HABIT FORMATION IN A STRAIN OF ALBINO RATS OF LESS THAN NORMAL BRAIN WEIGHT

A DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF THE JOHNS HOPKINS UNIVERSITY, IN CONFORMITY WITH THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

By

GARDNER CHENEY BASSET

1914

(Reprinted from Behavior Monographs, Volume 2, Number 4, 1914)

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CONTENTS

ACKNOWLEDGMENTS

Before entering upon the body of this presentation I desire to express my obligations to those without whose co-operation my experiments would have been of less value.

Above all am I indebted to Professor John B. Watson, Director of the Johns Hopkins Psychological Laboratory, who has kept himself informed of the progress of my experimentation and who has been ready at all times with helpful suggestions and encouragement.

To Dr. Henry H. Donaldson I owe much: for suggesting the experiment; for placing the facilities and materials of the Wistar Institute at my disposal; for much helpful advice as to the evaluation of my results.

To Dr. Shinkishi Hatai for preparing the anatomical data referring to the rats used in my experiments.

To Dr. Helen D. King for keeping her sequences of inbreeding moving so perfectly that it was possible at any time to procure inbred rats of the desired age.

GARDNER CHENEY BASSET.

I. INTRODUCTION

A few years ago experimental inbreeding of the albino rat, *Mus norvegicus albinus*, was started at the Wistar Institute of Anatomy and Biology in order to determine the anatomical consequences of such procedure upon successive generations of progeny. Among other results obtained was a distinct and progressive decrease in actual and relative brain weight (relative, that is, in reference to body length) for four generations of close inbreeding. At the end of the fourth generation the rats seemed lacking in vitality and, for this reason, were subjected to a change in food. From this period until the end of the tenth generation (the extent of inbreeding at the time this paper was prepared) the relative brain weight remained, on the average, constant at six and one-half per cent less than that of the normal control rats.

When, early in October, 1911, Dr. Donaldson suggested to Professor Watson that the decrease in brain weight might be accompanied by a similar decrease in ability to form habits a new line of investigation in comparative psychology was opened up. The problem was offered to the writer and gladly accepted.

It is no part of the purpose of this paper to raise the question as to whether inbreeding, *per se*, results deleteriously upon the progeny. In this, as in all disputed questions, it is unsafe to be arbitrary, and authoritative testimony must await the results of further investigations. We know, upon the authority of historians, that the Incas of Peru for many generations married their sisters and were physically and mentally superior to their subjects. Breeders of domestic animals frequently resort to inbreeding in order to perfect desirable qualities in the strain. It may be, as many claim, that inbreeding results deleteriously only in cases where an hereditary taint, occurring in the common ancestor, is strengthened in the progeny of a consanguineous union. Of the rats used in the experiments hereinafter described, it is not postulated that the lesser ability to form habits is necessarily due either to inbreeding or to the environmental factor of

insufficient nourishment during the first four generations; but, the rats used for purposes of inbreeding produced a strain having a lesser relative brain weight on the average. This strain of rats I shall hereafter, for convenience, refer to as the Inbred Strain. The object, then, of the following experiments is to compare the habit-forming ability of the inbred strain *with lesser brain weights*, with the ability of a normal control series.

Owing to the fact that experimental work on the brain weight problem has not before been attempted there is no history and little literature to be presented. Donaldson[1] reproduces tables from Manouvrier[2] showing the brain weights of eminent men to be, on the average, greater than those of average Parisians. It is not necessarily true that the specific individual with greater brain weight is more intelligent or will contribute more to the world's arts and sciences than the specific individual of lesser brain weight; but, if the conclusions of Manouvrier are to be believed, individuals of brain weight above the average are more liable to be of superior intelligence and to do the world greater service.

The results of the experiments described in this paper agree closely with Manouvrier's conclusions. Tables of distribution of brain weights of the inbred strain and normal control series overlap; but the normal series, having a greater brain weight average, show greater ability in habit formation.

All the experiments here described were carried out at the Psychological Laboratory of the Johns Hopkins University.

II. METHODS

All the inbred rats used in this investigation were bred at the Wistar Institute of Anatomy and Biology by Dr. Helen D. King. Two strains were used, referred to in this paper as strains A and B. The original parents of each strain were taken at random, a male and female from each of two unrelated litters. The A male was mated to his sister, A female, and the B male to his sister, B female. Their respective litters constituted generation 1A and 1B. From this point inbreeding was carried on by selecting from the litter the healthiest appearing

[1] Donaldson: The Growth of the Brain. London and New York, 1909, pp. 128 ff.

[2] Manouvrier, Sur l'interprétation de la quantité dans l'encéphale, etc., Paris, 1885.

rats and mating brother to sister within the same litter, this constituting the closest possible inbreeding. At about thirty days of age the young rats were taken from their mother, and those to be used by the writer were shipped to the Johns Hopkins University. There were no fatalities in transit and all arrived apparently in good condition. The system of numbering individual rats for identification was as follows: the first number referred to the generation of inbreeding, the letter (A or B) to the strain, and the last number was that applied to the individual. For example, 7A90♀ may be analyzed as follows: 7th generation inbred, A strain, individual 90, female. Each rat had one or both ears punched or clipped to agree with the individual number, a system in use by Professors Castle and Yerkes at the Harvard laboratories.

It seemed advisable to secure normal control mating strains from different laboratories in order to avoid any possibility of inbreeding. In addition to our own Hopkins stock there were obtained rats from the Wistar Institute, Columbia University, animal dealers in Baltimore, and from Dr. Herbert M. Evans of the Johns Hopkins Medical School. Care was taken in mating the control series to avoid any approach to inbreeding. As in the case of inbred rats the young were taken from the mother at the age of thirty days. The system of numbering individual control rats for identification was as follows: the first letter, S, signified that it was a standard or normal control rat, letters within parentheses gave the pedigree, and the figures gave the individual number. For example, S(C/EB)70♂ may be analyzed as follows: standard, or normal control series, Columbia father, Hopkins Medical maternal grandfather, maternal grandmother purchased from a Baltimore dealer, individual 70, male. The same system of ear marking was used as in the case of the inbred rats.

When taken from the mother males and females were kept in separate cages. According to Watson[3] the bearing of young has some effect upon the central nervous system of the white rat; for this reason, and in order to keep conditions constant, neither males nor females used in these experiments were allowed to mate. As solitude may be a factor affecting behavior,

[3] Watson: The Effect of the Bearing of Young Upon the Body-Weight and the Weight of the Central Nervous System of the Female White Rat. *Journ. of Comp. Neur. and Psych.*, Vol. XV., No. 6, 1905.

from three to five rats were kept in each cage, the cages being made sufficiently large (24″ x 15″ x 15″) to permit it. Cages were frequently disinfected with a preparation the principal ingredient of which is carbolic acid. The rats were occasionally immersed in a solution of this preparation in order to destroy skin parasites. A layer of clean chips and shavings was kept on the floor of all cages. The food, from the time of weaning, consisted of bread soaked in milk every day, grain and sunflower seeds twice a week, and banana or carrot once a fortnight. Temperature was kept as uniformly as possible at 70° F. In order to facilitate this a small gas heater was installed and it proved very efficient even during the coldest days of winter. As the animal laboratory is located in the basement the temperature, during the summer, rarely rose above our norm.

At the age of sixty days the rats intended for experimental purposes were placed on a short allowance of feeding time (thirty minutes) in order to prepare them for experimentation. The experiments were begun with both inbreds and normal control at the age of seventy days. Care was taken in each experiment to use the same number of males and females in the control series as in the inbred; this was necessary because, as in man, the relative brain weight of the female is greater than that of the male. Experiments upon individual rats were conducted as nearly as possible at the same time of day, both to form feeding rhythms and in order not to interfere with other rhythms.

There are three methods of estimating perfection in experiments relating to the habit-forming abilities of animals: the number of errors, the distance traversed, the time consumed. It is hard, in any case, to form a judgment as to what constitutes an error in the behavior of an animal; especially is this true in a comparative study of this kind where it is possible for the personal prejudices of the experimenter to become a factor. At the time this investigation was begun there was no adequate means of measuring the distance traversed. This left at the disposal of the experimenter but one criterion: the time consumed. However, time consumed in learning is the criterion most frequently used by experimenters in the animal field.

Hicks,[4] in summing up the experimental results of several investigators, concludes that "time is the best single criterion, inasmuch as it represents all phases of the process of learning, and since it will yield the most comparable results at the hands of different investigators." In timing the rats a very accurate Swiss split-second stopwatch was used. Under ideal conditions, perhaps, the animal should be presented to the problem by one person, timed by another, while the experimenter himself should merely record the results. But timing very soon becomes automatic; when the rat is crossing the line it is almost impossible to inhibit the impulse to press the stem of the watch.

At the conclusion of the experiments all the rats were shipped to the Wistar Institute where Dr. Shinkishi Hatai ascertained the anatomical data necessary for the formulation of the comparison between relative brain weight and the ability to form habits.

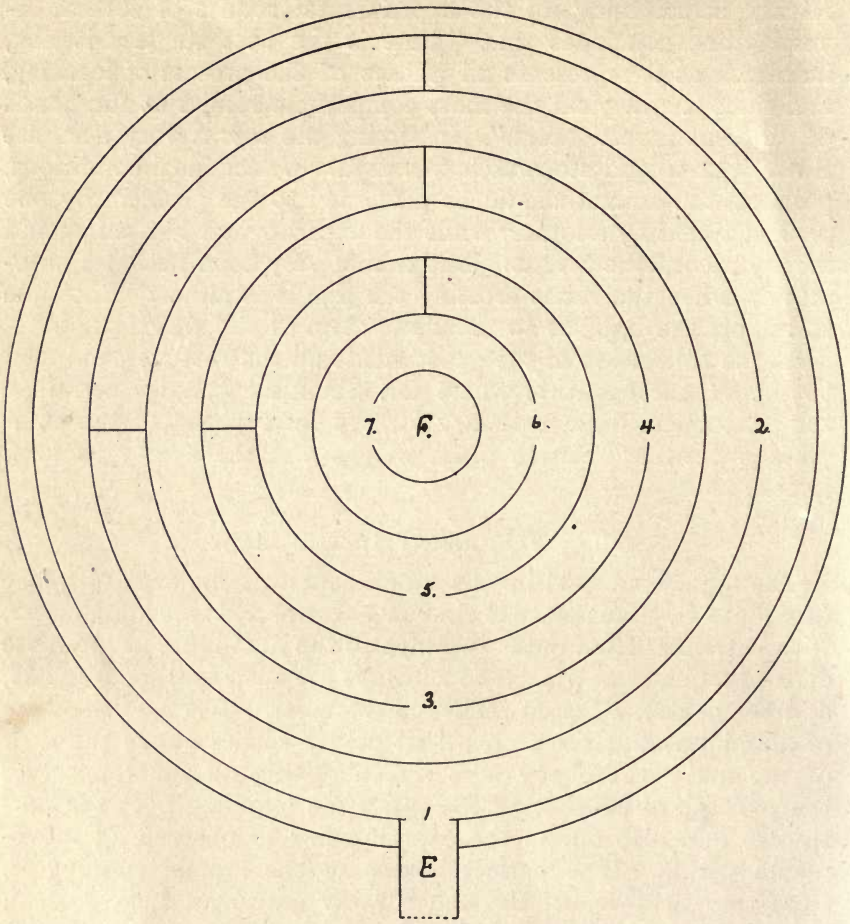
III. EXPERIMENT 1: THE MAZE

The apparatus used in this experiment was the Watson Maze (see Plate I). This maze is circular in form, five feet in diameter, with entrances from outer runways to the next inner at alternate ends of a quadrant arc. The runways are each four inches wide, and the centre, F, eight inches in diameter. The partitions are of aluminum and rise to a height of five inches above the floor of the maze. A heavy wire screen resting on the top serves the purpose of preventing the rats from climbing over the partitions, and also allows the experimenter to observe all movements within. The perfect course of the animal running is, from the entrance, E, through runway entrances 1, 2, 3, 4, 5, 6, and 7 to F (food). Each side of runway entrances 2 to 6 inclusive lead into *cul-de-sacs*.

The object of the experiment was to have each rat learn to reach the centre, F, in the least possible time, the starting time being taken when the animal crossed runway entrance 1, and the finishing time when he crossed entrance 7.

In preparation, each animal, beginning at the age of sixty-five days, was fed alone in the centre, F, ten minutes daily for

[4] Hicks, The Relative Values of the Different Curves of Learning. *Jour. Animal Behavior.*, Vol. I, pp. 138 ff.



The Watson Maze.

Plate I.

five consecutive days. During this period the centre was barred from the rest of the maze at entrance 6. At the age of seventy days the experiment began. Eleven males and ten females from the inbred strain were used and, as control, an equal number of males and females from the normal control series. Of the inbred rats, fourteen were from the sixth generation and seven from the seventh. The stimulus used was the food to which they had become accustomed, bread soaked in milk.

