temperature in the stratosphere, the mean temperature at 18 km. changing from 235° A. in June and July to about 210° A. in November to February. This very large change of temperature causes a seasonal change of pressure gradient between the temperate and polar regions causing easterly winds in the stratosphere in summer and westerly winds in winter.

The rise of temperature above 35 km. in the temperate latitudes is generally attributed to the absorption of ultra-violet solar radiation by ozone in the region 2,900–2,200 A.U. Taking the distribution of ozone in the vertical as worked out by Dobson, Götz, and Meetham, and assuming that the main radiating substance in the stratosphere below 50 km. is water-vapour (in such quantities as we may reasonably expect to be present) and carbon dioxide, it is easy to explain the course of temperatures over Europe deduced from experiments on the propagation of sound from explosions. But the fact that even in Polar regions in winter where the atmosphere has not received solar radiation for weeks, the phenomenon of anomalous propagation of sound is observed shows that the above explanation is insufficient.

Observations of the anomalous propagation of sound in the tropical atmosphere are practically absent, the only known instance in low latitudes being those of an explosion of a train-load of gelignite in South Africa in July 1932, when the sound was heard at a distance of 500 km.

It is obvious that the detailed investigation of the propagation of sound to great distances in low latitudes cannot fail to yield results of fundamental importance to the Physics of the Atmosphere. If the sympathetic co-operation of the Indian Military Department can be secured, the problem does not appear to present serious difficulties. Side by side with this, the problem of the vertical distribution of ozone in our latitudes would also have to be investigated.

The Nature and Origin of Insect Colours.

By M. S. Mani.

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THE nature, origin and significance of the colours of insects have attracted the attention of workers from very early times. Within recent years, great advances have been made along various directions. In this note attention is directed to the recent advances in the subject, in so far as they relate to the nature and origin of insect colours.

The great varieties of colours and markings exhibited by insects naturally fall into two groups: (1) Structural colours, and (2) Pigmentary colours. Structural colours are due to light scattering, reflection, refraction and diffraction effects, as a result of certain peculiarities in the minute structure of the integument of insects and not to special pigments. The pigmentary colours, on the other hand, result from some definite chemical substance such as chlorophyll, melanin, etc. Some insects, as the metallic coloured beetles, owe their brilliant colours to structural peculiarities, while in others like the larvæ of some Lepidoptera, the colours are due to pigments. In most insects, however, combination colours are more prevalent than purely structural colours; pigments exist side by side with structural peculiarities which by themselves are also colour producing. This, for instance, is the case with *Ornithoptera poseidon* investigated by Onslow[1] who found that the green colour of this insect results from a combination of yellow pigment with a structural blue.

It is very difficult to elucidate the origin of structural colours of insects and the results of recent workers differ in several important respects. The white colour of insects is due to the absence of any special pigments and results from the minute structural details of the cuticle irregularly scattering the light waves by multiple reflection and refraction. All the white colours of insects are ultimately to be traced to this source, though it is believed that in a few insects the presence of uric acid in a finely divided state is the cause of white colour. It has, however, been shown that in such cases even after the removal of the uric acid by treatment with dilute alkalies, the white colour remains unchanged. That the white is due to structural peculiarities is

[1] Onslow, H., *Biochem. Journ.*, **1916**, **10**, **26**.

further shown by the evidence obtained by the disappearance of the white when the air in contact with the white parts is replaced by a colourless liquid of nearly the same refractive index as the chitin of insects. The original white is fully restored when the liquid is removed and the chitinous part dried. The recent researches of Mason[2] further show that a colourless cuticle with an irregular reflecting surface is generally white.

The other structural colours of insects are of two types: (1) the iridescent or the so-called "metallic" colours, and (2) the non-iridescent or the non-metallic colours. The elytra of the metallic coloured beetles, the bodies of the enamelled Rose-chafers (*Cetoniids*) and the metallic Chalcids and the scales of certain brilliantly coloured Butterflies, etc., show marked iridescence. The non-iridescent colours are found only in the larvæ of some Lepidoptera.

