Our results agree with Eaton's as far as the influence of age on litter size is concerned, although we did not first get an increase up to a maximum and then a decrease. When litter size was kept constant, we, however, found no further influence of the dam's age on the birth weight. The influence King (1935) found was probably due to the indirect influence through litter size, for when we kept litter size constant then weight of the mother had no effect on the birth weights of the young. This is probably due to the fact that the rats have been inbred for so long that the weight differences were only due to non-genetic factors. This is substantiated by Hammond's (1934) results with rabbits where weight of mother showed a marked effect on the birth weights of the young when the different strains were compared, but within each of the inbred srains, weight of mother had no effect on the birth weight of the young. The influence of the size of the mother on the birth weight of the young was also shown in horses by Walton and Hammond (1938). The foal is, however, much further advanced than the rat or rabbit at birth hence maternal influence is more pronounced than when different strains of rabbits are taken.

The very marked effect of dam's age on litter size is of importance since our results differ entirely from those found by other investigators for various animals (cf. p. 371). We found a decrease in the number born from the youngest class onward, whereas most investigators found that litter size in the different species of multiparous animals first increased to a maximum and then decreased with increase in age. Our work on the prenatal growth of the rat showed at least a partial if not the whole cause of the decline in the number of young born from the youngest class of female to the oldest. Very young females (2-3 months old) showed practically no prenatal deaths, while old females (8 to 11 months old), whether for first or later litters, showed a prenatal death rate of at least 39 per cent. This only takes into account the embryos that have died after 11 days' pregnancy. The number that died during the first ten days after coitus was not determined. It has also not been determined whether the number that die before parturition increases as a straight line with an increase in age.

Another aspect which may play a rôle, is the question of maturity of the females under the new environment. Hammond (1933) showed that the ova shed in young growing animals shortly after puberty is less than later in life. With further increase in age less anterior pituitary secretion may be found and hence less ova shed. It has been shown that with injection of anterior pituitary hormone the number of ova shed was increased enormously. Whether our rats show an earlier development and hence a maximum production of anterior pituitary hormone at the age that the first litter is conceived, can only be answered by further investigations. It is, however, noteworthy that the growth and sexual maturity of our rats appear to be earlier than was reported for the Wistar rat (Greenman and Duhring, 1931). It will be shown in another section that shortly after weaning our rats were heavier and that the opening of the vaginas in the females occurred at an early age. The opening of the vaginas at such an early age (5-6 weeks) is especially an indication of the presence of a large amount of anterior pituitary hormone. When the serum of pregnant mares or women, for instance which has a high amount of anterior pituitary hormone, is injected into female rats of three weeks of age, the vaginas will open four to five days after the injection.

From our data it would, therefore, appear that litter size was the only factor which directly affected the birth weights of the young, and that the effect of age was only due to its effect on the litter size, the latter decreasing with an increase in age and consequently birth weight increase with an increase in age of the mothers. The litter size again determines how much of the internal secretion of the mother will be available for each young one. This internal secretion increases with the size of the mother when different strains and species are compared but remains constant when the strain is inbred. This explains why the weight of the mothers in our rats had no influence on the birth weights of the young.

3. *Growth from Birth to Weaning.*

(*a*) *Factors influencing litter size and average weights up to weaning.*

It is not enough if multiparous animals are fertile and if they produce a large number of young per litter, but a large percentage of those born should be raised to weaning age. Thus, for instance, the real measure of the pig's productive ability is given by the number and weight of the pigs weaned. A large number of young per litter is of no use if the mother cannot provide sufficient milk for the rapid growth of the young. Hence in studying the normal growth of the rat it is also of importance to determine which factors influence litter size and average weights of the young not only at birth but also up to the time when they are weaned.

In this section only those females that reared one or more pups per litter will be considered.

The data have been arranged in order to determine effects of the following factors on litter size and on average weights at weaning:—

(*a*) Litter size at birth.

(*b*) Litter size at weaning (influence on average weight).

(*c*) Age of mother.

(*d*) Litter rank (parity).

(*e*) Weight of mother at parturition.

The seasonal influence on the weaning percentage and the average weights at weaning will be discussed at a latter stage.

(*b*) *Influence of litter size at birth.*

The influence of litter size at birth on litter size at weaning is shown in Table 22 and in Fig. 19 (the age of 4 weeks is taken throughout as weaning age). The weaning percentages are given in Table 22 and in Fig. 20. The weaning percentage is the number of those weaned expressed as a percentage of those born alive. The curve illustrating the influence of litter size at birth on litter size at weaning forms nearly a straight line (Fig. 19), except for the largest litters. In these the number weaned is slightly smaller relatively than the number weaned in smaller litters. The same tendency is shown in Fig. 20 where the weaning percentages are plotted separately for the males, for the females, and also for both sexes together. At some points there are rather large variations, but there appears to be a slight trend in favour of larger weaning percentages for smaller litters. The weaning percentages for males, females, and for both sexes together are 84·5, 83·6 and 84·0 respectively. There is, therefore, only a very small difference in favour of the males.

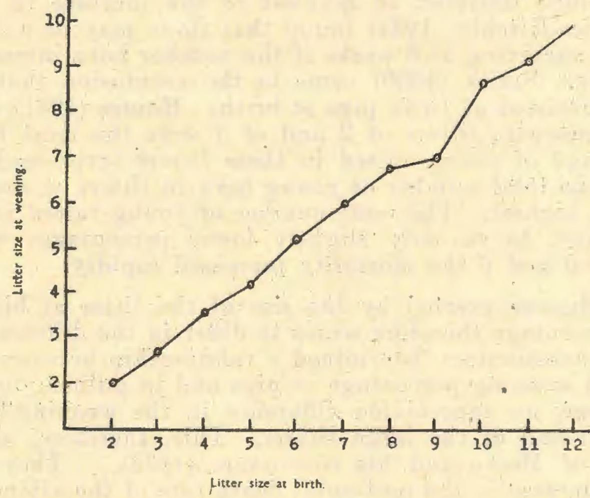

Fig. 19.—Number of young per litter at birth and at weaning.

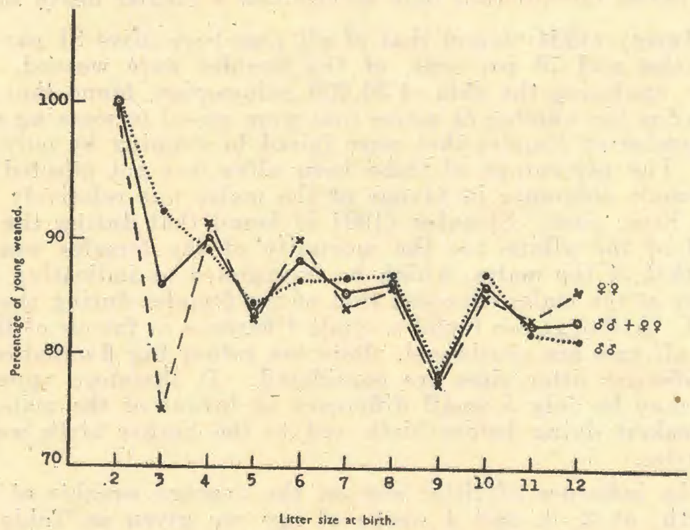

Fig. 20.—Influence of litter size at birth on the percentage of young weaned.

Wild (1927) found a close relationship between litter size at birth and weaning percentages in pigs. In litters of less than 8 at birth, including those born dead, 85 per cent. were weaned, whereas in larger litters smaller percentages were weaned, viz., in litters of 8-11, 80 per cent.; in litters of 12-16, 60 per cent.; and in litters of over 17, only 35 per cent. The total percentage weaned in all the litter sizes averaged 72 per cent. Although the number born dead is positively correlated with litter size, the differences in the number of dead at birth are much smaller than the above percentages at weaning. Wenck (1931) also found a high mortality in pig litters of over 13 per litter at birth. Johansson (1931-32) found that when the litter size in pigs increased above 12 at birth the number at 3 weeks remained constant on account of the increase in mortality, while Menzies-Kitchin (1937) found that there may be a decrease in the number surviving at 6 weeks if the number born increased above 12 per litter. Smith (1930) came to the conclusion that the ideal litter size consisted of 10-12 pigs at birth. Haines (1931) found that for the guinea-pig, litters of 2 and of 3 were the most favourable, the percentage of young raised in these litters (expressed as a percentage of the total number of young born in litters of each of these sizes) being highest. The total number of young raised in litters of one, amounted to an only slightly lower percentage; whereas in litters of 4, 5 and 6 the mortality increased rapidly.

The influence exerted by the size of the litter at birth on the weaning percentage therefore seems to differ in the different animals. The above investigators determined a relationship between litter size at birth and weaning percentage in pigs and in guinea-pigs, whereas our data show no appreciable difference in the weaning percentage of the small and of the large litters. This, therefore, agrees with the results of Moore and his co-workers (1932). They found no consistent increase in the post-natal death rate of the albino rat when litter size increased. It was only in very small (1-4) and in very large litters (13-16) that they determined a greater death rate.

Murray (1934) found that of all pigs born alive 81 per cent. of the males and 76 per cent. of the females were weaned. Haines (1931), analysing the data of 30,000 guinea-pigs, found that of those born alive the number of males that were raised to weaning exceeded the number of females that were raised to weaning by only one per cent. The percentage of those born alive was not affected by sex. This small difference in favour of the males was relatively uniform in all litter sizes. Slonaker (1931 e) found that during the nursing period of the albino rat the mortality of the females was greater than that of the males, which he interpreted as indicating that the vitality of the males exceeded that of the females during the nursing period. Although we found a small difference in favour of the males when all rats are considered, there are rather big fluctuations when the different litter sizes are considered. It therefore appears that there may be only a small difference in favour of the males due to the weakest dying before birth and to the higher birth weights of the males.

The influence of litter size on the average weights of the rats at birth, at 2, 3, and 4 weeks of age are given in Table 23 and illustrated in Fig. 21. The birth weight of all rats were given in a previous section. The birth weights in Table 23 are only from those litters in which rats were weaned. The average birth weights of the males, the females, and of both sexes are 5·23 g. (845), 5·00 g. (889), and 5·11 g. (1,734), respectively. The birth weights of the rats born alive in those litters where none was weaned are 5·01 g. (143), 4·74 g. (157), and 4·87 g. (300) for the males, the females, and for both sexes respectively. The numbers in brackets are the numbers of rats from which the average weights were obtained. Haines (1931) found a similar result in guinea-pigs, viz., that the birth weights of those which were raised to weaning age were heavier —about 19 g. for guinea-pigs—than those which died between birth and weaning.

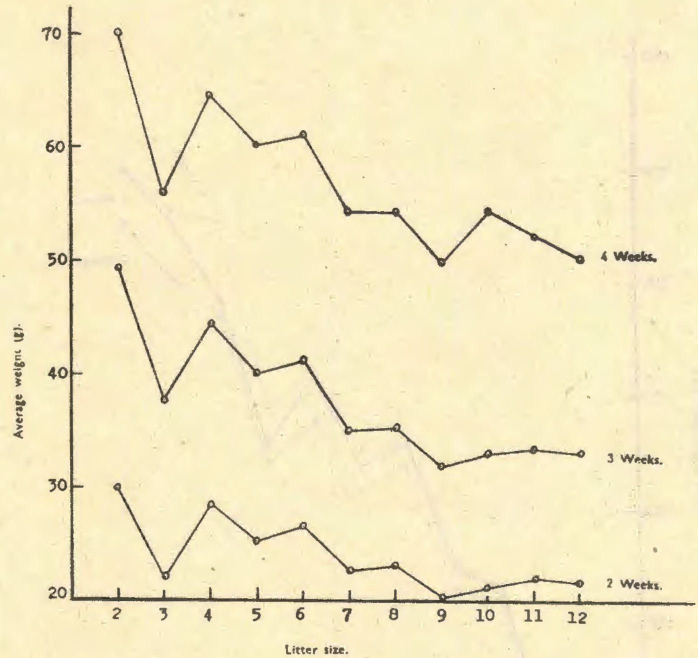

Fig. 21.—Influence of litter size at birth on average weight of young at 2, 3 and 4 weeks.

The same number of rats was alive at weaning as at 2 weeks of age. Females that destroy their young usually do so before they are 2 weeks of age. In most cases the young are destroyed before they are a week old. This agrees with Slonaker's (1931 e) results. He registered the highest mortality during the nursing period. The largest percentage of deaths usually occurred within the first six or eight days after birth. It was only in cases where females did not receive a balanced ration that they killed and often devoured some of their pups after these were two weeks old.

It will be seen from Table 23 and Figs. 21 and 22 that litter size at birth influenced the average weights of the rats from birth to weaning age. The curve for birth weights decreases as the litter size increases and then tends to flatten out (Fig. 11). Although there are some fluctuations, the same tendency is shown by each of the curves illustrating the average weights at 2, 3 and 4 weeks of age. In all cases the pups born in litters of two showed the heaviest weights, viz., 30·3 g. at 2 weeks, 49·5 g. at 3 weeks, and 70·1 g. at 4 weeks. Apart from some fluctuations, the weights for each separate age class decrease with an increase in litter size, until the litter size 9 is reached. The average weight per pup for this litter size is: 20·0 g. at 2 weeks, 31·9 g. at 3 weeks, and 49·8 g. at 4 weeks, i.e., significantly lower than the average weight of the pups born in litters of 2. After litter size 9 the average weights of rats may increase slightly or remain more or less the same, but in no litter size do they drop below the average weight of the pups of litter size 9.

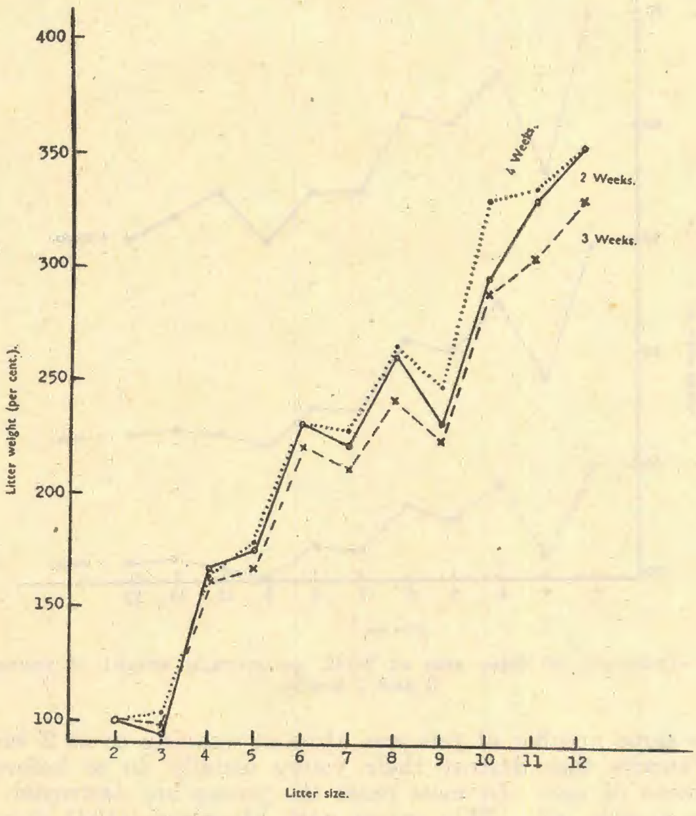

Fig. 22.—Percentage increase of total litter weight with increase in litter size. (At 2, 3, and 4 weeks the litter weight of 2 is taken as 100 in each case).

