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An Essay on Currents at Sea

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Currents of Ocean

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A N
E S S A Y
O N
CURRENTS at SEA;

By which it appears,

There is Reason to apprehend, that the SEA is not a FLUID in a STATE of REST, except those MOTIONS which are caused by the IMPULSE of WINDS, and that known by the Name of TIDES:

And consequently,

That this EARTH is not of a uniform Density, according to the Supposition of Sir ISAAC NEWTON; but that the CURRENTS of the Gulph of FLORIDA, also on the Coast of BRASIL, and the Northern In-draught on this Western Coast, are Currents of Circulation, kept up by different Densities in this Earth, and its Motion round its AXIS.

By JOSEPH MEAD.

L O N D O N :

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ERRATA.

P. iv. l. 28. for Sea's being in a Fluid, read Sea's being a Fluid. P. v. l. 28. for Guph, read Gulph. P. 13. l. 26. for difference Distances, read different Distances. P. 36. l. 21. for *Fewfoundland*, read *Newfoundland*. P. 39. l. 12. for Solar Heart, read Solar Heat. P. 39. l. 28. for Vegetation, read Vegetation.



T H E
P R E F A C E.



ERE an Art, or Science, to be more or less regarded, as it assisted in the Preservation of the Lives and Properties of some useful Members of a Community; in the Defence of our happy Constitution; or in the Accumulation of Wealth; it is probable, that *Navigation* might not be thought unworthy of the highest Esteem.

If we were to attempt to make any useful Discovery, in an Art of such great Utility to the Publick, I don't know that there could be any Method put in Practice that would promise greater Success, than first to consider in what Part or Parts we had been deficient, or had met with Losses, &c. than to endeavour to discover the Cause or Causes thereof, for the better enabling us to provide against the like for the future.

A

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Had there been an exact Account kept of the many Losses and Disappointments which have happened, by Ships falling into the Northward of what they had Reason to expect from their Reckoning; from which some of the * Royal Navy have not been exempt, it is not to be doubted, but they would extend beyond Imagination; and what may be thought to make the Loss of some of such Unfortunate as have suffered the more to be regretted is, that their Misfortunes seem to have been brought on them, by adhering strictly to what has been taken up for a Principle, which it is not unlikely will appear erroneous. I mean, that of *the Sea being a Fluid in a State of Rest, except what Motion is caused by the Impulse of Winds, and that known by the Name of Tides*. For it is obvious, if a Reckoning at Sea is kept on that Principle; and a Northern In-draught at the same Time, without any Opportunity of taking an Observation for several Days, to correct such Reckoning: Under similar Circumstances, if a Ship should be running in with this Western Coast, it must be attended with a dangerous Consequence. A particular Instance of which shall endeavour to repeat, as I had it from the Com-

* October 22, 1707, in the Night, Admiral Shovel, in his own Ship the *Association*, with the *Eagle*, and *Romney*, were dashed to Pieces upon the Rocks, called the *Bishops and his Clerks*, and all their Men lost; the *Firebrand* was also cast away, and but twenty-four of her Men saved. *Salmon's Chronology*.

mander of a Merchant Ship that was lost, who was allowed to be a Seaman of good Repute in the Port of *Liverpoole*.

It was in the Month of *November*, or Beginning of *December*, in or near the Year 1735, the *Hope*, of and bound for *Liverpoole*, from the River *Sherbroon* the Coast of *Guinea*, with Camwood and some Elephants Teeth, had a good Observation, by which they found they had the North Channel open; the Wind continued to blow strong between the South and West, but most inclined to the former. Having no other Observation for about six Days, in which Time they carried Sail continually. Then by their Reckonings, they judged they should fall in with *Cape Clear*, on the South West Coast of *Ireland*, or to Windward thereof; but in the following Night they fell in with the Horse Rock to Westward of the *Blasques*; and were so near, that in wearing Ship (to stand to the Westward) the Sea was reverberated from the Rock on board their Ship. In the Morning they stood in for the Land, and made it; but being unacquainted with those Parts, they could not tell what particular Land it was. Afternoon the Wind veered more Westerly, their Ship being very foul, and having strong Gales, with a great Sea from the Westward, thought it impracticable to keep the Ship off the Shore till Day-light next Morning, by carrying the greatest Sail the Ship, &c. could bear. Therefore, under these disagreeable Circumstances, judged it to be the most prudent

(for the Safety of the whole) to endeavour for a Harbour. They run into a small Bay within the *Blasques*, which to outward Appearance was a Harbour, but proved only fit for Boats, &c. where they saved themselves and Cargo, at the Expence of the Ship. At first it was thought their Compasses had been in Fault, but on Examination the Defect was not there.

From this Account, and taking particular Notice of a Northern In-draught when Opportunity served, can find no manner of Reason to doubt, if we were to enquire further of such as have suffered, for want of an Opportunity of taking Observations; but we should find they were carried to the Northward in a like insensible manner.

In order to obtain the clearest Insight I possibly could, into the Cause of the several Misfortunes which has happened by Ships falling into the Northward, have first considered a Part of the learned Dr. *Halley's* Directions for sailing into the *English* Channel; and how it differs from such Practice of sailing into the *English* and *Bristol* Channels, as is consistent with Safety. Next have endeavoured to shew how insufficient the Authority appears for what has been admitted as a Property of the Sea; that is, *the Sea's being in a Fluid in a State of Rest, except such Motions as are caused by the Impulse of Winds, and another known by the Name of Tides.* And have afterwards endeavoured to account for the Reasons which might induce some to believe, that that was an inseparable

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v

parable Property of the Sea. Then have considered particular Gravity of several Parts of this Earth, according to Sir *Isaac Newton's* Supposition of this Earth being all of a uniform Density; also the Shape thereof caused by its Motion round its Axis. But as there appears no solid Foundation for the Suggestion of a uniform Density of this Earth, I have formed the Hypothesis of a Circulation of the Sea, upon the Increase of Gravity from the Equator to the Poles, which has been confirmed by Experiments made with Pendulums; by which it may probably appear, that if there are subterranean submarine Caverns of Communication from Places in high Latitudes to Places near the Equator, this Earth may have such different Densities in different Parts thereof, that by its Motion round its Axis may cause the Sea to have a Circulation thro' them, by entering in at those Ends of the Caverns which are nearer the Poles, and rising at the other Ends which are nearer the Equator, then consequently descending from the Equator towards the Poles on the external Parts; which would be a Circulation, and produce such a Current as the Right Honourable Lord *Anson* has found on the Coast of *Brazil*; also alike to the Guph-stream, and to the Northern Indraught, that is observed on these Western Coasts.

But although forming Hypothesis on Suggestion, is sometimes of the greatest Service in making Discoveries, in the wonderful and beautiful

tiful Operations of Nature ; yet, if we should allow every Thing to be Fact, which Theory or Supposition admits of, the Mind might be involved in a Multitude of Errors ; whereas when Phenomena is found to agree with Hypothesis, it is allowed to be the highest Presumption in Favour thereof. Therefore have considered the several Phenomenon, that such a supposed Circulation might probably produce ; and have then made my Enquiries into the Appearances of Nature, and have found agreeable thereto, 1st, 2^{dly}, and 3^{dly}, the Whirlpools of *Malestream*, at the *Ferræ* Islands, and *Forbisler's Streights* ; also the rising of the Sea-water within the Torrid Zone ; and the great Quantity of Sea Vegetables, known by the Name of Gulph Weed, to favour the Hypothesis of the Sea having a Circulation.

4^{thly}, 5^{thly}, and 6^{thly}, Have considered the Currents within some Parts of the Torrid Zone gravitating towards the Temperate Zones ; also the Currents in the Temperate Zones gravitating towards the Poles. And the greater saltness of the Sea within the Torrid Zone (in some Parts of which the Sea-water is observed to rise) than that of Parts of the Sea in high Latitudes ; as Appearances of Nature sufficient to further countenance the Hypothesis of the Sea's having a Circulation.

7^{thly} and 8^{thly}, Have considered some Properties of Air, as its being rarified by Heat, and condensed by Cold, as set forth by Mr. *Boyle* and Mr. *Robins*, Fellows of the R. S. for the better

ter judging of Sea Breezes, so far as they might indicate a Circulation of the Sea. Also the greater Heat of the Temperate Zones, for some Months in the Year, than any Heat of our Islands within the Torrid Zone, although the latter have the Sun vertical twice every Year; which appears to agree with what has been thought requisite, to further favour the Hypothesis of the Circulation of the Sea.

9thly, Have considered the Motion of the Northern internal Magnet of these Kingdoms, as discovered by the best Observations which I could procure of the Dipping Needle from Mr. *Norman's* in 1576, to Mr. *Whiston's* in 1721; by which our great Northern Magnet appears to have a Southern, as well as a Western Motion, which agrees with Hypothesis, and what might further be expected if the Sea had a Circulation, as it probably may not be known, that there is any Example in Nature of Terrestrial Matter being moved continually for a Number of Years, except by Currents of a liquid Fluid. Therefore have thought, that the Agreement of so many Appearances of Nature with Hypothesis, might not be thought insufficient to alledge, that the Sea has a Circulation. But if those should not be thought conclusive, as Nature is known to be the most excellent in all its Operations; the cooler Regions supplying cooler Springs, and assuaging the scorching Heat of the Torrid Zone; and the same Fluid absorbing the greater Part of the Redundance of that solar Heat,
and

and gravitating with it with a slow Motion, and warming the Sea-coasts of the cooler Regions, appears so consistent with that magnificent Harmony and Perfection which may be observed through the Course of Nature; and the Benefits to Animal and Vegetable Life, which may probably appear to arise therefrom, are so much superior to any Thing that can be expected from *The Sea's being a Fluid in a State of Rest, except such Motions as are caused by the Impulse of Winds, and that known by the Name of Tides*; that they might be thought not an insufficient Support, if there were no other to favour the Hypothesis of the Sea's having a Circulation.

