Maury

On the saltness of the sea

ON THE SALTNESS OF THE SEA.

In order to comprehend aright the currents of the sea, and to study with advantage the system of oceanic circulation, it is necessary to understand the effects produced by the salts of the sea upon the equilibrium of its waters; for wherever equilibrium be destroyed, whether in the air or water, it is restored by motion; and motion among fluid particles gives rise to currents, which in turn, constitute circulation. The question is often asked, "why is the sea salt?" I want to show that the circulation of the ocean depends, in a great measure, upon the salts of sea water.

As a general rule, the sea is of a uniform degree of saltness and the constituents of sea water are as constant in their properties and as uniform in their proportions, as are the components of the atmosphere.

We sometimes come across arms of the sea, or places in the ocean, where we find the water more salt or less salt than sea water is generally; but this circumstance is due to local causes of easy explanation. For instance: When we come to an arm of the sea, as the Red Sea, where it never rains, and where the atmosphere is continually abstracting, by evaporation, fresh water from the salt, we may naturally expect to find a greater proportion of salt in the sea water that remains, than we do near the mouth of some great river, as the Amazon; or in the regions of constant precipitation, or other parts, where it rains more than it evaporates: and though therefore we do not find sea water from all parts of the ocean actually of the same degree of saltness, yet we do find, as in the case of the Red Sea, sea water that is continually giving off to evaporation fresh water in large quantities; nevertheless, for such water, there is a degree and a very moderate degree of saltness which is a maximum; and we moreover find, that though the constituents of sea water, like those of the atmosphere, are not for every place invariably the same as to their proportions, yet they are the same or nearly the same as to their character.

When therefore we take into consideration the fact, that as a general rule, sea water is, with the exception above stated, every where and always the same, we find grounds on which to base the conjecture, that the oceanic circulation is according to a system which is probably as complete, and as certain in its operations, as is the circulation of the atmosphere from pole to pole, or the circulation of blood through its appointed channels.

In order to investigate the currents of the sea, and to catch a glimpse of the laws by which they are governed, hypothesis, in the present meagre state of absolute knowledge with regard to them, seems to be as necessary to progress, as is a corner stone to a building. To make progress with such investigations, we want something to build upon. In the absence of facts we are sometimes permitted to suppose them; only, in making the selection of the various hypotheses which are suggested, we are bound to prefer that one by which the greatest

number of phenomena will be reconciled. When we have found, tried, and offered such an one, we are entitled to claim for it a respectful consideration at least, until we discover it leading us into some palpable absurdity; or until some other hypothesis be suggested which will account equally as well, but for a greater number of phenomena. Then, as honest searchers after truth, we should be ready to give up the former, adopt the latter, and to try it until some other better than either of the two be offered.

With this understanding, I venture to offer an hypothesis with regard to the effects of the salts or solid matter of the sea upon the currents of the ocean, and to suggest that one of the purposes which in the Grand Design it was probably intended to accomplish by having the sea salt, and not fresh, was to impart to its waters the forces and the powers necessary to make their circulation complete.

In the first place, we do but conjecture when we say, that there is a set of currents in the sea and a system of circulation in the sea, by which its waters are conveyed from place to place, with regularity, certainty and order. But this conjecture appears to be founded on reason, for if we take a sample of water which shall fairly represent in the proportion of its constituents the average water of the Pacific ocean, and analyse it;—and if we do the same by a similar sample from the Atlantic, we shall find the analysis of the one to resemble that of the other as closely as though the two samples had been taken from the same bottle after having been well shaken. How then shall we account for this, unless upon the supposition that sea water from one part of the world is in the process of time brought into contact and mixed up with sea water from all other parts of the world? Agents therefore, it would seem, are at work which shake up the waters of the sea as though they were in a bottle, and which, in the course of time, mingle those that are in one part of the ocean with those that are in another as thoroughly and as completely as it is possible for man to do by shaking them in a vessel of his own construction.