Parkes (1926) found a very close relationship in mice between litter size and weight at weaning. Mice in litters of one per litter were 3½ times as heavy as mice in litters of ten per litter. Parkes (1929) concluded that the variation in the growth of the various sizes of litters in the normal mouse is purely a question of differential nutrition.

MacDowell, Gates and MacDowell (1930) also found that the shape of the growth curve of mice was mainly due to the limitation in the quantity of milk in the suckling period and this again depended on the size of the litter.

Moore *et al* (1932) working with rats found hardly any correlation ($+0{\cdot}15 \pm 0{\cdot}08$) between average weight gains and the number of young per litter at weaning. This is, therefore, contrary to our results with regard to litter size at birth and subsequent growth rate. When the effect of litter size at weaning on the average weight at weaning is determined, then the influence appears to be different which may be the reason why Moore *et al* found no correlation. This will, however, be discussed in the next section.

Both Haines (1931) and Eaton (1932), working with guinea-pigs, found that as litter size at birth increased, the average weights of the guinea-pigs at weaning decreased. Eaton obtained a correlation coefficient between litter size and average weight at weaning of $-0{\cdot}42$ for inbred and $-0{\cdot}33$ for control stock. He does not mention whether the effect is linear or not. Haines, however, fitted his data by a second-order parabola; the differences in average weights decrease with increase in litter size and the curve eventually flattens out. Eaton states that the effect of litter size on gains from birth to weaning seems to be operative for only a short period.

This can be expected in the guinea-pig which is relatively very well developed at birth and suckles only for about two weeks. The rat, on the other hand, is very immature at birth and only starts eating at 18 to 21 days after birth. Hall and Pierce (1934) state that the growth of kittens does not seem to be affected by litter size.

(*c*) *Influence of litter size at weaning on average weight.*

In order to investigate whether litter size at birth and litter size at weaning have the same effect on the average weights at weaning, the average weights of the rats at weaning have been arranged according to litter size at weaning. As will be seen in Table 25 and Fig. 23 the average weights of the rats at weaning follow quite a different trend from that obtained in Table 23 and in Fig. 21.

There is at first an increase in the average weights as litter size increased from 2 to 4, then a decrease till 8, then again an increase till 10, then a very sharp decrease. It, therefore, appears as if some other factor or factors are affecting the average weights apart from litter size.

Moore *et al* (1932) found no significant correlation between average weight gains and the number of young per litter at weaning. If the trend of the average weights at weaning with increase in litter size had been the same as in our data, then it could be expected that no significant correlation would be obtained.

Work done on the pig show no agreement with regard to the influence of litter size and the weight at 3, 6 or 8 weeks of age. McMeekan (1936) concluded that the individual weight of the weaner at 8 weeks is not dependent upon the number of pigs in the litter. At 3 weeks, however, his average weights first show a decrease from

3 to 6 per litter, then some fluctuation with a tendency to flatten out and from 10 to 12 a continuous decrease. Menzies-Kitchin (1937) suggested that the high amount of dairy products given to pigs before weaning may be the cause that litter size at 8 weeks had no effect on average weight. Smith and Donald (1937) also came to the conclusion that there was no general relation between weaning (8 weeks) weight and litter size at weaning. The curve which they obtained is similar to the one McMeekan got for pigs at 3 weeks. Bywaters (1937) found that the size of the litter weaned had only a small effect on the weight of the pigs therein. Johansson (1931-32) Axelsson (1934) and Menzies-Kitchin (1937) working on much larger numbers of observations all found that as the litter size increased the average weights of the pigs decreased. The weights of Johansson and Axelsson were obtained when the pigs were 3 weeks old, while those of Menzies-Kitchin were obtained when the pigs were 6 weeks old. The latter found a difference of 24·4 per cent. in the average weight of the young in litters of 4 and 12.

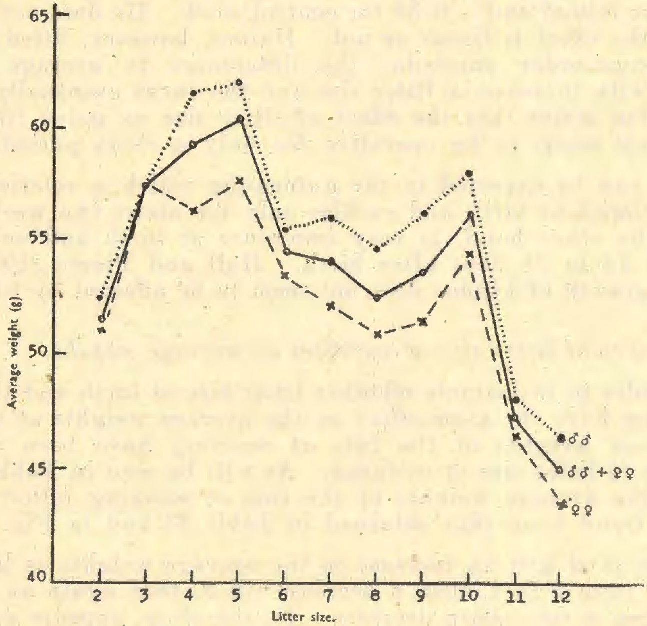

Fig. 23.—Influence of litter size at 4 weeks on average weight of young at 4 weeks.

Bonsma and Oosthuizen (1935) determined the amount of milk produced by sows with litters of different sizes. If their results are plotted then it would appear that after a litter size of 7 or 8 young the milk production may remain nearly constant for further increases in litter size. They also showed the average amount of milk obtained per pig in litters of different sizes after an eight week suckling period. A pig in a litter of 4 or less obtained 75 lb. of milk while one in a litter of 9 or 10 only got 44 lb. of milk. Unless pigs in large litters are fed exceptionally well especially on dairy products, when they start to eat, then it appears that litter size will have an influence on their average weights when they are weaned.

In Table 25 the corresponding litter sizes at birth are given for various weaning litter sizes. Expressed as percentages, the trend is illustrated in Fig. 24. The smallest litters at weaning were relatively the largest at birth. This may be a partial or even the whole explanation of the curve obtained in Fig. 23. Moore *et al* (1932), for instance, found that the rats in the smallest litters were of a poorer type and most often produced by second rate females. With mice, Parkes (1926) had the same experience; poor mothers, which would in any case rear a litter in an unsatisfactory manner, are undoubtedly the most prone to eat some or all of the young, while the large litters in which all are reared, will tend to be those of good mothers, which may be able to supply each individual of a large litter with as much nourishment as a poorer mother would be able to give to each individual of a smaller litter.

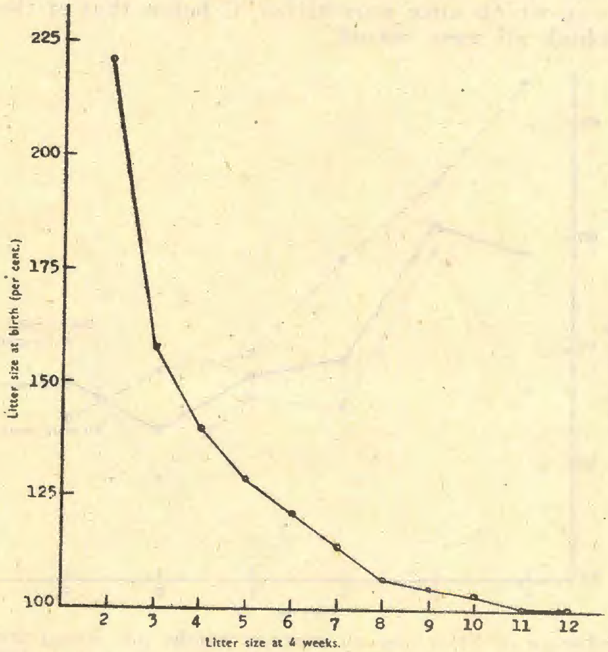

Fig. 24.—Litter size at 4 weeks and litter size at birth. (Litter size at birth expressed as a percentage of litter size at 4 weeks.)

To see whether the type of curve of Fig. 23 was due to the effect of poor and good mothers, the average weights of litters of which all pups were reared, are also given in Table 25 according to litter size. With the exception of the observations at litter sizes of 3 and 10, the average weight per rat shows a continuous decrease as the litter sizes increase from 2 to 12. The average weight per rat for a litter size of 2 is 70·7 g. but, when all litters are considered, only 51·6 g. The average birth weight of the rats in the litters where all were reared amounted to 5·32 g., as compared to 5·11 g. when all rats weaned are considered.

In Table 26 the average weights of pups are given from litters in which all were reared and from those in which one and more and also two and more were killed. The result is shown in Fig. 25. Only litters in which 4 to 9 pups were reared are considered, so as to eliminate fluctuations due to a too small number of observations. The average weight of rats from litters of which all were reared shows a continuous decrease with a tendency for the decrease to become smaller from a litter size of 7 and above. This is obtained more or less the same type of curve as was obtained for litter size at birth and average weight at weaning. The average weights of rats from litters in which one and more or two and more were killed, however, shows quite a different trend. There is first an increase, then a decrease, and again an increase, i.e., the same type of curve as in Fig. 23 when all litters are considered. It is, furthermore, noteworthy that at every point except at a litter size of 9, the average weight of rats from litters in which some were killed, is below that of the rats from litters in which all were reared.

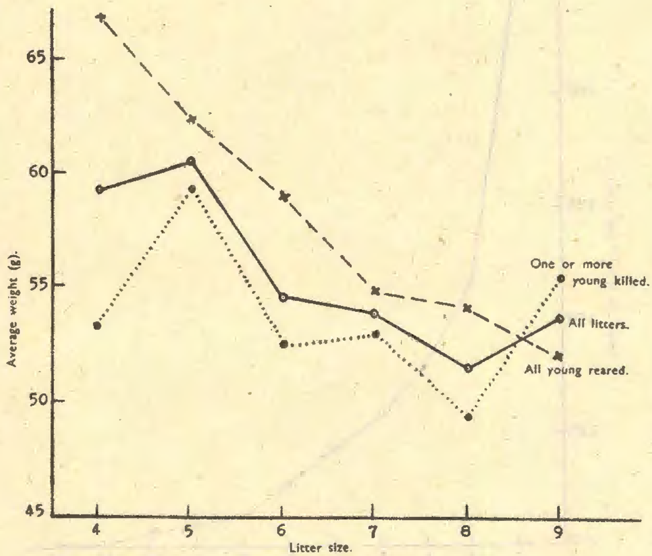

Fig. 25.—Influence of litter size on average weight per young from litters in which all were reared and in which one or more were killed.

Our results, therefore, agree with the experience of Moore *et al* (1932) with rats and of Parkes (1926) with mice in so far that those rats which destroyed some of their young, were poorer mothers, as regards milk supply, than those which reared all their young. The peculiar shape of the curve of average weights at weaning, on the other hand, appears to indicate that the rats rearing the smallest litters, of which some had been destroyed, were poorer milk producers than those rearing larger litters. If the females that reared the smallest litters, were the poorest females, it is possible that their quality increased according to the increase in their litter sizes, and hence there is an increase in the average weight as the litter increases up to 5. On account of the downward pull of litter size, there follows a decrease.

There is, however, another small increase before the sudden drop after a litter size of 10 has been reached. In the large litters, 8 and higher, the number of rats killed constitutes only a small percentage of the litter size at birth, i.e., if the litter size is 8 or more, it was only slightly larger at birth. Only good females produce such large litters so that the material becomes more uniform with regard to the quality of the females when the largest litters are considered.

The sex ratios at birth and at weaning show rather big differences for some litter sizes. There, however, appears to be no regular trend, i.e., more males for instance dying between birth and four weeks in some litters than in others. From Slonaker's (1931 e) results it, however, appeared that during the nursing period the mortality of the females was greater than that of the males.

(*d*) *Influence of age of mother.*

From Table 27 and Fig. 26 it will be seen that the youngest age class and the three oldest age classes have the highest weaning percentages. There is, however, some fluctuation between the remaining three age classes. In the age class of 10 to 11 months there is a marked increase above the previous class. This high percentage then remains constant. This is probably due to the fact that from the third litter onwards only those females that reared large litters, were used. From Table 31 it will be seen that at the birth of the third litter the average age of the mothers was 9·4 months.

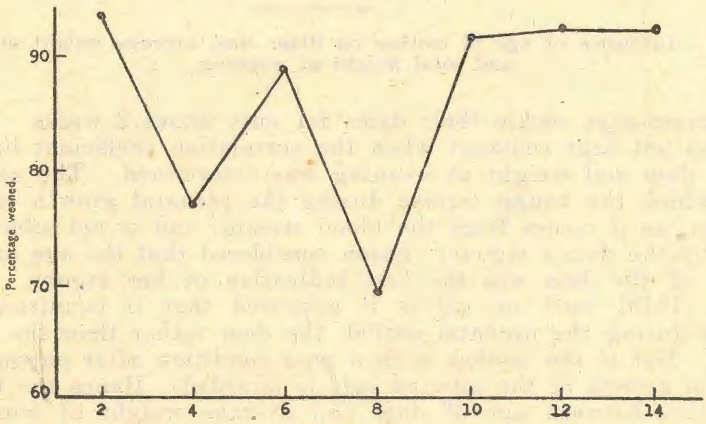

Fig. 26.—Influence of age of mother on the percentage of young weaned.

As the mothers grew older, the number of young weaned per litter followed the same downward trend as the number at birth (Fig. 27). The average weights of the rats on the other hand showed an increase up to the age of 10 to 11 months (Table 28). Then there is a drop with an increase again for the oldest mothers. Although the total litter weight was highest for the youngest mothers, the total litter weights for the remaining classes showed no upward or downward trend.

Eaton (1932) found in guinea-pigs a higher correlation between weaning weights and age of dam than between birth weights and age of dam. He considered that this might be due to the fact that older dams were better able to furnish the proper amount of nourishment for the young during the early period between birth and weaning, thus assuring good gains through the entire period to weaning.

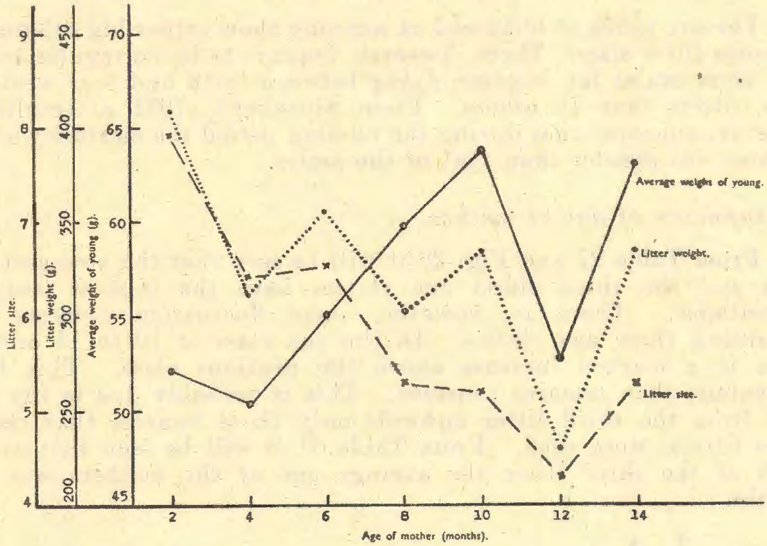

Fig. 27.—Influence of age of mother on litter size, average weight of young and total weight at weaning.