Indeed, had it been attempted in a Language suitable to the Importance of the Subject, it would have been much more agreeable to my Wishes, as well as to the Reader. But when the Advantages which may attend a new Discovery in Nature, and the few Opportunities, as well as Inexperience of most of the Learned, to make Observations on Currents at Sea are thoroughly considered, I flatter myself, that my Endeavours to proceed in a plain Way may not prove unacceptable.



A N

E S S A Y

O N

CURRENTS at SEA.



ALTHOUGH, from the earliest Accounts of Navigation, the Opinion has prevailed of the Sea's being a Fluid in a State of Rest, except those Motions which are caused by the Impulse of Winds, and that known by the Name of Tides. Yet when those strong Currents on the Coast of * *Brazil*, which are mentioned by the Rev. Mr. *Walter*; also the strong Current in the Gulph of *Florida*; and the many Losses and Disappointments which these Kingdoms have sustained, by Ships falling into the Northward, when designed for this Channel: I say, when these are thoroughly considered, I don't question, but it may appear, the Sea has a Motion from some natural

* Lord *Anson's* Voyage, p. 53.

Cause or Causes, that hath not been to this Time discovered.

Agreeable to this Opinion of the Sea being a Fluid in a State of Rest, &c. the learned Dr. *Halley*, in his * Directions for Sailing into the *English* Channel, says, the Variation being allowed, the Northern In-draught is insensible. But, I must beg Leave to observe, that the *Bristol* Merchantmen, which fall in with Cape *Clear* in their homeward bound Passage, in shaping their Course, with a large Wind from the Coast of *Ireland*, to the high Land near *Padstow*, which is the Land they chuse to make: That their Practice for some Years hath been to allow † two Points for the Variation and In-draught into St. *George's* Channel. Of this Allowance of two Points, which is $22^{\circ} 30'$, four or five Degrees must certainly be for Northern In-draught, as the magnetical Variation at this Time may be presumed to be not more than seventeen or eighteen Degrees in that Channel: And as this Allowance is made in Sailing from Land to Land, it doth not appear to admit of any Deception, but that the four or five Degrees must be adequate to a Northern In-draught.

If there should be an Enquiry made into the Practice of Sailing into the *English* Channel, I don't doubt, but that every discerning experienced Seaman would acknowledge, that the Safety of their Ships, &c. after they came into Soundings, to the Time they reached the Length of *Scilly*, depended on their making no less Allowance than the *Bristol* Men does, from the South Coast of

* *English* Pilot, Part I. p. 32.

† This Account I had from a Merchant of *Bristol*, who at my Request was so obliging, as to enquire of several Masters of Merchantmen which belonged to that Port.

Ireland to the high Land near *Padstow*. Should any Gentleman, &c. condescend to ask my Opinion of a Northern In-draught, I should answer, that Experience informed me, that from Commencement on Soundings in the Latitude of 49° , $30'$ North, to the Length of *Scilly* in fair Weather, I had found the Northern In-draught to be about six or eight Miles in twenty-four Hours; that on the West Coast of *Ireland*, off the *Shellocks*, &c. it was not less than four Leagues in twenty-four Hours, even when there was moderate Northern Gales: Also off the West Coast of the *Lewis* Islands, I had found it stronger than in Soundings, and also of *Foule Isle* to the Westward of *Sunborough Head*, *Shetland*, I had observed a Northern In-draught something weaker than the latter.

If we should desire to know what Authority we had for this Opinion of the Sea being a Fluid in a State of Rest, &c. would it not appear that the first reputed Seaman, of the latter Ages, were *Portuguese*, *Spaniards*, &c. who, we are assured, were not very expert in their Profession, as there has been * great Improvements made here in Na-

* Mr. *Robert Norman*, of this Kingdom, who was the first that found the Inclination of the Magnetick Needle below the Horizon, and invented the Dipping Needle, in his New Attractive, which might be published about the Year 1580, says it was then the Custom to have the Magnetick Needle placed in such Manner on the Compass Chart, as it would allow for the Magnetick Variation of those Places where they belonged to: This Practice is retained by some of the Coasters of *Normandy* to this Day, there being some Compasses of that Sort, taken from the *French* in the late War. Mr. *Gellibrand*, of this Kingdom, is said to be the first Discoverer of the Motion of the Internal Magnet: And Mr. *Wright*, of this Kingdom, is said by some Authors to be the first Projector of the Chart which has the Name of *Mercator's*, and to be the first Inventor of the Sailing, which is known by the same Name. And as to Instruments for taking the Sun's Altitude, there are scarce any made use of but such as were first invented in this Kingdom.

vigation and Sailing since that Time. Now as it would be an Affront to a Seaman of these Kingdoms, to have any Practice of those Nations in Marine Affairs offered as a Precedent, Pray is it more reasonable that we should accede to, or adopt implicitly, the Opinion of the Sea being a Fluid in a State of Rest, except those Motions which are caused by the Impulse of Winds, and that known by the Name of Tides, when there appears some Reason to believe to the contrary?

The Difficulties which have appeared to some, to account for these Currents, who only considered them superficially probably, arose from their taking it for granted, that this Terraqueous Globe had no other Mechanism in the Structure, than what might be expected from a very large Fish Pond; that is, the Land, &c. raked out and laid in Heaps and Patches, to make Room for the Water: But if we consider this Earth's Motion round its Axis, and apply that Motion to some Part of Sir *Isaac Newton's* Theory, but not of his Supposition of a uniform Density of every Part of this Earth, I think such an Hypothesis may be formed, as may not only help to explain the probable Cause of many Currents, but likewise of some other surprising Appearances of Nature, which have not yet been properly accounted for. In order to proceed, I shall beg Leave first to consider some Properties of particular Gravity.

I. All circumterrestrial Bodies do hereby tend towards a Point, which is either accurately, or very near the Center of Magnitude of the Terraqueous Globe.

II. In all Places equidistant from the Center of the Earth, the Force of Gravity is nearly equal, indeed all Places of the Earth's Surface are not at equal Distances from the Center, because the
Equatorial

Equatorial Parts are higher than the Polar Parts; the Difference between their Diameter being * forty one and a half *English* Miles.

III. † The Force of Gravity considered downwards from the Surface of the Earth, decreases nearly, in the Proportion of Distances from the Center; the Error being no greater than what may arise from Inequalities of the Density of different Parts thereof.

Then if a Body in Vacuo near the Surface of the Earth, should descend sixteen Feet in a Second of Time, a Body equally distant from the Center, and the Surface, would descend but eight Feet in a Second of Time, and at a fourth Part of the Distance from the Center, to the Surface, would descend but four Feet in a Second of Time: Or if we should suppose a Body at the Earth's Surface to weigh 16 Pounds, the same Body at a Place equally distant from the Surface and the Center, would weigh but eight Pound, and at a fourth Part of the Distance from the Center to the Surface, would weigh but four Pounds; or at Three-fourths of the Distance from the Center to the Surface, the same Body would weigh twelve Pounds.

As attractive or gravitating Force has been considered at difference Distances from the Earth's Center, I shall next proceed to Centrifugal Force. It is by Centrifugal Force, that a Body revolving round its Axis endeavours to recede from it: It is by this Force, that the Earth's Diameter at the Equator, is greater than at the Polar Axis. Philosophers have described it nearly in the following Manner.

* Dr. Bradley's Acc. Philos. Transf. N^o 432.

† Sir Isaac Newton's Meth. Princ. of Nat. Philos. by Motte, vol. II. b. III. p. 229.

Let Figure 1 represent the Earth; let PP be the Axis at the Poles EE , the Diameter at the Equator, perpendicular to the Axis: Let there be supposed a Canal to the Center of the Earth PCE , filled with a Liquid, this Fluid will descend by its Gravity in both Legs towards C , and will not be at rest till the Pressure at both Legs be equal, if the Earth be at rest; but if the Earth be moved about its Axis PP , all the Liquid in the Leg CE will endeavour to recede from the Center, by its Centrifugal Force; which Force in that Part acts directly contrary to Gravity; so that there is no Equilibrium till CE exceeds CP $20\frac{3}{4}$ Miles, that being the Quantity, the Semi-diameter of the Equator exceeds the Semi-diameter of the Poles; but this is all on the Supposition of the Earth's being all of a uniform Density.

The next Effect of Centrifugal Force, and this Figure of the Earth is, that Pendulums of the same Length, does not in different Distances from the Pole, make their Vibrations in the same Time; but towards the Pole, where the Power of Gravity is strongest, they move quicker than near the Equator, where they are less impelled to the Center. For since, from the Rotation of the Earth about its Axis, every Body endeavours to recede from the Center of the Circle it describes, by how much the greater those Circles are, by so much is the Centrifugal Force of the Bodies describing those Circles increased; which Force is therefore always as the Sine of the Distance from the Pole, which as it is greatest under the Equinoctial, is nothing at all under the Pole; so that the Force of Gravity is the least under the Equator, but at the Pole the greatest.

