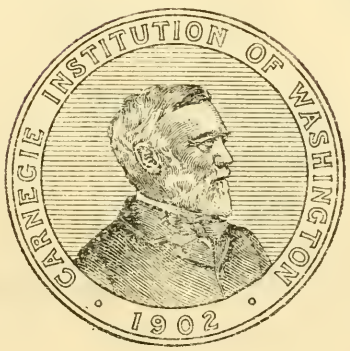
CARNEGIE INSTITUTION

OF

WASHINGTON

YEAR BOOK No. 14

1915



PUBLISHED BY THE INSTITUTION
WASHINGTON, U. S. A.

DEPARTMENT OF EXPERIMENTAL EVOLUTION.*

C. B. Davenport, Director.

Among the principal advances of the year have been the extension of the series showing the evolution of the chromosome complex of *Drosophila* and allied flies (perhaps the strongest purely cytological argument yet presented for the individuality of the chromosomes); the lack of dependence of the vigor of certain strains of parthenogenetic *Cladocera* upon the recurrence of sexual reproduction; the discovery that in different strains of *Lychnis* there is a difference in the dominance of one and the same trait, hermaphroditism (including maleness); the demonstration that in certain plant hybrids the characters whose determiners are derived from both parental germ-plasms develop more promptly than those whose determiners come from only one side of the house; the demonstration of a triple factorial basis of the foliage color of *Lychnis*, and of multiple determiners in the reduction of the number of bristles in *Drosophila;* the working out of a theory of a pair of factors (and their absence) that is capable of explaining the hereditary basis of temperament; the demonstration that the symptoms of certain diseases (Huntington's chorea, pellagra) are determined by several hereditary factors—are, indeed, "syndromes"; the demonstration that hereditary brittle-bone (or osteopsathyrosis) is due to a dominant factor; the production of a strain of beans with double the usual number of cotyledons and "first leaves" of the seedling; the preparation for the press of one volume of the unpublished scientific work of the late Professor Whitman.

STAFF.

The work of this Department during the present year has been carried on by seven resident investigators and various associates and assistants. The Director has, besides his other duties, put most of his time on the analysis of the data of human inheritance, assisted by Miss Mary T. Scudder. Dr. George H. Shull has used plant material for his studies in heredity and has been assisted part of the time by Mr. B. C. Helmick. Dr. J. A. Harris also has paid particular attention to the inheritance of abnormalities in beans, with the assistance of the Misses Lockwood and Margaret and Lillie Gavin.

Mr. Charles W. Metz is making studies on the subject of the mechanism of heredity and has been temporarily assisted by Mr. H. H. Plough. Dr. Oscar Riddle has worked on the chemical distinctions that lie at the basis of sex, with the assistance of Miss Adelaide Spohn and, later, of Mr. O. R. Clutter.

*Situated at Cold Spring Harbor, Long Island, New York.

The subject of inducing mutations is being pursued by Dr. E. C. MacDowell, both by the use of alcohol and by constant extreme atmospheric conditions applied to rats. He has been assisted in part by Mr. J. W. Gowen. Dr. A. M. Banta is also studying the problem of the possible genetic influence of absence of light, such as is experienced by cave animals. He has been assisted by Mr. D. C. Warren.

We are concerned with the processes by which species become adjusted to the environment. Drs. Harris, Banta, and MacDowell are studying the results and limits of the process of selection.

We do not lose sight of the fact that heredity is the control or direction of ontogeny and as opportunity permits we wish to continue and extend the studies that Dr. R. A. Gortner and others have initiated here on the biochemical changes accompanying the development of special traits. Drs. Harris and Riddle are doing something in this field, assisted especially by Mr. John V. Lawrence.

The staff has sustained a great loss in the resignation of Dr. George H. Shull, who has accepted a call to the chair of botany and genetics at Princeton University. Dr. Shull has been a member of the staff from the organization of the Station—over eleven years. By his persistence, thoroughness, clear insight, and single-mindedness in the pursuit of his investigations he quickly attained the first rank of botanical students of genetics. It is early to state which of the discoveries made by Shull at this station will come to be regarded as most important. His colleagues here have been much impressed with his demonstration of the isolation of the inferior biotypes in maize through inbreeding and the demonstration of the multiplicity of biotypes in a species regarded at one time as unique in its genus—the shepherd's purse. It is probable that a hundred biotypes (elementary species) could be isolated from the shepherd's purse. If this can be done with so constant a form as shepherd's purse, how vast must be the number of biotypes in notoriously variable species like golden-rod and ragweed. The idea of biotypes which Shull so greatly developed is bound to revolutionize, in time, our conceptions of zoological and botanical species and, most important of all, man himself. Shull also attacked with courage numerous difficulties that arose in his work—such as abnormal ratios, the amazing intricacies of *Oenothera* hybrids, and the sex ratios in a partially hermaphrodite plant (*Lychnis*). While some of these difficulties of ratios were cleared up, and yielded generalizations as to aberrancy due to duplicate, plural, and linked genes, others are still awaiting interpretation.

The vacancy created by Dr. Shull's resignation has been filled by the appointment of Professor Albert F. Blakeslee, of Storrs (Connecticut) Agricultural College. Dr. Blakeslee is no stranger to the Department; he carried on experiments here from October 1912 to June 1913, on mutation and sex in mucors, and, with Dr. Gortner, discovered the

Rhizopus toxin, upon which experiments are still being made with the assistance of the U. S. Department of Agriculture.

Dr. Harris and Mr. Lawrence spent some time in Jamaica studying the osmotic pressure of vegetable saps. Mr. Metz spent the winter months (January 15 to April 15) in Cuba and a few days in Jamaica, collecting and attempting to hybridize the *Drosophila* and allied flies there. He brought back numerous species to breed at the laboratory. Also pinned material, eggs, and notes on eggs, larvæ, pupæ, breeding habits, etc., were procured. Cuba proved to be unusually rich in *Drosophila*. Dr. A. M. Banta has spent the usual amount of time in exploring caves for animals to replenish our stock.

REPORTS ON INVESTIGATIONS IN PROGRESS.

The topics upon which work has been done in this Department during the past year may be classified as follows: (1) the germ-plasm and its modification; (2) the control of sex; (3) the inheritance of germinal peculiarities, especially those relating to sex; (4) the processes of forming species in nature and artificially; (5) general physiological topics.

THE GERM-PLASM AND ITS MODIFICATION.

More and more clear does it become that evolutionary changes are initiated in the germ-plasm—the chromosomes and adnexa. It therefore becomes of the first importance (*a*) to study the structure of the germ-plasm and the morphological differences in the chromosomes associated with differences in the soma; (*b*) to try to modify directly the composition and product of the germ-plasm.

MORPHOLOGICAL EVOLUTION OF THE GERM-PLASM.

