of the South Atlantic, and of both to that of the equatorial

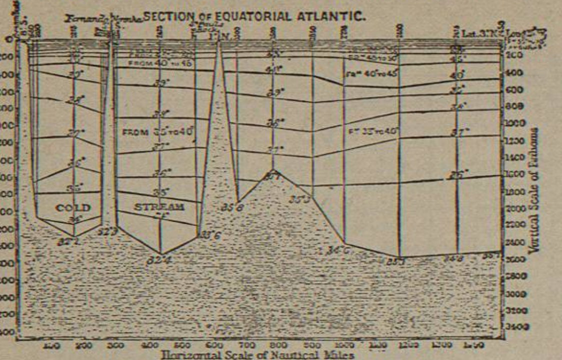

FIG. 3.—Section of Equatorial Atlantic.

belt. The isotherm of 40°, which in lat. 22° N. lies at a depth of about 700 fathoms, gradually rises as the equator is approached; and it is between the equator and 7° S., where the surface-temperature rises to nearly 80°, that cold water is soonest reached,—the isotherm of 40° rising to within 300 fathoms of the surface, while that of 55°, which in lat. 38° N. lies at nearly 400 fathoms' depth, and in lat. 22° N. at about 250 fathoms, actually comes up under the equator within 100 fathoms of the surface. At the same time, while the bottom-temperature under the equator is the lowest anywhere met with, namely, 32°·4,[1] the thickness of the stratum beneath the isotherm of 35° is not less than 600 fathoms. In passing southwards, the superficial isotherms are observed to separate again from each other, partly by the reduction of the surface-temperature, and partly by the descent of the isotherm of 40° to a depth of something less than 400 fathoms, which it keeps with little reduction as far south as the Cape of Good Hope. The significance of these facts becomes more remarkable, when we consider that if a portion of the oceanic area under the equator were to be secluded, like the Mediterranean or the

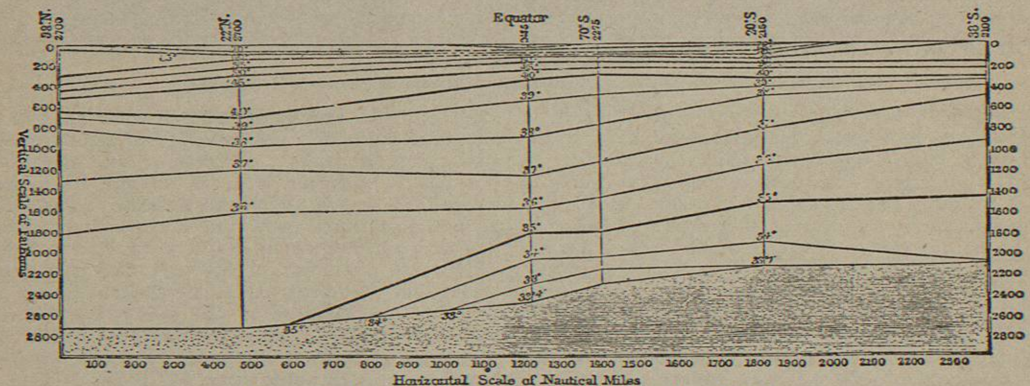

FIG. 4.—Section of Mid-Atlantic, taken nearly north and south

Red Sea, from all but local influences, the temperature of its water from the sub-surface stratum downwards to the bottom—whatever its depth—would be its *isocheimal* or mean winter-temperature, which, in the equatorial zone, would be certainly not below 75°.

Nothing, Dr Carpenter contends, could more conclusively support the general doctrine of a *Vertical Oceanic Circulation* sustained by opposition of temperature, than the precise conformity of the facts thus determined by observation to the predictions which his confidence in the theory had led him to put forth. These predictions were essentially as follows :—

"1. That instead of the local depressions of bottom-temperature imputed by previous writers to polar currents, the temperature of every part of the deep sea-bed in communication with either of the polar areas would be not many degrees above that of the polar areas themselves.

"2. That this general depression of bottom-temperature would be found to depend, not upon such a shallow glacial stream as might be maintained to be a return from the polar areas of water propelled towards them by wind-currents, but upon a creeping flow of the whole under-stratum, having a thickness of from 1000 to 2000 fathoms.