Guinea-pigs suckle their dams for only about 2 weeks. Litter size was not kept constant when the correlation coefficient between age of dam and weight at weaning was determined. The nourishment which the young receive during the prenatal growth is more uniform, as it comes from the blood stream, and is not affected so much by the dam's vigour. Eaton considered that the age and the weight of the dam was the best indication of her vigour. From Eckles (1919) work on calves it appeared that if conditions are adverse during the prenatal period, the dam rather than the foetus suffers. But if the mother is in a poor condition after parturition, then the growth of the nursing calf is retarded. Hence the higher correlation between age of dam and average weight of young at weaning than at birth.

Since the litter size decreased with an increase in the weight of the mother, the average weights of rats at weaning were arranged according to litter size at birth in Table 29 and according to litter size at weaning in Table 30. Litters of 6 and 7 and litters of 8 and 9 have been combined to get a large number of observations. The results are illustrated in Figs. 28 and 29.

At the extremes of the different curves there are some fluctuations, but nevertheless the general trends appear to be quite definite. In the different litter sizes at birth and at weaning, there was at first an increase in the average weight at weaning as the age of the mother increased. The maximum was reached at the age of 8 months, then there was a decrease again. When the effect of litter size was, therefore eliminated, the efficiency of the mothers increased until they were 8 to 9 months old. After that there was a decrease in efficiency.

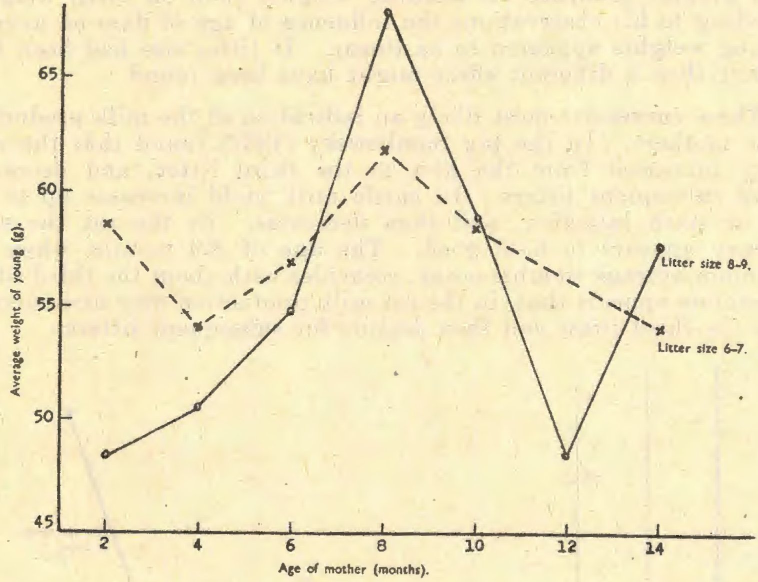

Fig. 28.—Influence of age of mother on average weight of young at weaning, litter size at birth remaining constant.

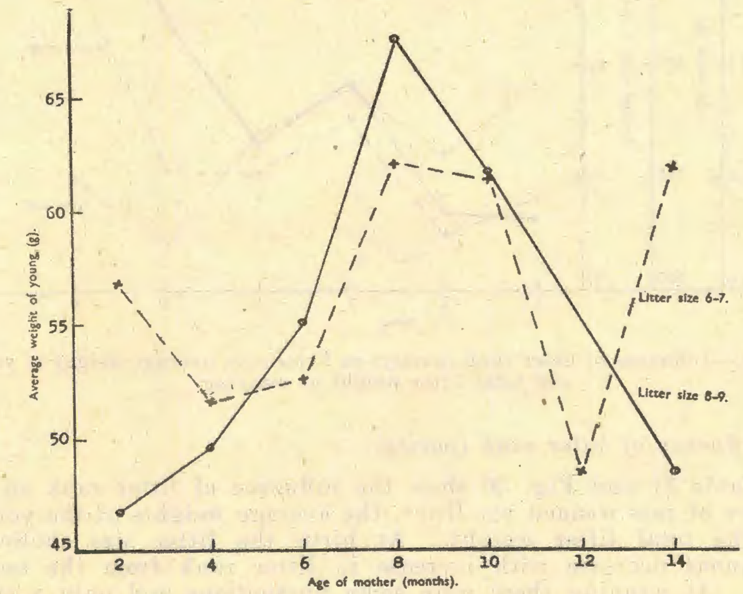

Fig. 29.—Influence of age of mother on average weight of young at weaning—litter size at weaning remaining constant.

This is, therefore, different to the effect of the age of the dam on the litter weights at birth. There the age did not affect the average birth weights when litter size remained constant. This agrees with Eaton's (1932) observations in guinea-pigs, viz., that age of dam has a greater influence on weaning weights than on birth weights. According to his observations the influence of age of dam on average weaning weights appeared to be linear. If litter size had been kept constant then a different effect might have been found.

These curves are most likely an indication of the milk production of the mothers. In the pig Sambowsky (1932) found that the milk supply increased from the first to the third litter, and decreased during subsequent litters. In cattle milk yield increases up to the fifth or sixth lactation, and then decreases. In the rat the same tendency appears to hold good. The age of 8-9 months when the maximum average weights occur, coincides with about the third litter. It therefore appears that, in the rat milk production may also increase up to the third litter and then decline for subsequent litters.

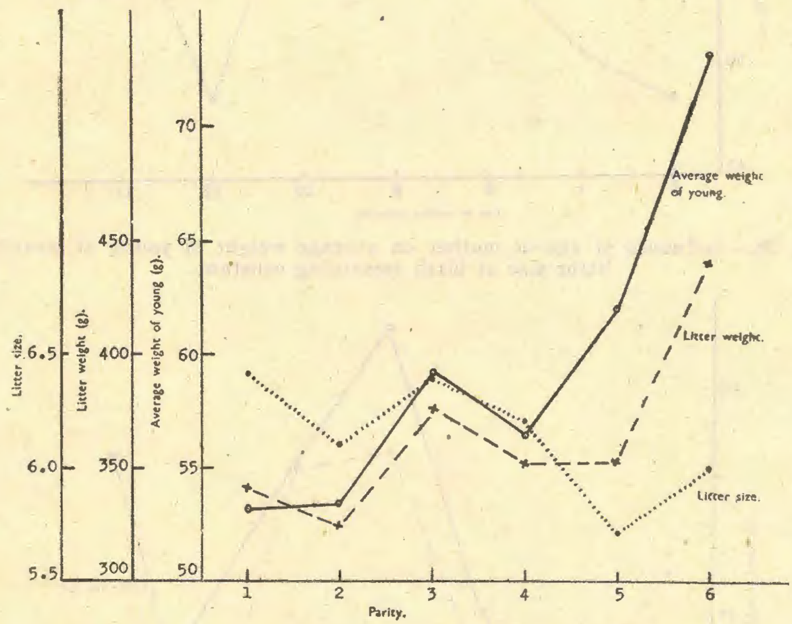

Fig. 30.—Influence of litter rank (parity) on litter size, average weight of young and total litter weight at weaning.

(e) Influence of litter rank (parity).

Table 31 and Fig. 30 show the influence of litter rank on the number of rats weaned per litter, the average weights of the young, and the total litter weight. At birth the litter size showed a continuous decrease with increase in litter rank from the second litter. At weaning there were some fluctuations and only a small decrease in the number per litter. This was due to the higher weaning percentages from the third litter onward.

The apparent discrepancy mentioned in a previous section was manifested again. Although the average age of the females of the fourth litter was 11·6 months, the average number of young reared was 6·2 per litter, whereas for the age class 10 to 11 months it was only 5·2 per litter. As was explained, the best females were selected after each litter that was reared. Age varied to quite a marked extent since the different litters were not produced when a female had reached a definite age. The influence of litter rank was, therefore, not manifested, except in the oldest rats, when the data were arranged according to the ages of the mothers.

By discarding poor mothers, the number of young weaned per litter remained nearly constant from the first to the sixth litter. The number born per litter was not affected. At a later stage it will be shown that the number per litter at birth did not increase during the four years that observations were made. This rat population is probably nearly homozygous for litter size by this time, so that the differences in litter size at birth have been influenced by non-genetic factors. The five females that produced five litters, weaned an average of 7·8 young per litter in the first litter and 6·4 in the fifth litter. If poor mothers are therefore not discarded, the trend of litter size at weaning with increase in litter rank will be the same as that at birth. By breeding only from females that produced the largest litters at weaning no selection for higher fertility took place. Only the poor mothers were discarded. Although the rats were so inbred, there was quite a marked variation in the temperament of some of the mothers. Certain females would destroy their young more readily than others when disturbed.

The average weight per rat remained constant for the first and second litters, then there was an increase to the third, a decrease to the fourth, then again increases at the fifth and sixth litters. On account of the small number of litters, it was not possible to arrange the data of litter sizes 6 and 7 or 8 and 9 according to parity. For litter sizes 6 to 7 there was only one in the fifth litter. The drop in the average weight per rat after the third litter, indicates the same influence as was found for age of dam when litter size remained constant. After that the influence of the few good females is seen. No definite conclusions can therefore be drawn with regard to the influence of litter rank on average weight when litter size is constant. When Tables 29 and 30 and Figs. 28 and 29 are considered in conjunction with the influence of litter rank, it would appear that when the rats are not selected, the average weights of the young at weaning will decrease after the third litter when the influence of litter size has been eliminated, as a result of a decrease in the milk production of the females after the third litter.

(f) Influence of weight of mother at parturition.

The influence of the weight of the mothers at birth on the number of pups weaned and on their average weights, is shown in Tables 33 and 34 and Fig. 31. With an increase in the weight of the mother there was no consistent influence on the percentage of the young weaned. Nor was there a consistent change when the first litters alone were considered. From general observations it sometimes appeared as if the heavy females overlay more of their young than the lighter females. From these figures, however, it appears that there was no difference.

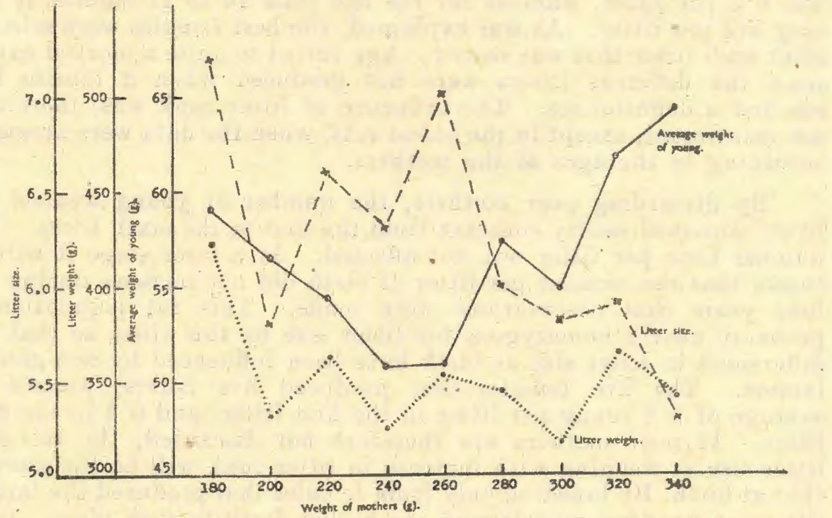

Fig. 31.—Influence of weight of mother on litter size, average weight of young and total litter weight at weaning.

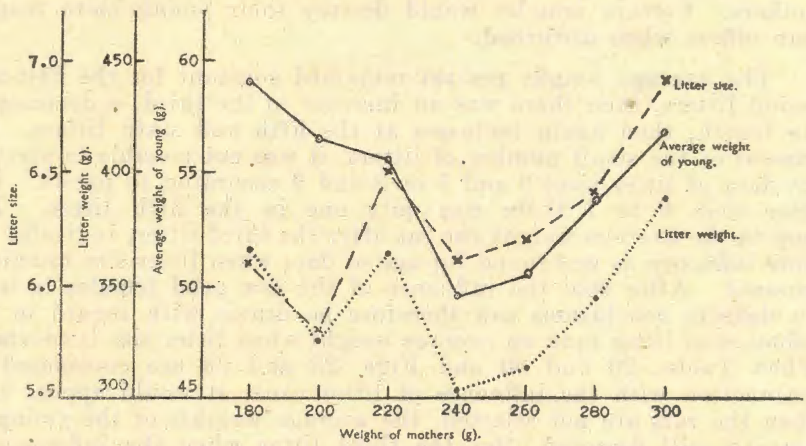

Fig. 32.—Influence of weight of mother on litter size, average weight of young and total litter weight at weaning in first litters only.

With regard to the influence of weight on the average litter size, apart from the initial drop, there was an increase up to the weight class 260 to 279 g. and then a continuous drop. The average weight per rat on the other hand at first showed a continuous decrease to the weight class 240 to 259 g., remained the same at the next weight class and after that the average weights increased. To eliminate most of the influence of litter size, only the data of the first litters were arranged in Table 35. The curves are illustrated in Fig. 32.

Litter size decreased as the weights of the mothers increased from 180 to 200 g. and from 220 to 240 g., then the increase was continuous. The curve illustrating the average weight per rat has practically the same shape as Fig. 31. There was first a continuous decrease in the average weight per pup as the weight of the mothers increased to the weight of 240-259 g. and then a continuous increase in the average weights of the young. In spite of the increase in litter size there was still an increase in the average weights.

Eaton (1932) found with guinea-pigs a positive correlation (0·35) between the weight of the dam and the weaning weight of the young. In the cat, however, Hall and Pierce (1934) found no relationship between the weight of the mothers and the rate of growth of the kittens.

When the litter size remains constant, the same influence is seen with an increase of the weight of the mother (Table 36 and Fig. 33).

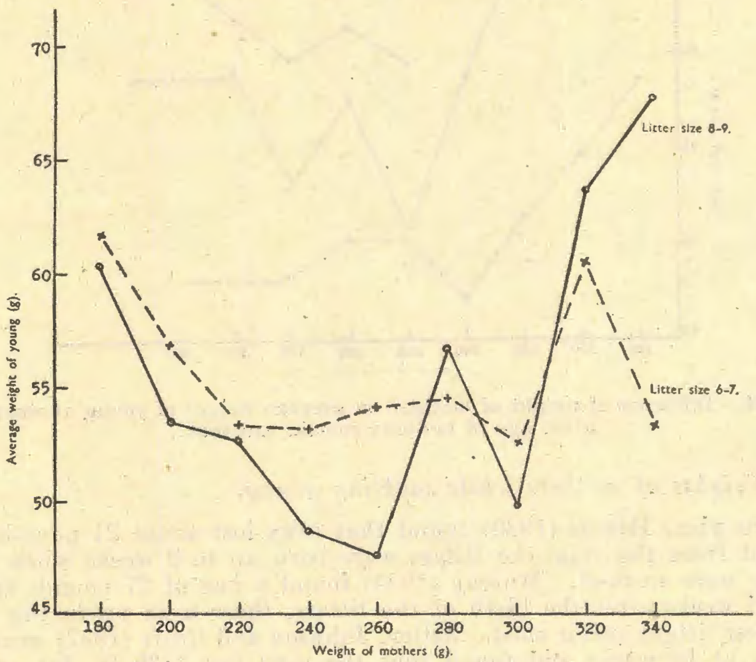

Fig. 33.—Influence of weight of mothers on average weight of young at weaning when litter size remains constant.

Even in the first litter the age of the mothers increased as they grew heavier. In Table 36 three age classes have therefore been taken in which to arrange the average weights as the weights of the mothers increased. The averages have been plotted in Fig. 34. The youngest age class (2-5 months) showed a decrease and then a tendency to remain more or less constant. In the second age class (6-9 months) there was also a decrease, but after that a tendency to increase, whereas in the oldest age class (10 months and over) there appears only a tendency to increase. It therefore appears that age of mother had some effect on the average weight curves in Figs. 31 and 32.