This fact as to uniformity of components, appears to call for the hypothesis that sea water which to-day is in any part of the ocean, will, in the process of time, be found in another part the most remote. It must therefore be carried about by currents; and as those currents have their offices to perform in the terrestrial economy, they probably do not flow by chance, but in obedience to physical laws; they no doubt therefore maintain the order and preserve the harmony which characterize every department of God's handy-work upon the threshhold of which man has as yet been permitted to stand, to observe or to comprehend.

And thus by a process of reasoning, which is perfectly philosophical, we are led still further to conjecture that there are regular and certain, if not appointed channels, through which the water travels from one part of the ocean to another, and that those channels belong to an arrangement which may make, and for ought we know to the contrary, which does make the system of oceanic circulation as complete, as perfect, and as harmonious as is that of the atmosphere or the blood. Every drop of water in the sea is as obedient to law and order, as are the members of the heavenly host in the remotest regions of space. For when the morning stars sang together, "the waves also lifted up their voice" in the Almighty anthem; and doubtless therefore, the harmony in the depths of the ocean is in tune with that which comes from the spheres above. We cannot doubt it. For were it not so, were there no channels of circulation from one ocean to another, and if accordingly the waters of the Atlantic were confined to the Atlantic, or if the waters of the arms and seas of the Atlantic were confined to these arms and seas, and had

no channels of circulation by which they could pass out into the ocean, and traverse different latitudes and climates, then the waters of these arms and seas would, as to their constituents, become in the process of time very different from the sea waters in other parts of the world.

For instance, take the Red sea and the Mediterranean by way of illustration: upon the Red sea there is no precipitation. It is in a rainless region; not a river runs down to it; not a brook empties into it; therefore there is no process by which the salts and washings of the earth which are taken up and held in solution by rain or river water, can be brought down into the Red sea. The air takes up from it in the process of evaporation fresh water, leaving behind all the solid matter which the sea there holds in solution.

On the other hand, numerous rivers discharge into the Mediterranean; some of which are filtered through soils and among minerals which yield one kind of salts or soluble matter; another river runs through a limestone or volcanic region of country, and brings down in solution solid matter, it may be common salt, sulphate or carbonate of lime, magnesia, soda, potash or iron; either or all may be in its waters. Still the constituents of sea water from the Mediterranean, and of sea water from the Red sea, are quite the same. But the waters of the Dead sea have no connection with those of the ocean: they are cut off from its channels of circulation and are therefore quite different as to their components from any arm, frith or gulf of the broad ocean.*

How therefore shall we account for this sameness of compound, but upon the supposition of a general system of circulation in the ocean, by which in the process of time, water from one part, is conveyed to another part the most remote, and by which a general interchange and commingling of the waters take place?

In like manner, the constituents of the atmosphere whether it be analysed at the equator or the poles, are the same. By cutting off and shutting up from the general channels of circulation any portion of sea water, as in the Dead sea, or of atmospheric air, as in mines or wells, we can easily fill either with gasses or other matter that shall very much effect its character and alter the proportions of its constituents

The principle agents that are supposed to be concerned in giving circulation to the atmosphere, and in preserving the ratio among its components, are light, heat, electricity and perhaps magnetism: but as far as the motive power is concerned, or that agency by which the atmosphere that may now be within the tropics is wafted to the poles, heat and electricity are supposed to be the chief among them.

But with regard to the sea, it is not known what office is performed by electricity and magnetism in giving dynamical force to the system of oceanic circulation. The chief motive power from which marine currents

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* "The solid constituents of sea water amount to about 3½ per cent. of its weight, or nearly half and ounce to the pound. Its saltness may be considered as a necessary result of the present order of things. Rivers which are constantly flowing into the ocean, contain salts varying in amount from 10 to 50 and even 100 grains per gallon. They are chiefly common salt, sulphate and carbonate of lime, magnesia, soda, potash and iron; and these are found to be the main constituents of sea water. The water which evaporates from the sea is nearly pure, containing but very minute traces of salts. Falling as rain upon the land, it washes the soil, percolates through the rocky layers, and becomes charged with saline substances which are borne seaward by the returning currents. The ocean, therefore, is the great depository of every thing that water can dissolve and carry down from the surface of the continents; and as there is no channel for their escape, they of course constantly accumulate."—(*Youmans' Chemistry.*)

