prominences and the faculæ. These observations, therefore, establish not only an important connexion between spots, metallic prominences, and faculæ but also the fact of the wonderful localization of these phenomena upon the sun. The spots are never seen higher in latitude than 40° north or south, and they are invariably seen in smaller quantity at the equator. Similarly, the faculæ and metallic prominences do not go much beyond 40° north or south, and their minima are also at the equator. But this does not hold good for prominences of the quiet sort and the veiled spots,—that is, spots without umbræ or very highly developed penumbræ. They extend from one pole of the sun to the other; hence there must exist a great difference between metallic and quiet prominences and between disturbed and veiled spots.

Although the more important of these solar phenomena are limited to certain zones of the sun's surface, and although they vary very violently, they have a cycle or regular succession of changes, during which the particular zone of the sun on which they appear alters. When there is the smallest number of spots on the sun—that is to say, when there is a sun-spot minimum—the spots that appear are seen in a high latitude, and the latitude decreases gradually until we arrive at the next minimum. Thus there are two perfectly distinct spotted areas, one corresponding to the end of the old period, the other to the beginning of the new period. At the maximum period of sun spots the latitude of the spot zone is about 15° Activity in the solar atmosphere, therefore, appears to begin in a high latitude—say about 30° or 35°—and very soon reaches the maximum in about latitude 15°; then it gradually dies away until spots, metallic prominences, and faculæ—all of reduced intensity—cling pretty near to the solar equator, and at the same time we get a new wave of activity, beginning again in a high latitude. This association of what may be called localized phenomena is quite in harmony with a similar association of phenomena which are more or less generally distributed over the whole surface of the sun.

Pores, which are in reality nothing but small sun spots may occur in any part of the sun, and are always accompanied by a slight waviness in the chromosphere. Veiled spots—spots which never attain full development—are also universally distributed over the sun's surface and are accompanied by small prominences (see below).

The main periodicity on the sun is that of about eleven years which elapses between two successive maxima or minima. When the sun is quietest, there are very few of the ordinary tree-like prominences visible, and there is an especial dearth of them near the poles and the equator. There are faculæ, but they do not present their usual bright appearance, and are confined to the regions between latitudes 20° N. and 20° S. On examining the chemical nature of the materials in the chromosphere at such a period by means of a spectroscope, we see only the four lines of hydrogen and the line D_3, whose chemical significance we do not know. Practically speaking, there are no spots visible and the disk appears to be perfectly pure, except the darkening towards the limb produced by absorption in the sun's atmosphere. As there are no spots, or only very small ones in high latitudes, it follows that there are no metallic prominences. The spectroscope searching right round the limb of the sun gathers no indications of violent action—no region giving many lines—nothing but the simple spectrum of hydrogen. Observations and photographs of the corona taken at solar eclipses occurring at minimum spot periods indicate that at two different sun-spot minima the appearances presented by the corona are very much alike. A drawing made during the eclipse of 1867, before the application of photography to solar investigations, exhibits a similar appearance to an absolutely trustworthy photograph obtained at the eclipse of 1878. At the minimum period the chief feature is a very great extension of the corona in the direction of the solar equator, and a wonderfully exquisite outcurving right and left at both poles. It is probable that the equatorial extension pictured in the above-mentioned photograph is, after all, only a part of a much more extended phenomenon, one going to almost incredible distances from the sun itself. At the eclipse of 1878 precaution was taken to shield the eye of the observer from the intense light of the inner corona, which is sometimes so bright as to be mistaken for the sun's limb, by erecting a screen which covered the moon and a space 12′ high around it. The observer, Professor Newcomb, saw on both sides of the dark moon a tremendous extension of the sun's equator, far greater than that recorded in the photographs taken at the same time. But the extended portions may have been so delicately illuminated that they could not impress their image on the photographic plate during the time it was exposed, or that the light itself is poor in chemically active rays. The extension, as observed by the shielded eye, amounted to six or seven times the diameter of the dark moon. In a more favourable situation the same extension, but to a less extent, was observed without the aid of a screen. At a sun-spot minimum, therefore, there exists a great equatorial extension of the corona east and west.

