

and the position of the apex of the direction of motion has been deduced by analysing the proper motions of the stars. A new determination on different lines (a spectroscopic method) appears in the *Astronomical Journal* (No. 298), and in this Mr. A. D. Risteen, the writer, bases his method on the three assumptions (1) that the stars used in the computation have no tendency to drift in any particular direction; (2) that their absolute velocities do not depend upon their apparent positions in the heavens; (3) that their absolute velocities are not functions of their own directions. Another minor assumption is that the absolute velocity of a star is not a function of the star's brightness. The values he gets for the right ascension and declination are given in the following table, in which we include those of Bischoff, Ubahgs, L. Struve, and Stumpe.

	R. A.	Decl.
Bischoff ...	285°2	+48°5
Ubahgs ...	262°4	26°6
L. Struve ...	273°3	27°3
Stumpe ...	285°1	36°2
Risteen ...	218°0	45°0

The value Risteen obtains shows that the method may prove a very valuable one in future when more stars can be included (here about 42 observation equations are used), and the result he obtains shows that at any rate the reality of the sun's motion (the value he gets is 10.9 English statute miles per second), and that our present knowledge of the direction of this motion is at any rate approximate.

AN ASCENDING METEOR.—Prof. von Niessl has been investigating the path of the meteor that appeared on July 7, 1892, and was seen both in Austria and Italy. The result of this computation has shown that, undoubtedly, the path of the meteor at the latter end of its course (*Naturwissenschaftliche Wochenschrift*, No. 26) was directed upwards. The length of its path measured 1100 kilometres from its nearest approach to the earth surface (68 kilometres above the surface) to the point where it disappeared, which was at a height of 158 kilometres. This is about the first time that the path of a rising meteor has been so accurately investigated.

THE SATELLITES OF JUPITER.—In this column for March 30 of this year we referred briefly to the very important results that were being reaped by Prof. W. H. Pickering, with the help of Mr. Douglas, at Arequipa, with reference to the peculiar forms which the satellites were found to assume at different periods of their rotation. In the June number of *Astronomy and Astrophysics* we have before us a much more detailed account of these and later observations, which seem to have confirmed those made previously in nearly all respects. In this article, which is of some length, the author deals first with the third satellite, the largest and most easily observed of the group. The results of twelve series of observations, taken on seven different nights, each series consisting of six independent observations, gave the value of $-10^{\circ}5$ for the position angle of the major axis, the satellite being on the eastern side of its orbit, and presenting an elliptical disc. The observations for the elliptical phase at the western side were not very satisfactory, owing to bad meteorological conditions, but the results suggested that "they would imply a revolution of the axis about the line perpendicular to the orbital plane, in about the same period as the satellites' rotation upon the axis itself." With regard to the surface features, there seems to be a marking having the appearance of a fork, the angle of the prongs varying from 30° to 60° . Sometimes this forked-shaped feature is turned to the left and sometimes to the right, and occasionally a double fork is seen. The position angle of the axis of the belt gave a value of $+15^{\circ}5$, and when the values obtained on January 1 and 16 are compared with those attained for the major axis on the same dates, they indicate that the two axis are inclined at between 46° to 35° to one another. The attempt to determine the direction and period of rotation indicated that perhaps the period of rotation coincided with that of the revolution of the satellite in its orbit. The surface features on the first satellite consisted of the bands lying in an approximately north and south direction, that on the second of a small patch detected only upon one occasion, and that on the fourth of a broad band (sometimes a narrow line), and also a bright spot recorded several times at the North Pole and once near the south. Later determinations of the period of rotation of the second satellite confirmed the earlier value (41h. 24m.), but sometimes discrepancies in the time of the flattening of the disc still occurred. The direction and period of rotation

of satellite 4 has not been determined, but its disc has been recorded upon fourteen different dates as being shortened in the direction of the plane of its orbit, and upon eleven other days as being circular in form.

After summing up the main facts with regard to these satellites respecting their small density, directions of rotation, changes of shape, &c., Prof. Pickering shows how Laplace's "ring theory" with the following premises, suits the facts:—

(1) Jupiter was formerly surrounded by a series of rings similar to those now surrounding Saturn.

(2) The direction of rotation of these rings was direct, like that of the planet.

(3) By some force, whose cause is not explained, they were shattered, their components uniting, but still retaining the same orbit.

(4) Like the original rings, each satellite still consists of a swarm of meteorites, their consolidation having been prevented by the enormous tides produced in them by their primary.