From the beginning of the experiment each rat was required to run from E to F five times daily. At the end of the fifth trial it was allowed to feed in the centre, F, for five minutes, but permitted no more food until the completion of the next day's experiment. Each rat was used daily until it had learned the course perfectly, the criterion of perfection being five perfect trials for each of three successive days. A perfect trial consisted in running the course within six seconds, a period of time so short that it was practically impossible for the rat to make a detectable error and reach the centre within that time. Those rats failing to learn within one hundred days (five hundred trials) were no longer used for experimentation. Such rats as learned the maze were, at the conclusion of the experimentation, fed for sixty days in a runway twenty-five feet long with a feeding-box at the right of the far end. At the end of this period they were tested for retention and relearning.

The shortest period of time required by an inbred rat to learn the maze perfectly was twelve days; for a control rat, ten days. Two inbred rats and one control failed to learn the maze habit within the one hundred days allowed. During the process of learning certain of the normal control series showed peculiarities of behavior similar to those exhibited by the inbred strains. These peculiarities, for the greater part, consisted in disorientation and persistent errors. All the normal control series, with the exception of five rats containing germ-plasm of the B strain, had perfected the maze habit by the twenty-fourth day. The control rat mentioned above as having failed to learn the maze within one hundred days was from this group. So erratic in behavior and so slow in learning were the B strain rats that the investigator suspected them to be of less than normal brain weight; and, when the returns were received from the Wistar Institute, this was indeed found to be the case.

For greater convenience in making a comparative study, I have placed together in Table I a summary consisting of the daily averages of the entire inbred group and, directly beneath, the corresponding daily averages of the entire normal control group. From this table, too, are constructed the comparative curves of learning.

Table I compares: (a) the progress of learning by days; (b) the "absolute retention" (this being a term used here to represent the time required to complete the first trial of the relearning series after the sixty days' rest; the greater the retention, the less is the time); (c) the progress of relearning by days; (d) the anatomical data.

Table Ia shows that two of the inbred and one of the control rats (the latter from the B strain) failed to learn the maze habit. The inbreds required, on the average, 36.62+ days to learn; the control but 24.67+ days. The absolute retention of the inbred rats (Table Ib) was, on the average, 81.558 seconds; of the control series, 59.640 seconds. The two inbreds and one control failing to learn the maze were not, of course, tested for retention and relearning. Of the inbreds so tested (Table Ic), two failed to relearn within fifty days, in consequence of which it was thought useless to carry them further. All the control series had relearned at the end of twenty-two days. The inbreds required, on the average, 12.68+ days to relearn; the normals but 5.75 days.

In all these criteria of ability: learning, absolute retention, and relearning, the rats of the normal control series are shown, on the average, to be superior to those of the inbred series.

There are two methods in use for estimating the relative brain weight: in reference to body length and in reference to body weight. In a healthy normal rat the difference between body weight in grams and body length in millimeters is slight; but, under conditions of overfeeding, underfeeding, or of sickness the body weight varies greatly while the body length remains constant. For this reason Dr. Donaldson of the Wistar Institute has accepted body length as the better method. I have laid greater stress on the body length criterion, although both are presented in the tables of anatomical data. Both body length and body weight of the inbred rats used in the maze (Table Id) are, on the average, slightly greater than is

the case with the normal controls. The relative brain weight (in reference to body length) of the inbreds is 4.43% less than that of the normals. The relative brain weight (in reference to body weight) of the inbreds is 7.99% less than that of the normal control. The percentage of water in brain and cord normally decreases with age; but in the inbreds used in the maze experiment, although killed, on the average, fourteen days later than the control rats, the percentage of water was greater.

The figures presented in Table I support the hypothesis that a less than normal average brain weight in a strain of rats is accompanied by an average lesser ability to form habits.

TABLE Ia

THE MAZE

DAILY LEARNING AVERAGES OF INBRED AND NORMAL CONTROL RATS
(Time in seconds)

	Day 1	Day 2	Day 3	Day 4	Day 5
Inbred Average	531.665	91.404	68.160	39.459	25.568
Control Average	505.128	110.739	53.851	28.404	25.613
	Day 6	Day 7	Day 8	Day 9	Day 10
Inbred Average	20.015	13.899	11.061	9.709	9.522
Control Average	17.366	13.381	11.994	12.440	9.619
	Day 11	Day 12	Day 13	Day 14	Day 15
Inbred Average	10.217	7.937	8.708	7.600	7.000
Control Average	7.295	7.748	7.354	6.904	7.277
	Day 16	Day 17	Day 18	Day 19	Day 20
Inbred Average	6.439	6.585	6.305	6.492	6.458
Control Average	6.687	6.428	5.900	6.209	5.851
	Day 21	Day 22	Day 23	Day 24	Day 25
Inbred Average	6.362	5.749	5.978	5.753	6.248
Control Average	5.630	5.816	5.710	5.675	5.420
	Day 26	Day 27	Day 28	Day 29	Day 30
Inbred Average	5.734	7.130	5.669	6.387	5.697
Control Average	5.389	5.442	5.479	5.496	5.437
	Day 31	Day 32	Day 33	Day 34	Day 35
Inbred Average	5.384	5.708	5.702	6.084	5.731
Control Average	5.700	5.502	5.378	5.499	5.308
	Day 36	Day 37	Day 38	Day 39	Day 40
Inbred Average	5.590	5.476	5.494	5.540	5.848
Control Average	5.272	5.249	5.327	5.363	5.316
	Day 41	Day 42	Day 43	Day 44	Day 45
Inbred Average	5.640	5.978	5.631	5.526	13.456
Control Average	5.343	5.573	5.375	5.250	5.444

TABLE Ia—Continued

	Day 46	Day 47	Day 48	Day 49	Day 50
Inbred Average	6.734	7.400	6.602	5.713	5.840
Control Average	5.282	5.162	5.147	5.198	5.223
	Day 51	Day 52	Day 53	Day 54	Day 55
Inbred Average	5.844	5.522	5.353	5.416	5.707
Control Average	5.322	5.360	5.192	5.615	5.261
	Day 56	Day 57	Day 58	Day 59	Day 60
Inbred Average	5.924	5.640	5.458	5.621	6.740
Control Average	5.286	5.181	5.358	5.286	5.257
	Day 61	Day 62	Day 63	Day 64	Day 65
Inbred Average	8.347	6.442	6.177	5.425	5.686
Control Average	5.398	5.952	5.743	5.299	5.288
	Day 66	Day 67	Day 68	Day 69	Day 70
Inbred Average	5.880	5.630	5.442	5.821	5.396
Control Average	5.345	5.339	5.173	5.360	5.223
	Day 71	Day 72	Day 73	Day 74	Day 75
Inbred Average	5.419	5.737	5.457	5.587	5.928
Control Average	5.244	5.170	5.130	5.206	5.110
	Day 76	Day 77	Day 78	Day 79	Day 80
Inbred Average	5.686	5.798	5.817	5.627	5.432
Control Average	5.183	5.288	5.170	5.143	5.421
	Day 81	Day 82	Day 83	Day 84	Day 85
Inbred Average	6.095	7.335	5.379	5.535	6.345
Control Average	5.263	5.236	5.211	5.208	5.160
	Day 86	Day 87	Day 88	Day 89	Day 90
Inbred Average	5.495	5.316	5.560	5.421	7.290
Control Average	5.288	5.156	5.181	5.152	5.152
	Day 91	Day 92	Day 93	Day 94	Day 95
Inbred Average	5.829	7.015	6.204	6.011	5.556
Control Average	5.257	5.095	5.141	5.210	5.166
	Day 96	Day 97	Day 98	Day 99	Day 100
Inbred Average	5.893	5.665	6.017	5.973	5.958
Control Average	5.217	5.149	5.118	5.187	5.215

	Failed to learn	Days required to learn
Inbr d Average	2	36.62+
Control Average	1	24.67+

TABLE Ib

THE MAZE

AVERAGE ABSOLUTE RETENTION OF INBRED AND NORMAL CONTROL RATS

	Absolute Retention after 60 days' rest
Inbred Average	81.558 seconds
Control Average	59.640 seconds

TABLE Ic

THE MAZE

DAILY RELEARNING AVERAGES OF INBRED AND NORMAL CONTROL RATS
(Time in seconds)

	Day 1	Day 2	Day 3	Day 4	Day 5
Inbred Average	35.415	12.208	10.069	9.560	8.069
Control Average	28.574	18.752	9.530	7.996	6.548
	Day 6	Day 7	Day 8	Day 9	Day 10
Inbred Average	7.672	7.659	6.642	6.232	6.604
Control Average	7.076	6.064	5.922	5.670	5.630
	Day 11	Day 12	Day 13	Day 14	Day 15
Inbred Average	6.200	5.966	6.067	5.660	5.587
Control Average	5.508	5.434	5.430	5.414	5.468
	Day 16	Day 17	Day 18	Day 19	Day 20
Inbred Average	5.634	5.669	5.680	6.029	5.718
Control Average	5.970	5.424	5.490	5.354	5.440
	Day 21	Day 22	Day 23	Day 24	Day 25
Inbred Average	6.046	5.834	5.844	6.061	5.771
Control Average	5.614	5.300	5.300	5.300	5.300
	Day 26	Day 27	Day 28	Day 29	Day 30
Inbred Average	6.166	5.697	5.914	5.842	5.817
Control Average	5.300	5.300	5.300	5.300	5.300
	Day 31	Day 32	Day 33	Day 34	Day 35
Inbred Average	5.901	5.905	5.640	5.846	5.939
Control Average	5.300	5.300	5.300	5.300	5.300
	Day 36	Day 37	Day 38	Day 39	Day 40
Inbred Average	5.920	5.956	5.903	5.766	5.726
Control Average	5.300	5.300	5.300	5.300	5.300
	Day 41	Day 42	Day 43	Day 44	Day 45
Inbred Average	5.657	5.848	5.779	5.745	5.861
Control Average	5.300	5.300	5.300	5.300	5.300
	Day 46	Day 47	Day 48	Day 49	Day 50
Inbred Average	6.032	5.815	5.920	5.762	5.697
Control Average	5.300	5.300	5.300	5.300	5.300

	Failed to relearn	Days required to relearn
Inbred Average	2	12.68+
Control Average	0	5.75

TABLE Id

THE MAZE

ANATOMICAL DATA OF INBRED AND NORMAL CONTROL RATS

	Body Length in mm.	Body Weight in grms.	Brain Weight in grms.	Cord Weight in grms.	Water in Brain per cent
Inbred Average	195.38	180.55	1.71122	.52852	78.497
Control Average	191.00	171.41	1.74930	.52740	78.319

	Water in Cord per cent	Per cent Brain Weight in Relation to Body Length	Per cent Brain Weight in Relation to Body Weight	Age killed Days
Inbred Average	71.723	.87685	.97052	200
Control Average	71.666	.91745	1.05479	186

