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DEPARTMENT OF EXPERIMENTAL EVOLUTION.*

C. B. DAVENPORT, DIRECTOR.

GENERAL STATEMENT OF RESULTS.

The principal developments of the year are (1) the initiation, at Cold Spring Harbor, in coöperation with this Department, of the Eugenics Record Office for the study of human heredity and the application of the laws of heredity to human affairs; (2) the discovery of the method of heredity of epilepsy in man, with clear indications of how it is reproduced and how its recurrence in later generations may be prevented; (3) the termination of Dr. Shull's work at Santa Rosa and the approach to completion of his book on Burbank's work; (4) the publication of Dr. Harris's statistical comparison of the fruits of *Staphylea* that develop with those that fail, showing the much greater symmetry of the former; (5) the publication of the researches of Dr. Frank E. Lutz, who bred fruit-flies for 43 generations, secured variations in the wing venation unlike anything known in nature in the group of Diptera (flies), found that despite long disuse of wing in these flies there was no evidence that this disuse affects their size, and discovered that when the flies are allowed to choose they tend to select normal consorts; (6) the discovery of two types of melanin and a clearer definition of the pigment-forming processes; (7) the publication of the demonstration by Castle in guinea-pigs and by myself in fowl of Guthrie's error in concluding that the germ-plasm is affected by the soma.

DETAILED REPORTS ON SCIENTIFIC WORK.

HEREDITY IN POULTRY.

Rumplessness.—Progress was made during the year in perfecting two strains of rumpless (tailless) fowl. These have been continued, not only to demonstrate their purity, but also to furnish material for the study that was begun last year by Miss Elizabeth S. Lum and continued by her during six weeks of the present summer. The study of the caudal vertebræ in a series of fowl, both with and without a uropygium, reveals a striking variation in their number. But in the rumpless fowl the number is invariably much smaller than in the tailed form and the bones are more or less fused together. The whole circulation and innervation of the region is rudimentary.

Control of the Form of Characters by Sex.—A special quantitative study is being made of various organs, such as the γ -comb and booting, to deter-

* Situated at Cold Spring Harbor, Long Island, N. Y. Grant No. 676. \$33,734 for investigations and maintenance during 1911. (For previous reports see Year Books Nos. 3-9.)

mine the degree to which their development is influenced by sex and in how far they differ in reciprocal crosses.

Heredity of Double Horn in Sheep.—A 4-horned ram presented by Mr. Alexander Graham Bell was used for the first time, both with two 4-horned ewes that he presented and also with other (even hornless) races. All males and all females showed to a striking degree the influence of the double horn, which appears to be dominant; *i. e.*, due to a special determiner.

Independence of Soma and Germ-plasm.—During the year the Director issued a paper entitled "The transplantation of ovaries in chickens." This paper gives the details concerning six experiments in which the ovaries were removed from each of two races of fowl and an exchange of the ovaries made from the body of one to the other. In opposition to the conclusions of Guthrie, it appeared first that the engrafted ovary did not enter into vital connection with the tissues of the host, but on the contrary became encysted. On the other hand, the tissue at the site of the removed ovary produced a new ovary by regeneration. It was shown that Guthrie's results are capable of the same interpretation. Therefore his results yielded no data as to the effect of the soma on the germ-plasm. It is proposed to extend the experiments with the aid of Mr. H. D. Goodale.

Reciprocal Crosses in Relation to Sex.—A series of experiments has been under way for several years on sex-limited characters in poultry. Some of these bring a confirmation from the breeding side of current cytological theories. Thus in a cross between a red-laced and a white-laced race, made reciprocally, it appears that all sons, in whichever way the cross is made, are white-laced, while daughters follow the sire in respect to the coloring of the lacing. This would indicate that the odd, or sex-differentiating, chromosome must, in poultry, be found in the female. Mr. H. D. Goodale, recently attached to this station, is extending researches into this subject, using ducks as well as fowl.

HEREDITY OF EPILEPSY IN MAN.

In connection with the Eugenics Record Office the Director coöperated with Dr. David F. Weeks, of the New Jersey State Village for Epileptics, in the study of over 200 families with one or more epileptics as children. The data concerning the families had been gathered with great care and at much expense by the field workers of the Eugenics Record Office and the State of New Jersey. Their studies of the product of certain selected human matings have much the value of experimental data. It appeared from this study that epilepsy behaves in inheritance as though it were due to the absence of some unit-character that makes for neural strength, and is an equivalent in inheritance of "feeble-mindedness." Thus if both parents are without the character that makes for neural strength, all of the children lack it; and if both parents, though neurally strong themselves, belong to weak

strains, one-fourth of their children will be nervously undeveloped. The consideration of the pedigrees shows that in the families studied the proportion of mental defectives has in each of the last two generations been doubled from what it was in the preceding generation.

