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BIOLOGY, EXPERIMENTAL.

STATION FOR EXPERIMENTAL EVOLUTION AT COLD SPRING HARBOR, NEW YORK.*

By Charles B. Davenport.

In planning an experimental study of evolution, investigations already in progress elsewhere were taken into consideration in order that work might not be duplicated, but rather that the more difficult, expensive, and time-consuming operations might be taken up, and that there might be brought about a coördination of the work being done in the subject all over the world.

The factors of evolution are three—variation, inheritance, and adjustment. Studies may be made on any one of these factors or on all three together; as a matter of fact, they can hardly be studied wholly independently. Variation has been much studied during the past decade by quantitative and other methods. These have been studies in evolutionary statics and have required no special plant. Since these studies can be as well made elsewhere, we have devoted little time to them. Inheritance of variants is a dynamical matter whose investigation is beyond the ordinary facilities of universities as at present organized, and requires continuity of work during long periods of time. Variants are of more or less significance for evolution, according to the method of their inheritance; so the study of heredity furnishes a test of the importance of the different kinds of variation. Since studies in inheritance have been relatively neglected, despite their importance for evolution, our first efforts have been directed primarily toward such studies. To lead to valid generalizations, such investigations should be made broadly; consequently work has been or is planned to be undertaken in cooperation with others on all the main groups of animals and plants.

There are two ways in which the work might be divided among the workers—by topics or by material. While the investigation of a topic by one person would be under conditions of completer knowledge the ideal method, it is better, in present practice, to divide on the basis of materials to be studied. The reason for this is that, especially among animals, each kind of material offers special difficulties in rearing and breeding that have to be mastered before further progress can be made; and the mastery of the difficulties in the breeding of a single species may demand an investigator's whole attention during one or many years.

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The work in progress may be classified into the following departments:

1. Investigations into inheritance and variability of plants.
2. Investigations into inheritance and variability of insects.
3. Investigations into inheritance and variability of other invertebrates.
4. Investigations upon aquatic vertebrates.
5. Studies on inheritance in domesticated animals.
6. Investigations into the cytological basis of heredity.
7. Coöperation with other investigators.
8. Work of subsidiary departments.
9. Care and development of the plant.

INVESTIGATIONS INTO INHERITANCE AND VARIABILITY IN PLANTS.

Since plants get their food from the soil and air, their maintenance is less expensive than that of animals; since they are stationary, less caging is required; but, on the other hand, since their fertilizing element is for the most part scattered by the wind or by insects, interbreeding is more difficult to control. Moreover, it is necessary to fight the other plants, weeds, with which they come into competition, parasitic plants and animals, and meteoric conditions of precipitation, temperature, and wind. About 2½ acres of land are devoted to the rearing of pedigreed plants. The fundamental physical conditions of the soil are satisfactory, and sufficient manure can be purchased in the vicinity. One laborer has been able to keep the ground cultivated. Danger from drought will be henceforth avoided by the new water system about to be installed. The out-door temperature favors growth during the season, and the growing season for certain plants will be continued through the year by the propagating house now nearly completed. The advantage of plants for studies in inheritance depends on the great number of characters that they offer and the comparative ease with which cross-fertilization, even between distantly allied forms, may be secured. On account of these advantages they have been more used for studies in heredity than animals.

The botanical investigations are at present being carried on by Dr. G. H. Shull alone. The work has been so multifarious as to demand an immense amount of his time. His report is given on pp. 96–100. As Dr. Shull reports, we have coöperated in our plant-breeding with Drs. Britton and MacDougal, of the New York Botanical Garden. Visits between the Station and the Garden by the staff of each have been numerous, and consultations on matters of mutual interest have been repeatedly held.

VIEW OF THE MAIN BUILDING OF THE STATION FOR EXPERIMENTAL EVOLUTION—FROM THE SOUTH.

GENERAL VIEW OF THE GROUNDS AND BUILDINGS OF THE STATION—FROM THE EAST.

Beginning at the road at the left there is shown first the stable, next the main building, and behind and above the director's residence. Then come a green-house, a colony house for poultry, and an instrument shelter. Further to the right appear a number of small colony houses in a poultry yard, then the Station launch and boat-house; behind the latter a brooder and pigeon-house. Cold Spring Harbor in the foreground.

INVESTIGATIONS ON INSECTS.

Insects are probably to-day the most rapidly evolving of all organisms. This conclusion is based on their great variability. The number of described species is reckoned at hundreds of thousands, about equal to the number of all other animals put together. The static study of their variability has long been carried on, but relatively little breeding of them has been done because of the technical difficulties. The greatest difficulties are uncertainty of pairing in captivity and the infertility of many crosses. To circumvent these difficulties it will be necessary to devise special methods of housing and caging them. We are planning an insectary. Smaller cages for individual experiments are being constantly devised. Each experiment with a new kind of insect requires a careful study of conditions of food, moisture, temperature, light, and air. Changing food of the insects and keeping the cages clean take much time and limit the number of experiments that one man can undertake; consequently results from insects come rather slowly at first. Fortunately they breed rapidly and produce a great number of offspring; so when the technical difficulties are overcome they should prove the best of material for our studies.

Mr. F. E. Lutz has attacked the difficulties of breeding insects with energy and success, and, barring accidents, should gain important results by another season. His report will be found on page 100.