"3. That as the depression of bottom-temperature in any part of the general oceanic basin would be proportional to the freedom of communication between its deeper portion and that of one or other of the polar areas, the bottom-temperature of the South Atlantic would probably range downwards to 32°, while that of the North Atlantic would not be below 35°, except where it first receives the Arctic flow, or comes under the influence of the Antarctic underflow, which would very probably extend itself to the north of the equator.

"4. That as the Arctic and Antarctic underflows must meet at or near the equator, whilst the surface-stratum is there continually being draughted off thence towards either pole, there would be a continual ascent of glacial water under the line, showing itself by a nearer approach of cold water to the surface in the *inter*-tropical than in the *extra*-tropical zone."

It was further pointed out by Lenz, and more recently (in ignorance of his doctrine) by Carpenter, that additional evidence of such ascent is furnished by the low salinity of the surface-water of the equatorial belt corresponding with that of polar water. For, as was originally observed by Humboldt, then by Lenz himself, and subsequently by many other voyagers, the specific gravity of the surface-water of the Atlantic gradually increases as either tropic is approached from the polar side of its own hemisphere, reaches its maximum a little nearer the equator, and then rapidly diminishes, coming down under the equator to the standard of polar water. Thus a mean of eight observations taken in the "Challenger" expedition between Bermuda (32° N.) and St Thomas (18½° N.) gave 1027·2 as the sp. gr. of *surface-water*, whilst a mean of seventeen observations between the Cape Verd Islands (16½° N.) and Bahia (13° S.) gave a sp. gr. of only 1026·3. Now, since between St Thomas and Bermuda the eight "Challenger" observations of *bottom* (polar) water gave a mean sp. gr. of 1026·3, whilst between Cape Verd and Bahia the mean sp. gr. of the bottom-water was even slightly lower (the results being

[1] That the bottom-temperature beneath the equator was lower than any that was met with in the South Atlantic, is attributable to the circumstance that, in consequence of unfavourable weather, the temperature-soundings were taken at intervals too wide to detect the deep channel through which the *coldest* Antarctic water doubtless flowed towards the equator.

in all cases expressed according to a common standard of temperature), such a close conformity subsists between the salinity of the equatorial water of the surface and that of the polar waters of the bottom, as can scarcely be accounted for in any other way than by the continual and tolerably rapid ascent of the latter.

Another indication of this ascent is given by the moderation of the surface-temperature of oceanic water, even under the equator. If there were no ascent of colder water from beneath, there seems no reason why the constant powerful insolation to which equatorial water is subjected should not raise the temperature of its surface to the highest possible elevation. The limit to that elevation, which is obviously set by the cooling influence of evaporation, is probably that which is met with in the Red Sea, where the monthly average for August rises to 86½° and for September to 88°, whilst the maxima rise much higher, temperatures of 100°, 106°, 100°, and 96° having been noted on four consecutive days. Moreover, along the Guinea Coast, and especially in the Bight of Biafra, the surface-temperature is stated to range as high as 90°. But in these cases there is no reduction of surface-temperature by the upward movement of polar water; for this is altogether excluded from the Red Sea by the shallowness of the Strait of Babelmandeb, whilst the depth of the bottom along the Guinea Coast is too small to allow of its being overflowed by the glacial stratum. Now, over the deeper parts of the equatorial Atlantic the surface-temperature usually ranges between 75° and 80°; and this is its ordinary range in the Mediterranean during the months of August and September. That the temperature of an equatorial ocean should be thus kept down to that of a sea of which the greater part lies between the parallels of 40° and 35°, can scarcely be accounted for in any other way than by the continual uprising of polar waters from beneath.

