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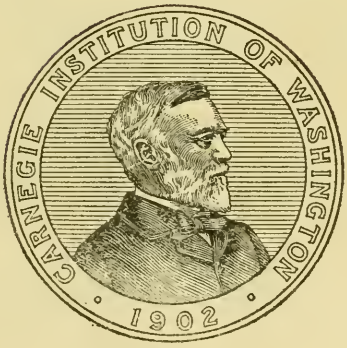

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DEPARTMENT OF EXPERIMENTAL EVOLUTION.*

C. B. Davenport, Director.

Among the principal advances of the year have been:

(1) The demonstration of the parallelism of the mutations in related species of the fruit-fly, *Drosophila*, and further evidence for the conclusion that the factors for them occupy corresponding places in the chromosomes.

(2) The discovery of a set of conditions of the environment which induces the appearance of males in a parthenogenetic species of entomostraca.

(3) The demonstration of the great effect of inhalation of alcohol on the growth and fecundity of rats.

(4) The acquisition of additional evidence that the *gradual* change in the somas of a population by selection of parents may be due merely to the isolation of individual factors out of many concerned with the same trait.

(5) The analysis of a new method of selecting the best egg-laying birds in a flock of poultry.

(6) The discovery of a form which acts much like a dominant mutant in jimson weed but which seems to depend on a parasite for its production.

(7) The production of a "pure" highly abnormal race of beans.

(8) The analysis of the juvenile traits and hereditary characteristics of successful naval men.

(9) The discovery of a method of forcing pigmentation in albinos.

(10) The discovery of an extraordinary variability in sap concentration in plants, which throws light on the rise of sap in trees, on the acquisition of food from their hosts by parasitic phanerogams, and on the relation of sap properties to the solutions in the substratum.

(11) The origination of mutations that are sterile with the parent species.

(12) The completion for press of the unpublished scientific work of Professor Charles O. Whitman.

STAFF.

The work of this Department during the present year has been carried on by seven resident investigators and various associates and assistants. In addition to his administrative duties the Director has prepared for publication a work on naval officers, their juvenile traits and family history. As a member of the Anthropological Committee

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of the National Research Council he cooperated in the report of the committee concerning physical criteria for the selection of recruits. Dr. J. A. Harris, besides carrying on here his extensive series of breeding experiments on beans, went to Florida and to the Dismal Swamp, North Carolina, to study the relations of tissue sap to the environment of plants. Dr. A. M. Banta, assisted by Mr. Obreshkove, has continued his extensive breeding experiments on sex in daphnids and has been getting into final form for publication his work on selection of strains of daphnids for sensitiveness to light. Dr. O. Riddle completed his editorial work on the Whitman manuscripts and is preparing a book embodying his researches on sex in pigeons. Dr. E. C. MacDowell, assisted by Miss Vicari, has continued his work on the effect of alcohol on the germinal qualities of rats. Dr. C. W. Metz continued his study on the evolution of the germ-plasm of Drosophilidæ. Dr. A. F. Blakeslee continued his genetic studies on plants and directed the work on poisons of the bread-mold carried on at this Station at the expense of the U. S. Department of Agriculture. He is also improving the adzuki bean as "an emergency war-research problem." During July to September Dr. Aute Richards, of Wabash College, was a guest at the Station, studying, cytologically, Dr. Banta's sex-intergrading daphnids; also, Dr. John Y. Pennypacker, of the University of Pennsylvania, studied, histologically, abnormal seedling beans.

REPORTS ON INVESTIGATIONS.

THE GERM-PLASM AND ITS MODIFICATION.

COMPARATIVE STUDY OF THE CHROMOSOME GROUPS IN DIPTERA.

Dr. Metz has during the year devoted some time to extending his studies on the chromosomes in the Diptera, and especially on their behavior in spermatogenesis. He has almost completed a study on spermatogenesis in the Asilidæ and one on spermatogenesis in the Drosophilidæ. Since the chromosomes are doubtless to be regarded as the true specific stuff, a study of their forms, and especially of the evolution of the chromosomal complex, becomes of great interest. Dr. Metz has shown that, starting with the generalized form found in *Drosophila ampelophila*, 12 types of chromosome-complexes may be distinguished in related species which are merely modifications of that generalized form. These types are shown in figure 1. It will be seen that A consists of 3 pairs of large chromosomes and 1 pair of small ones. Of the 3 large pairs one (the lower in each drawing) is the sex-chromosome pair. Of the others one or both may be divided, resulting in 4 or 5 large pairs. Thus in F there are 5 pairs of large chromosomes and 1 pair of small ones. The foregoing series doubtless represents stages in the evolution of the chromosome-complex—the germ-plasm—of one group of genetically related organisms.

COMPARATIVE STUDIES ON THE GERM-PLASM OF DROSOPHILA.

Dr. Metz initiated two or three years ago a series of breeding experiments on other species of *Drosophila* to provide for a detailed genetic comparison with the results on *Drosophila ampelophila*. Such a comparison involves numerous questions of wide genetic and evolutionary significance, as well as several of more technical interest. On some of these questions definite evidence has already been obtained, chiefly by the breeding of *Drosophila virilis*, although the work has not yet reached its most important stages. Among the results attained by Dr. Metz largely or wholly within the last year, he considers the following as the most important:

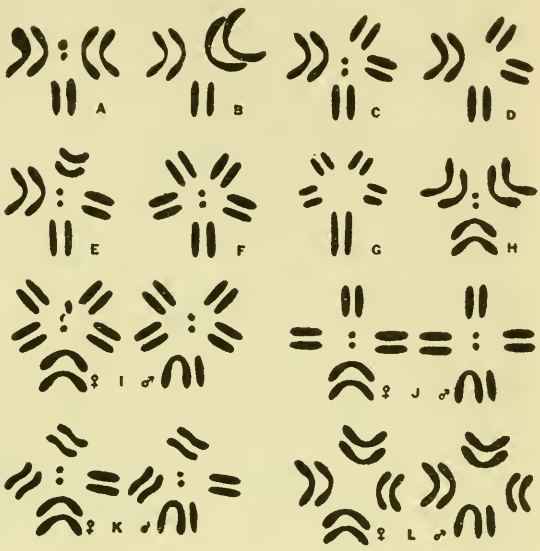

FIG. 1.

