

through considerable changes of temperature, and renewing the surface for repeated polishings, are also described. The mode of construction of a bed of hones for bringing the curve of the speculum back to the sphere, if it should happen to have gone beyond the parabola in the polishing, without reverting to the emery-grinder, is also explained; and a word or two is added respecting the treatment of the speculum when finished.

II. "Note on the Vertical Distribution of Temperature in the Ocean." By J. Y. BUCHANAN, Chemist on board H.M.S. 'Challenger.' Communicated by Prof. A. W. WILLIAMSON, For. Sec. R.S. Received November 11, 1874.

From newspapers and other reports which have been received by late mails, it appears that the distribution of temperature in the ocean is occupying the attention of a certain portion of the scientific public, and even giving rise to considerable discussion. The observations made on board this ship, and more especially in the Atlantic, have furnished the greater part of the material on which the various speculations have been founded. It appears to me that one point suggested by these observations has not received sufficient attention from those who have written and spoken on the subject: I mean, the effect of the changing seasons on sea-water. Consider the state of the water at and near the surface of the ocean, somewhere not in the tropics. To be more precise, let us suppose that we have taken up our position in the middle of the North Atlantic, somewhere about the 30th parallel. This part of the ocean is not vexed with currents, and affords the best possible field for the observation of the phenomenon in question. The whole ocean enclosed by the 20th and 40th parallels of north latitude and the meridians of 30° and 60° west longitude forms one oceanic lake, not affected by the perturbing influence of currents or of land, and where, therefore, the true effect of differences of atmospheric temperature on the waters of the ocean may be most advantageously studied. Let us assume the winter temperature of the surface-water to be 60° F. and the summer temperature to be 70° F. If we start from midwinter, we find that, as summer approaches, the surface-water must get gradually warmer, and that the temperature of the layers below the surface must decrease at a very rapid rate, until the stratum of winter temperature, or 60° F., is reached; in the language of the isothermal charts, the isothermal line for degrees between 70° F. (if we suppose that we have arrived at midsummer) and 60° F. open out or increase their distance from each other as the depth increases. Let us now consider the conditions after the summer heat has begun to waver. During the whole period of heating, the water, from its increasing temperature, has been always becoming lighter, so that heat communication by convection with the water below has been entirely suspended during the whole period. The heating of

the surface-water has, however, had another effect, besides increasing its volume; it has, by evaporation, rendered it denser than it was before, at the same temperature. Keeping in view this double effect of the summer heat upon the surface-water, let us consider the effect of the winter cold upon it. The superficial water having assumed the atmospheric temperature of, say, 60° F., will sink through the warmer water below it, until it reaches the stratum of water having the same temperature as itself. Arrived here, however, although it has the same temperature as the surrounding water, the two are no longer in equilibrium, for the water, which has come from the surface, has a greater density than that below at the same temperature. It will therefore not be arrested at the stratum of the same temperature, as would have been the case with fresh water; but it will continue to sink, carrying of course its higher temperature with it, and distributing it among the lower layers of colder water. At the end of the winter, therefore, and just before the summer heating recommences, we shall have at the surface a more or less thick stratum of water having a nearly uniform temperature of 60° F., and below this the temperature decreasing at a considerable but less rapid rate than at the termination of the summer heating. If we distinguish between *surface-water*, the temperature of which rises with the atmospheric temperature (following thus, in direction at least, the variation of the seasons), and *subsurface-water*, or the stratum immediately below it, we have for the latter the, at first sight, paradoxical effect of summer cooling and winter heating. The effect of this agency is to diffuse the same heat to a greater depth in the ocean, the greater the yearly range of atmospheric temperature at the surface. This effect is well shown in the chart of isothermals, on a vertical section, between Madeira and a position in lat. $3^{\circ} 8' N.$, long. $14^{\circ} 49' W.$ The isothermal line for 45° F. rises from a depth of 740 fathoms at Madeira to 240 fathoms at the above-mentioned position*. In equatorial regions there is hardly any variation in the surface-temperature of the sea; consequently we find cold water very close to the surface all along the line. On referring to the temperature section between the position lat. $3^{\circ} 8' N.$, long. $14^{\circ} 49' W.$, and St. Paul's rocks, it will be seen that, with a surface-temperature of from 75° F. to 79° F., water at 55° F. is reached at distances of less than 100 fathoms from the surface. Midway between the Azores and Bermuda, with a surface-temperature of 70° F., it is only at a depth of 400 fathoms that we reach water of 55° F.

