, ever been considered?

Is it likely that *iron ore* immediately existed when this globe was first formed; or may it not rather be supposed a gradual production of time?

If the earth is at present magnetical, in virtue of the masses of iron ore contained in it, might not some ages pass before it had magnetic polarity?

Since iron ore may exist without that polarity, and by being placed in certain circumstances may obtain it, from an external cause, is it not possible that the earth received its magnetism from some such cause?

In short, may not a magnetic power exist throughout our system, perhaps through all systems, so that if men could make a voyage in the starry regions, a compass might be of use? And may not such universal magnetism, with its uniform direction, be serviceable in keeping the diurnal revolution of a planet more steady to the same axis?

Lastly, as the poles of magnets may be changed by the presence of stronger magnets, might not, in ancient times, the near passing of some large comet of greater magnetic power than this globe of ours have been a means of changing its [127] poles, and thereby wrecking and deranging its surface, placing in different regions the effect of centrifugal force, so as to raise the waters of the sea in some, while they were depressed in others?

Let me add another question or two, not relating indeed to magnetism, but, however, to the theory of the earth.

Is not the finding of great quantities of shells and bones of animals (natural to hot climates) in the cold ones of our present world, some proof that its poles have been changed? Is not the supposition that the poles have been changed, the easiest way of accounting for the deluge, by getting rid of the old difficulty how to dispose of its waters after it was over? Since if the poles were again to be changed, and placed in the present equator, the sea would fall there about fifteen miles in height, and rise as much in the present polar regions; and the effect would be proportionable if the new poles were placed any where between the present and the equator.

Does not the apparent wreck of the surface of this globe, thrown up into long ridges of mountains, with strata in various positions, make it probable, that its internal mass is a fluid; but a fluid so dense as to float the heaviest of our substances? Do we know the limit of condensation air is capable of? Supposing it to grow denser *within* the surface, in the same proportion nearly as it does *without*, at what depth may it be equal in density with gold?

Can we easily conceive how the strata of the earth could have been so deranged, if it had not been a mere shell [128] supported by a heavier fluid? Would not such a supposed internal fluid globe be immediately sensible of a change in the situation of the earth's axis, alter its form, and thereby burst the shell, and throw up parts of it above the rest? As, if we would alter the position of the fluid contained in the shell of an egg, and place its longest diameter where the shortest now is, the shell must break; but would be much harder to break; if the whole internal substance were as solid and hard as the shell.

Might not a wave, by any means raised in this supposed internal ocean of extremely dense fluid, raise in some degree, as it passes, the present shell of incumbent earth, and break it in some places, as in earthquakes? And may not the progress of such wave, and the disorders it occasions among the solids of the shell, account for the rumbling sound being first heard at a distance, augmenting as it approaches, and gradually dying away as it proceeds? A circumstance observed by the inhabitants of South America in their last great earthquake, that noise coming from a place, some degrees north of Lima, and being traced by enquiry quite down to Buenos Ayres, proceeded regularly from north to south at the rate of [   ] leagues per minute, as I was informed by a very ingenious Peruvian whom I met with at Paris.

B. FRANKLIN.

TO M. DUBOURG.

On the Nature of Sea Coal.[22]

**** I am persuaded, as well as you, that the sea coal has a vegetable origin, and that it has been formed near the surface of the earth; but as preceding convulsions of nature had served to bring it very deep in many places, and covered it with many different strata, we are indebted to subsequent convulsions for having brought within our view the extremities of its veins, so as to lead us to penetrate the earth in search of it. I visited last summer a large coal-mine at Whitehaven, in Cumberland; and in following the vein and descending by degrees towards the sea, I penetrated below the ocean, where the level of its surface was more than eight hundred fathom above my head, and the miners assured me, that their works extended some miles beyond the place where I then was, continually and gradually descending under the sea. The slate, which forms the roof of this coal mine, is impressed in many places with the figures of leaves and branches of fern, which undoubtedly grew at the surface when the slate was in the state of sand on the banks of the sea. Thus it appears that this vein of coal has suffered a prodigious settlement. **** [129]

B. FRANKLIN.

FOOTNOTE:

[22] Retranslated from the French edition of Dr. Franklin's works. *Editor.*

TO DR. PRIESTLEY[23].

Effect of Vegetation on noxious Air.

**** That the vegetable creation should restore the air which is spoiled by the animal part of it, looks like a rational system, and seems to be of a piece with the rest. Thus fire purifies water all the world over. It purifies it by distillation, when it raises it in vapours, and lets it fall in rain; and farther still by filtration, when, keeping it fluid, it suffers that rain to percolate the earth. We knew before, that putrid animal substances were converted into sweet vegetables, when mixed with the earth, and applied as manure; and now, it seems, that the same putrid substances, mixed with the air, have a similar effect. The strong thriving state of your mint, in putrid air, seems to shew, that the air is mended by taking something from it, and not by adding to it. I hope this will give some check to the rage of destroying trees that grow near houses, which has accompanied our late improvements in gardening, from an opinion of their being unwholesome. I am certain, from long observation, that there is nothing unhealthy in the air of woods; for we Americans have every where our country habitations in the midst of woods, and no people on earth enjoy better health, or are more prolific. **** [130]

B. FRANKLIN.

FOOTNOTE:

[23] This extract is taken from Dr. Priestley's Experiments on Air, Vol. I. page 94. It was written in answer to a note from Dr. Priestley, informing our author of the result of certain experiments on some plants which he had seen at Dr. Priestley's house in a very flourishing state, in jars of highly noxious air. *Editor.*

TO THE SAME[24].

On the Inflammability of the Surface of certain Rivers in America.

Craven-street, April 10, 1774.

Dear Sir,

In compliance with your request, I have endeavoured to recollect the circumstances of the American experiments I formerly mentioned to you, of raising a flame on the surface of some waters there. [131]

When I passed through New Jersey in 1764, I heard it several times mentioned, that by applying a lighted candle near the surface of some of their rivers, a sudden flame would catch and spread on the water, continuing to burn for near half a minute. But the accounts I received were so imperfect, that I could form no guess at the cause of such an effect, and rather doubted the truth of it. I had no opportunity of seeing the experiment; but calling to see a friend who happened to be just returning home from making it himself, I learned from him the manner of it; which was to choose a shallow place, where the bottom could be reached by a walking-stick, and was muddy; the mud was first to be stirred with the stick, and when a number of small bubbles began to arise from it, the candle was applied. The flame was so sudden and so strong, that it catched his ruffle and spoiled it, as I saw. New Jersey having many pine-trees in many parts of it, I then imagined that something like a volatile oil of turpentine might be mixed with the waters from a pine-swamp, but this supposition did not quite satisfy me. I mentioned the fact to some philosophical friends on my return to England, but it was not much attended to. I suppose I was thought a little too credulous.

In 1765, the Reverend Dr. Chandler received a letter from Dr. Finley, President of the College in that province, relating the same experiment. It was read at the Royal Society, November 21 of that year, but not printed in the Transactions; perhaps because it was thought too strange to be true, and some ridicule might be apprehended, if any member should attempt to repeat it, in order to ascertain, or refute it. The following is a copy of that account. [132]

"A worthy gentleman, who lives at a few miles distance, informed me, that in a certain small cove of a mill-pond, near his house, he was surprized to see the surface of the water blaze like inflamed spirits. I soon after went to the place, and made the experiment with the same success. The bottom of the creek was muddy, and when stirred up, so as to cause a considerable curl on the surface, and a lighted candle held within two or three inches of it, the whole surface was in a blaze, as instantly as the vapour of warm inflammable spirits, and continued, when strongly agitated, for the space of several seconds. It was at first imagined to be peculiar to that place; but upon trial it was soon found, that such a bottom in other places exhibited the same phenomenon. The discovery was accidentally made by one belonging to the mill."

I have tried the experiment twice here in England, but without success. The first was in a slow running water with a muddy bottom. The second in a stagnant water at the bottom of a deep ditch. Being some time employed in stirring this water, I ascribed an intermitting fever, which seized me a few days after, to my breathing too much of that foul air, which I stirred up from the bottom, and which I could not avoid while I stooped, endeavouring to kindle it. The discoveries you have lately made, of the manner in which inflammable air is in some cases produced, may throw light on this experiment, and explain its succeeding in some cases, and not in others. With the highest esteem and respect,

I am, dear Sir, your most obedient humble servant,

B. FRANKLIN.

FOOTNOTE:

[24] From his Experiments on Air, Vol. I. page 321. *Editor.*

On the different Quantities of Rain which fall at different Heights over the same Ground.

[No date.]

On my return to London I found your favour of the 16th of May (1771). I wish I could, as you desire, give you a better explanation of the phenomenon in question, since you seem not quite satisfied with your own; but I think we want more and a greater variety of experiments, in different circumstances, to enable us to form a thoroughly satisfactory hypothesis. Not that I make the least doubt of the facts already related, as I know both Lord Charles Cavendish, and Dr. Heberden to be very accurate experimenters: but I wish to know the event of the trials proposed in your six queries; and also, whether in the same place where the lower vessel receives nearly twice the quantity of water that is received by the upper, a third vessel placed at half the height will receive a quantity proportionable. I will however endeavour to explain to you what occurred to me, when I first heard of the fact.

I suppose it will be generally allowed, on a little consideration of the subject, that scarce any drop of water was, when it began to fall from the clouds, of a magnitude equal to that it has acquired, when it arrives at the earth; the same of the several pieces of hail; because they are often so large and so weighty, that we cannot conceive a possibility of their being [134] suspended in the air, and remaining at rest there, for any time, how small soever; nor do we conceive any means of forming them so large, before they set out to fall. It seems then, that each beginning drop, and particle of hail, receives continual addition in its progress downwards. This may be several ways: by the union of numbers in their course, so that what was at first only descending mist, becomes a shower; or by each particle, in its descent through air that contains a great quantity of dissolved water, striking against, attaching to itself, and carrying down with it such particles of that dissolved water, as happen to be in its way; or attracting to itself such as do not lie directly in its course by its different state with regard either to common or electric fire; or by all these causes united.

In the first case, by the uniting of numbers, larger drops might be made, but the quantity falling in the same place would be the same at all heights; unless, as you mention, the whole should be contracted in falling, the lines described by all the drops converging, so that what set out to fall from a cloud of many thousand acres, should reach the earth in perhaps a third of that extent, of which I somewhat doubt. In the other cases we have two experiments.

1. A dry glass bottle filled with very cold water, in a warm day, will presently collect from the seemingly dry air that surrounds it a quantity of water, that shall cover its surface and run down its sides, which perhaps is done by the power wherewith the cold water attracts the fluid, common fire that had been united with the dissolved water in the air, and drawing the fire through the glass into itself, leaves the water on the outside.

2. An electrified body left in a room for some time, will be more covered with dust than other bodies in the same room [135] not electrified, which dust seems to be attracted from the circumambient air.

Now we know that the rain, even in our hottest days, comes from a very cold region. Its falling sometimes in the form of ice, shows this clearly; and perhaps even the rain is snow or ice, when it first moves downwards, though thawed in falling: and we know that the drops of rain are often electrified: but those causes of addition to each drop of water, or piece of hail, one would think could not long continue to produce the same effect; since the air, through which the drops fall, must soon be stripped of its previously dissolved water, so as to be no longer capable of augmenting them. Indeed very heavy showers, of either, are never of long continuance; but moderate rains often continue so long as to puzzle this hypothesis: so that upon the whole I think, as I intimated before, that we are yet hardly ripe for making one. ****

B. FRANKLIN.

FOOTNOTE:

[25] This letter is taken from the Memoirs of the Literary and Philosophical Society of Manchester, Vol. II. page 126. It was communicated by the person to whom it is addressed, and was read in the Society, January 21, 1784, as an appendix to a paper by Dr. Percival on the same subject. *Editor.*

TO MR. NAIRNE, OF LONDON[26].

Proposing a slowly sensible Hygrometer for certain Purposes.

Passy, near Paris, Nov. 13, 1780.

Sir,

The qualities hitherto sought in a hygrometer, or instrument to discover the degrees of moisture and dryness in the air, seem to have been, an aptitude to receive humidity readily from a moist air, and to part with it is as readily to a dry air. Different substances have been found to possess more or less of this quality; but when we shall have found the substance that has it in the greatest perfection, there will still remain some uncertainty in the conclusions to be drawn from the degree shown by the instrument, arising from the actual state of the instrument itself as to heat and cold. Thus, if two bottles or vessels of glass or metal being filled, the one with cold and the other with hot water, are brought into a room, the moisture of the air in the room will attach itself in quantities to the surface of the cold vessel, while if you actually wet the surface of the hot vessel, the moisture will immediately quit it, and be absorbed by the same air. And thus, in a sudden change of the air from cold to warm, the instrument remaining longer cold may condense and absorb more moisture, and mark the air as having become more humid than it is in reality, and the contrary in a change from warm to cold. [136]

But if such a suddenly changing instrument could be freed from these imperfections, yet when the design is to discover the different degrees of humidity in the air of different countries, I apprehend the quick sensibility of the instrument to be rather a disadvantage; since, to draw the desired conclusions from it, a constant and frequent observation day and night in each country will be necessary for a year or years, and the mean of each different set of observations is to be found and determined. After all which some uncertainty will remain respecting the different degrees of exactitude with which different persons may have made and taken notes of their observations. [137]

For these reasons, I apprehend that a substance which, though capable of being distended by moisture and contracted by dryness, is so slow in receiving and parting with its humidity, that the frequent changes in the atmosphere have not time to affect it sensibly, and which therefore should gradually take nearly the medium of all those changes and preserve it constantly, would be the most proper substance of which to make such an hygrometer.

Such an instrument, you, my dear sir, though without intending it, have made for me; and I, without desiring or expecting it, have received from you. It is therefore with propriety that I address to you the following account of it; and the more, as you have both a head to contrive and a hand to execute the means of perfecting it. And I do this with greater pleasure, as it affords me the opportunity of renewing that antient correspondence and acquaintance with you, which to me was always so pleasing and so instructive.

You may possibly remember, that in or about the year 1758, you made for me a set of artificial magnets, six in number, each five and a half inches long, half an inch broad, and one eighth of an inch thick. These, with two pieces of soft iron, which together equalled one of the magnets, were inclosed in a little box of mahogany wood, the grain of which ran with, and not across, the length of the box: and the box was closed by a little shutter of the same wood, the grain of which ran across the box; and the ends of this shutting piece were bevelled so as to fit and slide in a kind of dovetail groove when the box was to be shut or opened.

I had been of opinion, that good mahogany wood was not affected by moisture so as to change its dimensions, and that [138] it was always to be found as the tools of the workman left it. Indeed the difference at different times in the same country is so small as to be scarcely in a common way observable. Hence the box, which was made so as to allow sufficient room for the magnets to slide out and in freely, and, when in, afforded them so much play that by shaking the box one could make them strike the opposite sides alternately, continued in the same state all the time I remained in England, which was four years, without any apparent alteration. I left England in August 1762, and arrived at Philadelphia in October the same year. In a few weeks after my arrival, being desirous of showing your magnets to a philosophical friend, I found them so tight in the box, that it was with difficulty I got them out; and constantly during the two years I remained there, viz. till November 1764, this difficulty of getting them out and in continued. The little shutter too, as wood does not shrink lengthways of the grain, was found too long to enter its grooves, and, not being used, was mislaid and lost; and I afterwards had another made that fitted.

In December 1764 I returned to England, and after some time I observed that my box was become full big enough for my magnets, and too wide for my new shutter; which was so much too short for its grooves, that it was apt to fall out; and to make it keep in, I lengthened it by adding to each end a little coat of sealing-wax.

I continued in England more than ten years, and during all that time, after the first change, I perceived no alteration. The magnets had the same freedom in their box, and the little shutter continued with the added sealing-wax to fit its [139] grooves, till some weeks after my second return to America.

As I could not imagine any other cause for this change of dimensions in the box, when in the different countries, I concluded, first generally that the air of England was moister than that of America. And this I supposed an effect of its being an island, where every wind that blew must necessarily pass over some sea before it arrived, and of course lick up some vapour. I afterwards indeed doubted whether it might be just only so far as related to the city of London, where I resided; because there are many causes of moisture in the city air, which do not exist to the same degree in the country; such as the brewers' and dyers' boiling caldrons, and the great number of pots and tea-kettles continually on the fire, sending forth abundance of vapour; and also the number of animals who by their breath continually increase it; to which may be added, that even the vast quantity of sea coals burnt there, do in kindling discharge a great deal of moisture.

When I was in England, the last time, you also made for me a little achromatic pocket telescope, the body was brass, and it had a round case (I think of thin wood) covered with shagrin. All the while I remained in England, though possibly there might be some small changes in the dimensions of this case, I neither perceived nor suspected any. There was always comfortable room for the telescope to slip in and out. But soon after I arrived in America, which was in May 1775, the case became too small for the instrument, it was with much difficulty and various contrivances that I got it out, and I could never after get it in again, during my stay there, which was eighteen months. I brought it with me to Europe, but left [140] the case as useless, imagining that I should find the continental air of France as dry as that of Pennsylvania, where my magnet box had also returned a second time to its narrowness, and pinched the pieces, as heretofore, obliging me too, to scrape the sealing-wax off the ends of the shutter.

I had not been long in France, before I was surprised to find, that my box was become as large as it had always been in England, the magnets entered and came out with the same freedom, and, when in, I could rattle them against its sides; this has continued to be the case without sensible variation. My habitation is out of Paris distant almost a league, so that the moist air of the city cannot be supposed to have much effect upon the box. I am on a high dry hill, in a free air, as likely to be dry as any air in France. Whence it seems probable that the air of England in general may, as well as that of London, be moister than the air of America, since that of France is so, and in a part so distant from the sea.

The greater dryness of the air in America appears from some other observations. The cabinet work formerly sent us from London, which consisted in thin plates of fine wood glued upon fir, never would stand with us; the vaneering, as those plates are called, would get loose and come off; both woods shrinking, and their grains often crossing, they were forever cracking and flying. And in my electrical experiments there, it was remarkable, that a mahogany table, on which my jars stood under the prime conductor to be charged, would often be so dry, particularly when the wind had been some time at north-west, which with us is a very drying wind, as to isolate the jars, and prevent their being charged till I had [141] formed a communication between their coatings and the earth. I had a like table in London, which I used for the same purpose all the time I resided there; but it was never so dry as to refuse conducting the electricity.

Now what I would beg leave to recommend to you, is, that you would recollect, if you can, the species of mahogany of which you made my box, for you know there is a good deal of difference in woods that go under that name; or if that cannot be, that you would take a number of pieces of the closest and finest grained mahogany that you can meet with, plane them to the thinness of about a line, and the width of about two inches across the grain, and fix each of the pieces in some instrument that you can contrive, which will permit them to contract and dilate, and will show, in sensible degrees, by a moveable hand upon a marked scale, the otherwise less sensible quantities of such contraction and dilatation. If these instruments are all kept in the same place while making, and are graduated together while subject to the same degrees of moisture or dryness, I apprehend you will have so many comparable hygrometers, which, being sent into different countries, and continued there for some time, will find and show there the mean of the different dryness and moisture of the air of those countries, and that with much less trouble than by any hygrometer hitherto in use.

With great esteem, I am,

Dear Sir, your most obedient,

And most humble servant,

B. FRANKLIN.

FOOTNOTE:

[26] This letter is taken from the Transactions of the American Philosophical Society, in which it was read, January 26, 1786. *Editor.*

TO DR. P.[27] IN LONDON. [142]

Relating a curious Instance of the Effect of Oil on Water.

Philadelphia, Dec. 1, 1762.

Sir,

During our passage to Madeira, the weather being warm, and the cabin windows constantly open for the benefit of the air, the candles at night flared and run very much, which was an inconvenience. At Madeira, we got oil to burn, and with a common glass tumbler or beaker, slung in wire, and suspended to the cieling of the cabin, and a little wire hoop for the wick, furnished with corks to float on the oil, I made an Italian lamp, that gave us very good light all over the table.—The glass at bottom contained water to about one third of its height; another third was taken up with oil; the rest was left empty that the sides of the glass might protect the flame from the wind. There is nothing remarkable in all this; but what follows is particular. At supper, looking on the lamp, I remarked, that though the surface of the oil was perfectly tranquil, and duly preserved its position and distance with regard to the brim of the glass, the water under the oil was in great commotion, rising and falling in irregular waves, which continued during the whole evening. The lamp was kept burning as a watch light all night, till the oil was spent, and the water only remained. In the morning I observed, that though the motion of the ship continued the same, the water was now quiet, and its surface as tranquil as that of the oil had been the evening before.

[143] At night again, when oil was put upon it, the water resumed its irregular motions, rising in high waves almost to the surface of the oil, but without disturbing the smooth level of that surface. And this was repeated every day during the voyage.

Since my arrival in America, I have repeated the experiment frequently thus. I have put a pack-thread round a tumbler, with strings of the same, from each side, meeting above it in a knot at about a foot distance from the top of the tumbler. Then putting in as much water as would fill about one third part of the tumbler, I lifted it up by the knot, and swung it to and fro in the air; when the water appeared to keep its place in the tumbler as steadily as if it had been ice. But pouring gently in upon the water about as much oil, and then again swinging it in the air as before, the tranquility before possessed by the water, was transferred to the surface of the oil, and the water under it was agitated with the same commotions as at sea.

I have shewn this experiment to a number of ingenious persons. Those who are but slightly acquainted with the principles of hydrostatics, &c. are apt to fancy immediately that they understand it, and readily attempt to explain it; but their explanations have been different, and to me not very intelligible. Others, more deeply skilled in those principles, seem to wonder at it, and promise to consider it. And I think it is worth considering: for a new appearance, if it cannot be explained by our old principles, may afford us new ones, of use perhaps in explaining some other obscure parts of natural knowledge.

I am, &c.

B. FRANKLIN.

FOOTNOTE:

[27] Dr. Pringle. *Editor.*

Of the Stilling of Waves by Means of Oil. Extracted from Sundry Letters between Benjamin Franklin, L. L. D. F. R. S. William Brownrigg, M. D. F. R. S. and the Rev. Mr. Farish. [144]

Read at the Royal Society, June 2, 1774.

Extract of a Letter from Dr. Brownrigg to Dr. Franklin, dated Ormathwait, January 27, 1773.

By the enclosed from an old friend, a worthy clergyman at Carlisle, whose great learning and extensive knowledge in most sciences would have more distinguished him, had he been placed in a more conspicuous point of view, you will find, that he had heard of your experiment on Derwent Lake, and has thrown together what he could collect on that subject; to which I have subjoined one experiment from the relation of another gentleman.

Extract of a Letter from the Rev. Mr. Farish, to Dr. Brownrigg.

I some time ago met with Mr. Dun, who surprised me with an account of an experiment you had tried upon the Derwent Water, in company with Sir John Pringle and Dr. Franklin. According to his representation, the water, which had been in great agitation before, was instantly calmed upon pouring in only a very small quantity of oil, and that to so great a distance round the boat as seemed incredible. I have since had the same accounts from others, but I suspect all of a little exaggeration. Pliny mentions this property of oil as known particularly to the divers, who made use of it in his days, in [145]
order to have a more steady light at the bottom.[28] The sailors, I have been told, have observed something of the same kind in our days, that the water is always remarkably smoother, in the wake of a ship that has been newly tallowed, than it is in one that is foul. Mr. Pennant also mentions an observation of the like nature made by the seal catchers in Scotland.

Brit. Zool. Vol. IV. *Article* Seal. When these animals are devouring a very oily fish, which they always do under water, the waves alone are observed to be remarkably smooth, and by this mark the fishermen know where to look for them. Old Pliny does not usually meet with all the credit I am inclined to think he deserves. I shall be glad to have an authentic account of the Keswick experiment, and if it comes up to the representations that have been made of it, I shall not much hesitate to believe the old gentleman in another more wonderful phenomenon he relates of stilling a tempest only by throwing up a little vinegar into the air.

Extract of a Letter to Dr. Brownrigg from Dr. Franklin.

London Nov. 7, 1773.

Dear Sir,

I thank you for the remarks of your learned friend at Carlisle. I had, when a youth, read and smiled at Pliny's account of a practice among the seamen of his time, to still the waves in a storm by pouring oil into the sea; which he mentions, as well as the use made of oil by the divers; but the stilling a tempest by throwing vinegar into the air had escaped me. I think with your friend, that it has been of late too much the mode to slight the learning of the ancients. The learned, too, are apt to slight too much the knowledge of the vulgar. The cooling by evaporation was long an instance of the latter. This art of smoothing the waves by oil is an instance of both. [146]

Perhaps you may not dislike to have an account of all I have heard, and learnt, and done in this way. Take it if you please as follows.

In 1757, being at sea in a fleet of 96 sail bound against Louisbourg, I observed the wakes of two of the ships to be remarkably smooth, while all the others were ruffled by the wind, which blew fresh. Being puzzled with the differing appearance, I at last pointed it out to our captain, and asked him the meaning of it. "The cooks," says he, "have, I suppose, been just emptying their greasy water through the scuppers, which has greased the sides of those ships a little;" and this answer he gave me with an air of some little contempt, as to a person ignorant of what every body else knew. In my own mind I at first slighted his solution, though I was not able to think of another, but recollecting what I had formerly read in Pliny, I resolved to make some experiment of the effect of oil on water, when I should have opportunity.

Afterwards being again at sea in 1762, I first observed the wonderful quietness of oil on agitated water, in the swinging glass lamp I made to hang up in the cabin, as described in my printed papers[29]. This I was continually looking at and considering, as an appearance to me inexplicable. An old sea captain, then a passenger with me, thought little of it, supposing it an effect of the same kind with that of oil put on water to smooth it, which he said was a practice of the Bermudians when they would strike fish, which they could not see, if the surface of the water was ruffled by the wind. This practice I had never before heard of, and was obliged to him for the information; though I thought him mistaken as to the sameness of the experiment, the operations being different as well as the effects. In one case, the water is smooth till the oil is put on, and then becomes agitated. In the other it is agitated before the oil is applied, and then becomes smooth. The same gentleman told me, he had heard it was a practice with the fisherman of Lisbon when about to return into the river (if they saw before them too great a surf upon the bar, which they apprehended might fill their boats in passing) to [147] empty a bottle or two of oil into the sea, which would suppress the breakers, and allow them to pass safely. A confirmation of this I have not since had an opportunity of obtaining: but discoursing of it with another person, who had often been in the Mediterranean, I was informed, that the divers there, who, when under water in their business, need light, which the curling of the surface interrupts by the refractions of so many little waves, let a small quantity of oil now and then out of their mouths, which rising to the surface smooths it, and permits the light to come down to them. All these informations I at times revolved in my mind, and wondered to find no mention of them in our books of experimental [148] philosophy.

At length being at Clapham, where there is, on the common, a large pond, which I observed one day to be very rough with the wind, I fetched out a cruet of oil, and dropt a little of it on the water. I saw it spread itself with surprising swiftness upon the surface; but the effect of smoothing the waves was not produced; for I had applied it first on the leeward side of the pond, where the waves were largest, and the wind drove my oil back upon the shore. I then went to the windward side where they began to form; and there the oil, though not more than a tea spoonful, produced an instant calm over a space several yards square, which spread amazingly, and extended itself gradually till it reached the lee side, making all that quarter of the pond, perhaps half an acre, as smooth as a looking-glass.

After this I contrived to take with me, whenever I went into the country, a little oil in the upper hollow joint of my bamboo cane, with which I might repeat the experiment as opportunity should offer, and I found it constantly to succeed.

In these experiments, one circumstance struck me with particular surprise. This was the sudden, wide and forcible spreading of a drop of oil on the face of the water, which I do not know that any body has hitherto considered. If a drop of oil is put on a highly polished marble table, or on a looking-glass that lies horizontally, the drop remains in its place, spreading very little. But when put on water, it spreads instantly many feet round, becoming so thin as to produce the prismatic colours, for a considerable space, and beyond them so much thinner as to be invisible, except in its effect of [149] smoothing the waves at a much greater distance. It seems as if a mutual repulsion between its particles took place as soon as it touched the water, and a repulsion so strong as to act on other bodies swimming on the surface, as straw, leaves, chips, &c. forcing them to recede every way from the drop, as from a centre, leaving a large clear space. The quantity of this force, and the distance to which it will operate, I have not yet ascertained; but I think it a curious enquiry, and I wish to understand whence it arises.

In our journey to the north, when we had the pleasure of seeing you at Ormathwaite, we visited the celebrated Mr. Smeaton, near Leeds. Being about to show him the smoothing experiment on a little pond near his house, an ingenious pupil of his, Mr. Jessop, then present, told us of an odd appearance on that pond, which had lately occurred to him. He was about to clean a little cup in which he kept oil, and he threw upon the water some flies that had been drowned in the oil. These flies presently began to move, and turned round on the water very rapidly, as if they were vigorously alive, though on examination he found they were not so. I immediately concluded that the motion was occasioned by the power of the repulsion above mentioned, and that the oil issuing gradually from the spungy body of the fly continued the motion. He found some more flies drowned in oil, with which the experiment was repeated before us. To show that it was not any effect of life recovered by the flies, I imitated it by little bits of oiled chips and paper cut in the form of a comma, of the size of a common fly; when the stream of repelling particles issuing from the point made the comma turn round the [150] contrary way. This is not a chamber experiment; for it cannot be well repeated in a bowl or dish of water on a table. A considerable surface of water is necessary to give room for the expansion of a small quantity of oil. In a dish of water, if the smallest drop of oil be let fall in the middle, the whole surface is presently covered with a thin greasy film proceeding from the drop; but as soon as that film has reached the sides of the dish, no more will issue from the drop, but it remains in the form of oil, the sides of the dish putting a stop to its dissipation by prohibiting the farther expansion of the film.

Our friend Sir John Pringle, being soon after in Scotland, learned there, that those employed in the herring-fishery could at a distance see where the shoals of herrings were, by the smoothness of the water over them, which might possibly be occasioned, he thought, by some oiliness proceeding from their bodies.

A gentleman from Rhode-island told me, it had been remarked, that the harbour of Newport was ever smooth while any whaling vessels were in it; which probably arose from hence, that the blubber which they sometimes bring loose in the hold, or the leakage of their barrels, might afford some oil, to mix with that water, which from time to time they pump out to keep their vessel free, and that some oil might spread over the surface of the water in the harbour, and prevent the forming of any waves.

This prevention I would thus endeavour to explain.

There seems to be no natural repulsion between water and air, such as to keep them from coming into contact with each other. Hence we find a quantity of air in water; and if we extract it by means of the air-pump, the same water, again [151] exposed to the air, will soon imbibe an equal quantity.

Therefore air in motion, which is wind, in passing over the smooth surface of water, may rub, as it were, upon that surface, and raise it into wrinkles, which, if the wind continues, are the elements of future waves.

The smallest wave once raised does not immediately subside, and leave the neighbouring water quiet: but in subsiding raises nearly as much of the water next to it, the friction of the parts making little difference. Thus a stone dropped in a pool raises first a single wave round itself; and leaves it, by sinking to the bottom; but that first wave subsiding raises a second, the second a third, and so on in circles to a great extent.

A small power continually operating will produce a great action. A finger applied to a weighty suspended bell can at first move it but little; if repeatedly applied, though with no greater strength, the motion increases till the bell swings to its utmost height, and with a force that cannot be resisted by the whole strength of the arm and body. Thus the small first-raised waves, being continually acted upon by the wind, are, though the wind does not increase in strength, continually increased in magnitude, rising higher and extending their bases, so as to include a vast mass of water in each wave, which in its motion acts with great violence.

But if there be a mutual repulsion between the particles of oil, and no attraction between oil and water, oil dropped on water will not be held together by adhesion to the spot whereon it falls; it will not be imbibed by the water; it will be at liberty to expand itself; and it will spread on a surface that, besides being smooth to the most perfect degree of polish, [152] prevents, perhaps by repelling the oil, all immediate contact, keeping it at a minute distance from itself; and the expansion will continue till the mutual repulsion between the particles of the oil is weakened and reduced to nothing by their distance.

Now I imagine that the wind, blowing over water thus covered with a film of oil, cannot easily *catch* upon it, so as to raise the first wrinkles, but slides over it, and leaves it smooth as it finds it. It moves a little the oil indeed, which being between it and the water, serves it to slide with, and prevents friction, as oil does between those parts of a machine, that would otherwise rub hard together. Hence the oil dropped on the windward side of a pond proceeds gradually to leeward, as may be seen by the smoothness it carries with it, quite to the opposite side. For the wind being thus prevented from raising the first wrinkles, that I call the elements of waves, cannot produce waves, which are to be made by continually acting upon, and enlarging those elements, and thus the whole pond is calmed.

Totally therefore we might suppress the waves in any required place, if we could come at the windward place where they take their rise. This in the ocean can seldom if ever be done. But perhaps something may be done on particular occasions, to moderate the violence of the waves when we are in the midst of them, and prevent their breaking where that would be inconvenient.

For when the wind blows fresh, there are continually rising on the back of every great wave a number of small ones, which roughen its surface, and give the wind hold, as it were, to push it with greater force. This hold is diminished, by [153] preventing the generation of those small ones. And possibly too, when a wave's surface is oiled, the wind, in passing over it, may rather in some degree press it down, and contribute to prevent it, rising again, instead of promoting it.

This as mere conjecture would have little weight, if the apparent effects of pouring oil into the midst of waves were not considerable, and as yet not otherwise accounted for.

When the wind blows so fresh, as that the waves are not sufficiently quick in obeying its impulse, their tops being thinner and lighter are pushed forward, broken, and turned over in a white foam. Common waves lift a vessel without entering it; but these when large sometimes break above and pour over it, doing great damage.

That this effect might in any degree be prevented, or the height and violence of waves in the sea moderated, we had no certain account; Pliny's authority for the practice of seamen in his time being slighted. But discoursing lately on this subject with his excellency Count Bentinck, of Holland, his son the honourable Captain Bentinck, and the learned professor Allemand (to all whom I showed the experiment of smoothing in a windy day the large piece of water at the head of the Green Park) a letter was mentioned, which had been received by the Count from Batavia, relative to the saving of a Dutch ship in a storm by pouring oil into the sea. I much desired to see that letter, and a copy of it was promised me, which I afterward received.

FOOTNOTES:

[28] Note by Dr. Brownrigg.

Sir Gilfred Lawson, who served long in the army at Gibraltar, assures me, that the fishermen in that place are accustomed to pour a little oil on the sea, in order to still its motion, that they may be enabled to see the oysters lying at its bottom; which are there very large, and which they take up with a proper instrument. This Sir Gilfred had often seen there performed, and said the same was practised on other parts of the Spanish coast.

[29] See the preceding paper. *Editor.*

Extract of a Letter from Mr. Tengnagel to Count Bentinck, dated at Batavia, the 5th of January, 1770. [154]

"Near the islands Paul and Amsterdam, we met with a storm, which had nothing particular in it worthy of being communicated to you, except that the captain found himself obliged for greater safety in wearing the ship, to pour oil into the sea, to prevent the waves breaking over her, which had an excellent effect, and succeeded in preserving us. As he poured out but a little at a time, the East India Company owes perhaps its ship to only six demi-ames of oil-olive. I was present upon deck when this was done; and I should not have mentioned this circumstance to you, but that we have found people here so prejudiced against the experiment, as to make it necessary for the officers on board and myself to give a certificate of the truth on this head, of which we made no difficulty."

On this occasion, I mentioned to Captain Bentinck, a thought which had occurred to me in reading the voyages of our late circumnavigators, particularly where accounts are given of pleasant and fertile islands which they much desired to land upon, when sickness made it more necessary, but could not effect a landing through a violent surf breaking on the shore, which rendered it impracticable. My idea was, that possibly by sailing to and fro at some distance from such lee-shore, continually pouring oil into the sea, the waves might be so much depressed, and lessened before they reached the shore, as to abate the height and violence of the surf, and permit a landing; which, in such circumstances, was a point of sufficient importance to justify the expense of the oil that might be requisite for the purpose. That gentleman, who is ever [155] ready to promote what may be of public utility, though his own ingenious inventions have not always met with the countenance they merited, was so obliging as to invite me to Portsmouth, where an opportunity would probably offer, in the course of a few days, of making the experiment on some of the shores about Spithead, in which he kindly proposed to accompany me, and to give assistance with such boats as might be necessary. Accordingly, about the middle of October last, I went with some friends to Portsmouth; and a day of wind happening, which made a lee-shore between Haslar-hospital and the point near Jillkecker, we went from the Centaur with the long-boat and barge towards that shore. Our disposition was this: the long-boat was anchored about a quarter of a mile from the shore; part of the company were landed behind the point (a place more sheltered from the sea) who came round and placed themselves opposite to the long-boat, where they might observe the surf, and note if any change occurred in it upon using the oil. Another party, in the barge, plied to windward of the long-boat, as far from her as she was from the shore, making trips of about half a mile each, pouring oil continually out of a large stone-bottle, through a hole in the cork, somewhat bigger than a goose-quill. The experiment had not, in the main point, the success we wished, for no material difference was observed in the height or force of the surf upon the shore; but those who were in the long-boat could observe a tract of smoothed water, the whole of the distance in which the barge poured the oil, and gradually spreading in breadth towards the long-boat. I call it [156] smoothed, not that it was laid level; but because, though the swell continued, its surface was not roughened by the wrinkles, or smaller waves, before-mentioned; and none or very few white caps (or waves whose tops turn over in foam) appeared in that whole space, though to windward and leeward of it there were plenty; and a wherry, that came round the point under sail, in her way to Portsmouth, seemed to turn into that tract of choice, and to use it from end to end, as a piece of turnpike-road.

It may be of use to relate the circumstances of an experiment that does not succeed, since they may give hints of amendment in future trials: it is therefore I have been thus particular. I shall only add what I apprehend may have been the reason of our disappointment.

I conceive, that the operation of oil on water is, first, to prevent the raising of new waves by the wind; and, secondly, to prevent its pushing those before raised with such force, and consequently their continuance of the same repeated height, as they would have done, if their surface were not oiled. But oil will not prevent waves being raised by another power, by a stone, for instance, falling into a still pool; for they then rise by the mechanical impulse of the stone, which the greasiness on the surrounding water cannot lessen or prevent, as it can prevent the winds catching the surface and raising it into waves. Now waves once raised, whether by the wind or any other power, have the same mechanical operation, by which they continue to rise and fall, as a *pendulum* will continue to swing, a long time after the force ceases to act by which the motion was first produced: that motion will, however, cease in time; but time is necessary. Therefore, though [157]
oil spread on an agitated sea may weaken the push of the wind on those waves whose surfaces are covered by it, and so, by receiving less fresh impulse, they may gradually subside; yet a considerable time, or a distance through which they will take time to move, may be necessary to make the effect sensible on any shore in a diminution of the surf: for we know, that when wind ceases suddenly, the waves it has raised do not as suddenly subside, but settle gradually, and are not quite down till after the wind has ceased. So though we should, by oiling them, take off the effect of wind on waves already raised, it is not to be expected that those waves should be instantly levelled. The motion they have received will, for some time, continue; and if the shore is not far distant, they arrive there so soon, that their effect upon it will not be visibly diminished. Possibly, therefore, if we had begun our operations at a greater distance, the effect might have been more sensible. And perhaps we did not pour oil in sufficient quantity. Future experiments may determine this.

I was, however, greatly obliged to Captain Bentinck, for the chearful and ready aids he gave me: and I ought not to omit mentioning Mr. Banks, Dr. Solander, General Carnoc, and Dr. Blagden, who all assisted at the experiment, during that blustering unpleasant day, with a patience and activity that could only be inspired by a zeal for the improvement of knowledge, such especially as might possibly be of use to men in situations of distress.

I would wish you to communicate this to your ingenious friend, Mr. Farish, with my respects; and believe me to be, [158]
with sincere esteem,

Dear Sir,

Your most obedient, humble servant,

B. FRANKLIN.

On the Difference of Navigation in shoal and deep Water.

Craven-street, May 10, 1768.

Sir,

You may remember, that when, we were travelling together in Holland, you remarked, that the trackschuyt in one of the stages went slower than usual, and enquired of the boatman, what might be the reason; who answered, that it had been a dry season, and the water in the canal was low. On being again asked if it was so low as that the boat touched the muddy bottom; he said, no, not so low as that, but so low as to make it harder for the horse to draw the boat. We neither of us at first could conceive that if there was water enough for the boat to swim clear of the bottom, its being deeper would make any difference; but as the man affirmed it seriously as a thing well known among them; and as the punctuality required in their stages was likely to make such difference, if any there were, more readily observed by them, than by other watermen who did not pass so regularly and constantly backwards and forwards in the same track; I began to apprehend there might [159] be something in it, and attempted to account for it from this consideration, that the boat in proceeding along the canal, must in every boat's length of her course, move out of her way a body of water, equal in bulk to the room her bottom took up in the water; that the water so moved must pass on each side of her and under her bottom to get behind her; that if the passage under her bottom was straitened by the shallows, more of that water must pass by her sides, and with a swifter motion, which would retard her, as moving the contrary way; or that the water becoming lower behind the boat than before, she was pressed back by the weight of its difference in height, and her motion retarded by having that weight constantly to overcome. But as it is often lost time to attempt accounting for uncertain facts, I determined to make an experiment of this when I should have convenient time and opportunity.

After our return to England, as often as I happened to be on the Thames, I enquired of our watermen whether they were sensible of any difference in rowing over shallow or deep water. I found them all agreeing in the fact, that there was a very great difference, but they differed widely in expressing the quantity of the difference; some supposing it was equal to a mile in six, others to a mile in three, &c. As I did not recollect to have met with any mention of this matter in our philosophical books, and conceiving that if the difference should really be great, it might be an object of consideration in the many projects now on foot for digging new navigable canals in this island, I lately put my design of making the [160] experiment in execution, in the following manner.

I provided a trough of plained boards fourteen feet long, six inches wide and six inches deep, in the clear, filled with water within half an inch of the edge, to represent a canal. I had a loose board of nearly the same length and breadth, that, being put into the water, might be sunk to any depth, and fixed by little wedges where I would chuse to have it stay, in order to make different depths of water, leaving the surface at the same height with regard to the sides of the trough. I had a little boat in form of a lighter or boat of burthen, six inches long, two inches and a quarter wide, and one inch and a quarter deep. When swimming, it drew one inch water. To give motion to the boat, I fixed one end of a long silk thread to its bow, just even with the water's edge, the other end passed over a well-made brass pully, of about an inch diameter, turning freely on a small axis; and a shilling was the weight. Then placing the boat at one end of the trough, the weight would draw it through the water to the other.

Not having a watch that shows seconds, in order to measure the time taken up by the boat in passing from end to end, I counted as fast as I could count to ten repeatedly, keeping an account of the number of tens on my fingers. And as much as possible to correct any little inequalities in my counting, I repeated the experiment a number of times at each depth of water, that I might take the medium. And the following are the results.

	Water 1½ inches deep.	2 inches.	4½ inches.
1st exp.	100	94	79	[161]
2	104	93	78
3	104	91	77
4	106	87	79
5	100	88	79
6	99	86	80
7	100	90	79
8	100	88	81
	813	717	632
	Medium 101	Medium 89	Medium 79

I made many other experiments, but the above are those in which I was most exact; and they serve sufficiently to show that the difference is considerable. Between the deepest and shallowest it appears to be somewhat more than one fifth. So that supposing large canals and boats and depths of water to bear the same proportions, and that four men or horses would draw a boat in deep water four leagues in four hours, it would require five to draw the same boat in the same time as far in shallow water; or four would require five hours.

Whether this difference is of consequence enough to justify a greater expence in deepening canals, is a matter of calculation, which our ingenious engineers in that way will readily determine.

I am, &c.

B. FRANKLIN.

TO MR. ALPHONSUS LE ROY, MEMBER OF SEVERAL ACADEMIES AT PARIS.[30] [162]

Containing sundry Maritime Observations.

At Sea, on board the London Packet, Capt. Truxton.

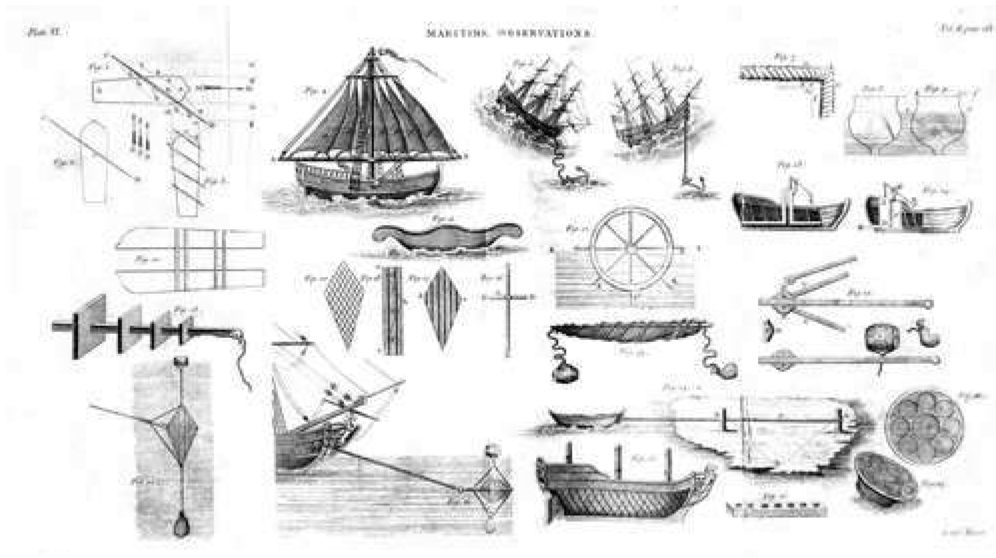
Aug. 1785.

Sir,

Your learned writings on the navigation of the antients, which contain a great deal of curious information, and your very ingenious contrivances for improving the modern sails (*voilure*) of which I saw with great pleasure a successful trial on the river Seine, have induced me to submit to your consideration and judgment, some thoughts I have had on the latter subject.

Those mathematicians, who have endeavoured to improve the swiftness of vessels, by calculating to find the form of least resistance, seem to have considered a ship as a body moving through one fluid only, the water; and to have given little attention to the circumstance of her moving through another fluid, the air. It is true that when a vessel sails right before the wind, this circumstance is of no importance, because the wind goes with her; but in every deviation from that course, the resistance of the air is something, and becomes greater in proportion as that deviation increases. I wave at present the consideration of those different degrees of resistance given by the air to that part of the hull which is above water, and confine myself to that given to the sails; for their motion through the air is resisted by the air, as the motion of [163] the hull through the water is resisted by the water, though with less force as the air is a lighter fluid. And to simplify the discussion as much as possible, I would state one situation only, to wit, that of the wind upon the beam, the ship's course being directly across the wind; and I would suppose the sail set in an angle of 45 degrees with the keel, as in the following figure; wherein (Plate VI, Fig. 1.)

MARITIME OBSERVATIONS.



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Published as the Act directs, April 1, 1806, by Longman, Hurst, Rees & Orme, Paternoster Row.

A B represents the body of the vessel, C D the position of the sail, EEE the direction of the wind, MM the line of motion. In observing this figure it will appear, that so much of the body of the vessel as is immersed in the water must, to go forward, remove out of its way what water it meets with between the pricked lines FF. And the sail, to go forward, must move out of its way all the air its whole dimension meets with between the pricked lines CG and DG. Thus both the fluids give resistance to the motion, each in proportion to the quantity of matter contained in the dimension to be removed. And though the air is vastly lighter than the water, and therefore more easily removed, yet the dimension being much greater its effect is very considerable.

It is true that in the case stated, the resistance given by the air between those lines to the motion of the sail is not apparent to the eye, because the greater force of the wind, which strikes it in the direction EEE, overpowers its effect, and keeps the sail full in the curve a, a, a, a, a. But suppose the wind to cease, and the vessel in a calm to be impelled with the same swiftness by oars, the sail would then appear filled in the contrary curve b, b, b, b, b, when prudent men would immediately perceive, that the air resisted its motion, and would order it to be taken in. [164]

Is there any possible means of diminishing this resistance, while the same quantity of sail is exposed to the action of the wind, and therefore the same force obtained from it? I think there is, and that it may be done by dividing the sail into a number of parts, and placing those parts in a line one behind the other; thus instead of one sail extending from C to D, figure 2, if four sails containing together the same quantity of canvas, were placed as in figure 3, each having one quarter of the dimensions of the great sail, and exposing a quarter of its surface to the wind, would give a quarter of the force; so that the whole force obtained from the wind would be the same, while the resistance from the air would be nearly reduced to the space between the pricked lines *a b* and *c d*, before the foremost sail.

It may perhaps be doubted whether the resistance from the air would be so diminished; since possibly each of the following small sails having also air before it, which must be removed, the resistance on the whole would be the same.

This is then a matter to be determined by experiment. I will mention one that I many years since made with success for another purpose; and I will propose another small one easily made. If that too succeeds, I should think it worth while to make a larger, though at some expense, on a river boat; and perhaps time, and the improvements experience will afford, may make it applicable with advantage to larger vessels.

Having near my kitchen chimney a round hole of eight inches diameter, through which was a constant steady current of [165]
air, increasing or diminishing only as the fire increased or diminished, I contrived to place my jack so as to receive that current; and taking off the flyers, I fixed in their stead on the same pivot a round tin plate of nearly the same diameter with the hole; and having cut it in radial lines almost to the centre, so as to have six equal vanes, I gave to each of them the obliquity of forty-five degrees. They moved round, without the weight, by the impression only of the current of air, but too slowly for the purpose of roasting. I suspected that the air struck by the back of each vane might possibly by its resistance retard the motion; and to try this, I cut each of them into two, and I placed the twelve, each having the same obliquity, in a line behind each other, when I perceived a great augmentation in its velocity, which encouraged me to divide them once more, and, continuing the same obliquity, I placed the twenty-four behind each other in a line, when the force of the wind being the same, and the surface of vane the same, they moved round with much greater rapidity, and perfectly answered my purpose.

The second experiment that I propose, is, to take two playing cards of the same dimensions, and cut one of them transversely into eight equal pieces; then with a needle string them upon two threads one near each end, and place them so upon the threads that, when hung up, they may be one exactly over the other, at a distance equal to their breadth, each in a horizontal position; and let a small weight, such as a bird-shot, be hung under them, to make them fall in a straight line when let loose. Suspend also the whole card by threads from its four corners, and hang to it an equal weight, so as to draw [166]
it downwards when let fall, its whole breadth pressing against the air. Let those two bodies be attached, one of them to one end of a thread a yard long, the other to the other end. Extend a twine under the ceiling of a room, and put through it at thirty inches distance two pins bent in the form of fish-hooks. On these two hooks hang the two bodies, the thread that connects them extending parallel to the twine, which thread being cut, they must begin to fall at the same instant. If they take equal time in falling to the floor, it is a proof that the resistance of the air is in both cases equal. If the whole card requires a longer time, it shows that the sum of the resistances to the pieces of the cut card is not equal to the resistance of the whole one[31].

This principle so far confirmed, I would proceed to make a larger experiment, with a shallop, which I would rig in this manner. (Plate VI. Fig. 4.)

A B is a long boom, from which are hoisted seven jibs, a, b, c, d, e, f, g, each a seventh part of the whole dimensions, and as much more as will fill the whole space when set in an angle of forty-five degrees, so that they may lap when going before the wind, and hold more wind when going large. Thus rigged, when going right before the wind, the boom should be brought at right angles with the keel, by means of the sheet ropes C D, and all the sails hauled flat to the boom.

These positions of boom and sails to be varied as the wind quarters. But when the wind is on the beam, or when you [167] would turn to windward, the boom is to be hauled right fore and aft, and the sails trimmed according as the wind is more or less against your course.

It seems to me, that the management of a shallop so rigged would be very easy, the sails being run up and down separately, so that more or less sail may be made at pleasure; and I imagine, that there being full as much sail exposed to the force of the wind which impels the vessel in its course, as if the whole were in one piece, and the resistance of the dead air against the foreside of the sail being diminished, the advantage of swiftness would be very considerable; besides that the vessel would lie nearer the wind.

Since we are on the subject of improvements in navigation, permit me to detain you a little longer with a small relative observation. Being, in one of my voyages, with ten merchant-ships under convoy of a frigate at anchor in Torbay, waiting for a wind to go to the westward; it came fair, but brought in with it a considerable swell. A signal was given for weighing, and we put to sea all together; but three of the ships left their anchors, their cables parting just as the anchors came a-peak. Our cable held, and we got up our anchor; but the shocks the ship felt before the anchor got loose from the ground, made me reflect on what might possibly have caused the breaking of the other cables; and I imagined it might be the short bending of the cable just without the hause-hole, from a horizontal to an almost vertical position, and the sudden violent jerk it receives by the rising of the head of the ship on the swell of a wave while in that position. For example, suppose a vessel hove up so as to have her head nearly over her anchor, which still keeps its hold, perhaps in a tough [168] bottom; if it were calm, the cable still out would form nearly a perpendicular line, measuring the distance between the hause-hole and the anchor; but if there is a swell, her head in the trough of the sea will fall below the level, and when lifted on the wave will be much above it. In the first case the cable will hang loose and bend perhaps as in figure 5. In the second case, figure 6, the cable will be drawn straight with a jerk, must sustain the whole force of the rising ship, and must either loosen the anchor, resist the rising force of the ship, or break. But why does it break at the hause-hole?

Let us suppose it a cable of three inches diameter, and represented by figure 7. If this cable is to be bent round the corner A, it is evident that either the part of the triangle contained between the letters a, b, c, must stretch considerably, and those most that are nearest the surface; or that the parts between d, e, f, must be compressed; or both, which most probably happens. In this case the lower half of the thickness affords no strength against the jerk, it not being strained, the upper half bears the whole, and the yarns near the upper surface being first and most strained, break first, and the next yarns follow; for in this bent situation they cannot bear the strain all together, and each contributes its strength to the whole, as they do when the cable is strained in a straight line.

To remedy this, methinks it would be well to have a kind of large pulley wheel, fixed in the hause-hole, suppose of two feet diameter, over which the cable might pass; and being there bent gradually to the round of the wheel, would thereby be more equally strained, and better able to bear the jerk, which may save the anchor, and by that means in the course of the [169] voyage may happen to save the ship.

One maritime observation more shall finish this letter. I have been a reader of news-papers now near seventy years, and I think few years pass without an account of some vessel met with at sea, with no living soul on board, and so many feet of water in her hold, which vessel has nevertheless been saved and brought into port: and when not met with at sea, such forsaken vessels have often come ashore on some coast. The crews, who have taken to their boats and thus abandoned such vessels, are sometimes met with and taken up at sea by other ships, sometimes reach a coast, and are sometimes never heard of. Those that give an account of quitting their vessels generally say, that she sprung a leak, that they pumped for some time, that the water continued to rise upon them, and that, despairing to save her, they had quitted her lest they should go down with her. It seems by the event that this fear was not always well founded, and I have endeavoured to guess at the reason of the people's too hasty discouragement.

When a vessel springs a leak near her bottom, the water enters with all the force given by the weight of the column of water, without, which force is in proportion to the difference of level between the water without and that within. It enters therefore with more force at first and in greater quantity, than it can afterwards when the water within is higher. The bottom of the vessel too is narrower, so that the same quantity of water coming into that narrow part, rises faster than when the space for it to flow in is larger. This helps to terrify. But as the quantity entering is less and less as the surfaces without and within become more nearly equal in height, the pumps that could not keep the water from rising at first, [170] might afterwards be able to prevent its rising higher, and the people might have remained on board in safety, without hazarding themselves in an open boat on the wide ocean.(Fig. 8.)

Besides the greater equality in the height of the two surfaces, there may sometimes be other causes that retard the farther sinking of a leaky vessel. The rising water within may arrive at quantities of light wooden work, empty chests, and particularly empty water-casks, which if fixed so as not to float themselves may help to sustain her. Many bodies which compose a ship's cargo may be specifically lighter than water, all these when out of water are an additional weight to that of the ship, and she is in proportion pressed deeper into the water; but as soon as these bodies are immersed, they weigh no longer on the ship, but on the contrary, if fixed, they help to support her, in proportion as they are specifically lighter than the water. And it should be remembered, that the largest body of a ship may be so balanced in the water, that an ounce less or more of weight may leave her at the surface or sink her to the bottom. There are also certain heavy cargoes, that, when the water gets at them, are continually dissolving, and thereby lightening the vessel, such as salt and sugar. And as to water-casks mentioned above, since the quantity of them must be great in ships of war where the number of men consume a great deal of water every day, if it had been made a constant rule to bung them up as fast as they were emptied, and to dispose the empty casks in proper situations, I am persuaded that many ships which have been sunk in engagements, or have gone down afterwards, might with the unhappy people have been saved; as well as many of those [171] which in the last war foundered, and were never heard of. While on this topic of sinking, one cannot help recollecting the well known practice of the Chinese, to divide the hold of a great ship into a number of separate chambers by partitions tight caulked (of which you gave a model in your boat upon the Seine) so that if a leak should spring in one of them the others are not affected by it; and though that chamber should fill to a level with the sea, it would not be sufficient to sink the vessel. We have not imitated this practice. Some little disadvantage it might occasion in the stowage is perhaps one reason, though that I think might be more than compensated by an abatement in the insurance that would be reasonable, and by a higher price taken of passengers, who would rather prefer going in such a vessel. But our seafaring people are brave, despise danger, and reject such precautions of safety, being cowards only in one sense, that of *fearing* to be *thought afraid*.

