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To the Graduate Council:

I am submitting herewith a dissertation written by Najeeb Tawfik Kazzal entitled "Evaluation of Some Genetic and Environmental Factors Affecting Growth and Development of Awassi Sheep in Iraq." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

J B McLaren
Major Professor

We have read this dissertation
and recommend its acceptance:

Karl M. Barth

Robert S. Dotson

Robert R. Shrode

Don O. Richardson

Accepted for the Council:

Hilton A. Smith
Vice Chancellor for
Graduate Studies and Research

EVALUATION OF SOME GENETIC AND ENVIRONMENTAL FACTORS AFFECTING GROWTH AND DEVELOPMENT OF AWASSI SHEEP IN IRAQ

A Dissertation

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

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by

Najeeb Tawfik Kazzal

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ABSTRACT

The objectives of this study were (1) to measure the effects of certain environmental factors on growth and body dimensions, (2) to obtain estimates of heritability of these traits, (3) to determine the phenotypic and genetic correlations between traits and (4) to study the potential of principal-component analyses as a means of identifying lambs of different sizes and shapes for selection purposes.

Data were obtained from 257 Awassi lambs sired by 13 rams in the Agricultural Experiment Station sheep flock at the University of Mosul, Iraq, during 1966, 1967 and 1970. The traits studied were rate of gain, body weight, selected body measurements and certain principal components at birth, at weaning and at a year of age. A total of 14 traits of each lamb at each age were considered. Environmental effects studied were year of birth, sex of lamb, type of birth, age of dam and month of birth.

Most of the environmental factors significantly ($P < .05$) affected all of the dependent variables. However, the effects of age of dam and month of birth varied with age of lamb. Some factors were important at early ages and decreased as lamb age increased. Other environmental factors influenced various traits only during the post weaning period. Constants which reflected the average effect of age of dam, sex, type of birth and month of birth, were calculated and used to adjust the individual records when the effects had a definite ($P < .05$) impact on the dependent variable.

Estimates of heritability were calculated from paternal half-sib correlations calculated from the adjusted data. These estimates at birth, weaning and a year of age, respectively, were: body weight, 0.19, 0.06 and 0.20; body length, 0.16, 0.04 and 0.60; heart girth, 0.13, 0.19 and -.05; wither height, 0.31, -.06 and 0.59; hip width, 0.12, -.08 and 0.82; shoulder width, 0.15, 0.34 and 0.60 and hip width 0.11, 0.16 and 0.35.

Most of the estimates of genetic and phenotypic correlations between pairs of traits were high. Some of these estimates approached or exceeded 1.0, indicating that large sampling errors were associated with these estimates.

Principal-component analyses were preformed using six body measurements and body weights at birth, weaning and one year of age. The first three components accounted for 87, 89 and 94 percent of the total variation in the correlation structure of all body size measures at the three ages, respectively. The first principal component reflected general size and the second and thrid components were measures of shape. However, the shape components tended to contrast different body dimensions at the various ages. Estimates of heritability of the first three principal components at the three different ages were low to medium in magnitude. These results indicate that principal-component indexes could be used to describe size and shape in lambs more efficiently than weights and body dimensions *per se*. They suggest also a genetic basis for these indexes and that genetic progress would result from a selection program based on the use of principal-component indexes.

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CHAPTER I

INTRODUCTION

Iraq is a country rich in sheep, the number of sheep per capita being 1.5, the highest in the Mideast area. The sheep population is almost evenly distributed over all parts of the country and has always been sufficient to provide the country with meat, milk and carpet wool. However, the ever-increasing demand for food of animal origin has exceeded the anticipated development of production resources and has caused concern regarding the nation's ability to remain self-sufficient with respect to these commodities.

Unfortunately, Iraqi sheep are not as productive as would be expected in view of the country's resources with respect to potential nutrition and breeding and cliamte conditions are evaluated.

Sheep are still managed on the margin of agriculture since they are required to obtain their livelihood by foraging over vast distances. This level of management is prevelant in all areas, in the mountains, in the plains, in the marshlands or in the forests.

The sheep-fattening enterprise has diminished in importance over the past few years as a result of the decline in the exportation of mutton. In view of the fact that consumers desire less fat meat, sheep are fed concentrates only for a few months of the year. During November and December, supplemental feed is often required for sheep to survive until after the rainfall is sufficient for natural pastures to be available. Recently, some of the marginal land has been cultivated, and this has actually reduced the best natural pasture areas in the country.

As feed and other variable costs continue to increase and as Iraqi sheep producers face more competition from other meat sources, it becomes very important that the efficiency of lamb and wool production be increased. Unless new selection procedures and improved husbandry practices are used, the economic pressure on the sheep industry will increase.

Efforts to increase the commercial value and production of wool and mutton were started about thirty years ago by the Directorate of Animal Husbandry, Ministry of Agriculture. These efforts were almost wholly confined to the introduction of so-called improved breeds or strains of sheep. However, these first efforts failed to increase income from sheep production, largely because they were based primarily on improving wool quality and provided no basis for improvement of methods of selection for other economically important traits. An extensive study of the economic traits, milk, wool and meat production, and evaluation of some genetic and environmental factors affecting these traits needs to be conducted in order to improve sheep production efficiency.

The objectives of this study were (1) to measure the effects of environmental factors including year of birth, month of birth, age of dam, sex and type of birth on the weight, gain and selected body measurements of Awassi lambs at birth, weaning and as yearlings. It was intended also to derive constants to be used as correction factors to adjust performance records of lambs for these effects,

(2) to obtain estimates of heritability of body weight, pre-weaning gain, post-weaning gain, total gain, average daily gain, body length, heart girth, wither height, hip height, shoulder width and hip width and to evaluate the phenotypic and genetic correlations among these traits and (3) to study the potential of use of principal components in identifying lambs of different sizes and shapes.

CHAPTER II

REVIEW OF LITERATURE

I. ENVIRONMENTAL FACTORS AFFECTING BODY WEIGHT AND BODY MEASUREMENTS

Improved productivity in sheep depends on selection of genetically superior individuals as flock replacements. The effectiveness of such selection depends on the accuracy with which environmental factors masking genetic merit are recognized and allowed for when evaluating individuals within the flock.

Variation in body size, defined in terms of body weight and/or body measurements, is the result of many factors acting independently or collectively. Some are genetic factors enbodied in the genotype of each individual, others are non-genetic, (*i.e.*, environmental factors). Only part of the variability in most economic traits is genetic, and the rest is caused by environmental factors.

It would be desirable to base selection on genetic variability alone. However, it is impossible to exclude all of the variation due to environmental effects. The accuracy of selection for genetic merit or breeding value can be increased by adjusting individual values to remove average differences due to environmental effects such as age of dam, sex of lamb, year, month and type of birth.

Information is needed on the extent and magnitude of these effects in sheep in order to adjust performance records before genetic parameters are estimated and selections are made. Thus, the accuracy of selection of superior breeding stock would be greatly increased if all breeding animals were comapred under a standard environment from which certain variation is removed by physical control procedures. However, when certain environmental factors vary from animal to animal but are known and recorded, much can be accomplished by "statistical" control.

Factors Affecting Birth Weight

Phillips and Dawson (1937) were among the pioneers in sheep research. They reported that single lambs were heavier at birth than twins and that, on the average, one would expect an increase of 4.3 lb. in weight at three months of age for each increase of one pound in birth weight of single male lambs. In Wisconsin, Karam *et al*. (1949) studied birth weights of 437 lambs and found that single lambs were heavier at birth and were 6.2 lb. heavier at 25 weeks of age. Nelson and Venkatachalam (1949) stated that significant portions of the variation in birth weight of five breeds of lambs studied in the Michigan State College flock were due to differences in sex, type of birth and age of dam. They also found that female lambs were 5 percent lighter than male lambs at birth, lambs from mature ewes were 10 percent heavier than those from two-year-old ewes and single lambs were 22 percent heavier than twins. Ali (1952) reported that lambs from mature ewes were 0.67 lb. heavier at birth than those from young ewes. He observed also that single lambs were 1.75 lb. heavier than twin lambs and that males were 0.05 lb. heavier than fameles. Blackwell and Henderson (1955), in an analysis of the birth weights of 2,186 lambs raised under farm flock conditions in New York, found that males exceeded females and singles exceeded twins by 0.54 lb. and 1.85 lb., respectively, at birth. In Arkansas, Brown et al. (1961) studied the records of 132 crossbred and 121 inbread Hampshire lambs. They found that birth weight of single lambs was about 1 lb. greater than that of twins raised as twins and about one-half pound greater than that of lambs born as twins but reared as singles. In Tennessee, Webb (1963) found that age of dam, season of birth, sex of lamb, type of birth and year of birth significantly affected birth weight. Records of 923 single and 88 twin Awassi lambs in Iraq were analyzed by Juma and Faraj (1966). They suggested that month of birth, sex and type of birth significantly affected birth weight. Data obtained by Vesely and Robinson (1970) from 150 Romnelet ewes during 1962 to 1966 in Canada indicated that year of birth, age of dam, sex and type of rearing significantly affected birth weight of the Romnelet lambs while only age of dam and type of birth had significant effect on birth weight of Rambouillet lambs.

Many other research workers have found results similar to those mentioned above (Asker et al., 1952; Ragab et al., 1953a; Bogart et al., 1957; Starke et al., 1958; Karam, 1959; Dalton, 1962; Asker, 1964; Sidwell et al., 1964; Frederiksen et al., 1967; McLaren et al., 1968; Kaushik and Singh, 1968a; Eliya, 1969; Srinivasan, 1969 Ercanbrack and Price, 1969; Thrift and Whiteman, 1969; Vesely et al., 1970; Gould and Whiteman, 1971; Thrift et al., 1971; Aboul-Naga et al., 1972; Malik and Acharya, 1972).

<u>Factors Affecting Weaning Weight</u>

Numerous reports suggest that year of birth, age of dam, type of birth, type of rearing and sex of lamb all affect weaning weight. Phillips and Dawson (1940) found that sex, type and time of birth had a strong influence upon the lamb weight in famr flocks at six months of age. Phillips <u>et al</u>. (1940) reported that year of birth as well as sex of lamb and type of birth influenced the weight of Corriedale and Rambouillet lambs raised on western range throughout the first year of life. The influence of environmental factors upon weanling traits in Rambouillet, Columbia, Corriedale and Targhee lambs were studied by Hazel and Terrill (1945a and 1946b) who found that sex, age of dam, type of birth, age at weaning and level of inbreeding all had a significant effect on most weanling characteristics. Sidwell and Grandstaff (1949), working with Navajo sheep in New Mexico, also found significant differences in weaning weight due to age of dam, sex, type of birth and rearing and age of lamb. Brown <u>et al</u>. (1961) reported that there was a significant difference in weight between inbred male and female lambs at 120 days of age, with males averaging about 2 lb. heavier. The 120-day weight for inbred single lambs was 8 lb. greater than that of twins reared as twins. Crossbred single lambs were 7 lb. heavier than twins reared as twins. Sabin and Brown (1962) found that wethers were 3.26 lb. heavier than ewe lambs at weaning. They found also that single lambs were about 8 lb. heavier at 120 days of age than were twin lambs. In 1963, Webb reported that age of dam, season of birth, sex of lamb, type of birth and rearing and year of birth all had a significant effect upon weaning weights of

Hampshire lambs. Sidwell et al. (1970) stated that breed of sire, year of birth, age of dam, type of birth and rearing, sex and age of lamb all affected weight of Navajo lambs. A difference of more than 12 lb. per weanling was found between the best and poorest years. Two-year-old ewes weaned the smallest lambs; 4- to 8-year-old ewes weaned the heaviest and the 3-year-old and the 8- to 11-year-old groups weaned lambs of intermediate weight. In the same study they found also that at weaning, single lambs were 11.2 lb. heavier than twins raised as twins and 2.9 lb. heavier than twins raised as singles. Ewe lambs averaged 4.4 lb. less than ram lambs. These factors accounted for 56 percent of the variation in the actual weaning weight. Malik and Acharya (1972) studied the effect of some non-genetic factors on pre- and post-weaning body weights of 767 Nali and Lohi lambs and crosses of these breeds with Nellore and Mandya sheep. They reported that year and season of birth significantly affected the weaning weight whereas the ewe's weight at lambing, sex of lamb and breeding group (sire differences) did not significantly affect this trait.

Many other investigators (Nelson and Venkatachalam, 1949; Ercanbrach, 1952; Asker et al., 1952; Blackwell and Henderson, 1955; Botkin et al., 1956; Cassard and Weir, 1956; Karam, 1959; Ray and Smith, 1966; Gjedrem, 1967; Fahmy and Galal, 1968; McLaren et al., 1968; Kaushik and Singh, 1968b; Juma et al., 1969; Fahmy et al., 1969; Vesely et al., 1970; Vesely and Robinson, 1970; Eltawil et al., 1970; Thrift et al., 1970; Carter et al., 1971; Sidwell and Miller, 1971b) found similar evidence regarding the effects of the environmental factors on weaning weight.

Factors Affecting Yearling Weight

In a study involving data from Rambouillet yearling ewes, Hazel and Terrill (1946c) found that ewes from mature dams were 2.6 lb. heavier at one year of age than those from two-year-old dams and that ewes born as singles were 6.0 and 0.5 lb. heavier, respectively, than twins raised as twins and twins raised as singles. However, Terrill *et al*. (1947) did not agree with these results regarding the affect of environmental factors on yearling traits in Columbia and Targhee ewes. Phillips *et al*. (1940) found that singles were heavier at one year of age than twin lambs and males gained more rapidly than females from birth to one year. Terrill *et al*. (1948a) found the same trend with respect to the affect of type of birth on yearling weight. Single ewes exceeded twins by 6.5 lb. in yearling weight, according to Sidwell and Grandstaff (1949), but they observed only 1.47-lb. difference in yearling weight between singles and twins raised as singles. In New Zealand, age of dam and type of birth had significant effects on yearling body weights of Romney Marsh sheep, according to Rae (1950). A report by Karam (1959) regarding variation in yearling Rahmani sheep indicated that type of birth, year and season of birth all significantly effected body weights. Price *et al*. (1962) reported that 48 percent of the total variation in body weight of yearling ewes was due to environmental factors and difference between breeding groups. Ewes from mature dams were 3 lb. heavier at yearling age than were the ewes from 2-year-old dams. The effect of breeding group, age of dam, type of birth, type of rearing and year of birth on yearling weight of Navajo ewes were studied by Sidwell *et al*. (1970).

They found that these factors accounted for 48 percent of the total variation in yearling weight. They stated also that yearling ewes from nature dams were 3 lb. heavier than those from 2-year-old dams. A number of other workers (Vesely and Slen, 1961; Bichard and Cooper, 1966; Trail and Sacker, 1969; Fahmy et al., 1969; Vesely et al., 1970; Eltawil et al., 1970; Dass and Acharya, 1970; Chopra and Acharya, 1971; Aboul-Naga et al., 1972; Ercanbrack and Price, 1972; Malik and Acharya, 1972) showed these effects to be important in other breeds of sheep.

Factors Affecting Rate of Gain

Environmental factors including season, year, sex and type of birth, were found by Webb (1963) to have highly significant effects on average daily gain in Hampshire lambs. He reported also that variation due to difference in age of dam was not significant. However, there was a trend toward increased average daily gain of lambs from older ewes. He concluded that one possible reason for the lack of significance could have been the fact that data used in this study were from a select group of purebred Hampshire sheep maintained on a high level of nutrition.

McLaren et al. (1968) summarized the pre-weaning performance of 1,038 lambs born over a six-year period and found that male lambs gained 0.04 lb. more per head per day than females. Lambs born as twins and raised as singles gained 0.53. per head per day compared to 0.48 lb. per head per day of lambs born and raised as twins. The birth-to-weaning average daily gain of lambs born in December, January, February and March were 0.64, 0.57, 0.47 and 0.38 lb., respectively. They found also that breed of ewe and age of dam both had significant effects on total gain and average daily gain.

Juma *et al*. (1969) reported that pre-weaning rate of growth in Awassi lambs in Iraq, was higher than post-weaning growth rate. In their study, they found also that gains in weight were highest for single males followed by single females, twin males and twin ewes. Growth rate was highest in the single males and lowest in the twin females, and twin males gained faster than single females. Vesely and Robison (1970) observed differences in average daily gain and total gain of Rambouillet sheep due to year, sex, type-of-birth and age-of-dam differences; however, only the last three factors significantly affected these traits. Sidwell and Miller (1971b) studied the differences in birth weight, weaning weight, gain from birth to weaning and average daily gain in Hampshire, Columbia-Southdale, Targhee, Suffolk and Dorset lambs and all possible crossbred lambs of crosses among these breeds. They found that age of dam, year, type of birth and rearing, sex and breed group all had significant effects on the traits studied. Evidence of such influences was also reported by Hazel and Terrill (1946b), Karam *et al*. (1949), Givens *et al*. (1960), Smith and Lidvall (1964), Srinivasan (1969), Vesely *et al*. (1970; Carter *et al*. (1971) and Thrift *et al*. (1973).

Factors Affecting Body Measurements

Pioneers in this work with sheep were Cassard *et al*. (1953) who studied the effect of environmental factors on various body measurements of the Rambouillet breed at first-shearing age at the University of California over a period of 13 years. Body measurements included in this study were wither height, depth and width of chest, loin width, heart girth, round measurement and body weight. They found that age of lamb was an important source of variation in all measurements except wither height. Twin lambs were smaller than singles in all measurements except heart girth and round measurement. Twin lambs from 2-year-old ewes were smaller in body weight, heart girth and round than twins from older ewes. According to Matthews et al. (1965), birth weight and body measurements of single lambs were significantly greater than those of twins. They concluded that differences in measurements were a reflection of differences in birth weight. In another study, Cassard et al. (1956) studied the variation in body measurements of Hampshire ewes in order to evaluate the importance of certain known environmental differences in determining body size and conformation. They found that older animals were significantly larger than younger ones in body weight, heart girth, round measurement, chest width and depth and loin width. Single ewes were larger than twins in all individual measurements studied except chest depth. Foote and Matthews (1959) reported that males were heavier than females and also consistently larger in body measurement.

Eloksh et al. (1962) found that year of birth had the largest influence on birth weight, body length, heart girth, head width and loin width of Columbia-Rambouillet crossbred ewes, followed by type of birth, generation, age of dam and sex. Matthews et al. (1965) studied the effects of sex, type of birth and type of rearing on the performance of crossbred and straightbred lambs from Rambouillet, Columbia and Targhee ewes and on crossbred lambs resulting from mating different combinations of crossbred ewes of these breeds to Suffolk sires. They found that weight and most body measurements at birth were similar for lambs of various breeds and crosses. Differences in head circumference of various breed groups were non-significant ($P > .05$). Variations in average birth weights and measurements attributable to sex difference were generally small and nonsignificant; however, metatarsal length of male lambs averaged 0.5 cm. longer than that of females. This did not agree with the results reported by Bennett et al. (1963), Sidwell et al. (1964) and many other workers. Fahmy and Galal (1968) found that there were significant differences among body length and heart girth measurements at birth while sex had a significant effect only on heart girth of Barki, Merino and Awassi lambs and their crosses. In Iraq, Juma et al. (1969) studied the growth pattern of Awassi lambs and variation in body weight and various body measurements at four different ages from birth to 48 weeks of age. They found that males and single lambs weighed more than females and twin lambs at birth and at other ages. Body measurements increased with age at a decreasing rate. Single ram lambs were the largest and twin ewe lambs were the smallest. They found also that sex differences did not significantly effect any body measurement; while type of birth significantly affected body measurements at birth. They reported that these effects decreased gradually as age increased.

II. HERITABILITY

In quantitative inheritance many genes are involved and there is no sharp distinction between the different phenotypes. Many economically important traits in farm animals such as fertility, rate of gain, efficiency of gain, fleece weight, body weight, body measurements and milk production are examples of this kind of inheritance. The expression of these traits is affected by many pairs of genes as well as by various environmental factors.