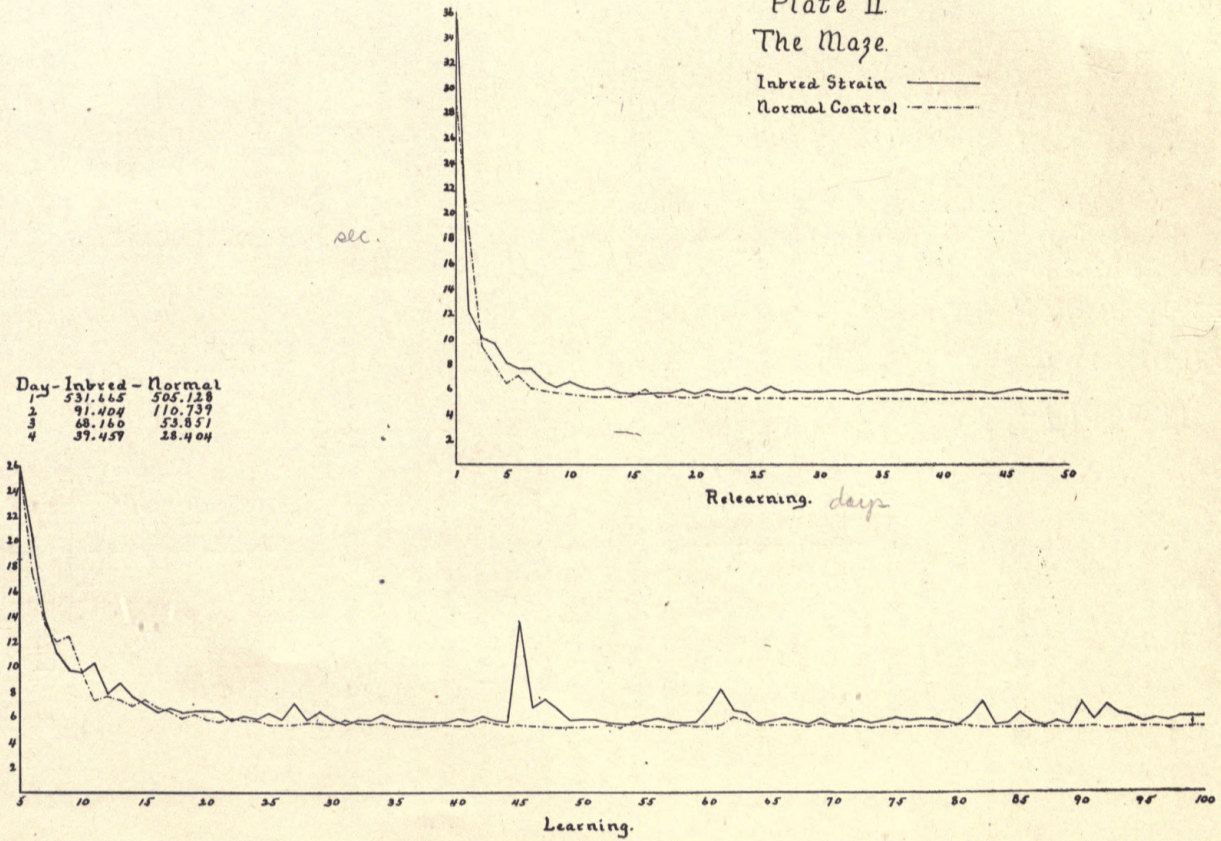
In Plate II is shown the curve of learning (below) and of relearning (above) of the inbred rats compared with those of the normal control. These curves are constructed from figures given in Table I. The curve of the inbred rats is indicated by the solid line, that of the normal control by the broken line. The ordinates give the average daily time in seconds for each group, and the abscissae the number of the day in which such time was made. The time required by both inbred and control rats for the first four days was so long that it is represented here by figures and does not appear in the curve. For the first few days the descent in time for both the inbreds and the control is very rapid. From the twentieth day the curve of the control rats lies entirely below the six-second mark. The curve of the inbred rats never reaches even an approximately flattened appearance, but exhibits great irregularities, particularly on the forty-fifth, sixty-first, eighty-second, ninetieth and ninety-second days. The inbreds' curve of relearning is more similar to that of the controls, but it must be borne in mind that the two inbreds and one control rat that failed to learn the maze are not represented in the relearning curve, and for this reason this curve applies to selected groups. From the twenty-second day the control curve of relearning is perfectly flat at 5.3 seconds, all the control rats having relearned. Two of the inbred rats having failed to relearn, their curve of relearning remains slightly irregular and above that of the control in time.

In Plate III may be seen the curves representing the distribution of learning and relearning of both inbreds and control for the maze experiment. The time is given in days—in groups of five for learning, in groups of two for relearning. As may readily be seen, the advantage from the standpoint of time (days required to learn and relearn) lies wholly in favor of the normal control group.

The question arises as to whether the later generations of inbred rats differ from the earlier in the ability to form habits; that is, is decrease in this ability progressive even if, as earlier stated, decrease in relative brain weight after the 4th generation is not. Of the inbred rats used in the maze experiment, fourteen were from the 6th generation and seven from the 7th generation. In Table II is presented a comparative summary consisting of the daily averages of the 6th and 7th generation

Plate II.

The Maze.



Day	Inbred	Normal
1	531.665	505.128
2	91.404	110.739
3	68.160	53.851
4	39.459	28.404

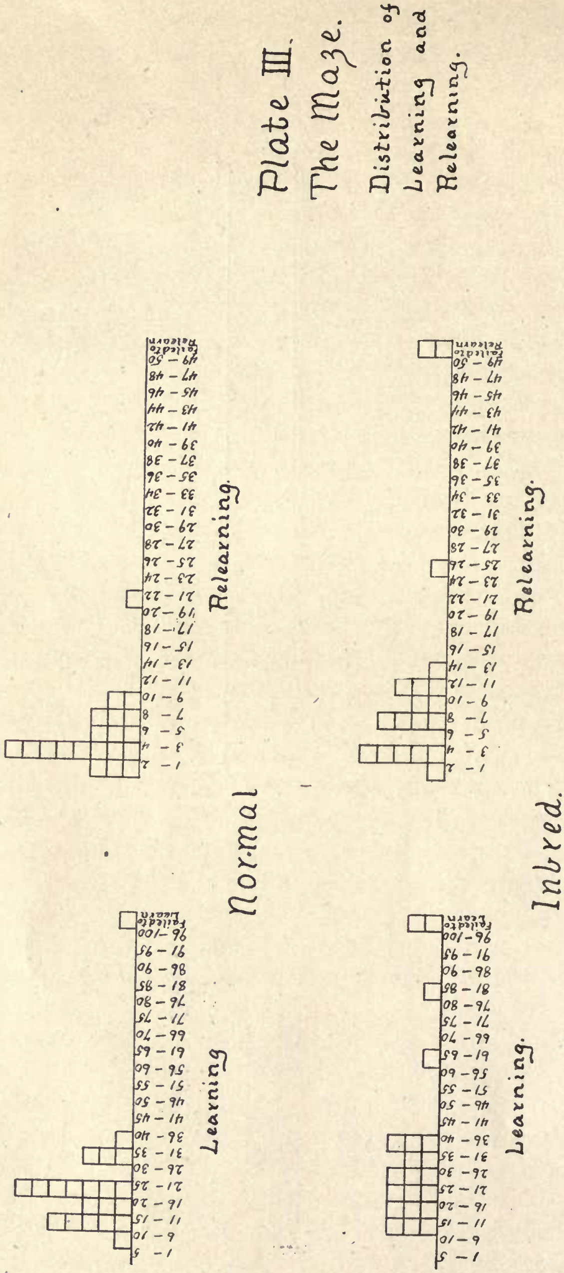


Plate III.
The Maze.
Distribution of Learning and Relearning.
Normal
Learning
Relearning
Inbred.
Learning.
Relearning.

inbred rats used in this experiment. Two of the 7th generation failed to learn the maze; all the 6th generation had learned it after eighty-three days. The 6th generation required, on the average, 32.93 days in which to learn; the 7th generation, 44.00+ days. The absolute retention of the 6th generation was, on the average, 65.443 seconds; of the 7th generation, 126.680 seconds. Two of the 6th generation failed to relearn; all the 7th generation had relearned at the end of fourteen days. The 6th generation required, on the average, 14.14+ days to relearn; the 7th generation but 8.60 days.

In these criteria of ability, the 6th generation excelled in learning and absolute retention; the 7th in relearning. It must be remembered, however, that the 7th generation rats used in the relearning test formed a selected group, the two rats having failed to learn having been from this generation. On the whole, the ability of the 7th generation inbreds in the maze experiment appears to be somewhat inferior to that of the 6th generation.

The body length and body weight of the 6th generation average greater than those of the 7th. The average actual brain weight of the 6th generation is greater than that of the 7th. The relative brain weight (in reference to body length) of the 6th generation is .91% less than that of the 7th generation. The relative brain weight (in reference to body weight) of the 6th generation is 1.50% less than that of the 7th generation. The relative brain weight of the inbred rats used in the maze has not decreased from one generation to the next; but all the 7th generation rats were females, and the females normally have relatively greater brain weights than the males. The percentage of water in brain and cord is within .03% of the same figure in the two generations.

TABLE IIa

THE MAZE

DAILY LEARNING AVERAGES OF SIXTH AND SEVENTH GENERATION INBRED RATS
(Time in seconds)

	Day 1	Day 2	Day 3	Day 4	Day 5
Sixth Average.....	541.423	73.343	79.997	37.449	30.014
Seventh Average.....	512.149	127.526	44.486	43.480	16.674
	Day 6	Day 7	Day 8	Day 9	Day 10
Sixth Average.....	24.457	16.371	10.646	10.486	9.789
Seventh Average.....	11.131	8.954	11.891	8.154	8.989

TABLE IIa—(Continued)

	Day 11	Day 12	Day 13	Day 14	Day 15
Sixth Average	11.157	8.294	9.825	7.958	7.130
Seventh Average	8.337	7.223	6.760	6.926	6.741
	Day 16	Day 17	Day 18	Day 19	Day 20
Sixth Average	6.767	6.690	6.350	6.376	6.421
Seventh Average	5.781	6.376	6.216	6.724	6.530
	Day 21	Day 22	Day 23	Day 24	Day 25
Sixth Average	6.276	5.741	5.899	5.576	6.004
Seventh Average	6.536	5.764	6.136	6.107	6.736
	Day 26	Day 27	Day 28	Day 29	Day 30
Sixth Average	5.604	5.716	5.455	5.441	5.466
Seventh Average	5.993	9.959	6.096	8.279	6.159
	Day 31	Day 32	Day 33	Day 34	Day 35
Sixth Average	5.320	5.674	5.594	5.658	5.464
Seventh Average	5.513	5.776	5.919	6.936	6.267
	Day 36	Day 37	Day 38	Day 39	Day 40
Sixth Average	5.406	5.444	5.284	5.316	5.236
Seventh Average	5.959	5.541	5.913	5.987	7.073
	Day 41	Day 42	Day 43	Day 44	Day 45
Sixth Average	5.399	5.853	5.396	5.261	5.461
Seventh Average	6.124	6.227	6.101	6.056	29.444
	Day 46	Day 47	Day 48	Day 49	Day 50
Sixth Average	5.364	5.259	5.361	5.396	5.387
Seventh Average	9.473	11.684	9.084	6.347	6.747
	Day 51	Day 52	Day 53	Day 54	Day 55
Sixth Average	5.713	5.447	5.230	5.244	5.647
Seventh Average	6.107	5.673	5.599	5.759	5.827
	Day 56	Day 57	Day 58	Day 59	Day 60
Sixth Average	5.336	5.359	5.301	5.210	5.241
Seventh Average	7.101	6.204	5.770	6.444	9.736
	Day 61	Day 62	Day 63	Day 64	Day 65
Sixth Average	5.333	5.366	5.312	5.198	5.209
Seventh Average	14.376	8.593	7.907	5.879	6.639
	Day 66	Day 67	Day 68	Day 69	Day 70
Sixth Average	5.198	5.264	5.186	5.286	5.166
Seventh Average	7.244	6.364	5.953	6.890	5.856
	Day 71	Day 72	Day 73	Day 74	Day 75
Sixth Average	5.158	5.184	5.192	5.158	5.212
Seventh Average	5.941	6.844	5.987	6.444	7.359
	Day 76	Day 77	Day 78	Day 79	Day 80
Si th Average	5.249	5.189	5.209	5.269	5.169
Seventh Average	6.559	7.016	7.033	6.341	5.959
	Day 81	Day 82	Day 83	Day 84	Day 85
Sixth Average	5.155	5.149	5.158	5.153	5.158
Seventh Average	7.976	11.707	5.821	6.290	8.730

TABLE IIa—(Continued)

	Day 86	Day 87	Day 88	Day 89	Day 90
Sixth Average	5.158	5.158	5.158	5.158	5.158
Seventh Average	6.170	5.633	6.364	5.947	11.553
	Day 91	**Day 92**	**Day 93**	**Day 94**	**Day 95**
Sixth Average	5.158	5.158	5.158	5.158	5.158
Seventh Average	7.170	10.730	8.296	7.719	6.353
	Day 96	**Day 97**	**Day 98**	**Day 99**	**Day 100**
Sixth Average	5.158	5.158	5.158	5.158	5.158
Seventh Average	7.364	6.679	7.736	7.604	7.559

	Failed to learn	Days required to learn
Sixth Average	0	32.93
Seventh Average	2	44.00+

TABLE IIb

THE MAZE

AVERAGE ABSOLUTE RETENTION OF SIXTH AND SEVENTH GENERATION INBRED RATS

	Absolute Retention after 60 Days' Rest
Sixth Average	65.443 seconds
Seventh Average	126.680 seconds

TABLE IIc

THE MAZE

DAILY RELEARNING AVERAGES OF SIXTH AND SEVENTH GENERATION INBRED RATS
(Time in seconds)

	Day 1	Day 2	Day 3	Day 4	Day 5
Sixth Average	31.866	10.357	11.043	9.009	8.071
Seventh Average	45.352	17.392	7.344	11.104	8.064
	Day 6	**Day 7**	**Day 8**	**Day 9**	**Day 10**
Sixth Average	8.174	7.426	6.351	6.111	6.129
Seventh Average	6.264	8.312	7.456	6.584	7.936
	Day 11	**Day 12**	**Day 13**	**Day 14**	**Day 15**
Sixth Average	6.163	6.054	5.886	5.660	5.563
Seventh Average	6.304	5.720	6.576	5.656	5.656
	Day 16	**Day 17**	**Day 18**	**Day 19**	**Day 20**
Sixth Average	5.628	5.674	5.689	6.163	5.740
Seventh Average	5.656	5.656	5.656	5.656	5.656
	Day 21	**Day 22**	**Day 23**	**Day 24**	**Day 25**
Sixth Average	6.186	5.897	5.911	6.206	5.811
Seventh Average	5.656	5.656	5.656	5.656	5.656
	Day 26	**Day 27**	**Day 28**	**Day 29**	**Day 30**
Sixth Average	6.349	5.711	6.006	5.909	5.874
Seventh Average	5.656	5.656	5.656	5.656	5.656