The same principle, once admitted, fully accounts for that amelioration of the cold of north-western Europe, which (as already shown) cannot be fairly attributed to the Florida Current or true Gulf Stream. For it is obvious that a continual efflux of the lower stratum from the polar areas towards the equatorial must involve a continual indraught of the upper stratum towards the polar areas; and this indraught will be much more marked in the Northern than in the Southern Atlantic, on account of the progressive narrowing of the former, whilst the latter progressively widens out. Of such a slow northerly set of a stratum of water, extending downwards to a depth of at least 600 fathoms, we have evidence in a comparison of the temperature-soundings taken in the "Porcupine" expedi-

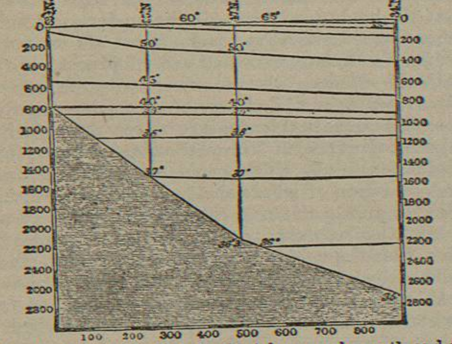

FIG. 5.—Section of North Atlantic, taken nearly north and south.

tions of 1869 and 1870, between the coast of Portugal (34° N.) and the Faroe Islands (59½° N.), from which the section fig. 5, has been worked out. For it is there seen that, although the surface-temperature is reduced by the thinning-out of the superficial stratum, there is but a slight change in the position of the bathymetrical isotherms of 45° and 40°; so that there is an obvious continuity of a stratum of many hundred fathoms' thickness between these two points, notwithstanding their separation by 25½° of latitude. The contrast between the position of the isotherm of 40° at 800 fathoms' depth off the Faroes, and its position at less than 300 fathoms' depth under the equator, is most remarkable. We have seen that the isocheimal in the latter area would not be below 75°, and yet we find water colder than 40° lying at within 300 fathoms of the surface; whilst, on the other hand, the normal isocheimal at 59½° N. would certainly be below 40° (probably no more than 35°), and yet we find water above 43° extending downwards to 600 fathoms, and water above 40° to 800 fathoms. Thus the vertical oceanic circulation carries a vast mass of water which is *below* the normal off the coast of Portugal, into a region where it is *above* the normal, with very little loss of heat by the way, except in its surface-film; and a little consideration will show that such a movement must be much more effectual as a *heater* than a corresponding movement of a thin stratum of much warmer water. For the latter, when it passes beneath an atmosphere much colder than itself, will soon be brought down to a like standard, not having warmer water from below to take its place when it has been cooled down; whilst in the former, each surface-layer, when cooled below the temperature of the warmer stratum beneath, will sink and be replaced by it. Now since the true Gulf Stream, when we last know it, has been so thinned out that it could not long retain any excess of temperature, it seems inconceivable that it should exert any decided effect on the temperature of the Faroes and the coast of Norway, unless (as supposed by Dr Petermann and Professor Wyville Thomson) its thickness undergoes an increase from less than 100 fathoms to 600. But since the course of Dr Petermann's isotherms shows that the northward flow extends across the whole breadth of the Atlantic between Newfoundland and the British Isles—a distance of about 2000 miles—we are required to believe that a rivulet (for such it is by comparison) of 60 miles' breadth and 100 fathoms' depth (see section, fig. 5), of which the greater part turns southwards round the Azores, and of which the remainder is flowing due east when we last recognise it, is able to impart a northerly movement to a stratum of 2000 miles in breadth, and at least 600 fathoms' depth. On the other hand, the eastward set of this stratum, considered as a northward *indraught* into the polar area, is readily accounted for by the excess of easterly momentum which it derives from the earth's rotation, this being only half as rapid in lat. 60° as it is under the equator; and since there is a still more rapid reduction in the rate of this rotation in yet higher latitudes, the continually increasing excess of easterly momentum will give to the northward flow a progressively stronger eastward set.

On the other hand, the deficiency of easterly momentum in the cold underflow coming from the pole towards the equator will tend to produce a lagging-behind, or *westward* set of that underflow; and this has been shown by the "Challenger" temperature-soundings to be the case,—the cold deep strata of the Western Atlantic surging upwards along the slope of the North American coast-line, as is shown in fig. 6, where we see not only the bathymetrical isotherms of 60°, 55°, and 50°, but the yet deeper isotherms of 45° and 40°, successively rising to the surface as we approach the land; while at a depth of only 83 fathoms, a temperature of 35° was encountered, which, at no great distance to the south, would only be found at a depth of 2000 fathoms. That the cold water should thus run up-hill is quite conformable to what we see in other cases, in which a heavier under-stratum has a definite set towards a slope; and whilst the existence of such a westerly set is, *ex hypothesi*, a necessary consequence of the southerly movement of the Arctic underflow, no other explanation of it has been suggested. We now see that the cold Labrador Current overlies a band of water as cold as itself; and the southward extension of this cold band, far beyond that of any definite current-movement, and its entrance into the Gulf of Mexico, through the Florida Channel, at the side of and beneath the outflowing Gulf Stream, are thus accounted for.