CONSANGUINEOUS MARRIAGE AND ITS EFFECTS.

During a vacation of ten days the Director visited a series of islands off the coast of Maine for the purpose of making a reconnaissance of a suitable locality for studies upon consanguineous marriage and its effects. Visits to both Hancock and Washington counties showed several places in which such consanguineous marriages are unusually frequent, chiefly on account of the barrier of water, and it is proposed, with the voluntary assistance of the people, to see in how far the results have or have not been deleterious. The study will be made by the Eugenics Record Office.

HEREDITY OF SEX IN A DICECIOUS HERMAPHRODITE PLANT.

Now that sex is generally regarded as controlled by a sex-determiner in the nucleus, the absence or presence of which results in one sex or the other, peculiar interest attaches to the behavior of sex-inheritance in a partially hermaphrodite species. Suitable material for this study is afforded by the cockle, *Lychnis*, and for several years past Dr. Shull has had about an acre of these plants under cultivation. This year his studies on *Lychnis* have dealt more particularly with the character of the vestigial organs of the one sex in individuals of the opposite sex, in order to learn to what degree the gap between each sex and the hermaphrodite condition is bridged by variations in the development of such vestiges. Only one individual in an aggregate of over 7,500 females and hermaphrodites permitted a doubt whether it should be classified as a female with exceptional development of staminodes or a hermaphrodite with aborted stamens. The gap between males and hermaphrodites is closed by the occurrence of every degree of development of female organs, from a minute bristle which is the usual condition in the male to a fully developed and functional ovary; but the number of these intergrading forms is very small relative to the number of normal males. Some evidence has been secured indicating that the eggs of the hermaphrodites may carry the hermaphrodite character, though heretofore hermaphroditism has seemed to be borne only by the sperms. A special series of crosses has been made to test this matter.

HEREDITY OF FLOWER COLORS.

Lychnis.—The study of the inheritance of the color of the flowers of *Lychnis* has been continued. The search for homozygous or pure-bred purple-flowered strains has been rewarded with success in the blue-flowered series, but not in the red. In the latter, failure has again resulted, because in each of the small number of crosses made for this purpose, one of the

chosen parents proved to be heterozygous. A wild strain, known in Germany as *Melandrium rubrum*, has been found homozygous for the red color; but this form is not wholly satisfactory for experimental purposes, because of its fixed biennial habit. The effort to secure a homozygous red-flowered strain among the annual forms has therefore been continued. New features in the color-inheritance of *Lychnis* are the discovery of a "dominant white," which has given an F_1 mainly white-flowered when crossed with a homozygous red-flowered individual, and an all purple-flowered F_1 when crossed with a recessive white. A new Mendelian unit-character has been demonstrated by the unexpected appearance of a type of *Lychnis* having yellowish-green foliage, which is hypostatic to the full dark green of the usual type. Several sorts of variegation and several bud-sports are being investigated.

Poppies.—The problem of analyzing the hereditary factors which serve to differentiate the many garden derivatives of *Papaver rhæas* from each other and from their wild prototype has been resumed. The orange-red body-color of the petals in the wild form is epistatic to all the shades and tints displayed by the garden forms, but the presence of a distinct margin and of doubling often found in the cultivated strains are epistatic to the self-colored, single form of the wild poppy. Interesting phenomena of "repulsion" and inhibition of characters have been discovered and appropriate crosses have been made for further study.

AN ABERRANT INHERITANCE RATIO AND ITS INTERPRETATION.

On the principle of segregation of the determiners of characters, the characters should appear in the offspring of hybrids in certain definite ratios. An exceptional case appeared in breeding two kinds of shepherd's purse in the ratio of the two forms of seed-capsules and some leaf-characters that re-appeared in the second hybrid generation. After several years of work Dr. Shull has reached a nearly complete explanation of the aberrant ratios, as follows: (a) There are two independent genes determining the triangular capsule, thus leading to the expected ratio 15:1 in the F_2 and both 15:1 and 3:1 in the F_3 ; (b) the *heegeri* individuals are less successful in the embryonic stages than the *bursa-pastoris* individuals, so that the ratio 15:1 becomes about 22:1, and 3:1 becomes 4.67:1; (c) that there is a variation in the relative potency of the genes determining certain features of the rosette-leaves which has led to the classification of a portion of the heterozygotes with the negative homozygotes. Further data are being sought bearing on these points.

