well explored localities, we probably have even now a very fair representation of the littoral Echini of the world. It would of course be rash to make any predictions as to the number of new forms that will doubtless be brought to light by the researches of Wyville Thomson—but these will probably be deep-sea forms. Did space allow we would gladly have dwelt longer on this most interesting portion of Agassiz's memoir.

The total number of genera adopted is 90, with 207 species. The atlas accompanying these parts contains 49 plates—the first seven are devoted to charts, representing the distribution of the Echini throughout the old and new worlds, and the remaining portion to figures of some of the new or little known species. Some of the plates are photographs—and very excellent ones – others are photo-printed by the albert type process, and while these have scarcely the brilliancy or evenness of detail as such engravings as those of Echini in the expedition to Egypt, yet when the enormous difference in cost is taken into account, these photo-printed plates must be a subject of congratulation to the working and not over-rich naturalist. Some others of the plates are lithographed from Agassiz's drawings, and these we would select as being the most useful in this atlas.

Next we would mention a very important paper by Prof. Lovén, published in "Öfversigt af Kongl. Vetenskaps-Akademiens Förhandlingar," 1871, No. 8. This paper was read on June 14, 1871, but was not, we think, published until the summer of 1872, and as a translation of it in full by Mr. Dallas has been published in the "Annals and Magazine of Natural History," vol. x., 4th series, October to December 1872, we will but very briefly allude to it here. Prof. Lovén describes some very small spheroidal button-like bodies furnished with a short stalk, which is normally attached to a small, slightly projecting tubercle, which he calls *Spheridia*; these occur apparently in all Echinoidea except *Cidaris*; they are fully described as they occur in the different families. Lovén next describes the order which prevails in the disposition of the ambulacral plates throughout the whole class, for which he even gives a formula.

Passing from the sea urchins to the Brittle stars, we have also, from the Proceedings of the Royal Academy of Stockholm, a paper by Ljungman describing the collection of Ophiuroids made by Dr. Goës in the West Indies, in the Josephine Expedition. Fifty-seven species are enumerated, of which fifteen are described as new. Many of these latter were dredged from very considerable depths. The author adds to his paper a conspectus of the genera of Ophiodermatidæ and a conspectus of the Atlantic species of the genera *Amphiura* and *Amphipholis*.

Lütken, in an important memoir published in the Proceedings of the Royal Academy of Copenhagen, Part 2, 1872, entitled "Ophiuridarum novarum vel minus cognitarum descriptiones nonnullæ," describes a number of new species from different parts of the world, as well as gives some details of little known species. To this memoir there is appended a chapter "On Spontaneous Division in the Star Fishes," at the conclusion of which the author sums up with the following general propositions:—(1), The most energetic manifestations of the faculty of regeneration in animals is the power of divisibility; (2), In certain forms of Radiates, in which the faculty of regeneration is very highly developed, spontaneous division takes place alone, as in Ophiuroids and Asteroids, or together with gemmation, as in Actinia; (3), Actual spontaneous division or "Schizogony," in the Actinia, Medusa, Asteroids, and Ophiuroids (which must not be confounded with the disguised forms of gemmation met with in Infusoria and certain Chetopods) may be regarded as a peculiar form of Agamic reproduction such as Blastogony, Sporogony, and Parthenogony.

Lastly we have to mention the appearance of a modest catalogue of Echinodermata of New Zealand, with diagnosis of the species, by Capt. F. W. Hutton, F.G.S., Assistant Geologist, Colonial Department. In it thirty-four species are described, eighteen of them being described as probably new to science.

E. PERCEVAL WRIGHT

ON THE SPECTROSCOPE AND ITS APPLICATIONS

X.

I HAVE not yet done with the spot-spectrum referred to in last article. Not only is there general absorption, but there are indications of increased selective absorption in the case of the line D, as I could also show if I were dealing with the iron lines, the magnesium lines, or the other well-known lines of the solar spectrum. Not only, then, have we a general absorption, increasing as the middle of the sunspot is approached, but this sodium line D is also thickened, so that we have, as a result of a single examination of a single sunspot, the fact that a sunspot is due to general absorption, *plus* special absorption in some particular lines.