I promised to finish my letter with the last observation, but the garrulity of the old man has got hold of me, and as I may never have another occasion of writing on this subject, I think I may as well now, once for all, empty my nautical budget, and give you all the thoughts that have in my various long voyages occurred to me relating to navigation. I am sure that in you they will meet with a candid judge, who will excuse my mistakes on account of my good intention.

There are six accidents that may occasion the loss of ships at sea. We have considered one of them, that of foundering by a leak. The other five are, 1. Oversetting by sudden flaws of wind, or by carrying sail beyond the bearing. 2. Fire by [172] accident or carelessness. 3. A heavy stroke of lightning, making a breach in the ship, or firing the powder. 4. Meeting and shocking with other ships in the night. 5. Meeting in the night with islands of ice.

To that of oversetting, privateers in their first cruize have, as far as has fallen within my knowledge or information, been more subject than any other kind of vessels. The double desire of being able to overtake a weaker flying enemy, or to escape when pursued by a stronger, has induced the owners to overmast their cruizers, and to spread too much canvass; and the great number of men, many of them not seamen, who being upon deck when a ship heels suddenly are huddled down to leeward, and increase by their weight the effect of the wind. This therefore should be more attended to and guarded against, especially as the advantage of lofty masts is problematical. For the upper sails have greater power to lay a vessel more on her side, which is not the most advantageous position for going swiftly through the water. And hence it is that vessels, which have lost their lofty masts, and been able to make little more sail afterwards than permitted the ship to sail upon an even keel, have made so much way, even under jury masts, as to surprize the mariners themselves. But there is besides, something in the modern form of our ships that seems as if calculated expressly to allow their oversetting more easily. The sides of a ship, instead of spreading out as they formerly did in the upper works, are of late years turned in, so as to make the body nearly round, and more resembling a cask. I do not know what the advantages of this construction are, except that such ships are not easily boarded. To me it seems a contrivance to have less room in a ship at [173] nearly the same expense. For it is evident that the same timber and plank consumed in raising the sides from a to b, and from d to c, would have raised them from a to e, and from d to f, fig. 9. In this form all the spaces between e, a, b, and c, d, f, would have been gained, the deck would have been larger, the men would have had more room to act, and not have stood so thick in the way of the enemy's shot; and the vessel, the more she was laid down on her side, the more bearing she would meet with, and more effectual to support her, as being farther from the centre. Whereas in the present form, her ballast makes the chief part of her bearing, without which she would turn in the sea almost as easily as a barrel. More ballast by this means becomes necessary, and that sinking a vessel deeper in the water occasions more resistance to her going through it. The Bermudian sloops still keep with advantage to the old spreading form. The islanders in the great Pacific ocean, though they have no large ships, are the most expert boat-sailors in the world, navigating that sea safely with their proas, which they prevent oversetting by various means. Their sailing proas for this purpose have outriggers generally to windward, above the water, on which, one or more men are placed, to move occasionally further from or nearer to the vessel as the wind freshens or slackens. But some have their outriggers to leeward, which, resting on the water, support the boat so as to keep her upright when pressed down by the wind. Their boats moved by oars or rather by paddles are, for long voyages, fixed two together by cross bars of wood that keep them at some distance from each other, and so render their oversetting next to impossible. How far this may be practicable in larger vessels, we have not yet [174] sufficient experience. I know of but one trial made in Europe, which was about one hundred years since, by Sir William Petty. He built a double vessel, to serve as a packet boat between England and Ireland. Her model still exists in the museum of the Royal Society, where I have seen it. By the accounts we have of her, she answered well the purpose of her construction, making several voyages; and though wrecked at last by a storm, the misfortune did not appear owing to her particular construction, since many other vessels of the common form were wrecked at the same time. The advantage of such a vessel is, that she needs no ballast, therefore swims either lighter or will carry more goods; and that passengers are not so much incommoded by her rolling: to which may be added, that if she is to defend herself by her cannon, they will probably have more effect, being kept more generally in a horizontal position, than those in common vessels. I think, however, that it would be an improvement of that model, to make the sides which are opposed to each other perfectly parallel, though the other sides are formed as in common thus, figure 10.

The building of a double ship would indeed be more expensive in proportion to her burthen; and that perhaps is sufficient to discourage the method.

The accident of fire is generally well guarded against by the prudent captain's strict orders against smoking between decks, or carrying a candle there out of a lanthorn. But there is one dangerous practice which frequent terrible accidents have not yet been sufficient to abolish; that of carrying store-spirits to sea in casks. Two large ships, the Seraphis and the [175] Duke of Athol, one an East-Indiaman, the other a frigate, have been burnt within these two last years, and many lives miserably destroyed, by drawing spirits out of a cask near a candle. It is high time to make it a general rule, that all the ship's store of spirits should be carried in bottles.

The misfortune by a stroke of lightning I have in my former writings endeavoured to show a method of guarding against, by a chain and pointed rod, extending, when run up, from above the top of the mast to the sea. These instruments are now made and sold at a reasonable price by Nairne & Co. in London, and there are several instances of success attending the use of them. They are kept in a box, and may be ran up and fixed in about five minutes, on the apparent approach of a thunder gust.

Of the meeting and shocking with other ships in the night, I have known two instances in voyages between London and America. In one both ships arrived though much damaged, each reporting their belief that the other must have gone to the bottom. In the other, only one got to port; the other was never afterwards heard of. These instances happened many years ago, when the commerce between Europe and America was not a tenth part of what it is at present, ships of course thinner scattered, and the chance of meeting proportionably less. It has long been the practice to keep a *look-out before* in the channel, but at sea it has been neglected. If it is not at present thought worth while to take that precaution, it will in time become of more consequence; since the number of ships at sea is continually augmenting. A drum frequently beat, or a [176] bell rung in a dark night, might help to prevent such accidents.

Islands of ice are frequently seen off the banks of Newfoundland, by ships going between North-America and Europe. In the day time they are easily avoided, unless in a very thick fog. I remember two instances of ship's running against them in the night. The first lost her bowsprit, but received little other damage. The other struck where the warmth of the sea had wasted the ice next to it, and a part hung over above. This perhaps saved her, for she was under great way; but the upper part of the cliff taking her foretopmast, broke the shock, though it carried away the mast. She disengaged herself with some difficulty, and got safe into port; but the accident shows the possibility of other ships being wrecked and sunk by striking those vast masses of ice, of which I have seen one that we judged to be seventy feet high above the water, consequently eight times as much under water; and it is another reason for keeping a good *look-out before*, though far from any coast that may threaten danger.

It is remarkable, that the people we consider as savages have improved the art of sailing and rowing-boats in several points beyond what we can pretend to. We have no sailing-boats equal to the flying proas of of the South Seas, no rowing or paddling-boat equal to that of the Greenlanders for swiftness and safety. The birch canoes of the North-American Indians have also some advantageous properties. They are so light that two men may carry one of them over land, which is capable of carrying a dozen upon the water; and in heeling they are not so subject to take in water as our boats, the sides of which are lowest in the middle where it is most likely to enter, this being highest in that part, as in figure 11. [177]

The Chinese are an enlightened people, the most antiently civilized of any existing, and their arts are antient, a presumption in their favour: their method of rowing their boats differs from ours, the oars being worked either two a-stern as we scull, or on the sides with the same kind of motion, being hung parallel to the keel on a rail and always acting in the water, not perpendicular to the side as ours are, nor lifted out at every stroke, which is a loss of time, and the boat in the interval loses motion. They see our manner, and we theirs, but neither are disposed to learn of or copy the other.

To the several means of moving boats mentioned above, may be added the singular one lately exhibited at Javelle, on the Seine below Paris, where a clumsy boat was moved across that river in three minutes by rowing, not in the water, but in the air, that is, by whirling round a set of windmill vanes fixed to a horizontal axis, parallel to the keel, and placed at the head of the boat. The axis was bent into an elbow at the end, by the help of which it was turned by one man at a time. I saw the operation at a distance. The four vanes appeared to be about five feet long, and perhaps two and a half wide. The weather was calm. The labour appeared to be great for one man, as the two several times relieved each other. But the action upon the air by the oblique surfaces of the vanes must have been considerable, as the motion of the boat appeared tolerably quick going and returning; and she returned to the same place from whence she first set out, notwithstanding the current. This machine is since applied to the moving of air-balloons: an instrument similar may be contrived to move a [178]
boat by turning under water.

Several mechanical projectors have at different times proposed to give motion to boats, and even to ships, by means of circular rowing, or paddles placed on the circumference of wheels to be turned constantly on each side of the vessel; but this method, though frequently tried, has never been found so effectual as to encourage a continuance of the practice. I do not know that the reason has hitherto been given. Perhaps it may be this, that great part of the force employed contributes little to the motion. For instance, (fig. 12) of the four paddles a, b, c, d, all under water, and turning to move a boat from X to Y, c has the most power, b nearly though not quite as much, their motion being nearly horizontal; but the force employed in moving a, is consumed in pressing almost downright upon the water till it comes to the place of b; and the force employed in moving d is consumed in lifting the water till d arrives at the surface; by which means much of the labour is lost. It is true, that by placing the wheels higher out of the water, this waste labour will be diminished in a calm, but where a sea runs, the wheels must unavoidably be often dipt deep in the waves, and the turning of them thereby rendered very laborious to little purpose.

Among the various means of giving motion to a boat, that of M. Bernoulli appears one of the most singular, which was to have fixed in the boat a tube in the form of an L, the upright part to have a funnel-kind of opening at top, convenient for filling the tube with water; which, descending and passing through the lower horizontal part, and issuing in the middle of [179]
the stern, but under the surface of the river, should push the boat forward. There is no doubt that the force of the descending water would have a considerable effect, greater in proportion to the height from which it descended; but then it is to be considered, that every bucket-full pumped or dipped up into the boat, from its side or through its bottom, must have its *vis inertiæ* overcome so as to receive the motion of the boat, before it can come to give motion by its descent; and that will be a deduction from the moving power. To remedy this, I would propose the addition of another such L pipe, and that they should stand back to back in the boat thus, figure 13, the forward one being worked as a pump, and sucking in

the water at the head of the boat, would draw it forward while pushed in the same direction by the force at the stern. And after all it should be calculated whether the labour of pumping would be less than that of rowing. A fire-engine might possibly in some cases be applied in this operation with advantage.

Perhaps this labour of raising water might be spared, and the whole force of a man applied to the moving of a boat by the use of air instead of water; suppose the boat constructed in this form, figure 14. A, a tube round or square of two feet diameter, in which a piston may move up and down. The piston to have valves in it, opening inwards to admit air when the piston rises; and shutting, when it is forced down by means of the lever B turning on the centre C. The tube to have a valve D, to open when the piston is forced down, and let the air pass out at E, which striking forcibly against the water abaft must push the boat forward. If there is added an air-vessel F properly valved and placed, the force would continue to [180] act while a fresh stroke is taken with the lever. The boat-man might stand with his back to the stern, and putting his hands behind him, work the motion by taking hold of the cross bar at B, while another should steer; or if he had two such pumps, one on each side of the stern, with a lever for each hand, he might steer himself by working occasionally more or harder with either hand, as watermen now do with a pair of sculls. There is no position in which the body of a man can exert more strength than in pulling right upwards. To obtain more swiftness, greasing the bottom of a vessel is sometimes used, and with good effect. I do not know that any writer has hitherto attempted to explain this. At first sight one would imagine, that though the friction of a hard body, sliding on another hard body, and the resistance occasioned by that friction, might be diminished by putting grease between them, yet that a body sliding on a fluid, such as water, should have no need of, nor receive any advantage from such greasing. But the fact is not disputed. And the reason perhaps may be this—The particles of water have a mutual attraction, called the attraction of adhesion. Water also adheres to wood, and to many other substances, but not to grease: on the contrary they have a mutual repulsion, so that it is a question whether when oil is poured on water, they ever actually touch each other; for a drop of oil upon water, instead of sticking to the spot where it falls, as it would if it fell on a looking-glass, spreads instantly to an immense distance in a film extremely thin, which it could not easily do if it touched and rubbed or adhered even in a small degree to the surface of [181] the water. Now the adhesive force of water to itself, and to other substances, may be estimated from the weight of it necessary to separate a drop, which adheres, while growing, till it has weight enough to force the separation and break the drop off. Let us suppose the drop to be the size of a pea, then there will be as many of these adhesions as there are drops of that size touching the bottom of a vessel, and these must be broken by the moving power, every step of her motion that amounts to a drop's breadth: and there being no such adhesions to break between the water and a greased bottom, may occasion the difference.

So much respecting the motion of vessels. But we have sometimes occasion to stop their motion; and if a bottom is near enough we can cast anchor: where there are no soundings, we have as yet no means to prevent driving in a storm, but by lying-to, which still permits driving at the rate of about two miles an hour; so that in a storm continuing fifty hours, which is not an uncommon case, the ship may drive one hundred miles out of her course; and should she in that distance meet with a lee shore, she may be lost.

To prevent this driving to leeward in deep water, a swimming anchor is wanting, which ought to have these properties.

1. It should have a surface so large as, being at the end of a hauser in the water, and placed perpendicularly, should hold so much of it, as to bring the ship's head to the wind, in which situation the wind has least power to drive her.

2. It should be able by its resistance to prevent the ship's receiving way.

3. It should be capable of being situated below the heave of the sea, but not below the undertow. [182]

4. It should not take up much room in the ship.

5. It should be easily thrown out, and put into its proper situation.

6. It should be easy to take in again, and stow away.

An ingenious old mariner, whom I formerly knew, proposed, as a swimming anchor for a large ship, to have a stem of wood twenty-five feet long and four inches square, with four boards of 18, 16, 14, and 12, feet long, and one foot wide, the boards to have their substance thickened several inches in the middle by additional wood, and to have each a four inch square hole through its middle, to permit its being slipt on occasionally upon the stem, and at right angles with it; where all being placed and fixed at four feet distance from each other, it would have the appearance of the old mathematical instrument called a forestaff. This thrown into the sea, and held by a hauser veered out to some length, he conceived would bring a vessel up, and prevent her driving, and when taken in might be stowed away by separating the boards from the stem. Figure 15. Probably such a swimming anchor would have some good effect, but it is subject to this objection, that lying on the surface of the sea, it is liable to be hove forward by every wave, and thereby give so much leave for the ship to drive.

Two machines for this purpose have occurred to me, which, though not so simple as the above, I imagine would be more effectual, and more easily manageable. I will endeavour to describe them, that they may be submitted to your [183] judgment, whether either would be serviceable; and if they would, to which we should give the preference.

The first is to be formed, and to be used in the water on almost the same principles with those of a paper kite used in the air. Only as the paper kite rises in the air, this is to descend in the water. Its dimensions will be different for ships of different size.

To make one of suppose fifteen feet high; take a small spar of that length for the back-bone, AB, figure 16, a smaller of half that length CD, for the cross piece. Let these be united by a bolt at E, yet so as that by turning on the bolt they may be laid parallel to each other. Then make a sail of strong canvas, in the shape of figure 17. To form this, without waste of sail-cloth, sew together pieces of the proper length, and for half the breadth, as in figure 18, then cut the whole in the diagonal lines a, b, c, and turn the piece F so as to place its broad part opposite to that of the piece G, and the piece H in like manner opposite to I, which when all sewed together will appear as in fig. 17. This sail is to be extended on the cross of figure 16, the top and bottom points well secured to the ends of the long spar; the two side points d, e, fastened to the ends of two cords, which coming from the angle of the loop (which must be similar to the loop of a kite) pass through two rings at the ends of the short spar, so as that on pulling upon the loop the sail will be drawn to its extent. The whole may, when aboard, be furled up, as in figure 19, having a rope from its broad end, to which is tied a bag of ballast for keeping that end downwards when in the water, and at the other end another rope with an empty keg at its end to float on the [184] surface; this rope long enough to permit the kite's descending into the undertow, or if you please lower into still water. It should be held by a hauser. To get it home easily, a small loose rope may be veered out with it, fixed to the keg. Hauling on that rope will bring the kite home with small force, the resistance being small as it will then come end ways.

It seems probable that such a kite at the end of a long hauser would keep a ship with her head to the wind, and, resisting every tug, would prevent her driving so fast as when her side is exposed to it, and nothing to hold her back. If only half the driving is prevented, so as that she moves but fifty miles instead of the hundred during a storm, it may be some advantage, both in holding so much distance as is saved, and in keeping from a lee-shore. If single canvas should not be found strong enough to bear the tug without splitting, it may be doubled, or strengthened by a netting behind it, represented by figure 20.

The other machine for the same purpose, is to be made more in the form of an umbrella, as represented, figure 21. The stem of the umbrella a square spar of proper length, with four moveable arms, of which two are represented C, C, figure 22. These arms to be fixed in four joint cleats, as D, D, &c. one on each side of the spar, but so as that the four arms may open by turning on a pin in the joint. When open they form a cross, on which a four-square canvas sail is to be extended, its corners fastened to the ends of the four arms. Those ends are also to be stayed by ropes fastened to the stem or spar, so as to keep them short of being at right angles with it: and to the end of one of the arms should be hung the small bag of
ballast, and to the end of the opposite arm the empty keg. This, on being thrown into the sea, would immediately open; [185]
and when it had performed its function, and the storm over, a small rope from its other end being pulled on, would turn it, close it, and draw it easily home to the ship. This machine seems more simple in its operation, and more easily manageable than the first, and perhaps may be as effectual[32].

Vessels are sometimes retarded, and sometimes forwarded in their voyages, by currents at sea, which are often not perceived. About the year 1769 or 70, there was an application made by the board of customs at Boston, to the lords of the treasury in London, complaining that the packets between Falmouth and New-York, were generally a fortnight longer in their passages, than merchant-ships from London to Rhode-Island, and proposing that for the future they should be ordered to Rhode-Island instead of New-York. Being then concerned in the management of the American post-office, I happened to be consulted on the occasion; and it appearing strange to me that there should be such a difference between two places, scarce a day's run asunder, especially when the merchant-ships are generally deeper laden, and more weakly manned than the packets, and had from London the whole length of the river and channel to run before they left the land of England, while the packets had only to go from Falmouth, I could not but think the fact misunderstood or
misrepresented. There happened then to be in London a Nantucket sea-captain of my acquaintance, to whom I [186]
communicated the affair. He told me he believed the fact might be true; but the difference was owing to this, that the Rhode-Island captains were acquainted with the gulf-stream, which those of the English packets were not. We are well acquainted with that stream, says he, because in our pursuit of whales, which keep near the sides of it, but are not to be met with in it, we run down along the sides, and frequently cross it to change our side: and in crossing it have sometimes met and spoke with those packets, who were in the middle of it, and stemming it. We have informed them that they were stemming a current, that was against them to the value of three miles an hour; and advised them to cross it and get out of it; but they were too wise to be counselled by simple American fishermen. When the winds are but light, he added, they are carried back by the current more than they are forwarded by the wind: and if the wind be good, the subtraction of 70 miles a day from their course is of some importance. I then observed it was a pity no notice was taken of this current upon the charts, and requested him to mark it out for me, which he readily complied with, adding directions for avoiding it in sailing from Europe to North-America. I procured it to be engraved by order from the general post-office, on the old chart of the Atlantic, at Mount and Page's, Tower-hill; and copies were sent down to Falmouth for the captains of the packets, who slighted it however; but it is since printed in France, of which edition I hereto annex a copy.

This stream is probably generated by the great accumulation of water on the eastern coast of America between the [187]
tropics, by the trade-winds which constantly blow there. It is known that a large piece of water ten miles broad and generally only three feet deep, has by a strong wind had its waters driven to one side and sustained so as to become six

feet deep, while the windward side was laid dry. This may give some idea of the quantity heaped up on the American coast, and the reason of its running down in a strong current through the islands into the bay of Mexico, and from thence issuing through the gulph of Florida, and proceeding along the coast to the banks of Newfoundland, where it turns off towards and runs down through the Western Islands. Having since crossed this stream several times in passing between America and Europe, I have been attentive to sundry circumstances relating to it, by which to know when one is in it; and besides the gulph weed with which it is interspersed, I find that it is always warmer than the sea on each side of it, and that it does not sparkle in the night: I annex hereto the observations made with the thermometer in two voyages, and possibly may add a third. It will appear from them, that the thermometer may be an useful instrument to a navigator, since currents coming from the northward into southern seas, will probably be found colder than the water of those seas, as the currents from southern seas into northern are found warmer. And it is not to be wondered that so vast a body of deep warm water, several leagues wide, coming from between the tropics and issuing out of the gulph into the northern seas, should retain its warmth longer than the twenty or thirty days required to its passing the banks of Newfoundland. The quantity is too great, and it is too deep to be suddenly cooled by passing under a cooler air. The air immediately over it, [188] however, may receive so much warmth from it as to be rarefied and rise, being rendered lighter than the air on each side of the stream; hence those airs must flow in to supply the place of the rising warm air, and, meeting with each other, form those tornados and water-spouts frequently met with, and seen near and over the stream; and as the vapour from a cup of tea in a warm room, and the breath of an animal in the same room, are hardly visible, but become sensible immediately when out in the cold air, so the vapour from the gulph stream, in warm latitudes is scarcely visible, but when it comes into the cool air from Newfoundland, it is condensed into the fogs, for which those parts are so remarkable.

The power of wind to raise water above its common level in the sea is known to us in America, by the high tides occasioned in all our sea-ports when a strong north-easter blows against the gulph stream.

The conclusion from these remarks is, that a vessel from Europe to North-America may shorten her passage by avoiding to stem the stream, in which the thermometer will be very useful; and a vessel from America to Europe may do the same by the same means of keeping in it. It may have often happened accidentally, that voyages have been shortened by these circumstances. It is well to have the command of them.

But may there not be another cause, independent of winds and currents, why passages are generally shorter from America to Europe than from Europe to America? This question I formerly considered in the following short paper.

On board the Pennsylvania Packet, Capt. Osborne. [189]

At Sea, April 5, 1775.

"Suppose a ship to make a voyage eastward from a place in lat. 40° north, to a place in lat. 50° north, distance in longitude 75 degrees.

"In sailing from 40 to 50, she goes from a place where a degree of longitude is about eight miles greater than in the place she is going to. A degree is equal to four minutes of time; consequently the ship in the harbour she leaves, partaking of the diurnal motion of the earth, moves two miles in a minute faster, than when in the port she is going to; which is 120 miles in an hour.

"This motion in a ship and cargo is of great force; and if she could be lifted up suddenly from the harbour in which she lay quiet, and set down instantly in the latitude of the port she was bound to, though in a calm, that force contained in her would make her run a great way at a prodigious rate. This force must be lost gradually in her voyage, by gradual impulse against the water, and probably thence shorten the voyage. Query, In returning does the contrary happen, and is her voyage thereby retarded and lengthened?"[33]

Would it not be a more secure method of planking ships, if, instead of thick single planks laid horizontally, we were to use planks of half the thickness, and lay them double and across each other as in figure 23? To me it seems that the difference of expence would not be considerable, and that the ship would be both tighter and stronger. [190]

The securing of the ship is not the only necessary thing; securing the health of the sailors, a brave and valuable order of men, is likewise of great importance. With this view the methods so successfully practised by Captain Cook in his long voyages cannot be too closely studied or carefully imitated. A full account of those methods is found in Sir John Pringle's speech, when the medal of the Royal Society was given to that illustrious navigator. I am glad to see in his last voyage that he found the means effectual which I had proposed for preserving flour, bread, &c. from moisture and damage. They were found dry and good after being at sea four years. The method is described in my printed works, page 452, fifth edition[34]. In the same, page 469, 470[35], is proposed a means of allaying thirst in case of want of fresh water. This has since been practised in two instances with success. Happy if their hunger, when the other provisions are consumed, could be relieved as commodiously; and perhaps in time this may be found not impossible. An addition might be made to their present vegetable provision, by drying various roots in slices by the means of an oven. The sweet potatoe of America and Spain is excellent for this purpose. Other potatoes, with carrots, parsnips and turnips, might be prepared and preserved in the same manner.

With regard to make-shifts in cases of necessity, seamen are generally very ingenious themselves. They will excuse however the mention of two or three. [191] If they happen in any circumstance, such as after shipwreck, taking to their boat, or the like, to want a compass, a fine sewing-needle laid on clear water in a cup will generally point to the north, most of them being a little magnetical, or may be made so by being strongly rubbed or hammered, lying in a north and south direction. If their needle is too heavy to float by itself, it may be supported by little pieces of cork or wood. A man who can swim, may be aided in a long traverse by his handkerchief formed into a kite, by two cross sticks extending to the four corners; which, being raised in the air when the wind is fair and fresh, will tow him along while lying on his back. Where force is wanted to move a heavy body, and there are but few hands and no machines, a long and strong rope may make a powerful instrument. Suppose a boat is to be drawn up on a beach, that she may be out of the surf; a stake drove into the beach where you would have the boat drawn, and another to fasten the end of the rope to, which comes from the boat, and then applying what force you have to pull upon the middle of the rope at right angles with it, the power will be augmented in proportion to the length of rope between the posts. The rope being fastened to the stake A, and drawn upon in the direction C D, will slide over the stake B; and when the rope is bent to the angle A D B, represented by the pricked line in figure 24, the boat will be at B.

Some sailors may think the writer has given himself unnecessary trouble in pretending to advise them; for they have a little repugnance to the advice of landmen, whom they esteem ignorant and incapable of giving any worth notice; though it is certain that most of their instruments were the invention of landmen. At least the first vessel ever made to go on the water was certainly such. I will therefore add only a few words more, and they shall be addressed to passengers. [192]

When you intend a long voyage, you may do well to keep your intention as much as possible a secret, or at least the time of your departure; otherwise you will be continually interrupted in your preparations by the visits of friends and acquaintance, who will not only rob you of the time you want, but put things out of your mind, so that when you come to sea, you have the mortification to recollect points of business that ought to have been done, accounts you intended to settle, and conveniencies you had proposed to bring with you, &c. &c. all which have been omitted through the effect of these officious friendly visits. Would it not be well if this custom could be changed; if the voyager after having, without interruption, made all his preparations, should use some of the time he has left, in going himself to take leave of his friends at their own houses, and let them come to congratulate him on his happy return.

It is not always in your power to make a choice in your captain, though much of your comfort in the passage may depend on his personal character, as you must for so long a time be confined to his company, and under his direction; if he be a sensible, sociable, good-natured, obliging man, you will be so much the happier. Such there are; but if he happens to be otherwise, and is only skilful, careful, watchful and active in the conduct of his ship, excuse the rest, for these are the essentials.

Whatever right you may have by agreement in the mass of stores laid in by him for the passengers, it is good to have some particular things in your own possession, so as to be always at your own command.

1. Good water, that of the ship being often bad. You can be sure of having it good only by bottling it from a clear spring [193] or well and in clean bottles. 2. Good tea. 3. Coffee ground. 4. Chocolate. 5. Wine of the sort you particularly like, and cyder. 6. Raisins. 7. Almonds. 8. Sugar. 9. Capillaire. 10. Lemons. 11. Jamaica spirits. 12. Eggs greased. 13. Diet bread 14. Portable soup. 15. Rusks. As to fowls, it is not worth while to have any called yours, unless you could have the feeding and managing of them according to your own judgment under your own eye. As they are generally treated at present in ships, they are for the most part sick, and their flesh tough and hard as whit-leather. All seamen have an opinion, broached I supposed at first prudently, for saving of water when short, that fowls do not know when they have drank enough, and will kill themselves if you give them too much, so they are served with a little only once in two days. This is poured into troughs that lie sloping, and therefore immediately runs down to the lower end. There the fowls ride upon one another's backs to get at it, and some are not happy enough to reach and once dip their bills in it. Thus tantalized, and tormented with thirst, they cannot digest their dry food, they fret, pine, sicken and die. Some are found dead, and thrown overboard every morning, and those killed for the table are not eatable. Their troughs should be in little divisions, like cups, to hold the water separately, figure 25. But this is never done. The sheep and hogs are therefore your best dependance for fresh meat at sea, the mutton being generally tolerable and the pork excellent.

It is possible your captain may have provided so well in the general stores, as to render some of the particulars above [194] recommended of little or no use to you. But there are frequently in the ship poorer passengers, who are taken at a lower price, lodge in the steerage, and have no claim to any of the cabin provisions, or to any but those kinds that are allowed the sailors. These people are sometimes dejected, sometimes sick, there may be women and children among them. In a situation where there is no going to market, to purchase such necessaries, a few of these your superfluities distributed occasionally may be of great service, restore health, save life, make the miserable happy, and thereby afford you infinite pleasure.

The worst thing in ordinary merchant ships is the cookery. They have no professed cook, and the worst hand as a seaman is appointed to that office, in which he is not only very ignorant but very dirty. The sailors have therefore a saying, that *God sends meat and the devil cooks*. Passengers more piously disposed, and willing to believe heaven orders all things for the best, may suppose, that, knowing the sea-air and constant exercise by the motion of the vessel would give us extraordinary appetites, bad cooks were kindly sent to prevent our eating too much; or that, foreseeing we should have bad cooks, good appetites were furnished to prevent our starving. If you cannot trust to these circumstances, a spirit-lamp, with a blaze-pan, may enable you to cook some little things for yourself; such as a hash, a soup, &c. And it might be well also to have among your stores some potted meats, which if well put up will keep long good. A small tin oven, to place with the open side before the fire, may be another good utensil, in which your own servant may roast for you a bit of pork or mutton. You will sometimes be induced to eat of the ship's salt beef, as it is often good. You will find cyder the [195] best quencher of that thirst which salt meat or fish occasions. The ship biscuit is too hard for some sets of teeth. It may be softened by toasting. But rusk is better; for being made of good fermented bread, sliced and baked a second time, the pieces imbibe the water easily, soften immediately, digest more kindly, and are therefore more wholesome than the unfermented biscuit. By the way, rusk is the true original biscuit, so prepared to keep for sea, biscuit in French signifying twice baked. If your dry peas boil hard, a two-pound iron shot put with them into the pot, will by the motion of the ship grind them as fine as mustard.

The accidents I have seen at sea with large dishes of soup upon a table, from the motion of the ship, have made me wish, that our potters or pewterers would make soup-dishes in divisions, like a set of small bowls united together, each containing about sufficient for one person, in some such form as fig. 26; for then when the ship should make a sudden heel, the soup would not in a body flow over one side, and fall into people's laps and scald them, as is sometimes the case, but would be retained in the separate divisions, as in figure 27.

After these trifles, permit the addition of a few general reflections. Navigation, when employed in supplying necessary provisions to a country in want, and thereby preventing famines, which were more frequent and destructive before the invention of that art, is undoubtedly a blessing to mankind. When employed merely in transporting superfluities, it is a question whether the advantage of the employment it affords is equal to the mischief of hazarding so many lives on the [196] ocean. But when employed in pillaging merchants and transporting slaves, it is clearly the means of augmenting the mass of human misery. It is amazing to think of the ships and lives risqued in fetching tea from China, coffee from Arabia, sugar and tobacco from America, all which our ancestors did well without. Sugar employs near one thousand ships, tobacco almost as many. For the utility of tobacco there is little to be said; and for that of sugar, how much more commendable would it be if we could give up the few minutes gratification afforded once or twice a day by the taste of sugar in our tea, rather than encourage the cruelties exercised in producing it. An eminent French moralist says, that when he considers the wars we excite in Africa to obtain slaves, the numbers necessarily slain in those wars, the many prisoners who perish at sea by sickness, bad provisions, foul air, &c. &c. in the transportation, and how many afterwards die from the hardships of slavery, he cannot look on a piece of sugar without conceiving it stained with spots of human blood! Had he added the consideration of the wars we make to take and retake the sugar islands from one another, and the fleets and armies that perish in those expeditions, he might have seen his sugar not merely spotted, but thoroughly dyed scarlet in grain. It is these wars that make the maritime powers of Europe, the inhabitants of London and Paris, pay dearer for sugar than those of Vienna, a thousand miles from the sea; because their sugar costs not only the price they pay for it by the pound, but all they pay in taxes to maintain the fleets and armies that fight for it.

With great esteem, I am, Sir,

Your most obedient humble servant,

B. FRANKLIN.

FOOTNOTES:

[30] This letter and the annexed paper on the Gulph stream, are taken from the Transactions of the American Philosophical Society, in which they were read December 2, 1785. *Editor.*

[31] The motion of the vessel made it inconvenient to try this simple experiment at sea, when the proposal of it was written. But it has been tried since we came on shore, and succeeded as the other.

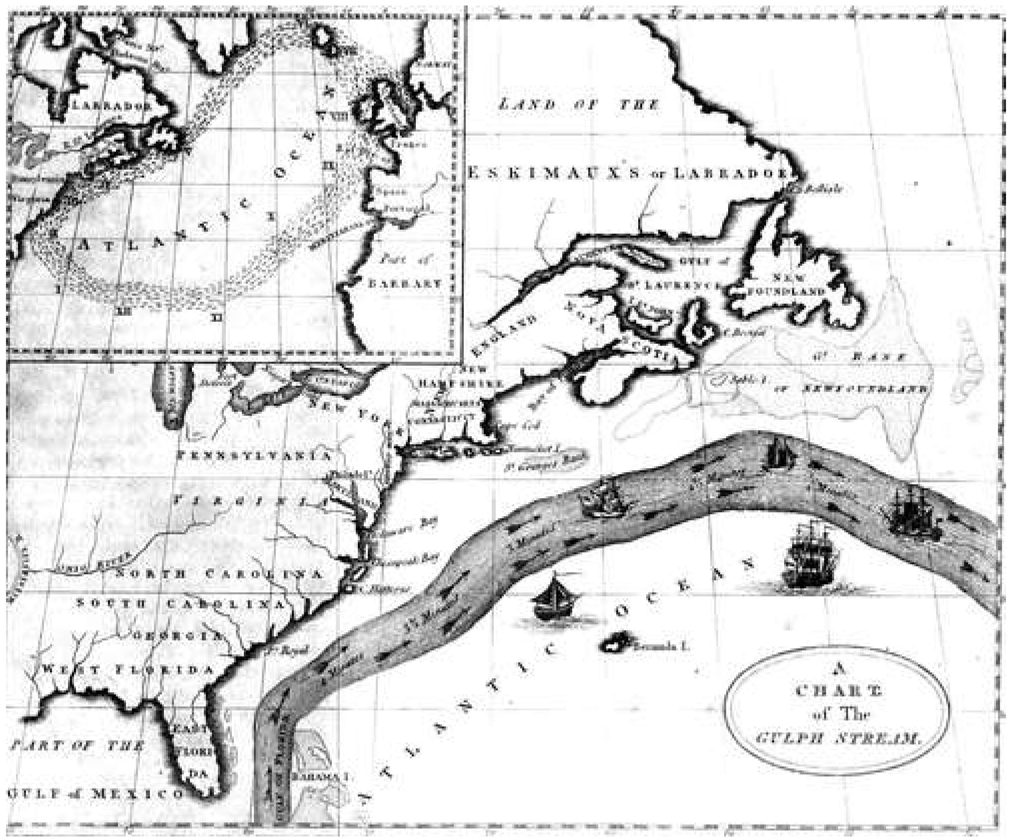
[32] Captain Truxton, on board whose ship this was written, has executed this proposed machine; he has given six arms to the umbrella, they are joined to the stem by iron hinges, and the canvas is double. He has taken it with him to China. February, 1786.

[33] Since this paper was read at the Society, an ingenious member, Mr. Patterson, has convinced the writer that the returning voyage would not, from this cause, be retarded.

[34] See the Paper referred to, Vol. I. p. 376. *Editor.*

[35] See Vol. II. p. 104. *Editor.*

A CHART of The *GULPH STREAM*.



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Remarks upon the Navigation from Newfoundland to New-York, in order to avoid the Gulph Stream on one hand, and on the other the Shoals that lie to the Southward of Nantucket and of St. George's Banks.

After you have passed the banks of Newfoundland in about the 44th degree of latitude, you will meet with nothing, till you draw near the Isle of Sables, which we commonly pass in latitude 43. Southward of this isle, the current is found to extend itself as far north as 41° 20′ or 30′, then it turns towards the E. S. E. or S. E. ¼ E.

Having passed the Isle of Sables, shape your course for the St. George's Banks, so as to pass them in about latitude 40°, because the current southward of those banks reaches as far north as 39°. The shoals of those banks lie in 41° 35′.

After having passed St. George's Banks, you must, to clear Nantucket, form your course so as to pass between the latitudes 38° 30′ and 40° 45′.

The most southern part of the shoals of Nantucket lie in about 40° 45′. The northern part of the current directly to the south of Nantucket is felt in about latitude 38° 30′.

By observing these directions and keeping between the stream and the shoals, the passage from the Banks of Newfoundland to New-York, Delaware, or Virginia, may be considerably shortened; for so you will have the advantage of the eddy current, which moves contrary to the Gulph Stream. Whereas if to avoid the shoals you keep too far to the southward, and get into that stream, you will be retarded by it at the rate of 60 or 70 miles a day.

The Nantucket whale-men being extremely well acquainted with the Gulph Stream, its course, strength, and extent, by [198] their constant practice of whaling on the edges of it, from their island quite down to the Bahamas, this draft of that stream was obtained from one of them, Captain Folges, and caused to be engraved on the old chart in London, for the benefit of navigators, by

B. FRANKLIN.

Note, The Nantucket captains who are acquainted with this stream, make their voyages from England to Boston in as short a time generally as others take in going from Boston to England, viz. from twenty to thirty days.

A stranger may know when he is in the Gulph Stream, by the warmth of the water, which is much greater than that of the water on each side of it. If then he is bound to the westward, he should cross the stream to get out of it as soon as possible.

B. FRANKLIN.

Observations *of the Warmth of the* Sea-water, *&c. by Fahrenheit's Thermometer, in crossing the Gulph Stream; with other Remarks made on board the Pennsylvania Packet, Capt. Osborne, bound from London to Philadelphia, in April and May, 1775.*

Date	Hour	Temp. of Air.	Temp. of Wat.	Wind	Course	Distance	Latitude N.	Longitude W.	Remarks
April 10			62						
11			61						
12			64						
13			65						
14			65				° ′	° ′	
26		60	70				37 39	60 38	Much gulph weed; saw a whale.
27		60	70	SSE	WbS		37 13	62 29	Colour of water changed.
28	8 A.M.	70	64	SW	WNW		37 48	64 35	No gulph weed.
—	6 P.M.	67	60			34			Sounded, no bottom.
29	8 A.M.	63	71	N	W	44	37 26	66 0	Much light in the water last night.
—	5 P.M.	65	72	NE		57			Water again of the usual deep sea colour, little or no light in it at night.
—	11 dit.	66	66	NWbN	WbS	57			
30	8 A.M.	64	70	NE	WbN	69			
—	12	62	70		EbS	24	37 20	68 53	Frequent gulph weed, water continues of sea colour, little light.
—	6 P.M.	64	72	ESE	WbN	43			
—	10 dit.	65	65	S		25			Much light.
May 1	7 A.M.	68	63			60			Much light all last night.
—	12	65	56	SSW	WNW	44	38 13	72 23	Colour of water changed.
—	4 P.M.	64	56		WbN	21			
—	10 dit.	64	57	SW	WNW	31			Much light.
2	8 A.M.	62	53			18	38 43	74 3	Much light. Thunder-gust.
—	12	60	53	WSW	NW	18			
—	6 P.M.	64	55	NW	WSW	15			
—	10	65	55	NbW	WbN	10			
3	7 A.M.	62	54			30	38 30	75 0	

Observations of the Warmth of the Sea-water, &c. by Fahrenheit's Thermometer; with other Remarks made on board the Reprisal, Capt. Wycks, bound from Philadelphia to France, in October and November, 1776.

Date	Hour A.M.	Hour P.M.	Temp. of Air	Temp. of Water	Wind	Course	Distance	Lat. N.	Long. W.	Remarks
Octo. 31	10		76	70	SSE	EbS	135	38 12	70 30	Left the capes Thursday night, October 29, 1776
—		4		71						
Nov. 1	10			78	WSW	E½N	109	No ob.	68 12	
—		4	71	81						
2	8		71	75	N					
—	12			78			141	ditto.	65 23	
—		4	67	76						Some sparks in the water these two last nights.
3	8			76	NW	ESE½E				
—	12			76		EbS	160	37 0	62 7	
—		4	70	76						
4	9		68	76		NbE				Ditto.
—		1		76			194	36 26	58 8	
—		4	68	76						
—		8		78						
5	8		68	76		NE				Ditto.
—	12		70	75			163	35 21	55 3	
—		4		75						
—		8		75						
6	8			76	EbN	S50E				
—	12			77			75	35 33	53 52	
7	8			78	SEbE	N30W				
—	12			77			108	36 6	52 46	
—		4		77						
8	9		75	77	SbE	N49E				
—	12			77			175	38 2	50 1	
—		4		77						
9	9		75	77						
—	12		75	70	SW	N33E	175	39 39	46 55	

Date	Hour A.M.	Hour P.M.	Temp. of Air	Temp. of Water	Wind	Course	Distance	Latit. N.	Long. W.	Remarks.
Nov 9		4		71						
10	8		70	68						
—	12			64	E	N 17 E	64	40 39	46 27	
11	8			63						
—	12			61	S E	N 8 E	41	41 19	46 19	
12	8		56	59						
—		4		69	NNW	N 80 E	120	41 39	43 42	
13	all	day		68	E	S 82 E	69	41 29	42 10	
14	8		70	70		N 74 E	111	42 0	39 57	
—		Noon		72	ESE					
—		4		71						
15	8		61	69						
—		Noon		68	WSW	N 70 E	186	43 3	35 51	
—		4		67						
16		Noon	65	67	S W	N 67 W	48	43 22	34 50	
—		4		63						
17	8			63	ESE	N 19 E	56	44 15	34 25	
18	all	day		65	SbW	N 75 E	210	45 6	29 43	Some gulph weed.
19		Noon	65	64	S W	N 80 E	238	45 46	24 2	
20	8			62	N	S 80 E	155	45 19	20 30	
—		4		60						
21	9			62	S	N 88 E	94	45 22	18 17	
22	10		60	62	SSW	S 89 E	133	45 19	15 19	
23		Noon		61	WSW	S 86 E	194	45 6	10 35	
24		do.		60	NNE	N 78 E	191	45 46	6 10	
25		do.		60	N E	S 76 E	125	45 4	3 23	
26		do.	56	60	E	N 73 E	31	45 13	2 20	
27		do.		58						Soundings off Bellisle.
28		do.	54	56						

A Journal of a Voyage from the Channel between France and England towards America.

Dates	Latit. N.	Long. W.	Therm. A.M.		Therm. P.M.		Winds	Course	Distance	Variation of the Needle	Therm. Noon	
			Air	Water	Air	Water					A.	W.
July 29			62	57			{ These are taken on an average of 24 hours. }					
30			62	58	63	58						
31			60	58	62	62			Miles.	West.		
Aug 1	49 15	4 15	63	62	60	64	East	SW ½W	60	22° 0		
2	48 28	8 58	64	64	64	63	E S E	WbS ½S	174			
3	47 0	12 13	60	67	omitted		N E	SW bW	160			
4	45 0	15 43	66	66	do.	66	NWbW	SW ½W	190			
5	43 5	17 25	67	65	65	68	N E	SW bS	131	20 0		
6	41 3	19 44	70	68	71	69	N E	SW ½S	166	16 30		
7	38 45	21 34	70	70	68	70	N E	SSW ¾W	165	11 30		
8	36 42	23 10	72	71	73	72	N E	SSW ¾W	149	11 15		
9	35 40	25 40	73	73	73	74	N E	WSW ¼S	137			
10	35 0	27 0	71	73	77	75	N W	WSW ¾S	76			
11	33 51	28 42	74	74	76	77	North	SW ¾W	112			
12	33 30	31 30	76	75	76	76	North	W ¾S	143			
13	33 17	33 32	76	76	78	77	N E	W ½ S	103		77	78
14	33 22	34 31	76	76	81	79	S S E	W ½ N	50		81	79
15	33 45	35 0	78	79	79	78	W N W	SW ¼W	35		79	79
16	34 14	35 30	79	78	81	80	West	NW ½N	38		81	80
17	35 37	36 4	80	79	80	78	W S W	N N W	75		80	78
18	36 7	37 16	80	78	omitted		NW bW	WNW ½N	65		80	79
19	36 38	38 0	78	77	78	77	W S W	NW ½W	49		79	77

Dates	Latit. N.	Long. W.	Therm. A.M.		Therm. P.M.		Winds	Course	Distance	Variation of the Needle	Therm. Noon	
			Air	Water	Air	Water					A.	W.
Aug 20	37 38	38 6	78	76	omitted		West	N ¼ W	62		77	75
21	36 15	38 26	73	74	78	76	W N W	S b W	82		77	75
22	35 40	38 44	77	76	80	77	W b S	S S W	38		80	77
23	35 35	40 52	79	77	78	75	North	W ¼ S	100		omitted.	
24	35 12	41 31	75	73	75	74	W N W	S W b W	41		75	74
25	35 40	42 33	79	76	79	76	W b N	W N W ¾ N	60		80	76
26	35 30	42 44	79	76	80	76	S W b W	S W ½ S	14		80	76
27	35 14	43 23	79	77	81	79	West	W S W ¼ S	38		81	78
28	34 23	44 0	78	76	78	78	N N E	S W b S	60		78	78
29	34 12	45 52	77	78	78	78	N E	W ¼ S	94	8 0	79	78
30	34 5	48 31	78	78	78	78	East	W ½ S	134		78	78
31	34 20	51 4	80	79	81	79	East	W ¾ S	129		80	80
Sept 1	34 20	52 47	81	78	omitted		S S W	W ¼ N	86		83	80
2	34 55	55 12	81	80	83	80	S W	W b N ½ W	125		83	80
3	35 30	57 24	83	80	83	80	S W b S	W b N ½ N	114	6 0	84	81
4	35 50	59 1	82	80	83	80	S W ½ W	W b N ¼ N	82		83	81
5	35 55	61 0	81	80	82	81	S S W	W ¼ N	96		82	81
6	36 20	62 30	80	81	79	80	N W b N	W b N	75		78	80
7	34 50	63 10	87	80	78	81	N W b N	S S W	86		78	81
8	34 45	64 40	75	79	75	79	North	W ¼ S	74		75	79
9	35 43	66 42	75	79	77	73	N E	W N W	108		78	80
10	37 20	68 40	77	73	77	70	E N E	N W	126		78	72

N.B. Longitude is reckoned from London, and the Thermometer is according to Fahrenheit.

OBSERVATIONS. [204]

July 31. At one P.M. the Start bore WNW. distant six leagues.

August 1. The water appears luminous in the ship's wake.

---- 2. The temperature of the water is taken at eight in the morning and at eight in the evening.

---- 6. The water appears less luminous.

---- 7. Formegas SW. dist 32½ deg. St. Mary's SW½S. 33 leagues.

---- 8. From this date the temperature of the water is taken at eight in the morning and at six in the evening.

---- 10. Moonlight, which prevents the luminous appearance of the water.

---- 11. A strong southerly current.

---- 12. Ditto. From this date the temperature of the air and water was taken at noon, as well as morning and evening.

---- 16. Northerly current.

---- 19. First saw gulph weed.

---- 21. Southerly current.

---- 22. Again saw gulph weed.

---- 24. The water appeared luminous in a small degree before the moon rose.

---- 29. No moon, yet very little light in the water.

---- 30. Much gulph weed to-day.

---- 31. Ditto.

Sept. 1. Ditto.

---- 2. A little more light in the water.

---- 4. No gulph weed to-day. More light in the water.

---- 5. Some gulph weed again.

---- 6. Little light in the water. A very hard thunder-gust in the night.

---- 7. Little gulph weed.

---- 8. More light in the water. Little gulph weed.

---- 9. Little gulph weed. Little light in the water last evening.

---- 10. Saw some beds of rock-weed; and we were surprised to observe the water six degrees colder by the thermometer than the preceding noon.

This day (10th) the thermometer still kept descending, and at five in the morning of the 11th, it was in water as low as 70, when we struck soundings. The same evening the pilot came on board, and we found our ship about five degrees of longitude a-head of the reckoning, which our captain accounted for by supposing our course to have been near the edge of the gulph stream, and thus an eddy-current always in our favour. By the distance we ran from Sept. 9, in the evening, till we struck soundings, we must have then been at the western edge of the gulph stream, and the change in the temperature of the water was probably owing to our suddenly passing from that current, into the waters of our own climate. [205]

On the 14th of August the following experiment was made. The weather being perfectly calm, an empty bottle, corked very tight, was sent down 20 fathoms, and it was drawn up still empty. It was then sent down again 35 fathoms, when the weight of the water having forced in the cork, it was drawn up full; the water it contained was immediately tried by the thermometer, and found to be 70, which was six degrees colder than at the surface: the lead and bottle were visible, but not very distinctly so, at the depth of 12 fathoms, but when only 7 fathoms deep, they were perfectly seen from the ship. This experiment was thus repeated Sept. 11, when we were in soundings of 18 fathoms. A keg was previously prepared with a valve at each end, one opening inward, the other outward; this was sent to the bottom in expectation that by the valves being both open when going down, and both shut when coming up, it would keep within it the water received at bottom. The upper valve performed its office well, but the under one did not shut quite close, so that much of the water was lost in hauling it up the ship's side. As the water in the keg's passage upwards could not enter at the top, it was concluded that what water remained in it was of that near the ground, and on trying this by the thermometer, it was found to be at 58, which was 12 degrees colder than at the surface.

This last Journal was obligingly kept for me by Mr. J. Williams, my fellow-passenger in the London Packet, who made all the experiments with great exactness.

TO MR. O. N[36]. [206]

On the Art of Swimming.

[No date.]

Dear Sir,

I cannot be of opinion with you that it is too late in life for you to learn to swim. The river near the bottom of your garden affords a most convenient place for the purpose. And as your new employment requires your being often on the water, of which you have such a dread, I think you would do well to make the trial; nothing being so likely to remove those apprehensions as the consciousness of an ability to swim to the shore, in case of an accident, or of supporting yourself in the water till a boat could come to take you up.

I do not know how far corks or bladders may be useful in learning to swim, having never seen much trial of them. Possibly they may be of service in supporting the body while you are learning what is called the stroke, or that manner of drawing in and striking out the hands and feet that is necessary to produce progressive motion. But you will be no swimmer till you can place some confidence in the power of the water to support you; I would therefore advise the acquiring that confidence in the first place; especially as I have known several who, by a little of the practice necessary for that purpose, have insensibly acquired the stroke, taught as it were by nature.

The practice I mean is this. Chusing a place where the water deepens gradually, walk coolly into it till it is up to your breast, then turn round, your face to the shore, and throw an egg into the water between you and the shore. It will sink to [207] the bottom, and be easily seen there, as your water is clear. It must lie in water so deep as that you cannot reach it to take it up but by diving for it. To encourage yourself in order to do this, reflect that your progress will be from deeper to shallower water, and that at any time you may, by bringing your legs under you and standing on the bottom, raise your head far above the water. Then plunge under it with your eyes open, throwing yourself towards the egg, and endeavouring by the action of your hands and feet against the water to get forward till within reach of it. In this attempt you will find, that the water buoys you up against your inclination; that it is not so easy a thing to sink as you imagined; that you cannot but by active force get down to the egg. Thus you feel the power of the water to support you, and learn to confide in that power; while your endeavours to overcome it, and to reach the egg, teach you the manner of acting on the water with your feet and hands, which action is afterwards used in swimming to support your head higher above water, or to go forward through it.

I would the more earnestly press you to the trial of this method, because, though I think I satisfied you that your body is lighter than water, and that you might float in it a long time with your mouth free for breathing, if you would put yourself in a proper posture, and would be still and forbear struggling; yet till you have obtained this experimental confidence in the water, I cannot depend on your having the necessary presence of mind to recollect that posture and the directions I gave you relating to it. The surprize may put all out of your mind. For though we value ourselves on being reasonable [208] knowing creatures, reason and knowledge seem on such occasions to be of little use to us; and the brutes to whom we allow scarce a glimmering of either, appear to have the advantage of us.

I will, however, take this opportunity of repeating, those particulars to you, which I mentioned in our last conversation, as, by perusing them at your leisure, you may possibly imprint them so in your memory as on occasion to be of some use to you.

1. That though the legs, arms, and head, of a human body, being solid parts, are specifically something heavier than fresh water, yet the trunk, particularly the upper part, from its hollowness, is so much lighter than water, as that the whole of the body taken together is too light to sink wholly under water, but some part will remain above, until the lungs become filled with water, which happens from drawing water into them instead of air, when a person in the fright attempts breathing while the mouth and nostrils are under water.

2. That the legs and arms are specifically lighter than salt water, and will be supported by it, so that a human body would not sink in salt-water, though the lungs were filled as above, but from the greater specific gravity of the head.

3. That therefore a person throwing himself on his back in salt water, and extending his arms, may easily lie so as to keep his mouth and nostrils free for breathing; and by a small motion of his hands may prevent turning, if he should perceive any tendency to it.

4. That in fresh water, if a man throws himself on his back, near the surface, he cannot long continue in that situation but by proper action of his hands on the water. If he uses no such action, the legs and lower part of the body will gradually sink till he comes into an upright position, in which he will continue suspended, the hollow of the breast keeping the head uppermost. [209]

5. But if, in this erect position, the head is kept upright above the shoulders, as when we stand on the ground, the immersion will, by the weight of that part of the head that is out of water, reach above the mouth and nostrils, perhaps a little above the eyes, so that a man cannot long remain suspended in water with his head in that position.

6. The body continuing suspended as before, and upright, if the head be leaned quite back, so that the face looks upwards, all the back part of the head being then under water, and its weight consequently in a great measure supported by it, the face will remain above water quite free for breathing, will rise an inch higher every inspiration, and sink as much every expiration, but never so low as that the water may come over the mouth.

7. If therefore a person unacquainted with swimming and falling accidentally into the water, could have presence of mind sufficient to avoid struggling and plunging, and to let the body take this natural position, he might continue long safe from drowning till perhaps help would come. For as to the cloaths, their additional weight while immersed is very inconsiderable, the water supporting it though, when he comes out of the water, he would find them very heavy indeed.

But, as I said before, I would not advise you or any one to depend on having this presence of mind on such an occasion, but learn fairly to swim; as I wish all men were taught to do in their youth; they would, on many occurrences, be the safer for having that skill, and on many more the happier, as freer from painful apprehensions of danger, to say nothing of the enjoyment in so delightful and wholesome an exercise. Soldiers particularly should, methinks, all be taught to swim; it might be of frequent use either in surprising an enemy, or saving themselves. And if I had now boys to educate, I should prefer those schools (other things being equal) where an opportunity was afforded for acquiring so advantageous an art, which once learned is never forgotten. [210]

I am, Sir, &c.

B. FRANKLIN.

FOOTNOTE:

[36] Oliver Neale. *Editor.*

ON THE SAME SUBJECT,

In Answer to some Enquiries of M. Dubourg[37].

**** I am apprehensive that I shall not be able to find leisure for making all the disquisitions and experiments which would be desirable on this subject. I must, therefore, content myself with a few remarks.

The specific gravity of some human bodies, in comparison to that of water, has been examined by Mr. Robinson, in our Philosophical Transactions, volume 50, page 30, for the year 1757. He asserts, that fat persons with small bones float most easily upon the water.

The diving-bell is accurately described in our Transactions.

When I was a boy, I made two oval pallets, each about ten inches long, and six broad, with a hole for the thumb, in order to retain it fast in the palm of my hand. They much resembled a painter's pallets. In swimming I pushed the edges of these forward, and I struck the water with their flat surfaces as I drew them back. I remember I swam faster by means of these pallets, but they fatigued my wrists. I also fitted to the soles of my feet a kind of sandals; but I was not satisfied with [211] them, because I observed that the stroke is partly given by the inside of the feet and the ancles, and not entirely with the soles of the feet.

We have here waistcoats for swimming, which are made of double sail-cloth, with small pieces of cork quilted in between them.

I know nothing of the *scaphandre* of M. de la Chapelle.

I know by experience, that it is a great comfort to a swimmer, who has a considerable distance to go, to turn himself sometimes on his back, and to vary in other respects the means of procuring a progressive motion.

When he is seized with the cramp in the leg, the method of driving it away is to give to the parts affected a sudden, vigorous and violent shock; which he may do in the air as he swims on his back.

During the great heats of summer there is no danger in bathing, however warm we may be, in rivers which have been thoroughly warmed by the sun. But to throw oneself into cold spring water, when the body has been heated by exercise in the sun, is an imprudence which may prove fatal. I once knew an instance of four young men, who, having worked at harvest in the heat of the day, with a view of refreshing themselves plunged into a spring of cold water: two died upon the spot, a third the next morning, and the fourth recovered with great difficulty. A copious draught of cold water, in similar circumstances, is frequently attended with the same effect in North America.

The exercise of swimming is one of the most healthy and agreeable in the world. After having swam for an hour or two in the evening, one sleeps coolly the whole night, even during the most ardent heat of summer. Perhaps the pores being [212] cleansed, the insensible perspiration increases and occasions this coolness. It is certain that much swimming is the means of stopping a diarrhœa, and even of producing a constipation. With respect to those who do not know how to swim, or who are affected with a diarrhœa at a season which does not permit them to use that exercise, a warm bath, by cleansing and purifying the skin, is found very salutary, and often effects a radical cure. I speak from my own experience, frequently repeated, and that of others to whom I have recommended this.