This phase of our work is being carried out by Mr. Metz, who is using in his studies the genus *Drosophila* and the closely related genera of *Chymomyza*, *Scaptomyza*, and *Cladochæta*. Over 30 related species were thus examined cytologically. In these species 10 or 11 different types of chromosome complexes have been revealed; and, most important of all, these types are all closely related morphologically and can be derived, hypothetically, from an unspecialized central type by simple modifications in two or three directions. Thus, Mr. Metz has greatly extended the results of his studies that were briefly described in the Year Book for 1914 (p. 129). The analysis of these various types of chromosome groups and the task of relating them to one another has been rendered more difficult because of the interesting and complicated relations of the pair of sex-chromosomes. In some species the sex-chromosomes appear to be alike in both sexes (*i. e.*, X and Y are equal in size), while in other species that have the same type of chromosome group, X and Y are obviously dimorphic. This study appears to be the first in which the chromosome group has been analyzed in a large

number of related species and in which it has been possible to trace an evolution of morphological type. After this demonstration it will be impossible to deny the "individuality of the chromosomes." Obviously it will be of great importance to compare the inheritance of traits of which the determiners are carried in these dissimilar but closely related germ-plasms.

Mr. Metz further reports:

"In addition to the *Drosophila* work, the study of the phenomena of chromosome pairing and their significance has been followed up extensively. This has involved the cytological study of at least 60 or 70 species of flies representing various families of the order (including the Drosophilidæ). The essential features of chromosome behavior have been found to agree in all, and to point definitely to the conclusion that in all of them the chromosomes are permanent, qualitatively different, individuals; and, further, that the two members of each pair of chromosomes are *homologous maternal and paternal elements which remain associated with one another by reason of their qualitative similarity.* To my mind this latter forms one of the strongest cytological supports of the chromosome theory of heredity, if the evidence for it is conclusive, as I believe it to be. The report of this study is now nearly completed and will soon be ready for publication.

"In connection with the above study many interesting facts have been observed with regard to the sex-chromosomes, and the general relation between chromosome groups in the different families studied. It is astonishing what a variety of conditions has been found as regards shape, size, and number of chromosomes, presence or absence of chromatoid bodies, and other chromatic structures, etc., in these various groups of flies. There has been no opportunity to work these features out in detail, but there is material on hand for numerous valuable studies.

"One question upon which this material throws light has received definite attention, however—namely, that of the maturation phenomena. Very little is known about this question in the Diptera, yet it is one of especial importance in connection with current theories of chromosome behavior, *e. g.*, the "chiasmatype hypothesis," etc. Recently a supply of good material has been secured from the Asilidæ (robber flies), which are most favorable for studying maturation phenomena. This will be worked up and published as soon as possible, but it will require many detailed and careful drawings, in addition to observational study, and just now more immediate work occupies all available resources.

"At present, especial attention is being paid to the study of oogenesis in *Drosophila ampelophila* and to the work of determining the sex-chromosome relations in the males of that species, because of their bearing upon genetic data. Nothing very definite has resulted from this so far, however, although a quantity of material has been studied. The problem is one of especial difficulty as well as especial interest.

"Throughout the year the principal problem attacked has been that of hybridizing species of *Drosophila* possessing different chromosome groups. A large amount of time has been devoted to this, but without success. The experiments have now come to the stage in which it will be necessary either to perfect a method for artificially fertilizing eggs of one species with sperm of another or else to keep on getting additional species from localities hitherto not worked until some are secured which will hybridize. Either of these methods would give extremely important results if successful, but the latter would

lead, of course, to more far-reaching results by making breeding experiments possible. I shall continue to regard this problem as the most important one upon which to work during the coming year."

EXPERIMENTAL MODIFICATION OF THE GERM-PLASM.

This, which may be said to be the loftiest aim of the experimental evolutionist, has been so rarely achieved that all reported successes in this direction are received with critical skepticism. We are now provided with means for carrying out experiments on this difficult topic. In the Year Book for 1914 (p. 121) is mentioned the work, begun by Dr. G. C. Bassett, of inducing changes in the germ-plasm of rats by subjecting them to the action of alcohol vapor. This work is now in the charge of Dr. MacDowell, who reports as follows:

"Besides having a theoretical scientific interest, this problem has immediate sociological importance. It is frequently asserted that, in man, alcoholism in the parents results in their children having less than normal mentality. In order to prove this, much has been said and done. There are countless complexities which largely veil a clear solution of such a problem when man is considered directly. Since the problem depends largely on a pyschological analysis, it may be that, by employing the psychologists' indirect method of studying lower animals first, the essential relationships may be more accurately secured. If one could understand the mental methods of a lower or more primitive organism, those of the higher type might be mastered more easily. For other reasons than this is the use of a more simple form advantageous: the germ-plasm to be treated, as well as that of the controls, can be more easily selected in the first instance and bred in subsequent generations, the individuals to be compared can be maintained under like conditions, and the experimental treatment of all animals in the same group can be uniform.

"Since the white rat is a very satisfactory subject for behavior studies, this animal has been used. Since the beginning of this year the parental generation has been raised. Half of the rats were made to inhale alcohol fumes, for 90 minutes a day, following Stockard's method; the rest were saved as controls. The alcoholization was made daily for at least 100 days before mating, and then continued, in the case of the females, till immediately preceding the birth of her young. For every mating of alcoholics there was a mating of normal males and females from the same litters. The offspring from these two sets of rats have all been trained to enter a puzzle-box of a type planned by Watson and modified by Bassett. The comparison between the rats of normal and of alcoholic percentage has been made on the basis of the time required to gain access to the puzzle-box. The sooner a rat learns the trick, the higher his ability is rated. The training of each rat lasts 96 days, during which time the number of seconds required to make each of 225 successful trials is recorded. The number of rats included in this training is 145. Since the training of all these rats is not quite completed, no final statement of the results of this work can be made.

"Whereas the above method gives a fairly accurate comparison of the abilities to form a habit, it can not be claimed to measure the general intelligence of the rats. In order to secure data of a higher mental activity than that supposedly involved in solving the puzzle-box problem, a method has been adopted that was planned by Yerkes and called by him the multiple-choice method. As adapted for rats, the apparatus consists of a row of nine compartments with front and back doors. The rats are trained by punitive con-

finement (by closing the front door) when a compartment is wrongly chosen and by reward of food (which is revealed by raising the back door) when the right compartment is entered. The right compartment is never the same one in successive trials, but always bears a certain relation to the other open front doors. There may be some question as to whether a rat can have such an idea as the first door to the right (this being the relation of the correct door in the first problem), yet it is easily seen that in mastering such a problem the activity of the rats offers considerable insight into their relative mental capacities. As far as possible, all the rats trained with the puzzle-box will be further used in this experiment on the effects of alcohol. An additional reason for employing the multiple-choice method is to provide a check on the results of the puzzle-box training. Agreement in the two sets of results would give a basis for generalizations; disagreement would leave doubt as to the validity of either method. The technique of training has been developed, and at present twenty rats are being tested for intelligence by this apparatus."

A second investigation that has been planned is on the effect of temperature and humidity upon the germ-plasm. To make this experiment possible an extensive air-conditioning apparatus was installed in the animal house by the Harry Bentz Engineering Company. A detailed description of it is given toward the end of this report. Dr. MacDowell assumed charge of the experiments planned for this apparatus. About 20 rats were raised from infancy under the various combinations of conditions afforded by the air-conditioning apparatus, viz, hot dry, hot moist, cold dry, and cold moist. From these animals 10 controlled matings were made. Just when the next generation appeared it became necessary, through lack of funds, to discontinue the operation of the refrigerating machine. It is highly desirable to resume the experiment, even though it is expensive.