The time between the minimum and the maximum sun-spot periods is three or four years, and that from maximum to minimum seven or eight years, so that the sun increases in activity much more rapidly than it afterwards decreases in passing to the next minimum. Starting, then, about half way between minimum and maximum, we find an increased activity in every direction. The quiet prominences, consisting of hydrogen, are more numerous, and the faculæ are brighter. If at this time we examine the spectrum of the chromosphere, we find hydrogen and D_3 are not the only constituents: we get other short lines, the chief being the three lines of magnesium b_1, b_2, b_4. The spots are more numerous and are in a lower latitude, having moved from near 35° to about 25°. Metallic prominences now constantly accompany the spots; and the number of bright lines visible in their spectra gradually increases from month to month. These changes are accompanied by changes in the corona, which affect not only its form but also its spectrum. At the minimum spot period the corona gives an almost continuous spectrum, differing only in the presence of a few dark lines, and occasionally a few not very obvious bright lines, whence we conclude that at the minimum the corona is not entirely gaseous. In passing from the minimum to the maximum the spectrum is no longer continuous: bright lines begin to appear, emanating from the incandescent gaseous portions of the corona, and at the same time there is an increase in brilliancy. At this period there is no longer any remarkable equatorial extension, although here and there streamers of strange outlines occur. A drawing of the eclipse of 1858, a period between minimum and maximum, shows in middle latitudes, both north and south, four remarkable luminous cones standing with their bases on the chromosphere. The amount of light and structure in the corona has increased to such an extent that the beautiful double curves seen at the poles at the minimum are now hidden in a strong radiance.

During the maximum period all the solar forces are doing their utmost, and we see in prominences and spots, and indeed in every outcome of action that we can refer to, indications of the most gigantic energies being at work. The ordinary prominences, instead of clinging to

the equator, now occur most frequently at the poles. The faculæ are brighter and are more widely distributed, and the chromosphere is richer in lines. The spots at this period occupy broad zones with mean latitudes of about 18° N. and 18° S. There are no spots near the poles and none near the equator; but large spots, indicating a state of violent agitation, surrounded by gigantic faculæ, follow each other in these zones. Each of these indicators of solar activity is accompanied by a prominence. At this time also we note the greatest velocities of down-rush in the vapours which form the spots and of up-rush in those which form the prominences. These changes are accompanied by corresponding changes in the corona; and, fortunately, we have photographic records for two periods of maximum,—1871 and 1882. In these the streamers, instead of being limited to the equator or to mid-latitudes, exist in all latitudes, so that they practically extend to every part of the sun. Their directions, which may be called lines of force, are very varied, some being straight and some curved; but it is difficult to unravel the appearances, because what we see are only projections of the actual things, and this is especially the case when the sun's pole is tipped towards or away from the earth to the greatest extent. In the eclipse of 1882 the corona indicated a more equal distribution of action than that of 1871, but the general result was the same.

After the maximum period there is a gradual falling off of all the various energies, the mean latitudes of the spots decreasing until they reach 8° N. and 8° S.; then another series of spots breaks out about 35° N. and 35° S. lat., and the cycle begins anew.

General Theory.

It has been very generally accepted for some time that sun-spots are depressions in the photosphere, produced by downfalls of cool material. The following sketch shows how, if we accept this view and also the hypothesis that the chemical elements are dissociated in the lower parts of the solar atmosphere, many of the more important solar phenomena may be explained and correlated.

We know that small meteorites in our own cold atmosphere are heated to incandescence by friction, that is, by the conversion of their kinetic energy into heat, and it is therefore not difficult to imagine that enormous masses, falling with great velocities through the sun's highly heated atmosphere, would be competent to give rise to such disturbances as those with which we are familiar on the sun's surface. This cool material is produced by the condensation, in the upper cool regions of the sun's atmosphere, of the hot ascending vapours produced at the lower levels, and this is probably the main source of supply of spot-producing material. The faculæ and other disturbances of the general surface do not precede but follow the formation of a spot, so that a spot may be considered as the initial disturbance of the photosphere in the region where it is observed. Large spots almost invariably appear first as little dots, frequently in groups, and then suddenly grow large. The little dots, according to the view of spot formation now under discussion, are formed by small masses which precede the main fall. The heat produced by friction with the atmosphere and the arrested motion causes up-rushes of heated vapours, which eventually cool and condense, and afterwards fall to the photosphere and produce fresh disturbances. Down-rushes of cool material must take place all over the sun's surface, and, although the most violent results of such falls are restricted to certain regions, minor disturbances are distributed over the whole surface. These generally distributed phenomena are well known to be merely different degrees of the same kind of energies that operate in producing the more restricted ones.

