WEIGHT AND HISTOLOGY OF THE MOUSE ADRENAL AND TESTIS : AN INHERITANCE STUDY

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Thesis
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March 30, 1970.

Certified that Shri Kavuri Lakshmi Narayana of Post Graduate College of Animal Sciences, I.V.R.I., Izatnagar, a candidate for M.V.Sc. (Final) examination of 1970 in Animal Genetics & Breeding has been working under my supervision during the session and that the accompanying thesis entitled "WEIGHT AND HISTOLOGY OF THE MOUSE ADRENAL AND TESTIS : AN INHERITANCE STUDY", which he is submitting is his genuine work.

D. P. Mukherjee

(D.P. MUKHERJEE)

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[K.L.N.]

C O N T E N T S

INTRODUCTION

In breeding farm or laboratory animals either by artificial insemination or by natural mating a fewer of males are needed to breed a large number of females. Hence the fertility of the male is more important than the fertility of the female. The fertility of the male depends on the testicular activity. It is well known, that the testicular activity is influenced by a number of other endocrine glands of the body such as, pituitary, thyroid, adrenal *etc*. A considerable work has been done on the thyroid-testicular relationship. Opinion of workers, however, on the role of the thyroid on the testicular function varies. A number of workers hold the view that the thyroid has no direct influence on reproduction. Some believe that change in the male or female reproduction in hyper or hypothyroidism is mainly due to changed metabolic status (Moor, 1939; Anderson, 1948); or due to nervous irritability (Lerman, 1942) or due to disturbances in growth (Schneider, 1939), or due to the complex inter-relationship in the endocrine system and body metabolism as a whole (Cameron, 1945), than to specific endocrine imbalance. Inspite of disagreement among the thyroid physiologists regarding the action of the thyroid on the testicular function, there is unanimity of opinion as reviewed by Mukherjee *et al.* (1960a) that the thyroid does influence fertility in male.

The information on the role of the adrenal on the testicular activity is scanty. Hence the present study has been made with a view to determine (i) if there is any correlation between the adrenal and testicular activity and (ii) if the activity of the two glands is under the genetic control.

For genetical study especially quantitative aspect, the unit of study is extended to populations, i.e. large groups of individuals. Keeping in view the above consideration some laboratory organisms should be selected for such studies. Therefore, in the present study mouse was taken as an experimental animal as it is easily available, easy to feed, raise, mate, handle and comparatively much shorter gestation period and increased litter size than farm animals. It is considered that the basic results obtained may be applicable not only to the males of mammalian farm animals but also to males of other mammalian species.

REVIEW OF LITERATURE

Correlation Between Body and Adrenal Weight

Mice

Houssay and Molinelli (1926) observed that the relationship of adrenal weight to body weight was exponential, the weight of the adrenal per given surface area remained constant. Adrenal and body weights do not change in the same direction and for this reason gland weights are frequently given in mg/100 g of body weight (relative weight).

Cole *et al*. (1942) observed straight line relationships between adrenal weight and body weight in Yale and Wistar strains.

Christian (1955) observed in highly inbred albino mice that the mean adrenal weight increased with population size over a limited range (16 per cage) and decreased when population increased further. Christian (1956) observed that at higher density levels both sexes of freely growing populations of wild mice showed hypertrophy and hyperplacia of adrenal cortex, especially of the *zonafasciculata* and a suppression of reproductive function which appeared to be related to the population size.

Rat

Donaldson (1924) observed in albino and the Norway rat that the weight of the adrenal gland increasing regularly, paripassue with age, to a plateau and shown the occurrence of changes in the mouse at puberty and pregnancy.

Yeakel and Rhoades (1941) observed that the body weight is similar in the emotional and non-emotional strains of rats and found the emotional males have heavier adrenals than non-emotional strains.

Cattle

Usuelli (1936) observed the correlation between live weight and weight of the adrenals in Marche bulls and found the correlation of 0.69 ± 0.034. He has, however, not stated how far this correlation is influenced by wide range of age of the animals.

Correlation Between Body and Testis Weight

Mice

Saller (1933) observed in mice that the right testis is heavier than the left and correlation between body weight and testis weight exists. Nord (1963) tabulated the data on body weight and testis weight in 139 male mice and observed the absolute weight of both testes varied from 0.005 g to 0.215 g. Testis weight tended to increase at a relative faster rate than total body weight.

Cattle

Usuelli (1936) observed the correlation between live weight and weight of the testes in Marche bulls and found the correlation of 0.76 ± 0.027. He has, however, not stated how far this correlation is influenced by wide range of age of the animals.

Poljakov (1966) observed in Schwyz bulls that the testes volume was correlated with body weight (0.97).

Correlation Between Adrenal and Testis Weight

Pratt (1927) observed that the chief source of information concerning the relation of the supra-renal glands to sex function has come through the study of disturbance manifested in the presence of cortical tumors. The time at which disturbance of cortical function begins has a definite relation to the effects on the sexual organs and their function. The adrenal cortex would seem to be primarily a male gland.

Parkes (1945) observed adrenal and gonadal relationship. Distinct changes in the adrenals may be associated with the reproductive cycle and also occur following removal of the gonads. Removal of the adrenals has in general a suppressing effect on gonad activity, which is corrected by cortical extract treatment. There is evidence that under certain conditions the adrenals may secrete, substances having sex hormone activity.

Grollman (1947) observed that the integrity of the adrenal cortex is necessary for normal reproductive activity. Testes become atrophic in adrenal cortical insufficiency. Insufficiency of the adrenal cortex is accompanied by changes in the structure and functional activity of other endocrine glands.

Houssay (1950) observed that the adrenal cortex secretes hormones that exert a direct influence on the sexual characters.

Zizine *et al.* (1950) observed the inter-relationship between the adrenals and the reproductive system has been well studied. The other aspect, the effect of the gonads on the adrenals, has not been given as much attention. The action of the androgenic substances on the adrenals seems, in particular, somewhat obscure and contradictory.