THE SIGNIFICANCE AND CONTROL OF SEX.

While the view that a difference in the sex chromosomes is sufficient to account for differences in sex characters is widely accepted by biologists, yet evidence is accumulating that the chromosomal difference is merely one differential and that there are probably others. Dr. Riddle has continued to collect evidence that supports the conclusion that an important differential associated with sex is the storage metabolism of the egg (Year Book, No. 13, pp. 117–119). Riddle's work during the present year confirms and amplifies his earlier conclusions.

As is well known, certain entomostracans of the group Cladocera are ordinarily parthenogenetic and for long periods females only are produced. Recently Keilhack, after going over all of the evidence, concluded that, while *Simocephalus* may behave differently, all species of the genus *Daphnia* and many other species of Cladocera which he names can not reproduce parthenogenetically for as long a period as six months. Unfavorable conditions may, indeed, hasten sexual reproduction, but constant conditions can not postpone the production of

sexual forms. Practically all workers with Cladocera (except the genus *Simocephalus*, in one case) who have reached a conclusion on the matter are in accord with Keilhack's statement.

In Dr. Banta's laboratory, however, quite a different result has been gained. Two *Simocephalus* lines have been reared for three years, during which time reproduction has been solely by parthenogenesis for 123 generations, and, indeed, no males have appeared. Another species, a long-spined species of *Daphnia*, has been kept reproducing by parthenogenesis only for 87 generations. Lines of *Daphnia culex* have been carried for nearly four years, and in several lines for from 148 to 157 generations, solely by parthenogenesis and without the production of males. In all of these cases there is no sign of loss of vigor in the stock. Periods of depression have, indeed, occurred, but these have always been obviously due to poor food conditions. As a test for possibly reduced vigor, careful comparisons between the lines reproducing for nearly 150 generations parthenogenetically and "wild" lines recently brought under laboratory conditions have been made throughout a period of several months. Three bases of comparison were used: the size of the first brood a mother produces, the age at which the first brood is produced, and the interval between the production of the first and second broods. The results of comparison on each of these points show that the young mothers in lines which have long reproduced parthenogenetically produce as large first broods, produce them at as early an age, and produce a second brood as quickly, as the young mothers in "wild" lines recently brought in from natural ponds. Dr. Banta concludes that, since no diminution in vigor or need for sexual reproduction is apparent in the different species after 87, 124, and 157 generations, respectively, sexual reproduction and the sexual cycle in these Cladocera are probably not inherently necessary, but are consequences of certain special environmental conditions.

That such special conditions may induce the production of males has, indeed, been demonstrated for rotifers by Whitney; and observations made by Dr. Banta show the same thing in Cladocera. In the "long spine" *Daphnia* one gynandromorph and a few males in two successive generations in two strains appeared at a time when males of other species of Cladocera (*Daphnia pulex* and *Moina*) were extremely abundant in the pond from which were obtained the food and water in which these cultures were maintained. The fact that a few males appeared in two strains reared under laboratory conditions simultaneously with the appearance of numerous males of two other species living in the outdoor pond which furnished the culture water strongly suggests the environmental control of the production of males.

THE INHERITANCE OF GERMINAL PECULIARITIES.

SEX.

Studies in inheritance in sex in *Lychnis*, so long conducted by Dr. Shull, were continued by him. This year has to a large extent confirmed the anomalous results previously secured (Year Book No. 13, p. 119) without, however, giving a clue to their explanation. The narrow-leafed males have again produced in most crosses only male offspring, and one narrow-leafed hermaphrodite which was crossed with 31 different females has produced a total progeny of 1,287 hermaphrodites, 2 females, and 1 male. It appears, however, that not all narrow-leafed males are alike in regard to the proportion of males which they are capable of producing. Of 17 families from crosses in which narrow-leafed males were used, 10 consisted of 517 males and no females, 4 contained 160 males and 5 females, and 3 had 95 males and 41 females. In this last group the females were also all broad-leafed individuals. There has still been not a single narrow-leafed female, and the little dwarf female which was classed as a narrow-leafed female in 1913 has yielded only broad-leafed progenies when crossed with narrow-leafed males.

While hermaphrodites of *Lychnis* have usually yielded a mixture of hermaphrodites and females and less frequently males and females, Dr. Shull found in a white-flowered German strain of *Lychnis* (*Melandrium album* Garcke) a single hermaphrodite mutant which, in 1913, produced only female offspring in three different families for which it served as the male parent. In 1915 this result has been exactly duplicated in 8 progenies from a second hermaphrodite mutant which occurred in the German strain in 1913. These 8 families have included 187 females and not a single hermaphrodite nor male.

INHERITANCE RATIOS OF BURSA.

During the current year Dr. Shull has continued his prolonged experiments on the breeding of *Bursa* and has been able to show: (*a*) that there is no significant correlation between the number of seeds in the capsule and the ratio of *bursa-pastoris* to *heegeri* plants in the progenies produced from those seeds, thus indicating that if selective elimination is involved in the production of defective ratios such elimination is independent of the causes which affect the number of ovules which develop into seeds; (*b*) that the plants which are homozygous with respect to the long, sharp lobes characteristic of *tenuis* develop this character at an earlier age than do those which are heterozygous for this character; (*c*) that there is a rather strong correlation between the time of flowering and the extent of development of the leaf-characters in certain biotypes from western America, the lobation of the leaves being less well developed in precocious plants than in those which develop more tardily—the same fact was apparent in a similar, though not identical, biotype from Holland; (*d*) that there is a close agreement between the number of recessives and of homozygous

dominants, and, in harmony with his earlier discovery of a ratio approximating 1:4:1, have been the results of an extensive test of a family in which the recessives were in *excess* of expectation, for in this family there proved to be an *excess* of homozygous dominants also, so that the ratio of DD:DR:RR was approximately 1:1.7:1; (*e*) that there is a correlation between the date at which the plants begin to bloom and the number of dominant genes which they possess. In harmony with this general result, the *heegeri* individuals usually begin blooming, on the average, several days later than the *bursa-pastoris* individuals of the same family.

In tracing the geographic distribution of the duplicate capsule-determiners, the most important step has been the testing of 7 individuals growing in nature at Landau, Germany, where the original *B. heegeri* was discovered. Of these 7 individuals, 6 had both of the duplicate determiners, *C* and *D*, and the other had only a single determiner for the triangular capsule, and produced an F_2 ratio of about 4:1. This prevalence of duplicate determiners at Landau was a surprise to Dr. Shull, as he had thought it probable that a single determiner for the triangular capsule would be found *generally* in the *bursa-pastoris* from that place. The F_2 families from crosses between *B. heegeri* and a biotype of *B. bursa-pastoris* from Tucson, Arizona, gave ratios approaching 10:1. As this is directly between the expected ratios 3:1 and 15:1, only the F_2 will demonstrate with certainty to which of these ratios the 10:1 should be referred. In continuation of this geographic study, crosses have been made between *B. heegeri* and a number of biotypes of *Bursa* from various parts of Europe, Asia, and America, and seeds have been secured from as many new regions as possible. Cultures of *B. grandiflora*, *B. viguieri*, and *B. bursa-pastoris apetala* have also been grown and used in crosses with one another and with *B. heegeri*. In most cases these crosses seem to have been successful.

