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Stock colony studies III, The reproductive and lactating behavior of the female albino rat, Wistar stock, strain A

Mary Louise Greenwood
Iowa State College

STOCK COLONY STUDIES III. THE REPRODUCTIVE AND LACTATING BEHAVIOR OF THE FEMALE ALBINO RAT, WISTAR STOCK, STRAIN A

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Mary Louise Greenwood

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Approved:

Signature was redacted for privacy.

In charge of Major work

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

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INTRODUCTION

Establishment of Standards

The albino rat has contributed extensively to the knowledge of nutrition and is now so universally employed as an experimental animal in research that any statement in regard to its importance in this respect is unnecessary. However, in studying the reaction of experimental animals to the feeding of test diets it is evident that a knowledge of the behavior of normal animals is desirable as a basis for comparison. Any response of the animals to the experimental regime cannot be properly evaluated unless the normal condition of similar animals grown under standard conditions is known. Actually, very few norms have been established by investigators in the field.

Data pertaining to the particular colony from which the experimental animals are derived for use in the investigations offer material of importance for the development of needed norms. Data are required relating to physiological development such as rate of growth, ability to reproduce and rear young, physical condition in adult life, and records of longevity as well as certain physiological and biochemical indexes that are useful in judging physical development and integrity. Environmental conditions, methods of handling and breeding, the strain of the stock, diet, and probably other factors influence the animals.

Since these factors are not the same, and in fact cannot be the same, in all laboratories, the normal condition and behavior of the animals in any one laboratory must be determined before the influence of the diet on any physiological or biochemical measurement can be ascertained. It is known, for instance, that growth rates are not the same in all colonies. Earhart in 1935 charted the rates of growth of rats from colonies at several institutions including the Wistar Institute, Yale University, and the University of California, and found that they varied quite widely. It will become evident in the course of this dissertation that the average reproductive and lactating behavior of groups of normal rats also varies from colony to colony.

The stock colony of the Nutrition Laboratory of the Foods and Nutrition Department of Iowa State College furnishes data admirably suited to the establishment of standards of behavior and development. Since March 28, 1932, the colony has subsisted on a uniform diet. The animals have been kept in an environment maintained as nearly uniform as possible and have been subjected to similar treatment. They are derived from a pair of rats obtained from the Wistar Institute whose genetic history was known for fifty generations. Since then the colony has been propagated by close inbreeding (brother and sister matings).

Homogeneity of the Colony

It is also important to determine whether the stock colony is supplying experimental animals which maintain a reasonable homogeneity over a period of years. Is the observed response of the experimental animals due to the treatment or to changing conditions in the stock colony? It is possible that genetic differences have not been removed by the plan of breeding used in the various laboratories. In this event, changes produced in any measurement used to test the nutritional efficiency of a diet can not safely be ascribed to the dietary adjustment. An accelerated growth throughout more than ten generations (Mendel and Hubbell, 1935) has been reported as a characteristic of the colony belonging to the Connecticut Agricultural Experiment Station. The fertility, number of young born, and percentage of young weaned each showed a marked increase over this same period of time. In this particular instance the changes were attributed to an improvement in the stock ration. Obviously the colony was not a suitable source of test rats for specific experiments in this interval. Even if the genetic homogeneity of a colony is established there may be variation occasioned by changing seasons, the number of the litter, that is, whether first, second, etc., from which test rats are taken, the age of the mother, etc.

Suitable Criteria

It is becoming increasingly evident that gain in weight alone does not furnish sufficient information for the nutritional evaluation of any diet. As early as 1915 McCollum and Davis emphasized the fact that normal rate of growth was not sufficient evidence for judging a ration adequate. In studies on the effect of the addition of various minerals to the diet, female rats, although growing at the normal rate, were unable to produce and rear young. Sherman, Rouse, Allen, and Woods (1921) found that a diet consisting of white bread and milk (in the ratio of four parts to one) sufficed for normal growth but not for reproduction. Sherman and Muhlfeld (1922) noted that increasing the proportion of milk from one-sixth to two-thirds in a diet made up of whole milk powder, ground whole wheat and sodium chloride favorably affected both reproduction and lactation. Not only were a larger number of young born, but a larger percentage of those born were reared than in the first instance. Females matured at an earlier age, as shown by the birth of first litters, and showed a longer reproductive span (Sherman and Campbell, 1924).

Evans and Bishop (1922) discovered a very sensitive mechanism for indicating nutritional well-being in their studies on ovulation rhythm. When certain inadequate diets were fed they found that the number of oestrus cycles occurring in a certain interval were greatly reduced and that the average length of cycle was increased. In some cases ovulation ceased entirely. The abnormal oestrus behavior was sometimes accompanied by normal growth, at other times by subnormal. These authors state, however, "that ovulation in fact, when compared with implantation and placental function is a relatively hardy mechanism and that much if not most sterility must be traced to uterine failure" (p. 319).

However, the sensitiveness of this mechanism has been borne out in other studies. For instance, temperature has been found to affect the length of the oestrus cycle (Lee, 1926). Rats kept at a temperature of 22° C. showed oestrus cycles which averaged 4.8 days in length. These same rats when kept out of doors where the temperature dropped to as low as -15° C. showed cycles averaging 8.6 days in length. Light from ordinary electric light bulbs has also been reported as affecting the ovulation rhythm (Browman, 1937). Continuous light prolonged the period of cornification, this stage sometimes lasting through the whole of the lighting period.

The formulation of records pertaining to reproduction and lactation that may be used as criteria for judging the value of a diet are of special interest to the Nutrition Laboratory since in the extensive meat studies (Wilcox, 1937, and others) which are being conducted at the present time, it is these functions which suffer impairment.

Purpose of the Present Investigation

The present study is the third in a series in which an effort is being made to formulate norms representing the average behavior of the stock colony belonging to the Nutrition Laboratory of the Foods and Nutrition Department at Iowa State College. The first study (Timson, 1932) was an analysis of the growth of rats raised in the colony during the years 1928 to 1931. The second (Earhart, 1935) represented a preliminary analysis of the reproductive performance based on 95 female rats grown in the laboratory in 1934 and 1935.

The present study deals with the reproductive and lactating behavior of some 300 rats observed during the period of time dating from March, 1932 to April, 1938.

The purpose of the present investigation may be briefly summarized as follows:

1. To establish standards for

    a. Reproductive behavior

    b. Lactating behavior

2. To determine the homogeneity of the colony from 1932 to 1938 with respect to reproductive and lactating behavior.

EXPERIMENTAL PROCEDURE

Data

The data used in the establishment of the standards and in the tests for homogeneity were obtained from records kept from March 28, 1932, to April, 1938, in the Nutrition Laboratory of the Foods and Nutrition Department at Iowa State College.

Animals

Stock

The rats from which the data were obtained were of Wistar stock, strain A. They had been inbred by brother and sister matings for fifty generations previous to the time that the stock was secured by the Nutrition Laboratory in 1928. They comprise the sixth to the twenty-first generations inclusive, of the rats of the stock colony raised in the Nutrition Laboratory; thus they are rats representing the animals produced from the fifty-sixth to the seventy-first generations of the original strain of inbred rats.

Rats from second litters only were kept for breeding purposes.

Diet

The basal diet fed throughout the entire time is what is known as Steenbock V in the Nutrition Laboratory and is a modification of the diet recommended by Steenbock in 1923.

The composition of the Steenbock V basal ration is as follows:

	Per cent
Corn meal, yellow	64.0
Linseed meal	16.0
Alfalfa, ground	2.0
Casein, crude	5.0
Sodium chloride	0.5
Calcium carbonate	0.5
Yeast, bakers'	1.5
Yeast, irradiated	0.5
Wheat germ	10.0
Total	100.0

Supplements to the basal diet consisted of:

1. Klim, liquified and fortified
2. Lettuce
3. Beef, raw, ground round

The Klim was bought in sufficient quantities each winter to last throughout the year. It was liquified by mixing 130 grams of Klim and one quart of distilled water in a Hobart mixer at third speed for five minutes. The liquified Klim was then fortified as follows:

Klim, liquified	1 qt.
Cod liver oil	1 tsp.
Trace elements, solution	2 cc.

The solution of trace elements was made up as follows:

Water	100 cc.
Potassium iodide	0.080 gm.
Manganese sulphate	0.316 gm.
Potassium aluminum sulphate	0.098 gm.
Copper sulphate	0.407 gm.

The basal ration was fed ad libitum.

The Klim solution was fed at the rate of

1. 50 cc. per day to each female with a litter
2. 25 cc. per day to each pregnant female
3. 12.5 cc. per day to each resting female
4. 12.5 cc. per day to each male

The lettuce was fed in the amount of 10 gm. to each rat three times a week.

Beginning January 6, 1933, 5 gm. of meat were fed every day except Sunday. After April 18, 1933, this same amount was fed three times per week. It was measured from a spoon which had been calibrated to contain 5 gm.

Distilled water was supplied ad libitum.

The various supplements were added to the basal diet in an effort to make the ration more effective for the support of reproduction. During the fall of 1932 the mother rats were failing to raise their young. The young were born fully matured, but were undersized, dry, and scaly. In many cases they were eaten by the mother within a few days after they were born. The solution of trace elements and the meat were added in the hope that these difficulties would be prevented.

Fresh milk instead of Klim and cod liver oil were used in the diet until October 1, 1932, when it was found that the young could be depleted of their stores of vitamin A in about two weeks, resulting in experimental animals which were too small for use in vitamin A assays. The use of dried winter milk and the addition of cod liver oil, as records in the laboratory show, appreciably reduced the variability in the quantity of vitamin A that occurred in the stock diet when fresh milk was used.

Care

Until October 1, 1934, pairs of breeding rats were kept in large, wire-mesh cages 12 x 18 inches, with raised screen bottoms. When the female rats became pregnant they were placed in round wire-mesh cages nine inches in diameter and were kept there until the young were weaned, when they were returned to the breeding cages. After the above date, each female rat was kept in the nine-inch cage, being placed with the male only during oestrus. Bedding in the form of shredded tissue paper was supplied from the time that the young were born until they were two weeks old. At four days of age all litters containing more than eight young were reduced to this number.

The basal diet was placed in wide-mouth glass jars which were wired to the side of the cage. The water containers were either open glass jars or bubble bottles. The liquified Klim with the added supplements was placed in a small china cup.

The dishes were sterilized three times a week, the cages once.

The temperature was maintained as nearly constant as possible. During the greater portion of the year it usually remained at from 76° to 80° F. During the hot summer months, however, it occasionally rose as high as 90° to 94° F.

Vaginal Smears

Beginning on October 1, 1934, vaginal smears were taken daily after the opening of the vaginal orifice. The technique employed was that of Long and Evans (1922). The glass rods used were two millimeters in diameter and about 5 inches long, the tips being fire polished. The smear was examined in a drop of distilled water under the low power (10x) lens of a microscope.

The stages of the oestrus cycle (according to Long and Evans, 1922) were characterized as follows:

	Usual length in hours
1. Epithelial cells only - proestrus	12
2. Epithelial and cornified cells - oestrus)	27
3. Cornified cells)	

4. Cornified cells and leucocytes - meteostrus	6
5. Leucocytes, epithelial and cornified cells - dioestrus	48 or the remainder of the cycle

The time of implantation was determined by noting the day when red blood cells occurred in the smear, free blood in the vagina, or both.

Daily vaginal smears were taken on a group of unmated rats in order to study the oestrual behavior uninterrupted by pregnancy.

Mating

From March 28, 1932, to October 1, 1934, the females were first mated at weaning, that is at 28 days of age. After the latter date they were mated at sexual maturity, that is at the second oestrus (stage one or two) following the opening of the vaginal orifice. Copulation usually takes place in stage 2, sometimes late in stage 1 or early in stage 3 (Long and Evans, 1922).

A mating was considered positive when sperm were present in the smear, when a vaginal plug was found, or when both conditions prevailed. After a positive mating the male was removed from the cage. In case of failure to mate, the female was again isolated upon the appearance of stage four or five of the cycle. The female was remated at the first oestrus following the weaning of the litter at 28 days of age, or following the death of the litter, or at the next oestrus in the event that pregnancy did not ensue.

Certain of the females were bred for their entire reproductive spans; others only until they had borne two or three litters.

RESULTS AND DISCUSSION

Reproductive Behavior

In respect to size and quality of litters produced

The number of young born and reared and the weights of these young at critical periods from birth to weaning are important measures of the reproductive ability of a female rat.

Number of young rats born. On examination of the 1154 litters born

Table 1. Number of young rats born segregated as to generation

Generation	Number of litters	Number of young born: Total	Number of young born: Mean per litter
6	6	37	6.2
7	97	625	6.4
8	60	408	6.8
9	78	550	7.1
10	226	1806	8.0
11	29	236	8.1
12	70	600	8.6
13	76	684	9.0
14	67	589	8.8
15	115	951	8.3
16	78	683	8.8
17	66	539	8.2
18	44	405	9.2
19	84	801	9.5
20	56	506	9.0
21	2	23	11.5
Total	1154	9443	8.2

throughout the period of this study, it was found that the average number of young born per litter was 8.2 (table 1). To determine whether there might be variation occasioned by changing seasons, generations, or litter series* it was necessary to proceed in a cautious manner since data of this sort cannot be obtained in a regular pattern that lends itself well to some of the better known methods of analysis. The data were first set down according to generation as in table 1. From inspection of this table it can be seen that there was a tendency for the mean number of young born per litter to be lower in the early and somewhat higher in the late generations, the intermediate figures remaining more nearly constant. Consequently, the 10th to the 17th generations inclusive were selected for study.

It is obvious from table 2 that differences in the mean number of

Table 2. Number of young rats born segregated as to litter series

Litter series*	Number of litters	Number of young born: Total	Number of young born: Mean per litter
1	326	2667	8.2
2	316	2918	9.2
3	196	1623	8.3
4	138	1095	7.9
5	89	620	7.0
6	53	334	6.3
7	22	115	5.2
8	10	51	5.1
9	4	20	5.0
Total	1154	9443	8.2

*Litter series refers to the position of the litter borne by each female rat, i.e., whether first, second, third, or etc.

Table 3. Number of young born, generations 10-17, inclusive, segregated as to litter series and to month

Litter series	Month	Number of litters	Number of young born: Total	Number of young born: Mean per litter
1	1	11	95	8.6
	2	8	65	8.1
	3	20	175	8.8
	4	11	98	8.9
	5	15	117	7.8
	6	16	134	8.4
	7	8	57	7.1
	8	16	133	8.3
	9	20	133	6.6
	10	23	200	8.7
	11	31	245	7.9
	12	17	149	8.8
Total		196	1601	8.2
2	1	35	336	9.6
	2	10	91	9.1
	3	8	75	9.4
	4	8	72	9.0
	5	21	210	10.0
	6	11	98	8.9
	7	15	138	9.2
	8	14	109	7.8
	9	4	28	7.0
	10	24	227	9.5
	11	18	164	9.1
	12	25	250	10.0
Total		193	1798	9.3
3	1	18	149	8.3
	2	18	163	9.1
	3	30	261	8.7
	4	7	62	8.9
	5	8	65	8.1
	6	3	35	11.7
	7	1	11	11.0
	8	6	47	7.8
	9	10	73	7.3
	10	10	76	7.6
	11	3	16	5.3
	12	13	126	9.7
Total		127	1084	8.5

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Table 3 (continued)

4	1	3	20	6.6
	2	7	46	6.6
	3	15	110	7.3
	4	24	205	8.5
	5	20	188	9.4
	6	7	60	8.6
	7	8	64	8.0
	8	2	17	8.5
	9	1	10	10.0
	10	4	30	7.5
	11	4	31	7.8
	12	5	45	9.0
Total		100	826	
5	1	1	6	6.0
	2	2	14	7.0
	3	5	44	8.8
	4	3	18	6.0
	5	18	138	7.7
	6	14	103	7.4
	7	6	47	7.8
	8	5	30	6.0
	9	6	40	6.7
	12	1	9	9.0
Total		61	449	7.4
6	2	1	12	12.0
	4	1	9	9.0
	5	4	30	7.5
	6	4	32	8.0
	7	12	77	6.4
	8	5	27	5.4
	9	5	46	9.2
	10	2	9	4.5
Total		34	242	7.1
1, 2, 3, & 4	1	67	600	9.0
	2	43	365	8.5
	3	73	621	8.5
	4	50	437	8.7
	5	64	580	9.1
	6	37	327	8.8
	7	32	270	8.4

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Table 3 (continued)

1, 2,	8	38	306	8.1
3, & 4	9	35	244	7.0
cont.	10	61	533	8.7
	11	56	456	8.1
	12	60	570	9.5
Total		616	5309	8.6
Grand Total		711	6000	8.4

Table 4. The number of rats born in the seventh, eighth, and ninth months contrasted with those born during the remainder of the year

Litter series	Monthly intervals	Number of litters	Number of young born: Total	Number of young born: Mean per litter
1	10-6	152	1278	8.4
	7-9	44	323	7.3
	Difference			1.1
2	10-6	160	1523	9.5
	7-9	33	275	8.3
	Difference			1.2
3	10-6	110	953	8.7
	7-9	17	131	7.7
	Difference			1.0
4	10-6	89	735	8.3
	7-9	11	91	8.3
	Difference			0.0
5	10-6	44	332	7.5
	7-9	17	117	6.9
	Difference			0.6
6	10-6	12	92	7.7
	7-9	22	150	6.8
	Difference			0.9

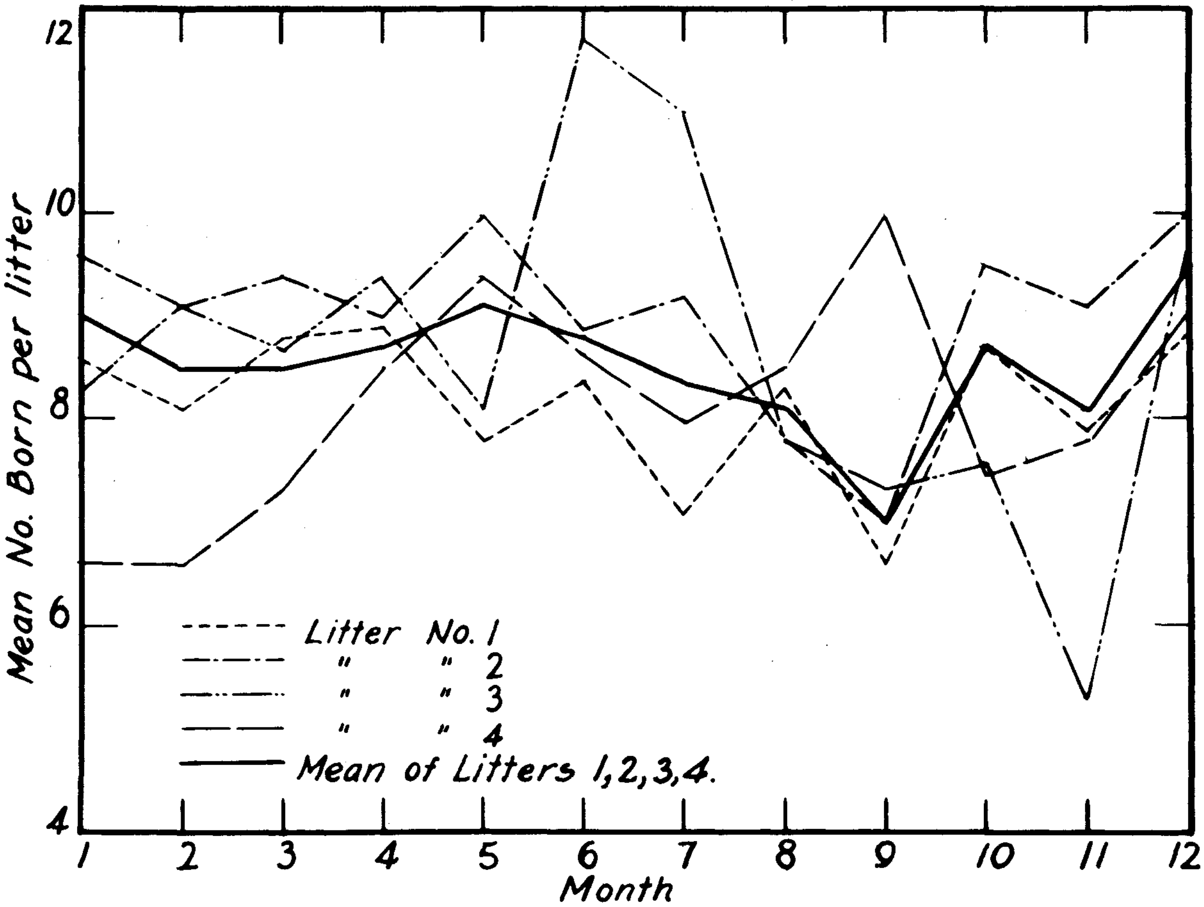

Fig. 1 Mean number of young born per litter, generations 10-17, segregated as to litter series and to month.

No. of Litters for — line

1	2	3	4	5	6	7	8	9	10	11	12
67	43	73	50	64	37	32	38	35	61	56	60

young born per litter existed in the litter series; hence, in order to determine whether seasonal variation existed, the data from generations 10 to 17 were set out by litter series and by month as in table 3. Figure 1 presents the same data graphically. No marked seasonal variation is noted in the data. However, figure 1 indicates a downward trend and greater irregularity during the summer and early fall. If an interval of three months be chosen as representing a season, it is found that the mean number of young born per litter from the 7th to the 9th month inclusive is smaller than the mean obtained for the remaining months of the year (table 4). As great differences could not be detected for any other three months interval. The ninth month, on the average, showed a lower figure than any other single month. It has previously been noted that the laboratory temperatures for the summer months remained much less constant than for the winter months, sometimes reaching temperatures of 90° to 94° F. It seems strange indeed that these increased temperatures could in any way affect the numbers of young born. A possible explanation might be that either the number of ova produced or the intra-uterine mortality was affected. It is possible also that the viability of the sperm was affected by the high temperatures. A somewhat lower temperature is maintained normally in the scrotum than in the abdominal cavity (Dukes, 1937). If the testicles are confined to the abdominal cavity in adult guinea pigs the seminiferous tubules show marked degeneration with cessation of spermatogenesis. Spermatozoa are again produced if the testicles are allowed to re-enter the scrotum. During the hot weather the temperature of the scrotum may have exceeded the point which is optimal for the production of spermatozoa.

King and Stotsenburg (1915) observed no seasonal variation in the number of young born to the albino rat. They found the average number to be 7.0 in 1089 litters. Again in 1935, in her studies of the gray Norway rat, King found no seasonal variation in the numbers of young born. She reported that the laboratory temperature ranged from a minimum of 55° F. in the winter to a maximum of 90° F. or more in the summer. It is possible, however, that if the data had been treated in a manner similar to that used in the present study, similar facts would have been brought to light.

To observe more critically the variation from generation to generation with the effect of possible seasonal influence ruled out, the data were set out by litter series and by generation with months 7 to 9 excluded (table 5).

Table 5. Number of young born, months 7-9 excluded, segregated as to litter series and to generation

Litter series	Generation	Number of litters	Number of young born: Total	Number of young born: Mean per litter
1	7	6	37	6.2
	8	9	59	6.6
	9	9	49	5.4
	10	41	332	8.1
	11	6	48	8.0
	12	9	77	8.6
	13	19	163	8.6
	14	13	115	8.8
	15	21	172	8.2
	16	37	314	8.5
	17	6	57	9.5
	18	19	162	8.5
	19	10	87	8.7
	20	17	165	9.7
Total		222	1837	8.3
2	6	1	8	8.0
	7	7	53	7.6
	8	11	100	9.1

(Continued on next page)

Table 5 (continued)

2	9	4	26	6.5
	10	46	410	8.9
	11	3	28	9.3
	12	9	91	10.1
	13	19	180	9.5
	14	7	67	9.6
	15	24	245	10.2
	16	31	303	9.8
	17	21	199	9.5
	18	15	155	10.3
	19	20	210	10.5
	20	24	219	9.1
	21	1	11	11.0
Total		243	2305	9.5
3	6	1	6	6.0
	7	13	89	6.8
	8	10	73	7.3
	9	8	67	8.4
	10	43	358	8.3
	11	3	24	8.0
	12	13	122	9.4
	13	15	148	9.9
	14	9	76	8.4
	15	19	170	8.9
	16	1	2	2.0
	17	7	53	7.6
	18	10	88	8.8
	19	9	82	9.1
	20	6	40	6.7
	21	1	12	12.0
Total		168	1410	8.4
4	6	1	6	6.0
	7	13	93	7.2
	8	9	57	6.3
	9	13	98	7.5
	10	38	320	8.4
	11	1	5	5.0
	12	14	115	8.2
	13	6	51	8.5
	14	10	83	8.3
	15	19	154	8.1
	17	1	7	7.0
Total		125	989	7.9

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Table 5 (continued)

5	6	1	7	7.0
	7	12	77	6.4
	8	3	21	7.0
	9	10	57	5.7
	10	21	159	7.6
	11	1	9	9.0
	12	9	67	7.4
	13	1	8	8.0
	14	2	16	8.0
	15	10	73	7.3
Total		70	494	7.1
6	6	1	3	3.0
	7	10	41	4.1
	8	2	9	4.5
	9	3	15	5.0
	10	3	8	2.7
	11	1	12	12.0
	12	4	41	10.2
	14	1	5	5.0
	15	3	26	8.7
Total		28	160	5.7
1, 2, & 3	6	2	14	7.0
	7	26	179	6.9
	8	30	232	7.7
	9	21	142	6.8
	10	130	1100	8.5
	11	12	100	8.3
	12	31	290	9.4
	13	53	491	9.3
	14	29	258	8.9
	15	64	587	9.2
	16	69	619	9.0
	17	34	309	9.1
	18	44	405	9.2
	19	39	379	9.7
	20	47	424	9.0
	21	2	23	11.5
Total		633	5552	8.8
Grand Total		856	7195	8.4

The first six litters only were included since the data for the remaining litters were too meager to warrant an analysis. Considerable heterogeneity is observed in the mean number born per litter even in these litters, due partly to the fact that the data were rather poorly distributed throughout the groups. However, it can be seen (figure 2) that smaller litters were

Table 6. Number of young born, months 7-9 excluded, generations grouped within each litter of the series

Litter series	Generation	Number of litters	Number of young born		
			Total	Mean per litter	Increase in mean %
1	7-9	24	145	6.0	-
	10-13	75	620	8.3	38.3
	14-17	77	658	8.5	2.4
	18-20	46	414	9.0	5.9
Total		222	1837	8.3	-
2	6-9	23	187	8.1	-
	10-13	77	709	9.2	13.6
	14-17	83	814	9.8	6.5
	18-21	60	595	9.9	1.0
Total		243	2305	9.5	-
3	6-9	32	235	7.3	-
	10-13	74	652	8.8	20.5
	14-17	36	301	8.4	-4.5
	18-21	26	222	8.5	1.2
Total		168	1410	8.4	-
4	6-9	36	254	7.1	-
	10-13	50	401	8.3	16.9
	14-17	30	244	8.1	-2.4
Total		125	989	7.9	-
5	6-9	26	162	6.2	-
	10-13	32	243	7.6	22.6
	14-15	12	89	7.4	-2.6
Total		70	494	7.1	-
6	6-9	16	68	4.2	-
	10-13	8	61	7.6	81.0
	14-15	4	31	7.8	-
Total		28	160	5.7	

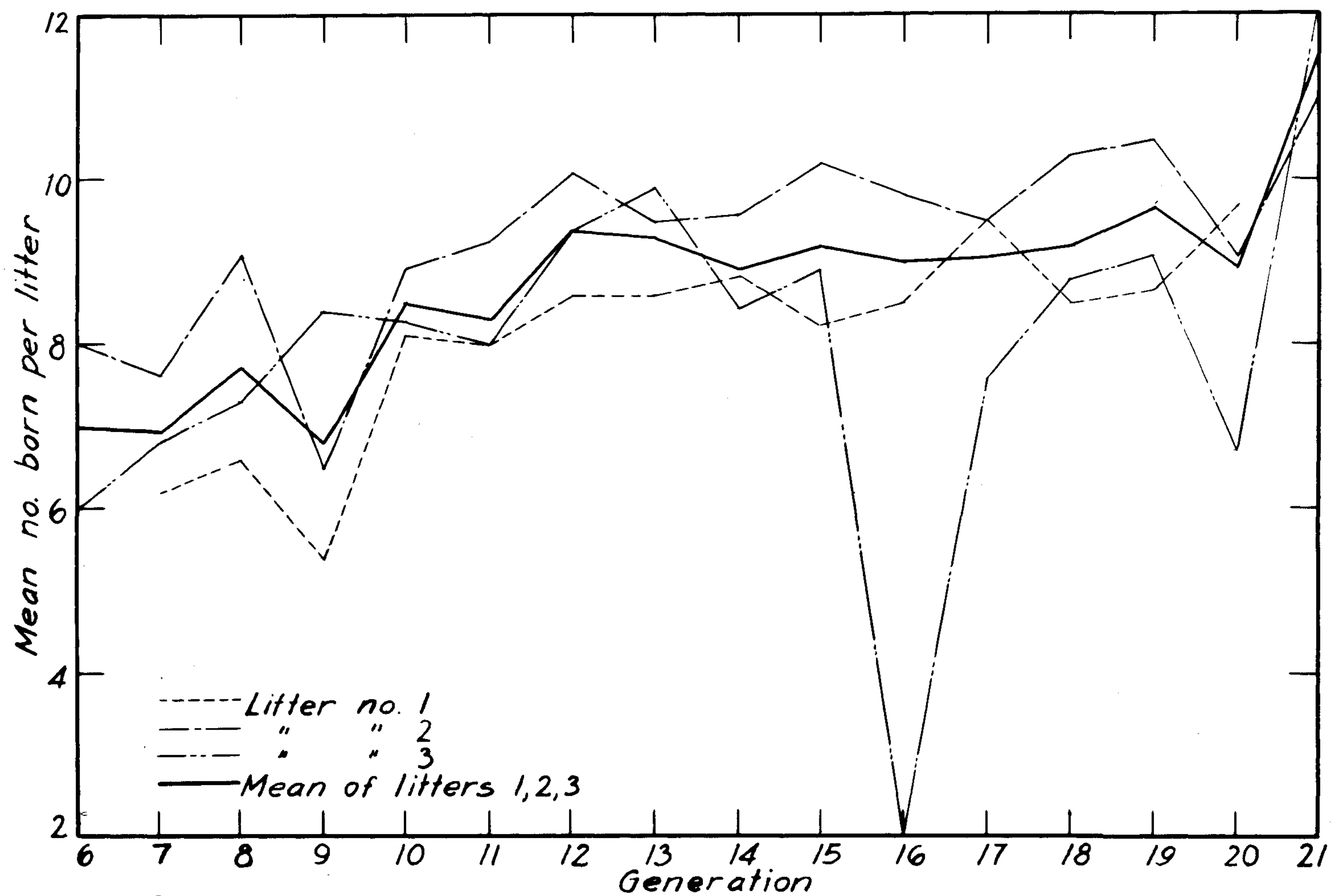

Fig 2. Mean number born per litter, months 7-9 excluded, segregated as to litter series and to generation.

