THE SUN'S PLACE IN NATURE.[1]

VII.

At the end of the last lecture, some evidence was brought forward which leads to the conclusion that in those stars in the spectrum of which bright lines are seen, we are dealing with bodies closelv associated with nebulæ. It was at once suggested that possibly by those new methods of inquiry to which I have already referred, we might be enabled to demonstrate the existence of the nebulæ, although we can never hope to see them by the unaided human eye. The idea occurred to me that long exposed photographs might give us stars surrounded by nebulæ. So I wrote to Dr. Roberts, who always kindly places himself at the disposal of any student, and asked him if he would be so good as to photograph that region of the heavens in which most of the bright-line stars have been observed. He at once acceded to my request, and took photographs, as desired, with his instrument, giving an exposure of three and a quarter hours. The result a little disappointed me, because he reported that there was no indication whatever of any nebulosity surrounding these stars. Possibly it was on this account that Dr. Huggins felt himself justified in objecting to the view which associated these stars with nebulous surroundings. But that is not the whole story. Some time afterwards, at the request of Mr. Espin, Dr. Max Wolf, who has an instrument which is even more competent to pick up faint nebulæ than the wonderful telescope employed by Dr. Roberts, also took photographs of this same region; and I need not tell you that, being anxious to carry the inquiry as far as he could, he made the exposure what we should consider almost impossibly long—so long, in fact, that one whole night was not sufficient. His first photograph of this region was exposed for thirteen hours on three nights; the next one was exposed for eleven hours. Now I will throw on the screen the result which was obtained by Dr. Wolf with the instrument which at the present moment is the most competent to give a verdict upon such inquiries as this. Here, in the first instance, we have a photograph of the region surrounding the brightest star in the constellation Cygnus, and you will observe that we have here and there indications of nebulous matter as well as of stars. That is rendered evident by the fact that in certain other regions we get a perfectly flat background, whilst in this the background itself is luminous.

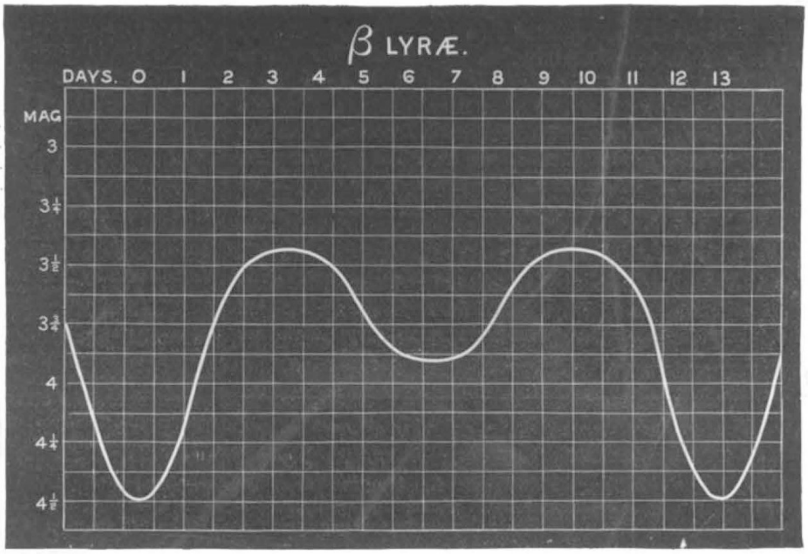

FIG. 29.—Light-curve of Algol.

Now we come to the region in which these bright-line stars have been recorded for several years, and you see it is almost impossible to point out in this photograph a large area in which there is not a most obvious indication of this luminous nebulosity. Patches here and there seem to indicate that the great differentiation between this part of the sky and others, lies not in the wealth of stars, but in the wealth of the luminosity in which they are situated.

It was obvious therefore, from this experiment, that I was perfectly justified in stating that these bright line stars were associated with nebulæ, since we find the statement made on theoretical grounds now backed up by these exquisite data, which indicate that most certainly there is a complete association of nebulous matter with these stars.

I do not want to part with that diagram until I have pointed out to you the enormous advantage students of science now have in possessing such magnificent photographs as these. Not only is the wealth of science rendered obvious, but the wealth of nature. Here, you see, is what modern science makes of a little patch of the sky on which the naked eye sees nothing at all.

The conclusion is therefore this: there seems to be no doubt that bright-line stars are directly connected with nebulous matter. I am glad to add that this is also the conclusion of the American astronomers who have inquired into the subject.