Considerable attention has, within recent years, been devoted by such workers as Onslow, Suffert and Mason, to the investigation of the iridescent colours of insects and various causes have been regarded as responsible for them. It is now believed that the iridescent colours of insects are caused by:

(i) Diffraction effect due to the presence of a grooved surface or "grating".

(ii) Interference at surface due to simple or multiple films.

(iii) Tyndall effect or scattering of light waves by particles with diameters less than the wave-lengths of light.

(iv) Selective reflection of a narrow band of the spectrum from an opaque and highly reflecting surface.

According to Mason,[3] the brilliant iridescence of the elytra of the Lamellicorn beetle, *Sericea sericea*, is due to the diffraction effect produced by the fine striæ, about 20,000 per inch, running transverse to the length of the elytra. The iridescence of this beetle, owing to the grating being external, is transferable to collodion impressions. There are other insects recorded by Onslow[4] in which the iridescence is not transferable. This, for instance, is the case with the butterfly, *Morpho cypris*, whose scales are brilliantly iridescent. These instances, however, appear to be exceptions among insects and the general conclusions of Onslow,[4] Suffert[5] and Mason[3] are opposed to the view that diffraction plays an important part in insect colouration. Onslow has further observed instances where the collodion impressions of the gratings are brilliantly iridescent while the insects themselves are not.

Diffraction theory is entirely inadequate in the case of the non-pigmented wings of the Dragon flies, where no grating has yet been shown to exist. The view of most investigators in such cases is in favour of the interference theory. Mason's[3] work seems to show that the iridescence in this case is explainable on the basis of multiple thin films separated by a material of different refractive index, a phenomenon which was comprehensively dealt with by Rayleigh.[6] The recent preliminary studies of the writer indicate that the purplish iridescence of the wings of some species of the Chalcid genera *Leucospis* and *Dirhinus* is also due to interference. Scale iridescence is also explainable on the same lines. The result of swelling and compressing the scales and of permeating them with liquids of the same refractive indices seems to lend support to this view.

Mason[3] divides iridescent scales into three types: (1) *Urania* type, (2) *Morpho* type, and (3) *Entimus* type. In the first type of scales all the colour-producing films are parallel to the surface of the scale, overlaid by rib-like structures. The multiple films are either in the upper or the lower lamina of the scale. Suffert[5] demonstrated that in the second type of scales the reflecting films are situated in the rib-like structures themselves at an angle to the base of the scale, *i.e.*, inclined to it. The optical result of such a structure is a brilliant metallic blue. In the third the films are in the interior of the scales and inclined in different directions, so that corresponding colour patches are produced. This type is seen in various species of the Diamond beetles of the genus *Entimus*. Biedermann[7] and Mallock[8] explained the iridescence of these beetles wholly by the theory of thin films. Michelson,[9] on the other hand, held that stratified

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[2] Mason, C. W., *Journ. Phys. Chem.*, 1926, **30**, 383.

[3] Mason, C. W., *Journ. Phys. Chem.*, 1927, **31**, A, 321; B, 1856.

[4] Onslow, H., *Phil. Trans. Roy. Soc.*, 1921, **B 211**, 1.

[5] Suffert, F., *Zeit. Morphol. Ökol. Tiere.*, 1924, **1**, 172.

[6] Rayleigh, Lord, *Proc. Roy. Soc.*, 1917, **A 93**, 565.

[7] Biedermann, W., *Handb. Vergleich. Physiol.*, 1914, **3**, (2 B), 1657-1994.

[8] Mallock, A., *Proc. Roy. Soc.*, 1911, **A 85**, 598.

[9] Michelson, A. A., *Phil. Mag.*, 1911, (6), **21**, 564.

films could not be responsible for the varied colour of scales, and supposed that the effect must be due to diffraction by an internal grating of the scale. He was, on theoretical grounds, able to calculate that the grating should comprise 5,000–10,000 striæ per centimetre and this agreed with actual counts. Onslow postulated that to satisfy this theory it was necessary to suppose that the gratings are of the saw-tooth type, as all the light is concentrated in one spectrum. He did not, however, accept diffraction as the sole cause but concluded that interference by thin films also must play a part in the production of iridescence. Mason,[3] on the other hand, agreed with the earlier workers in explaining iridescence on the basis of the stratified films alone.