Mice

Poll (1933) observed in the mouse adrenal, that the existance of sexual dimorphism which becomes manifested only after puberty. He has observed that the *zona reticularis* is very wide in young individuals and absent in adult males. Castration prevents its disappearance in males. Chester Jones (1948, 1955) observed in the male mouse that the adrenal weight is between 57% and 77% of that of the coeval female, depending on strain, age and physiological status and also thought that this sexual dimorphism depends to some extent on the gonads.

Woolley (1950) observed in the mouse, that the gonadectomy of the newborn of certain strains, allows adrenal tumours to arise which produce excessive secretions of androgens and estrogens.

Rats

Grollman and Howard (1933) studied the effects of adrenal cortex on the reproductive system and observed in young male rats the testes averaged 20% heavier due to injection of cortical extract.

Lawless (1933) observed in male rats an increase in weight of adrenal glands due to castration at 21 days.

Chiodi (1938) observed in the male rat, an increased adrenal weight due to gonadectomy at 45-250 days.

Perry (1941) observed a slight decrease in testis size, some reduction in spermatogenesis and a marked reduction in the size of the accessory sexual organs of male rats due to experimental hyper adrenalism.

Leathern (1944) observed in hypophysectomized rats, that the adrenal and testis weight could partially be maintained for at least 15 days, by testosterone propionate.

Rennels <u>et al</u>. (1953) observed that the testosterone had no significant influence on the relative adrenal weight of hypophysectomized rats.

Ewing <u>et al</u>. (1967) observed in rats that continuous light and cold stress upto 30 days exhibited typical cold stress reactions in respect of body, adrenal and testis weights.

<u>Guinea pigs</u>

Eskin (1935) observed an increase in the weight of the testis by the addition of fresh adrenal cortex to the ordinary ration of guinea pigs.

Sheep and Goats

Mukherjee *et al.* (1960b) studied seasonal variations in the histology of the testis and the adrenal cortex of rams and goats. They observed that the activity of these glands as judged by the histological changes was less in summer and autumn than in winter and spring. They also observed that the activity of one gland was associated with the activity of the other.

Correlation Between Testis Weight and Diameter of the Seminiferous Tubules

Cattle

Hay *et al.* (1961) found that the mean tubular diameter in bulls belonging to six different breeds is closely related to the weight of the testis ($r = 0.92$, $p < 0.001$).

Heritability

Heritability of Body Weight

Mice

Castle (1941) studied the size inheritance and observed that the multifactorial explanation of the inheritance of body size in mammals is inadequate and many of the common mutant genes have effect on body size.

Butler and Metrakos (1950) observed maximum differences of size inheritance in the house mouse in the first four days, after which the differences decreased and became stabilized from about 36 days. They also analysed the sex differences.

Falconer (1953) reported the heritability of body weight at 6 weeks of age was 0.35.

Lewis and Warwick (1953) explained the effectiveness of selection for body weight in mice from inbred and outbred populations derived from common parent stocks. Heritability of 60 day weight was slightly lower in inbreds than in outbreds.

Chai (1956a) analysed the quantitative inheritance of body size in mice and observed the mean body weight of F_1 were all above the mid-parental value and observed that the maternal influence was more than a quarter of the total variation and slightly more than that due to the genetic constitution. Chai (1956b) observed the differences in the means, variances and inheritances of 60 day body weight in F_1 and F_2 crosses between large and small strains of mice as well as in backcross generations. The effective size genes were found to act additively. The dominance effect contributed to the total variability, if any, was considered to be trivial. The minimum number of segregating units were estimated to be 11.

Arnesen (1958) has studied the body weight of mice. He observed that the trait is polygenic in nature. However, the F_2 and backcross data did not follow the pattern expected for traits inherited in this manner.

Butler (1958) studied the inheritance of 30 and 60 day body weights and their variances and observed that the mother exerts the great influence on 30 day body weights in mice. The genotype of the young having little or no effect. The variance at 30 days was larger than the variance at 60 and 90 days.

Hull (1960) observed the heritability of body weight in mice at 3 weeks (0.74 ± 0.14) was greater than that at 6 weeks (0.57 ± 0.20).

Chai (1961) analysed the quantitative inheritance of body size in mice and attempted to isolate polygenes. The genes responsible for large body size are dominant over those for small body size.

Shibato (1965) observed that the heritability of body weight in inbred strain of mice was 0.719 ± 0.17, 0.751 ± 0.191, 1.137 ± 0.268, 0.099 ± 0.064 and 0.12 ± 0.07 at birth, 21 days, 28 days, 40 days and 60 days of age respectively by using sire component.

Eisen and Legates (1966) observed in Mus musculus that the genetic variances of the difference between males and females were large enough to be of biological significance for post-weaning growth rate and 8 week weight, but not for weight at 3 and 6 weeks. Corrected heritabilities of the sex difference in body weight at 3, 6 and 8 weeks were 0.010, 0.084 and 0.142 respectively.

Poultry

Lerner and Cruden (1950) reported the heritability of body weight of White Leghorn birds as 0.2 to 0.3 approximately and also observed the existance of significant maternal effects.

Pigs

Whately (1942) reported in Poland China pigs, that the heritability of body weight at 180 days was 0.3.

Sheep

Morley (1954) reported the heritability of 0.36 ± 0.08 for body weight in Australian Merino sheep, by parent offspring regression method.

Taneja (1954) studied the relative importance of heridity and environment in body weight increments at different ages in Australian Merino sheep. He observed that the environment plays a greater role in causing variation in the growth rates than does heridity.

Jacubec (1964) observed the heritability of body weight in Merinos in Czechoslovakia at 100 days was 0.40.

