

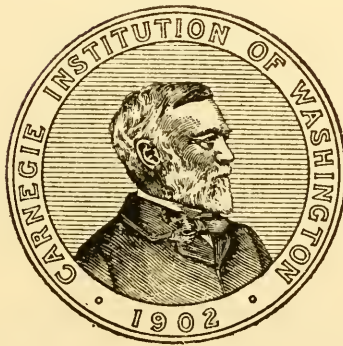
# CARNEGIE INSTITUTION

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## DEPARTMENT OF EXPERIMENTAL EVOLUTION. \*

C. B. DAVENPORT, DIRECTOR.

Among the principal advances of the year have been: (1) the origin from a line of parthenogenetic entomostraca of a strain that produces both sexes, in the same individual, in varying proportions; and the analysis of this condition; (2) the demonstration that, so far as studied, similar factors occupy similar chromosomes and have similar intrachromosomal relations in various different species of *Drosophila*, affording additional evidence of the fundamental nature of the structural mosaic of the germ-plasm; (3) the unraveling of the germinal factors present in the yellow daisy (*Rudbeckia hirta*) and the study of the numerous mutations that are arising in our strains; (4) the demonstration that the blood-plasma of fowls differs in the two sexes in fat and phosphorus content in the same way that pigeon eggs of prospectively different sex differ; (5) the demonstration of the inferiority, in solving the problems of the multiple-choice apparatus, of the offspring of alcoholic as contrasted with non-alcoholic parents; (6) the demonstration of dominant shortening factors in the genetic control of human stature; (7) the completion of the second volume of the unpublished scientific work of Professor Whitman.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. Staff meetings have been held weekly, at each of which a member of the staff reported on his own work. In addition to his other duties the Director has continued his analysis of the data of human inheritance, especially stature and the elements of success in achievement. In this he has been assisted by Miss Mary T. Scudder. Dr. J. A. Harris and his assistants have made an investigation of selective death-rate that has required the raising of 600,000 seedling beans. He has also spent some weeks in the Everglades region of southern Florida and in the neighborhood of the Desert Laboratory, southern Arizona, studying the physico-chemical properties of vegetable saps in their relation to environmental factors. Dr. A. M. Banta has continued the cave experiments, but has put most of his time on the work of selecting daphnids for sensitiveness to light, continuing parthenogenetic strains, attempting to control sex, and breeding sex intergrades. Dr. Riddle has continued his editorial work on the Whitman manuscripts and data and his studies on the control of sex in pigeons. Dr. E. C. MacDowell has carried on investigations into the modifiability of the germ-plasm and the effects of "selection" in the

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modification of a Mendelian unit. Dr. Metz has made progress in his study of the evolution of the chromosome groups in flies and in the comparative factorial structures of chromosomes of related species. Dr. Blakeslee is making genetical studies on a wide range of flowering plants.

## REPORTS ON INVESTIGATIONS.

### THE GERM-PLASM AND ITS MODIFICATION.

#### COMPARATIVE STUDY OF THE CHROMOSOME GROUPS IN DIPTERA.

Dr. Metz reports as follows:

"The chromosomes of Diptera, unlike those of most animals, are normally arranged in symmetrical pairs, the two members of each pair remaining in close association with one another during the greater part of the life of the fly. Stages were studied all the way from the egg to the adult, and in each the same paired association was found. During maturation these pairs undergo a reduction division essentially like that in other insects (a fact previously described by Stevens), and the two members go into different germ-cells. It appears, then, that the egg and the sperm contribute equivalent sets of chromosomes, and that in the fertilized egg corresponding members of the two sets become associated in pairs and remain associated throughout the life of the new individual. This is made extremely probable by the fact that in many cases the chromosomes are of different sizes and shapes and may be individually identified. In all cases (save X and Y in the male) the two members of a pair are alike in size, form, and behavior. Indeed, in one species it is possible easily to distinguish each individual pair from every other, and to see that every chromosome associates with its corresponding mate. If the chromosomes are genetically continuous, as there is great reason to believe, then these facts leave no doubt that in the flies each chromosome from one parent pairs up and remains associated with its mate from the other parent.

"A careful study of these phenomena—especially the evidence from tetraploid groups, as given in the paper—lends considerable support to the hypothesis that pairing is the result of a constitutional (chemico-physical) similarity or likeness between corresponding members, *i. e.*, each chromosome seems to have a definite make-up, similar to that of its mate, but different from that of the others; hence it associates with its particular partner and with no other.

"Obviously these results lend material support to the theory that Mendelian factors are located in the chromosomes—a theory necessitating just such a definite qualitative structure and individuality as that which appears to exist in these flies.