Improving the level of expression of economic characteristics in sheep through breeding depends on effective use of genetic variation. Pertinent to the effective use of this genetic variability is a knowledge of its magnitude as reflected by heritability of traits. Genetic and phenotypic correlations among various traits also are important in planning selection procedures. The first step essential to the successful application of genetic principles in improvement of sheep is the estimation of the heritabilities of traits the breeder desires to improve.

Traits are often described as being "highly" heritable or "lowly" heritable depending upon how closely parents and offsprings, brothers and sisters, or other close relatives resemble each other phenotypically. An accurate estimate of heritability is important because it indicates the fraction of the phenotypic superiority of selected parents which is transmitted to the offspring. Thus, progress from selection may be relatively rapid for some traits and relatively slow for others even when equally intense selection efforts are made to improve them. For this reason, knowledge of the respective heritabilities is an important factor in determinign how to practice selection for several traits simultaneously.

Although the estimate of heritability of weaning weight is often small, it is generally an estimate of value greater than zero. Some improvement in this trait can be attained over a period of years by means of individual selection. The expected selection progress (genetic gain for generation) can be expressed as:

$$\Delta G = \frac{z}{b} \quad \sigma p h^2$$

Where: $\frac{z}{b}$ = i, the selection differential in standardized units. The selection differential, S.D., (often called <u>reach</u>) in original units of measurements, is the difference between the phenotypic mean of the selected individuals and the phenotypic mean of the population from which they were selected. If the distribution were normal, the S.D. would be equal to z/b multiplied by the original phenotypic standard deviation (σ_p) of the trait concerned (S.D. = $z/b\sigma_p$). The ratio z/b is obtained from a table of values for the normal curve. The quantity b is the proportion remaining under the normal curve after part of the population is removed by truncation, and z is the ordinate of the curve at the point of truncation (Figure 1).

Accuracy of Estimates of Heritability

As pointed out by Lush (1945), the most important function of heritability in a genetic study involving quantitative traits is its predictive role in expressing the reliability of the phenotypic value

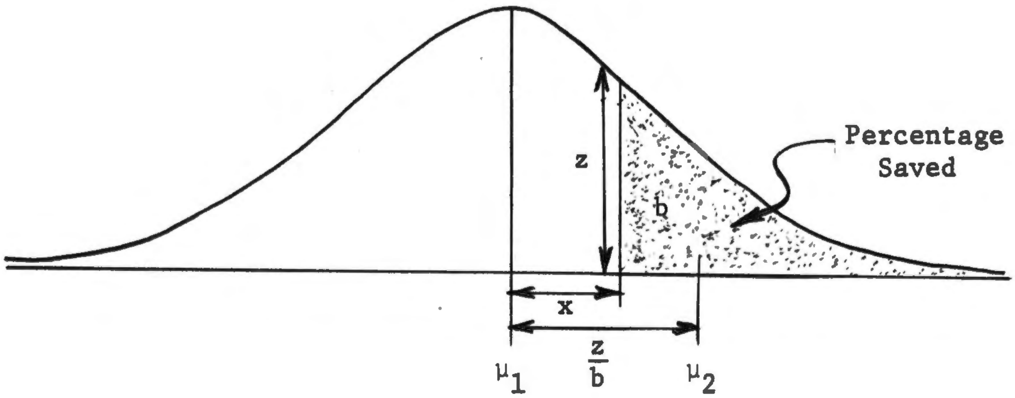

Figure 1. Selection differential in a standardized normal distribution.

Where: z is the ordinate at point of truncation.

b is the percentage of individuals saved.

$\frac{z}{b}$ is the selection differential, i.e. difference between mean of population (μ_1) and mean of individuals saved (μ_2).

x is the point of truncation.

as an estimate of breeding value. The size of the standard error of the estimate of heritability gives some indication of the precision of the estimate.

The heritability of a trait may be defined in two ways. In the broad sense it is the fraction of the phenotypic variation which is due to the effects of the genes singly and in complexes. Thus, it includes the additive effects of the genes plus any variation within the population due to non-allelic gene interaction, dominance and interaction between hereditary and environment. In the narrow sense, heritability is the fraction of the phenotypic variation which is attributable to the additive effect of the genes, that is, attributable to the linear regression of phenotype on genotype.

Lush (1945) has defined heritability in the broad sense as:

$$h^2 = \frac{\sigma_G^2 + \sigma_D^2 + \sigma_I^2 + \sigma_{EH}^2}{\sigma_G^2 + \sigma_D^2 + \sigma_I^2 + \sigma_{EH}^2 + \sigma_E^2}$$

and in the narrow sense as:

$$h^2 = \frac{\sigma_G^2}{\sigma_G^2 + \sigma_D^2 + \sigma_I^2 + \sigma_{EH}^2 + \sigma_E^2}$$

where: σ_G^2 = additively genetic variance

σ_D^2 = variance due to dominance

σ_I^2 = variance due to epistasis

σ_E^2 = variance due to environmental factors

σ_{EH}^2 = variance due to the effects of interaction between environment and heredity

Since only the additive genetic effects contribute to the permanent gain from selection in a population, an estimate of heritability in the narrow sense is more desirable for predicting the results of a selection procedure. As Lush (1945) pointed out, this estimate may contain some of the dominance deviations and usually a little of the epistatic variance, depending on the method by which it is obtained. Therefore, most of the estimates of heritability fall somewhere between the broad and narrow definitions of heritability. MacNaughton (1956) concluded that the exact magnitude of the included dominance and epistatic components can be specified for stipulated modes of gene action, but these are never known in practical situations involving quantitative traits.

Heritability Estimates

Published estimates of heritability of body weight, body measurements and gains at different ages are summarized in Tables 1 through 5. Estimates of heritability (h^2) of birth weight presented in Table 1 varied from 0.10 to 0.45. The highest estimate was that Osman and Bradford (1965), and the lowest estimates were those reported by both Butcher *et al*. (1964) and Srinivasan (1969).

The range in the estimates of heritability of weaning weight (Table 2) was from -0.06 to 0.45. The negative value was estimated by Vesely *et al*. (1970) while the high value of 0.45 was reported by Fahmy *et al*. (1969) for Barki sheep.

Table 3 shows different heritability values for yearling weight. These estimates vary widely. Vesely *et al*. (1970) found that heritability of yearling weight of Rambouillet was only 0.03 while Osman

TABLE 1

ESTIMATES OF HERITABILITY OF BIRTH WEIGHT CALCULATED FROM CORRELATIONS AMONG HALF-SIBS

Breed	Number of Observations	h^2	Author
Hampshire	1,019	0.30	Chapman and Lush (1932)
Avg. of 5 breed	504	0.15	Nelson and Venkatachalam (1949)
Three breeds and crosses	1,956	0.19	Ali (1952)
Karakul and crosses	728	0.18	Yao *et al*. (1953)
Rahmani sheep	252	0.16	Karam (1959)
Columbia X Rambouillet	1,785	0.54	Kloksh *et al*. (1962)
Avg. of 4 breeds	717	0.10	Butcher *et al*. (1964)
Navajo sheep	3,264	0.22	Eltawil (1965)
Avg. of 4 breeds	500	0.45	Osman and Bradford (1965)
Norway sheep	2,431	0.12	Gjedrem (1967)
Barki sheep	695	0.22	Fahmy *et al*. (1969)
Hampshire	415	0.10	Srinivasan (1969)
Rambouillet	796	0.30	Vesely *et al*. (1970)
Romnelet	724	0.28	Vesely *et al*. (1970)
Cross-bred	1,071	0.10	Thrift *et al*. (1973)

TABLE 2

ESTIMATES OF HERITABILITY OF WEANING WEIGHT CALCULATED FROM CORRELATIONS AMONG HALF-SIBS

Breeds	Number of Observations	h^2	Author
Rambouillet	2,183	0.27	Hazel and Terrill (1945b)
Columbia	820	0.16	Hazel and Terrill (1945b)
Corriedale	316	0.32	Hazel and Terrill (1945b)
Targhee	575	0.08	Hazel and Terrill (1945b)
Avg. of 5 breeds	348	0.42	Nelson and Venkatachalam (1949)
Shropshire	593	0.34	Karam _et al_. (1953)
Shropshire	890	0.14	Ali (1952)
Rahmani sheep	254	0.18	Karam (1959)
Hampshire	498	0.07	Givens _et al_. (1960)
Avg. of 4 breeds	402	0.00	Butcher _et al_. (1964)
Cross-bred	707	0.21	Botkin (1964)
Avg. of 4 breeds	432	0.40	Osman and Bradford (1965)
Navajo sheep	3,264	0.21	Eltawil (1965)
Rambouillet	504	0.38	Bassett _et al_. (1967)
Norway sheep	2,431	0.18	Gjedrem (1967)
Barki sheep	695	0.45	Fahmy _et al_. (1969)
Hampshire	414	0.19	Srinivasan (1969)
Rambouillet	796	0.13	Vesely _et al_. (1970)
Ramnelet	724	-.06	Vesely _et al_. (1970)
Avg. of 4 breeds	452	0.26	Galal _et al_. (1970)
Cross-bred	1,071	0.21	Thrift _et al_. (1973)

TABLE 3

ESTIMATES OF HERITABILITY OF YEARLING WEIGHT FROM CORRELATIONS AMONG HALF-SIBS

Breed	Number of Observations	h^2	Author
Avg. of 3 breeds:			
Rams	-	0.21	Kyle and Terrill (1953)
Ewes	-	0.40	Kyle and Terrill (1953)
Merino	700	0.09	Morley (1955)
Rahmani sheep	201	0.19	Karam (1959)
Avg. of 2 breeds	-	0.13	Balch (1962)
Avg. of 4 breeds	204	1.06	Osman and Bradford (1965)
Navajo sheep	3,264	0.19	Eltawil (1965)
Rambouillet	504	0.82	Bassett (1967)
Barki sheep	397	0.41	Fahmy et al. (1969)
Rambouillet	796	0.26	Vesely et al. (1970)
Ramnelet	724	0.03	Vesely et al. (1970)

TABLE 4

ESTIMATES OF HERITABILITY OF GAINS CALCULATED FROM CORRELATIONS AMONG HALF-SIBS

Trait and Breed	Number of Observations	h^2	Author
Average Daily Gain			
Rambouillet	576	0.58	Shelton *et al.* (1954)
---	89	0.84	Botkin (1955)
Hampshire	943	0.37	Hundley and Carter (1956)
Southdown	943	0.04	Hundley and Carter (1956)
Hampshire	498	0.18	Givens *et al.* (1960)
Hampshire	414	0.16	Srinivasan (1969)
Rambouillet	796	0.23	Vesely *et al.* (1970)
Ramnelet	724	0.21	Vesely *et al.* (1970)
Total Gain			
Rambouillet	796	0.23	Vesely *et al.* (1970)
Ramnelet	724	0.22	Vesely *et al.* (1970)
Pre-weaning Gain			
Cross-bred	943	0.37	Hundley and Carter (1956)
Cross-bred	150	-.02	Carter and McClue (1962)
Cross-bred	671	0.13	Harrington *et al.* (1962)
Barki	698	0.45	Fahmy *et al.* (1969)
Cross-bred	1,071	0.10	Thrift *et al.* (1973)
Post-weaning Gain			
Cross-bred	671	0.38	Harrington *et al.* (1962)
Barki	397	0.21	Fahmy *et al.* (1969)

TABLE 5

ESTIMATES OF HERITABILITY OF BODY MEASUREMENTS OF SHEEP, BEEF CATTLE AND DAIRY CATTLE

Breed	Number of Observations	Method of Estimate[a]	Trait: Body Length	Heart Girth	Wither Height	Hip Height	Chest Depth	Hook Width	Author
Jersey cows	6,000	(1)	0.68	0.65	0.60	-	0.61	0.81	Gowen (1933)
Cross-bred	176	(2)	0.48	0.34	0.76	-	0.20	0.62	Schutte (1935)
Holstein cows	187	(2)	0.58	0.61	0.73	-	0.80	-	Touchberry (1951)
Shorthorn	58	(3)	-	-	0.66	-	0.40	0.01	Dawson *et al.* (1955)
Angus calves	212	(3)	0.00	0.06	0.38	-	0.17	0.32	Brown (1958)
Hereford calves	255	(3)	0.10	0.44	0.29	-	0.33	0.15	Brown (1958)
Holstein cows	128	(2)	0.77	-	0.76	-	-	0.21	Johnson (1958)
Columbia X Rambouillet	1,785	(3)	0.42	0.46	-	-	-	-	Balch (1962)
Hereford and Angus	73	(2)	0.48	0.46	0.41	0.69	0.71	0.11	Brown and Frank (1964)
Cross-bred	471	(3)	0.51	0.41	-	-	-	0.18	Wilson (1973)

[a]Methods of estimation: (1) = Parent-offspring correlation
(2) = Intra-sire regression of offspring on dam
(3) = Patental half-sib correlation method

and Bradford (1965) reported an extremely high value of 1.06 for the same trait. A summary of estimates of heritability of average daily gain, pre-weaning, post-weaning and total gain is shown in Table 4, page 22. With the exception of two values, 0.04 and 0.84, reported by Hundley and Carter (1956) and Botkin (1955), respectively, heritability of gains appears to be of medium magnitude. Since the only estimates of heritability of body measurements in sheep found in the literature were those reported by Eloksh _et al_. (1962), papers reviewed here will consist mostly of those published concerning data obtained from cattle (Table 5, page 23).

In early work by Gowen (1933), records from more than 6,000 Jersey cows and bulls were analyzed to study the genetic construction of this breed as influenced by inheritance and different environmental factors. He used the parent-offspring correlation method to estimate heritability for body length, heart girth, wither height, chest depth and hook width. Estimates for these traits were 68, 65, 60, 61 and 81 percent, respectively. Schutte (1935) estimated the heritability of wither height, chest depth, body length, heart girth and hook width in crossbred beef cattle. He found that width measurements showed greater seasonal variation than the other body measurements. The estimates of heritability of these dimensions are shown in Table 5.

Eloksh _et al_. (1962) reported that the heritability estimates for body length, heart girth, head width and loin width of crossbred lambs were 0.42, 0.46, 0.40 and 0.29, respectively. From the estimates presented in Table 5, it appears that body measurements are moderately to highly heritable as compared to body weights at various stages of development. However, the magnitude of the estimates of heritability of gains is similar to that of estimates for skeletal dimensions.

III. GENETIC AND PHENOTYPIC CORRELATIONS

Genetic Correlation

Early work with respect to the statistical properties of livestock populations are largely concerned with estimating, one by one, the heritability of each trait comprising productivity. The heritability of a particular trait can be used to predict genetic gains from selecting for this trait. For these predictions to be reasonably accurate, it is necessary that selection be for one trait alone or that the trait not be genetically correlated with any of the other traits affecting productivity or fitness of the animal. If the genetic correlation between two traits is negative and large, selection for one trait may be negated later by selecting for the other trait. Thus, the actual genetic progress may be less than the expected genetic progress as computed from knowledge of heritability alone.

Since selection for one trait alone is a condition which is seldom desirable in any livestock enterprise, it is obvious that heritabilities are not sufficient to describe adequately the genetic properties of a population or to satisfactorily predict the overall consequences of selection. A more adequate description of the additively genetic causes of variation and covariation of different characters must include the genetic covariances or correlations between the traits considered in selection in addition to the genetic variances or heritabilities.

Statistically, the traits considered may be looked upon as having some multivariate distribution of additively genetic values which requires for its specification an array of genetic variances and covariances. Because genetic correlations are in standardized form, and are more easily interpreted and compared, they are used in preference to genetic covariances, as pointed out by Rae (1950).

The genetic correlation between two characters may be defined as the ratio of the genetic covariance to the product of their genic standard deviations (Falconer, 1967). A genetic correlation is thus a measure of the relationship between the genetically additive deviations of the two traits. When the genetic correlation between two traits is positive, simultaneous improvement of the two traits is facilitated. A negative genetic correlation, however, implies that selection for one trait will automatically cause some deterioration in the other. If both traits are important from the standpoint of productivity, selection for one of them cannot be maintained for long, but will need to be relaxed while efforts are directed toward repairing the damage done to the other trait. Basing selection on a properly balanced combination of the two traits avoids wide fluctuations in any one of them; however, the net progress in each trait will still be slower than that which could be achieved if the traits were independent or favorably correlated.

It was suggested by Lush (1945) that the cause of permanent or persisting genetic correlation is presumed to be the pleiotropic (multiple effects) action of genes in a population which has been mated at random for many generations. However, in newly formed population, linkage of genes may cause a temporary genetic correlation. Chapman (1962) stated that if a population is made up of several subgroups which have been differentially selected, genetic correlation may occur. Falconer (1967) also stated that due to the pleiotropic effect of genes, or because genes that affect different traits are located on the same chromosome (linkage), there is sometimes a correlation of two or more traits of economic importance. The breeder must be aware of these relationships in order to plan the most efficient selection program. For example, there is a high positive genetic correlation betwene birth and weaning weights in sheep. So it is advisable, in this case, to use birth records since these records can be obtained at an earlier stage of life.

Few reports were found concerning genetic relationship between body weights at different ages of sheep (Table 6). Ragab et al. (1953b) reported very high genetic correlations between birth and weaning weights (1.04), birth and market weights (0.82) and between weaning and market weight (0.96) in Ossimi sheep. These findings are in agreement with the results obtained by MacNaughton (1956); Givens et al. (1960), Gjedrem (1967); Srinivasan (1969) and Fahmy et al. (1969). Eltawil (1965) reported a value of 1.32 for genetic correlation between weaning and yearling weights. Ercanbrack and Price (1972) also found an extremely high correlation (1.07) between birth and weaning weights in Columbia sheep.

TABLE 6

ESTIMATES OF GENETIC CORRELATIONS OF VARIOUS TRAITS

Trait	Estimate	Breed	Author
Yearling Wt. - Staple L.	-1.11	Merino	Morley (1950)
Birth Wt. - Weaning Wt.	1.04	Ossimi	Ragab et al. (1953b)
Wean. Wt. - Fiber Diam.	1.19		
Body Wt. - Condition	-2.17	Navajo	Sidwell (1955)
Condition - Staple L.	-2.29		
Wean. Wt. - Yearling Wt.	1.32	Navajo	Eltawil (1965)
Birth Wt. - ADBG23kg.	-2.65±9.19		
Birth Wt. - ADGBW	1.00±0.38		
ADGB23kg. - ADGBW	1.26±0.26	Hampshire	Vogt et al. (1967)
ADGB23kg. - 120-day Wt.	1.02±0.18		
ADGBW - 120-day Wt.	1.05±0.06		
Birth Wt. - Weaning Wt.	-2.20±12.1		
Final Wt. - ADG	1.49±1.07		
Final Wt. - Total gain	1.50±1.08	Ramnelet	Vesely et al. (1970)
Final Wt. - Feed Effic.	1.71±1.91		
G. Fleece Wt. - C. Fleece Wt.	1.14±0.26		
C. Fleece % - C. Fleece Wt.	1.72±2.73	Nali	
G. Fleece Wt. - C. Fleece Wt.	1.03±0.40		Chopra and Chopra (1972)
C. Fleece % - Staple L.	1.27±0.55	Lohi	
Birth Wt. - Weaning Wt.	1.07	Columbia	Ercanbrack and Price (1972)
Specific Growth Rate(SGR)4- SGR 36-month	-1.25		
SGR12 - SGR36	-1.55	Hereford females	Brown et al. (1972)
SGR16 - SGR20	-1.72		
SGR16 - SGR24	-4.55		
Wean. Conf. Score(WCS) - Yearl. Wt./day of age	-1.48±0.70	Angus bulls	
WCS - YCS	1.07±0.05	Angus heif.	Francoise et al. (1973)
ADGWY - YCS	1.79±1.97	Hereford bulls	

Phenotypic Correlation

Phenotypic correlations estimate the extent to which characteristics in the current flock are associated, either positively or negatively. Hence, the extent to which selection will raise production in the current flock depends on the repeatability of production traits and, when more than one trait has to be considered, on the phenotypic correlations between traits. The objectives in determining the phenotypic correlations between productive traits are threefold.

Firstly, they are required for constructing selection indexes to attain the maximum rate of genetic improvement (Hazel, 1943).