"The case of the sea," says Fowner, "is but a magnified representation of what occurs in every lake into which rivers flow, but from which there is no outlet except by evaporation. Such a lake is invariably a salt lake. It is impossible that it can be otherwise. and it is curious to observe that this condition disappears when an artificial outlet is produced for the waters."

derive their velocity, has been ascribed to heat: but a close study of the agents concerned has suggested that an important—nay, a powerful and active agency in the system of oceanic circulation is derived, through the instrumentality of the winds, of marine plants and animals, from the salts of the sea water. They give the ocean great dynamical force.

Let us, for the sake of illustration and explanation, suppose the sea in all its parts—in its depths, and at the surface, at the equator and about the poles—to be of one uniform temperature, and to be all of fresh water. In this case, there would be nothing of heat to disturb its equilibrium, and there would be no motive power to beget currents, or to set the water in motion by reason of the difference of specific gravity due to water at different densities and temperatures.

As yet we have not taken into account in this supposition, the effects of the winds and of evaporation in begetting currents.

Let us therefore take them into account: but first the winds. The winds by their force create partial surface currents and agitate the waters to a certain depth, and thus would give rise to a feeble and partial aqueous circulation in the supposed seas of fresh water with a supposed uniform temperature.

This then is one of the sources whence power is given to the system of oceanic circulation; but though a feeble one, it is one which exists in reality, and, therefore, need not be regarded as hypothetical.

Let us next call in evaporation and precipitation, that we may examine the effects of another and a more powerful agent. Suppose the evaporation to commence from this fresh water ocean, and to go on as it does from the seas as they are. In those regions, as in the trade wind regions, where evaporation is in excess of precipitation, the general level of this supposed sea would be altered, and immediately as much water as is carried off by evaporation would commence to flow in from North and South towards the trade wind or evaporating region, to restore the level.

On the other hand, the winds have taken this vapor, borne it off to the extra-tropical regions and precipitated it, we will suppose, where precipitation is in excess of evaporation. Here is another alteration of sea level by elevation instead of by depression; and hence we have the motive power for a surface current from each pole towards the equator, the object of which is only to supply the demand for evaporation in the trade wind regions—demand for evaporation being taken here to mean the difference between evaporation and precipitation, or the quantity of water that is taken up into the air and carried, in the form of vapor, to other parts as before, from the trade wind region.

So far, we only derive from evaporation and precipitation over the supposed fresh water sea, a slight surface current towards the equator, and, of course, we have the forces for but a partial oceanic circulation. The motive power of such a current would be gravitation, acting upon an inclined plane.

So far in the progress of illustration we have apparent counteraction: for we have, on one hand, the sea-level lowered in the equatorial regions by evaporation, and raised by the expansive force of heat on the other; we have also the sea-level of the Polar regions raised on one hand by precipitation, and lowered on the other, by the contraction due the diminution of temperature there. But this counteraction is only apparent, for the

increase of temperature about the equatorial, and the decrease of it about the Polar regions can only produce a certain effect, which, like the effect of the centripedal force upon the figure of the Earth, in elevating the sea-level at the equator, becomes constant, and which like every other constant in nature, is compensated; whereas the process of evaporation and precipitation being continued, the difference of level created by these in different parts of the ocean is accumulative and not constant. It, therefore, remains for currents to restore.

We have now traced from their principles of action the effect of two agents, which in a sea of fresh water would tend to create currents, and to beget a system of aqueous circulation, but a set of currents and a system of circulation, which, it is readily perceived, would be quite different from those which we find in the salt sea. One of these agents would be employed in restoring, by means of one or more Polar currents, the water that is taken from one part of the ocean by evaporation, and deposited in another by precipitation. The other agent would be employed in restoring, by the forces due difference of specific gravity, the equilibrium, which has been disturbed by heating, and of course expanding, the waters of the Torrid Zone on one hand, and by cooling, and consequently contracting, those of the Frigid Zone on the other. This agency would, if it were not modified by others, find expression in a system of currents and counter currents, or rather in a set of surface currents of warm and light water from the equator towards the poles, and in another set of under currents of cooler, dense, and heavy water, from the poles towards the equator.

