apply to the General Court of New Hampshire for $1000 (tracing 14). Thereafter until the end of the book the money is all in English pounds.

We see in the above the gradual substitution of the conventional $ sign for the spelled word. The spelling out of the word becomes less and less frequent as the record proceeds. If we examine the tracings of the signs, we find that the first eleven have the S crossed by only one line. The last three have the double line as it is used at the present day.

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A NON-CHROMATIC REGION IN THE SPECTRUM FOR BEES

TO THE EDITOR OF SCIENCE: The brilliant work of Professor K. v. Frisch, of Munich, on the color sense of bees (which follows upon his very ingenious investigation of the color sense of fishes and of crabs) seems to have been strangely overlooked in this country, where more confidence is placed in the very insufficient (from the point of view of logic) conclusions of Hess than they deserve. v. Frisch carried on his experiments on bees in the open air, in the close vicinity of an aviary; he found that a single day's training was sufficient to enable many hundreds of bees to form the association: Whatever is blue is sweet, whatever is gray (of any one of thirty-two different shades) is not sweet. In the same way they were able to learn, later, that yellow indicates sweetness; no amount of training, however (they were tried steadily for ten successive days), could teach them to distinguish between red and black. Training for green had to be postponed for another year, on account of the oncoming of the cold and rainy weather of autumn, which rendered the bees too sluggish to carry on the work.

Professor v. Frisch's results are so striking, especially the proof of the total blindness to red of his bees (shown already by Washburn and by Watson in the case of higher animals), and his method (which I do not give here) was so good—so convincing and so little consumptive of time—that I was anxious to have him, when the weather permitted, put to the test a question which had been in my mind for some time, namely, whether, when animals are insensitive to red, there can not be found a certain blue-green (its complementary color) to which they are also insensitive—whether they have not, in other words, a dichromatic (yellow and blue) color system only. I therefore wrote to Professor v. Frisch some three weeks ago on this point, and I have now received a reply from him. He writes me that he has already tried the experiment, and that my *Vermuthung* is justified. There is a completely non-chromatic region for the bee in that part of the color-spectrum which corresponds to blue-green for the normal eye: no amount of training enabled the bees to pick out this color from the series of grays, although, as I have said, a single day sufficed to train them to alight, in hundreds, on yellow, or on blue, and to leave the grays entirely unvisited. This, combined with the fact that the point of maximum brightness for bees is shifted well towards the green (the circumstance which led Hess to the erroneous conclusion that bees, as well as all other invertebrates together with fishes, are insensitive to chroma—that they have achromatic vision only) shows in fact that their vision is dichromatic instead of tetrachromatic, that their colors are yellow and blue, and that their vision resembles in type the protanopic form of red-green blindness.

That this quite extraordinary fact—the non-specific quality to bees (as well as to fishes) of the blue-greens—has not hitherto been discovered by the investigators of the color sense of animals is easy to understand, for, since one can not readily try all the colors of the rainbow, one naturally tries first the "unitary" colors, red, green, yellow and blue, instead of the "color-blends," blue-green, yellow-green, red-yellow and red-blue (the two last are popularly but most unscientifically called orange and purple, respectively). One forgets, what ought to be a perfectly familiar fact, and would be were it not for the innumerable color-illusions which the Hering color-theory forces upon its adherents, that though the red-green blind individual never gets the sensation *green*, it is not the chlorogenic light-rays (*i. e.*, those which produce for us the pure green sensation) that are achromatic to him, but that it is exactly the "blue-green"-producing light-ray region to which he is wholly chroma-blind. This is a hard saying for the adherent of the Hering theory: one of the many logical *voltes-face* which he is obliged to perform, in order to follow his leader, is to believe at one moment that red and green are complementary colors (which every kindergarten child knows they are not),[1] and to admit at the next moment that the mid-spectrum region which gives an "achroma"-sensation to the partially color-blind is not green but blue-green. This latter fact demands (and receives) countless most complicated purely *ad hoc* hypotheses by way of explanation on the part of the adherents of Hering (or so many of them as have recognized its damaging character).[2] In my color theory[3] this fact is a matter of course—it is one of the facts which the theory was devised for the purpose of taking account of.

Our shockingly inadequate color-language does not readily permit us to state—and hence still less to remember—that objective light-rays of a given periodicity are not in themselves, *e. g.*, "green," but only a cause of a green sensation, in a normal eye, after their effect on the retina has been transmitted to the cortex. What looks pure[4] green to a person with normal vision will look pure yellow to the partially color blind, with equal justification—a fact which is quite destructive to the Hering theory. We have here good proof that it is important to have a reasonable color-theory in the back of one's mind, or at least not to have an unreasonable one. Those who maintain that color-theories are, in the present stage of our knowledge, of no consequence are those who are nevertheless, subconsciously, fully dominated by the Hering theory. They will tell you, for example, that the brightness of the most brilliant of reds is wholly due to its whiteness, quite as if they were making, not a wildly improbable theoretical statement, but a plain statement of fact. One of them said to me lately, "But I can not think of red and green as anything but complementary colors!" No physicist, of course, can give a moment's attention to a theory which flies in the face of fact to this extent. On the other hand, the open-mindedness to psychological considerations which the physicist is sure to develop some time is already evidenced in a phrase lately dropped by Robert Wood (in his wonderful book on "Physical Optics"); he speaks of an even red and green light-mixture as producing "subjective yellow." This is probably the first time that any physicist has ever found occasion to admit that though red, green and blue spectral lights, if mixed, will furnish matches for all the intervening colors of the spectrum, it still needs to be explained that the series matched by the red-greens contains, for sensation, no trace of red-greenness. Helmholtz himself said that the yellowness of red-green, and the whiteness of red-green-blue were quite immaterial circumstances.

