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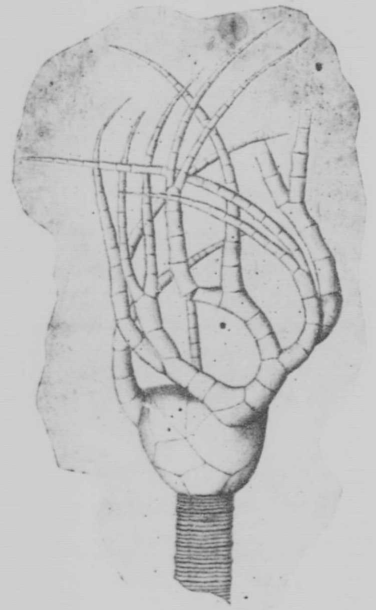

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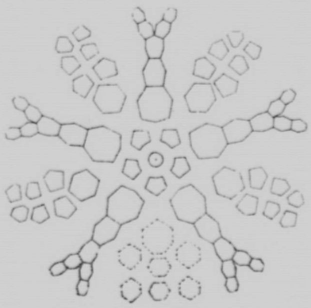

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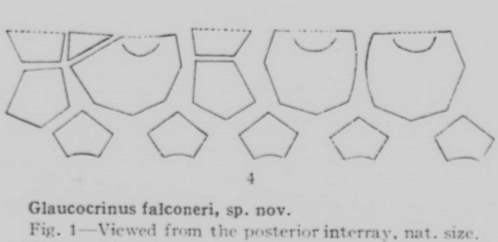

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ON TWO NEW CRINOIDS FROM THE TRENTON FORMATION OF ONTARIO.

(Plate IV, Figures 1-4).

BY W. A. PARKS AND F. J. ALCOCK, UNIVERSITY OF TORONTO.

In his recent memoir on Trenton Echinoderms prepared for the Geological Survey of Canada, Mr. Frank Springer refers to a specimen in the museum of the University of Toronto as a new species of *Carabocrinus*.* This opinion was expressed in confirmation of a diagnosis by the writers which was based on the character of the arms alone. A careful cleaning of the specimen has revealed the cup in a fair state of preservation but insufficiently perfect to warrant conclusions as to certain of the plates. Despite this imperfection, it is highly probable that the specimen represents a new genus of the Inadunate Monocyclic Crinoids referable to the family *Heterocrinidae*.

The cup.—The cup is about 15 mm. high and 17 mm. wide. Five pentagonal and approximately equal basals are presented. The plates of the radial ring differ greatly from one another: three of them are large with a facet extending across the middle third for the insertion of the arms. The other two radials are transversely divided and do not appear to bear arms of the same character as those arising from the larger plates. Owing to the crushed condition of the specimen it is impossible to be sure of the other points in the anatomy of the cup, but it would appear that one of the large radials is somewhat greater than either of the others and that its upper left corner is truncated for the insertion of a small anal. In the drawing (plate IV, fig. 1), the right-hand dotted line represents the uncertain suture between the supposed anal and the contiguous large radial. The middle dotted line is almost certainly a suture and the lefthand dotted line is, in all probability, due to a crack across the superradial. The dissection shown in fig. 4 is drawn on the assumption that the small triangular plate is a true anal. If this conclusion is correct, then the large radial is the right posterior and the divided plates are the left posterior and the

*Geol. Sur. Can., Memoir 15 P., Ottawa, 1911.

right anterior radials. It is to be noted that this arrangement is not in accord with the general habit of the *Heterocrinidae* in which the right posterior radial and the right and left anterior radials are usually the ones divided. All the plates of the cup are thick and heavy with the upper edges of the radials strongly inflected. The tegmen likewise was of fairly heavy construction, but it is not clearly observable.

The arms.—The arms are stout and bifurcate heteronomously: in life, they probably extended to a height of 50 mm. above the cup. The three normal radials bear arms which are inserted on a facet extending across the middle third of each plate. The first primibrach (costal) is axillary: the second or third secundibrach (distichal) is axillary: the third or fourth tertibrach (palmar) is axillary. The arm-segments are somewhat hour-glass shaped and the various branches are of unequal strength. The arms lie in a curved position, which is probably normal. There is some evidence of the occurrence of stout pinnulae at intervals, but the specimen is too poorly preserved to warrant remarks on their distribution.

The right anterior superradial is badly broken but it appears to have carried an arm which maintained its strength to a greater height than the normal arms. This arm does not appear to have arisen from a facet on the exterior face of the radial as in the case of the normal arms. The left posterior superradial shows no evidence of an arm but it is possible that one is hidden under the left ramus of the right posterior arm which lies across the top of the plate. It is certain, however, that the left posterior radial did not bear an arm analogous with the three normal ones.

The anal tube.—The anal tube is a very slender structure about 1.5 mm. thick: it shows three segments in a distance of 6 mm. The tube appears to have risen from the small triangular anal already mentioned. Owing to the imperfect preservation, the interpretation of this structure is attended with doubt. The coincidence of the supposed anal plate and this tube-like structure seems to justify the orientation decided on.