Mr. Roswell Hill Johnson, who began work here in August, is working on lady birds (*Coccinellidæ*) a family of beetles which contains thousands of species, many of uncertain systematic status. They feed on plant-lice (aphids). His experiments have led him to undertake the systematic cultivation of aphids by rearing their food plants, and even to a study of their diseases. Mr. Johnson reports on page 102.

Prof. W. J. Moenkhaus, of Indiana University, associate of the station, worked during two months of the summer at the station upon the question of sex-inheritance, using some small, rapidly breeding flies for the purpose. He reports on his work at page 102.

Prof. H. E. Crampton, Columbia University, an associate, has been working on selection in the Saturnid moths. He has made use of the facilities of both the biological laboratory and the station for his breeding work.

Mr. W. L. Tower, University of Chicago, an associate, has continued his investigations on the evolution of the Colorado potato

beetle and its allies in Mexico. He has a large report on earlier investigations ready for the press.

Dr. J. H. McGregor, of Columbia University, worked both in connection with the station and the biological laboratory upon inheritance in bees.

INVESTIGATIONS ON OTHER INVERTEBRATES.

Some *Helix nemoralis* of the Virginia colony are being bred to test inheritance of their variable markings. The snails are kept in 32 compartments out of doors. Results are not advanced enough for report. We have experimented with breeding various other species in captivity.

INVESTIGATIONS UPON AQUATIC VERTEBRATES.

Fishes afford excellent material for studies in inheritance, because they produce great numbers of offspring and because even distantly related forms are easily cross-fertilized. Dr. W. J. Moenkhaus, of Indiana University, who has published important investigations on the behavior of the germ plasm in fish hybrids, continued his work on hybridization of fishes at the station in the summer of 1904. His detailed report is given below. At present the station possesses about 100 crosses between brown trout and albinic sports of the same species. The crosses are pigmented exactly like the brown trout. This material was presented to the station by the New York State Forest, Fish, and Game Commission. The fish were bred by Mr. Grant E. Winchester at the Adirondack hatchery. We obtained them through the interest of Mr. John D. Whish, secretary of the commission. It appears that some albino trout suddenly appeared at the Adirondack hatchery, and that they were successfully reared to maturity. Some albino progeny were obtained, but these proved too weak and nearly all eventually died. Meanwhile Mr. Winchester had fertilized 424 eggs from the normal female with the albino male. The offspring, as stated, resembled the normal fish. On April 26, 1904, I wrote to Mr. Whish, urging that the hybrid eggs be kept separate from the others, and concluding: "I predict that if these fish are crossed with each other, when they become mature they will yield pure albinos in 25 per cent of the offspring, and that such albinos thereafter intercrossed will produce nothing but albinos." To test this prediction, the young hybrids are being reared partly at Saranac and partly at Cold Spring Harbor. As our fish ponds are not yet ready, the fish are being taken care of at the State fish hatchery, adjoining our grounds, through the kindness of Mr. Charles H. Walters, superintendent, and it is proposed to breed from them the present autumn.

STUDIES ON INHERITANCE IN DOMESTICATED ANIMALS.

This has been my major investigation. The following species are being bred at the station:

Systematic name.	Common name.	Number of original stock.	Number reared at station.
Gallus bankiva	The jungle fowl	2	8
G. domestica	The domestic fowl	20	810
Anas domestica	The domestic duck	2	10
Columba livia	The house pigeon	6	14
Serinus canarius	The canary bird	24	90
Fringilla cardualis	European goldfinch	1	†4
Capra hircus	The domestic goat	2	4
Ovis aries	The domestic sheep	5	2
Bos taurus*	Domestic cattle	2	2
Felis domestica	The domestic cat	5	13

*In coöperation with Dr. Walter B. James. † Hybrids.

The results with poultry and those with canaries will be made the subject of special papers upon which I am now at work. A progress report will here be made upon the mammals bred.

Goats.—Two Irish goats were purchased in September, 1905. The male possesses a pair of well-developed accessory auricles and the female has a very small accessory auricle (wattle) on the right side of the neck; on the other side there is no extra auricle, but a change in color of the hair marks the site where it has failed to develop. The interest attaching to the accessory auricles depends on the facts that they are typical abnormalties and subserve no function. They have been repeatedly observed in man and are sometimes associated with cervical fistulæ. They are regarded as serially homologous with the normal auricles. Among domesticated animals they are found in pigs, sheep, and goats. The sheep of the Wilster marshes are said to have the auricles associated with a neck bare of wool, and in the Merino breed, as a whole, this abnormality is especially common. A case of inheritance of these pendants is cited by Bateson (Variation, 1894, p. 180). Gouboux (Rec. de Med. Veter., ser. 3, IX, p. 335) gives a case of two she-goats on a farm, one having cervical appendages, the other having none. Each gave birth to a pair of kids at the same time. Each pair consisted of a male and a female, and in the one the male only had the appendages, in the other the female only. The characteristics of the sire of these kids were not known.