Cattle

Ragab and Elsalam (1963) observed that the heritability of body weight in Egyptian buffaloes and cattle at birth, 4, 6, 12, 18 and 24 months of age from paternal half-sib correlations as 0.475, 0.147, 0.092, 0.0002, 0.355 and 0.685 respectively for cattle and 0.315, 0.735, 0.699, > 1, 0.588 and > 1 respectively for buffaloes.

Alpan (1968) observed in Karacabey brown cattle that the heritability of birth weight, 6 months weight was 0.34 and 0.33 respectively by paternal half-sib correlations.

Heritability of Adrenal Weight

Mice

Meckler and Collins (1965) observed that both qualitative and quantitative genetic differences in the adrenal weight and histology. The results of the diallel study indicate the presence of systematic genetic influences underlying histological and morphological differences in the mouse adrenal.

Shire (1965) observed genetic variation in different strains in degeneration of the X-zone of female mice and found a strain is homozygous for a dominant gene that results in early degeneration.

Spickett *et al.* (1965) studied the genetic variability in adrenal structure and function. By using regression analysis they found that there were sex and strain differences in adrenal weight and body weight. The character behaved as a typical metric character. The proportion of medulla and the amount of cortex was found to vary between sexes and strains.

Shire and Spickett (1967) observed genetic variation in adrenal structure and explained the qualitative differences in the *zona glomerulosa*.

Badr and Shire (1968) studied the genetic variation in adrenal weight and also strain differences in the development of the adrenal glands of mice. The relative growth of the adrenals of male mice can be divided into two phases, an early rapid one and a latter slower one. There is considerable evidence for the existance of strain differences in the absolute and relative weight of the adrenal glands of adult mice. The changes in adrenal weight with increasing age were followed in male and female mice.

Shire and Spickett (1968) studied five quantitative parameters of adrenal structure of young adult mice of 3 inbred strains. They observed significant strain differences, sex differences and strain differences in sex difference.

Heritability of Testis Weight

Mice

Godowicz (1965) observed genetic variation of testicular changes and size of the testis in different strains of male mice.

MATERIALS AND METHODS

Sixty two colony-bred, healthy male and the same number of female albino mice between 21 and 24 days were selected at random from the colony maintained in the Biological Products Division of the Institute. Each male when 60 days old was mated to a female of the same age in a separate cage. Out of the 62 matings, nine were infertile and in six matings only females were born. Of the remaining 47 matings, both male and female were born but in nine, the males died before they were 90 to 100 days old. In the present study, therefore, only thirty-eight sires and their seventy-four male progeny were used. All the males and their male progeny when they were 90 to 100 days old were weighed and killed by dislocation of the neck. Their testes and adrenals were dissected out, weighed in chainomatic balance, fixed in 10% formol saline and serially sectioned at 7 µ. The sections were stained with haemotoxylin and eosin according to the usual method and mounted in D.P.X. From each male and its progeny, only one slide for the adrenal and one for testis sections were used. Hence there were altogether 112 slides for the adrenal and the same number for the testis.

Examination of the Adrenal Sections

The adrenal sections were studied for the ratio between

Fig. 1 - Transverse section of the adrenal gland (X 65). AB/AC represented the ratio between the width of the cortex and the perimedullary connective tissue.

Fig. 1 - Transverse section of the adrenal gland (X 65). AB/AC represented the ratio between the width of the cortex and the perimedullary connective tissue.

the width of the total cortex and the perimedullary connective tissue. To study the ratio, from each slide three sections were selected at random on a slide. In each section the width of the total cortex and connective tissue was measured (Fig. 1) at ten different places by means of a screw ocular micrometer with 15 X eyepiece and 10 X objective, using artificial light with blue filter as a source of illumination. The average of the ten measurements was taken as the average ratio between the total cortex and perimedullary connective tissue for the section. Thus from each slide, three averages were obtained for three sections and they represented the average variation in one male.

Examination of the Testicular Sections

The testicular sections were studied for the diameters of the seminiferous tubules. Three sections were selected at random on a slide. In each section, 10 tubules cut transversly were selected at random. In a selected tubule two diameters at right angles to each other (Fig. 2) were measured according to the method used for measuring the ratio of the total cortex and the connective tissue of the adrenal sections. The average of the two diameters was taken as the diameter of the tubule and the average of 10 diameters obtained from 10 tubules was taken as the average tubular diameter of a

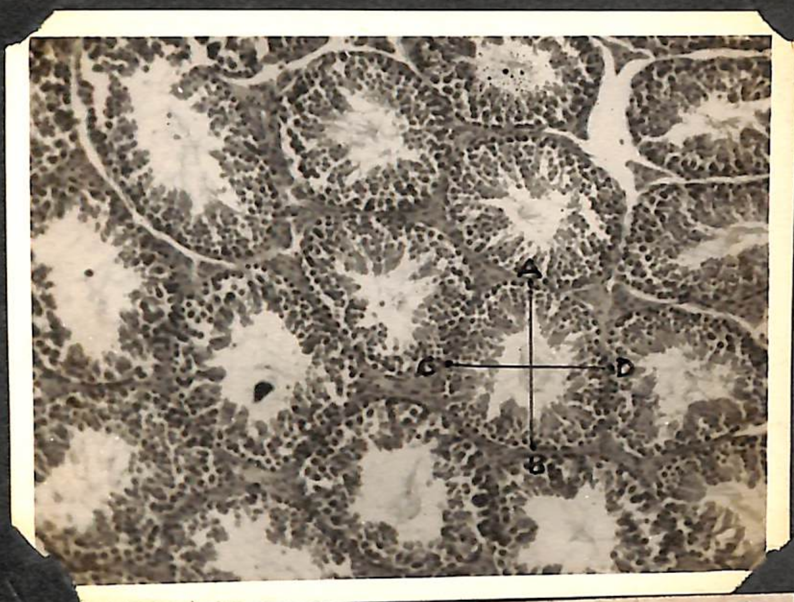

Fig. 2 - Transverse section of the testis (X 110).
AB and CD represented the two diameters in a tubule.

section. Thus from each slide, three averages for three sections were obtained and they represented the average variation in one male.