No. of litters for — line

2	26	30	21	130	12	31	53	29	64	69	34	44	39	47	2

born to the earlier generations, the number of young per litter tending to increase with the passing generations. The most abrupt increase was noted at the close of the 9th generation, which fact becomes more apparent if the generations are grouped as in table 6. In each litter of the series, a distinct increase in the mean number born per litter, varying from 14% to 81%, was observed at this point. In the remaining generations as grouped, there was no consistent variation. In the first two litters of the series, the average number of young continued to show an increase through the 20th and 21st generations, while the third litter showed a decrease. The remaining litters cover fewer generations. In months 7-9 the mean number born per litter showed the same general upward trend from the early to the late generations (table 7).

Table 7. Number of young born, months 7-9, generations grouped within each litter of the series

Litter series	Generation	Number of litters	Number of young born: Total	Number of young born: Mean per litter
1	6-9	24	171	7.1
	10-13	10	68	6.8
	14-17	34	255	7.5
	18-20	35	327	9.3
Total		103	821	8.0
2	7-9	22	172	7.8
	10-13	7	55	7.9
	14-17	26	220	8.4
	18-20	18	166	9.2
Total		73	613	8.4
3	7-9	10	71	7.1
	10-13	7	59	8.4
	14-17	10	72	7.2
	19	1	11	11.0
Total		28	213	7.6

There are some inconsistencies which may likely be explained by the scarcity of data.

It has already been noted that the mean number of young born per litter varied with the litter series. From inspection of any of the preceding tables and figures it becomes apparent that litter 2 was the largest of the series. The fact that second litters only were kept for breeding purposes may account for the increase in the number of young born to the succeeding generations. Moore and his coworkers (1932) in the report of their study of small and large litters of rats, state that they increased the size of the litters by selecting breeding stock only from litters of nine or more. The mean number of young born to their rats was 7.07 in 1926 and 1927, 9.26 in 1928 and 1929, and 8.65 in 1930 and 1931.

In a study made at the Connecticut Agricultural Experiment Station, Smith, Anderson, and Hubbell (1938) found very little difference in the average number of young born per litter through seven generations. The average number was 9.0 in the 1597 litters which they observed. As breeding stock they kept fourth litters only, this litter being the last that the females were allowed to produce. The average number born in this litter was 8.9 as against 9.4 for second litters.

The effect of changes in the diet on litter size has been reported in several instances. Slonaker (1939), in his extended study on the effect of different levels of protein on the behavior of the albino rat, found the average size of litter to be as follows:

Diet	Per cent protein	Mean number of young per litter
I	10.3	4.82
II	14.2	4.73
III	18.2	4.43
IV	22.2	4.71
V	23.6	5.48

The largest litter was obtained with the highest percentage of protein; the second largest with the lowest percentage. Mendel and Hubbell (1935) reported an increase in the average number born per litter from 6.3 in 1919 to 9.6 in 1935. They attributed this increase to changes in the ration, more particularly to the greater amount of protein (23% in 1935). They kept as breeding stock, animals from the first, second, or third litters. Russell (1932) was also able to increase the average number born per litter by changes in the diet. With Sherman's Diet B (two-thirds ground whole wheat and one-third powdered whole milk, Sherman and Muhlfeld, 1922) the average number was 6.4. When raw beef was added, the number rose to 8.4; when meat scrap was added, to 8.9. In the present study no dietary changes were made during the period in which the data were collected.

The mean number of young born in the litter series merits further comment. If the data from table 3 are set down by litter series as in table 8, it can be seen that the mean number of young in the second litter showed an increase over the first and the remaining litters showed a gradual decrease from the third through the sixth. A chi-square test (table 9) indicates that these differences are highly significant. A little less than half the value of chi-square is contributed by the second litter which is considerably larger than would be expected; about one-half by the fifth

Table 8. Number of young born, generations 10-17, inclusive, segregated as to litter series

Litter series	Number of litters	Number of young born: Total	Number of young born: Mean per litter
1	196	1601	8.2
2	193	1798	9.3
3	127	1084	8.5
4	100	826	8.3
5	61	449	7.4
6	34	242	7.1
Total	711	6000	8.4

and sixth litters combined which are smaller than would be expected. The remaining litters contribute but little to the value of the chi-square, deviating only slightly from their expected values.

Table 9. Chi-square test for significance of differences in the mean number born in the litter series

Litter series	Observed: Total	Observed: Mean per litter	Expected total	Number of litters	Obs.-Exp.	X^2 $\frac{(\text{Obs.-Exp.})^2}{\text{Exp.}}$	Contribution %
1	1601	8.2	1654.01	196	-53.01	1.70	4.8
2	1798	9.3	1628.69	193	169.31	17.60	49.9
3	1084	8.5	1071.73	127	12.27	0.14	0.4
4	826	8.3	843.88	100	-17.88	0.38	1.1
5	449	7.4	514.77	61	-65.77	8.40	23.8
6	242	7.1	286.92	34	-44.92	7.03	20.0
Total	6000	8.4	6000.00	711	0.00	35.25	100.0

df = 5, P = <1%

King and Stotsenburg (1915) also observed differences in the average number of young born. Their figures were as follows for their stock rats:

Litter series	Mean number of young
1	6.2
2	7.7
3	7.0
4	6.4

The peak was also in the second litter here though the first litter was considerably smaller than the third. King (1915) found a slightly different trend when data were pooled for stock and inbred rats:

Litter series	Mean number of young
1	8.5
2	8.9
3	9.4
4	7.5

She, however, states that this is not the usual pattern, that the first is usually smallest, the second and third the largest, and the fourth a little larger than the first.

If the figures based on three schemes of mating and seven generations in the Smith, Anderson, and Hubbell (1938) data be combined, the following results are obtained:

Mating	Number of litters	Number born Total	Number born Mean
1	382	3185	8.3
2	414	3877	9.4
3	410	3782	9.2
4	391	3492	8.9
Total	1597	14336	9.0

A chi-square test (table 10) indicates that these differences are highly significant. The same general trend was followed as in the data presented herein. However, in the above case 63.9% of the value of the chi-square was contributed by the first litter which was much smaller than expected. The data were not entirely consistent within each generation.

Table 10. Chi-square test for significance of differences in the mean number born in the litter series, Smith, Anderson, and Hubbell's data

Litter series	Observed Total	Observed Mean per litter	Expected total	Number of litters	Obs.-Exp.	X^2 $\frac{(Obs.-Exp.)^2}{Exp.}$	Contribution %
1	3185	8.3	3429.15	382	-244.15	17.38	63.9
2	3877	9.4	3716.41	414	160.59	6.94	
3	3782	9.2	3680.50	410	101.50	2.80	
4	3492	8.9	3509.94	391	-17.94	0.09	
Total	14336	9.0	14336.00	1597	0.00	27.21	

$df = 3, P = < 1\%$

Number and percentage of young reared. In order to determine whether or not the data were homogeneous, the number of young reared were segregated first as to generation (table 11), as had been done in the case of the number of young born. Through the early and late generations the figures for the average number reared were rather irregular but became quite stable for the intermediate generations. In this intermediate group generations 10 to 17 inclusive were again selected for study.

Table 11. Number of young reared segregated as to generation

Generation	Number of litters	Number of young reared	
		Total	Mean per litter
6	6	35	5.8
7	91	343	3.8
8	59	204	3.5
9	61	257	4.2
10	206	1000	4.9
11	28	152	5.4
12	79	409	5.2
13	76	398	5.2
14	68	348	5.1
15	118	611	5.1
16	77	411	5.3
17	66	340	5.2
18	44	230	5.2
19	84	569	6.8
20	56	300	5.3
21	1	8	8.0
Total	1120	5615	5.0

In a study of the number of young reared, the percentage reared would seem to be a necessary figure in addition to the average number reared per litter. Since the females were not allowed to raise more than eight young per litter, the actual number of young born could not be used in figuring this percentage. Instead, the number which was used was either the actual number of young born when this number did not exceed eight per litter, or the uniform figure of eight when the number of young born exceeded eight per litter. This number will be referred to as the number of young in "reduced litters".

Again, there were found to be differences in the litter series (table 12). Litter 2 showed the greatest mean number of young, 7.4, in the reduced litters as of course would be inferred from the high figure in litter 2 for the actual number born (table 8). The <u>mean number</u> reared per litter, 5.9, was also highest for this litter. In <u>percentage</u> reared, litter 5 showed a higher figure than litter 2, 83.2% as against 79.4%. However, a chi-square test indicates that this difference is not significant ($X^2 = 2.73$, df = 1, P = 10%), so that litter 2 may still be considered as one of the highest ranking litters, if not the highest.

Table 12. Number and percentage of young reared, generations 10 to 17, inclusive, segregated as to litter series

Litter series	Number of litters	Number of young in reduced litters: Total	Number of young in reduced litters: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Number of young reared: Per cent
1	190	1309	6.9	878	4.6	67.1
2	193	1425	7.4	1132	5.9	79.4
3	124	862	7.0	614	5.0	71.2
4	98	694	7.1	502	5.1	72.3
5	62	398	6.4	331	5.3	83.2
6	34	207	6.1	162	4.8	78.3
7	12	64	5.3	40	3.3	62.5
8	4	22	5.5	6	1.5	27.3
9	1	4	4.0	4	4.0	100.0
Total	718	4985	6.9	3669	5.1	73.6

In litters 1, 3, 4, 5, and 6, a chi-square test indicates that the differences for the percentage reared were highly significant ($X^2 = 44.18$, df = 4, P = <1%). Litter 1 showed the smallest percentage, litters 3 and 4 were almost identical, and litters 5 and 6 showed the highest values.

In summary form, the Smith, Anderson, and Hubbell (1938) data (table 13) present a somewhat different picture for the mean number of young reared in different litters. The first litter was the smallest both in mean number and percentage reared, but the second, third, and fourth litters differed little from one another in either of these classifications. Their figures were somewhat higher in every case than in the present study. In the authors' own analysis of their data, however, the trends were not entirely consistent throughout either the seven generations or the four groups.

Table 13. Number and percentage of young reared, the Smith, Anderson, and Hubbell data

Litter series	Number of litters	Number of young in reduced litters: Total	Number of young in reduced litters: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Number of young reared: Per cent
1	382	2748	7.2	2084	5.5	75.8
2	414	3115	7.5	2494	6.0	80.1
3	410	2998	7.3	2469	6.0	82.4
4	391	2777	7.1	2212	5.7	79.7
Total	1597	11638	7.3	9259	5.8	79.6

In order to determine whether there might be any seasonal variation, the data were set out by litter series and by month as in table 14, and illustrated graphically as in figure 3. The monthly percentages varied

Table 14. Number of young in reduced litters, number reared, and percentage reared, generations 10 to 17 inclusive, segregated as to litter series, and to month

Litter series	Month	Number of litters	Number of young in reduced litters: Total	Number of young in reduced litters: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Number of young reared: Per cent
1	1	11	81	7.4	34	3.1	42.0
	2	8	52	6.5	29	3.6	55.8
	3	15	102	6.8	65	4.3	63.7
	4	10	75	7.5	61	6.1	81.3
	5	15	108	7.2	57	3.8	52.8
	6	17	116	6.8	81	4.8	69.8
	7	11	60	5.5	43	3.9	71.7
	8	16	120	7.5	104	6.5	86.7
	9	21	130	6.2	71	3.4	54.6
	10	19	138	7.3	111	5.8	80.4
	11	30	202	6.7	137	4.6	67.8
	12	17	125	7.4	85	5.0	68.0
Total		190	1309	6.9	878	4.6	67.1
2	1	32	229	7.2	164	5.1	71.6
	2	11	81	7.4	54	4.9	66.7
	3	8	62	7.8	59	7.4	95.2
	4	8	57	7.1	44	5.5	77.2
	5	21	164	7.8	144	6.9	87.8
	6	11	82	7.5	74	6.7	90.2
	7	15	115	7.7	97	6.5	84.3
	8	15	98	6.5	82	5.5	83.7
	9	5	35	7.0	29	5.8	82.9
	10	26	197	7.6	147	5.7	74.6
	11	18	130	7.2	93	5.2	71.5
	12	23	175	7.6	145	6.3	82.9
Total		193	1425	7.4	1132	5.9	79.4
3	1	17	119	7.0	92	5.4	77.3
	2	18	129	7.2	104	5.8	80.6
	3	27	188	7.0	140	5.2	74.5
	4	6	42	7.0	37	6.2	88.1
	5	8	53	6.6	36	4.5	67.9
	6	3	24	8.0	16	5.3	66.7
	7	1	8	8.0	8	8.0	100.0
	8	7	46	6.6	29	4.1	63.0
	9	10	63	6.3	40	4.0	63.5
	10	11	74	6.7	42	3.8	56.8
	11	3	16	5.3	6	2.0	37.5
	12	13	100	7.7	64	4.9	64.0
Total		124	862	7.0	614	5.0	71.2

(Continued on next page)

Table 14 (continued)

4	1	3	15	5.0	8	2.7	53.3
	2	7	46	6.6	22	3.1	47.8
	3	13	86	6.6	61	4.7	70.9
	4	23	165	7.2	135	5.9	81.8
	5	20	151	7.6	128	6.4	84.7
	6	7	52	7.4	46	6.6	88.5
	7	9	61	6.8	42	4.7	68.9
	8	2	15	7.5	15	7.5	100.0
	9	1	8	8.0	8	8.0	100.0
	10	4	26	6.5	8	2.0	30.8
	11	4	29	7.2	19	4.8	65.5
	12	5	40	8.0	10	2.0	25.0
Total		98	694	7.1	502	5.1	72.3
1, 2, 3, & 4	1	63	444	7.0	298	4.7	67.1
	2	44	308	7.0	209	4.8	67.9
	3	63	438	7.0	325	5.2	74.2
	4	47	339	7.2	277	5.9	81.7
	5	64	476	7.4	365	5.7	76.7
	6	38	274	7.2	217	5.7	79.2
	7	36	244	6.8	190	5.3	77.9
	8	40	279	7.0	230	5.8	82.4
	9	37	236	6.4	148	4.0	62.7
	10	60	435	7.2	308	5.1	70.8
	11	55	397	6.9	255	4.6	67.6
	12	58	440	7.6	304	5.2	69.1
Total		605	4290	7.1	3126	5.2	72.9

widely. In litter 1 these variations were found to be highly significant (X^2 = 85.75, df = 11, p = <1%), as was also the case in litter 2. The mean line, litters 1 to 4, for percentage reared (figure 3) indicates that a higher percentage of young was reared in the spring and summer months than in the fall and winter months. Hence, the data were grouped by intervals of six months for the first four litters as in table 15. As can be seen, in every litter a higher percentage of young was reared in the summer months, 3 to 8 inclusive, than in the winter months, 9 to

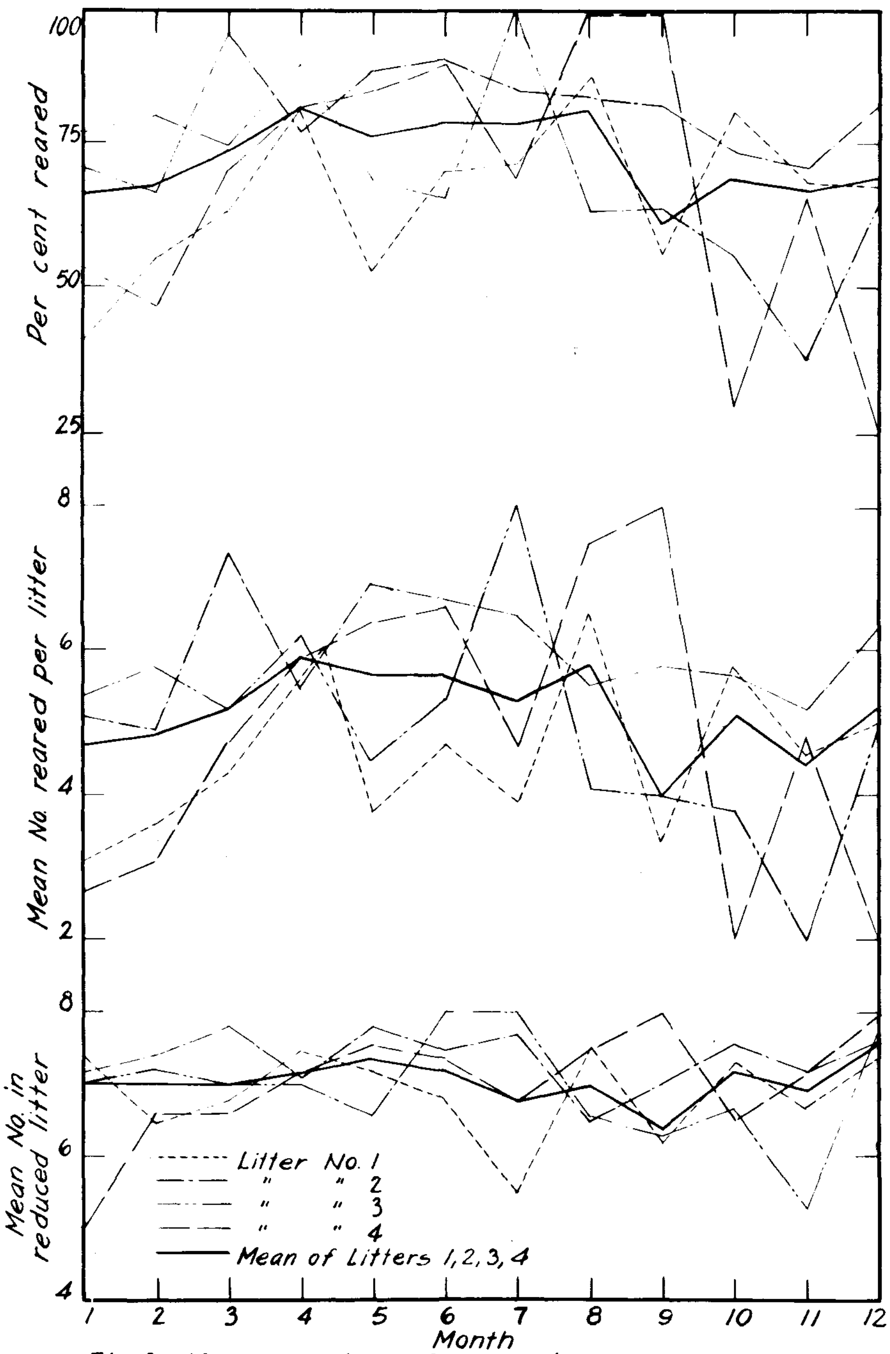

Fig. 3 Mean number of young in reduced litters, mean number reared per litter, and percentage reared, generations 10-17 inclusive, segregated as to litter series and to month.

No. of litters for — Line											
63	44	63	47	64	38	36	40	37	60	55	58

Table 15. Number of young in reduced litters, number reared, and percentage reared, generations 10-17 inclusive, segregated as to litter series and to month, grouped in intervals of six months (from table 14)

Litter series	Month	Number of litters	Number of young in reduced litters: Total	Number of young in reduced litters: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Number of young reared: Per cent
1	9-2	106	728	6.9	467	4.4	64.1
	3-8	84	581	6.9	411	4.9	70.7
Total		190	1309	6.9	878	4.6	67.1
2	9-2	115	847	7.4	632	5.5	74.6
	3-8	78	578	7.4	500	6.4	86.5
Total		193	1425	7.4	1132	5.9	79.4
3	9-2	72	501	7.0	348	4.8	69.5
	3-8	52	361	6.9	266	5.1	73.7
Total		124	862	6.9	614	4.9	71.2
4	9-2	24	164	6.8	75	3.1	45.7
	3-8	74	530	7.2	427	5.8	80.6
Total		98	694	7.1	502	5.1	72.3
1, 2,	9-2	317	2240	7.1	1522	4.8	67.9
3, & 4	3-8	288	2050	7.1	1604	5.6	78.2
Total		605	4290	7.1	3126	5.2	72.9

2 inclusive. Chi-square tests indicated these differences to be highly significant. This higher percentage could scarcely be due to the fact that a smaller number per litter were born during the summer (table 4) as will be shown in the discussion on the relation of the percentage reared to the size of the litter.

To study more carefully any changes which might have taken place in the number or percentage of young reared with the passing generations, the data were arranged by litter series and by generation (table 16 and figure 4). Only the first three litters of the series were examined because of the scarcity of data for the remaining litters.

Table 16. Number of young in reduced litters, number reared, and percentage reared, segregated as to litter series and to generation

Litter series	Generation	Number of litters	Number of young in reduced litters: Total	Number of young in reduced litters: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Number of young reared: Per cent
1	6	1	7	7.0	6	6.0	85.7
	7	18	110	6.1	80	4.4	72.7
	8	14	86	6.1	39	2.8	45.3
	9	13	74	5.7	55	4.2	74.3
	10	41	279	6.8	181	4.4	64.9
	11	6	45	7.5	31	5.2	68.9
	12	17	113	6.6	73	4.3	64.6
	13	18	128	7.1	53	2.9	41.4
	14	19	142	7.5	82	4.3	57.7
	15	25	174	7.0	129	5.2	74.1
	16	34	225	6.6	157	4.6	69.8
	17	30	203	6.8	172	5.7	84.7
	18	19	133	7.0	84	4.4	63.2
	19	37	277	7.5	254	6.9	91.7
	20	25	194	7.8	126	5.0	64.9
Total		317	2190	6.9	1522	4.8	69.5
2	6	1	8	8.0	8	8.0	100.0
	7	14	89	6.4	52	3.7	58.4
	8	12	90	7.5	53	4.4	58.9
	9	9	55	6.1	52	5.8	94.5
	10	43	303	7.0	200	4.7	66.0
	11	6	42	7.0	39	6.5	92.9
	12	16	115	7.2	105	6.6	91.3
	13	19	143	7.5	115	6.1	80.4
	14	19	147	7.7	125	6.6	85.0
	15	25	190	7.6	151	6.0	79.5
	16	37	282	7.6	248	6.7	87.9
	17	28	203	7.2	149	5.3	73.4
	18	15	115	7.7	89	5.9	77.4
	19	37	286	7.7	242	6.5	84.6
	20	25	186	7.4	151	6.0	81.2
	21	1	8	8.0	8	8.0	100.0
Total		307	2262	7.4	1787	5.8	79.0
3	6	1	6	6.0	6	6.0	100.0
	7	14	89	6.4	61	4.4	68.5
	8	10	56	5.6	37	3.7	66.0

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Table 16 (continued)

3	9	10	63	6.3	46	4.6	73.0
cont.	10	36	242	6.7	179	5.0	74.0
	11	6	43	7.2	29	4.8	67.4
	12	15	109	7.3	82	5.5	75.2
	13	17	132	7.8	101	5.9	76.5
	14	17	124	7.3	85	5.0	68.5
	15	20	140	7.0	113	5.6	80.7
	16	6	26	4.3	6	1.0	23.1
	17	7	46	6.6	19	2.7	41.3
	18	10	72	7.2	57	5.7	79.2
	19	10	76	7.6	73	7.3	96.1
	20	6	34	5.7	23	3.8	67.6
Total		185	1258	6.8	917	5.0	72.9
1, 2,	6	3	21	7.0	20	6.7	95.2
& 3	7	46	288	6.3	193	4.2	67.0
	8	36	232	6.4	129	3.6	55.6
	9	32	192	6.0	153	4.8	79.7
	10	120	824	6.9	560	4.7	68.0
	11	18	130	7.2	99	5.5	76.2
	12	48	337	7.0	260	5.4	77.2
	13	54	403	7.5	269	5.0	66.7
	14	55	413	7.5	292	5.3	70.7
	15	70	504	7.2	393	5.6	78.0
	16	77	533	6.9	411	5.3	77.1
	17	65	452	7.0	340	5.2	75.2
	18	44	320	7.3	230	5.2	71.9
	19	84	639	7.6	569	6.8	89.0
	20	56	414	7.4	300	5.4	72.5
	21	1	8	8.0	8	8.0	100.0
Total		809	5710	7.1	4226	5.2	74.0

The mean number reared per litter showed considerable variation, likely due in part to the scarcity of data even in these litters, some of the generations being but poorly represented. However, it can be seen from figure 4 that the general trend is upward from the early to the late generations. Such an increase would be expected since it has already been shown (figure 2) that the mean number of young born per litter, and

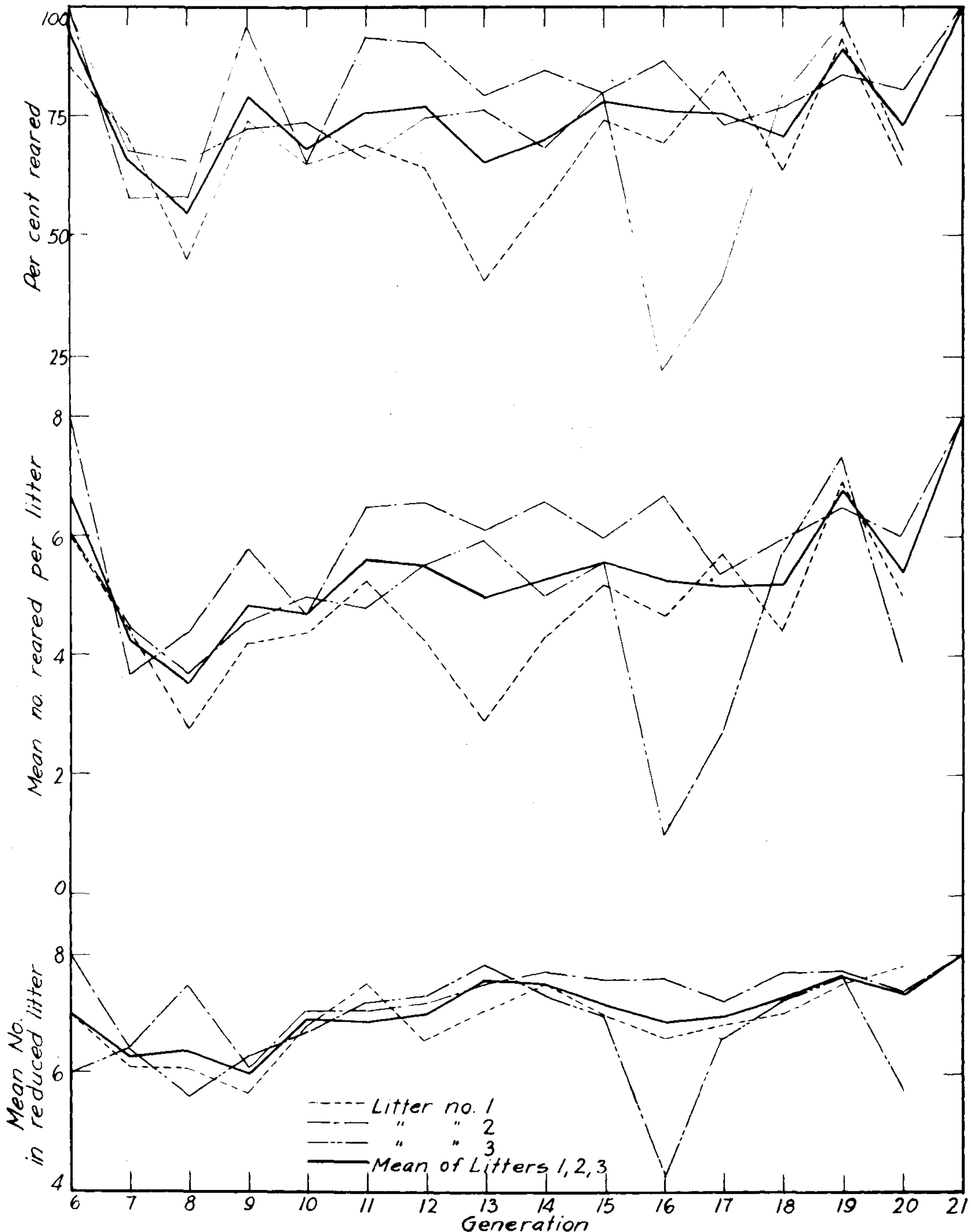

Fig. 4 Mean number of young in reduced litters, mean number reared per litter, and percentage reared, segregated as to litter series and to generation.

No. of litters for —— line

3 46 36 32 120 18 48 54 55 70 77 65 44 84 56 1

consequently the mean number in the reduced litter, increased with the succeeding generations. The upward trend is more clearly seen if the generations are grouped as in table 17, the same groupings being used

Table 17. Number of young in reduced litters, number reared, and percentage reared, segregated as to litter series and to generation, grouped

Litter series	Generation	Number of litters	Number of young in reduced litters		Number of young reared		
			Total	Mean per litter	Total	Mean per litter	Per cent
1	6-9	46	277	6.0	180	3.9	65.0
	10-13	82	565	6.9	338	4.1	59.8
	14-17	108	744	6.9	540	5.0	72.6
	18-20	81	604	7.5	464	5.7	76.8
Total		317	2190	6.9	1522	4.8	69.5
2	6-9	36	242	6.7	162	4.5	66.9
	10-13	84	603	7.2	459	5.5	76.1
	14-17	109	822	7.5	673	6.2	81.9
	18-21	78	595	7.6	490	6.3	82.4
Total		307	2262	7.4	1787	5.8	79.0
3	6-9	35	214	6.1	150	4.3	70.1
	10-13	74	526	7.1	391	5.3	74.3
	14-17	50	336	6.7	223	4.5	66.4
	18-20	26	182	7.0	153	5.9	84.1
Total		185	1258	6.8	917	5.0	72.9
1, 2, & 3	6-9	117	733	6.3	495	4.2	67.5
	10-13	240	1694	7.1	1188	5.0	70.1
	14-17	267	1902	7.1	1436	5.4	75.5
	18-21	185	1381	7.5	1107	6.0	80.2
Total		809	5710	7.1	4226	5.2	74.0

as were used previously in the case of the number of young born. The mean number of young reared increased consistently with the passing generations, in the first two litters of the series and in the summary figures obtained from all three litters. In the third litter there is a slight inconsistency.