Secondly, it may be desirable to use an easily measurable trait, to preduct another trait which is expensive and difficult to measure (Eltawil, 1965).

Thirdly, they provide a means of describing the relationships existing among the traits in the population under study (Sidwell, 1954).

Terrill (1939) reported phenotypic correlations of 0.46 between weaning weight and average lifetime weight (average weight from two to five years of age), and 0.54 between 18-month weight and average lifetime weight. Working with Ossimi sheep in Egypt, Ragab et al. (1953b) obtained correlations of 0.59, 0.48 and 0.86 between birth and weaning weight, birth and market weights and between weaning and market weights, respectively. Karam (1959) reported correlations between birth and weaning weights, birth and yearling weights and weaning and yearling weights of 0.21, 0.20 and 0.31, respectively, in Rambouillet sheep. These results were similar to correlations between birth and weaning weight obtained by Kassab and Karam (1961), Butcher *et al*. (1964), Gjedrem (1967), Fahmy *et al*. (1969) and Srinivasan (1969). The latter also reported phenotypic correlations of 0.26 and 0.91 between birth weight and average daily gain from birth to weaning and between weaning weight and average daily gain, respectively.

Recently, Ercanbrack and Price (1972) reported phenotypic correlations of 0.45, 0.46, 0.37 and 0.36 between birth and weaning weight in crossbred, Rambouillet, Targhee and Columbia sheep, respectively. They reported phenotypic correlations also between birth weight and average daily gain from birth to weaning of 0.30, 0.31, 0.20 and 0.20 and between birth weight and average daily gain from weaning to a year of age of -.01, 0.06, 0.06 and 0.09, for those breed groups, respectively. In addition, phenotypic correlations between weaning weight and pre-weaning average daily gain were 0.98, 0.98, 0.97 and 0.98, respectively. Coefficients of correlation between weaning weight and post-weaning average daily gain were -.16, -.22 and -.15, respectively, for the same breeds.

IV. PRINCIPAL COMPONENTS

The use of linear and curvilinear lines to represent growth patterns of animals is very common in animal breeding studies. However, when data on several related biometrical traits are available, more information can be obtained by description of relative growth curve data in terms of several axes of variation and, therefore, appears more appropriate than their description in terms of a simple growth curve. Such information can be gathered by utilizing principal components calculation of which is one of the multivariate techniques.

Principal-component analysis was described by Karl Pearson in 1901, and has been used by many research workers since that time (Wright, 1932; Anderson, 1958; Jolicoeur and Mosimann, 1960; Hope, 1968; Eller, 1972; and Brown _et al_., 1973). Jolicoeur and Mosimann (1960) studied size and shape variation by using three mutually perpendicular directions of space, that is length, width and height of painted turtles' carapaces. They concluded that principal component analysis of variation in size and shape would be appropriate for studying relative growth when biometrical characters are considered. They stated also that:

> Partitioning biometrical variation into size and shape components is often highly desirable as the size of most organisms is more affected than their shape by fluctuations of the external environment; size variation is also more likely to reflect heterogeneity of samples with respect to age-composition. Shape tends thus generally to provide more reliable indications than size on the internal constitution of organisms; this makes the analysis of size and shape a basic step in the study of biometrical variation.

Coefficients and variances of the principal components, shown in Table 7, were extracted from the covariance matrices of the length, width and height measurements of the carapaces of 24 female and 24 male turtles by Jolicoeur and Mosimann (1960). These results indicate that turtles can be ranked according to their carapace size by the following formula obtained from the first principle component (Y_1).

$$Y_1 = .8401 \text{ (length)} + .4919 \text{ (width)} + .2285 \text{ (height)}$$

where: individual body measurements, _i.e._, length, width and height are substituted in the above equation. Then Y_1 becomes a new weighted mean of the carapace measurements, and the size of the turtle shells

TABLE 7

CARAPACE PRINCIPAL-COMPONENT COEFFICIENTS

	24 Males--Component			24 Females--Component		
Measurement	1	2	3	1	2	3
Length	.8401	-.4881	-.2365	.8126	-.5454	-.2054
Width	.4919	.8694	-.0469	.4955	.8321	-.2491
Height	.2285	-.0770	.9705	.3068	.1006	.9465
Percentage of total variance	97.61	1.84	0.55	98.64	0.94	0.41

are characterized by this single variable. Little information is lost because the first principal component accounts for 97.61 percent of the total variance in the three dimensions.

In an extensive study of the growth and development of beef cattle Brown et al. (1973) utilized principal component procedures. Nine skeletal dimensions and body weights of 267 Hereford and 283 Angus bulls at ages of 4, 8 and 12 months were used. Principal component analyses were performed for each breed and age group. The authors found the first principal component, at each age, accounted for 56 to 68 percent of the total variation in the system, while the second component accounted for only about 10 percent. This indicates that three-fourths of the variation of the 10 variates which defined size and shape was expressed as a tendency for bulls high in one dimension to be larger for all of the other body measurements. It was indicated also that unrestricted selection based on size, measured as body weight, would produce bulls which varied in shapes at later ages.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. SOURCE AND DESCRIPTION OF DATA

The Awassi fat-tail breed of sheep is found throughout the Middle East and is a triple-purpose breed which provides meat, milk and carpet wool. In addition to flocks managed extensively by individual sheep producers, some 3,000 head are now raised on different experiment stations, mainly by The Abu-Ghraib Agricultural Experiment Station, Ministry of Agriculture, Iraq. These flocks are maintained under a higher standard of feeding and management than other flocks in that country.

The data used in this study were collected over a 3-year period (1966, 1967 and 1970) from the Awassi flock maintained by The Agricultural Experiment Station, Hammam Al-Alil, Mosul University.

Experimental Sheep Flock

The flock was established in 1965 by purchasing 100 ewes and 10 rams ranging from 2 to 5 years of age from the Abu-Ghraib Station. It was established, mainly, to produce improved purebred rams for sheep producers in that area and also to provide animals to study the effects of crossbreeding with the Karadi (fat-tailed) breed, which is the most popular breed in the Northern part of Iraq.

In general, the climate of Iraq is described as sub-tropical, continental, or sub-tropical Mediterranean type. This climate is characterized by very hot summers and the very cold winters. Mosul, where this study was conducted, is distinguished by it's extremely hot weather in the summer. This area is a medium plateau (its elevation is approximately 750 ft.). There are no clouds to cut off the sunshine in the summer. The mean diurnal temperature in July is 45°C while in January the mean is -5°C. However, Mosul is usually called the land of "the two springs" because of the very short spring and fall seasons. The country is also described as being without rain for eight months. The rainy season in Mosul lasts about 60 days, with about 13 inches total precipitation. The average daily amount of sunshine in July is 14 hours, which is almost three hours longer than that of January.

Breeding and Management

The breeding season begins about June 15 and extends over a period of about 70 days. The majority of the lambs were dropped during November and December. At the beginning of each breeding season the available ewes were randomly divided into five to six sire-breeding groups. Each group consisted of about 25 ewes of different ages (from 18 months to 8 years) and one ram. Each ram was used in a certain group for only one breeding season. In subsequent years he was mated to different groups of ewes.

Ewes were "flushed" for about two weeks prior to the breeding season by providing additional feed in the form of concentrate and fresh-cut alfalfa. The ration consisted of ground barley, wheat bran, cottonseed meal, dried beet pulp, salt and minerals. All ewes grazed straw, which was a residual from harvesting of wheat and barley, during the breeding season. During the day the ewes grazed as one flock and were returned from the pasture at about 4:00 p.m. During the night they were allotted according to breeding groups, and the assigned ram remained with each group. They were fed about one-half kilogram of concentrate per head daily while gleaning the wheat fields, and this supplementation continued until good pasture was available in the middle of March. The amount of the concentrate was then decreased to about one-fourth kg per head per day until the next breeding season when ewes again were flushed and grazed dry pasture.

Ewes lambed in a closed lambing barn. Ewes and lambs were placed in temporary, portable, lambing pens immediately after lambing. Lambs were identified by both tattoo and metal tag within a few hours after birth.

The following information and measurements were recorded for each lamb:

1. Date of birth
2. Type of birth
3. Body weight
4. Body measurements
5. Sex of lamb(s)
6. Parentage
7. Age of dam

Ewes and lambs remained in the lambing pens for one week. Lambs were kept with their mothers except during the daily period when ewes were allowed to graze the pasture. The lambs received creep feed from ten days until eight to ten weeks of age. After that time, generally about the middle of March, the lambs were allowed to run with their dams on pasture without creep feed until they were weaned at approximately 120 days of age.

Shortly after weaning, most of the ram lambs, culled ewe lambs and ewes which had failed to lamb in two consecutive years were either slaughtered or sold. Ram and ewe lambs selected for replacements were kept in separate groups until they were one year old. At this time the ewe lambs were added to the flock and the ram lambs kept with the mature rams.

Record Obtained

Body weight and dimensions were measured at birth, weaning and yearling ages on a total of 240, 257 and 151 lambs, respectively. Body weight was recorded to the nearest 0.1 hg, and heart birth, body length, height at shoulders, height at hips, width at withers and width at hips were measured to the nearest 0.5 cm. Heart girth and body dimensions were measured with metal calipers. Each lamb, after being weighed, was held in as nearly a normal standing position as possible. The following reference points were used in taking the measurements (Figure 2):

1. Heart girth (HG) - the distance along a steel tape drawn snugly around the body immediately posterior to the shoulders.
2. Body length (BL) - the distance from the shoulder point to the point of the pin bone.
3. Wither height (WH) - the vertical distance from the floor to the top of the shoulder.

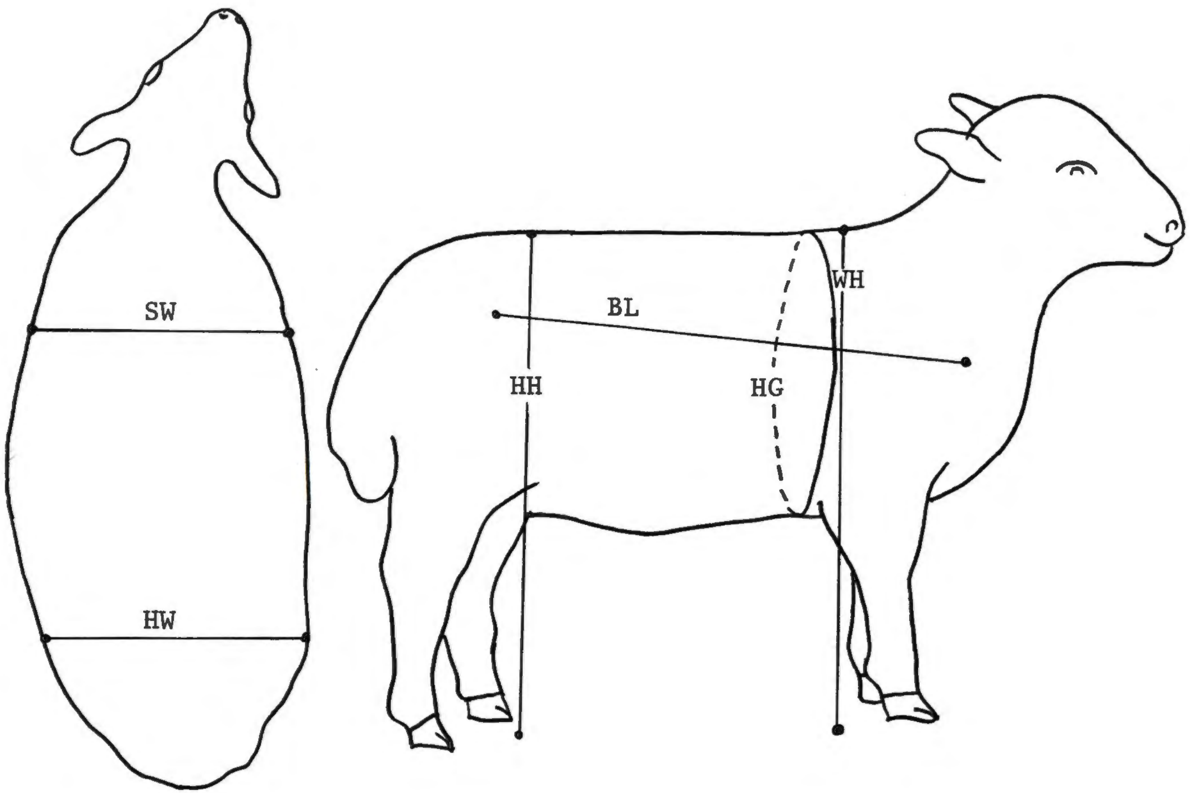

Figure 2. Relative positions of body measures taken on lambs.

4. Hip height (HH) - the vertical distance from the floor to the highest point in the region of the hooks.
5. Shoulder width (SW) - the horizontal distance across the widest point of the shoulders.
6. Hip width (HW) - the horizontal distance across the widest point of the hips.

II. METHODS OF STATISTICAL ANALYSIS

Environmental Factors

The number of individual records obtained at birth, weaning and yearling ages were unequal; therefore, it was necessary to analyze these data separately according to age in order to obtain correlations among several traits measured at that time. Because of unequal subclass numbers, least-squares estimates of the effect of year of birth, six of lamb, type of birth, age of dam and month of birth on the various traits were obtained by the procedure of fitting of constants as described by Harvey (1960). The following general additive model was used to describe the data, including effects of certain environmental factors at each of the three growth periods.

$$Y_{ijklmn} = \mu + y_i + x_j + t_k + a_l + b_m + e_{ijklmn}$$

where: Y_{ijklmn} = the observation value of a given trait of the ijklmn-th individual record

μ = the population mean with equal subclass numbers, i.e., an effect common to all individuals

y_i = effect of i-th year of birth

x_j = effect of j-th sex of lamb

t_k = effect of k-th type of birth

a_l = effect of l-th age of dam

b_m = effect of m-th month of birth

e_{ijklmn} = random error associated with an individual record.

Heritability Estimates

When estimating genetic parameters for various traits, environmental effects were included in the model only when those effects proved to influence significantly a specific trait at a given age. Estimates of heritability were obtained by quadrupling paternal half-sib correlations among paternal half-sibs. Procedures for estimating variance components when subclass numbers are unequal have been discussed in detail by Hazel et al. (1943), Henderson (1953) and Snedecor and Cochran (1967). Sire variance components derived from the between-sire mean squares were assumed to be estimates of 25 percent of the additive by genetic variance. The variance components computed from the within-sire mean squares were assumed to contain all environmental variance plus 75 percent of the additive by genetic variance (see Table 8).

Heritability was estimated by the following formula:

$$h^2 = \frac{4\, s_S^2}{s_S^2 + s_W^2}$$

Estimates of the standard errors of the heritability estimates were calculated according to Osborne and Paterson (1952) formula:

TABLE 8

FORM OF THE ANALYSIS OF VARIANCE FOR ESTIMATING HERITABILITY FROM PATERNAL HALF-SIB CORRELATION

Source of Variation	Degrees of Freedom	Composition of Mean Square[1]
Between Sires	(S - 1)	$s_W^2 + k_o\ s_S^2$
Within Sires	(k. - S)	s_W^2

[1]Explanation of symbols are as follows:

S = number of sires

k. = total number of offspring

s_W^2 = variance due to differences between offspring of same sire

s_S^2 = variance due to sire differences

K_o = average numbers of progeny per sire group

$$\text{Standard Error} = \sqrt{\frac{2(s_W^2)^2 \left| s_W^2 + K_o \, s_S^2 \right|^2}{(s_W^2 + s_S^2)^4 \, K_o \, (K. - S)}}$$

The general form of these calculations are shown in Table 8.

The average number of progeny (k_o) per sire was computed according to the following formula outlined by Becker (1968):

$$k_o = \frac{1}{s. - 1} \left[k. - \frac{\Sigma \, k_i^2}{k.} \right]$$

where: $k. = \Sigma k_i$ and k_i = number of offspring of the i-th sire.

Genetic and Phenotypic Correlations

Genetic and phenotypic variance and covariance components were estimated from the adjusted data using the method described by Hazel (1943) and Hazel _et al_. (1943). Estimates of genetic correlation were calculated using the following formula:

$$r_G = \frac{Cov_s \, (XY)}{\sqrt{S_s^2 \, (X) \, S_s^2 (Y)}}$$

where: r_G = estimate of genetic correlation

Cov_s (XY) = sire component of covariance of trait X and trait Y

S_s^2 (X) = sire component of variance of trait X

S_s^2 (Y) = sire component of variance of trait Y.

and estimates of phenotypic correlations by the following formula:

$$r_p = \frac{Cov_{pxy}}{S_{px} \, S_{py}}$$

where: r_p = estimate of phenotypic correlation

Cov_{pxy} = the phenotypic covariance between trait X and trait Y

S_{px} = the phenotypic standard deviation of trait X

S_{py} = the phenotypic standard deviation of trait Y.

Principal Components

Multivariate techniques were used to evaluate the applicability of principal component analyses in defining sources of size and shape variation in lambs. This technique provided a method of explaining the variance-covariance and/or correlation structure among a large system of measurements by generating a smaller numbers of artificial variates, *i.e.*, principal components, which contrast lambs of different sizes and shapes. For a more detailed discussion of principal component analysis, the reader is referred to the standard texts of Morrison (1967), Anderson (1958), and Hope (1968), Hotelling (1936) and Joilcoeur and Mosimann (1960).

Analysis of the dependence structure centers around the estimation of coefficients (a_{ij}) of the j^{th} principal component (Y_j). Therefore, all principal components (Y_j) were of the form,

$$Y_j = a_1z_1 + a_2z_2 + \cdots + a_7z_7$$

where: a_i = coefficient of the i^{th} body measurement

z_i = i^{th} standardized body measurement,

$$\left(\frac{X_i - \bar{X}_i}{S_{x_i}}\right)$$

Since the original units of response (measurements) were different, *i.e.*, kilograms and centimeters, it was necessary to transform each response to a standard score (Z_i) and use the correlation matrix rather than the variance-covariance matrix to derive the principal components.

The data used in this analysis consisted of body weights and six body measurements of 136 lambs taken at birth, weaning and yearling ages. Principal-component indexes were calculated for each lamb and these indexes were analyzed using the same procedure employed to partition genetic and environmental variation in the original data. Least-squares constants were calculated and used to adjust the data for environmental factors. These adjusted data were used to obtain genetic and phenotypic correlations among the various pairs of principal component indexes at the three different ages. Heritability of those components were estimated using paternal half-sib correlation method as described earlier.

CHAPTER IV

RESULTS AND DISCUSSION

I. ENVIRONMENTAL EFFECTS

A preliminary analysis was based on a linear mathematical model to determine the effects of certain environmental factors on body weight, rate of gain and various body dimensions of lambs at birth, weaning and yearling ages. Least-squares means were calculated to determine the influence of various levels of the independent variables, year of birth, sex of lamb, type of birth, month of birth and age of dam; on the performance traits at various ages.

Various independent variables were added to the model in a stepwise procedure to assess their contribution to the total variance. The fraction of the variation associated with each environmental factor includes only the variation associated with that element after previous factor(s) were considered. These values are expressed as change in R^2 (ΔR^2) or the fraction of the variation of the performance trait attributed to the most recently added independent variable after variation due to previously included fixed environmental effect(s) had been considered. Thus, the order of incorporation of the environmental factors, as elements in the model, is important if any pair of these elements are correlated. The order of incorporation established for this analysis was based on the practical sequence of correcting individual records for fixed environmental effects and on the magnitude of their contribution to variation in the various performance traits, an approach suggested by McLaren (1970). Results of these stepwise analyses, with respect to the influence of these environmental effects at birth, weaning and yearling ages, are presented in Table 9. The effect of these factors at various ages will be discussed separately in the following sections.

Body Weight and Measurements at Birth

The effects of year, type of birth and month of birth on birth weight and all body measurements at birth are shown in Table 10 and were generally highly significant ($P < .01$). However the effect of type of birth was significant only at the 0.05 probability level. Sex of lamb significantly affected body weight ($P < .01$), wither ($P < .05$) and hip height ($P < .05$). Age of dam significantly affected body length and wither height ($P < .05$).

