

THURSDAY, JUNE 8, 1871

## THE GENERAL OCEANIC CIRCULATION

AMONG the results of the *Porcupine* Expeditions of 1869 and 1870, there are perhaps none more important than those relating to the Temperature of the Deep Sea. For it is only to such accurate determinations of ocean temperatures as have now been made for the first time, not only at the surface and the bottom, but also at intermediate depths, that a really scientific theory can be framed of that great Oceanic Circulation, which, while it eludes all ordinary means of direct observation, seems to produce a far more important effect, both on terrestrial climate and on the distribution of the marine fauna, than that of the entire aggregate of the surface-currents which are more patent to sight. The latter usually have winds for their prime motors, and their direction is mainly determined by the configuration of the land; so that their course and action will change with any superficial alteration which either opens out a new passage or blocks up an old one. The former, on the other hand, depending solely on difference of temperature, will (to use Sir J. Herschel's apposite language) have its movements, direction, and channels of concentration mainly determined by the configuration of the sea-bottom; and vast elevations and subsidences may take place in this, without producing any change that is discernible at the surface.

The history of the doctrine of the general oceanic circulation has been recently given in the Anniversary Address of the President of the Geological Society, with a completeness which (so far as we are aware) had never been previously paralleled. But this doctrine has hitherto rested on the very insecure foundation of observations which were alike inadequate and inaccurate; and it has consequently been discredited, both by physicists and by physical geographers. It is now impossible to assign a precise value to the older observations upon deep-sea temperatures. For it was shown by the careful experiments which were made by Mr. Casella two years ago, under the direction of the late Prof. W. A. Miller, Dr. Carpenter, and Captain Davis of the Admiralty, that the pressure of sea-water at great depths on the bulb of the thermometer—a pressure amounting to about a ton per square inch for every 800 fathoms—exerts so great an influence on even the very best instruments of the ordinary construction, as to cause a rise of eight or ten degrees under an amount equivalent to that which would be exerted at from 2,000 to 2,500 fathoms' depth;\* and the error of many thermometers under the same pressure was two or three times that amount. There is reason to believe that some of the thermometers formerly employed, especially in the French scientific expeditions, were protected against that influence; but no such protection appears to have been applied to the thermometers supplied to Sir James Ross's Antarctic Expedition; and the observations by which he supposed himself to have established the existence of a uniform deep-sea temperature of

\* Mr. Priestwich cites Dr. Carpenter as estimating the error from pressure "at 2' or 3' or even more." The error is said by Dr. Carpenter to have been from 2' to 3' on the depths of from 500 to 700 fathoms first explored; but would have been from 8' to 10' at the depths subsequently reached.

about 39°, now seem to have been altogether fallacious. So again, Captain Spratt's observations in the Mediterranean, though made with great care, were seriously vitiated by this source of error.

It appears from Mr. Prestwich's exhaustive summary, that as long ago as 1812 Humboldt had maintained that such a low temperature exists at great depths in tropical seas, as can only be accounted for by the hypothesis of under currents from the Poles to the Equator. And this view was adopted by D'Aubuisson, Lenz, and Pouillet; the latter of whom considered it certain "that there is generally an upper current carrying the warm tropical waters towards the Polar seas, and an under current carrying the cold waters of the Arctic regions from the Poles to the Equator." Our Arctic navigators had met with temperatures in the Polar seas as low as 29° at 1,000 fathoms; and these observations have been more recently confirmed by those of M. Charles Martins and others in the neighbourhood of Spitzbergen. Several instances are recorded, on the other hand, in which temperatures of from 38° to 35° were observed at great depths nearly under the Equator; and this alike in the Atlantic, Pacific, and Indian Oceans.

The Temperature-soundings taken in the *Lightning* and *Porcupine* Expeditions, with trustworthy instruments, have shown:—(1) That in the channel of from 600 to 700 fathoms' depth which lies between the North of Scotland, the Orkney and Shetland Islands, and the Faroes, there is an upper stratum of which the temperature is considerably higher than the normal of the latitude; whilst there is stratum occupying the lower half of this channel, of which the temperature ranges as low as from 32° to 29°·5; and a "stratum of intermixture" lying between these two, in which the temperature rapidly falls—as much as 15° in 100 fathoms. (2.) That off the coast of Portugal, beneath the surface-stratum, which (like that of the Mediterranean) is super-heated during the summer by direct solar radiation, there is a nearly uniform temperature down to about 800 fathoms; but that there is a "stratum of intermixture" about 200 fathoms thick, in which the thermometer sinks 9°; and that below 1,000 fathoms the temperature ranges from 39° down to about 36°·5. (3.) That in the Mediterranean the temperature beneath the super-heated surface-stratum is uniform to any depth; being at 1,500 or 1,700 fathoms whatever it is at 100 fathoms, namely from 56° to 54°, according to the locality. To these may be added (4) the observations recently made by Commander Chimmo, with the like trustworthy thermometers, which, in lat. 3° 18½' S., and long. 95° 39' E., gave 35°·2 as the bottom temperature at 1,806 fathoms and 33°·6 at 2,306 fathoms. These seem to be the lowest temperatures yet observed in any part of the deep ocean basins outside the Polar area.