The percentage reared is also highly variable though here again there is a general, though less well marked, upward trend (figure 4 and table 17). Chi-square tests indicate the group differences except for litter 2, to be highly significant. Although there are some irregularities, the last group (generation 18-20 or 21) is consistent in showing the greatest percentage reared. The summary figures for litters 1, 2, and 3 increase steadily through the four groups of generations.

Because of the seasonal variation which has been noted in number and percentage reared, the generational differences were reexamined when separated into two groups of six months each (tables 18 and 19, and figures

Table 18. Number of young in reduced litters, number reared, and percentage reared, months 9-2 inclusive, segregated as to litter series and to generation, grouped

Litter series	Generation	Number of litters	Number of young in reduced litters		Number of young reared		
			Total	Mean per litter	Total	Mean per litter	Per cent
1	7-8	16	94	5.9	32	2.0	34.0
	10-13	65	457	7.0	270	4.2	59.1
	14-17	41	271	6.6	197	4.8	72.7
	18-20	39	287	7.4	169	4.3	58.9
Total		161	1109	6.9	668	4.1	60.2
2	6-9	27	193	7.2	120	4.4	62.2
	10,12,13	64	461	7.2	346	5.4	75.1
	14,15,17	51	386	7.6	286	5.6	74.1
	18-21	59	454	7.7	359	6.1	79.1
Total		201	1494	7.4	1111	5.5	74.4

(Continued on next page)

Table 18 (continued)

3	6-9	26	153	5.9	92	3.5	60.1
	10-13	36	253	7.0	182	5.1	71.9
	14-17	36	248	6.9	166	4.6	66.9
	19-20	<u>16</u>	<u>110</u>	6.9	<u>96</u>	6.0	87.3
Total		114	764	6.7	536	4.7	70.2
1, 2,	6-9	69	440	6.4	244	3.5	55.5
& 3	10-13	165	1171	7.1	798	4.8	68.1
	14-17	128	906	7.1	649	5.1	71.7
	18-21	<u>114</u>	<u>851</u>	7.5	<u>624</u>	5.5	73.3
Total		476	3367	7.1	2315	4.9	68.8

5 and 6). With the necessary reduction in the data accompanying this procedure, the figures exhibit even greater variability, some of the generations lacking data entirely in each of the litters of the series. The trends are all but lost. The summary figures, litters 1, 2, and 3, for months 9-2 inclusive still show a regular increase for the successive generations, but this is not altogether true for months 3-8 nor for any of the litters of the series (tables 18 and 20). Chi-square tests still indicate that all of the group differences in percentage reared are highly significant. Lacking a regular pattern, however, such differences lose any reasonable explanation. It is evident that large numbers of rats are necessary to establish definite trends and that small groups may show great irregularities without seeming cause.

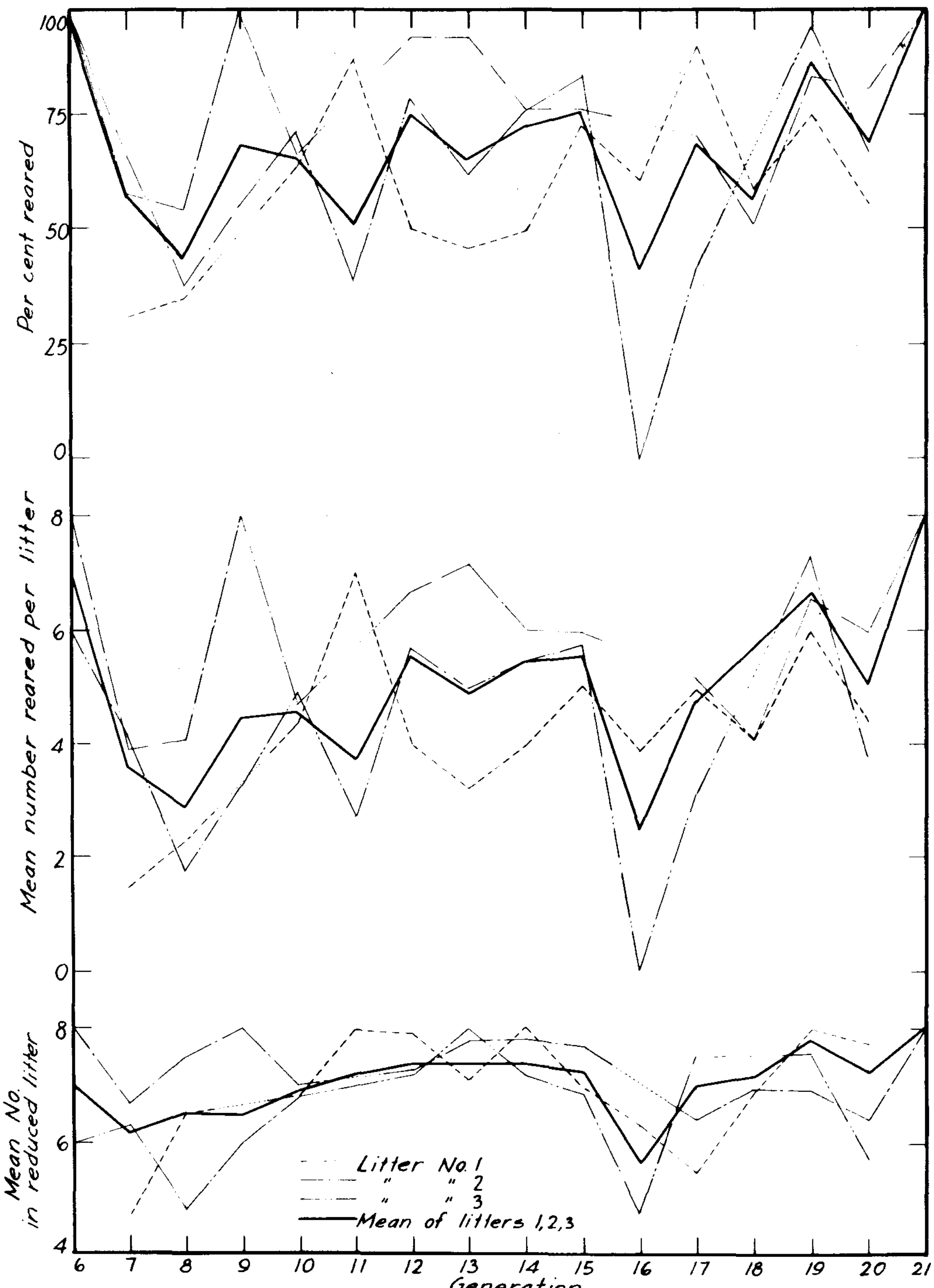

Fig. 5 Mean number of young in reduced litters, mean number reared per litter, and percentage reared, months 9-2 inclusive, segregated as to litter series and to generation.

No. of litters for —— line

2 32 27 8 102 4 34 25 21 58 11 38 24 38 51 1

Table 19. Number of young in reduced litters, number reared, and percentage reared, months 3-8, inclusive, segregated as to litter series and to generation, grouped

Litter series	Generation	Number of litters	Number of young in reduced litters: Total	Number of young in reduced litters: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Per cent
1	6-9	30	183	6.1	148	4.9	80.9
	11-13	17	108	6.4	68	4.0	63.0
	14-17	67	473	7.1	343	5.1	72.5
	18-20	42	317	7.6	295	7.0	93.1
Total		156	1081	6.9	854	5.5	79.0
2	7-9	9	49	5.4	45	5.0	91.8
	11-13	20	142	7.1	113	5.7	79.6
	14-17	58	436	7.5	387	6.7	88.8
	18-19	19	141	7.4	131	6.9	92.9
Total		106	768	7.2	676	6.4	88.0
3	7-9	9	61	6.8	58	6.4	95.1
	10-13	38	273	7.2	209	5.5	76.6
	14-17	14	88	6.3	57	4.1	64.8
	18	10	72	7.2	57	5.7	79.2
Total		71	494	7.0	381	5.4	77.1
1, 2, & 3	6-9	48	293	6.1	251	5.2	85.7
	10-13	75	523	7.0	390	5.2	74.6
	14-17	139	997	7.2	787	5.7	78.9
	18-20	71	530	7.5	483	6.8	91.9
Total		333	2343	7.0	1911	5.7	81.6

Figures 5 and 6 serve to emphasize the seasonal differences. In the number reared all of the points but one for the mean line (litters 1, 2, and 3) are above five for the summer months, while for the winter months more than half of the points are below five. In percentage reared, all of the points but two for the mean lie above 75% for the summer months, while for the winter months only three points lie any considerable difference above 75%.

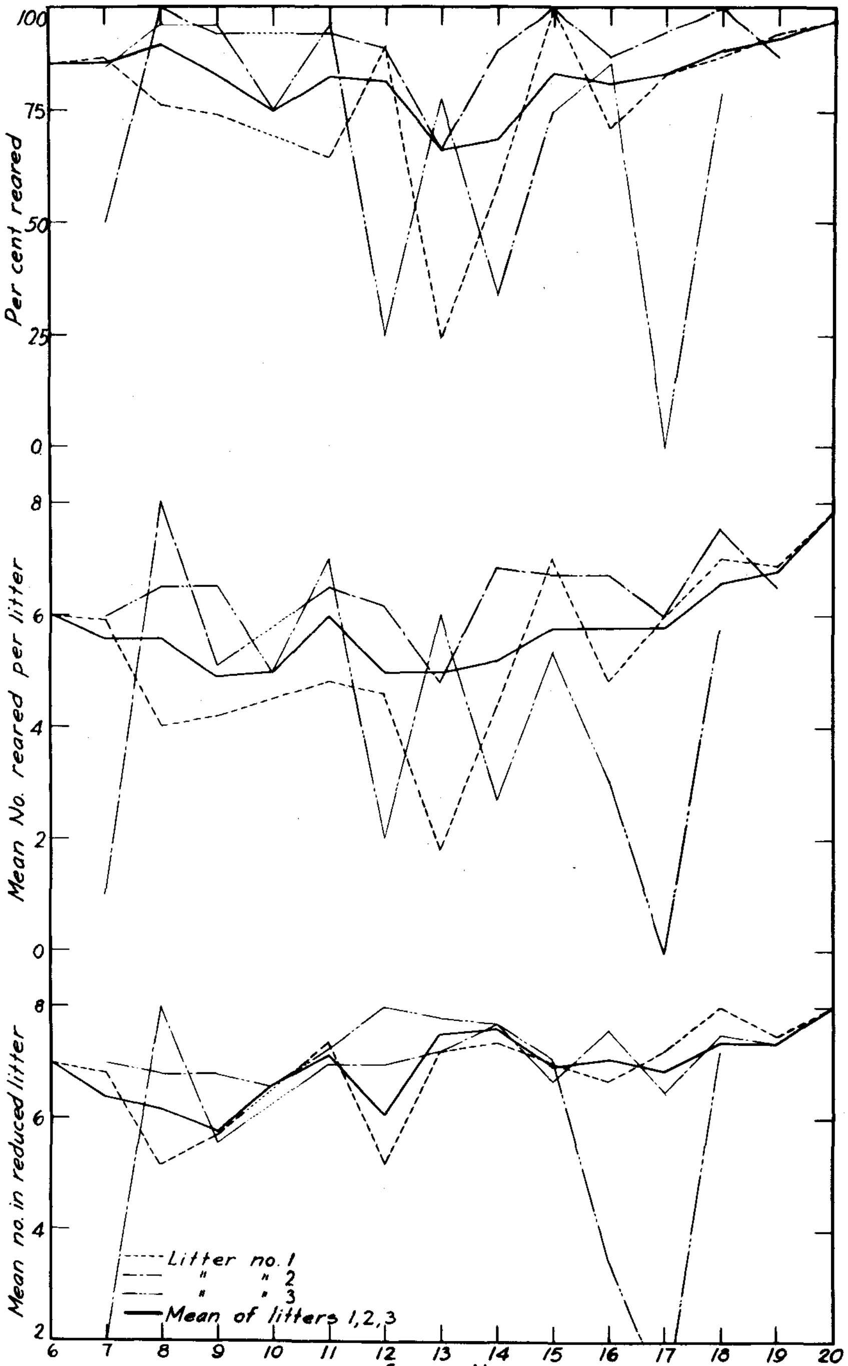

Fig. 6 Mean number of young in reduced litters, mean number reared per litter, and percentage reared, months 3-8 inclusive, segregated as to litter series and to generation.

No. of litters for—line														
1	14	9	24	18	14	14	29	34	12	66	27	20	46	5

Smith, Anderson, and Hubbell (1938) also observed differences in the number and percentage reared through the seven generations which they studied. If the groups and the litter series be disregarded their data may be presented in summary form as follows:

Generation	Number of young reared: Mean per litter	Per cent
1	6.5	85.6
2	6.2	83.1
3	5.7	77.6
4	5.2	71.2
5	5.2	71.7
6	5.8	83.1
7	6.0	84.5
Total	5.8	79.6

The fourth and the fifth generations showed inferior performance, a tendency which they had noted in the percentage of fertility as well. They state that the decrease "would seem to be associated with constitutional factors which in turn are conditioned by the reproductive stress. Such factors include congenital vigor or debility as well as the efficiency of lactation," (p. 92).

Through the six generations which he studied, Slonaker (1939) finds the results so variable as to "preclude(s) any conclusion as to the effect of this number of generations on the mortality of the young from birth to the weaning age" (p. 48).

Slonaker (1939), however, observed variations in the percentage reared in relation to the amount of protein in the diet. The figures which he obtained are as follows:

Group	Per cent protein	Number reared	
		Mean per litter	Per cent
I	10.3	4.49	53.9
II	14.2	4.63	68.9
III	18.2	4.46	73.0
IV	22.2	4.96	63.7
V	26.3	5.38	70.4

Omitting group IV, the figures for which Slonaker believes to be unreliable due to scarcity of data, it is seen that the percentage reared increased as the percentage of protein in the diet increased, until, in the last group, the optimal amount of protein had apparently been exceeded. The variations noted by Macomber (1933) were similar, the percentage reared increasing almost directly with an increase in the percentage of protein. With 5% of protein in the diet, 78% were reared; with 20.8% protein 93% were reared. Russell (1932) found the percentage reared to increase from 30.0% on Sherman's Diet B (Sherman and Muhlfeld, 1922) to 75.5% when raw beef was added to the diet. With improvement in the ration, Mendel and Hubbell (1935) found the percentage reared to increase from 67% in 1919 to 90% in 1935.

In order to ascertain whether or not the number and percentage of young reared were in any way affected by the size of the litter, that is, the number born, the data were arranged as in table 20 and figure 7. It can be seen (figure 7) that the mean number reared per litter increased in general as the size of the litter increased, as would be expected at least until the number of young in a litter reached eight. As a matter of fact, the increase continued for the larger litters even though the young

Table 20. Number and percentage of young reared in relation to the size of the litter, generations 10-17, inclusive, segregated as to litter series

Litter series	Size of litter*	Number of litters	Number of young in reduced litter	Number of young reared		
				Total	Mean per litter	Per cent
1	1	7	7	0	0.0	0.0
	2	3	6	2	0.7	33.3
	3	6	18	6	1.0	33.3
	4	8	32	19	2.4	59.4
	5	11	55	34	3.1	61.8
	6	14	84	37	2.6	44.0
	7	21	147	121	5.8	82.3
	8	22	176	90	4.1	51.1
	9	34	272	213	6.3	78.3
	10	36	288	205	5.7	71.2
	11	16	128	77	4.8	60.2
	12	9	72	61	6.8	84.7
	13	3	24	13	4.3	54.2
Total		190	1309	878	4.6	67.1
2	1	1	1	0	0.0	0.0
	2	5	10	4	0.8	40.0
	3	3	9	3	1.0	33.3
	4	4	16	15	3.8	93.8
	5	8	40	25	3.1	62.5
	6	9	54	42	4.7	77.8
	7	9	63	53	5.9	84.1
	8	14	112	82	5.9	73.2
	9	31	248	191	6.2	77.0
	10	36	288	253	7.0	87.8
	11	42	336	262	6.2	78.0
	12	17	136	116	6.8	85.3
	13	10	80	60	6.0	75.0
	14	3	24	21	7.0	87.5
	15	1	8	5	5.0	62.5
Total		193	1425	1132	5.9	79.4
3	1	2	2	0	0.0	0.0
	2	4	8	0	0.0	0.0
	3	5	15	3	0.6	20.0
	4	7	28	16	2.3	57.1
	5	3	15	6	2.0	40.0

*Number born

(Continued on next page)

Table 20 (continued)

3 cont.	6	10	60	28	2.8	46.7
	7	10	70	32	3.2	45.7
	8	17	136	105	6.2	77.2
	9	16	128	106	6.6	82.8
	10	20	160	126	6.3	78.8
	11	16	128	104	6.5	81.2
	12	10	80	60	6.0	75.0
	13	3	24	20	6.7	83.3
	14	1	8	8	8.0	100.0
Total		124	862	614	5.0	71.2
4	2	3	6	2	0.7	33.3
	3	2	6	0	0.0	0.0
	4	4	16	15	3.8	93.8
	5	10	50	28	2.8	56.0
	6	5	30	23	4.6	76.7
	7	6	42	26	4.4	61.9
	8	18	144	100	5.6	69.4
	9	18	144	107	5.9	74.3
	10	17	136	95	5.6	69.9
	11	6	48	42	7.0	87.5
	12	6	48	40	6.7	83.3
	13	3	24	24	8.0	100.0
Total		98	694	502	5.1	72.3
1, 2, 3, & 4	1	10	10	0	0.0	0.0
	2	15	30	8	0.5	26.7
	3	16	48	12	0.8	25.0
	4	23	92	65	2.8	70.7
	5	32	160	93	2.9	58.1
	6	38	228	130	3.4	57.0
	7	46	322	232	5.0	72.0
	8	71	568	377	5.3	66.4
	9	99	792	617	6.2	77.9
	10	109	872	679	6.2	77.9
	11	80	640	485	6.1	75.8
	12	42	336	277	6.6	82.4
	13	19	152	117	6.2	77.0
	14	4	32	29	7.2	90.6
	15	1	8	5	5.0	62.5
Total		605	4290	3126	5.2	72.9

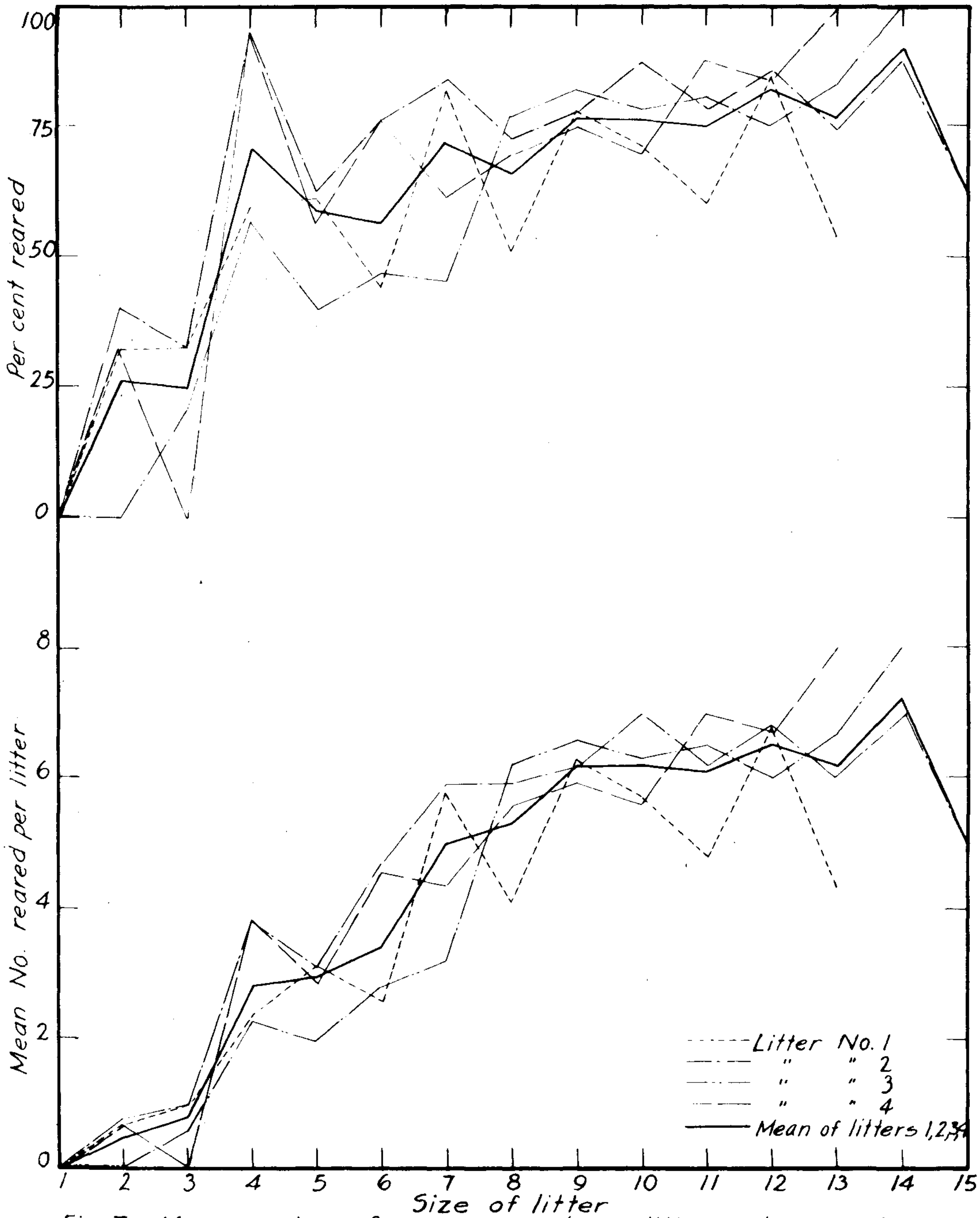

Fig 7. Mean number of young reared per litter and percentage reared in relation to size of litter, generations 10-17, inclusive, segregated as to litter series.

No. of litters for —— Line														
10	15	16	23	32	38	46	71	99	109	80	42	19	4	1

Table 21. Number and percentage of young reared in relation to the size of the litter, grouped, generations 10 to 17, inclusive, segregated as to litter series

Litter series	Size of litter	Number of litters: Total	Number of litters: Per cent	Number of young in reduced litter	Number of young reared: Total	Number of young reared: Mean per litter	Number of young reared: Per cent
1	1-3	16	8.5	31	8	0.5	25.8
	4-6	33	17.4	171	90	2.7	52.6
	7-8	43	22.6	323	211	4.9	65.3
	9-10	70	36.8	560	418	6.0	74.6
	11-13	28	14.7	224	151	5.4	67.4
Total		190	100.0	1309	878	4.6	67.1
2	1-3	9	4.7	20	7	0.8	35.0
	4-6	21	10.9	110	82	3.9	74.5
	7-8	23	11.9	175	135	5.9	77.1
	9-10	67	34.7	536	444	6.6	82.8
	11-13	69	35.7	552	438	6.3	79.3
	14-15	4	2.1	32	26	6.5	81.2
Total		193	100.0	1425	1132	5.9	79.4
3	1-3	11	8.8	25	3	0.3	12.0
	4-6	20	16.1	103	50	2.5	48.5
	7-8	27	21.8	206	137	5.1	66.5
	9-10	36	29.1	288	232	6.4	80.6
	11-13	29	23.4	232	184	6.3	79.3
	14	1	0.8	8	8	8.0	100.0
Total		124	100.0	862	614	5.0	71.2
4	2-3	5	5.1	12	2	0.4	16.7
	4-6	19	19.4	96	66	3.5	68.8
	7-8	24	24.5	186	126	5.2	67.7
	9-10	35	35.7	280	202	5.8	72.1
	11-13	15	15.3	120	106	7.1	88.3
Total		98	100.0	694	502	5.1	72.3
1, 2, 3, & 4	1-3	41	6.8	88	20	0.5	22.7
	4-6	93	15.4	480	288	3.1	60.0
	7-8	117	19.3	890	609	5.2	68.4
	9-10	208	34.4	1664	1296	6.2	77.9
	11-13	141	23.3	1128	879	6.2	77.9
	14-15	5	.8	40	34	6.8	85.0
Total		605	100.0	4290	3126	5.2	72.9

in these litters were all reduced to a common number of eight. This increase can be more clearly seen if the litter sizes are grouped as in table 21. In all of the litters of the series the mean number reared showed a steady increase until the number born exceeded ten. Beyond this point the results were variable. A partial explanation for the greater number reared in the larger litters may be that in the litters which numbered less than eight it was necessary to retain the weaklings of the litter. It does not seem likely, however, that this would account for the whole of the increase.

The percentage of young reared also increased as the size of the litter increased (figure 7, table 21). The pattern here is similar to that which has just been noted for the number reared per litter. Greater significance would seem to be attached, however, to such a marked increase in the percentage reared. Apparently, for a multiparous animal such as the rat, there is an optimal number of young which will result in a lowered mortality rate. It may be that the factors which operate to reduce the number of young which are born also operate to reduce the viability of the young which are born.

Moore and his coworkers (1932) also observed differences in the percentage reared in relation to the size of the litter. They found the percentage to be as follows:

Litter size	Number of litters	Per cent reared
1-4	14	81.0
5-8	68	95.5
9-12	101	95.8
13-16	6	91.9

The litters intermediate in size showed the highest figures. Contrary to the present study, litters containing 9 to 12 showed no higher figures than those containing 5 to 8. All of the percentages were very high.

The relative distribution of litters of various sizes is also interesting (table 21). In all of the litters except litter 2, the greatest percentage of litters was in the 9 to 10 size group. In litter 2, litters of 9 to 10, and 11 to 13 inclusive were almost identical in number. In all of the litters except litter 2, more than 50% of the litters contained from 7 to 10 young. In litter 2 about 70% of the litters contained from 9 to 13 young. Litters 1 and 4 were almost identical in their distributions. Litter 3 showed a greater percentage in the 11 to 13 group than did either litters 1 or 4, but not as great as litter 2. The greatest number born was 15 in a second litter.

The percentages reared in relation to the size of the litter were also figured when the data were separated into two groups for months 9 to 2 and 3 to 8 inclusive, because of the seasonal variation which has previously been noted. The same general trends in number and percentage reared were again observed.

Since the percentage of young reared varied with the size of the litter, it seemed advisable to reexamine the data for variation occasioned by the changing seasons, the passing generations, and the litter series, using litters of selected sizes. Litters which contained more than eight young at birth were chosen since these showed less variation (figure 7) than did the smaller litters and also because these litters were all reduced to the same size.

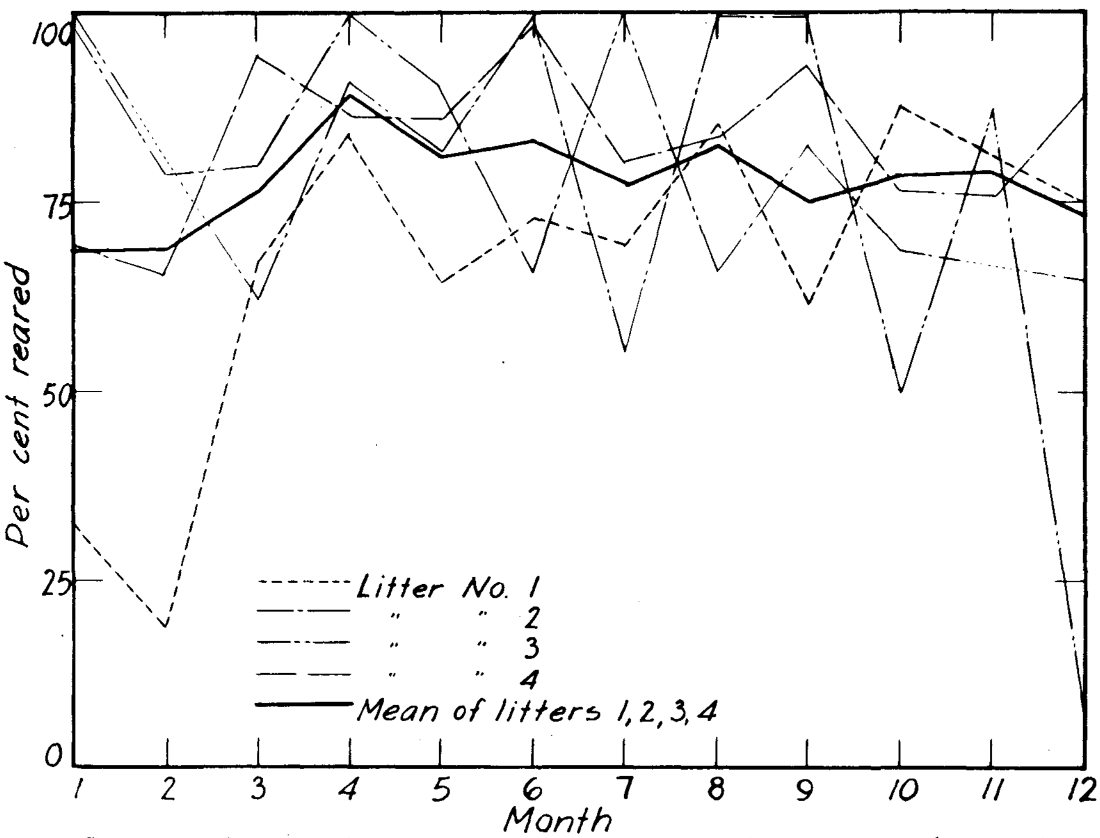

Fig. 8 Percentage of young reared, generations 10-17, inclusive, litter size greater than 8, segregated as to litter series and to month.

No. of litters for —— line

39 23 32 29 41 23 23 21 17 38 28 40

It would seem that the uniformity in litter size was more than offset by the reduction in the amount of data since the monthly figures for percentage reared (figure 8) are even more variable than when all of the litter sizes (figure 3) were included. However, as can be seen from table 22, the same general differences that have previously been noted were found to exist, that is, that a greater percentage of young was reared in the spring and summer months than in the fall and winter months. Chi-square tests indicate

Table 22. Number of young in reduced litters, number reared, and percentage reared, generations 10-17 inclusive, litter size greater than 8, segregated as to litter series and to month, grouped in intervals of six months

Litter series	Month	Number of litters	Number of young in reduced litters: Total	Number of young in reduced litters: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Number of young reared: Per cent
1	9-2	55	440	8.0	310	5.6	70.5
	3-8	43	344	8.0	259	6.0	75.3
Total		98	784	8.0	569	5.8	72.6
2	9-2	84	672	8.0	516	6.1	76.8
	3-8	56	448	8.0	392	7.0	87.5
Total		140	1120	8.0	908	6.5	81.1
3	9-2	37	296	8.0	234	6.3	79.1
	3-8	29	232	8.0	190	6.6	81.9
Total		66	528	8.0	424	6.4	80.3
4	9-2	9	72	8.0	40	4.4	55.6
	3-8	41	328	8.0	268	6.5	81.7
Total		50	400	8.0	308	6.2	77.0
1, 2,	9-2	185	1480	8.0	1100	5.9	74.3
3, & 4	3-8	169	1352	8.0	1109	6.6	82.0
Total		354	2832	8.0	2209	6.2	78.0

that the differences in the second and fourth litters and in the summary figures are highly significant, but that the differences in the first and third litters are not. However, since the differences are all in the same direction the general conclusion would still seem to be warranted.