Now, in what I said some time since on the radiation of hydrogen, I pointed out to you that the F line of hydrogen was different from the C line—in fact, I showed that it widened out towards the sun—and I also told you that Dr. Frankland and myself have asserted that that widening out is due to pressure, and we have been able artificially to widen out this F line of hydrogen by increasing the pressure. Now it struck us that possibly we might find some connection between that widening out of the F line of hydrogen and the widening out of the sodium line in the spot which I have just shown you. There is an experiment by which it is perfectly easy for us to reproduce this artificially, so that you see we can begin at the very outside of the sun by means of hydrogen, and see the widening of the hydrogen lines as the sun is approached; and then we can take the very sun itself to pieces, and, by examining the pieces, see that the sodium lines vary in thickness in different parts of the spot, as the hydrogen does outside the spot region altogether: in fact, the pressure is continually increasing down in the spot exactly in the same way as it increases in the hydrogen envelope towards the sun.

If we take a tube containing some metallic sodium sealed up in hydrogen, and pass a beam of light from the electric lamp through it, by decomposing this beam with our prisms we shall obtain an ordinary continuous spectrum without either bright or dark lines, but by heating the metallic sodium in the tube which is placed in front of the slit, we really fill that tube with the vapour of sodium; and as the heating will be slow, the sodium vapour will rise very gently from the metal at the bottom, so that we shall get layers of different densities of sodium vapour filling the tube. Immediately the sodium begins to rise in vapour, a black absorption line shows itself in our spectrum in precisely the same position as the yellow line of sodium, and you will find that the thickness of the sodium absorption line will vary with the density of the stratum of vapour through which the light passes. Thus from the upper part of the tube we obtain a fine delicate line, which gradually thickens as we approach the bottom; and thus we reproduce the appearance in the spectrum of the spot where the layers of sodium vapour are very dense, and the very fine delicate line of the sodium vapour when thrown up into the sun's chromosphere.

We must next speak of what happens in the case of the magnesium lines. A very obvious magnesium line is lettered *b* in the solar spectrum. It is a triple line, separated by different intervals. There is a very important fact connected with these lines, which appear when magnesium vapour is thrown up into the envelope which I have called the Chromosphere. By means of the new method of research, it is quite possible to see, as I explained to you on a former occasion, what passes, which the eye could not possibly see. For instance, it is quite possible, by means of the spectroscope, to detect the existence of magnesium vapour outside the sun, although you know that, except during eclipses, we are never able to see these vapours. What I wish to call your attention to in the present case is this. We have there the three magnesium lines, and two of them are much thicker than the remaining one: and these two lines travel very much higher into the outside region than does the third one. Now, you will see in a moment that that indicates to us a fact something like this,—that the spectrum of magnesium, such as is generally at work, which cuts out these very black absorption lines in the solar spectrum, while the sodium gives us the yellow line D, is really a thing which is competent to give us three lines. This vapour, I say, is a thing, generally speaking, competent to give us three lines in this position; but if it so happens that when the magnesium is thrown up to a particular height we simply get two lines, the third stopping short, I think you will see that there is some force in one's reasoning, when one suggests that possibly in those regions where we find the hydrogen F line thin instead of thick, as I have shown it to you, and where the magnesium lines become reduced to two instead of three, the spectrum of magnesium vapour, like the spectrum of hydrogen, becomes very much more simple by *the reduction of pressure*, and therefore, that we should be able artificially, as in the case of hydrogen, and as in the case of sodium, to reproduce this result. In fact, it is perfectly easy to reproduce it, for we find by reducing the pressure of magnesium vapour we really can reduce that triple line of magnesium to a double one; so that, you see, we have three distinct lines of research, all leading us to the fact that where Kirchhoff placed an immensely dense atmosphere around a liquid sun, we really have vapour of considerable tenuity, by no means so dense as he supposed.

There is another point of very great interest which I should bring before you.