BRISTLE INHERITANCE IN THE VINEGAR FLY, DROSOPHILA.

Among the burning questions in genetics is the significance of characters that seem not to be discrete units but to show all grades. Such a character is skin color in man (Carnegie Inst. Wash. Pub. No. 195) and size of body in rabbits and poultry. Recent studies indicate that the apparent blends are due to the numerous factors involved in the character. Another contribution to this subject has been made by Dr. MacDowell, to whom the analysis of "Size Inheritance in Rabbits" is due (Carnegie Inst. Wash. Pub. No. 196). In *Drosophila* there are normally four bristles (2 rows of 2 bristles each) on the back of the thorax. In other cases there may be one pair, or 2, 3, or 4 pairs of *extra* bristles, or the extra bristles may be uneven in number. Dr. MacDowell's studies show that there is a Mendelian factor involved in the inheritance of extra bristles, and as *normal* dominates *extra* it is concluded that there is a dominant factor which restricts the number

of bristles to 4. Without having rigidly demonstrated the conclusion, Dr. MacDowell finds it probable that the variation in the number of extra bristles is due to the absence of one or more accessory restricting factors.

OTHER STRAINS OF DROSOPHILA.

To provide material for the cytological work a large number of cultures of *Drosophila* have to be maintained. Mr. Metz has carried at all times between 100 and 200 cultures and at times there have been double these numbers. In attempts to hybridize different species, scores of special cultures have been made up and carried on. Also, mutant races have been sought and bred in species having different chromosome groups.

Mr. Albert M. Brown, of Columbia University, spent about two months of the summer at the laboratory studying the linkage of characters in heredity in *Drosophila*. Mutants with eosin-colored eyes and miniature wings were mated to individuals of wild stock from France, Australia, Central America, Cuba, and several points within the United States, and the linkage of the above mutant characters was studied. Over 56,000 F_2 progeny were embraced in the data obtained.

FOLIAGE COLOR OF LYCHNIS.

The foliage color of *Lychnis* has been shown by Dr. Shull to depend upon the presence of several independently inheritable factors, *Z*, *N*, and *Y*. When *Z* is absent albinos appear. When *Z* is present, together with both *N* and *Y*, the plants are of the normal dark-green color usually seen in this species. *Z* and *N* without *Y* produce a light-green race which Dr. Shull calls *pallida*, and *Z* and *Y* without *N* produce a variable yellowish-green race, which has been named *chlorina*. These two light-green races produce (when crossed together) only dark-green offspring, which yield F_2 progenies when bred *inter se*, consisting of dark-green and light-green individuals in approximately the expected ratio 9:7. The last term of this ratio should include 3 *pallida* (*ZZNNyy*), 3 *chlorina* (*ZZnnYY*), and 1 "*subchlorina*" (*ZZnnyy*). It was not known until this year whether such a form as *subchlorina* could exist, and it was conceivable that the ratio of dark green to light green in the F_2 might be 9:6 instead of 9:7. The existence of the heretofore purely hypothetical *subchlorina* has been demonstrated by this year's cultures, as two individuals used in crosses in 1913 had the *subchlorina* constitution.

INHERITANCE IN ŒNOTHERA.

Investigation of the hybridization phenomena in the œnotheras has been continued by Dr. Shull, and many of the F_2 combinations which had not been grown hitherto have been added this year, so that most of the possible combinations of *Œnothera lamarckiana* and the

three cruciate species, *Œnothera cleistantha, atrovirens,* and *venosa* have now been grown. In many combinations the evidences of segregation are clear, but in almost no instance does this segregation result in apparently typical Mendelian groupings.

A complete series of reciprocal crosses between each of the above-mentioned species and a local *biennis*-like species (unnamed) has given results which parallel in an interesting manner the results secured in the F_1 families already reported. These studies have now been extended to include two new cruciate species, *Œnothera robinsonii* and *stenomeres,* and two broad-petaled species, *Œnothera oakesiana* and *Œnothera biennis* L.

Special attention has been given to putative Mendelian characters, such as nanism, brevistyly, pigmentation of rubricalyx, etc., with the hope of discovering to what extent these characteristics are actually distributed in typical Mendelian fashion. The inverse correlation between the red pigmentation of the buds and that of the stems has been fully confirmed in the hybrids between a form of *Oenothera rubricalyx* and *rubrinervis* and between the same form and *Oenothera lamarckiana.*

PITCHER-LEAFED ASH TREES.

This season has again added a few specimens of pitcher-leafed ash trees to those previously noted in the pedigree families. The ratios in these two families now stand 1.18:1 and 2.17:1 as compared with the expected ratios 1:1 and 3:1, the pitcher evidently depending upon the presence of a single Mendelian gene. The precocity of development of this character, together with the degree of development attained, are largely influenced by environmental factors. Most of the trees have been transplanted, 153 which had not shown pitchers during the first three seasons of growth being sent to an otherwise vacant space in the northeast corner of the Hill Field of the Station for Experimental Evolution, and 137 of those with pitchers being sent to 131 universities, colleges, botanical gardens, etc. Other institutions are to receive trees this fall.

The survey of the area on which pitcher-leafed ash trees occur in nature has been completed, and this area has been found to be about twice as large as had been supposed heretofore, but no trees of considerable size have been discovered outside of the previously known area. The area occupied by pitcher-bearing trees is about 400 meters in diameter. All the ash trees on this area, from 1 dm. in height to large trees, have been carefully examined for pitchers, with the result that 357 have been found with pitchers and 5,806 with only normal leaflets. Trees having a trunk-diameter of more than 15 cm. are limited to a very small area, about 400 square meters in extent.

HEREDITY IN MAN.

The Director has been primarily engaged in analyzing data afforded by the Eugenics Record Office. The following studies have been completed or are, at the present writing, about to be published.

(1) *Violent temper.*—An analysis of 66 family histories shows that the tendency to this reaction reappears in successive generations, rarely skipping a generation. In one history it is traced through 5 generations; in a large proportion of the histories it is traced through 3 consecutive generations. The few cases in which neither parent of an affected individual is reported to have the tendency to outbursts are explained by obvious insufficiency of the record. The fact that the tendency to outbursts of temper does not skip a generation indicates that it is a positive or dominant trait. That segregation of this tendency occurs is shown by the ratio of affected offspring in any fraternity to the total number of offspring whose emotional history is fully described. From the mating of an uncontrolled and a normal person expectation is that 50 per cent of the children will be uncontrolled. A summation of all such children gives a total of 106 affected among 219 sufficiently described, or close to the 50 per cent expected on the hypothesis that the tendency to outbursts of temper is a simple, positive trait.