The stem.—The stem is relatively large, having a diameter of 7 mm. at its proximal end. In the 18 mm. exposed by the specimen, there is little evidence of tapering distally. A quinquepartite arrangement is clearly indicated with the subdivisions interradial in position and therefore continuous with the basals. If Wachsmuth and Springer are correct in stating that the segments of quinquepartite stems alternate with the cup-plates of the proximal row, then this form is dicyclic with invisible infra-basals. The stem shows transverse elevated ridges at intervals of about 2 mm. with finer, somewhat sinuous lines between the heavier ones.

Remarks.—It must be admitted that both the anal tube and the anal plate are of doubtful interpretation and consequently the orientation of the form is questionable. Notwithstanding this uncertainty, the existence of two, and two only, divided radials, together with the lack of symmetry in the arms and their peculiar insertion, justify the creation of a new genus and species. The form seems to foreshadow the *Platycrinidae* of a later period.

GLAUCOCRINUS, GEN. NOV.

Basals five, equal. Radials relatively large. The right anterior and the left posterior radials transversely divided. A small anal rests on the upper left shoulder of the right posterior radial. The three normal radials bear stout bifurcating arms. The other radials support arms of a different character or may lack arms on at least one of the plates.

GLAUCOCRINUS FALCONERI, SP. NOV.

Specific characters as in the general description given above.
Named for President Falconer of the University of Toronto.
Type—No. 610 T., University of Toronto Museum.
Formation—Trenton.
Locality—Kirkfield, Ont.
Collector—Joseph Townsend.

The second species herein described is founded on two specimens which are evidently referable to the genus *Glyptocrinus.* Each of the specimens shows a considerable portion of the cup with the stem attached: one exhibits the plates of the cup in an admirable manner; the other, which is less perfect in this respect, shows, however, almost the full extent of the arms. The accompanying figure (plate, IV, fig. 2) has been prepared by combining the features exhibited by the two specimens. It is regrettable that neither example reveals the arrangement of the plates in the posterior interray.

The cup.—In one specimen, the cup is 19 mm. high and 15 mm. wide; in the other, it is about 14 mm. high and 11 mm. wide. As far as can be observed, the basals consist of five similar pentagonal plates, considerably smaller than the radials. These latter plates are of equal size and of an heptagonal outline. The radials are succeeded by two somewhat elongated primibrachs (costals), the first of which is hexagonal and the second heptagonal. The second primibrach is axillary and is succeeded by the secundibrachs (distichals) which occur in single series. The interray shows a lower plate which is hexagonal in outline: this is followed by three pairs of interbrachial plates of which the last pair is interdistichal in position. Above this point, the arrangement of the plates is not clearly shown, but apparently a fourth pair of interbrachial plates continue the interray to the margin of the cup.

The characteristic features of the species lie more particularly in the ornamentation of the cup plates. From the centre of each radial a strongly marked carina runs up the ray to the middle of the second costal, where it bifurcates and continues over the distichals to the point of origin of the arms. A strong ridge-like carina with sharp, square shoulders connects the centres of the radials, and forms a very characteristic, sharply defined band passing around the cup in this zone. Downwards from the centre of the radial, the carina is broken into two halves, each of which passes to the contiguous basal. No other stellate ornamentation appears on any of the plates, except a faint radial striation on the first interbrachial. All the plates, however, are marked with a distinct granulation which is more pronounced on some plates than on others.

The stem.—The stem is composed of thin discs which are alternately large and small. Near the cup, the larger joints are about two mm. in diameter and occur to the number of three in the space of one mm. Distally, the stem tapers rapidly and the joints become more elongated. Externally the stem-joints are round in section: the shape of the internal passage was not observed.

The arms.—The arms are ten in number: they appear to become free and to be provided with pinnules beyond the second distichal. The joints are distinctly uniserial in arrangement and occur to the number of three in the distance of one mm. in the lower portions of the arms. Bifurcation of the arms was observed in one instance only: the division in this case occurs above the sixtieth joint. The present species is distinguished, more particularly, by the strong carina passing around the cups in the radial zone. The lack of stellate ornamentation on the interbrachial plates distinguishes it from *G. decadactylus* and *G. dyeri*, which are, moreover, Cincinnatian forms.

The species of *Glyptocrinus* hitherto described from the Trenton of Ontario are *G. ramulosus*, *G. ornatus* and *G. marginatus*: none of these shows a prominent carina encircling the cup. The small basal plates and slender branching arms of *G. ramulosus* sufficiently differentiate that species. The striking ornamentation of *G. ornatus*, which consists of five or six conspicuous, finely striated ridges radiating from the centres of the plates, serves to distinguish it from the present species. The margined plates of *G. marginatus* and the different arrangement of the interbrachials in that species render impossible any confusion with the present form.

Glyptocrinus circumcarinatus, *sp. nov.*
Type specimen—No. 668 *T, University of Toronto Museum.*
Formation—Trenton.
Locality—Kirkfield, Ont.
Collector—Joseph Townsend.

A FOSSIL STARFISH WITH AMBULACRAL COVERING PLATES.

By George H. Hudson.

(Continued from May number).

The Covering Pieces or Epineurals.

This specimen still retains 23 plates covering the food grooves in such perfectly normal positions that there can be no doubt whatever as to their being strictly homologous with the epineurals of Edrioasteroidea.