At the conclusion of this discussion, in which Prof. Pickering takes each point individually, he has drawn up a syllabus regarding the points to which an observer can be most profitably directed in the case of each satellite, subdividing them into grades according to the difficulty of the observations.

TURACIN: A REMARKABLE ANIMAL PIGMENT CONTAINING COPPER.¹

THE study of natural colouring matters is at once peculiarly fascinating and peculiarly difficult. The nature of the colouring matters in animals and plants, and even in some minerals (ruby, sapphire, emerald, and aethyst, for example) is still, in the majority of cases, not completely fathomed.

Animal pigments are generally less easily extracted and are more complex than those of plants. They appear invariably to contain nitrogen—an observation in accord with the comparative richness in that element of animal cells and their contents. Then, too, much of the colouration of animals, being due to microscopic structure, and therefore having a mechanical and not a pigmentary origin, differs essentially from the colouration of plants. Those animal colours which are primarily due to structure do, however, involve the presence of a dark pigment—brown or black—which acts at once as a foil and as an absorbent of those incident rays which are not reflected.

Many spectroscopic examinations of animal pigments have been made. Except in the case of blood and bile pigments very few have been submitted to exhaustive chemical study. Spectral analysis, when uncontrolled by chemical, and when the influence of the solvent employed is not taken into account, is very likely to mislead the investigator. And, unfortunately, the non-crystalline character of many animal pigments, and the difficulty of purifying them by means of the formation of salts and of separations by the use of appropriate solvents, oppose serious obstacles to their elucidation. Of blood-red or hæmoglobin it cannot be said that we know the centesimal composition, much less its molecular weight. Even of hæmatin the empirical formula has not yet been firmly established. The group of black and brown pigments to which the various melanins belong still await adequate investigation. We know they contain nitrogen ($8\frac{1}{2}$ to 13 per cent.), and sometimes iron, but the analytical results do not warrant the suggestion of empirical formulæ for them. The more nearly they appear to approach purity, the freer the majority of them seem from any fixed constituent such as iron or other metal. It is to be regretted that Dr. Krukenberg, to whom we are indebted for much valuable work on several pigments extracted from feathers, has not submitted the interesting substances he has described to quantitative chemical analysis.

I must not, however, dwell further upon these preliminary matters. I have introduced them mainly in order to indicate how little precise information has yet been gathered as to the constitution of the greater number of animal pigments, and how difficult is their study.

And now let me draw your attention to a pigment which I had the good fortune to discover, and to the investigation of which I have devoted I am afraid to say how many years.

It was so long ago as the year 1866 that the solubility in water of the red colouring matter in the wing-feathers of a plantain-eater was pointed out to me. [One of these feathers,

¹ A discourse delivered at the Royal Institution by Prof. A. H. Church, F.R.S.

freed from grease, was shown to yield its pigment to pure water.] I soon found that alkaline liquids were more effective solvents than pure water, and that the pigment could be precipitated from its solution by the addition of an acid. [The pigment was extracted from a feather by very dilute ammonia, and then precipitated by adding excess of hydrochloric acid.] The next step was to filter off the separated colouring matter, and to wash and dry it. The processes of washing and drying are tedious, and cannot be shown in a lecture. But the product obtained was a solid of a dark crimson hue, non-crystalline, and having a purple semi-metallic lustre. I named it "turacin" (in a paper published in a now long defunct periodical, *The Student and Intellectual Observer*, of April, 1868). The name was taken from "Turaco," the appellation by which the plantain-eaters are known—the most extensive genus of this family of birds being *Turacus*.

From the striking resemblance between the colour of arterial blood and that of the red touraco feathers I was led to compare their spectra. Two similar absorption bands were present in both cases, but their positions and intensities differed somewhat. Naturally I sought for iron in my new pigment. I burnt a portion, dissolved the ash in hydrochloric acid, and then added sodium acetate and potassium ferrocyanide. To my astonishment I got a precipitate, not of Prussian blue, but of Prussian brown. This indication of the presence of copper in turacin was confirmed by many tests, the metal itself being also obtained by electrolysis. It was obvious that the proportion of copper present in the pigment was very considerable—greatly in excess of that of the iron (less than $\frac{1}{2}$ per cent.) in the pigment of blood.