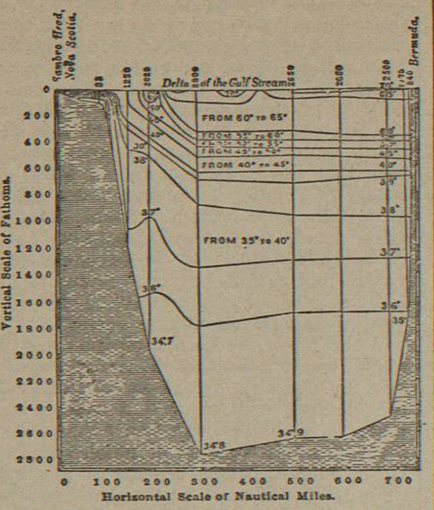

FIG. 6.—Section from Bermuda to Halifax.

The remarkable accordance of so many facts or actual observation, in the Atlantic area, with the probabilities deducible from a theory whose soundness can scarcely be disputed, seems now to justify the admission of the general (vertical) oceanic circulation sustained by opposition of temperature as an accepted doctrine of terrestrial physics.

Distribution of Organic Life.—All that will be attempted under this head will be to indicate the general conditions that seem, from recent researches, to have the greatest influence on the distribution of plants and animals through this great oceanic basin.

The distribution of marine plants seems mainly determined by light, temperature, and depth,—a further influence being exerted by the character of the shores. The diminution of light in its passage through sea-water is so rapid, that the quantity which penetrates to a depth of 250 or 300 fathoms may be regarded as almost infinitesimal; and in conformity with this we find a very rapid diminution of Algal life below the depth of 100 fathoms. The upper stratum is occupied for the most part by the larger and coarser forms of the *Fucaceæ*, or olive-green sea-weeds, whilst the more delicate *Ceramiaceæ*, or red sea-weeds, frequent deeper waters; and, as it appears from experiments made in aquaria that the latter do not flourish in full light, but grow well in shadow, it may be concluded that their preference for a moderate depth is rather for reduced light and stillness than for depth *per se*. At a depth of 150 fathoms very few ordinary sea-weeds maintain their ground; and below this we seldom find any Algæ, save the Corallines and Nullipores consolidated by calcareous deposit. The distribution of particular types over different parts of the Atlantic area appears to be mainly regulated by temperature; and this would seem to be remarkably the case with the floating *Diatomaceæ*, which, though they form green bands in the surface-water of polar seas, have not been encountered in like abundance in the Atlantic, and do not contribute largely, by the subsidence of their siliceous *loricæ*, to the composition of its bottom-deposit. Although it is the habit of the larger Algæ to grow from a base of attachment (their roots serving no other purpose however, than that of anchorage), the enormous mass of Gulf-weed found in the Sargasso Sea seems quite independent of any such attachment. It was at one time supposed that this originally grew on the Bahama and Florida shores, and was torn thence by the powerful current of the Gulf Stream; but it seems certain that if such was its original source, the "Gulf-weed" now lives and propagates whilst freely floating on the ocean-surface, having become adapted by various modifications to its present mode of existence.

The distribution of the animals that habitually live in that upper stratum of the ocean whose degree of warmth varies with the latitude, seems mainly determined by temperature. Thus the "right whale" of Arctic seas, and its representative in the Antarctic, seems never to enter the inter-tropical area, generally keeping away from even the temperate seas, whilst, on the other hand, the sperm-whale ranges through the parts of the ocean where the "right whales" are never seen.

The distribution of fishes seems generally to follow the same rule; as does also that of floating mollusks. Thus the little *Clio* (a Pteropod mollusk), which is a principal article of the food of the "right whales" in polar seas, is rarely met with in the Atlantic, where, however, other pteropods, as *Hyalœa*, present themselves in abundance. On the other hand, the warmer parts of its area swarm with Salpa-chains, which are not frequent in higher latitudes; and the few representatives of the Nautiloid Cephalopods, that were so abundant in Cretaceous seas, are now restricted to tropical or sub-tropical areas. And the distribution of the mollusks, echinoderms, and corals, which habitually live on the bottom, seems to be determined, within certain limits at least, by temperature rather than by depth.