We will now review the several phenomena in turn, beginning with the most widely distributed.

Besides the general darkening near the edge of the sun's disk, the surface is seen to be strangely mottled near the poles, near the equator, and in fact universally. Moreover, small black specks, called *granulations* or *pores*, are everywhere visible, and spectroscopic examination shows that every one of these is a true spot. The fine mottlings frequently indicate the existence of powerful currents in that they take definite directions, sometimes in straight lines, sometimes in lines suggesting cyclonic swirls. In addition to the pores spots of a smudgy kind, called *veiled spots*, are sometimes seen, and it is probable that in such cases the force of the down-rush is insufficient to depress the photosphere to an extent competent to give rise to the ordinary dark spots. Some spots appear as large pores, that is, they consist of nothing but umbra; others appear as well-developed veiled spots, consisting almost entirely of penumbra. The obvious large spots consisting of umbra and penumbra follow next in order of intensity, and, as has been previously pointed out, their appearance is confined to definite spot zones. Minute observation, therefore, shows that the whole of the sun's surface is traversed by down-rushes of varying intensities, from almost infinitesimal dimensions to the most powerful that we can conceive. Some of the ordinary spots do not appear to be in any violent state of agitation: the penumbra and umbra are well defined, and the ridge of faculæ round such a spot does not indicate any disturbance by either lateral or convexion currents. Other spots, however, indicate very violent commotion, the penumbra and umbra being tremendously contorted and mixed up. In this kind of spot the disturbance often affects enormous areas of the sun's surface; one spot in 1851 was 140,000 miles across, and the commotions were so great that they could be detected by eye observation with the telescope. It appears as if the material carried in the first instance below the level of the photosphere produces a disturbance in the interior regions, which exhibits itself at the surface by an increase in the quantity and brilliancy of the surrounding faculæ. As a spot dies away it is replaced by faculæ, and these remain long after the spot has closed up. It often happens that new spots break out in the places occupied by previous spots. The spot-producing material in its descent is dissociated either before or when it reaches the photosphere, and the rapidity and energy of the dissociation depend upon the velocity with which it travels. Gravitation is of course the main factor operating in the production of a down-rush. The velocity produced by gravitation in matter falling from great heights above the photosphere must be very great, and in consequence the kinetic energy of the moving mass must also be great. The motion is impeded by friction with the gases in the sun's atmosphere, and some or perhaps all the kinetic energy becomes heat. The heat thus developed must produce sudden expansions, and the initial down-rush is surrounded by up-rushes along the lines of least resistance. The effects of such down-rushes vary in degree according to the quantity of matter falling and the height from which it falls.

Effects of up-rush.

