chromatic light, and that light of the very colour composing the various layers, each layer being, as I have shown, so much brighter than the outer ones that its light predominates over them. Is it too much to suggest to those who may be anxious to attempt to elucidate this subject, that probably if they would consider all the conditions of the problem presented by that great screen, the moon, allowing each of these layers by turn to throw its light earthwards, the inequalities of the edge of the *globular* moon allowing here light to pass from a richer region, here stopping light from even the dimmer ones, they would be able to explain the rays, their colours, variations, apparent twistings, and change of side? I do not hesitate to ask this question, because it is a difficult one to answer, since the whole question is one of enormous difficulty. But difficult though it be, I trust I have shown you that we are on the right track, and that in spite of our bad weather, the observations made by the English and American Government Eclipse Expedition of 1870 have largely increased our knowledge.

With increase of knowledge generally comes a necessity for changing the nomenclature belonging to a time when it was imperfect. The researches to which I have drawn your attention form no exception to this rule. A few years ago our science was satisfied with the terms prominences, sierra, and corona, to represent the phenomena I have brought before you, the nature of both being absolutely unknown, as is indicated by the fact that the term *sierra* was employed, and aptly so, when it was imagined the prominences might be solar mountains! We now know many of the constituent materials of these strange things; we know that we are dealing with the exterior portion of the solar atmosphere, and a large knowledge of solar meteorology is already acquired, which shows us the whole mechanism of these prominences. But we also know that part of the corona is not at the sun at all. Hence the terms *leucosphere* and *halo* have been suggested to designate in the one case the regions where the general radiation, owing to a reduced pressure and temperature, is no longer subordinate to the selective radiation, and in the other, that part of the corona which is non-solar. Neither of these terms is apt, nor is either necessary. All purposes will be served if the term corona be retained as a name for the exterior region, including the rays, rifts, and the like, about which doubt still exists, though it is now *proved* that some part is *non-solar*, while for the undoubted solar portion the term Chromosphere—the bright-line region—as it was defined in this theatre now two years ago, exactly expresses its characteristic features, and differentiates it from the photosphere and the associated portion of the solar atmosphere.

Here my discourse would end, if it were not incumbent on me to state how grateful I feel to Her Majesty's Government for giving us the opportunity of going to the eclipse; to place on record the pleasure we all felt in being so closely associated in our work with the distinguished American astronomers who from first to last aided us greatly; and to express our great gratitude to all sorts of new friends whom we found wherever we went, and who welcomed us as if they had known us from our childhood.

J. NORMAN LOCKYER

ON THE DISTRIBUTION OF TEMPERATURE IN THE NORTH ATLANTIC *

AT the request of the Council of the Scottish Meteorological Society, I beg to bring before you a sketch of the more recent results of investigations into the causes of the abnormal climate of the surface of a great portion of the North Atlantic Ocean, and of the lands which form its north-eastern borders; and especially the results of the deep-sea exploring expeditions of the last three years, in which I have taken a part, so far as they bear upon this point.

In a recent valuable report on the Gulf Stream in the "Geographische Mittheilungen," of last year, Dr. Petermann severely and, I think, too justly, reflected upon us students of ocean temperatures for giving ourselves up to wild and gratuitous speculation. I wish, if possible, on the present occasion, to avoid all risk of such impeachment, by limiting our inquiry rigidly for the few minutes I have at my disposal to the present condition of our knowledge of facts, and to such deductions from these as may be fairly considered proved.

* Address delivered to the Meteorological Society of Scotland at the General Meeting of the Society, July 5.