With regard to the relative mutability of species.—On this point the evidence from *virilis* indicates a degree of mutability at least equal to that in *ampelophila*. Hence the supposed phenomenal mutability of the latter is not limited to one species alone. At least 23 mutant races have been obtained in *D. virilis* up to date. Considering the relatively limited number of individuals examined, this undoubtedly represents a rate of mutation approximately equal to that of *ampelophila*.

With respect to the nature of mutations arising in related species.—On this point the evidence agrees with expectation in that the mutants in *virilis* are of the same general types as in *ampelophila; i. e.*, they represent modifications in the color, shape, and structure of the eyes, in the color and shape of the body, in the size, shape, and venation of the wings, in the number and morphological character of the bristles, etc. Some of these modifications show strong indications of actually being homologous in the two species—a point that will be considered later.

With respect to the phenomena of linkage and "crossing-over" in related species.—Most of Dr. Metz's work has centered around this feature. In general the results show a series of linkage and cross-over phenomena similar to those in *ampelophila*, leaving no doubt that the genetic processes are fundamentally the same in the two species. One especially significant point of resemblance is in the dissimilar genetic behavior of the two sexes. In *ampelophila*, as is well known, crossing-over occurs only in the female; linkage is absolute in the male. This is a genetic

peculiarity not found in all organisms and probably results from peculiarities in chromosome behavior. In *virilis* Dr. Metz has found this sexual difference to exist exactly as in *ampelophila*. At least this is true in respect to all of the characters thus far studied and they are sufficient to give strong evidence of the universality of the rule in this species.

With respect to the general chromosome theory of heredity.—Drosophila virilis provides an exceptionally good opportunity to test this theory by means of a comparison between its linkage phenomena and those of *ampelophila*. In *ampelophila* there are 4 pairs of chromosomes and 4 groups of linked factors to correspond; in *virilis* there are 6 pairs of chromosomes and hence, according to the hypothesis, there should correspondingly be 6 linkage groups. It is very significant, Dr. Metz believes, that 5 such linkage groups have already been located in this species. Since this is one more than the number in *ampelophila*, it argues strongly in favor of the chromosome hypothesis and makes it probable that the discovery of the sixth group is only a matter of time.

With respect to the relations between corresponding linkage groups in related species.—Data on this subject are furnished by the sex-linked factors in *virilis* taken in connection with those in *ampelophila*. Eight factors belonging to the sex-linked group in *virilis* have been carefully studied by means of crosses involving various combinations of characters. This series of experiments alone has involved upwards of 10,000 individuals. As a result the sex-linked factors are found to be related, upon the basis of linkage, as shown in the accompanying diagram. It is significant that they fall into a linear series just as do those of *ampelophila*, and that when the position of a factor is known with respect to any two previously located factors, one can predict its position with respect to any other factor in the series.

FIG. 2.—Chart of the sex-chromosome in *Drosophila virilis*.

y, yellow; *fr*, frayed; *v*, vesiculated; *h*, hairy; *m*, magenta; *f*, forked; *r*, rugose; *g*, glazed.

Comparing this linkage group as a whole with that of *ampelophila*, its relatively greater "length" is to be noticed at once. Similarly constructed diagrams in the two species are respectively 67 to 68 "units" (*ampelophila*) and 80 to 90 "units" (*virilis*)—a unit representing 1 per cent of crossing-over. Since the "length" increases somewhat with an increase in the number of factors involved in a given region (*i. e.*, the length is thus more accurately determined, because double crossing-over is largely eliminated), the discrepancy is really greater than that indicated in these figures and the diagram in *virilis* will probably include 90 to 100 units when more intermediate factors are studied. This leaves no doubt that there is a difference in "length" of the two linkage groups here; and since "length" represents amount

of crossing-over, it appears that crossing-over is more frequent in *virilis* than in *ampelophila*. Whether this is due to a difference in the length (or amount) of the sex-chromosome involved in the two cases (assuming that the chromosomes carry the factors) or to an actual difference in rate of crossing-over per unit of chromosome length, is not certain, but the available evidence suggests the latter.

With respect to the relation between particular characters and their factors in two related species.—Striking, although not extensive, evidence has been obtained on this question. It was partly included in last year's report, but has been more fully worked out this year. Two of the mutant characters in *virilis*—"yellow" body-color, and "forked" bristles—appear to be almost exact duplicates of two in *ampelophila*. A careful comparison under the microscope reveals a remarkable likeness in each case, and there seems to be great probability that the characters are actually homologous in the two species. Considering this fact, it is very significant to note that in both cases the characters are sex-linked and that their factors occupy similar relative positions in the factorial (linkage) group. Such a series of correlations strongly suggests a common germinal basis in the two species—in other words, lends material weight to the assumption of a definite organization in the germ-plasm and to the assumption that this organization persists from species to species.

In addition to the above more or less anticipated results, another series of phenomena of an entirely different nature was observed. This bears more particularly upon the general question of "evolution by mutation." The case is as follows: Two sex-linked mutants (allelomorphs) were found in hybridization experiments to exhibit an incompatibility that differs little, if any, from cases of incompatibility between species in nature. When reciprocal matings are made between these mutants one of the combinations entirely fails to produce offspring and the other gives hybrids that are all sterile. As a result, it is impossible to get a second generation from the cross. To Dr. Metz's mind this suggests the possible origin of species in nature by means of mutations that involve incompatibility. If three forms exist in nature (as they do in the laboratory), of which two are fertile with the third but infertile with one another, then the disappearance of the third form, by means of natural selection or otherwise, would leave the other two isolated as distinct species. No matter how slightly they differed to begin with, the fact of isolation would allow them to develop independently and to diverge into well-marked species.

EFFECT OF ALCOHOL ON GERM-PLASM.

The study of the effects of alcohol upon the germ-plasm of rats, described in earlier reports, has been continued during the year by Dr. MacDowell. While he has accumulated many data, it has been thought best, before publishing, to note the results on a new set of

experiments. In this new set the amount of alcohol given has been greatly increased and certain changes have been made in the method of training; also, a new stock of rats from the Wistar Institute was made use of. The treated rats were left in the alcohol-vapor every day until they were in deep stupor.

