in the backwaters and marginal pools of the lower reaches of larger rivers; we are not only entitled, but we are bound to consider this to have been the case in Greenland, and to base our estimate of its climate in the lower tertiaries upon this view and no other. Now what geologists and physicists ought to do, and what they resolutely won't do, is before going farther afield for cause and effect, to take the map of the world on Mercator's projection, and consider how far, if the Atlantic were a closed ocean to the north, as we know it must have been, the required climatic conditions would be produced. The difference between the arbutus nooks of Ireland on the one side and the desolation of Labrador on the other is brought about solely by ocean currents. At the period of the Greenland floras the arctic currents were excluded, and consequently the whole Atlantic basin was filled with the circulation of equatorial and temperate waters only. The distribution of plants and animals renders it extremely probable that during much of the tertiary period, the antarctic waters were equally excluded from the Atlantic by land connecting Africa and South America. What, under these circumstances, would happen to the climate of the Atlantic littoral? It would, it appears to me, be more philosophical to dispose of this question, which is supported by a weight of evidence, before invoking shifting of the earth's axis, or other hypothetical causes supported by none. J. STARKIE GARDNER.

London, February 13.

An Optical Phenomenon.

IN NATURE, vol. xlvii. p. 303, you mention that "a beautiful optical phenomenon, which has not yet been satisfactorily explained, is described by M. F. Folie in the *Bulletin* of the Belgian Academy." From what follows, it is evidently the same as that described in Tyndall's "Glaciers of the Alps" (Murray, 1860), p. 177 *et seq.* Tyndall gives a description of it in a letter from Prof. Necker to Sir David Brewster, from which I quote the following:—"You must conceive the observer placed at the foot of a hill between him and the place where the sun is rising, and thus entirely in the shade; the upper margin of the mountain is covered with woods, or detached trees and shrubs, which are projected as dark objects on a very bright and clear sky, except at the very place where the sun is just going to rise; for there all the trees and shrubs bordering the margin are of a pure and brilliant white, appearing extremely bright and luminous, although projected on a most brilliant and luminous sky. You would fancy you saw these trees made of the purest silver."

Prof. Necker says that he saw it at the Saleve, which is not so high above the Lake of Geneva as some of our British mountains above the sea, and has no permanent snow near it; so that M. Folie's suggestion, that it is due to light reflected from snow, must be wrong. I have seen it from the König-See, near which I believe there is no permanent snow.

This appearance is always to be seen under the circumstances described, when the sky is clear and bright enough. I had read of it in Tyndall's book, and when in the Alps I sought for and found it. I have often seen a distant approach to it produced by furze bushes, quite near, seen against sunlight, and by leaves against moonlight. JOSEPH JOHN MURPHY.

P.S.—Ruskin somewhere describes this phenomenon.

Belfast, February 6.

Foraminifer or Sponge?

A PAPER by A. Goës "On a peculiar type of Arenaceous Foraminifer from the American tropical Pacific, *Neusina Agassizi*," has just been published in the "Bulletin of the Museum of Comp. Zoology, at Harvard College," vol. xxiii. No. 5, in which the author describes some remarkable forms dredged by the *Albatross* expedition in the Pacific of Central America. They are supposed to be foraminifera, are of leaf-like shape, measure up to 190 mm. in breadth, and are marked by concentric lines of growth. Their interior shows a stroma, consisting of fine chitinous threads, enclosing sand and *débris* of shells. Without wishing to recapitulate all the various points of structure, I will only say that there can be no doubt that these forms belong to Hæckel's deep sea keratosa (see *Challenger* report, vol. xxxii.) from the tropical Pacific, and I should think that *Neusina Agassizi* is identical with *Stannophyllum zonarium*, Hæckel. I happen to have here a *Challenger* specimen of this latter species, kindly lent to me by the Manchester Museum, and its microscopic examination convinces me of the identity of the two forms.

University College, Liverpool. R. HANITSCH.

Unusual Origin of Arteries in the Rabbit.