"In connection with this investigation it became of considerable interest to learn the distribution of the phenomenon of chromosome pairing; and for this reason the study became much more comprehensive than it would otherwise have been. It involved about 80 species, from among the highest to the lowest families of Diptera. The chromosome behavior was found to be the same in all of them, leading to the conclusion that the paired association is characteristic of the order Diptera."

#### COMPARATIVE STUDY OF CHROMOSOMES THROUGH THE GENUS *DROSOPHILA*.

Dr. Metz has also undertaken a comparative study of the chromosomes in the genus *Drosophila*. In its entirety this study is a very

extensive one, which would require years for its completion, owing to the great number and wide geographic distribution of the species. As a contribution to this topic, Dr. Metz has sent to press a paper which includes descriptions of 12 distinct types of chromosome groups, distributed in about 30 species that have been studied.

#### GENETICAL STUDIES ON TWO SPECIES OF *DROSOPHILA*.

Dr. Metz has selected two species of *Drosophila* that have different chromosome groups from *D. ampelophila* for comparison of genetical behavior in the three. He has secured at least 16 mutations in these two species within the last 12 months. In the species (as yet unnamed) upon which most time has been spent 14 or more mutants have appeared and are now being studied, and some very significant facts have already appeared, even though some of the most interesting features still remain to be investigated.

"First and foremost appears the fact that some of the mutants in this species are almost exact replicas of some in *Drosophila ampelophila* (studied by Morgan, et al.), although the two species are in many ways very different. Not only this, but in so far as they have been studied these characters fall into similar groups on the basis of linkage. The most definite evidence of this kind is shown by the sex-linked characters (which have been studied more fully than the others). Two characters, "yellow" body-color and "forked" bristles, are, so far as their characteristics show, almost exact duplicates of the same (named) mutants in *ampelophila*, and a third character, "magenta" eye, may perhaps bear a similar relation to that called "garnet" in *ampelophila*. In both species these three characters are sex-linked. Furthermore, it seems probable from evidence now being obtained that they show similar linkage relations to one another in both cases. The evidence is not yet complete, but it suggests that the factors compose a similar linear series in each species. This, if it proves to be the case, can only be considered as indicating that these two species possess a similar germinal organization, and that the organization is a permanent feature; that is, a genetic continuity of germinal structure, in so far as the factors are concerned, will be shown to exist in the *Drosophilas*. If the sex-linked factors are located in the sex-chromosome (X-chromosome), as seems altogether probable, then this would mean that the sex-chromosomes in these flies are genetically continuous; that they must be transmitted essentially unchanged from one generation to another and from one species to another in the course of evolution.

"A brief review of these results has been published in *Science*, and a more detailed report is in press in *Genetics*.

"Further work with this new species and with the others I am studying offers a most promising field for further investigations. It remains to be seen whether the number of linkage groups in these will correspond to the chromosome number, as in *ampelophila*, and whether the euchromosomes can be related to those in *amelophila* as can the sex-chromosomes. Since the number and size relations of the chromosomes are different in each of the three species, some very interesting questions are involved. Likewise, it will be of importance to learn whether or not the two sexes differ in respect to "crossing-over" in my two species as they do in *ampelophila*, and whether this is correlated with observable cytological evidence. In fact, a wealth of promising lines

is now opened up and, what is most important, the study has already progressed far enough to make it reasonably sure that the results may actually be obtained."

#### EXPERIMENTAL MODIFICATION OF THE GERM-PLASM.

The attempt to induce changes in the germ-plasm of rats by means of alcohol vapor, described fully in the Year Book for 1915, page 130, has been continued by Dr. MacDowell. An abstract of his work to that date was published in *Science*, November 12, 1915, and is reprinted here:

"The purpose of this investigation is to compare the mental capabilities of rats whose parents were alcoholic with those of rats of normal parentage. It is commonly claimed that, in man, the children of alcoholics are less teachable than children of normals. However, the exceeding difficulty of obtaining genetically comparable controls in man makes the study of a lower animal, although vastly different psychologically, of great interest, since double first cousins—the closest relationship possible for such comparisons—can be used. The first criterion used for judging mental activity has been habit formation in a Watson puzzle-box. The habit to be learned consists of a trip to the rear of the box, breaking an electric circuit, and so opening the front door, and, returning to the front, entering the box for the reward of food. The data recorded consist in the times required to open and enter the door of the puzzle-box. Each rat has been given 225 trials; 145 rats have been employed in this training. The data, summarized in various ways, have been represented by graphs. Awaiting the results of a second set of training experiments of a different nature, which are being conducted as a check on the first method, no general conclusions are given and only provisional conclusions are drawn about the present work."