Thus far two striking peculiarities of the pigment had been revealed, namely, its easy removal from the web of the feather, and the presence in it of a notable quantity of copper. Both facts remain unique in the history of animal pigments. The solubility was readily admitted on all hands, not so the presence of copper. It was suggested that it was derived from the Bunsen burner used in the incineration, or from some preservative solution applied to the bird-skins. And it was asked, "How did the copper get into the feathers?" The doubters might have satisfied themselves as to copper being normally and invariably present by applying a few easy tests, and by the expenditure of half-a-crown in acquiring a touraco wing. My results were, however, confirmed (in 1872) by several independent observers, including Mr. W. Crookes, Dr. Gladstone, and Mr. Greville Williams. And in 1873 Mr. Henry Bassett, at the request of the late Mr. J. J. Monteiro, pushed the inquiry somewhat further. I quote from Monteiro's "Angola and the River Congo," published in 1875 (vol. ii. pp. 75-77):—"I purchased a large bunch of the red wing-feathers in the market at Sierra Leone, with which Mr. H. Bassett has verified Prof. Church's results conclusively," &c., &c. Mr. Bassett's results were published in the *Chemical News* in 1873, three years after the appearance of my research in the *Phil. Trans.* As concentrated hydrochloric acid removes no copper from turacin, even on boiling, the metal present could not have been a mere casual impurity; as the proportion is constant in the turacin obtained from different species of touraco, the existence of a single definite compound is indicated. The presence of traces of copper in a very large number of plants, as well as of animals, has been incontestably established. And, as I pointed out in 1868, copper can be readily detected in the ash of banana fruits, the favourite food of several species of the "turacin-bearers." The feathers of a single bird contain on the average two grains of turacin, corresponding to '14 of a grain of metallic copper; or, putting the amount of pigment present at its highest, just one-fifth of a grain. This is not a large amount to be furnished by its food to one of these birds once annually during the season of renewal of its feathers. I am bound, however, to say that in the blood and tissues of one of these birds, which I analysed immediately after death, I could not detect more than faint traces of copper. The particular specimen examined was in full plumage; I conclude that the copper in its food, not being then wanted, was not assimilated.

Let us now look a little more closely at these curious birds themselves. Their nearest allies are the cuckoos, with which they were formerly united by systematists. It has, however, been long conceded that they constitute a family of equal rank with the Cuculidæ. According to the classification adopted in the Natural History Museum, the order Picariæ contains eight sub-orders, the last of which, the Cocyges, consist of two families,

the Cuculidæ and the Musophagidæ. To the same order belong the Hoopoes, the Trogons, the Woodpeckers. The plantain-eaters, or Musophagidæ, are arranged in six genera and comprise twenty-five species. In three genera—*Turacus*, *Gallirex*, and *Musophaga*—comprising eighteen species, and following one another in zoological sequence, turacin occurs; from three genera (seven species)—*Corythæola*, *Schizorhis*, and *Gymnoschizorhis*—the pigment is absent. [The coloured illustrations to H. Schlegel's Monograph (Amsterdam, 1860) on the Musophagidæ were exhibited.] The family is confined to Africa—eight of the turacin-bearers are found in the west sub-region, one in the south-west, two in the south, two in the south-east, four in the east, two in the central, and two in the north-east. It is noteworthy that, in all these sub-regions save the south-east, turacin-bearers are found along with those plantain-eaters which do not contain the pigment. Oddly enough two of the latter species, *Schizorhis africana* and *S. zonura*, possess white patches destitute of pigment in those parts of the feathers which in the turacin-bearers are crimson. These birds do not—I will not say cannot—decorate these bare patches with this curiously complex pigment. [Some extracts were here given from the late Mr. Monteiro's book on Angola, vol. ii. pp. 74-79, and from letters by Dr. B. Hinde. These extracts contained references to curious traits of the Touracos.]

Usually from twelve to eighteen of the primaries or metacarpodigitals and of the secondaries or cubitals amongst the wing-feathers of the turacin-bearers have the crimson patches in their web. Occasionally the crimson patches are limited to six or seven of the eleven primaries. I have observed this particularly with the violet plantain-eater (*Musophaga violacea*). In these cases the crimson head-feathers, which also owe their colour to turacin, are few in number, as if the bird, otherwise healthy, had been unable to manufacture a sufficiency of the pigment. I may here add that the red tips of the crest-feathers of *Turacus meriani* also contain turacin.

In all the birds in which turacin occurs this pigment is strictly confined to the red parts of the web, and is there unaccompanied by any other colouring matter. It is therefore found that if a single barb from a feather be analysed, its black base and its black termination possess no copper, while the intermediate portion gives the blue-green flash of copper when incinerated in the Bunsen flame. [A parti-coloured feather was burnt in the Bunsen flame with the result indicated.]

Where it occurs turacin is homogeneously distributed in the barbs, barbicels, and crochets of the web, and is not found in granules or corpuscles.