Mason's[2] work also seems to show that the blue colour of certain insects, such as the Dragon flies, can be interpreted on the basis of Tyndall effect. According to this view the colour is due to the scattering of light by minute particles of a transparent substance immersed in a medium of a different refractive index to their own. When the size of particles is small as compared with the wave-lengths of light, the shorter waves are scattered, while the longer ones pass unhindered, and the scattered light is of a blue colour.

Experimenting with highly iridescent beetles, Onslow[4] concluded that in some beetles at least the surface film absorbs only a certain part of the spectrum, while the rest is strongly reflected. According to this view the iridescence of these beetles is a case of selective reflection. It is not, however, clear how such a film is formed and Mason[3] has discussed at length the weak points of this theory. According to him the colours of the metallic beetles and the enamelled Rose chafers result from multiple stratified films of considerable thickness lying on the integument. The colours are further supposed to be modified by the action of certain rod-like structures which are arranged in the cuticle perpendicular to the surface.

The main work on the pigmentary colours of insects is perhaps that of Poulton,[10] whose experiments with Lepidopterous larvæ are well known. Recent workers such as Przibram,[11] Glaser,[12] Palmer[13,14] Hungerford,[15] Wigglesworth,[16] Knight,[17] Thompson[18] and Brindley[19] have also contributed materially to our knowledge of the various pigments of the insects.

The pigments most commonly met with in insects are (1) chlorophyll and its derivatives, (2) hæmoglobin and allied pigments, (3) pigments of protein origin, and (4) pigments with purine bases. The spectroscopic investigations of Poulton indicated the presence of chlorophyll and its derivative xanthophyll in the blood and integuments of some caterpillars, such as the green larvæ of some moths. These pigments are absorbed with the food, and do not undergo any marked changes in the blood of the insect. Przibram[11] is opposed to Poulton's conclusions. He does not agree that spectroscopic evidence alone is sufficient to establish the presence of chlorophyll in insects and stresses the necessity of chemical tests. He proposes a new name "Tiergrun" for the green colour of animals. Gerould,[20] however, criticises Przibram's chemical tests as inconclusive and in general agrees with Poulton. In this connection the work of Gräfin von Linden[21] is of special interest; she found that the red and yellow pigments found in the wing scales of the butterflies of *Vanessa* spp. are derived from the chlorophyll absorbed during larval life. The red and yellow colours of Coccinellid and Chrysomelid beetles and the red colour of the Reduviid bug, *Perillus bioculatus*, have been shown by Palmer and Knight[14] to be due to the carotin derived from their food. They also demonstrated the presence of anthocyanin in the vermilion-coloured Aphid, *Tritogenaphis rudbeckiæ*; a similar conclusion was arrived at by Glaser[12] in regard to the red Aphid, *Pterocomma smithiæ*.

Hæmoglobin is of rare occurrence among insects and is only found in some larvæ

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[10] Poulton, E. B., *Proc. Roy. Soc.*, 1873, **B 504**, 417.

[11] Przibram, H., *Pfluger's Arch. Physiol.*, 1913, **153**, 385.

[12] Glaser, R. W., *Psyche.*, 1917, **24**, 30.

[13] Palmer, L. S., *Carotinoids and Related Pigments*, New York, 1922.

[14] Palmer, L. S., and Knight, H. H., *Journ. Biol. Chem.*, 1924, **59**, (A), 443; (B), 451.

[15] Hungerford, H. B., *Canad. Entomol.*, 1922, **54**, 262.

[16] Wigglesworth, V. B., *Proc. Roy. Soc.*, 1924, **B 98**, 149.

[17] Knight, H. H., *Ann. Entomol. Soc. America*, 1924, **17**, 258

[18] Thompson, D. L., *Biochem. Journ.*, 1926, **20**, 73, 1026.