The following additional conclusions have been reached:

"First, it is clear that breathing the fumes of alcohol for 90 minutes a day for 100 days does not cause rats to produce young with any sort of physical abnormalities that can be observed. It has also been determined that, for judging the mental valuations, different tests may give opposite results, and the most closely related pairs of families may give opposite results, even when tested by the same method. In the light of these facts it immediately becomes apparent that no final answer to the main problem can be justified until the relative values of the different tests have been established and something is known of the range of variations in mental ability that may be normally inherited in white rats.

"In support of the above conclusions the following examples are cited: Experiment I includes a litter of rats from normal parents and one from alcoholized parents. The fathers were brothers, the mothers sisters, so that the offspring were double first cousins. Experiment II includes two corresponding litters, similarly related, from normal and alcoholized parents. Moreover, the fathers in this experiment were brothers to the mothers in experiment I. Therefore the relationship between the normal litters in experiments I and II was just as close as that between the two litters in each experiment; they were all double first cousins, all from the same grandparents.

"However, although the alcoholized parents in both experiments were similarly treated, and although the training of all the offspring was alike, in experiment I the training with the puzzle-box showed from every standpoint that the rats from the alcoholized parents were more successful than the rats

from normal parents, while in experiment II similar criteria indicated that the normals were more successful than those from alcoholic parents. Data are quoted in the following table to support this statement. There are five methods of comparison: (1) the average time per trial of all the trials; (2) the average time per trial for the last ten trials; (3) the average number of "perfect trials" (4 seconds or less); (4) the average number of "perfect days" (3 trials of 4 seconds or less); (5) the number of rats with three successive "perfect days."

*Puzzle-box results for experiments I and II.*

	Exp. No.	Male parents.		Female parents.		Result.
		Normal.	Alcoholic.	Normal.	Alcoholic.	
1. Averages per trial, all trials.	I	7.93	7.53	12.67	9.91	Alcoholics faster.
	II	13.04	15.69	23.80	12.91	Normal males faster.
2. Averages per trial, last 10 trials.	I	4.33	3.65	7.06	6.29	Alcoholics faster.
	II	4.10	6.43	4.64	7.47	Normals faster.
3. Average number of "perfect trials."	I	69.5	121.0	48.5	79.5	Alcoholics better.
	II	85.7	55.0	99.0	62.0	Normals better.
4. Average number of "perfect days."	I	6.0	16.4	0.75	9.5	Alcoholics better.
	II	7.0	2.0	9.0	0.5	Normals better.
5. Number of rats with 3 successive "perfect days."	I	1	4	0	1	Alcoholics better.
	II	3	0	1	0	Normals better.
6. Total number of rats used.	I	6	5	4	4	
	II	9	3	2	4	

"The multiple-choice apparatus has previously been described (Year Book for 1915, page 131). As explained, the method consists of teaching the rats to go for food to a door that bears a certain relationship to the other doors opened; and the correct door, in different trials, is always a different one. Now, this is obviously a more difficult proposition than learning to run behind the puzzle-box in order to open the door to the food chamber. Instead of basing the test on time the results of the multiple-choice training are based on the numbers of right and wrong doors that are chosen. For every trial the path taken by the rat is graphically recorded on a separate slip of paper, and the doors that are correctly or wrongly chosen are indicated thereon. This method was adopted partly to form a check on the results obtained from the puzzle-box; as such it has clearly demonstrated that the characteristics of a rat that make for the speedy solution of the puzzle-box problem are quite different from those called into play by the multiple-choice method. The same group of rats described as experiment I were trained on the multiple-choice apparatus. Three problems were presented, as well as a memory test, on the multiple-choice apparatus. In problem I the opened door farthest to the right was the correct one; in problem II the opened door farthest to the left was the correct one; in problem III the second opened door from the left was the correct one. The averages of the numbers of correct first choices and the averages of the numbers of wrong choices in these three problems are shown in the annexed table. There can be no question that the normal rats are superior, from the standpoint of this test, to those from alcoholic parents, thus reversing the results of the puzzle-box training.

"Since the two methods described have offered different results, the importance of a third method is manifest. Accordingly, to give further evidence on the relative abilities of the different rats, a circular maze of the Watson type has been built, equipped with a camera-lucida device for obtaining accurate

records of the paths taken by the rats. Two large-sized mirrors are suspended over the maze in such a way that the rays of light from the illuminated maze are twice reflected and passed through a lens in the top of a small camera-box. Inside this box the image of the maze is projected upon the record sheets. As a rat travels about in the maze its image is followed with a pencil on the record sheet, and in this way an accurate record of every trial is

*Multiple-choice apparatus—Rats in experiment I.*

Problem.	Parents normal.		Parents alcoholic.		More successful group.
	Correct.	Wrong.	Correct.	Wrong.	
I	5.63	7.55	5.13	8.61	Normal.
II	4.40	12.62	3.56	16.14	Normal.
III	3.82	11.81	2.52	18.56	Normal.

obtained. These lines are subsequently measured with a chartometer, so that the distances traveled may be calculated. The time per trial is also recorded. Although 29 rats have been tested on this maze, no statement of results can be made at present.

