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GENETIC AND ENVIRONMENTAL INFLUENCES UPON CERTAIN HEPATIC AND BLOOD CONSTITUENT CONCENTRATIONS IN SOUTHWESTERN RANGE CATTLE

by

Robert Love Taylor

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I hereby recommend that this dissertation prepared under my direction by ROBERT LOVE TAYLOR

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be accepted as fulfilling the dissertation requirement of the degree of Doctor of Philosophy

Carl Roubicek — July 10, 1967

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ABSTRACT

Data from essentially unselected bull and heifer progeny of registered Hereford cattle were used to estimate mean concentrations and study genetic and broad environmental sources of variation in hepatic and plasma carotene and vitamin A, hemoglobin and plasma phosphorus. These cattle were maintained under ordinary semiarid range conditions and herd size varied from approximately 280 to 435 cows with 9 to 14 sires per year over the period of the study.

Estimated mean concentrations of all hepatic and blood components studied fell within the range of previously reported normal values. Female hepatic carotene levels were significantly higher at weaning and 20 months age than male concentrations while no significant differences between sexes were found at 12 and 24 months ages. Female concentrations of hepatic vitamin A were greater than those of the males at weaning, but the reverse was true at 20 months age. No difference between the sexes in hepatic vitamin A levels was detected at 12 or 24 months age. Heifer progeny were found to maintain significantly higher concentrations of plasma carotene and vitamin A at all four ages observed. The differences were particularly wide at 24 months age. Hemoglobin concentrations of females were also found higher than those of the males at all sampling periods. Plasma phosphorus concentration

was found higher in heifers than bulls at weaning, but no differences existed between sexes at 12, 20 or 24 months age.

Year of birth effects were generally by far the most important source of variation considered for all hepatic and blood constituents observed.

Age of dam was a significant source of variation only in male hepatic and plasma carotene concentrations at weaning.

Estimates of genetic influences upon hepatic and blood constituent concentrations were highly variable and differed appreciably between sexes in a number of instances. Hepatic vitamin A and plasma carotene tended to show greatest overall response to genetic influence of all constituents investigated. Hepatic carotene concentration of females showed moderate heritability except at 24 months age. Plasma vitamin A concentration showed evidence of genetic influence only at weaning in both sexes and at 12 months age in heifers. Hemoglobin concentration was indicated to be moderately influenced by genetic factors at weaning and 20 months age in both sexes, but little or no genetic effect at 12 and 24 months age in males or at 12 months in females. Plasma phosphorus concentration showed little evidence of genetic influence except in bulls at 24 months age.

Differences in age within sampling period showed their greatest influence at weaning. Weaning concentrations of hepatic vitamin A, plasma carotene, plasma vitamin A and plasma phosphorus were all influenced in both sexes by age differences. Hemoglobin concentration in male progeny at weaning was also affected by age differences. At 12 months age only male hepatic carotene concentrations were affected by

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regression on age. Plasma vitamin A concentration showed significant effects of age differences in both sexes at 20 months while none of the other constituents were detectably affected at this age. None of the constituents were affected by age differences at 24 months.

Simple correlation estimates among hepatic and blood concentrations of the investigated components at the four stages of development and between these concentrations and contemporary and subsequent growth traits ranged from moderate to low, seldom exceeding 0.60. None appear to have predictive value.

INTRODUCTION

The ultimate aim of the livestock producer is to produce the most acceptable product at the least expense in terms of time, labor and money. It is the objective and responsibility of the researcher to provide the most effective means for the producer to attain his goal. Research in animal breeding must continually seek improved selection and mating techniques which will enable the practical animal breeder to make the most rapid genetic progress possible within the limits imposed by economic and practical considerations of the available genetic material and the environmental conditions under which he must operate. For many years beef cattle breeding research has, quite properly, been directed toward estimation of genetic parameters and relationships directly involving such economically important traits as size, rate of gain, feed efficiency, conformation, carcass traits, etc. In recent years an increasing number of research workers in animal breeding and genetics have diverted their attention somewhat toward seeking physiological explanations for deviations in growth and developmental characteristics. Since the physiological characteristics and responses must be dependent upon the genetic constitution of the individual and the environments to which the individual is exposed, a better understanding of genetic and environmental influences upon physiological process and their resulting influence upon economic traits is desirable.

In view of the fact that blood, in addition to other functions, serves as the principal transport agent for the various metabolites

of mammals, its composition and the function of its various components are of interest in the search for a better understanding of the reasons that some animals, apparently under essentially the same environmental influences, grow more rapidly and/or more economically than others of the same species.

One fundamental problem of coming to conclusions in the interpretation of bovine blood characteristics is the lack of knowledge as to what constitutes a "normal" blood composition under the environmental conditions which prevail over a period of years in a specified area. Most studies of bovine blood characteristics have been carried out under more or less controlled environments, usually with a rather limited number of animals, whereas there have been few investigations reported involving large numbers of animals, all exposed to an essentially uncontrolled and highly variable environment.

It would be of great utility to the producer or feedlot operator if some readily determined characteristic or characteristics of the blood could be found which are highly enough correlated with production potential of the animal so as to be useful for prediction purposes. If, in addition, reliable genetic correlations were found to be sufficiently high between highly heritable traits, the animal breeder might profitably place a portion of his selection pressure on the blood analysis, thus avoiding the expense of having to carry genetically undesirable animals to more advanced ages before culling. Previous investigations attempting to relate blood characteristics to growth traits have met with varying degrees of success and failure, but in no case has it been possible to reliably use blood analysis as a predictor of production

potential. However, enough relationships have been indicated to encourage further investigation.