Our female goat produced January 12, 1905, at the station, of unknown paternity, two kids—one male and one female. The female

kid only had accessory auricles. The female goat again gave birth on September 19, 1905, to two kids by the wattled male—one a male and one a female. The male kid only has accessory auricles. Consequently it is probable that both of the wattled parents are heterozygous, and that the non-wattled condition is in them recessive. On this hypothesis we should expect, with larger numbers, to get three times as many wattled as non-wattled offspring. In regard to the inheritance of coat color, I may say that both parents are of mixed color—black, white, and buff. Of the first offspring (sire unknown), one was pure white and the other buff and white. Of the second pair, one is black and the other buff and white.

Sheep.— The valuable gift to the station by Dr. Alexander Graham Bell of two 5-nippled ewes and one 6-nippled ram, born in the spring of 1904 in his Nova Scotia flock, was mentioned in my first report. One of the ewes is white like the ram ; the other is black ; all are thriving. Two horned Dorsets—a race that has the reputation of bearing twins—were purchased in December, 1904, of W. R. Selleck, Huntington. Both were in kid and each gave birth to one young in the spring of 1905. I am consequently disappointed in my strain, but as the Dorsets are still young there is a chance that they may improve in fecundity. Meanwhile the examination of sheep at county fairs has shown that 3 or 4 nippled individuals are not rare on Long Island, and goats and cows with extra nipples can be procured ; and it is proposed to extend experiments in the very practical direction of increasing the number of functional mammary glands.

An examination of Dr. Bell's printed list of multinippled sheep has brought out an interesting fact in regard to the inheritance of color. In all cases (20) but one, when both parents are black the offspring are black. From correspondence with Dr. Bell it appears that the one exception may be due to an error in the record. It may be concluded, therefore, that two blacks always throw blacks only. This indicates that black color is a Mendelian recessive in sheep.

Cattle.—The two chief races of dairy cattle, Jersey and Holstein, are characterized by a great difference in color, build, and quantity and quality of milk. I have wished to see if the quality of the Holstein milk, noted for its remarkable quantity, could be improved by breeding with the Jersey. Owing to the practical importance of the proposed experiment, it should be carried out by some one with greater resources than we have. It will probably be necessary to proceed on a small scale, trusting to the chance of the single die throw, instead of the certainty of the frequently repeated, to get a favorable combination of characteristics (viz, quality and quantity) in the second hybrid generation.

Cats.—If characteristics are for the most part inherited entire and can be combined in various ways, like atoms in chemistry, it should be possible to obtain any desired combination. At the beginning of the year I set myself the task of producing a white, blue-eyed, deaf, long-haired, tailless, polydactyl cat. My parental stock consists of: No. 1, black Manx male (tailless); No. 2, black, tailed, polydactyl female; No. 3, female Maltese polydactyl; No. 4, white, blue-eyed, deaf, polydactyl female; No. 5, black and yellow polydactyl female. The Manx male was bred to these females. The results so far are represented below in tabular form.

[Abbreviations: N, black; W, white; Tig., tiger; Malt., maltese; Gy., gray.]

	No. to litter.	Cat No.	Sex.	Hair color.				Eye.		Hearing.		Hair.		Tail.		Toes.	
				N.*	W.	Tig.	Malt.	Gy.*	Blue.	Acute.*	Deaf.	Short.*	Long.	Pres.	Abs.*	Norm.*	Abnor.
Mothers.																	
3 ♀							×	×		×		×					7-7 5-5
	6	6	♂			×		×							×		6-6 6-6
		7	♀				×	×						×		5-5 4-4	
		8	♀				×	×							×		7-7 5-5
		9	♀	×				×							×	×	
		10	♀				×	×							×	×	
		a	♂				×								×	×	
4 ♀					×				×		×	×		×			7-7 5-5
	5	14	♀		×				×		×	×		×		×	
		b			×										×	×	
		c		×										×		×	
		d					×								×		6-6 5-5
		e				×									×	×	
2 ♀				×				×						×			
	2	11	♀			×										×	
		12	♂	×				×							×		6-6 5-6

* Paternal characteristics.

As a result, I obtained a great variety of combinations of characteristics, viz:

Black, tailed, normal toed ..... No. "c."
Do. tailless, normal toed ..... No. 9 ♀.
Do. tailless, abnormal toed ..... No. 12 ♂.
White, tailed, normal toed ..... No. 14 ♀.
Do. tailless, normal toed ..... No. "b."
Tiger, tailed, normal toed ..... No. 11 ♀.
Do. tailless, abnormal toed ..... Nos. 6 ♂, "e."
Maltese, tailed, normal toed ..... No. 7 ♀.
Do. tailless, normal toed ..... Nos. 10 ♀, "a."
Do. tailless, abnormal toed ..... Nos. 8 ♀, "d."

CYTOLOGICAL INVESTIGATIONS.

The results of the last three years confirm the belief in the importance of the chromatic material in inheritance. This chromatic material exhibits a bewildering complexity and diversity scarcely less than that of adult organisms. It is of the greatest importance to find the relation of chromatic diversity and somatic diversity. Miss Lutz has made progress in this difficult and time-consuming work (page 101).

COÖPERATION WITH OTHER INVESTIGATORS.

It has been part of the plan of the station to come into friendly and coöperative relations with workers in our field everywhere. This idea has been carried out by the establishment of the two classes of associates and correspondents, the former constituting a non-resident staff of the station, the latter other workers in the same field. We have added to the list of our correspondents the following :

Prof. E. B. Poulton, of Oxford University, England. Professor Poulton has long been known for his experimental researches upon the adaptive significance of color-markings in animals and their control in many cases through direct stimulation.