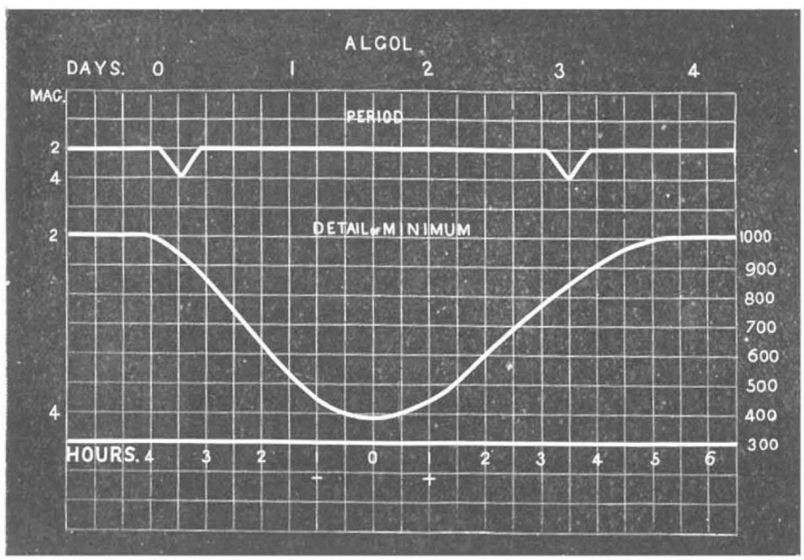

FIG. 30.—Light-curve of β Lyræ.

The next point in the meteoritic hypothesis—that some of the heavenly bodies are increasing, others diminishing their temperature—is one which I have brought out in that strong form, but I do not propose to say very much about it to-night. You may remember what has been said with reference to the hypothesis of Kant and Laplace, and especially Laplace's view that in the nebulæ we have to deal. as also in the stars

[1] Revised from shorthand notes of a course of Lectures to Working Men at the Museum of Practical Geology during November and December, 1894. (Continued from page 158.)

associated with them, with gases at a very high temperature. Now, in the hypothesis which I have ventured to put before the world of science, I differ in this particular both from Laplace and also from Vogel, who has most industriously attempted to establish a classification of the celestial bodies. I pointed out that in accordance with thermo-dynamical principles, the temperature must increase with condensation, and of course it will depend, therefore, upon the condensation of the gas, whether we have to deal with high or low temperatures in the bright-line stars and the nebulæ. I wish to take this occasion to state that Prof. Darwin has recently shown, as the result of a most profound inquiry, that swarms of meteorites in space will behave exactly like a gas; therefore, what can be said of the thermo-dynamics of a gas may be said also of the thermo-dynamics of a meteoritic swarm.

Now we come to a very interesting part of the inquiry, because it lands us among phenomena which so far have been considered to be exceptional. I refer to the phenomena of the so-called variable stars. You will see in a moment that if there is any truth in what has been brought before you, the light of stars as they pass from the nebulous to the more luminous stage must change during the progress of that evolution. But remember, that change will not be visible to one generation of men, probably not to a thousand generations of men. It is a change which will require millions, and possibly billions, of years for its accomplishment; and therefore we must not associate the word "variable" with any change which depends wholly upon the evolution of these various stellar conditions. But in addition to that, we can see almost in hours, certainly in days, frequently in months, sometimes in years, changes in the light of certain stars; and it is these short period changes which mark out and define for us the phenomena of variable stars.

Take a star like the sun. It is pretty obvious to you that any change in the sun, such as we see it now, would require a very considerable time for its accomplishment, so as to be obviously visible to us all; but if you take two bodies like the sun, you might imagine a condition of things in which one body would come exactly in the line between the earth and the other body, and would so eclipse the further one. There you have at once the possibility of an eclipse due to the passage of one body in front of another, and therefore of a variability which depends upon eclipses. So much for two bodies like the sun; but we know that in various parts of celestial space some of the stars have run through their life of light, and exist as dark bodies. Obviously we should get the same eclipse phenomena when dealing with one star like the sun and another dark body, provided always that the dark body came and eclipsed the light one. That is a very well known and accepted cause of variability, and one of the most obvious cases of this kind we have in the star Algol. There we have two bodies, a bright and a dark one, and a diagram will give us what is called the light-curve, the curve indicating the variability brought out by such a condition as that I refer to. When we come to examine the light-curve of a body like this, we find that the luminosity of the star remains constant for some considerable time in relation to the period of variability, and then it suddenly decreases. It almost at once—in an hour or two—goes up again, continues then for another period, and suddenly diminishes again (Fig. 29).