The increase in percentage of young reared with the passing generation is not as marked (figure 9, table 23) as had previously been noted (figure 4, table 17). The last generations (18 to 20 or 21) always show

Table 23. Number of young in reduced litters, number reared, and percentage reared, litter size greater than 8, segregated as to litter series and to generation, grouped

Litter series	Generation	Number of litters	Number of young in reduced litters: Total	Number of young in reduced litters: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Number of young reared: Per cent
1	7-9	9	72	8.0	57	6.3	79.2
	10-13	41	328	8.0	228	5.6	69.5
	14-17	57	456	8.0	341	5.9	74.8
	18-20	56	448	8.0	388	6.9	86.6
Total		163	1304	8.0	1014	6.2	77.8
2	7-9	15	120	8.0	87	5.8	72.5
	10-13	57	456	8.0	364	6.4	79.8
	14-17	83	664	8.0	544	6.6	81.9
	18-21	62	496	8.0	429	6.9	86.5
Total		217	1736	8.0	1424	6.6	82.0
3	7-9	9	72	8.0	61	6.8	84.7
	10-13	40	320	8.0	270	6.8	84.4
	14,15,17	26	208	8.0	154	5.9	74.0
	18-20	16	128	8.0	112	7.0	87.5
Total		91	728	8.0	597	6.6	82.0
1, 2, & 3	7-9	33	264	8.0	205	6.2	77.7
	10-13	138	1104	8.0	862	6.2	78.1
	14-17	166	1328	8.0	1039	6.3	78.2
	18-21	134	1072	8.0	929	6.9	86.7
Total		471	3768	8.0	3035	6.4	80.5

the greatest percentage but in other respects, the data are not consistent. With the further division of the data into intervals of six months (figure 10, tables 24 and 25), the figures show scarcely any uniformity. In one case, litter 3, table 25, the order is completely reversed, the percentage reared decreasing with the passing generations. Here, also, a chi-square test indicates that the differences are highly significant. To be sure,

Table 24. Number of young in reduced litters, number reared, and percentage reared, litter size greater than 8, months 9-2 inclusive, segregated as to litter series and to generation, grouped

Litter series	Generation	Number of litters	Number of young in reduced litter: Total	Number of young in reduced litter: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Number of young reared: Per cent
1	7	1	8	8.0	0	0.0	0.0
	10,12,13	36	288	8.0	199	5.5	69.1
	14-17	19	152	8.0	111	5.8	73.0
	18-20	24	192	8.0	147	6.1	76.6
Total		80	640	8.0	457	5.7	71.4
2	7-9	15	120	8.0	87	5.8	72.5
	10,12,13	44	352	8.0	272	6.2	77.3
	14,15,17	40	320	8.0	244	6.1	76.2
	18-21	49	392	8.0	333	6.8	84.9
Total		148	1184	8.0	936	6.3	79.1
3	7,9	6	48	8.0	38	6.3	79.2
	10,11,12	18	144	8.0	122	6.8	84.7
	14,15,17	19	152	8.0	112	5.9	73.7
	19,20	10	80	8.0	77	7.7	96.2
Total		53	424	8.0	349	6.6	82.3
1, 2, & 3	7-9	22	176	8.0	125	5.7	71.0
	10-13	98	784	8.0	593	6.1	75.6
	14-17	78	624	8.0	467	6.0	74.8
	18-21	83	664	8.0	557	6.7	83.9
Total		281	2248	8.0	1742	6.2	77.5

the number of litters from which the information was gathered is small, which but serves again to emphasize the great heterogeneity of the data and the necessity for large numbers of rats before conclusions drawn from this sort of data can be said to be dependable.

The order of the percentage reared in the litter series seems to be fairly stable. It has already been pointed out (table 12) that in first litters the percentage of young reared was comparatively small, in second litters comparatively high, and in third litters intermediate in value.

Table 25. Number of young in reduced litters, number reared, and percentage reared, litter size greater than 8, months 3-8 inclusive, segregated as to litter series and to generation

Litter series	Generation	Number of litters	Number of young in reduced litters: Total	Number of young in reduced litters: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Number of young reared: Per cent
1	7-9	8	64	8.0	57	7.1	89.1
	11,12,13	5	40	8.0	29	5.8	72.5
	14,16,17	38	304	8.0	230	6.1	75.7
	18-20	32	256	8.0	241	7.5	94.1
Total		83	664	8.0	557	6.7	83.9
2	11,12,13	13	104	8.0	92	7.1	88.5
	14-17	43	344	8.0	300	7.0	87.2
	18,19	13	104	8.0	96	7.4	92.3
Total		69	552	8.0	488	7.1	88.4
3	8	3	24	8.0	23	7.7	95.8
	10-13	22	176	8.0	148	6.7	84.1
	14,15	7	56	8.0	42	6.0	75.0
	18	6	48	8.0	35	5.8	72.9
Total		38	304	8.0	248	6.5	81.6
1, 2, & 3	7-9	11	88	8.0	80	7.3	90.9
	10-13	40	320	8.0	269	6.7	84.1
	14-17	88	704	8.0	572	6.5	81.2
	18-20	51	408	8.0	372	7.3	91.2
Total		190	1520	8.0	1293	6.8	85.1

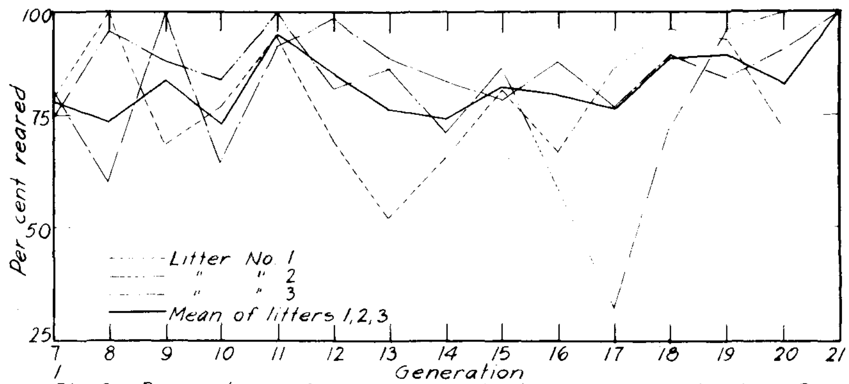

Fig. 9 Percentage of young reared, litter size greater than 8, segregated as to litter series and to generation.

No of litters for—line
7 11 5 60 9 33 36 37 45 47 37 28 66 39 1

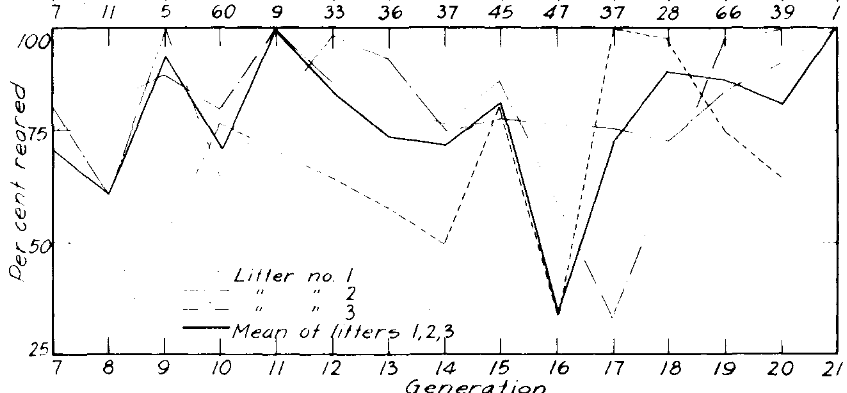

Fig. 10 Percentage of young reared, litter size greater than 8, months 9-2 inclusive, segregated as to litter series and to generation.

No of litters for—line
12 7 3 52 1 26 19 14 39 3 22 13 34 35 1

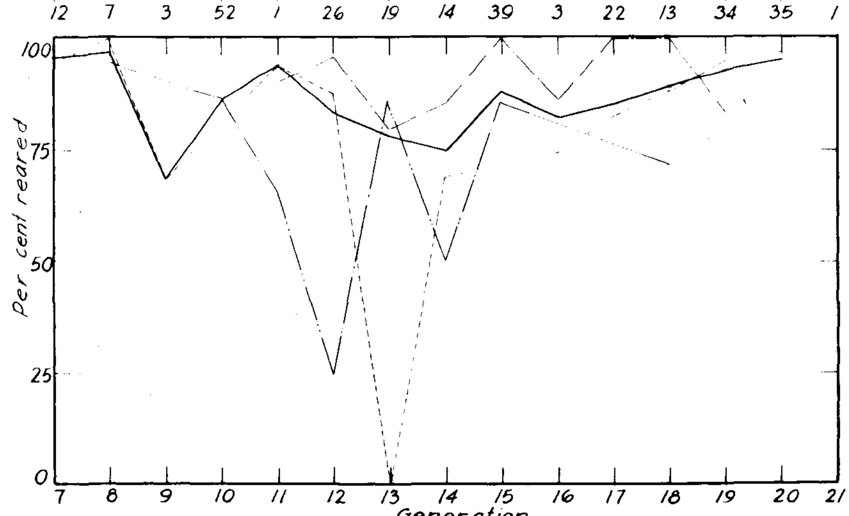

Fig 11 Percentage of young reared, litter size greater than 8, months 3-8 inclusive, segregated as to litter series and to generation.

No. of litters for—line
5 4 2 8 8 7 17 23 6 44 15 15 32 4

This same order is maintained when the data for all the generations are included as in table 17, and also when these same data are divided into the six months intervals as in tables 18 and 19. When only the litters in which more than eight young were born are considered as in tables 22, 23, 24, and 25, the percentage reared in first litters is still always the least, but in third litters, it is not always intermediate in value between the first and the second. In table 23, the figures for the second and third litters were identical and in table 24, the figure for the third litter exceeded slightly that for the second. The reduction in the data produced no marked effects, however. Apparently the variations occasioned by the litter series and the size of the litter far overshadow those of the other factors examined in the present study.

Weight of young at birth. Since only the total litter weight was recorded, it was necessary to obtain the mean weight of the young by dividing the total litter weight by the number of young born. From the standpoint of the mean, itself, this procedure furnished a fairly satisfactory figure, but from the standpoint of a measure of variability or any suitable tests of significance, it left much to be desired. Also, the inequality in the number of litters in the various classes yielded means which, as a matter of fact, are not strictly comparable. However, analysis of variance of the mean weights supplied tests from which at least tentative conclusions can be drawn. While the young were weighed as soon as possible after birth, no attempt was made to prevent them from suckling. Hence, the birth weight as here recorded is actually somewhat in excess of the true birth weight in many cases.

The size of the litter was found to affect the birth weight of the young (table 26). In order to determine the extent of this effect, the

Table 26. Mean weight of young at birth, generations 10-17 inclusive, segregated as to litter series and to size of litter

Litter series	Size of litter at birth	Number of litters	Total number of young	Weight of young: Total gm.	Weight of young: Mean per rat gm.
1	1	5	5	26	5.20
	2	2	4	20	5.00
	3	6	18	90	5.00
	4	8	32	158	4.94
	5	11	55	268	4.87
	6	14	84	405	4.82
	7	22	154	796	5.17
	8	21	168	793	4.72
	9	35	315	1529	4.85
	10	41	410	1964	4.79
	11	19	209	978	4.68
	12	9	108	518	4.80
	13	3	39	183	4.69
Total		196	1601	7728	4.83
2	1	1	1	4	4.00
	2	5	10	44	4.40
	3	3	9	48	5.33
	4	4	16	86	5.38
	5	8	40	202	5.05
	6	9	54	275	5.09
	7	9	63	310	4.92
	8	14	112	543	4.85
	9	29	261	1275	4.89
	10	37	370	1841	4.98
	11	44	484	2307	4.77
	12	17	204	955	4.68
	13	9	117	558	4.77
	14	3	42	191	4.55
	15	1	15	68	4.53
Total		193	1798	8707	4.84

(Continued on next page)

Table 26 (continued)

3	1	2	2	13	6.50
	2	3	6	28	4.67
	3	5	15	69	4.60
	4	7	28	132	4.71
	5	3	15	68	4.53
	6	9	54	259	4.80
	7	9	63	302	4.79
	8	16	128	636	4.97
	9	17	153	727	4.75
	10	21	210	1008	4.80
	11	17	187	896	4.79
	12	12	144	669	4.65
	13	5	65	315	4.85
	14	1	14	70	5.00
Total		127	1084	5192	4.79
4	2	3	6	24	4.00
	3	2	6	27	4.50
	4	4	16	82	5.12
	5	10	50	247	4.94
	6	5	30	146	4.87
	7	6	42	204	4.86
	8	18	144	693	4.81
	9	18	162	757	4.67
	10	17	170	815	4.79
	11	7	77	356	4.62
	12	7	84	382	4.55
	13	3	39	181	4.64
Total		100	826	3914	4.74
1, 2, 3, & 4	1	8	8	43	5.38
	2	13	26	116	4.46
	3	16	48	234	4.88
	4	23	92	458	4.98
	5	32	160	785	4.91
	6	37	222	1085	4.89
	7	46	322	1612	5.01
	8	69	552	2665	4.83
	9	99	891	4288	4.81
	10	116	1160	5628	4.85
	11	87	957	4537	4.74
	12	45	540	2524	4.67
	13	20	260	1237	4.76
	14	4	56	261	4.66
	15	1	15	68	4.53
Total		616	5309	25541	4.81

regression of the mean birth weight on the litter size was figured. When the points are plotted as in figure 12, it can be seen that the mean birth weights in the small sized litters are highly variable. Also, since the data in both the very small and very large litters were obtained from relatively few litters, the regression line was drawn for the litters which contained from 3-13 young only. While the slope of the line is not steep, the regression is nevertheless found to be highly significant. The pertinent figures, using Snedecor's (1938) notation, are as follows:

$Sx^2 = 440.0000$ $Sxy = -10.8900$ $Sy^2 = 1.5627$

$$b = Sxy/Sx^2 = \frac{-10.89}{440}$$

$$= -0.02475 \text{ gm., the regression coefficient}$$

$$E = \bar{y} + b(X - \bar{x})$$

$$= 4.833 - 0.02475(X-8.00)$$

$$= 5.031 - 0.02475X, \text{ the regression equation}$$

To test for significance,

$$r = -0.4153,^{**} df = 42$$

The mean weight of the young is thus found to decrease 0.02475 gm. for every increase of one in the size of the litter.

In an attempt to learn whether any seasonal variation existed, the data for generations 10-17 were arranged by litter series and by month (table 27, figure 13) as had been done in the case of the number of young born. It can be seen that the birth weight varied but little, either from month to month or from series to series. As one might expect, an analysis of variance of the mean weights (table VII, appendix) indicates that the

*One star will be used throughout to indicate significance, two stars high significance.

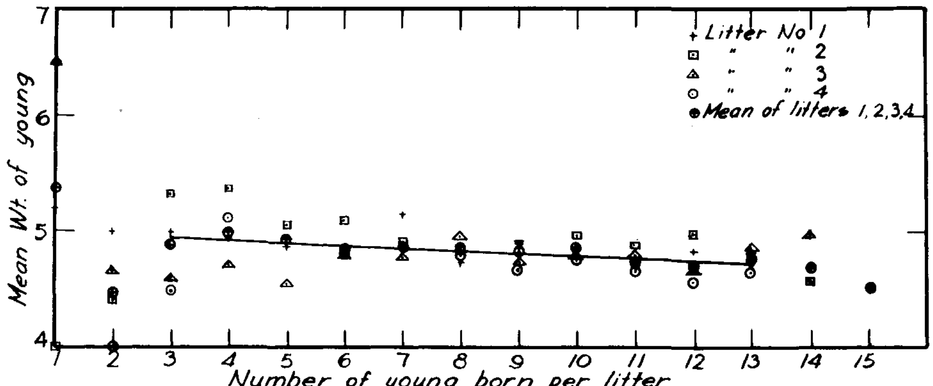

Fig. 12 Regression of mean weight of young at birth on size of litter, generations 10-17. (Line drawn for litters with 3-13 young)

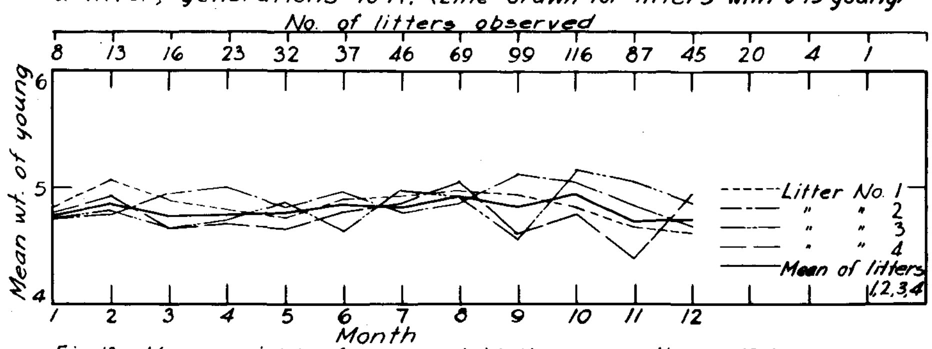

Fig 13 Mean weight of young at birth, generations 10-17, segregated as to litter series and to month.

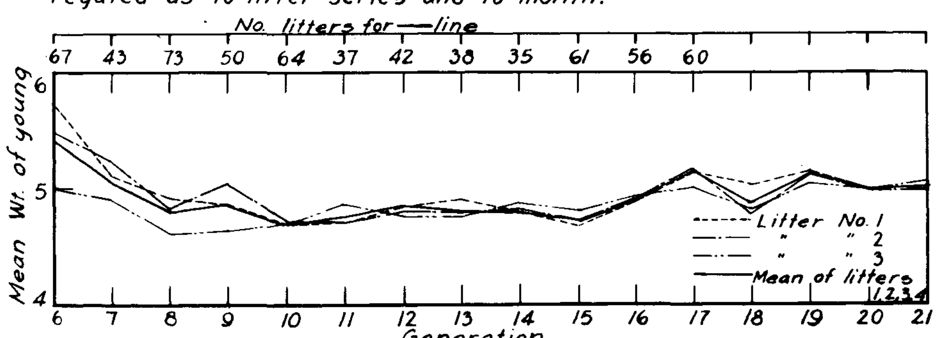

Fig 14 Mean weight of young at birth segregated as to litter series and to generation.

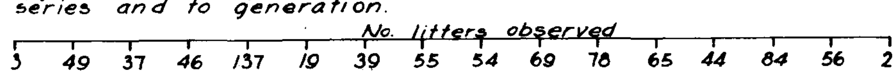

Table 27. Mean weight of young at birth, generations 10-17 inclusive, segregated as to litter series and to month

Litter series	Month	Number of litters	Number of young born: Total	Number of young born: Mean per litter	Weight of young: Total gm.	Weight of young: Mean per rat gm.
1	1	11	95	8.6	458	4.82
	2	8	65	8.1	331	5.09
	3	20	175	8.8	859	4.91
	4	11	98	8.9	474	4.84
	5	15	117	7.8	556	4.75
	6	16	134	8.4	656	4.90
	7	8	57	7.1	281	4.93
	8	16	133	8.3	664	4.99
	9	20	133	6.6	659	4.95
	10	23	200	8.7	963	4.82
	11	31	245	7.9	1141	4.66
	12	17	149	8.8	686	4.60
Total		196	1601	8.17	7728	4.83
2	1	35	336	9.6	1590	4.73
	2	10	91	9.1	435	4.78
	3	8	75	9.4	373	4.97
	4	8	72	9.0	361	5.01
	5	21	210	10.0	1014	4.83
	6	11	98	8.9	488	4.98
	7	15	138	9.2	661	4.79
	8	14	109	7.8	532	4.88
	9	4	28	7.0	143	5.11
	10	24	227	9.5	1144	5.04
	11	18	164	9.1	793	4.84
	12	25	250	10.0	1173	4.69
Total		193	1798	9.32	8707	4.84
3	1	18	149	8.3	704	4.72
	2	18	163	9.1	786	4.82
	3	30	261	8.7	1218	4.67
	4	7	62	8.9	293	4.73
	5	8	65	8.1	318	4.89
	6	3	35	11.7	163	4.66
	7	1	11	11.0	55	5.00
	8	6	47	7.8	233	4.96
	9	10	73	7.3	334	4.58
	10	10	76	7.6	393	5.17
	11	3	16	5.3	81	5.06
	12	13	126	9.7	614	4.87
Total		127	1084	8.54	5192	4.79

(Continued on next page)

Table 27 (continued)

4	1	3	20	6.6	96	4.80
	2	7	46	6.6	228	4.96
	3	15	110	7.3	515	4.68
	4	24	205	8.5	963	4.70
	5	20	188	9.4	877	4.66
	6	7	60	8.6	288	4.80
	7	8	64	8.0	313	4.89
	8	2	17	8.5	86	5.06
	9	1	10	10.0	46	4.60
	10	4	30	7.5	143	4.77
	11	4	31	7.8	136	4.39
	12	5	45	9.0	223	4.96
Total		100	826	8.26	3914	4.74
1, 2, 3, & 4	1	67	600	9.0	2848	4.75
	2	43	365	8.5	1780	4.88
	3	73	621	8.5	2965	4.77
	4	50	437	8.7	2091	4.78
	5	64	580	9.1	2765	4.77
	6	37	327	8.8	1595	4.88
	7	32	270	8.4	1310	4.85
	8	38	306	8.1	1515	4.95
	9	35	244	7.0	1182	4.84
	10	61	533	8.7	2643	4.96
	11	56	456	8.1	2151	4.72
	12	60	570	9.5	2696	4.73
Total		616	5309	8.62	25541	4.81

differences were not significant for either the months or the litter series. However, in view of the fact that the birth-weight varied with the size of the litter, a test such as is supplied by the analysis of variance is valid only on the assumption that the various sized litters are distributed at random through all the months of the year. This would not seem to be entirely true since it was found that a smaller number of young were born for months 7-9 than for the remaining months of the year. With the use of summary figures for the first four litters, the mean birth weight for months 7-9 was found to be slightly higher than that for the remaining months, 4.89, as against 4.80 gm. By means of the regression equation, E = 5.031 - 0.02475X, the estimated values for the mean rat weights for the two groups of months may be calculated approximately as follows:

Litters	Months	Number of litters	Mean number of young per litter: X	Mean wt. of young: Y	Estimated: mean wt. E	Error of estimate Y-E
1,2,3, & 4	10-6	511	8.78	4.80	4.814	-0.014
	7-9	105	7.81	4.89	4.838	0.052
	Difference			0.09		0.066

The difference in the two groups is found to be even less when the errors of estimate are compared. No accurate test is available for testing the significance of this difference, but in any event it would not seem to be large. Apparently there is no reason to suspect that the birth weight varied with the season of the year. In the gray Norway rat, King (1935) found the birth weight to be at a minimum in the summer with the maximum for the males in the winter and for the females in the autumn.

The birth weights for the several generations showed somewhat greater variability as can be seen from table 28 and figure 14. There was a tendency for the mean weights to be higher in both the early and the late generations with lower values in the intervening generations. An analysis of variance (table VIII, appendix) indicates that these differences are highly significant. In view of the fact that the mean number of young born per

Table 28. Mean weight of young at birth segregated as to litter series and to generation

Litter series	Generation	Number of litters	Number of young born: Total	Number of young born: Mean per litter	Weight of young: Total gm.	Weight of young: Mean per rat gm.
1	6	1	7	7.0	40	5.71
	7	19	128	6.7	654	5.11
	8	14	93	6.6	459	4.94
	9	14	88	6.3	428	4.86
	10	48	374	7.8	1745	4.67
	11	7	57	8.1	268	4.70
	12	11	94	8.5	454	4.83
	13	19	163	8.6	798	4.90
	14	19	169	8.9	812	4.80
	15	25	199	8.0	927	4.66
	16	37	314	8.5	1537	4.89
	17	30	231	7.7	1187	5.14
	18	19	162	8.5	811	5.01
	19	37	343	9.3	1770	5.16
	20	25	236	9.4	1180	5.00
Total		325	2658	8.18	13070	4.92
2	6	1	8	8.0	44	5.50
	7	16	116	7.2	608	5.24
	8	12	108	9.0	522	4.83
	9	16	127	7.9	641	5.05
	10	46	410	8.9	1927	4.70
	11	6	50	8.3	235	4.70
	12	13	124	9.5	596	4.81
	13	19	180	9.5	861	4.78
	14	19	178	9.4	857	4.81
	15	25	251	10.0	1197	4.77
	16	37	357	9.6	1750	4.90
	17	28	248	8.9	1284	5.18
	18	15	155	10.3	739	4.77
	19	37	365	9.9	1867	5.12
	20	25	230	9.2	1149	5.00
	21	1	11	11.0	55	5.00
Total		316	2918	9.23	14332	4.91
3	6	1	6	6.0	30	5.00
	7	14	96	6.9	470	4.90
	8	11	76	6.9	350	4.61
	9	16	128	8.0	595	4.65
	10	43	358	8.3	1684	4.70

(Continued on next page)

Table 28 (continued)

3 cont.	11	6	51	8.5	249	4.88
	12	15	136	9.1	658	4.84
	13	17	166	9.8	791	4.77
	14	16	138	8.6	670	4.86
	15	19	170	8.9	816	4.80
	16	4	12	3.0	59	4.92
	17	7	53	7.6	265	5.00
	18	10	88	8.8	422	4.80
	19	10	93	9.3	467	5.02
	20	6	40	6.7	200	5.00
	21	1	12	12.0	61	5.08
Total		196	1623	8.28	7787	4.80
1, 2, & 3	6	3	21	7.0	114	5.43
	7	49	340	6.9	1732	5.09
	8	37	277	7.5	1331	4.81
	9	46	343	7.5	1664	4.85
	10	137	1142	8.3	5356	4.69
	11	19	158	8.3	752	4.76
	12	39	354	9.1	1708	4.82
	13	55	509	9.3	2450	4.81
	14	54	485	9.0	2339	4.82
	15	69	620	9.0	2940	4.74
	16	78	683	8.8	3346	4.90
	17	65	532	8.2	2736	5.14
	18	44	405	9.2	1972	4.87
	19	84	801	9.5	4104	5.12
	20	56	1506	9.0	2529	5.00
	21	2	23	11.5	116	5.04
Total		837	7199	8.60	35189	4.89

litter increased with the passing generations, the increase in the mean weight of the young in the late generations is unexpected. The errors of estimate would thus simply serve to emphasize the differences already noted. The inclusion of the early and the late generations (and possibly also the exclusion of the fourth litter) raises the general average from 4.81 to 4.89 gm. The data from all the months were included since it had been found that there was no seasonal variation.

Just what physiological significance can be attached to the changes in the birth weight with the changing generations, one can only conjecture. It may be that the weights tend to run in cycles. One would not expect the birth weight to increase permanently unless the size of the adult animals were actually increasing. Obviously there must be both an upper and a lower limit, the one compatible with the survival of the mother and the other with the survival of the young.

In the six generations which Slonaker (1939) observed, there was no indication of any consistent changes in the birth weight.

King (1915) found the birth weight of the young to increase with the litter series as follows:

Litter series	Number of litters	Mean weight of young: Males gm.	Mean weight of young: Females gm.
1	22	4.39	4.06
2	21	4.52	4.27
3	25	4.61	4.43
4	17	4.64	4.36

On the contrary, in the present study there is some slight indication (tables 26 and 27) that the weight of the young decreased with advance in the litter series. The mean weights of the first two litters were nearly identical but those for the third and fourth litters were somewhat less.

Slonaker (1939) found the birth weight to vary with the percentage of protein in the diet as follows:

Per cent protein	Mean weight of young Males gm.	Females gm.
10.3	5.15	4.97
14.2	5.22	4.98
18.2	5.37	5.14
22.2	5.29	4.98
26.3	5.19	4.98

The largest weights were found with 18.2% protein in both the males and females. Macomber (1933) observed an increase in birth weight from 4.98 gm. with 5% protein to 5.25 gm. with 20.8% protein. Mendel and Hubbell (1935) report the high mean birth weight of 5.8 gm.

Weight of young at 21 days of age. Young rats from the stock colony are usually separated from the mother and placed upon experimental diets when they are from 21 to 30 days of age, depending upon the type of experiment for which they are to be used. The weights of the young at any age in this interval are therefore extremely important. It is always to be hoped that a well-managed colony will furnish animals which vary but little, that is, that the young will be from a homogeneous population. In the present study the weights at both 21 and 28 days of age will be discussed.