RESULTS

The means with standard error of the characters studied in sires and their progeny are presented in Table 1.

TABLE 1

Means with standard error of the characters studied in sires and their progeny

Characters studied	Means with standard error: Sires	Means with standard error: Progeny	Difference
Body weight (g)	25.550±0.4896	27.064±0.7683	1.514
Relative adrenal weight (mg/100 g body weight)	14.455±0.7268	7.081±0.2804	7.374***
Ratio between cortex and perimedullary connective tissue	2.699±0.0581	2.431±0.0396	0.268**
Relative testis weight (mg/100 g body weight)	365.158±8.9068	333.810±7.5489	31.348*
Diameter of the seminiferous tubules (μ)	165.753±2.1210	155.198±1.6358	10.555**

* $0.02 < P < 0.05$; ** $0.002 < P < 0.005$; *** $P < 0.001$

It is apparent from the table that the means differed. To test if the differences observed were real or due to chance, the data were subjected to paired t-test. For the test, the mean of the progeny was used against their respective sire to get 38 son-sire pairs of observations. The t-value was determined by using the following formula (Snedecor and Cochron, 1967).

$$t = \frac{\bar{d}}{S.E.(\bar{d})}, \text{ based on } (n-1) \text{ degrees of freedom.}$$

In the above formula $\bar{d}$ represented the mean difference between the sires and mean of their progeny; S.E. $(\bar{d})$ represented the standard error of the $(\bar{d})$.

It will be seen from the table that except the body weight and the testicular weight, the other characters studied varied significantly between the sires and their progeny.

To determine if (i) the body weight influenced the adrenal and testicular weight, (ii) the weight of the glands influenced their histological structures and (iii) the histological structure of one gland influenced by the histological structure of the other gland, various correlation coefficients were worked out and presented in Table 2. It is apparent from the table that the correlation between the body and the relative adrenal weight and the correlation between the relative adrenal and relative testis weight were not significant either in sires or in their progeny. The other characters studied were statistically significant in sires as well as in their progeny.

TABLE 2

Correlation coefficients of the characters studied in sires and their progeny

Characters studied	Sires	Progeny
Correlation between body and relative adrenal weight	0.150	0.120
Correlation between relative adrenal weight and ratio between cortex and perimedullary connective tissue	0.563**	0.394**
Correlation between body and relative testis weight	0.367*	0.384**
Correlation between testis weight and diameter of the seminiferous tubules	0.917**	0.891**
Correlation between adrenal weight and testis weight (relative weights, mg/100 g body weight)	0.207	0.143

* $0.02 < P < 0.05$; ** $P < 0.001$

To determine the relative importance of genetic and non-genetic effects on body weight and the various characteristics of the adrenal and testis, heritability estimates were made. Though there are various methods of estimating the heritability of a character, in the present study son-sire regression was used. The heritability was obtained by doubling the regression of son on sire.

To determine son-sire regression, three methods were followed as described below.

(A) The average of all the offspring of a parent was regressed with appropriate parent's record by using the following formula (Becker, 1968).

$$b = \frac{\Sigma X_i Z_i - \frac{(\Sigma X_i)(\Sigma Z_i)}{n}}{\Sigma X^2_i - \frac{(\Sigma X_i)^2}{n}}$$

The standard error of the heritability was obtained by utilising the following formula (Becker, 1968).

$$SE_{(h^2)} = 2\sqrt{\frac{\left[\Sigma Z^2_i - \frac{(\Sigma Z_i)^2}{n}\right] - b\left[\Sigma X_i Z_i - \frac{(\Sigma X_i)(\Sigma Z_i)}{n}\right]}{[n-2]\left[\Sigma X^2_i - \frac{(\Sigma X_i)^2}{n}\right]}}$$

In the above two formulae, b represented the regression of offspring on parent,

Z_i represented the average of the progenies of i^{th} sire,

X_i represented the value of the i^{th} sire,

n represented the number of pairs of observations, and $SE_{(h^2)}$ represented the standard error of heritability.

(B) The parent record was repeated with each offspring's record by using the following formula (Becker, 1968).

$$b = \frac{\left[\sum_i X_i \sum_j Y_{ij} - \frac{(\sum_i n_i X_i)(\sum_{ij}\sum Y_{ij})}{\sum n_i} \right]}{\left[\sum n_i X^2_i - \frac{(\sum n_i X_i)^2}{\sum n_i} \right]}$$

The standard error of heritability was obtained by using the following formula (Becker, 1968).

$$SE_{(h^2)} = 2\sqrt{\frac{\left[\sum_{ij}\sum Y^2_{ij} - \frac{(\sum Y_{ij})^2}{\sum n_i} \right] - b\left[\sum_i X_i \sum_j Y_{ij} - \frac{(\sum n_i X_i)(\sum_{ij}\sum Y_{ij})}{\sum n_i} \right]}{\left[\sum n_i - 2 \right] \left[\sum n_i X^2_i - \frac{(\sum n_i X_i)^2}{\sum n_i} \right]}}$$

In the above two formulae,

X_i represented the observation on the i^{th} sire,

Y_{ij} represented the observation on the j^{th} progeny of the i^{th} sire,

n_i represented the number of progeny of i^{th} sire.