TOWARDS the close of last month Prof. W. N. Parker reported in your columns an abnormality in the veins of the rabbit, and although the same interest does not attach to it, it may be worth while recording an unusual arrangement of the vessels arising from the aortic arch. In the case which has just come under my notice, the two carotids arise together from the arch, at the point usually occupied by the innominate artery, while the right subclavian artery arises beside the left subclavian, which occupies the usual position. PHILIP J. WHITE.

University College of North Wales, February 7.

Holmes's Comet.

ON February 11, 10h. to 10h. 35m., I re-observed this object with powers of 40 and 60 on my newly-silvered 10-inch reflector. The comet was in the same field as β Trianguli and south preceding that star. I found it fairly conspicuous. The nucleus, or brighter portion of the head, presented a distinctly granulated appearance. Applying a power of 145, single lens, I saw that it really consisted of a number of very small knots of nebulosity, so closely approximating the stellar form that they might readily have been mistaken for one of the very faint, barely resolvable clusters in which the components are only to be caught by glimpses. The multiple nucleus was involved and surrounded with feeble nebulosity, and a faint tapering tail flowed from it in a N.E. direction. I believe that outlying this there was an excessively faint fan-shaped tail, but could not be absolutely certain.

The sky was not good, being lighter than usual, with suffused mist. On February 12, at 10h. 15m., I picked up the comet again, but details were invisible, owing to the veil of thin cloud overspreading the N.W. sky at the time.

Bristol, February 13. W. F. DENNING.

HELMHOLTZ ON HERING'S THEORY OF COLOUR.

THE following translation of the critical account given by von Helmholtz of the colour-theory of E. Hering, in the new edition of his *Handbuch der Physiologischen Optik*, commencing at page 376, has been made by Prof. Everett for NATURE. The translator aims at clearness rather than literal rendering, and three obvious misprints in the paragraph on the transformation of coordinates have been corrected. "Lambert's colour-pyramid" is another name for the "cone of colour" described in Maxwell's papers and in § 1074 of Everett's "Deschanel."

This much-talked-of theory is a modification of Young's theory, which, by the choice of other fundamental sensations, endeavours to give better explanations of what it regards as immediate facts of internal observation. It assumes three elementary sensations, related to three different parts of the nerve-apparatus or "visual substance." Two at least of these physiological processes exhibit the opposition of positive and negative. One of the three "visual substances" gives in the condition of excitement the sensation of white, and in the condition of rest the sensation of black. The second gives the two sensations of blue and yellow, which are accordingly designated "opposed colour-sensations." The third gives the other pair of "opposed colour-sensations," red and green. But by "red" is denoted not the colour usually so called, but the complementary of green, which is purple.

It is possible to specify "elementary sensations" (in the sense in which we have previously defined the term) which would correspond to Hering's elementary sensations, and would be capable of giving by their combination all other colour-sensations. If we take three rectangular axes of coordinates, x, y, z, as the edges of Lambert's colour-pyramid, x corresponding to red, y to green, and

z to violet, Hering's coordinates u, v, w will have the values

$$u = \frac{x+y+z}{\sqrt{3}}, \quad v = \frac{x-z}{\sqrt{2}}, \quad w = \frac{x-2y+z}{\sqrt{6}}$$

u denoting the white element, and being measured along the axis of the pyramid; w denoting the red-green element, and being measured at right angles to the axis of white, in the plane containing the green edge of the pyramid; v denoting the yellow-blue element, and being measured at right angles to the plane of u, w.

Positive values of w correspond to purple red, and negative values to green. Positive values of v correspond to yellow, and negative values to blue.

I give these equations in this definite shape for the purpose of showing, by a definite system of representation, that the arbitrariness which attends the choice of three colours, in terms of which the rest are to be specified, affords sufficient latitude to admit of the employment of three such different specifying elements as are adopted by Hering.

