blindly enraptured with that theory, as he is pleased to state, I only reply that very clever men have held it, as he is perhaps aware; and certainly none of the modern theories, cumbrous vagaries of the brain, can compare with it. I have never said that the meteoric theory is the real explanation, but I doubt if we shall ever arrive at a more truthful representation of the solar phenomena.

Lastly, he culminates by saying I am "either innocently or wilfully ignorant of the palpably cyclonic appearance which spots frequently present." All I can say in answer to this is that, having observed sun-spots myself for many years, probably as often as the reviewer, I have *never* observed one single appearance of a cyclonic nature. As I possess Mr. Carrington's valuable work, I have again referred to it, and find it in agreement with the assertion in my book and my own observation. I must apologise for my lengthy letter.

A. M. DAVIES

2, Gloucester Terrace, Sandgate, July 4

On an Error in Regnault's Calculation of the Heat Converted into Work in the Steam Engine

IN Watts's "Dictionary of Chemistry" (vol. iii. p. 125), in the article on Heat by Prof. G. C. Foster, it appears to me that an important error has crept into the discussion of the above calculation.

The nature of the calculation is as follows:—A unit weight of saturated steam at the temperature of 152°C . contains 653 units of heat. Suppose we allow the steam to expand and to do work until the temperature falls to 503°C . the steam then contains 621 units or 32 units less than before, hence starting with water at 0°C ., we give it 653 units of heat, and of this 32 only are converted into work, giving us the fraction $\frac{621}{653}$ as the amount of heat converted into work; but the real work produced by an engine is more than twice this. This difference in theory and practice is accounted for by the fact that saturated steam, in expanding and doing work, is partly condensed, hence the body with which we have to deal at the lower temperature is not all steam, but partly condensed water, therefore, does not contain so much heat as was allowed it.

This explanation is so intelligible as to be at first sight sufficient to account for the whole difference; there is, however, another cause, quite as important, and which is this; every time steam passes from the boiler to the cylinder it does work before it is cut off, and allowed to expand; this work is not done at the expense of the steam that passes into the cylinder, but of the whole mass of steam in the cylinder and boiler, which expands and is thereby cooled. The mass of water and steam in the boiler is, however, so large compared to that which passes into the cylinder, that a thermometer could scarcely detect the cooling effect upon it, and before the next stroke this loss of temperature is made up by the fire. Though thus inappreciable, it is nevertheless very important, and in most engines would amount to one-third the work done; in fact all the work done by the steam before it is cut off and allowed to expand is entirely neglected in this calculation, and a source of error introduced.

To correct it there should be added to the heat in the steam at the initial temperature, as many units of heat as the work done before the steam is cut off, would, if converted into heat, raise the amount of water which passes at every stroke in the form of steam into the cylinder.

A. W. BICKERTON

Hartley Institution, Southampton, June 26

THE CAUSES OF THE COLOURS OF THE SEA *

PROF. TYNDALL, in his article in the *Fortnightly Review* for the 1st of March, attributes the greenness of the sea to the matter which it holds in solution. Perhaps the following may corroborate his theory. About the Andaman Islands, where the sea is of the deepest blue, there are most startling and sharply-defined changes of colour, from bright blue to green, where a bed of coral exists. This coral is white out of the water, what its colour when growing may be I know not, but the change I mention appears to corroborate the remarks in the article in question, which are appended below, about the green hues observed upon the plate, the screw blades, and

the white bellies of the porpoises. One looks down from a hill into a bay of the brightest blue; you see it broken up here and there like a child's puzzle map by irregular patches of as bright green, often crossing several acres as sharply defined as it is possible to imagine, and indicating the existence of coral beds or reefs just below.

Bellary, Madras Presidency

W. M'MASTER

[We give the passages referred to from Prof. Tyndall's lecture.—ED.]

"Let us clear our way by a few experiments towards an explanation of the dark hue of the deep ocean.* Colour, you know, resides in white light, appearing generally when any constituent of the white light is withdrawn. Here is a liquid which colours a beam sent through it purple, and this colour is immediately accounted for by the action of the solution on a spectrum. It cuts out the yellow and green, and allows red and blue to pass through. The blending of these two colours produces the purple. Does the liquid allow absolutely free passage to the red and blue? No. It enfeebles the whole spectrum, but attacks with special energy the yellow and green colours. By increasing the thickness of the stratum traversed by the beam, we cut off the whole of the spectrum. Through the deeper layer, which I now place in the path of the beam, no colour can pass. Here, again, is a blue liquid. Why is it blue? Its action on the spectrum answers the question. It first extinguishes the red; then as the thickness augments it attacks the orange, yellow, and green in succession; the blue alone finally remains, but everything might be extinguished by a sufficient depth of the liquid.

"And now we are prepared for a concentrated but tolerably complete statement of the action of sea water upon light, to which it owes its blackness. Here is our spectrum. This embraces three classes of rays—the thermal, the visual, and the chemical. These divisions overlap each other; the thermal rays are in part visual, the visual rays in part chemical, and *vice versa*. The vast body of thermal rays is here beyond the red and invisible. They are attacked with exceeding energy by water. They are absorbed close to the surface of the sea, and are the great agents in evaporation. At the same time the whole spectrum suffers enfeeblement; water attacks all its rays, but with different degrees of energy. Of the visual rays the red are attacked first, and first extinguished. While the red is extinguished, the remaining colours are enfeebled. As the solar beam plunges deeper into the sea, orange follows red, yellow follows orange, green follows yellow, and the various shades of blue, where the water is deep enough, follow green. Absolute extinction of the solar beam would be the consequence if the water were deep and uniform, and contained no suspended matter. Such water would be as black as ink. A reflected glimmer of ordinary light would reach us from its surface, as it would from the surface of actual ink; but no light, hence no colour, would reach us from the body of the water. In very clear and very deep sea water this condition is approximately fulfilled, and hence the extraordinary darkness of such water. The indigo, to which I have already referred, is, I believe, to be ascribed in part to the suspended matter, which is never absent, even in the purest natural water, and in part to the slight reflection of the light from the limiting surfaces of strata of different densities. A modicum of light is thus thrown back to the eye, before the depth necessary to absolute extinction has been attained. An effect precisely similar occurs under the moraines of the Swiss glaciers. The ice here is exceptionally compact, and owing to the absence of the internal scattering common in bubbled ice, the light plunges into the mass, is extinguished, and the perfectly clear ice presents an appearance of pitchy blackness.

"The green colour of the sea when it contains matter in a state of mechanical suspension has now to be accounted for; and here, again, let us fall back upon the sure basis of experiment. This white plate was once a complete dinner-plate, very thick and strong. It is, you see, surrounded securely by cord, and to it a lead weight is fastened. Forty or fifty yards of strong hempen line were attached to the plate. With it in his hand, my assistant, Thorogood, occupied a boat fastened as usual to the davits of

* A note written to me the 22nd of October, by my friend Canon Kingsley, contains the following reference to this point:—"I have never seen the Lake of Geneva, but I thought of the brilliant, dazzling dark blue of the mid Atlantic under the sunlight, and its black blue under-cloud, both so solid that one might leap off the sponson on to it without fear; this was to me the most wonderful thing which I saw on my voyage to and from the West Indies."—J. T.

* Communicated by Prof. Tyndall.