"As the rats grew to be more than a year old, there appeared a very high incidence of tuberculosis, so that in many of the experiments the maze and memory test could not be made.

*Summary of rat training, 1915-16.*

Investigation.	Test No.	No. of rats.	No. of trials.	
Puzzle box:	I	15	810	
	II	15	828	
	Memory tests.	III	10	459
		V	8	423
Multiple choice:	I	17	8,500	
	VI	8	2,240	
	Problem 1.	VIII	11	3,080
		IX	26	5,460
Problem 2.....	I	17	1,190	
	VI	8	2,240	
	VIII	11	3,080	
	IX	26	5,460	
Problem 3.....	I	17	1,190	
Memory:				
Problem 1.....	I	17	2,040	
Problem 2.....	I	17	4,420	
	IX	13	1,820	
Maze.....	A	19	1,596	
	IX	10	840	

"As it became more and more evident that the alcohol taken in by the parents had not made any very striking modification in their children, plans were made to start a second group of experiments in which the amount of alcohol administered should be greatly increased. A start has been made on this work with 8 pairs of rats, which are being made dead drunk every day. There has been developed a much shortened and standardized system of train-

ing which will enable the rats to be fully tested before the age of the high incidence of tuberculosis.

"The table following gives some idea of the number of tests made in getting evidence as to the relative intelligence displayed by the offspring of alcoholized and of non-alcoholized rats."

Insufficient funds have prevented the continuance of the experiment on the modification of the germ-plasm by extremes of atmospheric conditions. Meantime the plant is being maintained in good condition for future use. Even though we may have doubts of getting positive results, still, in view of the assurances of other biologists that they have gained modifications by this means, it is eminently our work to make the trial.

#### THE SIGNIFICANCE AND CONTROL OF SEX.

##### SEX IN BIRDS.

To this Station seems to have fallen the opportunity of demonstrating that the current view that sex is determined solely by the sex-chromosome is too narrow. It is chiefly Riddle who is developing this field. A summary of his results were presented before the American Society of Naturalists at the Columbus meeting and has been recently published in the *American Naturalist* under the title: "Sex control and known correlations in pigeons." In this is set forth 10 lines of evidence that the inherent tendencies of the fertilized egg in respect to sex may be altered by other factors. Riddle's chemical studies on eggs destined to produce males or females, together with a review of the literature, have led him to the conclusion "that sex-control, in the several forms in which it has been accomplished, has been accomplished fundamentally by the same means in all—a changed metabolism, in which a higher water-content of germ and higher metabolism for male production, and lower water-content and decreased metabolism for female production have been definitely shown to be associated in a number of instances." He concludes:

"The studies that have thus far been made on sex, and on the experimental control of sex, in pigeons go very far, we believe, towards an adequate demonstration that germs prospectively of one sex have been forced to produce an adult of the opposite sex; that germs normally female-producing have, under experiment, been made to develop into males; and that germs which were prospectively male-producing have been made to form female adults. That neither selective fertilization, differential maturation, nor a selective elimination of ova in the ovary can account for the observed results. Further, and perhaps of more importance, these studies throw much new light on the nature of the difference between the germs of the two sexes. This difference seems to rest on modifiable metabolic levels of the germs; males arise from germs at the higher levels, females from the lower; and such basic sex-differences are quantitative rather than qualitative in kind."

Of special interest, as demonstrating the chemical basis of sex, is a paper published by Riddle and Lawrence, Sexual differences in the



fat and phosphorus content of the blood of fowls, (*American Journal of Physiology*, vol. 41, 430-437). They show that in adult male fowl, non-laying females, and females laying eggs the relative amounts of phosphorus are as 100:115:205, and the alcohol-soluble fractions (fat) are as 100:116:181, respectively.

"When one begins from the point of vantage of the demonstrated initial difference in storage metabolism (particularly of fat and lecithin) of male- and female-producing ova of the pigeon, it is clear that every new and subsidiary hypothesis are unnecessary for the general understanding of many hitherto puzzling sex phenomena. A higher fat-content of the blood of woman, female crab, and hen than of man, male crab, and cock is [my view] the expected result of a mere continuance or persistence of the observed relative powers of the eggs."