While it is not possible, as yet, to give the results of this new experiment in relation to the main problem, certain side-topics have received much light. The effect of the alcohol upon the growth of the rats receiving it has been determined. Weekly weighings have been made of all the alcoholized rats and their normal controls and from these weights individual growth-curves have been plotted. The average size at stated ages has been found. These results are given in table 1. Since the females were continuously breeding, only males are included in the data given. The loss in weight of the alcoholics after 6 months of alcoholization amounts to more than 20 per cent of the weight of the normals.

TABLE 1.—*Average weights, in grams, of alcoholized male rats compared with their normal brothers.*

Age in days.	Normals.		Alcoholics.		Differences; normals heavier by—
	Average weight.	No. of rats.	Average weight.	No. of rats.	
30	45.4	22	46.2	27	0.8
40	74.5	22	70.5	27	4.0
60	128.7	22	116.1	27	12.6
90	174.9	22	142.3	27	32.6
120	239.8	21	192.5	22	47.3
151	267.0	18	211.7	16	55.3
182	285.0	13	227.1	10	57.9

TABLE 2.—*Fecundity records of alcoholic rats compared with normal rats.*

[Matings of the alcoholics and the corresponding normals made on the same day, and the record of births taken during equal periods.]

Group.	No. of pairs.		No. of young born.	
	Alcoholics.	Normals.	Alcoholics.	Normals.
A	10	10	23	75
B	4	3	13	31
C	7	8	30	81
KC	9	8	42	113
Total.	30	29	108	300

Another immediate effect of alcohol is upon the fecundity. In one set of experiments a male and a female rat that had been alcoholized were mated and the number of their progeny was compared with that of unalcoholized controls. The results are given in table 2. Since 30 pairs of alcoholized rats produced 108 young, while 29 pairs of unalcoholized rats produced 300 young, it can not be doubted that the imbibition of alcohol causes, either directly or indirectly, a reduction in the number of offspring born.

A test was made also upon the learning capacity of the alcoholized rats as compared with that of their normal brothers and sisters. The training was given each morning before the alcohol was administered. No summaries have been made from these data.

A study of the second generation, which constitutes the main objective of the experiment, has been pushed rapidly ahead. A large number of rats (see table 3) has been taken through a 3 months' schedule, but no summary of the results can be offered at present.

TABLE 3.—*Number of rats trained November 1916 to August 1917.*

	Total.
Parents	12
First generation offspring (alcoholized, 62; normal, 57)	119
Second generation offspring (from alcoholized parents, 49; from control parents, 66)	115
Second generation offspring (one parent alcoholized and one normal, 6; from control parents, 7)	13
Total	259

EFFECT OF STARVATION ON THE GERM-PLASM OF BEANS.

Dr. Harris has continued his studies on the influence (or rather the absence of influence) of the depauperization through starvation of the earlier generations upon later generations of beans. This work is nearly completed.

ALTERATION OF THE QUALITY OF THE GERM-PLASM OF A POPULATION BY SOMATIC SELECTION.

Experiments with Drosophila.—The question of the degree to which the quality of the germ-plasm of a population may be altered by somatic selection remains much mooted, despite Castle's prolonged investigations of the subject. During the year under review Dr. MacDowell has contributed to this topic in his paper, "Bristle Inheritance in *Drosophila:* II. Selection." Like Castle in his studies of rats, MacDowell with *Drosophila* has selected for more and for less, only MacDowell, unlike Castle, has dealt with a numerical trait—the number of bristles on the back of this rapidly breeding fly. Castle has selected his rats for only 16 or 17 generations; MacDowell selected his flies for 49 generations. Castle believes his experiments prove that by selecting parents with the greatest amount of pigmentation the germ-plasm in the later generation tends to produce a more extensive pigmentation than in the earlier generations and that this change may go on indefinitely or until the rat is entirely covered with pigment.

MacDowell, from his more extensive numerical series, concludes that, at the beginning, selection as parents of individuals with the greatest number of bristles isolates a many-bristle-producing germ-plasm. But the maximum potentiality in this respect is reached in about 8 generations, after which the somatic selection does not result in the isolation of a germ-plasm with the potency of still more bristles. The effect of somatic selection on the quality of the germ-plasm of the population is thus *nil* after the germ-plasm has been rendered homozygous in consequence of the selection of the first 8 generations.

Experiments with pigeons.—In our pigeon pens Dr. Riddle has discovered two fully pigmented but "weak" individuals, male and female (in whose immediate ancestry or collaterals no whites have appeared) that have become progenitors of lines in which for four generations partially white pigeons have appeared. Inbreeding and "crowded reproduction" have been practiced. In a second line, pigeons of partially white plumage occurred in one branch of the ancestry. Inbreeding, "crowded reproduction," and selection have been practiced in this series also and in the later generations birds with increased white in the plumage have arisen. In both of these lines, however, the darkest forms have also been selected for breeding, and from these forms also partially white birds have been produced; and greater amounts and proportions of white were obtained, as in the cases cited above, from the later eggs of the the season; *i. e.*, from those obtained under "crowded reproduction."

THE SIGNIFICANCE AND CONTROL OF SEX.

SEX IN PIGEONS.

Dr. Riddle has continued his studies on sex in pigeons. The results of these studies he has recently stated in the following terms:

"The studies that have thus far been made on sex, and on the experimental control of sex, in pigeons go very far, we believe, toward 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, or 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 differences are quantitative rather than qualitative in kind."

Support for Dr. Riddle's views as to the significance of sex are believed by him to be given by certain recent discoveries. Thus he finds, first, that in pigeons a high proportion of the males that result from crosses between genera bear testes whose size and shape relations are reversed from the condition normal for males and approach the

conditions found in normal females. The significance of this lies in the fact that it is in the wide (generic) crosses that we are able to obtain males from eggs of initial female-producing tendency. In other words, additional evidence is thus obtained for the reality of sex-control in the generic crosses; and in this group of male hybrids the gonads frequently retain or approximate to the gonad size and weight relations of the female.