The above theory of vertical diffusion of temperature in the ocean, owing to convection brought about by the yearly range of temperature at the surface, presupposes that (at least in regions where the range is considerable, and where the great vertical diffusion of heat in question is

* There will, I think, be no violence in assuming an acquaintance with these charts, at least among the scientific public, as they have lately formed the subject of lectures by Dr. Carpenter, and will, no doubt, have been published before this reaches England.

observed) the slightly concentrated water descending from the surface as the winter approaches does not meet water of greater density at the same temperature than its own. Unfortunately the determination of the specific gravity of water below the surface is much less simple than that of the temperature; for although we have an instrument which gives, within any required degree of accuracy, the density of the water at any depth in exactly the same way as the thermometer gives its temperature, the results of the observations are composed of three factors, which depend on the temperature, the pressure, and the *salinity*. By sending down a thermometer along with it we might clear the result for temperature; by noting the depth we might clear for pressure; but the result so cleared would not represent the salinity of the water at the depth in question, but the average excess of salinity of the column of water above it, over or under the mean salinity assumed for sea-water in the calculation of the pressure exercised by a column of it. There remains, therefore, nothing for it but to fetch a sample of water from each depth, and determine its specific gravity on board. As this is an operation which takes up some time, the number of "serial specific-gravity" determinations is comparatively small.

The following are the results of two which were obtained on the voyage between Bermuda and the Azores. The results show the specific gravity at 60° F., that of water at 39°·2 F. being taken as unity.

I. was taken on the 18th June, 1873, in lat. 35° 7' N., long. 52° 32' W.

II. was taken on the 24th June, 1873, in lat. 38° 3' N., long. 39° 19' W.

For comparison I give one equatorial and one South-Atlantic "serial specific-gravity" determination.

III. was taken on the 21st August, 1873, in lat. 3° 8' N., long. 14° 49' W.

IV. was taken on the 3rd October, 1873, in lat. 26° 15' S., long. 32° 56' W.

Depth in fathoms.	Specific gravity at 60° F. Distilled water at 39°·2=1.			
	I.	II.	III.	IV.
0	1·02712	1·02684	1·02591	1·02703
50	..	..	1·02658	1·02682
100	..	..	1·02643	1·02649
150	1·02701	1·02677		
200	..	..	1·02620	1·02608
250	1·02683	1·02641		
300	..	..	1·02610	1·02573
400	..	..	1·02629	1·02554
500	1·02604	1·02608		

From the figures in the Table it will be seen that in that part of the ocean the specific gravity of the water in summer decreases from the surface downwards. As a rule it attains an inferior limit at a depth of from 400 to 500 fathoms, which it preserves to the bottom. In those latitudes, therefore, the stratum of intermixture extends down to 500 fathoms; and this may be said also to be the depth to which the sun's influence at the surface penetrates. The results in column III. show the curious phenomenon of the surface-water being specifically lighter than any water below it, and that under an equatorial sun. The position of this sounding was peculiar, inasmuch as it was within line of separation between the Guinea and the equatorial currents. All along the equatorial section the water at 50 and 100 fathoms was found to be specifically heavier than either at the surface or that at greater depths. All along the equator, however, a current runs with great velocity; and I have invariably observed that strong surface-currents introduce considerable irregularities into the specific gravity of the water near the surface. The effect of the greater specific gravity at 100 fathoms conspires, of course, within the small yearly range of temperature, in preventing vertical diffusion in the above described manner. Column IV. shows a return in the southern hemisphere to a state of things similar to that which obtains in the North Atlantic.