#### SEX INTERGRADES IN CRUSTACEA.

Dr. Banta has found that in the midst of a parthenogenetic series of *Daphnia*-like forms—a species of *Simocephalus*—there occurred a female which produced some normal males and also some of mixed or intergrading sex. The animals are transparent, so that the constituents of their sex-glands may be seen; in addition 8 secondary sex-characters are recognized. As for the 2 sex-glands, they may be of the same or of opposite sex. Even one and the same gland may produce sperm at one time, eggs at another, or sperm and eggs simultaneously. As for the 8 differentiating secondary sex-characters, they may be all such as belong to one sex, or 1, 2, 3, or 4 may belong to one sex and the remainder to the other. Most of the possible combinations of primary and secondary sex-characters are realized in the sex-intergrades studied; *e. g.*, female intergrade, normal except for one male secondary character; female intergrade, with several or all of its secondary sex-characters those of a male; hermaphrodites with various combinations of secondary sex-characters; male intergrades with several, though never as many as 8, female secondary sex-characters; male intergrades with a single female secondary sex character.

"The percentages of the various sexual types produced by different mothers varies greatly. In general there is some relation between the secondary sex-characters of the female intergrade and the sex array and the proportions of each type in her offspring. Female intergrades with few male characters tend, in general, to produce fewer males and male intergrades than female intergrades with several male characters. Some of the female intergrades with a large number of male secondary characters are almost sterile. Many others, including nearly all those with as many as 6 or 7 male secondary characters, are entirely sterile. None with 8 male secondary characters have been known to produce young. The sterile female intergrades produce eggs, but the eggs fail to complete their development in the brood-pouch, or, as in the most extreme female intergrades, the ovarian development of the eggs is not completed and the eggs disintegrate within the ovary.

"The testes in the male intergrades frequently do not contain large amounts of sperm. In such individuals the sperm-ducts are frequently lacking and the

testes shorter than normal. In the majority of the male intergrades some such abnormality exists in the reproductive system. These details are given to show how complete a series the sex intergrades really form.

"Sex here reveals itself not as a fixed and definite state, but as a purely relative thing. With this material no arbitrary classification into males and females is justifiable or possible, not only because of the confusing admixtures of male and female secondary characters, but also because the same individual, even the same sex-gland, may develop eggs and sperm at the same time or sperm at one time and eggs at another time.

"By selecting as mothers female intergrades with several male characters the production of sex intergrades has been continued for 19 generations. There has been no apparent reduction in vigor or change in the character of the offspring produced, and (contrary to my earlier expectations) it is now hoped that the material may be maintained as long as desired.

"Several normal females from the sex-intergrade stock produced only normal females, and from these only normal females were produced throughout succeeding generations. The origin of the sex-intergrade strain may be referred to as a mutation. The origin of all-female-producing strains from within this sex-intergrade stock is a return mutation. Several of these return mutations have been observed and probably others occurred but escaped observation, since some of the mutants were not used in propagation of the stock.

"On another point the occurrence of these sexual forms (in the sex-intergrade strain) throws important light on the problem of sex in *Cladocera*, indicating that the capacity for sexual reproduction is not lost after long-continued parthenogenetic reproduction (130 generations). Furthermore, the origin of subsidiary lines within the sex-intergrade strain which produced normal females exclusively (except that in the thirteenth and fourteenth generations of one of these all-female-producing strains several normal males were produced) indicates rather clearly that the sex-intergrade strain did not occur in stock which had lost or had undergone any retrogression in sexual capacity."

The similarity of the general results as to sex obtained by Doctors Riddle and Banta is obvious. Combined with the observations of Goldschmidt on gipsy moths they lead to the conclusion, which Dr. Banta draws, that probably similar but less readily recognizable intermediate sexual states may be of somewhat common occurrence and that sex in general is a much less fixed and precise state than is commonly supposed.

In the case of the sex intergrades of *Simocephalus* it is not maintained that they were brought about by external conditions. They suddenly appeared and were continued because of some change in the germ-plasm. But, as hinted at in Year Book No. 14, page 133, there is evidence that the exclusively female-producing series may be interrupted and males made to appear with special changes in the environment. On this point Dr. Banta reports:

"This evidence came in part from the fact that the very few occurrences of sexual forms among the stock began at times of poor experimental conditions—poor food or otherwise inferior breeding conditions. The sex-intergrade strain originated after the continuation for several generations of conditions unfavorable to *Simocephalus*. One strain of the 'long spine' *Daphnia*, after three or four generations of depression, produced a relatively

large number of males. In one case a 'wild' *Daphnia pulex*, immediately after having been brought under laboratory conditions, produced a large preponderance of males. Some discarded *Daphnia pulex* in a neglected jar long left standing in the laboratory produced males at a time when none of the 18 *Daphnia pulex* lines receiving the usual laboratory treatment showed any tendency to the production of sexual forms. The above were the cases of the occurrences of sexual forms during the past year. The few earlier appearances of sex forms in my cultures were under similar circumstances."