You will not be displeased if I conclude these hasty remarks by informing you, that as the ordinary method of swimming is reduced to the act of rowing with the arms and legs, and is consequently a laborious and fatiguing operation when the space of water to be crossed is considerable; there is a method in which a swimmer may pass to great distances with much facility, by means of a sail. This discovery I fortunately made by accident, and in the following manner.

When I was a boy I amused myself one day with flying a paper kite; and approaching the bank of a pond, which was near a mile broad, I tied the string to a stake, and the kite ascended to a very considerable height above the pond, while I was swimming. In a little time, being desirous of amusing myself with my kite, and enjoying at the same time the pleasure of swimming, I returned; and loosing from the stake the string with the little stick which was fastened to it, went again into the water, where I found, that, lying on my back and holding the stick in my hands, I was drawn along the surface of the water in a very agreeable manner. Having then engaged another boy to carry my clothes round the pond, to a place [213] which I pointed out to him on the other side, I began to cross the pond with my kite, which carried me quite over without the least fatigue, and with the greatest pleasure imaginable. I was only obliged occasionally to halt a little in my course, and resist its progress, when it appeared that, by following too quick, I lowered the kite too much; by doing which occasionally I made it rise again. I have never since that time practised this singular mode of swimming, though I think it not impossible to cross in this manner from Dover to Calais. The packet-boat, however, is still preferable. ****

B. FRANKLIN.

FOOTNOTE:

[37] This and the four following extracts of letters to M. Dubourg, are re-translated from the French edition of Dr. Franklin's works. *Editor.*

TO M. DUBOURG.

On the free Use of Air.

London, July 28, 1760.

**** I greatly approve the epithet which you give, in your letter of the 8th of June, to the new method of treating the small-pox, which you call the *tonic* or bracing method; I will take occasion, from it, to mention a practice to which I have accustomed myself. You know the cold bath has long been in vogue here as a tonic; but the shock of the cold water has always appeared to me, generally speaking, as too violent, and I have found it much more agreeable to my constitution to bathe in another element, I mean cold air. With this view I rise almost every morning, and sit in my chamber without any clothes whatever, half an hour or an hour, according to the season, either reading or writing. This practice is not in the [214] least painful, but, on the contrary, agreeable; and if I return to bed afterwards, before I dress myself, as sometimes happens, I make a supplement to my night's rest of one or two hours of the most pleasing sleep that can be imagined. I find no ill consequences whatever resulting from it, and that at least it does not injure my health, if it does not in fact contribute much to its preservation. I shall therefore call it for the future a *bracing* or *tonic* bath. ****

B. FRANKLIN.

On the Causes of Colds.

March 10, 1773.

**** I shall not attempt to explain why damp clothes occasion colds, rather than wet ones, because I doubt the fact; I imagine that neither the one nor the other contribute to this effect, and that the causes of colds are totally independent of wet and even of cold. I propose writing a short paper on this subject, the first moment of leisure I have at my disposal. In the mean time I can only say, that having some suspicions that the common notion, which attributes to cold the property of stopping the pores and obstructing perspiration, was ill founded, I engaged a young physician, who is making some experiments with Sanctorius's balance, to estimate the different proportions of his perspiration, when remaining one hour quite naked, and another warmly clothed. He pursued the experiment in this alternate manner for eight hours successively, and found his perspiration almost double during those hours in which he was naked. ****

B. FRANKLIN.

Dr. Stark[38]. [215]

May 4, 1773.

**** The young physician whom I mentioned is dead, and all the notes which he had left of his curious experiments are by some accident lost between our friends Sir John Pringle and Dr. Huck (Saunders); but these gentlemen, if the papers cannot be recovered, it is to be presumed, will repeat the experiments themselves ****

B. FRANKLIN.

Dr. Lettsom.

London, August 30, 1769.

**** This letter will be forwarded to you by Dr. Lettsom, a young American physician of much merit, and one of the peaceable sect of Quakers: you will therefore at least regard him as a curiosity, even though you should have embraced all the opinions of the majority of your countrymen concerning these people ****

B. FRANKLIN.

FROM DR. ——[39] OF BOSTON, TO BENJAMIN FRANKLIN, ESQ. OF PHILADELPHIA.

Respecting the Number of Deaths in Philadelphia by Inoculation.

Boston, Aug. 3, 1752.

Sir,

This comes to you on account of Dr. Douglass: he desired me to write to you for what you know of the number that died of the inoculation in Philadelphia, telling me he designed to write something on the small-pox shortly. We shall both be obliged to you for a word on this affair. [216]

The chief particulars of our visitation, you have in the public prints. But the less degree of mortality than usual in the common way of infection, seems chiefly owing to the purging method designed to prevent the secondary fever; a method first begun and carried on in this town, and with success beyond expectation. We lost one in eleven one-sixth, but had we been experienced in this way, at the first coming of the distemper, probably the proportion had been but one in thirteen or fourteen. In the year 1730 we lost one in nine, which is more favourable than ever before with us. The distemper pretty much the same then as now, but some circumstances not so kind this time.

If there be any particulars which you want to know, please to signify what they are, and I shall send them.

The number of our inhabitants decreases[40]. On a strict inquiry, the overseers of the poor find but fourteen thousand one hundred and ninety Whites, and one thousand five hundred and forty-four Blacks, including those absent, on account of the small-pox, many of whom, it is probable, will never return.

I pass this opportunity without any particulars of my old theme. One thing, however, I must mention, which is, that perhaps my last letters contained something that seemed to militate with your doctrine of the *Origin*, &c. But my design [217] was only to relate the phenomena as they appeared to me. I have received so much light and pleasure from your writings, as to prejudice me in favour of every thing from your hand, and leave me only liberty to observe, and a power of dissenting when some great probability might oblige me: and if at any time that be the case, you will certainly hear of it.

I am, Sir, &c.

FOOTNOTES:

[38] The works of Dr. Stark, including the experiments alluded to, have since been published. *Editor.*

[39] Dr. Perkins. *Editor.*

[40] Boston is an old town, and was formerly the seat of all the trade of the country, that was carried on by sea. New towns, and ports, have, of late, divided the trade with it, and diminished its inhabitants, though the inhabitants of the country, in general, have greatly increased.

FROM BENJAMIN FRANKLIN, ESQ. OF PHILADELPHIA.

In Answer to the preceding.

Philadelphia, Aug. 13, 1752.

Sir,

I received your favour of the 3d instant. Some time last winter I procured from one of our physicians an account of the number of persons inoculated during the five visitations of the small-pox we have had in twenty-two years; which account I sent to Mr. W. V. of your town, and have no copy. If I remember right, the number exceeded eight hundred, and the deaths were but four. I suppose Mr. V. will show you the account, if he ever received it. Those four were all that our doctors allow to have died of the small-pox by inoculation, though I think there were two more of the inoculated who died of the distemper; but the eruptions appearing soon after the operation, it is supposed they had taken the infection before, in the common way.

I shall be glad to see what Dr. Douglass may write on the subject. I have a French piece printed at Paris, 1724, entitled, *Observations sur la Saignée du Pied, et sur la Purgation au commencement de la Petite Verole, & Raisons de doubte* [218] *contre l' Inoculation.*—A letter of the doctor's is mentioned in it. If he or you have it not, and desire to see it, I will send it.—Please to favour me with the particulars of your purging method, to prevent the secondary fever.

I am indebted for your preceding letter, but business sometimes obliges one to postpone philosophical amusements. Whatever I have wrote of that kind, are really, as they are entitled, but *Conjectures* and *Suppositions*; which ought always to give place, when careful observation militates against them. I own I have too strong a penchant to the building of hypotheses; they indulge my natural indolence: I wish I had more of your patience and accuracy in making observations, on which, alone, true philosophy can be founded. And, I assure you, nothing can be more obliging to me, than your kind communication of those you make, however they may disagree with my pre-conceived notions.

I am sorry to hear that the number of your inhabitants decreases. I some time since, wrote a small paper of *Thoughts on the peopling of Countries*[41], which, if I can find, I will send you, to obtain your sentiments. The favourable opinion you express of my writings, may, you see, occasion you more trouble than you expected from,

Sir, yours, &c.

B. FRANKLIN.

FOOTNOTE:

[41] This paper will be found in a subsequent part of the present volume. *Editor.*

TO BENJAMIN VAUGHAN, ESQ. [219]

On the Effects of Lead upon the human Constitution.[42]

Philadelphia, July 31, 1786.

DEAR FRIEND,

I recollect that when I had last the pleasure of seeing you at Southampton, now a twelvemonth since, we had some conversation on the bad effects of lead taken inwardly; and that at your request I promised to send you in writing a particular account of several facts I then mentioned to you, of which you thought some good use might be made. I now sit down to fulfil that promise.

The first thing I remember of this kind was a general discourse in Boston when I was a boy, of a complaint from North Carolina against New-England rum, that it poisoned their people, giving them the dry-belly-ach, with a loss of the use of their limbs. The distilleries being examined on the occasion, it was found, that several of them used leaden still-heads and worms, and the physicians were of opinion, that the mischief was occasioned by that use of lead. The legislature of

Massachussetts thereupon passed an act, prohibiting, under severe penalties, the use of such still-heads and worms hereafter.

In 1724, being in London, I went to work in the printing-house of Mr. Palmer, Bartholomew-close, as a compositor. I there found a practice, I had never seen before, of drying a case of types (which are wet in distribution) by placing it sloping before the fire. I found this had the additional advantage, when the types were not only dried but heated, of being [220] comfortable to the hands working over them in cold weather. I therefore sometimes heated my case when the types did not want drying. But an old workman observing it advised me not to do so, telling me I might lose the use of my hands by it, as two of our companions had nearly done, one of whom, that used to earn his guinea a week, could not then make more than ten shillings, and the other, who had the dangles, but seven and sixpence. This, with a kind of obscure pain, that I had sometimes felt, as it were, in the bones of my hand when working over the types made very hot, induced me to omit the practice. But talking afterwards with Mr. James, a letter-founder in the same Close, and asking him if his people, who worked over the little furnaces of melted metal, were not subject to that disorder; he made light of any danger from the effluvia, but ascribed it to particles of the metal swallowed with their food by slovenly workmen, who went to their meals after handling the metal, without well washing their fingers, so that some of the metalline particles were taken off by their bread and eaten with it. This appeared to have some reason in it. But the pain I had experienced made me still afraid of those effluvia.

Being in Derbyshire at some of the furnaces for smelting of lead ore, I was told, that the smoke of those furnaces was pernicious to the neighbouring grass and other vegetables; but I do not recollect to have heard any thing of the effect of such vegetables eaten by animals. It may be well to make the enquiry.

In America I have often observed, that on the roofs of our shingled-houses, where moss is apt to grow in northern [221] exposures, if there be any thing on the roof painted with white lead, such as balusters, or frames of dormant windows, &c. there is constantly a streak on the shingles from such paint down to the eaves, on which no moss will grow, but the wood remains constantly clean and free from it. We seldom drink rain-water that fall on our houses; and if we did, perhaps the small quantity of lead descending from such paint might not be sufficient to produce any sensible ill-effect on our bodies. But I have been told of a case in Europe, I forget the place, where a whole family was afflicted with what we call the dry-belly-ach, or *colica pictorum*, by drinking rain-water. It was at a country-seat, which, being situated too high to have the advantage of a well, was supplied with water from a tank, which received the water from the leaded roofs. This had been drank several years without mischief, but some young trees planted near the house growing up above the roof, and shedding their leaves upon it, it was supposed, that an acid in those leaves had corroded the lead they covered, and furnished the water of that year with its baneful particles and qualities.

When I was in Paris with Sir John Pringle in 1767, he visited *La Charité*, an hospital particularly famous for the cure of that malady, and brought from thence a pamphlet, containing a list of the names of persons, specifying their professions or trades, who had been cured there. I had the curiosity to examine that list, and found, that all the patients were of trades, that some way or other use or work in lead; such as plumbers, glaziers, painters, &c. excepting only two kinds, stone- [222] cutters and soldiers. In them, I could not reconcile it to my notion, that lead was the cause of that disorder. But on my mentioning it to a physician of that hospital, he informed me, that the stone-cutters are continually using melted lead to fix the ends of iron balustrades in stone; and that the soldiers had been employed by painters as labourers in grinding of colours.

This, my dear friend, is all I can at present recollect on the subject. You will see by it, that the opinion of this mischievous effect from lead, is at least above sixty years old; and you will observe with concern how long a useful truth may be known and exist, before it is generally received and practised on.

I am, ever, yours most affectionately,

B. FRANKLIN.

FOOTNOTE:

[42] This letter is taken from a work by Dr. John Hunter, entitled *Observations on the Diseases of the Army*. *Editor.*

TO M. DUBOURG[43].

Observations on the prevailing Doctrines of Life and Death.

**** Your observations on the causes of death, and the experiments which you propose for recalling to life those who appear to be killed by lightning, demonstrate equally your sagacity and your humanity. It appears, that the doctrines of life and death, in general, are yet but little understood.

A toad buried in sand will live, it is said, till the sand becomes petrified: and then, being inclosed in the stone, it may still live for we know not how many ages. [223] The facts which are cited in support of this opinion are too numerous, and too circumstantial, not to deserve a certain degree of credit. As we are accustomed to see all the animals, with which we are acquainted, eat and drink, it appears to us difficult to conceive, how a toad can be supported in such a dungeon: but if we reflect, that the necessity of nourishment, which animals experience in their ordinary state, proceeds from the continual waste of their substance by perspiration, it will appear less incredible, that some animals in a torpid state, perspiring less because they use no exercise, should have less need of aliment; and that others, which are covered with scales or shells, which stop perspiration, such as land and sea-turtles, serpents, and some species of fish, should be able to subsist a considerable time without any nourishment whatever.—A plant, with its flowers, fades and dies immediately, if exposed to the air without having its root immersed in a humid soil, from which it may draw a sufficient quantity of moisture to supply that which exhales from its substance and is carried off continually by the air. Perhaps, however, if it were buried in quicksilver, it might preserve for a considerable space of time its vegetable life, its smell and colour. If this be the case, it might prove a commodious method of transporting from distant countries those delicate plants, which are unable to sustain the inclemency of the weather at sea, and which require particular care and attention. I have seen an instance of common flies preserved in a manner somewhat similar. They had been drowned in Madeira wine, apparently about the time when it was bottled in Virginia, to be sent hither (to London). At the opening of one of the bottles, at the house of a [224] friend where I then was, three drowned flies fell into the first glass that was filled. Having heard it remarked, that drowned flies were capable of being revived by the rays of the sun, I proposed making the experiment upon these: they were therefore exposed to the sun upon a sieve, which had been employed to strain them out of the wine. In less than three hours, two of them began by degrees to recover life. They commenced by some convulsive motions of the thighs, and at length they raised themselves upon their legs, wiped their eyes with their fore-feet, beat and brushed their wings with their hind-feet, and soon after began to fly, finding themselves in Old England, without knowing how they came thither. The third continued lifeless till sunset, when, losing all hopes of him, he was thrown away.

I wish it were possible, from this instance, to invent a method of embalming drowned persons, in such a manner that they may be recalled to life at any period, however distant; for having a very ardent desire to see and observe the state of America an hundred years hence, I should prefer to any ordinary death, the being immersed in a cask of Madeira wine, with a few friends till that time, to be then recalled to life by the solar warmth of my dear country! But since in all probability we live in an age too early and too near the infancy of science, to hope to see such an art brought in our time to its perfection, I must for the present content myself with the treat, which you are so kind as to promise me, of the resurrection of a fowl or a turkey-cock.

I am, &c.

B. FRANKLIN.

FOOTNOTE:

[43] This letter is translated from the French edition of Dr. Franklin's works. It has no date, but the letter to which it is an answer is dated 15th April, 1773.

An Account of the new-invented Pensylvanian Fire-Places: [225]

wherein their Construction and Manner of Operation is particularly explained; their Advantages above every other Method of warming Rooms demonstrated; and all Objections that have been raised against the Use of them answered and obviated. With Directions for putting them up, and for using them to the best Advantage. And a Copper-Plate, in which the several parts of the Machine are exactly laid down, from a Scale of Equal Parts.

BY B. FRANKLIN.

(First printed at Philadelphia in 1745.)

In these northern colonies the inhabitants keep fires to sit by generally seven months in the year; that is, from the beginning of October, to the end of April; and, in some winters, near eight months, by taking in part of September and May.

Wood, our common fuel, which within these hundred years might be had at every man's door, must now be fetched near one hundred miles to some towns, and makes a very considerable article in the expence of families.

As therefore so much of the comfort and conveniency of our lives, for so great a part of the year, depends on the article of *fire*; since fuel is become so expensive, and (as the country is more cleared and settled) will of course grow scarcer and dearer, any new proposal for saving the wood, and for lessening the charge, and augmenting the benefit of fire, by some particular method of making and managing it, may at least be thought worth consideration.

The new fire-places are a late invention to that purpose, of which this paper is intended to give a particular account. [226]

That the reader may the better judge whether this method of managing fire has any advantage over those heretofore in use, it may be proper to consider both the old and new methods separately and particularly, and afterwards make the comparison.

In order to this, it is necessary to understand well, some few of the properties of air and fire, viz.

1. Air is rarefied by *heat*, and condensed by *cold*, *i. e.* the same quantity of air takes up more space when warm than when cold. This may be shown by several very easy experiments. Take any clear glass bottle (a Florence flask stript of the straw is best) place it before the fire, and as the air within is warmed and rarefied, part of it will be driven out of the bottle; turn it up, place its mouth in a vessel of water, and remove it from the fire; then, as the air within cools and contracts, you will see the water rise in the neck of the bottle, supplying the place of just so much air as was driven out. Hold a large hot coal near the side of the bottle, and as the air within feels the heat, it will again distend and force out the

water.—Or, fill a bladder not quite full of air, tie the neck tight, and lay it before a fire as near as may be without scorching the bladder; as the air within heats, you will perceive it to swell and fill the bladder, till it becomes tight, as if full blown: remove it to a cool place, and you will see it fall gradually, till it becomes as lank as at first.

2. Air rarefied and distended by heat is[44] specifically

lighter than it was before, and will rise in other air of greater density. As wood, oil, or any other matter specifically lighter than water, if placed at the bottom of a vessel of water, will rise till it comes to the top; so rarefied air will rise in common air, till it either comes to air of equal weight, or is by cold reduced to its former density. [227]

A fire then being made in any chimney, the air over the fire is rarefied by the heat, becomes lighter, and therefore immediately rises in the funnel, and goes out; the other air in the room (flowing towards the chimney) supplies its place, is rarefied in its turn, and rises likewise; the place of the air thus carried out of the room, is supplied by fresh air coming in through doors and windows, or, if they be shut, through every crevice with violence, as may be seen by holding a candle to a key-hole: If the room be so tight as that all the crevices together will not supply so much air as is continually carried off, then, in a little time, the current up the funnel must flag, and the smoke being no longer driven up, must come into the room.

1. Fire (*i. e.* common fire) throws out light, heat, and smoke (or fume.) The two first move in right lines, and with great swiftness, the latter is but just separated from the fuel, and then moves only as it is carried by the stream of rarefied air: and without a continual accession and recession of air, to carry off the smoaky fumes, they would remain crouded about the fire, and stifle it.

2. Heat may be separated from the smoke as well as from the light, by means of a plate of iron, which will suffer heat to pass through it without the others.

3. Fire sends out its rays of heat as well as rays of light, equally every way; but the greatest sensible heat is over the fire, where there is, besides the rays of heat shot upwards, a continual rising stream of hot air, heated by the rays shot round on every side. [228]

These things being understood, we proceed to consider the fire-places heretofore in use, *viz.*

1. The large open fire-places used in the days of our fathers, and still generally in the country, and in kitchens.

2. The newer-fashioned fire-places, with low breasts, and narrow hearths.

3. Fire-places with hollow backs, hearths, and jams of iron (described by M. Gauger, in his tract entitled, *La Mechanique de Feu*) for warming the air as it comes into the room.

4. The Holland stoves, with iron doors opening into the room.

5. The German stoves, which have no opening in the room where they are used, but the fire is put in from some other room, or from without.

6. Iron pots, with open charcoal fires, placed in the middle of a room.

1. The first of these methods has generally the conveniency of two warm seats, one in each corner; but they are sometimes too hot to abide in, and, at other times, incommoded with the smoke; there is likewise good room for the cook

to move, to hang on pots, &c. Their inconveniencies are, that they almost always smoke, if the door be not left open; that they require a large funnel, and a large funnel carries off a great quantity of air, which occasions what is called a strong draft to the chimney, without which strong draft the smoke would come out of some part or other of so large an opening, [229] so that the door can seldom be shut; and the cold air so nips the backs and heels of those that sit before the fire, that they have no comfort till either screens or settles are provided (at a considerable expence) to keep it off, which both cumber the room, and darken the fire-side. A moderate quantity of wood on the fire, in so large a hearth, seems but little; and, in so strong and cold a draught, warms but little; so that people are continually laying on more. In short, it is next to impossible to warm a room with such a fire-place: and I suppose our ancestors never thought of warming rooms to sit in; all they purposed was, to have a place to make a fire in, by which they might warm themselves when cold.

2. Most of these old-fashioned chimneys in towns and cities, have been, of late years, reduced to the second sort mentioned, by building jambs within them, narrowing the hearth, and making a low arch or breast. It is strange, methinks, that though chimneys have been so long in use, their construction should be so little understood till lately, that no workman pretended to make one which should always carry off all smoke, but a chimney-cloth was looked upon as essential to a chimney. This improvement, however, by small openings and low breasts, has been made in our days; and success in the first experiments has brought it into general use in cities, so that almost all new chimneys are now made of that sort, and much fewer bricks will make a stack of chimneys now than formerly. An improvement, so lately made, may give us room to believe, that still farther improvements may be found to remedy the inconveniencies yet remaining. For these new chimneys, though they keep rooms generally free from smoke, and, the opening being contracted, will allow [230] the door to be shut, yet the funnel still requiring a considerable quantity of air, it rushes in at every crevice so strongly, as to make a continual whistling or howling; and it is very uncomfortable, as well as dangerous, to sit against any such crevice. Many colds are caught from this cause only, it being safer to sit in the open street, for then the pores do all close together, and the air does not strike so sharply against any particular part of the body.

The Spaniards have a proverbial saying,

> If the wind blows on you through a hole,
> Make your will, and take care of your soul.

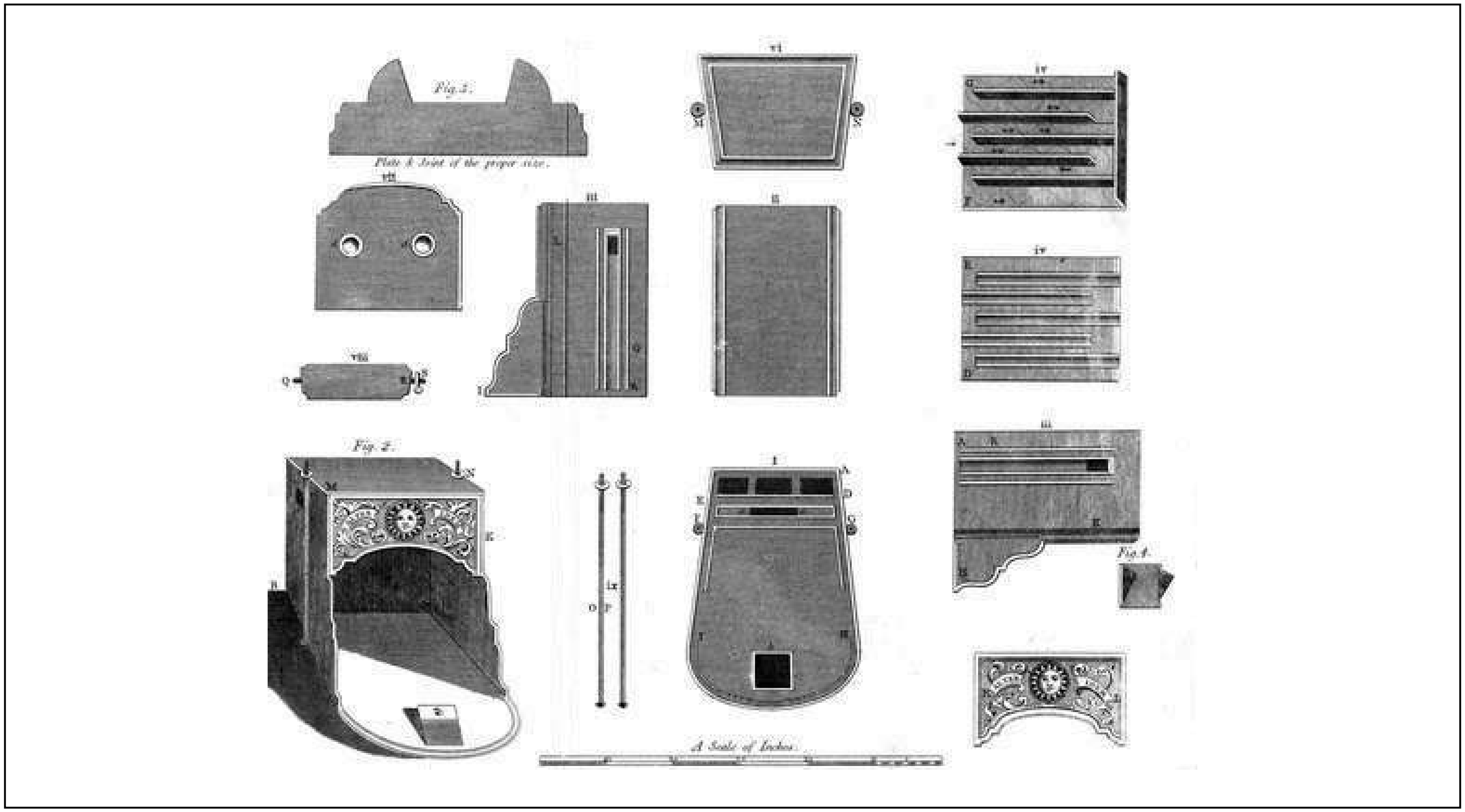
Women particularly, from this cause, as they sit much in the house, get colds in the head, rheums and defluctions, which fall into their jaws and gums, and have destroyed early many a fine set of teeth in these northern colonies. Great and bright fires do also very much contribute to damage the eyes, dry and shrivel the skin, and bring on early the appearances of old age. In short, many of the diseases proceeding from colds, as fevers, pleurisies, &c. fatal to very great numbers of people, may be ascribed to strong drawing chimneys, whereby, in severe weather, a man is scorched before while he is froze behind.[45] In the mean time, very little is done by these chimneys towards warming the room; for the air [231] round the fire-place, which is warmed by the direct rays from the fire, does not continue in the room, but is continually [232] crouded and gathered into the chimney by the current of cold air coming behind it, and so is presently carried off.

In both these sorts of fire-places, the greatest part of the heat from the fire is lost; for as fire naturally darts heat every way, the back, the two jambs, and the hearth, drink up almost all that is given them, very little being reflected from bodies so dark, porous, and unpolished; and the upright heat, which is by far the greatest, flies directly up the chimney. Thus five-sixths at least of the heat (and consequently of the fuel) is wasted, and contributes nothing towards warming the room.

3. To remedy this, the Sieur Gauger gives, in his book entitled, La Mechanique de Feu, published in 1709, seven different constructions of the third sort of chimneys mentioned above, in which there are hollow cavities made by iron plates in the back, jambs, and hearths, through which plates the heat passing warms the air in those cavities, which is continually coming into the room fresh and warm. The invention was very ingenious, and had many conveniencies: the [233] room was warmed in all parts, by the air flowing into it through the heated cavities: cold air was prevented rushing through the crevices, the funnel being sufficiently supplied by those cavities: much less fuel would serve, &c. But the first expence, which was very great, the intricacy of the design, and the difficulty of the execution, especially in old chimneys, discouraged the propagation of the invention; so that there are, I suppose, very few such chimneys now in use. [The upright heat, too, was almost all lost in these, as in the common chimneys.]

4. The Holland iron stove, which has a flue proceeding from the top, and a small iron door opening into the room, comes next to be considered. Its conveniencies are, that it makes a room all over warm; for the chimney being wholly closed, except the flue of the stove, very little air is required to supply that, and therefore not much rushes in at crevices, or at the door when it is opened. Little fuel serves, the heat being almost all saved; for it rays out almost equally from the four sides, the bottom and the top, into the room, and presently warms the air around it, which, being rarefied, rises to the ceiling, and its place is supplied by the lower air of the room, which flows gradually towards the stove, and is there warmed, and rises in its turn, so that there is a continual circulation till all the air in the room is warmed. The air, too, is gradually changed, by the stove-door's being in the room, through which part of it is continually passing, and that makes these stoves wholesomer, or at least pleasanter than the German stoves, next to be spoken of. But they have these inconveniencies. There is no sight of the fire, which is in itself a pleasant thing. One cannot conveniently make any other [234] use of the fire but that of warming the room. When the room is warm, people, not seeing the fire, are apt to forget supplying it with fuel till it is almost out, then, growing cold, a great deal of wood is put in, which soon makes it too hot. The change of air is not carried on quite quick enough, so that if any smoke or ill smell happens in the room, it is a long time before it is discharged. For these reasons the Holland stove has not obtained much among the English (who love the sight of the fire) unless in some workshops, where people are obliged to sit near windows for the light, and in such places they have been found of good use.

5. The German stove is like a box, one side wanting. It is composed of five iron plates screwed together, and fixed so as that you may put the fuel into it from another room, or from the outside of the house. It is a kind of oven reversed, its mouth being without, and body within the room that is to be warmed by it. This invention certainly warms a room very speedily and thoroughly with little fuel: no quantity of cold air comes in at any crevice, because there is no discharge of air which it might supply, there being no passage into the stove from the room. These are its conveniencies. Its inconveniencies are, that people have not even so much sight or use of the fire as in the Holland stoves, and are, moreover, obliged to breathe the same unchanged air continually, mixed with the breath and perspiration from one another's bodies, which is very disagreeable to those who have not been accustomed to it.



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6. Charcoal fires in pots are used chiefly in the shops of handicraftsmen. They warm a room (that is kept close, and has no chimney to carry off the warmed air) very speedily and uniformly; but there being no draught to change the air, the sulphurous fumes from the coals [be they ever so well kindled before they are brought in, there will be some] mix with it, render it disagreeable, hurtful to some constitutions, and sometimes, when the door is long kept shut, produce fatal consequences. [235]

To avoid the several inconveniencies, and at the same time retain all the advantages of other fire-places, was contrived the Pensylvania fire-place, now to be described.

This machine consists of

A bottom-plate, (i) (*See the Plate annexed*.)

A back plate, (ii)

Two side plates, (iii iii)

Two middle plates, (iv iv) which, joined together, form a tight box, with winding passages in it for warming the air.

A front plate, (v)

A top plate (vi)

These are all cast of iron, with mouldings or ledges where the plates come together, to hold them fast, and retain the mortar used for pointing to make tight joints. When the plates are all in their places, a pair of slender rods, with screws, are sufficient to bind the whole very firmly together, as it appears in Fig. 2.

There are, moreover, two thin plates of wrought iron, viz. the shutter, (vii) and the register, (viii); besides the screw-rods O P, all which we shall explain in their order.

(i) The bottom plate, or hearth-piece, is round before, with a rising moulding, that serves as a fender to keep coals and ashes from coming to the floor, &c. It has two ears, F G, perforated to receive the screw-rods O P; a long air-hole, *a a*, through which the fresh outward air passes up into the air-box; and three smoke-holes B C, through which the smoke descends and passes away; all represented by dark squares. It has also double ledges to receive between them the bottom edges of the back plate, the two side-plates, and the two middle plates. These ledges are about an inch asunder, and about half an inch high; a profile of two of them, joined to a fragment of plate, appears in Fig. 3. [236]

(ii) The back plate is without holes, having only a pair of ledges on each side, to receive the back edges of the two.

(iii iii) Side-plates: These have each a pair of ledges to receive the side-edges of the front-plate, and a little shoulder for it to rest on; also two pair of ledges to receive the side-edges of the two middle plates which form the air-box; and an oblong air-hole near the top, through which is discharged into the room the air warmed in the air-box. Each has also a wing or bracket, H and I, to keep in falling brands, coals, &c. and a small hole, Q and R, for the axis of the register to turn in.

(iv iv) The air-box is composed of the two middle plates, D E and F G. The first has five thin ledges or partitions cast on it, two inches deep, the edges of which are received in so many pair of ledges cast in the other. The tops of all the cavities formed by these thin deep ledges, are also covered by a ledge of the same form and depth, cast with them; so that when the plates are put together, and the joints luted, there is no communication between the air-box and the smoke. In the winding passages of this box, fresh air is warmed as it passes into the room. [237]

(v) The front plate is arched on the under side, and ornamented with foliages, &c. it has no ledges.

(vi) The top plate has a pair of ears, M N, answerable to those in the bottom plate, and perforated for the same purpose: it has also a pair of ledges running round the under side, to receive the top edges of the front, back, and side-plates. The air-box does not reach up to the top plate by two inches and a half.

(vii) The shutter is of thin wrought iron and light, of such a length and breadth as to close well the opening of the fire-place. It is used to blow up the fire, and to shut up and secure it at nights. It has two brass knobs for handles, *d d*, and commonly slides up and down in a groove, left, in putting up the fire-place, between the foremost ledge of the side-plates, and the face of the front plate; but some chuse to set it aside when it is not in use, and apply it on occasion.

(viii) The register is also of thin wrought iron. It is placed between the back plate and air-box, and can, by means of the key S, be turned on its axis so as to lie in any position between level and upright.

The screw-rods O P are of wrought iron, about a third of an inch thick, with a button at bottom, and a screw and nut at top, and may be ornamented with two small brasses screwed on above the nuts.

To put this machine to work,

1. A false back of four inch (or, in shallow small chimneys, two inch) brick work is to be made in the chimney, four inches or more from the true back; from the top of this false back a closing is to be made over to the breast of the [238] chimney, that no air may pass into the chimney, but what goes under the false back, and up behind it.

2. Some bricks of the hearth are to be taken up, to form a hollow under the bottom plate; across which hollow runs a thin tight partition, to keep apart the air entering the hollow and the smoke; and is therefore placed between the air-hole and smoke-holes.

3. A passage is made, communicating with the outward air, to introduce that air into the fore part of the hollow under the bottom plate, whence it may rise through the air-hole into the air-box.

4. A passage is made from the back part of the hollow, communicating with the flue behind the false back: through this passage the smoke is to pass.

The fire-place is to be erected upon these hollows, by putting all the plates in their places, and screwing them together.

Its operation may be conceived by observing the plate entitled, Profile of the Chimney and Fire-Place.

M The mantle-piece, or breast of the chimney.

C The funnel.

B The false back and closing.

E True back of the chimney.

T Top of the fire-place.

F The front of it.

A The place where the fire is made.

D The air-box.

K The hole in the side-plate, through which the warmed air is discharged out of the air-box into the room.

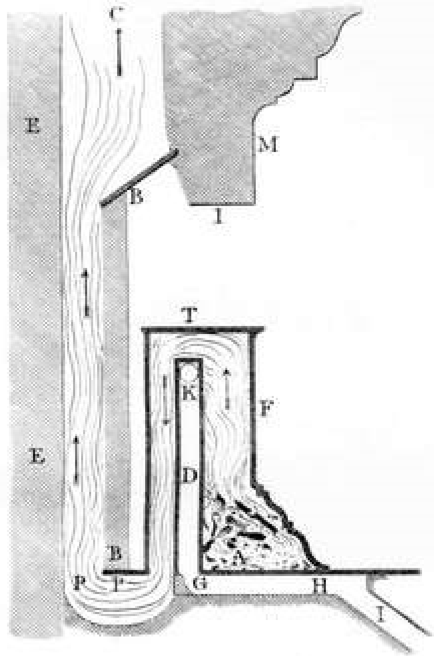
H The hollow filled with fresh air, entering at the passage *I*, and ascending into the air-box through the air-hole in the [239] bottom plate near

G The partition in the hollow to keep the air and smoke apart.

P The passage under the false back and part of the hearth for the smoke.

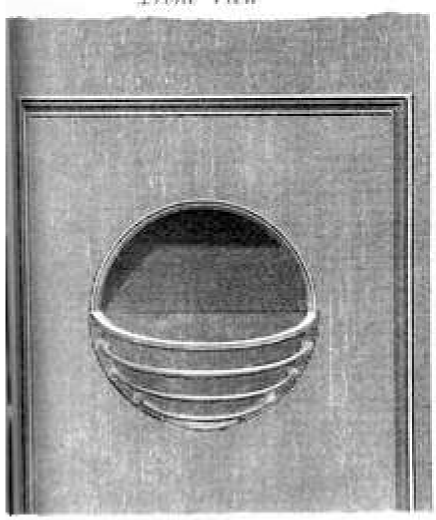
The arrows show the course of the smoke.

Profile of the Pensylvania Chimney & Fire-Place.

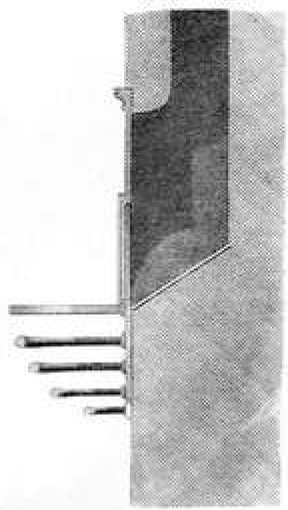


STAFFORDSHIRE FIRE-PLACE.

Front View



Side View



Front View *STAFFORDSHIRE FIRE-PLACE.* *Side View*

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The fire being made at A, the flame and smoke will ascend and strike the top T, which will thereby receive a considerable heat. The smoke, finding no passage upwards, turns over the top of the air-box, and descends between it and the back plate to the holes in the bottom plate, heating, as it passes, both plates of the air-box, and the said back plate; the front plate, bottom and side plates are also all heated at the same time. The smoke proceeds in the passage that leads it under and behind the false back, and so rises into the chimney. The air of the room, warmed behind the back plate, and by the sides, front, and top plates, becoming specifically lighter than the other air in the room, is obliged to rise; but the closure over the fireplace hindering it from going up the chimney, it is forced out into the room, rises by the mantle-piece to the cieling, and spreads all over the top of the room, whence being crouded down gradually by the stream of newly-warmed air that follows and rises above it, the whole room becomes in a short time equally warmed.

At the same time the air, warmed under the bottom plate, and in the air-box, rises and comes out of the holes in the side-plates, very swiftly, if the door of the room be shut, and joins its current with the stream before-mentioned, rising from the side, back, and top plates.

The air that enters the room through the air-box is fresh, though warm; and, computing the swiftness of its motion with [240] the areas of the holes, it is found that near ten barrels of fresh air are hourly introduced by the air-box; and by this means the air in the room is continually changed, and kept, at the same time, sweet and warm.

It is to be observed, that the entering air will not be warm at first lighting the fire, but heats gradually as the fire increases.

A square opening for a trap-door should be left in the closing of the chimney, for the sweeper to go up: the door may be made of slate or tin, and commonly kept close shut, but so placed as that, turning up against the back of the chimney when open, it closes the vacancy behind the false back, and shoots the soot, that falls in sweeping, out upon the hearth. This trap-door is a very convenient thing.

In rooms where much smoking of tobacco is used, it is also convenient to have a small hole, about five or six inches square, cut near the ceiling through into the funnel: this hole must have a shutter, by which it may be closed or opened at pleasure. When open, there will be a strong draught of air through it into the chimney, which will presently carry off a cloud of smoke, and keep the room clear: if the room be too hot like-wise, it will carry off as much of the warm air as you please, and then you may stop it entirely, or in part, as you think fit. By this means it is, that the tobacco smoke does not descend among the heads of the company near the fire, as it must do before it can get into common chimneys.

[241]

The Manner of using this Fire-Place.

Your cord-wood must be cut into three lengths; or else a short piece, fit for the fire-place, cut off, and the longer left for the kitchen or other fires. Dry hickery, or ash, or any woods that burn with a clear flame are rather to be chosen, because such are less apt to foul the smoke-passages with soot; and flame communicates with its light, as well as by contact, greater heat to the plates and room. But where more ordinary wood is used, half a dry faggot of brush-wood, burnt at the first making the fire in the morning, is very advantageous, as it immediately, by its sudden blaze, heats the plates, and warms the room (which with bad wood slowly kindling would not be done so soon) and at the same time by the length of its flame, turning in the passages, consumes and cleanses away the soot that such bad smoaky wood had produced therein the preceding day, and so keeps them always free and clean. When you have laid a little back log, and placed your billets on small dogs, as in common chimneys, and put some fire to them, then slide down your shutter as low as the dogs, and the opening being by that means contracted, the air rushes in briskly, and presently blows up the flames. When the fire is sufficiently kindled, slide it up again.[46] In some of these fire-places there is a little six-inch square trap-door of thin [242] wrought iron or brass, covering a hole of like dimensions near the fore-part of the bottom plate, which being by a ring lifted up towards the fire, about an inch, where it will be retained by two springing sides fixed to it perpendicularly (*See the Plate, Fig. 4.*) the air rushes in from the hollow under the bottom plate, and blows the fire. Where this is used, the shutter serves only to close the fire at nights. The more forward you can make your fire on the hearth-plate, not to be incommoded by the smoke, the sooner and more will the room be warmed. At night, when you go to bed, cover the coals or brands with ashes as usual; then take away the dogs, and slide down the shutter close to the bottom-plate, sweeping a little ashes against it, that no air may pass under it; then turn the register, so as very near to stop the flue behind. If no smoke then comes out at crevices into the room, it is right: if any smoke is perceived to come out, move the register, so as to give a little draught, and it will go the right way. Thus the room will be kept warm all night; for the chimney being almost entirely stopt, very little cold air, if any, will enter the room at any crevice. When you come to re-kindle the fire in the morning, turn open the register before you lift up the slider, otherwise, if there be any smoke in the fireplace, it will come out into the room. By the same use of the shutter and register, a blazing fire may be presently stifled, as well as secured, when you have occasion to leave it for any time; and at your return you will find the brands warm, and ready for a speedy rekindling. The shutter alone will not stifle a fire, for it cannot well be made to fit so exactly but that air will enter, and that in a violent stream, so as to blow up and keep alive the flames, and consume the wood, if the draught be [243] not checked by turning the register to shut the flue behind. The register has also two other uses. If you observe the draught of air into your fire-place to be stronger than is necessary (as in extreme cold weather it often is) so that the wood is consumed faster than usual; in that case, a quarter, half, or two-thirds turn of the register, will check the violence of the draught, and let your fire burn with the moderation you desire: and at the same time both the fire-place and the room will be the warmer, because less cold air will enter and pass through them. And if the chimney should happen to take fire (which indeed there is very little danger of, if the preceding direction be observed in making fires, and it be well swept once a year; for, much less wood being burnt, less soot is proportionably made; and the fuel being soon blown into flame by the shutter, or the trap-door bellows, there is consequently less smoke from the fuel to make soot; then, though the funnel should be foul, yet the sparks have such a crooked up and down round about way to go, that they are out before they get at it). I say, if ever it should be on fire, a turn of the register shuts all close, and prevents any air going into the chimney, and so the fire may easily be stifled and mastered.

The Advantages of this Fire-Place.

Its advantages above the common fire-places are,

1. That your whole room is equally warmed, so that people need not croud so close round the fire, but may sit near the window, and have the benefit of the light for reading, writing, needle-work, &c. They may sit with comfort in any part of the room, which is a very considerable advantage in a large family, where there must often be two fires kept, because all [244] cannot conveniently come at one.

2. If you sit near the fire, you have not that cold draught of uncomfortable air nipping your back and heels, as when before common fires, by which many catch cold, being scorched before, and, as it were, froze behind.

3. If you sit against a crevice, there is not that sharp draught of cold air playing on you, as in rooms where there are fires in the common way; by which many catch cold, whence proceed coughs[47], catarrhs, tooth-achs, fevers, pleurisies, and many other diseases.

4. In case of sickness, they make most excellent nursing rooms; as they constantly supply a sufficiency of fresh air, so warmed at the same time as to be no way inconvenient or dangerous. A small one does well in a chamber; and, the chimneys, being fitted for it, it may be removed from one room to another, as occasion requires, and fixed in half an hour. The equal temper too, and warmth of the air of the room, is thought to be particularly advantageous in some distempers; for it was observed in the winters of 1730 and 1736, when the small-pox spread in Pensylvania, that very few children of the Germans died of that distemper in proportion to those of the English; which was ascribed, by some, to the warmth and [245] equal temper of air in their stove-rooms, which made the disease as favourable as it commonly is in the West Indies. But this conjecture we submit to the judgment of physicians.

5. In common chimneys, the strongest heat from the fire, which is upwards, goes directly up the chimney, and is lost; and there is such a strong draught into the chimney that not only the upright heat, but also the back, sides, and downward heats are carried up the chimney by that draught of air; and the warmth given before the fire, by the rays that strike out towards the room, is continually driven back, crouded into the chimney, and carried up by the same draught of air. But here the upright heat strikes and heats the top plate, which warms the air above it, and that comes into the room. The heat likewise, which the fire communicates to the sides, back, bottom, and air-box, is all brought into the room; for you will find a constant current of warm air coming out of the chimney-corner into the room. Hold a candle just under the mantle-piece, or breast of your chimney, and you will see the flame bent outwards: by laying a piece of smoaking paper on the hearth, on either side, you may see how the current of air moves, and where it tends, for it will turn and carry the smoke with it.

6. Thus, as very little of the heat is lost, when this fire-place is used, *much less wood*[48] will serve you, which is a considerable advantage where wood is dear.

7. When you burn candles near this fire-place, you will find that the flame burns quite upright, and does not blare and [246] run the tallow down, by drawing towards the chimney, as against common fires.

8. This fire-place cures most smoaky chimneys, and thereby preserves both the eyes and furniture.

9. It prevents the fouling of chimneys; much of the lint and dust that contributes to foul a chimney being, by the low arch, obliged to pass through the flame, where it is consumed. Then, less wood being burnt, there is less smoke made. Again, the shutter, or trap-bellows, soon blowing the wood into a flame, the same wood does not yield so much smoke as if burnt in a common chimney: for as soon as flame begins, smoke in proportion ceases.

10. And if a chimney should be foul, it is much less likely to take fire. If it should take fire, it is easily stifled and extinguished.

11. A fire may be very speedily made in this fire-place by the help of the shutter, or trap-bellows, as aforesaid.

12. A fire may be soon extinguished, by closing it with the shutter before, and turning the register behind, which will stifle it, and the brands will remain ready to rekindle.

13. The room being once warm, the warmth may be retained in it all night.

14. And lastly, the fire is so secured at night, that not one spark can fly out into the room to do damage. [247]

With all these conveniences, you do not lose the pleasing sight nor use of the fire, as in the Dutch stoves, but may boil the tea-kettle, warm the flat-irons, heat heaters, keep warm a dish of victuals by setting it on the top, &c.

Objections answered.

There are some objections commonly made by people that are unacquainted with these fire-places, which it may not be amiss to endeavour to remove, as they arise from prejudices which might otherwise obstruct, in some degree, the general use of this beneficial machine. We frequently hear it said, *They are of the nature of Dutch stoves*; *stoves have an unpleasant smell*; *stoves are unwholesome*; *and, warm rooms make people tender, and apt to catch cold*.—As to the first, that they are of the nature of Dutch stoves, the description of those stoves, in the beginning of this paper, compared with that of these machines, shows that there is a most material difference, and that these have vastly the advantage, if it were only in the single article of the admission and circulation of the fresh air. But it must be allowed there may have been some cause to complain of the offensive smell of iron stoves. This smell, however, never proceeded from the iron itself, which, in its nature, whether hot or cold, is one of the sweetest of metals, but from the general uncleanly manner of using those stoves. If they are kept clean, they are as sweet as an ironing-box, which though ever so hot, never offends the smell of the nicest lady: but it is common to let them be greased, by setting candlesticks on them, or otherwise; to rub greasy [248] hands on them; and, above all, to spit upon them, to try how hot they are, which is an inconsiderate filthy unmannerly custom; for the slimy matter of spittle drying on burns and fumes when the stove is hot, as well as the grease, and smells most nauseously, which makes such close stove-rooms, where there is no draught to carry off those filthy vapours, almost intolerable to those that are not from their infancy accustomed to them. At the same time nothing is more easy than to keep them clean; for when by any accident they happen to be fouled, a lee made of ashes and water, with a brush, will scour them perfectly: as will also a little strong soft soap and water.

That hot iron of itself gives no offensive smell, those know very well who have (as the writer of this has) been present at a furnace when the workmen were pouring out the flowing metal to cast large plates, and not the least smell of it to be perceived. That hot iron does not, like lead, brass, and some other metals, give out unwholesome vapours, is plain from the general health and strength of those who constantly work in iron, as furnace-men, forge-men, and smiths; that it is in its nature a metal perfectly wholesome to the body of man, is known from the beneficial use of chalybeate or iron-mine-waters; from the good done by taking steel filings in several disorders; and that even the smithy water in which hot irons are quenched, is found advantageous to the human constitution.—The ingenious and learned Dr. Desaguliers, to whose instructive writings the contriver of this machine acknowledges himself much indebted, relates an experiment he made, to try whether heated iron would yield unwholesome vapours: he took a cube of iron, and having given it a very great heat, [249] he fixed it so to a receiver, exhausted by the air-pump, that all the air rushing in to fill the receiver, should first pass through a hole in the hot iron. He then put a small bird into the receiver, who breathed that air without any inconvenience, or suffering the least disorder. But the same experiment being made with a cube of hot brass, a bird put into that air died in a few minutes. Brass, indeed, stinks even when cold, and much more when hot; lead, too, when hot, yields a very unwholesome steam; but iron is always sweet and every way taken is wholesome and friendly to the human body—except in weapons.

That warmed rooms make people tender, and apt to catch cold, is a mistake as great as it is (among the English) general. We have seen in the preceding pages how the common rooms are apt to give colds; but the writer of this paper may affirm from his own experience, and that of his family and friends who have used warm rooms for these four winters past, that by the use of such rooms, people are rendered *less liable* to take cold, and, indeed, *actually hardened*. If sitting warm in a room made one subject to take cold on going out, lying warm in bed, should by a parity of reason, produce the same effect when we rise. Yet we find we can leap out of the warmest bed naked, in the coldest morning, without any such danger; and in the same manner out of warm cloaths into a cold bed. The reason is, that in these cases the pores all close at once, the cold is shut out, and the heat within augmented, as we soon after feel by the glowing of the flesh and skin. Thus no one was ever known to catch cold by the use of the cold bath: and are not cold baths allowed to harden the [250] bodies of those that use them? Are they not therefore frequently prescribed to the tenderest constitutions? Now every time you go out of a warm room into the cold freezing air, you do as it were plunge into a cold bath, and the effect is in proportion the same; for (though perhaps you may feel somewhat chilly at first) you find in a little time your bodies hardened and strengthened, your blood is driven round with a brisker circulation, and a comfortable steady uniform inward warmth succeeds that equal outward warmth you first received in the room. Farther to confirm this assertion, we instance the Swedes, the Danes, and the Russians: these nations are said to live in rooms, compared to ours, as hot as ovens[49]; yet where are the hardy soldiers, though bred in their boasted cool houses, that can, like these people, bear the fatigues of a winter campaign in so severe a climate, march whole days to the neck in snow, and at night entrench in ice as they do?

The mentioning of those northern nations, puts me in mind of a considerable *public advantage* that may arise from the [251] general use of these fire-places. It is observable, that though those countries have been well inhabited for many ages, wood is still their fuel, and yet at no very great price; which could not have been, if they had not universally used stoves, but consumed it as we do, in great quantities, by open fires. By the help of this saving invention our wood may grow as fast as we consume it, and our posterity may warm themselves at a moderate rate, without, being obliged to fetch their fuel over the Atlantic; as, if pit-coal should not be here discovered (which is an uncertainty) they must necessarily do.

We leave it to the *political arithmetician* to compute how much money will be saved to a country, by its spending two-thirds less of fuel; how much labour saved in cutting and carriage of it; how much more land may be cleared by cultivation; how great the profit by the additional quantity of work done, in those trades particularly that do not exercise the body so much, but that the workfolks are obliged to run frequently to the fire to warm themselves: and to physicians to say, how much healthier thick-built towns and cities will be, now half-suffocated with sulphury smoke, when so much less of that smoke shall be made, and the air breathed by the inhabitants be consequently so much purer. These things it will suffice just to have mentioned; let us proceed to give some necessary directions to the workman who is to fix or set up these fire-places.

Directions to the Bricklayer.

The chimney being first well swept and cleansed from soot, &c. lay the bottom plate down on the hearth, in the place [252] where the fire-place is to stand, which may be as forward as the hearth will allow. Chalk a line from one of its back corners round the plate to the other corner, that you may afterwards know its place when you come to fix it; and from those corners, two parallel lines to the back of the chimney: make marks also on each side, that you may know where the partition is to stand, which is to prevent any communication between the air and smoke. Then, removing the plate, make a

hollow under it and beyond it, by taking up as many of the bricks or tiles as you can, within your chalked lines, quite to the chimney-back. Dig out six or eight inches deep of the earth or rubbish, all the breadth and length of your hollow; then make a passage of four inches square (if the place will allow so much) leading from the hollow to some place communicating with the outer air; by *outer air* we mean air without the room you intend to warm. This passage may be made to enter your hollow on either side, or in the fore part, just as you find most convenient, the circumstances of your chimney considered. If the fire-place is to be put up in a chamber, you may have this communication of outer air from the stair-case; or sometimes more easily from between the chamber floor, and the ceiling of the lower room, making only a small hole in the wall of the house entering the space betwixt those two joists with which your air-passage in the hearth communicates. If this air passage be so situated as that mice may enter it, and nestle in the hollow, a little grate of wire will keep them out. This passage being made, and, if it runs under any part of the earth, tiled over securely, you may proceed to raise your false back. This may be of four inches or two inches thickness, as you have room, but let it stand at [253]
least four inches from the true chimney-back. In narrow chimneys this false back runs from jamb to jamb, but in large old-fashioned chimneys, you need not make it wider than the back of the fire-place. To begin it, you may form an arch nearly flat, of three bricks end to end, over the hollow, to leave a passage the breadth of the iron fire-place, and five or six inches deep, rounding at bottom, for the smoke to turn and pass under the false back, and so behind it up the chimney. The false back is to rise till it is as high as the breast of the chimney, and then to close over to the breast[50]; always observing, if there is a wooden mantle-tree, to close above it. If there is no wood in the breast, you may arch over and close even with the lower part of the breast. By this closing the chimney is made tight, that no air or smoke can pass up it, without going under the false back. Then from side to side of your hollow, against the marks you made with chalk, raise a tight partition, brick-on-edge, to separate the air from the smoke, bevelling away to half an inch the brick that comes just under the air-hole, that the air may have a free passage up into the air-box: lastly, close the hearth over that part of the hollow that is between the false back and the place of the bottom plate, coming about half an inch under the plate, which piece of hollow hearth may be supported by a bit or two of old iron-hoop; then is your chimney fitted to receive the fire-place.

To set it, lay first a little bed of mortar all round the edges of the hollow, and over the top of the partition: then lay down [254]
your bottom plate in its place (with the rods in it) and tread it till it lies firm. Then put a little fine mortar (made of loam and lime, with a little hair) into its joints, and set in your back plate, leaning it for the present against the false back: then set in your air-box, with a little mortar in its joints; then put in the two sides, closing them up against the air-box, with mortar in their grooves, and fixing at the same time your register: then bring up your back to its place, with mortar in its grooves, and that will bind the sides together. Then put in your front plate, placing it as far back in the groove as you can, to leave room for the sliding plate: then lay on your top plate, with mortar in its grooves also, screwing the whole firmly together by means of the rods. The capital letters A B D E, &c. in Plate VIII., shew the corresponding parts of the several plates. Lastly, the joints being pointed all round on the outside, the fire-place is fit for use.

When you make your first fire in it, perhaps if the chimney be thoroughly cold, it may not draw, the work too being all cold and damp. In such case, put first a few shovels of hot coals in the fire-place, then lift up the chimney-sweeper's trap-door, and putting in a sheet or two of flaming paper, shut it again, which will set the chimney a drawing immediately, and when once it is filled with a column of warm air, it will draw strongly and continually.

The drying of the mortar and work by the first fire may smell unpleasantly, but that will soon be over.

In some shallow chimneys, to make more room for the false back and its flue, four inches or more of the chimney back may be picked away.

Let the room be made as tight as conveniently it may be, so will the outer air, that must come in to supply the room and [255] draught of the fire, be all obliged to enter through the passage under the bottom plate, and up through the air-box, by which means it will not come cold to your backs, but be warmed as it comes in, and mixed with the warm air round the fire-place, before it spreads in the room.

But as a great quantity of cold air, in extreme cold weather especially, will presently enter a room if the door be carelessly left open, it is good to have some contrivance to shut it, either by means of screw hinges, a spring, or a pulley.

When the pointing in the joints is all dry and hard, get some powder of black lead (broken bits of black lead crucibles from the silver-smiths, pounded fine, will do) and mixing it with a little rum and water, lay it on, when the plates are warm, with a hard brush, over the top and front-plates, part of the side and bottom-plates, and over all the pointing; and, as it dries, rub it to a gloss with the same brush, so the joints will not be discerned, but it will look all of a piece, and shine like new iron. And the false back being plaistered and white-washed, and the hearth reddened, the whole will make a pretty appearance. Before the black lead is laid on, it would not be amiss to wash the plates with strong lee and a brush, or soap and water, to cleanse them from any spots of grease or filth that may be on them. If any grease should afterwards come on them, a little wet ashes will get it out.