Dr. Riddle has obtained two pairs of identical twins among the pigeons. Both were pairs of females. He says:

"The importance of the finding lies in the fact that the *storage metabolism* of the germs (ova) which produced these pairs of twins is known to have been higher than in the other ova which arose from the same ovaries and which produced only single (not twin) embryos. It seems that similar information concerning the germ from which such twins have arisen in any other animal forms has never hitherto been obtained. In addition, the fact that the two twin-producing ova were of *high storage value*, and both produced *females*, is a further confirmation of my views as to the metabolic basis of sex."

SEX DETERMINATION IN CLADOCERA.

Dr. Banta has made marked progress in his studies of sexuality in *Daphnia* and related genera. He reports as follows:

"With my work the most important and most desired advance of the year has been in the further light obtained as to the factors controlling sex in *Cladocera*. The general and long-standing belief has been that there is a periodicity in the occurrence of sexual forms in *Cladocera* and that this is controlled by internal factors. In former reports (1915 and 1916) I pointed out that the long-continued and uninterrupted parthenogenetic reproduction in the five species being bred in the laboratory did not result in reduced vigor or in any evidence of need for sexual reproduction. I also pointed out that in the few isolated cases in which males had appeared in the laboratory cultures there was evidence of changed environmental conditions as the causative factors. During the past year overwhelming evidence, it seems to me, has been obtained that environmental factors induce the occurrence of sexual forms."

Evidence from the observed incidence of males.—It may be safely stated that with our methods of handling and observing the *Cladocera* material few males occur without our knowledge; yet for a period of $5\frac{1}{2}$ years 7 strains of *Daphnia pulex* passed through, on the average, more than 225 generations in the laboratory cultures without producing males or sexual eggs. For a lesser period of time, but throughout 186 generations, of 10 strains of *Simocephalus vetulus* no males or fertilizable eggs were produced (except under the special conditions obtaining in the sex-intergrade strain). Of 5 lines of *Moina* 150 generations and of 3 lines of *Simocephalus serrulatus* 65 generations did the same. During 146 generations of *Daphnia longispina* males had occurred only twice and then only in very small numbers. Additional strains (many of which are no longer being bred) of all the above species have been in the laboratory for various lengths of time. None of them produced males.

Table 4 gives an account of the history of all the strains at present in the laboratory, together with the records of their production of males.

TABLE 4.—*Male production in pure strains of Cladocera.*

Species.	Number of strains.	Length of time bred, to May 1917.	Number of generations to May 1917.	Occurrences of males.		
				Previous to May 1917.	Number of strains in which—	
					Males occurred.	Males did not occur.
		months.				
Daphnia pulex.....	7	66	219–233	None, except in some discarded material of this stock.	4	3
	2	26	96– 97	Do.....	1	1
	3	23	81– 85	Do.....	2	1
Daphnia longispina ..	3	42	133–157	Some at two different times.	2	1
	3	7	20– 25	None.....	3	..
Simocephalus vetulus.	7	57	182–195	In sex-intergrade strain only.	4	3
	3	55	181–186	None.....	3	..
	6	29	91– 97	None.....	5	1
Simocephalus serrulatus.	3	19	63– 67	None.....	3	..
	10	1½	4– 6	None.....	10	..
Moina brachiata	5	22	145–155	None.....	5	..
	52	.....	.....		42	10

In marked contrast with the extreme rarity of the occurrence of males in the cultures, in May 1917 males suddenly began to appear in the laboratory in numbers and in the vast majority of the strains. There were males in 7 of the 12 strains of *Daphnia pulex;* in 12 of the 16 strains of *Simocephalus vetulus;* in all of the 5 lines of *Moina;* in all of the 13 lines of *Simocephalus serrulatus,* and in all except one of the 6 strains of *Daphnia longispina.* Thus in 42 of the total number of 52 strains in the laboratory, males occurred within a short time and in considerable numbers. Yet this material consisted of 5 different species of 3 genera of *Cladocera,* was obtained from various localities, including two Florida localities separated by nearly 100 miles, and had been reproducing parthenogenetically in the laboratory for periods varying from 1½ months to 5½ years and had descended solely by parthenogenetic reproduction for from 4 to 233 generations. Of *Daphnia pulex,* 7 lines had been in the laboratory for 66 months and had descended 225 generations during that time without producing males; 2 other lines of the same species had been in the laboratory for 26 months and 96 generations, and 3 others for 83 generations, exclusively female; yet 7 out of 12 of these strains produced males at the same time. Likewise with the other species, 3 lines of *Daphnia longispina* reared

for 145 generations, and 3 for 22 generations produced males in all but one line. With *Simocephalus vetulus* 12 of the 16 strains, some of which had been in the laboratory for 188 generations, the others for 81 to 97 generations, produced males; 3 lines of *Simocephalus serrulatus* reared in the laboratory for 65 generations and 10 lines—one from Lakeland, Florida, and 9 from Eustis, Florida—reared for only 4 to 6 generations responded almost simultaneously in the production of males. With *Moina* the story is the same; all the lines produced males at once.

Such synchronism in independently reared and diverse stock can be thought of only in terms of a common influence. It seems a logical impossibility that this synchronism could be due to an internal factor, for it seems hard to believe that in 42 out of 52 strains of quite diverse material the appropriate periods for production of males in an innate sexual cycle should occur almost simultaneously. One must then ascribe the synchronism to an external—an environmental—factor or, perhaps, to a number of such factors.

It was noted in last year's report that in cases in which males had been observed environmental changes had obviously occurred. In the present case the environmental influence was strongly in evidence. In the outdoor pond from which the culture-water was obtained males were occurring in great numbers in the wild stock—just as in the few earlier and very restricted occurrences of males in the laboratory, males had been noted in the wild stock in the outdoor ponds from which the culture-water was gotten, or else (in the absence of wild stock in the outdoor ponds) the culture-water was recognized as somewhat different from the material ordinarily used. During none of the earlier occurrences of males in outdoor ponds had there been such a great number of males either in the ponds or in the laboratory as during the past spring. During the recent epidemic of males the environmental influences tending to produce males were very much more pronounced on the wild stock as well as upon that reared in the laboratory.

Experimental evidence.—Direct experimental evidence adds to the conviction (if additional evidence were necessary) that environmental factors cause the production of males.

In one of these experiments the newly released young of a single brood from one mother were used. These were isolated in individual bottles—5 in culture-water from a pond in which were present great numbers of males of another species of *Cladocera*, and 4 in water from a pond in which no males were present. None of the latter 4 produced any males; all of the 5 in food material from the pond in which occurred wild males produced males.