(C) Weighted regression method (Kempthorne and Tandon, 1953).

$$\hat{B} = \frac{\Sigma W_i X_i Z_i - \left[\frac{(\Sigma W_i X_i)(\Sigma W_i Z_i)}{\Sigma W_i}\right]}{\Sigma W_i X^2_i - \frac{(\Sigma W_i X_i)^2}{\Sigma W_i}}$$

The standard error of heritability was obtained by using the following formula (Kempthorne and Tandon, 1953).

$$SE(h^2) = 2\sqrt{\frac{\text{Within sire M.S. of Y}}{\left[\Sigma W_i X^2_i - \frac{(\Sigma W_i X_i)^2}{\Sigma W_i}\right]^2} \cdots \cdot \cdot \cdot \sum_{i=1}^{S} n_i \left[\frac{1 + n_i\hat{T}}{(1 + n_i t)^2}\right](X_i - X)^2}$$

In the above mentioned formulae,

X_i represented the value of i^{th} sire,

$W_i = \frac{n_i}{1+n_i t}$, where n_i represented the number of progenies of i^{th} sire,

t represented the guessed value of T,

Z_i represented the average of the progeny values of i^{th} sire,

X represented the weighted average and it was calculated as below :

$$\tilde{X} = \frac{\sum_{i=1}^{S} W_i X_i}{\sum W_i}$$

S represented the number of sires.

The heritability estimates obtained by the three methods are presented in Table 3.

TABLE 3

Heritability estimates with their standard errors of the characters studied

Characters studied	By taking means of son's on sires	By repeating the sires record with each son's record	By using weighted regression
Body weight	0.211± 0.6164	0.169± 0.5900	0.217± 0.4906
Adrenal weight	0.327± 0.1618*	0.400± 0.1100**	0.275± 0.0410**
Ratio between cortex and perimedullary connective tissue	0.176± 0.3232	0.238± 0.2120	0.187± 0.2784
Testis weight	-0.066± 0.2942	-0.130± 0.2680	-0.077± 0.0982
Diameter of the seminiferous tubules	-0.184± 0.3162	-0.366± 0.2410	-0.290± 0.3690

* $0.01 < P < 0.05$; ** $P < 0.001$

The estimates were tested for their significance by t-test. It is apparent from the table that the estimates of heritability of each of the characters studied were not the same. It is also apparent that except the heritability of the adrenal weight, heritability estimates of other characters are not significant.

Genetic correlation between the adrenal weight and the ratio between cortex and perimedullary connective tissue was determined by using the following formula (Becker, 1968).

$$r_A = \frac{Cov.\ Z_2X_1 + Cov.\ Z_1X_2}{2\sqrt{(Cov.Z_1X_1)(Cov.Z_2X_2)}}$$

In the formula r_A represented the genetic correlation,

$Cov.Z_2X_1$ represented the covariance of trait 2 in offspring and trait 1 in sire,

$Cov.Z_1X_2$ represented the covariance of trait 1 in offspring and trait 2 in sire,

$Cov.Z_1X_1$ represented the covariance of trait 1 in offspring and trait 1 in sire;

$Cov.Z_2X_2$ represented the covariance of trait 2 in offspring and trait 2 in sire.

The standard error of genetic correlation was obtained by using the following formula (Reeve, 1955).

$$SE_{(r_A)} = \frac{1 - r^2_A}{\sqrt{2}} \sqrt{\frac{SE_{(h^2_1)} \cdot SE_{(h^2_2)}}{h^2_1 \cdot h^2_2}}$$

In the above formula, $SE_{(r_A)}$ represented the standard error of genetic correlation, $SE_{(h^2_1)}$ and $SE_{(h^2_2)}$ represented the standard error of the heritability of trait one and two respectively.

The genetic correlation between the adrenal weight and the ratio between cortex and perimedullary connective tissue was found to be 0.1103 ± 0.1852, which was not significant.

DISCUSSION

In the present investigation, non-significant correlations between body and adrenal weight were obtained in sires and in their progeny. This result is in agreement with what has been reported in mice and rats by Donaldson (1924); Houssay and Molinelli (1926); Yeakel and Rhoades (1941) and Christian (1955). The result, however, is not in agreement with what has been stated by Cole _et al_. (1942) in mice and Usuelli (1936) in cattle (0.69 ± 0.034). It appears that significant positive correlation exists between these two characters in cattle and in some strains of mice.

The significant correlations were obtained between the body and testis weight in sires and their progeny. This result is in agreement with that reported by Saller (1933) in mice and Usuelli (1936) and Poljakov (1966) in cattle. Nord (1963), however, did not observe significant correlation between the body and testicular weight in mice.

The mouse adrenal cortex possesses a juxtamedullary zone, varying in expression according to age and sex and referred to as the X-zone, Howard (1927). The zone is clearly recognizable at about 14 days of age in mouse (Howard, 1930). In the male the X-zone collapses by the direct action of the androgens produced at maturity (Deanesly and Parkes, 1937; Chester Jones, 1949) and forms into a medullary connective tissue capsule (perimedullary connective tissue). There is no evidence that the X-zone secretes anything, certainly not sex hormones (Grollman, 1936; Gersh and Grollman, 1939; Howard and Gengradom, 1940 and Chester Jones, 1949, 1950).

In the present study non-significant correlations were obtained between the adrenal and testis weight in sires and their progeny. It appears from the literature that such correlations between adrenal and testis weight have not been studied so far. However, the influence of the adrenal on testicular activity was reported (Pratt, 1927; Parkes, 1945; Grollman, 1947; Houssay, 1950). The same was also reported in mice by Poll (1933); Chester Jones (1948, 1955); and Woolley (1950) and in rats by Grollman and Howard (1933); Leathern (1944); Ewing <u>et al</u>. (1967); in guinea pigs by Eskin (1935); and in sheep and goats by Mukherjee <u>et al</u>. (1960b). Some workers hold the opinion that the adrenal is not influencing the testicular activity in rats (Lawless, 1933; Chiodi, 1938; Perry, 1941 and Rennels, 1953). However, Zizine <u>et al</u>. (1950) maintained that in rats the action of the androgenic substances on the adrenal appeared to be obscure and contradictory.

The significant correlations were obtained between the adrenal weight and the ratio between cortex and perimedullary connective tissue in sires and their progeny. It appears from the literature that such correlations between the adrenal weight and histology have not been studied so far in other animals.