On the less developed portion of arm I (plate II. figs. 1, 2, 3 and 6) there are 16 of these and on the mature portion of arm IV. next the disc (plates I, figs. 1 and 3; III, figs. 3 and 4) there are seven more. In addition there are 10 other epineurals which are but slightly displaced and whose proper position may be easily recognized—one on radius III, seven on radius IV and two on radius V. Three other displaced and weathered epineurals are also present.

The most distal epineural on arm IV (the eighth of a series) lies flat on the floor of the food groove and clearly reveals the shape of the arm members of a series. They are pentagonal in outline, twice as long as broad, the two long sides parallel; the ends next the marginals have three angles each, the central one of about 85° and well rounded at the apex; each free end is truncate, having two right angles.

Now when we have an ambulacral groove with straight bordering walls we would expect the epineurals to be placed alternately, their truncate ends against the wall and their pointed ends toward the entrant angles between two neighbors of the opposite row as in Cyathocystis. We also would expect these inner ends to meet with their marginal faces apposed to each other in close fitting valvate closure and the ridge formed by the plates, when closed, to be low and comparatively smooth (plates flush), to secure additional strength against attack.

Our specimen violates every one of these conditions. The epineurals are opposite; their pointed ends against the straight border of the food groove; their thick, blunted, truncate ends apposed to those of their neighbors of the opposite row; their great length allows these ends to touch only by the inner edges of their end faces (closure not valvate); when closed the ridge is high, the angle at the summit being about 65° (plate II, figs. 3 and 6); the closure at the ends is often very imperfect (see 13th epineural in upper row, plate II, figs. 1 and 2 and the 5th epineural in lower row on arm IV, plate III, fig. 4); the plates are too wide to secure valvate closure at their lateral margins and the majority have these margins imbricated and with either the orad or aborad margins under. These plates, in shape and arrangement, are so at variance with what we would naturally expect that they call to mind the double row of flat spines that protect the food grooves in Pentaceros. To derive the latter from the former would seem to require less alteration that that which has already taken place.

Some of these changes might be considered as indicative of a loss of the primary function, but the specialized form of joint and free end and the marked increase in length, breath, and thickness must be taken to indicate that these changes are all adaptations secured by a new function or functions that were added to the primitive one and finally came to surpass it in importance.

Two possible new functions will be considered; the first of these a new method of securing food supply and the second a new aid to locomotion. Before taking up either it will be necessary to make a brief study of the evidences of the muscular system which our specimen possessed.

MUSCULATION.

That the epineurals are arranged alternately with the adambulacrals below them may be seen by an examination of the fourth and sixth epineurals of the lower row in plate III, fig. 4. The position of the eleventh epineural of the upper row in plate II, fig. 1, and the position which the tenth of this series must have occupied will give additional evidence. In the last figure the epineurals have their free ends swung aborad, in the former figure they are swung orad. This indicates that the epineural adductors were in pairs and their origins were in the very prominent, central, elongated, sunken muscle fields which are so clearly shown on the oral surfaces of all adambulacrals except the first of a series. The muscle pits are commensurate with the size and importance of the epineurals themselves. The abductors were also probably arranged in pairs and the muscle fields of their origins were on the oral faces of the marginals. These fields were outside of a highly specialized area, were therefore more diffused and their limits are not recognizable.

As all the adambulacrals were free to move in a direction perpendicular to the oral plane, the attachment of the epineural adductors to them necessitated a series of ambulacral depressors with origins on the aborad ambulacral edges of the marginals. The adambulacral floor could be thus raised or lowered while the epineurals were closed.

Plate II, fig. 5, shows also marked muscle pits on the aborad surfaces of the seventh pair of adambulacrals of arm V, while the photomicrographs made for fig. 7 of the same plate showed but faint muscle pits on the aborad surfaces of the fifteenth pair of adambulacrals. These pits represent the places of attachment of one of a series of three adambulacral adductors for each row. It is very evident that the muscles of the peristomial ring could act as abductors of the older adambulacrals.

On younger portions of the arm the orad—aborad movement of the adambulacrals (allowing the adambulacral jaw to be advanced or retracted) was not permitted, as may be seen by an examination of the fourth and fifth arm marginals of arm II (plate III, fig. 1). The ossicles were here so slightly attached to the carbonized bed of the substratum that an attempt to find ambulacrals and aboral plates resulted in the loss of the 13th adambulacral of the lower row. Further attempt to develop this locality was immediately abandoned but the accidental removal of the single ossicle left a perfectly fresh surface, showing the semi-cylindrical groove in which movement perpendicular to the oral plane was allowed while movement along the ray was prevented. The median vertical ridges on the ambulacral faces of these younger marginals may be clearly seen. The younger and weaker ambulacral adductors were thus protected from the pull of the peristomial ring. The change in outline of cross section of the prismatic flooring pieces, while passing orad, is indicative also of change in function. The very marked increase in curvature of what were once prism angles was in part due to a demand for larger fields for origin and insertion of muscles other than those already mentioned.

FOOD CAPTURE.

That the open epineurals of ciliated food grooves had occasionally the chance to capture animals somewhat larger than the organisms making up the mass of the food, cannot be doubted. When our primitive stellerid abandoned the fixed habit and began to find a more abundant food supply in the ooze of the sea floor such opportunities became more numerous and the covering pieces began to develop along new lines.