It was necessary to determine the mean weights of the individual young at 21 days of age by dividing the total litter weight by the number of young in the litter as had been done in the case of the weight at birth. Again, the mean weight of the young was found to vary with the size of the litter as can be seen from table 29. Disregarding the small litters, the mean weight of the young showed a consistent decrease with an increase in the size of the litter. The regression line is shown in figure 15. Owing

Table 29. Mean weight of young at 21 days of age, generations 10-17 inclusive, segregated as to litter series and to size of litter at 21 days

Litter series	Size of litter at 21 days	Number of litters	Total number of young	Weight of young Total gm.	Weight of young Mean per rat gm.
1	2	5	10	233	23.3
	3	7	21	671	32.0
	4	6	24	758	31.6
	5	14	70	2093	29.9
	6	13	78	2393	30.7
	7	29	203	6008	29.6
	8	52	416	11478	27.6
Total		126	822	23634	28.75
2	1	2	2	34	17.0
	2	3	6	218	36.3
	3	5	15	513	34.2
	4	5	20	727	36.4
	5	15	75	2398	32.0
	6	13	78	2502	32.1
	7	22	154	4848	31.5
	8	91	728	21292	29.2
Total		156	1078	32532	30.18
3	2	3	6	202	33.7
	3	3	9	325	36.1
	4	7	28	872	31.1
	5	8	40	1284	32.1
	6	7	42	1293	30.8
	7	13	91	2814	30.9
	8	46	368	10959	29.8
Total		87	584	17749	30.39
1, 2, & 3	1	2	2	34	17.0
	2	11	22	653	29.7
	3	15	45	1509	33.5
	4	18	72	2357	32.7
	5	37	185	5775	31.2
	6	33	198	6188	31.3
	7	64	448	13670	30.5
	8	189	1512	43729	28.9
Total		369	2484	73915	29.76

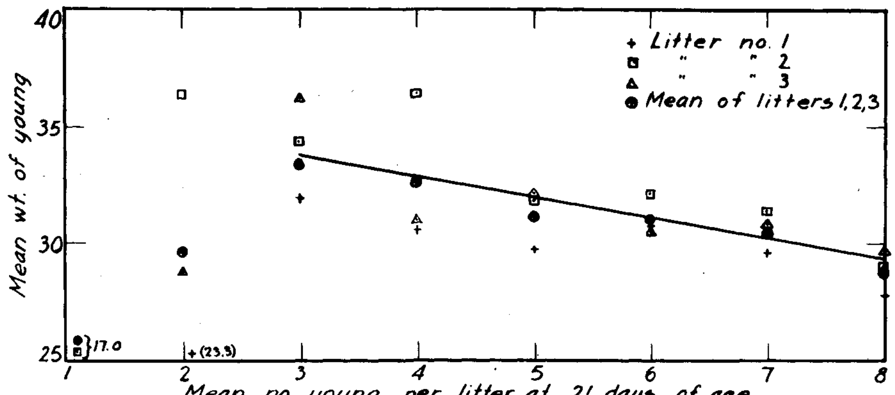

Fig. 15 Regression of mean weight of young at 21 days of age on size of litter (Line drawn for litters with 3 or more young)

No. litters observed

2 11 15 18 37 33 64 189

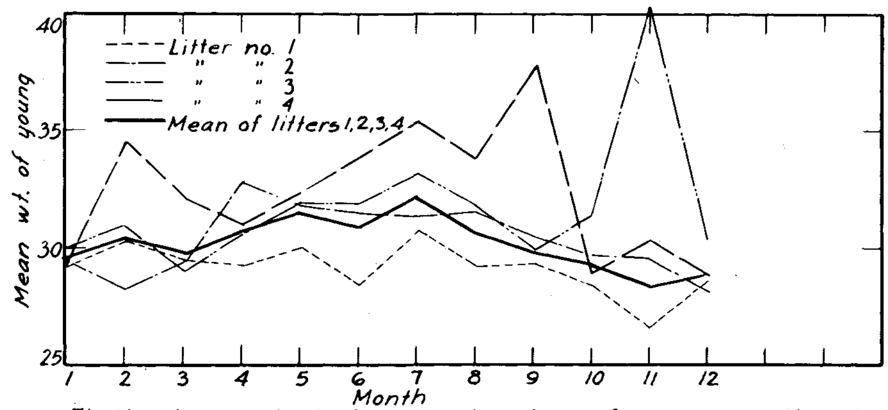

Fig. 16 Mean weight of young at 21 days of age, generations 10-17, segregated as to litter series and to month.

No. litters for — line

41 29 52 38 49 31 25 32 21 40 38 44

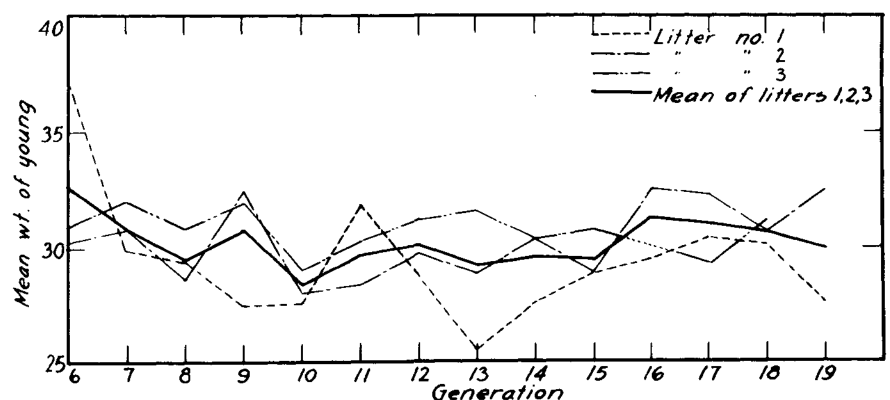

Fig. 17 Mean weight of young at 21 days of age segregated as to litter series and to generation.

No. litters for — line

3 30 21 22 84 13 28 39 41 56 60 49 27 11

to the inconsistency of the data and the few litters which were observed for the small-sized litters, the line was drawn for the litters which contained three or more young. The figures which are of interest may be summarized as follows:

$S x^2 = 52.5000 \qquad Sxy = -50.1000 \qquad Sy^2 = 84.8800$

$$b = Sxy/Sx^2 = \frac{-50.10}{52.50}$$

$$= -0.9543 \text{ gm., the regression coefficient}$$

$$E = \bar{y} + b(X - \bar{x})$$

$$= 31.53 - 0.9543(X - 5.50)$$

$$= 36.78 - 0.9543X, \text{ the regression equation}$$

To test for significance,

$$r = -0.7506^{**}, \text{ df} = 16$$

The mean weight of the young decreased 0.9543 gm. for every increase of one in the size of the litter.

In order to judge whether there might be any seasonal variation in the mean weight of the young at 21 days of age, the data were arranged as in table 30. An analysis of variance (table IX, appendix) indicates that the monthly mean weights did not differ significantly from one another. However, the mean line in figure 16 suggests that these weights were somewhat higher for the summer months than for the winter months. The months were grouped in the same intervals that had been used in studying the number of young reared, that is, months 9-2 and 3-8 inclusive, and the means for these groups determined (table 31). In all of the litters of the series except the third, the mean weight was slightly higher for the spring and summer months than for the fall and winter months. Again, one

Table 30. Mean number of young per litter and mean weight of young at 21 days of age, generations 10-17 inclusive, segregated as to litter series and to month

Litter series	Months	Number of litters	Number of young: Total	Number of young: Mean per litter	Weight of young: Total gm.	Weight of young: Mean per rat gm.
1	1	5	34	6.8	986	29.0
	2	5	29	5.8	880	30.3
	3	10	65	6.5	1920	29.5
	4	8	62	7.8	1809	29.2
	5	8	43	5.4	1289	30.0
	6	12	79	6.6	2247	28.4
	7	5	31	6.2	955	30.9
	8	15	98	6.5	2862	29.2
	9	11	62	5.6	1814	29.3
	10	15	103	6.9	2925	28.4
	11	20	131	6.6	3505	26.8
	12	12	85	7.1	2442	28.7
Total		126	822	6.52	23634	28.75
2	1	21	150	7.1	4414	29.4
	2	7	54	7.7	1535	28.4
	3	8	59	7.4	1740	29.5
	4	7	44	6.3	1448	32.9
	5	19	141	7.4	4482	31.8
	6	10	66	6.6	2084	31.6
	7	13	91	7.0	2848	31.3
	8	12	74	6.2	2324	31.4
	9	4	22	5.5	668	30.4
	10	20	139	7.0	4146	29.8
	11	14	93	6.6	2758	29.7
	12	21	145	6.9	4085	28.2
Total		156	1078	6.91	32532	30.18
3	1	14	92	6.6	2761	30.0
	2	14	97	6.9	2998	30.9
	3	23	140	6.1	4080	29.1
	4	5	37	7.4	1130	30.5
	5	6	36	6.0	1148	31.9
	6	2	16	8.0	510	31.9
	7	1	8	8.0	266	33.2
	8	3	23	7.7	730	31.7
	9	5	40	8.0	1163	29.1

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Table 30 (continued)

3	10	4	25	6.2	782	31.3
cont.	11	1	6	6.0	242	40.3
	12	9	64	7.1	1939	30.3
Total		87	584	6.71	17749	30.39
4	1	1	8	8.0	232	29.0
	2	3	17	5.7	586	34.5
	3	11	61	5.5	1951	32.0
	4	18	127	7.1	3938	31.0
	5	16	112	7.0	3603	32.2
	6	7	46	6.6	1560	33.9
	7	6	40	6.7	1411	35.3
	8	2	15	7.5	508	33.9
	9	1	8	8.0	302	37.8
	10	1	8	8.0	230	28.8
	11	3	19	6.3	573	30.2
	12	2	10	5.0	290	29.0
Total		71	471	6.63	15184	32.24
1, 2,	1	41	284	6.9	8393	29.6
3, & 4	2	29	197	6.8	5999	30.5
	3	52	325	6.2	9691	29.8
	4	38	270	7.1	8325	30.8
	5	49	332	6.8	10522	31.7
	6	31	207	6.7	6401	30.9
	7	25	170	6.8	5480	32.2
	8	32	210	6.6	6424	30.6
	9	21	132	6.3	3947	29.9
	10	40	275	6.9	8083	29.4
	11	38	249	6.6	7078	28.4
	12	44	304	6.9	8756	28.8
Total		440	2955	6.71	89099	30.11

wonders whether differences in the size of the litter might be responsible for the differences in weight. The estimated weights were calculated from the regression equation shown above and were entered in table 32. The differences observed in the errors of estimate are not greatly different from those observed on the actual values. They are all in the

Table 31. Mean number of young per litter and mean weight of young at 21 days of age, generations 10-17 inclusive, segregated as to litter series and to month, grouped in intervals of six months

Litter series	Months	Number of litters	Number of young Total	Number of young Mean per litter	Weight of young Total gm.	Weight of young Mean per rat gm.
1	9-2	68	444	6.53	12,522	28.27
	3-8	58	378	6.52	11,082	29.32
Total		126	822	6.52	23,634	28.75
2	9-2	87	603	6.93	17,606	29.20
	3-8	69	475	6.88	14,926	31.42
Total		156	1078	6.91	32,532	30.18
3	9-2	47	324	6.89	9,885	30.51
	3-8	40	260	6.50	7,864	30.25
Total		87	584	6.71	17,749	30.39
4	9-2	11	70	6.36	12,971	31.61
	3-8	60	401	6.68	2,213	32.35
Total		71	471	6.63	15,184	32.24
1, 2, 3, & 4	9-2	213	1441	6.77	42,256	29.32
	3-8	227	1514	6.67	46,843	30.94
Total		440	2955	6.71	89,099	30.11

same direction as before but are somewhat accentuated in the third and fourth litters. Attention should again be called to the fact that these errors of estimate are truly "estimates" and that too much confidence can not be placed in them. Apparently the weight at this age is but little affected by the season of the year. It is interesting to note, however, that the slightly larger weights were associated with the same period of the year in which the greater number and percentage of young were reared.

Table 32. Errors of estimate for mean weight of young at 21 days of age, generations 10-17, inclusive, segregated as to litter series and to month, grouped in intervals of six months

Litter series	Months	Number of litters	Mean number young per litter	Mean weight of rat: Observed Y gm.	Estimated E gm.	Y-E
1	9-2	68	6.53	28.27	30.55	-2.28
	3-8	58	6.52	29.32	30.56	-1.25
Difference				1.05		1.04
2	9-2	87	6.93	29.20	30.17	-0.97
	3-8	69	6.88	31.42	30.21	1.21
Difference				2.22		2.18
3	9-2	47	6.89	30.51	30.20	0.31
	3-8	40	6.50	30.25	30.58	-0.33
Difference				-0.26		-0.64
4	9-2	11	6.36	31.61	30.71	0.90
	3-8	60	6.68	32.35	30.41	1.94
Difference				0.74		1.04
1, 2,	9-2	213	6.77	29.32	30.32	-1.00
3, & 4	3-8	227	6.67	30.94	30.41	0.55
Difference				1.62		1.55

$$E = 36.78 - 0.9543X$$

There is no indication that the mean weight of the young at 21 days of age changed from generation to generation (table 33, figure 17). If the generations are grouped as in table 34, the mean weights still remain remarkably constant. This would scarcely be expected in view of the fact that the mean number of young per litter increased from the early to the late generations. The uniformity might mean that the vigor of the colony had increased sufficiently to maintain the weight in spite of the increased number of young. The increase in the number and percentage reared

Table 35. Mean number of young per litter and mean weight of young at 21 days of age, segregated as to litter series and to generation

Litter series	Generation	Number of litters	Number of young: Total	Number of young: Mean per litter	Weight of young: Total gm.	Weight of young: Mean per rat gm.
1	6	1	7	7.0	260	37.1
	7	11	72	6.5	2160	30.0
	8	7	39	5.6	1148	29.4
	9	7	39	5.6	1074	27.5
	10	28	181	6.5	5020	27.7
	11	3	17	5.7	542	31.9
	12	7	49	7.0	1407	28.7
	13	7	53	7.6	1353	25.5
	14	13	82	6.3	2262	27.6
	15	19	121	6.4	3498	28.9
	16	25	158	6.3	4674	29.6
	17	24	161	6.7	4878	30.3
	18	9	70	7.8	2109	30.1
	19	6	40	6.7	1109	27.7
Total		167	1089	6.52	31494	28.92
2	6	1	8	8.0	242	30.2
	7	8	52	6.5	1602	30.8
	8	8	53	6.6	1514	28.6
	9	8	52	6.5	1688	32.5
	10	28	193	6.9	5442	28.2
	11	6	39	6.5	1112	28.5
	12	11	76	6.9	2268	29.8
	13	17	115	6.8	3337	29.0
	14	16	120	7.5	3646	30.4
	15	20	144	7.2	4181	29.0
	16	35	242	6.9	7871	32.5
	17	24	150	6.2	4839	32.3
	18	11	81	7.4	2497	30.8
	19	5	35	7.0	1139	32.5
Total		198	1360	6.87	41378	30.42
3	6	1	6	6.0	184	30.7
	7	11	61	5.5	1955	32.0
	8	6	37	6.2	1143	30.9
	9	7	46	6.6	1468	31.9
	10	28	179	6.4	5216	29.1
	11	4	29	7.2	878	30.3

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Table 33 (continued)

3 cont.	12	10	69	6.9	2159	31.3
	13	15	101	6.7	3204	31.7
	14	12	85	7.1	2573	30.3
	15	17	113	6.6	3484	30.8
	17	1	8	8.0	235	29.4
	18	7	50	7.1	1558	31.2
Total		119	784	6.59	24057	30.68
1, 2, & 3	6	3	21	7.0	686	32.7
	7	30	185	6.2	5717	30.9
	8	21	129	6.1	3805	29.5
	9	22	137	6.2	4230	30.9
	10	84	553	6.6	15678	28.4
	11	13	85	6.5	2532	29.8
	12	28	194	6.9	5834	30.1
	13	39	269	6.9	7894	29.3
	14	41	287	7.0	8481	29.6
	15	56	378	6.8	11163	29.5
	16	60	400	6.7	12545	31.4
	17	49	319	6.5	9952	31.2
	18	27	201	7.4	6164	30.7
	19	11	75	6.8	2248	30.0
Total		484	3233	6.68	96929	29.98

which has already been noted, with the passing generations might also indicate such an increased vigor.

Smith, Anderson, and Hubbell (1938) observed a striking uniformity in the weights of the young at 21 days of age. Throughout the seven generations which they observed, the weights of the males varied from 42 to 46 gm. and the females from 40 to 43 gm. Slonaker (1939), however, found the weights of the young at 25 days of age to increase from the first through the sixth generations.

In the present study the mean weight of the young was found to increase with the litter series (table 30). An analysis of variance (table IX, appendix) indicates that these differences are highly significant. Smith, Anderson, and Hubbell (1938) found a similar, though not equally consistent trend. Their figures are as follows:

Litter series	Weight of young at 21 days	
	Male	Female
1	42	40
2	40	41
3	45	43
4	45	43

Table 34. Mean number of young per litter and mean weight of young at 21 days of age, segregated as to litter series and to generation, grouped

Litter series	Generation	Number of litters	Number of young		Weight of young	
			Total	Mean per litter	Total gm.	Mean per rat gm.
1	6-9	26	157	6.04	4642	29.57
	10-13	45	300	6.67	8322	27.74
	14-17	81	522	6.44	15312	29.33
	18-19	15	110	7.33	3218	29.25
Total		167	1089	6.52	31494	28.92
2	6-9	25	165	6.60	5046	30.58
	10-13	62	423	6.82	12159	28.74
	14-17	95	656	6.91	20537	31.31
	18-19	16	116	7.25	3636	31.34
Total		198	1360	6.87	41378	30.42
3	6-9	25	150	6.00	4750	31.67
	10-13	57	378	6.63	11457	30.31
	14-17	30	206	6.87	6292	30.54
	18-19	7	50	7.14	1558	31.16
Total		119	784	6.59	24057	30.68

(Continued on next page)

Table 34 (continued)

1, 2,	6-9	76	472	6.21	14438	30.59
& 3	10-13	164	1101	6.71	31938	29.01
	14-17	206	1384	6.72	42141	30.45
	18-19	38	276	7.26	8412	30.48
Total		484	3233	6.68	96929	29.98

The mean weight of the young at 25 days of age was found by Slonaker (1939) to vary with the percentage of protein in the diet:

Group	Per cent protein	Weight of young at 25 days	
		Male	Female
I	10.3	20.8	20.2
II	14.2	26.7	25.2
III	18.2	30.8	30.8
IV	22.2	28.4	26.5
V	26.3	32.5	31.0

With the exception of the fourth group, the weights of the young increased with each addition of protein. The low figure in group IV, Slonaker believes to be due to too close a discarding of animals, and he concludes that an increase in the protein of the diet up to 26.3% results in accelerated growth in rats from birth to 25 days of age. Macomber (1933) found a similar increase in the weight with an increase of protein in the diet:

Per cent protein	Weight of young at 21 days
5	19.8
10	30.1
16.8	31.5
20.8	36.2

Over a period of years, Mendel and Hubbell (1935) observed an increase in the weight of the young which they attribute to improvement in the ration:

Year	Weight of young at 21 days	
	Male	Female
1912	23	26
1919	31	31
1925	31	30
1935	48	47

The percentage of protein was 13% in 1912 and 23% in 1935.

Considerable variation can be noted in the mean weights which are reported from the various colonies. Slonaker's highest figures for 25 days of age are similar to those for 21 days of age given in the present study. Those of Smith, *et al.*, for 21 days of age are much higher.

Weight of young at 28 days of age. The mean weight of the young at 28 days of age presents a picture which is similar to that for the mean weight at 21 days with some slight variation in the detail. The number of generations for the study of the variation with litter size and with season was extended to include the twentieth generation. The weight was again found to decrease as the size of the litter increased (table 35, figure 18). The regression coefficient is nearly identical with that found for 21 days, -0.9390 gm. as against -0.9543 gm. The information necessary for determining the regression coefficient and the regression equation may be summarized as follows:

$S\,x^2 = 52.5000 \qquad Sxy = -49.3000 \qquad Sy^2 = 172.6000$

$$b = -49.30/52.50 = -0.9390 \text{ gm.}$$

$$r = -0.5179^{*}, \ df = 16$$

$$\bar{Y} = 5129 - 0.9390(X - 5.50)$$

$$= 56.45 - 0.9390X$$

No seasonal trends could be detected in the mean weights (table 36, figure 19). The monthly means varied considerably but an analysis of variance (table X, appendix) indicates that there were no significant differences. There is no indication that the weights were higher for the spring and summer months, which fact might lead one to suspect that perhaps there was no real increase for this same period at 21 days of age.

Likewise, the mean weights did not vary significantly from generation to generation (table 37, figure 20), as tested by an analysis of variance.

The same general trends were observed in the litter series (tables 36 and 37) as at 21 days of age though the differences were not as great. The smaller differences are verified in the analysis of variance where the F-value for the litter series is significant at 28 days (table X) and highly significant at 21 days (table IX).

Table 35. Mean weight of young at 28 days of age, generations 10-20 inclusive, segregated as to litter series and to size of litter at 28 days

Litter series	Size of litter at 28 days	Number of litters	Total number of young	Weight of young: Total gm.	Weight of young: Mean per rat gm.
1	2	6	12	490	40.8
	3	4	12	628	52.3
	4	4	16	848	53.0
	5	11	55	2661	48.4
	6	17	102	5281	51.8
	7	23	161	7712	47.9
	8	57	456	20600	45.2
Total		122	814	38220	46.95
2	1	2	2	52	26.0
	2	3	6	346	57.7
	3	7	21	1055	50.2
	4	10	40	2281	57.0
	5	9	45	2397	53.3
	6	13	78	4355	55.8
	7	23	161	7974	49.5
	8	101	808	39328	48.7
Total		168	1161	57788	49.77
3	2	2	4	232	58.0
	3	2	6	312	52.0
	4	5	20	1087	54.4
	5	5	25	1233	49.3
	6	4	24	1340	55.8
	7	9	63	3147	50.0
	8	28	224	10885	48.6
Total		55	366	18236	49.83
1, 2, & 3	1	2	2	52	26.0
	2	11	22	1068	48.5
	3	13	39	1995	51.2
	4	19	76	4216	55.5
	5	25	125	6291	50.3
	6	34	204	10976	53.8
	7	55	385	18833	48.9
	8	186	1488	70813	47.6
Total		345	2341	114244	48.80

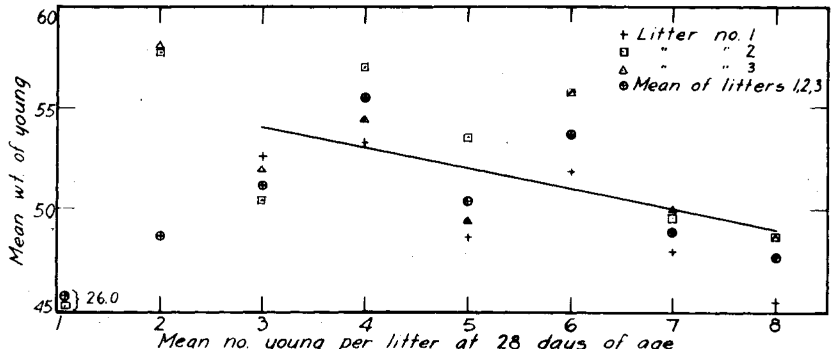

Fig 18 Regression of mean weight of young at 28 days of age on size of litter, generations 10-20 (Line drawn for litters with 3 or more young.)

No. litters observed

2 11 13 19 25 34 55 186

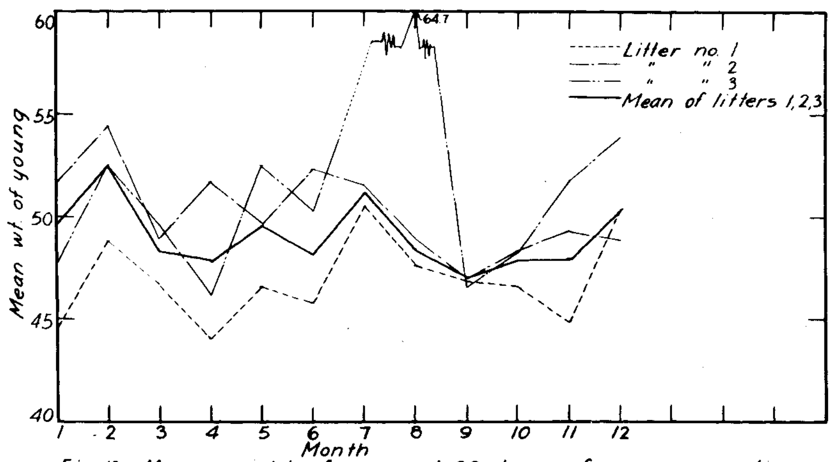

Fig 19 Mean weight of young at 28 days of age, generations 10-20, segregated as to litter series and to month.

No. litters for—line

23 13 26 18 35 25 21 53 23 60 27 21

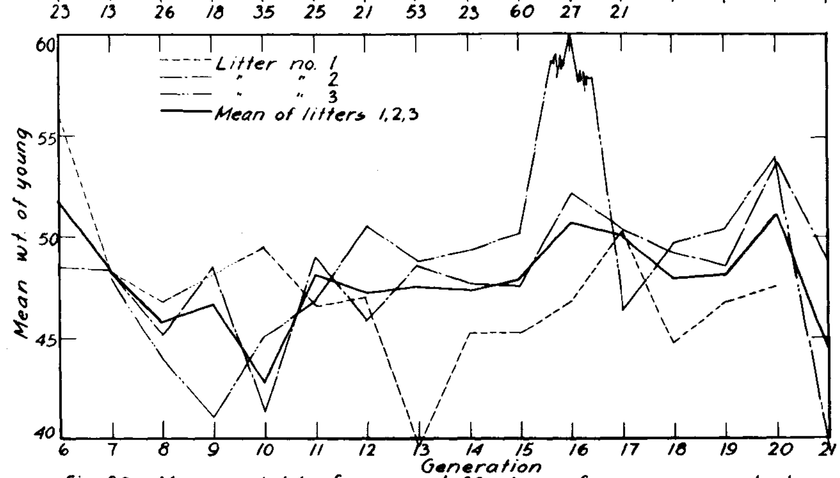

Fig. 20 Mean weight of young at 28 days of age segregated as to litter series and to generation.

No. litters for line

2 22 10 4 10 7 12 20 25 33 55 44 20 78 41 2

Table 36. Mean number of young per litter and mean weight of young at 28 days of age, generations 10-20 inclusive, segregated as to litter series and to month

Litter series	Month	Number of litters	Number of young: Total	Number of young: Mean per litter	Weight of young: Total gm.	Weight of young: Mean per rat gm.
1	1	5	35	7.0	1569	44.8
	2	4	22	5.5	1071	48.7
	3	8	54	6.8	2524	46.7
	4	3	23	7.7	1011	44.0
	5	8	48	6.0	2234	46.5
	6	15	96	6.4	4389	45.7
	7	10	61	6.1	3080	50.5
	8	34	244	7.2	11595	47.5
	9	9	44	4.9	2064	46.9
	10	10	72	7.2	3338	46.4
	11	11	80	7.3	3589	44.9
	12	5	35	7.0	1756	50.2
Total		122	814	6.67	38220	46.95
2	1	15	103	6.9	5326	51.7
	2	6	46	7.7	2498	54.3
	3	8	59	7.4	2895	49.1
	4	8	52	6.5	2689	51.7
	5	21	148	7.0	7377	49.8
	6	9	57	6.3	2975	52.2
	7	11	74	6.7	3818	51.6
	8	18	106	5.9	5293	49.9
	9	10	65	6.5	3063	47.1
	10	40	292	7.3	14070	48.2
	11	11	84	7.6	4122	49.1
	12	11	75	6.8	3662	48.8
Total		168	1161	6.91	57788	49.77
3	1	3	23	7.7	1102	47.9
	2	3	18	6.0	945	52.5
	3	10	57	5.7	2827	49.6
	4	7	52	7.4	2397	46.1
	5	6	36	6.0	1886	52.4
	6	1	8	8.0	402	50.2
	8	1	6	6.0	388	64.7
	9	4	32	8.0	1502	46.9
	10	10	66	6.6	3192	48.4
	11	5	34	6.8	1764	51.9
	12	5	34	6.8	1829	53.8
Total		55	366	6.66	18236	49.83

(Continued on next page)

Table 36 (continued)

1, 2, & 3	1	23	161	7.0	7997	49.7
	2	13	86	6.6	4514	52.5
	3	26	170	6.5	8246	48.5
	4	18	127	7.1	6097	48.0
	5	35	232	6.6	11499	49.6
	6	25	161	6.4	7766	48.2
	7	21	135	6.4	6898	51.1
	8	53	356	6.7	17276	48.5
	9	23	141	6.1	6629	47.0
	10	60	430	7.2	20600	47.9
	11	27	198	7.3	9475	47.9
	12	21	144	6.9	7247	50.3
Total		345	2341	6.79	14244	48.80

The mean weights at 28 days of age exhibited greater variability throughout than did the mean weights at 21 days of age as can be seen from comparing figures 16 and 17 with figures 19 and 20 respectively. Also, when the mean squares for error in tables IX and X are compared, the one at 28 days of age is seen to be nearly twice as great as the one at 21 days of age. The greater variation is probably explained in part by the fact that the data from fewer litters were available for examination at 28 days than at 21 days of age. It is likely due also in part to the fact that at 28 days of age more time had elapsed to allow for the appearance of individual variation. It seems likely that with each additional lapse of time up to adulthood a greater variability in the weights of the individuals would be encountered.

Table 37. Mean number of young per litter and mean weight of young at 28 days of age segregated as to litter series and to generation

Litter series	Generation	Number of litters	Number of young: Total	Number of young: Mean per litter	Weight of young: Total gm.	Weight of young: Mean per rat gm.
1	6	1	6	6.0	336	56.0
	7	11	72	6.5	3475	48.3
	8	6	35	5.8	1638	46.8
	10	1	4	4.0	198	49.5
	11	1	7	7.0	326	46.6
	12	4	28	7.0	1315	47.0
	13	2	16	8.0	632	39.5
	14	9	53	5.9	2391	45.1
	15	9	51	5.7	2299	45.1
	16	18	108	6.0	5061	46.9
	17	20	127	6.4	6370	50.2
	18	7	53	7.6	2378	44.9
	19	34	241	7.1	11267	46.8
	20	17	126	7.4	5983	47.5
Total		140	927	6.62	43669	47.11
2	6	1	8	8.0	388	48.5
	7	6	43	7.2	2076	48.3
	8	3	23	7.7	1039	45.2
	9	3	22	7.3	1068	48.5
	10	5	39	7.8	1602	41.1
	11	5	31	6.2	1518	49.0
	12	5	31	6.2	1423	45.9
	13	10	61	6.1	2961	48.5
	14	10	72	7.2	3443	47.8
	15	13	92	7.1	4376	47.6
	16	36	239	6.6	12441	52.1
	17	22	138	6.3	6958	50.4
	18	8	57	7.1	2806	49.2
	19	34	250	7.4	12143	48.6
	20	20	151	7.6	8117	53.8
	21	1	8	8.0	391	48.9
Total		182	1265	6.95	62750	49.60

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Table 37 (continued)

3	7	5	22	4.4	1061	48.2
	8	1	7	7.0	308	44.0
	9	1	7	7.0	288	41.1
	10	4	25	6.2	1127	45.1
	11	1	8	8.0	375	46.9
	12	3	17	5.7	860	50.6
	13	8	55	6.9	2685	48.8
	14	6	43	7.2	2125	49.4
	15	11	69	6.3	3458	50.1
	16	1	6	6.0	388	64.7
	17	2	12	6.0	557	46.4
	18	5	35	7.0	1743	49.8
	19	10	73	7.3	3676	50.4
	20	4	23	5.8	1242	54.0
	21	1	8	8.0	315	39.4
Total		63	410	6.51	20208	49.29
1, 2, & 3	6	2	14	7.0	724	51.7
	7	22	137	6.2	6612	48.3
	8	10	65	6.5	2985	45.9
	9	4	29	7.2	1356	46.8
	10	10	68	6.8	2927	43.0
	11	7	46	6.6	2219	48.2
	12	12	76	6.3	3598	47.3
	13	20	132	6.6	6278	47.6
	14	25	168	6.7	7959	47.4
	15	33	212	6.4	10133	47.8
	16	55	353	6.4	17890	50.7
	17	44	277	6.3	13885	50.1
	18	20	145	7.2	6927	47.8
	19	78	564	7.2	27086	48.0
	20	41	300	7.3	15342	51.1
	21	2	16	8.0	706	44.1
Total		385	2602	6.76	126627	48.67

<u>In respect to oestrus cycles</u>

<u>Length of cycle</u>. The length of the cycles was determined by noting the lapse of time from one stage in the oestrus cycle to its recurrence. The rats were observed for various periods of time, one group being observed for the entire span of life. Since the length of cycle varies with age (Earhart, 1935; Emery, 1935), it was studied in rats of four different age groups. Each time interval was of six months duration, i.e., 0-182 days, 183-365 days, etc. The first interval, 0-182 days, carried the rat through the conception of the third litter,* thus probably through the period of the greatest sexual activity. No cycles were observed after the 730th day.**

The frequency distribution of cycles of different lengths observed in a group of 275 regular stock colony rats is shown in table 38. The range in the length of cycles is seen to be fairly wide, especially with advance in age. It is interesting to note, however, that while the mean increased from 7.7 in the first interval to 44.3 in the last, the mode remained at 5 in three of the intervals and at 4 in the fourth. Apparently a cycle of about 5 days may be considered as "normal" for the group of rats studied and it is the abberations from this normal which caused the increase in the mean.