Very highly significant correlations were obtained between the testis weight and the diameter of the seminiferous tubules in sires and their progeny. This result is in agreement with what has been reported in bulls by Hay *et al.* (1961). They have found that the mean tubular diameter in bulls belonging to six different breeds is closely related to the weight of the testis ($r = 0.92$, $P < 0.001$).

Heritability expresses the proportion of the total variance that is attributable to the average or additive effects of genes. In the present experiment, as stated earlier, heritability of the body weight and various characteristics of the adrenal and the testis were obtained by the following three methods of regression : (i) taking the means of sons on sires, (ii) repeating the sire's record with each son's record and (iii) weighted regression.

Heritability estimates of the body weight according to the three methods used have been found to be 0.211 ± 0.6164; 0.169 ± 0.5900 and 0.217 ± 0.4906 respectively. The results are in agreement with what has been reported in mice by Eisen and Legates (1966) and in sheep by Taneja (1954) and not with what has been stated in mice by Falconer (1953); Hull (1960); and Shibato (1965). Hull reported 0.74 ± 0.14 at 3 weeks and 0.57 ± 0.20 at 6 weeks. Shibato reported in inbred mice 0.719 ± 0.17; 0.751 ± 0.191; 1.137 ± 0.268; 0.099 ± 0.064 and 0.12 ± 0.07 at birth, 21, 28, 40 and 60 days respectively. The present result is also not in agreement with what has been reported in poultry by Lerner and Cruden (1950), in pigs by Whately (1942) and in sheep by Morley (1954); Ragab and Elsalam (1963) and Jacubec (1964) and Alpan (1968).

The heritability of the adrenal weight according to the three methods have been found to be 0.327 ± 0.1618; 0.400 ± 0.1100 and 0.275 ± 0.0410 and they are found to be significant. It appears from the literature that heritability estimates of the adrenal weight have not been studied so far. There are however, qualitative and quantitative genetic differences in the adrenal weight and histology as stated earlier (vide review of literature page No. 13).

Heritability estimates of the ratio between total cortex and perimedullary connective tissue according to three methods have been found to be 0.176 ± 0.3232; 0.238 ± 0.2120 and 0.187 ± 0.2784 respectively. It appears from the literature that similar studies have not been made prior to the present study.

The weight of the gland is an indication of the functional status, which depends on its histological structure. Although there is a significant correlation coefficient between weight of the adrenal and its histology (ratio of cortex and perimedullary connective tissue in this case), the former character only significantly heritable, but not the latter. It appears, therefore, that the adrenal weight and not its activity as shown by the histological structure is influenced by the genetic factors.

Heritability estimates of the testis weight according to the three methods have been found to be -0.066 ± 0.2942; -0.130 ± 0.2680 and -0.077 ± 0.0982 respectively. It appears from the literature that similar studies on the testicular weight have not been made so far in other animals. There are, however, evidences that the testicular size varies in different strains of mice (vide review of literature page No. 15).

The heritability of the diameter of seminiferous tubules according to the three methods have been found to be -0.184 ± 0.3162; -0.366 ± 0.2410 and -0.290 ± 0.3690 respectively. It appears from the literature that similar studies on the diameter of seminiferous tubules have also not been studied in other animals.

The diameter of the seminiferous tubules is an indication

SUMMARY

In the present investigation, the data pertaining to 38 male mice and their 74 male progeny at the age of 90-100 days were used to determine the correlation coefficients between body weight and weight of the two endocrine glands and between weight of the endocrine glands and their histological structures in sires and their progeny. The heritability estimates of the body weight and the various characteristics of the two glands were also determined. The study revealed the following :

(i) The average body weight of the sires and their progeny was 25.550 ± 0.4896 and 27.064 ± 0.7683 g respectively.

(ii) The average adrenal weight in sires and their progeny was 3.705 ± 0.1975 and 1.884 ± 0.0702 mg respectively.

(iii) The average relative adrenal weight in sires and their progeny was 14.455 ± 0.7268 and 7.081 ± 0.2804 mg/100 g body weight respectively.

(iv) The average testis weight in sires and their progeny was 92.990 ± 2.2363 and 90.055 ± 2.1756 mg respectively.

(v) The average relative testis weight in sires and their progeny was 365.158 ± 8.9068 and 333.810 ± 7.5489 mg/100 g body weight respectively.

of the testicular activity; an increased diameter of the tubules indicates the possibility of increase in the testicular activity, whereas, decreased diameter of the tubules indicates decrease in the testicular activity. The present experiment shows that neither the weight nor the activity of the testis are significantly influenced by the genetic factors.

The genetic correlation between the adrenal weight and the ratio between cortex and perimedullary connective tissue was estimated with a view to determine if these two traits were influenced by the same set of genes. It was found that the correlation (0.110 ± 0.1852) was not significant. This indicated that the same set of genes might not influence the two traits.

(vi) The average ratio between adrenal cortex and perimedullary connective tissue in sires and their progeny was 2.699 ± 0.0581 and 2.431 ± 0.0396 respectively.

(vii) The average diameter of the seminiferous tubules in sires and their progeny was 165.753 ± 2.1210 and 155.198 ± 1.6358 µ respectively.

(viii) The correlation coefficient between the body and the relative adrenal weight in sires and their progeny was 0.150 and 0.120 respectively.

(ix) The correlation between relative adrenal weight and the ratio between cortex and perimedullary connective tissue in sires and their progeny was 0.563 and 0.394 respectively.

(x) The correlation between the body and relative testis weight in sires and their progeny was 0.367 and 0.384 respectively.

(xi) The correlation between testis weight and diameter of the seminiferous tubules in sires and their progeny was 0.917 and 0.891 respectively.

(xii) The correlation between the adrenal and testis weight (relative weights) in sires and their progeny was 0.207 and 0.143 respectively.