If it be well set up, and in a tolerable good chimney, smoke will draw in from as far as the fore part of the bottom plate, as you may try by a bit of burning paper.

People are at first apt to make their rooms too warm, not imagining how little a fire will be sufficient. When the plates [256] are no hotter than that one may just bear the hand on them, the room will generally be as warm as you desire it.

Soon after the foregoing piece was published, some persons in England, in imitation of Mr. Franklin's invention, made what they call Pensylvanian Fire-places, with improvements; *the principal of which pretended improvements is, a contraction of the passages in the air-box, originally designed for admitting a quantity of fresh air, and warming it as it entered the room. The contracting these passages gains indeed more room for the grate, but in a great measure defeats their intention. For if the passages in the air-box do not greatly exceed in dimensions the amount of all the crevices by which cold air can enter the room, they will not considerably prevent, as they were intended to do, the entry of cold air through these crevices.*

FOOTNOTES:

[44] Body or matter of any sort, is said to be *specifically* heavier or lighter than other matter, when it has more or less substance or weight in the same dimensions.

[45] As the writer is neither physician nor philosopher, the reader may expect he should justify these his opinions by the authority of some that are so. M. Clare, F. R. S. in his treatise of *The Motion of Fluids*, says, page 246, &c. "And here it may be remarked, that it is more prejudicial to health to sit near a window or door, in

a room where there are many candles and a fire, than in a room without; for the consumption of air thereby occasioned, will always be very considerable, and this must necessarily be replaced by cold air from without. Down the chimney can enter none, the stream of warm air always arising therein absolutely forbids it, the supply must therefore come in wherever other openings shall be found. If these happen to be small, *let those who sit near them beware*; the smaller the floodgate, the smarter will be the stream. Was a man, even in a sweat, to leap into a cold bath, or jump from his warm bed, in the intensest cold, even in a frost, provided he do not continue over-long therein, and be in health when he does this, we see by experience that he gets no harm. If he sits a little while against a window, into which a successive current of cold air comes, his pores are closed, and he gets a fever. In the first case, the shock the body endures, is general, uniform, and therefore less fierce; in the other, a single part, a neck, or ear perchance, is attacked, and that with the greater violence probably, as it is done by a successive stream of cold air. And the cannon of a battery, pointed against a single part of a bastion, will easier make a breach than were they directed to play singly upon the whole face, and will admit the enemy much sooner into the town."

That warm rooms, and keeping the body warm in winter, are means of preventing such diseases, take the opinion of that learned Italian physician Antonino Parcio, in the preface to his tract *de Militis Sanitate tuenda*, where, speaking of a particular wet and cold winter, remarkable at Venice for its sickliness, he says, "Popularis autem pleuritis quæ Venetiis sæviit mensibus *Dec. Jan. Feb.* ex cæli, aërisque inclementia facta est, quod non habeant hypocausta [*stove-rooms*] & quod non soliciti sunt Itali omnes de auribus, temporibus, collo, totoque corpore defendendis ab injuriis aëris; et tegmina domorum Veneti disponant parum inclinata, ut nives diutius permaneant super tegmina. E contra, Germani, qui experiuntur cæli inclementiam, perdidicere sese defendere ab aëris injuria. Tecta construunt multum inclinata, ut decidant nives. Germani abundant lignis, domusque *hypocaustis*; foris autem incedunt pannis pellibus, gossipio, bene mehercule loricati atque muniti. In Bavaria interrogabam (curiositate motus videndi Germaniam) quot nam elapsis mensibus pleuritide vel peripneumonia fuissent absumti: dicebant vix unus aut alter illis temporibus pleuritide fuit correptus."

The great Dr. Boerhaave, whose authority alone might be sufficient, in his *Aphorisms*, mentions, as one antecedent cause of pleurisies, "A cold air, driven violently through some narrow passage upon the body, overheated by labour or fire."

The eastern physicians agree with the Europeans in this point; witness the Chinese treatise entitled, *Tschang seng*; i.e. *The Art of procuring Health and long Life*, as translated in Pere Du Halde's account of China, which has this passage. "As, of all the passions which ruffle us, anger does the most mischief, so of all the malignant affections of the air, a wind that comes through any narrow passage, which is cold and piercing, is most dangerous; and coming upon us unawares insinuates itself into the body, often causing grievous diseases. It should therefore be avoided, according to the advice of the ancient proverb, as carefully as the point of an arrow." These mischiefs are avoided by the use of the new-invented fire-places, as will be shown hereafter.

[46] The shutter is slid up and down in this manner, only in those fire-places which are so made as that the distance between the top of the arched opening, and the bottom plate, is the same as the distance between it and the top plate. Where the arch is higher, as it is in the draught annexed (which is agreeable to the last improvements) the shutter is set by, and applied occasionally; because if it were made deep enough to close the whole opening when slid down, it would hide part of it when up.

[47] My Lord Molesworth, in his account of Denmark, says, "That few or none of the people there are troubled with coughs, catarrhs, consumptions, or such like diseases of the lungs; so that in the midst of winter in the churches, which are very much frequented, there is no noise to interrupt the attention due to the preacher. I am persuaded (says he) their *warm stoves* contribute to their freedom from these kind of maladies." page 91.

[48] People who have used these fire-places, differ much in their accounts of the wood saved by them. Some say five-sixths, others three-fourths, and others much less. This is owing to the great difference there was in their former fires; some (according to the different circumstances of their rooms and chimneys) having been used to make very large, others middling, and others, of a more sparing temper, very small ones: while in these fire-places (their size and draught being nearly the same), the consumption is more equal. I suppose, taking a number of families together, that two-thirds, or half the wood, at least, is saved. My common room, I know, is made thrice as warm as it used to be, with a quarter of the wood I formerly consumed there.

[49] Mr. Boyle, in his experiments and observations upon cold, *Shaw's Abridgement*, Vol. I. p. 684, says, "It is remarkable, that while the cold has strange and tragical effects at Moscow, and elsewhere, the Russians and Livonians should be exempt from them, who accustom themselves to pass immediately from a great degree of heat, to as great an one of cold, without receiving any visible prejudice thereby. I remember being told by a person of unquestionable credit, that it was a common practice among them, to go from a hot stove, into cold water; the same was also affirmed to me by another who resided at Moscow. This tradition is likewise abundantly confirmed by Olearius."—"It is a surprising thing, says he, to see how far the Russians can endure heat; and how, when it makes them ready to faint, they can go out of their stoves, stark naked, both men and women, and throw themselves into cold water; and even in winter wallow in the snow."

[50] See page 240, where the trap-door is described that ought to be in this closing.

TO DR. INGENHAUSZ, PHYSICIAN TO THE EMPEROR, AT VIENNA[51].

On the Causes and Cure of Smoky Chimnies.

At Sea, Aug., 28, 1785.

DEAR FRIEND,

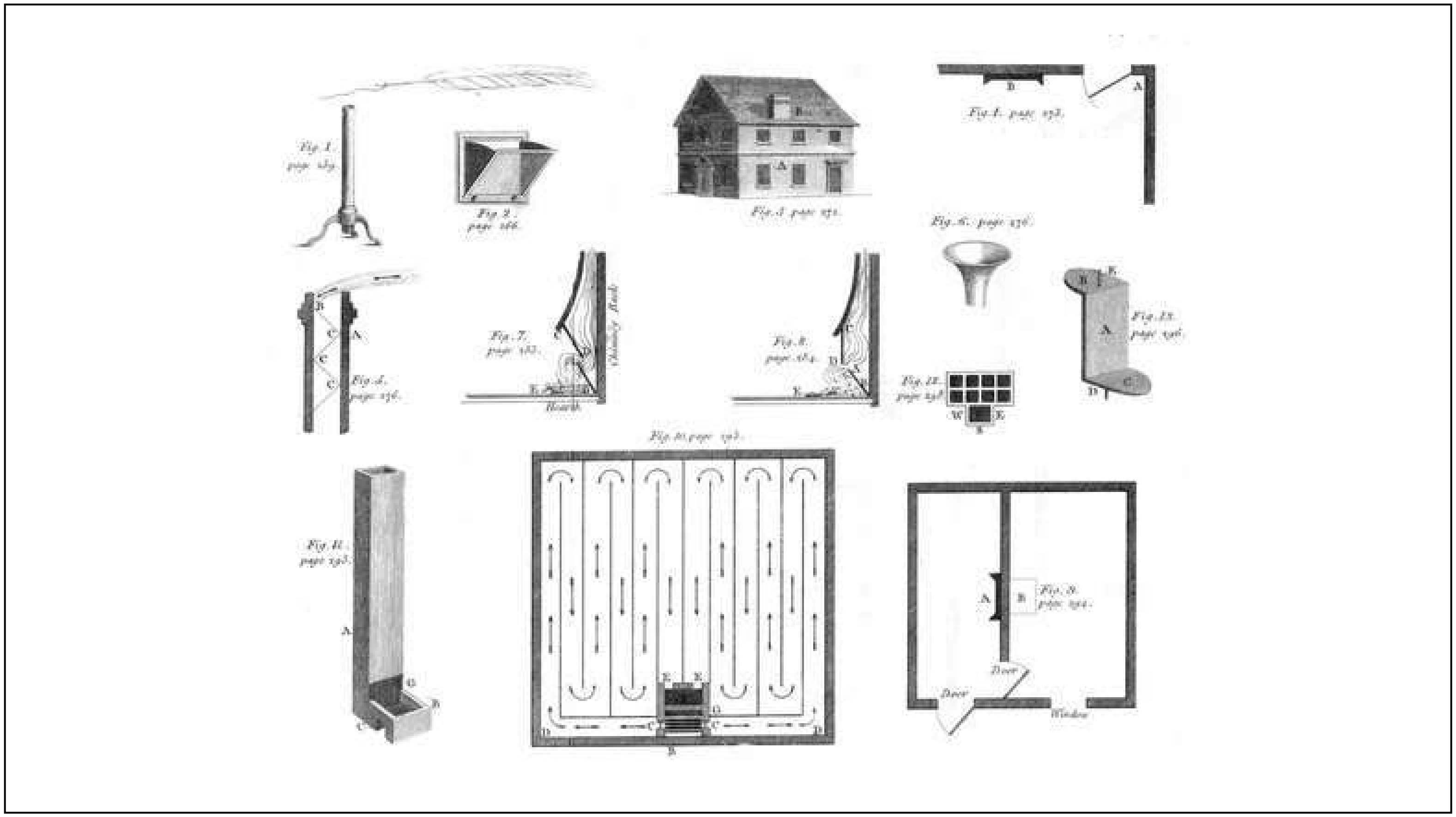
In one of your letters, a little before I left France, you desire me to give you in writing my thoughts upon the construction and use of chimneys, a subject you had sometimes heard me touch upon in conversation. I embrace willingly [257] this leisure afforded by my present situation to comply with your request, as it will not only show my regard to the desires of a friend, but may at the same time be of some utility to others; the doctrine of chimneys appearing not to be as yet generally well understood, and mistakes respecting them being attended with constant inconvenience, if not remedied, and with fruitless expence, if the true remedies are mistaken.

Those who would be acquainted with this subject should begin by considering on what principle smoke ascends in any chimney. At first many are apt to think that smoke is in its nature and of itself specifically lighter than air, and rises in it for the same reason that cork rises in water. These see no case why smoke should not rise in the chimney, though the room be ever so close. Others think there is a power in chimneys to *draw* up the smoke, and that there are different forms of chimneys which afford more or less of this power. These amuse themselves with searching for the best form. The equal dimensions of a funnel in its whole length is not thought artificial enough, and it is made, for fancied reasons, sometimes tapering and narrowing from below upwards, and sometimes the contrary, &c. &c. A simple experiment or two may serve to give more correct ideas. Having lit a pipe of tobacco, plunge the stem to the bottom of a decanter half filled with cold water; then putting a rag over the bowl, blow through it and make the smoke descend in the stem of the pipe, from the end of which it will rise in bubbles through the water; and being thus cooled, will not afterwards rise to go out through the neck of the decanter, but remain spreading itself and resting on the surface of the water. This shows that smoke is really [258] heavier than air, and that it is carried upwards only when attached to, or acted upon, by air that is heated, and thereby rarefied and rendered specifically lighter than the air in its neighbourhood.

Smoke being rarely seen but in company with heated air, and its upward motion being visible, though that of the rarefied air that drives it is not so, has naturally given rise to the error.

I need not explain to you, my learned friend, what is meant by rarefied air; but if you make the public use you propose of this letter, it may fall into the hands of some who are unacquainted with the term and with the thing. These then may be told, that air is a fluid which has weight as well as others, though about eight hundred times lighter than water. That heat makes the particles of air recede from each other and take up more space, so that the same weight of air heated will have more bulk, than equal weights of cold air which may surround it, and in that case must rise, being forced upwards by such colder and heavier air, which presses to get under it and take its place. That air is so rarefied or expanded by heat may be proved to their comprehension, by a lank blown bladder, which, laid before a fire, will soon swell, grow tight and burst.

Plate IX. *Vol. II. page 269.*



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Another experiment may be to take a glass tube about an inch in diameter, and twelve inches long, open at both ends and fixed upright on legs, so that it need not be handled, for the hands might warm it. At the end of a quill fasten five or six inches of the finest light filament of silk, so that it may be held either above the upper end of the tube or under the [259] lower end, your warm hand being at a distance by the length of the quill. (Plate IX. fig. 1.) If there were any motion of air through the tube, it would manifest itself by its effect on the silk; but if the tube and the air in it are of the same temperature with the surrounding air, there will be no such motion, whatever may be the form of the tube, whether crooked or strait, narrow below and widening upwards, or the contrary; the air in it will be quiescent. Warm the tube, and you will find, as long as it continues warm, a constant current of air entering below and passing up through it, till discharged at the top; because the warmth of the tube being communicated to the air it contains rarefies that air and makes it lighter than the air without, which therefore presses in below, forces it upwards, and follows and takes its place, and is rarefied in its turn. And, without warming the tube, if you hold under it a knob of hot iron, the air thereby heated will rise and fill the tube, going out at its top, and this motion in the tube will continue as long as the knob remains hot, because the air entering the tube below is heated and rarefied by passing near and over that knob.

That this motion is produced merely by the difference of specific gravity between the fluid within and that without the tube, and not by any fancied form of the tube itself, may appear by plunging it into water contained in a glass jar a foot deep, through which such motion might be seen. The water within and without the tube being of the same specific gravity, balance each other, and both remain at rest. But take out the tube, stop its bottom with a finger and fill it with olive oil, which is lighter than water, then stopping the top, place it as before, its lower end under water, its top a very little above. [260] As long as you keep the bottom stopt, the fluids remain at rest, but the moment it is unstopt, the heavier enters below, forces up the lighter, and takes its place. And the motion then ceases, merely because the new fluid cannot be successively made lighter, as air may be by a warm tube.

In fact, no form of the funnel of a chimney has any share in its operation or effect respecting smoke, except its height. The longer the funnel, if erect, the greater its force when filled with heated and rarefied air, to *draw* in below and drive up the smoke, if one may, in compliance with custom, use the expression *draw*, when in fact it is the superior weight of the surrounding atmosphere that *presses* to enter the funnel below, and so *drives up* before it the smoke and warm air it meets with in its passage.

I have been the more particular in explaining these first principles, because, for want of clear ideas respecting them, much fruitless expence has been occasioned; not only single chimneys, but in some instances, within my knowledge, whole stacks having been pulled down and rebuilt with funnels of different forms, imagined more powerful in *drawing* smoke; but having still the same height and the same opening below, have performed no better than their predecessors.

What is it then which makes a *smoky chimney*, that is, a chimney which, instead of conveying up all the smoke, discharges a part of it into the room, offending the eyes and damaging the furniture?

The causes of this effect, which have fallen under my observation, amount to *nine*, differing from each other, and therefore requiring different remedies.

1. *Smoky chimneys in a new house, are such, frequently from mere want of air.* The workmanship of the rooms being all [261] good, and just out of the workman's hand, the joints of the boards of the flooring, and of the pannels of wainscotting are all true and tight, the more so as the walls, perhaps not yet thoroughly dry, preserve a dampness in the air of the room which keeps the wood-work swelled and close. The doors and the sashes too, being worked with truth, shut with exactness, so that the room is as tight as a snuff-box, no passage being left open for air to enter, except the key-hole, and even that is sometimes covered by a little dropping shutter. Now if smoke cannot rise but as connected with rarefied air, and a column of such air, suppose it filling the funnel, cannot rise, unless other air be admitted to supply its place; and if, therefore, no current of air enter the opening of the chimney, there is nothing to prevent the smoke coming out into the room. If the motion upwards of the air in a chimney that is freely supplied, be observed by the rising of the smoke or a feather in it, and it be considered that in the time such feather takes in rising from the fire to the top of the chimney, a column of air equal to the content of the funnel must be discharged, and an equal quantity supplied from the room below, it will appear absolutely impossible that this operation should go on if the tight room is kept shut; for were there any force capable of drawing constantly so much air out of it, it must soon be exhausted like the receiver of an air-pump, and no

animal could live in it. Those therefore who stop every crevice in a room to prevent the admission of fresh air, and yet would have their chimney carry up the smoke, require inconsistencies, and expect impossibilities. Yet under this situation, [262] I have seen the owner of a new house, in despair, and ready to sell it for much less than it cost, conceiving it uninhabitable, because not a chimney in any one of its rooms would carry off the smoke, unless a door or window were left open. Much expence has also been made, to alter and amend new chimneys which had really no fault; in one house particularly that I knew, of a nobleman in Westminster, that expence amounted to no less than three hundred pounds, *after* his house had been, as he thought, finished and all charges paid. And after all, several of the alterations were ineffectual, for want of understanding the true principles.

Remedies. When you find on trial, that opening the door or a window, enables the chimney to carry up all the smoke, you may be sure that want of air *from without*, was the cause of its smoking. I say *from without*, to guard you against a common mistake of those who may tell you, the room is large, contains abundance of air, sufficient to supply any chimney, and therefore it cannot be that the chimney wants air. These reasoners are ignorant, that the largeness of a room, if tight, is in this case of small importance, since it cannot part with a chimney full of its air without occasioning so much vacuum; which it requires a great force to effect, and could not be borne if effected.

It appearing plainly, then, that some of the outward air must be admitted, the question will be, how much is *absolutely necessary*; for you would avoid admitting more, as being contrary to one of your intentions in having a fire, viz. that of warming your room. To discover this quantity, shut the door gradually while a middling fire is burning, till you find that, [263] before it is quite shut, the smoke begins to come out into the room, then open it a little till you perceive the smoke comes out no longer. There hold the door, and observe the width of the open crevice between the edge of the door and the rabbit it should shut into. Suppose the distance to be half an inch, and the door eight feet high, you find thence that your room requires an entrance for air equal in area to ninety-six half inches, or forty-eight square inches, or a passage of six inches by eight. This however is a large supposition, there being few chimneys, that, having a moderate opening and a tolerable height of funnel, will not be satisfied with such a crevice of a quarter of an inch; and I have found a square of six by six, or thirty-six square inches, to be a pretty good medium, that will serve for most chimneys. High funnels, with small and low openings, may indeed be supplied thro' a less space, because, for reasons that will appear hereafter, the *force of levity*, if one may so speak, being greater in such funnels, the cool air enters the room with greater velocity, and consequently more enters in the same time. This however has its limits; for experience shows, that no increased velocity, so occasioned, has made the admission of air through the key-hole equal in quantity to that through an open door; though through the door the current moves slowly, and through the key-hole with great rapidity.

It remains then to be considered how and where this necessary quantity of air from without is to be admitted so as to be least inconvenient. For if at the door, left so much open, the air thence proceeds directly to the chimney, and in its way [264] comes cold to your back and heels as you sit before your fire. If you keep the door shut, and raise a little the sash of your window, you feel the same inconvenience. Various have been the contrivances to avoid this, such as bringing in fresh air through pipes in the jams of the chimney, which, pointing upwards, should blow the smoke up the funnel; opening passages into the funnel above, to let in air for the same purpose. But these produce an effect contrary to that intended: for as it is the constant current of air passing from the room *through the opening of the chimney* into the funnel which prevents the smoke coming out into the room, if you supply the funnel by other means or in other ways with the air it wants, and especially if that air be cold, you diminish the force of that current, and the smoke in its effort to enter the room finds less resistance.

The wanted air must then *indispensably* be admitted into the room, to supply what goes off through the opening of the chimney. M. Gauger, a very ingenious and intelligent French writer on the subject, proposes with judgment to admit it *above* the opening of the chimney; and to prevent inconvenience from its coldness, he directs its being made to pass in its entrance through winding cavities made behind the iron back and sides of the fire-place, and under the iron hearth-plate; in which cavities it will be warmed, and even heated, so as to contribute much, instead of cooling, to the warming of the room. This invention is excellent in itself, and may be used with advantage in building new houses; because the chimneys may then be so disposed, as to admit conveniently the cold air to enter such passages: but in houses built without such views, the chimneys are often so situated, as not to afford that convenience, without great and expensive alterations. Easy [265] and cheap methods, though not quite so perfect in themselves, are of more general utility; and such are the following.

In all rooms where there is a fire, the body of air warmed and rarefied before the chimney is continually changing place, and making room for other air that is to be warmed in its turn. Part of it enters and goes up the chimney, and the rest rises and takes place near the ceiling. If the room be lofty, that warm air remains above our heads as long as it continues warm, and we are little benefited by it, because it does not descend till it is cooler. Few can imagine the difference of climate between the upper and lower parts of such a room, who have not tried it by the thermometer, or by going up a ladder till their heads are near the ceiling. It is then among this warm air that the wanted quantity of outward air is best admitted, with which being mixed, its coldness is abated, and its inconvenience diminished so as to become scarce observable. This may be easily done, by drawing down about an inch the upper sash of a window; or, if not moveable, by cutting such a crevice through its frame; in both which cases, it will be well to place a thin shelf of the length, to conceal the opening, and sloping upwards to direct the entering air horizontally along and under the ceiling. In some houses the air may be admitted by such a crevice made in the wainscot, cornish or plastering, near the ceiling and over the opening of the chimney. This, if practicable, is to be chosen, because the entering cold air will there meet with the warmest rising air from before the fire, and be soonest tempered by the mixture. The same kind of shelf should also be [266] placed here. Another way, and not a very difficult one, is to take out an upper pane of glass in one of your sashes, set in a tin frame, (Plate, Fig. 2.) giving it two springing angular sides, and then replacing it, with hinges below on which it may be turned to open more or less above. It will then have the appearance of an internal sky light. By drawing this pane in, more or less, you may admit what air you find necessary. Its position will naturally throw that air up and along the ceiling. This is what is called in France a *Was ist das?* As this is a German question, the invention is probably of that nation, and takes its name from the frequent asking of that question when it first appeared. In England, some have of late years cut a round hole about five inches diameter in a pane of the sash and placed against it a circular plate of tin hung on an axis, and cut into vanes, which, being separately bent a little obliquely, are acted upon by the entering air, so as to force the plate continually round like the vanes of a windmill. This admits the outward air, and by the continual whirling of the vanes, does in some degree disperse it. The noise only, is a little inconvenient.

2. A second cause of the smoking of chimneys is, *their openings in the room being too large*; that is, too wide, too high, or both. Architects in general have no other ideas of proportion in the opening of a chimney, than what relate to symmetry and beauty, respecting the dimensions of the room;[52] while its true proportion, respecting its function and utility depends on quite other principles; and they might as properly proportion the step in a stair-case to the height of the story, instead of [267] the natural elevation of men's legs in mounting. The proportion then to be regarded, is what relates to the height of the funnel. For as the funnels in the different stories of a house are necessarily of different heights or lengths, that from the lowest floor being the highest or longest, and those of the other floors shorter and shorter, till we come to those in the garrets, which are of course the shortest; and the force of draft being, as already said, in proportion to the height of funnel

filled with rarefied air; and a current of air from the room into the chimney, sufficient to fill the opening, being necessary to oppose and prevent the smoke coming out into the room; it follows, that the openings of the longest funnels may be larger, and that those of the shorter funnels should be smaller. For if there be a large opening to a chimney that does not draw strongly, the funnel may happen to be furnished with the air it demands by a partial current entering on one side of the opening, and, leaving the other side free of any opposing current, may permit the smoke to issue there into the room. Much too of the force of draft in a funnel depends on the degree of rarefaction in the air it contains, and that depends on the nearness to the fire of its passage in entering the funnel. If it can enter far from the fire on each side, or far above the fire in a wide or high opening, it receives little heat in passing by the fire, and the contents of the funnel is by that means less different in levity from the surrounding atmosphere, and its force in drawing consequently weaker. Hence if too large an opening be given to chimneys in upper rooms, those rooms will be smoky: on the other hand, if too small openings be given to chimneys in the lower rooms, the entering air, operating too directly and violently on the fire, and afterwards [268]
strengthening the draft as it ascends the funnel, will consume the fuel too rapidly.

Remedy. As different circumstances frequently mix themselves in these matters, it is difficult to give precise dimensions for the openings of all chimneys. Our fathers made them generally much too large; we have lessened them; but they are often still of greater dimension than they should be, the human eye not being easily reconciled to sudden and great changes. If you suspect that your chimney smokes from the too great dimension of its opening, contract it by placing moveable boards so as to lower and narrow it gradually, till you find the smoke no longer issues into the room. The proportion so found will be that which is proper for that chimney, and you may employ the bricklayer or mason to reduce it accordingly. However, as, in building new houses, something must be sometimes hazarded, I would make the openings in my lower rooms about thirty inches square and eighteen deep, and those in the upper, only eighteen inches square and not quite so deep; the intermediate ones diminishing in proportion as the height of funnel diminished. In the larger openings, billets of two feet long, or half the common length of cordwood, may be burnt conveniently; and for the smaller, such wood may be sawed into thirds. Where coals are the fuel, the grates will be proportioned to the openings. The same depth is nearly necessary to all, the funnels being all made of a size proper to admit a chimney-sweeper. If in large and elegant rooms custom or fancy should require the appearance of a larger chimney, it may be formed of [269]
expensive marginal decorations, in marble, &c. In time perhaps, that which is fittest in the nature of things may come to be thought handsomest. But at present, when men and women in different countries show themselves dissatisfied with the forms God has given to their heads, waists and feet, and pretend to shape them more perfectly, it is hardly to be expected that they will be content always with the best form of a chimney. And there are some, I know, so bigotted to the fancy of a large noble opening, that rather than change it, they would submit to have damaged furniture, sore eyes, and skins almost smoked to bacon.

3. Another cause of smoky chimneys is, *too short a funnel*. This happens necessarily in some cases, as where a chimney is required in a low building; for, if the funnel be raised high above the roof, in order to strengthen its draft, it is then in danger of being blown down, and crushing the roof in its fall.

Remedies. Contract the opening of the chimney, so as to oblige all the entering air to pass through or very near the fire; whereby it will be more heated and rarefied, the funnel itself be more warmed, and its contents have more of what may be called the force of levity, so as to rise strongly and maintain a good draft at the opening.

Or you may in some cases, to advantage, build additional stories over the low building, which will support a high funnel.

If the low building be used as a kitchen, and a contraction of the opening therefore inconvenient, a large one being necessary, at least when there are great dinners, for the free management of so many cooking utensils; in such case, I would advise the building of two more funnels joining to the first, and having three moderate openings, one to each [270]
funnel, instead of one large one. When there is occasion to use but one, the other two may be kept shut by sliding plates, hereafter to be described;[53] and two or all of them may be used together when wanted. This will indeed be an expence, but not an useless one, since your cooks will work with more comfort, see better than in a smoky kitchen what they are about, your victuals will be cleaner dressed, and not taste of smoke, as is often the case; and to render the effect more certain, a stack of three funnels may be safely built higher above the roof than a single funnel.

The case of too short a funnel is more general than would be imagined, and often found where one would not expect it. For it is not uncommon, in ill-contrived buildings, instead of having a funnel for each room or fire-place, to bend and turn the funnel of an upper room so as to make it enter the side of another funnel that comes from below. By this means the upper room funnel is made short of course, since its length can only be reckoned from the place where it enters the lower room funnel; and that funnel is also shortened by all the distance between the entrance of the second funnel and the top of the stack: for all that part being readily supplied with air through the second funnel, adds no strength to the draught, especially as that air is cold when there is no fire in the second chimney. The only easy remedy here is, to keep the opening shut of that funnel in which there is no fire.

4. Another very common cause of the smoking of

chimneys, is, *their overpowering one another*. For instance, if there be two chimneys in one large room, and you make [271]
fires in both of them, the doors and windows close shut, you will find that the greater and stronger fire shall overpower the weaker, and draw air down its funnel to supply its own demand; which air descending in the weaker funnel will drive down its smoke, and force it into the room. If, instead of being in one room, the two chimneys are in two different rooms, communicating by a door, the case is the same whenever that door is open. In a very tight house, I have known a kitchen chimney on the lowest floor, when it had a great fire in, it, overpower any other chimney in the house, and draw air and smoke into its room, as often as the door was opened communicating with the stair-case.

Remedy. Take care that every room has the means of supplying itself from without, with the air its chimney may require, so that no one of them may be obliged to borrow from another, nor under the necessity of lending. A variety of these means have been already described.

5. Another cause of smoking is, *when the tops of chimneys are commanded by higher buildings, or by a hill*, so that the wind blowing over such eminences falls like water over a dam, sometimes almost perpendicularly on the tops of the chimneys that lie in its way, and beats down the smoke contained in them.

Remedy. That commonly applied to this case, is a turncap made of tin or plate iron, covering the chimney above and on three sides, open on one side, turning on a spindle, and which, being guided or governed by a vane, always presents its back to the current. This I believe may be generally effectual, though not certain, as there may be cases in which it will [272]
not succeed. Raising your funnels, if practicable, so as their tops may be higher, or at least equal with the commanding eminence, is more to be depended on. But the turning cap, being easier and cheaper, should first be tried. If obliged to build in such a situation, I would chuse to place my doors on the side next the hill, and the backs of my chimneys on the furthest side; for then the column of air falling over the eminence, and of course pressing on that below and forcing it to

enter the doors or *Was ist das*es on that side, would tend to balance the pressure down the chimneys, and leave the funnels more free in the exercise of their functions.

6. There is another case of command, the reverse of that last mentioned. It is where the commanding eminence is farther from the wind than the chimney commanded. To explain this a figure may be necessary. Suppose then a building whose side A happens to be exposed to the wind, and forms a kind of dam against its progress. (Plate, Figure 3.) The air obstructed by this dam will, like water, press and search for passages through it; and finding the top of the chimney B, below the top of the dam, it will force itself down that funnel, in order to get through by some door or window open on the other side of the building. And if there be a fire in such chimney, its smoke is of course beat down, and fills the room.

Remedy. I know of but one, which is to raise such funnel higher than the roof, supporting it, if necessary by iron bars. For a turn-cap in this case has no effect, the dammed up air pressing down through it in whatever position the wind may have placed its opening.

I know a city in which many houses are rendered smoky by this operation. For their kitchens being built behind, and connected by a passage with the houses, and the tops of the kitchen chimneys lower than the top of the houses, the whole side of a street, when the wind blows against its back, forms such a dam, as above described; and the wind, so obstructed, forces down those kitchen chimneys (especially when they have but weak fires in them) to pass through the passage and house into the street. Kitchen chimneys, so formed and situated, have another inconvenience. In summer, if you open your upper room windows for air, a light breeze blowing over your kitchen chimney towards the house, though not strong enough to force down its smoke as aforesaid, is sufficient to waft it into your windows, and fill the rooms with it; which, besides the disagreeableness, damages your furniture. [273]

7. Chimneys, otherwise drawing well, are sometimes made to smoke by *the improper and inconvenient situation of a door*. When the door and chimney are on the same side of the room as in the figure, if the door A, being in the corner, is made to open against the wall (Plate, Figure 4) which is common, as being there, when open, more out of the way, it follows, that when the door is only opened in part, a current of air rushing in passes along the wall into and across the opening of the chimney B, and flirts some of the smoke out into the room. This happens more certainly when the door is shutting, for then the force of the current is augmented, and becomes very inconvenient to those who, warming themselves by the fire, happen to sit in its way.

The *remedies* are obvious and easy. Either put an intervening skreen from the wall round great part of the fire-place; or, which is perhaps preferable, shift the hinges of your door, so as it may open the other way, and when open throw the air along the other wall. [274]

8. A room, that has no fire in its chimney, is sometimes filled with *smoke which is received at the top of its funnel and descends into the room*. In a former paper[54] I have already explained the descending currents of air in cold funnels; it may not be amiss however to repeat here, that funnels without fires have an effect, according to their degree of coldness or warmth, on the air that happens to be contained in them. The surrounding atmosphere is frequently changing its temperature; but stacks of funnels, covered from winds and sun by the house that contains them, retain a more equal temperature. If, after a warm season, the outward air suddenly grows cold, the empty warm funnels begin to draw strongly upward; that is, they rarefy the air contained in them, which of course rises, cooler air enters below to supply its place, is rarefied in its turn and rises; and this operation continues till the funnel grows cooler, or the outward air warmer, or both, when the motion ceases. On the other hand, if after a cold season, the outward air suddenly grows warm and of course

lighter, the air contained in the cool funnels, being heavier, descends into the room; and the warmer air which enters their tops being cooled in its turn, and made heavier, continues to descend; and this operation goes on, till the funnels are warmed by the passing of warm air through them, or the air itself grows cooler. When the temperature of the air and of the funnels is nearly equal, the difference of warmth in the air between day and night is sufficient to produce these currents, [275] the air will begin to ascend the funnels as the cool of the evening comes on, and this current will continue till perhaps nine or ten o'clock the next morning, when it begins to hesitate; and as the heat of the day approaches, it sets downwards, and continues so till towards evening, when it again hesitates for some time, and then goes upwards constantly during the night, as before mentioned. Now when smoke issuing from the tops of neighbouring funnels passes over the tops of funnels which are at the time drawing downwards, as they often are in the middle part of the day, such smoke is of necessity drawn into these funnels, and descends with the air into the chamber.

The *remedy* is to have a sliding plate, hereafter described[55], that will shut perfectly the offending funnel.

9. Chimneys which generally draw well, do nevertheless sometimes give smoke into the rooms, *it being driven down by strong winds passing over the tops of their funnels*, though not descending from any commanding eminence. This case is most frequent where the funnel is short, and the opening turned from the wind. It is the more grievous, when it happens to be a cold wind that produces the effect, because when you most want your fire, you are sometimes obliged to extinguish it. To understand this, it may be considered that the rising light air, to obtain a free issue from the funnel, must push out of its way or oblige the air that is over it to rise. In a time of calm or of little wind this is done visibly, for we see the smoke [276] that is brought up by that air rise in a column above the chimney. But when a violent current of air, that is, a strong wind, passes over the top of a chimney, its particles have received so much force, which keeps them in a horizontal direction and follow each other so rapidly, that the rising light air has not strength sufficient to oblige them to quit that direction and move upwards to permit its issue. Add to this, that some of the current passing over that side of the funnel which it first meets with, viz. at A, (Plate IX. Figure 5.) having been compressed by the resistance of the funnel, may expand itself over the flue, and strike the interior opposite side at B, from whence it may be reflected downwards and from side to side in the direction of the pricked lines c c c.

Remedies. In some places, particularly in Venice, where they have not stacks of chimneys but single flues, the custom is, to open or widen the top of the flue rounding in the true form of a funnel; (Plate, Figure 6) which some think may prevent the effect just mentioned, for that the wind blowing over one of the edges into the funnel may be slanted out again on the other side by its form. I have had no experience of this; but I have lived in a windy country, where the contrary is practised, the tops of the flues being *narrowed* inwards, so as to form a slit for the issue of the smoke, long as the breadth of the funnel, and only four inches wide. This seems to have been contrived on a supposition, that the entry of the wind would thereby be obstructed, and perhaps it might have been imagined, that the whole force of the rising warm air being condensed, as it were, in the narrow opening, would thereby be strengthened, so as to overcome the resistance of the [277] wind. This however did not always succeed; for when the wind was at north-east and blew fresh, the smoke was forced down by fits into the room I commonly sat in, so as to oblige me to shift the fire into another. The position of the slit of this funnel was indeed north-east and south-west. Perhaps if it had lain across the wind, the effect might have been different. But on this I can give no certainty. It seems a matter proper to be referred to experiment. Possibly a turn-cap might have been serviceable, but it was not tried.

Chimneys have not been long in use in England. I formerly saw a book printed in the time of queen Elizabeth, which remarked the then modern improvements of living, and mentioned among others the convenience of chimneys. "Our forefathers," said the author, "had no chimneys. There was in each dwelling house only one place for a fire, and the smoke went out through a hole in the roof; but now there is scarce a gentleman's house in England that has not at least one chimney in it."—When there was but one chimney, its top might then be opened as a funnel, and perhaps, borrowing the form from the Venetians, it was then the flue of a chimney got that name. Such is now the growth of luxury, that in both England and France we must have a chimney for every room, and in some houses every possessor of a chamber, and almost every servant, will have a fire; so that the flues being necessarily built in stacks, the opening of each as a funnel is impracticable. This change of manners soon consumed the firewood of England, and will soon render fuel extremely [278] scarce and dear in France, if the use of coals be not introduced in the latter kingdom as it has been in the former, where it at first met with opposition; for there is extant in the records of one of queen Elizabeth's parliaments, a motion made by a member, reciting, "That many dyers, brewers, smiths, and other artificers of London, had of late taken to the use of pit-coal for their fires, instead of wood, which filled the air with noxious vapours and smoke, very prejudicial to the health, particularly of persons coming out of the country; and therefore moving that a law might pass to prohibit the use of such fuel (at least during the session of parliament) by those artificers."—It seems it was not then commonly used in private houses. Its supposed unwholesomeness was an objection. Luckily the inhabitants of London have got over that objection, and now think it rather contributes to render their air salubrious, as they have had no general pestilential disorder since the general use of coals, when, before it, such were frequent. Paris still burns wood at an enormous expence continually augmenting, the inhabitants having still that prejudice to overcome. In Germany you are happy in the use of stoves, which save fuel wonderfully: your people are very ingenious in the management of fire; but they may still learn something in that art from the Chinese[56], whose country being greatly populous and fully cultivated, has little room left for the growth of wood, and having not much other fuel that is good, have been forced upon many inventions during a course of ages, for making a little fire go as far as possible.

I have thus gone through all the common causes of the smoking of chimneys that I can at present recollect as having [279] fallen under my observation; communicating the remedies that I have known successfully used for the different cases, together with the principles on which both the disease and the remedy depend, and confessing my ignorance wherever I have been sensible of it. You will do well, if you publish, as you propose, this letter, to add in notes, or as you please, such observations as may have occurred to your attentive mind; and if other philosophers will do the same, this part of science, though humble, yet of great utility, may in time be perfected. For many years past, I have rarely met with a case of a smoky chimney, which has not been solvable on these principles, and cured by these remedies, where people have been willing to apply them; which is indeed not always the case; for many have prejudices in favour of the nostrums of pretending chimney-doctors and fumists, and some have conceits and fancies of their own, which they rather chuse to try, than to lengthen a funnel, alter the size of an opening, or admit air into a room, however necessary; for some are as much afraid of fresh air as persons in the hydrophobia are of fresh water. I myself had formerly this prejudice, this *aerophobia*, as I now account it, and dreading the supposed dangerous effects of cool air, I considered it as an enemy, and closed with extreme care every crevice in the rooms I inhabited. Experience has convinced me of my error. I now look upon fresh air as a friend: I even sleep with an open window. I am persuaded that no common air from without, is so unwholesome as the air within a close room that has been often breathed and not changed. Moist air too, which formerly I thought [280] pernicious, gives me now no apprehensions: for considering that no dampness of air applied to the outside of my skin can be equal to what is applied to and touches it within, my whole body being full of moisture, and finding that I can lie two hours in a bath twice a week, covered with water, which certainly is much damper than any air can be, and this for years together, without catching cold, or being in any other manner disordered by it, I no longer dread mere moisture, either in air or in sheets or shirts: and I find it of importance to the happiness of life, the being freed from vain terrors, especially of objects that we are every day exposed inevitably to meet with. You physicians have of late happily discovered, after a contrary opinion had prevailed some ages, that fresh and cool air does good to persons in the small pox and other fevers. It is to be hoped, that in another century or two we may all find out, that it is not bad even for people in health. And as to moist air, here I am at this present writing in a ship with above forty persons, who have had no other but moist air to breathe for six weeks past; every thing we touch is damp, and nothing dries, yet we are all as healthy as we should be on the mountains of Switzerland, whose inhabitants are not more so than those of Bermuda or St. Helena, islands on whose rocks the waves are dashed into millions of particles, which fill the air with damp, but produce no diseases, the moisture being pure, unmixed with the poisonous vapours arising from putrid marshes and stagnant pools, in which many insects die and corrupt the water. These places only, in my opinion (which however I submit to yours) afford unwholesome air; and that it is not the mere water contained in damp air, but the volatile particles of corrupted animal matter mixed with [281] that water, which renders such air pernicious to those who breathe it. And I imagine it a cause of the same kind that renders the air in close rooms, where the perspirable matter is breathed over and over again by a number of assembled, people so hurtful to health. After being in such a situation, many find themselves affected by that *febricula*, which the English alone call a *cold*, and, perhaps from the name, imagine that they caught the malady by *going out* of the room, when it was in fact by being in it.

You begin to think that I wander from my subject, and go out of my depth. So I return again to my chimneys.

We have of late many lecturers in experimental philosophy. I have wished that some of them would study this branch of that science, and give experiments in it as a part of their lectures. The addition to their present apparatus need not be very expensive. A number of little representations of rooms composed each of five panes of sash glass, framed in wood at the corners, with proportionable doors, and moveable glass chimneys, with openings of different sizes, and different lengths of funnel, and some of the rooms so contrived as to communicate on occasion with others, so as to form different combinations, and exemplify different cases; with quantities of green wax taper cut into pieces of an inch and half, sixteen of which stuck together in a square, and lit, would make a strong fire for a little glass chimney, and blown out would continue to burn and give smoke as long as desired. With such an apparatus all the operations of smoke and rarified air in rooms and chimneys might be seen through their transparent sides; and the effect of winds on chimneys, commanded or [282] otherwise, might be shown, by letting the entering air blow upon them through an opened window of the lecturer's chamber, where it would be constant while he kept a good fire in his chimney. By the help of such lectures our fumists would become better instructed. At present they have generally but one remedy, which perhaps they have known effectual in some one case of smoky chimneys, and they apply that indiscriminately to all the other cases, without success,—but not without expence to their employers.

With all the science, however, that a man shall suppose himself possessed of in this article, he may sometimes meet with cases that shall puzzle him. I once lodged in a house at London, which, in a little room, had a single chimney and funnel. The opening was very small, yet it did not keep in the smoke, and all attempts to have a fire in this room were fruitless. I could not imagine the reason, till at length observing that the chamber over it, which had no fire-place in it, was always filled with smoke when a fire was kindled below and that the smoke came through the cracks and crevices of the wainscot; I had the wainscot taken down, and discovered that the funnel, which went up behind it, had a crack many feet in length, and wide enough to admit my arm, a breach very dangerous with regard to fire, and occasioned probably by an apparent irregular settling of one side of the house. The air entering this breach freely, destroyed the drawing force of the funnel. The remedy would have been, filling up the breach or rather rebuilding the funnel: but the landlord rather chose to stop up the chimney.

Another puzzling case I met with at a friend's country house near London. His best room had a chimney in which, he told me, he never could have a fire, for all the smoke came out into the room. I flattered myself I could easily find the cause, and prescribe the cure. I had a fire made there, and found it as he said. I opened the door, and perceived it was not want of air. I made a temporary contraction of the opening of the chimney, and found that it was not its being too large that caused the smoke to issue. I went out and looked up at the top of the chimney: its funnel was joined in the same stack with others, some of them shorter, that drew very well, and I saw nothing to prevent its doing the same. In fine, after every other examination I could think of, I was obliged to own the insufficiency of my skill. But my friend, who made no pretension to such kind of knowledge, afterwards discovered the cause himself. He got to the top of the funnel by a ladder, and looking down, found it filled with twigs and straw cemented by earth, and lined with feathers. It seems the house, after being built, had stood empty some years before he occupied it; and he concluded that some large birds had taken the advantage of its retired situation to make their nest there. The rubbish, considerable in quantity, being removed, and the funnel cleared, the chimney drew well, and gave satisfaction. [283]

In general smoke is a very tractable thing, easily governed and directed when one knows the principles, and is well informed of the circumstances. You know I made it *descend* in my Pensylvania stove. I formerly had a more simple construction, in which the same effect was produced, but visible to the eye (Plate, Figure 7). It was composed of two plates A B and C D, placed as in the figure. The lower plate A B rested with its edge in the angle made by the hearth with the back of the chimney. The upper plate was fixed to the breast, and lapped over the lower about six inches wide and the length of the plates (near two feet) between them. Every other passage of air into the funnel was well stopped. When therefore a fire was made at E, for the first time with charcoal, till the air in the funnel was a little heated through the plates, and then wood laid on, the smoke would rise to A, turn over the edge of that plate, descend to D, then turn under the edge of the upper plate, and go up the chimney. It was pretty to see, but of no great use. Placing therefore the under plate in a higher situation, I removed the upper plate C D, and placed it perpendicularly (Plate, Figure 8) so that the upper edge of the lower plate A B came within about three inches of it, and might be pushed farther from it, or suffered to come nearer to it, by a moveable wedge between them. The flame then ascending from the fire at E, was, carried to strike the upper plate, made it very hot, and its heat rose and spread with the rarefied air into the room. [284]

I believe you have seen in use with me, the contrivance of a sliding-plate over the fire, seemingly placed to oppose the rising of the smoke, leaving but a small passage for it, between the edge of the plate and the back of the chimney. It is particularly described, and its uses explained, in my former printed letter, and I mention it here only as another instance of the tractability of smoke[57].

What is called the Staffordshire chimney, (see the Plate, facing page 238) affords an example of the same kind. The opening of the chimney is bricked up, even with the fore-edge of its jams, leaving open only a passage over the grate of the same width, and perhaps eight inches high. The grate consists of semicircular bars, their upper bar of the greatest diameter, the others under it smaller and smaller, so that it has the appearance of half a round basket. It is, with the coals it contains, wholly without the wall that shuts up the chimney, yet the smoke bends and enters the passage above it, the draft being strong, because no air can enter that is not obliged to pass near or through the fire, so that all that the funnel is filled with is much heated, and of course much rarefied. [285]

Much more of the prosperity of a winter country depends on the plenty and cheapness of fuel, than is generally imagined. In travelling I have observed, that in those parts where the inhabitants can have neither wood nor coal nor turf but at excessive prices, the working people live in miserable hovels, are ragged, and have nothing comfortable about them. But when fuel is cheap (or where they have the art of managing it to advantage) they are well furnished with necessaries, and have decent habitations. The obvious reason is, that the working hours of such people are the profitable hours, and they who cannot afford sufficient fuel have fewer such hours in the twenty four, than those who have it cheap and plenty: for much of the domestic work of poor women, such as spinning, sewing, knitting; and of the men in those manufactures that require little bodily exercise, cannot well be performed where the fingers are numbed with cold, those people, therefore, in cold weather, are induced to go to bed sooner, and lie longer in a morning, than they would do if they [286] could have good fires or warm stoves to sit by; and their hours of work are not sufficient to produce the means of comfortable subsistence. Those public works, therefore, such as roads, canals, &c. by which fuel may be brought cheap into such countries from distant places, are of great utility; and those who promote them may be reckoned among the benefactors of mankind.

I have great pleasure in having thus complied with your request, and in the reflection, that the friendship you honour me with, and in which I have ever been so happy, has continued so many years without the smallest interruption. Our distance from each other is now augmented, and nature must soon put an end to the possibility of my continuing our correspondence: but if consciousness and memory remain in a future state, my esteem and respect for you, my dear friend, will be everlasting.

B. FRANKLIN.

Notes for the Letter upon Chimneys.

No. I.

The latest work on architecture that I have seen, is that entitled *Nutshells*, which appears to be written by a very ingenious man, and contains a table of the proportions of the openings of chimneys; but they relate solely to the proportions he gives his rooms, without the smallest regard to the funnels. And he remarks, respecting those proportions, that they are similar to the harmonic divisions of a monochord.[58] He does not indeed lay much stress on this; but it [287] shows that we like the appearance of principles; and where we have not true ones, we have some satisfaction in producing such as are imaginary.

No. II.

The description of the sliding plates here promised, and which hath been since brought into use under various names, with some immaterial changes, is contained in a former letter to J. B. Esq. as follows:

TO J. B.[59] ESQ. AT BOSTON, IN NEW-ENGLAND.

London, Dec. 2, 1758,

Dear Sir,

I have executed here an easy simple contrivance, that I have long since had in speculation, for keeping rooms warmer in cold weather than they generally are, and with less fire. It is this. The opening of the chimney is contracted, by brick-work faced with marble slabs, to about two feet between the jams, and the breast brought down to within about three feet of the hearth. An iron frame is placed just under the breast, and extending quite to the back of the chimney, so that a plate [288] of the same metal may slide horizontally backwards and forwards in the grooves on each side of the frame. This plate is just so large as to fill the whole space, and shut the chimney entirely when thrust quite in, which is convenient when there is no fire. Drawing it out, so as to leave a space between its further edge and the back, of about two inches; this space is sufficient for the smoke to pass; and so large a part of the funnel being stopt by the rest of the plate, the passage of warm air out of the room, up the chimney, is obstructed and retarded, and by that means much cold air is prevented from coming in through crevices, to supply its place. This effect is made manifest three ways. First, when the fire burns briskly in cold weather, the howling or whistling noise made by the wind, as it enters the room through the crevices, when the chimney is open as usual, ceases as soon as the plate is slid in to its proper distance. Secondly, opening the door of the room about half an inch, and holding your hand against the opening, near the top of the door, you feel the cold air coming in against your hand, but weakly, if the plate be in. Let another person suddenly draw it out, so as to let the air of the room go up the chimney, with its usual freedom where chimneys are open, and you immediately feel the cold air rushing in strongly. Thirdly, if something be set against the door, just sufficient, when the plate is in, to keep the door nearly shut, by resisting the pressure of the air that would force it open: then, when the plate is drawn out, the door will be forced open by the increased pressure of the outward cold air endeavouring to get in to supply the place of the warm air, that now passes out of the room to go up the chimney. In our common open chimneys, half the fuel is wasted, and its effect lost; the air it has [289] warmed being immediately drawn off. Several of my acquaintance, having seen this simple machine in my room, have imitated it at their own houses, and it seems likely to become pretty common. I describe it thus particularly to you, because I think it would be useful in Boston, where firing is often dear.

Mentioning chimneys puts me in mind of a property I formerly had occasion to observe in them, which I have not found taken notice of by others; it is, that in the summer time, when no fire is made in the chimneys, there is, nevertheless, a regular draft of air through them, continually passing upwards, from about five or six o'clock in the afternoon, till eight or nine o'clock the next morning, when the current begins to slacken and hesitate a little, for about half an hour, and then sets as strongly down again, which it continues to do till towards five in the afternoon, then slackens and hesitates as before, going sometimes a little up, then a little down, till, in about a half an hour, it gets into a steady upward current for the night, which continues till eight or nine the next day; the hours varying a little as the days lengthen and shorten, and sometimes varying from sudden changes in the weather; as if, after being long warm, it should begin to grow cool about noon, while the air was coming down the chimney, the current will then change earlier than the usual hour, &c.

This property in chimneys I imagine we might turn to some account, and render improper, for the future, the old saying, *as useless as a chimney in summer*. If the opening of the chimney, from the breast down to the hearth, be closed by a slight moveable frame or two, in the manner of doors, covered with canvas, that will let the air through, but keep out the [290] flies; and another little frame set within upon the hearth, with hooks on which to hang joints of meat, fowls, &c. wrapt well in wet linen cloths, three or four fold, I am confident, that if the linen is kept wet, by sprinkling it once a day, the meat would be so cooled by the evaporation, carried on continually by means of the passing air, that it would keep a week or more in the hottest weather. Butter and milk might likewise be kept cool, in vessels or bottles covered with wet cloths.

A shallow tray, or keeler, should be under the frame to receive any water that might drip from the wetted cloths. I think, too, that this property of chimneys might, by means of smoke-jack vanes, be applied to some mechanical purposes, where a small but pretty constant power only is wanted.

If you would have my opinion of the cause of this changing current of air in chimneys, it is, in short, as follows. In summer time there is generally a great difference in the warmth of the air at mid-day and mid-night, and, of course, a difference of specific gravity in the air, as the more it is warmed the more it is rarefied. The funnel of a chimney, being for the most part surrounded by the house, is protected, in a great measure, from the direct action of the sun's rays, and also from the coldness of the night air. It thence preserves a middle temperature between the heat of the day, and the coldness of the night. This middle temperature it communicates to the air contained in it. If the state of the outward air be cooler than that in the funnel of the chimney, it will, by being heavier, force it to rise, and go out at the top. What supplies its place from below, being warmed, in its turn, by the warmer funnel, is likewise forced up by the colder and weightier air [291]
below, and so the current is continued till the next day, when the sun gradually changes the state of the outward air, makes it first as warm as the funnel of the chimney can make it (when the current begins to hesitate) and afterwards warmer. Then the funnel, being cooler than the air that comes into it, cools that air, makes it heavier than the outward air, of course it descends; and what succeeds it from above being cooled in its turn, the descending current continues till towards evening, when it again hesitates and changes its course, from the change of warmth in the outward air, and the nearly remaining same middle temperature in the funnel.

Upon this principle, if a house were built behind Beacon-hill, an adit carried from one of the doors into the hill horizontally, till it meet with a perpendicular shaft sunk from its top, it seems probable to me, that those who lived in the house would constantly, in the heat even of the calmest day, have as much cool air passing through the house, as they should chuse; and the same, though reversed in its current, during the stillest night.

I think, too, this property might be made of use to miners; as, where several shafts or pits are sunk perpendicularly into the earth, communicating at bottom by horizontal passages, which is a common case, if a chimney of thirty or forty feet high were built over one of the shafts, or so near the shaft, that the chimney might communicate with the top of the shaft, all air being excluded but what should pass up or down by the shaft, a constant change of air would, by this means, be produced in the passages below, tending to secure the workmen from those damps, which so frequently incommode them. [292]
For the fresh air would be almost always going down the open shaft, to go up the chimney, or down the chimney, to go up the shaft. Let me add one observation more, which is, that if that part of the funnel of a chimney, which appears above the roof of a house, be pretty long, and have three of its sides exposed to the heat of the sun successively, viz. when he is in the east, in the south, and in the west, while the north side is sheltered by the building from the cool northerly winds; such a chimney will often be so heated by the sun, as to continue the draft strongly upwards, through the whole twenty-four hours, and often for many days together. If the outside of such a chimney be painted black, the effect will be still greater, and the current stronger.

No. III.

It is said the northern Chinese have a method of warming their ground floors, which is ingenious. Those floors are made of tiles, a foot square and two inches thick, their corners being supported by bricks set on end, that are a foot long and four inches square; the tiles, too, join into each other, by ridges and hollows along their sides. This forms a hollow under the whole floor, which on one side of the house has an opening into the air, where a fire is made, and it has a funnel rising from the other side to carry off the smoke. The fuel is a sulphurous pitcoal, the smell of which in the room is thus avoided, while the floor, and of course the room, is well warmed. But as the underside of the floor must grow foul with soot, and a thick coat of soot prevents much of the direct application of the hot air to the tiles, I conceive that burning the [293] smoke, by obliging it to descend through red coals, would in this construction be very advantageous, as more heat would be given by the flame than by the smoke, and the floor being thereby kept free from soot would be more heated with less fire. For this purpose I would propose erecting the funnel close to the grate, so as to have only an iron plate between the fire and the funnel, through which plate, the air in the funnel being heated, it will be sure to draw well, and force the smoke to descend, as in the figure (Plate, Figure 9.) where A is the funnel or chimney, B the grate on which the fire is placed, C one of the apertures through which the descending smoke is drawn into the channel D of figure 10, along which channel it is conveyed by a circuitous route, as designated by the arrows, until it arrives at the small aperture E, figure 10, through which it enters the funnel F. G in both figures is the iron plate against which the fire is made, which, being heated thereby, will rarefy the air in that part of the funnel, and cause the smoke to ascend rapidly. The flame thus dividing from the grate to the right and left, and turning in passages, disposed, as in figure 10, so as that every part of the floor may be visited by it before it enters the funnel F, by the two passages E E, very little of the heat will be lost, and a winter room thus rendered very comfortable.

No. IV.

Page 265. *Few can imagine*, &c. It is said the Icelanders have very little fuel, chiefly drift wood that comes upon their coast. To receive more advantage from its heat, they make their doors low, and have a stage round the room above the [294] door, like a gallery, wherein the women can sit and work, the men read or write, &c. The roof being tight, the warm air is confined by it and kept from rising higher and escaping; and the cold air, which enters the house when the door is opened, cannot rise above the level of the top of the door, because it is heavier than the warm air above the door, and so those in the gallery are not incommoded by it. Some of our too lofty rooms might have a stage so constructed as to make a temporary gallery above, for the winter, to be taken away in summer. Sedentary people would find much comfort there in cold weather.

