the bibliographic references that accompany each chapter are well chosen, and the story is fascinating of how many advances in different and apparently unrelated fields of medicine have been correlated to advance knowledge. The final chapter gives a fair and impartial account of the current trend towards the socialization of medicine.

The second edition of "A Hundred Years of Medicine" bids fair to achieve the general popularity it deserves. After a seven-years' sleep, and in a new dress, at last the book will come into its own.

REGINALD FITZ

CALCULUS

Calculus. By LYMAN M. KELLS. Prentice-Hall. $3.75.

PROFESSOR KELLS'S attractive new book can be warmly recommended as an introduction to the calculus. He has given real life to the fundamental abstract ideas, by well-chosen and often original verbal and pictorial illustrations (there are 325 figures). In the same spirit, he has driven home the practical value of the calculus as a method by an immense variety of concrete problems. The result should be to embed the calculus permanently in the thinking processes of even mediocre students, and the reviewer intends to try the text in his own first-year courses.

On the other hand, he does not feel that Professor Kells's book will develop sufficiently the critical ability of more advanced students. No warning is given that one may be led into error by believing the "obvious," and no apology is made for introducing convenient "assumptions" in order to minimize the difficulties of proof. In fact, the "proof" at the top of page 409 is grossly wrong; so is the "assumption" at the beginning of §174; the function $\exp(-1/x^2)$ being a well-known counter example which appears in most rigorous texts. When such errors are corrected in later editions together with numerous misprints, the book should be admirably suited to first-year students.

GARRETT BIRKHOFF

HARVARD UNIVERSITY

SPECIAL ARTICLES

THE RED AND GREEN LIGHTS OF THE "RAILROAD WORM"

A FEW luminous animals are known which emit light of two different colors. One of the most striking of these is the South American railroad worm or "ferrocarril," of the genus, Phryxothrix, a beetle of the family Phengodidae, related to fireflies. The adult male has typical beetle characteristics and long branched antennae. The adult female, nearly two inches long, is larviform, with eleven pairs of brilliant greenish yellow luminescent spots on the sides of the body and a red luminous area in the head. The larvae of both male and female also possess similar luminescent spots. In North America, the rare closely related insect, Phengodes, occurs, with rows of green lights, but lacking the red light in the head.[1]

Thanks to the kindness of Dr. H. L. Parker, of the U. S. Department of Agriculture, I have recently received from Uruguay several living specimens of Phryxothrix in excellent condition. One was an adult female and the others probably larvae. They showed no light when at rest but if disturbed very slightly, by knocking the table gently or blowing air over them, they responded by shining the red light. When the disturbance was greater the rows of greenish lights also appeared and the animal explored its environment with a brilliant display of pyrotechnics. The red light in the head resembled the tip of a glowing cigarette. Sometimes all and sometimes only certain of the greenish lights would be turned on. Later the greenish lights went out while the red remained on for some time, finally to disappear as the animal became quiet again.

With these specimens it has been possible to determine the nature of the red luminescence. There are three ways in which a red light might be produced: (1) By emission of red wave-lengths, a red chemiluminescence; (2) by the presence of a red color screen transmitting red but absorbing other wavelengths; (3) by red fluorescence of a compound, excited by shorter wave-lengths emitted by some chemiluminescent reaction. The first method is the one used in producing the red light, as indicated by the following experiments.

If the red luminescent material is dissected out of the head of Phryxothrix and examined on a slide in day-light, no red pigment can be detected.[2] The tissue appears colorless and the easily visible (in the dark) red luminescence could not be due to a red color screen or to absorption by the chitin of the head, which is a light brown in color.

When hydrogen or nitrogen gas is passed over the excised red luminescent tissue in the dark, the red light disappears, and if the potentially luminous substance is now exposed to near ultra-violet light without the visible (from a mercury arc filtered through Wood's

[1] See the description in "Living Light," by E. N. Harvey, Princeton University Press, 1940, p. 69.

[2] A very weak solution of some red compound might be present, too dilute to appear red by absorption but concentrated enough to luminesce with a red emission. The luminescence of colored compounds can be detected in concentrations too weak to appear colored.

nickel glass), no red fluorescence can be detected. Since this near ultra-violet light is especially active in exciting fluorescence of a wide variety of organic compounds, we can conclude that the red luminescence is not a fluorescence.

When oxygen is readmitted to the luminous organ the red luminescence reappears, indicating that the red light is a red oxidative chemiluminescence comparable to that resulting from oxidation of Mg and Zn complexes of certain porphyrins, phthalocyanines and chlorophyll derivatives, as described by a mumber of investigators.[3] Although no red pigment is visible in the luminous tissue, a red pigment is present in the body of Phryxothrix. It is not known whether this pigment is a porphyrin or whether it is concerned in light production.