We have seen that the effect of climate in equatorial regions is to render the subsurface-water much colder than it is in temperate regions; let us consider what would be the effect of a polar climate on the sea-water. It must be observed that the effect of the atmospheric temperature on the sea is determined by the temperature assumed by the surface-water; now the lowest temperature which surface-water can attain is its freezing-point. As the temperature of the air when the 'Challenger' was beyond the 60th parallel was almost constantly below 32° F., freezing must go on to a very great extent in winter; and the effect of freezing such water is, in the end, similar to that of evaporating it; it is separated into lighter ice and denser mother-liquor, which sinks, leaving the ice on the surface. This ice I found to be a mixture; and on determining the melting-point of some in crystals, which had formed in a bucketful of sea-water, I found it began to melt at 29°·5 F., the water produced by it being almost fresh in comparison with sea-water. The lowest temperature of surface-water registered was 27° F.; this happened on two occasions, but was quite exceptional, the usual surface-temperature varying from 32° to 34° F. At this temperature a sensible quantity of ice would melt, giving very light surface-water. On two occasions the specific gravity of the surface-water was found between 1·02400 and 1·02410. The specific gravity increased rapidly up to a depth of 100 fathoms, when it remained pretty uniform to the bottom. Here, as at the equator, it is in winter that the subsurface-water perceives the effect of the change of season, the mother-liquor of the forming ice diffusing in its descent the temperature of its formation.

In the discussion of oceanic phenomena too much attention is usually paid to the great currents. When it is wished to study the phenomena due to temperature, or to any single cause, the effect of the winds, which is seen in its most intense form in the ocean-currents, should be eliminated as far as possible; which in this case can only be done by selecting comparatively motionless seas, like the one which I have mentioned in the North Atlantic*. When the effect of atmospheric climate has been studied on the ocean at large, it would then be proper to apply the experience gained to the consideration of the more complicated phenomena of the currents.

I am at present engaged in a detailed consideration of the temperature and specific gravity results, principally in the direction above indicated, and hope shortly to be able to send it home for publication.

III. "Preliminary Note upon the Brain and Skull of *Amphioxus lanceolatus*." By T. H. HUXLEY, Sec. R.S. Received December 17, 1874.

The singular little fish *Amphioxus lanceolatus* has been universally regarded as an extremely anomalous member of the Vertebrate series, by reason of the supposed absence of renal organs and of any proper skull and brain. On these grounds, chiefly, Agassiz proposed to separate it from all other fishes, and Haeckel, going further, made a distinct division of the Vertebrata (*Aerania*) for its reception; while Semper†, in a lately published paper, separates it from the Vertebrata altogether.

In a recent communication to the Linnean Society, I have described what I believe to be the representative of the ducts of the Wolffian bodies, or "primordial kidneys" of the higher Vertebrata, in *Amphioxus*; and I propose, in this preliminary notice, to point out that although *Amphioxus* has no completely differentiated brain or skull, yet it possesses very well-marked and relatively large divisions of the cerebro-spinal nervous axis and of the spinal column, which answer to the encephalon and the cranium of the higher Vertebrata.

The oral aperture of *Amphioxus* is large, of a long oval shape, and

* It will be seen that the principle that the depth to which the effect of the sun's rays penetrates depends on the yearly range of temperature of the water at the surface, explains the presence of the large body of comparatively warm water in the North Atlantic, the existence of which has been usually ascribed to an assumed reflux or back water of the Gulf-stream. The warm water is due to no extraneous cause, but is the natural effect of the conditions of climate at the surface; and the effect of these conditions of climate are so apparent in the temperature of the water, just because it is free from the influence of oceanic currents and exposed to the effects of climate alone.

† "Die Stammverwandschaft der Wirbelthiere und Wirbellosen," Arbeiten aus dem zool.-zootom. Institut in Würzburg, Bd. ii. 1874, p. 42.