The total reduction in the variability in birth weight, when all environmental factors were included in the model was 34.26 percent as measured by the squared multiple correlation coefficient (R^2). The fraction of the total variation attributed to each of these sources, when previous elements in the model were held constant, are shown in Table 9. The effect of year of birth on body weight was greater at birth ($\Delta R^2 = .18$) than at any other age. This probably reflects nutritional differences between years and the effect of this variation on prenatal development. The effect of sex of lamb was lower at birth ($\Delta R^2 = .01$) than at weaning or yearling age. The magnitude of the change in $R^2 (\Delta R^2)$ indicates the relative importance of each effect when other factors in the model were held constant. These ΔR^2 values, along with the mean squares presented in Table 10, suggest that it

TABLE 9

ADDITIONAL SUM OF SQUARES EXPLAINED BY SEQUENTIALLY ADDING ENVIRONMENTAL FACTORS IN ANALYSES OF BODY WEIGHT AT VARIOUS AGES*

Source of Variation	ΔR^2 Birth Weight	Weaning Weight	Yearling Weight
Year of birth	18.39	14.89	0.17
Sex of lamb	1.38	0.52	36.34
Type of birth	9.15	5.13	0.55
Month of birth	2.66	3.15	8.73
Age of dam	2.68	0.58	0.22
Variation accounted for by all sources in the model**	34.26	24.27	46.01

*Number of records included were 240, 257 and 151 at birth, weaning and yearling age, respectively.

**$Y_{ijklmn} = \mu + y_i + x_j + t_k + a_l + b_m + e_{ijklmn}$

Description of the above model is on page 38.

TABLE 10

ANALYSIS OF VARIANCE OF BIRTH WEIGHT AND BODY MEASUREMENTS

Source of Variation	Degrees of Freedom	Mean Square						
		Body Weight	Body Length	Heart Girth	Wither Height	Hip Height	Shoulder Width	Hip Width
Year of birth	2	17.93**	3.54	116.83**	594.85**	1,087.17**	52.62**	77.17**
Sex of lamb	1	3.46**	5.75	17.02	19.22*	20.69*	1.03	1.56
Type of birth	1	9.86**	62.85**	86.39*	74.43**	87.80**	6.97**	5.71**
Age of dam	6	0.72	8.47*	7.39	7.92*	5.43	0.11	0.43
Month of birth	4	1.81**	12.60**	34.31**	45.87**	52.58**	2.38**	3.00**
Error	225	0.37	3.47	5.62	3.44	3.58	0.42	0.49
Total	240							

*$P < .05$

**$P < .01$

may not be necessary to adjust birth records (weights and dimensions) for age of dam or, in some cases, sex of lamb. Appendix Table 31 reflects the influences of each environmental factor on various body dimensions at birth.

Least-squares means for weight and body measurements at birth are shown in Table 11. Lambs born in 1967 were 0.97 kg heavier at birth than lambs born in 1970 and lambs born in 1966 were 0.66 kg heavier at birth. These results can be explained by the fact that during 1967 very good pasture was available to ewes following the breeding season while in 1970 the ewes were faced with a very dry season. Eltawil (1965) reported that year of birth could affect many lamb traits at birth through the amount of feed available, the amount of rainfall, management practices and variations in the general health of the flock. Many other workers have reported that temperature, rainfall and other climatic factors resulted in yearly variation in weight or size of lambs at birth and that these variations were reflected by the least-squares constants for year (Ali, 1952; Blackwell and Henderson, 1955; Bogart _et al_., 1957; Harrington _et al_., 1958; Karam, 1959; Webb, 1963; Juma and Faraj, 1966; Gjedrem, 1967; McLaren _et al_., 1968; Srinivasan, 1969; Eliya, 1969; Vesely and Robison, 1970; Eltawil _et al_., 1970; and Sidwell and Miller, 1971a,b). Lambs born in 1967 had longer bodies ($P < .05$) and greater heart girth measurements than lambs born in 1966 and 1970, while other body dimensions were greatest for lambs born in 1966. Lambs born in 1970 were smallest with respect to body size.

TABLE 11

LEAST-SQUARES MEANS (AND THEIR STANDARD ERRORS) OF THE EFFECTS OF THE ENVIRONMENTAL FACTORS ON WEIGHT AND SELECTED BODY MEASUREMENTS AT BIRTH

Effect	Number of Lambs (Observations)	Body Weight (kg)	Body Length (cm)	Heart Girth (cm)	Wither Height (cm)	Hip Height (cm)	Shoulder Width (cm)	Hip Width (cm)
Overall mean	240	4.44±.09	30.33±.27	35.52±.35	34.45±.27	34.64±.28	7.39±.09	8.47±.10
<u>Year of Birth</u>		**		**	**	**	**	**
1. 1966	62	$4.56\pm.10^{a}$	30.19±.30	$39.87\pm.38^{a}$	$37.85\pm.30^{a}$	$38.63\pm.30^{a}$	$8.37\pm.10^{a}$	$9.49\pm.12^{a}$
2. 1967	84	$4.87\pm.12^{a}$	30.60±.37	$40.58\pm.47^{a}$	$34.93\pm.37^{b}$	$35.83\pm.37^{b}$	$7.56\pm.13^{b}$	$8.83\pm.14^{b}$
3. 1970	94	$3.90\pm.13^{b}$	30.21±.40	$38.12\pm.51^{b}$	$30.57\pm.40^{c}$	$29.45\pm.41^{c}$	$6.24\pm.14^{c}$	$7.10\pm.15^{c}$
<u>Sex of Lamb</u>		**			*	*		
1. Male	126	$4.56\pm.09^{a}$	30.49±.28	39.79±.36	$34.74\pm.31^{a}$	$34.94\pm.29^{a}$	7.46±.10	8.55±.11
2. Female	114	$4.32\pm.10^{b}$	30.17±.32	39.25±.40	$34.16\pm.30^{b}$	$34.34\pm.32^{b}$	7.32±.11	8.39±.12
<u>Type of Birth</u>		**	**	*	**	**	**	**
1. Single	205	$4.75\pm.09^{a}$	$31.11\pm.27^{a}$	$40.43\pm.34^{a}$	$35.29\pm.27^{a}$	$35.55\pm.27^{a}$	$7.65\pm.09^{a}$	$8.71\pm.10^{a}$
2. Twin	35	$4.13\pm.12^{b}$	$29.55\pm.38^{b}$	$38.61\pm.48^{b}$	$33.60\pm.38^{b}$	$33.72\pm.39^{b}$	$7.13\pm.13^{b}$	$8.24\pm.14^{b}$
<u>Age of Dam</u>			*		*			
1. 1.5 year	10	4.29±.21	$29.71\pm.65^{a}$	38.91±.83	$34.09\pm.65^{a}$	34.55±.66	7.35±.23	8.61±.24
2. 2.5 year	58	4.39±.12	$30.51\pm.36^{b}$	39.66±.45	$33.70\pm.35^{b}$	33.93±.35	7.33±.12	8.30±.13
3. 3.5 year	41	4.27±.13	$29.67\pm.40^{ab}$	38.91±.45	$34.24\pm.40^{a}$	34.51±.40	7.36±.14	8.49±.14
4. 4.5 year	55	4.68±.11	$31.09\pm.35^{b}$	40.20±.45	$34.44\pm.35^{a}$	34.54±.35	7.40±.12	8.49±.13

TABLE 11 (continued)

Effect	Number of Lambs (Observations)	Body Weight (kg)	Body Length (cm)	Heart Girth (cm)	Wither Height (cm)	Hip Height (cm)	Shoulder Width (cm)	Hip Width (cm)
5. 5.5 year	37	$4.54 \pm .13$	$30.65 \pm .41^{b}$	$39.97 \pm .52$	$34.88 \pm .41^{a}$	$34.90 \pm .41$	$7.42 \pm .14$	$8.48 \pm .15$
6. 6.5 year	22	$4.44 \pm .15$	$30.59 \pm .45^{b}$	$39.68 \pm .58$	$35.13 \pm .45^{c}$	$35.01 \pm .47$	$7.52 \pm .17$	$8.62 \pm .17$
7. 7.5 year and above	17	$4.49 \pm .17$	$30.09 \pm .50^{b}$	$39.32 \pm .64$	$34.67 \pm .50^{a}$	$35.02 \pm .51$	$7.34 \pm .18$	$8.31 \pm .19$
Month of Birth		**	**	**	**	**	**	**
1. January	12	$4.49 \pm .20^{a}$	$30.86 \pm .61^{a}$	$41.02 \pm .78^{a}$	$34.29 \pm .61^{a}$	$34.50 \pm .62^{a}$	$7.37 \pm .21^{a}$	$8.38 \pm .22^{a}$
2. February	7	$4.64 \pm .25^{a}$	$31.68 \pm .77^{b}$	$41.29 \pm .99^{a}$	$35.62 \pm .77^{a}$	$35.50 \pm .79^{b}$	$7.00 \pm .27^{b}$	$8.99 \pm .29^{a}$
3. March	16	$3.89 \pm .18^{b}$	$28.81 \pm .55^{c}$	$37.18 \pm .71^{b}$	$32.63 \pm .55^{b}$	$32.99 \pm .57^{c}$	$6.91 \pm .19^{b}$	$7.81 \pm .10^{b}$
4. November	142	$4.48 \pm .09^{a}$	$29.98 \pm .27^{c}$	$38.75 \pm .35^{b}$	$35.88 \pm .27^{b}$	$36.26 \pm .29^{b}$	$7.92 \pm .09^{c}$	$8.99 \pm .10^{c}$
5. December	63	$4.70 \pm .09^{a}$	$30.33 \pm .28^{ab}$	$39.37 \pm .35^{c}$	$33.83 \pm .28^{c}$	$33.92 \pm .29^{c}$	$7.74 \pm .10^{c}$	$8.85 \pm .11^{c}$

[a,b,c] Least-squares means within column and effect superscripted with the same letter do not differ significantly. All others differ significantly ($P < .05$).

*$P < .05$. **$P < .01$.

Single lambs were 0.62 kg heavier at birth than twins. Single lambs were larger also with respect to all body measurements than were twin lambs. These results were similar to those reported by many investigators, especially with respect to birth weight (Phillips and Dawson, 1937; Nelson and Venkatachalam, 1949; Asker et al., 1952; Ragab et al., 1953a; Blackewell and Henderson, 1955; Cassard and Weir, 1956; Bogart et al., 1957; Karam, 1959; Brown et al., 1961; Bennett et al., 1963; Webb, 1963; Sidwell et al., 1964; Juma and Faraj, 1966; Gjedrem, 1967; Frederiksen et al., 1967; McLaren et al., 1968; Srinivasan, 1969; Trail and Sacker, 1969; Eliya, 1969; Eltawil et al., 1970 and Sidwell and Miller, 1971b).

The effect of month of birth on weight and body dimensions of lambs were also highly significant ($P < .01$). Lambs born during December, January and February were heavier at birth than lambs born in November or March (Table 11). This result agrees with those of Sanchez Belda and Esteban Munoz (1960) who indicated that Marchia lambs born in Spain during the last weeks of each lambing season weighed more at birth than those born earlier in the season. Eliya (1969) also stated that lambs born earlier in the lambing season weighed significantly less than those born later in the season. In the same investigation, he observed a difference of 0.80 lb. between average birth weight of lambs born in January and that of those born in October. On the other hand, Juma and Faraj (1966) and McLaren et al., (1968) reported that lambs born earlier and alter in the lambing season were heavier than lambs dorpped in mid-season.

The influence of sex of lamb on birth weight was highly significant ($P < .01$). The average birth weight was 4.56 kg for male lambs and 4.32 kg for female lambs with a difference of .24 kg in favor of males (Table 11, page 49). McLaren _et al._, (1968) reported a difference of 0.61 lb. Many other investigators have found similar differences in birth weight between male and female lambs. (Ali, 1952; Asker _et al._, 1952; Blackwell and Henderson, 1955; Harrington _et al._, 1958; Sabin and Brown, 1962; Webb, 1963; Datta _et al._, 1963; Sidwell _et al._, 1964; Smith and Lidvall, 1964; Juma and Faraj, 1966; Gjedrem, 1967; Srinivasan, 1969; Jama _et al._, 1969; Eliya, 1969; Vesely and Robison, 1970; Eltawil _et al._, 1970 and Sidwell and Miller, 1971b). However, Bogart _et al._ (1957), Brown _et al._ (1961) and Trail and Sacker (1969) found no significant difference in weight between male and female lambs at birth.

Differences in body length and wither height of lambs due to the effect of age of dam were significant ($P < .05$) as shown in Table 9, page 46). In contrast to its effects on the above mentioned traits, age of dam appeared to have no significant influence on birth weight or other body measurements. Juma and Faraj (1966) reported similar trends, with respect to birth weight, based on a larger volume of data from the same breed. Values obtained by Weir (1956) also were in agreement in this respect. However, many research workers have reported significant differences due to the effect of dam age in many different breeds and breed crosses (Brown _et al._, 1961; Bennett _et al._, 1963; Webb, 1963; Gjedrem, 1967; McLaren _et al._, 1968; Eliya, 1969; Srinivaran, 1969; Vesely and Robison, 1970; Eltawil _et al._, 1970 and Sidwell and Miller, 1971b).

Body Weight and Measurements at Weaning

Weaning body weight and measurements were significantly influenced by year of birth (Table 12). Differences due to year accounted for the major part of the environmental variability (Table 9, page 46, and Appendix Table 32). Lambs born in 1966 had the highest average weaning weight (23 kg) while those born in 1967 had the lowest weaning weight (16 kg). Mean body weight and body measurements at weaning (Table 13) reflect yearly differences in nutrition, climate and other factors which generally affect rate of growth. These findings are in agreement with those reported by Karam (1959), Sabin and Brown (1962), Bennett *et al*., (1963), Webb (1963), Eltawil (1965), Gjedrem (1967), McLaren *et al*. (1968), Srinivasan (1969), Vesely and Robison (1970) and Sidwell and Miller (1971b). However, Hazel and Terrill (1945a) found no significant effect of year of birth on weaning weight of range Rambouillet lambs.

Body weight, heart girth, wither and hip height of male lambs were greater ($p < .01$) than those of female lambs, and hip width was also larger in males ($P < .05$). Ram lambs averaged 1.17 kg heavier than ewe lambs (Table 13). Sex differences in these data were similar in direction and magnitude to those reported from other studies (Hazel and Terrill, 1945a,b and 1946a,b; Karam *et al*., 1949; Blackwell and Henderson, 1955; Karam, 1959; Brown *et al*., 1961; Sabin and Brown, 1962; Bennett *et al*., 1963; Webb, 1963; Gjedrem, 1967; McLaren *et al*., 1968; Eliya, 1969; Srinivasan, 1969; Eltawil *et al*., 1970; Vesely *et al*., 1970 and Sidwell and Miller, 1971b). In contrast, Trail and Sacker (1969) reported that no significant differences were

TABLE 12

ANALYSIS OF VARIANCE OF WEANING WEIGHT AND BODY MEASUREMENTS

Source of Variation	Degrees of Freedom	Mean Square						
		Body Weight	Body Length	Heart Girth	Wither Height	Hip Height	Shoulder Width	Hip Width
Year of birth	2	586.56**	287.40**	791.67**	348.40**	688.63**	48.80**	84.28**
Sex of lamb	1	84.01**	11.35	83.25**	167.42**	173.76**	1.77	3.07*
Type of birth	1	171.01**	45.51*	279.89**	258.57**	184.54**	17.88**	13.99**
Age of dam	6	7.06	2.52	6.63	8.04	4.45	0.49	0.85
Month of birth	4	35.54**	109.07**	90.15**	15.47*	8.84	3.91**	2.94**
Error	242	8.80	8.84	11.76	5.13	5.24	0.72	0.89
Total	257							

*P < .05

**P < .01

TABLE 13

LEAST-SQUARES MEANS (AND THEIR STANDARD ERRORS) OF THE EFFECTS OF THE ENVIRONMENTAL FACTORS ON WEIGHT AND SELECTED BODY MEASUREMENTS AT WEANING

Effect	Number of Lambs (Observations)	Body Weight (kg)	Body Length (cm)	Heart Girth (cm)	Wither Height (cm)	Hip Height (cm)	Shoulder Width (cm)	Hip Width (cm)
Overall mean	257	18.67±.39	50.58±.39	63.08±.45	51.72±.30	52.10±.30	13.07±.11	14.61±.12
Year of Birth		**	**	**	**	**	**	**
1. 1966	85	23.27±.41[a]	53.85±.40[a]	68.32±.46[a]	54.68±.31[a]	55.65±.31[a]	13.39±.12[a]	14.31±.13[a]
2. 1967	92	16.09±.53[b]	49.52±.53[b]	59.89±.62[b]	51.73±.41[b]	52.79±.41[b]	13.72±.15[a]	15.79±.17[b]
3. 1970	80	16.64±.61[b]	48.38±.61[c]	61.01±.71[c]	48.75±.47[c]	47.85±.47[c]	12.09±.18[b]	13.74±.20[c]
Sex of Lamb		**		**	**	**		*
1. Male	130	19.25±.42[a]	50.80±.42	63.66±.49[a]	52.54±.32[a]	52.93±.34[a]	13.15±.12	14.72±.13[a]
2. Female	127	18.09±.44[b]	50.37±.44	62.50±.51[b]	50.90±.34[b]	51.26±.34[b]	12.99±.13	14.50±.14[b]
Type of Birth		**	*	**	**	**	**	**
1. Single	223	19.94±.37[a]	51.24±.37[a]	64.71±.43[a]	53.29±.28[a]	53.42±.28[a]	13.48±.11[a]	14.98±.12[a]
2. Twin	34	17.40±.57[b]	49.92±.58[b]	61.44±.42[b]	50.15±.44[b]	50.77±.44[b]	12.66±.16[b]	14.25±.18[b]
Age of Dam								
1. 1.5 year	17	18.30±.83	50.14±.83	62.66±.66	51.65±.63	51.42±.64	13.03±.24	14.83±.26
2. 2.5 year	60	18.65±.55	50.42±.55	62.40±.63	50.91±.42	51.81±.42	13.04±.16	14.48±.17
3. 3.5 year	41	18.14±.61	50.25±.61	62.98±.71	51.69±.49	51.95±.47	12.95±.18	14.44±.20
4. 4.5 year	57	19.27±.54	50.79±.54	63.13±.62	51.67±.41	52.12±.41	13.15±.15	14.51±.17

TABLE 13 (continued)

Effect	Number of Lambs (Observations)	Body Weight (kg)	Body Length (cm)	Heart Girth (cm)	Wither Height (cm)	Hip Height (cm)	Shoulder Width (cm)	Hip Width (cm)
5. 5.5 year	41	$19.22 \pm .59$	$50.76 \pm .59$	$63.32 \pm .68$	$52.20 \pm .45$	$52.44 \pm .45$	$13.29 \pm .17$	$14.83 \pm .19$
6. 6.5 year	21	$18.43 \pm .72$	$50.97 \pm .72$	$63.21 \pm .83$	$51.76 \pm .55$	$52.09 \pm .55$	$13.01 \pm .21$	$14.64 \pm .23$
7. 7.5 year and above	20	$18.68 \pm .73$	$50.76 \pm .73$	$63.82 \pm .85$	$52.17 \pm .56$	$52.86 \pm .57$	$13.02 \pm .21$	$14.54 \pm .23$
<u>Month of Birth</u>		**	**	**	*		**	**
1. January	17	$20.09 \pm .83^{a}$	$50.64 \pm .83^{a}$	$63.77 \pm .96^{a}$	$53.07 \pm .63^{a}$	$53.09 \pm .64$	$13.29 \pm .24^{a}$	$14.83 \pm .26^{a}$
2. February	14	$16.81 \pm .96^{b}$	$48.44 \pm .97^{b}$	$61.93 \pm .99^{b}$	$51.01 \pm .74^{b}$	$51.62 \pm .74$	$12.56 \pm .28^{a}$	$13.96 \pm .31^{b}$
3. March	18	$17.11 \pm .83^{c}$	$47.87 \pm .83^{b}$	$59.65 \pm .96^{c}$	$50.84 \pm .63^{a}$	$51.27 \pm .64$	$12.50 \pm .28^{a}$	$14.27 \pm .26^{a}$
4. November	138	$19.71 \pm .42^{a}$	$52.62 \pm .42^{c}$	$64.90 \pm .48^{a}$	$51.54 \pm .32^{ab}$	$52.09 \pm .32$	$13.67 \pm .12^{b}$	$15.06 \pm .13^{ac}$
5. December	70	$19.62 \pm .45^{ab}$	$53.34 \pm .45^{c}$	$65.13 \pm .51^{a}$	$52.13 \pm .34^{ab}$	$52.42 \pm .34$	$13.33 \pm .13^{b}$	$14.94 \pm .14^{a}$

[a,b,c]Least-squares means followed by the same letter within column and subclass do not differ significantly. All others differ significantly ($P < .05$).