In the sex-intergrade stock similarly modified sex-ratios occurred contemporaneously in the offspring of large numbers of mothers; but whether this result is due to a similar change of environment acting on all lines or to simultaneous mutation is uncertain.

The following lines of *Cladocera* are being bred in Dr. Banta's laboratory:

Species.	No. of strains.	Length of time bred.	No. of generations.	Males.	
		<i>months.</i>			
<i>Daphnia pulex</i> . . . . .	{	7	58	189 to 201	None } Except in some dis- None } carded stock of None } some of these lines. In one strain, in first laboratory generation.
		2	18	67 69	
		3	15	54 60	
		4	3½	13 17	
<i>Daphnia</i> sp. (long spine) . .	3	34	117 130	Several at two different times.	
<i>Simocephalus vetulus</i> . . . . .	{	6	49	158 169	In sex-intergrade strain only.
		4	47	158 162	None.
		3	34	141 144	None.
<i>Simocephalus serrulatus</i> . . .	{	6	21	65 71	None.
		5	11	40 44	None.
<i>Moina bracliiata</i> . . . . .	5	14	102 105	None.	

"(a) These 48 strains of 5 species of *Cladocera* have produced males in only a few isolated instances and under the conditions in the laboratory have shown no evidence of an innate sexual cycle which it is generally supposed exists in *Cladocera*. Strains of four of these species have been reared for over 100 generations solely by parthenogenetic reproduction. One of these species has been reared 169 generations and another over 200 generations, the former for a period of more than four years and the latter for almost five years. If sexual reproduction were necessary or a sexual cycle an innate necessary thing, such ought long since to have become manifest.

"(b) In spite of this long-continued and uninterrupted parthenogenetic reproduction these strains show no decrease in reproductive vigor. Tests show that these strains have apparently as great virility and reproductive capacity as 'wild' lines recently brought under laboratory conditions.

"(c) These pure lines further serve as material on which to do additional work on inheritance in parthenogenetic reproduction."

#### SEX IN MUCORS.

Dr. Blakeslee brings to this Station his problem on sexual differentiation in the mucors upon which he has worked for many years; but in adjusting himself to the new conditions he has not found time to work on this topic.

## THE INHERITANCE OF GERMINAL PECULIARITIES.

GENETICAL CONSTITUTION OF *RUDBECKIA*.

Dr. Blakeslee has brought to this Station the investigation of variability and heredity in the yellow daisy (*Rudbeckia hirta*), which he has been making for several years; this year he had under cultivation over 15,000 pedigree plants. He states:

"Variations in the following characters have been found in wild plants: Absence of rays and their presence in rather definite numbers from 8 to 30 and to perfectly double forms; width of rays; diameter of head from 1 to 5½ inches; color of rays from pale straw color to deep orange; relative intensity of color in inner half of ray forming a lighter or darker ring; different intensities of mahogany color at base of ray on upper side; mahogany on under side of ray; constriction of ray at tip, at middle, or at base—those constricted at tip, either rolled in or rolled out to give the "cactus" type seen in dahlias—those constricted at base without change in color or characterized by lighter color or by presence of black pigment on constricted areas; transformation of rays into tubes, giving 'quilled' type; the position of rays, bending upward, horizontal, reflexed, straight, or variously twisted; the shape and size of disk; the color of disk, from yellowish green through several grades of purple to almost black; vegetative characters, such as height, branching, size and shape of leaf, fasciations, etc.

"Evidence from the distribution of the variants in nature and from their reappearance in sowings from open-pollinated heads shows that most if not all of these variations are inherited. Certain of these characters appear to be inherited in simple Mendelian manner; giving 3 : 1 ratios in the F<sub>2</sub> generation. Thus basal 'mahogany' on the ray acts as a dominant, while a type of reddening of the back and base of the ray which I call 'chocolate' acts as a recessive. In both, however, pattern factors undoubtedly exist and are responsible for the extreme variability in arrangement and intensity of the pigment.

"One character, the presence of yellow in place of the normal purple in the cone, has proven of considerable interest. I have obtained this variation from several different localities. The peculiarity seems to be inherited as a simple recessive. The fact, however, that the yellow-coned plants A crossed with B, B with C, or C with A all produce purple-coned offspring shows that the yellow-coned forms are not alike genetically. That they differ chemically is indicated by treatment with KOH when the cone flowers of A turn black and those of B and C turn bright crimson. Since seedlings that are destined to produce yellow cones have no red pigment in their stems, it should be possible to save considerable time by selection in the seed-pans, and my plans therefore are to make a more intensive study of this character the coming season.