[19] Brindley, M. H., *Trans. Entomol. Soc. London*, 1929, **57**, 5.

[20] Gerould, J. H., *Journ. Exp. Zool.*, 1921, **34**, 385.

[21] Linden, Gräfin G. von, *Ann. Sc. Nat. Zool.*, 1905, **20**, 158.

of the Dipterous family Chironomidæ. It has recently been found by Hungerford[15] in the Notonectid, *Buenoa*.

The most important pigment of protein origin found in insects is melanin; it is commonly found in many groups. Of the pigments with purine bases, uric acid and its derivatives have been shown by Hopkins[22] to be the cause of white and yellow colour of wings of butterflies of the family Pieridæ.

22 Hopkins, Sir F. G., *Phil. Trans. Roy. Soc.*, 1896, **B 186**, (2), 661.

The Mathematical Theory of a New Relativity.*

BY SIR SHAH MUHAMMAD SULAIMAN—A CRITICAL REVIEW.

§ 1. In the two papers published in the *Proceedings of the U. P. Academy of Sciences*, the author claims to have given a modification of Newtonian kinematics and Newtonian dynamics which not only yields all the results deducible from relativity but disproves the assumptions of relativity by deriving results more in accord with observation. He further derives some equations which, superficially, at any rate, look like generalisations of relativistic equations and then deduces Newton's forms as first approximations and Einstein's as higher ones. The first article consisting of Chapters 1 and 2 is devoted mainly to the theory of gravitation and the second article consisting of Chapters 3, 4 and 5 deals with Cosmology and questions of special relativity.

The first of these articles was included by Shapley[1] as "one of the high lights of Astronomy during 1934" in his remarks at the annual dinner of the American Association of Variable Star Observers on October 20, 1934.

It is not clear from Shapley's speech whether such a reference was based on a critical study of the article in question or on a tacit assumption, at its face value, of the claims put forward by the author. Quite recently this article has been critically reviewed by D. R. Hamilton,[2] who, confining himself to Sulaiman's explanation of the advance of perihelion, comes to conclusions which suggest that Sulaiman's work is absurdly erroneous. On the mathematical side not much notice has been taken of the work, the *Zentralblatt für Math.*,[3] satisfying itself with a bare mention of the article.

§ 2. Before undertaking a detailed review, a few general observations might be made. In the first place, it must be remarked that for the author to call his theory a new relativity is to give a completely false impression of his own work. If anything at all, the main thesis of the work is purely anti-relativistic and is vehemently opposed to a principle of relativity in any form whatsoever. Further one is struck by the large preponderance of books on popular expositions of relativity in the references to literature given at the end of the articles and this perhaps gives a clue to the great aversion to relativity which is manifest in the author's work. For, as is well known, the champions of the Theory of Relativity too often delight to bring forward those results of the theory which appear to them to be specially fitted to shock the common sense of people who take statements too literally and relativity is not the only example of a physical theory which appears absurd when its logical consequences are pushed to their very limit. In the list of references placed at the end of the second article it is curious to find the book "*Mysterious Universe*" ascribed to Eddington.

There are some mis-statements of facts in the author's references to relativity the most serious of which are in connection with the observational verifications of the general Theory of Relativity. The author says, (p. 4, Ch. 1), "It is now established that the supposed verifications are not exact," but the references to literature in support of this statement do not refer to the best observational data which are universally accepted. For the advance in the longitude of perihelion of Mercury the observational value is given as 40″·00 per century (the reference being to Eddington's *Mathematical Theory of Relativity*) whereas the best determinations are due to Chazy[4] and give 43″·5 as against the

* The Mathematical Theory of a New Relativity by Sir Shah Muhammad Sulaiman, *Proceedings of the U. P. Academy of Sciences*, 1934-35, Vol. IV, Part 2, pp. 1-36 and Vol. IV, Part 4, pp. 217-261.

1 *Science*, 1934, **80**, 439.

2 *Science*, 1935, **81**, 271-272.

3 *Zentrablatt für Math.*, 1935, **10**, 88.

4 *Comptes Rendus*, 1926, **182**, 1134.