These curves (Fig. 34) also indicate that in the case of young females, the heavy ones are not the best mothers. It does not appear that litter size played any part, as is shown in Table 35 and Fig. 32. In the oldest age class again the heavier females were slightly better than the lighter ones. Since there were no observations in the lighter weight classes of the oldest group (10 months and over), no definite conclusions can be drawn with regard to the influence of the weights of old rats on the average weaning weights of their young. These results, however, indicate that in the case of young females that were very heavy, a large fat deposition had taken place with the result that the milk production was affected. Further experimental work will, however, be necessary to test this out conclusively.

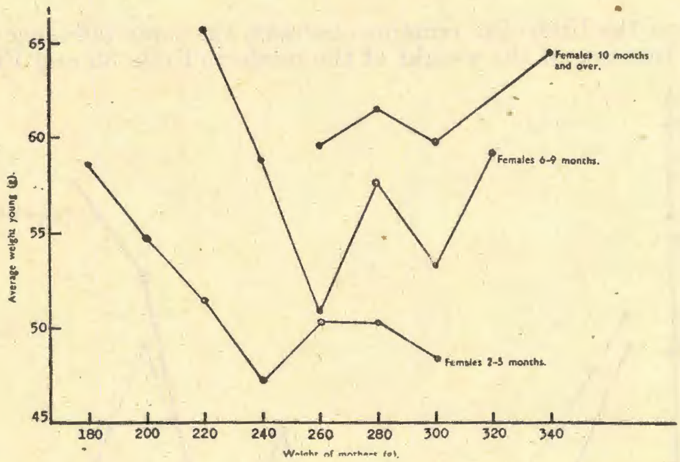

Fig. 34.—Influence of weight of mothers on average weight of young at weaning when age of mothers remain constant.

(*g*) *Weights of mothers while suckling young.*

In pigs, Huszti (1930) found that sows lost about 21 pounds in weight from the time the litters were born up to 9 weeks when the young were weaned. Murray (1934) found a loss of 27 pounds from 4 to 8 weeks after the birth of the litters, those sows producing the heaviest litters losing most. Zeller, Johnson and Craft (1937) weaned litters at 10 weeks and found that the sows lost 7·35 lb. for every additional pig weaned.

In order to ascertain whether a nursing rat is affected in the same manner, the weights of the females have been arranged according to the litter sizes at four weeks. About half the litters were weaned at three weeks and the rest at four weeks. The rats weaned at four weeks showed the same trends as all suckling females showed up to three weeks. Only those weaned at four weeks were, therefore, included in Table 37 so as to get a longer lactation period. To get a better indication of the change in the weight of the mothers, the average weight for each litter size at birth was taken as 100 and the weights at 2, 3, and 4 weeks were then expressed as percentages of the weights at birth.

On account of the fluctuations, a trend is not clearly shown with an increase in litter size. The weights of two litter sizes have therefore been combined and the results plotted in Fig. 35. Here it will be seen that at two weeks the weights of the mothers were not affected as the litter size increased. At three weeks, there was a continuous decrease after a litter size of six had been reached. At four weeks a decrease is observed after a litter size of 8 had been reached.

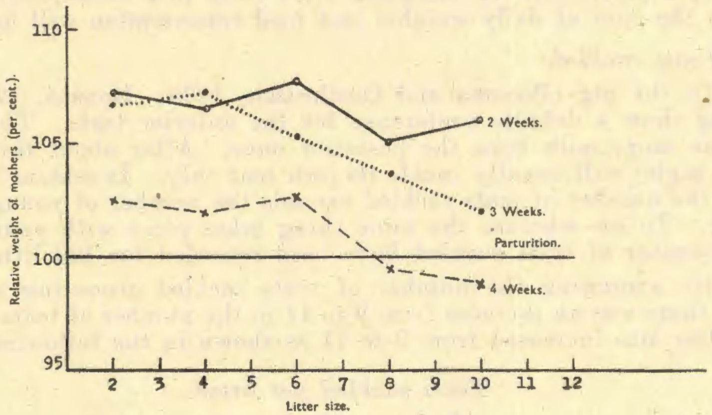

Fig. 35.—Influence of litter size on relative weight of mothers at 2, 3 and 4 weeks after birth of litters.

In all litter sizes, except 2, the mothers gained in weight from the birth of the litters up to 2 weeks. From the second to the third week there was only a small decrease (1·5 per cent.), but a larger decrease (about 4 per cent.) from the third to the fourth week. When the litters were weaned, the mothers were only just above their weights after the birth of the litters.

The total litter weight at weaning increased with litter size up to a litter size of 10, then there was a decrease. The influence of the total litter weight produced on relative weights of mothers will, therefore, be the same as in Table 37 and in Fig. 35 for litter size. The size and the weight of the litter, therefore, had only a slight influence on the weight of the mother so that it would appear that the rat regulates her food intake according to her production and consequently does not lose in weight. This is also indicated by the fact that during the period that the young subsist only on the milk of the mother, she puts on weight. At three weeks the pups usually start eating and after that the weight of the mother shows a greater decrease.

Moore *et al* (1932), however, found that the weight of the nursing rat decreased during the lactation period. The first week after the birth of the litter, weight remained constant but after that decreased slightly every week. Their results, however, agree with ours in that the size of the litter had no effect on the weight of the mother.

Slonaker (1931 f), on the other hand, considers that in general a mother nursing a large litter loses more weight than one nursing a small litter. His data were, however, obtained with rats which received different amounts of protein. The group receiving most protein lost least in weight (2 g.) while suckling their pups. The two groups receiving the lowest percentage of protein in their ration had the largest litters whereas those on the highest protein ration and which lost only 2 g. had the smallest average litter at birth and at weaning.

This question of food consumption of the mothers during the lactation period will be discussed more fully in a subsequent section when the data of daily weights and food consumption will be given.

(*h*) *Teats suckled.*

In the pig (Bonsma and Oosthuizen, 1935; Donald, 1937) the young show a definite preference for the anterior teats. These also secrete more milk than the posterior ones. After about three days each piglet will usually suckle its own teat only. It seldom happens that the number of teats suckled exceeds the number of young in the litter. To see whether the same thing takes place with young rats, the number of teats suckled have been recorded for 129 litters.

By arranging the number of teats suckled according to litter size, there was an increase from 9 to 11 in the number of teats suckled as litter size increased from 2 to 11 as shown in the following table.

Teats suckled per litter.
(*Different litter sizes.*)

Litter Size.	Number Litters.	Average Number Teats Suckled per Litter.
2	8	9·0
3	8	9·3
4	22	9·3
5	10	9·7
6	21	10·4
7	14	10·2
8	22	10·2
9	14	10·9
10	6	11·0
11	4	11·0

Teats not suckled.
(*Teats numbered from the front.*)

Teat.	No. Obs.	R. and L.	Percentage Times not Suckled.
R. 1	8	1	4·4
R. 2	18	2	8·4
R. 3	4	3	3·2
R. 4	4	4	3·2
R. 5	15	5	10·8
R. 6	87	6	70·0
L. 1	3		
L. 2	3		
L. 3	4		
L. 4	4		
L. 5	12		
L. 6	89		

Rats usually have six pairs of teats. The pair left most often was the sixth pair counting from the front. Out of a total of 249 teats not suckled, the number of times that the last pair was not suckled, constituted 70 per cent of this total. The second last pair came next, with 10.8 per cent of the total. The two second from the front came third with 8.4 per cent. The right second from the front was left 18 times in comparison with the 3 of the left second. The other pairs were all round 3 and 4 per cent. The rat, therefore, does not keep to one teat as the pig. One rat may suckle as many as 4·5 teats. There is also no gradual increase in the number of times the teats from the front to the back were not suckled. Only the last pair showed a sudden rise, being discarded more than twice as often as the remaining ten teats together.

(i) General discussion and resumé of factors influencing the average weights of young rats at weaning.

Litter size at birth does not seem to influence the weaning percentage in the rat to the same extent as in the case of the pig and the guinea-pig. Litter size at birth showed the same influence on the average weights at 2, 3, and 4 weeks, as it did on the birth weights. There is at first a decreasing decline in the curve as litter size increases, until a litter size of 9 has been reached, then the average weights remained more or less constant up to the largest litter size (12). The guinea-pig (Haines 1931) shows the same type of curve, whereas in the cat (Hall and Pierce 1934) no such influence was found.

On account of the nearly straight line obtained between litter size at birth and litter size at weaning, one would expect about the same influence on average weaning weights. Litter size at weaning, however, shows quite a different influence. The shape of the curve as litter size (at weaning) increases indicates that some other factor or factors exert an influence at the same time.

From our data it would appear that this peculiar influence of litter size at weaning on the average weights of the young (Fig. 23) was due to the relationship between the number weaned and the quality of the female, i.e., the milking ability of the females increased with the litter size. Increase in litter size, however, had the opposite effect on the average weight of young at birth, with the result that the peculiar curve was obtained.

In arranging data according to litter size, it should therefore be stated whether litter size at birth or at weaning is taken. The nearly linear effect of litter size at birth on the average weights at weaning, indicates that it would be preferable to work with litter size at birth when correction factors for litter size are determined, than to work with litter size at weaning.

As the females grew older, the litter size at weaning decreased while the average weights at weaning increased. When the litter size at birth and at weaning remained constant, the increase in age of the mothers showed quite a differnt influence on the average weights at weaning. At first there was an increase up to an age of 8 to 9 months when there was again a decrease in the weights. It was shown in a previous section when litter size remained constant, age of mother had no effect on the average birth weights. This therefore indicates the influence of age on milk production and consequently on the average weights of the young. The foetus obtains its nourishment from the blood stream which remains nearly constant with increase in age, while the milk production in those animals, where observations have been made, first show an increase and then a decrease. From these results it would appear that the same holds good for the rat, a maximum milk production being attained at the age of 8 to 9 months under our conditions. This age coincides more or less with the birth of the third litter.

With an increase in litter rank the percentage of young weaned tended to increase with the result that, although the average number per litter at birth decreased, the average number at weaning remained nearly constant from the first to the sixth litter. The increase in the weaning percentage was probably due to the selection of those females that gave the best results at weaning. The average litter size of the five females that produced five litters decreased from 7·8 to 6·4 young per litter at weaning. No selection for higher fertility had therefore taken place, only poor mothers had been discarded since some females will destroy their young more readily than others when disturbed. Since this strain of the albino rat had been inbred for such a long time, it appears that they are nearly homozygous for fertility. The average variation in litter size must therefore have been caused by non-genetic factor or factors. Whether it will be possible to select for higher milk yield can only be answered after such work had been done for a larger number of generations, unselected stock being kept at the same time for control purposes.

On account of the small number of rats that had five and six litters, no definite conclusion can be drawn with regard to the effect of litter rank on average weights of young at weaning. When considered in conjunction with the influence of age, it would appear that in an unselected population the average weights at weaning will decrease after the third litter as a result of the decrease in milk production. These results indicate that under our conditions the best results will be obtained by using females only until they are 8 to 9 months old and to let them produce three litters. After this age only the best females should be selected to be used for further breeding if individual records had been kept.

On the average birth weights the weight of the mothers had no effect. On the average weaning weights there was a decided influence, also when litter size and parity remained constant. As the weight of the mother increased up to 260 g. the average weight of the young at weaning decreased. After that the average weights increased again. The litter size showed the opposite trend when all the data are considered, but in the first litters only, litter size at weaning also increased after some fluctuations. A strong factor must influence the average litter weight since it usually decreased when average litter size increased. This influence is probably exerted through the milk supply.

One factor that appears to have some influence as the weight of the mother increases, is her age. Young females (2-5 months old) showed a decrease in the average weaning weights with an increase in weight at parturition. From a weight of 240 g. the average weaning weights remained more or less constant. In the old group (10 months and over) there was a tendency for the average weaning weights to increase as the weights of the mothers increased. As mentioned before this influence is most likely through the milk production of the mothers. These results indicate that young heavy females are poorer milkers on acccount of excessive fat deposition. The weight of old heavy females on the other hand is made up of extra growth in bone and flesh covering since the rat still grows after a year. The milk production of the old females was, therefore, not affected by the increase in live weight. As indicated, conclusive work to test out these different points has still to be done.

B. Influence of Environment.

When the influence of environmental factors on living organisms is studied, one difficulty that immediately confronts the investigator, is that these factors can not be controlled. Such observations should, therefore, extend over one year at least to get the influence of all the seasons. By studying the reactions of the organisms to the environment during different seasons one may obtain certain indications as to the factors or combination of factors exerting an influence. In the introduction we have mentioned some of the work that has been done on environmental influence on animals, especially on the seasonal effect of the environment. In this section we will indicate how the environment influences different phases of the growing animal.

1. *Number of days females took to become pregnant during different months.*

It was only after our investigations had been carried on for some time that a record was kept of the number of days that had elapsed since a female was put with a male until her young were born. From general observations it appeared that there were quite marked differences among the various females. As has been shown, the average gestation period is 22 days. There was one female which gave birth to a litter only 21 days after she had been put with a male, whereas the longest period that elapsed from the time that a female was put with a male until her litter was born was 53 days.

In order to see whether the age, weight, reproduction, and milk production of the females differed according to the different number of days that had elapsed since a female had been put with a male until her litter was born, the females were grouped together in Table 38 according to the number of days that elapsed since they were put with the males until their litters were born.

Although Table 38 shows that the rats in the two classes that were the longest with the males are the oldest, there appears to be no definite trend. The same holds good for the weights of the rats. Age and condition, therefore, appear to have no effect on the time that a female was with a male.

The number of young born and weaned per litter shows rather large variations but no definite trend is shown. The same is the case with the average weights at birth and at weaning. The young that were the heaviest (65·2 g.) and the lightest (49·8 g.) at weaning were from the classes 31 to 32 and 23 to 24) with the largest average litters (7·09 and 7·04 respectively). According to these figures there is, therefore, no positive or negative correlation between fertility and time with males, or between amount of milk produced and time with males. The figures in Table 38, therefore, indicate that there was no differences between females that remained for a short or for a long time with the males.

The females were consequently grouped according to the time of the year that they were put with the males. As is shown in Table 39 and in Fig. 36 it appears that the time of the year had no effect on the length of time that the females were with the males. Although there were fluctuations, especially at the September and November points of the curve, there appears to be a general trend, which shows up better when the moving average is used, i.e., by grouping 3 months at every point. From March to July (inclusive) the females tended to remain long with the males, whereas from August to February they tended to remain for a shorter period. After February there was a sudden increase in the number of days that the females remained with the males.

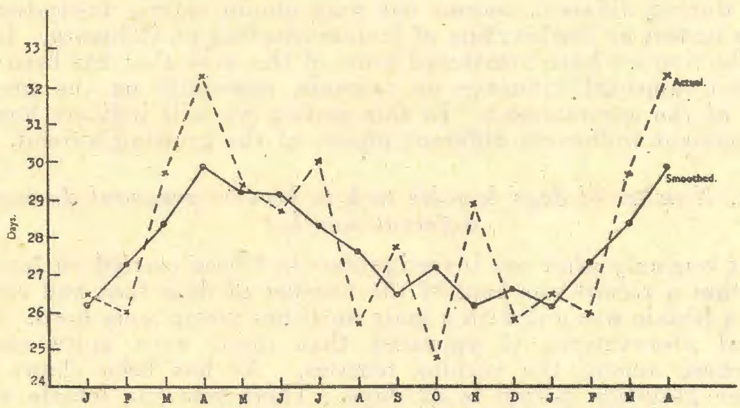

Fig. 36.—Time of year and number of days females were with males before becoming pregnent.