Let us then first inquire for a moment what the phenomena are which we are called upon to correlate and to explain. There is no dispute about these facts, and a glance at the chart will at once recall them to your recollection. In the first place, the lines of equal mean annual temperature, instead of showing any tendency to coincide with the parallels of latitude, run up into the North Atlantic and into the North Sea, in the form of a series of long loops. This diversion of the isothermal lines from their normal direction is admittedly caused by surface ocean-currents conveying the warm tropical water towards the polar regions, whence there is a constant counter-flow of cold water beneath to supply its place. This phenomenon is not confined to the North Atlantic. A corresponding series of loops, though not so well defined, passes southwards along the east coast of South America, and a very marked series occupies the north-eastern angle of the Pacific, off the Aleutian Islands and the coast of California. The temperature of the land is not affected directly by the temperature of the sea in its immediate neighbourhood, but by the temperature of the prevailing wind, which is determined by that of the sea. Setting aside the still more important point of the equalisation of summer and winter temperature, the mean annual temperature of Bergen, lat. 60° 24′ N., subject to the ameliorating influence of the south-west wind blowing over the temperate water of the North Atlantic, is 6·7° C. while that of Tobolsk, lat. 58° 13′, is −2·4° C.

But the temperature of the North Atlantic is not only raised greatly above that of places on the same parallel of latitude having a continental climate by this interchange of tropical and polar water, but it is greatly higher than that of places apparently similarly circumstanced as to a general interchange of water in the Southern Hemisphere. Thus, the mean annual temperature of the Faroe Islands, lat. 62° 2′ N. is 7·1° C. nearly equal to that of the Falkland Islands, lat. 52° S., which is 8·2° C., and the temperature of Dublin, lat. 53° 21′ N., is 9·6° C., while that of Port Famine, lat. 53° 8′ S., is 5·3° C. Again the high temperature of the North Atlantic is not equally distributed, but is very marked in its special determination to the north-east coasts. Thus, the mean annual temperature of Halifax, lat. 44° 39′, is 6·2° C., while that of Dublin, lat. 53° 21′ is 9·6 C., and the temperature of Boston (Mass.) lat. 42° 21′ is exactly the same as that of Dublin.

We thus arrive at the well-known general result, that the temperature of the sea bathing the north-east shores of the North Atlantic is greatly raised above its normal point by currents involving an interchange of tropical and polar water; and that the lands bordering on the North Atlantic participate in this amelioration of climate by the heat imparted by the water to their prevailing winds.

We shall now examine this distribution of ocean temperature a little more minutely. During the last many years a prodigious amount of data have been accumulating with reference to the detailed distribution of heat on the surface of the North Atlantic basin, and last year M. Petermann, of Gotha, published in his "Geographische Mittheilungen" a series of invaluable temperature charts embodying the results of the reduction of upwards of 100,000 observations derived mainly from the following sources:—

1st. From the wind and current charts of Lieut. Maury, embodying about 30,000 distinct temperature observations.

2nd. From 50,000 observations made by Dutch sea captains and published by the Government of the Netherlands.

3rd. From the journal of the Cunard steamers between Liverpool and New York, and of the steamers of the Montreal Company between Glasgow and Belleisle.

4th. From the data collected by our excellent secretary, Mr. Buchan, with regard to the temperature of the coast of Scotland.

5th. From the publications of the Norwegian Institute on sea temperatures between Norway, Scotland, and Iceland.

6th. From the data furnished by the Danish Rear-admiral Irminger on sea temperatures between Denmark and the Danish settlements in Greenland.

7th. From the observations made by Lord Dufferin on board his yacht *Foam* between Scotland, Iceland, Spitzbergen, and Norway.

And finally from the recent observations collected by the English, German, Swedish, and Russian expeditions to the Arctic Regions and towards the North Pole.