This Increase of Gravity from the Equator to the Poles, hath been confirmed by several Experiments

ments made with Pendulum Clocks, at different Times and Places. In 1672, in the Island of *Cayenne*, by M. *Richer*. In 1677, in the Island of *St. Helena*, by the learned * Dr. *Halley*: And in 1682, by M. *Varin*, and M. *Des Hayes*, at the Observatory at *Paris*; in the Island of *Goree*, and at the Islands of *Martinico* and *Guarda Coupe*; also by several others at different Times and Places. But the most accurate Observations appear to be made in *London*, by † Mr. *George Graham*, F. R. S. and at *Black River* in *Jamaica*, by *Colin Campbell*, Esq; F. R. S. From which the excellent Dr. *Bradley* hath shewn (from Mathematical Reasoning thereon) the Difference of the Length of a single Pendulum that will keep true Time at the Equator, and at every five Degrees of Latitude from thence to the Poles, also the Number of Seconds that a Clock would gain in a Day in those several Latitudes, supposing it went true when at the Equator. And likewise it appearing that the whole Time of the Swing, when a Pendulum moves thro' small Arches, bears to the Time required for a Body to fall down thro' half the Length of the Pendulum very nearly the same Proportion, as the Circumference of a Circle bears to the Diameter; that is, very nearly the Proportion of 355 to 113: It may be said to further illustrate the Increase of Gravity from the Equinoctial to the Poles.

Now as we are well assured, the Increase of Gravity, from the Equator to the Poles, hath been confirmed by Experiments, which might have been transcribed more fully, if my Intention had not

* Sir *Isaac Newton's* Math. Princ. of Nat. Philos. by *Motte*, vol. II. p. 248.

† *Philos. Trans.* N^o 432, or *Martyn's* Abridgment, vol. VIII. p. 23.

been to use all the Brevity that those Subjects would bear, for explaining my Thoughts

It might have been observed, that by the former Explanation of a Centrifugal Force by a supposed Canal, the Water at the two Ends thereof were supposed to be confined by Land, and the Earth was supposed to be of a uniform Density. But my Intention being to discover what a like Canal would produce, on a Supposition that the Ends of it was under the Sea, and that the Earth has such different Densities in the internal Parts, as would favour the Sea's having such Motion, as might be expected by the Increase of Gravity from the Equator to the Poles, on statical Principles. And as there are several Caverns of Communication, from one Part to another of the Earth's Surface, as the River *Niger* is hid by the Mountains of *Nubia*, and rises again on the Western Side of those Mountains; the *Tigris* is lost in the Mountain *Taurus*; the *Guediana* in *Spain* rises in *New Castile*, and a little lower is hid for ten Leagues. Therefore it is not a Thought altogether inconsistent with Nature, that there may be subterranean submarine Caverns of Communication from one Part or Parts of the Sea to others. Nor if there were no such Passages from some Parts of the Earth's Surface to others: If it should appear that subterranean submarine Caverns and Fissures of Communication from one Part, or Parts of the Sea, to others, can be of Service to animal and vegetable Life, it may not be thought inconsistent with the Perfection of Nature, to admit it as a Circumstance, if not a Reason, to believe there may be such. Therefore in order to discover what Effect subterranean submarine Caverns of Communication would produce, on such supposed Principles of favourable different Densities of this Earth, let

Figure

Figure 2d represent the Earth, let PP be the Polar Axis, EE the Equator, and C the Centre: F 's and E 's represent some supposed submarine Caverns of Communication, and the Darts be Sea-water. By the Force of Gravity, being greater at F 's than at E 's from statical Principles, there will be a continual Descent of Sea-water at F 's; and the lesser Force of Gravity being at E 's, the same Water which descended at F 's, will be a continual Spring at E 's: And it being a Property of all Fluids to endeavour to preserve an Equilibrium, by the continual Descent of the Water at F 's, and no less Springs at E 's, there will be a Decrease at the former, and a Redundancy at the latter, by which the Water that Springs at the Ends of such supposed Caverns, which are near the Equator, will gravitate to the other Ends which are nearer the Poles (the Poles being $20\frac{3}{4}$ *English* Miles nearer the Center of the Earth than the Equator) and become a perpetual Motion.

It may probably be thought a Presumption in me, to attempt to form any Hypothesis, on a Supposition of the Earth being of different Densities; as Sir *Isaac Newton* has formed his Calculation on a contrary Principle, that is, of the Earth being of a * uniform Density, the Consequence of which would be, the Power of Gravitation would be in Lines, at right Angles, or perpendicular to the Surface; by which such a Fluid as the Sea would be at rest, except disturbed by some external

* The ingenious Mr. *Simpson* has shewn, from Mathematical Principles, that if a Planet is of a *uniform Density*, and if the Difference between the Polar and Equatorial Diameters are ever so great, by the Velocity of its Motion round its Axis, the Power of Gravitation or Attraction will be in Lines perpendicular to the Surface.

Power, as Winds or the Moon, &c. But as the Current of the Gulph-stream, and some others, have a continual Motion, which appears to disagree with the Supposition of a uniform Density of this Earth, it may be better, before the Mind assents to any Hypothesis, first to consider what Phenomena a supposed Circulation of the Sea would produce, then to enquire if there are such that make an Appearance in Nature; and at last, to form our Judgment only on such Principles, as are consistent with Phenomena.

Then admitting we were to apply ourselves to such a Consideration, upon a Supposition of what might be expected from such Caverns of Communication, and favourable different Densities in this Earth, it would appear,

1st, That if the Sea had a Circulation, and the Mouths of any such Caverns as was nearest the Poles, should not be in deep Water, the Sea-water would descend in a Whirlpool. For it is very well known, when Fluids descend thro' Pipes of Conduct, that if the Surface of such Fluid falls near such Pipe, it generates into a small Whirlpool.

2^{dly}, It is very likely, the Sea-water might be observed to rise within the Torrid Zone, or in Places near it.

3^{dly}, If there should be such Caverns of Communication, and they should afford Vegetation, it is possible that great Quantities of such Vegetables would be seen within and near the Torrid Zone, at great Distances from Land, as they might be brought up to the Surface by the Currents and Springs of Circulation.

4^{thly}, If such Circulation should have taken Place, it may not be unreasonable to imagine, that there may be Currents within the Torrid Zone, observed to gravitate towards the Temperate Zones.

5^{thly},

5thly, It might further be expected, that those Currents might be observed to continue their fore-mentioned Courses, in some Parts of the Temperate Zones towards the Poles.

6thly, There being known to be many Springs strongly impregnated with Fossils, Minerals, &c. which is undoubtedly by the Water circulating thro' Strata of those Sorts of Matter which they have incorporated; consequently then, if the Sea has such a supposed Circulation, it is not improbable, but after a subterranean Passage of such a great Length, but those Parts of the Sea which are within, or near the Torrid Zone, would be more strongly impregnated with Fossils, Minerals, &c. than Places near the Poles, which are further from those Springs of Circulation.

7thly, As Air is rarified by Heat, and condensed by Cold, and Land being known to reflect Solar Heat powerfully, while Water absorbs it, which must rarify the Air over the Land considerably, while over the Sea it might be expected to be greatly condensed; then if there are Springs of Circulation that condense the Air over the Sea within the Torrid Zone, the Sea Breezes must fall more powerfully on the Land in Places within the Torrid Zone, than on Places which are at some Times equally hot, within the Temperate Zones.

8thly, If there were such supposed Caverns, 'tis probable that Places on the Sea-coasts within the Temperate Zones, might be found hotter at some Part of the Year, than Places within the Torrid Zone, although the Solar Rays might have a more oblique Descent at that Time on the former than on the latter; as cooling Springs might be reasonably supposed to greatly assuage the scorching Heat of the Torrid Zone.

gibly, The difficulties which some find who live on the Sea-coasts, or on the Banks of great Rivers, to confine Water to desired Bounds, or particular Channels, might induce us to think, that if so immense a Body of Water as the Ocean was to have a Circulation, the subterranean submarine Currents in such supposed Caverns, would have a powerful Influence over such terrestrial Matter as had not the strongest Cohesion. And if there should be a Quantity of such, whose Cohesion was not sufficiently strong to resist such supposed Currents of Circulation, and indued with a magnetic Property, 'tis probable such internal Magnets might be observed by a dipping Needle to approach nearer the Equator.

Therefore, in order to discover if there are such Phenomenon in Nature, as hath been here thought sufficient to conclude that there are subterranean submarine Caverns of Communication, from Places in high Latitudes to Places nearer the Equator; and the Sea circulating thro' them, I must beg the Reader's attention to the following Accounts and Observations; likewise to some Queries on some of them.

The first Appearance of Nature which favours the Hypothesis of a Circulation, which I shall beg Leave to mention, is Whirlpools.

“ * In *Frobister's* Streights, after the making of
 “ Mount *Warwick*, there lyes a Whirlpool, where
 “ Ships are whirled about in a Moment, the
 “ Water making a Noise a great Way off.

“ † *Malestrand*, by the *Dutch* called *Malestroom*,
 “ a Whirlpool on the Coast of *Lapland*, which,
 “ from half Ebb to half Flood, maketh a most

* *English Pilot*, 4th Book, Part I.

† *Bokun's Geographical Dictionary*, under the Letters *M. A. L.*

“ terrible Noise, which is heard at the Islands of
 “ *Rost* and *Lofoot*, ten Miles off. If any Whale
 “ is taken in by the Current, it makes a most
 “ pitiful Outcry; and Trees, when they fall into
 “ it, are torn like Flax or Hemp.

“ * South West of *Swinna* (one of the *Orcades*)
 “ are two dreadful Whirlpools in the Sea, com-
 “ monly termed the Wells of *Swinna*, with another
 “ between *Yla* and *Jura* (two of the Western
 “ Islands) during the first three Hours of Flood,
 “ all of them are very terrible to Passengers, and
 “ probably occasioned by some subterranean *Hiatus*.

“ † Near *Sundera*, one of the *Feræ* Islands, is
 “ another Whirlpool, of about a Mile over; it is
 “ near *Sumbo* Rock.”

