

University for the encouragement of research in physics has been awarded to R. B. Owen, a graduate of the School of Engineering and professor of engineering in the University of Nebraska. Of the twenty-four fellowships annually awarded, the following fall more immediately within the field covered by this JOURNAL: T. E. Hazen, botany; B. H. Owen, philosophy; J. D. Irving, geology; E. Kasner, mathematics; W. C. Kretz, astronomy; J. W. Miller, Jr., mechanics; F. C. Paulmier, zoology; F. J. Pope, chemistry; C. E. Prevey, statistics; R. S. Woodworth, psychology.

HERR KRUPP has given 20,000 M. to the Institute of Physical Chemistry at Göttingen.

A COMMISSION of ten members of the Paris Municipal Council has been appointed to study the relations between the city and the University.

SOMETIME since we called attention to the decree excluding foreigners from the engineering departments of the Berlin School of Technology. The *Scientific American* quotes some German opinions of the subject. Thus the *Deutsche Zeitung* remarks: "At the non-Prussian high schools at Munich, Dresden, Stuttgart, Karlsruhe, Darmstadt and Brunswick there are 1,200 foreigners out of 8,682 students. We hope that, as the foreigners use their knowledge to the detriment of German industry, the non-Prussian governments will forthwith exclude them." It is learned that for some time past there has been an exchange of views between Prussia and the other German governments on this subject, and there is no telling how soon the policy may become general throughout Germany. The following expression by a high German official indicates the feeling on the subject: "There is no question that the German technological schools and industrial and scientific institutions will soon be forced to adopt a less liberal policy with foreigners. The tricks of trade we have been teaching them so long are now being used against us to the great injury of our industry."

DISCUSSION AND CORRESPONDENCE.

COLOR VISION.

IN a paper upon Color Vision, published in SCIENCE, April 15, 1898, Professor W. Le Conte

Stevens deplores the unsettled state of psychological opinion on matters of visual theory. "The bewildered physicist * * * * desparingly beseeches the psychologists to agree among themselves, but they will not agree; on the contrary, the prospect seems to be that additional color hypotheses will continue to appear until from their abundance they cease to receive attention." In the present article I hope to be able to show that the psychology of Color Vision is not quite so chaotic as to Professor Stevens it seems to be.

First of all, however, I desire to express my appreciation of the courtesy and frankness with which the author's challenge to the psychologists is made. The work of scientific men to-day is very highly specialized, and it taxes one's energies to the utmost to keep abreast of the movement of thought in one's own special province. Nevertheless, we are all, to some extent and in certain cases, dependent upon our neighbors; we must at times make excursions into adjacent scientific fields. Here, then, is a great difficulty. If we stay at home we fail of knowing something that we ought to know; if we travel into another domain we are apt to go astray. We have no perspective in the unfamiliar science; we cannot distinguish the important from the unimportant; our reading of the literature has been intermittent and perfunctory. However earnest our attempt to find out what is doing next door, its result must oftentimes be a personal bewilderment and confusion, which we may very easily make objective and ascribe to what is in reality a perfectly orderly household. I have sometimes left the study of a disputed point in nerve physiology with the feeling that the whole issue was a matter of the merest conjecture; but a subsequent talk with a working neurologist has given me a scale of values, and indicated definitely enough to which side the balance of probability inclined.

Professor Stevens, writing as a physicist, gives up the psychological problem of Color Vision, and calls upon the psychologists to settle the question for him. We cannot quite do that, because Color Vision is, and will for some time remain, debatable ground. But we can, returning his candid appeal an equally candid answer, give him the clue to the maze of hypothesis, or,

to take up the former metaphor again, show him the competing theories in their right perspective.

It may be said, without any hesitation, that there are now only two discussable theories of Color Vision, those of Helmholtz and of Hering. The theories of König, von Kries and Mrs. Ladd Franklin are simply improvements on (or modifications of) the 'tri-component' theory of Helmholtz. The theories of G. E. Müller and of Ebbinghaus stand in a like relation to the 'antagonistic color' theory of Hering. I will say a few words upon both theories.

I. The Helmholtz theory.—This theory was devised to explain 'the phenomena of color mixture and color analysis' (Stevens, p. 520). It does explain them, admirably; it explains nothing else. It breaks down in face of the facts of color blindness, of indirect vision, of after-images and contrast, of the Purkinje phenomenon, etc. Hence, its original and most attractive simplicity (p. 516) has been given up in favor of König's shift of excitability in the three elementary substances, von Kries' double white-process (one-fibre white and three-fibre white), and Mrs. Ladd Franklin's hypothetical molecule of suicidal tendency. All these modifications are of the nature of subsidiary or 'bolstering' hypotheses; each of them has had grave experimental objection urged against it.