Dr. Petermann has devoted the special attention of a great part of his life to this question, and the accuracy of his results in every detail is beyond the shadow of a doubt. Every curve of equal temperature, whether for the summer, for the winter, or for the

whole year, instantly declares itself as one of a system of curves which are referred to the Strait of Florida as the source of heat, and the warm water may be traced (and this is not begging the question, for the temperature is got by dipping the thermometer in the water), in a continuous stream, indicated where its movement can no longer be observed by its form, fanning out from the neighbourhnod of the Strait across the Atlantic, skirting the coasts of France, Britain, and Scandinavia, rounding the North Cape, and passing the White Sea and the Sea of Kari, bathing the western shores of Novaja Semla and Spitzbergen, and finally coursing round the coast of Siberia, a trace of it still remaining to try to find its way through the narrow and shallow Behring's Strait into the North Pacific. Now it seems to me that if we had these observations alone, which are merely detailed and careful corroborations of many previous ones, and could depend upon them, without even having any clue to their *rationale*, we should be forced to admit that whatever might be the amount and distribution of heat derived from a general oceanic circulation, whether produced by the prevailing winds of the region, by convection, by unequal barometric pressure, by tropical heat, or by arctic cold, there is besides this some other source of heat at the point referred to by these curves sufficiently powerful to mask all the rest, and, broadly speaking, to produce of itself all the perceptible deviations of the isotherms from their normal course.

But we have no difficulty in accounting for this source of heat. As is well-known, about the equator, the north-east and south-east trade winds reduced to meridional directions by the eastward frictional impulse of the earth's rotation, drive before them a magnificent surface current of hot water, the equatorial current, 4,000 miles long and 450 miles broad, at an average rate of thirty miles a-day. This current splits upon Cape St. Roque, and one portion trends southwards to deflect the isotherms of 21° 15·5°, 10°, and 4·5° C. into loops, thus carrying a scrap of comfort towards the Falklands and Cape Horn. While the remainder, "having made the circuit of the Gulf of Mexico, issues through the Straits of Florida, clinging in shore round Cape Florida, whence it issues as the Gulf Stream, in a majestic current upwards of 30 miles broad, 2,200 feet deep, with an average velocity of 4 miles an hour, and a temperature of 86° Fahr." (Herschel.)

I need scarcely follow the course of the Gulf Stream in detail, it is generally so well known. After leaving the Strait of Florida, it strikes in a north-easterly direction conformable generally to the easterly impulse given by its excess of diurnal rotation, towards the coast of Northern Europe. About 42° N. a large portion of it, still maintaining the high surface temperature of 24° C., turns eastward and southward, and, eddying round the Sargasso Sea, fuses with the northern edge of the equatorial current, and rejoins the main circulation. The main body, however, moves northwards. Mr. Croll, in a very suggestive paper in the *Philosophical Magazine* on Ocean Currents, estimates the Gulf Stream as equal to a stream of water fifty miles broad and 1,000 feet deep, flowing at a rate of four miles an hour, with a mean temperature of 18° C. I see no reason whatever to believe this calculation to be excessive, and it gives a graphic idea of the forces at work.

The North Atlantic and the Arctic Seas form together a basin closed to the northward, for there is practically no passage for a body of water through Behring's Strait. Into the corner of this basin, as if it were a bath, with a north-easterly direction given to it, as if the supply pipe of the bath were turned so as to give the hot water a definite impulse, this enormous flood is poured day and night, winter and summer; almost appalling in its volume and the continuity of its warmth, and its blueness, and brilliant transparency *in sæcula sæculorum!*

The hot water pours, not entirely from the Strait of Florida, but partly from the Strait and partly in a more diffused current outside the islands, with a decided, though slight, north-easterly impulse on account of its great initial velocity. The North Atlantic is with the Arctic Sea a *cul-de-sac*. When this basin is full—and not till then—overcoming its northern impulse, the water tends southwards in the southern eddy, so that there is a certain tendency for the hot water to accumulate in the northern basin. It is to this tendency, produced by the absence of a free outlet to the Arctic Sea, that I would be inclined to attribute the special excess of the warmth of the north-eastern shores of the North Atlantic.