TABLE IIc—(Continued)

	Day 31	Day 32	Day 33	Day 34	Day 35
Sixth Average	5.989	5.994	5.634	5.914	6.040
Seventh Average	5.656	5.656	5.656	5.656	5.656
	Day 36	Day 37	Day 38	Day 39	Day 40
Sixth Average	6.014	6.063	5.991	5.806	5.751
Seventh Average	5.656	5.656	5.656	5.656	5.656
	Day 41	Day 42	Day 43	Day 44	Day 45
Sixth Average	5.657	5.917	5.823	5.777	5.934
Seventh Average	5.656	5.656	5.656	5.656	5.656
	Day 46	Day 47	Day 48	Day 49	Day 50
Sixth Average	6.166	5.871	6.014	5.800	5.711
Seventh Average	5.656	5.656	5.656	5.656	5.656

	Failed to Relearn	Days Required to Relearn
Sixth Average	2	14.14+
Seventh Average	0	8.60

TABLE IId

THE MAZE

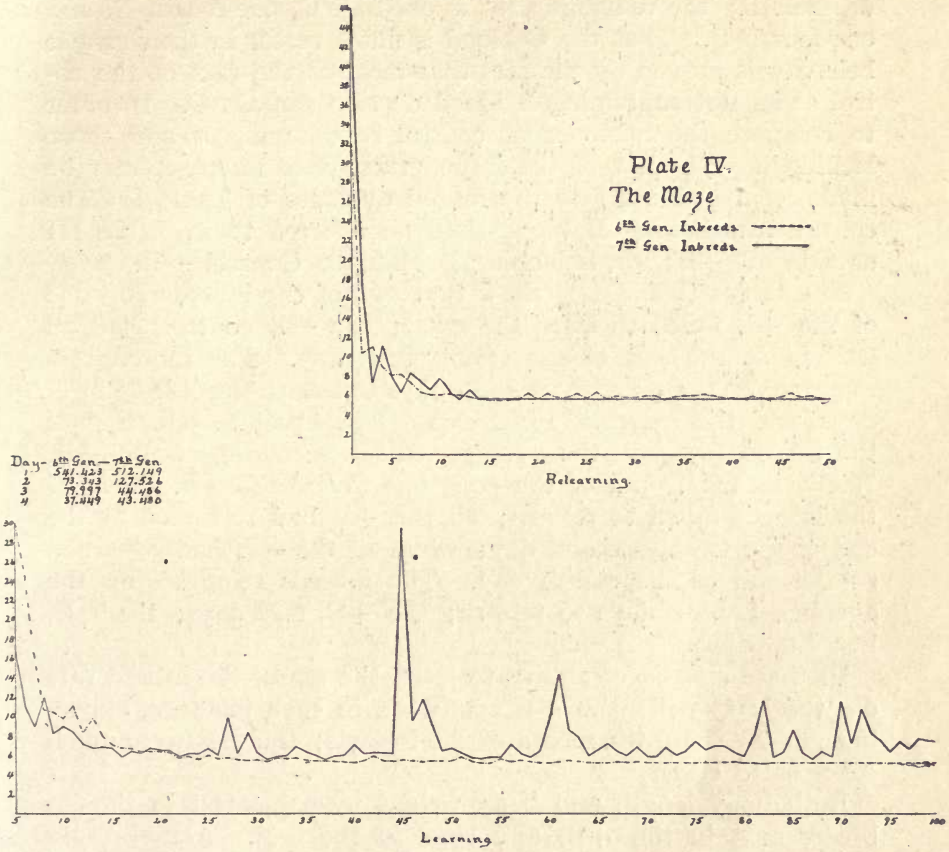
ANATOMICAL DATA OF SIXTH AND SEVENTH GENERATION INBRED RATS

	Body Length in mm.	Body Weight in grms.	Brain Weight in grms.	Cord Weight in grms.	Water in Brain per cent
Sixth Average	200.71	195.04	1.75234	.53881	78.49
Seventh Average	184.71	152.47	1.63286	.50794	78.51

	Water in Cord per cent	Per cent Brain Weight in Relation to Body Length	Per cent Brain Weight in Relation to Body Weight	Age killed Days
Sixth Average	71.73	.87418	.91653	196
Seventh Average	71.70	.88219	1.07851	207

In Plate IV is shown the curve of learning (below) and of relearning (above) of the 6th generation of inbred rats compared with those of the 7th. These curves are constructed from figures given in Table II. The curve of the 6th generation rats is indicated by the broken line, that of the 7th generation by the solid line. The ordinates show the average daily time in seconds for each group, and the abscissae the number of the day in which such time was made. From the twenty-second day the curve of learning of the 6th generation lies below the six-second mark, and from the eighty-third day is flat at 5.158 seconds, signifying that on that day the last of this group had perfected the habit. The 7th generation learning curve is very irregular

throughout its length and never approaches the appearance of perfect learning. The 7th generation relearning curve, however, is slightly better than that of the 6th, being flat from the fourteenth day at 5.656 seconds. But it is again necessary to call attention to the fact that this was a selected group, the two



rats failing to learn having been thrown out and not tested for relearning.

The similarity in behavior of the rats of the control series containing blood of the B strain (of which the original parents were purchased from a Baltimore dealer) to the behavior of the inbreds has already been mentioned. The length of time re-

quired by them to learn the maze had led the investigator to suspect a less than normal brain weight; and, when the brains were weighed, this was found to be the case. Table III presents a comparative summary consisting of the daily averages of the nine rats containing B blood and of the twelve control rats lacking it. Eight of the rats containing B are one-half C and one-half B; the remaining rat is one-half C, one-fourth E, and one-fourth B. That the C blood is not a factor in their erratic behavior is proven by the fact that most of the rats of the control series not containing B blood do also contain C. In order to compare the behavior of control rats having B and those lacking it with that of the inbred rats, cross reference may be made from Table III to the inbred averages of Table I. The control rats having B blood shall be referred to in Table III as Control +B; those lacking B blood as Control —B.

The tables (I and III) show that two of the inbreds and one of the +B failed to learn the maze; the —B controls had all learned at the end of the twenty-fifth day. The inbred rats required, on the average, 36.62+ days to learn; the +B 35.67+ days, and the —B but 16.42 days. The absolute retention of the inbreds was, on the average, 81.558 seconds; of the +B, 72.475 seconds; and of the —B, but 51.083 seconds. Two of the inbreds failed to relearn; all the +B had relearned at the end of the twenty-second day; while all the —B had relearned at the end of the eighth day. The inbreds required, on the average, 12.68+ days to relearn; the +B, 8.24 days; the —B, but 4.08 days.

In these criteria of ability to learn the maze, the inbred rats did the least well; the +B rats were, in each instance, above, but not far from, the record of the inbreds; the —B were much superior to either.

Both body length and body weight were greatest in the inbreds, next in the +B, and least in the —B. Actual brain weight was least in the inbreds, much greater in the +B, and slightly greater in the —B than in the +B. The relative brain weight (in reference to body length) of the inbreds was 5.46% less than that of the —B; that of the +B was 2.53% less than that of the —B. The relative brain weight (in reference to body weight) of the inbred rats was 10.02% less than that of the —B; that of the +B was 5.15% less than that of the —B. As might

be expected, from our hypothesis and the behavior, the average relative brain weight of the +B rats lies between that of the inbreds and of the —B.

The results obtained from the supposedly normal B rats reinforce the former conclusion that a lesser relative brain weight is accompanied in a similar degree by a lesser ability to form habits.

TABLE IIIa

THE MAZE

DAILY LEARNING AVERAGES OF +B AND —B NORMAL CONTROL RATS
(Time in seconds)

	Day 1	Day 2	Day 3	Day 4	Day 5
Control +B	849.458	187.729	88.511	36.160	29.689
Control —B	248.380	52.997	27.857	15.085	22.557
	Day 6	Day 7	Day 8	Day 9	Day 10
Control +B	20.093	15.822	13.066	10.276	12.964
Control —B	15.320	11.550	11.223	14.063	7.110
	Day 11	Day 12	Day 13	Day 14	Day 15
Control +B	8.142	9.544	8.907	7.476	9.289
Control —B	6.652	6.393	6.190	6.475	5.768
	Day 16	Day 17	Day 18	Day 19	Day 20
Control +B	6.702	7.822	7.067	7.467	7.040
Control —B	6.675	5.382	5.025	5.265	4.959
	Day 21	Day 22	Day 23	Day 24	Day 25
Control +B	6.529	6.973	6.804	6.719	6.102
Control —B	4.956	4.948	4.888	4.892	4.908
	Day 26	Day 27	Day 28	Day 29	Day 30
Control +B	6.031	6.156	6.240	6.280	6.142
Control —B	4.908	4.908	4.908	4.908	4.908
	Day 31	Day 32	Day 33	Day 34	Day 35
Control +B	6.756	6.294	6.006	6.287	5.842
Control —B	4.908	4.908	4.908	4.908	4.908
	Day 36	Day 37	Day 38	Day 39	Day 40
Control +B	5.758	5.704	5.887	5.971	5.861
Control —B	4.908	4.908	4.908	4.908	4.908
	Day 41	Day 42	Day 43	Day 44	Day 45
Control +B	5.923	6.461	5.999	5.706	6.159
Control —B	4.908	4.908	4.908	4.908	4.908
	Day 46	Day 47	Day 48	Day 49	Day 50
Control +B	5.791	5.501	5.466	5.586	5.643
Control —B	4.908	4.908	4.908	4.908	4.908
	Day 51	Day 52	Day 53	Day 54	Day 55
Control +B	5.874	5.963	5.572	6.559	5.732
Control —B	4.908	4.908	4.908	4.908	4.908
	Day 56	Day 57	Day 58	Day 59	Day 60
Control +B	5.679	5.546	5.959	5.690	5.723
Control —B	4.908	4.908	4.908	4.908	4.908

TABLE IIIa—(Continued

	Day 61	Day 62	Day 63	Day 64	Day 65
Control +B	6.052	7.346	6.857	5.821	5.794
Control —B	4.908	4.908	4.908	4.908	4.908
	Day 66	Day 67	Day 68	Day 69	Day 70
Control +B	5.928	5.914	5.528	5.963	5.643
Control —B	4.908	4.908	4.908	4.908	4.908
	Day 71	Day 72	Day 73	Day 74	Day 75
Control +B	5.692	5.519	5.426	5.603	5.381
Control —B	4.908	4.908	4.908	4.908	4.908
	Day 76	Day 77	Day 78	Day 79	Day 80
Control +B	5.550	5.794	5.519	5.457	6.106
Control —B	4.908	4.908	4.908	4.908	4.908
	Day 81	Day 82	Day 83	Day 84	Day 85
Control +B	5.746	5.673	5.617	5.608	5.497
Control —B	4.908	4.908	4.908	4.908	4.908
	Day 86	Day 87	Day 88	Day 89	Day 90
Control +B	5.794	5.488	5.546	5.479	5.479
Control —B	4.908	4.908	4.908	4.908	4.908
	Day 91	Day 92	Day 93	Day 94	Day 95
Control +B	5.723	5.346	5.452	5.612	5.510
Control —B	4.908	4.908	4.908	4.908	4.908
	Day 96	Day 97	Day 98	Day 99	Day 100
Control +B	5.630	5.470	5.399	5.559	5.626
Control —B	4.908	4.908	4.908	4.908	4.908

	Failed to Learn	Days Required to Learn
Control +B	1	35.67+
Control —B	0	16.42

TABLE IIIb

THE MAZE

AVERAGE ABSOLUTE RETENTION OF +B AND —B NORMAL CONTROL RATS

	Absolute Retention After 60 Days' Rest
Control +B	72.475 seconds
Control —B	51.083 seconds

TABLE IIIc

THE MAZE

DAILY RELEARNING AVERAGES OF +B AND —B NORMAL CONTROL RATS

	Day 1	Day 2	Day 3	Day 4	Day 5
Control +B	36.215	29.230	10.930	11.180	7.990
Control —B	23.480	11.767	8.597	5.873	5.587
	Day 6	Day 7	Day 8	Day 9	Day 10
Control +B	8.075	7.200	6.970	6.340	6.240
Control —B	6.410	5.307	5.223	5.223	5.223

TABLE IIIc—(Continued)

	Day 11	Day 12	Day 13	Day 14	Day 15
Control +B	5.935	5.750	5.740	5.700	5.835
Control —B	5.223	5.223	5.223	5.223	5.223

	Day 16	Day 17	Day 18	Day 19	Day 20
Control +B	7.090	5.725	5.890	5.550	5.765
Control —B	5.223	5.223	5.223	5.223	5.223

	Day 21	Day 22 to Day 50
Control +B	6.200	5.415
Control —B	5.223	5.223

	Failed to Relearn	Days Required to Relearn
Control +B	0	8.24
Control —B	0	4.08

TABLE IIId

THE MAZE

ANATOMICAL DATA OF +B AND —B NORMAL CONTROL RATS

	Body Length in mm.	Body Weight in grms.	Brain Weight in grms.	Cord Weight in grms.	Water in Brain, per cent
Control +B	193.00	175.73	1.75378	.54191	78.25
Control —B	189.50	168.18	1.75428	.51643	78.37

	Water in Cord, Per cent	Per cent Brain Weight in Relation to Body Length	Per cent Brain Weight in Relation to Body Weight	Age killed, Days
Control +B	71.48	.90406	1.02303	200
Control —B	71.81	.92748	1.07861	175

In Plate V is shown the curve of learning (below) and of relearning (above) of the inbred and +B rats compared with those of the —B. The inbred curve is represented by the solid line, the +B by the heavy broken line, and the —B by the lighter broken line. The ordinates show the average daily time in seconds for each group, and the abscissae the number of the day in which such time was made. From the twentieth day the —B curve is flat at 4.9 seconds. Neither the inbred nor the +B curves flatten entirely, although the +B curve of learning is more regular than that of the inbreds. The curve of relearning (lacking the two inbreds and one +B that failed to learn) shows little difference between the three groups. But even here, although the inbred and +B are selected groups, the —B remains superior to both, and the +B is slightly superior to the inbred rats.