Mr. A. D. Darbishire, of Owens College, Manchester, England, who has published a series of papers giving the results of his experiments on breeding mice.

The titles of a number of works in experimental evolution published by our associates and correspondents and showing the present trend of the science are given on pages 106 and 107.

A large number of biologists have visited the station to view the work or to consult on general methods or special points in their work. We have gladly given much time to such inquirers.

Miss Edith M. Brace, of the Western Maryland College, spent two or three weeks at the station studying the physiology of the snake's tongue. Mr. Ivey N. Lewis, of Johns Hopkins University, was accommodated during about six weeks of the early spring while making collections of Coleochæte, parasitic on the water-weed *Nitella*, for further investigation.

WORK OF SUBSIDIARY DEPARTMENTS.

The library is an important adjunct of the literary part of our scientific work. An extensive library of biological literature was clearly out of the question ; moreover, it is not necessary on account of our proximity to New York City. But one kind of a library has been regarded as essential. Our isolation has demanded that we should have a set of synoptic works on systematic and anatomical

biology ; complete bibliographic indices, so that we may know what has been published and is being published on any biological subject that we may have to refer to ; as nearly as possible, all the more important speculative and experimental books and papers dealing with evolution, including variation, heredity, and plant and animal breeding ; and current zoötechnical and phytotechnical journals, that we may learn of advances in methods of caring for animals and plants and keep advised of available material. Our accessions of bound books number 575. During the winter of 1904–05 the library was installed and catalogued by Miss Mabel E. Smallwood.

During the winter and spring the staff met regularly to review the articles bearing on experimental evolution that appeared in the literature received.

The papers of the station, of which three have already appeared and three others are nearly ready for the printer, have been distributed to over 250 learned societies and institutions, from which we are receiving many publications in exchange. We receive currently the publications of nearly all of the State agricultural experiment stations.

The necessity of making records by photography has led us to furnish the dark-room quite fully. Mr. H. A. Hackett divided his time between making photographs and helping care for the poultry. Animal photography is the most difficult phase of the art. We need the best lens attainable for this purpose and have included the purchase price in our budget for next year.

The observations of the meteorological instruments have been made daily, under the charge of Mr. F. E. Lutz.

CARE AND DEVELOPMENT OF THE PLANT.

On January 1, 1905, the station building was finally ready for occupancy, and our real work under satisfactory conditions must date from that time. The building is substantially made, is semi-fireproof, and is highly convenient for our work. That work has, however, grown so far in excess of our anticipations that it has already become evident that the building is to be used chiefly for office work and the preservation of books and records, and that the breeding of organisms will be done in separate buildings. In pursuance of this plan, there have already been erected one poultry-house 10 feet by 60 feet, a brooder-house about 30 feet by 40 feet, and a green-house 59 by 18 feet ; 14 small chicken-houses have been purchased, and it is intended to construct about 20 more. A glass-covered vivarium for rearing insects and snails is also planned. We hope in time to have a substantial birdhouse, with flying-cages, for breeding canaries, sparrows, and other small birds.

The completion of the main building left us with a large number of finishing operations that could be completed only in the spring. At that time the ground about the building was graded, a drive made from the highway to the building, the water system completed, and the electric cables finally laid. During the coming year we plan to introduce a new water supply, which will furnish about 2,000 gallons of water per hour, with a head of 20 feet, to be used for the fish-ponds, the indoor fish-troughs, and irrigation of the gardens, green-house, and insectary. It is hoped also to complete the salt-water system to the main building.

The general care of the place—cutting grass, keeping drive in order, and washing windows—has required some attention and has been done by a laborer, who has, in addition, dug ditches for draining, water pipes, and cables, done detailed grading, and helped in many of the heavy operations.

It is a feature of experimental work in biology that it tends to increase geometrically, and it is evident that more land will eventually be required.

That the work of the station is widely known and generally appreciated is shown by the variety of gifts received from many sources. These comprise books and papers pertaining to the work, together with interesting specimens of animals, plants, and so forth.

The station is especially indebted to Dr. O. L. Jones for the gift of much sand, gravel, and forest loam, as well as for numerous other courtesies.

REPORT OF DR. GEORGE H. SHULL.

The botanical experiments may be considered under the two natural subdivisions, variation and inheritance. Recognizing that variations are of two kinds, mutations and fluctuations, both of which doubtless have important bearing upon evolution, the study of variation resolves itself into (1) a search for mutations, and (2) the investigation of the causes, modification, and fixation of fluctuating characters.

In the search for suitable material for studies on the origin and permanence of variations among plants, 160 lots of seeds were collected, representing 108 species. Certain limitations of space available for germinating and caring for these plants made it impossible to handle so many lots; consequently a selection was made involving 128 lots of seeds of the 81 species that were thought to be most promising. Sowings of the biennial and perennial species were made in the latter part of February and early in March with the hope that

PART OF MAIN EXPERIMENTAL GARDEN OF THE STATION, JULY, 1905.

Evening primroses in the foreground, Russian sunflowers at the right, Indian corn at left.