*$P < .05$. **$P < .01$.

observed between male and female lambs at weaning. However, they concluded that males at five months of age were approximately 2 percent heavier than females of the same age.

The type of birth effects on all weanling lamb traits studied were highly significant ($P < .01$) except on body length, on which the effect was only significant ($P < .05$) as shown in Table 12, page 54. Least-squares means indicated that single lambs weighed 19.9 kg while twins weighed 17.4 kg at weaning (Table 13, page 55). This agrees with work of Phillips and Dawson (1940), Hazel and Terrill (1945a,b and 1946a,b), Blackwell and Henderson (1955), Givens _et al_. (1960), Brown _et al_. (1961), Sabin and Brown (1962), Bennett _et al_. (1963), Webb (1963), Gjedrem (1967), McLaren _et al_. (1968), Eliya (1969), Srinivasan (1969), Trail and Sacker (1969), Vesely and Robison (1970), Eltawil _et al_. (1970) and Sidwell and Miller (1971b). Type of birth accounted for the second largest amount of variation in weaning weight. Eltawil's (1965) results were similar. It should be noted that the differences due to sex and type of birth were more important at birth than at weaning. In contrast, the effects of month of birth greater at weaning (Table 9, page 46). Total variation due to these environmental factors was higher at birth than at weaning age.

The influence of month of birth on body weight, body length, heart girth and on shoulder and hip width was highly significant ($P < .01$). Its effect was significant ($P < .05$) on wither height also (Table 12, page 54). Lambs born in January were 0.36, 0.45, 3.27 and 2.96 kg heavier than lambs born during November, December, February and March, respectively, and 1.40 kg greater than the overall mean (Table 13, page 55). Phillips and Dawson (1940) Smith and Lidvall (1964), Juma and Faraj (1966), McLaren et al. (1968), Eliya (1969), Srinivasan (1969) and Malik and Acharya (1972) reported similar results with respect to the effect of month of birth on weight, size and shape of lambs at weaning.

Although age of dam did not significantly affect any of the traits studied (Table 12, page 54), there was a general tendency for weaning weight and various body measurements of lambs to increase with increases in age of dam up to 5.5 years and then decline through an age of dam of 7.5 years (Table 13). Sidwell and Miller (1971b) reported that weaning weight was not affected by variation in age of dam. However, many other workers observed significant effects of age of dam on weaning weight of lambs (Hazel and Terrill, 1945a and 1946b; Sidwell and Grandstaff, 1949; Asker et al., 1952; Webb, 1963; Sidwell et al., 1964; Frederiksen et al., 1967; McLaren et al., 1968; Eliya, 1969 and Vesely and Robison, 1970).

Body Weight and Measurements at Yearling

Differences in yearling weight and body measurements attributable to year of birth were highly significantly ($P < .01$) as shown in Table 14. The influence of year of birth in yearling lambs tended to be very low, both in direction and magnitude, to those observed at birth and weaning ages (Table 9, page 46). Yearling ewes weighed in 1967 were 3.50 kg heavier than similar aged ewes in 1970. The overall average yearling weight was 38.47 kg (Table 15). Similar results with respect to year of birth influence were reported by

TABLE 14

ANALYSIS OF VARIANCE OF YEARLING WEIGHT AND BODY MEASUREMENTS

Source of Variation	Degrees of Freedom	Mean Square						
		Body Weight	Body Length	Heart Girth	Wither Height	Hip Height	Shoulder Width	Hip Width
Year of birth	2	199.64**	260.95**	194.88**	315.76**	411.53**	229.50**	164.74**
Sex of lamb	1	2,111.34**	136.94**	111.60**	695.70**	556.12**	81.94**	111.63**
Type of birth	1	144.68*	14.63	326.94**	143.86**	137.78**	8.36	6.04
Age of dam	6	24.91	10.87	19.26	18.63	13.82	1.43	1.44
Month of birth	4	111.38**	69.35**	272.85**	41.77**	52.96*	3.78	3.57
Error	136	28.20	14.09	41.36	10.54	15.83	3.19	3.60
Total	151							

*P < .05

**P < .01

TABLE 15

LEAST-SQUARES MEANS (AND THEIR STANDARD ERRORS) OF THE EFFECTS OF THE ENVIRONMENTAL FACTORS ON WEIGHT AND SELECTED BODY MEASUREMENTS AT YEARLING

Effect	Number of Lambs (Observations)	Body Weight (kg)	Body Length (cm)	Heart Girth (cm)	Wither Height (cm)	Hip Height (cm)	Shoulder Width (cm)	Hip Width (cm)
Overall mean	151	37.60±0.97	64.34±0.68	87.20±1.17	61.81±0.59	62.66±0.73	19.15±0.33	22.51±0.35
Year of Birth		**	**	**	**	**	**	**
1. 1966	61	38.47 ± 0.99^{a}	66.63 ± 0.70^{a}	89.83 ± 1.20^{a}	63.80 ± 0.61^{a}	65.12 ± 0.75^{a}	19.09 ± 0.33^{a}	21.84 ± 0.36^{a}
2. 1967	49	39.37 ± 1.28^{b}	65.28 ± 0.90^{b}	87.20 ± 1.55^{b}	63.33 ± 0.78^{a}	64.32 ± 0.96^{b}	21.60 ± 0.43^{b}	24.83 ± 0.46^{b}
3. 1970	41	34.97 ± 1.41^{c}	61.12 ± 0.99^{c}	84.57 ± 1.71^{c}	58.29 ± 0.86^{b}	58.62 ± 1.06^{c}	16.75 ± 0.48^{c}	20.86 ± 0.51^{c}
Sex of Lamb		**	**	**	**	**	**	**
1. Male	78	41.49 ± 1.07^{a}	65.33 ± 0.76^{a}	88.09 ± 1.30^{a}	64.04 ± 0.66^{a}	64.65 ± 0.80^{a}	19.91 ± 0.36^{a}	23.40 ± 0.38^{a}
2. Female	73	33.71 ± 1.06^{b}	63.35 ± 0.75^{b}	86.31 ± 1.29^{b}	59.58 ± 0.55^{b}	60.66 ± 0.80^{b}	18.38 ± 0.36^{b}	21.62 ± 0.38^{b}
Type of Birth		*		**	**	**		
1. Single	131	39.12 ± 0.89^{a}	63.86±0.63	89.49 ± 1.07^{a}	63.32 ± 0.54^{a}	64.14 ± 0.66^{a}	19.51±0.30	22.82±0.32
2. Twin	20	36.08 ± 1.41^{b}	64.83±1.00	84.91 ± 1.71^{b}	60.29 ± 0.83^{b}	61.17 ± 1.06^{b}	18.78±0.48	22.19±0.50
Age of Dam								
1. 1.5 year	12	37.31±1.96	65.36±1.38	86.15±2.37	62.66±1.20	64.27±1.47	18.41±0.66	22.47±0.70
2. 2.5 year	34	36.20±1.40	64.59±0.99	86.36±1.70	60.60±0.86	62.05±1.05	19.19±0.47	22.19±0.50
3. 3.5 year	21	38.51±1.56	64.21±1.10	86.96±1.88	62.44±0.95	63.18±1.17	19.11±0.52	22.25±0.56
4. 4.5 year	31	39.13±1.37	64.78±0.98	88.88±1.66	62.18±0.84	61.73±1.03	19.22±0.46	22.82±0.49

TABLE 15 (continued)

Effect	Number of Lambs (Observations)	Body Weight (kg)	Body Length (cm)	Heart Girth (cm)	Wither Height (cm)	Hip Height (cm)	Shoulder Width (cm)	Hip Width (cm)
5. 5.5 year	25	37.37±1.42	64.96±1.00	87.34±1.72	61.80±0.59	63.45±1.07	19.57±0.48	22.74±0.51
6. 6.5 year	16	37.37±1.53	64.07±1.08	87.93±1.86	61.74±0.94	62.40±1.15	19.37±0.52	22.58±0.55
7. 7.5 year and above	12	37.31±1.75	62.44±1.24	86.78±2.12	60.29±0.99	61.51±1.31	19.15±0.59	22.52±0.63
<u>Month of Birth</u>		**	**	**	**	*		
1. January	14	36.21±1.66[a]	63.77±1.18[a]	81.29±2.17[a]	61.65±1.01[a]	63.00±1.25[a]	18.92±0.57	22.63±0.59
2. February	11	32.11±2.20[b]	59.11±1.55[b]	81.39±2.67[a]	58.46±1.35[b]	58.13±1.65[b]	20.07±0.74	23.25±0.79
3. March	4	38.78±2.87[c]	66.70±2.03[c]	93.40±3.47[b]	61.48±1.75[a]	63.18±2.15[a]	18.64±0.95	22.76±1.03
4. November	74	40.85±0.91[c]	66.44±0.64[c]	90.18±1.10[c]	63.84±0.55[ac]	64.99±0.70[a]	19.29±0.31	22.01±0.32
5. December	48	40.04±0.99[c]	65.70±0.70[ac]	89.72±1.20[c]	63.59±0.59[ac]	63.97±0.74[a]	18.79±0.33	21.89±0.35

[a,b,c]Least-squares means followed by the same letter within column and subclass do not differ significantly. All others differ significantly ($P < .05$).

*$P < .05$. **$P < .01$.

Terrill *et al*. (1948a and 1948b), Karam (1959), Price *et al*. (1962), Eltawil *et al*. (1970), Sidwell *et al*. (1970), Vesely and Robison (1970) and Vesely *et al*. (1970).

The effect of sex on body weight and all body dimensions were highly significant ($P < .01$) at yearling age (Table 14, page 59). Male lambs exceeded female lambs by 7.78 kg in body weight and by 1.98, 1.78, 4.46, 3.98, 1.54 and 1.98 cm. for body length, heart girth, wither height, hip height, shoulder width and hop width, respectively (Table 15, page 60). Yearling males weighed 41.49 kg and yearling females weighed only 33.71 kg. These results are in general agreement with those of Donald and McLean (1935), Phillips *et al*. (1940), Hazel and Terrill (1946c), Karam (1959), Trail and Sacker (1969) and Vesely *et al*. (1970).

After variation due to sex and year of birth were removed, the other environmental factors (type of birth, age of dam and month of birth) exerted less pronounced effects on yearling body weight and body measurements than on weight and body dimensions at earlier ages (Table 9, page 46, and Appendix Table 33).

Type of birth had a significant effect on heart girth, wither and hip height and body weight of yearling lambs. Single yearling lambs were 3.04 kg heavier than twins. These differences were in the same direction as at birth and weaning but considerably smaller (Table 15). Similar results, *i.e.*, decrease in magnitude of the effect of type of birth as age of lamb increases, have been reported by other wrokers (Phillips and Dawson, 1940; Hazel and Terrill, 1946c; Terrill *et al*., 1948a,b; Sidwell and Grandstaff, 1949; Rae, 1950;

Cassard *et al*., 1956; Karam, 1959; Price *et al*., 1962; Trail and Sacker, 1969; Eltawil *et al*., 1970; Sidwell *et al*., 1970 and Vesely *et al*., 1970).

Month of birth had a highly significant ($P < .01$) effect on weight, length, heart girth and wither height of lambs at yearling age and a significant ($P < .05$) effect on hip height also (Table 15, page 60). Lambs born during November were heavier at yearling age, while those born in February were the lightest (Table 15). Since lambs born early in the season had access to spring pasture at pre- and post-weaning while lambs born later in the season were too young to utilize pasture forage available at that time, this result was expected. Trail and Sacker (1969) reported similar findings with respect to the growth advantage of lambs born early in the lambing season.

Age of dam had no significant effects on any of the yearling traits evaluated in this study (Table 14, page 59, and Table 15). Terrill *et al*. (1948a) stated that age of dam had a significant effect on yearling weight in Columbia ewes but not in Targhee ewes. Results obtained from the present study are in agreement with those of Karam (1959), Vesely *et al*. (1970) and Vessely and Robison (1970). However, other workers have observed that age of dam was an important source of variation in yearling weight of lambs (Hazel and Terrill, 1946c; Rae, 1950; Price *et al*., 1962; Sidwell *et al*., 1970 and Eltawil *et al*., 1970).

Rate of Gain

Differences in year of birth, sex of lamb and month of birth were responsible for significant variation in pre-weaning, post-weaning and lifetime (to yearling) average daily gains of lambs included in this study (Table 16). Pre-weaning gain of lambs born during 1967 was much lower ($P < .05$) than that observed in other years. Lambs born in 1966 gained 7.93 and 2.53 kg more during the pre-weaning periods than did lambs born in 1966 and 1970, respectively. These differences were probably due to management and weather differences as well as genetic differences. In contrast, post-weaning gain of lambs born in 1967 was the highest (22.27 kg), whereas, the lowest post-weaning gain (16.28 kg) was made by lambs born in 1966. These results indicate that lambs born in 1967 were reared under more adverse environmental conditions, such as worse weather, shortage of forage and restricted milk production, than were other lambs. Similar results were observed with respect to total gain and average daily gain from birth to yearling age (Table 17).

Generally, lambs born early in the season gained more rapidly to the pre-weaning age than did lambs born later. This was probably due to higher temperatures later in the lambing season and, possibly, to greater infestation of internal parasites. These results are in agreement with the findings of Karam _et al_. (1949), Givens _et al_. (1960), Webb (1963), McLaren _et al_. (1968), Srinivasan (1969), Fahmy _et al_. (1969), Vesely _et al_. (1970), Vesely and Robison (1970), Thrift _et al_. (1971), Sidwell and Miller (1971c) and Ercanbrack and Price (1972).

In contrast to its effect on body weight and various body measurements, type of birth appeared to have no significant influence

TABLE 16

ANALYSIS OF VARIANCE OF GAIN OF AWASSI LAMBS

Source of Variation	Degrees of Freedom	Mean Square			
		Pre-weaning Gain	Post-weaning Gain	Total Gain	Average Daily Gain
Year of birth	2	407.68**	613.84**	123.64*	0.0009*
Sex of lamb	1	60.26**	1,128.19**	1,698.09**	0.0128**
Type of birth	1	19.68	18.79	77.41	0.0006
Age of dam	6	5.28	17.22	23.41	0.0002
Month of birth	4	14.20*	136.42**	63.86	0.0008**
Error	121	5.22	20.79	28.35	0.0002
Total	136				

*P < .05

**P < .01

TABLE 17

LEAST-SQUARES MEANS (AND THEIR STANDARD ERRORS) OF GAINS

Effect	Number of Lambs (Observations)	Pre-weaning Gain (kg)	Post-weaning Gain (kg)	Total Gain (kg)	Average Daily Gain (kg)
Overall mean	136	15.49±0.47	17.33±0.94	33.32±1.09	0.090±.003
<u>Year of Birth</u>		**	**	*	*
1. 1966	45	19.93 ± 0.50^a	13.44 ± 0.99^a	33.76 ± 1.16^a	$0.091 \pm .003^a$
2. 1967	50	12.00 ± 0.59^b	22.27 ± 1.18^b	34.88 ± 1.38^a	$0.094 \pm .004^a$
3. 1970	41	14.53 ± 0.65^c	16.28 ± 1.30^c	31.32 ± 1.52^b	$0.084 \pm .004^b$
<u>Sex of Lamb</u>		**	**	**	**
1. Male	71	16.18 ± 0.51^a	20.33 ± 1.01^a	37.00 ± 1.18^a	$0.100 \pm .003^a$
2. Female	65	14.80 ± 0.52^b	14.33 ± 1.03^b	29.64 ± 1.20^b	$0.080 \pm .003^b$
<u>Type of Birth</u>					
1. Single	117	16.07±0.43	17.90±0.87	34.47±1.01	0.093±.003
2. Twin	19	14.91±0.66	16.76±1.31	32.16±1.53	0.087±.004
<u>Age of Dam</u>					
1. 1.5 year	6	15.39±1.07	18.73±2.14	33.66±2.50	0.094±.007
2. 2.5 year	32	15.16±0.66	16.22±1.25	32.15±1.47	0.086±.004

TABLE 17 (continued)

Effect	Number of Lambs (Observations)	Pre-weaning Gain (kg)	Post-weaning Gain (kg)	Total Gain (kg)	Average Daily Gain (kg)
3. 3.5 year	22	15.49±0.70	18.51±1.40	34.61±1.63	0.093±.004
4. 4.5 year	27	16.28±0.64	17.74±1.27	34.69±1.49	0.093±.004
5. 5.5 year	24	16.06±0.67	16.25±1.34	32.94±1.57	0.089±.004
6. 6.5 year	14	15.28±0.73	16.86±1.45	32.77±1.70	0.088±.005
7. 7.5 year	11	14.76±0.81	17.02±1.61	32.41±1.88	0.087±.005
<u>Month of Birth</u>		*	**		**
1. January	10	17.53±0.84[a]	14.57±1.63[a]	31.95±1.97	0.088±.005[a]
2. February	4	15.38±1.31[b]	9.68±2.62[b]	28.00±3.06	0.069±.008[b]
3. March	4	13.60±1.25[c]	21.67±2.50[c]	35.22±2.92	0.097±.008[c]
4. November	74	15.71±0.42[b]	20.92±0.83[c]	36.43±0.97	0.100±.003[c]
5. December	44	15.23±0.44[b]	19.82±0.87[c]	34.99±1.02	0.096±.003[c]

[a,b,c]Least-squares means followed by the same letter within column and subclass do not differ significantly. All others differ significantly ($P < .05$).

*$P < .05$. *$P < .01$.

on any of the traits measuring rate of gain. Age of dam also had no significant effect on gain traits (Tables 16 and 17, pages 65 and 66). Therefore, these variables were not included in the model used in estimating genetic parameters. Similar results were reported by Vesely and Robison (1970) and Sidwell and Miller (1970) with respect to age of dam. The effects of age of dam becomes less pronounced as lambs approach yearling age. This was expected since, as the lambs increased in age, they obtained more of their feed independent of their mothers. This trend was observed also by Eltawil (1965) and Terrill _et al_. (1947). Sex differences, as shown in Table 18, accounted for a major portion of the variation in all traits reflecting post-weaning gain. Year of birth was the most important factor contributing to variation in pre-weaning gain; however, type of birth, month of birth and age of dam also significantly influenced this variation.

II. ESTIMATES OF HERITABILITY

Estimates of heritability were calculated by quadrupling paternal half-sibs correlations based on the between-sire and within-sire components of variance. These components were obtained from the analysis of variance of various traits, after adjustments by adding to each value least-squares constants for independent variables with significant effects.

In these data the number of comparisons between sets of twins was less than 1 percent of the total number of comparisons among offspring of the same sire. Some of these would be monozygotic

TABLE 18

ADDITIONAL SUM OF SQUARES EXPLAINED BY SEQUENTIALLY ADDING ENVIRONMENTAL FACTORS IN ANALYSES OF BODY GAINS*

Source of Variation	ΔR^2			
	Pre-weaning Gain	Post-weaning Gain	Total Gain	Average Daily Gain
Year of birth	10.59	2.00	0.20	0.11
Sex of lamb	0.14	25.22	33.87	34.21
Type of birth	6.27	0.62	0.39	0.37
Month of birth	6.65	11.17	4.06	4.98
Age of dam	0.50	0.07	0.01	0.01
Variation account for all sources in the model**	24.15	39.06	38.53	39.68

*The number of records included was 136 at each age with progeny of 13 sires represented.