Mr. Huggins, who has done so much in his researches on stars, told us some few years ago that the spectrum of that wonderful variable star τ Coronæ, which had been just discovered, indicated that, over and above the light which we got from the star generally, we get evidence of incandescent hydrogen in the spectrum, so that the spectrum was a thing such as had never been seen before; for we got, in addition to the ordinary evidence of absorption visible in the spectrum of a star, as in the spectrum of the sun, indications also of selective radiation. There are indications of bright lines superposed above the others. Now, let me tell you—and this is a very important part of the question—that by observing the various changes that take place in our central luminary, it is quite possible to see on the sun almost any day evidence of its being violently agitated; that there are certain regions of the sun which appear exactly as that variable star did—that is to say, in addition to the ordinary absorption lines visible in the solar spectrum, the spectrum of these regions indicates to us that the hydrogen, instead of being black, instead of reversing the spectrum, as you have seen it in these spectra that I have shown you, really is bright, or else the hydrogen lines cease to be visible altogether, as in α Orionis.

I have to give you, as the last application of spectrum analysis, the power which the prism gives us of investigating, so to speak, the meteorology of the sun, the velocity with which the different stars are moving through space, and the velocity with which the storms are travelling over the face of our central luminary. Many of you know, no doubt, that Mr. Huggins, in his observations of the spectrum of the star Sirius, saw that the hydrogen lines were much developed; and in a further examination, carried on by the method in which the spectrum of hydrogen and other vapours which he wished to examine were absolutely visible in the field of view at the same time as was the spectrum of the star, Mr. Huggins was astonished to find that the hydrogen lines no longer occupied their usual positions, but that they were all jerked, so to speak, a little to the side of the place which they occupied in the spectrum of the hydrogen which he rendered incandescent in his tubes. The F line of hydrogen which he observed in the spectrum of Sirius he found did not exactly occupy the same position in the spectrum as did the actual F line of hydrogen, the incandescent hydrogen with which he compared it (*Fig.* 53). Owing to a physical law, which I have not time to explain to you now, it is perfectly easy, by means of the prism, to determine the velocity with which the light-source is moving to or from us; and therefore, if this holds good for absorption, we could determine the velocity with which any absorbing medium is rushing to or receding from us. In the case of Sirius, for instance, Mr. Huggins determined that the velocity of the star in a direction from the eye, the measure of recession, was something like twenty miles a second. I am sorry I have not time to fully explain this very beautiful adaptation of the spectroscope, but I may say that the position of a line, bright or dark, in the spectrum depends upon its wave-length—that is to say, the length of the wave of light which produces that colour. Thus, the length of a wave of red light is about $\frac{1}{39000}$ of an inch, and that of a wave of violet light is about $\frac{1}{57500}$ of an inch. I think when I mention that, you will see at once the possibility of determining any alteration of velocity—for an alteration of wave velocity we have, or appear to have, whether we move towards an object, or whether an object moves towards us, just in the same way as in the case of sound, and in the case of a wave reaching the shore. Suppose yourself a swimmer carried on a wave; if you are going with the wave it seems long, but if you attempt to swim against it it seems short. So with all these waves, beating from all these orbs peopling the depths of space on to the earth. If by the motion of those bodies or by our own motion, the waves are crushed together, we get an alteration in the light, which the prism alone is able to determine. If the luminous object is approaching the eye rapidly, the vibrations causing light will, of course, fall on the eye more frequently in the same time than if the bodies were at rest—or, in other words, the waves will be shortened; then the position of the dark or bright lines, as the case may be, will be shifted in the direction of the most refrangible rays—that is to say, towards the violet; whilst if the bodies are separating, the shifting will take place in the direction of the red or least refrangible rays. In the case of Sirius, the star was receding from us, and we got longer waves, and the lines are nearer the red end of the spectrum to such an extent as to leave unaccounted for a motion of recession from our sun amounting to something between 18 and 22 miles per second. Other stars, such as Betelgeux, Rigel, Castor, Regulus, and many of the stars in Ursa Major, are found to be moving away from the sun. Some, however, move rapidly towards us. Arcturus approaches us with a velocity of 55 miles per second; Vega and α Cygni, Pollux and α Ursa Majoris, also approach the sun with a velocity varying from 40 to 60 miles per second. If now we take a spot-spectrum (Fig. 54), in which, instead of the sodium line D, we have the F line of hydrogen, this strange crookedness which you notice is really a crookedness due to the fact that in one place we have incandescent hydrogen rising up with tremendous velocity, and in another we have it rushing down cool with tremendous velocity; again, we have hydrogen in a different condition altogether. We know that in this case we have a variation of velocity, because we get distinct changes in one direction or the other, and we get changes in both directions. We can determine by the amount of crookedness of the hydrogen, whether bright or dark, how far it is driven from its normal condition, and then how fast per second the hydrogen is travelling. In one case the velocity was something like 38 miles a second; in other words, we had heated hydrogen coming up at the rate of something like 38 miles a second, and cool hydrogen rushing down at something like an equivalent rate. Now, we are not only enabled, by a practical application of the prism, to determine these up and down rushes on the sun, by which we are enabled to learn much of its physical constitution, but also the rate at which storms travel over the sun—what we should call winds. The way that has been done will be perfectly clear on an inspection of the engraving (Fig. 55). It may appear strange to you that we should be able to observe a cyclone on the sun, but I hope to be able to prove to you that this is really a cyclone. Here is a spectrum of the region of the sun near the limb, and here is the hydrogen line. It is clear, if what I have said is true, that the incandescent hydrogen is there receding from us because the line inclines to the red. It is evident also, that in this case, when we get the line widened out towards the violet, it is coming towards us; therefore we have the thing travelling in both directions. It is obvious to you, I think, that if the slit enabled us to take in the whole cyclone, we should get an indication of motion in two directions; we should have the line diverted both towards the violet part of the spectrum, in the case of the hydrogen rushing towards us, and towards the red in the case of the hydrogen rushing away from us in this circular storm, and the extreme velocity will be determined by the extreme limit to which the hydrogen line extends. In this case, the storm was moving with a velocity of something like 100 miles a second, which, I dare say, strikes you as something terrible; but if you compare the size of the sun with that of the earth, I think you will see it was nothing very wonderful after all.