When ascertaining with the utmost care and with the most trustworthy instruments, by serial soundings, the temperature of the area surveyed by the *Porcupine* in 1869, we found at a depth of 2,435 fathoms in the Bay of Biscay, that down to 50 fathoms the temperature of the sea was greatly affected by direct solar radiation; from 100 to 900 fathoms the temperature gradually fell from 10° C. to 4° C., and from 900 fathoms to 2,435 the fall of temperature was almost imperceptibly gradual from 4° to 2°·5 C.

The comparatively high temperature from 100 fathoms to 900 fathoms I am certainly inclined to attribute to the northern accumulation of the water of the Gulf Stream. The radiant heat derived directly from the sun must of course be regarded as a constant quantity superadded to the original temperature of the water derived from other sources. Taking this into account, the surface temperatures in what we were in the habit of calling the "warm area" coincided precisely with Petermann's curves indicating the northward path of the Gulf Stream.

It is scarcely necessary to say that for every unit of water which enters the basin of the North Atlantic, an equivalent must return. From its low velocity, the Arctic return current or indraught will doubtless tend slightly to a westerly direction, and the higher specific gravity of the cold water may probably even more powerfully lead it into the deepest channels; or possibly the two causes may combine, and in the course of ages the currents may tend to hollow out deep south-westerly grooves. At all events, the main Arctic return currents are very visible on the chart taking that direction, indicated by marked deflections of the isothermal lines. The most marked is the Labrador current, which passes down inside the Gulf Stream along the coasts of Carolina and New Jersey, meeting it in the strange, abrupt "cold wall," dipping under it as it issues from the Gulf, coming to the surface again on the other side, and a portion of it actually passing under the Gulf Stream as a cold counter-current into the deeper part of the Gulf of Mexico.

Fifty or sixty miles out from the west coast of Scotland, I believe the Gulf Stream forms another through a very mitigated "cold wall." In 1868 Dr. Carpenter and I investigated a very remarkable cold indraught into the channel between Shetland and Faroe. In a lecture on deep-sea climates, which was published in NATURE, in July last, I stated my belief that the current was entirely banked up in the Faroe channel by the Gulf Stream passing its gorge.

Since that time I have been led to suspect that a part of the Arctic water oozes down the Scottish coast much mixed, and sufficiently shallow to be affected throughout by solar radiation. About sixty or seventy miles from shore the isothermal lines have a slight but uniform deflection. Within that line types characteristic of the Scandinavian fauna are numerous, and in the course of many years' use of the towing net, I have never met with any of the Gulf Stream pteropods, or of the lovely Polycystinæ and Acanthometrinæ, which absolutely swarm beyond that limit. The differences in mean temperature between the east and west coasts of Scotland, amounting to between 1° and 2° Fahr., is also somewhat less than might have been expected.

There is another point which is worthy of consideration. It is often said that about the latitude 45° N. the Gulf Stream thins out and disappears. The course of a warm current is traced farther on the maps, even to the coast of Norway and the North Cape, but this north-easterly extension is called the Gulf Stream drift, and is supposed to be a surface flow caused by the prevailing S.W. anti-trades. There seem to me to be several arguments against this view. The surface of the sea, at all events between 40° and 55° N., has a mean temperature higher than that of the air, and that could scarcely be the case unless there were a constant supply, independent of the wind, of water from a warmer source; and any question is, to my mind, entirely set at rest by our establishment of the mass of warm water moving to the north-eastward, whose curves of excess of temperature, so far as they have as yet been ascertained, correspond entirely with those of the Gulf Stream.

I cannot at present enter at any length into the very fundamental question which has lately given rise to so much discussion, whether the Gulf Stream is actually the agent in conveying heat to the North Atlantic and ameliorating the climate of its north-eastern shores, or whether these results are not rather produced by a "general oceanic circulation."