Spectroscopically we can inquire into the question as to whether there is or is not any physical change connected with this. Obviously, if it is merely an eclipse, there should be no physical change, and therefore no change in the spectrum. Here, by the kindness of Prof. Pickering, I can show you two photographs of the spectrum of this star, when it is most luminous, and when it is least luminous, and the spectra of these two conditions are, you see, quite similar. The broad lines are alike; in other dark lines also there is no change. Therefore, spectroscopically, we are justified in saying that the theory that variability is caused by eclipses is a perfectly justifiable one.

But supposing we consider no longer two bodies like the sun, or even one sun and another body more condensed and colder than the sun, but two not completely condensed meteoritic swarms; various probabilities never before considered will lie open to our inquiry.

We may take the remarkable case of variability presented to us by one of the brighter stars in the constellation of the Lyre, β Lyræ. The spectrum of that star has been very carefully studied, and if you will look at the details now on this diagram, you will see a series of the most marvellous spectral changes showing at once that we are not in the presence of phenomena at all similar to those presented in the last star examined. Fig. 30 shows the light curve of β Lyræ, which when at its lowest brightness is a $4\frac{1}{2}$ magnitude star, and at its greatest brightness is a $3\frac{1}{2}$ magnitude star, the changes going through one magnitude. In this scale you see that the changes are run through in a period of thirteen days. From the period of the greatest obscuration of

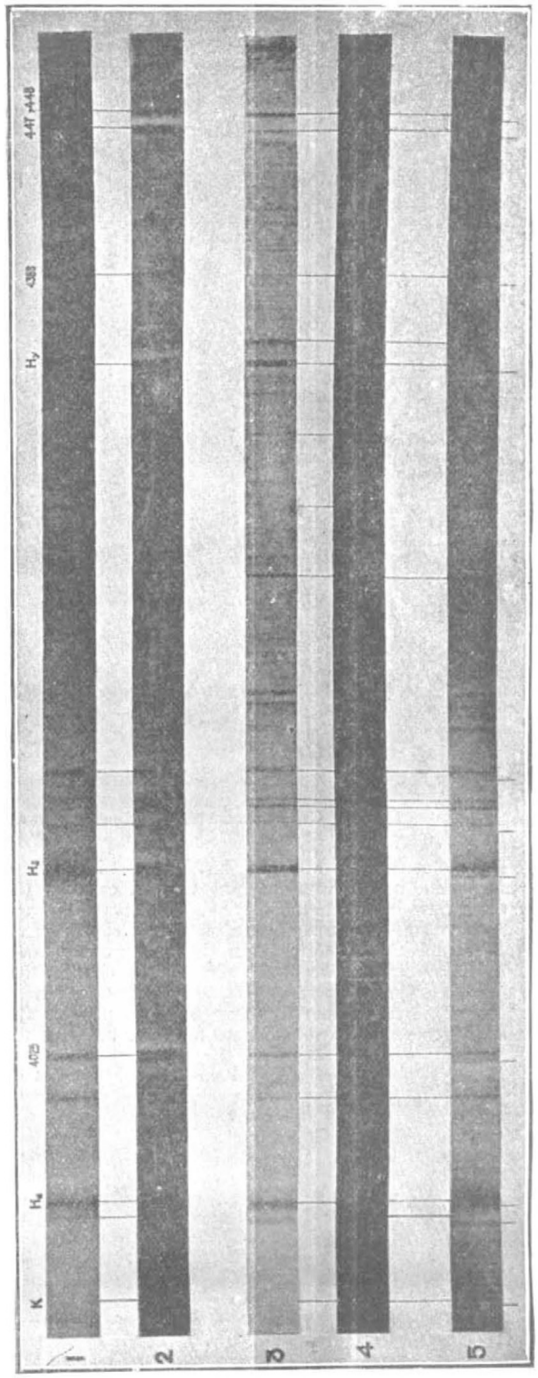

FIG. 31.—Spectra of β Lyræ (2, 3, 5) compared with Bellatrix (1) and Rigel (4).