These trends during the different months appear to suggest that the length of day may have some influence. Rats do not breed at low temperatures, but the effect of low temperatures can, however, be ruled out since the room was heated during the winter months. Although rats are rather susceptible to high temperatures, it does not appear that high temperatures had any influence on the length of time the females were with the males, since the warm months show the shortest periods.

Up to the present it does not appear as if any observations have been made on the regularity of the oestrous cycles of the rat and the mouse during different seasons under laboratory conditions. Baker and Ranson (1932, a, b, 1933), however, carried out experiments on the factors that affected the breeding of the field mouse (*Microtus agrestis*). The shortening of the daily period of exposure to light from 15 hours to 9 hours almost prevented reproduction. It was the female that was chiefly affected. When the mice were fed summer food and allowed 15 hours of light each day, they bred less at low temperatures (5° C.) than at summer temperatures. The fecundity of the males was not affected by the low temperature. From their observations on the mice trapped in the fields, they found that there existed a general correlation between the hours of sunshine per month and the breeding condition of mice. No correlation was found between temperature or rainfall and breeding.

It would, therefore, appear from our observations that the regularity of the oestrous cycle of the albino rat may be affected by the lengthening and shortening of the days when the rats are kept under conditions where type of food remains constant and where temperature is controlled. It would, therefore, appear to be quite probable that under field conditions the oestrous cycle of the rat will be influenced to a greater extent. Man, for instance, is not influenced appreciably by season under temperate conditions, but it was mentioned by Bissonnette (1936) that extreme conditions have a decided influence. The women of Patagonia and the Eskimo fail to have sexual or menstrual cycles in the long arctic night and the men lose all sexual activity and libido. They recover and resume sexual cycles when the daylight reappears in spring. Men of an expedition were affected similarly by the conditions.

During the winter of 1938, i.e., after the observations of the four years had already been concluded, a number of males and females were transferred to a room in which the temperature was not controlled. The minimum temperature often went below 40° F. while the maximum did not go above 70° F. The males and females were kept together. The females were inspected daily for signs of oestrus and vaginal plugs. Of the 48 females, half were young virgins and the rest old females that had had litters, but none was more than a year old. Most of the females did not show oestrus. Of the young, 7 showed oestrus during 3 weeks; about the same number among the multiparae females also showed oestrus. From the general observations it did not appear as if the males were affected, for the females that showed oestrus were usually served. After about 6 weeks the rats were taken back to the room in which the temperature was controlled. After 2 weeks there was an increase in the numbr of females which showed oestrus and which were served. There were, however, a few that even after two months had not shown oestrus.

2. *Litter Sizes and Weights up to Weaning.*

(a) At birth.

(i) *Different years.*—In Table 40 are shown the average birth weights and litter sizes covering the period of four years. Litter size first decreased and then again increased during the last year. The average birth weight on the other hand decreased slightly every year. The average birth weight was 5·19 g. during the first year and 4·96 g. during the fourth year. The average weights of the males and females were 5·31 g. and 5·06 g. for the first and 5·07 g. and 4.·86 g. for the fourth year respectively. These weights are, therefore, appreciably lower than those of the stock of the Wistar colony as shown by Greenman and Duhring (1931). The average weight of 1,195 rats was 5·67 g. The average weights of the males and the females were 5·8 and 5·56 g. respectively. Whether some external influence had been at work on the birth weights causing a decrease can only be determined after the rats had been bred for a longer period at this Institution.

(ii) *Different months.*—We have mentioned the conclusions of several investigators with regard to the influence of environment on litter size and birth weight. Some were of the opinion that litter size and not birth weight was affected by environment, while others held the reverse to be the case.

In Table 41 the average birth weights and litter sizes for the different months are given. As will be seen in Fig. 37 average litter size shows rather wide fluctuations with a high tendency during the summer months and a low tendency during the winter months. The average birth weights show a high tendency only during the early winter. To obtain smoother curves, three months have been averaged to obtain one point. For February, for instance, the results of January, February and March have been averaged: for March, those of February, March and April, and so forth. These averages are illustrated in Fig. 38. These curves show that the litter sizes were at their lowest during June and July. There was then a continuous increase up to December, a slight drop to January, and then again an increase to April. After that there was a sudden drop till June. The birth weights showed hardly any change, except for May, June, and July, when they were slightly higher than during the rest of the year.

When the four seasons are considered, the following average litter sizes and birth weights are obtained:—

		Average Litter Size.	Average Birth Weight.
			g.
Winter	May June July	6·8	5·26
Spring	August September October	7·2	5·04
Summer	November December January	7·8	5·02
Autumn	February March April	7·6	5·04

The average litter size was highest during the summer and lowest during the winter. The average birth weight on the other hand was highest during the winter, but showed hardly any difference during the other three seasons. If differences in litter size is taken into consideration, the difference between the average birth weight during winter and summer will be still less, not more than ·14 g.

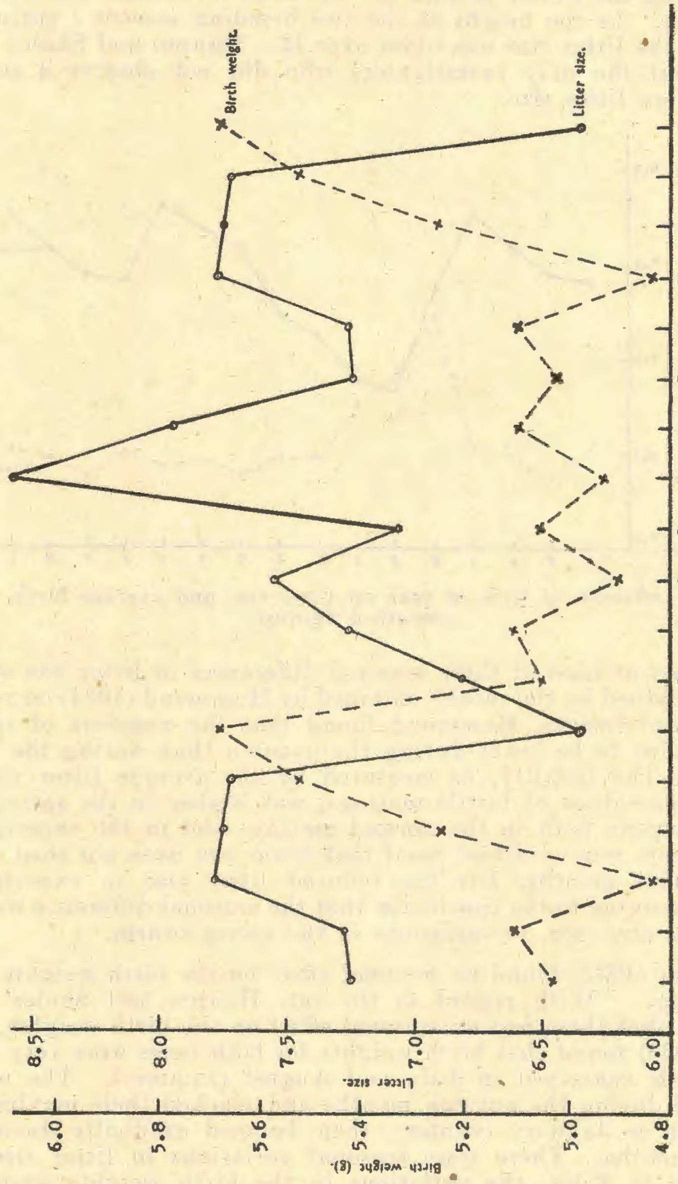

Fig. 37.—Influence of time of year on litter size and average birth weights.

Our results, therefore, agree with those of Wright (1922) and Eaton (1932) on guinea-pigs, viz., that the largest litters are born in summer and the smallest in winth. Eaton (1932) stated that it was the seasonal condition at the time of conception and not at the time of birth of the litter, that affected the litter size. In the guinea-pig this is 68 days before the birth of the litter, while in the rat it is only 22 days. Hartwell, Mottram and Mottram (1923) found that only during the winter months did the litter size of the rat fall below 6 at birth. In the height of the two breeding seasons (spring and autumn) the litter size was often over 12. Hanson and Sholes (1924) were about the only investigators who did not observe a seasonal influence on litter size.

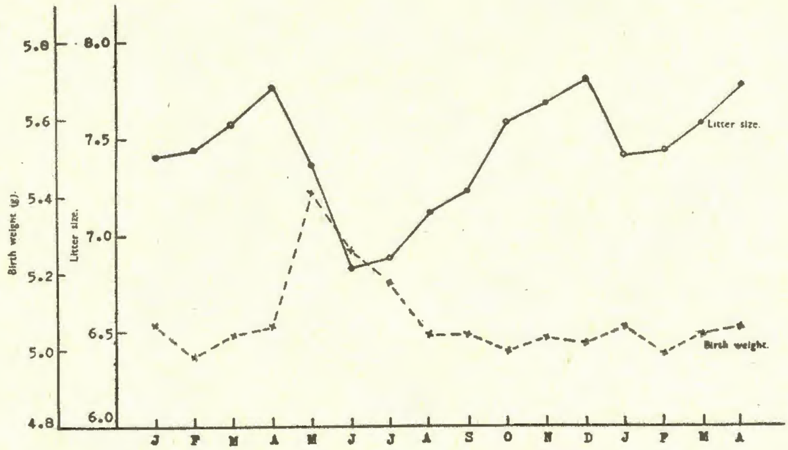

Fig. 38.—Influence of time of year on litter size and average birth weights (smoothed figures).

A part at least of these seasonal differences in litter size appears to be explained by the results obtained by Hammond (1934) on rabbits. In his experiments, Hammond found that the numbers of spermatozoa tended to be lower during the autumn than during the spring months. The fertility, as measured by the average litter size and by the percentage of fertile matings, was higher in the spring than in the autumn both in the normal matings and in the experimental ones. There was no direct proof that fewer ova were not shed during the autumn months, but the reduced litter size in experimental matings pointed to the conclusion that the seasonal difference was due, in part at any rate, to variations in the sperm swarm.

Eaton (1932) found no seasonal effect on the birth weights of the guinea-pig. With regard to the rat, Hanson and Sholes (1924) maintain that there was no seasonal effect on the birth weights, while King (1935) found that birth weights for both sexes were very low in individuals conceived in July and August (summer). The weights increased during the autumn months and reached their maximum in December or January (winter), then dropped gradually during the spring months. There were seasonal variations in litter size also, according to King, the variations in the birth weights were independent of litter size. King suggested that the low birth weights during the summer months could probably be attributed mainly to the devitalising effect of heat and humidity on the pregnant females, producing some metabolic disturbance that interfered with the proper nutrition of the young regardless of the size of the litter. In the autumn and winter months, when the temperature was under control, the rats regained their normal vigour, which resulted in the maximum birth weights.

Our results, however, indicate that temperature had no influence on the birth weights of the young. During the warm months (October to January) the temperature in the room went up to nearly 90° F. during the day, so that our rats could have been exposed to as severe temperatures as those of King. Eckles (1919) found that even under adverse conditions of nutrition the blood composition tended to remain constant, and that in the case of a pregnant female the mother suffered and not the foetus. This, however, does not hold good in all cases for Vergés (1939) found that when ewes were given poor rations single lambs were not affected while twin lambs from well-fed ewes were 47 per cent. heavier than twins of poorly-fed ewes. It has been shown that the phosphorus content (Hess and Lundhagen, 1922) and the calcium content (Bakwin and Bakwin, 1927) of the blood of children were highest during the summer and lowest toward the end of the winter. No such determinations have yet been made on rats so that we cannot say whether the blood composition was the same during the different seasons.

The sex ratios during the different months showed rather wide fluctuations. By taking seasons only, the sex ratios were:—

	♂	♀
Winter	84	: 100
Spring	107	: 100
Summer	87	: 100
Autumn	98	: 100

In different races of the Norway rat, King (1927) showed that the yearly cycle in the sex ratio reached its highest point in conceptions occurring in the spring or summer, and fell to its lowest point in autumn or winter conceptions. Our results agree in the low winter and the high spring ratios. The summer and the autumn ratios are, however, different.

Our results and those of King are, therefore, different to those found by Whitney (1939) for dogs. Those conceived during the warm months (June to November) showed a sex ratio of 116 : 100, whereas those conceived during the colder months (December to May) showed a sex ratio of 143: 100. Huntington (1938) mentions that in Japan it was noticed that after a hot and humid summer there is an astonishing preponderance of boys.

(*b*) *At weaning.*

In determining the litter sizes and weights of the young up to weaning only those litters in which one or more young were weaned, were taken into account.

Percentage of young weaned.—During the four years there were 238 litters in which one or more young were reared. In these litters there were 1,789 young of which 872 were males and 917 females. Of the males 84·4 per cent. were weaned, of the females 83·9 per cent., and the average for all was 84·1 per cent. weaned.

The percentage of young weaned in the first year (1933-34) was 81·3. The second year showed an increase to 89·1 per cent., after while the percentage weaned decreased again to 87·5 per cent. for the third and to 82·8 per cent. for the fourth year.

The average number of young per litter at birth and at four weeks and also the weaning percentages are given in Table 42. Both the actual and the smoothed averages are given. The smoothed averages were again obtained by taking three months every time to get one point. By this means the normal variation is eliminated to a large extent so that smoother curves are obtained.

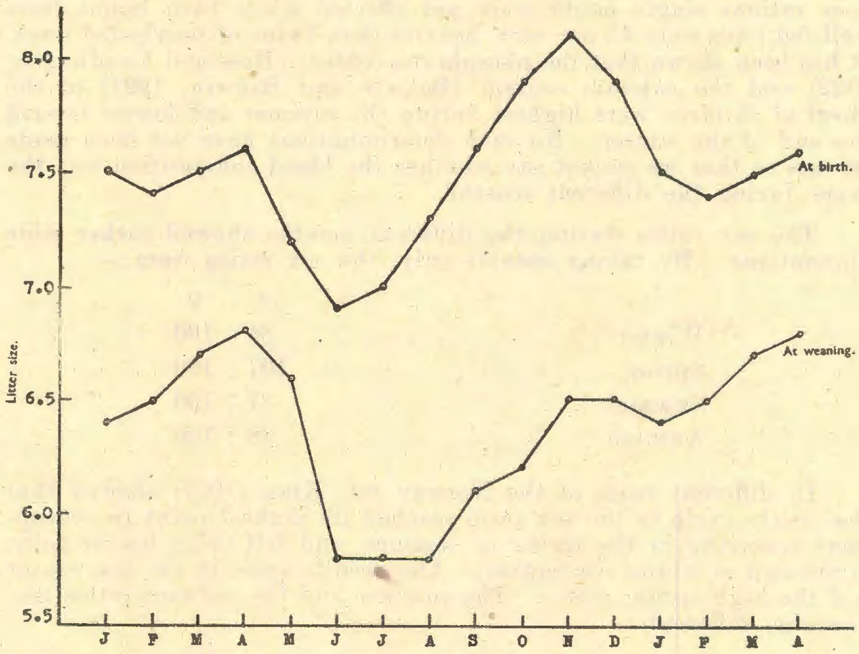

Fig. 39.—Influence of time of year on litter size at birth and at weaning.