No. V.

Page 285. *Where they have the art of managing it*, &c. In some houses of the lower people among the northern nations of Europe, and among the poorer sort of Germans in Pensylvania, I have observed this construction, which appears very advantageous. (Plate Figure 11.) A is the kitchen with its chimney; B an iron stove in the stove-room. In a corner of the chimney is a hole through the back into the stove, to put in fuel, and another hole above it to let the smoke of the stove come back into the chimney. As soon as the cooking is over, the brands in the kitchen chimney are put through the hole to supply the stove, so that there is seldom more than one fire burning at a time. In the floor over the stove-room, is a small trap door, to let the warm air rise occasionally into the chamber. Thus the whole house is warmed at little expence of wood, and the stove-room kept constantly warm; so that in the coldest winter nights, they can work late, and find the room still comfortable when they rise to work early. An English farmer in America, who makes great fires in large open [295] chimneys, needs the constant employment of one man to cut and haul wood for supplying them; and the draft of cold air to them is so strong, that the heels of his family are frozen while they are scorching their faces, and the room is never warm, so that little sedentary work can be done by them in winter. The difference in this article alone of economy shall, in a course of years, enable the German to buy out the Englishman, and take possession of his plantation.

Chimneys, whose funnels go up in the north wall of a house and are exposed to the north winds, are not so apt to draw well as those in a south wall; because, when rendered cold by those winds, they draw downwards.

Chimneys, enclosed in the body of a house, are better than those whose funnels are exposed in cold walls.

Chimneys in stacks are apt to draw better than separate funnels, because the funnels, that have constant fires in them, warm the others, in some degree, that have none.

One of the funnels, in a house I once occupied, had a particular funnel joined to the south side of the stack, so that three of its sides were exposed to the sun in the course of the day, viz. (Plate, Figure 12.) the east side E during the morning, the south side S in the middle part of the day, and the west side W during the afternoon, while its north side was sheltered by the stack from the cold winds. This funnel, which came from the ground-floor, and had a considerable height above the [296] roof, was constantly in a strong drawing state day and night, winter and summer.

Blacking of funnels, exposed to the sun, would probably make them draw still stronger.

In Paris I saw a fire-place so ingeniously contrived as to serve conveniently two rooms, a bedchamber and a study. The funnel over the fire was round. The fire-place was of cast iron (Plate, Figure 13.) having an upright back A, and two horizontal semicircular plates B C, the whole so ordered as to turn on the pivots D E. The plate B always stopped that part of the round funnel that was next to the room without fire, while the other half of the funnel over the fire was always open. By this means a servant in the morning could make a fire on the hearth C, then in the study, without disturbing the master by going into his chamber; and the master, when he rose, could, with a touch of his foot, turn the chimney on its pivots, and bring the fire into his chamber, keep it there as long as he wanted it, and turn it again, when he went out, into his study. The room which had no fire in it was also warmed by the heat coming through the back plate, and spreading in the room, as it could not go up the chimney.

FOOTNOTES:

[51] This letter, which has been published in a separate pamphlet, both in this country and America, first appeared in the Transactions of the American Philosophical Society, in which it was read Oct. 21, 1785. *Editor.*

[52] See Notes at the end of the Letter, No. I.

[53] See Notes at the end of the Letter, No. II.

[54] See Notes at the end of the letter, No. II.

[55] See Notes at the end of the letter, No. II.

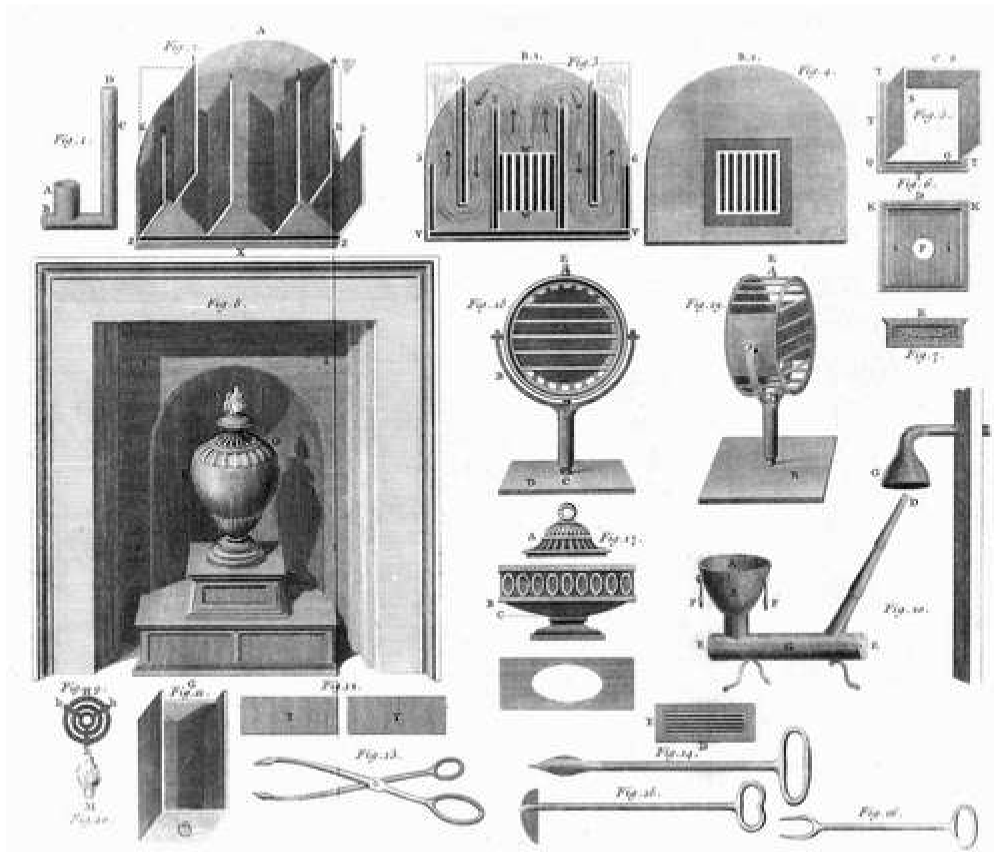
[56] See Notes at the end of the letter, No. III.

[57] See Notes at the end of the Letter, No. II.

[58] "It may be just remarked here, that upon comparing these proportions with those arising from the common divisions of the monochord, it happens that the first answers to unisons, and although the second is a discord, the third answers to the third minor, the fourth to the third major, the fifth to the fourth, the sixth to the fifth, and the seventh to the octave." NUTSHELLS, page 85.

[59] Badoin. *Editor.*

STOVE FOR BURNING PIT-COAL.



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Published as the Act directs, April 1, 1806, by Longman, Hurst, Rees & Orme, Paternoster Row.

Description of a new Stove for burning of Pitcoal, and consuming all its smoke.[60]

By Dr. B. FRANKLIN.

Towards the end of the last century an ingenious French philosopher, whose name I am sorry I cannot recollect, [297] exhibited an experiment to show, that very offensive things might be burnt in the middle of a chamber, such as woollen rags, feathers, &c. without creating the least smoke or smell. The machine in which it was made, if I remember right, was of this form, (Plate X. Figure 1.) made of plate iron. Some clear burning charcoals were put into the opening of the short tube A, and supported there by the grate B. The air, as soon as the tubes grew warm, would ascend in the longer leg C and go out at D, consequently air must enter at A descending to B. In this course it must be heated by the burning coals through which it passed, and rise more forcibly in the longer tube, in proportion to its degree of heat or rarefaction, and length of that tube. For such a machine is a kind of inverted syphon; and as the greater weight of water in the longer leg of a common syphon in descending is accompanied by an ascent of the same fluid in the shorter; so, in this inverted syphon, the greater quantity of levity of air in the longer leg, in rising is accompanied by the descent of air in the shorter. The things to be burned being laid on the hot coals at A, the smoke must descend through those coals, be converted into flame, which, after destroying the offensive smell, came out at the end of the longer tube as mere heated air.

Whoever would repeat this experiment with success must take care that the part A, B, of the short tube, be quite full of burning coals, so that no part of the smoke may descend and pass by them without going through them, and being converted into flame; and that the longer tube be so heated as that the current of ascending hot air is established in it before the things to be burnt are laid on the coals; otherwise there will be a disappointment. [298]

It does not appear either in the Memoirs of the Academy of Sciences, or Philosophical Transactions of the English Royal Society, that any improvement was ever made of this ingenious experiment, by applying it to useful purposes. But there is a German book, entitled *Vulcanus Famulans*, by Joh. George Leutmann, P. D. printed at Wirtemberg in 1723, which describes, among a great variety of other stoves for warming rooms, one, which seems to have been formed on the same principle, and probably from the hint thereby given, though the French experiment is not mentioned. This book being scarce, I have translated the chapter describing the stove, viz.

"*Vulcanus Famulans, by John George Leutmann, P. D.*
"*Wirtemberg, 1723.*

"CHAP. VII.

"On a Stove, which draws downwards.

"Here follows the description of a sort of stove, which can easily be removed and again replaced at pleasure. This drives the fire down under itself, and gives no smoke, but however a very unwholesome vapour.

"In the figure, A is an iron vessel like a funnel, (Plate X. Figure 20.) in diameter at the top about twelve inches, at the bottom near the grate about five inches; its height twelve inches. This is set on the barrel C, which is ten inches diameter and two feet long, closed at each end E E. From one end rises a pipe or flue about four inches diameter, on which other [299] pieces of pipe are set, which are gradually contracted to D, where the opening is but about two inches. Those pipes must together be at least four feet high. B is an iron grate. F F are iron handles guarded with wood, by which the stove is to be lifted and moved. It stands on three legs. Care must be taken to stop well all the joints, that no smoke may leak through.

"When this stove is to be used, it must first be carried into the kitchen and placed in the chimney near the fire. There burning wood must be laid and left upon its grate till the barrel C is warm, and the smoke no longer rises at A, but descends towards C. Then it is to be carried into the room which it is to warm. When once the barrel C is warm, fresh wood may be thrown into the vessel A as often as one pleases, the flame descends and without smoke, which is so consumed that only a vapour passes out at D.

"As this vapour is unwholesome, and affects the head, one may be freed from it, by fixing in the wall of the room an inverted funnel, such as people use to hang over lamps, through which their smoke goes out as through a chimney. This funnel carries out all the vapour cleverly, so that one finds no inconvenience from it, even though the opening D be placed a span below the mouth of the said funnel G. The neck of the funnel is better when made gradually bending, than if turned in a right angle.

"The cause of the draft downwards in the stove is the pressure of the outward air, which, falling into the vessel A in a column of twelve inches diameter, finds only a resisting passage at the grate B, of five inches, and one at D, of two inches, [300] which are much too weak to drive it back again; besides, A stands much higher than B, and so the pressure on it is greater and more forcible, and beats down the frame to that part where it finds the least resistance. Carrying the machine first to the kitchen fire for preparation, is on this account, that in the beginning the fire and smoke naturally ascend, till the air in the close barrel C is made thinner by the warmth. When that vessel is heated, the air in it is rarefied, and then all the smoke and fire descends under it.

"The wood should be thoroughly dry, and cut into pieces five or six inches long, to fit it for being thrown into the funnel A." Thus far the German book.

It appears to me, by Mr. Leutmann's explanation of the operation of this machine, that he did not understand the principles of it, whence I conclude he was not the inventor of it; and by the description of it, wherein the opening at A is made so large, and the pipe E, D, so short, I am persuaded he never made nor saw the experiment, for the first ought to be much smaller and the last much higher, or it hardly will succeed. The carrying it in the kitchen, too, every time the fire should happen to be out, must be so troublesome, that it is not likely ever to have been in practice, and probably has never been shown but as a philosophical experiment. The funnel for conveying the vapour out of the room would besides have been uncertain in its operation, as a wind blowing against its mouth would drive the vapour back.

The stove I am about to describe was also formed on the idea given by the French experiment, and completely carried into execution before I had any knowledge of the German invention; which I wonder should remain so many years in a [301] country, where men are so ingenious in the management of fire, without receiving long since the improvements I have given it.

Description of the Parts.

A, the bottom plate which lies flat upon the hearth, with its partitions, 1, 2, 3, 4, 5, 6, (Plate X. Figure 2.) that are cast with it, and a groove Z Z, in which are to slide, the bottom edges of the small plates Y, Y, figure 12; which plates meeting at X close the front.

B 1, figure 3, is the cover plate showing its under side, with the grooves 1, 2, 3, 4, 5, 6, to receive the top edges of the partitions that are fixed to the bottom plate. It shows also the grate W W, the bars of which are cast in the plate, and a groove V V, which comes right over the groove Z Z, figure 2, receiving the upper edges of the small sliding plates Y Y, figure 12.

B 2, figure 4, shows the upper side of the same plate, with a square impression or groove for receiving the bottom mouldings T T T T of the three-sided box C, figure 5, which is cast in one piece.

D, figure 6, its cover, showing its under side with grooves to receive the upper edges S S S of the sides of C, figure 5, also a groove R, R, which when the cover is put on comes right over another Q Q in C, figure 5, between which it is to slide.

E, figure 7, the front plate of the box.

P, a hole three inches diameter through the cover D, figure 6, over which hole stands the vase F, figure 8, which has a corresponding hole two inches diameter through its bottom.

The top of the vase opens at O, O, O, figure 8, and turns back upon a hinge behind when coals are to be put in; the vase has a grate within at N N of cast iron H, figure 9, and a hole in the top, one and a half inches diameter, to admit air, and to receive the ornamental brass guilt flame M, figure 10, which stands in that hole, and, being itself hollow and open, suffers air to pass through it to the fire. [302]

G, figure 11, is a drawer of plate iron, that slips in between in the partitions 2 and 3, figure 2, to receive the falling ashes. It is concealed when the small sliding plates Y Y, figure 12, are shut together.

I, I, I, I, figure 8, is a niche built of brick in the chimney and plastered. It closes the chimney over the vase, but leaves two funnels, one in each corner, communicating with the bottom box K K, figure 2.

Dimensions of the Parts.

	Feet.	*In.*
Front of the bottom box,	2	0
Height of its partitions,	0	4¼
Length of No. 1,2, 3 and 4, each,	1	3
Length of No. 5 and 6, each,	0	8¼
Breadth of the passage between No. 2 and 3,	0	6
Breadth of the other passages each,	0	3½
Breadth of the grate,	0	6½
Length of ditto,	0	8
Bottom moulding of box C, square,	1	0
Height of the sides of ditto,	0	4
Length of the back side,	0	10
Length of the right and left sides, each,	0	9½
Length of the front plate E, where longest,	0	11
The cover D, square,	0	12
Hole in ditto, diameter,	0	3 [303]
Sliding plates Y Y, their length, each,	1	0

——————— their breadth, each,	0	4½
Drawer G, its length,	1	0
————— breadth,	0	5¾
————— depth,	0	4
————— depth of its further end, only,	0	1
Grate H in the vase, its diameter to the extremity of its knobs,	0	5¾
Thickness of the bars at top,	0	0¼
————————— at bottom, less,	0	0
Depth of the bars at the top,	0	0¾
Height of the vase,	1	6
Diameter of the opening O, O, in the clear,	0	8
Diameter of the air-hole at top,	0	1½
——— of the flame hole at bottom,	0	2

To fix this Machine.

Spread mortar on the hearth to bed the bottom plate A, then lay that plate level, equally distant from each jamb, and projecting out as far as you think proper. Then putting some Windsor loam in the grooves of the cover B, lay that on: trying the sliding plates Y Y, to see if they move freely in the grooves Z Z, V V, designed for them.

Then begin to build the niche, observing to leave the square corners of the chimney unfilled; for they are to be funnels. And observe also to leave a free open communication between the passages at K K, and the bottom of those funnels, and mind to close the chimney above the top of the niche, that no air may pass up that way. The concave back of the niche [304]
will rest on the circular iron partition 1 A 4, figure 2, then, with a little loam, put on the box C over the grate, the open side of the box in front.

Then, with loam in three of its grooves, the groove R R being left clean, and brought directly over the groove Q Q in the box, put on the cover D, trying the front plate E, to see if it slides freely in those grooves.

Lastly, set on the vase, which has small holes in the moulding of its bottom to receive two iron pins that rise out of the plate D at I I, for the better keeping it steady.

Then putting in the grate H, which rests on its three knobs h h h against the inside of the vase, and slipping the drawer into its place; the machine is fit for use.

To use it.

Let the first fire be made after eight in the evening or before eight in the morning, for at those times and between those hours all night, there is usually a draft up a chimney, though it has long been without fire; but between those hours in the day there is often, in a cold chimney, a draft downwards, when, if you attempt to kindle a fire, the smoke will come into the room.

But to be certain of your proper time, hold a flame over the air-hole at the top. If the flame is drawn strongly down for a continuance, without whiffling, you may begin to kindle a fire.

First put in a few charcoals on the grate H.

Lay some small sticks on the charcoals,

Lay some pieces of paper on the sticks, [305]

Kindle the paper with a candle,

Then shut down the top, and the air will pass down through the air-hole, blow the flame of the paper down through the sticks, kindle them, and their flame passing lower kindles the charcoal.

When the charcoal is well kindled, lay on it the sea-coals, observing not to choak the fire by putting on too much at first.

The flame descending through the hole in the bottom of the vase, and that in plate D into the box C, passes down farther through the grate W W in plate B 1, then passes horizontally towards the back of the chimney; there dividing, and turning to the right and left, one part of it passes round the far end of the partition 2, then coming forward it turns round the near end of partition 1, then moving backward it arrives at the opening into the bottom of one of the upright corner funnels behind the niche, through which it ascends into the chimney, thus heating that half of the box and that side of the niche. The other part of the divided flame passes round the far end of partition 3, round the near end of partition 4, and so into and up the other corner funnel, thus heating the other half of the box, and the other side of the niche. The vase itself, and the box C will also be very hot, and the air surrounding them being heated, and rising, as it cannot get into the chimney, it spreads in the room, colder air succeeding is warmed in its turn, rises and spreads, till by the continual circulation the whole is warmed.

If you should have occasion to make your first fire at hours not so convenient as those above mentioned, and when the chimney does not draw, do not begin it in the vase, but in one or more of the passages of the lower plate, first covering the [306] mouth of the vase. After the chimney has drawn a while with the fire thus low, and begins to be a little warm, you may close those passages and kindle another fire in the box C, leaving its sliding shutter a little open; and when you find after some time that the chimney being warmed draws forcibly, you may shut that passage, open your vase, and kindle your fire there, as above directed. The chimney well warmed by the first day's fire will continue to draw constantly all winter, if fires are made daily.

You will, in the management of your fire, have need of the following implements:

A pair of small light tongs, twelve or fifteen inches long, plate, figure 13.

A light poker about the same length with a flat broad point, figure 14.

A rake to draw ashes out of the passages of the lower plate, where the lighter kind escaping the ash-box will gather by degrees, and perhaps once in a week or ten days require being removed, figure 15.

And a fork with its prongs wide enough to slip on the neck of the vase cover, in order to raise and open it when hot, to put in fresh coals, figure 16.

In the management of this stove there are certain precautions to be observed, at first with attention, till they become habitual. To avoid the inconvenience of smoke, see that the grate H be clear before you begin to light a fresh fire. If you find it clogged with cinders and ashes, turn it up with your tongs and let them fall upon the grate below; the ashes will go through it, and the cinders may be raked off and returned into the vase when you would burn them. Then see that all the [307] sliding plates are in their places and close shut, that no air may enter the stove but through the round opening at the top of the vase. And to avoid the inconvenience of dust from the ashes, let the ash-drawer be taken out of the room to be emptied; and when you rake the passages, do it when the draft of the air is strong inwards, and put the ashes carefully into the ash-box, that remaining in its place.

If, being about to go abroad, you would prevent your fire burning in your absence, you may do it by taking the brass flame from the top of the vase, and covering the passage with a round tin plate, which will prevent the entry of more air than barely sufficient to keep a few of the coals alive. When you return, though some hours absent, by taking off the tin plate and admitting the air, your fire will soon be recovered.

The effect of this machine, well managed, is to burn not only the coals, but all the smoke of the coals, so that while the fire is burning, if you go out and observe the top of your chimney, you will see no smoke issuing, nor any thing but clear warm air, which as usual makes the bodies seen through it appear waving.

But let none imagine from this, that it may be a cure for bad or smoky chimneys, much less, that as it burns the smoke it may be used in a room that has no chimney. It is by the help of a good chimney, the higher the better, that it produces its effect; and though a flue of plate iron sufficiently high might be raised in a very lofty room, the management to prevent all disagreeable vapour would be too nice for common practice, and small errors would have unpleasing consequences.

It is certain that clean iron yields no offensive smell when heated. Whatever of that kind you perceive, where there are [308] iron stoves, proceeds therefore from some foulness burning or fuming on their surface. They should therefore never be spit upon, or greased, nor should any dust be suffered to lie upon them. But as the greatest care will not always prevent these things, it is well once a week to wash the stove with soap lees and a brush, rinsing it with clean water.

The Advantages of this Stove.

1. The chimney does not grow foul, nor ever need sweeping; for as no smoke enters it, no soot can form in it.

2. The air heated over common fires instantly quits the room and goes up the chimney with the smoke; but in the stove, it is obliged to descend in flame and pass through the long winding horizontal passages, communicating its heat to a body of iron plate, which, having thus time to receive the heat, communicates the same to the air of the room, and thereby warms it to a greater degree.

3. The whole of the fuel is consumed by being turned into flame, and you have the benefit of its heat, whereas in common chimneys a great part goes away in smoke which you see as it rises, but it affords you no rays of warmth. One may obtain some notion of the quantity of fuel thus wasted in smoke, by reflecting on the quantity of soot that a few weeks firing will lodge against the sides of the chimney, and yet this is formed only of those particles of the column of

smoke that happen to touch the sides in its ascent. How much more must have passed off in the air? And we know that this soot is still fuel; for it will burn and flame as such, and when hard caked together is indeed very like and almost as [309] solid as the coal it proceeds from. The destruction of your fuel goes on nearly in the same quantity whether in smoke or in flame: but there is no comparison in the difference of heat given. Observe when fresh coals are first put on your fire, what a body of smoke arises. This smoke is for a long time too cold to take flame. If you then plunge a burning candle into it, the candle instead of inflaming the smoke will instantly be itself extinguished. Smoke must have a certain degree of heat to be inflammable. As soon as it has acquired that degree, the approach of a candle will inflame the whole body, and you will be very sensible of the difference of the heat it gives. A still easier experiment may be made with the candle itself. Hold your hand near the side of its flame, and observe the heat it gives; then blow it out, the hand remaining in the same place, and observe what heat may be given by the smoke that rises from the still burning snuff. You will find it very little. And yet that smoke has in it the substance of so much flame, and will instantly produce it, if you hold another candle above it so as to kindle it. Now the smoke from the fresh coals laid on this stove, instead of ascending and leaving the fire while too cold to burn, being obliged to descend through the burning coals, receives among them that degree of heat which converts it into flame, and the heat of that flame is communicated to the air of the room, as above explained.

4. The flame from the fresh coals laid on in this stove, descending through the coals already ignited, preserves them long from consuming, and continues them in the state of red coals as long as the flame continues that surrounds them, by which means the fires made in this stove are of much longer duration than in any other, and fewer coals are therefore [310] necessary for a day. This is a very material advantage indeed. That flame should be a kind of pickle, to preserve burning coals from consuming, may seem a paradox to many, and very unlikely to be true, as it appeared to me the first time I observed the fact. I must therefore relate the circumstances, and shall mention an easy experiment, by which my reader may be in possession of every thing necessary to the understanding of it. In the first trial I made of this kind of stove, which was constructed of thin plate iron, I had instead of the vase a kind of inverted pyramid like a mill-hopper; and fearing at first that the small grate contained in it might be clogged by cinders, and the passage of the flame sometimes obstructed, I ordered a little door near the grate, by means of which I might on occasion clear it: though after the stove was made, and before I tried it, I began to think this precaution superfluous, from an imagination, that the flame being contracted in the narrow part where the grate was placed, would be more powerful in consuming what it should there meet with, and that any cinders between or near the bars would be presently destroyed and the passage opened. After the stove was fixed and in action, I had a pleasure now and then in opening that door a little, to see through the crevice how the flame descended among the red coals, and observing once a single coal lodged on the bars in the middle of the focus, a fancy took me to observe by my watch in how short a time it would be consumed. I looked at it long without perceiving it to be at all diminished, which surprised me greatly. At length it occurred to me, that I and many others had seen the [311] same thing thousands of times, in the conservation of the red coal formed in the snuff of a burning candle, which while envelloped in flame, and thereby prevented from the contact of passing air, is long continued and augments instead of diminishing, so that we are often obliged to remove it by the snuffers, or bend it out of the flame into the air, where it consumes presently to ashes. I then supposed, that to consume a body by fire, passing air was necessary to receive and carry off the separated particles of the body: and that the air passing in the flame of my stove, and in the flame of a candle, being already saturated with such particles, could not receive more, and therefore left the coal undiminished as long as the outward air was prevented from coming to it by the surrounding flame, which kept it in a situation somewhat like that of charcoal in a well luted crucible, which, though long kept in a strong fire, comes out unconsumed.

An easy experiment will satisfy any one of this conserving power of flame envelloping red coal. Take a small stick of deal or other wood the size of a goose quill, and hold it horizontally and steadily in the flame of the candle above the wick, without touching it, but in the body of the flame. The wood will first be inflamed, and burn beyond the edge of the flame of the candle, perhaps a quarter of an inch. When the flame of the wood goes out, it will leave a red coal at the end of the stick, part of which will be in the flame of the candle and part out in the air. In a minute or two you will perceive the coal in the air diminish gradually, so as to form a neck; while the part in the flame continues of its first size, and at length the neck being quite consumed it drops off; and by rolling it between your fingers when extinguished you will find [312] it still a solid coal.

However, as one cannot be always putting on fresh fuel in this stove to furnish a continual flame as is done in a candle, the air in the intervals of time gets at the red coals and consumes them. Yet the conservation while it lasted, so much delayed the consumption of the coals, that two fires, one made in the morning, and the other in the afternoon, each made by only a hatfull of coals, were sufficient to keep my writing room, about sixteen feet square and ten high, warm a whole day. The fire kindled at seven in the morning would burn till noon; and all the iron of the machine with the walls of the niche being thereby heated, the room kept warm till evening, when another smaller fire kindled kept it warm till midnight.

Instead of the sliding plate E, which shuts the front of the box C, I sometimes used another which had a pane of glass, or, which is better, of Muscovy talc, that the flame might be seen descending from the bottom of the vase and passing in a column through the box C, into the cavities of the bottom plate, like water falling from a funnel, admirable to such as are not acquainted with the nature of the machine, and in itself a pleasing spectacle.

Every utensil, however properly contrived to serve its purpose, requires some practice before it can be used adroitly. Put into the hands of a man for the first time a gimblet or a hammer (very simple instruments) and tell him the use of them, he shall neither bore a hole or drive a nail with the dexterity and success of another who has been accustomed to handle them. The beginner therefore in the use of this machine will do well not to be discouraged with little accidents that [313] may arise at first from his want of experience. Being somewhat complex, it requires as already said a variety of attentions; habit will render them unnecessary. And the studious man who is much in his chamber, and has a pleasure in managing his own fire, will soon find this a machine most comfortable and delightful. To others who leave their fires to the care of ignorant servants, I do not recommend it. They will with difficulty acquire the knowledge necessary, and will make frequent blunders that will fill your room with smoke. It is therefore by no means fit for common use in families. It may be adviseable to begin with the flaming kind of stone coal, which is large, and, not caking together, is not so apt to clog the grate. After some experience, any kind of coal may be used, and with this advantage, that no smell, even from the most sulphurous kind can come into your room, the current of air being constantly into the vase, where too that smell is all consumed.

The vase form was chosen as being elegant in itself, and very proper for burning of coals: where wood is the usual fuel, and must be burned in pieces of some length, a long square chest may be substituted, in which A is the cover opening by a hinge behind, B the grate, C the hearth-box with its divisions as in the other, D the plan of the chest, E the long narrow grate. (Plate, Figure 17.) This I have not tried, but the vase machine was completed in 1771, and used by me in London three winters, and one afterwards in America, much to my satisfaction; and I have not yet thought of any improvement it may be capable of, though such may occur to others. For common use, while in France, I have contrived another grate for [314] coals, which has in part the same property of burning the smoke and preserving the red coals longer by the flame, though not so completely as in the vase, yet sufficiently to be very useful, which I shall now describe as follows.

A, is a round grate, one foot (French) in diameter, and eight inches deep between the bars and the back; (Plate, Figure 18.) the sides and back of plate iron; the sides having holes of half an inch diameter distant three or four inches from each other, to let in air for enlivening the fire. The back without holes. The sides do not meet at top nor at bottom by eight inches: that square is filled by grates of small bars crossing front to back to let in air below, and let out the smoke or flame above. The three middle bars of the front grate are fixed, the upper and lower may be taken out and put in at pleasure, when hot, with a pair of pincers. This round grate turns upon, an axis, supported by the crotchet B, the stem of which is an inverted conical tube five inches deep, which comes on as many inches upon a pin that fits it, and which is fixed upright in cast iron plate D, that lies upon the hearth; in the middle of the top and bottom grates are fixed small upright pieces E E about an inch high, which as the whole is turned on its axis stop it when the grate is perpendicular. Figure 19 is another view of the same machine.

In making the first fire in a morning with this grate, there is nothing particular to be observed. It is made as in other grates, the coals being put in above, after taking out the upper bar, and replacing it when they are in. The round figure of the fire when thoroughly kindled is agreeable, it represents the great giver of warmth to our system. As it burns down and [315] leaves a vacancy above, which you would fill with fresh coals, the upper bar is to be taken out, and afterwards replaced. The fresh coals, while the grate continues in the same position, will throw up as usual a body of thick smoke. But every one accustomed to coal fires in common grates must have observed, that pieces of fresh coal stuck in below among the red coals have their smoke so heated as that it becomes flame as fast as it is produced, which flame rises among the coals and enlivens the appearance of the fire. Here then is the use of this swivel grate. By a push with your tongs or poker, you turn it on its pin till it faces the back of the chimney, then turn it over on its axis gently till it again faces the room, whereby all the fresh coals will be found under the live coals, and the greater part of the smoke arising from the fresh coals will in its passage through the live ones be heated so as to be converted into flame: whence you have much more heat from them, and your red coals are longer preserved from consuming. I conceive this construction, though not so complete a consumer of all the smoke as the vase, yet to be fitter for common use, and very advantageous. It gives too a full sight of the fire, always a pleasing object, which we have not in the other. It may with a touch be turned more or less from any one of the company that desires to have less of its heat, or presented full to one just come out of the cold. And supported in a horizontal position, a tea-kettle may be boiled on it.

The author's description of his Pensylvania fireplace, first published in 1744, having fallen into the hands of workmen in Europe, who did not, it seems, well comprehend the principles of that machine, it was much disfigured in their [316] imitations of it; and one of its main intentions, that of admitting a sufficient quantity of fresh air warmed in entering through the air-box, nearly defeated, by a pretended improvement, in lessening its passages to make more room for coals in a grate. On pretence of such improvements, they obtained patents for the invention, and for a while made great profit by the sale, till the public became sensible of that defect, in the expected operation. If the same thing should be attempted with this vase stove, it will be well for the buyer to examine thoroughly such pretended improvements, lest, being the mere productions of ignorance, they diminish or defeat the advantages of the machine, and produce inconvenience and disappointment.

The method of burning smoke, by obliging it to descend through hot coals, may be of great use in heating the walls of a hot-house. In the common way, the horizontal passages or flues that are made to go and return in those walls, lose a great deal of their effect when they come to be foul with soot; for a thick blanket-like lining of soot prevents much of the hot air from touching and heating the brick work in its passage, so that more fire must be made as the flue grows fouler: but by burning the smoke they are kept always clean. The same method may also be of great advantage to those businesses in which large coppers or caldrons are to be heated.

Written at Sea, 1785.

FOOTNOTE:

[60] From the Transactions of the American Philosophical Society, in which it was read January 28, 1786. *Editor.*

TO MISS STEPHENSON. [317]

Method of Contracting Chimneys. Modesty in Disputation.

Craven-Street, Saturday Evening, past 10.

The question you ask me is a very sensible one, and I shall be glad if I can give you a satisfactory answer. There are two ways of contracting a chimney; one, by contracting the opening *before* the fire; the other, by contracting the funnel *above* the fire. If the funnel above the fire is left open in its full dimensions, and the opening before the fire is contracted; then the coals, I imagine, will burn faster, because more air is directed through the fire, and in a stronger stream; that air which before passed over it, and on each side of it, now passing *through* it. This is seen in narrow stove chimneys, when a sacheverell or blower is used, which still more contracts the narrow opening.—But if the funnel only *above* the fire is contracted, then, as a less stream of air is passing up the chimney, less must pass through the fire, and consequently it should seem that the consuming of the coals would rather be checked than augmented by such contraction. And this will also be the case, when both the opening *before* the fire, and the funnel *above* the fire are contracted, provided the funnel above the fire is more contracted in proportion than the opening before the fire.—So you see I think you had the best of the argument; and as you notwithstanding gave it up in complaisance to the company, I think you had also the best of the dispute. [318] There are few, though convinced, that know how to give up, even an error, they have been once engaged in maintaining; there is therefore the more merit in dropping a contest where one thinks one's self right; it is at least respectful to those we converse with. And indeed all our knowledge is so imperfect, and we are from a thousand causes so perpetually subject to mistake and error, that positiveness can scarce ever become even the most knowing; and modesty in advancing any opinion, however plain and true we may suppose it, is always decent, and generally more likely to procure assent. Pope's rule

To speak, though sure, with seeming diffidence,

is therefore a good one; and if I had ever seen in your conversation the least deviation from it, I should earnestly recommend it to your observation.

I am, &c.

B. FRANKLIN.

TO MICHAEL HILLEGRAS ESQ.

Respecting covering Houses with Copper.[61]

London, March 17, 1770.

Dear Sir,

I received your favour of November 25, and have made enquiries, as you desired, concerning the copper covering of houses. It has been used here in a few instances only, and the practice does not seem to gain ground. The copper is about [319] the thickness of a common playing card, and though a dearer metal than lead, I am told, that, as less weight serves, on account of its being so much thinner, and as slighter woodwork in the roof is sufficient to support it, the roof is not dearer on the whole, than one covered with lead. It is said, that hail and rain make a disagreeable drumming noise on copper; but this I suppose is rather fancy; for the plates being fastened on the rafters, must, in a great measure, deaden such sound. The first cost, whatever it is, will be all, as a copper covering must last for ages; and when the house decays, the plates will still have intrinsic worth. In Russia, I am informed many houses are covered with plates of iron tinned, such as our tin pots and other vases are made of, laid on over the edges of one another like tiles; and which, it is said, last very long, the tin preserving the iron from much decay by rusting. In France and the Low Countries, I have seen many spouts or pipes for conveying the water down from the roofs of houses, made of the same kind of tin plates soldered together; and they seem to stand very well.

With sincere regard, I am,

Yours, &c.

B. FRANKLIN.

FOOTNOTE:

[61] The two following letters, and the accompanying paper, appeared in several periodical publications, both English and American, many years before the death of Franklin, which is sufficient to give them authenticity. *Editor.*

TO SAMUEL RHOADS, ESQ. [320]

On the same Subject.

London, June 26, 1770.

Dear Friend,

It is a long time since I had the pleasure of hearing from you directly. Mrs. Franklin has indeed now and then acquainted me of your welfare, which I am always glad to hear of. It is, I fear, partly, if not altogether, my fault, that our correspondence has not been regularly continued. One thing I am sure of, that it has been from no want of regard on either side, but rather from too much business, and avocations of various kinds, and my having little of importance to communicate.

One of our good citizens, Mr. Hillegras, anxious for the future safety of our town, wrote to me some time since, desiring I would enquire concerning the covering of our houses here with copper. I sent him the best information I could then obtain, but have since received the inclosed from an ingenious friend, who is what they call here a civil engineer. I should be glad you would peruse it, think of the matter a little and give me your sentiments of it. When you have done with the paper, please to give it to Mr. Hillegras. I am told by Lord Despencer, who has covered a long piazza, or gallery, with copper, that the expence is charged in this account too high, for his cost but one shilling and ten-pence per foot, all charges included. I suppose his copper must have been thinner. And, indeed, it is so strong a metal, that I think it may well be used very thin.

It appears to me of great importance, to build our dwelling houses, if we can, in a manner more secure from danger by [321] fire. We scarcely ever hear of fire in Paris. When I was there I took particular notice of the construction of their houses, and I did not see how one of them could well be burnt, the roofs are slate or tile, the walls are stone, the walls generally lined with stucco or plaster, instead of wainscot, the floors of stucco, or of six square tiles painted brown, or of flag stone, or of marble; if any floors were of wood, it was of oak wood, which is not so inflammable as pine. Carpets prevent the coldness of stone or brick floors offending the feet in winter, and the noise of treading on such floors, overhead, is less inconvenient than on boards. The stairs too, at Paris, are either stone or brick, with only a wooden edge or corner for the step; so that on the whole, though the Parisians commonly burn wood in their chimneys, a more dangerous kind of fuel than that used here, yet their houses escape extremely well, as there is little in a room that can be consumed by fire except the furniture: whereas in London, perhaps scarcely a year passes in which half a million of property and many lives are not lost by this destructive element. Of late, indeed, they begin here to leave off wainscoting their rooms, and instead of it cover the walls with stucco, often formed into pannels like wainscot, which being painted, is very strong and warm. Stone staircases too, with iron rails, grow more and more into fashion here: but stone steps cannot, in some circumstances, be fixed; and there, methinks, oak is safer than pine; and I assure you, that in many genteel houses here, both old and new, the stairs and floors are oak, and look extremely well. Perhaps solid oak for the steps would be still safer than boards; and [322] two steps might be cut diagonally out of one piece. Excuse my talking to you on a subject with which you must be so much better acquainted than I am. It is partly to make out a letter, and partly in hope, that, by turning your attention to the point, some methods of greater security in our future building may be thought of and promoted by you, whose judgment I know has deservedly great weight with our fellow-citizens. For though our town has not hitherto suffered very greatly by fire, yet I am apprehensive, that some time or other, by a concurrence of unlucky circumstances, such as dry weather, hard frost, and high winds, a fire then happening may suddenly spread far and wide over our cedar roofs, and do us an immense mischief. I am,

Yours, &c.

B. FRANKLIN.

Paper referred to in the preceding Letter.

The carpentry of the roof being formed with its proper descents, is, in the first place, sheeted or covered with deals, nailed horizontally upon the rafters, after the same manner as when intended to be covered with lead. The sheets of the copper for this covering are two feet by four, and for covering the slopes of the roof are cast so thin, as to weigh eight or nine pounds, and for covering the flats or gutters, ten or eleven pounds each, or about one pound, or a pound and a quarter, to the superficial foot.

A string of strong cartridge paper (over-lapping a little at its joints) is regularly tacked down upon the sheeting, under [323] the copper covering, as the work proceeds from eaves to ridge. It prevents the jingling sound of hail or rain falling upon the roof, and answers another purpose to be mentioned by-and-by.

In order to shew the regular process of laying down the roof, we must begin with fastening two sheets together lengthwise. The edges of two sheets are laid down so as to lap or cover each other an inch, and a slip of the same copper, about three and a half inches broad, called the reeve, is introduced between them. Four oblong holes, or slits, are then cut or punched through the whole, and they are fastened or riveted together by copper nails, with small round shanks and flat heads. Indents are then cut 1¾ inch deep upon the seam at top and bottom. The right hand sheet and the reeve are then folded back to the left. The reeve is then folded to the right, and the sheets being laid on the roof in their place, it is nailed down to the sheeting with flat-headed short copper nails. The right hand sheet is then folded over the reeve to the right, and the whole beat down flat upon the cartridge paper covering the sheeting, and thus they are fastened and laid in their places, by nailing down the reeve only; and by reason of the oblong holes through them and the reeve, have a little liberty to expand or contract with the heat and cold, without raising themselves up from the sheeting, or tearing themselves or the fastening to pieces. Two other sheets are then fixed together, according to the first and second operations above, and their seam, with the reeve, introduced under the upper ends of the seam of the former, so as to cover down about two inches upon the upper ends of the former sheets: and so far the cartridge paper is allowed to cover the two first sheets. This edge [324] of the paper is dipped in oil, or in turpentine, so far before its application, and thus a body between the sheets is formed impenetrable to wet, and the reeve belonging to the two last sheets is nailed down to the sheeting as before, and the left hand sheet is turned down to the right. Four sheets are now laid down, with the seam or joint rising to the ridge; and thus the work is continued, both vertically and horizontally, till the roof be covered, the sides and ends of each sheet being alternately each way, undermost and uppermost.

The price for copper, nails, and workmanship, runs at about eight pounds ten shillings per hundred weight, or two shillings and three-pence per foot, superficial, exclusive of the lappings; and about two shillings and eight-pence per foot upon the whole; which is rather above half as much more as the price of doing it well with lead.

TO PETER COLLINSON, ESQ. AT LONDON.

Magical Square of Squares.

Sir,

According to your request I now send you the arithmetical curiosity, of which this is the history.

Being one day in the country, at the house of our common friend, the late learned Mr. Logan, he showed me a folio French book filled with magic squares, wrote, if I forget not, by one M. Frenicle, in which he said the author had discovered great ingenuity and dexterity in the management of numbers; and though several other foreigners had [325] distinguished themselves in the same way, he did not recollect that any one Englishman had done any thing of the kind remarkable.

I said, it was, perhaps, a mark of the good sense of our English mathematicians, that they would not spend their time in things that were merely *difficiles nugæ*, incapable of any useful application. He answered, that many of the arithmetical or mathematical questions, publicly proposed and answered in England, were equally trifling and useless. Perhaps the considering and answering such questions, I replied, may not be altogether useless, if it produces by practice an habitual readiness and exactness in mathematical disquisitions, which readiness may, on many occasions, be of real use. In the same way, says he, may the making of these squares be of use. I then confessed to him, that in my younger days, having once some leisure (which I still think I might have employed more usefully) I had amused myself in making these kind of magic squares, and, at length, had acquired such a knack at it, that I could fill the cells of any magic square of reasonable size, with a series of numbers as fast as I could write them, disposed in such a manner as that the sums of every row, horizontal, perpendicular, or diagonal, should be equal; but not being satisfied with these, which I looked on as common and easy things, I had imposed on myself more difficult tasks, and succeeded in making other magic squares, with a variety of properties, and much more curious. He then shewed me several in the same book, of an uncommon and more curious kind; but as I thought none of them equal to some I remembered to have made, he desired me to let him see them; [326] and accordingly, the next time I visited him, I carried him a square of 8, which I found among my old papers, and which I will now give you, with an account of its properties. (*See Plate* V. Fig. 3.)

The properties are,

1. That every strait row (horizontal or vertical) of 8 numbers added together makes 260, and half each row half 260.

2. That the bent row of 8 numbers, ascending and descending diagonally, viz. from 16 ascending to 10, and from 23 descending to 17; and every one of its parallel bent rows of 8 numbers make 260.—Also the bent row from 52 descending to 54, and from 43 ascending to 45; and every one of its parallel bent rows of 8 numbers make 260.—Also the bent row from 45 to 43, descending to the left, and from 23 to 17, descending to the right, and every one of its parallel bent rows of 8 numbers, make 260.—Also the bent row from 52 to 54, descending to the right, and from 10 to 16, descending to the left, and every one of its parallel bent rows of 8 numbers make 260.—Also the parallel bent rows next to the above-mentioned, which are shortened to 3 numbers ascending, and 3 descending, &c. as from 53 to 4 ascending, and from 29 to 44 descending, make, with the two corner numbers, 260.—Also the 2 numbers 14, 61 ascending, and 36, 19 descending, with the lower 4 numbers situated like them, viz. 50, 1, descending, and 32, 47, ascending, make 260.—And, lastly, the 4 corner numbers, with the 4 middle numbers, make 260.

A Magic Square of Squares.

200	217	232	249	8	25	40	57	72	89	104	121	136	153	168	181
58	39	26	7	250	231	218	199	186	167	154	135	122	103	90	71
198	219	230	251	6	27	38	59	70	91	102	123	134	155	166	187
60	37	28	5	252	229	220	197	188	165	156	133	124	101	92	69
201	216	233	248	9	24	41	56	73	88	105	120	137	152	169	184
55	42	23	10	247	234	215	202	183	170	151	138	119	106	87	74
20	214	225	246	11	22	43	54	75	86	107	118	139	150	171	182
53	44	21	12	245	236	213	204	181	172	149	140	117	108	85	76
205	212	237	244	13	20	45	52	77	84	109	116	141	148	173	180
51	46	19	14	243	238	241	206	179	174	147	142	115	110	83	78
207	240	239	242	15	18	47	50	79	82	111	114	143	146	175	178
49	48	17	16	241	240	209	208	177	176	145	144	113	112	81	80
196	221	228	253	4	29	36	61	68	93	100	125	132	157	164	189
62	35	30	3	254	227	222	195	190	163	158	131	126	99	94	67
194	223	226	255	2	31	34	63	66	95	98	127	130	159	162	191
64	33	32	1	256	225	224	193	192	161	160	129	128	97	96	65

View larger image here

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So this magical square seems perfect in its kind. But these are not all its properties; there are 5 other curious ones, which, at some other time, I will explain to you. [327]

Mr. Logan then shewed me an old arithmetical book, in quarto, wrote, I think, by one Stifelius, which contained a square of 16, that he said he should imagine must have been a work of great labour; but if I forget not, it had only the common properties of making the same sum, viz. 2056, in every row, horizontal, vertical, and diagonal. Not willing to be out-done by Mr. Stifelius, even in the size of my square, I went home, and made, that evening, the following magical square of 16, which, besides having all the properties of the foregoing square of 8, *i. e.* it would make the 2056 in all the same rows and diagonals, had this added, that a four-square hole being cut in a piece of paper of such a size as to take in and show through it just 16 of the little squares, when laid on the greater square, the sum of the 16 numbers so appearing through the hole, wherever it was placed on the greater square, should likewise make 2056. This I sent to our friend the next morning, who, after some days, sent it back in a letter with these words: "I return to thee thy astonishing or most stupendous piece of the magical square, in which——" but the compliment is too extravagant, and therefore, for his sake, as well as my own, I ought not to repeat it. Nor is it necessary; for I make no question but you will readily allow this square of 16 to be the most magically magical of any magic square ever made by any magician. (*See the Plate.*)

I did not, however, end with squares, but composed also a magic circle, consisting of 8 concentric circles, and 8 radial rows, filled with a series of numbers from 12 to 75 inclusive, so disposed as that the numbers of each circle, or each radial [328]
row, being added to the central number 12, they make exactly 360, the number of degrees in a circle; and this circle had, moreover, all the properties of the square of 8. If you desire it, I will send it; but at present, I believe, you have enough on this subject. I am, &c.

B. FRANKLIN.

TO THE SAME.

Magical Circle.

Sir,

I am glad the perusal of the magical squares afforded you any amusement. I now send you the magical circle. (*See Plate* XII.)

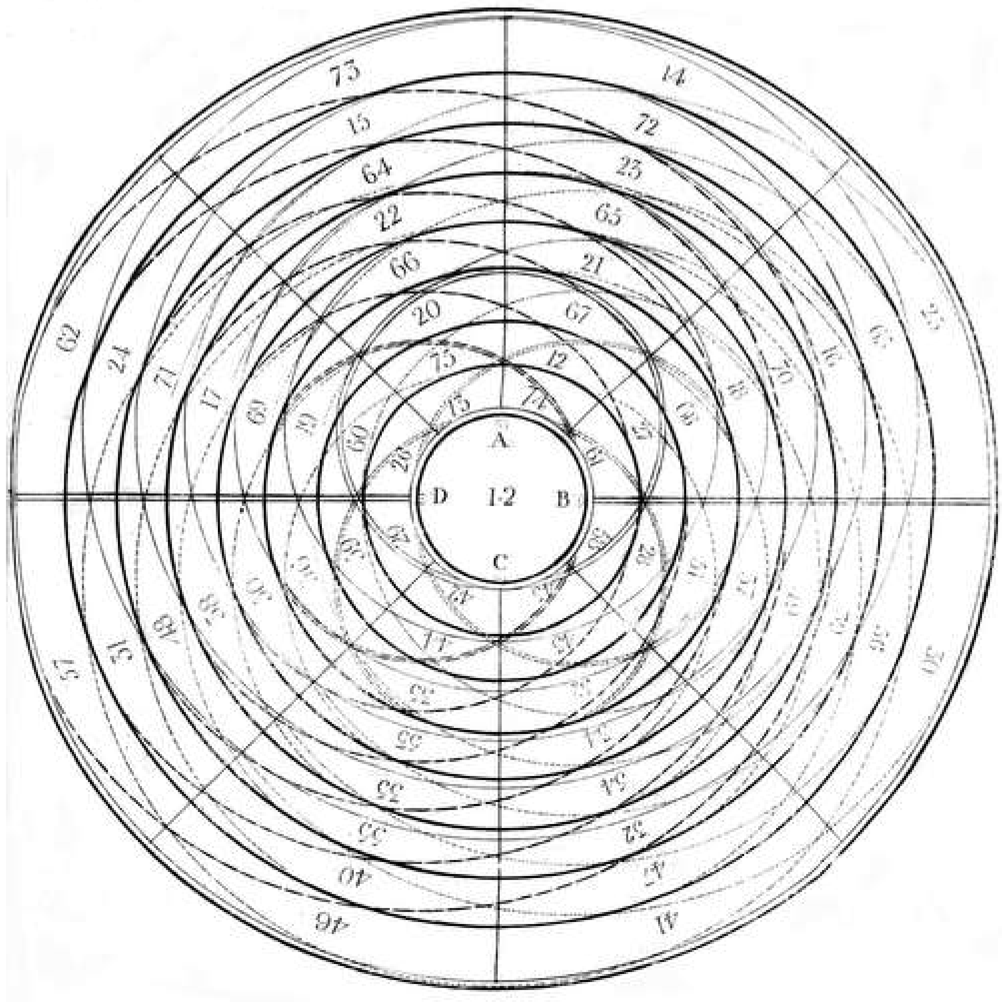
Its properties, besides those mentioned in my former, are these.

Half the number in any radial row, added with half the central number, make 180, equal to the number of degrees in a semi-circle.

Also half the numbers in any one of the concentric circles, taken either above or below the horizontal double line, with half the central number, make 180.

And if any four adjoining numbers, standing nearly in a square, be taken from any part, and added with half the central number, they make 180.

A Magic Circle of Circles



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There are, moreover, included four other sets of circular spaces, excentric with respect to the first, each of these sets containing five spaces. The centres of the circles that bound them, are at A, B, C, and D. Each set, for the more easy distinguishing them from the first, are drawn with a different coloured ink, red, blue, green, and yellow.[62] [329]

These sets of excentric circular spaces intersect those of the concentric, and each other; and yet the numbers contained in each of the twenty excentric spaces, taken all around, make, with the central number, the same sum as those in each of the 8 concentric, viz. 360. The halves, also of those drawn from the centres A and C, taken above or below the double horizontal line, and of those drawn from centres B and D, taken to the right or left of the vertical line, do, with half the central number, make just 180.

It may be observed, that there is not one of the numbers but what belongs at least to two of the different circular spaces; some to three, some to four, some to five; and yet they are all so placed as never to break the required number 360, in any of the 28 circular spaces within the primitive circle.

These interwoven circles make so perplexed an appearance, that it is not easy for the eye to trace every circle of numbers one would examine, through all the maze of circles intersected by it; but if you fix one foot of the compasses in either of the centres, and extend the other to any number in the circle you would examine belonging to that centre, the moving foot will point the others out, by passing round over all the numbers of that circle successively. I am, &c.

B. FRANKLIN.

FOOTNOTE:

[62] In the plate they are distinguished by dashed or dotted lines, as different as the engraver could well make them.

 [330]

Describing a new musical Instrument composed of Glasses.

London, July 13, 1762.

Rev. Sir,

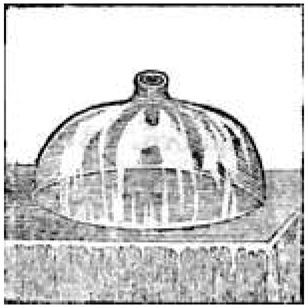
I once promised myself the pleasure of seeing you at Turin, but as that is not now likely to happen, being just about returning to my native country, America, I sit down to take leave of you (among others of my European friends that I cannot see) by writing.

I thank you for the honourable mention you have so frequently made of me in your letters to Mr. Collinson and others, for the generous defence you undertook and executed with so much success, of my electrical opinions; and for the valuable present you have made me of your new work, from which I have received great information and pleasure. I wish I could in return entertain you with any thing new of mine on that subject; but I have not lately pursued it. Nor do I know of any one here that is at present much engaged in it.

Perhaps, however, it may be agreeable to you, as you live in a musical country, to have an account of the new instrument lately added here to the great number that charming science was before possessed of.—As it is an instrument that seems peculiarly adapted to Italian music, especially that of the soft and plaintive kind, I will endeavour to give you such a description of it, and of the manner of constructing it, that you or any of your friends, may be enabled to imitate it, if you incline so to do, without being at the expence and trouble of the many experiments I have made in endeavouring to bring it to its present perfection.

You have doubtless heard the sweet tone that is drawn from a drinking glass, by passing a wet finger round its brim. [331]
One Mr. Puckeridge, a gentleman from Ireland, was the first who thought of playing tunes, formed of these tones. He collected a number of glasses of different sizes, fixed them near each other on a table, and tuned them by putting into them water more or less, as each note required. The tones were brought out by passing his fingers round their brims.—He was unfortunately burned here, with his instrument, in a fire which consumed the house he lived in. Mr. E. Delaval, a most ingenious member of our Royal Society, made one in imitation of it, with a better choice and form of glasses, which was the first I saw or heard. Being charmed with the sweetness of its tones, and the music he produced from it, I wished only to see the glasses disposed in a more convenient form, and brought together in a narrower compass, so as to admit of a greater number of tones, and all within reach of hand to a person sitting before the instrument, which I accomplished, after various intermediate trials, and less commodious forms, both of glasses and construction, in the following manner.

The glasses are blown as near as possible in the form of hemispheres, having each an open neck or socket in the middle. The thickness of the glass near the brim about a tenth of an inch, or hardly quite so much, but thicker as it comes nearer the neck, which in the largest glasses is about an inch deep, and an inch and half wide within, these dimensions lessening as the glasses themselves diminish in size, except that the neck of the smallest ought not to be shorter than half [332]
an inch.—The largest glass is nine inches diameter, and the smallest three inches. Between these three are twenty-three different sizes, differing from each other a quarter of an inch in diameter.—To make a single instrument there should be at least six glasses blown of each size; and out of this number one may probably pick thirty-seven glasses (which are sufficient for three octaves with all the semitones) that will be each either the note one wants or a little sharper than that note, and all fitting so well into each other as to taper pretty regularly from the largest to the smallest. It is true there are



not thirty-seven sizes, but it often happens that two of the same size differ a note or half note in tone, by reason of a difference in thickness, and these may be placed one in the other without sensibly hurting the regularity of the taper form.

The glasses being chosen, and every one marked with a diamond the note you intend it for, they are to be tuned by diminishing the thickness of those that are too sharp. This is done by grinding them round from the neck towards the brim, the breadth of one or two inches, as may be required; often trying the glass by a well tuned harpsichord, comparing the tone drawn from the glass by your finger, with the note you want, as sounded by that string of the harpsichord. When you come nearer the matter, be careful to wipe the glass clean and dry before each trial, because the tone is something flatter when the glass is wet, than it will be when dry;—and grinding a very little between each trial, you will thereby tune to great exactness. The more care is necessary in this, because if you go below your [333] required tone, there is no sharpening it again but by grinding somewhat off the brim, which will afterwards require polishing, and thus increase the trouble.

The glasses being thus tuned, you are to be provided with a case for them, and a spindle on which they are to be fixed. My case is about three feet long, eleven inches every way wide within at the biggest end, and five inches at the smallest end; for it tapers all the way, to adapt it better to the conical figure of the set of glasses. This case opens in the middle of its height, and the upper part turns up by hinges fixed behind. The spindle, which is of hard iron, lies horizontally from end to end of the box within, exactly in the middle, and is made to turn on brass gudgeons at each end. It is round, an inch diameter at the thickest end, and tapering to a quarter of an inch at the smallest.—A square shank comes from its thickest end through the box, on which shank a wheel is fixed by a screw. This wheel serves as a fly to make the motion equable, when the spindle, with the glasses, is turned by the foot like a spinning-wheel. My wheel is of mahogany, eighteen inches diameter, and pretty thick, so as to conceal near its circumference about 25lb of lead.—An ivory pin is fixed in the face of this wheel, and about four inches from the axis. Over the neck of this pin is put the loop of the string that comes up from the moveable step to give it motion. The case stands on a neat frame with four legs.