Now I must beg Leave to observe, although the Whirlpool called *Malestrand*, makes a Noise but from half Ebb to half Flood, that is, while the Tide is low, I have no Manner of Doubt, but the Water descends as fast at high Water when it is smooth, as at low when there is a Whirlpool: For if it may be permitted to judge of great Things, by the Observation of small, something like it will appear in filling a large Cask with any Liquid, that is, when the Funnel is full up to the Top, and consequently the greater Pressure of Water upon the Pipe of Conduct (which guides the Fluid into the Cask) there is nearly a smooth Surface; but when the Surface subsides near the Bottom of the Funnel, it generates into a Whirlpool.

Or if these Whirlpools should be considered in a natural Way, it is not to be questioned, but it would appear as impossible for these Whirlpools to

* *Gordon's Geographical Grammar*, p. 198.

† *Compleat System of Geography*, Fol. Vol. I. p. 926. the Bishop of *Bergen* gives an Account of three Whirlpools near the *Feræ* Islands, in his *Natural History of Norway*.

be kept in Motion, without large Quantities of Water descending towards the Earth's Centre, as it would be for the liquid Water of a Cataract to keep a Station on the Side of a Precipice.

I don't imagine any one can think the Water which descends at those Whirlpools undergoes Annihilation after its Descent, consequently then, we may reasonably suppose, it must rise somewhere.

And as the Force of Gravity at those Parts of the Sea where those Whirlpools are observed, is superior to the Power of Gravity, in Places nearer the Equator; also as those Whirlpools appear to contradict the Supposition of a uniform Density of this Earth; Quere, if it is not probable this Water may arise in Places within or near the Torrid Zone.

Those Whirlpools perhaps may be thought insufficient for carrying off so large a Quantity of Water, as would be requisite to make any sensible Difference in the Saltness of the Sea, or to assuage the scorching Heat of the Torrid Zone, or to make a Northern In-draught, or a Gulph-stream. But I must beg Leave to observe, that those centripetal Currents, would not have made Whirlpools, at the Surface of the Sea, if they had not been in Places where there was not a great Depth of Water; therefore there may be Numbers of subterraneous submarine Caverns of Communication in deep Water, that may carry on a Circulation sufficient to impregnate the Water of the whole Ocean, with Fossils, Minerals, &c. to assuage the scorching Heat of the Torrid Zone, and to cause all those Currents which have been observed at Sea, without disturbing the Surface of the Sea, over the Parts where the Water enters, that might enable us to discover where the Mouths of such Caverns of Communication are.

Fig. 1.

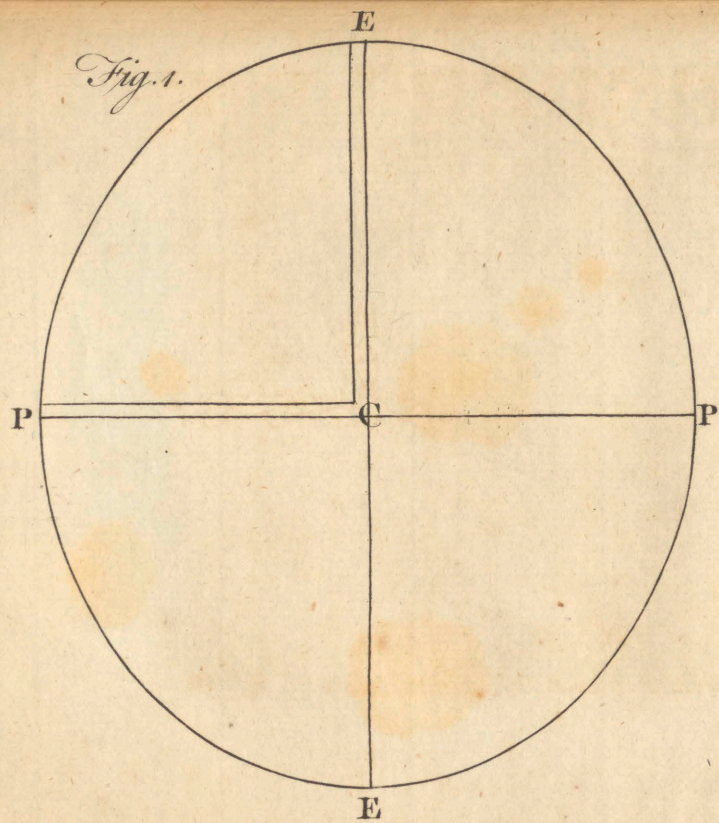
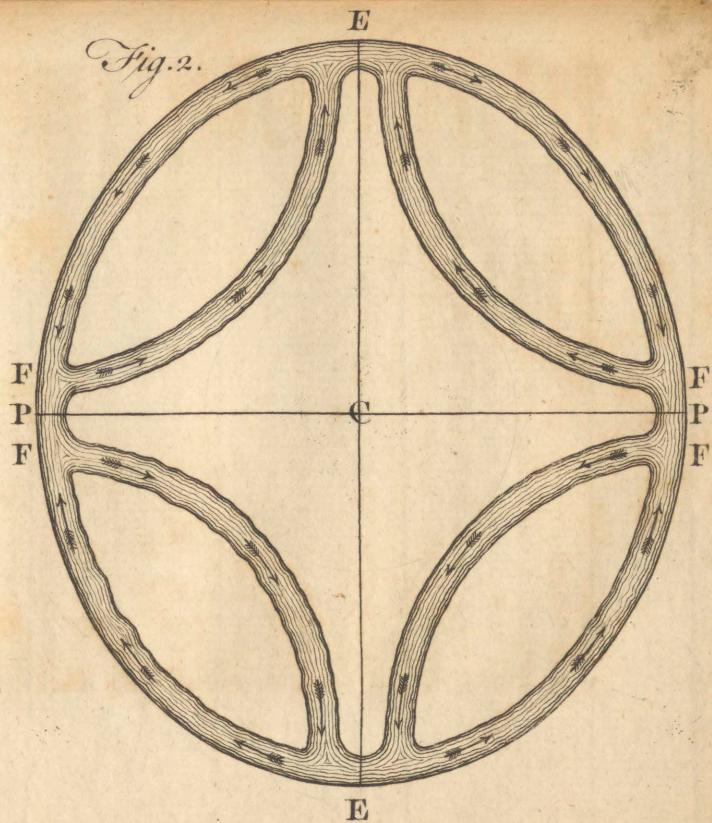


Fig. 2.



The second Appearance of Nature, which favours the Hypothesis of the Sea's having a Circulation, is, the rising of the Water of the Sea from below to the Surface in several Places within and near the Torrid Zone.

Although Things which present themselves commonly to our View, frequently make little or no Impression on the Mind, yet Water of the Sea rising from below to the Top, and spreading a smooth Surface of a considerable Breadth with a rippling round the Verge in fair Weather, in several Places within and near the Torrid Zone, I think, cannot have escaped any Person's Notice, that have been at any of our Islands in the *West Indies*: This rising of the lower Water to the Surface is also very discernible by the Sea Vegetable, known to Seamen by the Name of Gulph Weed, rising with it with a much greater Velocity, than it could rise through still Water, by the small Difference which is between the specifick Gravity of that Vegetable, and the Fluid which it swims in. Likewise Experience tells us, there is not any Tide, or collateral Current, sufficient to produce such an Effect: Neither is any such rising of the lower Water to the Surface observed in these Latitudes, at such Distances from Land and Soundings, as where that is seen in and near the Torrid Zone.

The third Appearance of Nature that favours the Hypothesis of the Circulation of the Sea, is the large Quantities of the Sea Vegetable, known by the Name of Gulph Weed *, which is in several

* As I proceeded with great Caution, before I attempted to publish this Essay, by enquiring into the Opinion of some, whose Judgment and Veracity could be relied on, was inform'd, there was an Author that gave an Account of a particular Weed, which

ral Parts of the Sea within and near the Torrid Zone.

If the Manner of Growth of Sea Vegetables should be observed, it would be found that the Generality of them were rooted to Rocks, &c. or other hard Substances, such as it could scarcely be imagined they could draw any Nutriment from; and that some Species of them grew to be very large, in Places where there were very strong Tides; or if the Colour of those of the same Species that grow in deep Water, and those that grow near the Surface, should be compared, it would be found, that the former had much the lighter Complexion; and I don't know but the same Rule governs Terrestrial Vegetables; that is, that those which are most exposed to the open air, are of the darkest Hue; by the lively yellow Colour of Gulph Weed it appears to grow in very deep Water; or if the Quantity of it should be observed, which seems like scattered over a great Part of the Sea, from about one hundred Leagues South West of the Western Islands, to over a great Part of the Torrid Zone; and I cannot say how far it may be to the Southward, as I never was in South Latitude: I say, if this Gulph Weed was not brought up to the Surface of the Sea, from its Place of Vegetation, by Springs of Circulation, How would it be possible for so many Pieces to be seen, which appear to be broke from other Parts by some Violence? Or how can we account for the large Quantity thereof,

which grew in great Abundance in the *Caspian* Sea, and although there was no such Weed known to grow in the *Persian* Gulph, it was found in the latter Place in great Abundance; but as there was none that appeared fresh, it was conjectured it was brought from the *Caspian* Sea, thro' some subterranean Cavern of Communication, as there is no visible Passage between that Sea and Gulph, but the Name of the Author or Book could not be recollected.

when

when in sailing several hundred Leagues we are never out of Sight of it? Whereas in these Latitudes, if one hundred Leagues from Land, and Soundings, we may sail fifty Leagues without seeing any Sort of Sea Vegetable whatsoever.

The fourth Appearance of Nature that favours the Hypothesis of a Circulation, is Currents in several Places near the Continent of *America*, and the Islands within and near the Torrid Zone.