A group of unmated rats, 10 in number, was observed through the first two age intervals (table 39). Here again is noted the same tendency for the mean to increase with age while the mode remains practically the same.

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* The average age at which a positive mating occurred for the third litter was found to be 179.2 days (table 56).
**The age at which the last oestrus was observed was 722 days (table 58).

Table 38. Frequency distribution of length of oestrus cycles observed in 275 mated rats

0-182 days		183 - 365 days	
Length of cycle in days	Frequency	Length of cycle in days	Frequency
2	12	2	4
3	43	3	21
4	108	4	67
5	226	5	86
6	116	6	38
7	56	7	24
8	43	8	33
9	22	9	22
10	41	10	20
11	27	11	8
12	17	12	12
13	10	13	14
14	9	14	9
15	19	15	13
16	11	16	10
17	19	17	2
18	12	18	1
19	5	19	7
20	7	20	4
21	4	21	1
22	4	22	1
23	1	23	5
24	2	24	4
25	1	25	4
26-35	11	26	3
		27	2
67	1	28	3
		29	1
		30-39	11
		40-49	13
		50-59	7
		60-140	11
		198	1
Mean = 7.7		Mean = 13.1	
Mode = 5		Mode = 5	

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Table 58 (continued)

366-547 days		548 - 730 days	
Length of cycle in days	Frequency	Length of cycle in days	Frequency
2	3	3	1
3	4		
4	25	5	4
5	15	6	1
6	14	7	2
7	14		
8	16	9	2
9	16	10	1
10	13	11	2
11	11		
12	15	13	1
13	7	14	1
14	8	15	1
15	5		
16	6	28	1
17	1		
18	11	30-39	7
19	8	40-69	8
20	5	70-123	11
21	4		
22	6	138	1
23	4		
24	3		
25	1		
26	1		
27	3		
28	2		
29	2		
30-39	24		
40-49	11		
50-59	6		
60-69	5		
70-79	4		
80-89	3		
90-99	3		
100-150	12		
196	1		
Mean = 23.9		Mean = 44.3	
Mode = 4		Mode = 5	

Table 39. Frequency distribution of length of oestrus cycles observed in 10 unmated rats

0-182 days		183-365 days	
Length of cycle in days	Frequency	Length of cycle in days	Frequency
2	1	3	5
3	6	4	7
4	34	5	4
5	56	6	4
6	26	7	4
7	14	8	1
8	10	9	3
9	11	10	2
10	5	11	2
11	1	12	2
12	1	13	2
13	3	14	1
14	1	15	1
15	1	16	2
16	1	17	1
17	3		
		23	1
27	1	24	1
28	1		
29	1	26	2
47	1	29	1
		30-39	3
72	1	40-49	6
		53	1
		54	1
		55	1
Mean = 7.2		Mean = 16.9	
Mode = 5		Mode = 4	

The mode for the first interval was identical with that found in the mated rats. Table 40 presents in a summary form a portion of the information obtained from the two groups.

Table 40. Summary table of the frequency distribution of length of oestrus cycles observed in 275 mated and 10 unmated rats

	Age interval in days	Number of rats	Cycles Number	Sum	Mean in days	Mode in days
Mated rats	0-182	235	827	6407	7.7	5
	183-365	122	462	6072	13.1	5
	366-547	73	292	6989	23.9	4
	548-730	21	44	1949	44.3	5
Unmated rats	0-182	10	179	1280	7.2	5
	183-365	9	58	978	16.9	4

The average length of the oestrus cycles observed in the present study are longer than those reported from a number of other laboratories. Long and Evans (1922) reported a mean of 5.4 with a mode of 4 on 1999 cycles which they observed. Evans and Bishop (1922), on a more select group of rats which were fed diets either of table scraps or a standard diet made up largely of whole wheat, casein, and whole milk, reported a mean of 5.4 with a mode of 5 on 1000 cycles. The range was from 3 to 49. Lee (1926) found an average cycle of 4.8 days in a group of 47 rats observed between the ages of 120 and 180 days, an interval similar to the first interval used in the present study. The average length of cycle in 16 rats was found by Emery (1935) to increase slightly from the sixth month through the twelfth. The lowest average found was 4.5 days for the sixth month, the longest 6.4 for the tenth month.

Tables 41 and 42 give the percentage distribution when the cycles are grouped into periods of different lengths. (These particular intervals were chosen because they had been used previously in the meat studies carried on in the Nutrition Laboratory.) In the mated rats the percentage distribution was practically reversed in the first

Table 41. Percentage distribution of length of oestrus cycles in 275 mated rats

Length of cycle in days	0-182 days Cycles No.	Per cent	183-365 days Cycles No.	Per cent	366-547 days Cycles No.	Per cent	548-730 days Cycles No.	Per cent
2-6	505	61.1	216	46.8	61	20.9	6	13.6
7-10	162	19.6	99	21.4	59	20.2	5	11.4
11-15	82	9.9	56	12.1	46	15.8	5	11.4
16 and over	78	9.4	91	19.7	126	43.1	28	63.6
Total	827	100.0	462	100.0	292	100.0	44	100.0

and last age intervals. 61.1% of the cycles were 2-6 days in length in the first age interval; 63.6%, 16 days and over in the last age interval. Intermediate values were found in the other two intervals. The percentage distribution in the unmated rats (table 42) followed a similar pattern. However, a chi-square test indicates that the differences in the percentage distributions in the mated and unmated rats are significant:

Age interval	X	DF	P
0-182 days	11.234	3	1%
183-365 days	7.536	3	5%

In the first interval in the mated rats 80.7% of the cycles were less than 10 days in length, while in the unmated rats 91.1% were of this length. In the second interval, however, the mated rats showed a greater percentage of the shorter cycles, 68.2% against 51.7%.

Table 42. Percentage distribution of length of oestrus cycles in 10 unmated rats

Length of cycle in days	0-182 days Cycles		183-365 days Cycles	
	Number	Per cent	Number	Per cent
2-6	123	68.7	20	34.5
7-10	40	22.4	10	17.2
11-15	7	3.9	8	13.8
16 and over	9	5.0	20	34.5
Total	179	100.0	58	100.0

Whether these facts have any physiological significance is questionable. They may be only a peculiarity of this particular set of data since the number of unmated rats studied was small.

Evans and Bishop (1922) found that the cycles varying in length from 3 to 6 days included 89.5% of all the cycles observed. The greatest percentage of cycles in a 2 to 6 day grouping in the present study was 61.1% (table 41). 85% of the cycles which Emery (1935) observed were 6 days or less in length.

Number of days elapsing from parturition to the appearance of the next oestrus. The number of days elapsing from parturition to the appearance of the next oestrus was determined. The average for 391 cases was found to be 31.5 days (table 43), indicating that in general, oestrus appeared soon after the weaning of the litter. Oestrus, normally occurring on the day of parturition, was observed only occasionally, probably due to the plan of procedure. However, Donaldson (1924) states that it is

Table 43. Days from parturition to next oestrus, young suckled

Litter series	Number of cases	Days from parturition to next oestrus Mean
1	111	30.0
2	136	31.6
3	60	30.4
4	38	33.7
5	29	35.0
6	14	33.9
7	3	30.3
Total	391	31.5

only from April to October that females ovulate regularly 15-24 hours after parturition. Such cases were not included in the above average. The shortest time observed was 19 days, the longest 56.

Table 43 shows the mean number of days from parturition to the next oestrus for the successive litters when the young were suckled. An analysis of variance (table 44) indicates that these means differ significantly from one another. Following the suckling period for the

Table 44. Analysis of variance of the days from parturition to the next oestrus, following suckling of the litter, for successive litters

Source of variation	Degrees of freedom	Mean square
Total	390	
Between litter series	6	156.96*
Within litter series	384	61.64

F = 2.55

first three litters oestrus reappeared in an orderly and rhythmical fashion. As the rats grew older there was a slowing up of the reproductive function as reflected in the re-establishment of the oestrual cycle. The figure for the seventh litter was drawn from such a few cases that it is practically meaningless.

If the litter died during lactation, oestrus reappeared much earlier, the average figure for 95 cases being 11.7 days (table 45). The means for the litter series show no discernible trends. The data were

Table 45. Days from parturition to next oestrus, young not reared

Litter series	Number of cases	Days from parturition to next oestrus Mean
1	45	9.4
2	16	12.6
3	13	11.7
4	16	13.4
5	2	36.0
6	1	9.0
7	1	17.0
8	1	25.0
Total	95	11.7

so heterogeneous that an analysis did not seem to be warranted.

Long and Evans (1922) found the interval between weaning and the next oestrus to vary from 3.4 to 14.5 days depending on the size of the litter which had been suckled. These figures agree fairly well with those found in the present study if 28 days be deducted from the means in table 43. The figures thus obtained vary from 2.0 to 7.0 days with an average of 3.5.

In respect to mating tendencies

Fertility per cent. The ratio of the number of successful parturitions to the number of positive matings has been used by Evans and Bishop (1923) and others as an index of fertility in the female rat. If the whole of the data in the present study is considered, there were 638 litters obtained from 708 positive matings yielding a fertility per cent of 90.1. However, if the fertility of the female is considered at successive pregnancies it can be seen (table 46) that the index for litter 1 is 81.3%, a lower value than for the other litters.

Table 46. Fertility per cent for successive litters

Litter series	(a) Number of matings	(b) Number positive matings	(c) Number of litters	(c)/(b) Fertility per cent	(b)/(a)
1	541	262	213	81.3	48.4
2	283	219	212	96.8	77.4
3	148	109	103	94.5	73.6
4	107	57	55	96.5	53.3
5	70	38	33	86.8	54.3
6	31	18	17	94.4	58.1
7	5	4	4	100.0	80.0
8	2	1	1	100.0	50.0
Total	1187	708	638	90.1	59.6

When the fertility of the female at various litterings was examined throughout several generations, the fertility of the animal showed decided differences only in litter 1. Hence, the fertility per cents for first litters were divided as to generation, as shown in table 47, and tested for significant differences. A chi-square of 14.50 with

Table 47. Fertility per cent by generation in litter 1

Generation	Number of positive matings	Number of litters X	Fertility per cent p	Products pX
13	23	18	78.2609	
14	21	19	90.4762	
15	28	25	89.2857	
16	45	39	86.6667	
17	32	30	93.7500	
18	23	19	82.6087	
19	53	37	69.8113	
20	36	25	69.4444	
	261	SX = 212	$\bar{p}$ = 81.2261	SpX=17,441.0812

$$X^2 = \frac{100(SpX - \bar{p}SX)}{\bar{p}(100 - \bar{p})} = \frac{100(17,441.0812 - 17,219.9332)}{(81.2261)\ (18.7739)}$$

$$= 14.50,\ df = 7,\ p = 5\%$$

seven degrees of freedom indicates a significant difference in the generations. Generations 19 and 20 showed considerably lower percentages than did any of the others. This fact might lead one to suspect that the fertility of the stock is decreasing. However, it would be necessary to determine the fertility per cents for the generations to follow before such a statement could be made with certainty. It may be that for some unknown reason these particular generations exhibited a lower fertility.

Because of the low values found in generations 19 and 20, these were removed (as well as generation 12 for which only a small amount of data on the earlier litters was recorded) and the litter differences in fertility per cents again examined as shown in table 48. The litter series still show significant differences in fertility per cents as indicated by the chi-square test. Litter 1 is still low in comparison to all the others except litter 5. Such a low figure may be a characteristic of first litters only in the particular colony studied. It

Table 48. Fertility per cent for successive litters, generations 13-18, inclusive

Litter series	(b) Number positive matings	Number of litters X	Fertility per cent p	(a) Number of matings	(a)/(b)
1	172	150	87.2093	337	51.0
2	147	143	97.2789	186	79.0
3	82	77	93.9024	115	71.3
4	46	44	95.6522	83	55.4
5	30	25	83.3333	58	51.7
6	13	12	92.3077	25	52.0
7	3	3	100.0000	4	75.0
8	1	1	100.0000	2	50.0
	494	SX = 455	$\bar{p}$ = 92.1053	810	61.0

SpX = 42,022.4842

X^2 = 15.757, df = 7, p = 3%

may be due to the fact that the rats were mated while still very young, that is, at sexual maturity as shown by the opening of the vagina at which time all maturation processes may not be completed. Supporting evidence for this premise is found in a study relating to a group of 14 rats mated at three months compared with litter mate controls mated at sexual maturity. The fertility per cent for litter 1 is found to be 92.9 in the one case as against 82.4 in the other (table 49). If one resorption is deducted from the figure for the three months rats the per cent becomes 100.0. If fertility is through of as referring to viability of ova it would be correct to use the latter figure, though strictly speaking this is not the fertility per cent of Evans and Bishop (1923). However, in neither case does the chi-square test indicate that

Table 49. Fertility per cents of 14 rats mated when three months old, compared with litter controls mated at sexual maturity

Litter series	3-months old rats: Number positive matings	Number of litters	Fertility per cent	Control rats: Number positive matings	Number of litters	Fertility per cent
1	14	13	92.9	17	14	82.4
Less one resorption	13	13	100.0			
2	14	13	92.9	14	14	100.0

the percentages in the two groups differ significantly. A larger number of rats treated similarly would be necessary to determine whether the indicated difference is real or due merely to chance variation.

In a study in which female rats were first mated when 110 to 120 days old, Smith, Anderson, and Hubbell (1938) found only two groups (averaging about 18 rats per group) out of the 27 examined that showed evidence of lower fertility per cents for first matings. In these two groups the figures obtained for first matings were 16.7% and 47.4%, which would be considered very low inasmuch as the average figures for four matings were 45.5% and 75.0% respectively. The two groups were members of the third generation, seven being studied in all. A statement is made that "During the period of the third, and extending over to the fourth and fifth generations, undetermined influences brought about a decrease in the percentage of fertility of a large number of rats bred at those times" (p. 91). The average fertility per cent of the rats belonging to the Connecticut Station based on all of the groups studied was 88 (an average derived from the percentages given, not from the original figures). The group showing the best performance had a fertility per cent of 91.8; the one showing the poorest, 80.4. The slightly higher figures obtained in the present study may result from some confusion in the use of the term "percentage of fertility." Smith, Anderson, and Hubbell define the "percentage of fertility" as the "relationship of the fertile to the total matings." It is uncertain whether their term "mating" can be understood to mean a positive mating as evidenced by the presence of sperm in the vaginal smear or other copulatory sign.

Evans and Bishop (1923) reported an average fertility of 83.6%. Slonaker (1931) found the fertility per cents to decrease from 96 to 50 as the percentage of the protein in the diet was increased. Mendel and Hubbell (1935) also have reported changes coincident with changes in the ration. For instance, the per cent of fertile matings in the Connecticut colony rats was 86 in 1912, 65 in 1919, 68 in 1925, and 93 in 1935.

The greatest number of positive matings that was observed before a pregnancy was induced was four. This figure was found only once and for a first litter. Three positive matings were observed twice for first litters. Never more than two positive matings per litter were needed for other than first litters.

Ratio of positive matings to total number of matings. When the ratio of the number of positive matings to the total number of matings is determined (tables 46 and 48) litter 1 is again found to yield a low value. If, as seems to be the case, the males of the colony studied mature at a later age than do the females, the first positive mating would be associated with the maturity of the male rather than that of the female, since only brother and sister matings were made. Another explanation for the low figures obtained throughout for this ratio may lie in the possibility that the stage of the oestrus cycle suitable for mating was not always correctly ascertained.

Sterility. Of the total number of 233 rats observed, six were found to be sterile. Out of 641 conceptions there were three resorptions. If the three positive matings in connection with the resorptions and three observed on one sterile rat are added to the total (table 58) the fertility per cent is lowered slightly to 89.4. The ratio of (b)/(a) is also lowered to 55.8.

In respect to sexual maturity and activity

Opening of the vagina and first oestrus. The occurrence of the first oestrus is an indication of the first ovaluation and hence of sexual maturity. This event may or may not be coincident with the opening of the vagina but never precedes it (Long and Evans, 1922). In the present study the mean age for the opening of the vagina was found to be 41.3 days (table 50), while that for the first oestrus

Table 50. Frequency distribution of the age and weight at the opening of the vagina of 233 rats

Age in days	Frequency
33	1
34	4
35	7
36	13
37	28
38	22
39	31
40	13
41	17
42	16
43	12
44	14
45	11
46	5
47	4
48	6
49	5
50-59	13
73	1
Mean = 41.3	
Mode = 39	

Weight in grams	Frequency
64.5	12
74.5	47
84.5	84
94.5	48
104.5	17
114.5	9
124.5	5
136	1
Mean = 86.7	
Mode = 84.5	

was 47.9 days (table 51), a difference of 6.6 days. However, from inspection of table 52, which gives the distribution of days from the opening of the vagina to the first oestrus, it can be seen that in the

Table 51. Frequency distribution of the age at first oestrus of 223 rats

Age in days	Frequency
36	2
37	5
38	4
39	10
40	5
41	13
42	16
43	11
44	10
45	19
46	17
47	16
48	11
49	8
50	9
51	9
52	7
53	7
54	6
55	8
56	3
57	6
58	2
59	3
60-75	15
77	1

Mean = 47.9
Mode = 45

greatest number of cases, first oestrus was coincident with the rupture. The frequency shows a gradual decline up to the thirteenth day with scattered cases to the thirty-fourth. Evans and Bishop (1922) found a much closer agreement between the ages at the opening of the vagina and first oestrus with means of 46.8 and 47.3 days respectively.

Table 52. Frequency distribution of the number of days elapsing from the opening of the vagina to the first oestrus in 223 rats

Days	Frequency
1	30
2	16
3	20
4	27
5	25
6	18
7	16
8	6
9	7
10	10
11	8
12	7
13	4
14	1
15	4
16	3
17	4
18	1
19	2
20-32	13
34	1

Mean = 7.2
Mode = 1

The discrepancy in the two cases may be more apparent than real. It is possible that in the present study the stage of the cycle at first oestrus might have been missed in some cases since observations were made only once in every 24 hours.

The mean age for the opening of the vagina, 41.3 days, was almost identical with that, 42.1 days, observed by Rigdon (1936) on 250 albino rats. Rigdon found no evidence of seasonal variation. Macy, et al., (1927) found the rupture to occur between the 35th and 42nd days. Long and Evans in their earlier work (1922) observed a mean of 76.5 days in 466 rats, one of 72 days in another group of 200 rats. Guilbert and Goss (1932) noted that sexual maturity took place when the female was about 50 days of age.

Slonaker (1939) observed a wide range, from 23 to 154 days, in the age at the opening of the vagina. The average ages varied somewhat, though not markedly, with the percentages of protein in the diet:

Protein per cent	Age at the opening of the vagina
10.3	70.8
14.2	61.4
18.2	60.2
22.2	63.8
26.3	62.4

The least amount of protein seems to have delayed sexual development.

The weight of the rat at the opening of the vagina was found to exhibit considerable variability, showing a mean of 86.7 gm. (table 50).

Mating. Since the rats were not mated until the second oestrus, a period of time, 8 days on the average (tables 51 and 53), elapsed between the first oestrus and the first mating. There was still further delay in obtaining a positive mating. The average age at first mating for this

Table 53. Frequency distribution of the age at first mating of 217 rats

Age in days	Frequency
42	2
44	3
45	3
46	4
47	8
48	9
49	8
50	16
51	12
52	20
53	10
54	15
55	15
56	13
57	7
58	5
59	7
60	9
61	5
62	8
63	5
64	6
65	6
66	5
67	8
68-78	6
94	1
108	1

Mean = 55.9
Mode = 52

colony was 55.9 days while that of the first positive mating was 66.8 days (table 54), a difference of 10.9 days. A study of the distribution of days in the interval elapsing from the first oestrus to the

Table 54. Frequency distribution of the age and weight at the first positive mating of 213 rats

Age in days	Frequency
45-46	2
53	7
56	20
59	35
62	30
65	29
68	25
71	17
74	19
77	6
80	6
83	7
86	3
89	3
106-125	4

Mean = 66.8
Mode = 35

Weight in grams	Frequency
91	1
109.5	29
119.5	40
129.5	56
139.5	40
149.5	33
159.5	12
177-180	2

Mean = 132.1
Mode = 129.5

first positive mating (table 55) indicates quite a uniform spread up to 30 days. The one-day interval, however, was responsible for 17 of the 23 in the first class. The longest interval observed was 74 days.

The weight again was found to be quite variable (table 54), the average weight at the first positive mating being 132.1 gm.

Mean ages and weights of the female rats at positive matings for successive litters are shown in table 56. Intervals from one pregnancy to another remained nearly constant. Apparently the female rat maintained her sexual vigor so far as ability to conceive is concerned up to the age of 300 to 350 days. The variation in the last three litters

Table 55. Frequency distribution of days elapsing from first oestrus to first positive mating in 208 rats

Days	Frequency
3	23
8	24
13	36
18	47
23	30
28	24
33	11
38	6
43	3
64-74	3

Mean = 18.5
Mode = 18

may be due to the small number of litters observed. The differences in mean weight showed a progressive decrease which is to be expected, since the gain in weight is made at a consistently lower rate with advancing age.

Table 56. Age and weight of female rat at positive mating for successive litters

Litter series	Number of litters	Mean age in days	Difference	Mean weight in grams	Difference
1	218	72.6		140.5	
2	212	125.3	52.7	179.1	38.6
3	103	179.2	53.9	193.9	14.8
4	55	236.8	57.6	207.8	13.9
5	33	293.8	57.0	214.8	7.0
6	17	342.3	48.5	221.6	6.8
7	4	412.0	69.7	219.2	-2.4
8	2	487.0	75.0	225.5	6.3

The weight at maturity of the females of the colony was approximately 220 gm.

Slonaker (1939) found group averages for the age of the female at the birth of first litters to vary from 168 to 273 days with the various levels of protein in the diet. An increase in the amount of protein delayed the time at which the litters were born. If 22.3 days, the average length of the gestation period observed in the present study, be added to 72.6, the mean age at positive mating of first litters, the mean age for birth of first litters is found to be 94.9 days, a considerably lower figure than that found by Slonaker.

There was no indication that the age and weight at positive mating varied either from generation to generation or from month to month.

Reproductive span. The reproductive span, or days from the first to the last positive matings resulting in litters, was observed on 112 rats which were mated as long as oestrus persisted as shown by the vaginal smear. This span showed a wide range, varying from 39 to 413 days (table 57). However, the data show an approximately normal distribution with a mean of 197.1 days. The reproductive spans observed by Slonaker (1939) varied with the percentage of protein in the diet as follows:

Protein per cent	Reproductive span in days
10.3	221
14.2	239
18.2	197
22.2	134
26.3	207

The two groups with the smallest percentages of protein gave the longest reproductive spans. Slonaker concludes that diets with 18.2% or more of protein interfered with reproduction by shortening the reproductive span.

Table 57. Frequency distribution of the length of the reproductive span of 112 rats

Days	Frequency
39	1
51-100	18
101-150	17
151-200	24
201-250	20
251-300	17
301-350	8
351-400	4
400-450*	3
Mean = 197.1	

*Longest span = 413 days

<u>Final oestrus</u>. Periods of oestrus were observed for a considerable time after the last positive mating occurred. A wide range in the age of the rats at the time of the final oestrus was also observed, the lowest value being 160 days and the highest 722 in a group of 57 rats (table 58). The frequency distribution based on these data is quite flat, the mean lying at 440.0 days.

<u>Life span</u>. A group of 51 female rats were allowed to live out their natural life spans. The earliest age at which one of the rats died was 207 days, the latest 1103 days, or a little over three years.

Table 58. Frequency distribution of the age at last oestrus of 57 female rats

Age in days	Frequency
160	1
188	1
250	9
350	13
450	13
550	11
650	8
722	1
Mean = 440.0	

The distribution (table 59) shows scarcely any peak with a mean at 618.5 days.

Table 59. Frequency distribution of the age at death of 51 female rats

Age in days	Frequency
207-300	3
350	10
450	7
550	5
650	7
750	3
850	8
950	4
1001-1103	4
Mean = 618.5	

In respect to intra-uterine behavior

Implantation and placental per cents. Certain easily observable signs and calculated indexes may be considered as indicative of intra-uterine behavior during the course of gestation. Long and Evans (1922) consider the "placental leak" to be the earliest infallible sign of established pregnancy. Usually at some time between the 12th and 15th day of gestation free blood may be observed in the vagina as well as red blood cells in the smear. If this leak is observed it can be assumed that implantation has been successful and the placental function established. Evans and Bishop (1923) calculated two indexes from the information thus afforded:

$$\text{Implantation \%} = \frac{\text{Implantations}}{\text{Positive matings}}$$

$$\text{Placental \%} = \frac{\text{Litters born}}{\text{Implantations}}$$

Table 60 gives these indexes calculated from the data obtained in the present study. The only evidences of implantations other than those assured by the birth of litters were in the three resorptions noted. Hence, the number of implantations was 641. If the one sterile rat which exhibited abnormal behavior is disregarded, the implantation per cent is 90.2, nearly identical with the fertility per cent. The inclusion of the sterile rat lowers the figure only slightly. The only evidence of placental failure was likewise in the three resorptions. However, it is difficult to distinguish with certainty between resorptions and pseudo-pregnancies (described below) unless the uterus is examined at autopsy for resorption sites. It is possible that some of the pseudo-pregnancies should have been designated as resorptions. The latter can usually be distinguished by a slow decline in weight in contrast to the precipitous drop observed at the birth of a litter.

Table 60. Implantation and placental per cents

	(a) Number of matings	(b) Number positive matings	(c) Number of litters	(d) Number of implantations	(c)/(b) Fertility %	(d)/(b) Implantation %	(c)/(d) Placental %
Total from table 46	1187	708	638	638	90.1		
Resorptions	4	3	0	3			
Total	1191	711	638	641		90.2	99.5
Sterile	88	3	0				
Grand total	1279	714	638	641	89.4	89.8	

The implantation per cent of 90.2 is somewhat higher than that of 85.7 found by Evans and Bishop (1923). The placental indexes, 99.5% and 97.5%, observed in the two laboratories were nearly the same.

Pseudo-pregnancy. Following non-fertile matings or undue stimulation of the cervical canal, rats sometimes exhibit what is known as pseudo-pregnancy. During this time the vaginal smear is that of typical dioestrus, the regular ovulation rhythm having temporarily ceased. The pseudo-pregnancies observed varied from 9 to 25 days in length.

Gestation period. The length of gestation period was found to cover a very narrow range (table 61), 71% of all the observations falling in the 22 day period ($\pm$ 12 hours). The shortest period observed, as noted in whole days, was 21, the longest 25. An analysis of variance

Table 61. Frequency distribution of the length of gestation period in 641 pregnancies

Days	Frequency
21	10
22	458
23	146
24	26
25	1
Total	641

Mean = 22.3
Mode = 22

(table 63), omitting litter 8, indicates that the mean lengths (table 62) of successive gestation periods differ significantly from one another. In fact, the F value falls just short of the 1% point, the

Table 62. Length of gestation period showing means for successive litters

Litter series	Number of cases	Length of gestation period in mean number of days
1	216	22.20
2	212	22.29
3	103	22.34
4	55	22.42
5	33	22.42
6	17	22.65
7	4	22.25
8	1	23.00
Total	641	22.30

point which indicates high significance. If litters 6, 7, and 8 are omitted so that the high mean, 22.65, for litter 6 is not included in

Table 63. Analysis of variance of the length of gestation period for successive litters, omitting litter 8

Source of variation	Degrees of freedom	Mean square
Total	639	
Between litter series	6	0.9179*
Within litter series	633	0.3256

F = 2.82

the analysis, the means for the remaining litters are still found to differ significantly from one another (table 64). However, some error was undoubtedly introduced into the mean values due to the fact that

Table 64. Analysis of variance of the length of gestation period for successive litters, omitting litters 6, 7, and 8

Source of variation	Degrees of freedom	Mean square
Total	618	
Between litter series	4	0.8400*
Within litter series	614	0.3183

F = 2.64

the length of the gestation period was recorded in whole days. For greater accuracy the exact times of conception and parturition would need to be noted. Apparently there was a tendency for the gestation period to increase slightly with each successive pregnancy.

The average gestation period of 22.3 days occupies an intermediate position compared to those found in other laboratories. Long and Evans (1922) found a mean length of 21.8 days with a mode of 22 days, the latter being identical with that found in the present study. The range was from 20 to 24 days. Macy, et al., (1927) observed a gestation period of 23 days. The averages in the different groups observed by Slonaker (1931) varied from 22.4 to 22.8 days. The shortest period which he observed was 20 days, the longest 25 days.