Such, keeping out of view the influence of the winds which we may suppose would be the same whether the sea were salt or fresh, would be the system of oceanic circulation were the sea all of fresh water. But fresh water in cooling begins to expand near the temperature of 40°, and expands more and more till it reaches the freezing point and ceases to be fluid. This law of expansion by cooling, would impart a peculiar feature to the system of oceanic circulation were the waters all fresh. Water at the temperature of 40° would be at its maximum of density. Raise or lower the temperature from that and the water would expand; of course, then, it would grow lighter and ascend to the surface. Therefore, when the warm waters of the Torrid Zone, by flowing North and cooling down to 40°, for instance, should meet the cold current coming from the Polar basin with a temperature of 34°, the current from the equator being of denser water would sink, and the current from the Frigid Zone would then appear as a surface current until the temperature should rise to 40° for example. Here the current from the equator would be 50° we may suppose, and there would be another node in the system of fresh water circulation; for here, at this latter place of meeting, the current from the Polar regions, which all along had been of the lighter water, and therefore on the surface, would now become the heavier, disappear from the surface, sink and continue its course as an under current.

If this train of reasoning be good, we may infer that in a system of oceanic circulation, the dynamical force to be derived from difference of temperature, where the waters are all fresh, would be quite feeble. And that were the sea not salt, we should probably have no such current in it as the Gulf Stream.

So far we have been reasoning hypothetically to show what would be the chief agents exclusive of the winds in disturbing the equilibrium of the ocean, were its waters fresh and not salt. And whatever disturbs equilibrium there, may be regarded as the *primum mobile* in the system of marine currents.

Let us now proceed another step in the process of explaining and illustrating the effect of the salts of the sea in the system of oceanic circulation. To this end, let us suppose this imaginary ocean of fresh water suddenly to become that which we have, viz: an ocean of salt water which contracts as its temperature is lowered, till it reaches 28° or thereabout.

Let evaporation now commence in the trade wind region, as it was supposed to do in the case of the fresh water seas, and as it actually goes on in nature—and what takes place? Why a lowering of the sea level as before. But as the vapor of salt water is fresh or nearly so, fresh water only is taken up from the ocean: that which remains behind is therefore more salt: thus while the level is lowered in the salt sea, the equilibrium is destroyed because of the saltness of the water, for the water that remains after the evaporation takes place, is, on account of the solid matter held in solution, specifically heavier than it was before any portion of it was converted into vapor.

The vapor is taken from the surface water; the surface water thereby becomes more salt and consequently heavier; it therefore sinks; and hence we have due to the salts of the sea, a vertical circulation, viz: a descent of heavier—because salter and cooler—water from the surface, and an ascent of water that is lighter—because it is not so salt—from the depths below.

This vapor then which is taken up from the evaporating regions—by which is meant those regions where the evaporation is greater than the precipitation,—is carried by the winds through their channels of circulation and poured back into the ocean where the regions of precipitation are;—and by the regions of precipitation I mean those parts of the ocean, as in the polar basins, where the ocean receives more fresh water in the shape of rain, snow, &c., than it returns to the atmosphere in the shape of vapor.

In the precipitating regions therefore, the level is destroyed, as before explained, by elevation; and in the evaporating regions, by depression; which as already stated, gives rise to a system of surface currents moved by gravity alone from the poles towards the equator.

But we are now considering the effects of evaporation and precipitation in giving impulse to the circulation of the ocean where its waters are salt.

The fresh water that has been taken from the evaporating regions is deposited upon those of precipitation which, for illustration merely, we will locate in the North Polar basin. Among the sources of supply of fresh water for this basin, we must include not only the precipitation which takes place over the basin itself, but also the amount of fresh water discharged into it by the rivers of the great hydrographical basins of Arctic Europe, Asia, and America.