The light of the greenish luminescent organs also disappears in absence of oxygen and returns in its presence, as does the luminescence of the firefly and many other luminous animals in which the light is also an oxidative chemiluminescence. It is futile to speculate concerning the nature of the luminous substance responsible for the red and green luminescences in the same animal. Indeed the mechanism of luminescence in the fireflies and related insects needs further investigation. There is some evidence that the luciferase-luciferin system is actually an enzyme-coenzyme system, as I have previously suggested.[4] A more abundant supply of this rare and fascinating South American beetle would greatly aid in clearing up some of the chemical aspects of bioluminescence.

E. Newton Harvey

Princeton University

IDENTIFICATION OF THE FLUORESCENT SUBSTANCE F_2[1]

In 1940 Najjar and Wood[2] described the presence of a fluorescent compound obtained from urine eluates after treatment with the alkali and butanol, which was dependent on the intake of nicotinic acid.

This substance, subsequently designated F_2, was unobtainable from the urine of pellagrins[3] and animals with black tongue,[4] a fact which has been made the basis of a useful test for identifying nicotinic acid deficiency.[5] The chemical nature of F_2 has been investigated in this laboratory[6] and elsewhere.[7-11] We reported striking similarities to the fluorescent reduction products of N-methyl nicotinamide. In a simultaneous and a subsequent report[8, 9] Huff and Perlzweig prepared N-methyl chloro-nicotinamide and claimed that F_2 could be identified as N^1-methyl nicotinamide, an obvious error in view of the fact that solutions of N-methyl chloro-nicotinamide are non-fluorescent.

It appears certain, however, that the precursor of F_2 is a derivative of N-methyl nicotinamide, since we have obtained the same fluorescent compound F_2 both from urinary eluates and from aqueous solutions of the chloro-, bromo- and iodo-derivatives of N-methyl nicotinamide. The final product is free from halide, indicating that alkali treatment displaces the anion of the F_2 precursor, thus obscuring its identity. Huff and Perlzweig showed that picrates made from urinary eluate and from N-methyl chloro-nicotinamide had identical melting points (189.5° C), a finding we have confirmed. This method of approach, however, does not shed any more light on the nature of the anion which is displaced by picric acid. We have prepared halogen-free picrates from N-methyl chloro-, bromo- and iodo-nicotinamide that were identical with that obtained from the F_2 precursor in urine eluate in individual and mixed melting points (189.5° C). It is, however, possible that treatment with picric acid may detach some substituent group at another portion of the molecule than that occupied by the halide. The identity of the picrates therefore does not prove that their precursors were identical. In this connection it is of interest to note that Coulson and Ellinger,[10, 11] although they confirmed the identity of the picrate from urine and from N-methyl chloro-nicotinamide, obtained an aurate from these two sources which differed both in color and melting point. For the present, therefore, the identification of the non-fluorescent precursor of F_2 remains incomplete.

The present communication deals with the chemical changes concerned in the conversion of the non-fluorescent precursor into the fluorescent F_2. Studies of N-methyl pyridines as well as N-methyl quinolines and acridines[12, 13] have shown that a quaternary pyridinium base is first formed which, by rearrange-

[3] See P. Rothemund, *Jour. Am. Chem. Soc.*, 60: 2005, 1938, and J. H. Helberger and D. B. Hever, *Ber. d. d. Chem. Ges.*, 72B: 11, 1939.

[4] E. N. Harvey, Science, 44: 652, 1916.

[1] The work described in this report was carried out under a grant from the Williams-Waterman Fund of the Research Corporation.

[2] V. A. Najjar and R. W. Wood, *Proc. Soc. Exp. Biol. and Med.*, 44: 386, 1940.

[3] V. A. Najjar and L. E. Holt, Science, 93: 20, 1941.

[4] V. A. Najjar, H. J. Stein, L. E. Holt and C. V. Kabler, *Jour. Clin. Invest.*, 21: 263, 1942.

[5] L. E. Holt and V. A. Najjar, *Journal-Lancet*, 63: 366, 1943.

[6] V. A. Najjar, D. B. M. Scott and L. E. Holt, Science, 97: 537, 1943.

[7] J. W. Huff and W. A. Perlzweig, Science, 97: 538, 1943.

[8] J. W. Huff and W. A. Perlzweig, *Jour. Biol. Chem.*, 150: 395, 1943.

[9] R. A. Coulson, P. Ellinger and B. S. Platt, *Biochem. Jour.*, 36: 12, 1942.

[10] P. Ellinger and R. A. Coulson, *Nature*, 152: 383, 1943.

[11] R. A. Coulson and C. Ellinger, *Biochem. Jour.*, 37: 17, 1943.

[12] E. Decker and A. J. Kaulfmann, *Pract. Chem.* (2) 84: 432, 1911.

[13] Taylor and Baker, ''Sidgwick's Organic Chemistry of Nitrogen,'' p. 524, Clarendon Press, Oxford, 1937.