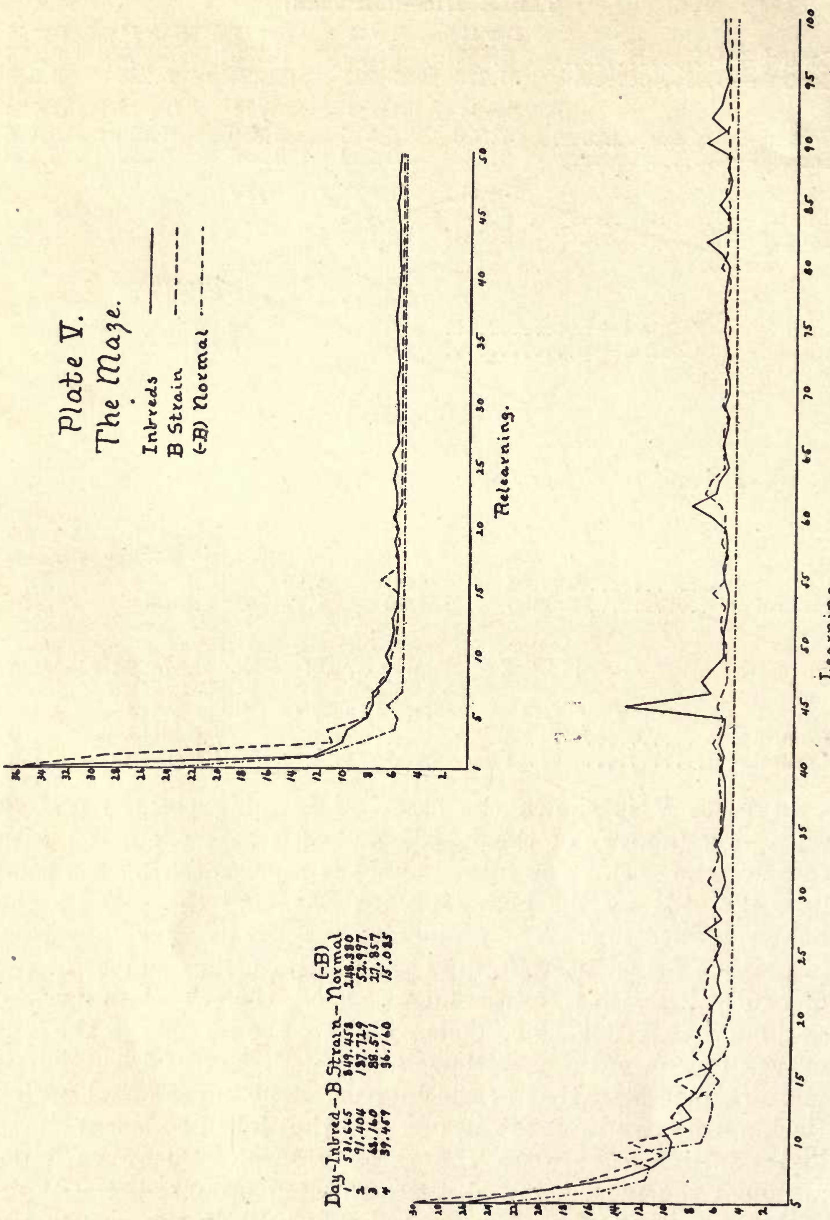


Plate V.
The Maze.
Inbreds
B Strain
(-B) Normal
Relearning.
Learning.
Day-Inbred-B Strain-(-B) Normal
1 531.665 849.458 248.380
2 91.404 137.729 52.997
3 65.160 88.511 27.857
4 39.459 36.160 15.085

IV. EXPERIMENT 2: THE PRELIMINARY INCLINED PLANE

The apparatus used in this experiment (see Plate VI) was designed especially to make a problem exceptionally difficult to learn, and in this purpose it exceeded expectations. The basic principle is the same as that of the apparatus designed and used

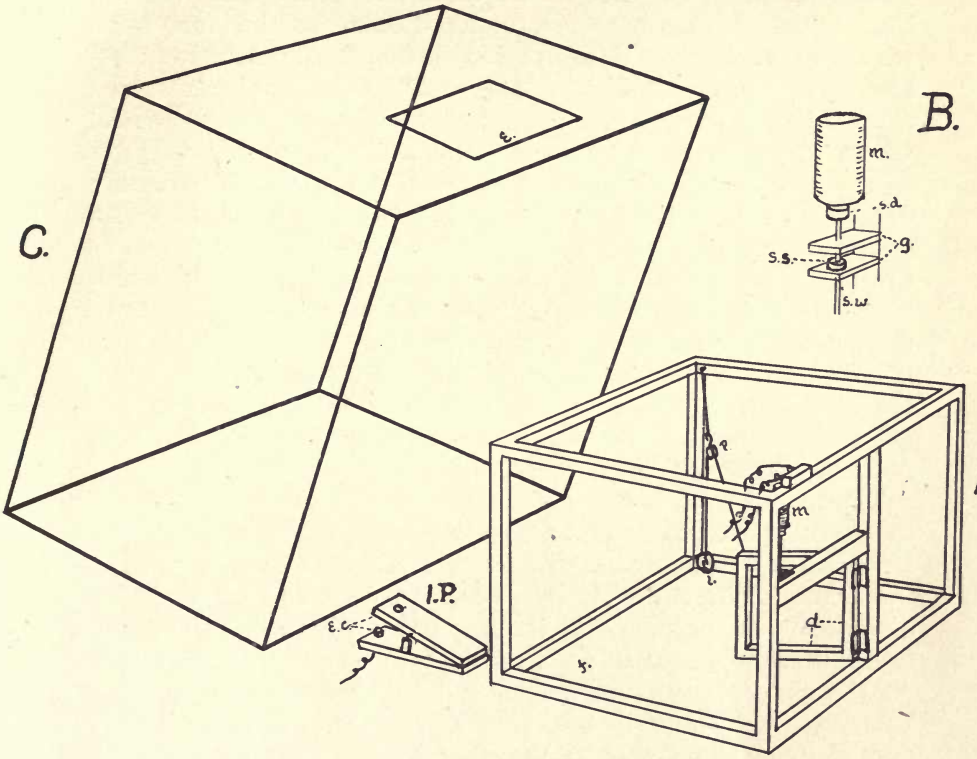


Plate VI. The Inclined Plane.

by Watson in his experiments at the University of Chicago, called by him the " Inclined Plane," and which is described and illustrated in his monograph "Animal Education," page 37.[5] But my apparatus differs from his in several respects.

Plate VI shows in detail the construction and method of operation. The food box, A, is framed of wood, eleven by

[5] Watson: Animal Education, Chicago, 1903.

twelve inches base, eleven inches in height, and is covered on top and sides with three-eighths inch heavy wire mesh. It is fitted with a hard rubber door, d, three-sixteenths inch thick, five inches high, and four and one-fourth inches wide. To the inner side of the door is fastened a cord which passes over a pulley, p, and is weighted at the other end with a piece of lead, l, of sufficient weight to insure the opening of the door upon releasing the latch. B shows the device for latching and releasing the door. A short distance above the door is fastened a three-inch electrical magnet, m; directly below that is a steel wire, s.w., surmounted by a steel disk, s.d., of the same diameter as the core of the magnet. The steel wire holds the door by dropping through holes in two brass plates, g, which serve as guides, to a point, behind another brass plate which is set at the top of and behind the door, one and one-half millimeters below the top. The setscrew, s.s., placed on the steel wire above the lower guide prevents any further drop. When the steel wire holds the door the disk is two mm. below the magnet; when the disk is drawn up to the magnet one-half mm. clearance is allowed for the door to swing back. Back of the feeding box, A, is placed the inclined plane, I.P.

The inclined plane has a hard rubber base three-eighths inch thick, six inches long, and two and three-eighths inches wide. Upon pivot standards rising from the middle of the base rests the plane itself. The plane is of wood fibre and of the same dimensions as the base. It is weighted at the end nearest the feeding box in order to insure its return to position after use. At the end opposite the weight and farthest from the feeding box, platinum electrical contacts, e.c., are placed in both base and plane. The power is provided through wires connecting the regular electric lighting system, 115 volts, direct current, with the wired apparatus. A 32 candle power lamp is placed in the series in order to avoid any danger of short-circuiting. To make the contact and allow the current to pass through the magnet, thus raising the steel wire and releasing the door, it is necessary for the rat to step on the point of operation, o, which lies well out toward the end of the plane. On account of a certain amount of latency in the operation of the magnet, the rat must not only make the contacts touch, but must also inhibit further action, remaining on the point of operation until

click of the disk meeting the magnet is heard. Over the food box and plane is placed a cage, C, constructed of one-half inch heavy wire mesh, the base measurements of which are twenty-four by twenty-four inches and the height fourteen inches. This allows the rat ample room to explore all sides of and above the food box. When the rat is placed within, the entrance, e, to the cage is closed.

The preliminary inclined plane experiment was not intended so much as a decisive experiment as to test the efficiency of the apparatus. The results, however, are significant and, therefore, included here.

The object of this experiment was to have each rat learn to reach the interior of the food box from the cage entrance in the least possible period of time. The procedure of a perfectly trained rat was to run from the entrance, e, to the point of operation, o, remaining there until the click of the disk against the magnet insured the door being open, then running through the door of the box to the food which was placed within at point f. The starting time was taken when the animal entered at e, another when the magnet clicked, and the final time when the food box was entered. The object of recording the two periods of time was that it had been anticipated that differences in association between the inbred series and the control rats might appear. But, as in both series the association was practically perfect by the third day, a comparison of such differences was thought useless.

In preparation for the experiment each animal, beginning at the age of sixty-five days, was fed alone in the food box, the door remaining open, ten minutes daily for five consecutive days. This gave the rat an opportunity to become acquainted with all parts of the interior of both box and cage, and also accustomed him to a reduced feeding time. At the age of seventy days the experiment began. Six males and five females from the inbred strain were used and, as control, an equal number of males and females from the normal series. All the inbred rats were from the 6th generation. The stimulus used was their regular food, bread soaked in milk.

As one of the first rats used consumed fourteen hours before his first accidental success, it was decided to use "cumulative time" for the first few trials. By this method each rat was

allowed to work thirty minutes and then, if unsuccessful, he was taken out, the food box door was opened, and he was then returned to feed for five minutes and used no more that day. When they began to succeed within the half hour, each rat was required to open and enter the food box five times daily. At the end of the fifth trial it was allowed to feed for five minutes, but was permitted no more food until the completion of the next day's experiment. Each rat was used daily for twenty days, making one hundred trials. As a time limit had been placed, no criterion of perfect learning was established for this experiment. At the conclusion of the learning experiment the rats were fed in the runway, which has already been described, for sixty days. At the end of this period they were tested for absolute retention and relearning, and were worked for five days, twenty-five trials, in order to ascertain the effects of the previous training.

In Table IV is a comparative summary consisting of the daily averages of the entire inbred group and, directly beneath, the corresponding daily averages of the entire normal control group.