light, in nearly three days we get to the highest luminosity, then at the sixth day we get to what is called a secondary minimum, *i.e.* the light has gone down a bit, but not so much as it had done at the beginning of this light cycle; then it goes up again, so that on the tenth day we get a maximum of light such as we had on the third day; after that it goes down, so that on the thirteenth day, or thereabouts, we get to another minimum, and then the cycle begins again. Associated with these changes we have considerable changes in the spectrum. We have been fortunate enough to get a spectrum of this marvellous star for every day included in this period of change, although of course the photographs have not been taken in a period of thirteen days or in ten periods of thirteen days; but by knowing this period, we have been able to place the different photographs together so as to see exactly what happens. We get bright lines and dark lines, and bright lines changing their places; but the main point we have been able to make out so far, is that we are dealing with two stars very much like a number of stars that we see in the constellation of Orion. In Fig. 31 we have photographs of the spectra of two of the stars in the constellation of Orion, and associated with them, three photographs of the spectrum of β Lyræ; from the change in the position and coincidence of these lines we are able to make out that the variability of β Lyræ is produced by the revolution round each other of two stars like certain stars in the constellation of Orion, and that part of the light is probably cut off by some kind of eclipse; also that a certain amount of light which writes out for us these bright lines is produced at a certain part of the light curve. The photographs show that about the time of principal minimum, the dark line spectrum of β Lyræ (2) is very similar to that of Bellatrix (1), while about the time of secondary minimum the spectrum of β Lyræ (3) becomes more like that of Rigel (4), the differences at these times being mainly in the intensities of the lines. The photograph of the spectrum about the time of second maximum (5) shows that there are two spectra displaced with respect to each other. The spectrum displaced to the less refrangible side is shown to resemble that of Rigel, while that displaced to the more refrangible side closely resembles Bellatrix. I do not profess for one moment to imagine that all the conditions of variability in that star have been thoroughly explained, but we know enough to say that it is something quite different from the condition which obtains in such a star as Algol. Also, from the fact that we are dealing with stars like those in Orion, we know that we have to do with more or less condensed bodies, bodies not so condensed as the sun is, but still condensed enough to be called stars without fear of making any great mistake.

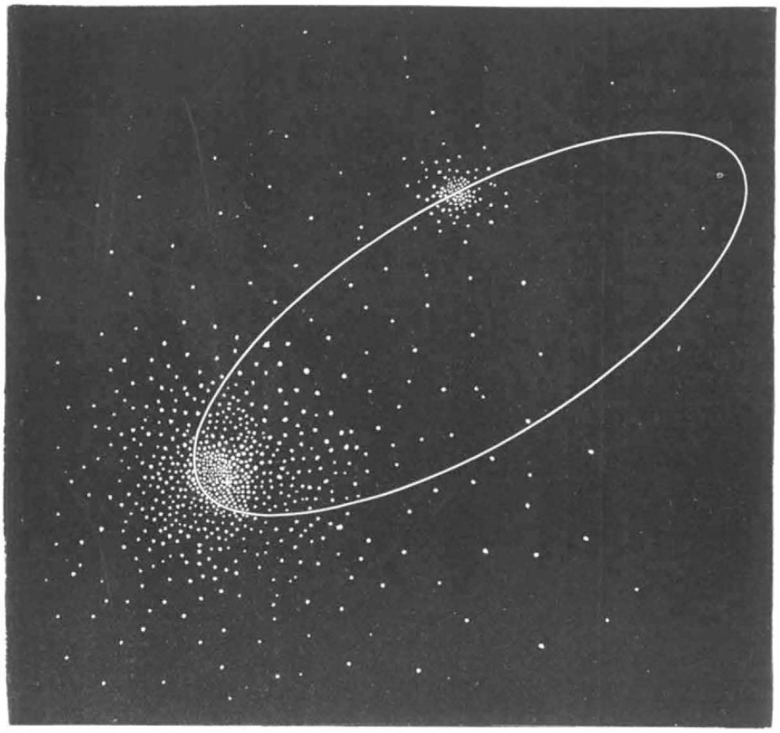

FIG. 32.—Cause of variability in uncondensed swarms.

But in this class of condensed bodies we have only really touched one part of the subject, because if that condition holds for bodies which are condensed, it will not have held good for them and for others when they were less condensed than they are now. How, then, can we explain the variability of uncondensed swarms? Fig. 32 shows this.

Here we are dealing with two swarms so sparse that they may be almost considered as nebulæ; and we will suppose that round the denser and larger one a smaller one is moving in the orbit represented on the diagram. You will see that for a considerable part of the orbit the smaller swarm can perform its movement along the orbit without any chance of running up against any of the constituents of the greater swarm; but when that little swarm has got to go round what is called the periastron, *i.e.* the region nearest the centre of gravity, which is occupied by the densest portion of the primary swarm, it is impossible that it can get through without a considerable number of collisions between its own constituents and the constituents of the majority (I am not talking politics). What will happen? You will get light and heat produced, forming a variable star, which will give the greatest amount of light when those two swarms are closest together, and the least amount of light when they are furthest apart.