Lactating Behavior

The lactating behavior of an animal such as the rat can be determined only indirectly, that is, at least for a group of animals maintained as a stock colony. Various indexes have been used to determine the relative success or failure of lactation. The number and percentage of young reared would seem to furnish some information though it is plain to be seen that lactation would not be the sole determining factor here. It has been assumed by some that the weight of the young at weaning is a suitable index. Smith, Anderson, and Hubbell (1938) state that the "data on weaning weights indicate that . . .lactation was highly satisfactory" (p. 92). However, the weaning weights are influenced by the amount of the ration which is consumed by the young as well as by the quantity and quality of the mother's milk. Daggs (1935) has suggested that the gain in the weight of the young from the fourth to the seventeenth day of age is a suitable figure to use to determine efficiency of lactation. He states that during the first three or four days of life there is considerable variation in the weight of the young due to dehydration and also to the stabilization of the habits of the mother. After the seventeenth day of age the young begin to eat the mother's ration.

The gains in the weight of the mother while suckling the young would also seem to furnish some information relative to lactation. The gain from parturition to the twenty-fourth day of lactation was used by Slonaker (1939) as an index; that from parturition to the twenty-first day by Macomber (1933). For the reasons given in relation to the gain in weight of the young, the gain in the weight of the mother from the fourth to the seventeenth day of lactation would seem to be a suitable figure to use.

The gain in the weight of both the young and the mother from the fourth to the seventeenth day of lactation were selected to be used in the present study as suitable indexes of the lactating behavior of the females of the colony. These same indexes, along with certain others, were employed by Gray (1936) in her study of the lactating ability of a portion of the rats which were used in the meat studies conducted in the Nutrition Laboratory of the Foods and Nutrition Department at Iowa State College.

<u>As reflected in gain in weight of young</u>

<u>Gain in weight of young from 4 to 17 days of age</u>. Having available only the total litter weights and the number of young per litter, it was again necessary to use the mean gains of the young. The relationship of the mean gain of the young to the size of the litter is indicated in table 65 and figure 21. It can be seen that, disregarding the small litters, the individual rats gained less as the size of the litter increased. As shown by the regression coefficient, the decrease amounted to 1.1238 gm. for each increase of one in the size of the litter. The necessary calculations may be shown as follows:

Table 65. Mean gain in weight of young from 4-17 days of age, segregated as to litter series and to size of litter at 17 days

Litter series	Size of litter at 17 days	Number of litters	Total number of young	Gain in weight: Total gm.	Gain in weight: Mean per rat gm.
1	1	1	1	6	6.0
	2	3	6	83	15.8
	3	6	18	293	16.3
	4	4	16	293	18.3
	5	7	35	625	17.9
	6	13	78	1253	16.1
	7	20	140	2267	16.2
	8	49	392	5737	14.6
Total		103	686	10557	15.39
2	1	2	2	13	6.5
	2	1	2	37	18.5
	3	3	9	196	21.8
	4	6	24	481	20.0
	5	8	40	755	18.9
	6	12	72	1280	17.8
	7	19	133	2159	16.2
	8	81	648	10318	15.9
Total		132	930	15239	16.39
3	2	2	4	93	23.2
	3	1	3	77	25.7
	4	2	8	163	20.4
	5	6	30	569	19.0
	6	4	24	422	17.6
	7	9	63	1098	17.4
	8	32	256	4061	15.9
Total		56	388	6483	16.71
1, 2, & 3	1	3	3	19	6.3
	2	6	12	213	17.8
	3	10	30	566	18.9
	4	12	48	937	19.5
	5	21	105	1949	18.6
	6	29	174	2955	17.0
	7	48	336	5524	16.4
	8	162	1296	20116	15.5
Total		291	2004	32279	16.11

$Sx^2 = 52.5000$ $\quad$ $Sxy = -59.0000$ $\quad$ $Sy^2 = 119.0978$

$$b = Sxy/Sx^2 = \frac{-5.9}{52.5}$$

$$= -1.1238 \text{ gm., the regression coefficient}$$

$$E = \overline{y} + b(X-\overline{x})$$

$$= 18.11 - 1.1238(X-5.50)$$

$$= 24.29 - 1.1238X, \text{ the regression equation}$$

$$r = -0.7461^{**}, \text{ df} = 16$$

To determine whether any seasonal variation existed, the mean gains in the weight of the young were arranged by litter series and by month as in table 66 and figure 22. No marked variations can be noted in the monthly mean gains, which observation is verified by an analysis of variance (table XI) which indicates that these means did not differ significantly from one another.

The mean gains in weight for the several generations showed somewhat greater variability (table 67, figure 23). An analysis of variance (table XII) indicates that this variation was significant. The lowest mean gain, 15.1 gm., was yielded by generation 14, the highest, 16.9 and 16.8 gm., by generations 16 and 18 respectively.

That the mean gains varied with the litter series can be seen from any of the foregoing tables and figures. In the litter series by month analysis of variance (table XI) the differences were found to be significant, in the litter series by generation analysis (table XII) highly significant. The mean gain increased with each of the litters of the series. Apparently the mother rat was better able to care for her young as she became more mature, at least up to the age at which she bore her third litter.

Table 66. Mean number of young per litter and mean gain in weight of young from 4-17 days of age, segregated as to litter series and to month

Litter series	Month	Number of litters	Number of young: Total	Number of young: Mean per litter	Gain in weight: Total gm.	Gain in weight: Mean per rat gm.
1	1	8	56	7.0	821	14.7
	2	7	46	6.6	795	17.3
	3	12	78	6.5	1326	17.0
	4	9	63	7.0	982	15.6
	5	8	53	6.6	830	15.7
	6	11	70	6.4	1014	14.5
	7	6	37	6.2	551	14.9
	8	15	101	6.7	1497	14.8
	9	9	53	5.9	818	15.4
	10	6	43	7.2	608	14.1
	11	10	71	7.1	1074	15.1
	12	2	15	7.5	241	16.1
Total		103	686	6.66	10557	15.39
2	1	10	66	6.6	1166	17.7
	2	6	48	8.0	761	15.9
	3	10	75	7.5	1224	16.3
	4	9	60	6.7	1044	17.4
	5	22	161	7.3	2687	16.7
	6	9	58	6.4	990	17.0
	7	12	88	7.3	1345	15.3
	8	13	80	6.2	1294	16.2
	9	3	19	6.3	308	16.2
	10	17	116	6.8	1943	16.8
	11	8	62	7.8	991	16.0
	12	13	97	7.5	1486	15.3
Total		132	930	7.05	15239	16.39
3	1	7	49	7.0	870	17.8
	2	8	57	7.1	866	15.2
	3	13	79	6.1	1374	17.4
	4	5	39	7.8	653	16.7
	5	5	32	6.4	606	18.9
	6	2	16	8.0	263	16.4
	8	3	23	7.7	341	14.8
	9	3	24	8.0	344	14.3

(Continued on next page)

Table 66 (continued)

3	10	3	21	7.0	350	16.7
cont.	11	1	6	6.0	111	18.5
	12	6	42	7.0	705	16.8
Total		56	388	6.93	6483	16.71
1, 2,	1	25	171	6.8	2857	16.7
& 3	2	21	151	7.2	2422	16.0
	3	35	232	6.6	3924	16.9
	4	23	162	7.0	2679	16.5
	5	35	246	7.0	4123	16.8
	6	22	144	6.5	2267	15.7
	7	18	125	6.9	1896	15.2
	8	31	204	6.6	3132	15.4
	9	15	96	6.4	1470	15.3
	10	26	180	6.9	2901	16.1
	11	19	139	7.3	2176	15.7
	12	21	154	7.3	2432	15.8
Total		291	2004	6.89	32279	16.11

Table 67. Mean number of young per litter and mean gain in weight of young from 4-17 days of age, segregated as to litter series and to generation

Litter series	Generation	Number of litters	Number of young		Gain in weight	
			Total	Mean per litter gm.	Total	Mean per rat gm.
1	13	6	38	6.3	494	13.0
	14	12	82	6.8	1153	14.1
	15	20	130	6.5	1993	15.3
	16	25	158	6.3	2613	16.5
	17	25	168	6.7	2572	15.3
	18	9	69	7.7	1125	16.3
	19	6	41	6.8	607	14.8
Total		103	686	6.66	10557	15.39

(Continued on next page)

Table 67 (continued)

2	12	3	24	8.0	388	16.2
	13	16	109	6.8	1696	15.6
	14	16	121	7.6	1852	15.3
	15	21	153	7.3	2432	15.9
	16	37	256	6.9	4370	17.1
	17	23	151	6.6	2572	17.0
	18	11	81	7.4	1364	16.8
	19	5	35	7.0	565	16.1
Total		132	930	7.05	15239	16.39
3	12	6	41	6.8	695	17.0
	13	14	98	7.0	1686	17.2
	14	12	85	7.1	1358	16.0
	15	16	106	6.6	1747	16.5
	17	1	8	8.0	134	16.8
	18	7	50	7.1	863	17.3
Total		56	388	6.93	6483	16.71
1, 2, & 3	12	9	65	7.2	1083	16.7
	13	36	245	6.8	3876	15.8
	14	40	288	7.2	4363	15.1
	15	57	389	6.8	6172	15.9
	16	62	414	6.7	6983	16.9
	17	49	327	6.7	5278	16.1
	18	27	200	7.4	3352	16.8
	19	11	76	6.9	1172	15.4
Total		291	2004	6.89	32279	16.11

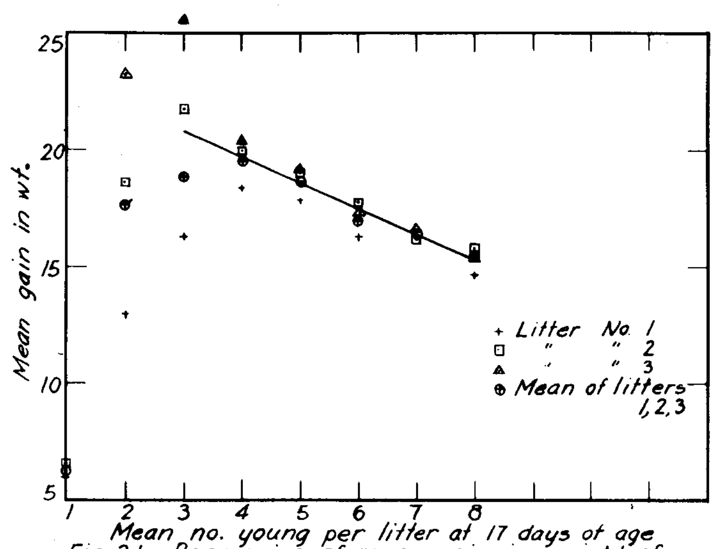


Fig. 21 Regression of mean gain in weight of young from 4-17 days of age on size of litter at 17 days. (Line drawn for litters with 3 or more young.)

No. litters observed

3 6 10 12 21 29 48 162

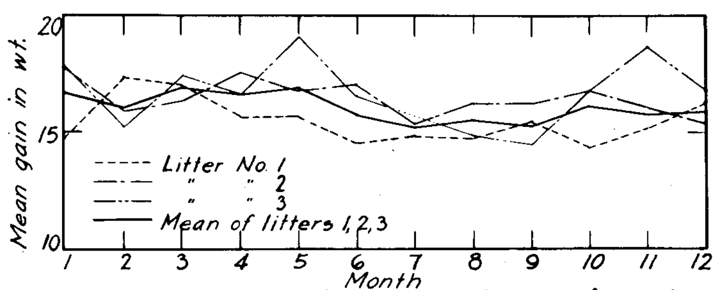


Fig. 22 Mean gain in weight of young from 4-17 days of age, segregated as to litter series and to month.

No. litters for —— line

25 21 35 23 35 22 18 31 15 26 19 21

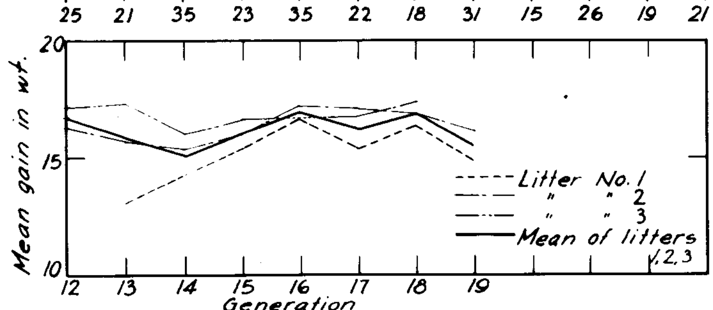


Fig. 23 Mean gain in weight of young from 4-17 days of age, segregated as to litter series and to generation.

No. litters for —— line

9 36 40 57 62 49 27 11

<u>As reflected in gain in weight of mother</u>

<u>Gain in weight of mother from 4th to 17th day of lactation</u>. Contrary to expectation, the gain in the weight of the mother from the 4th to the 17th day of lactation showed no correlation with the size of the litter (table 68, figure 24). The regression line is practically straight. Slonaker (1939) states that "It has been fully demonstrated that during lactation the mothers lose weight and that the amount of this loss depends on the number of young nursed . . ." (p. 40). If one recalls that the mean gain in the weight of the young decreased with an increase in the size of the litter, the failure of the gain in the weight of the mother to show a similar negative regression would seem to indicate that the total quantity of milk secreted varied little, or at least that there was a definite upper limit. As the size of the litter increased, each young received a smaller quantity as his "share".

The seasonal variation in the gain in weight of the mother was found to be very great (table 69, figure 25). It can be seen that the mean gains were much smaller in the summer months than in the winter months. As suggested by figure 25, the year was divided into two seasons including months 11-4 and 5-10 inclusive. An analysis of variance (table XIII) indicates a highly significant difference in the mean gains, 9.17 and 4.43 gm., for these two seasons. Since the young exhibited no such seasonal differences, though the lowest mean gains were for months 7-9 inclusive, the mother must have maintained her milk supply at the expense of her own body tissue. It seems likely that the food intake was decreased

Table 68. Mean gain in weight of mother from 4th-17th day of lactation, segregated as to litter series and to size of litter at 17th day

Litter series	Size of litter at 17 days	Number of litters	Gain in weight: Coded Total	Gain in weight: Coded Mean	Gain in weight: Decoded* Mean gm.
1	1	1	54	54.0	4.0
	2	3	178	59.3	9.3
	3	6	346	57.7	7.7
	4	4	228	57.0	7.0
	5	5	328	65.6	15.6
	6	16	883	55.2	5.2
	7	21	1243	59.2	9.2
	8	47	2763	58.8	8.8
Total		103	6023	58.48	8.48
2	1	2	110	55.0	5.0
	2	1	61	61.0	11.0
	3	3	173	57.7	7.7
	4	6	355	59.2	9.2
	5	9	489	54.3	4.3
	6	12	638	53.2	3.2
	7	18	999	55.5	5.2
	8	81	4468	55.2	5.2
Total		132	7293	55.25	5.25
3	2	2	99	49.5	-0.5
	3	1	49	49.0	-1.0
	4	2	121	60.0	10.0
	5	6	362	60.3	10.3
	6	4	238	59.5	9.5
	7	9	497	55.2	5.2
	8	32	1796	56.1	6.1
Total		56	3162	56.46	6.46
1, 2, & 3	1	3	164	54.7	4.7
	2	6	338	56.3	6.3
	3	10	568	56.8	6.8
	4	12	704	58.7	8.7
	5	20	1179	59.0	9.0
	6	32	1759	55.0	5.0
	7	48	2739	57.1	7.1
	8	160	9027	56.4	6.4
Total		291	16478	56.63	6.63

*Coded means minus 50

Table 69. Mean gain in weight of mother from 4th-17th day of lactation, segregated as to litter series and to month

Litter series	Month	Number of litters	Number of young at 17th day: Total	Number of young at 17th day: Mean per litter	Gain in weight of mother, Coded: Total	Gain in weight of mother, Coded: Mean	Gain in weight of mother, Decoded: Mean gm.
1	1	8	56	7.0	498	62.2	12.2
	2	7	46	6.6	437	62.4	12.4
	3	12	78	6.5	764	63.7	13.7
	4	9	63	7.0	566	62.9	12.9
	5	9	53	5.9	497	55.2	5.2
	6	11	70	6.4	558	50.7	0.7
	7	6	36	6.0	338	56.3	6.3
	8	15	101	6.7	829	55.3	5.3
	9	9	53	5.9	542	60.2	10.2
	10	7	49	7.0	375	53.6	3.6
	11	10	63	6.3	609	60.9	10.9
	12	2	15	7.5	126	63.0	13.0
Total		105	683	6.50	6139	58.47	8.47
2	1	10	66	6.6	587	58.7	8.7
	2	7	48	6.9	413	59.0	9.0
	3	10	75	7.5	557	55.7	5.7
	4	9	60	6.7	506	56.2	6.2
	5	22	161	7.3	1211	55.0	5.0
	6	9	58	6.4	485	53.9	3.9
	7	12	88	7.3	566	47.2	-2.8
	8	13	80	6.2	700	53.8	3.8
	9	4	19	4.8	235	58.8	8.8
	10	17	116	6.8	936	55.1	5.1
	11	8	62	7.8	460	57.5	7.5
	12	16	97	6.1	947	59.2	9.2
Total		137	930	6.79	7603	55.50	5.50
3	1	7	49	7.0	407	58.1	8.1
	2	8	57	7.1	439	54.9	4.9
	3	14	79	5.6	829	59.2	9.2
	4	5	39	7.8	299	59.8	9.8
	5	6	32	5.3	381	63.5	13.5
	6	2	16	8.0	140	70.0	20.0
	8	3	23	7.7	149	49.6	-0.4
	9	3	24	8.0	106	35.3	-14.7
	10	3	21	7.0	171	57.0	7.0

(Continued on next page)

Table 69 (continued)

3	11	1	6	6.0	31	31.0	-19.0
cont.	12	8	42	5.3	460	57.5	7.5
Total		60	388	6.47	3412	56.87	6.87
1, 2,	1	25	171	6.8	1492	59.7	9.7
& 3	2	22	151	6.9	1289	58.6	8.6
	3	36	232	6.4	2150	59.7	9.7
	4	23	162	7.0	1371	59.6	9.6
	5	37	246	6.6	2089	56.5	6.5
	6	22	144	6.5	1183	53.8	3.8
	7	18	124	6.9	904	50.2	0.2
	8	31	204	6.6	1678	54.1	4.1
	9	16	96	6.0	883	55.2	5.2
	10	27	186	6.9	1482	54.9	4.9
	11	19	131	6.9	1100	57.9	7.9
	12	26	154	5.9	1533	59.0	9.0
Total		302	2001	6.63	17154	56.80	6.80

during the summer months though there is no evidence at hand to support such a statement.

In view of the seasonal variation it seemed advisable to separate the mean gains into the two groups, months 11-4 and 5-10 inclusive, before examining them for any generational differences. The mean gains arranged by litter series and by generation are shown in tables 70 and 71 and figures 26 and 27. Considerable variation in the mean gains is exhibited by the generations due in part to the small number of litters observed in many of the classes. Analyses of variance (tables XIV and XV) indicate that the mean gains differ significantly from one another for months 5-10 but not for months 11-4. The patterns for the two groups, however, are similar, in showing comparatively low figures, 1.1 and 1.8 gm. respectively, for generation 14. In other respects they are not much alike. While the

Table 70. Mean gain in weight of mother from 4th-17th day of lactation, segregated as to litter series and to generation, months 11-4

Litter series	Generation	Number of litters	Number of young at 17th day: Total	Number of young at 17th day: Mean per litter	Gain in weight of mother, Coded: Total	Gain in weight of mother, Coded: Mean	Gain in weight of mother, Decoded: Mean gm.
1	13	7	38	5.4	418	59.7	9.7
	14	1	8	8.0	56	56.0	6.0
	15	9	61	6.8	550	61.1	11.1
	16	21	139	6.6	1342	63.9	13.9
	17	1	8	8.0	71	71.0	21.0
	18	8	61	7.6	499	62.4	12.4
	19	1	6	6.0	64	44.0	14.0
		48	321	6.69	3000	62.50	12.50
2	12	6	24	4.0	386	64.3	14.3
	13	14	97	6.9	813	58.1	8.1
	15	19	139	7.3	1081	56.9	6.9
	16	7	42	6.0	392	56.0	6.0
	17	4	29	7.2	222	55.5	5.5
	18	10	77	7.7	576	57.6	7.6
Total		60	408	6.80	3470	57.83	7.83
3	12	8	41	5.1	470	58.8	8.8
	13	7	48	6.9	442	63.1	13.1
	14	5	32	6.4	255	51.0	1.0
	15	17	106	6.2	959	56.4	6.4
	17	1	8	8.0	60	60.0	10.0
	18	5	37	7.4	279	55.8	5.8
Total		43	272	6.33	2465	57.33	7.33
1, 2, & 3	12	14	65	4.6	856	61.1	11.1
	13	28	183	6.5	1673	59.8	9.8
	14	6	40	6.7	311	51.8	1.8
	15	45	306	6.8	2590	57.6	7.6
	16	28	181	6.5	1734	61.9	11.9
	17	6	45	7.5	353	58.8	8.8
	18	23	175	7.6	1354	58.9	8.9
	19	1	6	6.0	64	64.0	14.0
Total		151	1001	6.63	8935	59.17	9.17

Table 71. Mean gain in weight of mother, 4th-17th day of lactation, segregated as to litter series and to generation, months 5-10

Litter series	Generation	Number of litters	Number of young at 17th day: Total	Number of young at 17th day: Mean per litter	Gain in weight of mother, Coded: Total	Gain in weight of mother, Coded: Mean	Gain in weight of mother, Decoded: Mean gm.
1	14	12	74	6.2	694	57.8	7.8
	15	11	69	6.3	622	56.5	6.5
	16	4	19	4.7	212	53.0	3.0
	17	25	166	6.6	1344	53.8	3.8
	19	5	34	6.8	267	53.4	3.4
Total		57	362	6.35	3139	55.07	5.07
2	13	3	12	4.0	176	58.7	8.7
	14	16	121	7.6	768	48.0	-2.0
	15	2	14	7.0	110	55.0	5.0
	16	30	214	7.1	1617	53.9	3.9
	17	20	122	6.1	1122	56.1	6.1
	18	1	4	4.0	68	68.0	18.0
	19	5	35	7.0	272	54.4	4.4
Total		77	522	6.78	4133	53.68	3.68
3	13	8	50	6.2	507	63.4	13.4
	14	7	53	7.6	328	46.9	-3.1
	18	2	13	6.5	112	56.0	6.0
Total		17	116	6.8	947	55.71	5.71
1, 2, & 3	13	11	62	5.6	683	62.1	12.1
	14	35	248	7.1	1790	51.1	1.1
	15	13	83	6.4	732	56.3	6.3
	16	34	233	6.9	1829	53.8	3.8
	17	45	288	6.4	2466	54.8	4.8
	18	3	17	5.7	180	60.0	10.0
	19	10	69	6.9	539	53.9	3.9
Total		151	1000	6.62	8219	54.43	4.43

mean gains in the weight of the young (figure 23) did not show as great variability, it is interesting to note that the lowest figure was also for generation 14. One wonders if the 14th generation was inferior in other respects as well. In looking back over the data there is nothing to indicate that this was the case.

The mean gains in the weight of the mother also varied with the litter series (tables 69, 70, and 71). In the analysis of variance based on the classification according to litter series and to month (table XIII) these differences were found to be significant, and for months 11-4 in the classification according to litter series and to generation (table XIV) highly significant. In the latter classification for months 5-10 (table XV) the differences were not as marked and were found to be non-significant. The usual weight pattern in relation to the litter series, however, was practically reversed, the highest gains in this instance being found for litter 1. This relatively high figure is logical and to be expected since the female rats at the birth of first litters had not reached their full adult size and were continuing to gro . The growth impetus was evidently sufficient to carry them through periods of lactation. Slonaker (1939) also observed that young mothers could nurse their young with much less loss of weight. In mothers whose age averaged 457 days the weight loss was nearly double that in those whose age averaged 270 days.

Slonaker (1939) found that the weight lost by the mothers during lactation varied with the percentage of protein in the diet as follows:

Protein per cent	Loss in weight Mean	Per cent
10.3	14.64	7.82
14.2	16.95	8.03
18.2	12.50	5.82
22.2	7.92	3.73
26.3	14.40	6.49

The differences are not great but Slonaker concludes that the mothers in the two groups receiving the smallest amounts of protein were less well able to nurse their young. Attention should be called to the fact that all of Slonaker's mean figures represent weight losses. In the present study, while many individuals showed loss in weight, practically all of the mean figures represent weight gains. The average gain for the first three litters was between six and seven grams. During the winter months the mothers gained an average of 12.5 grams while nursing their first litters.

From observations on a small number of animals, Macomber (1933) noted an even greater variation of the weight of the mother with the percentage of protein in the diet. His figures are as follows:

Protein per cent	Number of litters	Mother's gain for 21 days	Mean weight of young at 21 days
20.8	8	-4.0	36.2
16.8	6	-19.3	31.5
10	6	-40.5	30.1
5	5	-74.0	19.8

It is very evident that in this case the weight of the young was maintained at the expense of the maternal organism.

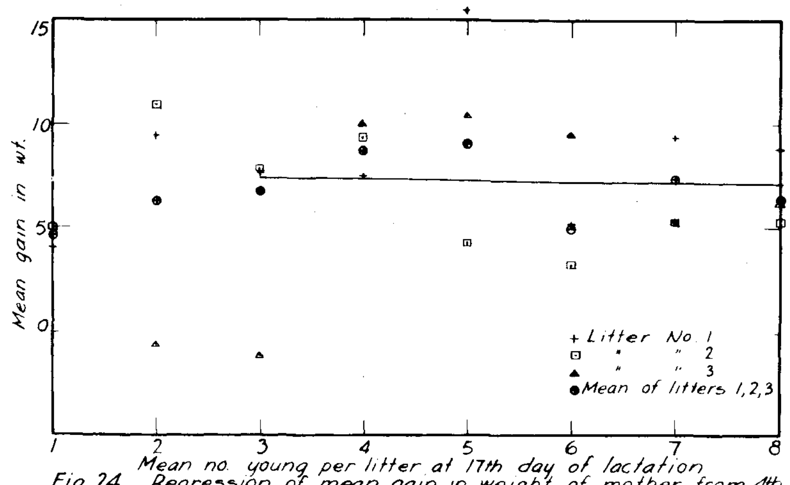


Fig. 24 Regression of mean gain in weight of mother from 4th to 17th day of lactation on size of litter at 17th day (line drawn for litters with 3 or more young.)

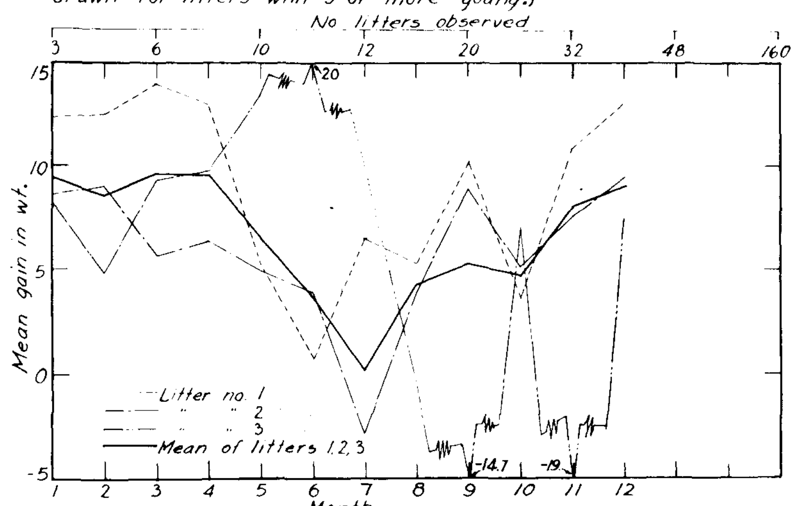
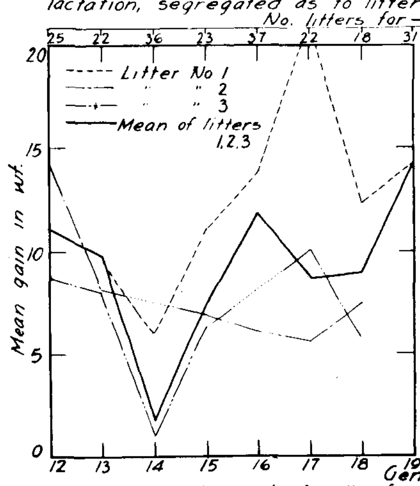


Fig. 25 Mean gain in weight of mother from 4th-17th day of lactation, segregated as to litter series and to month.



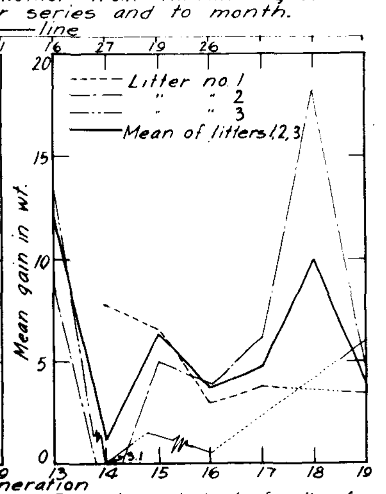


Fig. 26 Mean gain in wt. of mother from 4th-17th day of lactation segregated as to litter series and to generation, month 11-4.

Fig. 27 Mean gain in wt. of mother from 4th-17th day of lactation segregated as to litter series and to generation, month 5-10

No. mothers for — line

14 28 6 45 28 6 23 1   11 35 13 34 45 3 10

SUMMARY AND CONCLUSIONS

The mean number of young rats born per litter was found to be 8.2, based on the data from 1154 litters. The mean number born per litter was smaller during months 7 to 9 inclusive than for the remainder of the year. It increased with the passing generations and was greatest for the second litter of the series.

The mean number of young rats reared per litter was 5.1 in the 718 litters studied; the mean percentage reared, 73.6. Both the mean number and percentage reared were greater for the summer months, 3 to 8 inclusive, than for the winter months, 9 to 2 inclusive; they increased with the passing generations. The mean number of young reared was greatest for the second litter of the series, the percentage of young reared least for the first litter of the series. The percentage of young reared increased as the size of the litter increased, this in spite of the fact that the large litters were reduced to include only eight young.

The mean birth weight was 4.81 gm. in the 616 litters studied, including litters 1 to 4 of the series. It did not vary significantly either with the season of the year or the litter series. The mean weight decreased as the size of the litter increased. It was higher in the early and late generations and lower in the intermediate generations.

The mean weight of young at 21 days of age was 30.11 gm. in the 440 litters studied, including litters 1 to 4 of the series. The weight at this age was but little affected by the season of the year and did not vary significantly from generation to generation. It increased with the litter series and decreased as the size of the litter increased.