VIEW OF PART OF SHEEP AND GOAT PASTURE AND POULTRY RUNS. BROODER HOUSE TO THE LEFT.

they might thus be brought to flower and fruit in the first season, but only in the evening primroses was this hope fulfilled. Owing to an unfortunate delay of two months on the part of the Bausch and Lomb Optical Company in filling our order for a soil-sterilizer, recourse was had to means other than sterilization to avoid the contamination of the cultures with seeds of unknown origin. For this purpose sand was taken from a sand bank after the careful removal of the portion which might have received seeds carried by wind, birds, etc., or which might have been brought down from above in landslides. Many of the species chosen for these studies were woodland plants which find the best conditions for their development in a soil rich in humus. The attempt to start them in sand resulted in a greatly lessened measure of success in the germinations than might reasonably have been expected if they had been sown in soil. Of 128 lots of seeds sown, only 69 lots gave germinations, and in many cases only one or several specimens of a species were secured. Species having very small seeds, such as *Hypericum* and *Mimulus*, reached the limit of their development before they were large enough to be successfully transplanted from the sand to boxes of soil.

The number of pedigree-cultures which finally found their way into the garden was 48, belonging to the following 28 species :

Aquilegia canadensis	Oe. lata	L. spicata
Barbarea sp.	Oe. nanella	Ambrosia artemisiæfolia
Bursa bursa-pastoris	Oe. rubrinervis	Chrysopsis falcata
Sibbaldiopsis tridentata	Kneiffia pumila	Solidago alpestris
Potentilla monspeliensis	Lappula americana	S. macrophylla
Viola arvensis	Verbascum blattaria	Erigeron ramosus
Chamænerion angustifolium	Plantago lanceolata	Rudbeckia hirta
	P. major	Helianthus annuus
Oenothera gigas	Sonchus asper	H. debilis
Oe. lamarckiana	Lactuca canadensis	

In addition to these, the following species have been under observation, but were kept indoors, owing to their late germination :

Draba incana arabisans	Mimulus ringens	Viola spp.
Trifolium pratense	Chelone glabra	Sonchus oberaceus
T. hybridum	Pentstemon pentstemon	

The chief ends aimed at in the inception of these pedigree-cultures were : First, to determine in each case the presence and characterization of any elementary species within the systematic species ; second, to observe the nature and degree of the fluctuations normally present, in order to give a basis for selecting those variations which may be expected to prove transgressive or mutational ; third, to learn

such biological relations for each species as capacity for self-fertilization, either with or without artificial aid, adaptations for crossing, number of viable seeds produced, etc.; and, fourth, to find out their capacity for successful manipulation, both as regards ease of culture and of adequate control of the fertilization processes.

Of the species that have been under observation this year, several have shown notable variations, but the exact significance of these can be known only when continued culture shall have shown their behavior in inheritance.

In the study of the laws governing fluctuating variations, material has been collected for the investigation of secular variation in the ray-flowers of *Chrysanthemum leucanthemum*, a small plot has been set aside and fenced as a permanent chrysanthemum preserve to supplement the work I have done on *Aster prenanthoides*, and arrangements have been made for continuing the studies on the latter species.

The influence of self- and cross-fertilization and of the selection to particular types upon fluctuating variability and upon the fixation of fluctuations is being studied in *Zea mays*, the character chosen for this study being the number of rows on the ear.

The relation of fluctuating characters of mutants to the corresponding characters of the species from which they originated and the question as to whether or not there is any tendency on the part of the mutants to regress toward the parental condition has been investigated in *Oenothera lamarckiana*, *Oe. rubrinervis*, and *Oe. nanella*, and the results were published as part of Paper No. 2 of the Station for Experimental Evolution, entitled "Mutants and hybrids of the Oenotheras," by D. T. MacDougal, assisted by A. M. Vail, G. H. Shull, and J. K. Small. I have again collaborated with Dr. MacDougal and Miss Vail in a continuation of these studies, which will be published soon in the series of papers from this station.

Although experimental evolution is naturally divided into variation and inheritance, it must always consist in a combination of these two processes, so that in most cases the investigations involve both elements. Inheritance is always the test of mutations, and it is likewise involved in every problem of selection; but in the studies already mentioned variation is the prime object, while in those that follow, the laws of inheritance are the chief object in view.

In 1904 an attempt was made to repeat the investigations of Johannsen on the inheritance of seed-weights in beans, because his results were thought to be in disaccord with Galton's law of inheritance. The choice of Burpee's bush lima bean for the investigation was unfortunate, because it does not maintain a strict bush form, and

the work planned with this variety was abandoned. Occasion was taken, however, to point out in a paper presented before Section G, American Association for the Advancement of Science, December 30, 1904, and afterward published in Torreya, that Johannsen's results are in exact agreement with Galton's law, instead of being contrary to it. The importance of Johannsen's results, however interpreted, make it a matter of some regret that they were not elaborated by more approved statistical methods. As a corollary to his conclusions, every change in bean-weights capable of being segregated by selection within the individual pure line is of the nature of a mutation. To satisfy the desire for a more appropriate elaboration and to investigate the occurrence and behavior of these minor mutations, the study is being repeated this year with Henderson's bush limas. This variety has proved highly satisfactory, as it forms a bush of moderate size and blooms and fruits well when inclosed in bags of mosquito netting, this means being adopted to insure the purity of the hereditary lines.