(2) *Temperament.*—A later study involved a consideration of temperament in general, a subject which Galton discussed, inadequately, thirty years ago. It is generally recognized that temperament is hereditary, but there is great diversity of temperaments: some persons are prevailingly gay, others prevailingly somber, and still others pass through alternating cycles of elation and depression. The following hypothesis was tested and met the conditions very satisfactorily:

"There is in the germ-plasm a factor *E* which induces the more or less periodic occurrence of an excited condition (or an exceptionally strong reactibility to exciting presentations) and its absence, *e*, which results in a calmness. There is also the factor *C* which makes for normal cheerfulness of mood, and its absence, *c*, which permits a more or less periodic depression. Moreover, the factors behave as though in different chromosomes, so that they are inherited independently of each other and may occur in any combination."

For the test of the hypothesis 89 carefully described family histories were available, and these afforded 147 matings in which the mated pair, their parents (usually), and certain of their offspring were sufficiently described for the purposes of the test. The test of the hypothesis is found in a comparison of the expected and actual distribution of temperaments in the children of each sort of mating. Of the 45 possible kinds of matings, 29 were realized. The relations of the sums of the observed to the sums of the expected distributions among the nine classes of temperaments is shown in the following table:

	Observed	Expected		Observed	Expected
Choleric-cheerful	36	$41\frac{5}{8}$	Nervous-melancholic	63	$72\frac{6}{8}$
Choleric-phlegmatic	25	$46\frac{7}{8}$	Calm-cheerful	77	$51\frac{1}{8}$
Choleric-melancholic	30	$19\frac{5}{8}$	Calm-phlegmatic	79	$97\frac{3}{8}$
Nervous-cheerful	128	$98\frac{4}{8}$	Calm-melancholic	46	$49\frac{7}{8}$
Nervous-phlegmatic	149	$154\frac{6}{8}$			

There are several reasons for not realizing a very close relation between observed and expected; but the chief one is that there are sometimes several "expected" results; and in these cases the most varied result was taken as the "expected." Nevertheless, the relation between the two series is fairly close, the greatest difference being an unexpected excess of choleric-melancholics and corresponding deficiency of choleric-phlegmatics; also an excess of calm-cheerful and deficiency of calm-phlegmatic. These discrepancies imply a rather slight error in the classification of the observed cases.

We conclude, then, from our own data that the hypothesis is confirmed. In addition, an examination of the literature reveals clear evidence that a difference in the inheritance of extreme hyperkinesis (a dominant) and extreme hypokinesis (a recessive) has unconsciously been observed. And the differences in the conclusions of Rosanoff and Orr[1] and of Rüdin[2] concerning the inheritance of manic-depressive insanity—one regarding it as recessive and the other regarding it as sometimes dominant—are easily explained on the ground of its complex hereditary nature.

Finally the study throws light upon the "springs of conduct." Just what we shall do. in any situation, is determined by numerous factors, but the general nature of our reactions, whether violent or repressed, is determined by the hereditary nature of our temperaments. The romantic and the classic type of reacting, the hyperkinetic and the hypokinetic, the radical and the conservative, the feebly inhibited and the strongly inhibited, constitute a dualism that runs through our whole population.

(3) *Nomadism.*—A study was made of the records of 100 families one or more members of which have shown a tendency to run away from home, families, and duties or to engage in a nomadic occupation. In these families, out of 186 nomadics only 15 are females. The hypothesis that best fits the facts is that nomadism is a sex-linked trait. There is no clear case of a nomadic daughter whose father is known to be non-nomadic; all daughters (4) of two nomadic parents are nomadic. The criterion that half of the daughters and half of the sons of nomad-bearing fraternities derived from nomadic fathers are nomadic is satisfied so far as sons go, but the number of nomadic daughters is less than expected (only 26 instead of 50 per cent are nomadic). In general, our histories show that nomadic fathers may have no nomadic sons, but there is no case of a nomadic mother of more than two children none of whom is nomadic. Thus the hypothesis is supported with the proviso that certain cultural conditions may have a repressive effect even in the absence of natural inhibitions.

[1]Rosanoff, A. J., and Florence Orr, A study of insanity in the light of the Mendelian theory. Amer. J. Insanity, 68, 221–261 (1911); also Eugenics Records Office Bull., No. 5.

[2]Rüdin, E., Einige Wege und Ziele der Familienforschung, mit Rücksicht auf die Psychiatrie, Zs. ges. Neurol. Psychiat., 7 (Hft. 5), 487–585 (1911).

(4) *Dent in forehead.*—A fragment of a family history of a depression in the median frontal region of the cranium led to a publication (*Journal of Heredity*, April 1915) in which it was pointed out that the trait was inherited as a dominant.

(5) *Huntington's chorea.*—This disease, usually regarded as a "neuropathic entity," is defined by the following traits: (1) persistent tremors of the head, appendages, and trunk; (2) the onset of such tremors in middle or late life; (3) the progressive nature of the tremors; and (4) progressive mental deterioration. These characters are frequently found together; is their association a necessary one?

A study of four family complexes in eastern Long Island, southwestern Connecticut, south-central Connecticut, and eastern Massachusetts which show nearly 1,000 cases of Huntington's chorea yields the remarkable result that practically all can be traced back to some half-dozen individuals, including three (probable) brothers who migrated to America during the seventeenth century. But numerous "biotypes" with specific and differential hereditary behavior have already appeared. Thus, there is a biotype in which the tremors are absent, but mental deterioration is present; a biotype in which the tremors are not accompanied by mental deterioration; a biotype in which the chorea does not progress; and a biotype in which the onset of the choreic movements is in early life. In general, the symptomatology of chronic chorea is dissimilar in different strains of families. The age of onset, the degree of muscular involvement, the extent of mental deterioration—all show family differences and enable us to recognize various species, or biotypes, of the disease. These biotypes are less striking than they would be were it not for the extensive hybridization that is taking place between biotypes in random human matings. The data for the study were collected by Elizabeth B. Muncey, M. D., of the Eugenics Record Office.

The method of inheritance of some of the elements of Huntington's chorea has been worked out. In general, the choreic movements never skip a generation and in other respects show themselves clearly to be a dominant trait. The mental disorder is usually of the hyperkinetic or manic type, and this also shows itself as a dominant. The age of onset *apparently* tends to diminish in successive generations, "law of anticipation," but this is partly, if not wholly, illusory and is due to the fact that in comparing the age of onset in grandfathers with that in grandchildren we are not comparing on the same basis, for the grandparents are a selected lot (selected on the basis of late onset—at least late enough for them to become parents), while grandchildren include those in whom the onset is so early in life that they will never marry. If instead of comparing the average age of onset in successive generations, one compares the age of onset in a number of choreic parents, *their* parents, and their grandparents, then the evidence for anticipation vanishes. Eight such series give for average

age of onset of the propositus 35.5 years, parent 38.8, grandparents 36.9. In this series we can see no evidence of anticipation.