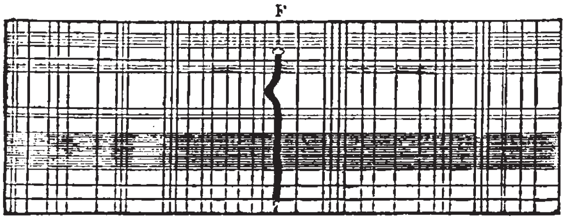

Fig. 54.—Deviation of the F line in a spot-spectrum.

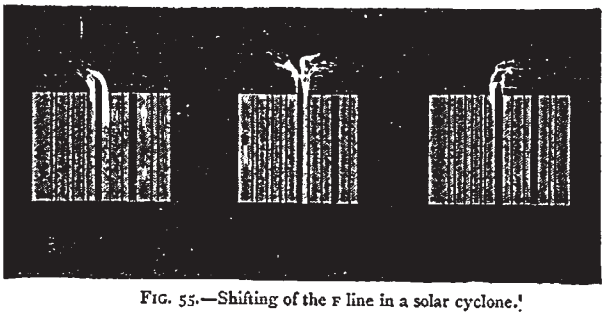

Fig. 55.—Shifting of the F line in a solar cyclone.

In further evidence of the truth of this, the last application of the spectroscope, I will show you two pictures of solar prominences 27,000 miles high, drawn at an interval of ten minutes. Here you see, first, the prominence as it appeared at a particular time on a particular day in March 1869 (Fig. 56). I wish to call your attention to the left-hand portion of the prominence, which you see is pretty straight. In ten minutes afterwards the whole thing changed, and, as you see by the next picture (Fig. 57), the nearly straight portion is quite gone. That will give you some idea of the indications which the spectroscope reveals to us of the enormous forces at work in the sun, merely as representing the stars, for everything we have to say about the sun, the prism tells us—and it was the first to tell us—we must assume to be said about the stars. I have little doubt that, as time rolls on, the spectroscope will become, in fact, almost the pocket companion of every one amongst us; and it is utterly impossible to foresee what depths of space will not in time be gauged and completely investigated by this new method of research.

Fig. 56.—Prominence observed March 14, 1869, 11h. 5m.

Fig. 57.—The same prominence, 11h. 15m.

J. Norman Lockyer