THE INJURIOUS EFFECTS OF SELF-FERTILIZATION OF CORN.

Dr. Shull has continued his researches, which have revealed the great complexity of the population of any cornfield. Self-fertilization, as is well known, yields seed that develop into inferior individuals, while outcrossing usually gives vigor. Dr. Shull has been working on the hypothesis that the

depauperate inbred strain represents a "pure line." If this is so, then cross-fertilization within the limits of the same pure-bred family ought not to result in the increased vigor that cross-fertilization at random does. Now, comparisons made between the effect of self-fertilization and crossing within the limits of the same pure-bred family and within the same F_1 showed in each case a very slight difference in favor of the crosses. This difference was so slight that the belief is entertained that it was due wholly to the fact that some of the families used were not yet completely homozygous, but there are other possibilities and these are being investigated. The F_1 hybrids between self-fertilized strains yielded on the average 68.07 bushels per acre as compared with only 44.62 bushels yielded by the corresponding F_2 families, a fact of great potential consequence to the practical grower. The conclusions derived from these investigations and published in 1908 have been still further strengthened by these results. These conclusions are (a) that the plants in an ordinary field of corn are generally very complex hybrids representing the combination of numerous elementary species or biotypes; (b) that none of these pure biotypes is sufficiently vigorous to be profitably grown in the pure state; (c) that the high physiological vigor of the ordinary maize-plant is the result of a stimulating effect produced by the union of unlike elements from the two parents; (d) that self-fertilization decreases the vigor by gradually reducing the strain to a pure-bred state, and not because there is any injury produced by self-fertilization or inbreeding *per se*. Comparisons are now being extended to the third and later generations, and tests are also being made to determine the effect of combining a number of different pure-bred strains into a single hybrid strain.

VARIATION AND MUTATION IN EVENING PRIMROSES.

Since the beginning of our work we have continued the studies of the evening primroses along the lines of Professor de Vries's work and with seed largely derived from his cultures. In the past year the particular directions of study, by Dr. Shull, have been the effects of cross and self fertilization. Families have been grown from seeds of a number of new forms which originated in the cultures of the preceding year. Some of these progenies have bred true to their new characters, others have split up into several types, and some have seemingly returned to typical *Oenothera lamarckiana*. Reciprocal crosses have been made among several biotypes of *O. cruciata*, and between each of these biotypes and *O. lamarckiana*.

THE THEORY OF PURE LINES.

This is quite the most hotly discussed of all topics in heredity to-day: Does selection proceed by the isolation of minute units or by shoving the character along a sliding scale? It is not clear whether there is any real contrast between these views, since if the steps of a flight be taken fine enough they will approach as close as possible to an inclined plane. Dr. Harris has

been testing the pure-line theory by the use of beans—the same kind of plants that Johannsen used in his fundamental experiments. Many of Dr. Harris's records go back to 1905, and they afford excellent material for a critique of the pure-line theory. We may expect an early publication of these data.

QUANTITATIVE STUDIES OF SELECTIVE ELIMINATION.

An outline of these studies, which are being made by Dr. Harris, appeared in Year Book No. 9. Since that report it has been shown that the elimination of ovaries demonstrated in *Staphylea* is probably not due to the combination of such simple factors as a differentiation of the ovaries associated with their position on the inflorescence and a proportionally higher but random failure of the ovaries situated in the more distal regions of the inflorescence. It seems, therefore, that failure to develop must depend upon some innate unfitness with which definite structural peculiarities are associated.

Dr. Harris has instituted several studies to obtain further light upon these questions. Tests with other species are being made to determine whether the results found for *Staphylea* are at all general. Other criteria of functional unfitness are being sought. But the problem is so complex—involving so many factors which may often screen each other's influence—that it can not now be discussed in greater detail.

INFLUENCE OF BECOMING FERAL ON DEVELOPMENT OF THE NERVOUS SYSTEM OF A DOMESTIC ANIMAL.

