of individual susceptibility to alcohol. Theoretically it seems to follow that the effect on the motor coördinations indicates a central tendency of alcohol.

A full presentation and discussion of the various techniques and the resulting measurements are given in Publication No. 232 of the Carnegie Institution of Washington.

[1] Tentative plan for a proposed investigation into the physiological action of ethyl alcohol in man. Privately printed and distributed January 1, 1913.

VARIATION AND INHERITANCE IN ABNORMALITIES OCCURRING AFTER CONJUGATION IN PARAMECIUM CAUDATUM

By Ruth J. Stocking

ZOOLOGICAL LABORATORY, JOHNS HOPKINS UNIVERSITY

Presented to the Academy, November 4, 1915

In view of the difficulty of interpreting from the standpoint of evolution the changes that occur in the complex phenomena of inheritance from two parents, the study of reproduction from a single parent becomes of great importance. One of the difficulties in such work is that the lower organisms, in which uniparental reproduction commonly occurs, present relatively few characteristics that are at the same time variable and hereditary, among closely related individuals; though this is a condition demanded for studies of heredity and evolution.

Certain abnormalities that appear after conjugation in the infusorian Paramecium appeared to offer a favorable opportunity in this respect. These abnormalities vary greatly in occurrence, character, and degree; at the same time they are partially heritable. This paper is a summary of an extended study of these abnormalities in relation to the problems of inheritance, variation, and racial change.

Among the progeny of a large proportion (from 36 to 81% in different experiments) of exconjugants of Paramecium caudatum, abnormalities appear frequently. These abnormalities consist of irregularities in body form and dimensions, of many diverse types. Among them are monsters due to partial or irregular fusion; single bodies some larger, some smaller than normal; and a great variety of abnormal shapes. These animals propagate by fission; some of the lines of individuals thus derived from the exconjugants are quite without abnormalities, in others under the same conditions the abnormalities reappear for generations. Thus the abnormalities are hereditary. But diversities appear also within the abnormal lines themselves. Some of the indi-

viduals of an abnormal line may be normal, others abnormal in various degrees. Different lines show diverse proportions of abnormal individuals. It thus becomes possible to test by selection the inheritance of degree and kind of abnormality within a single stock all derived by fission from a single parent.

In long continued uniparental reproduction of any sort, a remarkable constancy in hereditary characteristics has been generally reported. All the progeny thus coming from a single parent have seemed uniform in their hereditary characteristics, though they may differ in their bodily appearance. And this is quite in agreement with the known cytological processes accompanying the two types of reproduction. In biparental reproduction there is a reduction and recombination of the nuclear elements, of precisely the same sort as the variation and recombinations of characteristics in the progeny, in Mendelian inheritance. In uniparental reproduction, particularly of the vegetative kind, such nuclear reductions and recombinations are not known; and the uniformity of the progeny is in agreement with this. These relations, with others not necessary to recount here, have given origin to the conception of the *genotype*, as the hereditary constitution, in contradistinction to the bodily appearance. The genotype is commonly held not to change in vegetative reproduction, or but rarely, and then by marked sudden steps, or mutations. In biparental reproduction the genotype does indeed change, but seemingly by mere shiftings and recombinations, in numerically predictable ways; so that the relations here are quite in agreement with the condition sketched above for uniparental reproduction.

A somewhat rigid, stereotyped scheme of heredity naturally results from the view of the facts just set forth: in particular, evolution by gradual change, guided by natural selection, appears to be excluded. This becomes still more marked if we conclude with Bateson ('14) that all mutations consist in the dropping out of factors. On the other hand, certain investigators in genetics oppose strongly this rigid view, holding that, over and beyond Mendelian recombinations, hereditary variations of slight degree are frequently occurring, so that evolution may well be continuous and guided by selection. The recent papers of Castle give typical expression to this point of view.

If hereditary variations are frequently occurring, aside from Mendelian recombinations, it should be possible to find them in vegetative reproduction. Here we are freed from the mixing of types which makes these relations so difficult to interpret in biparental reproduction. The abnormalities in Paramecium were, therefore, studied mainly with rela-

tion to this question: Can we by continued selection of normal individuals on the one hand, of abnormal individuals on the other, break our single stock into two or more, differing in hereditary constitution?