From the eleventh day the daily time averages of the control rats are less than those of the inbreds. The absolute retention of the control rats is superior to that of the inbreds. In the five days allotted to testing the effects of previous training, the average time of the control rats is less each day than that of the inbreds.

In these criteria of ability the rats of the normal control series are shown to be, on the average, superior to those of the inbred series.

Body length of the inbred rats used in the preliminary inclined plane is, on the average, slightly greater than is the case with the control; body weight, however, is a trifle less. The average actual brain weight of the inbreds is less than that of the control. The relative brain weight (in reference to body length) of the inbreds is 11.61% less than that of the control. The relative brain weight (in reference to body weight) of the inbreds is 11.65% less than that of the control. Although killed at a later age, the percentage of water in brain and cord of the inbreds is greater than is the case with the control.

The preliminary inclined plane figures presented in this table (IV) support the hypothesis that a less than normal average brain weight in a strain of rats is accompanied by a lesser ability to form habits.

TABLE IVa

THE PRELIMINARY INCLINED PLANE

DAILY LEARNING AVERAGES OF INBRED AND NORMAL CONTROL RATS

(Time in seconds)

	Day 1	Day 2	Day 3	Day 4	Day 5
Inbred Average	1965.858	1631.178	60.302	45.916	28.116
Control Average	2470.393	971.102	79.775	27.564	21.840
	Day 6	Day 7	Day 8	Day 9	Day 10
Inbred Average	11.120	14.833	9.095	16.855	7.109
Control Average	20.305	10.375	9.869	8.971	8.058
	Day 11	Day 12	Day 13	Day 14	Day 15
Inbred Average	6.262	9.465	7.658	10.916	10.291
Control Average	5.342	5.015	5.055	4.425	4.513
	Day 16	Day 17	Day 18	Day 19	Day 20
Inbred Average	7.360	6.247	5.531	8.811	10.251
Control Average	5.062	3.727	4.800	5.815	5.622

TABLE IVb

THE PRELIMINARY INCLINED PLANE

AVERAGE ABSOLUTE RETENTION OF INBRED AND NORMAL CONTROL RATS.

	Absolute Retention After 60 Days' Rest
Inbred Average	59.309 seconds
Control Average	49.164 seconds

TABLE IVc

THE PRELIMINARY INCLINED PLANE

DAILY RELEARNING AVERAGES OF INBRED AND NORMAL CONTROL RATS

(Time in seconds)

	Day 1	Day 2	Day 3	Day 4	Day 5
Inbred Average	24.302	9.905	11.516	8.149	7.869
Control Average	17.102	5.498	5.869	4.262	6.651

TABLE IVd

THE PRELIMINARY INCLINED PLANE

ANATOMICAL DATA OF INBRED AND NORMAL CONTROL RATS

	Body Length in mm.	Body Weight in grms.	Brain Weight in grms.	Cord Weight in grms.	Water in Brain, per cent
Inbred Average	190.82	166.50	1.62031	.47535	78.565
Control Average	189.45	168.08	1.81946	.52819	77.982

	Water in Cord, Per cent	Per cent Brain Weight in Relation to Body Length	Per cent Brain Weight in Relation to Body Weight	Age killed, Days
Inbred Average	71.436	.84929	.98140	194
Control Average	71.128	.96084	1.09571	170

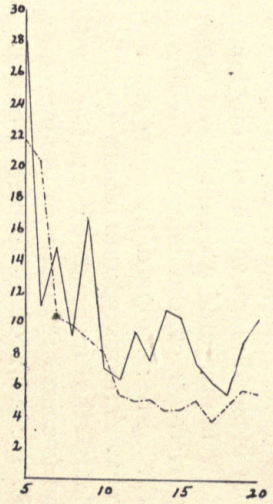
In Plate VII is shown the curve of learning (left) and of relearning (right) of the inbred rats compared with those of the normal control. These curves are constructed from figures given in Table IV. The curve of the inbred rats is indicated by the solid line, that of the normal control by the broken line. The ordinates give the average daily time in seconds for each group, and the abscissae the number of the day in which such time was made. The time required by both inbred and control rats for the first four days was so long that it is represented here by figures and does not appear in the curve. Both learning curves are irregular, but on the eleventh day that of the control passes permanently below that of the inbred. The curves of relearning show that the inbreds had failed to benefit by practice to so great an extent as the normal control.

V. EXPERIMENT 3: THE INCLINED PLANE

The apparatus used in this experiment was the same as that used in Experiment 2: the Preliminary Inclined Plane. The animals were prepared in the same way as for the previous experiment, and began work at the age of seventy days. Sixteen males and fourteen females from the inbred strain were used and, as control, an equal number of males and females from the normal series. Of the inbred rats, fifteen were from the seventh generation, fourteen from the eighth, and one from the ninth. As the behavior of the single ninth generation rat did not vary greatly from the average of the eighth generation, her results have been included in the tables and curves of the eighth generation. The stimulus used in this experiment was the same as in the two preceding, bread soaked in milk.

Cumulative time was used in recording the earlier trials as in the previous experiment. When the rats began to succeed in entering the food box within the half hour, each one was required to open and enter the food box three times each day. At the end of the third trial it was allowed to feed in the box for five minutes, but was permitted no more food until the completion of the next day's experiment. Each rat was used daily until it had learned the problem perfectly, the criterion of perfection being three perfect trials for each of three successive days. A perfect trial consisted in running from the entrance to the point of operation on the plane at the rear of the food box, opening the door, run-

Day	Inbred	Normal
1	1965.858	2470.393
2	1631.178	971.102
3	60.302	79.775
4	45.916	27.564



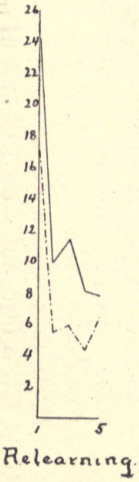


Plate VII.

Preliminary Inclined Plane.

Inbred Strain ———

Normal Control -·-·-·-

ning around and entering the box, all within four seconds; but, if the time consumed in opening the box after passing the entrance was more than two seconds, or if the time consumed in entering the box after having opened the door was more than two seconds, the trial was considered a failure. Thus it was possible for a rat to have a perfect trial in as long a total time as four seconds, or a failure in a less total time. Those rats failing to learn within one hundred days (three hundred trials) were no longer used for experimentation. Those rats learning the inclined plane were, at the conclusion of the experiment, fed for sixty days in the runway. At the end of this period they were tested for absolute retention and relearning.

Three of the rats formed the habit of *lifting* the plane at the end nearest the food box and thus formed the contact, but this method apparently affected neither the rapidity of each trial nor the number of days required for perfect learning. One of the normal rats placed his nose between the electrical contacts and received a shock, but other than one squeal and a vigorous rubbing of the nose, he showed no evidence of harm and had apparently forgotten the experience the following day. Some of the rats jumped to the point of operation from a distance; some placed the fore paws on the end of the plane and pressed down; and still others ran slowly around to the plane, halting an instant on the point of operation, and then continued the run around to the door. As a rule, the last made the best time. As in the maze experiment, many of the inbred rats were subject to errors which persisted throughout the experiment. In particular may be mentioned one rat that invariably formed a loop in the course from the entrance to the point of operation.

The shortest period of time required by an inbred rat to learn the inclined plane perfectly was twelve days; by a normal control rat, nine days. Eleven inbred rats and one control failed to learn the inclined plane within the one hundred days allowed.

In Table V is presented a comparative summary consisting of the daily averages of the entire inbred group and, directly beneath, the corresponding daily averages of the entire normal control group. The inbred rats required, on the average, 73.70+ days to learn the inclined plane; the controls but 45.97+ days. The absolute retention of the inbreds was, on the average, 31.842 seconds; of the controls, but 22.587 seconds. All

the inbreds had relearned at the end of the twenty-fourth day; but all the controls had relearned at the end of the seventeenth day. The inbred rats required, on the average, 6.74 days to relearn; the controls but 4.68 days.

In all these criteria of ability, learning, absolute retention and relearning, the rats of the normal control series are shown, on the average, to be superior to those of the inbred series.

The body length of the inbred rats used in the inclined plane experiment is, on the average, a trifle greater than that of the controls; the body weight is slightly less. The average actual brain weight of the inbreds is less than that of the controls. The relative brain weight (in reference to body length) of the inbreds is 5.89% less than that of the controls. The relative brain weight (in reference to body weight) of the inbreds is 2.38% less than that of the controls. Although the inbred rats were killed, on the average, at a more advanced age than the normal controls, the percentage of water in brain and cord is higher.

The figures presented in Table V support the hypothesis that a less than normal average brain weight in a strain of rats is accompanied by an average lesser ability to form habits.

TABLE Va

THE INCLINED PLANE

DAILY LEARNING AVERAGES OF INBRED AND NORMAL CONTROL RATS

(Time in seconds)

	Day 1	Day 2	Day 3	Day 4	Day 5
Inbred Average	4673.131	1218.976	166.997	56.576	22.926
Control Average	2769.953	1072.722	133.287	61.600	23.995
	Day 6	Day 7	Day 8	Day 9	Day 10
Inbred Average	36.878	12.422	11.061	10.751	8.136
Control Average	25.874	13.478	11.704	11.280	6.961
	Day 11	Day 12	Day 13	Day 14	Day 15
Inbred Average	9.383	7.876	8.625	7.188	9.586
Control Average	6.759	6.858	6.347	7.045	6.383
	Day 16	Day 17	Day 18	Day 19	Day 20
Inbred Average	8.710	8.069	7.364	9.191	6.717
Control Average	5.069	5.400	6.158	5.376	5.352
	Day 21	Day 22	Day 23	Day 24	Day 25
Inbred Average	6.919	6.363	6.951	6.458	7.329
Control Average	5.284	4.378	5.173	5.280	5.025
	Day 26	Day 27	Day 28	Day 29	Day 30
Inbred Average	5.674	6.262	6.627	5.514	27.802
Control Average	4.978	5.139	5.276	4.302	4.303

TABLE Va—(Continued)

	Day 31	Day 32	Day 33	Day 34	Day 35
Inbred Average	7.440	6.707	6.416	6.775	6.957
Control Average	4.354	5.075	3.583	3.868	4.024
	Day 36	Day 37	Day 38	Day 39	Day 40
Inbred Average	6.957	5.334	5.689	5.479	5.289
Control Average	4.121	4.457	3.958	4.905	4.096
	Day 41	Day 42	Day 43	Day 44	Day 45
Inbred Average	4.898	4.938	5.093	4.762	4.553
Control Average	3.748	4.033	3.446	3.729	3.857
	Day 46	Day 47	Day 48	Day 49	Day 50
Inbred Average	4.011	5.076	3.831	4.991	5.105
Control Average	3.367	3.091	3.159	3.050	3.113
	Day 51	Day 52	Day 53	Day 54	Day 55
Inbred Average	4.762	4.408	4.693	5.006	4.191
Control Average	3.044	3.160	2.841	2.924	3.759
	Day 56	Day 57	Day 58	Day 59	Day 60
Inbred Average	4.072	3.916	5.909	6.235	4.953
Control Average	3.000	3.392	3.047	2.991	3.375
	Day 61	Day 62	Day 63	Day 64	Day 65
Inbred Average	4.172	5.026	4.437	3.317	3.741
Control Average	3.173	3.251	2.848	3.951	3.035
	Day 66	Day 67	Day 68	Day 69	Day 70
Inbred Average	4.160	3.955	5.858	4.806	4.260
Control Average	3.098	3.109	3.155	3.138	2.949
	Day 71	Day 72	Day 73	Day 74	Day 75
Inbred Average	4.383	3.869	3.461	3.713	3.649
Control Average	2.976	3.072	3.163	2.640	3.129
	Day 76	Day 77	Day 78	Day 79	Day 80
Inbred Average	3.726	3.669	3.646	4.043	3.648
Control Average	2.667	2.799	2.770	2.750	2.839
	Day 81	Day 82	Day 83	Day 84	Day 85
Inbred Average	3.359	3.465	3.558	3.322	3.471
Control Average	3.094	2.663	2.665	2.652	2.823
	Day 86	Day 87	Day 88	Day 89	Day 90
Inbred Average	3.729	3.388	3.686	3.639	4.170
Control Average	2.763	2.834	2.669	2.681	2.663
	Day 91	Day 92	Day 93	Day 94	Day 95
Inbred Average	3.501	3.393	4.124	3.463	3.457
Control Average	2.683	2.665	2.623	2.732	2.846
	Day 96	Day 97	Day 98	Day 99	Day 100
Inbred Average	2.999	3.460	3.604	2.982	3.510
Control Average	2.772	2.657	2.608	2.946	2.637

	Failed to Learn	Days Required to Learn
Inbred Average	11	73.70+
Control Average	2	45.97+