Let us suppose that we have an original circlet of ten enlarged peristomial epineurals, that these occasionally capture and crush small organisms and that they can be drawn inward by adductors (turning on their long axis—a power possessed by all the epineurals of our specimen) and thus carry such particles to, and press them into, the oral cavity. The second pairs of epineurals could also occasionally capture organisms and thrust them under the peristomial circlet or move orad over this circlet when it was in the indrawn position. The first circlet might thus come to function as secondary jaws, moving on their inturned edges over the sloping oral surface of the adambulacral jaws and developing permanent sliding joints. At a later stage the second epineurals would come to be placed permanently over them and assume the original functions of the first circlet.

Now, in our specimen we have throughout the food groove an epineural for every adambulacral save the first. Orad of the first, however, and resting on it by a marginal face is a single plate which we must consider as a modified epineural of an earlier circlet which has wholly lost its original function.

How profoundly this earlier circlet has been modified may be seen by noting the present form of these plates. The marginal faces in contact with the adambulacrals have been widened and beveled to make a good sliding joint fitting the V shaped groove formed by the contact of the latter. This may be seen in plate III, fig. 2, a side view of a pair of these plates and taken before they had been more fully freed from the matrix. The faces apparently resting against the "torus?" are also widened. The outer marginal faces are narrower and consist of an aborad short portion and a longer orad portion that appears to be of the nature of a rounded, blunt, movable spine. The remaining marginal face of each plate shows an inner heavy blunt tooth below the smaller rounded tip of the spine-like piece. The broad contiguous face of each pair was flat and close fitting.

As the plates of the secondary jaws assumed more and more an indrawn position the second pairs of epineurals moved permanently orad and met over them. The secondary jaws being powerful organs of defense, a complete covering of the peristomial cavity by the second circlet was not necessary. This new circlet (marked as first epineurals in our figures) was thus free to increase the diameter of the central capturing ring, which they did by shifting their attached ends farther aborad. We find that they have encroached on the higher oral face of the interradial marginals and secured thereon well marked excavations with a clearly defined semicircular aborad border (plate

III, fig. 1). The proximal ends of each pair of these plates were cut to form a half circle and they could be drawn either aborad to the ridge, or some distance orad. We here have another ring of sliding joints aiding in food capture. The distal ends of these epineurals seem to have retained a primitive central angle that enabled them the better to hold their prey or to break the shells of small mollusca. molluscoidea or crustacea. These plates could be raised or lowered and each pair could open and close like a pair of pliers. The shifting of the position of their proximal ends allowed them to assist in the capture of eggs, young, or adult organisms up to 4 mm. in diameter and enabled them also to press food into the space where the secondary jaws could act upon it.

The epineurals marked (2) were directed orad and their attachments were along a diagonal edge which also rested in a somewhat elevated socket on the oral edges of the interradial marginals. The oral faces of these marginals also show the fields of origin of the abductors of these more specialized first and second epineurals.

The remaining epineurals could function somewhat after the manner of a duck's bill. for they could grub in the ooze and press the mud out between the plates. When the epineurals were all closed the captured and separated food contents could be moved orad by a progressive wave movement (trough and crest) of the ambulacral floor. The ability to shift the free ends of the epineurals orad or aborad and to move either half of an ambulacral floor would assist in the process. The evidence for this manner of food getting is abundant and should be conclusive.

THE HOMOLOGY OF THE PERISTOMIAL PLATES.

We must note that to carry the alternate arrangement between epineurals and adambulacrals to the interradial mouth angles and complete the paired series of epineural adductors would require the presence of either a single unpaired epineural or adambulacral in each interradius. If the primitive circlet of peristomial covering pieces were five in number the "torus?" may represent this primitive unpaired epineural. Figs. 3 and 5 of plate III (interradius 2) suggest such a derivation. If on the other hand the odd plate was an adambulacral our "torus?" might represent that plate. In the figures, however, it seems too far removed from the adambulacrals to belong to the series. What we have called the oral might be an odd adambulacral and in this case we should consider the interradial marginal to be the true oral. If the oral surface (left uppermost after death) sank into contact with the ossicles of an aboral circlet then our "torus?" might be an aborad interradial and the plate uncovered in interradius 1 (plate III, fig. 3) is strongly suggestive of such a plate with a genital opening. We should consider also the possibility of developing, from our "secondary joint", a true Ophiuroid torus with its spines. These suggestions are made here for the purpose of calling attention to the fact that we are in need of a consistent terminology that can be applied to all classes of Echinoderms and because of the evidence which this specimen, as yet only partially "developed", has to present concerning this matter. It is suggested that we may inaugurate a better terminology by using 'epineural" for "ambulacral" in the Crinoidea, and using a new term altogether for the term ambulacra as now used in the Asteroidea. Could I have used "ambulacra" in place of "adambulacra" in this paper I should have been glad to do so but the plates for which I would have used this term are not the ambulacra of Asteroidea.

LOCOMOTION.

The relatively short arms, the small number of marginal ossicles, their flat and close fitting contiguous faces, the absence of re-entrant angles for muscle fields and the marked broadening of the arm as it approaches the disc all speak of rigidity. The arm could neither be used for feeding after the manner of Asterias nor could its lateral bending alone have been its means of locomotion.

