farm crops in the College of Agriculture of Cornell University.

DR. H. BASSETT, of the University of Liverpool, has been appointed professor of chemistry at University College, Reading.

DR. W. R. BOYCE GIBSON, lecturer in philosophy at the University of Liverpool, has been appointed professor of mental and moral philosophy at the University of Melbourne.

DISCUSSION AND CORRESPONDENCE

"GENOTYPES," "BIOTYPES," "PURE LINES" AND "CLONES"

IN a recent issue of SCIENCE [1] Dr. Jennings calls attention to a double meaning which has been given to the word "genotype" by several recent writers, myself among them, and points out the desirability of limiting the word to the meaning assigned to it by its originator, Dr. Johannsen.

As one of the chief offenders, I wish to publicly repent my misuse of the term and to heartily join in the movement to limit the word "genotype" as used in the literature of genetics, to the fundamental hereditary constitution of an individual. The use of this word both for the hereditary constitution and for the group of individuals possessing an identical hereditary constitution, will lead to much confusion if continued.

The word which Dr. Jennings says is much needed "for a concrete, visible group of organisms" "all with the same hereditary characteristics," has been already supplied. In a symposium on the "Aspects of the Species Question" before the Botanical Society of America at Chicago, January 1, 1908, I pointed out [2] the same need and expressed a hope that some one would "come forward with an acceptable short designation" for these "elementary forms" which had been classified by de Vries as "elementary species" and "varieties." A few months later I discovered that my wish had been fulfilled before its utterance, by Dr. Johannsen, and his word "biotype" [3] was immediately adopted in my paper on "The Composition of a Field of Maize" [4] and made a part of the title of my work on "*Bursa bursa-pastoris* and *Bursa Heegeri:* Biotypes and Hybrids." [5] In view of these facts there was no excuse for my use of the word "genotype" in a taxonomic sense.

Dr. Jennings also calls attention to an important misuse of the expression "pure line," and here I must again admit a certain amount of guilt, as I was probably the first to include under this term groups of individuals related through the process of budding or any other method of vegetative reproduction. In 1904 I wrote: [6]

> By the "pure line" Johannsen means a series of individuals related only through the process of self-fertilization. On *a priori* grounds it seems proper to apply the term to every series of individuals that do not combine elements of two or more ancestral lines through the equivalent of a sexual process. Thus, so far as hereditary qualities are concerned, there should be no reason to expect in a self-fertilizing population conditions different from those in a population related through budding or other method of vegetative reproduction, provided, of course, that the self-fertilizing population has not been so recently modified by a cross as to allow the analysis and recombination of characters derived from different ancestral lines.

For this early departure from "the narrow path" I have in part atoned in my recent paper on the "Genotypes of Maize," [7] by referring to the vegetatively reproduced potato and paramecium as "clonal varieties," in contradistinction to the self-fertilizing "pure

[1] SCIENCE, December 15, 1911.

[2] *Amer. Nat.*, XLII., 278, May, 1908.

[3] This word was first proposed in 1905 in "Arvelighedslærens Elementer," the Danish forerunner of "Elemente der exakten Erblichkeitslehre," and was first used in English at the Third International Conference on Genetics in 1906. (See Report Third International Conference on Genetics, p. 98, 1906.)

[4] Report American Breeders' Association, IV., 296–301, 1908.

[5] Carnegie Institution of Washington Publication No. 112, 1909.

[6] *Torreya*, V., 22, February, 1905.

[7] *Amer. Nat.*, XLV., 234–252, April, 1911.

lines" of beans, barley, etc. I might equally well have called them simply "clones," as "clonal varieties" and "clones" should have identical meaning. The word "clone" (Greek κλων, a twig, spray, or slip) was proposed by Webber[8] for "groups of plants that are propagated by the use of any form of vegetative parts, such as bulbs, tubers, cuttings, grafts, buds, etc., and which are simply parts of the same individual seedling." I believe that no violence will be done by extending this term to include animals which are similarly propagated by any asexual method, and I suggest the general adoption of the word "clone" for all groups of individuals having identical genotypic character,[9] and arising by asexual reproduction of any sort, including apogamy (*i. e.*, so-called "parthenogenesis" unaccompanied by a reduction division).

For the purposes of my discussion in 1904 the distinction between "pure lines" and "clones" was of no consequence, because the particular hereditary principle then under consideration was common to both. The same thing is no doubt true of many of the recent investigations of others, but it is well to remember that there are certain fundamental differences between "pure lines" and "clones," which render it very important to maintain the distinction between them. I will mention but two of these differences by way of example: (1) In the "clone" it is possible to retain as a permanent feature of the group any purely heterozygous character, as for instance the vigorous constitution dependent upon the stimulation of heterozygosis; such a phenomenon is impossible in the "pure line." (2) When clonal individuals reproduce sexually, either by self-fertilization or by crossing with other individuals, they need not, and usually do not, produce genotypically equal offspring, because the individuals of the "clone" are not necessarily homozygous, as the individuals of the "pure line" generally are. The "clones" of horticultural plants are notorious for the heterogeneity of their seedling offspring. The investigator of intermittently parthenogenetic organisms like aphids, rotifers and Hieracium, and of intermittently vegetatively produced organisms like paramecium and many plants, can not properly assume that their races are genotypically pure in the sense that they are homozygous, while the worker with "pure lines" can make such assumption with small probability of error, in case his self-fertilizations have been controlled with adequate care during a sufficiently large number of generations.