(6) *Pellagra.*—At the request of the Thompson-Fadden Pellagra Commission of New York, the Director of this Department undertook a critical examination of a large number of fragmentary family histories collected by the commission with the assistance of a trained field worker from the Eugenics Record Office. Since Lombroso declared that the diathesis of pellagra is hereditary, the attempt to find what factors were present, if any, seemed worth while. The evidence seemed to justify the conclusion that, whatever the immediate cause of pellagra, the course that it followed, the particular symptons that it showed, had a clear hereditary basis. Thus, in certain families mental symptoms were pronounced, in others absent; in some families the intestinal derangements were most striking, in others they were hardly present. While the skin usually shows areas of extreme inflammation in some families, the dermal symptoms were hardly to be noticed in others. The characteristic differences in families affords the best evidence of certain constitutional hereditary differences—which determine or control the specific symptoms of pellagra.

(7) *Osteopsathyrosis.*—A study was made of all available pedigrees of hereditary brittleness of bones. The conclusion is drawn that the trouble is indeed hereditary and that the factor which determines the imperfect, brittle development of long bones is a dominant one. This conclusion is based on the fact that, as Griffith pointed out some years ago, the inheritance is generally direct, *i. e.*, does not skip a generation, but appears in one parent and one of that parent's parents. Further evidence that the trait depends on a single dominant factor is found in the proportions of the fraternity who are affected. Out of a total of 150 offspring of an affected parent 83 or 55 per cent are affected—not far from the 50 per cent that was to be expected on hypothesis. The phenomena associated with fragility of bones are not always alike in different families. In some families the bones are broken before birth; in others only after the infant has grown into a child. Families differ in the degree of pressure necessary to breakage and in the bone most apt to be broken. The "classical symptoms" of osteopsathyrosis constitute a syndrome whose elements are separately inheritable.

(8) *Stature.*—An analysis of the inheritance of the elements of human stature has been undertaken. Several hundred pedigrees of total stature have been analyzed, but more extensive data of another kind are being collected and analyzed.

THE PROCESSES OF FORMING SPECIES IN NATURE AND ARTIFICIALLY.

BUILDING UP A RACE BY SELECTION OF FAVORABLE MUTANTS.

Since the general acceptance of the mutation theory and its corollary, that of absence of evolution through the selection of non-inheritable fluctuations, it has become important to test the application of these principles in the production of new species. Dr. Harris has for the

fourth generation selected the bean (*Phaseolus vulgaris*) with respect to seedling characters. For the most part he has not succeeded in isolating strains of definite type, but in a few cases this has proved possible.

"A strain in which the number of cotyledons and of primordial leaves is far larger than normal has this year been grown in many thousands of individuals. Normally the number both of cotyledons and of primordial leaves is two. The great increase and the high variability in the number of both is shown by the accompanying table, based on a sample of seedlings of the 1915 culture. It is to be noted that the highest frequency for both number of cotyledons and number of leaves is double that which normally occurs. A peculiarity of this line of plants is the abundance of ascidia, already studied in another form, the ash, at this Station by Dr. Shull. At least two other highly but not completely abnormal strains are also available. These differ greatly in their morphological characteristics, but require further study before they can be tersely characterized.

"Material progress in the isolation of strains in chlorophyll production has been made. Several types of plants have been secured from those producing no chlorophyll to those normal in this regard, but the propagation of such strains, except through normal plants, is very difficult. Enough has been done, however, to indicate the heritability of a number of types."

Number of cotyledons.	Number of leaves.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Totals.
2	..	1	6	3	2	1	1	..	..	..	..	..	..	..	14
3	1	13	44	59	47	21	13	7	4	3	1	..	..	..	213
4	4	34	80	127	100	72	32	24	13	9	5	..	..	1	501
5	..	..	4	5	9	8	2	4	..	3	1	1	..	..	37
6	..	..	..	1	2	..	2	1	..	..	..	..	..	..	6
7	..	..	..	..	..	..	1	..	..	..	..	..	..	..	1
	5	48	134	195	160	102	51	36	17	15	7	1	..	1	772

SELECTION OF FLUCTUATING VARIATIONS.

It is still extremely profitable to study the limits of effective selection. The work of Castle might lead us to conclude that through selection practically any character might be gradually modified and—if the process was prolonged sufficiently—might be modified to almost any extent. Two extensive experiments that we are carrying on bear on this point.

(*a*) Dr. Banta has continued the selection of *Daphnia* for greatest and for least sensitiveness to light through more than 150 generations (compare Year Book No. 13, p. 131). The results are being prepared for publication.

(*b*) Dr. MacDowell has made the following three experiments upon vinegar flies with extra bristles, outlined in Year Book No. 13, pp. 132–133:

To continue selection till there remains no question as to its effect.—A year ago the report covered selections for 21 generations. At present

the same inbred race constantly selected for the highest numbers of extra bristles is in the forty-second generation. Since the sixth generation no advance has so far been determined that can be interpreted as the result of the selection.

To select in the opposite direction and so produce a race with few or no extra bristles.—It has, so far, been impossible to accomplish this end. Two series of return selections were made and in each of these the progenies from the low-grade parents were as high as those from the high-grade selections. Since the flies with few extra bristles are apt to be the smaller ones, after a few generations of selecting the lines become very weak, and the two series of selections were lost by the failure of the selected flies to produce large enough families from which to make the required selections.

To establish a race of low-grade extra-bristled flies by starting with extras that appeared in the F_2 of a cross with normals.—This has been accomplished. An inbred race that has fewer extra bristles than the high selected line has been obtained by this method. This difference between the two lines is clearly shown, even when both are bred under conditions as nearly identical as can be obtained. The year's work seems, then, strongly to support the conclusion that "selection" as a method of changing the germ-plasm is futile; further support is also afforded the hypothesis, outlined before, that the seeming response to selection shown in the first few generations was due to a sorting of factors, rather than to the modification of a single factor. If there is any significance in these conclusions, the cross between the high-grade and low-grade lines should provide a vital link in the evidence; but pressure of other researches has not yet permitted this.

SELECTION OF BEAN-PLANTS IN NATURE.

Dr. Harris has continued his experiments on selective mortality in nature of bean seedlings, and he planted out this year about 26,000 seedlings selected during the germination of about half a million. It is known that the death-rate is differential; the object of current work is to determine as accurately as possible the selective value of specific morphological features.

SELECTION OF FERTILITY AND FECUNDITY IN PLANTS.

These studies have been carried along by Dr. Harris in connection with other work as usual. Further series of data confirming results on fertility in *Cercis* stated in previous Year Books have been published. An extensive investigation of the relationship between the number of pods per plant and the characteristics of the pod in garden beans—an analysis of the data for 127,610 pods from 19,064 plants grown in 32 experimental cultures made under a wide range of environmental conditions—has also appeared. It is shown that the correlations between the number of pods per plant and the number of ovules per pod in the pods produced have always been found positive in sign, but

numerically low, ranging from 0.023 to 0.355, with an average value of 0.195. For pods per plant and seeds per pod the correlations are also for the most part positive. The values range from −0.046 to +0.338 with a mean of +0.126. By all available tests the correlations for pods per plant and number of ovules per pod seem to be significantly higher than those for pods per plant and number of seeds per pod. Analysis shows, however, that the relationship between the size of the plant and the number of seeds per pod is to some degree independent of that for number of pods per plant and number of ovules formed per pod.