Equally too there are observed different degrees of the effects of up-rushes. All over the sun's surface are seen domes of faculæ, either separate or in groups, and there is indication that they are hotter than the rest of the surface, for the bright lines of hydrogen are seen to surmount them. It is probably owing to this that the chromosphere exhibits a billowy outline when under conditions of little disturbance. The next condition of increased action exhibits itself in the growing complexity of the chemical nature and of the form of the chromosphere. Occasionally the whole level of the chromosphere over a large region seems to be quietly raised, and observation proves this to be due to the intrusion of other vapours. There is either a gradual evaporation from the photosphere or a gradual vaporization or expansion of slowly falling material over large regions, raising the level of the sea of hydrogen. The chromosphere then appears to contain different layers, and the lower we descend towards the photosphere the less we know about the substances that exist there. The next degree of disturbance is seen in what are called the *quiet prominences*, which very frequently occur in regions where the beginning of a disturbance has been previously indicated by the appearance of domes and metallic strata. As a rule the quiet prominences are not very high—not higher than 40,000 miles—and many of them resemble trees. They are almost entirely composed of hydrogen, or at least of a substance which gives some of the lines observed in the spectrum of hydrogen. Such a prominence grows upwards from the photosphere, being first of a small height, then getting higher and often broader, and finally a kind of condensation cloud may form at the top. The upward velocity of the gases forming these prominences is seldom very great. When a prominence disappears it does not follow that the substances of which it was composed have also disappeared, and there is evidence to show that the apparent disappearance is due to a reduction of temperature. The most intense degree of action of an up-rush is exhibited by the metallic prominences, which contain other substances in addition to hydrogen. They are seen mounting upwards to enormous heights with almost incredible velocities, and their ascent is accompanied by violent lateral motions. Such prominences have been seen with an upward velocity of 250 miles a second, and of a height as great as 400,000 miles. There is also evidence that some prominences consist of mixed up-rushes and down-rushes, and it may turn out eventually that this is the case in all the metallic prominences.

According to the gravitation-dissociation theory of the formation of spots, we ought to find that the effects, in various degrees, produced by down-rushes of associated matter are related to the effects, in like degrees, produced by the corresponding up-rushes of dissociated materials. Comparing, then, the facts already stated, we have :—

Effects of Down-rush.	Effects of Up-rush.
1. Pores.	1. Domes.
2. Veiled spots.	2. Metallic strata and small prominences.
3. Quiet spots.	3. Quiet prominences.
4. Disturbed spots.	4. Metallic prominences.

It is a fact that the pores and domes are very closely associated over all parts of the sun, and that the domes are most prominent in places previously occupied by spots. All large spots are seen to be accompanied by metallic prominences, when observed at the edge of the sun. There is also a strict relationship between the intensity of action going on in a spot and the associated prominence, so much so that a very violent change in a spot on the disk sometimes causes the bright prominence lines to become visible in its spectrum. The ordinary metallic prominences, as already stated, may consist of both ascending and descending material; this will be best understood by likening the whole phenomenon to a splash.

Physics of a sun-spot cycle.

We have previously seen that spots and metallic prominences are very intimately connected as regards their occurrence in zones, and this intimacy is easy to explain by supposing things to happen in the way here set forth. The height of the solar atmosphere is greater over the equator than at the poles; particles condensed on the outside at the poles have therefore a relatively small velocity when they fall into the photosphere, and are able to produce only pores or veiled spots. Over the equator the particles attain a higher velocity in their fall, but they also have to pass through a much greater thickness of atmosphere and undergo so much dissociation that on reaching the photosphere they are incompetent to produce spots. In mid-latitudes, therefore, the falls of condensed particles should be most effective in producing spots. In this way the absence of spots at the poles and equator is explained,—one of the best-known facts of solar physics. The falls of the condensed particles, or meteoric matter, into the sun increase the temperature of the atmosphere over the spots and prominences which they produce, so that other falls in the same region are not effective in producing spots on account of the increased dissociation which they must undergo before reaching the photosphere. If the material condensed in those regions is to produce a spot, it must be removed to some place where it can reach the photosphere without being dissociated. Hence from the first appearance of spots after a sun-spot minimum there is a continual change of latitude. From minimum to minimum there is a regular decrease in the latitude of spots; hence it is clear that there must be currents from the poles towards the equator in the upper atmosphere of the sun, causing the removal of condensed materials to lower and relatively cooler latitudes. Assuming the existence of such currents, we ought to find that successive spots have a tendency to form along the same meridians, for the polar currents would carry the condensed materials to lower latitudes in a nearly meridional direction. Examination of sun-spot records for 1878-79 shows that there is a marked tendency for spots to follow each other in meridians. The existence of such currents is further supported by the outcurving of the corona at the solar poles as observed in several eclipses. If these currents exist, there must also be compensating currents towards the poles in the lower parts of the sun's atmosphere, carrying incandescent vapours along with them. Small prominences often give indication of motion towards the poles which such currents would produce, and examination of sun-spot records also shows that the tendency of the proper motion of the spots is polewards. Hence, although the existence of these currents has not been definitely proved, there is strong evidence that there exists some circulation of this nature in the solar atmosphere.