On the other hand if progress was by means of tube feet with suckers, those long projecting epineurals would make a very effective drag. We may esily recognize the difficulty of moving this veritable harrow over seaweeds or dead shells on a hard bottom unless the epineurals could so shift their position as to adapt themselves to motion in any direction. If they could thus give passive aid there is no reason why they might not give active aid. Tube feet with suckers would be useless on soft bottoms, such as that on which our specimen died, while its spade like epineurals might be used to shift its position over its feeding ground.

Astropecten affords us an important suggestion. "Owing to the loss of suckers it is unable to climb over rocks and stones like the ordinary species, but it runs over the surfaces of the hard sand in which it lives by means of its pointed tube feet."[1] The long and heavy epineurals moved by powerful muscles ought at least to be as effctive agents of locomotion as pointed tube feet.

That some arm movement was allowed is shown by arm I in fig. 3 of plate I. The tip is not only turned toward one side

[1] McBride, "Cambridge Natural History" Vol. I, Page 468.

but it was curved toward the aboral surface. The joints formed by contact of the first arm marginals with the interradial marginals are all gently concave aborad and suggest sliding or shallow ball and socket joints. The movement may have been something like that of the Ophiuroidea, the side arms being lifted and set forward and the epineurals holding like anchors or helping in the forward thrust. In that case our orientation, based in part on arm position, may be in fault. Aside from the ability of the long epineurals to open widely and close, the angle at the fixed end of about 85 degrees indicates an ability to swing their free ends through an arc of some 95 degrees in a radial direction. We have already noted that the preserved plates on the two arms are set in opposite directions if considered radially. With reference to the environment, however, they are set in the same direction and are in the position we should expect if they had been used to assist in thrusting the creature in the direction of the third interradius.

SOME GENERAL CONSIDERATIONS.

We all know that the more primitive Echinodermata possessed food grooves with covering plates such as we find in Cystidea, Crinoidea and Edrioasteroidea. In 1907[1] I described the covering plates in Parablastoidea (Blastoidocrinus) and in 1911[2] after further work on the same species I endeavored to show that with regard to Pentremites we must "accept Doctor Carpenter's contention that the mouth, food grooves and pores were covered with small but well fitting plates." We now have found undoubted covering plates in the Stelleroidea.

I desire to point out that the food groove with a double row of flooring plates covered by a double row of epineurals and flanked by one or more marginal plates on either side is a very primitive type of food groove and I believe that *Protopalaeaster narrawayi* not only points out the fact that the Stelleroidea arose from such a type but that the Echinoidea also had a similar parentage.

With so simple a form before us we must ask ourselves if the ambulacra and interambulacra of Echinoidea and the "vertebral ossicles" and "lateral arm plates" of Ophiuroidea are not strictly homologous with the adambulacra and marginals of our type and of the Edrioasteroidea.

The very evident specialization of the peristomial covering plates of *P. narrawayi* for food capture and mastication would

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[1] "On Some Pelmatozoa from the Chazy Limestone of New York." In New York State Museum Bulletin 107, p. 112.

[2] "Studies of some Early Seluric Pelmatozoa." In New York State Museum Bulletin 149, p. 208.

suggest also that the Dental Apparatus of the Echinoidea had a similar origin. The still greater specialization here lead to an early loss of the littie used epineurals of the outer portions of the ambulacra. Covering plates or epineurals in Echinoidea were undoubtedly once present and if not already found we may with every reason still expect to find them in older members of this group.

The absence of the usual members of an aborad skeleton and the presence of the shifted interradial may lead others to consider that we are viewing the aborad face of the oral skeleton. This would make Stelleroid ambulacra of the plates here designated as epineurals. I may say that I have myself entertained this idea only to reject it and I am prepared to defend my position.

THE EVOLUTION OF THE WORLDS.

BY J. S. PLASKETT, B.A., F.R.S.C., THE OBSERVATORY, OTTAWA.

(Continued from page 34).

And now what happens when the particles begin to move towards the centre of gravity. Work is done by them and, as the form that work done eventually takes is heat, it is evident that, as the nebula condenses under its own attraction, the temperature rises, it grows hotter. A very striking example of condensation accompanied by heat must have been often noticed by those who use automobiles or bicycles. When air is pumped into the tires, the pump becomes quite hot. Possibly some of you have put this down to friction but you would find it impossible to generate much heat by running the plunger up and down in the open. You push the air particles closer together, do work on them, which is converted into heat and the temperature rises. On these two laws, that of gravitation, and that of the transference of work into heat is based the whole scheme of stellar evolution. Gravitation is the force that impels the particles to do the work that is transferred with heat. As condensation of the nebula proceeds it grows smaller, approximates in form to a sphere, gets hotter and hotter and becomes star or sun-like in its form and temperature.

It may be as well to digress for a moment and try to get a clear conception into our minds as to the physical condition of the stars. The great majority of the stars or suns are entirely gaseous, composed of incandescent vapors at enormously high temperatures, our sun about 11,000°F., while the white and blue stars are much hotter. The temperature cited is that of the outer visible radiating surface, that of the interior must be inconceivably hotter. Such enormous differences of temperature between the stars and the absolute zero—460°F. of space must inevitably produce a turbulent seething system with uprushes and outbursts of the hotter vapors from the interior producing violent eruptions examples of which, though probably on a comparatively mild and small scale are given by the solar prominences.