* “ Upon the Full and Change, the Currents
“ sets so strong to the Northward, between the
“ *Leeward Islands* and *Jamaica*, that the Allowance
“ of Five *per Cent.* is but sufficient, which is five
“ Leagues in a hundred.” Also Experience tells me, there is as strong a Current setting to the Eastward of *Barbadoes* as where that Author mentions.

“ From the *Grand Camaines*, it is usual for Ships
“ to direct their Course for the Island of *Pines*,
“ endeavouring to sail something to the Westward,
“ in doing of which, be sure to hawl Westerly enough,
“ at least a Point of the Compass more
“ Westerly than the Draughts lay it down, by
“ reason of the Current that sets strong to the
“ Northward out of the Bay of *Honduras*, which
“ if you should not take Notice of, will set you
“ upon the *Jourdans*, which are very dangerous
“ Shoals and Rocks.

“ From *Vera Cruz*, which is in the Latitude of
“ 19° 30' N. the Current sets Northerly as high
“ as 27° of Latitude along the Shore, and then
“ it rounds the Bay to the Eastward.”

Likewise I must beg Leave to observe, that the Current sets to Windward so often off the Island

* *English Pilot*, Book, IV. p. 47. N. B. if this was totally the Effect of the Moon's Influence, there would be a Southern Current adequate to the Northern.

of *Jamaica*, that it is common for Ships which are near ready to sail, to inquire of the Coasting Sloops and Pilot Boats, which come into Harbour, to inform them how they found the Current set out at Sea. Also those that sail from *Jamaica*, thro' the Gulph of *Florida*, find a windward Current, from the Time they get between the Capes of *St. Antonio*, and *Catoche*, till they reach the Gulph of *Florida*. Likewise at Sea, near the Continent on the Coast of *Caraccas*, not far from *Cartegena*, the Current sets so constantly to Windward, that it is the Practice for Ships, which are bound over for any of the Islands, or the Windward Passage, to ply up along that Coast, till they judge themselves sufficiently to Windward, to fetch their desired Port, &c. on a Stretch. But as Sir *Isaac Newton* has laid it down as a Rule, *that to the same natural Effects, we must as far as possible assign the same Causes*. For the better discovering what Currents are the Effect of Winds, or what may proceed from other Causes, I shall take the Liberty of mentioning some Observations, that have been made on Currents in the *Baltick* Sea and Sound.

Those who have frequented the *Baltick* Sea know, that let the Wind blow ever so long Westerly, there will be a strong Current set thro' the Sound, &c. into the *Baltick*; or if the Wind blows ever so long Easterly, the Current will continue to set out so strong that Ships can seldom work to Windward against them although they have moderate Gales: The Current setting in, never raising the Sea of the *Baltick* after the first two or three Days; and the Current setting out with an Easterly Wind, never making it fall after the like Time, occasion'd some Speculation, till * *Dr. Smith* was informed

* *Philos. Transf. N. 158. p. 564.*

by a Seaman that tried the Current, and found, there was as strong an under Current, as there was an upper Current, and that they had each a Motion counter to each other; which kept the Sea of the *Baltick* nearly at an Equilibrium with the Western Ocean: And as I now think these Observations on Currents sufficient for my present Purpose, I shall next proceed to make some Remarks thereon, and humbly submit their following Queries.

Remark the first. As there is a Northern Current sets between the *Leeward Islands* and *Jamaica*; and as the Continent stretches along to the Southward and Eastward to *Cape St. Roque*, which is about 890 Leagues S. E. $\frac{3}{4}$ E. from the East End of *Jamaica*, there being likewise a Southern Current, to the Southward of *Cape St. Roque* (which shews it cannot come from the Southward) and the Trade Winds, between the *Leeward Islands* and *Jamaica*, being from about N. E. to E. which is partly against the Current.

Quære, then can this Northern Current be supplied, except by Springs of Circulation, at the Full and Change; and if it is not an under Current when the Moon is in the Quadrature, but gravitates more strongly towards the Moon, when it has the most powerful Attraction.

Remark the Second. As there is a Windward Current from between the Capes *Catoche*, and *St. Antonio*, to the Gulph of *Florida*, and a Current from *La Vera Cruz*, in the Bay of *Mexico*, which sets to the Northward as high as 27° of Latitude, and then * rounds the Bay to the Eastward: Now

* From the Bay *Apalachio* to the In-draught of the Gulph-stream, Experience likewise informs me there is an Eastern Current.

La Vera Cruz being above 200 Leagues about W. by N. from Cape *Catoche*.

Quæ, if the Current from *La Vera Cruz*, which rounds the Bay of *Mexico* to the Northward, and Eastward, is not a Current supplied from Springs of Circulation; or if there is the least Probability of its coming into that Bay, between the Capes *Catoche*, and *St. Antonio*.

Remark the third. As there is continually a Northern Current sets between the Capes *Catoche*, and *St. Antonio*, and a very strong Current perpetually, thro' the Gulph of *Florida*; also, an Easterly Current generally on the Coast of *Caraccas*, and the like sometimes off *Jamaica*, which Currents are some in a direct, and others in an oblique Direction, against the trade Winds; and as the Currents in the *Baltick* Sound, &c. are altogether govern'd by the Winds, and have under Currents, which keep the Seas in Equilibrium; likewise the Winds in these Parts have a powerful influence on our Tides.

Quæ, then, if the fore-mentioned Currents can have a supply of Water, or if the Water, thus in Motion, can receive any Impulse from any Power whatsoever, sufficient to force them against the Force of Winds, except by Springs of Circulation.

The fifth Appearance of Nature, that favours the Hypothesis of a Circulation of the Sea, is Currents inclining towards the Poles, within the Temperate Zones.

“ The Rev. Mr. *Walter* says * we found a
“ considerable Current setting to the Southward,
“ after we had passed the Latitude of 16° South;
“ and the same took Place all along the Coast of
Brazil, and even to the Southward of the River of

* Lord *Anson's* Voyage, p. 53.

Plate, it amounting sometimes to above thirty Miles in twenty-four Hours, and once to above forty. * Also near a-breast with Cape *Virgin Mary* he concluded they had a Current, which set them twelve Miles to the Southward.

Likewise, if we proceed to Observations in this Northern Temperate Zone, those who sail to *South Carolina* can inform us, that they meet the N. E. Current from the Gulph of *Florida*, before they reach Soundings; and that this Current is sometimes discovered as far North as the Capes of *Virginia*.

† Sir *George Mackenzie* gives an Account of several Nuts, such as are called Cohoon Nuts in *Jamaica*, and of a Cabbage-tree being drove Ashore at the *Lewis Islands*, to the Westward of *Scotland*.

“ § Likewise all the Wood, which is thrown
“ on the Coasts of *Greenland*, *Nova Zembla*, *Lap-*
“ *land*, and other Northern Countries, is Worm-
“ eaten; which is a Proof this Wood comes from
“ warmer Climates; since it is certain, Ships are
“ not Worm-eaten in that Northern Sea.” Now,
as the N. E. Trade Wind commences to the North-
ward of those Places, which are most noted for the
Growth of Cabbage-trees, or Cohoon Nuts; and
by || Captain *Middleton's* Observations it appearing,
“ That in *New England*, the Wind blows from

* Lord *Anson's* Voyage. p. 103.

† *Lowthorp's* Abridgment, Philos. Transf. Vol. II. p. 785.

§ Compleat System of Geography, Fol. Vol. II. p. 785.

|| *Martyn's* Abridgement, Philos. Transf. Vol. IX. p. 47.

I have been informed by a Commander in the Navy, that it is reported that the Heel of the Topmast of his Majesty's Ship the *Tilbury* (which was burned between the Islands of *Jamaica* and *Hispaniola*) was ~~taken up at Sea to the Westward of~~ *dove ashore* *land*, that a Part of it was burnt, and the Ship's Name *Tilbury* was on the Part they took up. X

X Captⁿ *Gordon* inform'd me that the
this is a fact, since the above
was printed here also been told that
Adm^l Rodney had the Command of a Ship
at *Shetland*, when the Topmast was drove
ashore on those Islands

“ the North near four Months in the Winter, at
 “ *Canada*, about 5 Months, at *Danes Settlement*,
 “ *Straight Davies* in the Latitude of 63° N. near
 “ seven Months; and on the Coast of *Norway*,
 “ in the Latitude of 64° N. above $5\frac{1}{2}$ Months.

Quære, then if those Winds are not sufficient to keep Timber, &c. from being brought from warmer Climates, if the Sea was a Fluid which had no Motion, but by the Impulse of Winds, and that known by the Name of Tides; or if there is a Probability of their being brought so far to the Northward, except by Currents from Springs of Circulation.

The sixth Appearance of Nature, which favours the Hypothesis of the Sea having a Circulation, is, the Difference in the Saltness of several Parts of the Ocean.

“ * Mr. *Boyle* having recommended to a learned
 “ Physician who was sailing into *America*, and
 “ furnished him with a small Hydrostatical Instrument, to observe, from Time to Time, the
 “ Difference of Gravity he might meet with;
 “ this Account was returned him, that he found
 “ by the Glass, the Sea Water to increase in
 “ Weight the nearer he came to the Line, till he
 “ arrived at a certain Degree of Latitude, as he
 “ remembers, about the Thirtieth; after which the
 “ Water seemed to retain the same specifick Gravity, till he came to *Barbadoes* or *Jamaica*.

“ † Dr. *Stubbs* says, I observed at Sea, after
 “ we were out of the Narrow, the Sea grew
 “ darkish, and after a perfect Azure; yet was it
 “ much more Salt the farther we went, as I tried
 “ by a Water Poise, which arose about half an

* *Lowthorp's* Abridgment Philos. Transf. vol. II. p. 297.

† *Lowthorp's* Abridg. of the Philos. Transf. vol. 3. p. 547.