If only positive values of x, y, z are to be admissible, the expression for u shows that every kind of light must excite the white sensation positively, and consequently that no kind of objective light can produce a pure sensation either of the red-green or of the yellow-blue kind. Hence the pure unmixed "opposed colour-sensations" are such as we never have had or can have, and are separated from all colour-sensations that we have ever had by a much wider gap than the pure sensations which Young's theory supposes, although these latter extend somewhat beyond the range of objective colours. By subjecting portions of the retina to special influences (as we shall explain in treating of after-images) we can at least approximate to Young's elementary sensations; while these same methods, when we attempt to approximate to Hering's pure sensations, give results opposite to what his theory would lead us to expect.

Hering assumes, in accordance with the brief expression of his theory in the above equations, that white light excites only the white-black visual substance and excites it always positively; that yellow light, besides doing this, excites the blue-yellow visual substance, as does also blue light, but in opposite sense. On the other hand, when blue and yellow lights are in exact equilibrium, they have no action on the blue-yellow visual substance.[1] Similar remarks apply to the excitements of the red-green visual substance by red and green light.

The sensation of luminosity is identified by Hering with the sensation of white. He accordingly maintains that the pure sensation of blue or of yellow involves no sensation of luminosity. I must confess that personally I can form no conception of a colour which has no degree of less or greater luminosity, and therefore think such an abstraction not tolerable in a system which, on other points, makes its appeal to the immediate testimony of inner consciousness, and claims by this means to establish its superiority to other systems.

Differences of intensity must, however, occur in the opposed colour-sensations if they involve no difference of brightness. In comparing saturated blue with equally luminous pale blue, Hering would regard the white sensation as equally intense in both, but the blue sensation as stronger in the saturated blue.

As the physiological basis of the "opposed colour-sensations" Hering takes the two opposite processes of organic change, namely, the decomposition of the organic mass by activity, and its restoration under the influence of the circulation of the blood, which carries oxygen stored up in it and feebly united with it. The former process is called *dissimilation*, and the latter *assimilation*. Which of the two opposed sensations corresponds to dissimilation and which to assimilation is left undecided, both in the case of blue-yellow and of red-green. The physiological improbabilities of this assumption have in part been pointed out already, and we shall return to the subject in treating of after-images.

This assumption of double nerve-working was originally applied by Hering to the white-black visual substance also. At the present time he adheres to the hitherto-received doctrines of nerve-physiology to the extent of holding that, in the case of this substance, all light excites only dissimilation and the sensation of white; and on the other hand want of light produces only assimilation and restoration of excitability. That during this latter process a sensation of darkness is experienced, all are agreed. The difference is purely theoretical. According to the older view, which I have defended, we must, in order to perceive that there is luminosity in a particular part of the field of view at a given time, be able to distinguish at another time that this perception is wanting. This perception that a sensation which might be there is not there contains in itself a testimony as to the condition of the organ at the time, which is different from all sensations of incident light; and in this sense we call it also a sensation—the sensation of darkness.

Hering, on the contrary, maintains that the sensation of black must have its own special physiological basis of excitation, and seeks it in assimilation, going on in the white-black visual substance.

From the foregoing account the reader will gather that Hering's theory, if we overlook its physiological views, is able to explain all hitherto established facts of colour mixture as well as, but not better than, Young's theory. It differs only in its special choice of elementary excitations; and this choice, if we admit negative values of them, suffices for expressing the facts, just as any axes of co-ordinates suffice for a problem of solid geometry.

Hering's objections to Young's theory reduce themselves, in his latest statement, to the following:—

"In the Young-Helmholtz theory, the assumption of the three elementary colour-sensations is *à priori* repulsive, because these sensations are not presentable; and notoriously, according to necessity, now one set and now another set of elementary colour-sensations are assumed."

As to this, I have already remarked that the fundamental sensations of Young's theory, in so far as they differ from objective colours, can be approximated to, by the method of partial fatigue of the retina, much more closely than Hering's pure opposed-colour-sensations. If different upholders of Young's theory have made different assumptions as to the three primary colours, and have assigned different weights to various facts which bear on the distinction, this affords no justification whatever for the imputation that they have changed their assumptions according to necessity. It is always better to acknowledge existing doubt than to dogmatise.