The results of this study are as follows:

1. The diversities in abnormality occurring within a single line of descent (derived from a single exconjugant) are in some lines not hereditary, so far as can be determined by long continued selection. In a very large proportion of the races in which the abnormals were regularly discarded and only normals retained to carry on the race, the abnormal character persistently reappeared, the selected normals producing abnormal progeny. In all the abnormal races there is a wide variation in degree of abnormality of the individual, from those perfectly normal to the monsters so deformed that they would never be recognized as Paramecia if their history were not known. Yet, as stated above, in most cases the progeny of all these variations were alike, the daughter cells of normal individuals being often just as abnormal, or even more so, than the daughter cells of monsters. This of course agrees with the conditions found in most of the studies on inheritance in 'pure lines' or clones; the diversities within the lines are not inherited.

2. But in other lines, diversities within the line showed themselves to be heritable, so that selection gave very different results from those usually obtained in pure line work. By selection, single lines, derived by fission from a single parent, were divided into two or more races differing hereditarily. This was successfully accomplished in twenty-five races; from each of these were isolated two lines, one quite normal, the other continually producing abnormalities,—the two cultivated side by side.

Calkins and Gregory[1] have in some cases obtained four diverse races from the four primary daughter cells, or 'quadrants' of an exconjugant —these being the four individuals that receive the four macronuclei produced before fission occurs. It is to be noted that our selection resulting in the isolation of lines differing hereditarily in abnormality often has been brought about much later in the series of generations, so that the differentiation has often occurred within the compass of a single 'quadrant,' or indeed within a much narrower fraction of the descent. In several cases, differentiation through selection did not begin till after several weeks had passed, with production of a great number of generations. Thus the results of selection in the present case cannot be interpreted as due to a primary difference in the four original macronuclei produced during conjugation. Selection is effective when begun with progeny of a single individual that has appeared many generations after conjugation.

3. In a race of Paramecium which upon extended examination shows no hereditary abnormalities, conjugation results in the appearance of many lines which are hereditarily abnormal, others which are normal throughout.

4. In the diverse lines descended from the separate exconjugants of a conjugating culture, the two lines descended from the two individuals that have conjugated together tend to be alike in respect to normality or abnormality. That is, if the progeny of the exconjugant *a* are abnormal, the progeny of its mate *b* are more frequently abnormal than would be the case if the distribution of abnormal races were not affected by conjugation.

Our main result, therefore, is that in respect to these abnormalities, while some lines are constant in hereditary character, in others hereditable variations do occur within the line, so that by selection it is possible to break the single stock into a number of stocks differing hereditarily. The genotype in these cases therefore does not remain constant in uniparental reproduction. The condition on which evolution through selection depends is therefore realized in respect to these characters.

The complete paper of which this a summary appears in the *Journal of Experimental Zoölogy*.

[1] Calkins, G. N., and Gregory, L. H., Variations in the Progeny of a Single Exconjugant of Paramecium Caudatum, *J. Exp. Zoöl.*, 15, 467–525 (1913).

THE INFLUENCE OF THE MARGINAL SENSE ORGANS ON FUNCTIONAL ACTIVITY IN *CASSIOPEA XAMACHANA*

By Lewis R. Cary

DEPARTMENT OF BIOLOGY, PRINCETON UNIVERSITY

Presented to the Academy, October 27, 1915

1. *The Influence of the Sense Organs on the Rate of Regeneration.* The conclusion of many of the earlier workers on the problems of regeneration that the nervous system had an important part to play in the processes of regeneration has been attacked by most of the more recent students of these problems. While Bardeen ('01), Herbst ('96), Goldstein ('04), Wolff ('95, '02) and others maintained that there was some direct influence of the nervous system, or some portion of it (sensory ganglia Herbst), and Child ('04) recognized the indirect influence of the nervous system, exhibited through muscular activity; Goldfarb ('09), Stockard ('09) *et al* have denied that there is even an indirect influence of the nervous system.

An especially favorable opportunity for studying this problem is