“ Inch

“ Inch above the Sea Water, in the *Downs*, and
 “ at twenty-four Degrees more, two Inches; but
 “ after that I never observed any Difference unto
 “ *Jamaica*; the Sea being probably so strongly
 “ impregnated with Salt, as not to imbibe any
 “ more.”

If the Water, from saline or mineral Springs, should be examined at different Distances from Springs, I don't know there is the least Reason to doubt, but that they would be found weaker and weaker, the further they had gravitated from the Springs, by the more heavy Particles subsiding, and by fresh Water mixing therewith. Pray then, when the fore-mentioned Appearances of Nature are considered, is not the greater Saltiness of the Sea, within the Torrid Zone, and the gradual Decrease thereof, towards the Poles, a strong Indication of the Sea having a Circulation.

The seventh Appearance of Nature, which countenances the Hypothesis of the Sea having a Circulation, is, strong Sea Breezes falling constantly upon the Land within the Torrid Zone, when the Solar Heat is powerful, and little or not high so strong at some Places within the Temperate Zone, particularly at *South Carolina*.

* Mr. Boyle has shewn, by several Experiments, that Air is rarified by Heat and condensed by Cold; from whence he alledges, that the strongest Cold in *England* doth not contract the Air more than $\frac{1}{12}$ th Part.

† Mr. Robins concludes from some Experiments which he made, that Air is expanded by the Flame of fired Gun Powder, in the Ratio of $194\frac{1}{3}$ to 796.

* *Lowthorp's Abridgment*, vol. II. p. 9.

† *New Principles of Gunnery*, by B. Robin's, F. R. S.

“ * Sir William Beeston observed his Barometer
 “ in *Jamaica* diligently every Day ; and found in
 “ the Morning before the Sun arose, the Mercu-
 “ ry stood one Degree below changeable ; and as
 “ the Heat increased, it sunk within one Degree
 “ of above Rain.”

It is generally acknowledged by those, who have resided some Time at *Jamaica*, and *South Carolina*, that the Heat of the latter exceeds any Heat of the former Place, about three Months in the Summer.

† Dr. Lining, in a Letter from *South Carolina*, says, “ in Summer the Heat of the shaded Air about
 “ two or three in the Afternoon, is frequently be-
 “ tween 90 and 95 Degrees of *Fahrenheits* Mercuri-
 “ al Thermometer; on the 14th, 15th, and 16th
 “ of June, 1738, at 3 PM, it was at 98, a heat
 “ equal to the greatest Heat of the human Body.

Now, as it is a Property of Air, as has been observed, to be rarified by Heat, the Air of *South Carolina* must be thinner in a Summer's Day than the Air of *Jamaica*, admitting the Mercury in the Barometer at equal Height at both Places ; but by the Air at *Jamaica* gravitating very powerfully from the Sea upon the Land, in the Heat of the Day, from statical Principles, the Air of the Sea must be a great deal more condensed within the Torrid Zone, than near *South Carolina*, where they have not a regular Sea Breeze. Now, as it is likewise a Property of Air to be condensed by Cold, as has been observed. Queræ, How can the Air over the Sea within the Torrid Zone be more condensed, than the Air over the Sea in the Latitude of *South Carolina*, except by cooling Springs of Circulation rising within the Torrid Zone.

* *Lowthorp's* Abridg. *Philos. Transf.* vol. II. p. 9.

† *Philos. Transf.* N^o 487, Letter 12.

The 8th Appearance of Nature, which favours the Hypothesis of the Sea's having a Circulation, is the Coolness of the Torrid Zone; the greater Heat of some Places within the Temperate Zones, and the Difference of Heat of several Places in the same, and equal Latitudes.

Mr. *Boyle* relates an Experiment he made in the following Manner.

“ * We took some hard, black Pitch, and having, in a Bason, Porringer, or some such Vessel, placed it a convenient Distance under Water, we cast on it, with a good Burning-glass, the Sun Beams, in such a Manner, that notwithstanding the Refraction that they suffered in their Passage thro' the interposed Water, the Focus fell upon the Pitch; wherein it would produce sometimes Bubbles, sometimes Smoak, and quickly communicated a Degree of Heat, capable to make Pitch melt, if not to boil.”

† Captain *Henry Ellis*, F. R. S. in a Letter to the Reverend Dr. *Hales*, F. R. S. after mentioning some Advantages received from Dr. *Hales's* Ventilators, says, “ Upon the Passage I made several Trials with the Bucket Sea-gage, in the Latitude $25^{\circ} 13'$ N. Longitude $25^{\circ} 12'$ W. I charged it, and let it down to different Depths, from 360 Feet to 5346 Feet, when I discovered, by a small Thermometer of *Fahrenheit's*, made by Mr. *Bird*, which went down with it, that the Cold increased regularly, in Proportion to the Depths, 'till it descended to 3900 Feet; from where the Mercury in the Thermometer came up at 53 Degrees; and tho' I afterwards sunk it, to the Depth of 5346 Feet, that is, a

* *Boyle* on the Mechanical Origin of Heat and Cold; *Experiment the Third*.

† Philosophical Transactions, Vol. 47.

“ Mile and 66 Feet, it came up no lower. The
 “ Warmth of the Water upon the Surface, and
 “ that of the Air, was at that Time, by the Ther-
 “ mometer, 84 Degrees: I doubt not, but the
 “ Water was a Degree or two colder, when it en-
 “ tered the Bucket, at the greatest Depth, but in
 “ coming had acquired some Warmth of the
 “ Water upon the Surface; for I found, that the
 “ Water which came up in the Bucket, having
 “ stood 43 Minutes in the Air, the Time of
 “ winding it up, the Mercury rose above five De-
 “ grees. — When the Air had rendered it equally
 “ warm with the Water on the Surface, I tried
 “ their Weight, by weighing equal Quantities
 “ very exactly, as also by the Hydrometer; and
 “ found, from the greatest Depths the heaviest,
 “ and consequently the saltest Water, &c.”

If the Accuracy and Care, with which Captain
Ellis made this Experiment, is observed, and that
 the Mercury rose five Degrees, in an equal Time
 to that which the Bucket was winding up, I don't
 apprehend there can be any Difference in Opinion,
 as to the Water being a Degree or two colder,
 when it entered the Bucket, at the greatest Depth.

By this Experiment (for which we are obliged to
 the Reverend Dr. *Hales* and Captain *Ellis*) it ap-
 pears, the solar Heat penetrates into the Sea, to
 above the Depth of a Mile: and as the Sea is
 known to gravitate to the northward, in North La-
 titude, and to the Southward, in South Latitude,
 which has been observed when Currents were
 spoken of; I don't question but the acquired Heat,
 which the Sea had imbibed in its Passage to the
 Latitude of * 28° S. (and the Latitude of 32° 40' N.

* The Reverend Mr. *Walter* observes, “ That the Mercury
 “ in a Thermometer of *Fahrenheit's* was but once up at 76 De-
 “ grees in the whole Voyage, and that was at St. *Catherine's*.”
Lord Anson's Voyages, p. 254.

the latter being nearly the Latitude of *South Carolina*) may more than compensate for the oblique Descent of the solar Rays, and cause that greater Summers Heat, than of the Torrid Zone.

Now if it be admitted, that the Sea, in the Latitude of 28° S. or $32^{\circ} 40'$ N. is the most strongly impregnated with the solar Heat, which, I think, the superior Heat of *St. Catherine's* and *South Carolina* seems to indicate; it is very certain a Body of Water, several hundred Leagues over, heated to above a Mile deep, will retain the Heat a considerable Time, and will have a warm Influence on the Coasts, which are adjacent to it in its Passage to high Latitudes; which way of Reasoning, the Current on the Coast of *Brazil* seems to countenance, as there is always a Passage free from Ice round *Cape Horn*; which is nearly in the Latitude of $57^{\circ} 50'$ S. although *Dr. Halley* found the Icy Sea to commence in the Latitude of 52° S. at a great Distance to the eastward of that Coast. Nor is it the high Latitude of *South America* alone that enjoys that Blessing, we having a northern Indraught, as has been observed, on these Coasts: Therefore if the Heat of several Places in the same or equal Latitudes should be observed, it would be found, that the Latitude of a Place was not a certain Criterion, for to inform us of the Heat or Coldness thereof; but that neighbouring Countries and Seas participate of the Heat or Cold of each other. For, as the Reverend *Mr. Walter* has observed, the Pacifick Ocean, within the Torrid Zone, on the Coast of *Peru*, partakes of the Coolness of the frozen Summits of the *Andes*. — Now if we observe *Ireland* (which is not improbably warmer in the Winter than any other Island in the World, when its Largeness and Distance from the Equator are admitted) partakes of the Heat which is conveyed

veyed with the Sea from the Torrid Zone. Those Parts of *England*, which are in the same Latitude of Part of *Ireland*, being farther distant from the western Ocean, and consequently do not partake so much of its warm Influence, have the Winters cooler than those of *Ireland*: Likewise if we proceed to those Places on the Continent, which are still more remote from the western Ocean (and consequently from the warm Effects thereof) the Winter will be found colder than either of the former. But if we should proceed to Observations in *Hudson's Bay*, it would be found colder than any Part of the Continent of *Europe* in the same Latitude, although those Parts of *Hudson's Bay* may be nearer the Sea; yet when it is considered, that the western Springs of Circulation, which appear by Currents to be in the Bay of *Mexico*, gravitate from the Gulph of *Florida* in a North East Course for a considerable Way; and as there has not been any northern In-draught discovered on the Banks of *Newfoundland* by those that have * fished there, it appears to take a more easterly Course, which must carry it a great Distance from *Hudson's Bay*; whereas by the Clearness of our northern *European* Sea from Ice, and the worm-eaten Timber, which is brought to those northern Countries, the Sea appears to circulate a great way round the Northern Parts of *Europe*, which may probably make that

* I wrote down to a Merchant at *Bristol* to enquire of some of the Masters of Merchamen that used *Newfoundland*, concerning the Currents on the Banks; and had for Answer, That they had Currents which set, at different Times, several Ways; but, in the general, had no particular Tendency.— This Observation on Currents having an Eastern Course, is likewise countenanced by Ships often falling in with Cape *Finisfre*, in sailing to the South, when by reckoning they might have expected to have been considerably to the Westward of that Cape.