In another experiment, similarly conducted, food from two sources was used. Different bottles of each food were given different chemical treatment. A small amount of alkali was placed in some and a small amount of acid in others. Still others were untreated. The result was as shown in table 5.

TABLE 5.

Culture-water.	Untreated.	Acid added.	Alkali added.
Pond I.....	3 mothers, all female young.	2 mothers, all male young. 1 mother, dead.	3 mothers, all female young.
Pond II.....	2 mothers, all female young. 1 mother, all male young.	3 mothers, all female young.	2 mothers, all male young. 1 mother, all female young.

Where acid was added to the solution from Pond I, "all male" broods were produced; when untreated or with alkali added to this solution "all female" broods were produced. Just the reverse was true with the food solution from Pond II; the addition of alkali producing "all male" broods in 2 out of 3 cases and the addition of acid resulting in "all female" broods. There was 1 "all male" brood in the untreated food from Pond II. These are not completely differential results, but they are suggestive and, considered in connection with other experiments, this significance becomes unmistakable. Other sets of experiments similar to the two mentioned above resulted similarly. The experimental evidence may be said to have considerable weight.

The experiments were not all equally successful, however, and some produced no significant results at all. This lack of uniformity in the experimental results is attributed to variable factors in the culture-water. While the culture material is more or less the same at all times, it will readily be recognized that at different times considerable differences occur in the constituents of an outdoor pond-water in which live many small and larger organisms. So far as the relative degree of alkalinity is concerned, it apparently operates to influence the sex of the daphnids through some other factor or factors; hence it is a controlling influence apparently working through an unknown environmental factor. Its control of sex is none the less significant, however. (A standard culture medium, Dr. Banta suggests, would afford excellent opportunity to attain complete control of sex.)

Production of ephippia.—Strange as it may seem, the production of ephippia does not ordinarily occur in the laboratory simultaneously with the production of males, and frequently males and ephippia do not coexist in outdoor ponds. There is evidence that the production of ephippia, too, is controlled by environmental factors.

Origin of a second sex-intergrade strain.—During the occurrence of males in the spring, sex-intergrades were produced, in Dr. Banta's cultures, by several mothers in one of the strains of *Daphnia longispina*. These were mothers which also produced normal males. Propagation from these sex-intergrades has resulted in the establishment of a strain of sex-intergrades of *D. longispina*. This strain produces, in addition to normal females, sex-intergrades in every generation.

There are 8 easily recognized secondary sex-characters in this species: (1) *Body size*—the males are smaller than the females; (2) *outline of the head*—in the male the head-outline does not form a definite beak as it does in the female; (3) and (4) *character of the first pair of antennæ*—these in the male are considerably developed and distinctly different from the very rudimentary structure in the female; (5) and (6) *outline and hairiness of the ventral anterior margin of the carapace*—in the male this margin forms almost a right angle and is quite covered with hairs, in the female the margin is gently rounded and hairless; (7) and (8) *character of the first pair of thoracic appendages*—in the male these are relatively simple structures armed with a hook-shaped, finger-like projection; in the female they are branched into many long terminal filaments, while there is nothing resembling the hook-like structure of the male. These 8 secondary sex-characters, together with the character of the gonads (which is readily determined by microscopical examination of the living animal), make it possible to state definitely the degree of intersexuality of each individual intergrade (fig. 3).

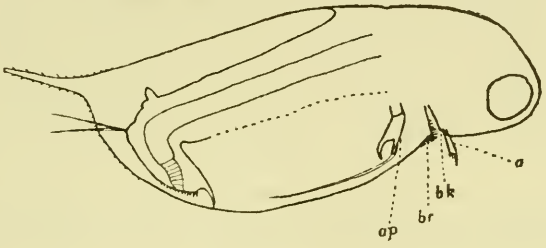

FIG. 3A.

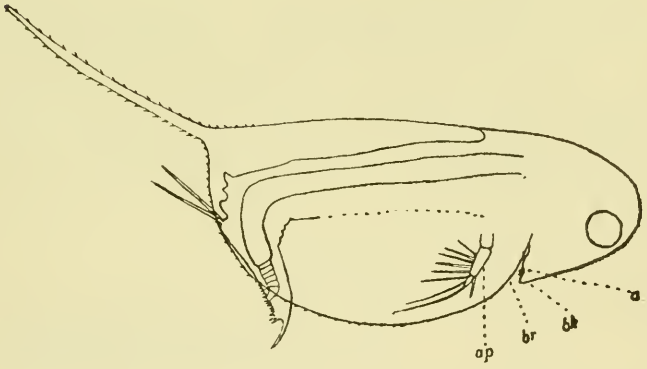

FIG. 3B.

a, antenna; *br*, breast (ventral anterior margin of carapace); *bk*, beak; *ap*, first thoracic appendage.

FIG. 3A. Normal male from sex-intergrade-producing strain of *Daphnia longispina*.

FIG. 3B. Normal female from sex-intergrade-producing strain of *Daphnia longispina*.

Sex intergrades may have any combination of these significant male and female secondary sex characters. Further, these characters are often present in intermediate condition. Obviously with such a sex difference as that between the female and male first thoracic appendage there is room for a wide variety of intermediate conditions. Such a great range actually occurs.

The intergrades are of all grades, ranging from female intergrades with one of the secondary sex-characters slightly male to female intergrades with all of the secondary sex-characters fully and strongly male. In the *Simocephalus* sex-intergrade strain reported a year ago there occur in addition to some normal females and many female intergrades: (1) a few hermaphrodites with various combinations of male and female secondary sex-characters; (2) some male intergrades with one to several female secondary sex-characters; and (3) a great many normal males. In the new *Daphnia longispina* sex-intergrade strain, however, no hermaphrodites or male intergrades have so far been observed while normal males are extremely rare in this strain, whereas in the *Simocephalus* intergrade strain a considerable percentage of the individuals are normal males. The sex-intergrade strain of *Daphnia longispina* runs distinctly less toward maleness than does that of *Simocephalus*.