This fresh water, being emptied into the Polar sea, and agitated by the winds, becomes mixed with the salt; but as the agitation of the sea by the winds extends to no great depth, it is only the upper layer of salt water, and that to a moderate depth, which becomes mixed with the fresh. The specific gravity of this upper layer therefore is diminished just as much as the specific gravity of the sea water in the evaporating regions was increased. And thus we have a surface current of saltish water from the poles towards the equator, and an under current of water salter and heavier from the equator towards the poles. This under current supplies in a great measure the salt which the upper current, freighted with fresh water from the clouds and rivers, carries back.

Thus it is to the salts of the sea, that we owe that feature in the system of oceanic circulation which causes an under current to flow from the Mediterranean into the Atlantic, and another from the Red sea into the Indian ocean. And it is evident since neither of these seas is salting up,—that just as much, or nearly just as much salt as the under current brings out, just so much must the upper currents carry in.

We now begin to perceive what a powerful impulse is derived from the salts of the sea in giving effective and active circulation to its waters.

Hence, we infer that the currents of the sea, by reason of its saltness, attain their maximum of velocity. Hence, too, we infer that the transportation of warm water from the Equator towards the frozen regions of the Poles, and of cold water from the Frigid towards the Torrid Zone, is facilitated; and consequently here, in the saltness of the sea, have we not an agent by which climates are mitigated, by which they are softened and rendered much more salubrious than it would be possible for them to be, were the waters of the ocean deprived of this property of saltness?

If these inferences as to the influence of the salts upon the currents of the sea, be correct, the same cause which produces an under current from the Mediterranean, and an under current from the Red sea into the ocean, should produce an under current from the ocean into the north polar basin—it being supposed merely for the present that there is a surface current through Davis' Straits, always setting out of the Polar sea. In each case the hypothesis with regard to the part performed by the salt in giving vigor to the system of oceanic circulation, requires that, counter to the surface current of water with less salt, there should be an under current of water with more salt in it.

That such is the case with regard both to the Mediterranean and the Red sea, has been amply shown in other parts of this work, and abundantly proved by other observers.

That there is a constant current setting out of the Arctic ocean through Davis' and other straits thereabout, which connect it with the Atlantic ocean, is generally admitted. Lieut. De Haven, U. S. N., when in command of the American expedition in search of Sir John Franklin, was frozen up with his vessels in the main channel of Wellington straits; and during the nine months that he was so frozen, his vessels holding their place in the ice, were drifted with it bodily for more than a thousand miles towards the south.

The ice in which they were bound was of sea water, and the currents by which they were drifted were of sea water—only, it may be supposed, the latter were not quite so salt as sea water generally is.

Then since there is salt always flowing out of the north polar basin, there must be salt always flowing into it, else it would either become fresh, or the whole Atlantic ocean would be finally silted up with salt.

It might be supposed, were there no evidence to the contrary, that this salt was supplied to the Polar seas, from the Atlantic around North Cape, and from the Pacific through Bhering's straits, and through no other channels.

But fortunately Arctic voyagers, who have cruised in the direction of Davis' straits, have afforded us proof positive as to the fact of this other source for supplying the Polar seas with salt. They tell us of an under current setting from the Atlantic towards the Polar basin. They describe huge icebergs with tops reaching high up in the air, and of course the bases of which extend far down into the depths of the ocean, ripping and tearing their way with terrific force and awful violence through the surface ice or against a surface current.

Passed Midshipman S. P. Griffin, who commanded the Brig "Rescue," in the American searching expedition after Sir John Franklin, informs me that one occasion the two vessels were endeavoring to warp up to the northward in or near Wellington channel, against a strong surface current, which of course was setting to the south; and that while so engaged, an iceberg with its top many feet above the water, came "difting up," from the south, and passed by them "like a shot," although they were stemming a surface current against both the berg and themselves. Such was the force and velocity of the under current, that it carried the berg to the northward faster than the crew could warp the vessel against a surface but counter current.

Capt. Duncan, Master of the English whale ship Dundee, says, at page 76 of his interesting little narrative:

"*Dec. 18th*, (1826)—It was awful to behold the immense icebergs working away to the northeast from us, and not one drop of water to be seen; they were working themselves right through the middle of the ice."