TABLE Vb

THE INCLINED PLANE

AVERAGE ABSOLUTE RETENTION OF INBRED AND NORMAL CONTROL RATS

	Absolute Retention After 60 Days' Rest
Inbred Average	31.842 seconds
Control Average	22.587 seconds

TABLE Vc

THE INCLINED PLANE

DAILY RELEARNING AVERAGES OF INBRED AND NORMAL CONTROL RATS

(Time in seconds)

	Day 1	Day 2	Day 3	Day 4	Day 5
Inbred Average	41.789	7.301	5.436	4.783	5.067
Control Average	22.598	6.198	4.279	3.985	5.021
	Day 6	Day 7	Day 8	Day 9	Day 10
Inbred Average	5.175	4.239	3.404	3.186	2.828
Control Average	3.057	3.569	3.598	3.021	3.293
	Day 11	Day 12	Day 13	Day 14	Day 15
Inbred Average	3.508	2.712	2.796	2.845	2.807
Control Average	2.929	3.676	3.200	2.633	2.664
	Day 16	Day 17	Day 18	Day 19	Day 20
Inbred Average	2.610	2.603	2.596	2.733	2.677
Control Average	2.776	2.586	2.586	2.586	2.586
	Day 21	Day 22	Day 23	Day 24	Day 25 to 50
Inbred Average	2.607	2.729	2.596	2.554	2.554
Control Average	2.586	2.586	2.586	2.586	2.586

	Failed to Relearn	Days Required to Relearn
Inbred Average	0	6.74
Control Average	0	4.68

TABLE Vd

THE INCLINED PLANE

ANATOMICAL DATA OF INBRED AND NORMAL CONTROL RATS

	Body Length in mm.	Body Weight in grms.	Brain Weight in grms.	Cord Weight in grms.	Water in Brain per cent,
Inbred Average	195.93	184.37	1.72083	.53787	78.363
Control Average	194.43	189.18	1.81840	.53922	78.319

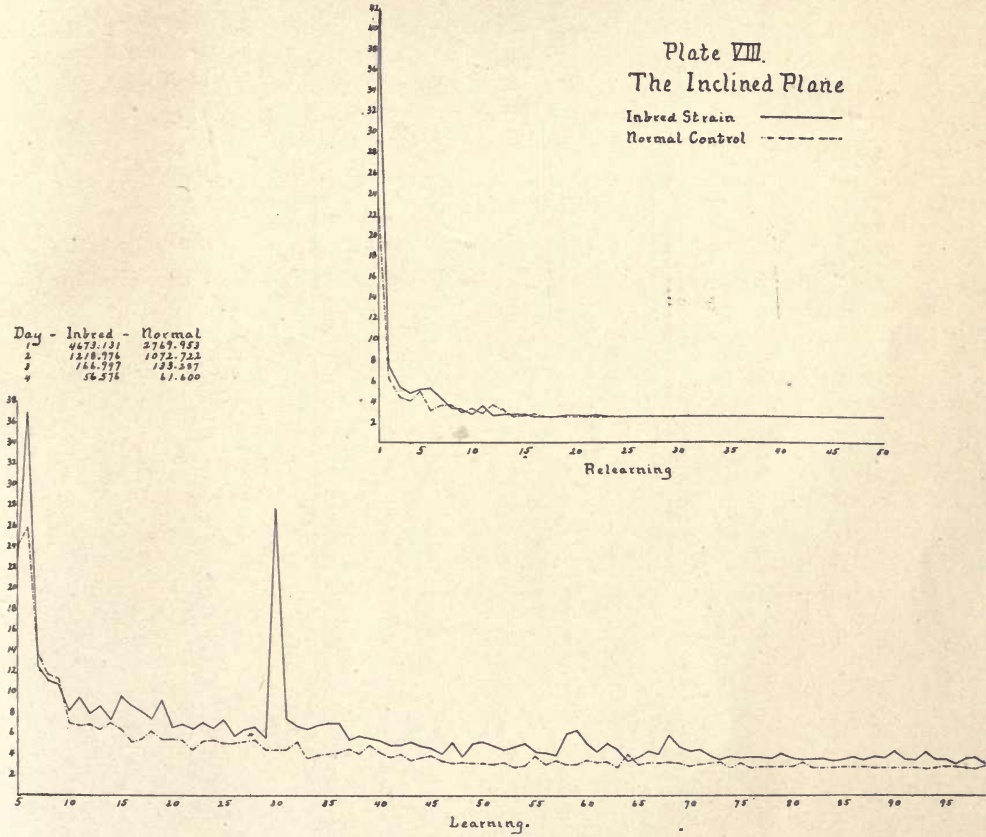
	Water in Cord, per cent	Per cent Brain Weight in Relation to Body Length	Per cent Brain Weight in Relation to Body Weight	Age killed, Days
Inbred Average	71.437	.87972	.97889	220
Control Average	71.223	.93474	1.00275	194

In Plate VIII is shown the curve of learning (below) and of relearning (above) of the inbred rats compared with those of the normal control. These curves are constructed from figures given in Table V. The curve of the inbred rats is indicated by the solid line, that of the normal control by the broken line. The ordinates give the average daily time in seconds for each group, and the abscissae the number of the day in which such time was made. As in the other learning curves, the time required by both inbred and control rats for the first four days was so long that it is represented here by figures and does not appear in the curve. The descent in time of both inbred and control rats for the first ten days is quite rapid, although both show retardation on the sixth day. From the forty-first day the curve of the controls lies entirely below the four second mark. The inbred curve, throughout, shows great irregularities, especially on the thirtieth day, when it rises to an average of nearly twenty-eight seconds. The inbred curve of relearning is very similar to that of the control, and from the twenty-third day coincides with it. But again, in relearning, we are dealing with selected groups, the eleven inbreds and two controls that failed to learn not being included. The inbreds of this selected group had all relearned at the end of the twenty-fourth day; the control at the end of the seventeenth day.

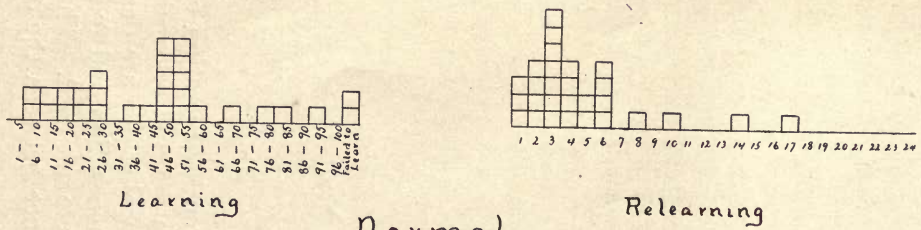
In Plate IX may be seen the distribution curves of learning of both the inbred and control series for the inclined plane experiment. The time is given in days—in groups of five for learning, singly for relearning. It is very apparent that the advantage lies wholly in favor of the normal control series.

Of the inbred rats used in the inclined plane experiment, fifteen were from the seventh generation, fourteen from the eighth, and one from the ninth. In Table VI is presented a comparative summary consisting of the daily averages of the seventh and eighth generation rats used in the inclined plane experiment. With the rats of the eighth generation may be included the one from the ninth, as her record was not far from the average of the eighth. The table shows that four of the seventh generation and seven of the eighth generation failed to learn the inclined plane. The seventh generation required, on the average, 59.60+ days to learn; the eighth generation, 86.53+ days. The absolute retention of the seventh genera-

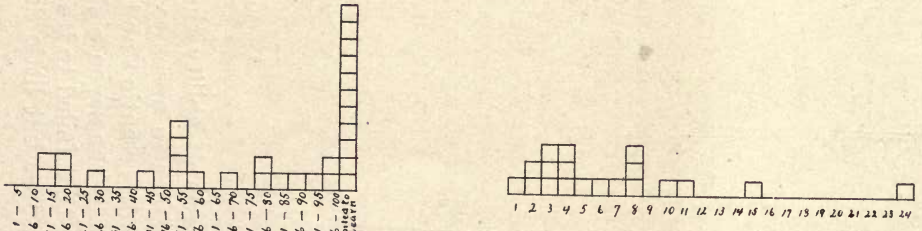
tion was, on the average, 44.945 seconds; of the eighth generation, 13.825 seconds. All the seventh generation had relearned at the end of the twenty-fourth day; but all the eighth generation had relearned at the end of the eighth day. The seventh generation required, on the average, 8.00 days to relearn; the eighth generation but 5.00 days.



In these criteria of ability the seventh generation excelled in learning, the eighth in absolute retention and relearning. But, again, in absolute retention and relearning, we are dealing with selected groups as the seven eighth generation and four seventh generation rats that failed to learn were not used. There seems, on the whole, to be but little difference between the abilities of



Normal.



Inbred.

Plate IX.

The Inclined Plane

Distribution of Learning and Relearning

the seventh and eighth generations except that the former excelled in learning.

The body length and body weight of the seventh generation average greater than those of the eighth. The relative brain weight (in reference to body length) of the seventh generation is 5.20% less than that of the eighth. The relative brain weight (in reference to body weight) of the seventh generation is 13.93% less than that of the eighth. The actual brain weight of the seventh generation, however, is greater than that of the eighth. The percentage of water in brain and cord of the seventh generation is greater than in the eighth.

TABLE VI

THE INCLINED PLANE

DAILY LEARNING AVERAGES OF SEVENTH AND EIGHTH GENERATION INBRED RATS

(Time in seconds)

	Day 1	Day 2	Day 3	Day 4	Day 5
Seventh Average.....	5656.546	1463.707	123.213	53.583	17.159
Eighth Average.....	3689.716	974.245	210.781	58.369	28.693
	Day 6	Day 7	Day 8	Day 9	Day 10
Seventh Average.....	11.142	11.373	8.160	8.845	5.853
Eighth Average.....	62.613	13.471	13.961	12.657	10.419
	Day 11	Day 12	Day 13	Day 14	Day 15
Seventh Average.....	10.855	5.459	6.037	5.197	6.367
Eighth Average.....	7.911	10.294	11.213	9.178	12.805
	Day 16	Day 17	Day 18	Day 19	Day 20
Seventh Average.....	5.821	4.732	6.714	6.351	5.310
Eighth Average.....	11.599	11.407	8.013	12.030	8.124
	Day 21	Day 22	Day 23	Day 24	Day 25
Seventh Average.....	5.592	5.538	4.934	6.116	5.481
Eighth Average.....	8.245	7.187	8.969	6.801	9.177
	Day 26	Day 27	Day 28	Day 29	Day 30
Seventh Average.....	6.204	5.636	5.809	3.965	4.875
Eighth Average.....	5.143	6.889	7.445	7.063	50.729
	Day 31	Day 32	Day 33	Day 34	Day 35
Seventh Average.....	4.085	5.884	4.733	4.195	4.526
Eighth Average.....	10.795	7.529	8.099	9.355	9.388
	Day 36	Day 37	Day 38	Day 39	Day 40
Seventh Average.....	4.481	3.921	4.192	4.467	4.561
Eighth Average.....	9.433	6.747	7.186	6.491	6.017
	Day 41	Day 42	Day 43	Day 44	Day 45
Seventh Average.....	4.667	4.462	4.396	4.338	3.734
Eighth Average.....	5.130	5.413	5.791	5.187	5.373

TABLE VI—(Continued

	Day 46	Day 47	Day 48	Day 49	Day 50
Seventh Average	3.435	4.121	3.636	3.867	4.277
Eighth Average	4.587	6.031	4.027	6.116	5.933
	Day 51	Day 52	Day 53	Day 54	Day 55
Seventh Average	4.289	3.591	4.219	4.969	3.627
Eighth Average	5.235	5.226	5.168	5.044	4.755
	Day 56	Day 57	Day 58	Day 59	Day 60
Seventh Average	3.251	3.584	4.406	7.917	4.325
Eighth Average	4.893	4.247	7.412	4.553	5.581
	Day 61	Day 62	Day 63	Day 64	Day 65
Seventh Average	4.295	5.753	4.731	3.006	3.331
Eighth Average	4.049	4.299	4.143	3.627	4.151
	Day 66	Day 67	Day 68	Day 69	Day 70
Seventh Average	3.331	3.571	4.317	5.175	4.565
Eighth Average	4.988	4.339	7.398	4.437	3.954
	Day 71	Day 72	Day 73	Day 74	Day 75
Seventh Average	4.415	3.717	3.388	3.233	3.620
Eighth Average	4.350	4.021	3.533	4.193	3.678
	Day 76	Day 77	Day 78	Day 79	Day 80
Seventh Average	3.760	3.601	4.130	4.705	3.623
Eighth Average	3.691	3.736	3.162	3.381	3.673
	Day 81	Day 82	Day 83	Day 84	Day 85
Seventh Average	3.319	3.039	3.322	3.135	3.424
Eighth Average	3.398	3.891	3.794	3.509	3.519
	Day 86	Day 87	Day 88	Day 89	Day 90
Seventh Average	3.251	3.037	3.144	3.361	3.837
Eighth Average	4.207	3.739	4.228	3.916	4.503
	Day 91	Day 92	Day 93	Day 94	Day 95
Seventh Average	3.211	3.157	3.273	2.913	2.678
Eighth Average	3.792	3.629	4.975	4.014	4.237
	Day 96	Day 97	Day 98	Day 99	Day 100
Seventh Average	2.725	2.650	3.085	3.201	3.067
Eighth Average	3.273	4.270	4.123	2.763	3.954