Hering goes on, "If the excitations belonging to the three elements have correspondingly distinct physiological causes, one would expect that these sensations would have something special about them."

This they have, in my opinion, in the prominent glow of colour-saturation; for which, again, the theory of opposed-colours furnishes no basis of explanation.

He continues, "Yellow gives, for example, much more the impression of a simple or elementary sensation than violet, and yet we are told that the latter is an elementary sensation and the former a mixture of simultaneous sensations of red and green, or at least, in some way, the product of the simultaneous existence of the principal excitations corresponding to these two elementary sensations."

What a deceitful test apparent inner consciousness is in such matters, we can see from the examples of two

[1] This was a point which Hering left doubtful in the earlier statements of his system, so that it was not clear whether he assumed three or six independent variables. According to his more recent explanations the statement given in the text may fairly be said to represent his view.

such authorities as Goethe and Brewster, both of whom believed that they saw in green the blue and yellow, of which, being misled by experience with pigments, they believed it to be composed.

He goes on, "Helmholtz says, quite correctly, 'so far as I see, no way has been found of determining one of the elementary colours except the investigation of colour blindness.' This investigation has notoriously not confirmed Young's theory."

This would, even if it were true, be in itself no argument against the admissibility of the theory. The theory of colour-blindness seems, as we shall shortly see, to be a particularly hard crux for Hering's theory; while the hitherto well-established facts of red-blindness and green-blindness admit of comparatively easy and perfect explanation by Young's theory.

He adds, "And the three sets of fibres, which, however, as Helmholtz remarks, are not essential to the theory, have hitherto been sought for in vain."

This objection applies to Hering's theory as much as to Young's.

The reader will easily convince himself that these objections are of no weight whatever. He follows them up by an enumeration of contradictions and inaccuracies which he professes to have found in Grassmann's and my own explanation of Newton's law of colour-mixture, and partly also in that of Kries, errors which, even if they existed, would in no way tell against Young's theory, but only against its interpreters. Here, however, the obscurity seems to me to lie on the side of our opponent.

These objections arise out of the fact that, in mixtures of a saturated colour with white, the tint of the mixture sometimes seems changed (pale red for example approaches more to rose, and pale blue to violet); and that, on the other hand, with increase of intensity, the colours of the spectrum appear sometimes paler, sometimes yellower. But if we speak of those elementary excitations which, from the point of view of Newton's law, are alone entitled with certainty to the name of elements, as being able to coexist without mutual disturbance, then the only sensation which can with certainty be regarded as corresponding to the coexistence of a white and a red elementary sensation is that which comes into existence under the simultaneous influence of the corresponding white and red lights. The term "elementary sensation" is in this connection to be taken, of course, not in the narrow sense of Young's hypothesis, but in the wider sense above explained—the sense in which we speak of linear relations between colour-sensations and linear superposition of elementary-sensations. In the domain of colour-mixture we know nothing of any elements but these superposable ones; and if we would preserve a constant meaning for our colour-equations we must interpret them in this sense, as I have explained above. This is what H. Grassmann and myself have always done.

Moreover, erroneous estimates of the difference between a pale and a more saturated colour are liable to be made, and hence those colours which are really most diluted with white do not always appear the palest. If, without sufficient experience of colour-mixture, we only guide our judgments by similarity of sensations, we are liable to make mistakes as to which colour contains white. The question of the power of perceiving differences will therefore arise. Further, it is found that colours of very strong luminosity do not differ so much from one another in the sensations they produce as colours of moderate luminosity,—a fact which finds its explanation in Young's theory, of which it is a natural consequence. Colours when highly luminous appear more similar to one another and more similar to white. We express this by calling them pale as compared with colours of feebler luminosity. I have, however, already mentioned that the law of superposability ceases to be applicable when the luminosity is excessive.

Nevertheless, in view of the fact that simple colours of high luminosity are always as saturated as colours of such luminosity can be, it is not necessary, or rather it is not correct, to designate them as less saturated. The true statement is that differences of tint become more uncertain at high intensity—an uncertainty which attaches also to the estimation of the intensity itself, as has long been known.