The bathymetrical range to which animal life of any higher type than the Rhizopodal might extend, was until recently quite unknown; but the researches initiated by Prof. Wyville Thomson and Dr Carpenter in 1868, and since prosecuted by the "Challenger" expedition, have fully established the existence of a varied and abundant fauna in ocean-depths ranging downwards to 2000 fathoms. And these researches have further established that the distribution of this fauna is mainly determined by the temperature of the sea-bed; so that whilst in the channel between the north of Scotland and the Faroes there were found at the same depths, and within a few miles of each other, two faunæ almost entirely distinct—one a boreal and the other a warmer-temperate—on sea-beds having respectively the temperatures of 30° and 43°, various types to which a low temperature is congenial are traceable continuously along the whole abyssal sea-bed that intervenes between those northern and southern polar areas within which they present themselves at or near the surface. And hence it becomes clear that, since glacial types are even now being embedded in the strata which are in process of formation beneath the equator, no inferences as to terrestrial climate can be drawn from the character of marine deposits.

One very remarkable feature which presents itself over a large proportion of the Atlantic basin is the abundance of the minute *Globigerinæ* and other Foraminifera, the accumulation of whose shells, and of their disintegrated remains, is giving rise to a calcareous deposit of unknown thickness, that corresponds in all essential particulars to Chalk. This deposit, in some parts of the North Atlantic, is replaced by an Arctic drift of fine sand, whilst in other parts there is a mixture of arenaceous and of calcareous components, such as is found in certain beds of the Cretaceous formation. Now on the surface of this deposit there have been found so many living types, especially belonging to the groups of Echinoderms, Corals, Siliceous Sponges, and Foraminifera, which closely correspond with types hitherto regarded as characteristic of the Cretaceous epoch, that the question naturally suggests itself whether

the existing are not the lineal descendants of the fossil types,—the differences they present being not greater than may be fairly attributed to the prolonged action of differences of temperature, food, pressure, &c. And when these facts are taken in connection with those previously stated as to the probable remoteness of the period when (if ever) the present sea-bed of the Atlantic was dry land, the doctrine first put forth by Prof. Wyville Thomson, that there has been a continuous formation of Globigerina-mud on the bottom of the Atlantic from the Cretaceous epoch to the present time—or, in other words, that the formation of chalk on the sea-bed of the Atlantic did not cease with the elevation of the European area, but has been going on through the whole Tertiary period,—must be admitted as (to say the least) a not improbable hypothesis. That some considerable change took place at the conclusion of the Cretaceous epoch, by which the temperature of the upper stratum was lowered, so as to be no longer compatible with the existence of the fishes and chambered cephalopods characteristic of the Cretaceous fauna, may be fairly assumed from their disappearance; but this would not so much affect the deeper part of the basin, in which those lower types that seem more capable of adapting themselves to changes in external conditions would continue to hold their ground. That the like conditions had prevailed also through long previous geological periods, may be surmised from the persistence, over various parts of the Atlantic sea-bed, of the *Apiocrinite* type, which carries us back to the Oolitic formation, and of the *Pentacrinus* type, which has come down with very little alteration from the Liassic; whilst many existing *Terebratulidæ* do not differ more from Oolitic types than the latter differ among each other. Going back still further, we find in the persistence of certain Foraminiferal types from the Carboniferous limestone to the present time, and in the character of its deep-sea beds, a strong indication that they originated in a Foraminiferal deposit, representing in all essential particulars that which is now going on; while the persistence of the *Lingula* from the early Silurian strata to the present time suggests the question whether certain oceanic areas may not have remained in the condition of deep sea throughout the whole subsequent succession of geological changes.