The transmissibility of certain abnormalities has been tested with the following results: Of eleven specimens of *Rudbeckia hirta*, the entire progeny of a strongly fasciated individual, only one showed evidence of fasciation, but the offspring of a fasciated *Ambrosia artemisiæfolia* had slight fasciations in 8 of the 15 specimens. Compound spikes of *Plantago lanceolata* were transmitted, fully developed, to one of 26 offspring. Six of the other specimens showed abnormalities which may be related in character to the compound spike. These consisted in the occasional production of scapes bearing one or several leaves, or even a well-formed rosette, while axillary to these leaves arose scapes terminated by single unbranched spikes. *Plantago major* did not transmit in a single well-marked case, in a progeny of more than 100 specimens, a rosette of leaves about the base of the flower-bearing portion of the scapes. The possibility is not excluded, however, in this case, nor in other cases in which a parental character is wanting in the offspring, that the young are heterozygotes in which the character in question is recessive. This point can only be determined by the study of a second generation.

In the common garden form of *Helianthus annuus*, known as the Russian sunflower, two characters have been chosen for the study of inheritance. One of these characters, the greater or less degree of bifission of the leaves at the second node above the cotyledons, is obviously a progressive character, while the other character—the branching habit—is, at least in a certain sense, atavistic or degressive. Both of these characters prove to be rather strongly inherited,

though to what extent this will be true when both parents are bearers of the characters in question must be determined by further investigation, as the pollen parent of this year's progeny is in each case unknown.

Hybridizations made last year between different varieties of beans give excellent material illustrative of one of Mendel's laws of inheritance, in that all pigments are dominant over white and in each case the darker pigment is dominant over the lighter. In every case the reciprocals are equal. Crosses with the "White Flageolet" give beautiful examples of *nova* and illustrate the nature of latency. The offspring from crosses between this variety and any pigmented bean, whether yellow, brown, or black, invariably bear purple-mottled seeds in the first hybrid generation.

Hybridizations have been attempted this year between varieties or species of *Lychnis*, *Eschscholtzia*, *Verbascum*, *Helianthus*, etc.

A study into the significance of stages in the development of *Sium cicutæfolium* was completed and published as No. 3 of the Papers of the Station for Experimental Evolution.

Most of the specimens collected during 1904 for the herbarium have been mounted and arranged according to Engler & Prantl's system of classification. These include: The Flora of Cold Spring Harbor, L. I., 190 specimens; seedling and juvenile forms, 3 specimens; pedigreed plants, 72 specimens; total, 265 specimens.

Among these the following have not been hitherto recorded from Long Island: *Panicum tennesscense*, *Agrostis scribneriana*, *Scirpus paludosus*, *Carex scoparia condensa*, *Rosa micrantha*, *Onagra oakesiana*, *Xanthium commune*, *Aster herveyi*, *A. salicifolius*, and *A. lowrieanus*.

The following recorded for other parts of Long Island have not been mentioned for Cold Spring Harbor: *Ammophila arenaria*, *Gyrostachys simplex*, *rifolium Thybridum*, *Hieracium marianum*, *Bidens cernua*, *Solidago rugosa*, and *S. juncea*.

The number of specimens added to the herbarium this year is estimated at 600.

REPORT OF F. E. LUTZ.

The biometrical and experimental work with *Gryllus* has been carried on throughout the year. From the matings made during September, 1904, 118 adult offspring were reared. There was a considerable mortality in the early stages. It is hoped this will be, to a great extent, avoided in future generations. All these adults, with the exception of three badly deformed ones, have been mated and a large quantity of eggs has already been obtained. These matings are, for the most part, *inter se*, but a number of the pedigree crickets have been

mated with individuals obtained (as nymphs, and reared with the sexes separated) in nature. Other matings have been made from material from various localities and representing several species. While the eggs of most of these are due to hatch in the spring of 1906, it is hoped that they may be hastened somewhat. The characters whose inheritance and variation are being studied in this connection are very diverse, including alternative and blending, integral and graduated.

As opportunity offered, experiments with other insects have been tried and a number of them are still being continued. These are chiefly concerned with the variations produced by changed environment and the inheritance, if any, of such variations. The principal insects used in these studies are *Isia isabella*, *Spilosoma virginica*, and *Estigmene acrea* among the Lepidoptera, and *Lena lapponica*, *L. scripta*, *Gastroidea polygoma*, *G. cyanea*, *Crioceris asparagi*, *C. 12-punctata*, and *Labioderma divicollis* among the Coleoptera.

The collection of local meteorological data is of great importance to the station. A summary is given at pages 105–106.

REPORT OF ANNE M. LUTZ.

The work of the year has been divided between the duties attendant upon the secretary of the station and the search for the interpretation of the laws of heredity in the germ glands of various plants and animals. A considerable number of species of animals have been collected, chiefly insects, and their germ glands sectioned and mounted secondarily for a reference cabinet, but primarily with the view of discovering suitable material for hybridization experiments. Recently the collection has been limited chiefly to two families of Coleoptera, Coccinellidæ and Chrysomelidæ, and as many representative species of each obtained as possible. Whenever obtainable, the late larvæ and pupæ have been selected in preference to adults. A fairly representative collection has been secured for the study of problems in mind.