J. B. and M. L. Watson, reporting on their work on the specific light response of some rodents, in which they seemed to find that the rat does not discriminate between red and green, nor between blue and yellow, say: "To the adherents of color theories the denial of a response based upon wave-length, in the case of red and green, and in the case of blue and yellow, is the equivalent of denying the possibility of a response on the basis of wave-length anywhere in the animal's spectrum." But this view is an indication that all theories look alike to them. On my theory, which was devised for the purpose of taking account of the *facts* of

1 Hering himself has explained to me that color does not mean much, because colors vary so with the illumination!

2 See G. E. Müller in the *Zeitschrift für Psychologie*, Bd. XIV., and passim.

3 See Baldwin's "Dictionary of Philosophy and Psychology," Art. Vision, and the "Psychology" of Professor Calkins, who has now relegated both Helmholtz and Hering to an appendix. My theory has lately been appropriated by F. Schenck. v. Brücke, *Zntrlb. f. Physiologie*, 20, No. 23.

4 That one can perfectly well form this judgment "imitary color," "color-blend," has lately been shown by Westphal, *Ztsch. f. Psychol.* (1), 44, p. 182, 1909.

color vision, it is exactly an even blue-green, which looks to the yellow-blue visioned individual achromatic. In this case, of course, there was no occasion for trying blue-green, since the rats could not be shown to have any color sense at all—a result which there are several reasons for having anticipated. Nevertheless, it remains true—what v. Frisch's discovery confirms—that you can not, as a matter of fact (nor in my theory), draw simple inferences from the unitary colors to the color-blends.

Professor v. Frisch has sent me specimens of the blue-greens to the chroma-quality of which his bees are insensitive; I should be glad to share them with any one who can proceed to test the blue-green sense of any animals which are already known to be blind to red.

Christine Ladd-Franklin
Columbia University,
November 7, 1913

NOTES ON A CHESTNUT-TREE INSECT

While in the employ of the Pennsylvania Chestnut Tree Blight Commission, last winter, my attention was called to numerous burrows almost always present in the bark of the chestnut tree, particularly in the smooth-barked trees. These are the burrows that Metcalf and Collins referred to in the U. S. Farmers' Bulletin, No. 467, as the work of *Agrilus bilineatus*. As we were sure the burrows were not made by this species, the commission force referred to the insect maker as the *Bast Miner*. Not much was accomplished on the study of this insect until the spring season advanced. Then much effort was directed to the solving of the life-history of this insect and what relation it bore to *Endothia parasitica*. When the work stopped in July, the life-history was nearing completion, and a number of experiments were in progress which would have given some interesting results. A detailed account of the description of the larva and its work, etc., was prepared for publication, but the only adult obtained was injured irreparably and probably can not be named. Because the adult insect emerged after July 1 (the time of my leaving Pennsylvania), it has been impossible to work out the egg-laying habits. The larvæ hibernate in the burrows in either the second or third instar. During the winter months they are inactive, but, as soon as spring opens, activity commences. When finished, the burrow is not very extensive, the longest not being more than six inches and extending longitudinally. In width, it extends only over a very short distance.

While the insect is living within the trees, the burrow can not be detected externally. After the emergence of the larvæ, however, the bark swells over the burrow, often cracking and making a conspicuous wound. The larvæ leave the trees during the first part of June through minute exit holes, dropping to the soil, in which they spin a seed-pod-like cocoon, characteristic of some of the Microlepidoptera.

Under insectary conditions, the adult insect emerges during August. The injured specimen was sent to Mr. W. D. Kearfott, but of course could not be named.

The number of exit holes made by these insect larvæ is enormous in any given area of chestnut forest and as these holes are made just at the time of year that the blight spores are very abundant, and conditions generally are favorable for their development, it is believed that this species of insect has an important bearing upon the spread of *Endothia parasitica*.

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November 10, 1913

A CONNECTING TYPE?

An illustration of how completely a student may become confused in a written examination is shown in the accompanying figure, which is an exact tracing, somewhat reduced, of the figure drawn by a freshman in an examination in elementary zoology.

The question was to make a sketch, from memory, of course, of the anatomy of *Amphioxus*, as seen in lateral view.

At first glance the sketch appears to be a fairly good representation of a lateral view of