Try and picture to yourselves such a body as I have described. A turbulent seething mass of gases and vapors at a temperature even on the outside several times as high as we can get on the earth and of almost inconceivable size up to 50 million or more miles in diameter. Even the most vivid imagination must fall far short of the stupendous reality.

Having this picture in our minds let us return to the nebulae and before going on with their development let us also have in our minds their appearance. I have a number of photographs of the nebulae, made by reflecting telescopes, which show us much more than can be seen visually and indicate the varied and complex structure of these objects.

Starting then with a nebula of comparatively simple form, whether gaseous or meteoric in character is immaterial, as the result will be the same, we have it condensing and growing smaller under the action of gravity and hotter under the conversion of work into heat. As the temperature rises it begins to glow, the more volatile elements are vaporized it becomes more nearly spherical in form and is a deep red star giving a banded or fluted spectrum, indicating the presence of chemical compounds only existent at moderate temperature. As condensation proceeds the body gets hotter and yellower, the flutings disappear from the spectrum, and large numbers of metallic lines, characteristic of the second type of spectrum, similar to our own sun, appear. At this stage the star is still very tenuous, probably considerably less dense than our own atmosphere, and at a temperature of about 10,000°F.

Further condensation with its resultant increase of temperature has the effect of driving to the outer atmosphere the more volatile and lighter elements such as hydrogen and helium and thus diminishing and suppressing the metallic lines resulting in a much simpler spectrum containing very broad and dense hydrogen lines and a few faint metallic lines and in some stars the hydrogen lines only. The star is now white or bluish white in color the temperature is from 15,000° to 18,000° F., and if the body is of moderate size, about the same as our sun, it has reached the height of its evolution, its maximum temperature;

and from now on, through condensation continues the temperature begins to fall. If, however, the star is very massive, the temperature rises still further and we have the lines of helium appearing with occasionally silicon and at the still higher temperature of 20,000° F. and over.

From this period onward the temperature begins to fall, very slowly of course, with pauses, and yet with a downward trend. The star is shrinking gradually, becoming denser but owing to its density the shrinkage is not so great, the quantity of heat produced does not quite equal that radiated, and the temperature must inevitably fall. Hence it becomes yellower and passes through the same or nearly the same spectral types as in its ascending phase. It is believed that our sun is on the descending scale of temperature, is at a stage where the change is very gradual, where the loss of heat through radiation is nearly neutralized by that gained through shrinkage. It has been calculated that a contraction in its diameter of 300 ft. a year is sufficient to compensate for the heat lost by radiation. At that rate in some 12,000,000 or 15,000,000 years it will be so dense as to be incapable of further contraction, will then relatively rapidly solidify and cool down and become a dead sun while its attendant planets will soon reach the temperature of outside space—460° F. and all life will become extinct. This comparatively short time that must have elapsed between the time when our globe was in a molten condition and the present, a time which according to the contraction theory can not be more than about 50,000,000 years and which is much too short for the geologists who require the earth to be hundreds or even thousands of millions of years old, may be indefinitely extended on the assumption of the presence of a comparatively small quantity of radio-active material. Even supposing that the energy given off by substances like radium played a very considerable part in compensating for the enormous loss due to radidation yet it is inevitable that finally there must be loss of temperature and gradual cooling down of all the stars.

The plan of evolution here developed which postulates both an ascending and descending scale of temperature differs from that generally held which assumes that the development is from the nebulae to the white and blue stars without intermediate stages and then by descending stages to yellowish and red stars and extinction. Although such a plan, requiring both ascending and descending scales of temperature was formulated by Sir Norman Lockyer many years ago it did not receive much support and it is only within the last year or two that it has come into favor chiefly by the evidence collected from many sources by Dr. H. N. Russell of Princeton University.

As we have seen, the whole tendency of stellar evolution is towards a loss of energy, a cooling down, and eventually all the stars we now see will become dead and invisible; and, unless there is some means of replenishing this energy, the whole universe will get to one level of coldness, invisibility, and deadness. Do we know any means by which such a dead system may be revivified? So far as any energy from within each body is concerned, no. Nevertheless, each of these bodies contains an inconceivably vast store of kinetic energy, energy of motion. They are all moving in all directions with velocities varying up to about 200 miles per second on the average about ten miles a second. Although they are relatively small as compared with the vast distances between them, nevertheless in the hundred million or so of stars in the visible universe, it is certain that some pairs will come within range of each other's attraction, will be drawn towards each other with constantly increasing velocity and will, under certain conditions, collide either directly or with grazing contact. What will then happen? We know what would happen if two projectiles from modern cannon, each moving with a velocity less than half a mile per second and weighing less than a ton were to collide. They would be practically destroyed and made intensely hot. We cannot conceive the destructive effects of the collision of two bodies, billions upon billions of times as massive as our cannon balls, and moving, as they would be at the instant of collision, about a thousand times as fast. They would certainly be entirely vaporized with explosive violence and scattered over an enormous space and we would have again a nebula which would undoubtedly pass through the process of evolution already described.