The acquisition of Goose Island has permitted this Station to begin an important experiment on the changes that a domesticated species undergoes in becoming feral. Last year, as already reported, in coöperation with Prof. H. H. Donaldson and the Wistar Institute of Anatomy and Biology, an attempt was made to kill off the brown rats and to colonize the island with white rats (June 21, 1910). On July 21 of this year Dr. Hatai, of the Wistar Institute, visited the island, set two dozen spring traps, mostly along the western bank, where there are many holes. Not a single albino rat was caught, but, instead, 8 brown rats (*Mus novegicus*) of various sizes. Thirty-four albino rats, each having its ears marked for future identification, were then liberated on the island.

On July 17 Dr. Hatai and myself visited Goose Island to see if the albino rats had established themselves. Two female albinos with marked ears were found dead from severe wounds, as though bitten to death by rats. At this time, in broad daylight, no living albino rats appeared on the island; and this is the more noteworthy since the liberated rats were very tame. Dr. Hatai then set four traps, two along the western bank, where most of the Norway rats had been caught, and two behind the house at the southern end of the island.

Dr. Hatai reports:

Toward evening I saw one albino rat running swiftly in front of the house, picking up some particles of food which I had thrown out. Later I found several more albino rats running about at the back [south side] of the house. The next morning I found one albino rat, whose ears were marked, trapped at the back of the house, and one large female Norway rat along the bank. During the night I heard several times the screaming of the rats in front of the house, but could not determine which kinds of rats they were.

It now remains to be seen if the white rats can survive the winter on the Island.

ADJUSTMENT TO CAVE LIFE.

The subject of adjustment to darkness is one that requires a long period for its full elucidation. At the outset many special difficulties have had to be met and overcome. We have had the difficulty of carbon-dioxide in the water, of solution of lime from the concrete tanks, and of the growth of fungi in the darkness of the cave. The difficulty of carbon-dioxide in the water of the artesian well will require the construction of a settling basin containing growing plants. Such a basin will be advantageous also, inasmuch as it will form a natural breeding-spot for the small organisms that can be used by the cave fishes. Dr. Banta spent two months last winter in the cave region of southern Indiana collecting materials and working on problems connected with cave-life. In order that parallel experiments may be run with cave animals in the light, a vivarium was constructed at the north end of the main building to provide conditions like those of the artificial cave except for light. It is provided with hot water pipes for winter heating, and being on the north side of the building will be largely sheltered from the summer sun.

Already the amphibia reared in the cave have yielded interesting results. The tadpoles of *Amblystoma tigrinum*, the common salamander of our ponds, when reared in the light are black, but in the cave are "white" or nearly so. The light is necessary for the production of the body pigment in the developing tadpole.

A part of Dr. Banta's work is the light reactions of animals of which related species or individuals live in the cave and in the open. While in Indiana he worked on the light reactions of the amphipod *Eucrangonyx gracilis* of Mayfield's cave and on the outdoor forms of the same species that live abundantly in the surface streams of the same region. Studies have also been made on the feeding and breeding habits of *Asellus* and other invertebrates which it is desired to propagate in the cave.

The following non-cavernicolous species are now kept in the cave: *Hydra*, *Copepoda*, *Asellus communis*, *Oniscus asellus*, *Armadillidium vulgare*, *Porcellio scaber*, *Porcellio rathkei*, *Eucrangonyx gracilis* (surface form), *Gammarus fasciatus*, *Cambarus bartoni*, *Meta menardi* and other spiders, *Thysanamma*, *Ceuthophilus*, *Planorbis*, *Limnea*, goldfish, sunfish, *Umbra limi*,



FIG. 1. Photograph taken on Goose Island, at its south end, looking northward through its long axis. Peck's Ledge lighthouse (from which fig. 2 was taken) is seen in the central background. In the foreground, right, is the shelter. At the left a wall can be seen running into the sea (low water). This is the south face of the 70-foot wharf. Sumach growing in foreground. Connecticut shore in the distance. Nov. 1911.