You can imagine also, that, instead of dealing with a highly elliptic orbit such as imagined in Fig. 32, we may have one in which the main mass is very much nearer the centre of the orbit of the smallest swarm, that orbit being much more circular than in the former case. There you will get a chance of a greater number of collisions in one part of the orbit than in another; but there will not be anything like so great a difference between the number of collisions at the two ends of the major axis of the orbit as there would have been in the first case supposed. In that way, therefore, we can explain the variability of these uncondensed swarms, and not only the variability, but a very considerable difference in the time of the cycle occupied by the changes and in the intensity of the greatest

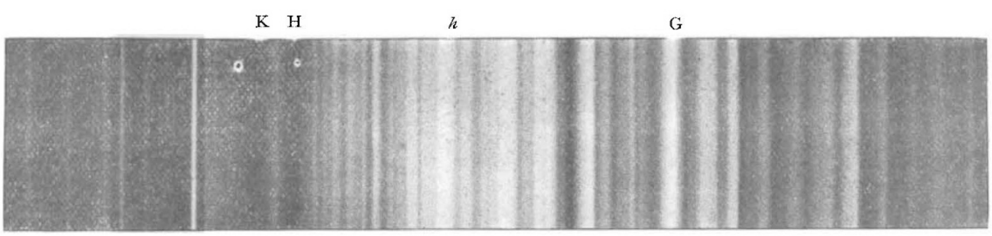

FIG 33.—Spectrum of o Ceti (Pickering).

light produced. So much is that to be anticipated, that I predicted in 1888 that when we got any indications of stars the spectra of which showed that they were really sparse swarms, such as that depicted on the diagram, at the maximum of their luminosity we should get bright lines, and in all probability bright lines of hydrogen, visible in their spectra. It so happened that shortly after this prediction was made—and when a man of science predicts he does it chiefly not for the sake of influencing others, but to point out where the path of truth really lies—I, in common with many other students in this country, received from Prof. Pickering a photograph of the spectrum of that most wonderful of all variable stars, commonly called Mira, or the marvellous star (Fig. 33). We knew before we received the photograph what its spectrum would in all probability be, but the interesting point was to see whether or not there were any bright lines in it. You see there is an obvious bright line at that part of the spectrum which represents the wave-length of one of the hydrogen lines; there is another where the wave-length of another hydrogen line is represented, and there is another very obvious bright line in another part of the spectrum. So that this photograph entirely justifies the prediction that had been made with regard to this class of stars. And so well is that now recognised that, quite independent of the meteoritic hypothesis, one of the most characteristic features of this class of stars is acknowledged to be the appearance at the top of the light curve—at the moment of the greatest giving out of light—the bright lines of hydrogen and possibly of other substances in the spectrum. Forty old variables of this class show bright lines, and twenty new variables have been detected by the appearance of bright lines, *i.e.* bright lines being seen in them suggested that they were variable, and a further inquiry into the old records showed that undoubtedly their light had varied.

J. NORMAN LOCKYER.

(*To be continued.*)

THE INSTITUTION OF NAVAL ARCHITECTS.

THE summer meeting of the Institution of Naval Architects has been held this year in Paris, and has proved one of the most successful gatherings of the kind it has ever been our good fortune to attend. It had become known amongst members for some time past that a very strong Reception Committee had been formed, consisting of many French gentlemen, eminent both in the scientific and naval world. A large part of the week devoted to the meeting was given up to purely pleasure excursions and entertainments. Of these it is not within our province to speak, but it would be ungracious on the part of any English journal, dealing with the meeting in any way, not to say a word in recognition of the generous hospitality so lavishly displayed by all those connected with the organisation of the programme in France.

There were three sittings for the reading and discussion of papers; Lord Brassey, the President of the Institution, taking the chair on each occasion. Members assembled for the first time in the new amphitheatre of the Sorbonne, which had been kindly placed at the disposal of the Executive by the Rector of the University of Paris, M. Octave Gréard. Vice-Admiral Charles Duperré, President of the Reception Committee, welcomed the members, and Lord Brassey responded in a brief address.

The following is a list of the papers set down for reading and discussion on the programme.