To fix the glasses on the spindle, a cork is first to be fitted in each neck pretty tight, and projecting a little without the neck, that the neck of one may not touch the inside of another when put together, for that would make a jarring.—These corks are to be perforated with holes of different diameters, so as to suit that part of the spindle on which they are to be [334] fixed. When a glass is put on, by holding it stiffly between both hands, while another turns the spindle, it may be gradually brought to its place. But care must be taken that the hole be not too small, lest in forcing it up the neck should split; nor too large, lest the glass not being firmly fixed should turn or move on the spindle, so as to touch and jar against its neighbouring glass. The glasses thus are placed one in another, the largest on the biggest end of the spindle which is to the left hand; the neck of this glass is towards the wheel, and the next goes into it in the same position, only about an inch of its brim appearing beyond the brim of the first; thus proceeding, every glass when fixed shews about an inch of its brim (or three quarters of an inch, or half an inch, as they grow smaller) beyond the brim of the glass that contains it; and it is from these exposed parts of each glass that the tone is drawn, by laying a finger upon one of them as the spindle and glasses turn round.

My largest glass is G, a little below the reach of a common voice, and my highest G, including three compleat octaves.—To distinguish the glasses the more readily to the eye, I have painted the apparent parts of the glasses within side, every semitone white, and the other notes of the octave with the seven prismatic colours, *viz.* C, red; D, orange; E, yellow; F, green; G, blue; A, indigo; B, purple; and C, red again;—so that glasses of the same colour (the white excepted) are always octaves to each other.

This instrument is played upon, by sitting before the middle of the set of glasses as before the keys of a harpsichord, turning them with the foot, and wetting them now and then with a spunge and clean water. The fingers should be first a little soaked in water, and quite free from all greasiness; a little fine chalk upon them is sometimes useful, to make them catch the glass and bring out the tone more readily. Both hands are used, by which means different parts are played together.—Observe, that the tones are best drawn out when the glasses turn *from* the ends of the fingers, not when they turn *to* them. [335]

The advantages of this instrument are, that its tones are incomparably sweet beyond those of any other; that they may be swelled and softened at pleasure by stronger or weaker pressures of the finger, and continued to any length; and that the instrument, being once well tuned, never again wants tuning.

In honour of your musical language, I have borrowed from it the name of this instrument, calling it the Armonica.

With great esteem and respect, I am, &c.

B. FRANKLIN.

TO A FRIEND[63].

Respecting the best Mediums for conveying Sound.

July 20, 1762.

Dear Sir,

I have perused your paper on sound, and would freely mention to you, as you desire it, every thing that appeared to me to need correction:—But nothing of that kind occurs to me, unless it be, where you speak of the air as "the *best* medium for conveying sound." Perhaps this is speaking rather too positively, if there be, as I think there are, some other mediums that will convey it farther and more readily.—It is a well-known experiment, that the scratching of a pin at one end of a long piece of timber, may be heard by an ear applied near the other end, though it could not be heard at the same distance through the air.—And two stones being struck smartly together under water, the stroke may be heard at a greater distance by an ear also placed under water, than it can be heard through the air. I think I have heard it near a mile; how much farther it may be heard I know not; but suppose a great deal farther, because the sound did not seem faint, as if at a distance, like distant sounds through air, but smart and strong, and as if present just at the ear.—I wish you would repeat these experiments now you are upon the subject, and add your own observations.—And if you were to repeat, with your naturally exact attention and observation, the common experiment of the bell in the exhausted receiver, possibly something new may occur to you, in considering, [336]

1. Whether the experiment is not ambiguous; *i. e.* whether the gradual exhausting of the air, as it creates an increasing difference of pressure on the outside, may not occasion in the glass a difficulty of vibrating, that renders it less fit to

communicate to the air without, the vibrations that strike it from within; and the diminution of the sound arise from this cause, rather than from the diminution of the air?

2. Whether, as the particles of air themselves are at a distance from each other, there must not be some medium between them, proper for conveying sound, since otherwise it would stop at the first particle? [337]

3. Whether the great difference we experience in hearing sounds at a distance, when the wind blows towards us from the sonorous body, or towards that from us, can be well accounted for by adding to or subtracting from the swiftness of sound, the degree of swiftness that is in the wind at the time? The latter is so small in proportion, that it seems as if it could scarce produce any sensible effect, and yet the difference is very great. Does not this give some hint, as if there might be a subtle fluid, the conductor of sound, which moves at different times in different directions over the surface of the earth, and whose motion may perhaps be much swifter than that of the air in our strongest winds; and that in passing through air, it may communicate that motion to the air which we call wind, though a motion in no degree so swift as its own?

4. It is somewhere related, that a pistol fired on the top of an exceeding high mountain, made a noise like thunder in the valleys below. Perhaps this fact is not exactly related: but if it is, would not one imagine from it, that the rarer the air, the greater sound might be produced in it from the same cause?

5. Those balls of fire which are sometimes seen passing over a country, computed by philosophers to be often thirty miles high at least, sometimes burst at that height; the air must be exceeding rare there, and yet the explosion produces a sound that is heard at that distance, and for seventy miles round on the surface of the earth, so violent too as to shake buildings, and give an apprehension of an earthquake. Does not this look as if a rare atmosphere, almost a vacuum, was [338] no bad conductor of sound?

I have not made up my own mind on these points, and only mention them for your consideration, knowing that every subject is the better for your handling it.

With the greatest esteem, I am, &c.

B. FRANKLIN.

FOOTNOTE:

[63] Mr. Oliver Neave. *Editor.*

TO LORD KAIMS, AT EDINBURGH.

On the Harmony and Melody of the old Scotch Tunes.

June 2, 1765.

**** In my passage to America I read your excellent work, the *Elements of Criticism*, in which I found great entertainment. I only wished you had examined more fully the subject of music, and demonstrated that the pleasure artists feel in hearing much of that composed in the modern taste, is not the natural pleasure arising from melody or harmony of sounds, but of the same kind with the pleasure we feel on seeing the surprising feats of tumblers and rope-dancers, who execute difficult things. For my part I take this to be really the case, and suppose it the reason why those who are unpractised in music, and therefore unacquainted with those difficulties, have little or no pleasure in hearing this music. Many pieces of it are mere compositions of tricks. I have sometimes, at a concert, attended by a common audience, placed myself so as to see all their faces, and observed no signs of pleasure in them during the performance of a great part that [339]
was admired by the performers themselves; while a plain old Scotch tune, which they disdained, and could scarcely be prevailed on to play, gave manifest and general delight. Give me leave, on this occasion, to extend a little the sense of your position, that "melody and harmony are separately agreeable, and in union delightful," and to give it as my opinion, that the reason why the Scotch tunes have lived so long, and will probably live for ever (if they escape being stifled in modern affected ornament) is merely this, that they are really compositions of melody and harmony united, or rather that their melody is harmony. I mean the simple tunes sung by a single voice. As this will appear paradoxical, I must explain my meaning. In common acceptation, indeed, only an agreeable *succession* of sounds is called *melody*, and only the *co-existence* of agreeable sounds, *harmony*. But since the memory is capable of retaining for some moments a perfect idea of the pitch of a past sound, so as to compare with it the pitch of a succeeding sound, and judge truly of their agreement or disagreement, there may and does arise from thence a sense of harmony between the present and past sounds, equally pleasing with that between two present sounds. Now the construction of the old Scotch tunes is this, that almost every succeeding emphatical note is a third, a fifth, an octave, or in short some note that is in concord with the preceding note. Thirds are chiefly used, which are very pleasing concords. I use the word *emphatical* to distinguish those notes which have a stress laid on them in singing the tune, from the lighter connecting notes, that serve merely, like grammar articles in common speech, to tack the whole together.

That we have a most perfect idea of a sound just past, I might appeal to all acquainted with music, who know how easy [340]
it is to repeat a sound in the same pitch with one just heard. In tuning an instrument, a good ear can as easily determine that two strings are in unison by sounding them separately, as by sounding them together; their disagreement is also as easily, I believe I may say more easily and better distinguished, when sounded separately; for when sounded together, though you know by the beating that one is higher than the other, you cannot tell which it is. I have ascribed to memory the ability of comparing the pitch of a present tone with that of one past. But if there should be, as possibly there may be, something in the ear, similar to what we find in the eye, that ability would not be entirely owing to memory. Possibly the vibrations given to the auditory nerves by a particular sound may actually continue some time after the cause of those vibrations is past, and the agreement or disagreement of a subsequent sound become by comparison with them more discernible. For the impression made on the visual nerves by a luminous object will continue for twenty or thirty seconds. Sitting in a room, look earnestly at the middle of a window a little while when the day is bright, and then shut your eyes; the figure of the window will still remain in the eye, and so distinct that you may count the panes. A remarkable circumstance attending this experiment, is, that the impression of forms is better retained than that of colours; for after the eyes are shut, when you first discern the image of the window, the panes appear dark, and the cross bars of the sashes, with the window frames and walls, appear white or bright; but if you still add to the darkness in the eyes by covering them [341]
with your hand, the reverse instantly takes place, the panes appear luminous and the cross bars dark. And by removing the

hand they are again reversed. This I know not how to account for.—Nor for the following; that after looking long through green spectacles, the white paper of a book will on first taking them off appear to have a blush of red; and after long looking through red glasses, a greenish cast; this seems to intimate a relation between green and red not yet explained. Farther, when we consider by whom these ancient tunes were composed, and how they were first performed, we shall see that such harmonical successions of sounds was natural and even necessary in their construction. They were composed by the minstrels of those days to be played on the harp accompanied by the voice. The harp was strung with wire, which gives a sound of long continuance, and had no contrivance like that in the modern harpsichord, by which the sound of the preceding could be stopt, the moment a succeeding note began. To avoid actual discord, it was therefore necessary that the succeeding emphatic note should be a chord with the preceding, as their sounds must exist at the same time. Hence arose that beauty in those tunes that has so long pleased, and will please for ever, though men scarce know why. That they were originally composed for the harp, and of the most simple kind, I mean a harp without any half notes but those in the natural scale, and with no more than two octaves of strings, from C to C, I conjecture from another circumstance, which is, that not one of those tunes, really ancient, has a single artificial half note in it, and that in tunes where it was most convenient for the voice to use the middle notes of the harp, and place the key in F, there the B, which if used should be a [342]
B flat, is always omitted, by passing over it with a third. The connoisseurs in modern music will say, I have no taste, but I cannot help adding, that I believe our ancestors, in hearing a good song, distinctly articulated, sung to one of those tunes, and accompanied by the harp, felt more real pleasure than is communicated by the generality of modern operas, exclusive of that arising from the scenery and dancing. Most tunes of late composition, not having this natural harmony united with their melody, have recourse to the artificial harmony of a bass, and other accompanying parts.[64] This support, in my [343]
opinion, the old tunes do not need, and are rather confused than aided by it. Whoever has heard James Oswald play them on his violoncello, will be less inclined to dispute this with me. I have more than once seen tears of pleasure in the eyes of his auditors; and yet, I think, even *his* playing those tunes would please more, if he gave them less modern ornament.

I am, &c.

B. FRANKLIN.

FOOTNOTE:

[64] The celebrated Rousseau in his Dictionnaire de Musique, printed 1768, appears to have similar sentiments of our modern harmony, viz.

"M. Rameau prétend que les dessus d'une certaine simplicité suggerènt naturellement leur basse, & qu'un homme ayant l'oreille juste & non exercée, entonnera naturellement cette basse. C'est-là un préjugé de musicien, démenti par toute expérience. Non seulement celui qui n'aura jamais entendu ni basse ni harmonie, ne trouvera, de lui-même, ni cette harmonie ni cette basse; mais elles lui déplairont si on les lui fait entendre, & il aimera beaucoup mieux le simple unisson.

Quand on songe que, de tous les peuples de la terre, qui tous ont une musique & un chant, les Européens sont les seuls qui aient une harmonie des accords, & qui trouvent ce mélange agréable; quand on songe que le monde a duré tant de siècles, sans que, de toutes les nations qui ont cultivé les beaux arts, aucune ait connu cette harmonie; qu'aucun animal, qu'aucun oiseau, qu'aucan être dans la nature ne produit d'autre accord que l'unisson, ni d'autre musique que la mélodie; que les langues orientales, si sonores, si musicales; que les oreilles Grecques, si délicates, si sensibles, exercées avec tant d'art, n'ont jamais guidé ces peuples voluptueax & passionnés vers notre harmonie; que, sans elle, leur musique avoits des effets si prodigieux: qu'avec elle la nôtre en a de si foibles: qu'entin il étoit réservé à des peuples du Nord, dont les organes durs & grossiers sont plus touchés de l'éclat & du bruit des voix, que de la douceur des accens, & de la mélodie des inflexions, de faire cette grande découverte, & de la donner pour principe à toutes les régles de l'art; quand, dis-je, on fait attention à tout cela, il est bien difficile de ne pas soupçonner que toute notre harmonie n'est qu'une invention gothique & barbare, dont nous ne nous fussions jamais avisés, si nous fussions été plus sensibles aux véritables beautés de l'art, & à la musique vraiment naturelle."

TO MR. PETER FRANKLIN, NEWPORT, NEW ENGLAND.

On the Defects of Modern Music.

[No date.]

Dear Brother,

**** I like your ballad, and think it well adapted for your purpose of discountenancing expensive foppery, and encouraging industry and frugality. If you can get it generally sung in your country, it may probably have a good deal of the effect you hope and expect from it. But as you aimed at making it general, I wonder you chose so uncommon a measure in poetry, that none of the tunes in common use will suit it. Had you fitted it to an old one, well known, it must have spread much faster than I doubt it will do from the best new tune we can get composed for it. I think too, that if you [344] had given it to some country girl in the heart of the Massachusets, who has never heard any other than psalm tunes, or *Chevy Chace*, the *Children in the Wood*, the *Spanish Lady*, and such old simple ditties, but has naturally a good ear, she might more probably have made a pleasing popular tune for you, than any of our masters here, and more proper for your purpose, which would best be answered, if every word could as it is sung be understood by all that hear it, and if the emphasis you intend for particular words could be given by the singer as well as by the reader; much of the force and impression of the song depending on those circumstances. I will however get it as well done for you as I can.

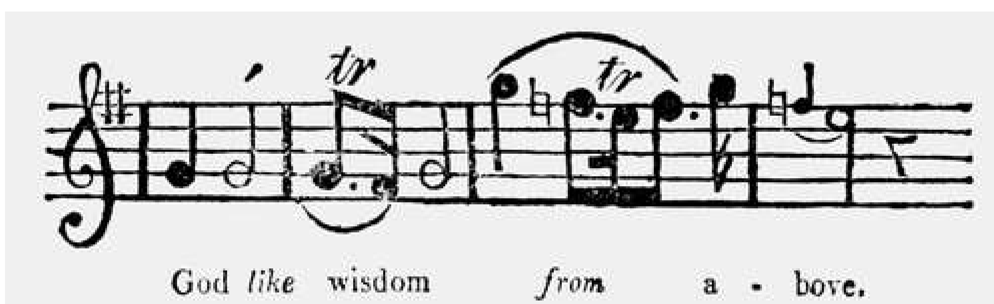
Do not imagine that I mean to depreciate the skill of our composers of music here; they are admirable at pleasing *practised* ears, and know how to delight *one another*; but, in composing for songs, the reigning taste seems to be quite out of nature, or rather the reverse of nature, and yet like a torrent, hurries them all away with it; one or two perhaps only excepted.

You, in the spirit of some ancient legislators, would influence the manners of your country by the united powers of poetry and music. By what I can learn of *their* songs, the music was simple, conformed itself to the usual pronunciation of words, as to measure, cadence or emphasis, &c. never disguised and confounded the language by making a long syllable short, or a short one long when sung; their singing was only a more pleasing, because a melodious manner of speaking; it was capable of all the graces of prose oratory, while it added the pleasure of harmony. A modern song, on the contrary, [345] neglects all the proprieties and beauties of common speech, and in their place introduces its *defects* and *absurdities* as so many graces. I am afraid you will hardly take my word for this, and therefore I must endeavour to support it by proof. Here is the first song I lay my hand on. It happens to be a composition of one of our greatest masters, the ever-famous Handel. It is not one of his juvenile performances, before his taste could be improved and formed: it appeared when his reputation was at the highest, is greatly admired by all his admirers, and is really excellent in its kind. It is called, "The additional favourite song in Judas Maccabeus." Now I reckon among the defects and improprieties of common speech, the following, viz.

1. *Wrong placing the accent or emphasis*, by laying it on words of no importance, or on wrong syllables.
2. *Drawling*; or extending the sound of words or syllables beyond their natural length.
3. *Stuttering*; or making many syllables of one.
4. *Unintelligibleness*; the result of the three foregoing united.
5. *Tautology*; and
6. *Screaming*, without cause.

For the *wrong placing of the accent, or emphasis*, see it on the word *their* instead of being on the word *vain*.

And on the word *from*, and the wrong syllable *like*. [346]



For the *drawling*, see the last syllable of the word *wounded*.

And in the syllable *wis*, and the word *from*, and syllable *bove*

For the *stuttering*, see the words *ne'er relieve*, in

Here are four syllables made of one, and eight of three; but this is moderate. I have seen in another song that I cannot now find, seventeen syllables made of three, and sixteen of one: the latter I remember was the word *charms*; viz. *cha, a, a,* [347] *a, a, a, a, a, a, a, a, a, a, a, a, a, arms*. Stammering with a witness!

For the *unintelligibleness*; give this whole song to any taught singer, and let her sing it to any company that have never heard it; you shall find they will not understand three words in ten. It is therefore, that at the oratorios and operas one sees with books in their hands all those who desire to understand what they hear sung by even our best performers.

For the *tautology*; you have, *with their vain mysterious art*, twice repeated; *magic charms can ne'er relieve you*, three times. *Nor can heal the wounded heart*, three times. *Godlike wisdom from above*, twice; and, *this alone can deceive you*, two or three times. But this is reasonable when compared with *the Monster Polypheme, the Monster Polypheme*, a hundred times over and over, in his admired *Acis and Galatea*.

As to the *screaming*; perhaps I cannot find a fair instance in this song; but whoever has frequented our operas will remember many. And yet here methinks the words *no* and *e'er*, when sung to these notes, have a little of the air of *screaming*, and would actually be screamed by some singers.

I send you inclosed the song with its music at length. Read the words without the repetitions. Observe how few they are, and what a shower of notes attend them: you will then perhaps be inclined to think with me, that though the words [348]
might be the principal part of an ancient song, they are of small importance in a modern one; they are in short only *a pretence for singing*.

I am, as ever,

Your affectionate brother,

B. FRANKLIN.

P. S. I might have mentioned *inarticulation* among the defects in common speech that are assumed as beauties in modern singing. But as that seems more the fault of the singer than of the composer, I omitted it in what related merely to the composition. The fine singer in the present mode, stifles all the hard consonants, and polishes away all the rougher parts of words that serve to distinguish them one from another; so that you hear nothing but an admirable pipe, and understand no more of the song, than you would from its tune played on any other instrument. If ever it was the ambition of musicians to make instruments that should imitate the human voice, that ambition seems now reversed, the voice aiming to be like an instrument. Thus wigs were first made to imitate a good natural head of hair;—but when they became fashionable, though in unnatural forms, we have seen natural hair dressed to look like wigs.

Description of the Process to be observed in making large Sheets of Paper in the Chinese Manner, with one smooth surface. [65] [349]

In Europe to have a large surface of paper connected together and smooth on one side, the following operations are performed.

1. A number of small sheets are to be made separately.

2. These are to be couched, one by one, between blankets.

3. When a heap is formed it must be put under a strong press, to force out the water.

4. Then the blankets are to be taken away, one by one, and the sheets hung up to dry.

5. When dry they are to be again pressed, or if to be sized, they must be dipped into size made of warm water, in which glue and alum are dissolved.

6. They must then be pressed again to force out the superfluous size.

7. They must then be hung up a second time to dry, which, if the air happens to be damp, requires some days.

8. They must then be taken down, laid together, and again pressed.

9. They must be pasted together at their edges.

10. The whole must be glazed by labour, with a flint.

In China, if they would make sheets, suppose of four and a half ells long and one and a half ells wide, they have two large vats, each five ells long and two ells wide, made of brick, lined with a plaster that holds water. In these the stuff is mixed ready to work. [350]

Between these vats is built a kiln or stove, with two inclining sides; each side something larger than the sheet of paper; they are covered with a fine stucco that takes a polish, and are so contrived as to be well heated by a small fire circulating in the walls.

The mould is made with thin but deep sides, that it may be both light and stiff: it is suspended at each end with cords that pass over pullies fastened to the cieling, their ends connected with a counterpoise nearly equal the weight of the mould.

Two men, one at each end of the mould, lifting it out of the water by the help of the counterpoise, turn it and apply it with the stuff to the smooth surface of the stove, against which they press it, to force out great part of the water through the wires. The heat of the wall soon evaporates the rest, and a boy takes off the dried sheet by rolling it up. The side next the stove receives the even polish of the stucco, and is thereby better fitted to receive the impression of fine prints. If a degree of sizing is required, a decoction of rice is mixed with the stuff in the vat.

Thus the great sheet is obtained, smooth and sized, and a number of the European operations saved.

As the stove has two polished sides, and there are two vats, the same operation is at the same time performed by two other men at the other vat; and one fire serves.

FOOTNOTE:

[65] Communicated by Dr. Franklin to the American Philosophical Society, in which it was read, June 20, 1788. *Editor.*

On Modern Innovations in the English Language and in Printing.

*Philadelphia, Dec.*26, 1789.

Dear Sir,

I received, some time since, your *Dissertations on the English Language*. It is an excellent work, and will be greatly useful in turning the thoughts of our countrymen to correct writing. Please to accept my thanks for it, as well as for the great honour you have done me in its dedication. I ought to have made this acknowledgment sooner, but much indisposition prevented me.

I cannot but applaud your zeal for preserving the purity of our language both in its expression and pronunciation, and in correcting the popular errors several of our states are continually falling into with respect to both. Give me leave to mention some of them, though possibly they may already have occurred to you. I wish, however, that in some future publication of yours, you would set a discountenancing mark upon them. The first I remember, is the word *improved*. When I left New England in the year 1723, this word had never been used among us, as far as I know, but in the sense of *ameliorated*, or *made better*, except once in a very old book of Dr. Mather's, entitled *Remarkable Providences*. As that man wrote a very obscure hand, I remember that when I read that word in his book used instead of the word *employed*, I conjectured that it was an error of the printer, who had mistaken a short *l* in the writing for an *r*, and a *y* with too short a tail for a *v*, whereby *employed* was converted into *improved*: but when I returned to Boston in 1733, I found this change [352] had obtained favour, and was then become common; for I met with it often in perusing the newspapers, where it frequently made an appearance rather ridiculous. Such, for instance, as the advertisement of a country house to be sold, which had been many years *improved* as a tavern; and in the character of a deceased country gentleman, that he had been, for more than thirty years, *improved* as a justice of the peace. This use of the word *improve* is peculiar to New England, and not to be met with among any other speakers of English, either on this or the other side of the water.

During my late absence in France, I find that several other new words have been introduced into our parliamentary language. For example, I find a verb from the substantive *notice*. *I should not have* noticed *this, were it not that the gentleman*, &c. Also another verb, from the substantive *advocate*; *The gentleman who* advocates, *or who has* advocated *that motion*,&c. Another from the substantive *progress*, the most awkward and abominable of the three: *the committee having* progressed, *resolved to adjourn*. The word *opposed*, though not a new word, I find used in a new manner, as, *the gentlemen who are* opposed *to this measure, to which I have also myself always been* opposed. If you should happen to be of my opinion with respect to these innovations, you will use your authority in reprobating them.

The Latin language, long the vehicle used in distributing knowledge among the different nations of Europe, is daily more and more neglected; and one of the modern tongues, viz. French, seems, in point of universality, to have supplied its place. It is spoken in all the courts of Europe; and most of the literati, those even who do not speak it, have acquired [353] enough knowledge of it, to enable them easily to read the books, that are written in it. This gives a considerable advantage to that nation. It enables its authors to inculcate and spread through other nations, such sentiments and opinions, on important points, as are most conducive to its interests, or which may contribute to its reputation, by promoting the common interests of mankind. It is, perhaps, owing to its being written in French, that Voltaire's Treatise on Toleration has had so sudden and so great an effect on the bigotry of Europe, as almost entirely to disarm it. The general use of the

French language has likewise a very advantageous effect on the profits of the bookselling branch of commerce, it being well known, that the more copies can be sold, that are struck off from one composition of types, the profits increase in a much greater proportion, than they do in making a greater number of pieces in any other kind of manufacture. And at present there is no capital town in Europe without a French bookseller's shop corresponding with Paris. Our English bids fair to obtain the second place. The great body of excellent printed sermons in our language, and the freedom of our writings on political subjects, have induced a great dumber of divines of different sects and nations, as well as gentlemen concerned in public affairs, to study it, so far at least as to read it. And if we were to endeavour the facilitating its progress, the study of our tongue might become much more general. Those, who have employed some part of their time in learning a new language, must have frequently observed, that while their acquaintance with it was imperfect, difficulties, [354] small in themselves, operated as great ones in obstructing their progress. A book, for example, ill printed, or a pronunciation in speaking, not well articulated, would render a sentence unintelligible, which, from a clear print, or a distinct speaker, would have been immediately comprehended. If, therefore, we would have the benefit of seeing our language more generally known among mankind, we should endeavour to remove all the difficulties, however small, that discourage the learning of it. But I am sorry to observe, that, of late years, those difficulties, instead of being diminished, have been augmented.

In examining the English books, that were printed between the restoration and the accession of George the Second, we may observe, that all the substantives were begun with a capital, in which we imitated our mother tongue, the German. This was more particularly useful to those, who were not well acquainted with the English, there being such a prodigious number of our words, that are both verbs and substantives, and spelt in the same manner, though often accented differently in pronunciation. This method has, by the fancy of printers, of late years been entirely laid aside; from an idea, that suppressing the capitals shows the character to greater advantage; those letters prominent above the line, disturbing its even, regular appearance. The effect of this change is so considerable, that a learned man of France, who used to read our books, though not perfectly acquainted with our language, in conversation with me on the subject of our authors, attributed the greater obscurity he found in our modern books, compared with those of the period above mentioned, to a change of style for the worse in our writers: of which mistake I convinced him, by marking for him each substantive with [355] a capital, in a paragraph, which he then easily understood, though before he could not comprehend it. This shows the inconvenience of that pretended improvement.

From the same fondness for an uniform and even appearance of characters in the line, the printers have of late banished also the Italic types, in which words, of importance to be attended to in the sense of the sentence, and words, on which an emphasis should be put in reading, used to be printed. And lately, another fancy has induced other printers to use the round *s* instead of the long one, which formerly served well to distinguish a word readily by its varied appearance. Certainly the omitting this prominent letter makes a line appear more even, but renders it less immediately legible; as the paring of all men's noses might smooth and level their faces, but would render their physiognomies less distinguishable. Add to all these improvements backwards, another modern fancy, that *grey* printing is more beautiful than black. Hence the English new books are printed in so dim a character, as to be read with difficulty by old eyes; unless in a very strong light and with good glasses. Whoever compares a volume of the Gentleman's Magazine, printed between the years 1731 and 1740, with one of those printed in the last ten years, will be convinced of the much greater degree of perspicuity given by black than by the grey. Lord Chesterfield pleasantly remarked this difference to Faulkener, the printer of the Dublin Journal, who was vainly making encomiums on his own paper, as the most complete of any in the world. "But Mr. Faulkener," says my lord, "don't you think it might be still farther improved, by using paper and ink not quite so near of a [356] colour?"—For all these reasons, I cannot but wish, that our American printers would, in their editions, avoid these fancied improvements, and thereby render their works more agreeable to foreigners in Europe, to the great advantage of our bookselling commerce.

Farther, to be more sensible of the advantage of clear and distinct printing, let us consider the assistance it affords in reading well aloud to an auditory. In so doing, the eye generally slides forward three or four words before the voice. If the sight clearly distinguishes what the coming words are, it gives time to order the modulation of the voice to express them properly. But if they are obscurely printed or disguised, by omitting the capitals and long *ſ*'s, or otherwise, the reader is apt to modulate wrong; and finding he has done so, he is obliged to go back and begin the sentence again; which lessens the pleasure of the hearers. This leads me to mention an old error in our mode of printing. We are sensible, that when a question is met with in the reading, there is a proper variation to be used in the management of the voice. We have therefore a point, called an interrogation, affixed to the question, in order to distinguish it. But this is absurdly placed at its end, so that the reader does not discover it till he finds, that he has wrongly modulated his voice, and is therefore obliged to begin again the sentence. To prevent this, the Spanish printers, more sensibly, place an interrogation at the beginning as well as at the end of the question. We have another error of the same kind in printing plays, where something often occurs, that is marked as spoken *aside*. But the word *aside* is placed at the end of the speech, when it ought to precede it, as a [357] direction to the reader, that he may govern his voice accordingly. The practice of our ladies in meeting five or six together, to form little busy parties, where each is employed in some useful work, while one reads to them, is so commendable in itself, that it deserves the attention of authors and printers to make it as pleasing as possible, both to the reader and hearers.

My best wishes attend you, being, with sincere esteem,

Sir,

Your most obedient and very humble servant,

B. FRANKLIN.

FOOTNOTE:

[66] This letter is taken from an American periodical publication entitled the Columbian Magazine. *Editor.*

A Scheme for a New Alphabet and reformed Mode of Spelling; with Remarks and Examples concerning the same; and an Enquiry into its Uses, in a Correspondence between Miss S——[67] *and Dr. Franklin, written in the Characters of the Alphabet*[68].

TABLE OF THE REFORMED ALPHABET

To face page 357,
Vol. II.

Characters	*Sounded* respectively, as in the Words in the Column below.	*Names* of Letters as expressed in the reformed Sounds and Characters.	*Manner of pronouncing* the Sounds.
o	Old.	*o*	The first VOWEL naturally, and deepest sound; requires only the mouth, and breathe through it.
**ɑ*	John, folly; awl, ball.	*ɑ*	The next requiring the mouth opened a little more, or hollower.
a	Man, can.	*a*	The next, a little more.
e	Men, lend, name, lane.	*e*	The next requires the *tongue* to be a little more elevated.
i	Did, sin, deed, seen.	*i*	The next still more.
u	Tool, fool, rule.	*u*	The next requires the *lips* to be gathered up, leaving a small opening.
**ɥ*	Um, un; as in umbrage, unto, &c. and as in *er*.	*ɥ*	The next a very short vowel, the sound of which we should express in our present letters thus, *uh*; a short, and not very strong *aspiration*.
h	Hunter, happy, high.	*huh*	A stronger or more forcible aspiration.
g	Give, gather,	*gi*	The first CONSONANT; being formed by the *root of the tongue*; this is the present hard *g*.
k	Keep, kick.	*ki*	A kindred sound; a little more acute; to be used instead of the hard *c*.
**ɦ*	(sh) Ship, wish.	*ish*	A new letter wanted in our language; our *sh*, separately taken, not being proper elements of the sound.
**ŋ*	(ng) ing, repeating, among,	*ing*	A new letter wanted for the same reason:—These are formed *back in the mouth*.
n	End.	*en*	Formed *more forward* in the mouth; the *tip of the tongue* to the *roof* of the mouth.
r	Art.	*r*	The same; the tip of the tongue a little loose or separate from the roof of the mouth, and vibrating.
t	Teeth.	*ti*	The tip of the tongue more forward; touching, and then leaving, the roof.
d	Deed.	*di*	The same; touching a little fuller.
l	ell, tell.	*el*	The same; touching just about the *gums* of the *upper teeth*.
s	Essence.	*es*	This sound is formed by the breath passing *between* the moist end of the *tongue* and the *upper teeth*.
z	(ez) Wages.	*ez*	The same; a little denser and duller.

*ɧ	(th) Think	*e*ɧ	The tongue under, and a little *behind*, the upper teeth; touching them, but so as to let the breath pass between.
*ꜧ	(dh) Thy.	*e*ꜧ	The same; a little fuller.
f	Effect.	*ef*	Formed by the *lower lip* against the upper teeth.
v	Ever.	*ev*	The same; fuller and duller.
b	Bees.	*b*	The *lips full together*, and *opened* as the air passes out.
p	Peep.	*pi*	The same; but a thinner sound.
m	Ember.	*em*	The *closing* of the lips, while the *e* [here annexed] is sounding.

* *N. B.* The six new letters are marked with an asterisk (*) to distinguish them, and show how few new characters are proposed. B. V.

Remarks [*on the Alphabetical Table*.] [358]

o to *huh*	It is endeavoured to give the alphabet a *more natural order*; beginning first with the simple sounds formed by the breath, with none or very little help of tongue, teeth, and lips, and produced chiefly in the windpipe.
g k	Then coming forward to those, formed by the roof of the tongue next to the windpipe.
r n *t d*	Then to those, formed more forward, the forepart of the tongue against the roof of the mouth.
l *s z*	Then those, formed still more forward in the mouth, by the tip of the tongue applied first to the roots of the upper teeth.
ɧ ꜧ	Then to those, formed by the tip of the tongue applied to the ends or edges of the upper teeth.
f *v*	Then to those, formed still more forward, by the under lip applied to the upper teeth.

b *p*	Then to those, formed yet more forward by the upper and under lip opening to let out the sounding breath.
m	And lastly, ending with the shutting up of the mouth, or closing the lips while any vowel is sounding.

In this alphabet *c* is *omitted* as unnecessary; *k* supplying its hard sound, and *s* the soft; *k* also supplies well the place of [359] *q*, and with an *s* added the place of *x*: *q* and *x* are therefore omitted. The vowel *u* being sounded as *oo* makes the *w* unnecessary. The *y*, where used simply, is supplied by *i*, and where as a dipthong, by two vowels: that letter is therefore omitted as useless. The jod *j* is also omitted, its sound being supplied by the new letter *ɦ*, *ish*, which serves other purposes, assisting in the formation of other sounds;—thus the *ɦ* with a *d* before it gives the sound of the jod *j* and soft *g*, as in "James, January, giant, gentle," "*dɦeems*, *dɦhanueri*, *dɦɥiant*, *dɦentel*;" with a *t* before it, it gives the sound of *ch*, as in "cherry, chip," "*tɦeri*, *tɦip*;" and with a *z* before it, the French sound of the jod *j*, as in "jamais," "*zɦame*."

Thus the *g* has no longer *two different* sounds, which occasioned confusion, but is, as every letter ought to be, confined to one. The same is to be observed in *all* the letters, vowels, and consonants, that wherever they are met with, or in whatever company, their sound is always the same. It is also intended, that there be *no superfluous* letters used in spelling; i. e. no letter that is not sounded; and this alphabet, by six new letters, provides, that, there be no distinct sounds in the language, *without letters* to express them. As to the difference between *short and long vowels*, it is naturally expressed by a single vowel where short, a double one where long; as for "mend," write "mend," but for "remain'd," write "remeen'd;" for "did" write "did," but for "deed" write "diid," &c.

What in our common alphabet is supposed the third vowel, *i*, as we sound it, is as a *dipthong*, consisting of two of our [360] vowels joined; [viz.] *ɥ* as sounded in "unto," and *i* in its true sound. Any one will be sensible of this who sounds those two vowels *ɥ i* quick after each other; the sounds begins *ɥ* and ends *ii*. The true sound of the *i* is that we now give to *e* in the words "deed, keep—[69]."

FOOTNOTES:

[67] Stephenson. Editor.

[68] For the nature and intention of this alphabet, &c. I must refer to what Dr. Franklin has himself said upon the subject, in answer to Miss S——n's objections; as the reader may understand the whole in an hour or two.—It is necessary to add, that the new letters; used in the course of printing this paper, are exactly copied from the *manuscript* in my possession; there being no provision for a distinction in the character as *written* or *printed*. I have no other way therefore of marking the scored parts of the manuscript (answering to *italics*)

than by placing such passages between inverted commas.—As to *capitals*, I should have provided for them by means of larger types, but the form of some of them would have made them too large for the page: however, were the author's general system ever adopted, nothing would be easier than to remedy this particular. B. V.

[69] The copy, from which this is printed, ends in the same abrupt way with the above, followed by a considerable blank space; so that more perhaps was intended to be added by our author. B. V.

Examples [*of writing in this Character*.]

Transcriber note:-
The following seven text segments with a black border are images of the original printed pages.

So huen sɥm Endɧel, bɥi divɥin kɑmand,
Uiɦ rɥiziŋ tempests ɧeeks e gilti Land;
(Sɥtɧ az ɑv leet or peel Britania past,)
Kalm and siriin hi drɥivs ɦi fiurɥs blast;
And, pliiz'd ɦ' ɑlmɥitis ɑrdɥrs tu pɥrfɑrm,
Rɥids in ɦi Huɥrluind and dɥirekts ɦi Stɑrm.

So ɦi piur limpid striim, huen fɑul uiɦ steens
ɑv rɥɧiŋ Tɑrents and disendiŋ Reens,
Uɥrks itself kliir; and az it rɥns rifɥins;
Til bɥi digriis, ɦe flotiŋ mirɥr ɧɥins,
Riflekts iitɧ flɑur ɦat ɑn its bɑrdɥr groz,
And e nu hev'n in its feer Bɥzɥm ɧoz.

Kensiŋtyn, Septembyr 26, 1768.

Diir Syr,

yi hav transkryb'd iur alfabet, &c. huitħ yi ɧink myit bi ɑv syrvis tu ɧoz, hu uiħ tu akuyir an akiuret pronynsiefiyn, if ɧat kuld bi fiks'd; byt yi si meni inkɑnviiniensis, az uel oz difikyltis, ɧat uuld atend ɧi briŋiŋ iur letyrs and ɑrɧɑgrafi intu kɑmyn ius. ɑɑl ɑur etimɑlodʒiz uuld be lɑst, kɑnsikuentli ui kuld nɑt asyrteen ɧi miiniŋ ɑv meni uyrds; ɧi distinkfiyn tu, bituiin uyrds ɑv difyrent miiniŋ and similar sɑund uuld bi iusles, ynles ui liviŋ ryiters pyblisħ nu iidiħ-yns. In ħɑrt yi biliiv ui myst let piipil spel ɑn in ɧeer old ue, and (az ui fyind it iisiiest) du ɧi seem ɑurselves. With ease and with sincerity I can, in the old way, subscribe myself,

Dear Sir,

Your faithful and affectionate Servant,

M. S.

ANSWER TO MISS S****.

Diir Madam,

ɧi ɑbdʃekʃyn iu meek to rektifyiiŋ ɑur alfabet, "ɧat it uil bi atended uiɧ inkɑnviniensiz and difikyltiz," iz e natural uyn; fɑr it ɑluaz ɑkyrz huen eni refɑrmeʃyn iz propozed; hueɧyr in rilidʃyn, gyvernment, lɑz, and iven dɑun az lo az rods and huil karidʃiz. ɧi tru kuestʃyn ɧen, is nɑt hueɧyr ɧaer uil bi no difikyltiz ɑr inkɑnviniensiz, byt hueɧer ɧi difikyltiz mê nɑt bi syrmɑunted; and hueɧeyr ɧi kɑnviniensiz uil nɑt, ɑn ɧi huol, bi grêtyr ɧan ɧi inkɑnviniensiz. In ɧis kes, ɧi difikyltiz er onli in ɧi biginiŋ ɑv ɧi praktis: huen ɧê er uyns ovyrkym, ɧi advantedʃez er lastiŋ.—To yiɧyr iu ɑr mi, hu spel uel in ɧi prezent mod, yi imadʃin ɧi difikylti ɑv tʃendiŋ ɧat mod fɑr ɧi nu, iz nɑt so grêt, byt ɧat ui myit pyrfektli git ovyr it in a uiiks rytiŋ.—Az to ɧoz hu du nɑ̆t spel uel, if ɧi tŭ difikɥltiz er kɥmpêrd, viz. ɧat ɑv titʃiŋ ɧem tru speliŋ in ɧi prezent mod, and ɧat ɑv titʃiŋ ɧem ɧi nu alfabet and ɧi nu speliŋ akɑrdiŋ to it, ɥi am

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kɑnfident ɧat ɧi latyr uuld bi byi far ɧi liist. ɧé nutyrali fɑl into ɧi nu meɧyd alreadi, az mytʃ az ɧi imperfekʃyn ɑv ɧer alfabet uil admit ɑv; ɧêr prezent bad speliŋ iz onli bad, bikɑz kɑntreri to ɧi prezent bad ruls: yndyr ɧi nu ruls it uuld bi gud.—ɧi difikylti ɑv lyrniŋ to spel uel in ɧi old uê iz so grêt, ɧat fiu atên it; ɧɑuzands and ɧɑuzands rytiŋ ɑn to old edʃ, uiɧɑut ever biiŋ ebil to akuyir it. 'Tiz, bisyidz, e difikylti kɑntinuali inkriisiŋ, az ɧi sɑund graduali veriz mor and mor frɑm ɧi speliŋ; and to fɑrenyrs* it mêks ɧi lyrniŋ to pronɑns ɑur laŋuedʃ, az riten in ɑur buks, almost impɑsibil.

Nɑu az to "ɧi inkɑnviniensiz" iu menʃyn. —ɧi fyrst iz, ɧat "ɑɑl ɑur etimɑlodʃiz uuld bi lɑst, kɑnsikuentli ui kuld nɑt asyrteen ɧi miiniŋ ɑv meni uyrds."—etimɑlodʃiz er at present veri ynsyrteen; byt sytʃ

Transcriber note:-
The * on the page above is a reference to Footnote [70]

az ħê er, ħi old buks uuld stil prizɥrv ħem, and etimolodɧiz uuld ħêr fɥind ħem. Uɥrds in ħi kors ɑv tɥim, tɧendɧ ħer miiniŋs, az uel az ħer speliŋ and pronɥnsieɧɥn; and ui du nɑt luk to etimɑlodɧi fɑr ħer prezent miiniŋs. If ɥi ɧuld kɑl e man e Neev and e Vilen, hi uuld hardli bi satisfɥid wiħ mɥi teliŋ him, ħat uɥn ɑv ħi uɥrds oridɧinali signifɥid onli e lad ɑr sɥrvant; and ħi ɥħɥr, an ɥndɥr plɑuman, ɑr ħi inhabitant ɑv e viledɧ. It iz frɑm prezent iusedɧ onli, ħi miiniŋ ɑv uɥrds iz to bi ditɥrmined.

Iur sekɥnd inkɑnviniens iz, ħat "ħi distinkɧɥn bituiin uɥrds ɑv difɥrent miiniŋ and similar sɑund uuld bi distrɑɥid."—ħat distinkɧɥn iz ɑlreadi distrɑɥid in pronɑunsiŋ ħem; and ui rilɥi ɑn ħi sens alon ɑv ħi sentens to asɥrteen, huitɧ ɑv ħi several uɥrds, similar in sɑund, ui intend. If ħis iz sɥfiɧent in ħi rapiditi ɑv diskors, it uil bi mutɧ mor so in riten sentenses, huitɧ mê bi red lezɧurli, and atended to mor partikularli in kes ɑv difikylti, ħan ui kan atend to e past sentens, huyil e spikyr iz hyryiŋ ys alɑŋ uiħ nu uyrs.

Iur ħyrd inkɑnviniens iz, ħat "ɑɑl ħi

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buks alredi riten uuld bi iusles."—ħis inkɑnviniens uuld onli kym ɑn graduali, in e kors ɑv edʃes. Iu and yi, and yħyr nɑu liviŋ ridyrs, uuld hardli fɑrget ħi ius ɑv ħem. Piipil uuld long lyrn to riid ħi old ryiting, ħo ħê praktist ħi nu.—And ħi inkɑnviniens iz nɑt greter, ħan huat kes aktuali hapend in a similar kes, in Iteli. Fɑrmerli its inhabitants ɑɑl spok and rot Latin: az ħi laŋuedʃ tʃendʃd, ħi speliŋ fɑlo'd it. It iz tru ħat at prezent, e miir ynlarn'd Italien knɑt riid ħi Latin buks; ħo ħe er stil red and yndyrstud byi meni. Byt, if ħi speliŋ had nevyr bin tʃendʃed, hi uuld nɑu hev fɑund it mytʃ mor difikylt to riid and ryit hiz on laŋuadʃ; fɑr riten uyrds uuld hev had no rilêʃyn to sɑunds, ħe uuld onli hev stud fɑr ħiŋs; so ħat if hi uuld ekspres in ryitiŋ ħi yiala hi hez, huen hi saunds ħi uyrd Vescovo, hi myst iuz ħi leterz Episcopus.—In ʃcart, huatever ħi difikyltiz and inkanviniensiz nau er, ħe uil bi mor iizili syrmaunted nau, ħan hiraftyr; and sym tyim ar yħyr, it myst bi dyn; ar aur ryitiŋ uil bikym ħi sêm uiħ ħi Tʃyiniiz*, az

Transcriber note:-
The * on the page above is a reference to Footnote [71]

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to ħi difikylti av iyrniŋ and iuzing it. And it uuld alredi hev bin sytʃt, if ui had kantinud ħi Saksyn speliŋ and ryitiŋ, iuzed byi our forfaħers.

yi am, myi diir frind,

iurs afekʃynetli,

B. FRANKLIN.

Lyndyn,
Kreven-striit, Sept. 28, 1768.

FOOTNOTES:

[70] Dr. Franklin used to lay some little stress on this circumstance, when he occasionally spoke on the subject. "A dictionary, formed on this model, would have been serviceable to him, he said, even as an American;" because, from the want of public examples of pronunciation in his own country, it was often difficult to learn the proper sound of certain words, which occurred very frequently in our English writings, and which of course every American very well understood as to their meaning. B. V.

[71] Chinese.

Rules for a Club formerly established in Philadelphia[72].

Previous question, to be answered at every meeting.

Have you read over these queries this morning, in order to consider what you might have to offer the Junto [touching] any one of them? viz.

1. Have you met with any thing, in the author you last read, remarkable, or suitable to be communicated to the Junto? particularly in history, morality, poetry, physic, travels, mechanic arts, or other parts of knowledge.

2. What new story have you lately heard agreeable for telling in conversation? [367]

3. Hath any citizen in your knowledge failed in his business lately, and what have you heard of the cause?

4. Have you lately heard of any citizen's thriving well, and by what means?

5. Have you lately heard how any present rich man, here or elsewhere, got his estate?

6. Do you know of any fellow citizen, who has lately done a worthy action, deserving praise and imitation? or who has lately committed an error, proper for us to be warned against and avoid?

[7. What unhappy effects of intemperance have you lately observed or heard? of imprudence? of passion? or of any other vice or folly?

8. What happy effects of temperance? of prudence? of moderation? or of any other virtue?]

9. Have you or any of your acquaintance been lately sick or wounded? If so, what remedies were used, and what were their effects?

10. Who do you know that are shortly going voyages or journies, if one should have occasion to send by them?

11. Do you think of any thing at present, in which the Junto may be serviceable to *mankind*? to their country, to their friends, or to themselves?

12. Hath any deserving stranger arrived in town since last meeting, that you heard of? and what have you heard or observed of his character or merits? and whether think you, it lies in the power of the Junto to oblige him, or encourage him as he deserves?

13. Do you know of any deserving young beginner lately set up, whom it lies in the power of the Junto any way to encourage? [368]

14. Have you lately observed any defect in the laws of your *country*, [of] which it would be proper to move the legislature for an amendment? or do you know of any beneficial law that is wanting?

15. Have you lately observed any encroachment on the just liberties of the people?

16. Hath any body attacked your reputation lately? and what can the Junto do towards securing it?

17. Is their any man whose friendship you want, and which the Junto, or any of them, can procure for you?

18. Have you lately heard any member's character attacked, and how have you defended it?

19. Hath any man injured you, from whom it is in the power of the Junto to procure redress?

20. In what manner can the Junto, or any of them, assist you in any of your honourable designs?

21. Have you any weighty affair in hand, in which you think the advice of the Junto may be of service[73]?

22. What benefits have you lately received from any man not present?

23. Is there any difficulty in matters of opinion, of justice, and injustice, which you would gladly have discussed at this time?

24. Do you see any thing amiss in the present customs or proceedings of the Junto, which might be amended?

Any person to be qualified, to stand up, and lay his hand on his breast, and be asked these questions; viz. [369]

1. Have you any particular disrespect to any present members?—*Answer.* I have not.

2. Do you sincerely declare, that you love mankind in general; of what profession or religion soever? *Ans.* I do.

3. Do you think any person ought to be harmed in his body, name or goods, for mere speculative opinions, or his external way of worship?—*Ans.* No.

4. Do you love truth for truth's sake, and will you endeavour impartially to find and receive it yourself and communicate it to others?—*Ans.* Yes.

FOOTNOTES:

[72] This was an early performance, and carries along with it an air of singularity, accompanied with such operative good sense and philanthropy, as characterizes it for Dr. Franklin's. The club, for which it was written, was held at Philadelphia; and, if I am well informed, was composed of men considerable for their influence and discretion; for though the chief measures of Pensylvania usually received their first formation in this club, it existed for thirty years without the nature of its institution being publicly known. B. V.

[73] Queries No. 7 and 8 follow here, in the original. B. V.

Questions discussed by the Junto forming the preceding Club[74].

Is *sound* an entity or body?

How may the phenomena of vapours be explained?

Is self-interest the rudder that steers mankind, the universal monarch to whom all are tributaries?

Which is the best form of government, and what was that form which first prevailed among mankind?

Can any one particular form of government suit all mankind?

What is the reason that the tides rise higher in the Bay of Fundy than the Bay of Delaware? [370]

Is the emission of paper-money safe?

What is the reason that men of the greatest knowledge not the most happy?

How may the possession of the Lakes be improved to our advantage?

Why are tumultuous, uneasy sensations, united with our desires?

Whether it ought to be the aim of philosophy to eradicate the passions?

How may smoaky chimneys be best cured?

Why does the flame of a candle tend upwards in a spire?

Which is least criminal, a *bad* action joined with a *good* intention, or a *good* action with a *bad* intention?

Is it consistent with the principles of liberty in a free government, to punish a man as a libeller, when he speaks the truth?

FOOTNOTE:

[74] These questions are from the Eulogium of Dr. Franklin, delivered before the American Philosophical Society, in 1791, of which the Junto was the foundation. On the formation of that society, a book, containing many of the questions discussed by the Junto, was delivered into Dr. Smith's hands, for the purpose of being digested, and in due time published among the transactions of that body. Many of the questions Dr. Smith observes are curious and curiously handled, and he selects the above as answering the description. *Editor.*

Sketch of an English School; for the Consideration of the Trustees of the Philadelphia Academy[75].

It is expected that every scholar, to be admitted into this school, be at least able to pronounce and divide the syllables in reading, and to write a legible hand. None to be received, that are under [ ] years of age.

First, or lowest Class.

Let the first class learn the English Grammar rules, and at the same time let particular care be taken to improve them in orthography. Perhaps the latter is best done by pairing the scholars; two of those nearest equal in their spelling to be put together. Let these strive for victory; each propounding ten words every day to the other to be spelled. He that spells truly most of the other's words is victor for that day; he that is victor most days in a month, to obtain a prize, a pretty neat book of some kind, useful in their future studies. This method fixes the attention of children extremely to the orthography of words, and makes them good spellers very early. It is a shame for a man to be so ignorant of this little art, in his own language, as to be perpetually confounding words of like sound and different significations; the consciousness of which defect makes some men, otherwise of good learning and understanding, averse to writing even a common letter. [371]

Let the pieces read by the scholars in this class be short; such as Croxal's fables, and little stories. In giving the lesson, let it be read to them; let the meaning of the difficult words in it be explained to them; and let them con over by themselves before they are called to read to the master or usher, who is to take particular care, that they do not read too fast, and that they duly observe the stops and pauses. A vocabulary of the most usual difficult words might be formed for their use, with explanations; and they might daily get a few of those words and explanations by heart, which would a little exercise their memories; or at least they might write a number of them in a small book for the purpose, which would help to fix the meaning of those words in their minds, and at the same time furnish every one with a little dictionary for his future use.

The Second Class [372]

To be taught, reading with attention, and with proper modulations of the voice, according to the sentiment and the subject.

Some short pieces, not exceeding the length of a Spectator, to be given this class for lessons (and some of the easier Spectators would be very suitable for the purpose). These lessons might be given every night as tasks; the scholars to study them against the morning. Let it then be required of them to give an account, first of the parts of speech, and construction of one or two sentences. This will oblige them to recur frequently to their grammar, and fix its principal rules in their memory. Next, of the intention of the writer, or the scope of the piece, the meaning of each sentence, and of every uncommon word. This would early acquaint them with the meaning and force of words, and give them that most necessary habit, of reading with attention.

The master then to read the piece with the proper modulations of voice, due emphasis, and suitable action, where action is required; and put the youth on imitating his manner.

Where the author has used an expression not the best, let it be pointed out; and let his beauties be particularly remarked to the youth.

Let the lessons for reading be varied, that the youth may be made acquainted with good styles of all kinds, in prose and verse, and the proper manner of reading each kind—sometimes a well-told story, a piece of a sermon, a general's speech to his soldiers, a speech in a tragedy, some part of a comedy, an ode, a satire, a letter, blank verse, Hudibrastic, heroic, &c. But let such lessons be chosen for reading, as contain some useful instruction, whereby the understanding or morals of the [373] youth may at the same time be improved.

It is required that they should first study and understand the lessons, before they are put upon reading them properly; to which end each boy should have an English dictionary, to help him over difficulties. When our boys read English to us, we are apt to imagine they understand what they read, because we do, and because it is their mother tongue. But they often read, as parrots speak, knowing little or nothing of the meaning. And it is impossible a reader should give the due modulation to his voice, and pronounce properly, unless his understanding goes before his tongue, and makes him master of the sentiment. Accustoming boys to read aloud what they do not first understand, is the cause of those even set tones, so common among readers, which, when they have once got a habit of using, they find so difficult to correct; by which means, among fifty readers we scarcely find a good one. For want of good reading, pieces published with a view to influence the minds of men, for their own or the public benefit, lose half their force. Were there but one good reader in a neighbourhood, a public orator might be heard throughout a nation with the same advantages, and have the same effect upon his audience, as if they stood within the reach of his voice.

The Third Class

To be taught speaking properly and gracefully; which is near a-kin to good reading, and naturally follows it in the studies of youth. Let the scholars of this class begin with learning the elements of rhetoric from some short system, so as [374] to be able to give an account of the most useful tropes and figures. Let all their bad habits of speaking, all offences against good grammar, all corrupt or foreign accents, and all improper phrases, be pointed out to them. Short speeches from the Romans, or other history, or from the parliamentary debates, might be got by heart, and delivered with the proper action, &c. Speeches and scenes in our best tragedies and comedies (avoiding every thing, that could injure the morals of youth) might likewise be got by rote, and the boys exercised in delivering or acting them: great care being taken to form their manner after the truest models.

For their farther improvement, and a little to vary their studies, let them now begin to read history, after having got by heart a short table of the principal epochs in chronology. They may begin with Rollin's ancient and Roman histories, and proceed at proper hours, as they go through the subsequent classes, with the best histories of our own nation and colonies. Let emulation be excited among the boys, by giving, weekly, little prizes, or other small encouragements to those, who are able to give the best account of what they have read, as to time, places, names of persons, &c. This will make them read with attention, and imprint the history well in their memories. In remarking on the history, the master will have fine opportunities of instilling instruction of various kinds, and improving the morals, as well as the understandings, of youth.

The natural and mechanic history, contained in the Spectacle de la Nature, might also be begun in this class, and continued through the subsequent classes, by other books of the same kind; for, next to the knowledge of duty, this kind of [375] knowledge is certainly the most useful, as well as the most entertaining. The merchant may thereby be enabled better to understand many commodities in trade; the handicraftsman, to improve his business by new instruments, mixtures and materials; and frequently hints are given for new manufactures, or new methods of improving land, that may be set on foot greatly to the advantage of a country.

The Fourth Class

To be taught composition. Writing one's own language well, is the next necessary accomplishment after good speaking. It is the writing-master's business, to take care that the boys make fair characters, and place them straight and even in the lines: but to form their style, and even to take care that the stops and capitals are properly disposed, is the part of the English master. The boys should be put on writing letters to each other on any common occurrences, and on various subjects, imaginary business, &c. containing little stories, accounts of their late reading, what parts of authors please them, and why; letters of congratulation, of compliment, of request, of thanks, of recommendation, of admonition, of consolation, of expostulation, excuse, &c. In these, they should be taught to express themselves clearly, concisely, and naturally, without affected words or high-flown phrases. All their letters to pass through the master's hand, who is to point out the faults, advise the corrections, and commend what he finds right. Some of the best letters published in our own language, as sir William Temple's, those of Pope and his friends, and some others, might be set before the youth as models, their beauties pointed out and explained by the master, the letters themselves transcribed by the scholar. [376]

Dr. Johnson's Ethices Elementa, or First Principles of Morality, may now be read by the scholars, and explained by the master, to lay a solid foundation of virtue and piety in their minds. And as this class continues the reading of history, let them now, at proper hours, receive some farther instruction in chronology, and in that part of geography (from the mathematical master) which is necessary to understand the maps and globes. They should also be acquainted with the modern names of the places they find mentioned in ancient writers. The exercises of good reading, and proper speaking, still continued at suitable times.