The heritability estimates were made by three methods of son-sire regression, (a) taking means of son's on sires, (b) repeating the sire's record with each son's record and (c) weighted regression.

According to three methods the heritability of

(1) body weight have been found to be 0.211 ± 0.6164; 0.1688 ± 0.5900; and 0.2169 ± 0.4906 respectively.

(2) Adrenal weight have been found to be 0.327 ± 0.1618; 0.400 ± 0.1100 and 0.275 ± 0.0410 respectively.

(3) Ratio between total cortex and perimedullary connective tissue have been found to be 0.176 ± 0.3232; 0.238 ± 0.2120 and 0.187 ± 0.2784 respectively.

(4) Testis weight have been found to be -0.066 ± 0.2942; -0.130 ± 0.2680 and 0.077 ± 0.0982 respectively.

(5) Diameter of the seminiferous tubules have been found to be -0.184 ± 0.3162; -0.366 ± 0.2410 and -0.290 ± 0.3690.

Non significant genetic correlation (0.1103 ± 0.1852) was obtained between the adrenal weight and the ratio between cortex and perimedullary connective tissue.

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APPENDIX I

Sire No.	Body weight (g)	Adrenal weight (mg)	Adrenal weight Relative weight*	Testis weight (mg)	Testis weight Relative weight*	Diameter of the seminiferous tubules** (ocular scale)	Ratio of total cortex / Connective tissue
1	25.4	2.7	10.630	79.2	311.811	1.779	2.4572
2	24.5	3.3	13.469	91.2	372.245	1.953	2.352
4	27.3	3.0	10.989	113.9	417.216	2.067	2.450
5	25.3	3.1	12.253	97.9	386.957	1.958	2.495
7	28.1	3.0	10.676	99.7	354.804	2.045	2.977
8	27.3	3.2	11.722	87.4	320.147	1.945	2.243
9	22.0	3.3	15.000	73.9	335.909	1.947	2.564
11	23.4	3.3	14.103	24.4	403.419	1.972	2.621
12	22.3	2.6	11.659	78.8	353.363	1.834	2.864
16	26.5	3.4	12.830	115.7	436.604	2.313	2.442
17	26.9	4.2	15.613	82.2	305.576	1.775	2.646
18	21.0	3.4	16.190	86.9	413.810	2.042	2.672
20	27.0	3.6	13.333	108.5	401.852	1.970	2.453
21	26.8	2.5	9.328	98.2	366.418	1.947	2.576
25	23.5	2.7	11.489	112.2	477.447	2.336	2.459
26	29.5	1.1	3.729	98.9	335.254	1.947	2.428
29	27.0	1.6	5.926	70.3	262.222	1.759	2.810
34	24.8	3.5	14.113	91.3	368.145	1.946	2.502
35	21.3	1.6	7.512	83.8	393.427	1.966	2.191
36	27.4	3.0	10.949	97.9	357.299	1.966	2.134
37	23.0	3.9	16.957	81.9	356.087	1.946	2.302

APPENDIX I (CONTD)

Sire No.	Body weight (g)	Adrenal weight (mg)	Adrenal weight Relative weight*	Testis weight (mg)	Testis weight Relative weight*	Diameter of the seminiferous tubules** (ocular scale)	Ratio of total cortex / Connective tissue
38	27.6	4.9	17.754	91.3	330.797	1.897	3.049
39	27.6	4.3	15.580	96.0	347.826	1.956	2.545
40	28.0	4.6	16.429	80.5	287.500	1.769	2.577
41	28.4	6.0	21.127	104.7	368.662	1.948	2.909
45	26.4	4.4	16.667	86.7	328.409	1.947	3.300
46	25.8	3.8	14.729	66.4	257.364	1.716	3.111
50	21.8	3.8	17.431	102.6	470.642	2.326	3.062
51	28.0	2.6	9.286	92.3	329.643	1.946	2.856
52	26.7	5.2	19.476	107.4	402.247	1.971	3.063
54	23.4	5.0	21.368	87.2	372.650	1.956	3.483
55	22.8	3.4	14.912	89.7	393.421	1.962	2.344
56	21.4	4.9	22.897	76.8	358.879	1.947	3.757
57	26.9	3.8	14.126	107.6	400.000	1.968	2.527
58	31.8	5.2	16.352	97.3	305.975	1.778	2.914
60	25.0	5.0	20.000	87.4	349.600	1.947	2.946
61	25.1	4.9	19.522	82.4	328.287	1.946	2.616
62	25.9	7.0	23.166	133.1	513.900	2.499	2.866

APPENDIX II

Sire No.	Progeny No.	Body weight (g)	Adrenal weight (mg)	Adrenal weight Relative weight*	Testis weight (mg)	Testis weight Relative weight*	Diameter of the seminiferous tubules** (ocular scale)	Ratio of total cortex / Connective tissue
1	i	27.5	1.1	4.000	78.0	283.636	1.663	2.336
	ii	32.8	1.9	5.793	82.8	252.439	1.593	2.326
2	i	33.6	2.1	6.250	79.4	236.310	1.491	2.124
	ii	27.9	2.0	7.169	72.2	258.781	1.600	2.173
4	i	33.3	3.2	9.610	83.9	251.952	1.588	2.861
5	i	29.5	2.0	6.780	102.3	346.780	1.888	2.510
	ii	26.6	1.6	6.015	92.1	346.241	1.873	2.315
	iii	27.4	1.9	6.934	96.1	350.730	1.927	2.304
7	i	28.8	1.7	5.903	76.2	264.583	1.618	2.925
	ii	28.5	1.4	4.912	70.8	248.421	1.586	2.174
	iii	28.0	1.0	3.571	70.6	252.143	1.592	2.185
8	i	32.9	1.6	4.863	109.8	333.739	1.863	2.151
9	i	37.1	2.2	5.930	126.2	340.162	1.868	2.607
11	i	25.1	1.4	5.578	94.4	376.096	1.949	2.682
	ii	21.8	1.0	4.587	71.0	325.688	1.889	2.350
	iii	27.9	1.8	6.452	99.0	354.839	1.928	2.154
12	i	27.0	2.3	8.519	109.8	406.667	2.098	2.163
	ii	25.7	2.5	9.728	104.4	406.226	2.093	2.194
16	i	28.2	1.9	6.738	83.0	294.326	1.693	2.359