If Hering's sensation of white and opposed-colour-sensations are truly to deserve the name of elements or constituent parts of sensation (as he plainly intends, since he assigns to them special visual-substances), either he must acknowledge them as the elements deducible from the law of addition, or else they are purely hypothetical processes of whose existence and superposability no one knows anything. His polemic against Grassmann and me then amounts to this—that at a time when his hypothesis had not been propounded we did not speak in the sense of it.

Hering seems to regard as the chief point of superiority of his own hypothesis its closer conformity with the names which have established themselves in language—names which, as I have explained above, relate rather to the colours of material bodies than to the colours of light. To this circumstance it is, in fact, indebted for a certain amount of popularity and facility of apprehension. He himself assumes that these names have sprung from an immediate perception of the simple elements of sensation by a kind of inner consciousness, and thinks that he has thus very certain and immediate knowledge of the pure red-sensation, the pure white-sensation, and so on.

In his publication of 1887 he has discussed the possibility of assuming, instead of three or six simple processes of sensation, a larger and perhaps indefinitely great number, and a corresponding number of "elementary powers" for the several kinds of objective light. He, however, gives the geometrical representations of such actions in such a manner that practically these powers all depend on three independent variables. On the other hand, as regards these independent variables, which are the most important factors in the problem, he gives as good as no clue to them; he only seeks to remove them as far as possible from the sphere of physiology. For my own part I am able to understand this whole series of descriptions only as meaning that an arbitrary number of visual substances can be assumed to exist in the brain, and that their respective strengths of excitation are different functions of the same three independent variables, each visual substance being unaffected by the excitations of the rest, and the excitation of each being susceptible of direct apprehension in consciousness. I do not think it is necessary, in this book, to go further into such hypothetical views.

Hering especially claims the credit of opening up the way to understanding colour-blindness. He makes all dichromasy depend upon a single cause, namely want of sensibility in the red-green visual-substance. The difference between red-blindness and green-blindness is, according to him, attributable to different colourations of the media of the eye; partly of the yellow spot of the retina, partly of the crystalline lens.

These colourations are chiefly met with in the sick or the very old, and, when occurring in otherwise useful eyes, are not of such strength that they could bring out conspicuous deficiency of brightness in different parts of the spectrum.

The colouration of the yellow spot of the retina takes effect in a very limited but very important part of the field of view, and in only a narrow band of the spectrum. The most trustworthy observations on the influence of the wave-length of the incident light upon the strength of the red and green excitations, have been made with kinds of light not liable to be absorbed in notable degree by the yellow pigment. On the whole, it is accordingly found that this pigmentation is subjectively influential only in cases in which the rays in the neighbourhood of the line F play a prominent part, as, for example, in a certain mixture of this blue with red (mentioned on page 354) which, if it looks white when our eyes are directly fixed upon it, will show blue predominant when we look in a slightly different direction.

As far as hitherto-known facts go, it appears very improbable that Hering's theory of dichromasy can be carried through. Nevertheless, further observations in this direction are very desirable. The influence which the colouration of the yellow spot has in individual eyes can be estimated by comparing the appearances of colour-mixtures in the centre of the field of view with their appearances very near the centre. Such comparisons will show with certainty where such influence is present and where it is absent.

The following is a summary, by Prof. Everett, of two passages from the new edition of Helmholtz's "Physiological Optics," which are important as supplementing the foregoing critique of Hering's theory:—

In discussing the results of experiments for determining the exact positions of the three elementary sensations with respect to actual colours, in Newton's diagram or in Lambert's pyramid, Helmholtz represents the results by a triangle with the three elementary sensations at its corners, and with the colours of the spectrum plotted along a curve which lies entirely in the central portion of the triangle. He says, p. 457:—

"This curve shows that every simple colour excites simultaneously in the trichromic eye the three nerve-elements which are sensitive to light, and excites them with only moderate differences of intensity. If we then hypothetically refer all these excitations to the presence of three photo-chemically alterable substances in the retina, we must conclude that all three of these must have nearly the same limits of sensibility to light, and must show, in the rates of their photo-chemical actions for the different wave-lengths, only secondary variations of moderate amount. Similar variations, arising from the presence of foreign substances, from substitutions of analogous atom-groups, and so on, occur also in other photo-chemically alterable substances as used in photography; for example, in the different haloid salts of silver."