This is a very fascinating hypothesis, that the universe contains in itself the forces which will keep it in existence, in undiminshed glory. Although we do know that such collisions will occur and have occurred, we do not know whether they are of sufficient frequency to renew the loss of energy constantly going on. That such collisions occur is attested by the appearance of new stars (Novae) which come from time to time. The most notable in recent years (1907) was in the constellation Perseus. It was discovered by a Dr. Anderson of Edinburgh, who only a short time previously discovered a less striking Nova; it suddenly appeared where no star had been previously, blazed up in the most spectacular manner so that in a few hours it was brighter than any star in the sky, and then nearly as rapidly faded. It now has the appearance and gives the spectrum of a nebula. There can hardly be any doubt that these novae are due to collisions and that after the vapour has cooled down they become nebulae ready to again develop into suns.

We may be able to roughly compute the probability of such collisions maintaining the energy of the universe. We may assume that the time required for a body to be developed from the nebula, pass through all its stages to extinction, is of the order of 500,000,000 years. If we further assume that there are 100,000,000 stars in the visible universe it is evident that if a new star and in consequence a nebula were to appear every five years, it would suffice to maintain the universe at its present brillancy. As a matter of fact, there seems to be no doubt that, from the past few years, new stars have appeared at intervals of from 5-10 years, which, allowing for the fact that the less brillant of such objects may easily escape detection, seems sufficient to establish a continuous cycle of development of the universe.

Hitherto we have considered the evolution of the stars or suns themselves from the primal nebula, and have passed over, what is fully as important from our standpoint, the formation and development of planetary systems. Now that we have, I hope, obtained some idea of the methods and laws governing the formation of suns, we will have to consider those relating to the attendants of the suns, the planets, and we will find that the same principles apply. We know, of course, that our own sun has a number of planets revolving around him, and travelling with him in his journey through space but we have no means of knowing except by analogy whether other stars are similarly accompanied for even the largest of telescopes could not possibly detect planets like ours. We do know that the double stars, pairs of suns revolving around one another, can not have attendant planets as the perturbations would soon cause them to be drawn into one or other of the pair. The latest estimate places the proportion of double stars as nearly one-third of the whole. Of the remaining two-thirds, it seems probable that the conditions, which gave rise to planets in our own system, should be effective in many if not most of them, and there are likely many millions of planetary systems throughout the universe.

The history of the development of planetary theories is a most interesting one, but I have not time to more than briefly touch upon it. Although some vague and curious notions were entertained by the ancients, it was not until the middle of the eighteenth century that Wright of Durham, England, published a theory of the universe. This was read by the young philosopher, Kant, who at once turned his brillant mind to the problems of cosmogony, and in 1755 published a treatise on the subject, marked by the beauty and generality of its treatment, but faulty in some of its arguments from his imperfect knowledge of physical laws.

The theory of the evolution of the solar systems commonly called the nebular hypothesis, which held undisputed sway for nearly a century, and which still, in spite of many contradictions recently discovered, occupies the premier position in the minds of scientific men generally, was enunciated by the great French scientist, Laplace in 1796.

Laplace called attention to the fact that all the motions of rotation and revolution in the solar system then known were in the same direction and almost in the same plane. He computed that the probability of this being a mere accident was about one part in 500,000,000, conclusively showing it to be due to some initial state from which the system had developed.

This theory as amended by himself, and with some later additions is, that our system was originally a nebula probably somewhat condensed towards the centre, which extended beyond the orbit of the farthest planet, that it rotated as one body in the direction in which the planets now move and that it gradually condensed and got hotter under the mutual gravitation of its parts, exactly as we have already postulated. Simultaneously with the contraction, the rate of rotation necessarily increased from a well known dynamical law. After some time the centrifugal force at the equator became equal to the central attraction, and a ring of nebulous matter was left off, the remainder continuing to contract and leave off rings at the distances of the planets. The rate of rotation and the temperature of course increased with the contraction.

The rings left off scarcely could have had a uniform structure and, separating at some point, would coalesce forming the planets, while the satellites would be formed from rings left off from the contracting planets, Saturn's ring being an example still remaining. By the time these rings had formed planets and these latter had cooled down to a solid condition, the central part, the sun, would have gone through some of the changes outlined previously, and would have reached its present condition of approximate equilibrium, the loss of heat due to radiation being compensated by the gain due to contraction.

Such is the nebular hypothesis which remained unquestioned for more than half a century, and which has exercised an incalculable influence on the science and philosophy of the nineteenth century. Unfortunately the nebular hypothesis, beautiful and complete as it is, can not, in the form it was left by Laplace be made to account for the facts as they are now known. It has, since about 1860, been subject to continuous attacks and if now accepted must be in a considerably modified form. A brief statement of the phenomena in agreement and disagreement with the theory may be of interest. In agreement:—

1. The planets all revolve nearly in the same plane and in the same direction.

2. Their orbits are all nearly circular.

3. The sun and the planets, so far as known, rotate in the direction in which the planets revolve.

4. The planes of the equators of the planets and of the orbits of their satellites are nearly coincident with the planes of their orbits (Uranus and Neptune excepted).

5. The satellites revolve in the direction that the primaries rotate (9th of Saturn and 8th of Jupiter exceptions).

6. According to the contraction theory of the sun's heat, this body was once vastly larger than at present.

Some facts inconsistent with the Nebular Theory. :—

1. The orbits of the asteroids are contradictory to the theory.

2. The rapid revolution of the inner satellite of Mars and of the particles of the inner ring of Saturn can not be satisfactorily explained.