** $Y_{ijklmn} = \mu + y_i + x_j + t_k + a_l + b_m + e_{ijklmn}$

Description of the above model is on page 38.

"litter" mates, but most would be dizygotic. However, in view of the small magnitude of this frequency of twins among the "half-sibs" compared, adjustment of the intraclass correlations for the presence of twins was not considered necessary. Hazel and Terrill (1945b) and Eltawil (1965) arrived at the same conclusion. They reported that heritability estimates were not corrected for full sibs in the analysis of half-sib correlations since only about 1.3 percent of their comparisons were between sets of twins within sire groups.

The estimates of heritability (along with their standard errors) of birth weight and various body measurements are shown in Table 19. The form of analysis of variance from which paternal half-sib correlations were calculated is shown in Appendix Table 34, which gives the calculations for body length. The estimate of heritability of birth weight (0.19) is in close agreement with most of those previously reported (Ali, 1952; Yao et al., 1953; Eltawil, 1965 and Fahmy et al., 1969). However, Chapman and Lust (1932) and Vesely et al., (1970) reported a value of 0.30 and 0.45 was obtained by Osman and Bradford (1965). On the other hand, it exceeded the estimates obtained by Nelson and Venkatachalam (1949), Karam (1959), Butcher et al. (1964), Gjedrem (1967), Srinivasan (1969) and Thrift et al. (1973) using the same method of estimation. Some differences in estimates obtained by various workers may be due to differences in adjustments which were made or not made, but it is always possible and, in some cases likely, that different investigators were estimating truly different parameters. Balch (1962) stated that body length and heart girth at birth were highly heritable traits (h^2 = 0.42 and 0.46, respectively). No other

TABLE 19

ESTIMATES OF HERITABILITY (AND THEIR STANDARD ERRORS) OF BODY WEIGHT AND BODY MEASUREMENTS AT VARIOUS AGES

Trait	Birth		Weaning		Yearling	
	h^2	S.E.	h^2	S.E.	h^2	S.E.
Number of lambs[1]	240		257		151	
Body weight	0.19	±.03	0.06	±.03	0.20	±.06
Body length	0.16	±.02	0.04	±.06	0.60	±.12
Heart girth	0.13	±.03	0.19	±.05	-.05	±.02
Wither height	0.31	±.04	-.06	±.13	0.59	±.07
Hip height	0.12	±.01	-.08	±.11	0.82	±.14
Shoulder width	0.15	±.04	0.34	±.03	0.60	±.08
Hip width	0.11	±.03	0.16	±.02	0.35	±.04

[1]These lambs were offspring of 13 sires.

heritability estimates of any body dimension of sheep have been reported. The estimates of heritabilities of the six body measurements were of about the same magnitude as those obtained by brown (1958) with data from Angus and Hereford calves. However, the present estimates in general, tended to be smaller than those reported by other workers (Table 5, page 23). It can be concluded that this discrepancy may have arisen because of differences in the variability of these weights and measurements in different breeds, types of animals, locations, method of estimation, number of observations used, and so forth. In addition, some unknown factors for which correction could not be made may have played an important part in making estimates differ. Despite the fact that heritability of birth weight obtained in the present study can be considered as a reliable estimate, it is only of academic interest because selection is not practiced at birth. Increased lambing problems, due to increased size of lambs at birth, would result if this trait were favored by selection.

Estimates of heritability of body weight and various body measurements at weaning are shown in Table 19. These estimates are of special interest because selection of replacement lambs is generally made when they are this age. The estimate of 0.06 for weaning weight was smaller than those reported by many workers (Table 2, page 20). This estimate was in very close agreement to values of 0.08 in Targhee by Hazel and Terrill (1946b) and 0.07 in Hampshire reported by Givens _et al._, (1960). However, it was larger than those of Butcher _et al._ (1964) and Vesely _et al._ (1970) shown in Table 2. No other estimates of heritability of body measurements of sheep have been reported. However, estimates for these traits in beef and dairy cattle have been reported by many workers (Table 5, page 23). The negative estimates obtained for wither and hip heights, in this study, appear to be due to sampling error and possibly to some environmental factors which were not eliminated in the analyses. Butcher et al., (1964) reported some negative estimates of heritabilities of birth and weaning weight in four breeds of sheep. Fitzhugh et al. (1967) also found some negative estimates for body weight in five breeds of cattle. They suggested that since variation due to individual cow differences was not included in the original model, some of the inherent variability between cows may have been removed when corrections were made for the fitted environmental effects. Brown (1958) gave similar reasons for the negative estimates for body measurements in beef cattle. Vesely et al. (1970) gave another reason for the negative estimate of heritability of weaning weight obtained in Canadian Romnelet. They suggested that selection for weaning weight had been practiced for several generations and may have caused the estimate to be small.

Although the estimate of heritability of weaning weight found in the present study is small, it is probably an estimate of a value greater than zero. Thus, if 40 percent of the Awassi ewe lambs were to be selected for breeding purposes, on weaning weight alone, S.D. would equal $\frac{z}{.40} \times 4.27$. The value for $i = \frac{z}{b}$, would be $0.97 \times 4.27 = 4.14$ kg for females. If 10 percent of the males were saved S.D. = $1.75 \times 4.27 = 7.47$ kg. The average for both sexes would be S.D. = $\frac{4.14 + 7.47}{2} = 5.81$ kg. Then expected genetic gain from one generation of selection would be 5.81 x h^2 = 0.35 kg, using the 0.06 estimate of h^2 obtained in the present study. This means that one would expect to increase the mean weaning weight in the offspring of selected parents by 0.35 kg above the mean of the population from which the parents were selected, assuming no change in average environment from one generation to the next. This is an example of the genetic progress with respect to weaning weight when only weaning weight is considered in selection. In practice, however, the total value of an animal depends on several traits, and simultaneous consideration of several traits reduces the selection intensity for each individual trait, which would decrease progress in each trait.

The estimates of heritability of yearling weight and various body measurements also are presented in Table 19, page 71. Heritability of yearling weight (h^2 = .20) agrees closely with estimates reported by Karam (1959) in the Rahmani breed (0.19) and Vesely _et al_. (1970) in Canadian Rambouillet (0.26). It is larger than those obtained by Morley (1955) in Merino (0.09) and Vesely _et al_. (1970) in Romnelet (0.03). However, it is much smaller than the estimates of 1.06 and 0.82 reported by Osman and Bradford (1965) and Bassett (1967) shown in Table 3, page 21. If selection were based on yearling weight alone, the expected genetic progress per generation in the Awassi lambs would be approximately 2.00 kg., 5.7 times as much increase as calculated earlier when selection was on weaning weight alone. Obviously, this is due to the higher estimate of heritability (0.20 vs. 0.06) a ratio of 5.7 in favor of yearling weight and to the larger standard deviation of this trait. All estimates of heritability of body measurements were large, except for that of heart girth, which was a very low negative value. This negative value was probably due to sampling error and should be considered as an estimate of zero. Values for the other body dimensions agreed closely with those reported by many workers (Table 5, page 23).

Estimates of heritability of traits reflecting rate of gain, shown in Table 20, were of small to medium magnitude. Generally, these estimates were slightly smaller than the mean of those reported by other workers (Table 4, page 22). The estimates of heritability of pre-weaning gain (0.09) was lower than that of post-weaning gain (0.13). This has been observed by many investigators (Hundley and Carter, 1956; Givens _et al._, 1960; Carter and McClure, 1962; Harrington _et al._, 1962; Butcher _et al._, 1964; Vogt _et al._, 1967; Thrift _et al._, 1971 and Thrift _et al._, 1973). Since estimates of heritability of weight, gain and various body measurements at weaning were lower than estimates for those traits at the post-weaning age, selection for post-weaning traits would be expected to yield a greater response than selection for pre-weaning traits.

III. GENETIC AND PHENOTYPIC CORRELATIONS

Genetic correlations among body weight and various body measurements at different ages and among gain traits are shown in Tables 21 through 24. The correlations were computed as paternal half-sib correlations discussed earlier. Most of the estimates of genetic correlation were positive and large, and some of them were greater than unity. These extreme values could have resulted from sampling

TABLE 20

ESTIMATES OF HERITABILITY (AND THEIR STANDARD ERRORS)
OF GROWTH RATE TRAITS

Trait	h^2	S.E.
Number of lambs[1]	136	
Pre-weaning gain	0.09	±.04
Post-weaning gain	0.13	±.05
Total gain	0.14	±.05
Average daily gain	0.20	±.06

[1]These lambs were offspring of 13 sires.

TABLE 21

GENETIC AND PHENOTYPIC CORRELATIONS[1] (AND THEIR STANDARD ERRORS) AMONG WEIGHT AND VARIOUS BODY MEASUREMENTS AT BIRTH

Trait	Estimate	Body Weight	Body Length	Heart Girth	Wither Height	Hip Height	Shoulder Width	Hip Width
Body weight	r		0.96	1.03	0.90	1.02	1.03	0.79
	S.E.		±0.29	±0.32	±0.31	±0.46	±0.25	±0.54
Body length	r	0.51		1.10	0.98	1.01	1.91	0.94
	S.E.	±0.14		±0.21	±0.31	±0.61	±1.93	±0.67
Heart girth	r	0.54	0.69		1.02	1.04	0.93	0.88
	S.E.	±0.07	±0.08		±0.36	±0.54	±1.00	±0.68
Wither height	r	0.36	0.35	0.37		1.04	0.90	0.81
	S.E.	±0.08	±0.11	±0.05		±0.12	±0.81	±0.43
Hip height	r	0.34	0.33	0.36	0.94		1.00	0.84
	S.E.	±0.09	±0.12	±0.06	±0.08		±0.98	±0.56
Shoulder width	r	0.28	0.24	0.24	0.39	0.38		0.87
	S.E.	±0.08	±0.12	±0.09	±0.05	±0.07		±0.43
Hip width	r	0.31	0.35	0.29	0.44	0.42	0.76	
	S.E.	±0.04	±0.08	±0.06	±0.10	±0.09	±0.07	

[1]Genetic correlations are above diagonal and phenotypic correlations are below.

TABLE 22

GENETIC AND PHENOTYPIC CORRELATIONS[1] (AND THEIR STANDARD ERRORS) AMONG WEIGHT AND VARIOUS BODY MEASUREMENTS AT WEANING

Trait	Estimate	Body Weight	Body Length	Heart Girth	Wither Height	Hip Height	Shoulder Width	Hip Width
Body weight	r		-0.98	1.00	–[2]	–	0.97	0.68
	S.E.		±0.58	±0.63	–	–	±0.64	±0.72
Body length	r	0.45		0.81	–	–	0.01	-0.43
	S.E.	±0.06		±0.11	–	–	±0.02	±0.56
Heart girth	r	0.58	0.46		–	–	0.92	0.57
	S.E.	±0.05	±0.07		–	–	±0.23	±0.49
Wither height	r	0.50	0.43	0.58		-0.78	–	–
	S.E.	±0.09	±0.08	±0.08		±0.43	–	–
Hip height	r	0.57	0.48	0.62	0.87		–	–
	S.E.	±0.06	±0.08	±0.10	±0.09		–	–
Shoulder width	r	0.51	0.31	0.53	0.39	0.45		1.02
	S.E.	±0.05	±0.08	±0.04	±0.06	±0.09		±0.12
Hip width	r	0.45	0.19	0.43	0.37	0.40	0.76	
	S.E.	±0.04	±0.07	±0.03	±0.04	±0.08	±0.21	

[1]Genetic correlations are above diagonal and phenotypic correlations are below.

[2]Estimate of sire component of variance was negative.

TABLE 23

GENETIC AND PHENOTYPIC CORRELATIONS[1] (AND THEIR STANDARD ERRORS) AMONG WEIGHT AND VARIOUS BODY MEASUREMENTS AT YEARLING

Trait	Estimate	Body Weight	Body Length	Heart Girth	Wither Height	Hip Height	Shoulder Width	Hip Width
Body weight	r		0.76	–[2]	0.67	0.64	1.10	1.06
	S.E.		±0.34	–	±0.36	±0.38	±0.36	±0.44
Body length	r	0.51		–	0.97	0.91	0.98	1.02
	S.E.	±0.06		–	±0.10	±0.10	±0.19	±0.29
Heart girth	r	0.58	0.56		–	–	–	–
	S.E.	-0.05	-0.08		–	–	–	–
Wither height	r	0.46	0.56	0.42		0.89	0.70	0.56
	S.E.	±0.07	±0.06	±0.03		±0.12	±0.27	±0.38
Hip height	r	0.46	0.52	0.41	0.71		0.90	0.68
	S.E.	±0.03	±0.07	±0.08	±0.08		±0.16	±0.32
Shoulder width	r	0.41	0.18	0.27	0.38	0.44		0.96
	S.E.	±0.03	±0.08	±0.05	±0.06	±0.09		±0.06
Hip width	r	0.39	0.13	0.21	0.32	0.33	0.89	
	S.E.	±0.03	±0.07	±0.01	±0.03	±0.04	±0.02	

[1]Genetic correlations are above diagonal and phenotypic correlations are below.

[2]Estimate of sire component of variance was negative.

TABLE 24

GENETIC AND PHENOTYPIC CORRELATIONS[1] (AND THEIR STANDARD ERRORS) AMONG SOME TRAITS

Trait	Estimate	Pre-weaning Gain	Post-weaning Gain	Total Gain	Average Daily Gain
Pre-weaning gain	r		0.94	1.01	1.02
	S.E.		±1.21	±0.82	±0.80
Post-weaning gain	r	0.17		0.98	0.99
	S.E.	±0.05		±0.14	±0.14
Total gain	r	0.52	0.92		1.00
	S.E.	±0.03	±0.02		±0.05
Average daily gain	r	0.51	0.93	0.99	
	S.E.	±0.05	±0.08	±0.05	

[1]Genetic correlations are above diagonal and phenotypic correlations are below.

errors or from the inclusion of some non-genetic covariance in the numerator of the estimate. However, the genetic correlations among these traits are expected to be very high and their real value may be nearly 1.0. Some of these extremely high genetic correlations (those which approach unity) may be due to the fact that the same genes control both growth and body size. Such explanations for this phenonema in different farm animals (Table 6, page 28) have been suggested by many research workers.

Genetic correlations of body length with body weight, shoulder width and hip width at weaning were negative (Table 22, page 78). No estimates were found in the literature for the genetic correlations between weight and any body dimension in sheep. However, Morley (1950) reported genetic correlation (-1.11) between yearling weight and staple length in Merino. Sidwell (1954) found that genetic correlations between body type and condition and between staple length and condition were larger than unity and negative (-2.17 and -2.29, respectively). Vogt et al. (1967) stated that the genetic correlation between birth weight and average daily gain from birth to weaning was -2.65 ± 9.19 and that between birth weight and weaning weight was -3.20 ± 12.09. Vesely et al. (1970), Ercanbrack and Price (1972), Brown et al. (1972) and Francoise et al. (1973) also reported negative genetic correlations in sheep and cattle traits (Table 6, page 28). Many of these values were less than -1.0.

Genetic correlations of wither and hip heights with all other traits at weaning and those between heart girth and other traits at the yearling age could not be calculated due to negative estimates of the sire component of variance of these traits. Such results were reported also by Vesely et al. (1970).

These findings with respect to genetic correlation make it appear that single-trait selection for increased post-weaning gain would result in maximum progress in this flock due to the moderate heritability of this trait and its large positive correlations with all other traits. The expected genetic progress from one generation of selection favoring this trait would be 1.35 kg (based on the previous assumption where 40 and 10 percent of the female and male lambs, respectively, were retained as herd replacements). Similar evidence supporting this procedure was reported by Vesely et al. (1970) and Thrift et al. (1973).

All phenotypic correlations among various traits were positive (Tables 21 through 24, pages 77 through 80), ranging from a low of 0.13 between body length and hip width at yearling age (Table 23, page 79) to a high of 0.99 between total gain and average daily gain (Table 24, page 80).

A phenotypic correlation between two traits does not necessarily mean that they have a common genetic basis. Selection for one trait does not always result in an increase in other traits or characters with which it is positively correlated phenotypically. In fact, the opposite may occur when the genetic correlation is negative, which it can be, even though the phenotypic correlation is positive. Morley (1950) showed that such a situation may occur in sheep. He found that the phenotypic correlation between grease fleece weight and staple length in Merinos was 0.22 while the corresponding genetic correlation was -0.39. If the latter figures is close to the true genetic correlation between the traits, selecting for increased fleece weight would lead to some reduction in staple length.

The relationship of the phenotypic, genetic and environmental correlations between two traits is illustrated in the path coefficient diagram in Figure 3. The formulas used for these calculations imply the assumption that no genotype-environment interaction existed (Eltawil, 1965). These relationships can be expressed also using the following formula:

$$r_p = r_g h_1 h_2 + r_e e_1 e_2$$

where: r_p, r_g and r_e are phenotypic, genetic and environmental correlations, respectively, between trait 1 and 2, and h_1^2, and h_2^2 are their heritabilities, respectively.

$$e_1 = 1 - h_1, \; e_2 = 1 - h_2$$

If r_e is large and positive, and heritabilities are small, r_p can be positive and r_g negative. Other situations may result in positive phenotypic correlations which are less than their corresponding, though positive, genetic correlation.

Environmental correlations (Appendix Table 35) are due to non-identifiable factors since adjustments are made for those which are unknown. Therefore, the remaining environmental factors are likely to be more temporary in nature, and the results of these transient effects may be either positive or negative. However, genetic effects are more permenent in nature since animals have the same sets of

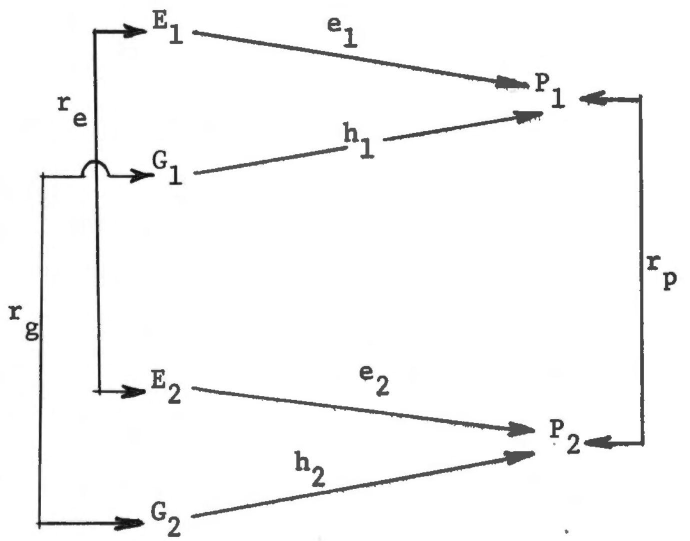

Figure 3. The relationship of phenotypic, genetic and environmental correlation between traits.

(Eltawil, 1965)

genes throughout their life and these effects change only when physiological processes change in the course of development. This reasoning leads to the hypothesis that genetic correlations could be larger than environmental correlations, but gives no real hint as to what sign it may be. This is a plausable explanation for the findings of impossibly large genetic correlation between various pairs of traits.

Correlations between different traits in some individuals may contain a large environmental component as well as a genetic component and, therefore, may not provide an accurate estimate of the actual genetic relationships involved. Hazel (1943) suggested that more accurate estimates of genetic relationships could be obtained from the correlation of a trait in one individual with another trait in a close relative.

Of all the parameter estimates calculated in this study, the estimates of genetic correlations were the least satisfactory. This is evident from the fact that about 30 percent of these estimates were larger than 1.0. In addition however, the standard errors are without doubt very large relative to the estimates.