THE PRODUCTION OF AN IMPROVED VARIETY OF SHEEP BY MODERN METHODS.

This research is carried on primarily by the New Hampshire Experiment Station with the collaboration of the Director. By crossing a mutton and a fine-wool type of sheep, and by judicious selection, it is hoped to secure a strain of sheep that will combine the most desirable characteristics. Already in the F_2 generation very valuable combinations of characters have appeared; but it is necessary to breed great numbers to get the desired quality, and by appropriate breeding to fix the desired combination of traits.

ORIGIN OF THE CHARACTERISTICS OF CAVE ANIMALS.

Selection experiments with Cladocera.—These investigations of the problem of the origin of the light-shunning reactions of cave animals give promise of affording further evidence of the validity of Johannsen's hypothesis. The mass of data is large, is being carefully compiled, and will undoubtedly constitute a sound piece of evidence bearing on a hypothesis the universal applicability of which is by no means demonstrated.

Additional Cladocera material.—Four lines of an additional species of *Moina*, of the order Cladocera, are now being kept under control conditions similar to those of the other species mentioned. All the lines of the four species of Cladocera now being bred parthenogenetically are being used in some phase of the experiments regarding the supposed sexual cycle and also in experiments on heredity in parthenogenetic reproduction.

Experiments on the cave problem.—Dr. Banta's experiments upon the effect of light on true cave species and of a cave environment upon outside forms are progressing favorably and as rapidly as the nature of the problem permits. Some additional cave species are being reared in daylight and some additional outside species in a cave environment. The second generation of the amphipod *Eucrangonyx gracilis*, derived from the non-cavernicolous race of this species, reared in the cave, is not yet large enough to determine how much, if any, pigment will be produced. The first-generation offspring derived from the surface stream race of this amphipod kept in the cave show in some individ-

uals a marked, though much reduced, pigmentation; in others only a trace of pigment is developed; and in still others no pigment can be detected. Enough has been seen to conclude that the difference between the outside normally pigmented form of this species and the cave form without body pigment is more than a mere ontogenetic difference, else the first generation offspring reared in the cave from pigmented parents should develop no body pigment.

As throwing light on the albinism of cave forms, Dr. Banta has made some observations on albinos in general. He has published a note giving a number of chance observations on albinos occurring in nature. One of these is the case of a persistent albino strain of the gray squirrel in nature and another is of an albino strain of *Asellus*, which, noted in the same locality for three years, has come to form a notable proportion of the population. It seems here to have undergone no differential elimination.

Exploration of caves.—A collecting trip made by Dr. Banta to the cave region in the Stockbridge limestone (marble and limestone) region of eastern New York, western Connecticut, western Massachusetts, and Vermont proved to be unexpectedly productive. This region contains numerous small caves, each in general known only to people living in its immediate vicinity. These caves are difficult to find and most difficult ones in which to collect. The high altitude of most of these caves is conducive to a limited water content and the sharp tilt of the limestone or marble strata brings about a rapid and complete drainage which is unfavorable for the occurrence of pools suitable for aquatic life. Suitable pools were found in only three of the eleven caves visited in this region. Of these, Newton's Cave, near Pittsfield, yielded no aquatic fauna, although conditions seemed favorable for such life, but in the Twin Lakes Caves near Canaan, Connecticut, two interesting typical cave animals were found, a pigmentless planarian and a small, eyeless and pigmentless amphipod. One of these species may prove identical with a similar form from the cave region in central New York, but this is doubtful. The occurrence of these highly modified species in New England caves from which no real cave fauna had been obtained previously is of much interest. In addition were secured a myriapod, a mite, and a thysanuran, all apparently more or less typical cave animals.

OTHER INVESTIGATIONS.

CORRELATION BETWEEN FERTILITY OF A PLANT AND ITS SOMATIC CHARACTERS.

The ability of a species or strain to hold its own in nature depends, among other things, on its fertility in relation to that of other, closely related, species. Dr. Harris has published a painstaking investigation into the relation between fertility in garden beans—or the average number of mature seeds that a plant produces per pod—and the

number of pods produced on the plant (which varies from 1 to 38 or more). It appears that, on the average, the more pods to a plant the more beans to a pod. This relation is, however, not close; for if perfect correlation be ± 1.00 and no correlation be 0.00, then the correlation found is represented by $+0.126 \pm 0.011$ merely.

RELATION OF PHYSICO-CHEMICAL PROPERTIES OF VEGETABLE SAP TO ENVIRONMENTAL FACTORS.

Dr. Harris and Mr. Lawrence, with the collaboration of the Department of Botanical Research, have been engaged on a continuation of work begun with Dr. Gortner upon the subject that heads this paragraph. Dr. Harris reports:

"Any attempt to influence the germ-plasm of species as a means of controlling evolutionary phenomena should, if it is to throw light upon the problem of the methods by which evolution has taken place in nature, be made by means of factors which are of fundamental biological importance in nature. Such factors are light, temperature, and moisture. Furthermore, the environmental factors chosen should affect not only the soma of the individual, but should have, directly or indirectly, an influence upon the developing germ-cells or fertilized egg. Such work as had been published indicated that soil moisture might be such a factor. It is physically or physiologically widely variable from one region to another, and is of primary importance in determining the characteristics of the vegetation of a region. Furthermore, evidence has been accumulating that the physico-chemical properties of the cell-sap of the plant individual are greatly influenced by this factor of the environment. Thus the immediate environment of the developing zygote may be very materially altered.

"Our objects, then, have been to obtain a comprehensive knowledge of the physico-chemical properties of saps in relation to environmental factors, as a preliminary to controlled experimental studies and transplantation experiments.

"In the field work about 1,400 determinations have so far been made, distributed in round numbers as follows:

Arizona deserts	160
Jamaican coastal deserts	140
Jamaican Blue Mountains, Windward rain forests, and Leeward slopes	480
Long Island mesophytic, hydrophytic, and halophytic habitats	620

"This series of determinations, which is more extensive than all others hitherto published, shows, among other points, that (*a*) there is a relationship between the growth form of the plant individual and the osmotic pressure or diffusion tension of its sap; (*b*) that in the regions studied differences in osmotic pressure of the sap of the plant species are correlated with local environmental factors; and (*c*) that the vegetation of different regions may differ greatly in the physico-chemical properties of its sap.

"The variation from region to region in the osmotic pressure in atmospheres of the extracted sap as determined by the depression of the freezing-point is shown by a comparison of the Arizona deserts with the more mesophytic habitats of Long Island or with the montane rain forests of Jamaica. The average concentration of the juices of the spring vegetation in the region of the Desert Laboratory is 19.4 atmospheres; that for the spring vegetation of Long Island is 11.5 atmospheres. The mean osmotic pressure of the sap of the

species of the Blue Mountain region of Jamaica studied by Shreve (Carnegie Inst. Wash. Pub. No. 199) is 9.4 atmospheres, whereas that of the Port Henderson strand flora, mangrove swamp, and coastal desert vegetation is 30.0 atmospheres. Such general averages, however, give only a fraction of the information necessary. Subdivisions of each of these habitats differ in osmotic pressure. Thus the salt spots of the Arizona deserts show an average of 37.1 atmospheres, whereas the arroyos give a mean of 13.9 atmospheres. On the xerophytic Jamaican coast one locality shows an average concentration of 25 atmospheres, whereas another has a mean of 48. Naturally the general averages for a region as complex as either of those studied will depend in large measure upon the relative number of determinations from each of the subhabitats. In detailed discussions the latter must be made the basis of comparison.