And again at page 92, &c:

"*Feb. 23d*—Latitude 68° 37′, N. Longitude about 63° W.

"The dreadful apprehensions that assailed us yesterday by the near approach of the iceberg, were this day most awfully verified. About 3 P. M. the iceberg came in contact with our floe, and in less than one minute it broke the ice; we were frozen in quite close to the shore; the floe was shivered to pieces for several miles, causing an explosion like an earthquake or one hundred pieces of heavy ordnance fired at the same moment. The iceberg, with awful but majestic grandeur, (in height and dimensions resembling a vast mountain,) came almost up to our stern, and every one expected it would have run over the ship. * * *

"The iceberg, as has been before observed, came up very near to the stern of our ship; the intermediate space between the berg and the vessel was filled with masses of heavy ice, which though they had been previously broken by the immense weight of the berg, were again formed into a compact body by its pressure. The berg was drifting at the rate of about four knots, and by its force on the mass of ice, was pushing the ship before her, as it appeared, to inevitable destruction."

"*Feb. 24th.*—The iceberg still in sight, but driving away fast to the N. E."

"*Feb. 25th.*—The iceberg that so lately threatened our destruction, had driven completely out of sight to the N. E. from us."—*Arctic Regions—voyage to Davis' Strait, by Dorea Duncan, Master of the Ship Dundee*, 1826–7.

Now then whence, unless from the difference of specific gravity due sea water of different degrees of saltness, can we derive a locomotive power with force sufficient to give such tremendous masses of ice such a velocity?

What is the temperature of this under current? Be that what it may, it is probably above the freezing point of sea water. Suppose it to be at 36°. Break through the ice in the northern seas, and the temperature of the water is always 28°. At least Lieut. De Haven so found it in his long imprisonment, and it may be supposed that as it was with him, so it generally is. Assuming then the water of the surface current which runs out with the ice to be all at 28°, we observe that it is not unreasonable to suppose that the water of the under current, inasmuch as it comes from the South, and therefore from warmer latitudes, is probably not so cold, and if it be

not so cold, its temperature before it comes out again must be reduced to 28°, or whatever be the average temperature of the outer but surface current.

Moreover, if it be true as some philosophers have suggested, that there is in the depths of the ocean a line from the equator to the poles, along which the water is of the same temperature all the way, then the question may be asked: should we not have in the depths of the ocean, a sort of isothermal floor, as it were, on the upper side of which all the changes of temperature are due to agents acting from above, and on the lower side of which the changes, if any, are due to agents acting from below?

This under Polar current water then, as it rises to the top, and is brought to the surface by the agitation of the sea in the Arctic regions, gives out its surplus heat and warms the atmosphere there till the temperature of this warm under current water is lowered to the requisite degree for going out on the surface.

And the heat that it loses in falling from its normal temperature, be that what it may, till it reaches the temperature of 28°, is so much caloric set free in the Polar regions to temper the air and mitigate the climate there. Now is not this one of those modifications of climate, which may be fairly traced back to the effect of the saltness of the sea in giving energy to its circulation?

Moreover, if there be a deep sea in the Polar basin which serves as a receptacle for the waters brought into it by this under current which, because it comes from towards the equatorial regions, comes from a milder climate, and is, therefore, warmer, we can easily imagine why there might be an open sea in the Polar regions;—why Lieut. De Haven in his instructions was directed to look for it; and why, both he, and Capt. Penny of one of the English searching vessels, found it there.

And in accounting for this Polynia, we see that its existence is not only consistent with the hypothesis with which we set out touching a perfect system of oceanic circulation, but that it may be ascribed, in a great degree at least, if not wholly, to the effect produced by the salts of the sea upon the mobility and circulation of its waters.

Here then is an office which the sea performs in the economy of the universe by virtue of its saltness, and which it could not perform were its waters altogether fresh. And thus philosophers have a clue placed in their hands which will probably guide them to one of the many hidden reasons that are embraced in the true answer to the question, "why is the sea salt?"

But we find in sea water other matter besides common salt. Lime is dissolved by the rains and the rivers, and emptied in vast quantities into the ocean. Out of it, coral islands and coral reefs of great extent—marl beds, shell banks, and infusorial deposits of large dimensions, have been constructed by the inhabitants of the deep.