"The Amplitude of Rolling on a Non-Synchronous Wave," by Émile Bertin, Directeur des Constructions Navales, and Directeur de l'École d'Application Maritime.

"On Wood and Copper Sheathing for Steel Ships," by Sir William White, Director of Naval Construction, and Assistant Controller of the Navy.

"The M.G. Metre," by Archibald Denny.

"On the utility of making the calculation of the total external volume of ships, and of drawing out the complete scale of solidity, from the triple point of view of tonnage laws, stability and load-line," by V. Daymard, Engineer in Chief of the Compagnie Générale Transatlantique.

"On Light Scantling Steamers," by B. Martell, Chief Surveyor Lloyd's Registry of Shipping.

"On Coupling Boilers of Different Systems," by Pierre Sigaudy, Engineer in Chief of the Forges et Chantiers de la Méditerranée.

"On the Cost of Warships," by Francis Elgar.

"On some necessary conditions for resisting intense firing in water tube boilers," by Augustin Normand.

"On the Niclausse Boiler," by Mark Robinson.

M. Bertin's paper, which was the first to be read, treated a highly technical subject from a strictly mathematical point of view. The author pointed out that perfect synchronism between the period of rolling and of the wave is practically a purely theoretical case. He referred to the latest calculations made which bear upon a large number of particular cases, and also to the principle of the graphic method, which has been previously described, and which is a simple extension of the method employed to determine the amplitude of rolling on a synchronous swell. The subject is one of extreme interest, but we fear we must refer those of our readers who are not acquainted with it to the published paper in the volume of the "Transactions" of the Institution. It would be impossible to give an abstract of M. Bertin's mathematics, or, indeed, to make the matter clear without the diagrams which accompanied the paper. One result, however, which may be quoted, is that M. Bertin confirms the facts brought out by Sir William White as to the great increase of efficiency of bilge-keels in large as compared with small ships. This, as our readers are aware, came somewhat as a surprise to those engaged in these matters. M. Bertin states: "We find, therefore, in bilge-keels a more powerful method of checking heavy rolling than has been foreseen. In a different condition of things, free liquid provides a more rapid means of extinguishing small rolls than could have been foreseen from any calculations founded on the known properties of liquids." M. Bertin states that the question upon which he treats is one that cannot be solved by calculation; accurate observations made at sea are the necessary complement of all the theoretical researches and experimental study made in port.

Sir William White opened the discussion on this paper. It will be remembered that at the spring meeting of the Institution the Director of Naval Construction was unable to be present, owing to a very severe illness. In spite of this, a paper which he had written on the subject now under consideration was read in his absence. His reappearance at the meetings was the occasion of a very general outburst of enthusiasm on the part of the members present, for no one is more popular, and indeed few have done more for the Institution, than Sir William White. Sir William pointed out that for mathematical purposes it was necessary to make assumptions which could be corrected by and applied to practical work. He paid a handsome compliment to the author by coupling his name with that of the late Mr. Froude.

The next paper read was Sir William White's own contribution on sheathed ships. This, as the author pointed out, was a direct contrast to the paper last read, being of a simply practical nature. As is well known, the purpose for which steel vessels of war are sheathed with wood, is in order that they may be coppered, and their bottoms may thus be preserved from fouling. It is needless to say that the wooden planking is applied as a means of preventing galvanic action between the copper and steel. In order to effect this, it is necessary that the planking should be water-tight, for sea water, in contact both with the copper and the steel skin, would set up galvanic action. It may be stated, however, in passing, that if the sea water is not in circulation, the galvanic action will not be intense or continuous, which is a fact that might be anticipated. In order to make the planking water-tight, it was originally thought necessary that a double skin should be used, and very elaborate precautions were taken in regard to fastenings. Sir William White, then Mr. White, came to the conclusion that the double planking was unnecessary, and that with proper care a single skin could be made to answer the purpose required. In this he was opposed by a large number of eminent authorities, but having the courage of his convictions, he introduced the new system into Her Majesty's Navy. The result has justified his anticipations, for after several years' experience, the hulls of ships thus sheathed have not been found to suffer.

Mr. Archibald Denny's paper described a small instrument he has invented by which the metacentric height of a vessel can be ascertained. It is intended for the use of captains of ships, so that they may ascertain the stability of their vessels under various conditions of load and trim. The instrument is simply a spirit-level pivoted at one end and adjusted at the other, by means of a micrometer screw. This combined with a diagram gives the value M.G. The method of using the instru-