	Failed to Learn	Days Required to Learn
Seventh Average	4	59.60+
Eighth Average	7	86.53+

TABLE VIb

THE INCLINED PLANE

AVERAGE ABSOLUTE RETENTION OF SEVENTH AND EIGHTH GENERATION INBRED RATS

	Absolute Retention After 60 Days' Rest
Seventh Average	44.945 seconds
Eighth Average	13.825 seconds

TABLE VIc

THE INCLINED PLANE

DAILY RELEARNING AVERAGES OF SEVENTH AND EIGHTH GENERATION INBRED RATS

(Time in seconds)

	Day 1	Day 2	Day 3	Day 4	Day 5
Seventh Average.....	66.322	9.265	6.322	5.758	6.279
Eighth Average.....	8.058	4.438	4.218	3.443	3.400
	Day 6	Day 7	Day 8	Day 9	Day 10
Seventh Average.....	6.297	4.467	5.879	3.728	3.109
Eighth Average.....	3.633	3.925	2.441	2.441	2.441
	Day 11	Day 12	Day 13	Day 14	Day 15
Seventh Average.....	4.285	2.909	3.055	3.139	3.073
Eighth Average.....	2.441	2.441	2.441	2.441	2.441
	Day 16	Day 17	Day 18	Day 19	Day 20
Seventh Average.....	2.733	2.721	2.709	2.945	2.848
Eighth Average.....	2.441	2.441	2.441	2.441	2.441
	Day 21	Day 22	Day 23	Day 24	Day 25 to 50
Seventh Average.....	2.727	2.939	2.709	2.636	2.636
Eighth Average.....	2.441	2.441	2.441	2.441	2.441

	Failed to Relearn	Days Required to Relearn
Seventh Average.....	0	8.00
Eighth Average.....	0	5.00

TABLE VId

THE INCLINED PLANE

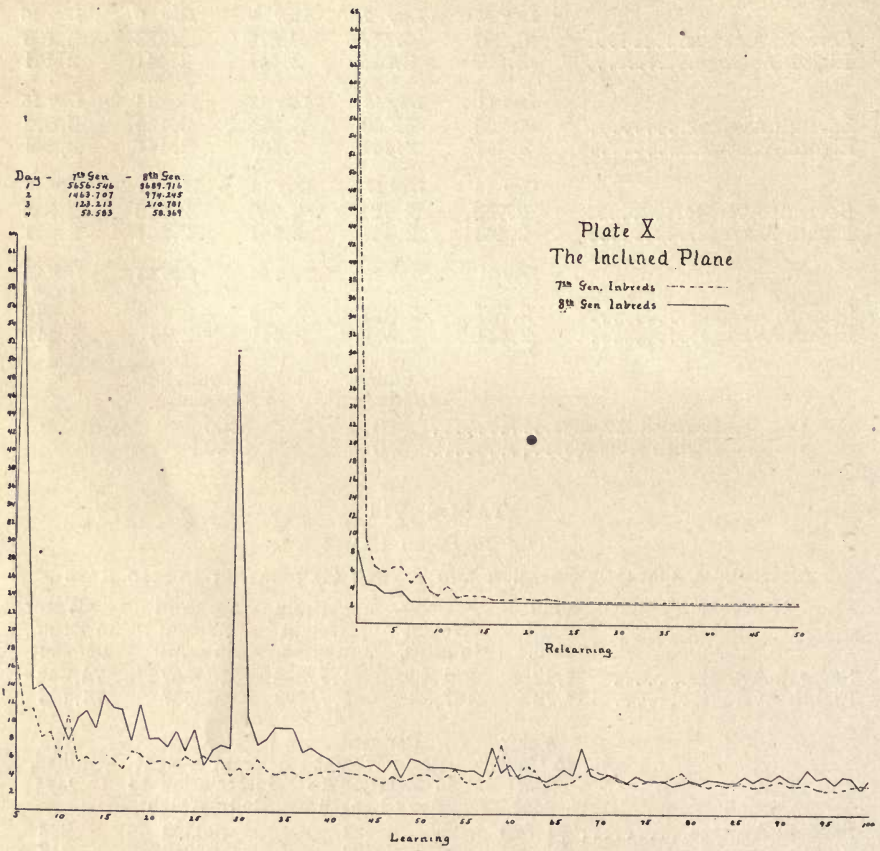
ANATOMICAL DATA OF SEVENTH AND EIGHTH GENERATION INBRED RATS

	Body Length in mm.	Body Weight in grms.	Brain Weight in grms.	Cord Weight in grms.	Water in Brain, per cent
Seventh Average.....	202.13	201.44	1.72868	.54607	78.542
Eighth Average.....	189.73	167.33	1.71299	.52967	78.185

	Water in Cord, per cent	Per cent Brain Weight in Relation to Body Length	Per cent Brain Weight in Relation to Body Weight	Age killed, Days
Seventh Average.....	71.569	.85622	.90560	223
Eighth Average.....	71.304	.90323	1.05218	217

In Plate X is shown the curve of learning (below) and of relearning (above) of the seventh generation of inbred rats compared with those of the eighth. These curves are constructed from figures given in Table VI. The curve of the seventh generation rats is indicated by the broken line, that of the eighth generation

by the solid line. The ordinates show the average daily time in seconds for each group, and the abscissae the number of the day in which such time was made. Both curves in the learning series are very irregular, especially so that of the eighth generation rats. Although irregular, the seventh generation curve lies



below that of the eighth except in a few instances. From the first, the relearning curves are similar and very regular, although the eighth generation curve remains below that of the seventh all the way. But both of the relearning groups are selected, four of the seventh and seven of the eighth generation having failed to learn the inclined plane.

VI. SUMMARY AND CONCLUSIONS

During a series of experiments in inbreeding conducted at the Wistar Institute of Anatomy and Biology, a strain of albino rats was produced, the relative brain weights of which averaged considerably less than normal. Whether such a condition was induced by the inbreeding or was due to environmental factors can not be stated with certitude at the present time. Inbreeding, *per se*, may not be, necessarily, productive of deleterious results if the parent stock be perfect in every respect; but it is impossible, by any means at our command, to determine physical perfection in any organism. An environmental factor that may have had some bearing on the lesser relative brain weight condition of the two strains of rats (A and B) used in these experiments was, that after four generations of inbreeding the rats did not appear to thrive; at that time a change of diet took place, after which they seemed in better health.

The writer spent two years in the task of attempting to ascertain whether or not the less than normal relative brain weight was accompanied by a corresponding lesser ability to form habits, and, also, if such ability was progressively less from one generation of inbreeding to the next. There were used in all the experiments one hundred and twenty-four rats: sixty-two inbreds and sixty-two normal controls. An equal number of males and females from inbreds and controls were used in each experiment. Plate XI shows the distribution of relative brain weights (with reference to body length) of the inbred rats and of the normal control series. The inbred distribution is represented by the lower curve, that of the normal control by the upper. The greatest frequency in the inbred curve occurs at .88%; in the normal curve at .92%. The entire inbred distribution is from .70% to .95%; that of the normal controls from .84% to 1.05%. The average relative brain weight (with reference to body length) of the sixty-two normal control rats is .93351%; that of the inbreds is .87335%, or 6.44% less than that of the normal control.

In order to compare the ability of the rats of the lesser brain weight strain (inbred rats) with a normal control series, three experiments were used:

1. The Maze, in which all the rats used were given five trials daily until they had learned perfectly, or, failing to learn, had

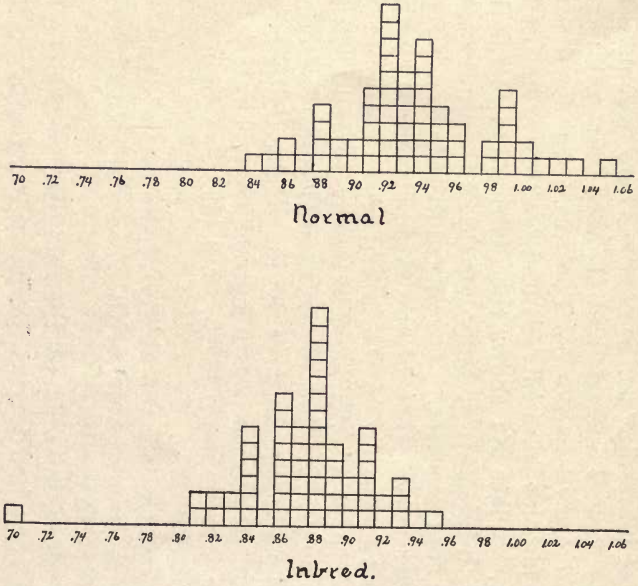


Plate XI

Distribution of Relative Brain Weights
(with reference to body length)

62 Inbred Rats.
62 Normal Rats.

worked one hundred days (500 trials). At the expiration of sixty days after perfect learning the rats, except those failing to learn, were tested for absolute retention and relearning until relearning was perfect, or, failing relearning, for fifty days (250 trials).

2. The Preliminary Inclined Plane, in which all the rats used were given five trials daily for twenty days (100 trials); at the expiration of sixty days after this period they were all tested for absolute retention and relearning for a period of five days (25 trials).

3. The Inclined Plane, in which all the rats used were given three trials daily until they had learned perfectly, or, failing to learn, had worked one hundred days (300 trials). At the expiration of sixty days after perfect learning the rats, except those failing to learn, were tested for absolute retention and relearning until relearning was perfect.

In all these experiments the strain of rats of lesser relative brain weight (the inbreds) learned less well, on the average, than the normal control series. In the maze and inclined plane experiments the average number of days required to learn and relearn, and the time of absolute retention, was far greater in the case of the inbred rats than in that of the normal control series. In the maze experiment, two inbreds and one control failed to learn; two inbreds failed to relearn. In the inclined plane experiment, eleven inbreds and two controls failed to learn.

The similarity of behavior of the control rats containing blood of the B strain to that of the inbreds suggests the importance of crossing a strain of inbred rats of lesser brain weight with normal rats, and carrying out a series of tests such as have been presented in this paper, with two controls: one of normal rats, and one of rats of lesser relative brain weight.

In the maze experiment the inbred rats of the seventh generation did a little less well than those of the sixth. In the inclined plane experiment the rats of the eighth generation did a little less well than those of the seventh. It would seem (although lessening of relative brain weight had ceased after the fourth generation of inbreds) that the ability to form habits lessened progressively with successive generations of inbreeding.

The writer had intended to attempt a correlation (if any existed) between the number of days required to learn a habit

and the number of days required to relearn after sixty days' rest. But most of the rats relearned very quickly without reference to the number of days required for learning; in numbers, too, the rats were too few for such mathematical consideration. An investigation along such a line should consist of but one relatively simple experiment; several hundred rats of one sex only should be used; and the period of time between the completion of learning and the beginning of relearning should be lengthened to, at the least, ninety days.

The general results of the experiments here set forth may be summed up as follows: On the average, the strain of inbred rats having a less than normal relative brain weight did less well in learning to form habits than did the normal control series.

From these results the following may be formulated: *A less than normal brain weight in a strain of rats is accompanied by a less than normal ability to form habits.*

ADDENDUM

The tables of individual daily averages, from which the tables of group averages contained in this monograph are derived, are so extensive as to preclude publication. If, however, any may be interested in them, the original copy is deposited with the library of the Wistar Institute of Anatomy and Biology, Philadelphia, Pennsylvania; and a duplicate is in the private library of the author.

VITA

Gardner Cheney Basset was born in Boston, Massachusetts, June 17, 1873. He received his elementary and secondary education in the public schools of Boston and Newton, Massachusetts. From the year 1890 to 1908 he was in the wholesale shoe business, serving successively as receiving clerk, buyer, traveling salesman and superintendent. He entered the Collegiate Department of Clark University in 1908; was assistant in Biology during the year 1909-1910; assistant in Psychology during the year 1910-1911; and in 1911 he received the degree of Bachelor of Arts with highest honor. He spent the summer of 1910 at Cornell University in the study of Experimental Psychology. In October, 1911, he entered the Johns Hopkins University, and was appointed University Fellow in that institution for the year 1912-1913.

While at the Johns Hopkins University Mr. Basset studied Psychology under Drs. Watson and Dunlap, Psychiatry under Dr. Meyer, Genetics under Dr. Jennings, and Neurology under Drs. Mall and Sabin.