The number of young at birth for the litters in which one or more young were weaned follows the same trend during the different months as when all litters are taken. The number of young per litter at weaning more or less follows the trend of the number of young at biith (Fig. 39). It, however, remains at a low level for three months (June to August) and does not show the drop from November to February as does the curve of the number of young at birth. This indicates that there had been some external factor or other which caused this effect.

By plotting the weaning percentages for the different months, a decided trend is shown (Fig. 40). Between May and June the curve illustrating the weaning percentage is at its highest. There is then a decrease up to August and the curve remains low till October. In November an increase is shown which continues every month till May. This trend of the weaning percentages therefore explains the modification of the litter sizes at weaning for the different months.

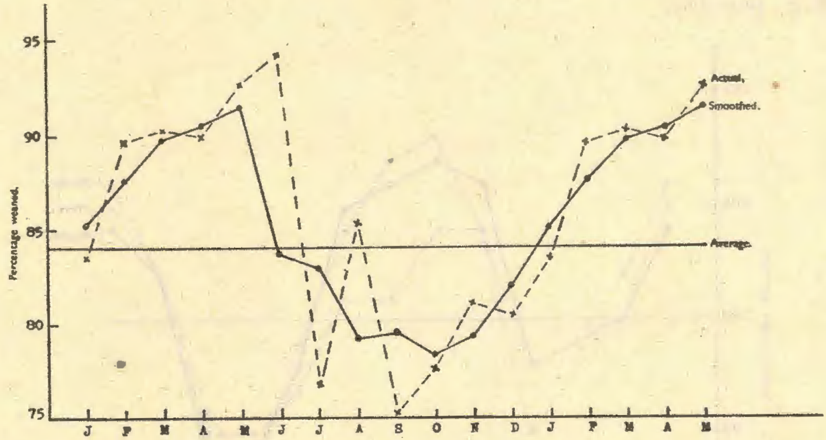

Fig. 40.—Influence of time of year on the percentage of young weaned.

It is not known what factor or factors were responsible for these differential weaning percentages. It is of interest to note, however, that during this period (September to January) the rats appear to breed best, i.e., an indication of regular oestrous cycles. The appearance of oestrus, however, during the lactation period could not have played any rôle since ovulation takes place 12 to 32 hours after parturition (Long and Evans, 1922) and then only after the litter has been weaned, except in the case of litters of 1 and 2 when the female may show regular oestrous cycles while suckling the young. In mice Crew and Mirskaia (1930) showed that oestrus appears 2 to 4 days after the removal of the litter at any time during the lactation period. They maintain that as in the case of pregnancy, the corpora lutea of ovulation is transformed into the corpora lutea of lactation by the reaction of the pituitary to the stimulus of suckling. Hain (1935) found that by injecting oestrone into lactating rats, it had injurious effects on the growth of the young while some females had no interest in their young any more. These findings are only mentioned to show the relationship between lactation and oestrus and that season may have some influence on these internal secretions. That the milk secretion may be affected, is indicated by the decrease in the weights of the young in Fig. 41. Although the high temperature from October may have had some influence, the decrease, however, had already commenced between July and August. With regard to the onset of the decrease in weaning percentage, it is long before the hot season. In the middle of the warm season it again begins to increase.

Average weights of young.—The weights of the suckling young may serve as an indication of the milk production of the females and hence of the seasonal effect on the milk production. Hain (1935), for example, estimated the milk production from the weight of the young at 20 days when they cease to be wholly dependent on their mothers. In the case of a litter of 6 rats she estimated that the female must produce 400 g. of milk in 20 days or 20 g. per day. When 12 young are suckled the milk-yield over the same period would be 500 g., or 25 g. per day.

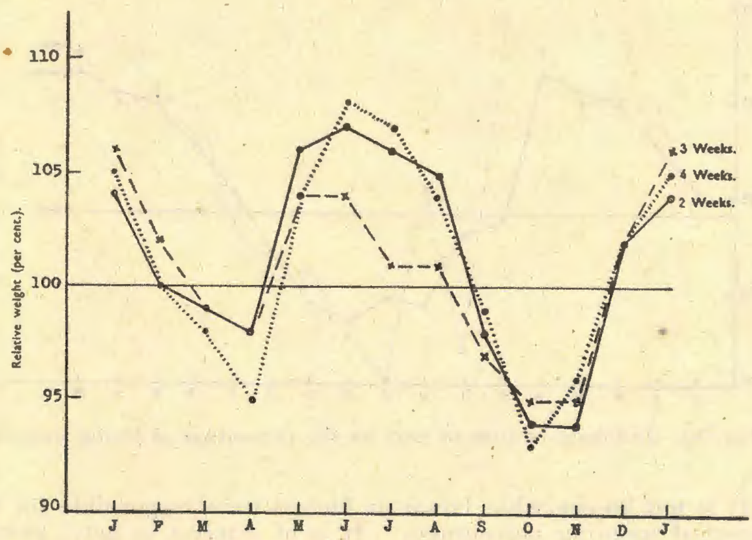

Fig. 41.—Relative weights (smoothed) of rats before weaning born during different months—males.

The weights of all the males and females at 2, 3 and at 4 weeks of age were 23·5, 36·5, and 56·5 g. for the males and 22·5, 34·5, and 53·0 g. for the females. During the four years that observations were made, there has been a tendency for the weights of both males and females at 2, 3, and 4 weeks to decrease (Table 43). Whether this reflects only a change in the milk production of the females or an influence on the growth rate of the young as well, is not possible to ascertain at this stage. It appears, however, that the decrease did not continue from the third to the fourth year. The decrease in the birth weights of the rats during the four years may be mentioned again (Table 40).

The average weights at 2, 3 and 4 weeks of the males and females born during the different months are given in Table 44. The average weights have been smoothed by grouping the observations of three months every time. The relative weights (actual and smoothed) for the different months are also included. The relative weights were obtained by expressing the average weights of each month as percentages of the standard weights, i.e., average weights of all rats. Only the smoothed relative weights of the males and the females have been plotted in Figs. 41 and 42.

Both these figures show clearly the seasonal effect on the weights of the suckling young. The males and the females show the same trends, although the latter are relatively heavier and lighter than the males during the favourable and the unfavourable months of the year respectively. Except in the case of the females of 2 weeks of age, it does not appear that season had a differential influence on the rats of different ages. If the milk production of the females had been mainly affected, one would have expected a difference in the relative weights of the rats at the ages of 2 and 3 weeks—i.e., at the ages when milk supply of the mother is their sole nourishment—and at the age of 4 weeks when they eat a large proportion of solid food. Although milk supply can be affected by seasonal factors, these figures, however, indicate that the seasonal factors may also affect the growth of the young rats directly.

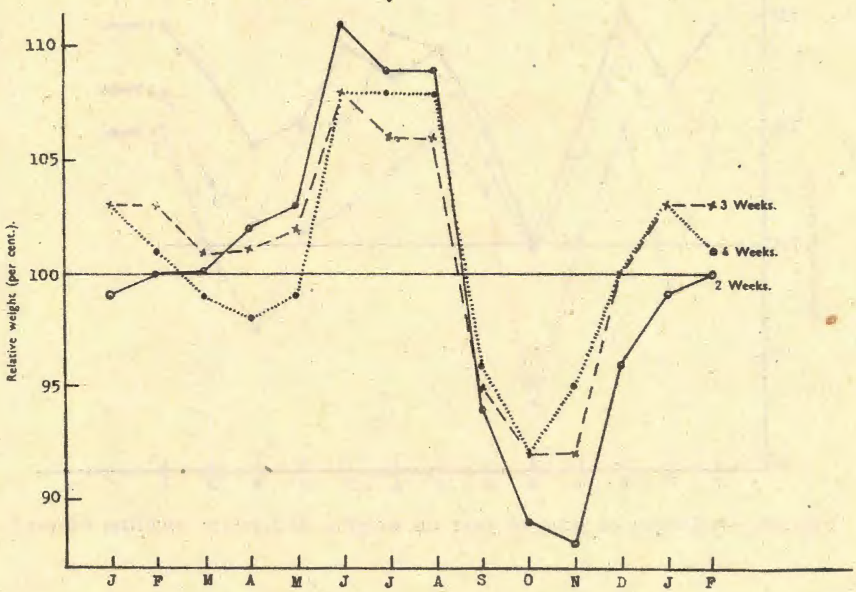

Fig. 42.—Relative weights of rats before weaning born during different months—females.

As in the case of the weaning percentages it does not appear likely that temperature was the main cause of the seasonal trends of the weights. The maximum weight is reached in winter and the decline commences in spring (August-September) before the warmest months. The minimum is, however, reached during the warm months, but there is again an increase during the warmest time (December-January) of the year.

It should be mentioned here that Hanson and Heys (1927) found no seasonal effect on the growth of young rats from birth to 20 days of age. At all later stages for females and after 40 days up to 100 days for males they found differences in the weights of rats born during the different seasons.

Weights of suckling females.—The weights of females suckling litters have been discussed in a previous section.

To ascertain the influence of season on the females, the weights have been arranged according to the months in which the litters were born. The monthly averages have again been smoothed by utilising the moving average. The birth weights were then taken as 100 and the weights at 2, 3, and at 4 weeks expressed as percentages thereof. These results are given in Table 45 and Figs. 43 and 44. The relative weights of the females at 2, 3, and at 4 weeks after the birth of the litters, showed more or less the same seasonal trends. From February there was a decrease until May. There was then an increase, and after August there was again a decrease until October or November,

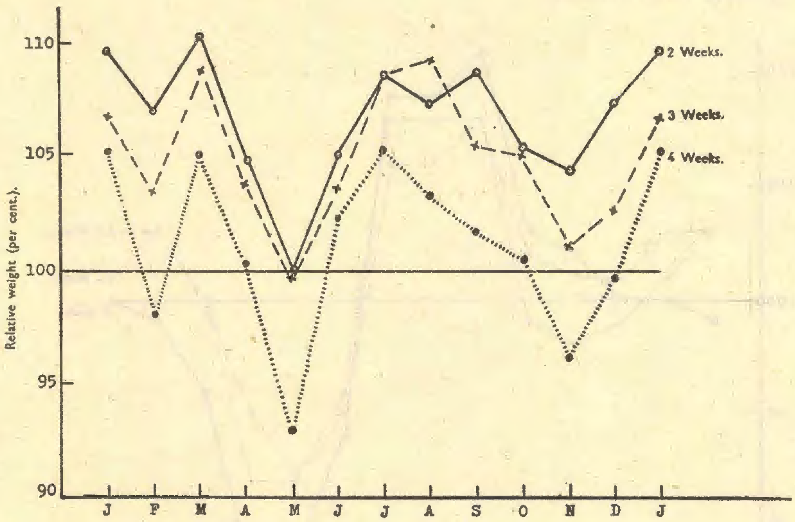

Fig. 43.—Influence of time of year on weights of females suckling litters.

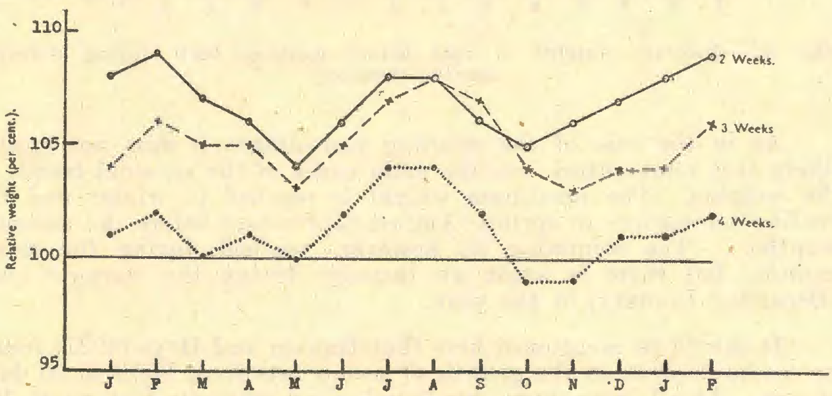

Fig. 44.—Influence of time of year on weights of females suckling litters—smoothed figures.

after which the weights increased until February. From May to October the relative weights at 2 and 3 weeks showed very little difference. For the rest of the year the weights at 2 weeks were above those at 3 weeks.

It will be seen that these curves follow about the same trend as those of the weights of the young. Both have a marked favourable period from between May and June to about August and a marked unfavourable period round about October and November. Both showed a less marked favourable period at about January and February and a less marked unfavourable period round March, April, and May. The similarity of these trends during the different months, i.e., of the weights of the females and of their young, indicate that some of the effect on the weights of the young is due to the milk production of the females, We have pointed out, however, that some other factor or factors probably also affect the young directly.

3. *Sexual Maturity in the Females.*

According to Mirskaia and Crew (1929-30) a distinction should be made between puberty and maturity. The former they define as " that stage of individual development characterised by the ability to elaborate functional gametes, and by the physical ability to, and the desire to, play the appropriate rôle in mating ". At this stage maturity of the individual has not been attained since neither the sex equipment nor the individual is full grown. Their definition for maturity is "" 'that stage of individual development which is characterised by the exhibition of the maximum fertility ratio with reference to the conditions of husbandry that are present, and in the case of the female by the ability to produce viable offspring and to rear them ". According to these definitions then " puberty marks the completion of those processes of development which equip the individual for fruitful mating: maturity marks the completion of those processes of development which equip the individual for efficient reproduction ". Working with mice they also showed that some individuals were mature at the time of puberty while others did not attain maturity until long afterwards.

Several workers have taken the opening of the vagina as an indication of the age when mice and rats attain puberty. Mirskaia and Crew (1930) have shown, however, that in mice first oestrus may only appear 24-120 hours after the opening of the vagina. They, therefore, discarded the age of the opening of the vagina as an indication of the onset of oestrus. For our purpose, however, we have taken the opening of the vaginas as an indication of the age of sexual maturity and shall show how this may be affected by environment. When the growth rate of rats is not restricted, the first oestrus appears within one or two days after the opening of the vaginas. Asdell and Crowell (1935) found that the appearance of first oestrus was 1·8 days after the opening of the vaginas, while Engle, Crafts and Zeithaml (1938) observed that first oestrus in 75 per cent. of the rats occurred on the same day as the opening of the vagina. On account of the difficulty of establishing at what age a rat is mature, we do not intend to make the distinction between puberty and maturity.

The average age of the 659 females, on which observations were made, when the vaginas opened was 43·3 days, and the average weight 97 g. The age corresponds with that found by Hains (1935) on rats obtained from the Wistar Institute and bred at Edinburgh. Her rats were sexually mature at 40 to 45 days of age when they weighed 75 to 80 g. Our females were, therefore, appreciably heavier when they were sexually mature. According to Long and Evans (1922) the vagina opened at about 72 days. It has been noted by experimenters that with increasing time the Wistar rat tends to mature at an earlier date than formerly. This tendency toward earlier maturity appears to have continued during the four years that observations were made at this Institution as shown by the following average ages and weights when the vaginas opened:—

	Number of Females.	Average Age. (Days).	Average Weight. g.
1933–34	164	47·2	106
1934–35	91	43·3	104
1935–36	111	43·0	97
1936–37	283	42·7	95

Two other points of comparison indicating the earlier maturity are found in the percentages of females of which the vaginas opened before they were six weeks old or before they had reached a weight of 100 g.:—

	Percentage of Sexually Mature Rats.	
	Before they were 6 Weeks old.	Before they Weighed 100 g.
1933–34	21	30
1934–35	36	29
1935–36	44	56
1936–37	46	61

To determine whether the ages of females of the same weight class had changed during the four years, the rats were grouped into different weight classes and the average ages given in Table 46. From these figures, however, there is no indication that the age of a certain weight class had changed significantly during the four years. There are fluctuations but no trend is manifested when those classes with large numbers are considered. When the observations of the four years are averaged, it will be seen that there was a continuous increase in the average age of each weight class in the weight classes of 80-89 g. and above. The two lightest classes showed no difference in age, whereas in the other classes the difference tended to increase the heavier the rats became. This seems to indicate that although there may be females which matured at ages younger than 37 days, the tendency for those below 80 g. of weight was to mature at the same average age. An increasing difference in age of those maturing at heavier weights, points to the slower growth rate of those maturing at heavy weights.