IV. PRINCIPAL COMPONENTS

The first three principal components obtained from body weight and measurements of lambs in this study at birth, weaning and yearling ages are shown in Tables 25 through 27. These three components accounted for 87, 89 and 94 percent of the total variation in the correlation structure of all body size measures at the three ages,

TABLE 25

COEFFICIENTS AND INTERPRETATIONS OF PRINCIPAL COMPONENTS OBTAINED FROM BODY MEASURES OF AWASSI LAMBS AT BIRTH

Birth Measurement	Component Number			Principal Component	Description of Lambs Having Large Positive Component Values
	1	2	3		
Weight	0.36	-0.20	-0.85	1	Large framed and heavy
Body Length	0.21	-0.72	0.42	2	Wide at shoulder and hips
Heart Girth	0.34	-0.48	-0.03		but short and shallow bodied
Wither Height	0.43	0.18	0.23	3	Long, tall at withers and
Hip Height	0.43	0.20	0.18		light weight
Shoulder Width	0.41	0.26	0.05		
Hip Width	0.42	0.28	0.09		
% Total Variance	62.0	18.0	7.0		

TABLE 26

COEFFICIENTS AND INTERPRETATIONS OF PRINCIPAL COMPONENTS OBTAINED FROM BODY MEASURES OF AWASSI LAMBS AT WEANING

Weaning Measurement	Component Number			Principal Component	Description of Lambs Having Large Positive Component Values
	1	2	3		
Weight	0.42	-0.27	-0.08	1	Large framed and heavy
Body Length	0.39	-0.12	-0.55	2	Wide at shoulder and hips
Heart Girth	0.42	-0.27	-0.31		but short and shallow bodied
Wither Height	0.45	0.00	0.53	3	Tall at withers and hips
Hip Height	0.45	0.06	0.50		but short and narrow-bidied
Shoulder Width	0.28	0.57	-0.25		
Hip Width	0.12	0.71	-0.08		
% Total Variance	58.0	24.0	7.0		

TABLE 27

COEFFICIENTS AND INTERPRETATIONS OF PRINCIPAL COMPONENTS OBTAINED FROM BODY MEASURES OF YEARLING AWASSI LAMBS

Yearling Measurement	Component Number			Principal Component	Description of Lambs Having Large Component Values
	1	2	3		
Weight	0.39	0.11	0.35	1	Large-framed and heavy
Body Length	0.34	0.37	-0.22	2	Long and deep bodied but
Heart Girth	0.30	0.60	0.52		narrow at shoulders and
Wither Height	0.41	0.07	-0.48		hips
Hip Height	0.40	0.20	-0.48	3	Deep, wide and short-bodied
Shoulder Width	0.40	-0.47	0.17		
Hip Width	0.39	-0.51	0.28		
% Total Variance	60.0	25.0	9.0		

respectively. The first principal component was considered to reflect general size and accounted for 62, 58 and 60 percent of the total variation at birth, weaning and yearling ages, respectively. Coefficients of the first component for body weight and each of the six body measurements were similar in magnitude and direction at the three ages. However, body length tended to be less important in describing size at birth than at other ages, and hip width was less important at the yearling age than at birth or weaning.

Principal component indexes for individual lambs are weighted linear combinations of the various factors. The first principal-component (size) index of any lamb at birth can be characterized by the following linear compound:

$$Y_1 = 0.36 \text{ (body weight)} + 0.21 \text{ (body length)} + 0.34 \text{ (heart girth)} + 0.43 \text{ (wither height)} + 0.43 \text{ (hip height)} + 0.41 \text{ (shoulder width)} + 0.42 \text{ (hip width)}$$

where: the body size measures in the above equation were transformed to standard deviates ($Z_i = \dfrac{X_i - \bar{X}_i}{S_i}$), i = 1

When all coefficients (a_{ij}), i.e. coefficient for the i^{th} variate in the j^{th} component, are positive, Brown et al., (1973) suggested that the animals were contrasted on a within measurement basis. They suggested further that each individual measurement was represented as a deviation from the respective mean at any given age. According to many investigators (Wright, 1932; Anderson, 1958; Jolicoeur and Mosiman, 1960; Hope, 1968; Morrison, 1967; Eller, 1972 and Brown et al., 1973) the first principal component calculated from body weight and dimensions is generally interpreted as a measure of general size. However, it is not necessary that animals having the same principal component values show equal body measurements (Brown et al., 1973). It is important to note also that the coefficients of the seven responses (a_{11}, a_{21}, $\cdots$ a_{71}) were positive and similar in magnitude. These coefficients reflected the relative importance of each original variable in the new derived component and indicated that weight and all body dimensions were important in describing size. As the magnitude of a coefficient increase, the importance of that factor in the component increases (Morrison, 1967 and Brown et al., 1973).

The second principal component is a measure of shape. It appears to contrast weight, length and heart girth with wither height, hip height, shoulder width and hip width at both birth and weaning. That is, in an array of lambs constructed using this component, the gradation would be from small to large with respect to weight, length and heart girth values, but the gradation of the same lambs would be from large to small with respect to wither height, hip height, shoulder width and hip width. This ranking would result from the sizeable negative coefficients of the first three variables in the additive combination of variables while, at the same time, the coefficients of the other four variables are sizeable and positive. However, the second component appears to contrast measures of body width with all other measurements at the yearling age (Tables 25, 26 and 27, pages 86 through 88). This component accounted for 18, 24, and 25 percent of the variation is the system of seven variables at birth, weaning and yearling ages, respectively. These results indicate that Awassi lambs become somewhat more varied with respect to shape as they increase image during their first year. This result is in agreement with those obtained by Brown _et al_., (1973) who suggested that the shape of beef cattle is more variable at 8 and 12 months of age than is shape at 4 months.

In general, the third principal component contrasted lambs which were long and tall with those which were light weight at birth (Table 25, page 86), tall lambs with those which were short and narrow-bodied at weaning (Table 26, page 87), and deep and wide lambs with short-bodied lambs at the yearling age (Table 27, page 88). Thus, this component also characterized shape but it was less important than the second component; however, it was useful in characterization of the lambs because of the additional fraction of the total variation it explained. Thus, it provided more information to explain and interpret variation of the whole structure.

Generally speaking, the first principal components obtained in this study at the various ages were similar in signs and magnitude and provided similar contrasts in the lambs. However, the second and third components represented contrasts which differed in direction and/or magnitude at the different ages. Jolicoeur and Mosimann (1960) suggested that shape of most organisms is affected more by fluctuations of the internal constitution than by size of the organism. Size, however, is affected by the external environment more than is shape and also is more likely to reflect sample heterogeneity with respect to age-composition.

Genetic and Phenotypic Correlations

Genetic and phenotypic correlations among components at various ages are presented in Tables 28 and 29. The first, second and third components at birth were genetically correlated with most of the weaning and yearling components but were phenotypically correlated and with only a few of them (Table 28). However, about one-third of those correlations both genetic and phenotypic, were negative. Similar results were obtained also with respect to correlations between weaning components and yearling components (Table 29). It was concluded that the same complex of genes associated with body size and shape at birth tended to maintain these traits at weaning. However, body shapes were more likely to change between birth and a year of age than other traits. The negative genetic correlation of components at birth and weaning and with those at yearling age could have resulted from these changes in shape or because shape components contrasted different body dimensions at various ages (Tables 25, 26 and 27, pages 86 through 88). These results suggest that selection for post-weaning gain, yearling body weight or body size would result in lambs of variable shapes. Brown et al., (1973) pointed out that when equal weighting is given to various measures of size, as in the first principal components, bulls selected at one age on this single composite value could be quite different in shape at later ages. Their results indicated also that unrestricted selection based on a composite trait, such as weight, size or gain, would result in calves of variable dimensions or shapes.

TABLE 28

GENETIC AND PHENOTYPIC CORRELATIONS BETWEEN PRINCIPAL COMPONENTS FROM BIRTH MEASURES AND PRINCIPAL COMPONENTS FROM WEANING AND YEARLING MEASURES[1]

Birth Components	Type of Correlation	Weaning Components			Yearling Components		
		1	2	3	1	2	3
1	G	0.88	0.45	0.98	0.77	-.23	-.97
	P	0.64	0.20	0.38	0.48	-.03	-.31
2	G	1.02	0.30	0.87	0.61	-.16	-.98
	P	0.08	0.15	-.10	0.12	0.08	-.01
3	G	0.67	-.75	-.10	-.61	0.88	-.71
	P	0.09	-.36	0.16	-.25	0.09	-.27

[1]Standard errors of genetic and phenotypic correlations were between 0.07 and 0.51, and between 0.01 and 0.09, respectively.

TABLE 29

GENETIC AND PHENOTYPIC CORRELATIONS BETWEEN PRINCIPAL COMPONENTS FROM WEANING MEASURES AND THOSE FROM YEARLING[1]

Weaning Components	Type of Correlation	Yearling Components 1	2	3
1	G	0.31	0.16	-1.02
	P	0.42	0.30	-.21
2	G	0.98	-1.01	0.12
	P	0.54	-.28	0.12
3	G	0.98	-.73	-.73
	P	0.06	-.24	-.25

[1]Standard errors of genetic and phenotypic correlations were between 0.06 and 0.61, and 0.03 and 0.12, respectively.

Estimates of Heritability of Principal Components

Estimates of heritability of the first three principal components obtained at the three different ages are shown in Table 30. First components at all ages were of low to moderate heritability, while the estimate of heritability of the shape components were of greater magnitude. Estimates of heritability of the second and third components were smaller at weaning than at birth and yearling ages. This result was expected since the first principal component reflects body size differences, the second and thrid represent shape components and estimates of heritability of weight and selected body measurements were, generally, smaller at weaning than corresponding estimates at birth and at yearling age. Brown *et al.*, (1973) reported that the estimates of heritability at 4 and 12 months were larger than those at 8 months.

These results indicate that principal component indexes could be used to describe size and shape of lambs more efficiently than weight and body dimensions *per se*. They suggest also a genetic basis for these indexes and that genetic progress would result from a selection program based on the use of principal-component indexes.

TABLE 30

HERITABILITY ESTIMATES (AND THEIR STANDARD ERRORS) OF SIZE AND SHAPE AT DIFFERENT AGES

Component Number	Component Description	Age of Lambs: Birth	Weaning	Yearling
1	Size	0.22±.14	0.10±.06	0.13±.14
2	Shape	0.75±.17	0.20±.10	0.67±.15
3	Shape	0.59±.13	0.27±.08	0.47±.11

CHAPTER V

SUMMARY

The objectives of this study were (1) to measure the effects of certain environmental factors on growth and body dimensions, (2) to obtain estimates of heritability of these traits, (3) to determine the phenotypic and genetic correlations between traits and (4) to study the potential of principal-component analyses as a means of identifying lambs of different sizes and shapes for selection purposes.

Data were obtained from 257 Awassi lambs sired by 13 rams in the Agricultural Experiment Station sheep flock at the University of Mosul, Iraq, during 1966, 1967 and 1970. The traits studied were rate of gain, body weight, selected body measurements and certain principal components at birth, at weaning and at a year of age. A total of 14 traits of each lamb at each age were considered. Environmental effects studied were year of birth, sex of lamb, type of birth, age of dam and month of birth.

Most of the environmental factors significantly ($P < .05$) affected all of the dependent variables. However, the effects of age of dam and month of birth varied with age of lamb. Some factors were important at early ages and decreased as lamb age increased. Other environmental factors influenced various traits only during the post weaning period. Constants which reflected the average effect of age of dam, sex, type of birth and month of birth, were calculated and used to adjust the individual records when the effects had a definite ($P < .05$) impact on the dependent variable.

Estimates of heritability were calculated from paternal half-sib correlations calculated from the adjusted data. These estimates at birth, weaning and a year of age, respectively, were: body weight, 0.19, 0.06 and 0.20; body length, 0.16, 0.04 and 0.60; heart girth, 0.13, 0.19 and -.05; wither height, 0.31, -.06 and 0.59; hip width, 0.12, -.08 and 0.82; shoulder width, 0.15, 0.34 and 0.60 and hip width 0.11, 0.16 and 0.35.

Most of the estimates of genetic and phenotypic correlations between pairs of traits were high. Some of these estimates approached or exceeded 1.0, indicating that large sampling errors were associated with these estimates.

Principal-component analyses were preformed using six body measurements and body weights at birth, weaning and one year of age. The first three components accounted for 87, 89 and 94 percent of the total variation in the correlation structure of all body size measures at the three ages, respectively. The first principal component reflected general size and the second and third components were measures of shape. However, the shape components tended to contrast different body dimensions at the various ages. Estimates of heritability of the first three principal components at the three different ages were low to medium in magnitude. These results indicate that principal-component indexes could be used to describe size and shape in lambs more efficiently than weights and body dimensions _per se_. They suggest also a genetic basis for these indexes and that genetic progress would result from a selection program based on the use of principal-component indexes.

LITERATURE CITED

LITERATURE CITED

Aboul-Naga, A., E. A. Eltawil, E. S. E. Galal, F. Labban and S. S. Khishin. 1972. The effects of crossing Merino with Ossimi and Barki sheep on some productive traits. J. Agric. Sci. 78:275.

Ali, K. T. 1952. The heritability of, and the effect of some environmental factors on the birth weight, the weaning weight, and the grease fleece weight of sheep. Ph.D. Dissertation. University of Minnesota. St. Paul.

Anderson, T. W. 1958. An Introduction to Multivariate Statistical Analysis. John Wiley and Sons, Inc., New York.

Asker, A. A. 1964. Some economic characters of Awassi sheep in Iraq. J. Anim. Prod. U.A.R. 4:1.

Asker, A. A., M. T. Ragab and A. E. Bastawisy. 1954. Effect of season of lambing on body weight and measurements of lambs in Egypt. Indian J. of Vet. Sci. and Anim. Husb. 24:137.

Asker, A. A., M. T. Ragab and M. R. Kadi. 1952. The influence of some environmental factors affecting weight of Ossimi and Rahmani sheep. Bul. Fac. Agri. 19:25. Fouad I University. Cairo.

Balch, D. J. 1962. Estimates of genetic and phenotypic parameters in Columbia x Southdale sheep. Ph.D. Dissertation. Virginia Polytechnical Institute. Blacksburg.

Bassett, J. W., T. C. Cartwright, J. L. Van Horn and F. S. Willson. 1967. Estimates of genetic and phenotypic parameters of weaning and yearling traits in range Rambouillet ewes. J. Anim. Sci. 26:254.

Becker, W. A. 1968. Manual of Procedures in Quantitative Genetics. Washington State University Press, Pullman, Washington.

Bennett, J. A., D. H. Matthews and M. A. Madsen. 1963. Range sheep breeding studies in southern Utah. Utah Exp. Sta. Bul. 442.

Bichard, M. and M. McG. Cooper. 1966. Analysis of production records from a lowland sheep flock. Anim. Prod. 8:401.

Blackwell, R. L. and C. R. Henderson. 1955. Variation in fleece weight, weaning weight and birth weight of sheep under farm conditions. J. Anim. Sci. 14:831.

Bogart, R., R. C. DeBaca, L. D. Calvin and O. M. Nelson. 1957. Factors affecting birth weights of crossbred lambs. J. Anim. Sci. 16:130.

Botkin, M. P. 1955. Selection for efficiency of gain in lambs. J. Anim. Sci. 14:1176 (Abstr.).

Botkin, M. P. 1964. Post-weaning performance in Columbia and Corriedale lambs. J. Anim. Sci. 23:132.

Botkin, M. P., P. O. Stratton and E. K. Faulkner. 1956. Some factors influencing weaning traits in purebred Rambouillet lambs. J. Anim. Sci. 15:1227.

Brown, C. J. 1958. Heritability of weight and certain body dimensions of beef calves at weaning. Ark. Agri. Exp. Sta. Bul. 597.

Brown, C. J. and L. Franks. 1964. Factors affecting size of young beef cows. J. Anim. Sci. 23:665.

Brown, J. E., C. J. Brown and W. T. Butts. 1973. Evaluation relationships among immature measures of size, shape and performance of beef bulls. I. Principal components as measures of size and shape in young Hereford and Angus bulls. J. Anim. Sci. 36:1010.

Brown, C. J., C. A. Baugus and S. Sabin. 1961. Evaluation of factors affecting the growth of spring lambs. Ark. Agri. Exp. Sta. Bul. 646.

Butcher, R. L., R. S. Dunbar, Jr. and J. A. Welch. 1964. Heritabilities of and correlations between lamb birth weight and 140-day weight. J. Anim. Sci. 23:12.

Carter, R. C. and W. H. McClure. 1962. Heritability of growth rate and grade in Hampshire lambs. J. Anim. Sci. 21:970 (Abstr.).

Carter, R. C., G. M. Carman, F. S. McClaugherty and P. S. Haydon. 1971. Genotype-environment interaction in sheep. II. Lamb performance traits. J. Anim. Sci. 33:732.

Cassard, D. W., P. W. Gregory, J. F. Wilson, W. C. Rollins and W. C. Weir. 1953. Environmental factors affecting body size and conformation in Rambouillet yearling ewes. J. Anim. Sci. 12:140.

Cassard, D. W., P. W. Gregory, W. C. Weir and J. F. Wilson. 1956. Environmental factors affecting body dimensions in yearling Hampshire ewes. J. Anim. Sci. 15:922.

Cassard, D. W. and W. C. Weir. 1956. Hereditary and environmental variation in the weights and growth rates of Suffolk lambs under farm conditions. J. Anim. Sci. 15:1221.

Chapman, A. B. 1962. Biometrical genetics related to breeding plans. Lecture notes - Genetics 110 - University of Wisconsin. (Cited by Gjedrem, 1967).

Chapman, A. B. and J. L. Lusk. 1932. Twinning, sex ratios and genetic variability in birth weight in sheep. J. Heredity 23: 472.

Chopra, S. C. and R. M. Acharya. 1971. A note on non-genetic factors affecting body weights of Bikaneri sheep. Anim. Prod. 13:349.

Chopra, S. C. and S. C. Chopra. 1972. Correlations among wool traits in Nali and Lohi sheep. Indian J. Anim. Sci. 42:569.

Dalton, O. C. 1962. Characters of economic importance in Welsh mountain sheep. Anim. Prod. 4:269.

Dass, G. S. and R. M. Acharya. 1970. Growth of Bikaneri sheep. J. Anim. Sci. 31:1.

Datta, I. C., K. L. Sahani, R. K. Bhatnagar and A. Roy. 1963. Studies on certain aspects of sheep and goat husbandry. II. Birth-weight, live-weight growth and rearing lambs and kids. Indian J. of Vet. Sci. and Anim. Husb. 33:71.

Donald, H. P. and J. W. McLean. 1935. The growth rate of lambs in Canterbury. N. Z. J. Sci. and Tech. 17:497.

Eliya, J. 1969. Studies on some economic characteristics in Awassi sheep. M.S. Thesis. University of Baghdad, Baghdad.

Eller, A. L. Jr. 1972. The utility of measures of fatness and skeletal size in explaining weight and size differences in yearling Angus and Hereford bulls. Ph.D. Dissertation, University of Tennessee, Knoxville.

Eloksh, H. A., T. M. Sutherland and V. B. Swanson. 1962. Birth weight and measurements as aids to selection of lambs. J. Anim. Sci. 21:663 (Abstr.).

Eltawil, E. A. 1965. Genetic and environmental factors of sheep under arid conditions. Ph.D. Dissertation. Iowa State University, Ames.

Eltawil, E. A., L. N. Hazel, G. M. Sidwell and C. E. Terrill. 1970. Evaluation of environmental factors affecting birth, weaning and yearling traits in Navajo sheep. J. Anim. Sci. 31:823.

Ercanbrack, S. K. and D. A. Price. 1969. Genetic and environmental interactions in growth rate of lambs. Proceedings, Western Section, American Society of Anim. Science. 20:373.

Ercanbrack, S. K. and D. A. Price. 1972. Selecting for weight and rate of gain in noninbred lambs. J. Anim. Sci. 34:713.

Fahmy, M. H. and E. S. E. Galal. 1968. A study of weights and body dimensions of lambs and the prediction of weights using some linear dimensions. Trop. Agric. 45:33.

Fahmy, M. H., E. S. E. Galal, Y. S. Ghanem and S. S. Khishin. 1969. Genetic parameters of Barki sheep raised under semi-arid conditions. Anim. Prod. 11:361.