Progress has been made on the solution of the problem of the infertility of the reciprocal crosses of long and short styled *Fagopyrum fagopyrum*. Work on the long crossed with the short has been completed, but the reciprocal, involving more delicate cytological details, was found to require better fixation than was obtained in the original lot, and a crop is now growing for this purpose. Fertilization in this case will be controlled within doors, and some of the dangers of error eliminated.

Early in July two species of *Gastroidea*, namely *G. cyanea* and *G. polygoni*, were found feeding together and freely interbreeding.

The colors of thorax, abdomen, and elytra were so strikingly different in the two species that they seemed to be favorable material for hybridization. Before going into the detailed study of the germ glands of the two species, it seemed advisable first to determine the fertility of the supposed hybrid eggs. Several generations of each species were first bred true, to be certain of parentage, and twelve or fifteen pairs of adults were hybridized reciprocally. They mated freely, and thousands of eggs were deposited, but no larvæ hatched. Control pairs of straight matings of each species were kept under observation at the same time, and while it was noted that fewer eggs were deposited than by the first generation, and a smaller percentage of eggs hatched, large numbers of larvæ were continually hatching and feeding. The experiment was abandoned for the present season, but will probably be undertaken by Mr. Lutz or myself on a larger scale next summer.

REPORT OF ROSWELL H. JOHNSON.

Since my work at the station began July 18, 1905, this report must be one of progress rather than results. Owing to the lack of running salt water, I have postponed the proposed work upon the shrimp and devoted myself wholly to the investigation of the lady beetles. These beetles offer the following advantages as material for the study of the method of evolution :

1. They are in general decidedly variable in color pattern in each locality, and in many species show geographical races.

2. There are many "varieties" in some species, ranging from mere "aberrations" to forms over which systematists are in disagreement as to their recognition as species.

3. There are some species whose relationships seem evident and which have doubtless only relatively recently become segregated.

4. Some species, I have found, are readily modified by change in environment.

5. The generations are short, and some species at least may be bred under glass in winter.

6. Being easily recognized and collected by correspondents, extensive collections are possible. This is especially true of some species which are gregarious.

Since they may be fed upon plant-lice or scale insects, I began a collection and catalogue of the local aphids and determined the best host-plants for use indoors and in the garden. The most suitable plants have been propagated in the breeding-room, that there may be an adequate supply of food when the aphids out of doors disappear for the season. I am now feeding many pairs from California, the Rocky

Mountains, and New York, awaiting further egg-laying, and have already 18 fraternities of larvæ from these pairs. The larvæ require from two weeks to a month from egg to pupa. About five days are required for the egg and pupa stage, respectively.

The questions to be answered by the earlier generations are :

1. To what extent are the various color patterns inheritable? and
2. Does rearing under local and indoor conditions modify them from the ancestral pattern?

With these questions answered I shall undertake hybridization, selection, and modification experiments.

Since many larvæ of one species could be collected this summer, I began a series of experiments upon modification by various changes in the environment. Some factors seemed relatively impotent, but temperature was effective in producing marked changes paralleling observed geographical races. These changes affected certain parts of the pattern only, thus producing more than a change in the amount of melanism.

Before taking up my work here I had collected large series of one species, *Hippodamia convergens*, from diverse regions, and I am now extending that collection by exchange and purchase. I find that some alleged species are connected by many intergrades, as might be expected. The various lines of orthogenetic variation in the different regions seems more remarkable. As a proper introduction to my experimental results in *Hippodamia*, I propose to submit in April a paper on "Orthogenetic variation in *Hippodamia convergens*."

REPORT OF DR. W. J. MOENKHAUS.

During the summer of 1904 material was collected at Woods Hole and Cold Spring Harbor for the study of the behavior of the maternal and paternal chromosomes in hybrid fishes. Early stages of the following crosses were preserved :

1. Fundulus heteroclitus × F. diaphanus.
2. Fundulus heteroclitus × F. majalis.
3. Fundulus heteroclitus × Tautogolabrus adspersus.
4. Fundulus heteroclitus × Stenotomus chrysops.
5. Fundulus heteroclitus × Gasterosteus bispinosus.

Crosses 2 and 5 have been worked up without results; 3 and 4 have not yet been studied, but I am hopeful that they may yield some important thing in the chromosomal behavior in early hybrid development.

Considerable work was done with the crosses between *Fundulus heteroclitus* and *Fundulus diaphanus*. In the cytological work on these I had the coöperation of Miss Anne M. Lutz. It was hoped

that the hybrids between these two species might be successfully reared to maturity, so that the behavior of the maternal and paternal chromosomes during sex-cell formation could be studied. About 4,000 hybrids (*Fundulus heteroclitus* × *F. diaphanus*) were hatched. On August 16, 1904, about 1,500 of these were successfully transported in Mason jars to Bloomington, Indiana. These were kept alive until September 20, 1904, when the last died. It was found impossible, under the adverse water conditions at my disposal, to keep down the attack of fungus.

A careful study of the germ glands of the three species of *Fundulus* has convinced me that fishes are unfavorable forms for the study of chromosomes in sex cells. This fact also determined me not to attempt the cross between the whitefish and lake herring which I had planned.