In Table 47 the observations have been grouped according to the ages of the females to show the distribution over the four years and also to give the average weights of the different age classes. The average weight (78·6 g.) of the females in the age class of 4 weeks, is above that of the average of all females of 5 weeks of age . The average of the 5 weeks' class is nearly that of females of 6 weeks old. At 6 weeks the average weights equal the standard weights or average for all females, but after 7 weeks the averages are below the standard weights or averages for all females. The early maturing females are, therefore, also quicker growers than the late maturing ones.

The age and weight distribution at the time when the vaginas opened show big variations. The youngest age was 31 days and the oldest 80 days. The lowest weight was 86·4 g. and the highest 144 g. Asdell and Crowell (1935), however, obtained a smaller variation in the age (49-59 days) when the vaginas opened if the growth was not restricted. They made observation on only 14 rats in the control group. The weights varied from 120 to 165 g. with an average of 136·7 g. They further observed that if the rats with ages at opening below the mean and those with ages above the mean were taken separately, the average weights at opening were 134·6 and 139·5 g. respectively, while for weights below and above the mean, the corresponding average ages fere 53·6 and 53·4 days. This they took as evidence proving that the age of the rat was a more important determiner of the time of opening of the vagina than the weight. Our results, however, do not support this view since an increase in weight at the time when the vaginas opened also showed a continuous increase in age. Only with the lighter groups, of 80 g. and below, did average age appear to remain constant. When the growth of the young were retarded during the lactation period by means of large litters, Engle, Crafts and Zeithaml (1938) found an increase in the average age when the vaginas opened from 47 to 78 days but the average weights only increased from 110 g. to 115 g. The average body lengths of the rats increased from 162 mm. to 169 mm. The body weights showed greater variability than body lengths. From their results they concluded that age was related only in a secondary degree to the time of the opening of the vaginas and that the only close agreement in their study was between the opening of the vaginas and body length.

Season.—The average ages and weights of the females born during the different months are given in Table 48. The averages have again been smoothed and illustrated in Fig. 45. The curves show that there were two high and two low periods for the ages and weights during the year. The two curves, however, follow opposite trends. During the periods when the vaginas opened at a low age, the weights were above the average; when the vaginas opened at a higher age, the weights were below the average. From June to August the females attained sexual maturity at the lowest ages and from March to May at the highest. In December and January there was again a decrease and an increase from September to November. The weight curve shows the same trend as the curves illustrating the relative weights of rats before weaning (Fig. 42) and also of rats ofter weaning (Fig. 55). The rats born from May or June to August had the highest weights at the different ages. During spring and the early summer there was a decrease, but again an increase during the late summer and again a decrease in the autumn. It therefore seems quite likely that season affected the growth rate which in turn affected the age at which sexual maturity was attained. Both age and weight played a rôle, for when growth rate was accelerated the vaginas open at a heavier weight and a younger age. When growth rate was again retarded, the vaginas opened at a lighter weight and a more advanced age.

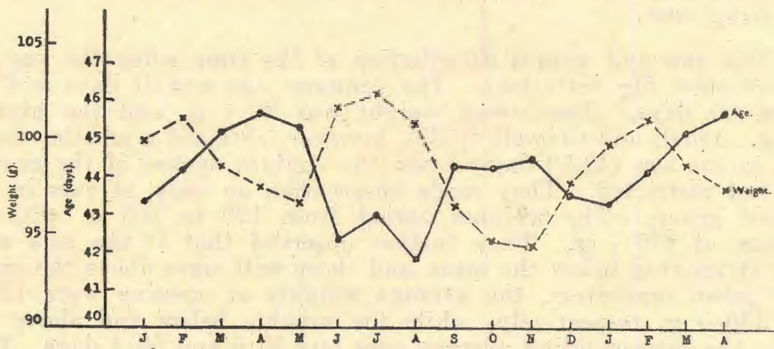

Fig. 45.—Influence of time of year on weight and age of young when vaginas open. (Rats grouped according to month of birth).

Prentice, Baskett and Robertson (1930) have shown in poultry how rate of growth, as influenced by nutrition, may influence the weight when maturity was reached, as measured by the weight when the first egg was produced. It has commonly been assumed that pullets which are permitted to mature rapidly are undersized and underdeveloped, and that after the first few weeks it is desirable to slow down the rate of development. The authors, however, found that those pullets fed on an intensive ration laid the first egg when 135 days old and weighing 1,800 g. while the slow growers laid the first egg when they were 186 days old and weighing 1,715 g. The early maturing birds also proved the best producers.

Working with coloured and albino mice Mirskaia and Crew (1930) made a study of the ages at which maturity was attained. They came to the conclusion that the attainment of sexual maturity of their mouse stocks—whether relatively early or relatively late—was due to genetic characters and was not influenced by differences in environmental conditions when animals were kept at an optimum and constant temperature. Although our rats were in a room where the temperature could go above the optimum during the summer, the temperature did not fall below the optimum since the room was heated during the winter. With the same management and feeding our results indicate that environment may have some influence on sexual maturity in rats, although this influence may only be indirect in so far that the primary influence may be on the growth rate.

Hammond (1940) suggested that while the bones are still growing the anterior pituitary secretes the growth hormone. When bone growth becomes slower or stops, there is an accumulation of this growth hormone in the blood which causes the anterior pituitary to switch over and secrete the gonadotrophic hormone which stimulates the ovaries or testes. In the quick growing animal, therefore, the bone growth is still quick enough to use up all the growth hormone, so that this switching over occurs at a heavier weight than in the slow growing animal, which stops or grows so slowly at a lower weight that the hormone concentration causes the switching over at a much lower weight.

4. *Weights and Tail Lengths.*

(*a*) *Standard curves.*

We mentioned previously that standard weights for rats under South African conditions have not yet been tabulated. When growth studies are carried out and especially when they are compared with those of other countries, it is advisable first to establish local standard weights. On account of the variability in the climate of the different areas in South Africa, the weights we obtained, can only be taken as typical of this Institute until other observations have been carried out, especially near the coast, to see whether there are large differences.

It is difficult to measure the body length of the rat. This can only be done when the animal is killed or anaesthetised. This method cannot, therefore, be utilised when a large number of rats are to be measured regularly. It is, however, comparatively easy to measure the length of the tail of the live rat. The main precautionary measure should be to make sure that the point from which the measurement at the base of the tail is taken should not vary. We have taken the anus as the point at the base of the tail. The tail length is taken as an indication of the skeletal development. According to Freudenberger (1932) the relation of tail length to body length changes from birth to 12 weeks of age. He found that the length of the tail was 35 per cent. of body length at birth and 97 per cent. at 12 weeks as well as at one year. But according to Donaldson (1915) this relationship between body length and tail length follows practically a straight line, so that tail length can, therefore, be used as an indication of the increase in body length.

Weights.—In Table 49 are tabulated the weekly weights of the males and the females from birth till 20 weeks. A number of rats were required for other purposes at the Institution with the result that fewer rats were available from 17 weeks onward. The remaining rats were born in those months during which growth was most rapid, with the result that the average weights for males and females from 17 weeks are too heavy. We have, therefore, plotted the actual weights and smoothed the curves for the males and females. From these we then read off the smoothed weights. In Fig. 46 the smoothed weights have been plotted.

The weights of the males were slightly above those of the females right from birth onwards. Up to 4 weeks, however, there was only a slight difference between the weekly gains of the males and of the females. From 5 weeks onward there was a decided increase in the difference between the gains of the males and of the females in favour of the males. As illustrated in Fig. 48 the weekly gains of the females reached a maximum at 5 weeks and then decreased continuously. The males, on the other hand, still showed an increase up to 7 weeks and only a very small decrease at 8 weeks. The males maintained more or less the same high level of weekly gain increases from 5 to 8 weeks inclusive. Only after 8 weeks did the weekly gains show a decided decrease.

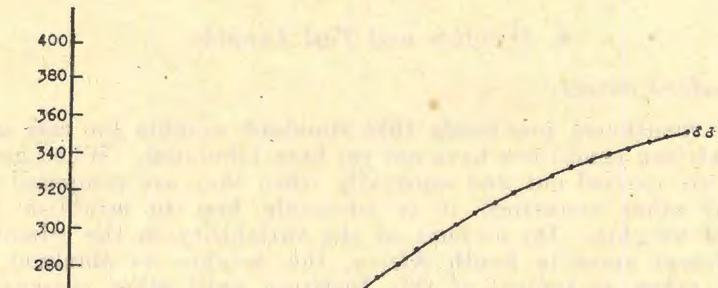

Fig. 46.—Smoothed growth curves of males and females.

It is of interest to compare our weights with those obtained at the Wistar Institute from where our rats originally came. Greenman and Duhring (1931) showed by means of a chart how the weights of the rats had increased after a number of years, that of the males more so than that of the females. They also gave the weights of their rats at different ages. We have plotted the weights and read off the weights at weekly intervals. The weights are given in Table 50 along with those of Hain (1934) who made observations at Edinburgh on rats obtained from the Wistar Institute.

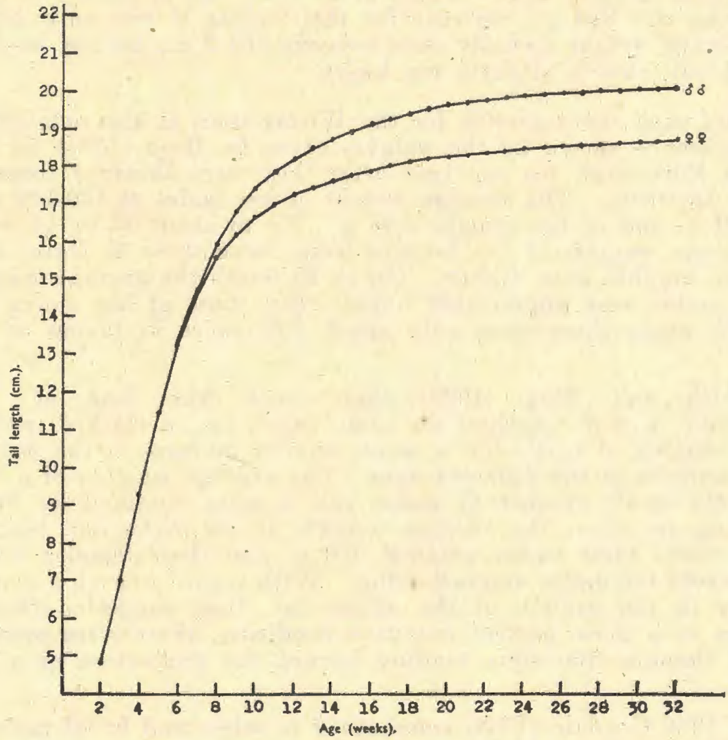

Fig. 47.—Tail lengths (smoothed) of males and females at different ages.

At 20 weeks the original weights, as obtained by Donaldson (1915), were 210 g. for males and 180 g. for females, while those of Greenman and Duhring were 270 g. for males and 190 g. for females, and for our rats the weights are 304 g. for males and 196 for females. The weights given for rats of one year of age are:—

	Males.	Females.
Donaldson	280 g.	230 g.
Greenman and Duhring ...	350 g.	250 g.

If we extend our curves up to one year for males and females we obtain the weights of 390 g. and 230 g. respectively. It is extraordinary that the weights of the females have changed only slightly while those of the males have increased appreciably.

On comparing our weights with those of Greenman and Duhring we see that the birth weights of their rats were appreciably higher (5·8 g. for males and 5·67 g. for females) than the birth weights of our rats (5·21 g. for males and 4·98 g. for females). At 2 weeks our rats were heavier. The weights of our females remained above theirs up to 11 weeks, when the weights were the same, and then remained more or less the same up to twenty weeks. Our males, on the other hand, showed a gradual but continuous increase over the weights of their males so that at 20 weeks the average weight of our males was 304 g., whereas for their males it was only 272 g. The average weight actually observed was 313·2 g., but, as we have pointed out, this is slightly too heavy.

That such rapid growth for the Wistar stock is also obtained at other places is shown by the weights given by Hain (1934) for rats bred at Edinburgh for one year after they were obtained from the Wistar Institute. The average weight of her males at 130-149 days was 300 g. and of her females 208 g. Up to about 13 or 14 weeks the average weights of our females were above those of Hain, after that her weights were higher. Up to 15 weeks the average weights of our males were appreciably higher than those of her males, but after 15 weeks there were only small differences in favour of our males.

Smith and Bing (1928)—their work was done at Yale University, U.S.A.—noticed the same trend, i.e., a marked increase in the weights of males but a much smaller increase in the weights of the females at the different ages. The average weights of a comparatively small number of males and females obtained by Smith and Bing are above the average weights of our males and females. At 20 weeks their males weighed 360 g. and their females 225 g. At 25 weeks the males weighed 400 g. With regard to such a marked increase in the growth of the albino rat, they suggested that in addition to a more perfect nutritive condition, there were morphological changes that were tending toward the production of a new species.

In 1930 Goodale (1938) commenced to select and breed mice for size. The weights at 60 days were taken as a basis up to 1937, when the present progress report was written, there had been a continuous increase in weight. The average gain for males was 1·48 g. per 1,000 mice recorded and for females ·99 per 1,000. The average weight of males in the first 500 was 26·0 g. and in the last 36·4 g., an increase of 40 per cent. The female weights were 21·3 g. and 29·3 g., an increase of nearly 37 per cent. The present average weight of the mice exceeds the maximum weight of mice in the early generations by several grs.

Tail Lenghts.—In Table 51 the average tail lengths for all the rats are given. As with the weights, the tail lengths have been smoothed after 16 weeks since the actual observations are too high. The observations (smoothed) have been plotted in Fig. 47. From 2 to 6 weeks the average tail lengths of the females were slightly above those of the males. At 7 weeks there was a small difference in favour of the males which then increased continuously.

The weekly gains in weight and in tail length have been plotted in Fig. 48. Whereas the weekly gains in the weights of the males and of the females first showed an increase and then again a decrease, the weekly gains in tail lengths were at a maximum at 3 and 4 weeks and then started decreasing. The length of the tail is earlier maturing than the body weight and hence reached its maximum growth rate at an earlier age. The weekly gains in weight and in tail length of the females showed much less difference in the age at which the maxima were reached than the gains of the males. It was shown by Dunlop and Hammond (1937) with rabbits that in a small breed the rate of maturity of body weight, a late maturing part, was speeded up. The adult female rat is much smaller than the adult male and hence shows earlier maturity as in the case of the different breeds of rabbits which differed in weight at maturity.