BIBLIOGRAPHY.—In addition to the ordinary sources of information, the following publications may be specially referred to for recent information in regard to the physical geography of the Atlantic:—"Reports of the Deep-Sea Explorations carried on in H.M. Steam-vessels 'Lightning,' 'Porcupine,' and 'Shearwater,'" in *Proceedings of the Royal Society* for 1868, 1869, 1870, and 1872; "On the Gibraltar Current, the Gulf Stream, and the General Oceanic Circulation," in the *Journal of the Royal Geographical Society* for 1871; and "Further Inquiries on Oceanic Circulation" (containing a summary of the "Challenger" Temperature Survey of the Atlantic), in the same journal for 1874; *Currents and Surface-Temperature of the North and South Atlantic*, published by the Meteorological Committee; and *The Depths of the Sea*, by Prof. Wyville Thomson. (W.B.C.)

ATLANTIS, ATALANTIS, or ATLANTICA, an island mentioned by Plato and other classical writers, concerning the real existence of which many disputes have been raised. In the *Timæus*, Critias relates how his grandfather Critias had been told by Solon some remarkable events in early Athenian history which he had learned from the Egyptian priests at Sais, whose records went much further back than the native accounts. "The most famous of all the Athenian exploits," Solon had been told, "was the overthrow of the island Atlantis. This was a continent lying over against the pillars of Hercules, in extent greater than Libya and Asia put together, and was the passage to other islands and to another continent, of which the Mediterranean Sea was only the harbour; and within the pillars the empire of Atlantis reached to Egypt and Tyrrhenia. This mighty power was arrayed against Egypt and Hellas and all the countries bordering on the Mediterranean. Then did your city bravely, and won renown over the whole earth. For at the peril of her own existence, and when the other Hellenes had deserted her, she repelled the invader, and of her own accord gave liberty to all the nations within the pillars. A little while afterwards there was a great earthquake, and your warrior race all sank into the earth; and the great island of Atlantis also disappeared in the sea. This is the explanation of the shallows which are found in that part of the Atlantic ocean."—(Jowett's *Introduction to the Timæus*.) Such is the main substance of the principal account of the island furnished by the ancients,—an account which, if not entirely fictitious, belongs to the most nebulous region of history. The story may embody some popular legend, and the legend may have rested on certain historical circumstances; but what these were it is (as the numerous theories advanced on the subject may be held as proving) impossible now to determine.

ATLAS (Ἄτλας), in *Greek Mythology*, called sometimes a son of Japetus and the nymph Asia, or of Uranus and Gaia, and at other times traced to a different parentage, but always known as the being who supported on his shoulders the pillars on which the sky rested. He knew the depths of the sea (*Odyssey*, vii. 245), and in the first instance seems to have been a marine creation. The pillars which he supported were thought to rest in the sea, immediately beyond the most western horizon. But by the time of Herodotus (iv. 184), a mountain is suggested as best suited to hold up the heavens, and the name of Atlas is transferred to a hill in the N.W. of Africa. Then the name is traced to a king of that district, rich in flocks and herds, and owning the garden of the Hesperides. Finally, Atlas was explained as the name of a primitive astronomer. He was the father of the Pleiades and Hyades. Perseus encountered him when he searched for Medusa. Heracles took the burden of the sky from his shoulders, but cleverly contrived to replace it. Atlas bearing up the heavens is mentioned as being represented on early works of art, *e.g.*, on the chest of Cypselus (Pausan., v. 18, 1), and on the throne of Apollo at Amyclæ (Pausan., iii. 18, 7); and this subject occurs on several existing works of art.

ATLAS, a mountain-chain of Northern Africa, between the great desert of the Sahara and the Mediterranean. The range has been but partially explored, and geographers differ as to its extent, some considering it to reach from Cape Ghir on the Atlantic to Cape Bon, the north-east point of Tunis, while others include under the name the whole mountain system between Cape Nun and the greater Syrtis. In this latter sense it forms the mountain-land of the countries of Marocco, Algeria, Tunis, and Tripoli. It is composed of ranges and groups of mountains, enclosing well-watered and fertile valleys and plains, and having a general direction from W. to E. The highest peaks are supposed to attain an elevation of nearly 15,000 feet; and although none of them reach the height of perpetual snow, some of their loftiest summits are covered with snow during the greater part of the year. Mount Miltsin, 27 miles S.E. of the city of Marocco, was ascertained by Captain Washington to be 11,400 feet high. The greatest heights are in Marocco, from which point they appear to diminish in