3. The presence of light elements in the earth is not to be expected.

4. A series of rings could not have been left off.

5. A ring could not have condensed into a planet.

6. The retrograde revolutions of the 9th satellite of Saturn and the 8th of Jupiter contradict the theory.

Various modifications of Laplace's theory to meet these objections have been brought forward by Roche, Faye, Ligoudes, Ball and others, the chief of which dispenses with the troublesome process of ring formation and condensation and starts the planets by condensations around accidental nuclei in the parent nebula. The most exhaustive criticism of the nebular theory is that by Moulton and Chamberlin, published in 1900, who, by combining observed facts with dynamical principles show that in its present form it fails to account for many of the phenomena of the Solar System.

An alternative hypothesis has been developed by these writers called the Planetesimal or Spiral Nebula Hypothesis. It probably owes its origin to the fact that the researches of Keeler with the Crossley Reflector at the Lick Observatory showed that the predominant form of nebula was the spiral, and that no known nebula has a form agreeing with Laplace's Ring Hypothesis.

The authors of this theory assume that our system was originally a small spiral nebula and explain the formation of the spiral nebulae by the collision theory already dealt with, or rather by the particular case of collision in which the contact is only grazing, or in which there is only a near approach. The chances of these two latter conditions are of course much greater than direct collision. In such cases the tidal strains induced, added to the eruptive tendencies of highly heated gaseous bodies, will cause masses of matter to burst out and recede to great distances. They show mathematically that the tendency will be to assume a two armed spiral form; and the secondary nuclei with the planetesimals, as the finer matter is called, will revolve in elliptic orbits around the central sun. The secondary nuclei at irregular intervals in the arms of the spiral will gradually attract the smaller finer matter in these arms, and will, in doing so, tend to have their orbits made more nearly circular and become the planets. Explanations are given by this hypothesis of many of the difficulties of Laplace's theory, but only in a qualitative way, and, it seems to me, it has yet to stand the test of the quantitative criticism that was so long directed at the older hypothesis.

More recently, about two years ago, a series of abstruse papers dealing with the effect of a resisting medium in modifying the orbits of planets and satellites has been published by T. J. J. See but so far as I can learn the author's opinion of them is much higher than that of any one else's.

The question of the origin and development of our own system, and of other systems as well, is still therefore in an unsettled condition. On some things all are agreed, the chemical unity of the cosmos, the nebular source of the whole system and its development under the action of gravitation, the transference of work into heat and other dynamical laws form common starting grounds and are in reality of course the essence of the whole matter. Whether the nebula was gaseous or pulverulent, planetary, spiral, or any other form, how it became ordered and organized and how it collected into spheres, the wisest are perplexed to decide. There seems to be no question that, while the Laplacian hpyothesis contains the germ of the truth, the process of development was by no means so simple and direct as was therein stated, and that we do not yet know the precise mode of development of the solar system.

And yet, behind and above and before all this development and evolution we have been talking about, even the most sceptical must admit the presence of a Supreme Power, a Power which must have created in the first place, and a Wisdom and Beneficence which so ordered and arranged the development of Creation as to make it the result of the action of natural laws. And yet not less wonderful is the Love, which created the human mind and gave to it the power, though inhabiting for only a few years this minute planet, the attendant of a comparatively insignificant star of the system, to reach out to the inconceivable depths of space and reduce the apparent confusion of stars to orderly systems, to deduce the laws which govern these systems and thus unify to a certain degree all the wonderful phenomena of suns, planets and comets, stars, nebulae and clusters into one whole. We are surely all convinced that it will not rest there, but will eventually still further unravel the mystery of the universe.

EXCURSIONS.

The first outing for the Spring of 1912 was held on Saturday afternoon, the 27th of April, to Beechwood. The weather was fine at first, and a large number of old and new members and leaders gathered at the place of meeting, and then walked along Beechwood Avenue to the woods on the left hand side of the road. Only a few of the early spring flowers were out, but they were welcome as old friends, and eagerly gathered. It is a well-explored locality and no new or rare plants were discovered, but some plants in their early stage of growth presented an unusual appearance that would puzzle all but an expert. This was exemplified afterwards when a leader in botany passed around a tiny seedling and no one recognized it. Then he said it was a cedar. The name sounded like "Sedum", and the needle-like leaves did not look unlike the linear leaves of some of the stone crop family. When he passed around a slightly more matured specimen with the ordinary foliage developing, everyone was able to recognize it.

Unfortunately the weather turned cold and cloudy, and the meeting closed abruptly without a complete list of specimens being named.

E.H.B.

NOTE.

The Riding Mts. of Manitoba will probably be noted in some future day as a game reserve. If present plans materialize a considerable section of the interior of the Forest Reserve will shortly be set aside as a permanent home for big game. Elk, moose, mule-deer, bear and beaver are plentiful. Beaver are so numerous along the Whirlpool and other streams flowing from the mountains that they are actually a menace to the farmers owning meadows. Whole clearings of poplar, log-slides, recently built dams and lodges are to be seen in various places.

J. M. S.

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