II. The Hering theory.—"The Hering hypothesis," says Professor Stevens, "is well known and probably universally rejected among physicists." The latter part of this statement I believe to be substantially true; the first half I must take leave to doubt. Hering's theory in its modern form has nowhere received complete exposition. Indeed, if Professor Stevens has not, in the course of his psychological reading, come upon Ebbinghaus' theory, which is readily accessible in a recent volume of the *Zeitschrift für Psychologie*, the conclusion is almost forced upon one that he has not himself followed up the Hering theory in its meanderings through a large number of scattered journals, some of which are now not at all easy to procure. A brief account of my own experience may, perhaps, serve to

justify the bluntness of this remark. Until recently there was one weak point in the Hering theory which absolutely forbade its acceptance by the psychologist. Having satisfied myself that this defect was really fatal to the theory, I was content for several years to know only the general accounts of it given, *e. g.*, in Helmholtz's *Optik*, Wundt's *Physiologische Psychologie*, Hermann's *Handbuch*, Hering's own *Zur Lehre vom Lichtsinn*, etc. Not till the publication of Müller's article, which removed the difficulty, did I make any serious effort to gain a thorough understanding of Hering's point of view. And if the psychologist is thus remiss, what can be expected of the physicist?

Hering's theory is, in actual fact, every whit as adequate to the phenomena of color mixture as is that of Helmholtz. It also offers a self-consistent explanation of the other phenomena referred to above. It has, further, on more than one occasion, been led to predict a certain state of sensitivity or sensible discrimination, and its predictions have been verified. I do not know what more can be demanded of a psychological theory. The objection to it was that the concept of antagonism was used in one sense for red-green and blue-yellow, and in another, quite different sense, for black-white; but Müller has demonstrated that the black-white antithesis may be of precisely the same nature as the other two, despite the existence of the sensation gray. Ebbinghaus' theory (which is, by the way, a model of expository method) attempts to find an anatomical substrate for the three visual substances of the 'antagonistic color' theory.

I have so far said nothing of Wundt's theory. This, the periodicity theory, did not, of course, originate in the *Philosophische Studien* article to which Professor Stevens refers; it antedates Hering's *Zur Lehre*, etc. (see *Phys. Psych.*, 1874, p. 388; 1880, p. 452). It arose by way of reaction against Helmholtz, and has the merit of possessing an independent white-process. But, though it covers all the facts, it covers them too loosely to serve as a genuine working hypothesis. Hence it has never succeeded in getting itself discussed. It was an excellent makeshift so long as definite factual objections could be urged against Helmholtz and Hering

alike; it loses its value as soon as we have a more explicit theory which leaves no important fact of psychological optics outstanding. I cannot at all assent to Professor Stevens' assertion that the theory 'has a good following among psychologists.'

M. Nicati's theory is contained in a single forty-page article, which has not as yet received the compliment of an abstract in the *Zeitschrift*, or the *Année psychologique*. M. Nicati and Professor Patten have, as Professor Stevens says (p. 515), a perfect right to the enunciation of their hypotheses if they believe that these add to the intelligibility of the observed facts. But the hypotheses must be worked out in fiftyfold greater detail, and set upon a fiftyfold wider basis of observation and experiment, before they cease to be the private property of their authors and command general attention. The psychologist must know them in the sense that he must know his literature at large. He is no more disturbed by them, however, than is the biologist by the thousand and one theories of heredity and transmission that have been formulated since the days of pangenesis.*

In conclusion, I must ask Professor Stevens and other readers to excuse the dogmatic tone of this communication and to attribute it to limitations of space. References could be given for every statement. I may add that my own conversion to the Hering theory has been exceedingly gradual, the result of a systematic working through of argument and counter-argument, under experimental control; and that, so far as I am aware, I have absolutely no bias in favor of any theory. There are three or four other theories of vision, not mentioned in these two papers, which I should rate higher than either that of M. Nicati or that of Professor Patten. Psychologists should be grateful to Professor Stevens, not only for raising a general question which concerns both physics and psychology, but for his 'physical' criticisms upon the Helmholtz theory.

E. B. TITCHENER.

* M. Nicati's hypothesis posits a primary gray-vision, and proceeds with a tri-component color theory on an electrical-physiological basis. It is apparently a remote offshoot of the Helmholtz theory.

THE DEBT OF THE WORLD TO PURE SCIENCE.

TO THE EDITOR OF SCIENCE: Professor Stevenson's admirable address, recently published in SCIENCE, calls to mind the sometimes forgotten fact that there are still those who in considering the labors of science, scornfully ask: "What is the use of all this?" Of all forms of scientific propagandism the exhibition of specimens in a scientific museum might seem least likely to bear fruit to financial profit. That even here, however, the practical benefits of science can be demonstrated, the following examples that have recently come under my observation may be cited. They are of no great consequence themselves, but illustrate a principle which undoubtedly has wide application and, coming to my notice quite by chance, are probably typical of hundreds of similar instances which occur.

A government contract was to be let for the building of a breakwater. The filling was required to be rock of a certain toughness and durability. The local contractors, with a unanimity born either of accident or design, declared that it would be necessary to go more than a hundred miles to obtain such rock and a railroad would have to be built to transport it. Their estimates of the cost of the work were made accordingly. There was not time for contractors at a distance to explore the region, but one contractor, living two thousand miles away, sent a prospector about in the vicinity of the proposed work, with instructions to forward him samples of such rock as might be suitable for the work, with information as to the quantity of each in sight. These samples the contractor brought to a museum, and by comparison with the specimens there, and consultation with the Curator, learned that one of the rocks collected possessed the required qualities. He also learned that the quantity was probably assured by the fact that it was an eruptive rock of which more could be obtained by deeper quarrying. Relying on this information, he made a bid on the work at a price \$75,000 lower than any of the other contractors had done. The information he had gained may be credited with having saved the government that amount.

A company endeavoring to sell stock in a