The mean weight of the young at 28 days of age was 48.80 gm. in the 345 litters studied, including litters 1 to 3 of the series. It showed no significant variation either with the season or the generation. It increased with the litter series and decreased as the size of the litter increased.

The normal length of the oestrus cycle in 275 rats as indicated by the mode was five days. The mean length increased from 7.7 days to 44.3 days as the age of the rat increased from the period including 0 to 182 days to the period including 548 to 730 days. The mean number of days elapsing from parturition to the next oestrus was 31.5.

The fertility per cent was lower for first litters than for the remaining litters of the series, 81.3 as against approximately 95. Generations 19 and 20 showed significantly lower fertility per cents, 69.8 and 69.4 respectively, in first litters. Of the total number of 233 rats observed, six were found to be sterile.

The mean age at the opening of the vagina in 223 rats was 41.3 days; the mean age at first oestrus, 47.9 days. The mean age at the first positive mating of 213 rats was 66.8 days. The mean length of the reproductive span in 112 rats was 197.1 days; the longest span, 413 days. The latest age at which oestrus was observed was 722 days. The longest life span in 51 female rats was 1103 days.

The implantation per cent was found to be 89.8; the placental per cent, 99.5. The normal length of gestation period as indicated by the mode was 22 days, a slight increase being noted with each successive pregnancy.

The mean gain in the weight of the young from 4 to 17 days of age was used as one of the indexes of lactation. This gain showed no significant seasonal variation. It varied significantly from generation to generation, the lowest figure being 15.1 gm. for generation 14, the highest figures 16.9 and 16.8 gm. for generations 16 and 18 respectively. It increased with the litter series and decreased as the size of the litter increased.

The mean gain in the weight of the mother from the 4th to the 17th day of lactation was used as a second index of lactation. It was found to vary significantly with the season, being 4.43 gm. for the summer months 5 to 10 inclusive and 9.17 gm. for the winter months 11 to 4 inclusive. Generation 14 exhibited the low values of 1.1 and 1.8 gm. for the summer and winter months respectively. The mean gain decreased with the litter series. It showed no correlation with the size of the litter.

Female albino rats normally exhibit great variability in their reproductive and lactating behavior. Before dependable conclusions can be drawn from experimental data suitable tests should be applied to determine the significance of the variation. Even with such tests a large number of animals from which to draw conclusions would seem to offer an almost necessary safeguard in the interpretation of results.

All of the criteria used for judging the reproductive and lactating ability of the female albino rat were not affected alike by the changing seasons, the passing generations, or the litter series. In general, the litter series seemed to exercise the greatest influence. In regard to the growth and mortality of the young the size of the litter also showed a marked effect.

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APPENDIX

Table I. Number of young in reduced litters, number reared, and percentage reared, months 9-2 inclusive, segregated as to litter series and to generation

Litter series	Generation	Number of litters	Number of young in reduced litters: Total	Number of young in reduced litters: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Number of young reared: Per cent
1	7	6	29	4.7	9	1.5	31.0
	8	10	65	6.5	23	2.3	35.4
	10	41	279	6.8	181	4.4	64.9
	11	1	8	8.0	7	7.0	87.5
	12	9	71	7.9	36	4.0	50.7
	13	14	99	7.1	46	3.3	46.5
	14	2	16	8.0	8	4.0	50.0
	15	24	167	7.0	22	5.1	73.1
	16	7	44	6.3	27	3.9	61.4
	17	8	44	5.5	40	5.0	90.9
	18	17	117	6.9	70	4.1	59.8
	19	2	16	8.0	12	6.0	75.0
	20	20	154	7.7	87	4.4	56.5
Total		161	1109	6.9	668	4.1	60.2
2	6	1	8	8.0	8	8.0	100.0
	7	13	87	6.7	51	3.9	58.6
	8	11	82	7.5	45	4.1	54.9
	9	2	16	8.0	16	8.0	100.0
	10	43	303	7.0	200	4.7	66.0
	12	11	80	7.3	74	6.7	92.5
	13	10	78	7.8	72	7.2	92.3
	14	5	39	7.8	30	6.0	76.9
	15	22	170	7.7	131	6.0	77.1
	17	24	177	7.4	125	5.2	70.6
	18	7	55	7.9	29	4.1	52.7
	19	26	205	7.9	171	6.6	83.4
	20	25	186	7.4	151	6.0	81.2
	21	1	8	8.0	8	8.0	100.0
Total		201	1494	7.4	1111	5.5	74.4

Table I (continued)

3	6	1	6	6.0	6	6.0	100.0
	7	13	82	6.3	55	4.2	67.1
	8	6	29	4.8	11	1.8	37.9
	9	6	36	6.0	20	3.3	55.6
	10	18	123	6.8	89	4.9	72.4
	11	3	21	7.0	8	2.7	38.1
	12	14	101	7.2	80	5.7	79.2
	13	1	8	8.0	5	5.0	62.5
	14	14	101	7.2	77	5.5	76.2
	15	12	83	6.9	70	5.8	84.3
	16	4	19	4.8	0	0.0	0.0
	17	6	45	7.5	19	3.2	42.2
	19	10	76	7.6	73	7.3	96.1
	20	6	34	5.7	23	3.8	67.6
Total		114	764	6.7	536	4.7	70.2
1, 2,	6	2	14	7.0	14	7.0	100.0
& 3	7	32	198	6.2	115	3.6	58.1
	8	27	176	6.5	79	2.9	44.9
	9	8	52	6.5	36	4.5	69.2
	10	102	705	6.9	470	4.6	66.7
	11	4	29	7.2	15	3.8	51.7
	12	34	252	7.4	190	5.6	75.4
	13	25	185	7.4	123	4.9	66.5
	14	21	156	7.4	115	5.5	73.7
	15	58	420	7.2	323	5.6	76.9
	16	11	63	5.7	27	2.5	42.9
	17	38	266	7.0	184	4.8	69.2
	18	24	172	7.2	99	4.1	57.6
	19	38	297	7.8	256	6.7	86.2
	20	51	374	7.3	261	5.1	69.8
	21	1	8	8.0	8	8.0	100.0
Total		476	3367	7.1	2315	4.9	68.8

NOTE: This table furnishes data for figure 5.

Table II. Number of young in reduced litters, number reared, and percentage reared, months 3-8 inclusive, segregated as to litter series and to generation

Litter series	Generation	Number of litters	Number of young in reduced litters		Number of young reared		
			Total	Mean per litter	Total	Mean per litter	Per cent
1	6	1	7	7.0	6	6.0	85.7
	7	12	81	6.8	71	5.9	87.7
	8	4	21	5.2	16	4.0	76.2
	9	13	74	5.7	55	4.2	74.3
	11	5	37	7.4	24	4.8	64.9
	12	8	42	5.2	37	4.6	88.1
	13	4	29	7.2	7	1.8	24.1
	14	17	126	7.4	74	4.4	58.7
	15	1	7	7.0	7	7.0	100.0
	16	27	181	6.7	130	4.8	71.8
	17	22	159	7.2	132	6.0	83.0
	18	2	16	8.0	14	7.0	87.5
	19	35	261	7.5	242	6.9	92.7
	20	5	40	8.0	39	7.8	97.5
Total		156	1081	6.9	854	5.5	79.0
2	7	1	2	2.0	1	1.0	50.0
	8	1	8	8.0	8	8.0	100.0
	9	7	39	5.6	36	5.1	92.3
	11	6	42	7.0	39	6.5	92.9
	12	5	35	7.0	31	6.2	88.6
	13	9	65	7.2	43	4.8	66.2
	14	14	108	7.7	95	6.8	88.0
	15	3	20	6.7	20	6.7	100.0
	16	37	282	7.6	248	6.7	87.9
	17	4	26	6.5	24	6.0	92.3
	18	8	60	7.5	60	7.5	100.0
	19	11	81	7.4	71	6.5	87.7
Total		106	768	7.2	676	6.4	88.0

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Table II (continued)

3	7	1	7	7.0	6	6.0	85.7
	8	4	27	6.8	26	6.5	96.3
	9	4	27	6.8	26	6.5	96.3
	10	18	119	6.6	90	5.0	75.6
	11	3	22	7.3	21	7.0	95.5
	12	1	8	8.0	2	2.0	25.0
	13	16	124	7.8	96	6.0	77.4
	14	3	23	7.7	8	2.7	34.8
	15	8	57	7.1	43	5.4	75.4
	16	2	7	3.5	6	3.0	85.7
	17	1	1	1.0	0	0.0	0.0
	18	10	72	7.2	57	5.7	79.2
Total		71	494	7.0	381	5.4	77.1
1, 2,	6	1	7	7.0	6	6.0	85.7
& 3	7	14	90	6.4	78	5.6	86.7
	8	9	56	6.2	50	5.6	89.3
	9	24	140	5.8	117	4.9	83.6
	10	18	119	6.6	90	5.0	75.6
	11	14	101	7.2	84	6.0	83.2
	12	14	85	6.1	70	5.0	82.4
	13	29	218	7.5	146	5.0	67.0
	14	34	257	7.6	177	5.2	68.9
	15	12	84	7.0	70	5.8	83.3
	16	66	470	7.1	384	5.8	81.7
	17	27	186	6.9	156	5.8	83.9
	18	20	148	7.4	131	6.6	88.5
	19	46	342	7.4	313	6.8	91.5
	20	5	40	8.0	39	7.8	97.5
Total		333	2343	7.0	1911	5.7	81.6

NOTE: This table furnishes data for figure 6.

Table III. Number of young in reduced litters, number reared, and percentage reared, generations 10-17 inclusive, litter size greater than 8, segregated as to litter series and to month

Litter series	Month	Number of litters	Number of young in reduced litters: Total	Number of young in reduced litters: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Per cent
1	1	7	56	8.0	19	2.7	33.9
	2	2	16	8.0	3	1.5	18.8
	3	8	64	8.0	43	5.4	67.2
	4	8	64	8.0	54	6.8	84.4
	5	5	40	8.0	26	5.2	65.0
	6	9	72	8.0	53	5.9	73.6
	7	5	40	8.0	28	5.6	70.0
	8	8	64	8.0	55	6.9	85.9
	9	8	64	8.0	40	5.0	62.5
	10	13	104	8.0	91	7.0	87.5
	11	14	112	8.0	91	6.5	81.2
	12	11	88	8.0	66	6.0	75.0
Total		98	784	8.0	569	5.8	72.6
2	1	24	192	8.0	136	5.7	70.8
	2	9	72	8.0	48	5.3	66.7
	3	5	40	8.0	38	7.6	95.0
	4	5	40	8.0	35	7.0	87.5
	5	18	144	8.0	125	6.9	86.8
	6	7	56	8.0	55	7.9	98.2
	7	12	96	8.0	78	6.5	81.2
	8	9	72	8.0	61	6.8	84.7
	9	2	16	8.0	15	7.5	93.8
	10	21	168	8.0	130	6.2	77.4
	11	12	96	8.0	73	6.1	76.0
	12	16	128	8.0	114	7.1	89.1
Total		140	1120	8.0	908	6.5	81.1
3	1	7	56	8.0	55	7.9	98.2
	2	12	96	8.0	76	6.3	79.2
	3	15	120	8.0	96	6.4	80.0
	4	4	32	8.0	32	8.0	100.0
	5	3	24	8.0	22	7.3	91.7
	6	3	24	8.0	16	5.3	66.7
	7	1	8	8.0	8	8.0	100.0
	8	3	24	8.0	16	5.3	66.7
	9	6	48	8.0	40	6.7	83.3
	10	2	16	8.0	11	5.5	68.8

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Table III (continued)

3 cont.	12	10	80	8.0	52	5.2	65.0
Total		66	528	8.0	424	6.4	80.3
4	1	1	8	8.0	8	8.0	100.0
	3	4	32	8.0	20	5.0	62.5
	4	12	96	8.0	87	7.2	90.6
	5	15	120	8.0	99	6.6	82.5
	6	4	32	8.0	32	8.0	100.0
	7	5	40	8.0	22	4.4	55.0
	8	1	8	8.0	8	8.0	100.0
	9	1	8	8.0	8	8.0	100.0
	10	2	16	8.0	8	4.0	50.0
	11	2	16	8.0	14	7.0	87.5
	12	3	24	8.0	2	0.7	8.3
Total		50	400	8.0	308	6.2	77.0
1, 2, 3, & 4	1	39	312	8.0	218	5.6	69.9
	2	23	184	8.0	127	5.5	69.0
	3	32	256	8.0	197	6.2	77.0
	4	29	232	8.0	208	7.2	89.7
	5	41	328	8.0	272	6.6	82.9
	6	23	184	8.0	156	6.8	84.8
	7	23	184	8.0	136	5.9	73.9
	8	21	168	8.0	140	6.7	83.3
	9	17	136	8.0	103	6.1	75.7
	10	38	304	8.0	240	6.3	78.9
	11	28	224	8.0	178	6.4	79.5
	12	40	320	8.0	234	5.9	73.1
Total		354	2832	8.0	2209	6.2	78.0

NOTE: This table furnishes data for figure 8.

Table IV. Number of young in reduced litters, number reared, and percentage reared, litter size greater than 8, segregated as to litter series and to generation

Litter series	Generation	Number of litters	Number of young in reduced litters: Total	Number of young in reduced litters: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Number of young reared: Per cent
1	7	6	48	8.0	38	6.3	79.2
	8	1	8	8.0	8	8.0	100.0
	9	2	16	8.0	11	5.5	68.8
	10	19	152	8.0	117	6.2	77.0
	11	2	16	8.0	15	7.5	93.8
	12	9	72	8.0	50	5.6	69.4
	13	11	88	8.0	46	4.2	52.3
	14	12	96	8.0	63	5.2	65.6
	15	11	88	8.0	71	6.5	80.7
	16	18	144	8.0	97	5.4	67.4
	17	16	128	8.0	110	6.9	85.9
	18	10	80	8.0	76	7.6	95.0
	19	28	224	8.0	208	7.4	92.9
	20	18	144	8.0	104	5.8	72.2
Total		165	1304	8.0	1014	6.2	77.8
2	7	7	56	8.0	45	6.4	80.4
	8	7	56	8.0	34	4.9	60.7
	9	1	8	8.0	8	8.0	100.0
	10	26	208	8.0	135	5.2	64.9
	11	4	32	8.0	29	7.2	90.6
	12	13	104	8.0	102	7.8	98.1
	13	14	112	8.0	98	7.0	87.5
	14	15	120	8.0	99	6.6	82.5
	15	21	168	8.0	132	6.3	78.6
	16	29	232	8.0	201	6.9	86.6
	17	18	144	8.0	112	6.2	77.8
	18	12	96	8.0	85	7.1	88.5
	19	30	240	8.0	200	6.7	83.3
	20	19	152	8.0	136	7.2	89.5
	21	1	8	8.0	8	8.0	100.0
Total		217	1736	8.0	1424	6.6	82.0

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Table IV (continued)

3	7	4	32	8.0	24	6.0	75.0
	8	3	24	8.0	23	7.7	95.8
	9	2	16	8.0	14	7.0	87.5
	10	15	120	8.0	100	6.7	83.3
	11	3	24	8.0	24	8.0	100.0
	12	11	88	8.0	71	6.5	80.7
	13	11	88	8.0	75	6.8	85.2
	14	10	80	8.0	57	5.7	71.2
	15	13	104	8.0	89	6.8	85.6
	17	3	24	8.0	8	2.7	33.3
	18	6	48	8.0	35	5.8	72.9
	19	8	64	8.0	61	7.6	95.3
	20	2	16	8.0	16	8.0	100.0
Total		91	728	8.0	597	6.6	82.0
1, 2, & 3	7	17	136	8.0	107	6.3	78.7
	8	11	88	8.0	65	5.9	73.9
	9	5	40	8.0	33	6.6	82.5
	10	60	480	8.0	352	5.9	73.3
	11	9	72	8.0	68	7.6	94.4
	12	33	264	8.0	223	6.8	84.5
	13	36	288	8.0	219	6.1	76.0
	14	37	296	8.0	219	5.9	74.0
	15	45	360	8.0	292	6.5	81.1
	16	47	376	8.0	298	6.3	79.3
	17	37	296	8.0	230	6.2	77.7
	18	28	224	8.0	196	7.0	87.5
	19	66	528	8.0	469	7.1	88.8
	20	39	312	8.0	256	6.6	82.1
	21	1	8	8.0	8	8.0	100.0
Total		471	3768	8.0	3035	6.4	80.5

NOTE: This table furnishes data for figure 9.

Table V. Number of young in reduced litters, number reared, and percentage reared, litter size greater than 8, months 9-2 inclusive, segregated as to litter series and to generation

Litter series	Generation	Number of litters	Number of young in reduced litters: Total	Number of young in reduced litters: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Number of young reared: Per cent
1	7	1	8	8.0	0	0.0	0.0
	10	19	152	8.0	117	6.2	77.0
	12	7	56	8.0	36	5.1	64.3
	13	10	80	8.0	46	4.6	57.5
	14	2	16	8.0	8	4.0	50.0
	15	11	88	8.0	71	6.5	80.7
	16	3	24	8.0	8	2.7	33.3
	17	3	24	8.0	24	8.0	100.0
	18	8	64	8.0	62	7.8	96.7
	19	2	16	8.0	12	6.0	75.0
	20	14	112	8.0	73	5.2	65.2
Total		80	640	8.0	457	5.7	71.4
2	7	7	56	8.0	45	6.4	80.4
	8	7	56	8.0	34	4.9	60.7
	9	1	8	8.0	8	8.0	100.0
	10	26	208	8.0	135	5.2	64.9
	12	9	72	8.0	71	7.9	98.6
	13	9	72	8.0	66	7.3	91.7
	14	4	32	8.0	24	6.0	75.0
	15	20	160	8.0	124	6.2	77.5
	17	16	128	8.0	96	6.0	75.0
	18	5	40	8.0	29	5.8	72.5
	19	24	192	8.0	160	6.7	83.3
	20	19	152	8.0	136	7.2	89.5
	21	1	8	8.0	8	8.0	100.0
Total		148	1184	8.0	936	6.3	79.1

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Table V (continued)

3	7	4	32	8.0	24	6.0	75.0
	9	2	16	8.0	14	7.0	87.5
	10	7	56	8.0	45	6.4	80.4
	11	1	8	8.0	8	8.0	100.0
	12	10	80	8.0	69	6.9	86.2
	14	8	64	8.0	49	6.1	76.6
	15	8	64	8.0	55	6.9	85.9
	17	3	24	8.0	8	2.7	33.3
	19	8	64	8.0	61	7.6	95.3
	20	2	16	8.0	16	8.0	100.0
Total		53	424	8.0	349	6.6	82.3
1, 2, & 3	7	12	96	8.0	69	5.8	71.9
	8	7	56	8.0	34	4.9	60.7
	9	3	24	8.0	22	7.3	91.7
	10	52	416	8.0	297	5.7	71.4
	11	1	8	8.0	8	8.0	100.0
	12	26	208	8.0	176	6.8	84.6
	13	19	152	8.0	112	5.9	73.7
	14	14	112	8.0	81	5.8	72.3
	15	39	312	8.0	250	6.4	80.1
	16	3	24	8.0	8	2.7	33.3
	17	22	176	8.0	128	5.8	72.7
	18	13	104	8.0	91	7.0	87.5
	19	34	272	8.0	233	6.9	85.7
	20	35	280	8.0	225	6.4	80.4
	21	1	8	8.0	8	8.0	100.0
Total		281	2248	8.0	1742	6.2	77.5

NOTE: This table furnishes data for figure 10.

Table VI. Number of young in reduced litters, number reared, and percentage reared, litter size greater than 8, months 3-8 inclusive, segregated as to litter series and to generation

Litter series	Generation	Number of litters	Number of young in reduced litter: Total	Number of young in reduced litter: Mean per litter	Number of young reared: Total	Number of young reared: Mean per litter	Number of young reared: Per cent
1	7	5	40	8.0	38	7.6	95.0
	8	1	8	8.0	8	8.0	100.0
	9	2	16	8.0	11	5.5	68.8
	11	2	16	8.0	15	7.5	93.8
	12	2	16	8.0	14	7.0	87.5
	13	1	8	8.0	0	0.0	0.0
	14	10	80	8.0	55	5.5	68.8
	16	15	120	8.0	89	5.9	74.2
	17	13	104	8.0	86	6.6	82.7
	18	2	16	8.0	14	7.0	87.5
	19	26	208	8.0	196	7.5	94.2
	20	4	32	8.0	31	7.8	96.9
Total		83	664	8.0	557	6.7	83.9
2	11	4	32	8.0	29	7.2	90.6
	12	4	32	8.0	31	7.8	96.9
	13	5	40	8.0	32	6.4	80.0
	14	11	88	8.0	75	6.8	85.2
	15	1	8	8.0	8	8.0	100.0
	16	29	232	8.0	201	6.9	86.6
	17	2	16	8.0	16	8.0	100.0
	18	7	56	8.0	56	8.0	100.0
	19	6	48	8.0	40	6.7	83.3
Total		69	552	8.0	488	7.1	88.4
3	8	3	24	8.0	23	7.7	95.8
	10	8	64	8.0	55	6.9	85.9
	11	2	16	8.0	16	8.0	100.0
	12	1	8	8.0	2	2.0	25.0
	13	11	88	8.0	75	6.8	85.2
	14	2	16	8.0	8	4.0	50.0
	15	5	40	8.0	34	6.8	85.0
	18	6	48	8.0	35	5.8	72.9
Total		38	304	8.0	248	6.5	81.6

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Table VI (continued)

1, 2,	7	5	40	8.0	38	7.6	95.0
& 3	8	4	32	8.0	31	7.8	96.9
	9	2	16	8.0	11	5.5	68.8
	10	8	64	8.0	55	6.9	85.9
	11	8	64	8.0	60	7.5	93.8
	12	7	56	8.0	47	6.7	83.9
	13	17	136	8.0	107	6.3	78.7
	14	23	184	8.0	138	6.0	75.0
	15	6	48	8.0	42	7.0	87.5
	16	44	352	8.0	290	6.6	82.4
	17	15	120	8.0	102	6.8	85.0
	18	15	120	8.0	105	7.0	87.5
	19	32	256	8.0	236	7.4	92.2
	20	4	32	8.0	31	7.8	96.9
Total		190	1520	8.0	1293	6.8	85.1

NOTE: **This table furnishes data for figure 11.**

Table VII. Mean weight of young at birth, generations 10-17, classified according to litter series and to month

	Litter series					
	1	2	3	4		
Month	gm.	gm.	gm.	gm.	Sum	Mean
1	4.82	4.73	4.72	4.80	19.07	4.77
2	5.09	4.78	4.82	4.96	19.65	4.91
3	4.91	4.97	4.67	4.68	19.23	4.81
4	4.84	5.01	4.73	4.70	19.28	4.82
5	4.75	4.83	4.89	4.66	19.13	4.78
6	4.90	4.98	4.66	4.80	19.34	4.84
7	4.93	4.79	5.00	4.89	19.61	4.90
8	4.99	4.88	4.96	5.06	19.89	4.97
9	4.95	5.11	4.58	4.60	19.24	4.81
10	4.82	5.04	5.17	4.77	19.80	4.95
11	4.66	4.84	5.06	4.39	18.95	4.74
12	4.60	4.69	4.87	4.96	19.12	4.78
Sum	58.26	58.65	58.13	57.27	232.31	
Mean	4.86	4.89	4.84	4.77		4.84

Analysis of Variance

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	47	1.2153	
Months	11	0.2555	.02323
Litter series	3	0.0847	.02823
Error	33	0.8751	.02652

Table VIII. Mean weight of young at birth classified according to litter series and to generation

Generation	Litter series 1 gm.	2 gm.	3 gm.	Sum	Mean
6	5.71	5.50	5.00	16.21	5.403
7	5.11	5.24	4.90	15.25	5.083
8	4.94	4.83	4.61	14.38	4.793
9	4.86	5.05	4.65	14.56	4.853
10	4.67	4.70	4.70	14.07	4.690
11	4.70	4.70	4.88	14.28	4.760
12	4.83	4.81	4.84	14.48	4.827
13	4.90	4.78	4.77	14.45	4.817
14	4.80	4.81	4.86	14.47	4.823
15	4.66	4.77	4.80	14.23	4.743
16	4.89	4.90	4.92	14.71	4.903
17	5.14	5.18	5.00	15.32	5.107
18	5.01	4.77	4.80	14.58	4.860
19	5.16	5.12	5.02	15.30	5.100
20	5.00	5.00	5.00	15.00	5.000
Sum	74.38	74.16	72.75	221.29	
Mean	4.959	4.944	4.850		4.918

Analysis of Variance

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	44	2.0604	
Generations	14	1.4899	.1064**
Litter series	2	.1043	.05215
Error	28	.4662	.01665

Table IX. Mean weight of young at 21 days of age, generations 10-17, classified according to litter series and to month

	Litter series					
	1	2	3	4		
Month	gm.	gm.	gm.	gm.	Sum	Mean
1	29.0	29.4	30.0	29.0	117.4	29.35
2	30.3	28.4	30.9	34.5	124.1	31.02
3	29.5	29.5	29.1	32.0	120.1	30.02
4	29.2	32.9	30.5	31.0	123.6	30.90
5	30.0	31.8	31.9	32.2	125.9	31.48
6	28.4	31.6	31.9	33.9	125.8	31.45
7	30.9	31.3	33.2	35.3	130.7	32.68
8	29.2	31.4	31.7	33.9	126.2	31.55
9	29.3	30.4	29.1	37.8	126.6	31.65
10	28.4	29.8	31.3	28.8	118.3	29.58
11	26.8	29.7	40.3	30.2	127.0	31.75
12	28.7	28.2	30.3	29.0	116.2	29.05
Sum	349.7	364.4	380.2	387.6	1481.9	
Mean	29.14	30.37	31.68	32.30		30.87

Analysis of Variance

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	47	292.7748	
Months	11	55.3773	5.034
Litter series	3	71.3623	23.787**
Error	33	166.0352	5.031

Table X. Mean weight of young at 28 days of age, generations 10-20, classified according to litter series and to month

Month	Litter series 1 gm.	Litter series 2 gm.	Litter series 3 gm.	Sum	Mean
1	44.8	51.7	47.9	144.4	48.1
2	48.7	54.3	52.5	155.5	51.8
3	46.7	49.1	49.6	145.4	48.5
4	44.0	51.7	46.1	141.8	47.3
5	46.5	49.8	52.4	148.7	49.6
6	45.7	52.2	50.2	148.1	49.4
7	50.5	51.6	(49.8)	151.9	50.6
8	47.5	49.9	64.7	162.1	54.0
9	46.9	47.1	46.9	140.9	47.0
10	46.4	48.2	48.4	143.0	47.7
11	44.9	49.1	51.9	145.9	48.6
12	50.2	48.8	53.8	152.8	50.9
Sum	562.8	603.5	614.2	1780.5	
Mean	46.90	50.29	51.18		49.46

Analysis of Variance

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	35	475.5275	
Months	11	143.3675	13.033
Litter series	2	122.5817	61.29*
Error	22	209.5783	9.526

Note: Figure in parentheses represents the mean for the litter, which was used to supply the missing figure.

Table XI. Mean gain in weight of young from 4-17 days of age classified according to litter series and to month

Month	Litter series 1 gm.	2 gm.	3 gm.	Sum	Mean
1	14.7	17.7	17.8	50.2	16.73
2	17.3	15.9	15.2	48.4	16.13
3	17.0	16.3	17.4	50.7	16.90
4	15.6	17.4	16.7	49.7	16.57
5	15.7	16.7	18.9	51.3	17.10
6	14.5	17.0	16.4	47.9	15.97
7	14.9	15.3	(16.7)	46.9	15.63
8	14.8	16.2	14.8	45.8	15.27
9	15.4	16.2	14.3	45.9	15.30
10	14.1	16.8	16.7	47.6	15.87
11	15.1	16.0	18.5	49.6	16.53
12	16.1	15.3	16.8	48.2	16.07
Sum	185.2	196.8	200.2	582.2	
Mean	15.43	16.40	16.68		16.17

Analysis of Variance

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	35	48.4922	
Months	11	12.0322	1.0938
Litter series	2	10.3089	5.1544*
Error	22	26.1511	1.1887

Table XII. Mean gain in weight of young from 4-17 days of age classified according to litter series and to generation

Generation	Litter series 1 gm.	2 gm.	3 gm.	Sum	Mean
12	(15.4)	16.2	17.0	48.6	16.20
13	13.0	15.6	17.2	45.8	15.27
14	14.1	15.3	16.0	45.4	15.13
15	15.3	15.9	16.5	47.7	15.90
16	16.5	17.1	(16.7)	50.3	16.77
17	15.3	17.0	16.8	49.1	16.37
18	16.3	16.8	17.3	50.4	16.80
19	14.8	16.1	(16.7)	47.6	15.87
Sum	120.7	130.0	134.2	384.9	
Mean	15.09	16.25	16.78		16.04

Analysis of Variance

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	23	25.2562	
Generations	7	8.1229	1.1604*
Litter series	2	11.9324	5.9662**
Error	14	5.2009	.37149

Table XIII. Mean gain in weight of mother from 4th-17th day of lactation, classified according to litter series and to months, grouped

Month	Litter 1		Litter 2		Litter 3		Sum		Mean gain	
	Number	Gain	Number	Gain	Number	Gain	Number	Gain	Coded	Decoded
11-4	48	3000	60	3470	43	2465	151	8935	59.17	9.17
5-10	57	3139	77	4133	17	947	151	8219	54.43	4.43
Sum	105	6139	137	7603	60	3412	302	17154		
Mean		58.47		55.50		56.87			56.80	
Decoded		8.47		5.50		6.87				6.80

Analysis of Variance

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	301	25162.0795	
Seasons	1	1697.5365	1697.54**
Litter series	2	524.7647	263.382*
Error	298	22939.7783	76.9791

Table XIV. Analysis of variance of mean gain in weight of mother from 4th-17th day of lactation, classified according to litter series and to generation within litters, months 11-4

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	150	9501.52	
Litters	2	785.75	392.88**
Generations within litters	16	1033.03	64.56
Error	132	7682.74	58.20

Table XV. Analysis of variance of mean gain in weight of mother from 4th-17th day of lactation, classified according to litter series and to generation within litters, months 5-10

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	150	13963.02	
Litters	2	94.89	47.44
Generations within litters	12	2128.86	177.40*
Error	136	11739.27	86.32

Note: The classification, "Generations within litters" was necessary because of missing data for certain generations within each litter of the series.