"Furthermore, the growth form of the plant species must be taken into account. Thus Arizona trees and shrubs show a mean concentration represented by 28.2 atmospheres as compared with 14.8 atmospheres for the winter annuals. The mean value obtained for a region will therefore depend upon the proportional frequency in the series of determinations based on the various growth forms. The consideration of all such questions must be reserved until the full data can be presented."

METHODS.

An important statistical study deals with the application of intra-class correlation formulæ to the problem of substratum heterogeneity. In all the plot-culture work of agricultural institutions—whether in the testing of the practical value of newly originated varieties of plants or in fertilizer tests—the factor of the heterogeneity of the field upon which the cultures are to be made must, if results of value are to be secured, receive far more attention. Dr. Harris had employed a formula which measures substratum heterogeneity, as expressed in actual crop yield, in terms of the correlation between associated ultimate plots. It takes the convenient form

$$r_{p1\,p2} = \frac{\{[S(C_p^2) - S(p^2)]/m[n(n-1)]\} - \bar{p}^2}{\sigma_p^2}$$

where p denotes the yield of an ultimate plot, C_p the yield of a combination plot, $\bar{p}$ the mean yield of the ultimate plots, and σ_p their standard deviation, n is the number of ultimate plots in each of the m combination plots, and S indicates summation, for either the ultimate or combination plots of the field. In this sample formula n is supposed to be constant, but calculation with n variable is only slightly more difficult.

Application of this formula to the best series of data available in the agricultural literature shows that, in practically every field dealt with, substratum heterogeneity might have had a marked influence upon the results of a comparative test.

A paper on spurious values of intra-class correlation coefficients arising from disorderly differentiation within the classes has also been published by Dr. Harris.

Considerable attention has been devoted to the problem of maintaining white rats so that they should not be a nuisance in the building

and should be free from disease. Dr. MacDowell has devised and installed a set of cage-holders (racks) of iron pipe. The cages of half-inch-mesh wire rest on sheet galvanized-iron bottoms, on which layers of blotting paper are placed to absorb odors.

EDITORIAL WORK.

The Whitman manuscripts have been edited assiduously by Dr. Riddle. It will be a source of satisfaction to all biologists that the remarkable results of this thorough and far-sighted geneticist are being made available for study.

STATISTICAL SUMMARY.

PLANTS.

The range of species, number of families, and individuals of each bred in Dr. Shull's experiments are shown in the following table.

Name.	Number of families.	Number of individuals.	Name.	Number of families.	Number of individuals.
Bursa bursa-pastoris	57	5,511	Œnothera lamarckiana	13	629
B. bursa-pastoris×heegeri F_1	4	116	Œ. lamarckiana×brevistylis	2	94
B. bursa-pastoris×heegeri F_2	30	6,527	Œ. lata×lamarckiana	1	53
B. bursa-pastoris×heegeri F_4	27	2,557	Œ. lamarckiana-venosa hybrids	11	529
B. bursa-pastoris×heegeri F_5	43	6,064	Œnothera nanella	1	38
B. bursa-pastoris×heegeri F_6	14	2,095	Œ. nanella scintillans	1	27
B. heegeri×bursa-pastoris F_3	1	188	Œ. nanella hybrids	8	479
B. heegeri×bursa-pastoris F_4	12	797	Œ. nanella-atrovirens hybrids	2	33
B. heegeri×bursa-pastoris F_6	51	10,933	Œ. nanella-cleistantha hybrids	2	30
B. heegeri	2	250	Œ. nanella-venosa hybrids	2	8
B. bursa-pastoris apetala	2	189	Œnothera oakesiana	2	267
B. bursa-pastoris rubella	1	69	Œnothera robinsonii	2	199
B. grandiflora	1	125	Œnothera rubricalyx	3	267
B. viguieri	1	49	Œ. rubricalyx-lamarckiana hybrids	3	148
Fragaria spp	6	290	Œ. rubricalyx-rubrinervis hybrids	1	47
Lychnis dioica	159	8,715	Œnothera rubrinervis	11	1,235
Œnothera atrovirens	1	49	Œnothera rubrinervis nanella	1	167
Œ. atrovirens-cleistantha hybrids	4	14	Œ. rubrinervis-atrovirens hybrids	3	47
Œ. atrovirens-lamarckiana hybrids	8	140	Œ. rubrinervis-cleistantha hybrids	2	20
Œ. atrovirens-venosa hybrids	1	2	Œnothera scintillans	1	52
Œnothera "biennis CSH"	1	103	Œnothera stenomeres	1	37
Œ. biennis CSH-atrovirens hybrids	2	48	Œnothera stenomeres gigas	1	52
Œ. biennis CSH-cleistantha hybrids	2	73	Œnothera venosa	1	26
Œ. biennis CSH-lamarckiana hybrids	2	206	Œnothera spp	8	913
Œ. biennis CSH-venosa hybrids	2	83	Ribes alpinum	2	61
Œnothera biennis L	2	232	Rumex acetosella	1	65
Œnothera cleistantha	1	71	Rumex scutatus	1	23
Œnothera cleistantha-lamarckiana hybrids	23	1,076	Urtica urens	1	45
Œ. cleistantha-venosa hybrids	17	786	Valeriana dioica	1	4
Œnothera gigas	1	209	Valeriana officinalis	1	4
Œnothera grandiflora	2	269	Valeriana tripteris	1	3
			Total	571	53,438

POULTRY.

There were maintained 26 breeding pens and 1,624 chicks were hatched. Selection experiments on plumage color were continued.

SHEEP.

Nineteen lambs were born, giving additional data on twin inheritance, extra nipples, and double horns.

CONSTRUCTION AND EQUIPMENT.

Two additional pigeon-houses (making 4 in all) have been completed, and the grading (including concrete walls and steps) has been done. Extensive grading south of the animal house was done and runs put in place for large mammals. Six sets of concrete cold frames were built in the west garden and two concrete service bridges over the ravine. Part of the earth moved in grading was placed on the salt marsh, increasing the garden area, and the sandier part was used for the foundation of a tennis court, near the animal house. A tool-house and shelter, 12 by 18 feet, were finished at the farm. A shelter for summer work with rats was installed on top of the animal house. The fence around the sheep pasture was painted. The south end of the second floor of the Laboratory was remodeled to meet new needs. Metal racks and cages for the rats were made, and numerous small bits of apparatus and cabinet-work made for the various investigators' rooms.

The largest and most expensive addition to our equipment has been an air-conditioning apparatus to furnish the required temperature and moisture conditions to 4 rooms in the animal house. The general method of refrigeration employed is that of compression of ammonia. The expansion of the ammonia in the tubes cools brine. Moisture and dryness in desired amount are secured and maintained at a constant level, as in the warming apparatus.