"We have some 12,000 plants of the jimson weed (*Datura stramonium*) under cultivation. Two mutations appeared in our cultures last year which are being studied. The first is characterized by a globose capsule and broad leaves and is apparently a recessive. The second has spineless capsules, slit corollas, and lacerated leaves, and is apparently a dominant. The *Daturas* have not yet been recorded this year, and it is therefore not possible to report upon the behavior of these types in crosses nor of others that are appearing.

"Among other problems under investigation may be mentioned inheritance of self-sterility in *Rudbeckia*, *Helianthus*, and *Verbena*, parthenocarpy in cucumbers, chemical and physical differences between the sexes in diœcious plants, the annual habit in beets, various characters in *Geodetia*, *Clarkia*, *Portulaca*, *Fraginus*, *Betula*, *Morus*, *Populus*, and *Salix*."

## HEREDITY IN MAN.

As was the case last year, the Director's main line of research has been the analysis of data afforded by the Eugenics Record Office as to the inheritance of human traits.

Through the generosity of Mrs. E. H. Harriman and the organization of the Eugenics Record Office, it has been possible to undertake a study of the well-known "Jukes" family from the time of Dugdale's work to the present—40 years later. The investigation was intrusted to Dr. Arthur H. Estabrook. Dr. Estabrook's results have been issued as Publication No. 240 of the Carnegie Institution of Washington. The main conclusions of this paper are:

"On the whole, the later descendants of the Jukes, in Connecticut, in New Jersey, even in Minnesota, still show the same feeble-mindedness, indolence, licentiousness, and dishonesty; even when not handicapped by the associations of their bad family name and despite the fact of being surrounded by better social conditions. This is because, wherever they go, they tend to marry persons like themselves. On the other hand, the dispersion has led some of these descendants to marry into better stocks, and this is improving the quality of the germ-plasm.

"Not merely institutional care, nor better community environment, will cause good social reactions in persons who are feeble-minded or feebly inhibited, although, on the other hand, better stimuli will secure better reactions from weak stock than will poor stimuli."

The whole study will, it is thought, bring home to those interested in social progress the grave importance of the constitutional or hereditary factor in determining behavior.

The Director has been engaged during the year in a study of heredity of human stature, a classical topic of research which offers almost insuperable obstacles to a satisfactory solution in terms of modern genetic theory. To see if various segments of stature, such as head and neck, trunk, thigh, and foreleg, are separately and independently inheritable the Director measured personally two generations in scores of families, chiefly on Long Island, but also in Lexington, Kentucky. The results are being prepared for publication.

The studies of the Director on the inheritance of elements of human behavior are being synthesized in an analysis of the life-activities and output of effective men. This topic demands extensive reading and analysis of biographies and family histories in order to determine the distribution in the family of the significant traits.

## HEREDITY IN SHEEP AND POULTRY.

The experiments on heredity of twin-production and multi-nippled condition have been continued. In the spring, from 10 ewes, 22 lambs were born, all multi-nippled. As the ewes have 4 functional mammary glands, they were successful in feeding and rearing their young.

The sheep experiment at the New Hampshire Experiment Station has been continued. A strain of Hampshiredown-Rambouillet hybrids has been nearly perfected, and shows in a high degree a union of especially valuable qualities of fine wool and good conformation. In addition the second hybrid generation of Southdown-Rambouillet origin is being produced.

With poultry we are continuing the prolonged selection for "new buff," studying the factors present in "bare neck," analyzing the genetic constitution of certain new rumpless strains and of syndactylism. There were 184 chicks hatched during the year.

#### OTHER INVESTIGATIONS.

##### CORRELATION BETWEEN CHARACTERS OF LEAVES IN NORMAL AND ABNORMAL BEAN SEEDLINGS.

Dr. J. A. Harris has been breeding a strain of beans that produces more than the two primordial leaves that constitute the normal number. His problem was, How do the abnormal and the normal plants compare in respect to total weight of leaves and sap density? The results are as follows: When the cotyledons are of the normal number, 2, but not attached at the same level, the total weight of the leaf laminae is about 81 per cent of that of strictly normal plants. In a sample of 100 seedlings, selected for greatest separation on the stem of the cotyledons, the ratio is 79 per cent. Where there are 3 instead of 2 cotyledons and 2 primordial leaves the leaf-tissue is about 78 per cent of normal. Even when with 3 cotyledons there are 3 primordial leaves in place of 2, the total weight of their laminae is 10 per cent less than that of the normals. In fasciated plants about 25 per cent less leaf-tissue is produced than in normals. As for the cell-sap, there is not a marked difference in concentration between normals and abnormal.