It is clear, therefore, that very strong evidence now exists, that instead of a uniform deep-sea temperature of 39°, which, on the authority of Sir James Ross, by whom the doctrine was first promulgated, and of Sir J. Herschel, by whom it was accepted and fathered, had come to be generally accepted in this country at the time when the recent deep-sea explorations commenced, not only is the temperature of the deeper parts of the Arctic basin below the freezing-point of fresh water, but the temperature of the deepest parts of the great oceanic basins, even under the Equator,

is not far above that point. And it seems impossible to account for the latter of these facts in any other mode, than by assuming that Polar water is continually finding its way from the depths of the Polar basins along the floor of the great oceanic areas, so as to reach or even to cross the Equator. And as no such deep efflux could continue to take place without a corresponding in-draught to replace it, a general circulation must be assumed to take place between the Polar and Equatorial areas, as was long since predicated by Pouillet.

Such a vertical circulation, it was affirmed by Prof. Buff, would be necessarily caused by the opposition of temperature between the Equatorial and the Polar seas; and this view was adopted by Dr. Carpenter, in his *Porcupine* Report of 1869, as harmonising with the temperature-phenomena which had been determined in the expedition of that year. It has been since contested, however, not only by Mr. Croll and Dr. Petermann, but also by Dr. Carpenter's colleague, Prof. Wyville Thomson, all of whom agree in regarding the amelioration of the temperature of the Arctic Sea as entirely due to an extension of the Gulf Stream, the underflow of Polar water being merely its complement. And the authority of Sir John Herschel was invoked against the idea that any general oceanic circulation could be maintained by difference of temperature alone; though his statements, when carefully examined, only go to prove that no such difference could produce *sensible currents*.

Such was the state of the question when the *Porcupine* Expedition of last year concluded its work; and the results obtained, whilst confirmatory of previous observations, suggested to Dr. Carpenter a definite Physical Theory, which now comes before us with the express approval of the great philosopher who had been said to be opposed to it.

Having ascertained, as our readers have learned from his report, the existence of an outward under-current in the Strait of Gibraltar, which carries back into the Atlantic the water of the Mediterranean that has undergone concentration by the excess of evaporation in its basin, Dr. Carpenter applied himself to the consideration of the forces by which the superficial in-current and the deep out-current are sustained; and came to the conclusion that, as had been previously urged by Captain Maury, a *vera causa* for both is to be found in excess of evaporation, which at the same time lowers the level and increases the density of the Mediterranean column as compared with a corresponding column of Atlantic water. This conclusion, when scientifically worked out, was found to be applicable, *mutatis mutandis*, to the converse case of the Baltic Sound; in which, as was long ago experimentally shown (with a result that has recently been confirmed by Dr. Forchhammer), a deep current of salt water flows inwards from the North Sea, whilst a strong current of brackish water sets outwards from the Baltic, the amount of fresh water that drains into which is greatly in excess of the evaporation from its surface.

Comparing, then, the Polar and Equatorial areas, it is shown by Dr. Carpenter that there will not only be a continual tendency in the former to a lowering of level and increase of density, which will place it in the same relation to the latter as the Mediterranean bears to the Atlantic; but that the influence of Polar cold will be to

produce a *continual descent* of the water within its area; thus constituting the *primum mobile* of the General Oceanic Circulation, of which no adequate account had previously been given. This conclusion, as our readers will have seen, has been most explicitly accepted by Sir John Herschel.

Our limits do not admit of our following Dr. Carpenter through his discussion of the relative shares of the Gulf Stream and of the General Oceanic Circulation in that amelioration of the temperature of the Polar area, of which the industry of Dr. Petermann has collected a vast body of indisputable evidence; and for this discussion we would refer such of our readers as are specially interested in the question to the last part of the "Proceedings of the Royal Geographical Society." But as Dr. Carpenter has now shown a capacity to deal not merely with Physiological but with Physical questions, in a manner which has obtained the approval of some of the ablest physicists of our time, we hope that he will not again be accused (as he was by some of those who opposed his views on their first promulgation) of venturing beyond his depth when he began to reason on these subjects, and of advancing doctrines which his own observations refuted. The exclusive doctrine of the thermal action of the Gulf Stream advocated by Mr. Croll, rests, as Dr. Carpenter has shown, upon so insecure a basis, that a very large body of careful observations must be collected before any reliable data can be obtained as to the heat it actually carries forth from the Gulf of Mexico. And how much of this heat is dissipated by evaporation, as well as by radiation, before one-half of the Stream reaches the banks of Newfoundland (the other half having turned round the Azores to re-enter the Equatorial current), is a question which there are as yet no adequate data for determining. On the other hand, in his conclusion that a great body of Ocean water slowly moving northwards, so as to carry with it a considerable excess of temperature even to the depth of 500 or 600 fathoms, must exert a much greater heating power than the thinned-out edge of the Gulf Stream, Dr. Carpenter seems to us to have both scientific probability and common sense on his side.

#### SCIENCE IN ITALY

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ITALY has become a nation. It is no longer enslaved by the barbarous despotism, of a single city, nor divided into mutual throat-cutting republics, nor diplomatically parcelled into heir-looms for royal families. It has at last become the country of its own people. The moral and intellectual laws of Natural Selection are now freely operating, and they will soon show what manner of people these Italians really are.

There are many ways of gauging the civilisation of a community. The consumption of soap has been suggested, and has the advantage, being numerically definite. Thus, let  $s$  represent the quantity of soap used,  $p$  the population,