In a mathematical discussion of colour-blindness, commencing at p. 458, he points out that in dichromic vision there must be a linear relation between the three independent elements of trichromic vision, and in Lambert's colour pyramid there must be a certain line through the vertex, such that any plane drawn through it is a plane of uniform colour. Newton's diagram of colour may be regarded as contained in any plane which cuts the axis of the pyramid; and it is very important to determine the point in which the above-mentioned line cuts such a plane; for any line in Newton's diagram that passes through this point is a line of uniform colour to the dichromic vision in question. Experiment shows that it always lies outside the triangle of actual presentable colours.

Addendum.

Prof. Everett adds the following remarks of his own on the present position of the problem of colour-vision:—

On the one hand, it is established, as a fact of experiment, that the excitation of colour-sensation in the normal eye depends upon only three variables, and that their effects are superposable, so as to admit of being expressed by equations of the first degree, otherwise called linear equations. The simplest choice of three variables is that adopted in Young's theory, because it only requires positive values of the variables.

On the other hand, the various colours regarded as subjective appearances do not naturally class themselves under a threefold heading. Yellow does not look as if it consisted of red and green. Colour-sensations as known to us in consciousness are not threefold but manifold.

The two facts taken together seem to imply two successive operations intervening between the incidence of light and the perception of colour. The first operation is threefold, and may consist (as above suggested by Helmholtz) of the photo-chemical decomposition of three different substances. The second operation consists in the effects of the first operation upon a complex organism, and the distinctions of colours as we see them arise out of the nature of this organism.

The number of independent variables required for specifying the condition of a system is a very different thing from the number of well-distinguished states in which the system can exist. For example, the state of a given mass of water-substance is completely determined if its volume and temperature are given, and therefore depends on only two variables. But the number of its well-distinguished states is three. In like manner colour depends on three variables, but the number of well-distinguished colours, besides white, may be said to be seven, namely the six principal colours of the spectrum and purple.

What differences of condition in the organism correspond to these eight distinct appearances in the field of view, and how these different conditions are produced by the three primary excitations, are problems awaiting solution.

AUTOMATIC MERCURIAL AIR-PUMPS.

OF late years, and more especially during the last decade, men of science have devoted much thought and ceaseless energy to the invention of an apparatus which should admit of the automatic working of mercurial air-pumps. Of the numerous inventions brought forward, the ingenious apparatus of Schuller and Stearn are especially deserving of mention.

But notwithstanding the present extensive employment of the mercurial air-pump in science as well as in technics these appliances are neither much known, nor have they been used to any great extent, although they are of great importance, and would probably be very advantageous. This may be explained by the fact that they are wanting in the necessary simplicity and trustworthiness, without which the advantages of automatically working mercurial air-pumps are somewhat doubtful.

We shall describe now an apparatus for the perfectly trustworthy and automatic working of mercurial air-pumps, as well as the shape of the glass pump used in connection with it, which, while possessing the greatest possible simplicity, admits of the highest rarefactions hitherto known.

The figure shows the automatic apparatus in connection with an improved Toepler mercurial air-pump. The glass ball H is connected on the one hand by flexible tubes with the pump Q, on the other hand by the tube L with the accumulator M. The water-pipe K runs into the bottom of the accumulator, and by means of a specially-constructed three-way cock K can either be connected with the hydrostatic pressure-pipe K_1 or the discharge-pipe K_2.

If water under pressure is admitted through the tubes k_1, K and k into M, the air contained in M is compressed. This air again exerts a pressure through the tube L on the mercury contained in H, and drives it into the pump Q. As soon as the mercury has risen sufficiently high and the cock K is reversed, the compressed air forces the water out again through k, K, and k_2, and the mercury