There is another prevalent misconception regarding "pure lines," to which attention needs to be called. The word "pure" in this connection does not refer to the genotypic equality of the individuals, but only to the exclusion of all crossing as a source of genotypic differentiation.

In Dr. Harris's criticism[10] of Roemer's work with peas, he points out with very evident satisfaction that two of Roemer's populations are historically traceable to individual selections and that they are therefore really "pure lines" (*i. e.*, providing, of course, that those originally selected individuals were strictly homozygous, and that no chance crossing has taken place since). If no genotypic changes can take place within the "pure line" all evolution is impossible in the large number of forms which naturally maintain "pure lines" by obligate self-fertilization. The only point to be made in regard to this feature of Roemer's results, is that, if his populations were really "pure lines," the numerous distinct biotypes he discovered by the "pure line" method in those populations, were the result of mutations which have taken place since the original selections were made. The occurrence of such mutations does not affect in the least the value of the genotype theory, nor the importance of the "pure line" method for the study of heredity.

[8] Science, XVIII., 501–503, October 16, 1903. For a discussion of the spelling of the word "clone" see Science, XXII., 89, July 21, 1905.

[9] This restriction is necessary in order to avoid confusion through the appearance of bud-mutations. Such a mutation if propagated vegetatively represents the origin of a new clone.

[10] *Amer. Nat.*, XLV., 686–700, November, 1911.

Definitions:

Genotype, the fundamental hereditary constitution or combination of genes of an organism.

Biotype, a group of individuals possessing the same genotype.

Pure line, a group of individuals traceable through solely self-fertilized lines to a single homozygous ancestor.

Clone, a group of individuals of like genotypic constitution, traceable through asexual reproductions to a single ancestral zygote, or else perpetually asexual.

GEO. H. SHULL

HISTORY OF MATHEMATICS IN THE RECENT EDITION OF THE ENCYCLOPÆDIA BRITANNICA

THE new edition of the Encyclopædia Britannica contains numerous articles which purport to deal with the history of various branches of mathematics. None of these have been written by specialists in this field and the articles bear abundant evidence of this fact. The history of mathematics may well ask of the editors of such an encyclopedia the same care in the selection of writers on these topics as that exercised in the selection of writers in other fields, ably represented in general in the Britannica by the leading scholars of the world.

In a recent issue of SCIENCE (December 1, 1911) Professor G. A. Miller has called attention to certain inaccuracies and errors, especially with reference to the theory of numbers and of groups. It seems to me unfortunate, in view of the general worthlessness of the historical passages, that Professor Miller has incidentally chosen for criticism one of the few correct statements. The passage in question occurs on page 867 in volume XIX., in the article on "Numerals" in which the writer states that our present decimal system is of Indian origin. Attention is rightly called by Professor Miller to the fact that the zero appeared in Babylon long before it appeared in India, although the writer on "Numerals" seems to be unaware of this. However, the date is not 1700 B.C., as Professor Miller states, but more than a thousand years later. Photographic reproduction of Babylonian tablets containing the zero appear in F. X. Kugler's "Die babylonische Mond-rechnung," Freiburg i. Br., 1900, and these tablets date from the centuries just before the Christian era. Furthermore, no historian of mathematics has made the claim that modern arithmetic is derived from the Babylonian arithmetic, as Professor Miller implies, but there is general agreement that our arithmetic comes to us from the Hindus through the Arabic writer (c. 825 A.D.) Mohammed ben Musa Al-Khowarizmi. This subject is fully discussed in "The Hindu-Arabic Numerals," Smith and Karpinski, Boston, 1911.

The article on "The History of Mathematics," Vol. XVII., pp. 882–883, is too brief to invite comment. The incorrect statement is made: "The medieval Arabians invented our system of numeration." Reference is given only to the works of Cantor ("1st Bd.," "2d Bd." and "3d Bd."!) and to W. W. R. Ball's "A Short History of Mathematics," London, 1888, and subsequent editions. The latter work is in no sense an authority on the subject.

The articles on "Algebra, History," Vol. I., pp. 616–620, and "Geometry, History," Vol. XI., pp. 675–677, contain so many inaccuracies and so much misinformation that selection becomes difficult. I will devote myself more particularly to the longer article on the history of algebra.

Some ridiculous statements made by Peter Ramus in his algebra of 1560 are quoted. Thus Ramus says: "There was a certain learned mathematician who sent his algebra, written in the Syriac language, to Alexander the Great, and he named it *almucabala,* that is, the book of dark or mysterious things, which others would rather call the doctrine of algebra . . . and by the Indians . . . it is called *aljabra* and *alboret.*" This nonsense, evident on its face, as *almucabala* and *aljabra* are Arabic words, is taken somewhat seriously by this writer in the Britannica. "The uncertain authority," he says, "of these statements, and the plausibility of the preceding explana-