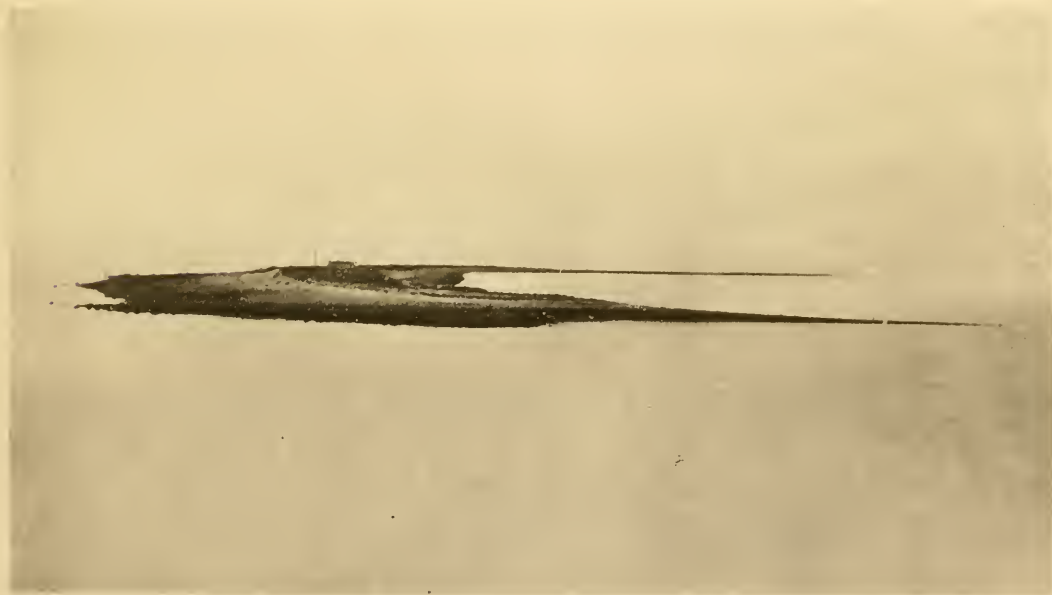


FIG. 2. Photograph of Goose Island, at low water, from lighthouse, looking south. Taken with rear combination of Zeiss *viii* lens, giving telephoto effect. Shelter built by Mr. Dodge in center of island. The wharf lies on the Harbor side, on the right, between the two long bars.

Amblystoma tigrinum (larvæ), *Rana sylvatica* (larvæ) and other frog larvæ.

These cave forms are in daylight: *Cæcidotea stygia*, *Eucrangonyx gracilis*, *Cambarus pellucidus*, *Sinella cavernarum*.

RELATION BETWEEN THE HEREDITARY AND THE CHEMICAL ACTION OF
PIGMENTS.

The studies of heredity of animal coloration quickly opened up questions upon which it seemed probable light could be thrown only by chemical studies. Accordingly a chemical laboratory was fitted up two years ago and Dr. R. A. Gortner put in charge of it. The first problem which he attacked was that of the melanins—their nature and behavior. To both these subjects he has made substantial contributions. He reports as follows:

The investigations as to the chemical nature of the animal pigments are as yet in a very preliminary state owing to the unusual difficulties in purifying these compounds. There appear to be two types of melanins, which are differentiated by their solubility or insolubility in dilute acids. Those melanins which are soluble in dilute acids are of a protein nature and do not appear as granules under the microscope, but rather they appear to be a part of the keratin structure and the coloration is diffuse as though the pigment were dissolved in the keratin. Such a pigment is found in auburn Caucasian hair.

The granular pigments are, apparently, insoluble in dilute acids and the nature of the molecule is still unknown. These melanins occur both alone (in negro hair, brown Caucasian hair, some black feathers, etc.) and in combination with the acid-soluble pigment or melano-protein (in black wool and horse hair).

In the study of these pigments there have been isolated 70 preparations, which are divided as follows:

	No. of preparations.		No. of preparations.
Black wool.....	35	Dominant white feathers.....	4
White wool.....	2	Light brown horse hair.....	5
Silky feathers.....	1	Dark brown horse hair.....	5
Black Minorca feathers.....	3	Brown Caucasian hair.....	6
Black rabbit hair.....	1	Auburn Caucasian hair.....	1
White rabbit hair.....	1	Other keratin structures.....	6

A considerable number of these preparations have been analyzed more or less completely, but much work is still necessary before the data can be correlated.

The formation of the animal pigments appears to be caused by an oxidation induced by the presence of an oxidizing enzyme. The origin of the pigment has been investigated in some of the insects: in the integuments of the meal worm (*Tenebrio molitor*), in the cuticula of the periodical cicada (*Tibicen septendecim*), and in the elytra of the Colorado potato beetle (*Leptinotarsa decemlineata*); the same general chemical reaction was found

in each, and in every case there was an active oxidizing enzyme (tyrosinase) which acted upon some unknown chromogen and produced the pigmentation. It was found that the color-pattern in the elytra of the potato beetle is due to the localized secretion of the oxidizable chromogen.

STATISTICAL SUMMARY.

Poultry.—There were maintained 52 breeding-pens and 2,214 chicks were hatched. Further data were gathered on reciprocal crosses, sex control of characters, syndactyl and polydactyl, nailless, combless, horned, rumpless, and triple-combed strains. Selection experiments on plumage color were continued.