Fifth Class

To improve the youth in composition, they may now, besides continuing to write letters, begin to write little essays in prose, and sometimes in verse; not to make them poets, but for this reason, that nothing acquaints a lad so speedily with variety of expression, as the necessity of finding such words and phrases as will suit the measure, sound and rhyme of verse, and at the same time well express the sentiment. These essays should all pass under the master's eye, who will point out their faults, and put the writer on correcting them. Where the judgment is not ripe enough for forming new essays, let the sentiments of a Spectator be given, and required to be clothed in the scholar's own words; or the circumstances of some good story, the scholar to find expression. Let them be put sometimes on abridging a paragraph of a diffuse author: sometimes on dilating or amplifying what is wrote more closely. And now let Dr. Johnson's Noetica, or First Principles of [377] Human Knowledge, containing a logic, or art of reasoning, &c. be read by the youth, and the difficulties, that may occur to them, be explained by the master. The reading of history, and the exercises of good reading and just speaking still continued.

Sixth Class

In this class, besides continuing the studies of the preceding in history, rhetoric, logic, moral and natural philosophy, the best English authors may be read and explained; as Tillotson, Milton, Locke, Addison, Pope, Swift, the higher papers in the Spectator and Guardian, the best translations of Homer, Virgil and Horace, of Telemachus, travels of Cyrus, &c.

Once a year, let there be public exercises in the hall; the trustees and citizens present. Then let fine gilt books be given as prizes to such boys, as distinguish themselves, and excel the others in any branch of learning, making three degrees of comparison: giving the best prize to him, that performs best; a less valuable one to him, that comes up next to the best, and another to the third. Commendations, encouragement, and advice to the rest; keeping up their hopes, that, by industry, they may excel another time. The names of those, that obtain the prize, to be yearly printed in a list.

The hours of each day are to be divided and disposed in such a manner, as that some classes may be with the writing-master, improving their hands; others with the mathematical master, learning arithmetic, accounts, geography, use of the globes, drawing, mechanics, &c. while the rest are in the English school, under the English master's care. [378]

Thus instructed, youth will come out of this school fitted for learning any business, calling, or profession, except such wherein languages are required: and, though unacquainted with any ancient or foreign tongue, they will be masters of their own, which is of more immediate and general use, and withal will have attained many other valuable accomplishments: the time usually spent in acquiring those languages, often without success, being here employed in laying such a foundation of knowledge and ability, as, properly improved, may qualify them to pass through and execute the several offices of civil life, with advantage and reputation to themselves and country.

FOOTNOTE:

[75] This piece, which we believe to be an early production of our author, is taken from the American Museum, Vol. V. p. 473. *Editor*.

TO MISS S——N[76], AT WANSTEAD.

Advice to Youth in Reading.

Craven-street, May 17, 1760.

I send my good girl the books I mentioned to her last night. I beg her to accept of them as a small mark of my esteem and friendship. They are written in the familiar easy manner for which the French are so remarkable, and afford a good deal of philosophic and practical knowledge, unembarrassed with the dry mathematics, used by more exact reasoners, but which is apt to discourage young beginners. I would advise you to read with a pen in your hand, and enter in a little book [379] short hints of what you find, that is curious, or that may be useful; for this will be the best method of imprinting such particulars in your memory, where they will be ready, either for practice on some future occasion, if they are matters of utility, or at least to adorn and improve your conversation, if they are rather points of curiosity. And as many of the terms of science are such, as you cannot have met with in your common reading, and may therefore be unacquainted with, I think it would be well for you to have a good dictionary at hand, to consult immediately when you meet with a word you do not comprehend the precise meaning of. This may at first seem troublesome and interrupting; but it is a trouble that will daily diminish, as you will daily find less and less occasion for your dictionary as you become more acquainted with the terms; and in the mean time you will read with more satisfaction, because with more understanding. When any point occurs, in which you would be glad to have farther information than your book affords you, I beg you would not in the least apprehend, that I should think it a trouble to receive and answer your questions. It will be a pleasure, and no trouble. For though I may not be able, out of my own little stock of knowledge, to afford you what you require, I can easily direct you to the books, where it may most readily be found. Adieu, and believe me ever, my dear friend,

Yours affectionately,

B. FRANKLIN.

FOOTNOTE:

[76] Stevenson. *Editor.*

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PAPERS

ON

SUBJECTS OF GENERAL POLITICS.

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PAPERS

ON

SUBJECTS OF GENERAL POLITICS.

Observations concerning the Increase of Mankind, peopling of Countries, &c[77].

Written in Pensylvania, 1751.

1. Tables of the proportion of marriages to births, of deaths to births, of marriages to the number of inhabitants, &c. formed on observations made upon the bills of mortality, christenings, &c. of populous cities, will not suit countries; nor will tables, formed on observations made on full settled old countries, as Europe, suit new countries, as America.

2. For people increase in proportion to the number of marriages, and that is greater, in proportion to the ease and convenience of supporting a family. When families can be easily supported, more persons marry, and earlier in life.

3. In cities, where all trades, occupations, and offices are full, many delay marrying, till they can see how to bear the charges of a family; which charges are greater in cities, as luxury is more common; many live single during life, and continue servants to families, journeymen to trades, &c. Hence cities do not, by natural generation, supply themselves [384]
with inhabitants; the deaths are more than the births.

4. In countries full settled, the case must be nearly the same, all lands being occupied and improved to the height; those who cannot get land, must labour for others, that have it; when labourers are plenty, their wages will be low; by low wages a family is supported with difficulty; this difficulty deters many from marriage, who therefore long continue

servants and single. Only, as the cities take supplies of people from the country, and thereby make a little more room in the country, marriage is a little more encouraged there, and the births exceed the deaths.

5. Great part of Europe is fully, settled with husbandmen, manufacturers, &c. and therefore cannot now much encrease in people. America is chiefly occupied by Indians, who subsist mostly by hunting. But as the hunter, of all men, requires the greatest quantity of land from whence to draw his subsistence, (the husbandman subsisting on much less, the gardener on still less, and the manufacturer requiring least of all) the Europeans found America as fully settled, as it well could be by hunters; yet these, having large tracts, were easily prevailed on to part with portions of territory to the new comers, who did not much interfere with the natives in hunting, and furnished them with many things they wanted.

6. Land being thus plenty in America, and so cheap, as that a labouring man, that understands husbandry, can, in a short time, save money enough to purchase a piece of new land, sufficient for a plantation, whereon he may subsist a family; such are not afraid to marry; for if they even look far enough forward to consider how their children, when grown up, are [385]
to be provided for, they see, that more land is to be had at rates equally easy, all circumstances considered.

7. Hence marriages in America are more general, and more generally early, than in Europe. And if it is reckoned there, that there is but one marriage *per annum* among 100 persons, perhaps we may here reckon two; and if in Europe, they have but four births to a marriage, (many of their marriages being late) we may here reckon eight, of which, if one half grow up, and our marriages are made, reckoning one with another, at twenty years of age, our people must at least be doubled every twenty years.

8. But notwithstanding this increase, so vast is the territory of North America, that it will require many ages to settle it fully, and till it is fully settled, labour will never be cheap here, where no man continues long a labourer for others, but gets a plantation of his own; no man continues long a journeyman to a trade, but goes among those new settlers, and sets up for himself, &c. Hence labour is no cheaper now, in Pensylvania, than it was thirty years ago, though so many thousand labouring people have been imported from Germany and Ireland.

9. The danger, therefore, of these colonies interfering with their mother country in trades, that depend on labour, manufactures, &c. is too remote to require the attention of Great Britain.

10. But, in proportion to the increase of the colonies, a vast demand is growing for British manufactures; a glorious market, wholly in the power of Britain, in which foreigners cannot interfere, which will increase, in a short time, even [386]
beyond her power of supplying, though her whole trade should be to her colonies.

* * * * *

12. It is an ill-grounded opinion, that, by the labour of slaves, America may possibly vie in cheapness of manufactures with Britain. The labour of slaves can never be so cheap here, as the labour of working men is in Britain. Any one may compute it. Interest of money is in the colonies from 6 to 10 per cent. Slaves, one with another, cost 30*l.* sterling per head. Reckon then the interest of the first purchase of a slave, the insurance or risque on his life, his clothing and diet, expences in his sickness, and loss of time, loss by his neglect of business, (neglect is natural to the man, who is not to be benefited by his own care or diligence) expence of a driver to keep him at work, and his pilfering from time to time, almost every slave being, from the nature of slavery, a thief, and compare the whole amount with the wages of a manufacturer of iron or wool in England, you will see, that labour is much cheaper there, than it ever can be by negroes here. Why then will

Americans purchase slaves? Because slaves may be kept as long as a man pleases, or has occasion for their labour, while hired men are continually leaving their master (often in the midst of his business) and setting up for themselves. §8.

13. As the increase of people depends on the encouragement of marriages, the following things must diminish a nation, viz. 1. The being conquered; for the conquerors will engross as many offices, and exact as much tribute or profit on the labour of the conquered, as will maintain them in their new establishment; and this diminishing the subsistence of the natives discourages their marriages, and so gradually diminishes them, while the foreigners increase. 2. Loss of territory. [387] Thus the Britons, being driven into Wales, and crouded together in a barren country, insufficient to support such great numbers, diminished, till the people bore a proportion to the produce; while the Saxons increased on then abandoned lands, till the island became full of English. And, were the English now driven into Wales by some foreign nation, there would, in a few years, be no more Englishmen in Britain, than there are now people in Wales. 3. Loss of trade. Manufactures, exported, draw subsistence from foreign countries for numbers, who are thereby enabled to marry and raise families. If the nation be deprived of any branch of trade, and no new employment is found for the people occupied in that branch, it will soon be deprived of so many people. 4. Loss of food. Suppose a nation has a fishery, which not only employs great numbers, but makes the food and subsistence of the people cheaper: if another nation becomes master of the seas, and prevents the fishery, the people will diminish in proportion as the loss of employ and dearness of provision makes it more difficult to subsist a family. 5. Bad government and insecure property. People not only leave such a country, and, settling abroad, incorporate with other nations, lose their native language, and become foreigners; but the industry of those that remain being discouraged, the quantity of subsistence in the country is lessened, and the support of a family becomes more difficult. So heavy taxes tend to diminish a people. 6. The introduction of slaves. The negroes, brought into the English sugar islands, have greatly diminished the whites there; the poor are by this means deprived of employment, [388] while a few families acquire vast estates, which they spend on foreign luxuries; and, educating their children in the habit of those luxuries, the same income is needed for the support of one, that might have maintained one hundred. The whites, who have slaves, not labouring; are enfeebled, and therefore not so generally prolific; the slaves being worked too hard, and ill fed, their constitutions are broken, and the deaths among them are more than the births; so that a continual supply is needed from Africa. The northern colonies, having few slaves, increase in whites. Slaves also pejorate the families that use them; the white children become proud, disgusted with labour, and, being educated in idleness, are rendered unfit to get a living by industry.

14. Hence the prince, that acquires new territory, if he finds it vacant, or removes the natives to give his own people room;—the legislator, that makes effectual laws for promoting of trade, increasing employment, improving land by more or better tillage, providing more food by fisheries, securing property, &c.—and the man that invents new trades, arts or manufactures, or new improvements in husbandry, may be properly called *fathers of their nation*, as they are the cause of the generation of multitudes, by the encouragement they afford to marriage.

15. As to privileges granted to the married, (such as the *jus trium liberorum* among the Romans) they may hasten the filling of a country, that has been thinned by war or pestilence, or that has otherwise vacant territory, but cannot increase a people beyond the means provided for their subsistence.

16. Foreign luxuries, and needless manufactures, imported and used in a nation, do, by the same reasoning, increase the [389] people of the nation, that furnishes them, and diminish the people of the nation, that uses them. Laws, therefore, that prevent such importations, and, on the contrary, promote the exportation of manufactures to be consumed in foreign countries, may be called (with respect to the people that make them) *generative laws*, as, by increasing subsistence, they

encourage marriage. Such laws likewise strengthen a country doubly, by increasing its own people, and diminishing its neighbours.

17. Some European nations prudently refuse to consume the manufactures of East India:—they should likewise forbid them to their colonies; for the gain to the merchant is not to be compared with the loss, by this means, of people to the nation.

18. Home luxury in the great increases the nation's manufacturers employed by it, who are many, and only tends to diminish the families that indulge in it, who are few. The greater the common fashionable expence of any rank of people, the more cautious they are of marriage. Therefore luxury should never be suffered to become common.

19. The great increase of offspring in particular families is not always owing to greater fecundity of nature, but sometimes to examples of industry in the heads, and industrious education, by which the children are enabled to provide better for themselves, and their marrying early is encouraged from the prospect of good subsistence.

20. If there be a sect, therefore, in our nation, that regard frugality and industry as religious duties, and educate their children therein, more than others commonly do, such sect must consequently increase more by natural generation than [390] any other sect in Britain.

21. The importation of foreigners into a country, that has as many inhabitants as the present employments and provisions for subsistence will bear, will be in the end no increase of people, unless the new-comers have more industry and frugality than the natives, and then they will provide more subsistence, and increase in the country; but they will gradually eat the natives out.—Nor is it necessary to bring in foreigners to fill up any occasional vacancy in a country; for such vacancy (if the laws are good, § 14, 16) will soon be filled by natural generation. Who can now find the vacancy made in Sweden, France, or other warlike nations, by the plague of heroism 40 years ago; in France, by the expulsion of the protestants; in England, by the settlement of her colonies; or in Guinea by a hundred years exportation of slaves, that has blackened half America? The thinness of the inhabitants in Spain is owing to national pride, and idleness, and other causes, rather than to the expulsion, of the Moors, or to the making of new settlements.

22. There is, in short, no bound to the prolific nature of plants or animals, but what is made by their crowding and interfering with each other's means of subsistence. Was the face of the earth vacant of other plants, it might be gradually sowed and the overspread with one kind only, as for instance, with fennel; and were it empty of other inhabitants, it might, in a few ages, be replenished from one nation only, as for instance, with Englishmen. Thus there are supposed to be now upwards of one million of English souls in North America (though it is thought scarce 80,000 have been brought [391] over sea) and yet perhaps there is not one the fewer in Britain, but rather many more, on account of the employment the colonies afford to manufacturers at home. This million doubling, suppose but once in 25 years, will, in another century, be more than the people of England, and the greatest number of Englishmen will be on this side the water. What an accession of power to the British empire by sea as well as land! What increase of trade and navigation! What numbers of ships and seamen! We have been here but little more than a hundred years, and yet the force of our privateers in the late war, united, was greater, both in men and guns, than that of the whole British navy in queen Elizabeth's time. How important an affair then to Britain is the present treaty[78] for settling the bounds between her colonies and the French! and how careful should she be to secure, room enough, since on the room depends so much the increase of her people?

23. In fine, a nation well regulated is like a polypus[79], take away a limb, its place is soon supplied; cut it in two, and each deficient part shall speedily grow out of the part remaining. Thus, if you have room and subsistence enough, as you may, by dividing, make ten polypuses out of one, you may, of one, make ten nations, equally populous and powerful; or, rather, increase a nation tenfold in numbers and strength.

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FOOTNOTES:

[77] This paper and the answer to it are the last we have to extract from Mr. Collinson's collection. The papers that follow, having notes with the signature B. V., are from the collection referred to before, Vol. I, p. 399. *Editor.*

[78] In 1751.

[79] A water insect, well-known to naturalists.

R. J.[80] ESQ. OF LONDON, TO BENJAMIN FRANKLIN, ESQ. AT PHILADELPHIA. [392]

Remarks on some of the foregoing Observations, showing particularly the Effect which manners have on Population.

DEAR SIR,

It is now near three years since I received your excellent *Observations on the Increase of Mankind*, &c. in which you have with so much sagacity and accuracy shown in what manner, and by what causes, that principal means of political grandeur is best promoted; and have so well supported those just inferences you have occasionally drawn, concerning the general state of our American colonies, and the views and conduct of some of the inhabitants of Great Britain.

You have abundantly proved, that natural fecundity is hardly to be considered, because the *vis generandi*, as far as we know, is unlimited, and because experience shows, that the numbers of nations is altogether governed by collateral causes, and among these none of so much force as quantity of subsistence, whether arising from climate, soil, improvement of tillage, trade, fisheries, secure property, conquest of new countries, or other favourable circumstances.

As I perfectly concurred with you in your sentiments on these heads, I have been very desirous of building somewhat on the foundation you have there laid; and was induced, by your hints in the twenty-first section, to trouble you with some thoughts on the influence manners have always had, and are always likely to have, on the numbers of a people, and their [393] political prosperity in general.

The end of every individual is its own private good. The rules it observes in the pursuit of this good are a system of propositions, almost every one founded in authority, that is, derive their weight from the credit given to one or more persons, and not from demonstration.

And this, in the most important as well as the other affairs of life, is the case even of the wisest and philosophical part of the human species; and that it should be so is the less strange, when we consider, that it is perhaps impossible to prove, that *being*, or life itself, has any other value than what is set on it by authority.

A confirmation of this may be derived from the observation, that, in every country in the universe, happiness is sought upon a different plan; and, even in the same country, we see it placed by different ages, professions, and ranks of men, in the attainment of enjoyments utterly unlike.

These propositions, as well as others framed upon them, become habitual by degrees, and, as they govern the determination of the will, I call them *moral habits*.

There are another set of habits, that have the direction of the members of the body, that I call therefore *mechanical habits*. These compose what we commonly call *the arts*, which are more or less liberal or mechanical, as they more or less partake of assistance from the operations of the mind.

The *cumulus* of the moral habits of each individual is the manners of that individual; the *cumulus* of the manners of individuals makes up the manners of a nation.

The happiness of individuals is evidently the end of political society; and political welfare, or the strength, splendour, [394]
and opulence of the state, have been always admitted, both by political writers, and the valuable part of mankind in general, to conduce to this end, and are therefore desirable.

The causes, that advance or obstruct any one of these three objects, are external or internal. The latter may be divided into physical, civil, and personal, under which last head I comprehend the moral and mechanical habits of mankind. The physical causes are principally climate, soil, and number of subjects; the civil, are government and laws; and political welfare is always in a ratio composed of the force of these particular causes; a multitude of external causes, and all these internal ones, not only control and qualify, but are constantly acting on, and thereby insensibly, as well as sensibly, altering one another, both for the better and the worse, and this not excepting the climate itself.

The powerful efficacy of manners in encreasing a people is manifest from the instance you mention, the Quakers; among them industry and frugality multiply and extend the use of the necessaries of life; to manners of a like kind are owing the populousness of Holland, Switzerland, China, Japan, and most parts of Indostan, &c. in every one of which, the force of extent of territory and fertility of soil is multiplied, or their want compensated by industry and frugality.

Neither nature nor art have contributed much to the production of subsistence in Switzerland, yet we see frugality preserves and even increases families, that live on their fortunes, and which, in England, we call the gentry; and the
observation we cannot but make in the southern part of this kingdom, that those families, including all superior ones, are [395]
gradually becoming extinct, affords the clearest proof, that luxury (that is, a greater expence of subsistence than in prudence a man ought to consume) is as destructive as a proportionable want of it; but in Scotland, as in Switzerland, the gentry, though one with another they have not one-fourth of the income, increase in number.

And here I cannot help remarking, by the by, how well founded your distinction is between the increase of mankind in old and new settled countries in general, and more particularly in the case of families of condition. In America, where the expences are more confined, to necessaries, and those necessaries are cheap, it is common to see above one hundred persons descended from one living old man. In England, it frequently happens, where a man has seven, eight, or more children, there has not been a descendant in the next generation, occasioned by the difficulties the number of children has brought on the family, in a luxurious dear country, and which have prevented their marrying.

That this is more owing to luxury than mere want appears from what I have said of Scotland, and more plainly from parts of England remote from London, in most of which the necessaries of life are nearly as dear, in some dearer than London, yet the people of all ranks marry and breed up children.

Again; among the lower ranks of life, none produce so few children as servants. This is, in some measure, to be attributed to their situation, which hinders marriage, but is also to be attributed to their luxury and corruption of manners, which are greater than among any other set of people in England, and is the consequence of a nearer view of the lives and [396] persons of a superior rank, than any inferior rank, without a proper education, ought to have.

The quantity of subsistence in England has unquestionably become greater for many ages; and yet if the inhabitants are more numerous, they certainly are not so in proportion to our improvement of the means of support. I am apt to think there are few parts of this kingdom, that have not been at some former time more populous than at present. I have several cogent reasons for thinking so of great part of the counties I am most intimately acquainted with; but as they were probably not all most populous at the same time, and as some of our towns are visibly and vastly grown in bulk, I dare not suppose, as judicious men have done, that England is less peopled than heretofore.

This growth of our towns is the effect of a change of manners, and improvement of arts, common to all Europe; and though it is not imagined, that it has lessened the country growth of necessaries, it has evidently, by introducing a greater consumption of them, (an infallible consequence of a nation's dwelling in towns) counteracted the effects of our prodigious advances in the arts.

But however frugality may supply the place, or prodigality counteract the effects, of the natural or acquired subsistence of a country, industry is, beyond doubt, a more efficacious cause of plenty than any natural advantage of extent or fertility. I have mentioned instances of frugality and industry united with extent and fertility. In Spain and Asia Minor, we see frugality joined to extent and fertility, without industry; in Ireland, we once saw the same; Scotland had then none of them [397] but frugality. The change in these two countries is obvious to every one, and it is owing to industry not yet very widely diffused in either. The effects of industry and frugality in England are surprising; both the rent and the value of the inheritance of land depend on them greatly more than on nature, and this, though there is no considerable difference in the prices of our markets. Land of equal goodness lets for double the rent of other land lying in the same county, and there are many years purchase difference between different counties, where rents are equally well paid and secure.

Thus manners operate upon the number of inhabitants, but of their silent effects upon a civil constitution, history, and even our own experience, yields us abundance of proofs, though they are not uncommonly attributed to external causes: their support of a government against external force is so great, that it is a common maxim among the advocates of liberty, that no free government was ever dissolved, or overcome, before the manners of its subjects were corrupted.

The superiority of Greece over Persia was singly owing to their difference of manners; and that, though all natural advantages were on the side of the latter, to which I might add the civil ones; for though the greatest of all civil advantages, liberty, was on the side of Greece, yet that added no political strength to her, than as it operated on her manners, and, when they were corrupted, the restoration of their liberty by the Romans, overturned the remains of their power.

Whether the manners of ancient Rome were at any period calculated to promote the happiness of individuals, it is not my design to examine; but that their manners, and the effects of those manners on their government and public conduct, founded, enlarged, and supported, and afterwards overthrew their empire, is beyond all doubt. One of the effects of their conquest furnishes us with a strong proof, how prevalent manners are even beyond quantity of subsistence; for, when the custom of bestowing on the citizens of Rome corn enough to support themselves and families was become established, and Egypt and Sicily produced the grain, that fed the inhabitants of Italy, this became less populous every day, and the *jus trium liberorum* was but an expedient, that could not balance the want of industry and frugality. [398]

But corruption of manners did not only thin the inhabitants of the Roman empire, it rendered the remainder incapable of defence, long before its fall, perhaps before the dissolution of the republic; so that without standing disciplined armies, composed of men, whose moral habits principally, and mechanical habits secondarily, made them different from the body of the people, the Roman empire had been a prey to the barbarians many ages before it was.

By the mechanical habits of the soldiery, I mean their discipline, and the art of war; and that this is but a secondary quality appears from the inequality that has in all ages been between raw, though well disciplined armies, and veterans, and more from the irresistible force a single moral habit, religion, has conferred on troops, frequently neither disciplined nor experienced.

The military manners of the noblesse in France, compose the chief force of that kingdom, and the enterprising manners and restless dispositions of the inhabitants of Canada have enabled a handful of men to harass our populous, and, generally, less martial colonies; yet neither are of the value they seem at first sight, because overbalanced by the defect they occasion of other habits, that would produce more eligible political good: and military manners in a people are not necessary in an age and country where such manners may be occasionally formed and preserved among men enough to defend the state; and such a country is Great Britain, where, though the lower class of people are by no means of a military cast, yet they make better soldiers than even the noblesse of France. [399]

The inhabitants of this country, a few ages back, were to the populous and rich provinces of France, what Canada is now to the British colonies. It is true, there was less disproportion between their natural strength; but I mean, that the riches of France were a real weakness, opposed to the military manners founded upon poverty and a rugged disposition, then the character of the English; But it must be remembered, that at this time the manners of a people were not distinct from that of their soldiery, for the use of standing armies has deprived a military people of the advantages they before had over others; and though it has been often said, that civil wars give power, because they render all men soldiers, I believe this has only been found true in internal wars following civil wars, and not in external ones; for now, in foreign wars, a small army, with ample means to support it, is of greater force than one more numerous, with less. This last fact has often happened between France and Germany.

The means of supporting armies, and consequently the power of exerting external strength, are best found in the industry and frugality of the body of a people living under a government and laws, that encourage commerce: for commerce is at this day almost the only stimulus, that forces every one to contribute a share of labour for the public benefit. [400]

But such is the human frame, and the world is so constituted, that it is a hard matter to possess ones self of a benefit, without laying ones self open to a loss on some other side; the improvements of manners of one sort often deprave those of another: thus we see industry and frugality under the influence of commerce, which I call a commercial spirit, tend to destroy, as well as support, the government it flourishes under.

Commerce perfects the arts, but more the mechanical than the liberal, and this for an obvious reason; it softens and enervates the manners. Steady virtue and unbending integrity are seldom to be found where a spirit of commerce pervades every thing; yet the perfection of commerce is, that every thing should have its price. We every day see its progress, both to our benefit and detriment here. Things, that *boni mores* forbid to be set to sale, are become its objects, and there are few things indeed *extra commercium*. The legislative power itself has been *in commercio*, and church livings are seldom given without consideration, even by sincere Christians, and, for consideration, not seldom to very unworthy persons. The rudeness of ancient military times and the fury of more modern enthusiastic ones are worn off; even the spirit of forensic contention is astonishingly diminished, all marks of manners softening; but luxury and corruption have taken their places, [401]
and seem the inseparable companions of commerce and the arts.

I cannot help observing, however, that this is much more the case in extensive countries, especially at their metropolis, than in other places. It is an old observation of politicians, and frequently made by historians, that small states always best preserve their manners. Whether this happens from the greater room there is for attention in the legislature, or from the less room there is for ambition and avarice, it is a strong argument, among others, against an incorporating union of the colonies in America, or even a federal one, that may tend to the future reducing them under one government.

Their power, while disunited, is less, but their liberty; as well as manners, is more secure; and, considering the little danger of any conquest to be made upon them, I had rather they should suffer something through disunion, than see them under a general administration less equitable than that concerted at Albany[81].

I take it, the inhabitants of Pensylvania are both frugal and industrious beyond those of any province in America. If luxury should spread, it cannot be extirpated by laws. We are told by Plutarch, that Plato used to say, *It was a hard thing to make laws for the Cyrenians, a people abounding in plenty and opulence*.

But from what I set out with, it is evident, if I be not mistaken, that education only can stem the torrent, and, without checking either true industry or frugality, prevent the sordid frugality and laziness of the old Irish, and many of the [402]
modern Scotch, (I mean the inhabitants of that country, those who leave it for another being generally industrious) or the industry, mixed with luxury, of this capital, from getting ground, and, by rendering ancient manners familiar, produce a reconciliation between disinterestedness and commerce; a thing we often see, but almost always in men of a liberal education.

To conclude: when we would form a people, soil and climate may be found at least sufficiently good; inhabitants may be encouraged to settle, and even supported for a while; a good government and laws may be framed, and even arts may be established, or their produce imported: but many necessary moral habits are hardly ever found among those who voluntary offer themselves in times of quiet at home, to people new colonies; besides that the moral, as well as mechanical habits adapted to a mother country are frequently not so to the new settled one, and to external events, many of which are always unforeseen. Hence it is we have seen such fruitless attempts to settle colonies, at an immense public and private expence, by several of the powers of Europe: and it is particularly observable, that none of the English colonies became any way considerable, till the necessary manners were born and grew up in the country, excepting those to which singular circumstances at home forced manners fit for the forming a new state.

I am, sir, &c.

R.J.

FOOTNOTES:

[80] Richard Jackson, an English barrister. *Editor.*

[81] The reader will see an account of this plan in the subsequent volume. *Editor.*

Plan, by Messieurs Franklin and Dalrymple, for benefitting distant unprovided Countries[82]. [403]

Aug. 29, 1771.

The country called in the maps New Zealand has been discovered by the Endeavour, to be two islands, together as large as Great Britain: these islands, named Acpy-nomawée and Tovy-poennammoo, are inhabited by a brave and generous race, who are destitute of *corn*, *fowls*, and *all quadrupeds*, except *dogs*.

These circumstances being mentioned lately in a company of men of liberal sentiments, it was observed, that it seemed incumbent on such a country as this, to communicate to all others the conveniences of life, which we enjoy.

Dr. Franklin, whose life has ever been directed to promote the true interest of society, said, "he would with all his heart *subscribe* to a voyage intended to communicate *in general* those benefits, which we enjoy, to countries destitute of them in the remote parts of the globe." This proposition being warmly adopted by the rest of the company, Mr. Dalrymple, then present, was induced to offer to undertake the command on such an expedition.

On mature reflection, this scheme appears the more honourable to the national character of any which can be conceived, as it is grounded on the noblest principle of benevolence. Good intentions are often frustrated by letting them remain indigested; on this consideration Mr. Dalrymple was induced to put the outlines on paper, which are now [404] published, that by an early communication there, may be a better opportunity of collecting all the hints, which can conduce to execute effectually the benevolent purpose of the expedition, in case it should meet with general approbation.

On this scheme being shown to Dr. Franklin, he communicated his sentiments, by way of introduction, to the following effect:

"Britain is said to have produced originally nothing but *sloes*. What vast advantages have been communicated to her by the fruits, seeds, roots, herbage, animals, and arts of other countries! We are by their means become a wealthy and a mighty nation, abounding in all good things. Does not some *duty* hence arise from us towards other countries, still remaining in our former state?

"Britain is now the first maritime power in the world. Her ships are innumerable, capable by their form, size, and strength, of sailing all seas. Our seamen are equally bold, skilful, and hardy; dexterous in exploring the remotest regions, and ready to engage in voyages to unknown countries, though attended with the greatest dangers. The inhabitants of those countries, our *fellow men*, have canoes only; not knowing iron, they cannot build ships; they have little astronomy, and no knowledge of the compass to guide them; they cannot therefore come to us, or obtain any of our advantages. From these circumstances, does not some duty seem to arise from us to them? Does not Providence, by these distinguishing favours, seem to call on us, to do something ourselves for the common interest of humanity!

"Those who think it their duty, to ask bread and other blessings daily from heaven, would they not think it equally a [405]
duty, to communicate of those blessings when they have received them, and show their gratitude to their great Benefactor by the only means in their power, promoting the happiness of his other children?

"Ceres is said to have made a journey through many countries to teach the use of corn, and the art of raising it. For this single benefit the grateful nations deified her. How much more may Englishmen deserve such honour, by communicating the knowledge and use not of corn only, but of all the other enjoyments earth can produce, and which they are now in possession of. *Communiter bona profundere, Deum est.*

"Many voyages have been undertaken with views of profit or of plunder, or to gratify resentment; to procure some advantage to ourselves, or do some mischief to others: but a voyage is now proposed, to visit a distant people on the other side the globe; not to cheat them, not to rob them, not to seize their lands, or enslave their persons; but merely to do them good, and make them, as far as in our power lies, to live as comfortably as ourselves.

"It seems a laudable wish, that all the nations of the earth were connected by a knowledge of each other, and a mutual exchange of benefits: but a commercial nation particularly should wish for a general civilization of mankind, since trade is always carried on to much greater extent with people who have the arts and conveniences of life, than it can be with naked savages. We may therefore hope, in this undertaking, to be of, some service to our country, as well as to those poor [406]
people, who, however distant from us, are in truth related to us, and whose interests do, in some degree, concern every one who can say, *Homo sum, &c.*"

Scheme of a voyage, by subscription, to convey the conveniences of life, as fowls, hogs, goats, cattle, corn, iron, &c., to those remote regions, which are destitute of them, and to bring from thence such productions, as can be cultivated in this kingdom to the advantage of society, in a ship under the command of Alexander Dalrymple.

Catt or bark, from the coal trade,		£
of 350 tons, estimated at about		2000
Extra expences, stores, boats, &c.		3000
To be manned with	60 men at	
	4 per man per month	

	240		
	12		
	2880	per annum	
	3		
Wages and provisions	8640	for three years	8640
			13640
Cargo included, supposed			15000

The expences of this expedition are calculated for *three* years: but the greatest part of the amount of wages will not be wanted till the ship returns, and a great part of the expence of provisions will be saved by what is obtained in the course of [407] the voyage, by barter, or otherwise, though it is proper to make provision for contingencies.

* * * * *

FOOTNOTE:

[82] These proposals were printed upon a sheet of paper some two or three years ago, and distributed. The parts written by Dr. Franklin and Mr. Dalrymple are easily distinguished. B. V.

TO DR. PERCIVAL.

Concerning the Provision made in China against Famine.

I have somewhere read, that in China an account is yearly taken of the number of people, and the quantities of provision produced. This account is transmitted to the emperor, whose ministers can thence foresee a scarcity, likely to happen in any province, and from what province it can best be supplied in good time. To facilitate the collecting of this account, and prevent the necessity of entering houses and spending time in asking and answering questions, each house is furnished with a little board, to be hung without the door during a certain time each year; on which board are marked certain words, against which the inhabitant is to mark number and quantity, somewhat in this manner:

Men, Women, Children, Rice, or Wheat, Flesh, &c.

All under sixteen are accounted children, and all above, men and women. Any other particulars, which the government desires information of, are occasionally marked on the same boards. Thus the officers, appointed to collect the accounts in each district, have only to pass before the doors, and enter into their book what they find marked on the board, without giving the least trouble to the family. There is a penalty on marking falsely, and as neighbours must know nearly the truth of each others account, they dare not expose themselves, by a false one, to each others accusation. Perhaps such a regulation is scarcely practicable with us[83]. [408]

FOOTNOTE:

[83] The above passage is taken from Dr. Percival's Essays, Vol. III. p. 25, being an extract from a letter written to him, by Dr. Franklin, on the subject of his observations on the state of population in Manchester and other adjacent places. B. V.

Positions to be examined, concerning national Wealth[84].

1. All food or subsistence for mankind arise from the earth or waters.

2. Necessaries of life, that are not foods, and all other conveniences, have their values estimated by the proportion of food consumed while we are employed in procuring them.

3. A small people, with a large territory, may subsist on the productions of nature, with no other labour than that of gathering the vegetables and catching the animals.

4. A large people, with a small territory, finds these insufficient, and, to subsist, must labour the earth, to make it produce greater quantities of vegetable food, suitable for the nourishment of men, and of the animals they intend to eat. [409]

5. From this labour arises a *great increase* of vegetable and animal food, and of materials for clothing, as flax, wool, silk, &c. The superfluity of these is wealth. With this wealth we pay for the labour employed in building our houses, cities, &c. which are therefore only subsistence thus metamorphosed.

6. *Manufactures* are only *another shape* into which so much provisions and subsistence are turned, as were equal in value to the manufactures produced. This appears from hence, that the manufacturer does not, in fact, obtain from the employer, for his labour, *more* than a mere subsistence, including raiment, fuel, and shelter: all which derive their value from the provisions consumed in procuring them.

7. The produce of the earth, thus converted into manufactures, may be more easily carried to distant markets than before such conversion.

8. *Fair commerce* is, where equal values are exchanged for equal, the expence of transport included. Thus, if it costs A in England as much labour and charge to raise a bushel of wheat, as it costs B in France to produce four gallons of wine, then are four gallons of wine the fair exchange for a bushel of wheat, A and B meeting at half distance with their commodities to make the exchange. The advantage of this fair commerce is, that each party increases the number of his enjoyments, having, instead of wheat alone, or wine alone, the use of both wheat and wine.

9. Where the labour and expence of producing both commodities are known to both parties, bargains will generally be fair and equal. Where they are known to one party only, bargains will often be unequal, knowledge taking its advantage of [410] ignorance.

10. Thus he, that carries one thousand bushels of wheat abroad to sell, may not probably obtain so great a profit thereon, as if he had first turned the wheat into manufactures, by subsisting therewith the workmen while producing those manufactures: since there are many expediting and facilitating methods of working, not generally known; and strangers to the manufactures, though they know pretty well the expence of raising wheat, are unacquainted with those short methods of working, and thence, being apt to suppose more labour employed in the manufactures than there really is, are more easily imposed on in their value, and induced to allow more for them than they are honestly worth.

11. Thus the advantage of having manufactures in a country does not consist, as is commonly supposed, in their highly advancing the value of rough materials, of which they are formed; since, though six-pennyworth of flax may be worth twenty shillings when worked into lace, yet the very cause of its being worth twenty shillings, is, that, besides the flax, it has cost nineteen shillings and sixpence in subsistence to the manufacturer. But the advantage of manufactures is, that

under their shape provisions may be more easily carried to a foreign market; and by their means our traders may more easily cheat strangers. Few, where it is not made, are judges of the value of lace. The importer may demand forty, and perhaps get thirty shillings for that, which cost him but twenty.

12. Finally, there seem to be but three ways for a nation to acquire wealth. The first is by *war*, as the Romans did, in plundering their conquered neighbours. This is *robbery*.—The second by *commerce*, which is generally *cheating*.—The third by *agriculture*, the only *honest way*, wherein man receives a real increase of the seed thrown into the ground, in a kind of continual miracle wrought by the hand of God in his favour, as a reward for his innocent life, and his virtuous industry. [411]

B. FRANKLIN.

April 4, 1769.

FOOTNOTE:

[84] This article has been inserted in The Repository for select Papers on Agriculture, Arts, and Manufactures. Vol. I, p. 350. B. V.

Political Fragments, supposed either to be written by Dr. Franklin, or to contain Sentiments nearly allied to his own[85].

[§ 1. *Of the Employment of Time, and of Indolence: particularly as respecting the State.*]

All that live must be subsisted. Subsistence costs something. He, that is industrious, produces, by his industry, something that is an equivalent, and pays for his subsistence: he is therefore no charge or burden to society. The indolent are an expence uncompensated.

There can be no doubt but all kinds of employment, that can be followed without prejudice from interruptions; work, that can be taken up, and laid down, often in a day, without damage; (such as spinning, knitting, weaving, &c.) are highly advantageous to a community; because in them may be collected all the produce of those fragments of time, that occur in family-business, between the constant and necessary parts of it, that usually occupy females; as the time between rising and preparing for breakfast, between breakfast and preparing for dinner, &c. &c. The amount of all these fragments is, in the course of a year, very considerable to a single family; to a state proportionably. Highly profitable therefore it is, in this case also, to follow that divine direction, *gather up the fragments that nothing be lost*. Lost time is lost subsistence; it is therefore lost treasure. [412]

Hereby, in several families, many yards of linen have been produced, from the employment of those fragments only, in one year, though such families were just the same in number as when not so employed.

It was an excellent saying of a certain Chinese emperor, *I will, if possible, have no idleness in my dominions; for if there be one man idle, some man must suffer cold or hunger*. We take this emperor's meaning to be, that the labour due to the public by each individual, not being performed by the indolent, must naturally fall to the share of others, who must thereby suffer.

[§ 2. *Of Embargoes upon Corn, and of the Poor.*]

In inland high countries, remote from the sea, and whose rivers are small, running *from* the country, and not *to* it, as is the case of Switzerland, great distress may arise from a course of bad harvests, if public granaries are not provided, and kept well stored. Anciently too, before navigation was so general, ships so plenty, and commercial connections so well [413] established, even maritime countries might be occasionally distressed by bad crops. But such is now the facility of communication between those countries, that an unrestrained commerce can scarce ever fail of procuring a sufficiency for any of them. If indeed any government is so imprudent, as to lay its hands on imported corn, forbid its exportation, or compel its sale at limited prices, there the people may suffer some famine from merchants avoiding their ports. But wherever commerce is known to be always free, and the merchant absolute master of his commodity, as in Holland, there will always be a reasonable supply.

When an exportation of corn takes place, occasioned by a higher price in some foreign countries, it is common to raise a clamour, on the supposition, that we shall thereby produce a domestic famine. Then follows a prohibition, founded on the imaginary distress of the poor. The poor, to be sure, if in distress, should be relieved; but if the farmer could have a high price for his corn from the foreign demand, must he, by a prohibition of exportation, be compelled to take a low price, not of the poor only, but of every one that eats bread, even the richest? the duty of relieving the poor is incumbent on the rich; but by this operation the whole burden of it is laid on the farmer, who is to relieve the rich at the same time. Of the poor too, those, who are maintained by the parishes, have no right to claim this sacrifice of the farmer; as, while they have their allowance, it makes no difference to them, whether bread be cheap or dear. Those working poor, who now mind business only *five* or *four* days in the week, if bread should be so dear, as to oblige them to work the whole *six* [414] required by the commandment, do not seem to be aggrieved, so as to have a right to public redress. There will then remain, comparatively, only a few families in every district, who, from sickness, or a great number of children, will be so distressed by a high price of corn, as to need relief; and these should be taken care of by particular benefactions, without restraining the farmer's profit.

Those, who fear, that exportation may so far drain the country of corn, as to starve ourselves, fear what never did, nor ever can happen. They may as well, when they view the tide ebbing towards the sea, fear, that all the water will leave the river. The price of corn, like water, will find its own level. The more we export, the dearer it becomes at home; the more is received abroad, the cheaper it becomes there; and as soon as these prices are equal, the exportation stops of course. As the seasons vary in different countries, the calamity of a bad harvest is never universal. If then, all ports were always open, and all commerce free, every maritime country would generally eat bread at the medium price, or average of all the harvests; which would probably be more equal than we can make it by out artificial regulations, and therefore a more steady encouragement to agriculture. The nation would all have bread at this middle price; and that nation, which at any time inhumanely refuses to relieve the distresses of another nation, deserves no compassion when in distress itself.

[§ 3. *Of the Effect of Dearness of Provisions upon Working, and upon Manufactures.*] [415]

The common people do not work for pleasure generally, but from necessity. Cheapness of provisions makes them more idle; less work is then done, it is then more in demand proportionally, and of course the price rises. Dearness of provisions obliges the manufacturer to work more days and more hours; thus more work is done than equals the usual demand; of course it becomes cheaper, and the manufactures in consequence.

[§ 4. *Of an open Trade.*]

Perhaps, in general, it would be better if government meddled no farther with trade, than to protect it, and let it take its course. Most of the statutes or acts, edicts, arrets, and placarts of parliaments, princes, and states, for regulating, directing, or restraining of trade, have, we think, been either political blunders, or jobs obtained by artful men, for private advantage, under pretence of public good. When Colbert assembled some wise old merchants of France, and desired their advice and opinion, how he could serve and promote commerce: their answer, after consultation, was in three words only, *Laissez nous faire*; "Let us alone."—It is said, by a very solid writer of the same nation, that he is well advanced in the science of politics, who knows the full force of that maxim, *Pas trop gouverner*, "Not to govern too much;" which, perhaps, would be of more use when applied to trade, than in any other public concern. It were therefore to be wished, that commerce were as free between all the nations of the world, as it is between the several counties of England; so [416] would all, by mutual communication, obtain more enjoyments. Those counties do not ruin each other by trade, neither would the nations. No nation was ever ruined by trade, even, seemingly, the most disadvantageous.

Wherever desirable superfluities are imported, industry is excited, and thereby plenty is produced. Were only necessaries permitted to be purchased, men would work no more than was necessary for that purpose.

[§ 5. *Of Prohibitions, with Respect to the Exportation of Gold and Silver.*]

Could Spain and Portugal have succeeded in executing their foolish laws for *hedging in the cuckoo*, as Locke calls it, and have kept at home all their gold and silver, those metals would by this time have been of little more value than so much lead or iron. Their plenty would have lessened their value. We see the folly of these edicts: but are not our own prohibitory and restrictive laws, that are professedly made with intention to bring a balance in our favour from our trade with foreign nations to be paid in money, and laws to prevent the necessity of exporting that money, which if they could be thoroughly executed, would make money as plenty, and of as little value; I say, are not such laws a kin to those Spanish edicts, follies of the same family?

[§ 6. *Of the Returns for foreign Articles.*]

In fact, the *produce of other countries* can hardly be obtained, unless by fraud and rapine, without giving the *produce of our land or our industry* in exchange for them. If we have mines of gold and silver, gold and silver may then be called the [417] produce of our land: if we have not, we can only fairly obtain those metals by giving for them the produce of our land or industry. When we have them, they are then only that produce or industry in another shape; which we may give, if the trade requires it, and our other produce will not suit, in exchange for the produce of some other country, that furnishes what we have more occasion for, or more desire. When we have, to an inconvenient degree, parted with our gold and silver, our industry is stimulated afresh to procure more; that, by its means, we may contrive to procure the same advantage.

[§ 7. *Of Restraints upon Commerce in Time of War.*]

When princes make war by prohibiting commerce, each may hurt himself as much as his enemy. Traders, who by their business are promoting the common good of mankind, as well as farmers and fishermen, who labour for the subsistence of all, should never be interrupted, or molested in their business, but enjoy the protection of all in the time of war, as well as in time of peace.

This policy, those, whom we are pleased to call Barbarians, have in a great measure adopted; for the trading subjects of any power with whom the emperor of Morocco may be at war, are not liable to capture, when within sight of his land, going or coming; and have otherwise free liberty to trade and reside in his dominions.

As a maritime power, we presume it is not thought right, that Great Britain should grant such freedom, except partially; as in the case of war with France, when tobacco is allowed to be sent thither under the sanction of passports.

[§ 8. *Exchanges in Trade may be gainful to each Party.*] [418]

In transactions of trade, it is not to be supposed, that, like gaming, what one party *gains* the other must necessarily *lose*. The gain to each may be equal. If A has more corn than he can consume, but wants cattle; and B has more cattle, but wants corn, exchange is gain to each: hereby the common stock of comforts in life is increased.

[§9. *Of Paper Credit.*]

It is impossible for government to circumscribe, or fix the extent of paper credit, which must of course fluctuate. Government may as well pretend to lay down rules for the operations, or the confidence of every individual in the course of his trade. Any seeming temporary evil arising, must naturally work its own cure.

FOOTNOTE:

[85] The political fragments, which are here presented to the reader, were gathered up from the notes, annexed to a pamphlet called The Principles of Trade, printed for Brotherton and Sewel, London, 1774, second edition. —The writer of this work speaks of assistance lent to him, in the following passage in his preface: "Some very respectable friends have indulged me with their ideas and opinions. It is with the greatest pleasure we, in this second edition, most gratefully acknowledge the favour; and must add, that should the public hold this performance in any estimation, no small share belongs to those friends." Our author is one of the respectable friends here alluded to. B. V.

On the Price of Corn, and Management of the Poor[86].

TO MESSIEURS THE PUBLIC.

I am one of that class of people, that feeds you all, and at present is abused by you all;—in short, I am a *farmer*.

[419]

By your news-papers we are told, that God had sent a very short harvest to some other countries of Europe. I thought this might be in favour of Old England; and that now we should get a good price for our grain, which would bring millions among us, and make us flow in money: that to be sure is scarce enough.

But the wisdom of government forbad the exportation[87].

Well, says I, then we must be content with the market-price at home.

No, say my lords the mob, you sha'n't have that. Bring your corn to market if your dare;—we'll sell it for you, for less money, or take it for nothing.

Being thus attacked by both ends *of the constitution*, the head and tail *of government*, what am I to do?

Must I keep my corn in the barn, to feed and increase

the breed of rats?—be it so;—they cannot be less thankful than those I have been used to feed. [420]

Are we farmers the only people to be grudged the profits of our honest labour?—And why? One of the late scribblers against us gives a bill of fare of the provisions at my daughter's wedding, and proclaims to all the world, that we had the insolence to eat beef and pudding!—Has he not read the precept in the good book, *Thou shalt not muzzle the mouth of the ox that treadeth out the corn*; or does he think us less worthy of good living than our oxen?

O, but the manufacturers! the manufacturers! they are to be favoured, and they must have bread at a cheap rate!

Hark ye, Mr. Oaf:—The farmers live splendidly, you say. And pray, would you have them hoard the money they get? Their fine clothes and furniture, do they make them themselves or for one another, and so keep the money among them? Or, do they employ these your darling manufacturers, and so scatter it again all over the nation?

The wool would produce me a better price, if it were suffered to go to foreign markets; but that, Messieurs the Public, your laws will not permit. It must be kept all at home, that our *dear* manufacturers may have it the cheaper. And then, having yourselves thus lessened our encouragement for raising sheep, you curse us for the scarcity of mutton!

I have heard my grandfather say, that the farmers submitted to the prohibition on the exportation of wool, being made to expect and believe, that when the manufacturer bought his wool cheaper, they should also have their cloth cheaper. But [421] the deuce a bit. It has been growing dearer and dearer from that day to this. How so? Why, truly, the cloth is exported; and that keeps up the price.

Now if it be a good principle, that the exportation of a commodity is to be restrained, that so our people at home may have it the cheaper; stick to that principle, and go thorough stitch with it. Prohibit the exportation of your cloth, your leather, and shoes, your ironware, and your manufactures of all sorts, to make them, all cheaper at home. And cheap enough they will be, I will warrant you—till people leave off making them.

Some folks seem to think they ought never to be easy till England becomes another Lubberland, where it is fancied the streets are paved with penny-rolls, the houses tiled with pancakes, and chickens, ready roasted, cry, Come eat me.

I say, when you are sure you have got a good principle, stick to it, and carry it thorough.—I hear it is said, that though it was *necessary and right* for the m——y to advise a prohibition of the exportation of corn, yet it was *contrary to law*; and also, that though it was *contrary to law* for the mob to obstruct waggons, yet it was *necessary and right*.—Just the same thing to a tittle. Now they tell me, an act of indemnity ought to pass in favour of the m——y, to secure them from the consequences of having acted illegally.—If so, pass another in favour of the mob. Others say, some of the mob ought to be hanged, by way of example.—-If so,—but I say no more than I have said before, *when you are sure that you have got a good principle, go through with it*.

You say, poor labourers cannot afford to buy bread at a high price, unless they had higher wages.—Possibly.—But how shall we farmers be able to afford our labourers higher wages, if you will not allow us to get, when we might have it, a higher price for our corn? [422]

By all that I can learn, we should at least have had a guinea a quarter more, if the exportation had been allowed. And this money England would have got from foreigners.

But, it seems, we farmers must take so much less, that the poor may have it so much cheaper.

This operates then as a tax for the maintenance of the poor. A very good thing, you will say. But I ask, why a partial tax? why laid on us farmers only? If it be a good thing, pray, Messieurs the Public, take your share of it, by indemnifying us a little out of your public treasury. In doing a good thing, there is both honour and pleasure—you are welcome to your share of both.

For my own part, I am not so well satisfied of the goodness of this thing. I am for doing good to the poor, but I differ in opinion about the means. I think the best way of doing good to the poor, is, not making them easy *in* poverty, but leading or driving them *out* of it. In my youth I travelled much, and I observed in different countries, that the more public provisions were made for the poor, the less they provided for themselves, and of course became poorer. And, on the contrary, the less was done for them, the more they did for themselves, and became richer. There is no country in the world where so many provisions are established for them; so many hospitals to receive them when they are sick or lame, [423] founded and maintained by voluntary charities; so many alms houses for the aged of both sexes, together with a solemn general law made by the rich to subject their estates to a heavy tax for the support of the poor. Under all these obligations, are our poor modest, humble, and thankful? And do they use their best endeavours to maintain themselves, and lighten our shoulders of this burthen? On the contrary, I affirm, that there is no country in the world in which the poor are more idle, dissolute, drunken, and insolent. The day you passed that act, you took away from before their eyes the greatest of all inducements to industry, frugality, and sobriety, by giving them a dependence on somewhat else than a careful accumulation during youth and health, for support in age or sickness. In short, you offered a premium for the encouragement of idleness, and you should not now wonder, that it has had its effect in the increase of poverty. Repeal that law, and you will soon see a change in their manners, *Saint Monday*, and *Saint Tuesday*, will soon cease to be holidays. Six *days shalt thou labour*, though one of the old commandments long treated as out of date, will again be looked upon as a respectable precept; industry will increase, and with it plenty among the lower people; their circumstances will mend, and more will be done for their happiness by inuring them to provide for themselves, than could be done by dividing all your estates among them.

Excuse me, Messieurs the Public, if upon this *interesting* subject, I put you to the trouble of reading a little of *my* nonsense; I am sure I have lately read a great deal of *yours*, and therefore from you (at least from those of you who are [424] writers) I deserve a little indulgence.

I am yours, &c.

ARATOR[88].

FOOTNOTES:

[86] The following extracts of a letter signed Columella, and addressed to the editors of the Repository for select Papers on Agriculture, Arts, and Manufactures (See Vol. I. p. 352.) will again serve the purpose of preparing those who read it, for entering upon this paper.

"Gentlemen,

"There is now publishing in France a periodical work, called Ephemeridis du Citoyen, in which several points, interesting to those concerned in agriculture, are from time to time discussed by some able hands. In looking over one of the volumes of this work a few days ago, I found a little piece written by one of our countrymen, and which our vigilant neighbours had taken from the London Chronicle in 1766. The author is a gentleman well known to every man of letters in Europe, and perhaps there is none, in this age, to whom mankind in general are more indebted.

"That this piece may not be lost to our own country, I beg you will give it a place in your Repository: it was written in favour of the farmers, when they suffered so much abuse in our public papers, and were also plundered by the mob in many places."

The principles on which this piece is grounded are given more at large in the Political Fragments, art. 2. B. V.

[87] It is not necessary to repeat in what degree Dr. Franklin respected the ministers, to whom he alludes.—The embargo upon corn was but a single measure, which, it is enough to say, an host of politicians thought well advised, but ill defended. Of the great and honourable services of the earl of Chatham to his country, Dr. Franklin has borne the amplest testimony. B. V.

[88] The late Mr. Owen Ruffhead, being some time ago employed in preparing *a digest of our poor laws*, communicated a copy of it to Dr. Franklin for his advice. Dr. Franklin recommended, that provision should be made therein, for the printing on a sheet of paper and dispersing, in each parish in the kingdom, annual accounts of every disbursement and receipt of its officers. It is obvious to remark, how greatly this must tend to check both the officers and the poor, and to inform and interest the parishioners with respect to parish concerns.—Some of the American colonies actually practise this measure with a success which might justify its adoption here. B. V.

TO BENJAMIN VAUGHAN, ESQ[89].

On Luxury, Idleness, and Industry.

Written in 1784.

It is wonderful how preposterously the affairs of this world are managed. Naturally one would imagine, that the interest of a few individuals should give way to general interest; but individuals manage their affairs with so much more application, industry, and address, than the public do theirs, that, general interest most commonly gives way to particular. We assemble parliaments and councils, to have the benefit of their collected wisdom; but we necessarily have, at the same [425] time, the inconvenience of their collected passions, prejudices, and private interests. By the help of these, artful men overpower their wisdom, and dupe its possessors: and if we may judge, by the acts, arrets, and edicts, all the world over, for regulating commerce, an assembly of great men is the greatest fool upon earth.

I have not yet, indeed, thought of a remedy for luxury. I am not sure that in a great state it is capable of a remedy, nor that the evil is in itself always so great as it is represented. Suppose we include in the definition of luxury all unnecessary expence, and then let us consider, whether laws to prevent such expence are possible to be executed in a great country, and whether, if they could be executed, our people generally would be happier, or even richer. Is not the hope of being one day able to purchase and enjoy luxuries, a great spur to labour and industry? May not luxury therefore produce more than it consumes, if, without such a spur, people would be, as they are naturally enough inclined to be, lazy and indolent? To this purpose I remember a circumstance. The skipper of a shallop, employed between Cape-May and Philadelphia, had done us some small service, for which he refused to be paid. My wife, understanding that he had a daughter, sent her a present of a new-fashioned cap. Three years after, this skipper being at my house with an old farmer of Cape-May, his passenger, he mentioned the cap, and how much his daughter had been pleased with it. "But (said he) it proved a dear cap to our congregation." "How so?" "When my daughter appeared with it at meeting, it was so much admired, that all the [426] girls resolved to get such caps from Philadelphia; and my wife and I computed, that the whole could not have cost less than a hundred pounds." "True (said the farmer), but you do not tell all the story. I think the cap was nevertheless an advantage to us, for it was the first thing that put our girls upon knitting worsted mittens for sale at Philadelphia, that they might have wherewithal to buy caps and ribbons there, and you know that that industry has continued, and is likely to continue and increase to a much greater value, and answer better purposes."—Upon the whole, I was more reconciled to this little piece of luxury, since not only the girls were made happier by having fine caps, but the Philadelphians by the supply of warm mittens.

In our commercial towns upon the sea-coast, fortunes will occasionally be made. Some of those who grow rich will be prudent, live within bounds, and preserve what they have gained for their posterity: others, fond of showing their wealth, will be extravagant, and ruin themselves. Laws cannot prevent this: and perhaps it is not always an evil to the public. A shilling spent idly by a fool, may be picked up by a wiser person, who knows better what to do with it. It is therefore not lost. A vain silly fellow builds a fine house, furnishes it richly, lives in it expensively, and in a few years ruins himself: but the masons, carpenters, smiths, and other honest tradesmen, have been by his employ assisted in maintaining and raising their families; the farmer has been paid for his labour, and encouraged, and the estate is now in better hands. In some cases, indeed, certain modes of luxury may be a public evil, in the same manner as it is a private one. If there be a nation, [427] for instance, that exports its beef and linen, to pay for the importation of claret and porter, while a great part of its people live upon potatoes, and wear no shirts, wherein does it differ from the sot, who lets his family starve, and sells his clothes to buy drink? Our American commerce is, I confess, a little in this way. We sell our victuals to the islands for rum and sugar; the substantial necessaries of life for superfluities. But we have plenty, and live well nevertheless, though, by being soberer, we might be richer.