When once the falls have commenced, if this hypothesis is true, they should rapidly increase in intensity, for, as it is the falls which increase the temperature of the lower atmosphere by the conversion of their kinetic energy into heat, the more falls there are the more material will be taken first to the poles and then towards the equator, and therefore there will be more available spot-forming material. But we know that this increase in intensity does not go on for ever, and there must therefore be some regulating influence. The increase of temperature and possibly of the height of the solar atmosphere, due to the increased falls, will eventually become such that the descending materials are dissociated before they reach the photosphere. The production of spots must therefore gradually diminish until they finally disappear and end the spot cycle. At the minimum period, therefore, pores and veiled spots, due to less powerful energies, are at a maximum.

Records of eclipses, occurring when the sun was quietest, show that the condensing and condensed materials brought to the equator by the polar currents probably extend far beyond the true atmosphere of the sun and are there collected, possibly in the form of a more or less regular ring the section of which widens towards the sun, the widest part being within the boundary of the sun's atmosphere. If we assume such a ring under absolutely stable conditions, there will be no fall of material, and therefore no prominences or spots. But suppose a disturbance caused, as before, by collisions, which most likely occur where the particles brought by the polar currents meet the surface of the ring. These particles then fall from where the ring first meets the atmosphere on to the photosphere, and form the first spots. Eclipse records show that this action takes place about 30° lat. According to this view, there are usually no spots above 30° lat., because there is no ring, and because the atmosphere is too low to give the height of fall necessary to produce spots. There are no spots at the equator for the reason that the condensed matter has to pass for perhaps millions of miles through strata of increasing temperature, and do not therefore reach the photosphere before being dissociated. Accordingly, we ought to find that at and after the maximum the corona is brighter and more truly a gaseous body on account of the increased temperature. This is in strict accordance with eclipse observations extending over twenty years. According to this view of the solar economy, the sun ought to give out more heat at a maximum than at a minimum period, when the number of falls is greatest; on this point see the article METEOROLOGY (vol. xvi. p. 167 *sq.*).

The Sun's Place among the Stars.

Star absorption of light.

The relative nearness of the sun makes it convenient as a type of those stars which on account of their great distance are less accessible to minute observation. If the sun were at a greater distance, its spectrum would become much fainter and would not show so much detail, but its general character would not be altered: its dark lines would not become bright ones. In the atmospheres of the various members of the solar system, including the earth, there is a very considerable absorption of blue light. We know also that this condition applies to the sun. The light we receive under present conditions we call white; but, if its own atmosphere and ours were removed or became so changed as to no longer absorb blue light, the sun would appear blue. If, on the other hand, the blue absorption were enormously increased, so that it extended into the green, the sun would appear red, because every other kind of light would be absorbed. If two kinds of absorption—one in the red, the other in the blue—were going on together, as they sometimes do in our laboratories, the sun would then appear green. Although these changes are not of actual occurrence in the sun, we find each of these conditions represented among the stars. In the coloured stars, which may be red, green, or blue, we are simply dealing with this kind of absorption phenomena. This difference in the conditions of absorption in the stars, however, is by no means the most important one: the difference of temperature as indicated by the spectrum is of primary importance. As in our laboratories the spectrum of a substance is changed by a variation of temperature, and always in a regular way, so the nature of a star's spectrum furnishes a clue to its probable state as regards heat. For example, we may submit carbon vapour to a low temperature, and we shall then obtain what is called a spectrum of flutings; on increasing the temperature, the flutings are replaced wholly or partially by lines, according to the amount of increase. From hundreds of observations of this kind, both on carbon and other substances, it may be safely inferred that a fluted spectrum indicates a lower temperature than a line spectrum. There are doubtless substances in the sun's atmosphere which, although represented by lines in its spectrum, can be submitted to low conditions of temperature so as to give fluted spectra. There can be little doubt, therefore, that a cooling of the sun would be followed by a change in its spectrum, which would cease to be one of lines and become one of flutings. While the sun was acquiring its present intensely heated state, it must at some period of its history have been in a condition of temperature in which its spectrum would consist of flutings, and similarly it must give a fluted spectrum at some future period when it has further cooled.