APPENDIX II (CONTD)

Sire No.	Progeny No.	Body weight (g)	Adrenal weight (mg)	Adrenal weight Relative weight*	Testis weight (mg)	Testis weight Relative weight*	Diameter of the seminiferous tubules** (ocular scale)	Ratio of total cortex / Connective tissue
17	i	28.8	2.7	9.375	83.5	289.931	1.681	2.244
	ii	27.4	2.2	8.029	82.2	300.000	1.727	2.094
18	i	31.1	2.5	8.039	112.9	363.023	1.937	2.464
	ii	28.1	2.3	8.185	77.3	275.089	1.657	2.263
20	i	22.3	2.2	9.865	81.8	366.816	1.922	2.619
21	i	28.6	1.5	5.245	101.0	353.147	1.927	2.788
25	i	31.8	3.3	10.377	102.6	322.642	1.860	3.429
26	i	28.9	1.1	3.806	101.1	349.827	1.912	2.401
	ii	25.4	1.0	3.937	101.9	401.181	1.993	2.907
	iii	29.8	1.2	4.027	132.1	443.289	2.119	2.332
	iv	25.1	0.8	3.187	56.1	223.506	1.450	2.279
29	i	41.9	2.5	5.967	134.3	320.525	1.859	2.344
34	i	32.1	1.7	5.296	105.7	329.283	1.847	2.560
35	i	25.9	1.1	4.247	89.4	345.174	1.895	2.121
36	i	15.4	1.8	11.688	46.8	303.896	1.746	2.892
37	i	21.0	2.0	9.524	79.8	380.000	1.964	2.154
38	i	25.5	1.2	4.706	83.4	327.059	1.890	2.571
	ii	25.3	2.5	9.881	90.7	358.498	1.962	2.096

APPENDIX II (CONTD)

Sire No.	Progeny No.	Body weight (g)	Adrenal weight (mg)	Adrenal weight Relative weight*	Testis weight (mg)	Testis weight Relative weight*	Diameter of the seminiferous tubules** (ocular scale)	Ratio of total cortex / Connective tissue
38	iii	27.8	1.3	4.676	100.1	360.072	1.918	2.094
	iv	26.9	1.4	5.204	94.0	349.442	1.909	2.197
39	i	31.6	1.6	5.063	82.1	259.810	1.600	2.108
40	i	23.7	1.3	5.485	84.7	357.384	1.929	2.112
	ii	27.9	1.5	5.376	105.8	379.212	1.961	2.134
	iii	23.9	1.0	4.184	73.7	308.368	1.768	2.183
	iv	26.1	0.9	3.448	99.8	382.376	1.963	2.047
41	i	30.1	2.1	6.977	104.3	346.512	1.875	2.394
	ii	31.3	2.3	7.348	105.2	336.102	1.874	2.378
45	i	27.4	2.6	9.489	85.3	311.314	1.820	2.170
	ii	22.2	2.2	9.910	78.4	353.153	1.926	2.315
46	i	19.1	2.0	10.471	73.5	384.817	1.966	2.215
	ii	24.8	2.3	9.274	84.6	341.129	1.885	2.316
	iii	20.0	2.1	10.500	74.3	371.500	1.943	2.334
	iv	25.4	2.7	10.630	90.9	357.874	1.932	2.379
50	i	26.4	1.2	4.528	72.2	272.453	1.643	2.576
	ii	27.6	1.5	5.435	74.4	269.565	1.638	2.391
	iii	25.7	1.1	4.280	74.3	289.105	1.779	2.315

APPENDIX II (CONTD)

Sire No.	Progeny No.	Body weight (g)	Adrenal weight (mg)	Adrenal weight Relative weight*	Testis weight (mg)	Testis weight Relative weight*	Diameter of the seminiferous tubules** (ocular scale)	Ratio of total cortex / connective tissue
51	i	25.8	0.9	3.488	94.5	366.279	1.911	2.059
	ii	27.1	1.7	6.273	94.6	349.078	1.899	2.304
52	i	24.9	2.3	9.237	84.5	339.357	1.916	2.736
	ii	22.4	2.3	10.268	79.3	354.018	1.925	2.935
54	i	25.1	2.3	9.163	84.2	335.458	1.869	2.258
	ii	25.6	2.5	9.766	84.6	330.469	1.863	2.735
	iii	22.4	2.1	9.375	74.5	332.589	1.822	2.115
55	i	28.2	2.3	8.156	141.1	500.355	2.446	2.695
	ii	26.3	2.8	10.646	106.0	403.042	2.016	3.231
56	i	16.6	1.8	10.843	52.9	318.675	1.833	3.331
	ii	24.9	2.7	10.843	57.8	232.129	1.470	3.201
	iii	25.2	2.0	7.937	67.2	266.667	1.643	2.573
57	i	30.9	2.5	8.091	105.2	340.453	1.824	2.090
58	i	26.9	2.4	8.922	84.4	313.755	1.883	2.074
	ii	27.9	1.7	6.093	98.0	351.255	1.928	2.290
60	i	28.8	3.3	11.458	136.0	472.222	2.133	3.427
61	i	25.3	1.2	4.743	82.5	326.087	1.859	2.396
62	i	25.7	1.5	5.837	95.8	372.763	1.949	2.585
	ii	30.9	1.8	5.825	118.8	384.466	1.896	2.766

In Appendix I & II
*Relative weight = mg/100 g body weight
**To convert into μ the scale reading is to be multiplied by 84.1.