The vast quantity of forest land we have yet to clear, and put in order for cultivation, will for a long time keep the body of our nation laborious and frugal. Forming an opinion of our people and their manners, by what is seen among the inhabitants of the sea-ports, is judging from an improper sample. The people of the trading towns may be rich and luxurious, while the country possesses all the virtues, that tend to promote happiness and public prosperity. Those towns are not much regarded by the country; they are hardly considered as an essential part of the states, and the experience of the last war has shown, that their being in the possession of the enemy did not necessarily draw on the subjection of the country, which bravely continued to maintain its freedom and independence notwithstanding.

It has been computed by some political arithmetician, that if every man and woman would work for four hours each day on something useful, that labour would produce sufficient to procure all the necessaries and comforts of life, want and misery would be banished out of the world, and the rest of the twenty-four hours might be leisure and pleasure.

What occasions then so much want and misery? It is the employment of men and women in works, that produce neither [428]
the necessaries nor conveniences of life, who, with those who do nothing, consume necessaries raised by the laborious. To explain this.

The first elements of wealth are obtained by labour, from the earth and waters. I have land, and raise corn. With this, if I feed a family that does nothing, my corn will be consumed, and at the end of the year I shall be no richer than I was at the beginning. But if, while I feed them, I employ them, some in spinning, others in making bricks, &c. for building, the value of my corn will be arrested and remain with me, and at the end of the year we may all be better clothed and better lodged. And if, instead of employing a man I feed in making bricks, I employ him in fiddling for me, the corn he eats is gone, and no part of his manufacture remains to augment the wealth and convenience of the family: I shall therefore be the poorer for this fiddling man, unless the rest of my family work more, or eat less, to make up the deficiency he occasions.

Look round the world, and see the millions employed in doing nothing, or in something that amounts to nothing, when the necessaries and conveniences of life are in question. What is the bulk of commerce, for which we fight and destroy each other, but the toil of millions for superfluities, to the great hazard and loss of many lives, by the constant dangers of the sea? How much labour is spent in building and fitting great ships, to go to China and Arabia for tea and coffee, to the West Indies for sugar, to America for tobacco? These things cannot be called the necessaries of life, for our ancestors [429]
lived very comfortably without them.

A question may be asked: could all these people now employed in raising, making, or carrying superfluities, be subsisted by raising necessaries? I think they might. The world is large, and a great part of it still uncultivated. Many hundred millions of acres in Asia, Africa, and America, are still in a forest, and a great deal even in Europe. On a hundred acres of this forest a man might become a substantial farmer, and a hundred thousand men, employed in clearing each his hundred acres, would hardly brighten a spot big enough to be visible from the moon, unless with Herschel's telescope; so vast are the regions still in wood.

It is, however, some comfort to reflect, that, upon the whole, the quantity of industry and prudence among mankind exceeds the quantity of idleness and folly. Hence the increase of good buildings, farms cultivated, and populous cities filled with wealth, all over Europe, which a few ages since were only to be found on the coasts of the Mediterranean; and this notwithstanding the mad wars continually raging, by which are often destroyed in one year the works of many years peace. So that we may hope the luxury of a few merchants on the coast will not be the ruin of America.

One reflection more, and I will end this long rambling letter. Almost all the parts of our bodies require some expence. The feet demand shoes; the legs stockings; the rest of the body clothing; and the belly a good deal of victuals. Our eyes, though exceedingly useful, ask, when reasonable, only the cheap assistance of spectacles, which could not much impair our finances. But the eyes of other people are the eyes that ruin us. If all but myself were blind, I should want neither fine clothes, fine houses, nor fine furniture. [430]

FOOTNOTE:

[89] This letter is taken from a periodical publication, that existed only for a short period, entitled, The Repository, to which it was communicated by the person to whom it is addressed. *Editor.*

On Smuggling, and its various Species[90].

SIR,

There are many people that would be thought, and even think themselves, *honest* men, who fail nevertheless in particular points of honesty; deviating from that character sometimes by the prevalence of mode or custom, and sometimes through mere inattention; so that their *honesty* is partial only, and not *general* or universal. Thus one, who would scorn to over-reach you in a bargain, shall make no scruple of tricking you a little now and then at cards; another, that plays with the utmost fairness, shall with great freedom cheat you in the sale of a horse. But there is no kind of dishonesty, into which otherwise good people more easily and frequently fall, than that of defrauding government of its revenues by smuggling, when they have an opportunity, or encouraging smugglers by buying their goods.

I fell into these reflections the other day, on hearing two gentlemen of reputation discoursing about a small estate, which one of them was inclined to sell, and the other to buy; when the seller, in recommending the place, remarked, that its situation was very advantageous on this account, that, being on the sea-coast in a smuggling country, one had frequent [431] opportunities of buying many of the expensive articles used in a family (such as tea, coffee, chocolate, brandy, wines, cambrics, Brussels laces, French silks, and all kinds of India goods), 20, 30, and in some articles 50 *per cent* cheaper, than they could be had in the more interior parts, of traders that paid duty.—The other *honest* gentlemen allowed this to be an advantage, but insisted, that the seller, in the advanced price he demanded on that account, rated the advantage much above its value. And neither of them seemed to think dealing with smugglers a practice, that an *honest* man (provided he got his goods cheap) had the least reason to be ashamed of.

At a time when the load of our, public debt, and the heavy expence of maintaining our fleets and armies to be ready for our defence on occasion, makes it necessary, not only to continue old taxes, but often to look out for new ones, perhaps it may not be unuseful to state this matter in a light, that few seem to have considered it in.

The people of Great Britain, under the happy constitution of this country, have a privilege few other countries enjoy, that of choosing the third branch of the legislature, which branch has alone the power of regulating their taxes. Now whenever the government finds it necessary for the common benefit, advantage, and safety of the nation, for the security of our liberties, property, religion, and every thing that is dear to us, that certain sums shall be yearly raised by taxes, duties, &c. and paid into the public treasury, thence to be dispensed by government for those purposes; ought not every *honest man* freely and willingly to pay his just proportion of this necessary expence? Can he possibly preserve a right to [432] that character, if, by any fraud, stratagem, or contrivance, he avoids that payment in whole or in part.

What should we think of a companion, who, having supped with his friends at a tavern, and partaken equally of the joys of the evening with the rest of us, would nevertheless contrive by some artifice to shift his share of the reckoning upon others, in order to go off scot-free? If a man who practised this would, when detected, be deemed and called a scoundrel, what ought he to be called, who can enjoy all the inestimable benefits of public society, and yet by smuggling, or dealing with smugglers, contrive to evade paying his just share of the expence, as settled by his own representatives in parliament; and wrongfully throw it upon his honester and perhaps much poorer neighbours? He will perhaps be ready to tell me, that he does not wrong his neighbours; he scorns the imputation, he only cheats the king a little, who is very able to bear it. This however is a mistake. The public treasure is the treasure of the nation, to be applied to national purposes. And when a duty is laid for a particular public and necessary purpose, if, through smuggling, that duty falls short of raising the sum required, and other duties must therefore be laid to make up the deficiency, all the additional sum laid by the new duties and paid by other people, though it should amount to no more than a halfpenny or a farthing per head, is so much actually picked out of the pockets of those other people by the smugglers and their abettors and encouragers. Are they then any better or other than pickpockets? and what mean, low, rascally pickpockets must those be, that can pick pockets for halfpence and for farthings?

I would not however be supposed to allow in what I have just said, that cheating the king is a less offence against [433] honesty, than cheating the public. The king and the public in this case are different names for the same thing; but if we consider the king distinctly it will not lessen the crime: it is no justification of a robbery, that the person robbed was rich and able to bear it. The king has as much right to justice as the meanest of his subjects; and as he is truly the common *father* of his people, those that rob him fall under the scripture woe, pronounced against the son *that robbeth his father, and saith it is no sin*.

Mean as this practice is, do we not daily see people of character and fortune engaged in it for trifling advantages to themselves?—Is any lady ashamed to request of a gentleman of her acquaintance, that when he returns from abroad, he would smuggle her home a piece of silk or lace from France or Flanders? Is any gentleman ashamed to undertake and execute the commission?—Not in the least. They will talk of it freely, even before others whose pockets they are thus contriving to pick by this piece of knavery.

Among other branches of the revenue, that of the post-office is, by a late law, appropriated to the discharge of our public debt, to defray the expences of the state. None but members of parliament, and a few public officers have now a right to avoid, by a frank, the payment of postage. When any letter, not written by them or on their business, is franked by any of them, it is a hurt to the revenue, an injury which they must now take the pains to conceal by writing the whole superscription themselves. And yet such is our insensibility to justice in this particular, that nothing is more common than [434] to see, even in a reputable company, a *very honest* gentleman or lady declare his or her intention to cheat the nation of three-pence by a frank, and without blushing apply to one of the very legislators themselves, with a modest request, that he would be pleased to become an accomplice in the crime, and assist in the perpetration.

There are those who by these practices take a great deal in a year out of the public purse, and put the money into their own private pockets. If, passing through a room where public treasure is deposited, a man takes the opportunity of clandestinely pocketing and carrying off a guinea, is he not truly and properly a thief? And if another evades paying into the treasury a guinea he ought to pay in, and applies it to his own use, when he knows it belongs to the public as much as that which has been paid in, what difference is there in the nature of the crime, or the baseness of committing it?

Some laws make the receiving of stolen goods equally penal with stealing, and upon this principle, that if there were no receivers there would be few thieves. Our proverb too says truly, that *the receiver is as bad as the thief*. By the same reasoning, as there would be few smugglers, if there were none who knowingly encouraged them by buying their goods, we may say, that the encouragers of smuggling are as bad as the smugglers; and that, as smugglers are a kind of thieves, both equally deserve the punishments of thievery.

In this view of wronging the revenue, what must we think of those who can evade paying for their wheels and their plate, in defiance of law and justice, and yet declaim against corruption and peculation, as if their own hands and hearts [435] were pure and unsullied? The Americans offend us grievously, when, contrary to our laws, they smuggle goods into their own country: and yet they had no hand in making those laws. I do not however pretend from thence to justify them. But I think the offence much greater in those who either directly or indirectly have been concerned in making the very laws they break. And when I hear them exclaiming against the Americans, and for every little infringement of the acts of trade, or obstruction given by a petty mob to an officer of our customs in that country, calling for vengeance against the whole people as REBELS and traitors, I cannot help thinking there are still those in the world who can *see a mote in their brother's eye, while they do not discern a beam in their own*; and that the old saying is as true now as ever it was, *one man may better steal a horse, than another look over the hedge*.

F. B.

FOOTNOTE:

[90] This letter is extracted from the London Chronicle, for November 24, 1767, and is addressed to the printer of that newspaper. B. V.

Observations on War[91].

By the original law of nations, war and extirpation were the punishment of injury. Humanizing by degrees, it admitted slavery instead of death: a farther step was the exchange of prisoners instead of slavery: another, to respect more the property of private persons under conquest, and be content with acquired dominion. Why should not this law of nations go on improving? Ages have intervened between its several steps: but as knowledge of late increases rapidly, why should not [436] those steps be quickened? Why should it not be agreed to, as the future law of nations, that in any war hereafter the following description of men should be undisturbed, have the protection of both sides, and be permitted to follow their employments in security? viz.

1. Cultivators of the earth, because they labour for the subsistence of mankind.

2. Fishermen, for the same reason.

3. Merchants and traders in unarmed ships, who accommodate different nations by communicating and exchanging the necessaries and conveniences of life.

4. Artists and mechanics, inhabiting and working in open towns.

It is hardly necessary to add, that the hospitals of enemies should be unmolested—they ought to be assisted. It is for the interest of humanity in general, that the occasions of war, and the inducements to it, should be diminished. If rapine be abolished, one of the encouragements to war is taken away; and peace therefore more likely to continue and be lasting.

The practice of robbing merchants on the high seas—a remnant of the antient piracy—though it may be accidentally beneficial to particular persons, is far from being profitable to all engaged in it, or to the nation that authorises it. In the beginning of a war, some rich ships are surprized and taken. This encourages the first adventurers to fit out more armed vessels, and many others to do the same. But the enemy at the same time become more careful, arm their merchant ships better, and render them not so easy to be taken: they go also more under the protection of convoys. Thus, while the [437] privateers to take them are multiplied, the vessels subject to be taken, and the chances of profit, are diminished; so that many cruises are made wherein the expences overgo the gains, and, as is the case in other lotteries, though particulars have got prizes, the mass of adventurers are losers, the whole expence of fitting out all the privateers during a war being much greater than the whole amount of goods taken.

Then there is the national loss of all the labour of so many men during the time they have been employed in robbing, who besides spend what they get in riot, drunkenness, and debauchery, lose their habits of industry, are rarely fit for any sober business after a peace, and serve only to increase the number of highwaymen and housebreakers. Even the undertakers, who have been fortunate, are by sudden wealth led into expensive living, the habit of which continues when the means of supporting it cease, and finally ruins them: a just punishment for their having wantonly and unfeelingly ruined many honest, innocent traders and their families, whose substance was employed in serving the common interest of mankind.

FOOTNOTE:

[91] From the American Museum, Vol. VII. p. 101. *Editor.*

Notes copied from Dr. Franklin's writing in pencil in the margin of Judge Foster's celebrated argument in favour of the Impressing of Seamen (published in the folio edition of his works)[92].

Judge Foster, p. 158. "Every man."—The conclusion here, from the *whole to a part*, does not seem to be good logic. If [438]
the alphabet should say, Let us all fight for the defence of the whole, that is equal, and may therefore be just. But if they should say, Let A B C and D go out and fight for us, while we stay at home and sleep in whole skins, that is not equal, and therefore cannot be just.

Ib. "Employ."—If you please. The word signifies engaging a man to work for me, by offering him such wages as are sufficient to induce him to prefer my service. This is very different from compelling him to work on such terms as I think proper.

Ib. "This service and employment, &c."—These are false facts. His employments and service are not the same.—Under the merchant he goes in an unarmed vessel, not obliged to fight, but to transport merchandise. In the king's service he is obliged to fight, and to hazard all the dangers of battle. Sickness on board of king's ships is also more common and more mortal. The merchant's service too he can quit at the end of the voyage, not the king's. Also, the merchant's wages are much higher.

Ib. "I am very sensible, &c."—Here are two things put in comparison that are not comparable: viz. injury to seamen, and inconvenience to trade. Inconvenience to the whole trade of a nation will not justify injustice to a single seaman. If the trade would suffer without his service, it is able and ought to be willing to offer him such wages, as may induce him to afford his service voluntarily.

Page 159. "Private mischief must be borne with patience, for preventing a national calamity."—Where is this maxim in
law and good policy to be found? And how can that be a maxim, which is not consistent with common sense? If the [439]
maxim had been, that private mischiefs, which prevent a national calamity, ought to be generously compensated by the nation, one might understand it: but that such private mischiefs are only to be borne with patience, is absurd!

Ib. "The expedient, &c. And, &c." (Paragraphs 2 and 3).—Twenty ineffectual or inconvenient schemes will not justify one that is unjust.

Ib. "Upon the foot of, &c."—Your reasoning, indeed, like a lie, stands but upon one *foot*, truth upon two.

Page 160. "Full wages."—Probably the same they had in the merchant's service.

Page 174. "I hardly admit, &c." (Paragraph 5).—When this author speaks of impressing, page 158, he diminishes the horror of the practice as much as possible, by presenting to the mind one sailor only suffering a "*hardship*" (as he tenderly calls it) in some "*particular cases*" only, and he places against this private mischief the inconvenience to the trade of the kingdom.—But if, as he supposes is often the case, the sailor who is pressed, and obliged to serve for the defence of trade, at the rate of twenty-five shillings a month, could get three pounds fifteen shillings in the merchant's service, you take from him fifty shillings a month; and if you have a 100,000 in your service, you rob this honest industrious part of society and their poor families of 250,000*l.* per month, or three millions a year, and at the same time oblige them to hazard their lives in fighting for the defence of your trade, to the defence of which all ought indeed to contribute (and sailors among the rest) in proportion to their profits by it: but this three millions is more than their share, if they did not pay with their [440] persons; but when you force that, methinks you should excuse the other.

But it may be said, to give the king's seamen merchant's wages would cost the nation too much, and call for more taxes. The question then will amount to this: whether it be just in a community, that the richer part should compel the poorer to fight in defence of them and their properties, for such wages as they think fit to allow, and punish them if they refuse? Our author tells us that it is "*legal*." I have not law enough to dispute his authorities, but I cannot persuade myself that it is equitable. I will, however, own for the present, that it may be lawful when necessary; but then I contend, that it may be used so as to produce the same good effects, *the public security*, without doing so much intolerable injustice as attends the impressing common seamen.—In order to be better understood I would premise two things: first, that voluntary seamen may be had for the service, if they were sufficiently paid. The proof is, that to serve in the same ship, and incur the same dangers, you have no occasion to impress captains, lieutenants, second lieutenants, midshipmen, pursers, nor many other officers. Why, but that the profits of their places, or the emoluments expected, are sufficient inducements? The business then is, to find money, by impressing, sufficient to make the sailors all volunteers, as well as their officers, and this without any fresh burthen upon trade.—The second of my premises is, that twenty-five shillings a month, with his share of the salt beef, pork, and peas-pudding, being found sufficient for the subsistence of a hard-working seaman, it will certainly be so for a sedentary scholar or gentleman. I would then propose to form a treasury, out of which [441] encouragements to seamen should be paid. To fill this treasury, I would impress a number of civil officers, who at present have great salaries, oblige them to serve in their respective offices for twenty-five shillings a month, with their shares of mess provisions, and throw the rest of their salaries into the seamen's treasury. If such a press-warrant were given me to execute, the first I would press should be a recorder of Bristol, or a Mr. Justice Foster, because I might have need of his edifying example, to show how much impressing ought to be borne with; for he would certainly find, that though to be reduced to twenty-five shillings a month might be a "*private mischief*," yet that, agreeably to his maxim of law and good policy, it "*ought to be borne with patience*," for preventing a national calamity. Then I would press the rest of the judges; and, opening the red book, I would press every civil officer of government from 50*l.* a year salary, up to 50,000*l.* which would throw an immense sum into our treasury: and these gentlemen could not complain, since they would receive twenty-five shillings a month, and their rations; and this without being obliged to fight. Lastly, I think I would impress
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FOOTNOTE:

[92] These notes are taken from the periodical publication mentioned in p. 424 of the present Vol. *Editor.*

TO BENJAMIN VAUGHAN, ESQ[93].

On the criminal Laws, and the Practice of Privateering.

March 14, 1785.

My dear Friend,

Among the pamphlets you lately sent me, was one, entitled, Thoughts on Executive Justice. In return for that, I send you a French one on the same subject, Observations concernant l'Exécution de l'Article II, de la Déclaration sur le Vol. They are both addressed to the judges, but written, as you will see, in a very different spirit. The English author is for hanging *all* thieves. The Frenchman is for proportioning punishments to offences. [442]

If we really believe, as we profess to believe, that the law of Moses was the law of God, the dictate of divine wisdom, infinitely superior to human; on what principles do we ordain death as the punishment of an offence, which, according to that law, was only to be punished by a restitution of fourfold? To put a man to death for an offence, which does not deserve death, is it not a murder? And, as the French writer says, *Doit on punir un délit contre la societé, par un crime contre la nature?*

Superfluous property is the creature of society. Simple and mild laws were sufficient to guard the property that was merely necessary. The savage's bow, his hatchet, and his coat of skins, were sufficiently secured, without law, by the fear of personal resentment and retaliation. When, by virtue of the first laws, part of the society accumulated wealth and grew powerful, they enacted others more severe, and would protect their property at the expence of humanity. This was abusing their power, and commencing a tyranny. If a savage, before he entered into society, had been told,—"Your neighbour, by this means, may become owner of an hundred deer; but if your brother, or your son, or yourself, having no deer of your own, and being hungry, should kill one, an infamous death must be the consequence:" he would probably have preferred his liberty, and his common right of killing any deer, to all the advantages of society that might be proposed to him. [443]

That it is better a hundred guilty persons should escape, than that one innocent person should suffer, is a maxim that has been long and generally approved; never, that I know of, controverted. Even the sanguinary author of the Thoughts agrees to it, adding well, "that the very thought of *injured* innocence, and much more that of *suffering* innocence, must awaken all our tenderest and most compassionate feelings, and at the same time raise our highest indignation against the instruments of it." "But," he adds, "there is no danger of *either*, from a strict adherence to the laws."—Really! Is it then impossible to make an unjust law? and if the law itself be unjust, may it not be the very "instrument" which ought "to raise the author's, and every body's highest indignation?" I see, in the last newspapers from London, that a woman is capitally convicted at the Old Bailey, for privately stealing out of a shop some gauze, value fourteen shillings and three-pence: is there any proportion between the injury done by a theft, value fourteen shillings and three-pence, and the punishment of a human creature, by death, on a gibbet? Might not that woman, by her labour, have made the reparation ordained by God, in paying fourfold? Is not all punishment, inflicted beyond the merit of the offence, so much punishment of innocence? In this light, how vast is the annual quantity, of not only *injured* but *suffering* innocence, in almost all the civilized states of Europe!

But it seems to have been thought, that this kind of innocence may be punished by way of *preventing* crimes. I have read, indeed, of a cruel Turk in Barbary, who, whenever he bought a new Christian slave, ordered him immediately to be [444]
hung up by the legs, and to receive a hundred blows of a cudgel on the soles of his feet, that the severe sense of the

punishment, and fear of incurring it thereafter, might prevent the faults, that should merit it. Our author himself would hardly approve entirely of this Turk's conduct in the government of slaves; and yet he appears to recommend something like it for the government of English subjects, when he applauds the reply of judge Burnet to the convict horse-stealer; who, being asked what he had to say why judgment of death should not pass against him, and answering, that it was hard to hang a man for *only* stealing a horse, was told by the judge, "Man, thou art not to be hanged *only* for stealing a horse, but that horses may not be stolen." The man's answer, if candidly examined, will, I imagine, appear reasonable, as being founded on the eternal principle of justice and equity, that punishments should be proportioned to offences; and the judge's reply brutal and unreasonable, though the writer "wishes all judges to carry it with them whenever they go the circuit, and to bear it in their minds, as containing a wise reason for all the penal statutes, which they are called upon to put in execution. "It at once illustrates," says he, "the true grounds and reasons of all capital punishments whatsoever, namely, that every man's property, as well as his life, may be held sacred and inviolate." Is there then no difference in value between property and life? If I think it right, that the crime of murder should be punished with death, not only as an equal punishment of the crime, but to prevent other murders, does it follow, that I must approve of inflicting the same punishment for a little invasion on my property by theft? If I am not myself so barbarous, so bloody-minded, and revengeful, as to kill a fellow-creature for stealing from me fourteen shillings and three-pence, how can I approve of a law [445]
that does it? Montesquieu, who was himself a judge, endeavours to impress other maxims. He must have known what humane judges feel on such occasions, and what the effects of those feelings; and, so far from thinking that severe and excessive punishments prevent crimes, he asserts, as quoted by our French writer, that

"*L'atrocité des loix en empêche l'exécution.*

"*L'orsque la peine est sans mesure, on est souvent obligé de lui préférer l'impunité.*

"*La cause de tous les relâchemens vient de l'impunité des crimes, et non de la modération des peines.*"

It is said by those who know Europe generally, that there are more thefts committed and punished annually in England, than in all the other nations put together. If this be so, there must be a cause or causes for such depravity in our common people. May not one be the deficiency of justice and morality in our national government, manifested in our oppressive conduct to subjects, and unjust wars on our neighbours? View the long-persisted in, unjust, monopolizing treatment of Ireland, at length acknowledged! View the plundering government exercised by our merchants in the Indies; the confiscating war made upon the American colonies; and, to say nothing of those upon France and Spain, view the late war upon Holland, which was seen by impartial Europe in no other light than that of a war of rapine and pillage; the hopes of an immense and easy prey being its only apparent, and probably its true and real motive and encouragement. Justice is as strictly due between neighbour nations, as between neighbour citizens. A highwayman is as much a robber when he [446]
plunders in a gang, as when single; and a nation, that makes an unjust war, is only a great gang. After employing your people in robbing the Dutch, strange is it, that, being put out of that employ by peace, they still continue robbing, and rob one another? *Piraterie*, as the French call it, or privateering, is the universal bent of the English nation, at home and abroad, wherever settled. No less than seven hundred privateers were, it is said, commissioned in the last war! These were fitted out by merchants, to prey upon other merchants, who had never done them any injury. Is there probably any one of those privateering merchants of London, who were so ready to rob the merchants of Amsterdam, that would not as readily plunder another London merchant of the next street, if he could do it with the same impunity! The avidity, the *alieni appetens*, is the same; it is the fear alone of the gallows that makes the difference. How then can a nation, which, among the honestest of its people, has so many thieves by inclination, and whose government encouraged and commissioned no

less than seven hundred gangs of robbers; how can such a nation have the face to condemn the crime in individuals, and hang up twenty of them in a morning! It naturally puts one in mind of a Newgate anecdote. One of the prisoners complained, that in the night somebody had taken his buckles out of his shoes. "What, the devil!" says another, "have we then *thieves* amongst us? It must not be suffered. Let us search out the rogue, and pump him to death."

There is, however, one late instance of an English merchant, who will not profit by such ill-gotten gain. He was, it seems, part-owner of a ship, which the other owners thought fit to employ as a letter of marque, and which took a number [447]
of French prizes. The booty being shared, he has now an agent here enquiring, by an advertisement in the Gazette, for those who suffered the loss, in order to make them, as far as in him lies, restitution. This conscientious man is a Quaker. The Scotch presbyterians were formerly as tender; for there is still extant an ordinance of the town-council of Edinburgh, made soon after the reformation, "forbidding the purchase of prize goods, under pain of losing the freedom of the burgh for ever, with other punishment at the will of the magistrate; the practice of making prizes being contrary to good conscience, and the rule of treating Christian brethren as we would wish to be treated; and such goods *are not to be sold by any godly men within this burgh*." The race of these godly men in Scotland is probably extinct, or their principles abandoned, since, as far as that nation had a hand in promoting the war against the colonies, prizes and confiscations are believed to have been a considerable motive.

It has been for some time a generally received opinion, that a military man is not to inquire whether a war be just or unjust; he is to execute his orders. All princes who are disposed to become tyrants must probably approve of this opinion, and be willing to establish it; but is it not a dangerous one? since, on that principle, if the tyrant commands his army to attack and destroy, not only an unoffending neighbour nation, but even his own subjects, the army is bound to obey. A negro slave, in our colonies, being commanded by his master to rob or murder a neighbour, or do any other immoral act, may refuse, and the magistrate will protect him in his refusal. The slavery then of a soldier is worse than that of a negro! [448]
A conscientious officer, if not restrained by the apprehension of its being imputed to another cause, may indeed resign, rather than be employed in an unjust war; but the private men are slaves for life; and they are perhaps incapable of judging for themselves. We can only lament their fate, and still more that of a sailor, who is often dragged by force from his honest occupation, and compelled to imbrue his hands in, perhaps, innocent blood. But methinks it well behoves merchants (men more enlightened by their education, and perfectly free from any such force or obligation) to consider well of the justice of a war, before they voluntarily engage a gang of ruffians to attack their fellow-merchants of a neighbouring nation, to plunder them of their property, and perhaps ruin them and their families, if they yield it; or to wound, maim, or murder them, if they endeavour to defend it. Yet these things are done by Christian merchants, whether a war be just or unjust; and it can hardly be just on both sides. They are done by English and American merchants, who, nevertheless, complain of private theft, and hang by dozens the thieves they have taught by their own example.

It is high time, for the sake of humanity, that a stop were put to this enormity. The United States of America, though better situated than any European nation to make profit by privateering (most of the trade of Europe, with the West Indies, passing before their doors) are, as far as in them lies, endeavouring to abolish the practice, by offering, in all their treaties with other powers, an article, engaging solemnly, that, in case of future war, no privateer shall be commissioned on either [449]
side; and that unarmed merchant-ships, on both sides, shall pursue their voyages unmolested[94]. This will be a happy improvement of the law of nations. The humane and the just cannot but wish general success to the proposition.

With unchangeable esteem and affection,

I am, my dear friend,

Ever yours.

FOOTNOTES:

[93] From a small collection of Dr. Franklin's papers, printed for Dilly. *Editor*.

[94] This offer having been accepted by the late king of Prussia, a treaty of amity and commerce was concluded between that monarch and the United States, containing the following humane, philanthropic article; in the formation of which Dr. Franklin, as one of the American plenipotentiaries, was principally concerned, viz.

ART. XXIII.

If war should arise between the two contracting parties, the merchants of either country, then residing in the other, shall be allowed to remain nine months to collect their debts and settle their affairs, and may depart freely, carrying off all their effects without molestation or hindrance; and all women and children, scholars of every faculty, cultivators of the earth, artisans, manufacturers, and fishermen, unarmed and inhabiting unfortified towns, villages, or places, and in general all others, whose occupations are for the common subsistence and benefit of mankind, shall be allowed to continue their respective employments, and shall not be molested in their persons, nor shall their houses and goods be burnt, or otherwise destroyed, nor their fields wasted, by the armed force of the enemy into whose power, by the events of war, they may happen to fall; but if any thing is necessary to be taken from them for the use of such armed force, the same shall be paid for at a reasonable price. And all merchant and trading vessels employed in exchanging the products of different places, and thereby rendering the necessaries, conveniences, and comforts of human life more easy to be obtained, and more general, shall be allowed to pass free and unmolested; and neither of the contracting powers shall grant or issue any commission to any private armed vessels, empowering them to take or destroy such trading vessels, or interrupt such commerce.

A Parable against Persecution, in Imitation of Scripture Language[95].

1. And it came to pass after these things, that Abraham sat in the door of his tent, about the going down of the sun.

2. And behold a man bent with age, coming from the way of the wilderness leaning on a staff.

3. And Abraham arose, and met him, and said unto him, Turn in, I pray thee, and wash thy feet, and tarry all night; and thou shalt arise early in the morning, and go on thy way.

4. And the man said, Nay; for I will abide under this tree.

5. But Abraham pressed him greatly: so he turned and they went into the tent: and Abraham baked unleaven bread, and they did eat.

6. And when Abraham saw that the man blessed not God, he said unto him, Wherefore dost thou not worship the most high God, creator of heaven and earth? [451]

7. And the man answered and said, I do not worship thy God, neither do I call upon his name, for I have made to myself a god, which abideth always in my house, and provideth me with all things.

8. And Abraham's zeal was kindled against the man, and he arose, and fell upon him, and drove him forth with blows into the wilderness.

9. And God called unto Abraham, saying, Abraham, where is the stranger?

10. And Abraham answered and said, Lord, he would not worship thee, neither would he call upon thy name, therefore have I driven him out from before my face into the wilderness.

11. And God said, Have I borne with him these hundred and ninety and eight years, and nourished him, and clothed him, notwithstanding his rebellion against me, and couldst not thou, who art thyself a sinner, bear with him one night?

12. And Abraham said, Let not the anger of my Lord wax hot against his servant; lo, I have sinned, forgive me I pray thee.

13. And Abraham arose, and went forth into the wilderness and diligently sought for the man and found him, and returned with him to the tent, and when he had entreated him kindly, he sent him away on the morrow with gifts.

14. And God spake again unto Abraham saying, For this thy sin shall thy seed be afflicted four hundred years in a strange land.

15. But for thy repentance will I deliver them, and they shall come forth with power, and with gladness of heart, and with much substance.[96] [452]

FOOTNOTES:

[95] I have taken this piece from Sketches of the History of Man, written by lord Kaims, and shall preface it with his lordship's own words. See Vol. II. p. 472, 473.

"The following Parable against Persecution was communicated to me by Dr. Franklin of Philadelphia, a man who makes a great figure in the learned world: and who would still make a greater figure for benevolence and candour, were virtue as much regarded in this declining age as knowledge."

*   *   *   *   *

"The historical style of the Old Testament is here finely imitated; and the moral must strike every one who is not sunk in stupidity and superstition. Were it really a chapter of Genesis, one is apt to think, that persecution could never have shown a bare face among Jews or Christians. But alas! that is a vain thought.

Such a passage in the Old Testament would avail as little against the rancorous passions of men, as the following passages in the New Testament, though persecution cannot be condemned in terms more explicit. *Him that is weak in the faith, receive you, but not to doubtful disputations. For, &c.*" B. V.

[96] Dr. Franklin, as I have been told, has often imposed this parable upon his friends and acquaintance, as part of a chapter of Genesis. B. V.

A Letter concerning Persecution in former Ages, the Maintenance of the Clergy, American Bishops, and the State of Toleration in Old England and New England compared[97].

SIR,

I understand from the public papers, that in the debates on the bill for relieving the dissenters in the point of subscription to the church articles, sundry reflections were thrown out against the people, importing, that they themselves are of a persecuting intolerant spirit, for that when they had the superiority, they persecuted the church, and still persecute it in America, where they compel its members to pay taxes for maintaining the presbyterian or independent worship, and at the same time refuse them a toleration in the full exercise of their religion, by the administrations of a bishop.

If we look back into history for the character of the present sects in Christianity, we shall find few that have not, in their [453] turns, been persecutors and complainers of persecution. The primitive christians thought persecution extremely wrong in the pagans, but practised it on one another. The first protestants of the church of England blamed persecution in the Romish church, but practised it against the puritans: these found it wrong in the bishops, but fell into the same practice both here and in New England.—To account for this, we should remember, that the doctrine of *toleration* was not then known, or had not prevailed in the world. Persecution was therefore not so much the fault of the sect as of the times. It was not in those days deemed wrong *in itself*. The general opinion was only, that those *who are in error* ought not to persecute *the truth*: but the *possessors of truth* were in the right to persecute error, in order to destroy it. Thus every sect believing itself possessed of *all truth*, and that every tenet differing from theirs was *error*, conceived, that when the power was in their hands, persecution was a duty required of them by that God whom they supposed to be offended with heresy. —By degrees, more moderate *and more modest* sentiments have taken place in the christian world; and among protestants particularly, all disclaim persecution, none vindicate it, and few practise it.—We should then cease to reproach each other with what was done by our ancestors, but judge of the present character of sects or churches by their *present conduct* only[98].

Now to determine on the justice of this charge against the present dissenters, particularly those in America, let us [454] consider the following facts. They went from England to establish a new country for themselves, *at their own expence*, where they might enjoy the free exercise of religion in their own way. When they had purchased the territory of the natives, they granted the lands out in townships, requiring for it neither purchase-money nor quit-rent, but this condition only to be complied with, that the freeholders should support a gospel-minister (meaning probably one of the then governing sects) and a free-school, within the township. Thus, what is commonly called presbyterianism became the *established religion* of that country. All went on well in this way, while the same religious opinions were general, the support of minister and school being raised by a proportionate tax on the lands. But, in process of time, some becoming quakers[99], some baptists, and of late years, some returning to the church of England (through the laudable endeavours and a *proper application*[100] of their funds by the society for propagating the gospel), objections were made to the [455] payment of a tax appropriated to the support of a church they disapproved and had forsaken. The civil magistrates, however, continued for a time to collect and apply the tax according to the original laws, which remained in force; and they did it the more freely as thinking it just and equitable, that the holders of lands should pay what was contracted to be paid when they were granted, as the only consideration for the grant, and what had been considered by all subsequent purchasers as a perpetual incumbrance on the estate, bought therefore at a proportionally cheaper rate; a payment which, it was thought, no honest man ought to avoid, under pretence of his having changed his religious persuasion: and this, I suppose, is one of the best grounds of demanding tythes of dissenters now in England. But the practice being clamoured against by the episcopalians as persecution, the legislature of the province of Massachusets Bay, near thirty years since, passed an act for their relief, requiring, indeed, the tax to be paid as usual, but directing that the several sums, levied from members of the church of England, should be paid over to the minister of that church with whom such members usually attended divine worship; which minister had power given him to receive, and, on occasion, *to recover the same by law*.

It seems that legislature considered, that the end of the tax was to secure and improve the morals of the people, and [456] promote their happiness, by supporting among them the public worship of God and the preaching of the gospel; that where particular people fancied a particular mode, that mode might probably, therefore, be of most use to those people, and that if the good was done, it was not so material in what mode or by whom it was done. The consideration, that their brethren, the dissenters in England, were still compelled to pay tythes to the clergy of the church, had not weight enough with the legislature to prevent this moderate act, which still continues in full force; and I hope no uncharitable conduct of the church toward the dissenters will ever provoke them to repeal it.——

With regard to *a bishop*, I know not upon what ground the dissenters, either here or in America, are charged with refusing the benefit of such an officer to the church in that country. *Here* they seem to have naturally no concern in the affair. *There* they have no power to prevent it, if government should think fit to send one. They would probably *dislike*, indeed, to see an order of men established among them, from whose persecutions their fathers fled into that wilderness, and whose future domination they might possibly fear, *not knowing that their natures are changed*.—But the non-appointment of bishops for America seems to arise from another quarter. The same wisdom of government, probably, that prevents the sitting of convocations, and forbids, by *noli prosequi's*, the persecution of dissenters for non-subscription, avoids establishing bishops, where the minds of people are not yet prepared to receive them cordially, lest the public peace should be endangered.

And now let us see how this *persecution-account* stands between the parties. [457]

In New England, where the legislative bodies are almost to a man dissenters from the church of England:

1. There is no test to prevent churchmen holding offices.

2. The sons of churchmen have the full benefit of the universities.

3. The taxes for support of public worship, when paid by churchmen, are given to the episcopal minister.

In Old England:

1. Dissenters are excluded from all offices of profit and honour.

2. The benefits of education in the universities are appropriated to the sons of churchmen.

3. The clergy of the dissenters receive none of the tythes paid by their people, who must be at the additional charge of maintaining their own separate worship.—

But it is said, that the dissenters of America *oppose* the introduction of a bishop.

In fact, it is not alone the dissenters there that give the opposition (if *not encouraging* must be termed *opposing*) but the laity in general dislike the project, and some even of the clergy. The inhabitants of Virginia are almost all episcopalians, the church is fully established there, and the council and general assembly are, perhaps to a man, its members: yet, when lately at a meeting of the clergy, a resolution was taken to apply for a bishop, against which several however protested; [458]
assembly of the province, at the next meeting, expressed their disapprobation of the thing in the strongest manner, by unanimously ordering the thanks of the house to the protesters; for many of the American laity of the church think it some advantage—whether their own young men come to England for ordination, and improve themselves at the same time by conversation with the learned here—or the congregations are supplied by Englishmen, who have had the benefit of education in English universities, and are ordained before they came abroad. They do not, therefore, see the necessity of a bishop merely for ordination; and confirmation is among them deemed a ceremony of no very great importance, since few seek it in England, where bishops are in plenty.—These sentiments prevail with many churchmen there, not to promote a design which they think must sooner or later saddle them with great expences to support it.—As to the dissenters, their minds might probably be more conciliated to the measure, if the bishops here should, in their wisdom and goodness, think fit to set their sacred character in a more friendly light, by dropping their opposition to the dissenters' application for relief in subscription, and declaring their willingness that dissenters should be capable of offices, enjoy the benefit of education in the universities, and the privilege of appropriating their tythes to the support of their own clergy. In all these points of toleration, they appear far behind the present dissenters of New England, and it may seem to some a step below the dignity of bishops, to follow the example of such inferiors. I do not, however, despair of their doing it some time or other, [459]
since nothing of the kind is too hard for *true christian humility*.

I am, sir, yours, &c.

A NEW-ENGLAND-MAN.

FOOTNOTES:

[97] The above letter first appeared in one of the public papers on June 3, 1772, and seems to have been addressed to the printer. The spirited writer of the *Two letters to the prelates* republished it in an appendix to that pamphlet, without, however, naming Dr. Franklin as the author, but expressing it to be the production "of a gentleman highly respected in the literary world." B. V.

[98] "Toleration in religion, though obvious to common understanding, was not however the production of reason, but of commerce. The advantage of toleration for promoting commerce was discovered long before by the Portuguese. They were too zealous Catholics to venture so bold a measure in Portugal; but it was

permitted in Goa, and the inquisition in that town was confined to Roman Catholics." Lord Kaim's Sketches of the History of Man, Vol. II. p. 474. B. V.

[99] "No person appeared in New England who professed the opinion of the Quakers, until 1656, (i. e. about 36 years after the first settling of the colony), when Mary Fisher and Ann Austin came from Barbadoes; and soon after, nine others arrived in the ship Speedwell from London." They were successful in their preaching, and the provincial government, wishing to keep the colony free from them, attempted to send away such as they discovered, and prevent the arrival of others. Securities, fines, banishment, imprisonment, and corporal punishments were instituted for this purpose, but with so little effect, that at last "a law was made for punishing with death, all such as should *return* into the jurisdiction *after banishment*. A few were hanged!" See the history of the British dominions, 4to, 1773, p. 118, 120. B. V.

[100] They were to spread the gospel, and maintain a learned and orthodox clergy, where ministers were wanted or ill-provided, administering God's word and sacraments, and preventing atheism, infidelity, popery, and idolatry. B. V.

On the Slave Trade[101].

Reading in the newspapers the speech of Mr. Jackson in congress, against meddling with the affair of slavery, or attempting to mend the condition of slaves, it put me in mind of a similar speech, made about one hundred years since, by Sidi Mehemet Ibrahim, a member of the divan of Algiers, which may be seen in Martin's account of his consulship, 1687. It was against granting the petition of the sect called erika, or purists, who prayed for the abolition of piracy and slavery, as being unjust.—Mr. Jackson does not quote it; perhaps he has not seen it. If therefore, some of its reasonings are to be found in his eloquent speech, it may only show, that men's interests operate, and are operated on, with surprising similarity, in all countries and climates, whenever they are under similar circumstances. The African speech, as translated, is as follows:

"Alla Bismillah, &c. God is great, and Mahomet is his prophet.

"Have these erika considered the consequences of granting their petition? If we cease our cruises against the christians, how shall we be furnished with the commodities their countries produce, and which are so necessary for us? If we forbear to make slaves of their people, who, in this hot climate, are to cultivate our lands? Who are to perform the common [460] labours of our city, and of our families? Must we not then be our own slaves? And is there not more compassion and more favour due to us mussulmen, than to those christian dogs?—We have now above fifty thousand slaves in and near Algiers. This number, if not kept up by fresh supplies, will soon diminish, and be gradually annihilated. If, then, we cease taking and plundering the infidel ships, and making slaves of the seamen and passengers, our lands will become of no value, for want of cultivation; the rents of houses in the city will sink one half; and the revenues of government, arising from the share of prizes, must be totally destroyed.—And for what? To gratify the whim of a whimsical sect, who would have us not only forbear making more slaves, but even manumit those we have. But who is to indemnify their masters for the loss? Will the state do it? Is our treasury sufficient? Will the erika do it? Can they do it? Or would they, to do what they think justice to the slaves, do a greater injustice to the owners? And if we set our slaves free, what is to be done with them? Few of them will return to their native countries; they know too well the greater hardships they must there be subject to. They will not embrace our holy religion: they will not adopt our manners: our people will not pollute themselves by intermarrying with them. Must we maintain them as beggars in our streets; or suffer our properties to be the prey of their pillage? for men, accustomed to slavery, will not work for a livelihood, when not compelled.—And what is there so pitiable in their present condition? Were they not slaves in their own countries? Are not Spain, Portugal, France, and the Italian states, governed by despots, who hold all their subjects in slavery, without exception? Even England treats [461] her sailors as slaves, for they are, whenever the government pleases, seized and confined in ships of war, condemned not only to work, but to fight for small wages, or a mere subsistence, not better than our slaves are allowed by us. Is their condition then made worse by their falling into our hands? no; they have only exchanged one slavery for another; and I may say a better: for here they are brought into a land, where the sun of islamism gives forth its light, and shines in full splendor, and they have an opportunity of making themselves acquainted with the true doctrine, and thereby saving their immortal souls. Those who remain at home have not that happiness. Sending the slaves home then, would be sending them out of light into darkness.

"I repeat the question, what is to be done with them? I have heard it suggested, that they may be planted in the wilderness, where there is plenty of land for them to subsist on, and where they may flourish as a free state.—But they are, I doubt, too little disposed to labour without compulsion, as well as too ignorant to establish good government: and the wild Arabs would soon molest and destroy, or again enslave them. While serving us, we take care to provide them with every thing; and they are treated with humanity. The labourers in their own countries are, as I am informed, worse fed, lodged, and clothed. The condition of most of them is therefore already mended, and requires no farther improvement. Here their lives are in safety. They are not liable to be impressed for soldiers, and forced to cut one another's christian throats, as in the wars of their own countries. If some of the religious mad bigots, who now tease us [462] with their silly petitions, have, in a fit of blind zeal, freed their slaves, it was not generosity, it was not humanity, that moved them to the action; it was from the conscious burthen of a load of sins, and hope, from the supposed merits of so good a work, to be excused from damnation.—How grossly are they mistaken, in imagining slavery to be disavowed by the Alcoran! Are not the two precepts, to quote no more, "Masters, treat your slaves with kindness—Slaves, serve your masters with cheerfulness and fidelity," clear proofs to the contrary? Nor can the plundering of infidels be in that sacred book forbidden; since it is well known from it, that God has given the world, and all that it contains, to his faithful mussulmen, who are to enjoy it, of right, as fast as they can conquer it. Let us then hear no more of this detestable proposition, the manumission of christian slaves, the adoption of which would, by depreciating our lands and houses, and thereby depriving so many good citizens of their properties, create universal discontent, and provoke insurrections, to the endangering of government and producing general confusion. I have, therefore, no doubt that this wise council will prefer the comfort and happiness of a whole nation of true believers, to the whim of a few erika, and dismiss their petition."

The result was, as Martin tells us, that the divan came to this resolution: "That the doctrine, that the plundering and enslaving the christians is unjust, is at best problematical; but that it is the interest of this state to continue the practice is clear; therefore, let the petition be rejected."——And it was rejected accordingly.

And since like motives are apt to produce, in the minds of men, like opinions and resolutions, may we not venture to [463] predict, from this account, that the petitions to the parliament of England for abolishing the slave-trade, to say nothing of other legislatures and the debates upon them, will have a similar conclusion.

HISTORICUS.

March 23, 1790.

FOOTNOTE:

[101] American Museum, Vol. IX. p. 336. *Editor.*

Account of the highest Court of Judicature in Pensylvania, viz. The Court of the Press[102].

Power of this Court.

It may receive and promulgate accusations of all kinds, against all persons and characters among the citizens of the state, and even against all inferior courts; and may judge, sentence, and condemn to infamy, not only private individuals, but public bodies, &c. with or without enquiry or hearing, at the court's discretion.

Whose Favour, or for whose Emolument this Court is established.

In favour of about one citizen in five hundred, who, by education, or practice in scribbling, has acquired a tolerable style as to grammar and construction, so as to bear printing; or who is possessed of a press and a few types. This five hundredth part of the citizens have the privilege of accusing and abusing the other four hundred and ninety-nine parts, at their pleasure; or they may hire out their pens and press to others, for that purpose. [464]

Practice of this Court.

It is not governed by any of the rules of the common courts of law. The accused is allowed no grand jury to judge of the truth of the accusation before it is publicly made; nor is the name of the accuser made known to him; nor has he an opportunity of confronting the witnesses against him, for they are kept in the dark, as in the Spanish court of inquisition. Nor is there any petty jury of his peers sworn to try the truth of the charges. The proceedings are also sometimes so rapid, that an honest good citizen may find himself suddenly and unexpectedly accused, and in the same morning judged and condemned, and sentence pronounced against him, that he is a rogue and a villain. Yet if an officer of this court receives the slightest check for misconduct in this his office, he claims immediately the rights of a free citizen by the constitution, and demands to know his accuser, to confront the witnesses, and to have a fair trial by a jury of his peers.

Foundation of its Authority.

It is said to be founded on an article in the state constitution, which establishes the liberty of the press—a liberty which every Pennsylvanian would fight and die for, though few of us, I believe, have distinct ideas of its nature and extent. It seems, indeed, somewhat like the liberty of the press, that felons have, by the common law of England, before conviction; that is, to be either pressed to death or hanged. If, by the liberty of the press, were understood merely the liberty of discussing the propriety of public measures and political opinions, let us have as much of it as you please; but if it means [465] the liberty of affronting, calumniating, and defaming one another, I, for my part, own myself willing to part with my share of it, whenever our legislators shall please so to alter the law; and shall cheerfully consent to exchange my liberty of abusing others, for the privilege of not being abused myself.

By whom this Court is commissioned or constituted.

It is not by any commission from the supreme executive council, who might previously judge of the abilities, integrity, knowledge, &c. of the persons to be appointed to this great trust, of deciding upon the characters and good fame of the citizens: for this court is above that council, and may accuse, judge, and condemn it at pleasure. Nor is it hereditary, as is the court of dernier resort in the peerage of England. But any man who can procure pen, ink, and paper, with a press, a few types, and a huge pair of blacking balls, may commissionate himself, and his court is immediately established in the plenary possession and exercise of its rights. For if you make the least complaint of the judge's conduct, he daubs his blacking balls in your face wherever he meets you; and, besides tearing your private character to splinters, marks you out for the odium of the public, as an enemy to the liberty of the press.

Of the natural Support of this Court.

Its support is founded in the depravity of such minds, as have not been mended by religion, nor improved by good education.

> There is a lust in man no charm can tame, [466]
> Of loudly publishing his neighbour's shame.

Hence,

> On eagles' wings, immortal scandals fly,
> While virtuous actions are but born and die.——DRYDEN.

Whoever feels pain in hearing a good character of his neighbour, will feel a pleasure in the reverse. And of those who, despairing to rise to distinction by their virtues, are happy if others can be depressed to a level with themselves, there are a number sufficient in every great town to maintain one of these courts by their subscription. A shrewd observer once said, that in walking the streets of a slippery morning, one might see where the good-natured people lived, by the ashes thrown on the ice before the doors: probably he would have formed a different conjecture of the temper of those whom he might find engaged in such subscriptions.

Of the Checks proper to be established against the Abuses of Power in those Courts.

Hitherto there are none. But since so much has been written and published on the federal constitution; and the necessity of checks, in all other parts of good government, has been so clearly and learnedly explained, I find myself so far enlightened as to suspect some check may be proper in this part also: but I have been at a loss to imagine any, that may not be construed an infringement of the sacred liberty of the press. At length, however, I think I have found one, that, instead of diminishing general liberty, shall augment it; which is, by restoring to the people a species of liberty of which they have been deprived by our laws, I mean the liberty of the cudgel! In the rude state of society, prior to the existence of [467] laws, if one man gave another ill-language, the affronted person might return it by a box on the ear; and if repeated, by a good drubbing; and this without offending against any law: but now the right of making such returns is denied, and they are punished as breaches of the peace, while the right of abusing seems to remain in full force; the laws made against it being rendered ineffectual by the liberty of the press.

My proposal then is, to leave the liberty of the press untouched, to be exercised in its full extent, force, and vigour, but to permit the liberty of the cudgel to go with it, *pari passu*. Thus, my fellow citizens, if an impudent writer attacks your reputation—dearer perhaps to you than your life, and puts his name to the charge, you may go to him as openly, and break his head. If he conceals himself behind the printer, and you can nevertheless discover who he is, you may, in like manner, way-lay him in the night, attack him behind, and give him a good drubbing. If your adversary hires better writers than himself to abuse you more effectually, you may hire brawny porters, stronger than yourself, to assist you in giving him a more effectual drubbing. Thus far goes my project, as to *private* resentment and retribution. But if the public should ever happen to be affronted, as it ought to be, with the conduct of such writers, I would not advise proceeding immediately to these extremities, but that we should in moderation content ourselves with tarring and feathering, and tossing them in a blanket.

If, however, it should be thought, that this proposal of mine may disturb the public peace, I would then humbly recommend to our legislators to take up the consideration of both liberties, that of the press, and that of the cudgel; and by [468] an explicit law mark their extent and limits: and at the same time that they secure the person of a citizen from assaults, they would likewise provide for the security of his reputation.

FOOTNOTE:

[102] Ut supra, Vol. VI. p. 295. *Editor.*

END OF VOLUME THE SECOND.

JAMES CUNDEE, PRINTER,
Ivy-Lane, Paternoster-Row.

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TRANSCRIBER'S NOTE

Obvious typographical errors and punctuation errors have been corrected after careful comparison with other occurrences within the text and consultation of external sources.

Several pages of the book contain a description and examples of a modified alphabet proposed by B.F. There are six new characters in his alphabet; these, and the example text using them (pages 360-366 in the original book) are shown as images in this ebook.

For consistency and clarity, the pound abbreviation 'l.' has been italicized, so for example '123,321l.' has been replaced by '123,321*l*.' in the etext.

For consistency, the date and salutation at the beginning of each letter, and the closing and name at the end of each letter, have been put on separate lines (they were sometimes placed on the same line in the original printed text).

A 'List of the Plates' has been created and added in front of the Errata.

Asterisks were used by the editor to indicate omitted text. For consistency, '****' is used when at the beginning or end of a letter, otherwise a line of 5 spaced asterisks is used.

A deliberate blank space in the text, eg pg 70, is indicated by [   ].

All the changes noted in the Errata (pg vi) have been applied to the text.

Many Footnotes have the signature 'B. V.' rather than 'Editor'. This is explained in Vol 1 p 399 Footnote [90], and is copied below for the reader's convenience:—

> Wherever this signature occurs, the note is taken from a volume of Dr. Franklin's writings, entitled Political, Miscellaneous, and Philosophical Pieces, printed for Johnson, 1779. The editor of that volume, though a young man at the time, had already evinced extraordinary talents, and was the friend and correspondent of our author. As he has chosen to withhold his name, we conceive ourselves not entitled to disclose it: but we shall take the freedom of an acquaintance to use the notes occasionally, deeming them in many instances valuable historical records. Editor.

Except for those changes noted below, misspelling in the text, and inconsistent or archaic usage, have been retained. For example, compleat; cieling; inclose; watry; smoak; spunge; Pensylvania; Massachussets; newspaper, news-paper; midnight, mid-night.

In addition:
Pg iv. 'Mr. Tengugel' replaced by 'Mr. Tengnagel'.
Pg vi. Errata: '254 47:' replaced by '254 17:'.
Pg 15. 'decending' replaced by 'descending'.
Pg 28. 'cirle' replaced by 'circle'.
Pg 49. 'immerged' replaced by 'immersed'.
Pg 54. 'canon-ball' replaced by 'cannon-ball'.
Pg 55 FN [10]. 'Cadwalader' replaced by 'Cadwallader'.
Pg 81. 'sik-worm' replaced by 'silk-worm'.
Pg 84. 'desarts' replaced by 'deserts'.
Pg 88 FN [16]. 'J. B.' is probably James Bowdoin, not 'I. Badoin'.
Pg 101. 'circumsance' replaced by 'circumstance'.
Pg 112. 'substracted' replaced by 'subtracted'.
Pg 126. 'larg ecomet' replaced by 'large comet'.
Pg 131. 'frome making' replaced by 'from making'.
Pg 137. 'ran acros' replaced by 'ran across'.
Pg 150. 'betwween water' replaced by 'between water'.
Pg 151. 'smoth surface' replaced by 'smooth surface'.
Pg 196. 'throughly' replaced by 'thoroughly'.
Pg 204. '33. Much' replaced by '30. Much'.
Pg 227. 'he separated' replaced by 'be separated'.

Pg 240. 'kept closes hut' replaced by 'kept close shut'.
Pg 247. 'bginning of this' replaced by 'beginning of this'.
Pg 272. 'for pasages' replaced by 'for passages'.
Pg 302. 'partions' replaced by 'partitions'.
Pg 322. 'unluckly' replaced by 'unlucky'.
Pg 328. 'mnke 180' replaced by 'make 180'.
Pg 331. 'on atable' replaced by 'on a table'.
Pg 337. 'substracting' replaced by 'subtracting'.
Pg 339. 'betwen two' replaced by 'between two'.
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Pg 359. 'place of z' replaced by 'place of q'.
Pg 375. 'sir Willam Temple' replaced by 'sir William Temple'.
Pg 385. '6. The danger' replaced by '9. The danger'.
Pg 411 FN [85]. 'presentedt ot he' replaced by 'presented to the'.
Pg 421. 'when yon' replaced by 'when you'.
Pg 424. 'of yonrs' replaced by 'of yours'.
Pg 448. 'not restained' replaced by 'not restrained'.
Pg 448. 'Englist and' replaced by 'English and'.
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Index Pg 4i. 'Animalcnles' replaced by 'Animalcules'.
Index Pg 29i. 'relation batween' replaced by 'relation between'.

The Index covers all three volumes and was originally printed at the end of Volume 1 only. It has been copied to the end of Volume 2 and 3 as a convenience for the reader.

The Index had no page numbers in the original text; page numbers from 1i to 36i have been added for completeness. For clarity, some volume identifiers (i. or ii. or iii.) have been added, or removed, in the index. Only references within this volume have been hyperlinked.

The Index has some references to page numbers with a *, eg 551*. These are valid references; the book printer inserted pages 543*-556* between pages 542 and 543 in Vol iii.

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