In other regards the two strains possess many characters in common. Both strains of sex-intergrades vary in their productivity. The more highly male a female intergrade is the less productive she is likely to be. Most of the female intergrades which have most of their secondary sex-characters those of a male are sterile. Ovarian eggs are produced and develop almost to the point of being transferred to the brood pouch, but their development then ceases and they disintegrate within the ovary.

The occurrence of a second sex-intergrade strain adds greatly to the interest and significance of such forms. Sex is again revealed not as a precise and definite state, not as an alternative condition, but as a purely relative condition.

Non-necessity or sexual reproduction in Cladocera.—In the last several reports I have referred to the significance of the fact that the lines of the various species of *Cladocera* continued reproducing parthenogenetically without apparent diminution of vigor. Such is still the case. The oldest lines of different species have now (September 1, 1917) been reproducing parthenogenetically in the laboratory as follows:

TABLE 6.

Species.	No. of strains.	No. of months in the laboratory.	No. of generations produced in laboratory.
Daphnia pulex.....	7	70	235 to 256
Daphnia longispina.....	3	46	151 to 175
Simocephalus vetulus...	10	61	198 to 206
Simocephalus serrulatus.	3	23	80 to 86
Moina brachiata.....	5	25	183 to 192

In spite of this long and continuous parthenogenetic reproduction the lines seem to be as vigorous as ever. No apparent need for sexual reproduction has manifested itself, for although males have appeared in response to the appropriate environmental influences, sexual reproduction has not occurred and the lines have continued parthenogenetic reproduction with undiminished vigor.

Sex in mucors.—Dr. Blakeslee reports that, in investigations on the common bread-mold, in which he was assisted by Mr. A. F. Schulze, some facts of interest were discovered relating to the distribution of the two sexual races in nature and to the differences between them.

THE INHERITANCE OF GERMINAL PECULIARITIES.

FLOWERING PLANTS.

Investigations on the flowering plants have been continued by Dr. Blakeslee along the lines reported on last year.

In the yellow daisy (*Rudbeckia hirta*) added evidence has been accumulated in regard to the inheritance of self-sterility and self-fertility and the effects of inbreeding which tends to bring about incompatibility between sibs, reduced germination, and dwarfed and weakened offspring. It has been definitely established that there are two types of variants with yellow cones. The one turns black, the other bright crimson, with KOH, but they are alike in outward appearance. When these two types are crossed they throw purple cones in the F_1 generation, and in the F_2 the two yellow types reappear. A repetition of crosses grown in the garden last year indicates that one of our original crosses on wild plants resulted from off pollination and that we have in hand only two instead of three genetically distinct types of yellow cones as reported last year. Investigation of doubling now under way indicates that this character is extremely complex.

The work on jimson weeds (*Datura stramonium*) has been extended, and a number of new mutants discovered. One called "Globe" reported upon last year we have grown for several generations without being able to obtain a line which breeds pure for this character. The "Globe" plants can be recognized in the seed-pans and extensive sowings are soon to be made of pedigrees from this mutant which will not be grown to maturity. It is suggested from work already done that the mutant character is transmitted through the female and not through the male parent.

The type with spineless capsules, slit corollas, and lacerated leaves which was grown last year and provisionally classed as a dominant character has been investigated in some detail. The character-complex appears first on the later branches of slightly over 1 per cent of the plants in the field from five different sources. When the character is well expressed the stamens contain no pollen. The seeds secured

by pollination with normal plants throw offspring with about 79 per cent showing the peculiarity in the seedling stage. The proportion of abnormal plants depends roughly upon the strength of the abnormality in the capsule producing the seed. In a single instance good pollen was obtained from an abnormal plant and crosses showed that the abnormality is transmitted through this pollen. Normal plants grafted on abnormal plants take on the complete abnormal complex, as shown in the new leaves, flowers, and fruits which subsequently develop. The abnormality, therefore, looks like a bacterial disease. Inoculations, however, with expressed juice of the abnormal plants have so far failed to infect normals.

One of the mutations in the jimson weeds is of considerable interest, since it suggests the way in which a new species having once originated by mutation may be able to establish itself as a perfectly distinct form without intergrading with the parent species alongside which it is growing. The mutation in question is perfectly self-fertile and the sibs in its offspring are fertile *inter se* and with the original parent mutant. Neither the mutant nor its offspring (with doubtful exceptions) have been found capable of crossing with any of the several different lines that we have under cultivation.

In *Portulaca*, a dwarf mutant has been found which apparently acts as a Mendelian recessive, but which occasionally produces branches reverting to the normal type which are heterozygous for the dwarf character. Other vegetative segregations as well as doubling and color types of flowers in this species are being studied. Doubling in *Portulaca* seems to be a Mendelian dominant, the homozygous full doubles having the stamens and pistils so strongly transformed into petals that they rarely set seed, the heterozygous semi-doubles segregating according to expectation into full doubles, semi-doubles, and singles.

Doubling and self-fertility are under investigation in *Helianthus*.

Verbena is being investigated for color-characters and self-fertility. The pollen of individual plants may be largely imperfect. The number of seeds produced by bagged clusters seems roughly proportionate to the amount of good pollen produced by the flowers.

For a number of years Dr. Blakeslee has been growing pure lines of the adzuki bean (*Phaseolus angularis*) largely for class demonstration purposes. The species is largely grown in Japan for human food and is reported to be, next to the soy bean, the most prolific yielder of seed of the leguminous plants in cultivation. In the vicinity of Washington, D. C., it gives about twice the yield of the common navy bean. Unlike the soy bean, which has to be prepared commercially, the adzuki bean may be used in the home in the same way as is the navy bean. Its high yield and its freedom from the so-called rust which has ruined the bean industry in certain regions suggested the adzuki as a valuable plant to

introduce for human food and improve by scientific breeding. This Department has been glad that the services of Dr. Blakeslee and his assistants could be offered to the Government for work with this new Japanese bean and the problem has been accepted by the National Research Council as "an emergency war-research problem." It is proposed as rapidly as possible to develop a stock of seed from the most prolific lines and get the beans on the market and in the meantime to combine, if possible, the desirable characters of size and color of seed, yield per acre, and early maturity. Dr. C. V. Piper, Agrostologist of Forage Crops Investigations of the Bureau of Plant Industry, U. S. Department of Agriculture, who has been growing different races of adzuki beans for several years as a possible forage crop, has kindly sent us seed material of desirable races for starting the hybridization work. Much of the hybridization work must be done in the greenhouse in order to gain an additional generation a year.