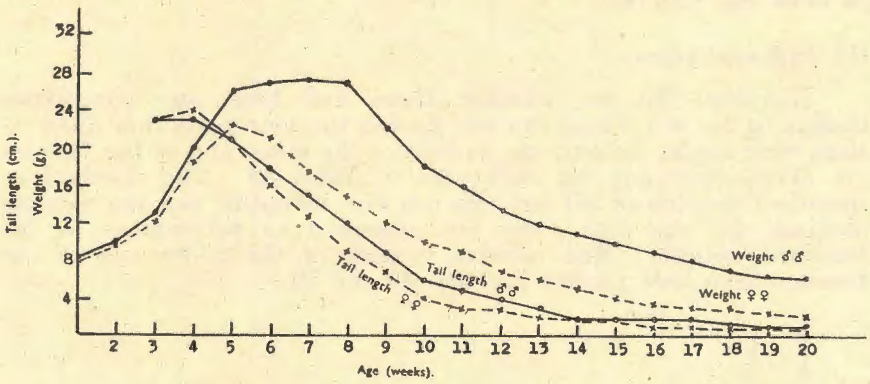

Fig. 48.—Average weekly gains in weight and tail length of males and females.

When the weights and the tail lengths at the different ages are expressed as percentages of the weight and the tail length at 20 weeks, we also obtain a good indication of the difference in maturity between males and females and between body weight and tail length. The following are the percentages:—

Age in Weeks.	Weight.		Tail Length.	
	Males.	Females.	Males.	Females.
	%	%	%	%
2	8	12	24	27
4	19	27	47	52
6	36	49	67	73
8	54	66	81	85
10	67	77	89	91
12	77	85	93	94
14	85	91	95	96
16	91	95	97	98
18	96	98	99	99
20	100	100	100	100

The relative difference between the weights of the males and of the females was 4 per cent. at 2 weeks and 13 per cent. at 6 weeks. After that the difference decreased gradually. The largest difference between the relative tail lengths of the males and of the females was 6 per cent. The difference in the rate of maturity of the weights of males and females was appreciably larger than the difference in the rate of maturity of their tail lengths. The tail lengths were about 4 weeks earlier in their maturity than the weights.

The relation of tail length to body length was determined by Freudenberger (1932). He found that at birth tail length—the sexes and two strains of rats together—was 35 per cent. of the body length, 77 per cent. at 3 weeks and 97 per cent. at 12 weeks and at one year. The tail was relatively longer in females than in males in most age groups.

(*b*) *Different years.*

Weights.—To see whether there had been any continuous change in the weights of the rats during the four years that observations were made, the average weights of the males and of the females are given separately for each year in Table 52. The standard or smoothed weights of all our rats are also included, and the weights obtained for the four years are expressed as percentages of the standard weights. The relative weights of the males and of the females have been plotted in Figs. 49 and 50.

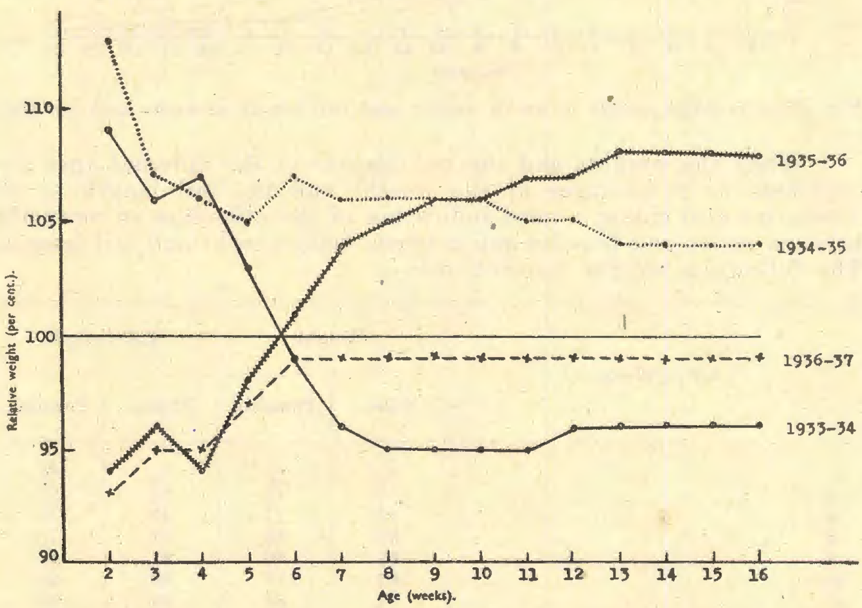

Fig. 49.—Relative weights during different years at different ages—males.

The relative weights of the first year showed a continuous decline from 2 to 8 weeks. After that age the weights ran parallel with the standard weights. The weights during the second year were above those of the first year but also showed a slight drop up to 5 weeks, after which they also ran more or less parallel with the standard weights. The weights during the second year never dropped below the standard weights. The relative weights during the third year were below the standard at the start. They increased more or less continuously up to 13 weeks and then ran parallel with the standard weights. Up to 5 weeks they were below the standard weights but from the 6th week onward, always above. The relative weights of the fourth year start at the same low level as those of the third year and increase up to the 6th week. At that age the weights were still below the standard and showed the same relative difference up to 16 weeks.

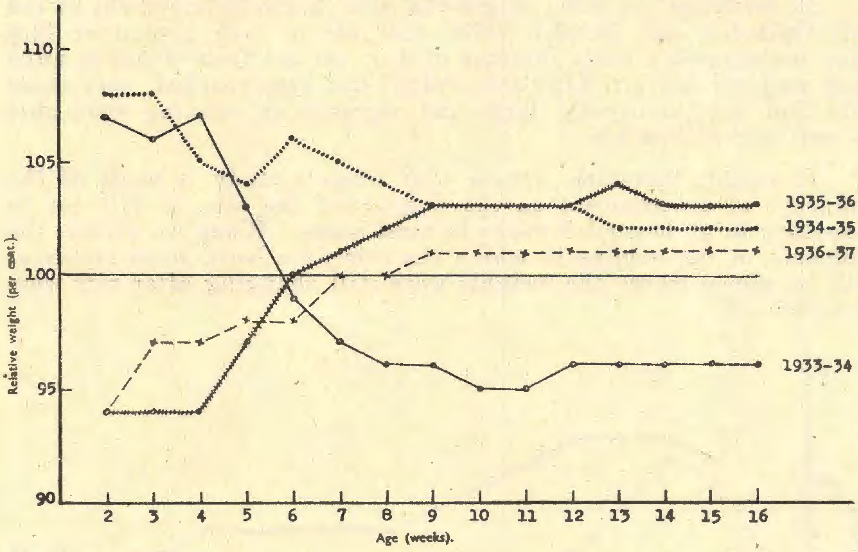

Fig. 50.—Relative weights during different years at different ages-females.

The curves of the females showed practically the same trends as those of the males. The differences from the standard were not quite so large for the females, and the weights during the last year were slightly above the standard while those of the males were slightly below.

There are a few points worth noting about these weights.

The weights for ages younger than 6 weeks during the first two years did not show much difference and were well above those of the third and fourth years. From the age of 6 weeks onward the average weights of the first year were the lowest while those of the second year remained high. The weights of the third and fourth years again, were low and about the same until the age of 6 weeks was reached. Those of the third year continue to increase until they were the heaviest after 10 weeks. Those of the fourth year did not increase after the sixth week.

The other point of interest is that most of the changes took place before the rats were 8 weeks old or, in other words, the weights at 8 weeks indicated what the weights at later ages would be. If the rats were above the standard they would remain above at the same level, or if they were below, they would remain below. This agrees with Dunlop and Hammond's (1937) work where they state that "animals which are larger than the mean weight when young are usually also larger than the mean weight when old". Kopec (1927, 1932) found differences in the weights of rabbits and mice at birth, which he maintained persisted until the animals had reached the adult stage. With rats Hanson and Heys (1927) found that those that were heaviest at 20 days were also heaviest at all later ages.

In studying the effect of growth rate on the development of the rat, Outhouse and Mendel (1933) fed rats in such a manner that they maintained a daily increase of 4 g. per rat from weaning until they weighed 360 g. After this weight had been reached, only those rats that were unusually large and vigorous at weaning were able to continue at this rate.

It would, therefore, appear that when a study is made of the influence of environment on the weights of the rats, it will not be necessary to go beyond 8 weeks in most cases. When we discuss the influence of the months in which the rats were born, some instances will be shown where the weights were still changing after rats were 8 weeks old.

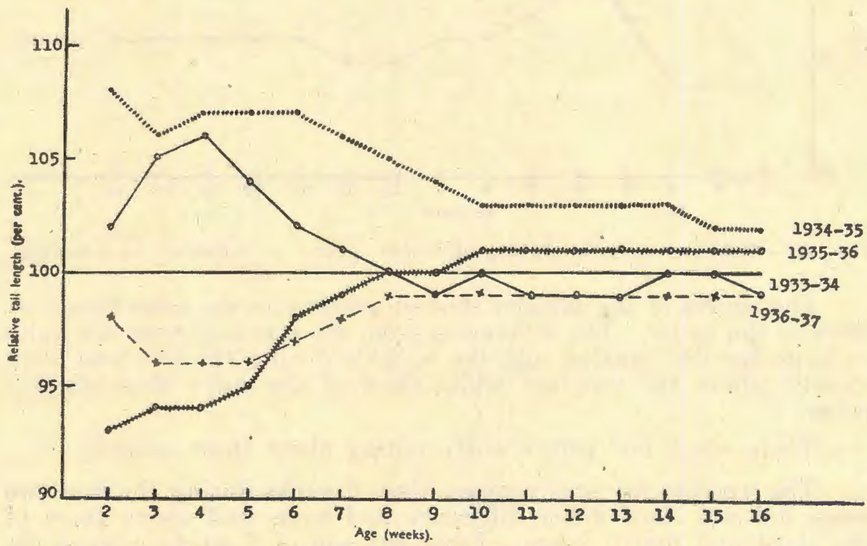

Fig. 51.—Relative tail lengths during different years at different ages—males.

Tail lengths.—The average tail lengths for the four years are given in Table 53. The standard tail lengths which are the smoothed average for all years, have been included and also the relative tail lengths. The relative tail lengths of the males and of the females have been plotted in Figs. 51 and 52. They show essentially the same trends as the weights; during the first two years the tail lengths were above the standard before the rats were 8 weeks old and below the standard during the third and fourth years. After 8 weeks all the years run parallel with the standard, also with only very slight deviations from the standard.

The same would appear to apply for tail length as for weight, i.e., that it is only affected before the rats are 8 weeks old.

Outhouse and Mendel (1933) found that increase in the body length of the rat was closely correlated with weight increase and showed little relationship to age. Dunlop and Hammond (1937) came to the same conclusion. They stated that the change in the proportions of the body as the animal grew, occurred with weight rather than with age as such.

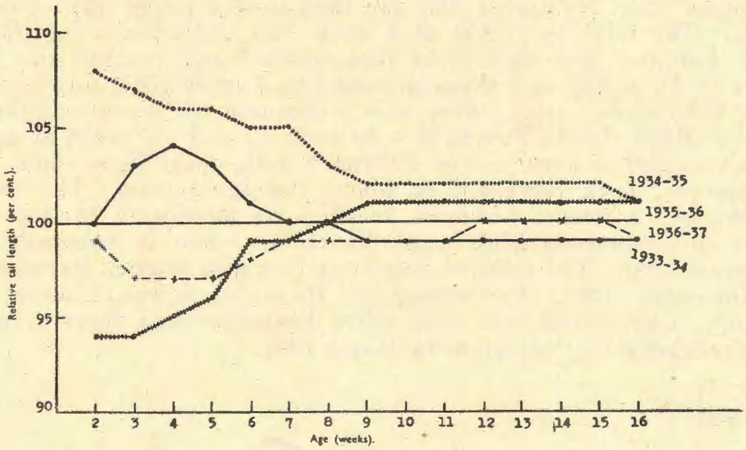

Fig. 52.—Relative tail lengths during different years at different ages—females.

MacArthur and Dafoe (1939) discussing the increase in weight and height of the Dionne quintuplets, noticed that the stature of the children showed smaller differences than their weights. They suggested that stature is evidently more hereditary than weight, in that it responds less sensitively to environmental influences. It, however, appears more likely that the differencce is due to the fact that stature is earlier maturing than weight and hence is affected to a lesser extent.

Although the body weights of the 1933-34 and 1935-36 rats were appreciably lower and higher than the standard weights respectively, the tail lengths of those years, however, showed hardly any deviation from the standard after 8 weeks. This is explained by the earlier maturity of the tail length as compared to body weight. After 8 weeks it appears that changes in weight do not affect the tail lengths to any marked degree any more. Early maturing parts are also affected much less by environment than late maturing parts.

(*c*) *Different months.*

Weights.—In analysing the influence of the time of the year on the weights of the rats, the average weights at the different ages for each month can be compared and no consideration taken of the month when the rats were born, or the average weights of the rats born during the different months can be compared at the different ages.

In Table 54 we have given the average weights of the males at 4, 8, 12, and 16 weeks of age for the different months. The average weights have been smoothed and the smoothed averages expressed as percentages (relative weights) of the standard weights at the four ages. The relative weights are illustrated in Fig. 53. All the weights showed fluctuations of about the same magnitude but the fluctuations did not coincide with regard to time of year. The relative weight at 4 weeks was high in February (106) and dropped until May (93), then rose to July (106) with August at the same level and after that decreased until November (93) and then started rising until February (106). The relative weight at 8 weeks was much lower in February (100) but also decreased from then onward and reached the lowest point in June (96) and then increased to August (107) and remained high till October when there was a decrease till January (97) with only a slight rise to February. At both 12 and 16 weeks of age the relative weights were low in February and, apart from some minor fluctuation, both increased at about the same rate. The relative weight at 12 weeks, however, reached its maximum in September (108) and remained high until November when it decreased until February (94). The relative weight at 16 weeks reached its maximum in November (109). In October and December it was, however, only slightly lower (108), and only after December was there a marked drop reaching the minimum in March (93).

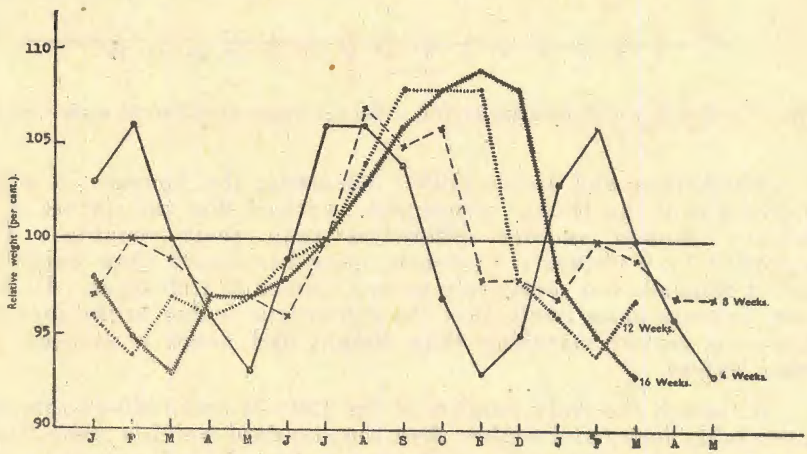

Fig. 53.—Influence of time of year on relative live weights at different ages—males.

The weights at 4 weeks showed two high (both 106) and two low (both 93) points during the year, the former in February and July—August and the latter in May and November. The weights at 8 weeks showed a slight rise in February (100) but this point was much lower than the maximum in August (107). The low points were the same. The weights at 12 and 16 weeks each had only one low point and one high point during the year.

These figures and curves show quite clearly that as the rats became older (4 to 16 weeks) the maximum and minimum points shifted about 3 to 4 months. From this it would therefore appear