##### CORRELATION BETWEEN HOMOLOGOUS PARTS OF A PLANT.

In plants there is obviously hereditary resemblance between the parts of one and the same plant. Dr. Harris has determined for the legume *Cercis canadensis* the correlations between the number of ovules to the pod, number of seeds to the pod, number of abortive ovules, etc., from different pods of one plant, and has compared his results with figures obtained by other statisticians. The correlation of ovules is higher in *Cercis* than in most other species studied; but the correlation in number of seeds is about the same as obtained in other cases.

##### VEGETABLE SAPS.

Gortner, Lawrence, and Harris show ("The extraction of sap from plant tissues by pressure," *Biochem. Bull.* No. 5, 139-142) that Dixon and Atkins are indeed right in their caution that a sample of sap

obtained by pressing untreated tissues can not be considered typical of the whole sap of the tissue. The authors show that there is a gradual increase in concentration in successive fractions of the expressed plant-sap.

Harris and Lawrence have also studied the plant-sap in relation to environment on the Arizona deserts, to determine the cryoscopic constants. For the region as a whole the average cryoscopic determinants are: trees and shrubs, 28.10 atmospheres; dwarfs and half shrubs, 27.45 atmospheres; perennial herbs, 16.35 atmospheres; winter annuals, 14.73 atmospheres. In relation to habitat the concentration of plant-juices increases in the following series: arroyos, Pima Cañon, rocky slopes, mesa-like slopes, salt-spots.

TABLE OF OSMOTIC PRESSURE BASED ON DEPRESSION OF FREEZING-POINT.

Dr. Harris has extended a table of osmotic pressures of vegetable saps, based on depression of the freezing-point, from 3.00 to 5.99.

STUDIES IN PERSONAL EQUATION AND STEADINESS OF JUDGMENT.

Dr. Harris, as results of his biometric work, has published two papers in the *Psychological Review*, entitled, "Experimental data on errors of judgment in the estimation of the number of objects in moderately large samples, with special reference to personal equation" (Nov. 1915), and "On the influence of previous experience on personal equation and steadiness of judgment in the estimation of the number of objects in moderately large samples" (Jan. 1916). He reaches the conclusion that errors in estimation (in the case of 50 beans) are due, among other things, to personal equation and steadiness of judgment. In three subjects—

"There is a slight but significant personal equation, which, notwithstanding the constant efforts to improve, persists throughout the two years during which the experiments were intermittently made. For a measure of steadiness of judgment is used the coefficient of variation. The subjects differed more strikingly in steadiness of judgment than in personal equation.

"Personal equation seems to be remarkably little influenced by experience. In some experiments it increases, in others it decreases.

"Steadiness of judgment is in rather conspicuous contrast with personal equation in that it is remarkably influenced by previous experience. The correlations between the number of previous trials within the period and steadiness of judgment and between the number of previous periods within the experiment and steadiness of judgment are numerically low, but almost without exception indicate that as experience becomes greater the scattering of the individual estimates about their mean value becomes less. Probably the rate of this change is not uniform, but is most rapid at first and then falls off."

BIOMETRIC MISCELLANY.

The correlation between a series of measures taken in one year and a series taken a subsequent year may be designated as direct interannual

correlation. Dr. Harris points out the value of knowing the correlation in egg-laying, milk-yield, crop-production, and the like between first and second year, as enabling one to predict the second year's performance from that of the first. A series of illustrative cases is given in "The value of interannual correlations" (*Amer. Nat.*, 49, 707-712).

The distribution and correlation of the sexes (staminate and pistillate flowers) in the inflorescence of certain weeds has been worked out by Dr. Harris (*Bull. Torrey Botanical Club*, 42, 663-673) from data of *Cannarella*.

Dr. Harris has also published "An outline of current progress in the theory of correlation and contingency," in the *American Naturalist* for January. Also a note on "standard dairy score-cards" (*Science*, Oct. 8, 1915).

"The incidence of the beetle *Bruchus* on beans" has been studied incidentally by Dr. Harris. His analysis shows that the larger pods are more apt to be parasitized, probably because of some relation of greater fitness to the size of the beetle.

#### GENERAL CONSIDERATIONS.

In a subject of such complexity as biology it is often desirable to spend some time in synthetic or general analytic discussion. The Director has written a paper on the topic "The form of evolutionary theory that modern genetical research seems to favor" (*American Naturalist*, Aug. 1916), in which the preformation view of phylogenesis—the view of orthogenesis—is accepted as a very useful hypothesis, and one with the most numerous probabilities in its favor. Some of the evidence for it is set forth and certain consequences of it as a theory.

A second general paper is an effort by Dr. E. C. MacDowell to clear up the differences that have developed between Castle and other geneticists, or rather to harmonize Castle's views with current theory. This paper, "Piebald rats and multiple factors," appeared in the *American Naturalist*, December 1916.

The Whitman manuscripts have been brought forward by Dr. Riddle, and, it is expected, will be completed by the end of the year.