Difference that is between the Winter's Cold of Places in *America* and *Europe*, which are situated in the same Latitude.

But if a Theory of the Summer's Heat of these forementioned Places should be attempted, the Sea absorbing the Solar Heat to a great Depth, the Atmosphere over it will be much cooler than that of the Land, which will reflect the Solar Heat: Therefore *Ireland*, by its Vicinity to the Western Ocean, will have cool Summers; and *England*, which is farther distant, will have its Summers warmer; and those Places in the same Latitude on the Continent must be warmer than either of the former, as the reflected Solar Heat from the Land cannot be so much assuaged by Currents of Air from the Sea, by reason of the latter's more remote Distance. And as to those Places in *Hudson's Bay* which are contiguous to the Sea, it is not improbable but that they may have their Summers cooler than any of the former; for as those Parts of the Sea have not any Supply of Warmth from the Torrid Zone, 'tis probable it will have a cooler Influence on the Air on the Shore than the Sea near these Kingdoms; for although some may probably imagine, by the Heat of this Part of the Western Ocean, which is near these Coasts, that Heat is an inseparable Property of Sea Water. — But if those that may be of that Way of thinking would give themselves Time to consider, that there is an Icy Sea, which commences in the Latitude of 52° South, at a great Distance from any known Land, 'tis probable, that would be sufficient to make them be of another Opinion. — Some others may possibly think, that as Sea Water will not congeal with the same Degree of Cold, as fresh Water will, that its retaining the Liquid State longer, is an
Indication

Indication of its greater Heat ; but that cannot be admitted as a Reason, for Mercury, which is as susceptible of Cold as any Fluid whatsoever, is never congealed ; therefore, that great Retention of a liquid State, which is observed in Sea Water, may proceed from some other Cause than Heat ; which may not improbably be, by having smaller or fewer Pores than fresh Water, or being impregnated with Sulphur, &c. not that it may be unreasonable to imagine, that that Part of the Sea which is saltest may be warmest, in high Latitudes, by having a quicker Circulation.

If there should be an Attempt made to estimate the Advantages this Earth appears to receive from a Circulation of the Sea, some might probably think, that the Winter of *Shetland*, which is in about the Latitude of $60^{\circ} 10'$ N. being warmer than *Cape Breton*, which is in about the Latitude of $46^{\circ} 30'$ N. is as great an Advantage as might be expected ; but if the Summer's Heat of *Charles Town, South Carolina*, is made the Standard to judge by, as to the Heat that might be expected within the Torrid Zone ; it may be observed, the Sun never comes nearer the Zenith of that Place than 9 Degrees. Then that Opinion of the Antients, that the Torrid Zone was uninhabitable, will not appear altogether inconsistent ; for altho' the frozen Crests of the *Andes* have a cool Influence on the Parts to the Westward thereof. The Trade Winds which may partly be caused by the Earth's Motion round its Axis, might prevent any cool Effect therefrom to the Eastern Coast ; consequently then, I say, if we judge by the Summer's Heat of *South Carolina*, all the Eastern Coast, and other Parts which have not any Benefit from the cool Influence of the Tops of frozen Mountains, would appear to be uninhabitable, except by fable
Africans ;

Africans; who, probably, have Constitutions better adapted to hot Climates, than the other Parts of the Human Species. — Or, if this Calculation should be extended to high Latitudes, it might be proper to observe, that there is an Icy Sea in the Latitude of 52° South, but as the Icy Sea doth not stretch far Eastward, or Westward, and as the Sun must have a like Influence on all Places of the Sea which are in the same or equal Latitudes; it is probable there is a Circulation to the Eastward and Westward thereof. Then beside the Advantage this Icy Sea hath from the Solar Heart, it must receive a great deal of Heat by Easterly and Westerly Winds, from those warm Currents, which are probably to the Eastward and Westward thereof; which it is not improbable, but that they may keep the Sea from congealing two or three Degrees nearer the Equator, than it would have done, had there been no Circulation; by which an Icy Sea might be expected to commence in the Latitude of 49 or 50° , which would totally stop the Passage round *Cape Horn*, or make it extremely difficult. And, as to our Parts in these Latitudes, it would consequently destroy all our Northern Navigation, and do much more Damage by rendering several Parts of the Earth (which at present are well inhabited) uninhabitable, for want of a sufficient Heat to supply Vegetation. All which Evils appears to be happily prevented by a wonderful Mechanism in Nature; by which the cooler Climates are sending constant Supplies of cool Water thro' Caverns of Fossils, Minerals, &c. which gives a Saltness to the Sea, also a Coolness and Salubrity to the scorching Air of the Torrid Zone; and the Torrid Zone in return, sends the Sea fully impregnated with Solar Heat, for the cooler Regions.

The

The ninth Appearance of Nature which favours the Hypothesis of a Circulation of the Sea, is, the Motion of Magnets within the Body of the Earth.

If we were to attempt to form a Judgment of what Sort of Matter the internal Part of this Earth was composed of, I don't know that it would be Philosophical to suppose it was made up of any other Materials, but such Earths, Fossils, Minerals, &c. &c. as Chance, or Industry had brought to our View. — Then, as there has been * Magnetical Sand brought, from the *East-Indies*, *Virginia*, *Italy*, &c. it is not a Thought inconsistent with Nature, to imagine that there is large Quantities of it within the Body of the Earth: Or, if we would willingly inform ourselves, by what natural Power, Earth, Sand, &c. had been moved, in nearly a colateral, uniform Motion at any Time, I don't know that we could discover any other Agent, so powerful as Water; the Power of that Fluid, in moving Terrestrial Matter, is so perspicuous, that if we believe the Testimony of others, or will take the Trouble of inspecting into Nature ourselves, it will give us no Reason to doubt of its being sufficient to move those Magnets (which have Motion) within the Body of the Earth.

“ † The going into *Cookmore Haven*, the Depth
“ is uncertain, when it blows a Storm out of the
“ Sea, the Harbour is barr'd up with Stringle,
“ and opened again with the Land Floods.

“ *New-Haven* is much alike in all Respects to
“ this and is subject to the like Inconvenience.

“ ‖ The River's Mouth of *Bayonne* lies in be-
“ twixt two plain Strands E. by N. and W. by S.

* *Martyn's Abridgment*, *Philos. Transf.* Vol. VIII. p. 739.

† *English Pilot*, Part I. p. 24. ‖ P. 69.

“ and

“ and sometimes more Easterly or Northerly, by
 “ reason of the shifting of the Sand before the Ri-
 “ ver’s Mouth.”

A Part of the Directions for sailing into *Port à Port*, says, * “ On the South Side of the River,
 “ goes in also a Land, deep to the Southward of
 “ the aforesaid funken Rock, which lies in the
 “ River’s Mouth, where the Pilots sometimes bring
 “ Ships in and out. That is a good Channel but
 “ subject to such sudden Alterations, as not to be
 “ depended upon.”

Some Part of *Narmouth* Sands have suffered such Alterations by the Tides, &c. that some of the Brethren of the *Trinity-House*, and Mr. *Lounder*, a Draughtsman of his Majesty’s Yard at *Woolwich*, went down there in 1753, and for the Safety of that Navigation, were obliged to make a new Survey. Now, as the Sea is known to be so powerful in the foremention’d Places, in moving terrestrial Matter, what may not be effected by Currents of Circulation, when some of them appear to make a Stream on the external Part, which is generally allowed to have a Motion of 120 Miles in 24 Hours, as the Gulph Stream; or of 30 or 40 Miles, as on the Coast of *Brazil*?

By the Magnet’s Motion, being generally taken Notice of to discover the Variation, some may probably imagine, that the Motion is only Westerly; but Mr. *Norman* (who was the first Inventor of the Dipping-needle) observed the Angle of the Dip below the Horizon, in the Year 1576 to be $71^{\circ} 50'$; in 1613 it was observed to be between 72 and 73° ; in 1676, Mr. *Bond*’s Scheme of the Dipping-needle informs us, it was about $73^{\circ} 30'$; and Mr. *Whiston* says †, in the Year 1721, it was

* *English Pilot*, Part I. p. 79.

† Mr. *Whiston*’s Account in his *Latitude and Longitude found out*.

by a Needle of one Foot, not poised, $73^{\circ} 45'$; but by one of four Foot, poised, above 75° ; which was also the true Dip of the smallest Needle. By which Observations the Magnet appears to have some Southing as well as Westing in its Motion; by which it must reach nearer the great Bay of *Mexico*, where the Springs partly supply that wonderful Current the Gulph Stream.

* Dr. *Cheyne*, when describing the Advantages this Earth receives from the Moon, says, “ She
“ raises our Tides twice in twenty four Hours;
“ which, how absolutely necessary that is towards
“ the Subsistence of Animals and Vegetables, we
“ shall now shew.