These creatures are endowed with the power of secreting, apparently for their own purposes only, solid matter which the waters of the sea hold in solution. But this power was given to them that they also might fulfil the part assigned them in the economy of the universe. For to them, probably, has been allotted the important office of assisting in giving circulation to the ocean, and of helping to regulate the climates of the earth.

The better to comprehend how such creatures may influence currents and climates, let us suppose the ocean to be perfectly at rest;—that throughout, it is in a state of complete equilibrium;—that, with the exception of those tenants of the deep which have the power of extracting from it the solid matter held in solution, there be no agent in

nature capable of disturbing that equilibrium;—and that all these fish, &c., have suspended their secretions in order that this state of a perfect aqueous equilibrium and repose throughout the sea, might be attained.

In this state of things—the waters of the sea being in perfect equilibrium—a single mollusk or coralline, we will suppose, commences his secretions, and abstracts from the sea water, solid matter for his shell. In that act, this animal has destroyed the equilibrium of the whole ocean; for the specific gravity of that portion of water from which this solid matter has been abstracted is altered. Having lost a portion of its solid contents, it has become specifically lighter than it was before; it must, therefore, give place to the pressure which the heavier water exerts to push it aside and to occupy its place, and it must consequently travel about and mingle with the waters of the other parts of the ocean until its proportion of solid matter be returned to it, and until it attains the exact degree of specific gravity due sea water generally.

How much solid matter do the whole host of marine plants and animals abstract from sea water daily? Is it a thousand pounds or a thousand millions of tons? No one can say. But whatever be its weight, it is so much of the power of gravity applied to the dynamical forces of the ocean. And this power is derived from the salts of the sea, through the agency of sea shells and other marine animals, that of themselves scarcely possess the power of locomotion. Yet they have power to put the whole sea in motion, from the equator to the poles, from the surface to the bottom.

Those powerful and strange equatorial currents which navigators tell us they encounter in the Pacific ocean—to what are they due? Coming from sources unknown, they are lost in the midst of the ocean. They appear to originate in the open sea, and in the open sea to terminate. How far may they be due to the derangement of equilibrium arising from the change of specific gravity caused by the secretions of the myriads of marine animals that are continually at work in those parts of the ocean? These abstract from sea water solid matter enough to build continents.

Thus when we consider the salts of the sea in one point of view, we see the winds and the marine animals operating upon the waters, and in certain parts of the ocean deriving from the solid contents of the same, those very principles of antagonistic forces which hold the earth in its orbit, and preserve the harmonies of the universe.

The sea breeze and the sea shell, in performing their appointed offices, act in such a way as to give rise to a reciprocating motion in the waters: thus they impart to the ocean dynamical forces for its circulation.

The sea breeze plays upon the surface: it converts only fresh water into vapor, and leaves the solid matter behind. The surface water thus becomes specifically heavier, and sinks. On the other hand, the little marine architect below, as he works upon his coral edifice at the bottom, abstracts from the water there a portion of its solid contents; it, therefore, becomes specifically lighter, and up it goes ascending to the top with increased velocity, to take the place of the descending column, which by the action of the winds has been sent down loaded with fresh food and materials for the busy little mason in the depths below.

Seeing then that the inhabitants of the sea with their powers of secretion are competent to exercise at least some degree of influence in disturbing equilibrium: are not these creatures entitled to be regarded as agents which have their offices to perform in the system of oceanic circulation? It is immaterial how great or how

small that influence may be supposed to be; for be it great or small, we may rest assured it is not a chance influence, but it is an influence exercised—if exercised at all—by design, and according to the commandment of Him whose "voice the winds and the sea obey."

It may therefore be supposed that the arrangements in the economy of nature are such as to require that the various kinds of marine animals, whose secretions are calculated to alter the specific gravity of sea water, to destroy its equilibrium, to beget currents in the ocean, and to control its circulation, should be distributed according to order.