Since the last report Dr. Blakeslee has grown approximately the following numbers of plants in garden and greenhouse:

TABLE 7.

	Garden.	Greenhouse only.		Garden.	Greenhouse only.
Datura.....	9,400	11,700	Helianthus..	1,000	.....
Rudbeckia....	14,000	.....	Portulaca....	3,000	3,000
Verbena.....	700	200	Adzuki beans	About 1.5 acres.	.....

Dr. Harris has undertaken systematic tests of the productivity of lines of navy beans as Dr. Blakeslee has of the adzuki beans. He is engaged on experiments upon the technique of variety testing, the theory of which is in especial need of investigation.

Tetracotyledonous beans.—In an extensive series of bean seedlings Dr. Harris has found some with more than the normal number of 2 cotyledons, and these have founded 7 lines which yield exclusively abnormal offspring, of which 7,602 were produced in 1915. The abnormalities, which are probably physiologically related, are: more or less fasciated axis; divided axis; cotyledons varying in number from 2 to 7, 4 being the commonest condition; primordial leaves varying in number from 1 to 14, with a mode at 4; foliar ascidia. It appears that the correlation between number of leaves and number of cotyledons in this abnormal series is low, only about 13 per cent. The field studies on the beans are being supplemented by various intensive physiological investigations. Work on the histology of the normal and teratological seedling in relation to the problem of variation correlation and selective death-rate has been begun by Dr. John Y. Pennypacker.

HEREDITY OF ATAXIA AND DEFECTIVE PLUMAGE IN PIGEONS.

These two defects have been studied together in the same stock of common pigeons by Dr. Riddle, and the fourth generation has now been obtained. The ataxia arose in a single individual, a female. The defective plumage ("scraggliness") has rarely appeared in our stock. It has been bred from the only adult living bird (a male) of this kind which we possessed. The fact is to be noted here that both these rarely occurring defects have been perpetuated quite undiminished to the fourth generation.

HEREDITY IN MAN.

Stature.—The Director, in cooperation with the Eugenics Record Office, has completed a study of inheritance of human stature, which has been published in Genetics. Stature has long been a classical object of investigation, largely because it is so readily measured. Thus, in 1889 Galton published his studies on stature in parents and children and their interrelation. This led to Professor Karl Pearson's remarkable series of investigations "Mathematical Contributions to the Theory of Evolution" that founded the biometric school, which has left its imprint on biology, though it has proved disappointing in its assistance to the study of heredity. Though stature is the end-result of a number of independently varying elements, still, because of facts that determine growth as a whole, and because the length of the separate segments of stature are separately inheritable, it is possible to find some law of inheritance of the trait.

The present study was made on data derived from 3,298 children, their 1,738 parents, and a number of grandparents, uncles, and aunts. A large proportion of these were especially measured at their homes in various parts of the country. The hypothesis is supported that while short parents tend, on the average, to have short children, they may, and frequently do, carry germ-cells which lack the shortening factors; on the other hand, all of the children of tall parents are tall. Consequently the offspring of two very short or short parents are more variable in stature than the offspring of two very tall or tall parents as 2.4 is to 2.2. Also, whereas the offspring of two very short or short parents tend, on the average, to be less extreme than the parents, this is not true of the offspring of two very tall or tall parents.

Not only is stature as a whole inherited, but also, and even more clearly, each segment of stature, such as neck, length of torso, thigh, and foreleg; and the inheritance of the length of these segments follows the same law as does stature as a whole. An interesting by-product of this study is that persons of similar stature tend to marry each other, and the more extreme their stature the more particular are persons in this respect. Among 869 matings that of a very short man to a very

tall woman occurred only once, or one-tenth the expected number of times, while the marriage of a very tall man to a very short woman did not occur at all.

Hereditary traits of naval men.—The Director, assisted by Miss Mary T. Scudder, has analyzed the juvenile and family history of naval officers representing 65 families and including over 100 naval officers of various grades. The result has been the formulation of a new method which may be utilized in the selection of naval officers, namely, the consideration of the facts of juvenile promise and family history. It is found that naval officers are of different types; there are naval fighters (like Nelson, Farragut, Porter, and Cushing), naval explorers (like Sir John Franklin, McClintock, and our own Wilkes), naval inventors (like Dahlgren), naval diplomats (like Hornby), and so on. To consider the fighters only, one finds nomadism, love of the sea, hyperkinesis, and absence of fear practically universal, even at a very early age. The hyperkinetic tendency shows in either father or mother; if in both it tends to be exaggerated in the son. The factors for the nomadic and adventurous traits usually come from the maternal germplasm only, though, in consequence of the fact that young naval officers frequently marry young women of naval stock, the traits may be shown in both sides of the house. It is concluded that the strong inclination toward the sea depends upon a recessive factor.

HEREDITY IN SHEEP AND POULTRY.

The experiments on heredity of twinning, multinippling, and production of a superior strain in sheep have been continued. At the station 22 lambs were born from 13 mothers, not quite so good a record as last year. The cooperative sheep experiment with the New Hampshire Experiment Station is being continued. A paper on "Family performance as a basis for selection in sheep" was published conjointly with Mr. E. G. Ritzman, animal husbandman at the New Hampshire station. Progress is being made with the poultry strains. During the year 338 chicks were hatched, mostly of "new buff" and "bareneck" strains.

EXPERIMENTAL PRODUCTION OF VARIATIONS.

COLORATION OF CAVE SPECIES IN SUNLIGHT.

Cave-inhabiting amphipods are without pigment and appear of an opaque white, nor will they gain pigment when exposed to sunlight. The young of one species from the caves of southern Indiana have been reared by Dr. Banta in daylight and gained a brownish-pink coloration. This color does not depend on chromatophores, nor does it lie in definite granules. Its significance remains undetermined, though it is clear that the light has induced some physiological change that leads to the production of a diffuse pigmentation.

FORCING PIGMENTATION IN ALBINOS.

Dr. Riddle, in collaboration with Mr. Victor K. LaMer, has been able to induce the formation of melanin pigment in the choroid of a species of dove in which such pigment is not ordinarily produced. They show that free oxygen is necessary for the process.