“ Every Body knows, that a Lake, or Lough,
“ that has no fresh Water running into it, will,
“ by the Heat of a few Months, and its Stagna-
“ tion, turn into a stinking, rotten, Puddle; send-
“ ing forth nauseous and poisonous Steams: for
“ though I don’t think the constituent Particles
“ of Water are altered by this Stagnation, yet no
“ Water is absolutely pure.” Now if it be pre-
sumed the Doctor was a Judge of what was sus-
ceptible of Putrification, it will appear there is a
Necessity for the Sea to have a Circulation, as
there are no Tides within a great Part of the
Torrid Zone, that have been thought worthy of
Consideration † in Navigation: whereas, if Tides
were to keep the Sea from Stagnation (the greater
Solar Heat being within the Torrid Zone) it
might not be unreasonable to imagine, that it
required the greater Tides; as the same Bodies are

* Philosophical Principles of Religion.

† At all our Islands in the *West Indies*, and in the Bay
of *Honduras*, it doth not flow more than three or four Feet in
at Full and Change; and the Moon hath no Influence over the
Sea in the Quadratures,

known to be more susceptible of Putrifaction in hot Weather than in cold. But as the greatest and most useful Discoveries have generally met with much Opposition, although they have had Men of great Learning and Genius to support them; therefore it would be the greatest Absurdity in me to expect, that the World should come into my Way of thinking, except from the Reasonableness thereof; inasmuch as there can be no stronger Presumption in favour of any Hypothesis, than its agreeing with the Appearances of Nature: Therefore I shall only desire to know, if we were to consider the Works of the great Author of Nature, from the most glorious celestial Bodies to the Comets, then this Planetary System of Primary and Secondary Planets, the Primary receiving and reflecting the Solar Light to their Attendants, the latter in return doing the like to their Primary Planets; and then the various Ways of Production and Maturation, in animal and vegetable Life, with the Magnificence, Beauty, and Harmony of the whole: I say, when these are fully considered, I shall only desire to know which appears most consistent with the Course of Nature; that the Ocean, which encompasses the greater Part of this Earth, should have no other Mechanism than a great Water, put sometimes in violent Motion by Wind, and some Part thereof having another Motion, by gravitating towards the Moon, &c. and that the external Part of the Earth, &c. was a Shell, containing a great loose Loadstone within, as a Neucleus, or Kernel, which would not obey the Laws of Gravitation, but was kept in Motion to imploy Philosophers to observe how it moved, and to give Seamen some Trouble to find out the Bearings of its nearest Pole. — Or that the submarine Earth hath several Caverns of Communication,

whose Northern Mouths are near *Nova Zembla*, and to the Westward and Southward thereof; some of which Caverns reach into the Bay of *Mexico*; and others from about one hundred Leagues S. W. of the Western Islands, over a great Part of the Torrid Zone. And that there are others in the Southern Hemisphere, some of which have their Southern Mouths to the S. E. of the *Cape of Good Hope*; and others to the Southward of *Terra del Fuego* of *America*, and the like in the *Pacifick* Ocean; all which have a Communication with the Torrid Zone, thro' Fossils, Minerals, &c. and by the Earth being of different Densities in different Parts thereof, and by the Motion round its Axis, this Water circulating from cooler Climates condensing the Air, and giving a Coolness and Salubrity to it in those Places, where it rises within the Torrid Zone, likewise will be strongly impregnated with those Fossils, Minerals, &c. which it glided on in its Passage. And when the Solar Heat becomes powerful on the Shore, the Land, by reflecting that Heat, must rarify the Air; while the Solar Heat at Sea will be absorbed by that Fluid, which will keep the Air over the Sea from being so much rarified as that over the Land, and consequently heavier; which, from Statical Principles, must gravitate from the Sea to Land, and make a Sea Breeze. And by the large Quantities of Water, which is continually receding from the Earth's Axis, there will be a Redundancy at the Equator, which will gravitate with a slow Motion towards the Mouths of the Caverns which are near the Poles, endeavouring to preserve an Equilibrium; but having imbibed great Quantities of the Solar Heat, &c. the Lands, &c. which are contiguous to it, or near it, in its Passage into the cooler Climates, will partake of its warm Influence;

fluence; while those Parts which are far distant, tho' in the same Latitude, may be considerably cooler; which may make that Difference of Heat, which is observed in Places in the same Latitude; and Magnetical Sand, &c. being in some one of those Caverns of Communication, may be carried on with a slow Motion. So, while the cooler Climates are continually affording a comfortable Coolness to the Torrid Zone, the Torrid Zone is continually returning that Favour, by sending, by the same Vehicle, its Redundance of Heat to the cooler Climates: I say, I should be glad to know which Theory appears most consistent with that Magnificence, Beauty, and Harmony, by which the Universe seems to be governed.

Indeed, our being brought up in the Opinion of the Sea's being a Fluid in a State of Rest, except those Motions which are caused by Winds and Tides, as has been observed; the strong Habits of the Mind to its usual Way of thinking, may be of such powerful Force as may make it very hard to conceive, that there are such vast subterraneous submarine Caverns of Communication, from the cooler Regions to the Torrid Zone, for cooling the scorching Heat of the latter, and warming the frigid State of the former, and impregnating the Sea with such Fossils, Minerals, &c. as will give a Salubrity to the Air; but if we give ourselves the Trouble to inspect into the wonderful Mechanism of Nature, in the Production of an Insect, or Vegetable, even of a Butterfly, or Mistletoe, &c. I think it may give no room to doubt, but that there may be something as wonderful in the Mechanism of this Planet, that may greatly enable it to produce Subsistence, for its great Number of Inhabitants; and that the Structure of the internal Parts, may not be of less Service thereto, than some Part of the External; and, I think,
that

that Coolness which has been observed in some Part of the Torrid Zone, seems to be a strong Indication thereof ; as well as that Difference in the Heat of Places which are in the same Latitude.

But if it should not be admitted that the Sea has a Circulation, and as it appears there is a sufficient Authority for the Minds assenting, to the Existence of Whirlpools ; the rising of Sea-Water, within and near the Torrid Zone ; the great Quantities of Gulph-Weed within the Torrid Zone, at great Distances from Land ; and no Sort of Weeds in the Temperate Zones far from Land ; Currents within the Torrid Zone, taking their Courses towards the Temperate Zones, and Currents in the Temperate Zones continuing their Courses towards the Frigid Zones : Also the Sea-Water within and near the Torrid Zone, where the Sea-Water is observed to rise, being saltier than Sea-Water in high Latitudes ; likewise the Sea Breezes being much more powerful within the Torrid Zone, than in Places that are hotter within the Temperate Zones ; Places in the Temperate Zones being hotter for three Months together than Places in the Torrid Zone ; Places in *Europe* near where a Northern In-draught is observed, being much warmer in the Winter, than Places in the same Latitude on the Coast of *America* ; and the internal Magnet of this Part of the Earth having a Southern as well as a Western Motion. I say, if any Person should be persuaded that these several Phenomenon are not the Effects of a Circulation of the Sea, I should esteem it the greatest Favour, if they would please to condescend to offer any other that is more consistent with the Magnificence, Beauty, and Simplicity of Nature ; as the Advantages which may attend a new Discovery in Nature, may be of greater Consequence to Navigation, &c. than might be at first imagined.

But

But if we were to admit that the Sea has a Circulation, it only remains to review what Losses or Disappointments have happened in the Practice of Navigation, which might have been occasioned by it; and what Advantage may be made by knowing and allowing for the circulating thereof.

The Losses and Disappointments by Ships falling into the Northward (when bound for this Channel) have been too considerable to escape Notice; and the Disappointments which have happened by Ships missing the Islands of *St. Helena* and *Barbadoes*, would appear to be by their falling to the Southward of the former, and to the Northward of the latter, being carried by the Streams, from Springs of Circulation gravitating towards the Poles, which if there were some Allowance made for them, the Practice of Navigation might be attended with greater Success, more particularly, when the Moon is near the Full or Change, the Currents setting strongest at those Times.

Whether this supposed Knowledge of a Circulation may be of any Service in enabling us to know, when we come near to any Continent in high Latitudes, Experiments can only shew; it may be observed, that the Saltness, with which the Ocean is so strongly impregnated, springs within and near the Torrid Zone; consequently in its Length of Passage to these Latitudes, it has a Number of fresh Water Rivers running into it, which never reach to any great Distance from Continents, or Soundings. Now as there is a considerable Difference between the Specific Gravity of Sea, and fresh Water; and as any Difference of the Saltness may be known to nearly a thousandth Part by the Swimming of a Hydrometer; it is not improbable, but we may be able to discover, when we come near to the Continent or Soundings in these Latitudes, by a Hydrometer swimming deeper, which may
be

be depended on; if that light Colour, which is observed in Sea-Water, when we approach Soundings, is caused by its being fuller of Pores; or, when it is considered that the extraordinary Heat, which is in the Sea-Water in the Winter, near these Coasts, is imbibed in the hotter Climates, to above a Mile deep. It is not improbable, but in the Winter, from the Beginning of *December* to the latter End of *March*, but the Sea-Water, when we come near, or into Soundings, may be something colder than in the same Latitude, at a good Distance from Land or Soundings. Now if it be so, we may discover by a Thermometer, when the Sea-Water becomes more cold; which may be of some Advantage in knowing when we are near Land, or in Soundings: But there can be very little said for either Way, 'till there is some Trial made thereof, by Way of Experiment.

P. S. Agreeable to what I apprehended from the Consistence of so many Appearances of Nature, favouring the Hypothesis of the Sea's having a Circulation; am since credibly informed, that there is a Current which sets to the S. W. off *St. Helena*: Consequently, as the Magnet of the *Cape of Good Hope* has a Variation of about one Degree in nine Years (according to the Account of the Learned *Dr. Halley*) it gives some Reason to expect, that if the Motion of that Magnet should be diligently observed by a Dipping-Needle for a great Number of Years, it may be found to approach nearer to the Equator.