To the natural question, "Does turacin occur in any other birds besides the touracos?" a negative answer must at present be given. At least my search for this pigment in scores of birds more or less nearly related to the Musophagidæ has met with no success. In some of the plantain-eaters (species of *Turacus* and *Gallirex*) there is, however, a second pigment closely related to turacin. It is of a dull grass-green colour, and was named turacoverdin by Dr. Krukenberg in 1881. I had obtained this pigment in 1868 by boiling turacin with a solution of caustic soda, and had figured its characteristic absorption band in my first paper (*Phil. Trans.*, vol. cliv., 1870, p. 630, fig. 4). My product was, however, mixed with unaltered turacin. But Dr. Krukenberg obtained what certainly seems to be the same pigment from the green feathers of *Turacus corythaix* by treating them with a two per cent. solution of caustic soda. I find, however, that a solution of this strength dissolves, even in the cold, not only a brown pigment associated with turacoverdin, but ultimately the whole substance of the web. By using a much weaker solution of alkali (1 part to 1000 of water) a far better result is obtained. [The characteristic absorption band of turacoverdin, which lies on the less refrangible side of D, was shown; also the absorption bands of various preparations of turacin.] I have refrained from the further investigation of turacoverdin, hoping that Dr. Krukenberg would complete his study of it. At present I can only express my opinion that it is identical with the green pigment into which turacin when moist is converted by long exposure to the air, or by ebullition with soda, and which seems to be present in traces in all preparations of isolated turacin, however carefully prepared.

A few observations may now be introduced on the physical and chemical characters of turacin. It is a colloid of colloids. And it enjoys in a high degree one of the peculiar properties of colloids—that of retaining when freshly precipitated, an immense proportion of water. Consequently when its solution in am-

monia is precipitated by an acid, the coagulum formed is very voluminous. [The experiment was shown.] One gram of turacin is capable of forming a semi-solid mass with 600 grams of water. Another character which turacin shares with many other colloids is its solubility in pure water and its insolubility in the presence of mere traces of saline matter. It would be tedious to enumerate all the observed properties of turacin, but its deportment on being heated, and the action of sulphuric acid upon it, demand particular attention.

At 100° C., and at considerably higher temperatures, turacin suffers no change. When, however, it is heated to the boiling-point of mercury it is wholly altered. No vapours are evolved, but the substance becomes black and is no longer soluble in alkaline liquids, nor, when still more strongly heated afterwards can it be made to yield the purple vapours which unchanged turacin gives off under the same circumstances. This peculiarity of turacin caused great difficulty in its analysis. For these purple vapours contain an organic crystalline compound in which both nitrogen and copper are present, and which resists further decomposition by heat. [Turacin was so heated as to show its purple vapours, and also the green flame with which they burn.] This production of a volatile organic compound of copper is perhaps comparable with the formation of nickel and ferro-carbonyl.

The action of concentrated sulphuric acid upon turacin presents some remarkable features. The pigment dissolves with a fine crimson colour and yields a new compound, the spectrum of which presents a very close resemblance to that of hæmatoporphyrin [turacin was dissolved in oil of vitriol; the spectrum of an ammoniacal solution of the turacoporphyrin thus produced was also shown], the product obtained by the same treatment from hæmatin; in other respects also this new derivative of turacin, which I call turacoporphyrin, reminds one of hæmatoporphyrin. But, unlike this derivative of hæmatin, it seems to retain some of its metallic constituent. The analogy between the two bodies cannot be very close, for if they were so nearly related as might be argued from the spectral observations, hæmatin ought to contain not more, but less metal than is found to be present therein.

The percentage composition of turacin is probably carbon 53·69, hydrogen 4·6, copper 7·01, nitrogen 6·95, and oxygen 27·74. These numbers correspond pretty nearly to the empirical formula $C_{89}H_{81}Cu_2N_9O_{32}$; but I lay no stress upon this expression.

I have before said that copper is very widely distributed in the animal kingdom. Dr. Giunti, of Naples, largely extended (1881) our knowledge on this point. I can hardly doubt that this metal will be found in traces in all animals. But, besides turacin, only one organic copper-compound has been as yet recognised in animals. This is a respiratory, and not a mere decorative pigment like turacin. Léon Fredericq discovered this substance, called hæmocyanin. It has been observed in several genera of Crustacea, Arachnida, Gastropoda, and Cephalopoda. I do not think it has ever been obtained in a state of purity, and I cannot accept for it the fantastic formula— $C_{807}H_{1369}CuS_4O_{258}$ —which has recently been assigned to it. On the other hand, I do not sympathise with the doubts as to its nature which F. Heim has recently formulated in the *Comptes Rendus*.