Finches.—These showed a return to normal fecundity and 65 young were reared from about 88 hatched.

Sheep and Goats.—Twenty-nine sheep and 2 goats were born. Important data on inheritance of the double-horned condition and on a new kind of coat color were gained.

Plants.—The range of species and number of individuals bred in Dr. Shull's experiments are shown in the following table:

Name of species.	No. of families.	No. of individuals.	Name of species.	No. of families.	No. of individuals.
<i>Argemone hispida</i>	1	6	<i>Papaver bracteatum</i>	2	213
<i>Agrostemma githago</i>	1	16	<i>Papaver commutatum</i>	2	350
<i>Bursa bursa pastoris</i>	1	64	<i>Papaver croceum</i>	2	233
<i>Bursa bursa pastoris</i> × <i>heegeri</i>	24	4,709	<i>Papaver glaucum</i>	2	100
<i>Chrysanthemum leucanthemum</i>	2	120	<i>Papaver nudicaule</i>	1	50
<i>Eschscholtzia californica</i>	1	33	<i>Papaver orientale</i>	3	304
<i>Lactuca canadensis</i>	5	252	<i>Papaver pilosum</i>	1	107
<i>Lychnis coeli-rosa</i>	1	101	<i>Papaver rhoeas</i>	66	8,618
<i>Lychnis coronaria</i>	3	204	<i>Papaver somniferum</i>	10	308
<i>Lychnis dioica</i>	176	12,127	<i>Papaver spp. and hybrids</i>	8	333
<i>Lychnis haageana</i>	6	455	<i>Silene antirrhina</i>	1	50
<i>Lychnis noctiflora</i>	1	7	<i>Silene vulgaris</i>	1	85
<i>Oenothera cruciata</i>	4	420	<i>Solanum guineense</i>	1	50
<i>Oenothera gigas</i>	4	456	<i>Solanum guineense</i> × <i>villosum</i>	1	50
<i>Oenothera lamarckiana</i>	10	808	<i>Solanum nigrum</i>	1	50
<i>Oenothera lata</i>	1	35	<i>Solanum villosum</i>	1	50
<i>Oenothera nanella</i>	1	177	<i>Tagetes lemmonii</i>	1	21
<i>Oenothera rubrinervis</i>	6	1,607	<i>Vaccaria vaccaria</i>	1	18
<i>Oenothera spp. and mutants</i>	22	1,191	<i>Zea mays</i>	111	6,751
<i>Papaver alpinum</i>	2	119			
			Total	488	40,748

STAFF.

Miss Anne M. Lutz, who has been associated with our work from the beginning, first as secretary and later as cytologist, resigned in February and is continuing her studies on the cytological differences of the *Oenotheras* in Belgium. A full report of her prolonged studies here has been nearly completed.

Mr. Hubert Dana Goodale, formerly with Mr. B. B. Horton, at his experimental farm "Oakwood," Stamford, Connecticut, has been appointed to carry out various breeding experiments with poultry.

During the past summer Dr. Shull was ably assisted by Mr. Eugene E. Barker, who recorded data and made crosses, especially in maize and poppies.

CONSTRUCTION AND EQUIPMENT.

Since the last report of this Department there have been built at Goose Island a small shelter of stone in concrete and a stone pier. These were erected upon the suggestion of Mr. Cleveland H. Dodge, who also furnished the funds. The windows are barred with steel rods and the outer doors are of iron. The shelter is furnished with two cots, a few chairs, a collapsible boat, and a kitchen outfit, so that it can be used by one or two persons who need to spend the night. It was so used during the summer by Dr. Hatai. The pier is 70 feet long by 6 feet wide and is built of the stones of the outer beach, partly laid in cement.

A glass-covered extension on the north side of the main building was completed during the winter and spring. This affords a means of comparing the development of animals in the light and dark under otherwise similar conditions. Concrete tanks were installed on the floor of this extension.

For some time in the main building we have been crowded for room. It became absolutely necessary to have a building that could be used for chemical studies on mammals and for operating upon them, and it was finally decided to move all breeding animals to a new building, relieving the main building of the dirt that is inseparable from their culture and allowing expansion in it of the space available for records and their study. Plans were drawn by Mr. Robert W. Gardner, architect, for such a building, but from lack of funds a beginning has been made upon only a small portion. It is hoped that we may be able to complete the building during the coming year.