Upon this supposition—the like of which nature warrants throughout her whole domain—we may conceive how the marine animals of which we have been speaking, assist also to regulate climates and to adjust the temperature of certain latitudes. For instance, let us suppose the waters in a certain part of the Torrid Zone to be 70°, but by reason of the fresh water which has been taken from them in a state of vapor, and consequently by reason of the proportionate increase of salts, these waters are heavier than waters that may be cooler but not so salt. This being the case, the tendency would be for this warm but salt and heavy water to flow off as an under current towards the Polar or some other regions of lighter water.

Such an under current, by reason of the limited conducting powers of water for heat, would preserve its high temperature for a length of time, and for great distances—cooling, of course, somewhat by the way.

This under current may be freighted with heat to temper some hyperborean region, or to soften some extratropical climate; for we know that such is among the effects of marine currents. At starting it might have been, if you please, so loaded with solid matter that though its temperature were 70°, yet by reason of the quantity of such matter held in solution, its specific gravity might have been greater than that of extratropical sea water generally at 28°.

Notwithstanding this, it may be brought into contact, by the way, with those kinds and quantities of marine organisms that shall abstract solid matter enough to reduce its specific gravity, and instead of leaving it greater than common sea water at 28°, to make it less than common sea water at 40°; consequently, in such a case this warm sea water, when it comes to the cold latitudes, would be brought to the surface through the instrumentality of shell fish and various other tribes that dwell far down in the depths of the ocean. Thus we perceive that these creatures, though they are regarded as being so low in the scale of creation, may, nevertheless, be regarded as agents of much importance in the terrestrial economy, for we perceive that they are capable of spreading over certain parts of the ocean those benign mantles of warmth which temper the winds and modify, more or less, all the marine climates of the earth.

The makers of nice astronomical instruments, when they have put the different parts of their machinery together and set it to work, find as in the chronometer for instance, that it is subject in its performance to many irregularities and imperfections. That in one state of things, there is expansion, and in another state contraction among cogs, springs and wheels with an increase or diminution of rate. This defect, the makers have sought to overcome; and with a beautiful display of ingenuity, they have attached to the works of the instrument a contrivance which has had the effect of correcting those irregularities, by counteracting the tendency of the instrument to change its performance with the changing influences of temperature.

This contrivance is called a *compensation;* and a chronometer that is well regulated, and properly compensated, will perform its office with certainty, and preserve its rate under all the vicissitudes of heat and cold to which it may be exposed.

So too in the clock-work of the ocean, and the machinery of the universe: order and regularity are maintained by a system of compensations. A celestial body as it revolves around its sun, flies off under the influence of centrifugal force; but immediately the forces of compensation begin to act: the planet is brought back to its elliptical path, and held in the orbit for which its mass, its motions and its distance were adjusted. Its compensation is perfect.

So too with the salts and the shells of the sea in the machinery of the ocean: from them are derived principles of compensation, the most perfect; through their agency the undue effects of heat and cold, of storm and rain in disturbing the equilibrium and producing thereby currents in the sea, are compensated, regulated, and controlled.

In every department of nature there is to be found this self-adjusting principle—this beautiful and exquisite system of compensation by which the operations of the grand machinery of the universe are maintained in the most perfect order.

Thus we behold sea shells and animalculæ in a new light. May we not now cease to regard them as beings which have little or nothing to do in maintaining the harmonies of creation? On the contrary, do we not see in them, the principles of the most admirable compensation in the system of oceanic circulation? We may even regard them as regulators, to some extent, of climates in parts of the earth far removed from their presence. There is something suggestive, both of the grand and beautiful, in the idea that while the insects of the sea are building up their coral islands in the perpetual summer of the tropics, they are also engaged in dispensing warmth to distant parts of the earth, and in mitigating the severe cold of the Polar winter.

Surely an hypothesis which, being followed out, suggests so much design, such perfect order and arrangement, and so many beauties for contemplation and admiration as does this, which for the want of a better I have ventured to offer with regard to the solid matter of the sea water, its salts and its shells, surely such an hypothesis, though it be not based entirely on the results of actual observation, cannot be regarded as wholly vain, or as altogether profitless.

May, 1852.