The ordinary Fraunhofer spectrum gives the sum total of the line absorptions of all the various layers in the sun's atmosphere, but by examining individual layers just off the edge of the disk we can single out the absorption lines produced by the lower layers. Thus the absorption produced by the hottest layer, the chromosphere—hottest because nearest the photosphere—is indicated by its usually simple radiation spectrum when examined in this way. If the sun were made hotter, therefore, the gases which give the simple chromosphere spectrum would have a larger share in the absorption, and the main features of the Fraunhofer spectrum would be the few dark lines corresponding to these bright ones. This being so, a star which gives practically the same absorption spectrum as the chromosphere of the sun must be hotter than the average temperature of the sun's atmosphere,—as hot as the hottest part of it. The bright central part of the sun is not very much less than the whole volume, but it is so much hotter that it gives out thousands of times more light than the atmosphere. The cool vapours in the atmosphere give the dark Fraunhofer lines by their absorption, and even if they are hot enough to give bright lines when seen on the sun's edge they can only reduce the intensity of the dark lines. Here the difference of area between the disk representing the central mass and that representing the sun's atmosphere is very small, and, the light from the central mass being so much more intense, we do not ordinarily see the evidences of radiation, but, in place of it, the absorption of the atmosphere. If, however, we suppose the central mass to be very small compared with its atmosphere, the total radiation of the atmosphere may be sufficiently powerful to overcome the intensity of the light from the smaller central part, so that the spectrum of such a star would contain bright lines from the exterior mixed up with the dark lines from the interior. The spectrum of a star, therefore, does not always depend upon its total diameter, but upon the relative diameters of the central mass and the outer atmosphere. It is a question of sectional areas.

Stellar spectra.

Observations of the spectra of a large number of stars show that, although there is a great difference between individual spectra, they still admit of arrangement in family groups. While some stars give line absorption spectra, others give fluted spectra, and others again give bright lines. They may be conveniently arranged as follows :—

		Example.
Class I.	Stars whose spectra consist of a few thick absorption lines.	α Lyræ.
Class II.	Stars whose spectra consist of a large number of fine absorption lines.	Sun, Capella, &c.
Class III.	Stars with fluted spectra, the maxima of the flutings being towards the red.	152 Schj.
Class IV.	Stars with fluted spectra, the maxima being towards the blue.	α Orionis.
Class V.	Stars whose spectra contain bright lines,—(*a*) of hydrogen, (*b*) of unknown substances.	β Lyræ.

This classification probably represents the stars in order of temperature, class I. being the hottest.

Although different stars may contain lines of identical wave-lengths, the thickness of these lines is very liable to variation in passing from one star to another. The thickest lines in the solar spectrum are H and K in the ultra-violet, both of equal thickness; on passing to some of the stars, however, we find H broad with K thin, and in others H without K. This is similar to what occurs in our laboratories when we study the spectrum of calcium, the substance which gives the lines H and K: at the temperature of the electric arc the blue line of calcium is very intense, while H and K are scarcely visible; but on passing to a higher temperature, that of the induction spark, H and K appear. In those stars which give H without K, namely, those in class I., it is probable that there is a very high temperature competent to separate H and K, just as H and K were conjointly separated from the blue line. A further indication of high temperature in the stars belonging to class I. is that the few lines which do occur in their spectra are almost the exact counterparts of those which occur in the hottest layer of the sun, hydrogen lines being especially prominent. The passage from class I. to class II. is by no means sudden: there are stars with every gradation of broad and fine lines. It will readily be understood that the stars of class II. are probably not so hot as those belonging to class I., and the change in the spectrum is supposed to be due to new combinations of the original substances, rendered possible by a reduction of temperature; that is, new lines are formed at the expense of the old ones. The hydrogen lines are very prominent in class II., though not so intense as in class I. The stars of these two classes may be grouped together and called hydrogen stars. Stars belonging to class III. exhibit unmistakable evidence of carbon vapour. Sodium and iron are also often present. All the stars in this class, of which fifty-five are known, agree in having a reddish tint. They are usually faint, and seldom exceed the fourth magnitude. There is evidence of the existence of carbon vapour in the sun's atmosphere, depending upon one solitary fluting, and hence stars of this class probably represent what the sun would become if it were cooled. Class III. therefore represents a lower temperature than classes II. and I. Class IV., containing 475 known members, includes the stars giving fluted spectra with the darkest edges of the flutings towards the violet. The origin of the substances of which they are mainly composed is not at present known. All the principal bands are absolutely unchanging in position, although there is considerable variation in the intensities. The bands in the spectrum appear to result from the rhythmical vibrations of the same substance, probably a complex one. Besides this unknown substance, there are also metallic lines in many of the stars, the complete spectrum consisting of the banded spectrum superposed upon the line spectrum. The metallic lines are generally seen in the spectra of sodium, iron, magnesium, or calcium; the hydrogen lines are very inconspicuous.