As, however, I am frequently quoted by my friend and colleague in much scientific work, Dr. Carpenter, as holding an opinion different from his, and as my present remarks place my views beyond doubt, it may be well to give a reason for my want of faith. Dr. Carpenter's view, if I understand him rightly, is that there is a great general convective circulation in the ocean, on the principle of a hot-water heating apparatus, and that the Gulf

Stream is only a modified and partial cause of this general circulation. Now in the first place, as I have already said, it seems to me that the distribution of warm water in the North Atlantic has been traced to its source, and all the general phenomena of the Gulf Stream, its origin, its course, its extension, and its depth at certain points, have been *proved* by the careful observations of many years, which I see no reason whatever to doubt. The constant impulse of the trade wind drives a broad current of equatorial water against the American coast. A great part of this current is observed to turn northwards through the Strait and round the islands, and to pour an eternal flood of hot water in a certain direction, under known laws, into the closed basin of the North Atlantic, and as a natural consequence the temperature is very considerably raised.

We are undoubtedly most deeply indebted to Dr. Carpenter for the forcible way in which he has brought forward the arguments on the other side; and, after carefully considering everything, I am thoroughly willing, with Sir John Herschel, to cede that "there is no refusing to admit that an oceanic circulation of some sort must arise from mere heat, cold, and evaporation as *veræ causæ*;" and that "henceforward the question of ocean currents will have to be studied under a twofold point of view;" but my strong conviction is that if the sagacious philosopher whose loss we now deplore, had been spared so to study it, he would have only been strengthened in his verdict of 1861 as to the Gulf Stream, that there can be no "possible ground for doubting that it owes its origin entirely to the trade-winds." Dr. Carpenter attributes the general oceanic circulation, of which he regards the Gulf Stream as only a modified case, to tropical heat and evaporation, and arctic cold, possibly aided by differences of barometric pressures; or to convection pure and simple, as illustrated in his experiments before the Royal Institution and the Geographical Society. Now what we expect of Dr. Carpenter before we are called upon to accept to the full his magnificent generalisation, is a calculation and demonstration of the amount of the effect of the causes upon which he depends acting under the special circumstances. We must remember that heat is received by the ocean at the surface only, and that owing to cold indraughts all over the globe, so far as we know the temperature falls the deeper we go; that all our observations tend to show that the temperature of the sea is only influenced by direct solar radiation to any amount to the depth of fifty fathoms, so that all currents depending upon difference between equatorial and polar temperatures must be produced and propagated in a film of water about the depth of the height of St. Paul's and 6,000 miles long. The black line bounding that chart represents pretty nearly the depth of the ocean, and even where the whole of the water supposed to be involved in the movement, it would be difficult to imagine a perceptible current to be produced in so thin and wide a sheet by such feeble cause. It would be impossible to indicate by the finest hair line the tenuity of the film which is actually affected by the direct rays of the sun. How differences in barometric pressure can produce constant currents I do not see. Rapid fluctuations in pressure in places within a short distance of one another will doubtless produce readjustment by a wave motion; but constant differences of pressure will simply produce constant differences of level and no currents. Varying pressures at very distant points cannot possibly produce a constant current. I freely admit that I am quite incapable of undertaking the investigations which might lead to the estimation of the relative or actual importance of these causes of currents. I have several times put the question to specialists in such physical inquiries, but they have always said that it was a matter of the greatest difficulty, but that their impression was that the effects would be infinitesimal.

I fear then that, in opposition to the views of my distinguished colleague, I must repeat that I have seen as yet no reason to modify the opinion which I have consistently held, that the remarkable conditions of climate on the coasts of Northern Europe are due in a broad sense solely to the Gulf Stream; that is to say, that while it would be madness to deny that in a great body of water at different temperatures, under varying barometric pressures, and subject to the surface drift of variable winds, currents of all kinds variable and more or less permanent must be set up, yet the influence of the great current which we call the Gulf Stream, the reflux in fact of the great equatorial current, is so paramount as to reduce all other causes to utter insignificance.