Falconer, D. S. 1967. Introduction to Quantitative Genetics. The Ronal Press Company, New York.

Fitzhugh, H. A. Jr., T. C. Cartwright and R. S. Temple. 1967. Genetic and environmental factors affecting weight of beef cows. J. Anim. Sci. 26:991.

Foote, W. C. and D. H. Matthews. 1959. Effect of breed classification, sex and sex of co-twin on fetal development in lambs. J. Anim. Sci. 18:1562.

Francoise, J. J., D. W. Vogt and J. C. Nolan, Jr. 1973. Heritabilities of and genetic and phenotypic correlations among some economically important traits of beef cattle. J. Anim. Sci. 36:635.

Frederiksen, K. R., D. A. Price and R. L. Blackwell. 1967. Environmental factors affecting rate and efficiency fo gain and other traits in Rambouillet lambs. J. Anim. Sci. 26:667.

Givens, C. S., Jr., R. C. Carter and J. A. Gaines. 1960. Selection indexes for weanling traits in spring lambs. J. Anim. Sci. 19:134.

Gjedrem, T. 1967. Phenotypic and genetic parameters for weight of lambs at five ages. Acta. Agri. Scandinavica. 17:199.

Gould, M. B. and J. V. Whiteman. 1971. Association of certain variables with the performance of spring vs. fall-born lambs. J. Anim. Sci. 33:531.

Gowen, J. W. 1933. On the genetic constitution of Jersey cattle as influenced by inheritance and environment. Genetics 18:415.

Harrington, R. B., D. G. Brothers and J. V. Whiteman. 1962. Heritability of gain of lambs measured at different times and by different methods. J. Anim. Sci. 21:78.

Harrington, R. B., J. V. Whiteman and R. D. Morrison. 1958. Estimates of some source of variation in the body weights of crossbred lambs at different ages. J. Anim. Sci. 17:743.

Harvey, W. R. 1960. Least-squares analysis of data with unequal subclass numbers. U.S.D.A., A.R.S. Bul. 20-8.

Hazel, L. N. 1943. Genetic basis for selection indices. Genetics 28:476.

Hazel, L. N., M. L. Baker and C. F. Reinmiller. 1943. Genetic and environmental correlations between the growth rates of pigs at different ages. J. Anim. Sci. 2:118.

Hazel, L. N. and C. E. Terrill. 1945a. Effects of some environmental factors on weanling traits of range Rambouillet lambs. J. Anim. Sci. 4:331.

Hazel, L. N. and C. E. Terrill. 1945b. Heritability of weaning weight and staple length in range Rambouillet sheep. J. Anim. Sci. 4:347.

Hazel, L. N. and C. E. Terrill. 1946a. Effects of some environmental factors on weanling traits of range Columbia, Corriedale and Targhee lambs. J. Anim. Sci. 5:318.

Hazel, L. N. and C. E. Terrill. 1946b. Heritability of weanling traits in range Columbia, Corriedale and Targhee lambs. J. Anim. Sci. 5:371.

Hazel, L. N. and C. E. Terrill. 1946c. Effects of some environmental factors on fleece and body characteristics of range Rambouillet yearling ewes. J. Anim. Sci. 5:382.

Henderson, C. R. 1953. Estimation of variance and covariance components. Biometrics 9:226.

Hope, K. 1968. Methods of Multivariate Analysis. University of London Press Ltd., London.

Hotelling, H. 1936. Simplified calculation of principal components. Psychometrika 1:27.

Hundley, W. S., Jr. and R. C. Carter. 1956. Heritability of growth rate and market grade in mutton lambs. J. Anim. Sci. 15:1226.

Johnson, J. C., Jr. 1958. Phenotype and genetic relationships between certain body measurements and milk production of first lactation Holsteins. Ph.D. Dissertation. Texas A & M University, College Station.

Jolicoeur, P. and J. E. Mosimann. 1960. Size and shape variation in the painted turtle: A Principal component analysis. Growth 24: 339.

Juma, K. H. and M. Faraj. 1966. Factors affecting birth weights of Awassi lambs. J. Agric. Sci. 67:169.

Juma, K. H., M. Faraj, J. Eliya and K. Al-Aubaidy. 1969. Studies on growth in Awassi sheep. Indian J. Anim. Sci. 39:503.

Karam, H. A. 1959. Birth, weaning and yearling weights of Rahmani sheep. I. Effects of some environmental factors. II. Heritability estimates and correlations. Empire Journ. Exper. Agric., 27:313.

Karam, H. A., A. B. Chapman and A. L. Pope. 1953. Selecting lambs under farm flock conditions. J. Anim. Sci. 12:148.

Karam, H. A., A. B. Chapman and A. L. Pope. 1949. Some of the sources of variation in body weight, rate of gain, type and condition of lambs raised under farm conditions. J. Anim. Sci. 8:606.

Kassab, S. A. and H. A. Karam. 1961. Effect of some environmental factors on body fleece weights of Barki sheep. J. Anim. Prod. U.A.R. 1:149.

Kaushik, S. N. and B. P. Singh. 1968a. Factors affecting birth weight of crossbred lambs. Indian Vet. Journ. 45:752.

Kaushik, S. N. and B. P. Singh. 1968b. Studies on the extent and nature of variation in body weight in Rampur Bushair X Polworth crossbred lambs. J. Anim. Morph. Physiol. 15:78.

Lash, J. L. 1945. Animal Breeding Plans. Iowa State College Press, Ames, Iowa.

MacNaughton, W. N. 1956. Repeatability and heritability of birth, weaning and shearling weights among range sheep in Canada. Ph.D. Dissertation. Iowa State University, Ames, Iowa.

Malik, R. C. and R. M. Acharya. 1972. Breed differences in pre- and post-weaning body weights of Indian sheep. The Indian J. of Anim. Sci. 42:22.

Mason, I. L. and P. Dasset. 1954. Milk, meat and wool production in the Langhe sheep of Italy. Z. Tierz. Zucht Biol. 62:197.

Matthews, D. H., M. A. Madsen and J. A. Bennett. 1965. Lambs measurements from Rambouillet, Columbia and Targhee ewes and their crosses when mated to Suffolk sires. Proc. West. Sec. Amer. Soc. of Anim. Sci. 16:IV-1.

McLaren, J. B. 1970. Procedures for developing selection indexes from BCIA data. Ph.D. Dissertation. Auburn University, Auburn.

McLaren, J. B., H. J. Smith, G. Srinivasan and E. J. Chapman. 1968. Performance of spring lambs in Tennessee. Tenn. Agric. Expt. Sta. Bul. 444.

Morley, F. H. W. 1950. Selection for economic characters in Merino sheep. Ph.D. Dissertation. Iowa State University, Ames, Iowa.

Morley, F. H. W. 1955. Selection for economic characters in Australian Merino sheep. V. Further estimates of phenotypic and genetic parameters. Aust. J. Agric. Res. 6:77.

Morrison, D. F. 1967. Multivariate Statistical Methods. McGraw-Hill Book Co., New York.

Nelson, R. H. and G. Venkatachalam. 1949. Estimates of heritability of birth weight and weaning weight of lambs. J. Anim. Sci. 8:607.

Osborne, R. and W. S. Patterson. 1952. On the sampling variance of heritability estimates derived from variance analysis. Proc. Roy. Soc. Edinburgh B64:456.

Osman, A. H. and G. E. Bradford. 1965. Effects of environment on phenotypic and genetic variation in sheep. J. Anim. Sci. 24:766.

Pearson, K. 1901. On lines and planes of closest fit to systems of points in space. Phil. Mag. 2:559.

Phillips, R. W. and W. M. Dawson. 1937. The relation of type and time of birth and birth weight of lambs to their survival, growth and suitability for breeding. Proc. American Anim. Prod. 296.

Phillips, R. W. and W. M. Dawson. 1940. Some factors affecting survival, growth and selection of lambs. U.S. Dept. Agric. Cir., Report Series 104.

Phillips, R. W., J. A. Stoehr and G. W. Brier. 1940. Growth in Corriedale and Rambouillet sheep under range conditions. Amer. Soc. Anim. Prod. 33rd Ann. Proc.

Price, D. A., G. M. Sidwell and J. O. Grandstaff. 1962. Effects of some genetic and environmental factors on yearling traits of Navajo and Navajo crossbred ewes. J. Anim. Sci. 12:697.

Rae, A. L. 1950. Genetic variation and covariation in productive characters of New Zealand Romney Marsh sheep. Ph.D. Dissertation. Iowa State University.

Ragab, M. T., A. A. Asker and A. A Youssef. 1953a. Comparative study of body weight and measurements of Ossimi and Rahmani sheep. No. 27. Cairo University.

Ragab, M. T., A. A. Asker and M. R. Kadi. 1953b. Genetic factors affecting weights of Ossimi lambs. Empire Journ. of Exper. Agric. 21:304.

Ray, E. E. and L. S. Smith. 1966. Effects of body weight of ewes on subsequent lamb production. J. Anim. Sci. 25:1172.

Sabin, S. W. and C. J. Brown. 1962. Analysis of sale weights and growth rates of Arkansas milk fat spring lambs. Ark. Exp. Stat. Report Series 104.

Sanchez Belda, A. and C. Esteban Munoz. 1960. A study of lamb birth weight and some factors which determine it. Anim. Breed. Abstr. 31:70.

Schutte, D. L. 1935. Factors affecting the growth of range cattle in semi-arid regions. Anim. Breed. Abstr. 4:415.

Sidwell, G. M. 1954. A selection index for Navajo crossbred range lambs. Ph.D. Dissertation. Iowa State College. Ames, Iowa.

Sidwell, G. M. and J. O. Grandstaff. 1949. Size of lambs at weaning as permanent characteristics of Navajo ewes. J. Anim. Sci. 8:373.

Sidwell, G. M. and L. R. Miller. 1971a. Production in some pure breeds of sheep and their crosses. I. Reproductive efficiency in ewes. J. Anim. Sci. 32:1084.

Sidwell, G. M. and L. R. Miller. 1971b. Production in some pure breeds of sheep and their crosses. II. Birth weights and weaning weights of lambs. J. Anim. Sci. 32:1090.

Sidwell, G. M. and L. R. Miller. 1971c. Production in some pure breeds of sheep and their crosses. III. Production indexes ewes. J. Anim. Sci. 32:1095.

Sidwell, G. M., D. A. Price and J. O. Grandstaff. 1961. Genetic and environmental factors affecting type and condition in Navajo and Navajo crossbred weanling lambs. J. Anim. Sci. 10:455.

Sidwell, G. M., J. L. Ruttle and E. E. Ray. 1970. Improvement of Navajo sheep. Agric. Exp. Stat. Res. Report 172.

Sidwell, G. M., D. O. Everson and C. E. Terrill. 1964. Lamb weights in some pure breeds and crosses. J. Anim. Sci. 23:105.

Smith, H. J. and E. R. Lidvall. 1964. Factors affecting birth weight, daily gains and 120-day weight of Hampshire lambs. J. Anim. Sci. 23:854 (Abstr.).

Snedecor, G. W. and W. G. Cochran. 1967. Statistical Methods. The Iowa State University Press. Ames, Iowa.

Srinivasan, G. 1969. A comparison of heritability estimates obtained by different methods. Ph.D. Dissertation. University of Tennessee, Knoxville.

Starke, J. S., J. B. Smith and D. M. Joubert. 1958. The birth weight of lamb. Anim. Breed. Abst. 27:63.

Terrill, C. E. 1939. Selection of range Rambouillet ewes. 32nd. Ann. Proc. Amer. Soc. Anim. Prod. 333.

Terrill, C. E., G. M. Sidwell and L. N. Hazel. 1947. Effects of some environmental factors on yearling traits of Columbia and Targhee ewes. J. Anim. Sci. 6:115.

Terrill, C. E., G. M. Sidwell and L. N. Hazel. 1948a. Effect of some environmental factors on traits of yearling and mature Rambouillet rams. J. Anim. Sci. 7:311.

Terrill, C. E., G. M. Sidwell and L. N. Hazel. 1948b. Effects of some environmental factors on yearling traits of Columbia and Targhee rams. J. Anim. Sci. 7:181.

Thrift, F. A., R. H. Dutt and P. G. Woolfolk. 1971. Phenotypic response and time trends to date of birth selection in Southdown sheep. J. Anim. Sci. 33:1216.

Thrift, F. A. and J. V. Whiteman. 1969. Comparison of the growth performance of lambs from Western and Dorset X Western ewes. J. Anim. Sci. 29:521.

Thrift, F. A., J. V. Whiteman and D. D. Kratzer. 1973. Genetic analysis of preweaning and postweaning lamb growth traits. J. Anim. Sci. 36:640.

Trail, J. C. M. and G. D. Sacker. 1969. Growth of crossbred Dorset Horn lambs from East African Blackheaded sheep. J. Agri. Sci. 73:239.

Vesely, J. A. and S. B. Slen. 1961. Heritabilities of weaning weight, yearling weight, and clean fleece weight in range Romnelet sheep. Can. J. Anim. Sci. 41:109.

Vesely, J. A. and O. W. Robison. 1970. Genotype-sex interactions in sheep. J. Anim. Sci. 31:273.

Vesely, J. A., H. F. Peters, S. B. Slen and O. W. Robison. 1970. Heritabilities and genetic correlations in growth and wool traits of Rambouillet and Romnelet sheep. J. Anim. Sci. 30:174.

Vogt, D. W., R. C. Carter and W. H. McClure. 1967. Genetic and phenotypic parameter estimates involving economically important traits in sheep. J. Anim. Sci. 26:1232.

Webb, C. E. 1963. Factors and their effects on birth weight, average daily gain and 120-day weight of purebred Hampshire lambs. M.S. Thesis. University of Tennessee, Knoxville.

Wilson, L. L. 1973. Effects of sire, calf sex and age, and age of dam on birth weight and body dimensions at one and three days of age. J. Anim. Sci. 36:452.

Wright, S. 1932. General group and special size factors. Genetics 17:603.

Yalcin, B. C. and M. Bichard. 1964. Crossbred sheep production. I. Factors affecting production from the crossbred ewe flock. Anim. Prod. 6:73.

Yao, T. S., V. L. Simmons and R. G. Schott. 1953. Heritability of fur characters and birth weight in Karakul lambs. J. Anim. Sci. 12:431.

APPENDIX

APPENDIX

TABLE 31

ADDITIONAL SUM OF SQUARES EXPLAINED BY SEQUENTIALLY ADDING ENVIRONMENTAL FACTORS IN ANALYSES OF BODY MEASUREMENTS AT BIRTH*

Source of Variation	ΔR^2					
	Body Length	Heart Girth	Wither Height	Hip Height	Shoulder Width	Hip Width
Year of birth	0.07	14.14	54.14	66.82	50.31	55.72
Sex of lamb	0.09	0.37	0.31	0.21	0.05	0.14
Type of birth	8.72	7.00	3.27	3.16	4.56	3.08
Month of birth	0.00	0.03	0.65	0.07	2.25	3.62
Age of dam	0.09	0.01	0.57	0.46	0.13	0.01
Variation accounted for all sources in the model	8.88	21.55	58.94	70.73	57.30	62.57

*240 records were used at birth age

TABLE 32

ADDITIONAL SUM OF SQUARES EXPLAINED BY SEQUENTIALLY ADDING ENVIRONMENTAL FACTORS IN ANALYSES OF BODY MEASUREMENTS AT WEANING*

Source of Variation	ΔR^2					
	Body Length	Heart Girth	Wither Height	Hip Height	Shoulder Width	Hip Width
Year of birth	12.51	10.62	42.60	58.62	13.46	5.16
Sex of lamb	0.09	0.25	3.59	3.11	0.51	1.11
Type of birth	2.84	6.98	8.42	4.69	7.03	3.20
Month of birth	3.89	0.65	0.51	0.06	9.81	16.23
Age of dam	0.63	1.06	1.17	0.68	0.03	0.01
Variation accounted for all sources in the model	19.98	19.56	56.11	67.16	30.84	25.71

*257 records were used at weaning age

TABLE 33

ADDITIONAL SUM OF SQUARES EXPLAINED BY SEQUENTIALLY ADDING ENVIRONMENTAL FACTORS IN ANALYSES OF BODY MEASUREMENTS AT YEARLING*

Source of Variation	ΔR^2					
	Body Length	Heart Girth	Wither Height	Hip Height	Shoulder Width	Hip Width
Year of birth	12.51	1.22	12.87	14.91	16.60	7.77
Sex of lamb	7.98	2.52	28.36	19.48	12.50	16.61
Type of birth	1.07	2.89	2.58	1.96	0.04	0.05
Month of birth	7.04	11.44	7.35	4.46	1.84	0.17
Age of dam	0.11	0.87	0.04	0.03	0.01	0.00
Variation accounted for all sources in the model	28.62	18.94	51.20	40.84	30.99	24.60

*151 records were used at yearling age

TABLE 34

ANALYSIS OF VARIANCE OF BODY LENGTH AT THE YEARLING AGE FOR CALCULATION OF PATERNAL HALF-SIB CORRELATION*

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Composition of Mean Square
Between sires	12	580.19	48.35	$s_w^2 + k\ s_S^2$
Within sires	136	2,249.07	16.54	s_w^2
Total	151**	101,938.50		

$$k = 10.9$$

$$s_S^2 = \frac{48.35 - 16.54}{10.9} = 2.918$$

$$\text{Estimates of heritability} = \frac{4\ (2.918)}{(2.918 + 16.54)} = 0.06$$

*Analysis of adjusted data.

**Fifteen degrees of freedom sacrificed as a result of adjusting the records for environmental effects.

TABLE 35

ENVIRONMENTAL CORRELATIONS AMONG BODY WEIGHTS AND MEASUREMENTS OF LAMBS AT DIFFERENT AGES

Traits	Age of Lamb: Birth	Weaning	Yearling
Number of lambs	240	257	151
Body weight - Body length	0.39	0.54	0.44
Body weight - Heart girth	0.42	0.53	0.61
Body weight - Wither height	0.20	0.56	0.41
Body weight - Hip height	0.20	0.63	0.51
Body weight - Shoulder width	0.17	0.47	0.07
Body weight - Hip width	0.23	0.43	-.01
Body length - Heart girth	0.63	0.44	0.47
Body length - Wither height	0.11	0.46	-.20
Body length - Hip height	0.15	0.47	-.69
Body length - Shoulder width	0.00	0.39	-.97
Body length - Hip width	0.12	0.25	-.65
Heart girth - Wither height	0.20	0.66	0.27
Heart girth - Hip height	0.22	0.68	0.38
Heart girth - Shoulder width	0.13	0.40	0.10
Heart girth - Hip width	0.14	0.40	0.08
Wither height - Hip height	0.94	0.87	0.32
Wither height - Shoulder width	0.34	0.43	-.07
Wither height - Hip width	0.37	0.40	0.15
Hip height - Shoulder width	0.32	0.51	-.68
Hip height - Hip width	0.37	0.45	-.09
Shoulder width - Hip width	0.75	0.70	0.88

VITA

Najeeb Tawfik Kazzal was born in Mosul, Iraq, on September 5, 1940. He attended elementary and secondary school in Mosul, and was graduated from Al-Adadia Al-Markazia High School June, 1961. In June 1965, he received a Bachelor's degree in Agriculture with a major in Animal Production from the University of Baghdad, College of Agriculture. He ranked second in his major area and the third among 85 agricultural students. In September 1965, he joined the University of Mosul staff and his responsibilities included both teaching and research. He was awarded one of the University of Mosul-Gulbenkian Foundation Scholarships to study towards a Master of Science degree in the United States.

In September 1968, he entered the Graduate School at the University of Tennessee and received a Master of Science degree with a major in Animal Husbandry in December 1969. He was appointed Instructor at Mosul University and served for two years. He was awarded a scholarship from the Iraqi Ministry of Higher Education and Scientific Research. He received the Doctor of Philosophy degree, with a major in Animal Breeding and Genetics from the University of Tennessee in December 1973.

He is a member of the American Society of Animal Science and of the Honor Society of Agriculture (Gamma Sigma Delta). He has published in scientific journals in Iraq, England and the United States.