It is noteworthy in connection with the periodic law that all the essential elements of animal and vegetable organic compounds have rather low atomic weights, iron, manganese, and copper representing the superior limit. Perhaps natural organic compounds containing manganese will some day be isolated, but at present such bodies are limited to a few containing iron, and to two—hæmocyanin and turacin—of which copper forms an essential part.

If I have not yet unravelled the whole mystery of the occurrence and properties of this strange pigment, it must be remembered that it is very rare and costly, and withal difficult to prepare in a state of assured purity. It belongs, moreover, to a class of bodies which my late master, Dr. A. W. von Hofmann, quaintly designated as "dirts" (a magnificent dirt, truly!)—substances which refuse to crystallise, and cannot be distilled. I have experienced likewise during the course of this investigation, frequent reminders of another definition propounded by the same great chemist when he described organic research as "a more or less circuitous route to the sink"!

I am very glad to have had the opportunity of sharing with an audience in this institution the few glimpses I have caught

from time to time during the progress of a tedious and still incomplete research into the nature of a pigment which presents physiological and chemical problems of high, if not of unique, interest.

Let my last word be a word of thanks. I am indebted to several friends for aid in this investigation, and particularly to Dr. MacMunn, of Wolverhampton, the recognised expert in the spectroscopy of animal pigments.

ARTIFICIAL IMMUNITY AND TYPHOID FEVER.

THE announcement by Metchnikoff of his beautiful theory of the "mechanism," as it were, of immunity, which he conceives as dependent upon the activity of the phagocytes or migratory cells of the body in the presence of disease germs, has called forth an immense number of researches in this direction from all parts of the world. But whilst some bacteriologists are engaged upon studying critically the experimental evidence which can be adduced in support of this theory, others are busy with the practical side of the subject and are devoting themselves to the investigation of what substances are capable of conferring immunity upon animals towards any particular disease, and hardly a month passes without some contribution being made to this important inquiry. The great discovery made by Behring that the blood serum of animals rendered artificially immune against a particular disease will, on being introduced into other animals, protect them from an attack of that particular disease, has been confirmed in the case of tetanus or lockjaw by Behring and Kitasato, and as regards diphtheria by Behring. In a more recent contribution Brieger, Kitasato, and Wassermann ("Ueber Immunität und Giftfestigung," *Zeitschrift für Hygiene*, vol. xii. 1892) have, amongst other investigations, succeeded in protecting and healing mice from the evil effects of inoculation with the typhoid bacillus by the introduction of serum obtained from a guinea-pig immune against typhoid. The further study of immunity with reference to this disease is the subject of two elaborate memoirs in the *Annales de l'Institut Pasteur*, November, 1892, by Sanarelli in Siena, and Chantemesse and Widal in Paris, and the ground covered by these two investigations is to a great extent identical. Sanarelli selected guinea-pigs as the subjects for his experiments, these animals being, as is well known, more difficult to protect from the fatal results of typhoid inoculations than mice. He states that if 0·5 c.c. of therapeutic serum be simultaneously introduced with an otherwise fatal dose of a typhoid culture, these animals *without exception* develop no typhoid symptoms, whilst guinea-pigs inoculated with an equally fatal dose of typhoid, but without the curative serum, invariably die. Chantemesse and Widal have pursued the inquiry still further, and have investigated the properties of serum taken from normal animals—that is to say, from animals which have not been infected with or rendered artificially immune from typhoid. Investigations similar to those made previously by Stern have also been conducted with human serum obtained from patients who have recovered from typhoid fever and also from those who have never been attacked by this malady.

Chantemesse and Widal state that whereas the serum derived from typhoid patients and from immune animals invariably confers protection upon infected animals, that obtained from normal animals and from people who have never had typhoid, only exceptionally exercises any curative power. These authors have also compared the degree of immunity induced in animals by the inoculation of curative serum and sterilised cultures of the typhoid bacillus respectively. This latter process is another method of protecting animals against infection, and was resorted to before the experiments with serum were made. It was found that whilst the serum acts rapidly, and confers immunity when administered in small quantities, its protective power only extends over a short period of time, apparently disappearing in less than a month. The sterilised typhoid cultures on the other hand, although working more slowly and requiring to be introduced in larger doses than the serum, endow the animal with immunity over a longer space of time, animals having been found immune even after the lapse of two months. Finally, attempts were made to arrest the progress of typhoid fever in people by the inoculation of therapeutic serum obtained from guinea pigs. So far, however, these investigations have not been successful, and if it be remembered that one point of cardinal importance in the