A portion of my time during the summer of 1905 was devoted to the problem of the variability of the sex ratios and their modification through selective breeding. The forms experimented upon are three species of flies. The experiments are not far enough along to permit of a statement of the results. I have at present (October 15, 1905) the data on 14 families. From these I isolated 2,378 eggs. The number of eggs hatched, the number that emerged, and the sex ratios of each of the families were determined. This is an exceedingly laboricus process, but my experience during the past winter has shown that in selective breeding for one sex or the other it is essential that account be taken of the mortality during the life history.

CLIMATIC DATA.

The first frost of 1904–05 occurred October 16, 1904. The first killing frost was on the 27th of the same month. The last freezing temperature was on May 2, 1905. The last frost was May 2, with a close approach to frost (37°) on May 21. The first frost in the autumn of 1905 was on October 8; the first killing frost October 31. The first snow fell November 25, 1904. The ground was covered with snow December 8 to January 19, and January 25 to February 28. The last snow flurry was on April 17.

PRECIPITATION BY MONTHS.

Time.	Total amount.	Snowfall.	Time.	Total amount.	Snowfall.
1904.	*Inches.*	*Inches.*	1905.	*Inches.*	*Inches.*
November.....	2.31	0.3	June.....	3.81	0.0
December.....	3.98	33.0	July.....	3.42	0 0
1905.			August	6.06	0.0
January.....	2.76	6.0	September....	5.76	0.0
February.....	2.69	4.5	October.....	2.64	0.0
March	4.11	1.0			
April.....	3.25	Trace.	Total.....	42.00	44.8
May.....	1.31	0.0			

TEMPERATURE AT COLD SPRING HARBOR, BY WEEKS.

1905.	Maximum.		Minimum.		Mean.*	Soil at 2 feet.†	Sensible at 5 p. m.
	Actual.	Mean.	Actual.	Mean.			
	°F.	°F.	°F.	°F.	°F.		
Feb. 5–Feb. 11....	31	27.4	—5	12.9	20.2	.....	.....
Feb. 12–Feb. 18....	40	29.4	0	8.3	18.9	....	.....
Feb. 19–Feb. 25....	36	32.7	+9	16.6	24.7	.. ..	.. ..
Feb. 26–Mar. 4....	39	35.1	10	15.3	25.2	.....	.....
Mar. 5–Mar. 11....	47	39.3	9	21.6	30.5	.....	. .....
Mar. 12–Mar. 18....	63	42.4	16	22.7	32.6	.....	.....
Mar. 19–Mar. 25....	55	47.7	25	32.1	39.9	.....	40.3
Mar. 26–April 1....	74	67.1	29	35.6	51.4	.. ..	51.0
April 2–April 8....	58	53.3	24	30.9	42.1	.....	43.1
April 9–April 15....	69	60.9	25	36.9	48.9	... .	48.9
April 16–April 22....	68	56.9	23	33.7	45.3	. . ....	44.1
April 23–April 29....	70	62.4	29	39.4	50.9	49 5	52.6
April 30–May 6....	77	66.9	31	44.1	55.5	51.0	51.5
May 7–May 13 ..	84	71.4	41	49.1	60.3	54.5	58.0
May 14–May 20....	76	67.1	45	50.1	58.6	55.5	49.3
May 21–May 27 ...	76	71.1	37	46.4	58.8	57.0	60.0
May 28–June 3....	80	72.3	47	53.9	63.1	61.0	62.5
June 4–June 10....	82	74.0	43	50.4	62.2	60.5	58.8
June 11–June 17....	85	78.6	58	60.0	69 3	62.5	69.6
June 18–June 24....	87	75.9	54	61.6	68.8	64.5	66.4
June 25–July 1....	88	80.1	51	56.9	68.5	65.0	68.0
July 2–July 8....	86	81.1	60	64.1	72.6	66.5	71.7
July 9–July 15....	90	87.9	66	69.4	78.7	70.5	77.7
July 16–July 22....	98	89.9	55	63.7	76.8	72.0	78.0
July 23–July 29....	84	79.7	53	58.4	69.1	69.5	69.1
July 30–Aug. 5....	84	79.9	54	61.1	70.5	69.0	70.1
Aug. 6–Aug. 12....	88	82.4	61	67.4	74.9	70.0	75.4
Aug. 13–Aug. 19....	83	74.1	47	57.9	66.0	69.0	63.9
Aug. 20–Aug. 26....	86	80.3	52	61.6	71.0	68.0	70.6
Aug. 27–Sept. 2....	78	73.4	50	57.0	65.2	67.0	66.1
Sept. 3–Sept. 9....	77	74.6	51	58.4	66.5	67.0	66.9
Sept. 10–Sept. 16....	80	72.1	39	51.7	61.9	66.0	62.6
Sept. 17–Sept. 23....	81	74.7	57	60.1	67.4	66.0	67.3
Sept. 24–Sept. 30...	85	71.4	36	46.4	58.9	63.5	58.9

* From maxima and minima. † Averages given to nearest half degree.

Papers on Experimental Evolution Published by Associates and Correspondents of the Station for Experimental Evolution, Year Ending October 1, 1905.

NOTE. So far as possible this list has been checked by the authors, but in some parts it is doubtless incomplete. Necessary additions will appear in the next report.

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