These considerations suggest the question of stellar evolution. Comets and nebulæ are now supposed to consist of clouds of stones or small meteorites, and the difference between their spectra may be due to a difference of temperature, that of the nebulæ being highest. Comets ordinarily give the spectrum of carbon, and, if we imagine such cometary matter to surround a central bright nucleus, we have the spectrum of a star of the third class. On the nebular hypothesis, starting with ordinary cometary materials, the small masses resulting from the first condensations gravitate towards each other, and their energy becomes heat by the retardation of their motion on coming in contact. As soon as the condensed mass is hot enough, it gives a fluted spectrum, like stars of the third class. As the energy of condensation increases, the temperature is raised and the spectrum passes from that of a third class star to that of a second class star, and then to that of a first class star. On the subsequent cooling of what is then a star the successive stages will be again passed through in inverse order. According to this view, we ought to find fewer hydrogen stars than carbon stars, because every star is a carbon star at two periods of its existence, but a hydrogen star only once. On this point, however, nothing definite can be stated, as the stars of classes I. and II. have, in consequence of their greater brightness, received more attention than carbon stars.

New and variable stars.

In 1866 a star of the tenth magnitude in the constellation Corona suddenly flashed up into a star of nearly the first magnitude; its spectrum as a tenth magnitude star differed from its spectrum as a first or second,—the latter containing bright lines of hydrogen. In about a month it again became a tenth magnitude star and appeared as if nothing had happened to it. There can be little doubt that here there was a sudden increase of temperature, as evidenced by the spectrum becoming like that of the chromosphere of the sun. Ten years afterwards a new star appeared in Cygnus; it had never been seen before, but appeared suddenly as a third or fourth magnitude star. In about a year it gradually dwindled down to the tenth magnitude, and its spectrum became that of a nebula. This mass was at a stellar distance, but it cannot be considered to have been a large mass of incandescent material, for in that case it would have taken millions of years, instead of only one, to cool down to the tenth magnitude. A possible explanation of most of the new and variable stars is to be found in the meteorite theory: the innumerable components of one group of meteorites colliding with those of another group would be competent to give out light sufficient to make the whole appear as a star. Each meteorite gives only a little light, but the total must be very considerable. The new star in Corona, and similarly all new stars, may have been the result of a collision of two groups of meteorites. They die out quickly because the components are small and far apart. The sudden increase in the brilliancy of the star in Cygnus would be produced by a collision of a meteor swarm with the star already existing. (J. N. L.)

SUN-BIRD, a name more or less in use for many years,[1] and now generally accepted as that of a group of

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[1] Certainly since 1826 (*cf.* Stephens, *Gen. Zoology*, xiv. pt. 1, p. 229). Swainson (*Nat. Hist. and Classif. Birds*, i. p. 145) says they are "so called by the natives of Asia in allusion to their splendid and shining plumage," but gives no hint as to the nation or language wherein the name originated. By the French they have been much longer known as "Souimangas," from the Madagascar name of one of the species given in 1658 by Flacourt as *Soumangha*.