WYVILLE THOMSON

PHYSIOLOGY

The Mouse's Ear as an Organ of Sensation*

DR. SCHOBL, of Prague, who lately published a remarkable paper on the wing of the bat, has made similar researches on the ear of the white mouse, with very interesting and surprising results (in "Schultze's Archiv," vol. vii. p. 260.) The first thing which struck Dr. Schöbl was the immense and "fabulous" richness of the ear in nerves. Even the bat's wing is but poorly supplied in comparison. The outer ear was carefully divided horizontally through the middle of the cartilage into two laminæ, each of which was found to be equally supplied with nerves, and was then examined by removing the epidermis and the Malpighian layer of the skin. In each of these laminæ were discovered three distinct strata of nerves, which are thus described: The first or lowest stratum lies immediately upon the cartilage; it consists of the largest trunks which enter the ear, 5 to 7 in number, and their next branches, varying from ·074 mm. to ·028 mm. in diameter. The mode of division of these trunks is mainly dichotomous, but they are connected by several different kinds of anastomoses; as, for instance, by decussation of two adjacent trunks, by transverse or oblique connecting branches, by plexuses, by loops, &c.; while branches also perforate the cartilage, and bring the nerves of the two halves of the ear into connection. The general distribution agrees with that of the larger blood-vessels. The second stratum lies immediately over the first, and is connected with it by a multitude of small branches, and by a fine marginal plexus at the outer border of the ear, which may be regarded as common to both. The diameter of its nerves is from ·0185 mm. to ·0098 mm.; it lies immediately under the capillary vascular network of the skin, and has a generally reticulated arrangement, forming plexuses of very various shapes. The third stratum of nerves, developed out of the very finest twigs of the second, lies at the level of the capillary network; it is composed of branches ·0098 mm. to ·0037 mm. in thickness, which (like those of the other strata) contain medullated nerve-fibres. It forms an extremely delicate network, like the second layer, but its finest branches may terminate in two ways. Some of them, each containing two to four medullated fibres, run directly to the hair follicles, and form a nervous ring round the shaft of the hair, terminating below the follicle in a nervous knot. Others, again, consisting of not more than two medullated fibres, bend towards the surface where the fibres lose their double outline, and form, immediately under the Malpighian layer of the skin, a fine terminal network of pale fibres, which is the fourth and ultimate stratum of nervous structures. The terminal "knots" or corpuscles, and the nervous rings, are inseparably connected with hairs and their sebaceous glands, so that through the whole of the external ear no hair can be found without this nervous apparatus, and *vice versâ*. The connection of the hair follicle with the nerve termination is as follows:—Under the bulk of the hair in each follicle is a more or less conical prolongation, composed of distinct nucleated cells, which run vertically downwards, and is enclosed within the limiting membrane of the follicle. The nervous twig which, as has been said, runs to each hair follicle from the third stratum of nerves, makes several turns round the shaft of the hair, and from the ring thus formed two to four nerve-fibres run vertically downwards to the prolongation of the follicle, immediately beneath which they form a knot. These knots are almost always spherical, sometimes oval, and about ·015 mm. in diameter. In each square millimetre of the marginal part of the ear there are about 90 such bodies, and near the base perhaps 20, so that the average number may be 30. Calculating from the average size of the ear of a common mouse, it is then found that there are on the average 3,000 nerve terminations on each of its surfaces, making 6,000 on each ear, or 12,000 altogether. The function of this elaborate arrangement would seem to be, like that in the wing of the bat, to supply by means of a very refined sense of touch, the want of vision to these subterranean animals.

* From the "Quarterly Journal of Microscopical Science" for July.

SCIENTIFIC SERIALS

PART ii. of the *Zeitschrift für Ethnologie* contains No. 6 of Dr. Hartmann's "Studies of the History of Domestic Animals," on the yak or grunting ox (*Bos grunniens*) living wild at immense altitudes in the mountains of Central Asia north of the Himalaya, and largely used in a domesticated state in Mongolia and