PHYSIOLOGY OF REPRODUCTION.

EGG-PRODUCTION AND SKIN-COLOR IN FOWLS.

Dr. Blakeslee, who discovered two or three years ago that yellow pigment on the ear-lobes and shanks of White Leghorn fowls was inversely correlated with fecundity, has published a fuller paper, with statistical analysis by Dr. Harris, on this subject. It appears that the percentage of yellow (as measured by the color top) in the ear-lobe during October is closely inversely correlated with the mean annual egg-production of any bird. The correlation is 0.55. The result is of great practical importance, since by it one can tell in October without trap-nesting which birds have been the heaviest layers during the past year. Birds showing only 10 to 20 per cent of yellow in their ear-lobes in October will have laid at the end of the following year on the average about 185 eggs; those exhibiting 55 to 65 per cent yellow will have laid on the average only about 130 eggs. This result is believed to be due to the circumstance that the growth of the eggs in the ovary abstracts yellow pigment from the body-tissue, or precludes its being deposited there. In any case the discovery, now abundantly demonstrated, is of great practical, and not a little theoretical, importance.

RELATION BETWEEN NUMBER OF OVULES PER POD AND FERTILITY IN BEANS.

A study of over 150,000 pods of beans was made to determine the degree of relationship between the number of ovules per pod and the capacity of the pod for maturing its ovules. The conclusion is that there is a negative relationship between these two qualities such that the greater the number of ovules the smaller the proportion that will develop into seeds. The correlation is not a very close one, however, being of the order of about 2 per cent. This investigation and that recorded in the following paragraph were made by Dr. Harris.

RELATION BETWEEN NUMBER OF PODS PER PLANT AND INDIVIDUAL SEED-WEIGHT IN BEANS.

From 15,897 bean plants 78,975 seeds were weighed and it was determined that uniformly in each of 27 cultures there was a positive correlation between the number of pods on the plant and the average size of the beans produced. The size of the correlation varied from $+0.005$ to $+0.339$, with a mean of 0.159 ± 0.012. This result agrees with others secured earlier that permit the conclusion that, on the average, the larger the number of pods on the navy-bean plant the

greater the number of ovules and of seeds per pod and the greater the average weight of the seeds.

RELATION BETWEEN SYMMETRY AND FECUNDITY.

The relation between symmetry in distribution of ovules in the bean-pod and the average number of seeds formed has been studied by Dr. Harris in navy beans. It appears that in pods with unsymmetrically placed ovules fewer of them, on the average, form seeds than in pods with symmetrically placed (even) ovules.

OTHER INVESTIGATIONS.

VEGETABLE SAPS.

By means of the method of measuring osmotic pressures of vegetable saps elaborated by Gortner and Harris, Dr. Harris and Mr. John V. Lawrence have made an interesting series of comparative investigations into the concentration of saps.

First, they have studied the relation between the osmotic concentration of leaf sap and height of leaf insertion in trees and have found that the concentration (as determined by the freezing-point-lowering method) increases from lower to higher levels, and it seems probable that it is by virtue of this increased concentration at higher levels that sap rises to the higher levels.

Second, they have considered the relation of concentration of sap of the whole plant to environmental conditions. Thus they find that about the Desert Laboratory at Tucson the plants of the arroyo or sandy wash show the lowest osmotic values, sometimes only half of those of related species growing in other habitats. Next higher in sap concentration came the plants of Pima Canyon, then those of the rocky slopes; next those of the mesa-like slopes, and, highest of all, those of the salt spots, where the osmotic values are 12 to 71 per cent greater than those of plants from the other habitats studied. It appears, also, that the sap concentration diminishes in the successive terms of the series—trees and shrubs, half-shrubs, perennial herbs, and winter annuals. In the Jamaican coastal deserts a similar high concentration of cell-sap is found. In sharp contrast with the condition in the deserts, the vegetation of the rain-forest of Jamaica is characterized by low sap-pressure, the concentration of the fluids of the latter being less than half that of the former.

Again, they have shown that phanogamic plants (Loranthaceæ), parasitic upon other plants, have, in general, a higher osmotic sap-pressure than their hosts. It is apparently by virtue of such higher concentration that they are able to steal fluids, by osmosis, from their hosts.

Dr. Harris, working with Mr. Wilson Popenoe, has been able to show that of three types of the tropical fruit avocado, whose cultivation is now being conducted in Florida, the Mexican type has a more concen-

trated sap, with lower freezing-point, than that of the West Indies, and this fact, doubtless, accounts for the circumstance that the Mexican type is the hardier. Dr. Harris suggests that a knowledge of the freezing-point-lowering of the sap of a species of plant would be of some service in predicting ability to withstand cold.

A study of the remarkable marine shrubs known as mangrove trees shows that some of them have a high internal pressure—up to 50 atmospheres or possibly more. Certain mangroves which live in nearly fresh water have only half of that concentration. Probably it is this capacity for developing a high sap-concentration that has permitted the mangrove to live in salt water.

TOXIN OF BREAD-MOLD.

The investigation of the toxicity in the common bread-mold (*Rhizopus nigricans*) carried on in our laboratories in cooperation with the Bureau of Chemistry of the U. S. Department of Agriculture has been brought to a close. An extended report upon the mycological findings has been written up and is now in the hands of the Bureau of Chemistry at Washington ready for publication. Mr. A. F. Schulze, who was employed here by the Bureau of Chemistry as Dr. Blakeslee's assistant in this work, has been called to a model food-preserving plant in Brooklyn.

BIOMETRIC MISCELLANY.

Dr. Harris has analyzed biometrically certain data on liability of potatoes to disease. The most important conclusion is that varieties of the potato which show more than the average amount of injury by one disease will, on the whole, show more than the average injury by another disease; accordingly, "to a considerable extent, susceptibility to disease is general rather than specific."

Dr. Harris has reviewed certain extensive data on the number of nipples in litters of pigs. He finds the variability in this number greater in males than females, as 1.48 is to 1.28. Also the correlation in nipple number between pigs of the same litter is 0.305 ± 0.019. This, as Harris justly concludes, is evidence of a strong inheritance of nipple number. Still it would be more significant to calculate the correlation inside the litter of some marked excess over or deficiency under the modal number.