Wootton (1962) has reviewed the literature dealing with various sources of normal variations in blood constituents. In addition to variation peculiar to the individual, there are other factors which operate upon the individual such as age and sex, time of day, season of the year, diet, geographical location, posture and activity immediately before the sample is drawn. In addition, according to Wootton, there is a large component of variance added by the analytical laboratory.

The present study was initiated to estimate mean concentrations and the variability to be expected of hepatic carotene and vitamin A, plasma carotene and vitamin A, hemoglobin and phosphorus of the blood in range cattle reared under semiarid southwestern range conditions. Secondarily, it was desired to obtain estimates of additive genetic effects and some broad environmental influences contributing to the variation in concentrations of these blood and liver components. Because of the uncontrolled environment and the many factors contributing to the variations in concentrations, it would be expected that effects would have to be large or many comparable observations made in order to establish the significance of a given factor statistically. This investigation was carried out in conjunction with a sire evaluation study and is thus fortunate in having unusually large numbers of observations available.

REVIEW OF LITERATURE

Vitamin A and Carotene

The importance of vitamin A in the maintenance of health in mammals has long been recognized and a great deal of research has been devoted to studying its precise biochemical functions. With the exception of its role in eyesight, very little is yet understood about the part vitamin A plays in maintaining the normal health and growth of epithelial tissue, bones and teeth. The necessity of vitamin A for maintenance of many other physiological functions is illustrated by observations on definite changes in certain epithelial tissues, bones and teeth of vitamin A-deficient Holstein calves by Dehority et al. (1960). These workers also noted that the first measurable effect of deficiency was an increase in cerebrospinal fluid pressure, apparently due either to an overproduction or an underabscrption of fluid without apparent change in concentration.

The primary storage site for vitamin A is known to be the liver and it has been noted by Wheeler et al. (1957) that the bovine can store adequate amounts of vitamin A to carry them through rather extended periods of virtually no vitamin A or carotene intake before they exhibit symptoms of vitamin A deficiency. While it is possible for a cow to survive these extended periods of vitamin A deprivation and remain in apparent good health, it is likely her offspring will suffer avitaminosis A unless supplemented. Poor reproductive performance of vitamin A-deprived cows in apparently good health has been noted by Davis and

Madsen (1941) and Baker et al. (1954) among others. Another suggestion of poor reproductive performance from vitamin A-deprived cows may be indicated by the finding of Braun and Carle (1943) from the study of 20 aborted bovine fetuses in which they found that the vitamin A content of the fetal liver, although low, was in direct relationship to the dam's diet. This finding is contrary to most previous reports.

A considerable amount of conflicting evidence has been presented regarding the interrelationships existing between the factors of hepatic stores of carotene and vitamin A and blood or plasma concentrations of carotene and vitamin A. Davis and Madsen (1941) concluded that vitamin A deficiency in cattle or an inadequate intake of carotene resulting in depletion can be detected by blood carotene and vitamin A analysis. They found blood carotene and vitamin A content closely related at lower levels of carotene intake. Lewis et al. (1941) suggested that, according to their findings with rats, the blood level of vitamin A might be of value in determining whether there is any storage in the liver. Almquist (1952) found a linear relationship between plasma vitamin A and the logarithm of liver vitamin A and concluded that liver vitamin A serves as a source of plasma vitamin A. Rousseau et al. (1954) investigated relationships between plasma vitamin A and liver vitamin A in calves fed a vitamin A-depletion ration and in calves fed minimum levels of vitamin A or carotene. They found that when plasma vitamin A and liver vitamin A were expressed as logarithms, a positive linear relationship existed. In calves fed the vitamin A-depletion ration, the plasma vitamin A level was found to be lower for a given concentration in the liver than in the calves fed the minimum levels of vitamin A or carotene. Partial

correlation coefficients relating hepatic carotene, hepatic vitamin A, plasma carotene and plasma vitamin A in beef cattle were reported by Ralston and Dyer (1960). These correlations indicated highly significant relationships between plasma carotene and hepatic carotene and between plasma carotene and plasma vitamin A. A significant relationship existed between plasma vitamin A and hepatic carotene, but no significant relationship was detected between hepatic vitamin A and any of the other components. These findings are in general agreement with those of Diven (1959) who reported quite variable interrelationships between concentrations of hepatic carotene, hepatic vitamin A, plasma carotene and plasma vitamin A in Arizona range Hereford cattle at four stages of maturity.

Braun (1945) observed in cattle that a tendency toward a direct relationship between vitamin A stores in the liver and the vitamin A of the blood existed only when vitamin A stores fell below normal levels, hence little evidence of close relationship between liver stores of vitamin A and blood vitamin A or carotene. Frey et al. (1947) concluded that serum levels and hepatic stores of vitamin A in cattle appear to be controlled by different body mechanisms. Krause (1949) noted an inverse relationship between blood and liver concentrations of vitamin A in normal male and female rats. However, when total content in the liver fell below 600 I.U. in the male rats there was a parallelism between blood and liver levels. From these observations he concluded it would be difficult to assess the body need or reserves of vitamin A on the basis of blood concentrations. Leong (1941) concluded that a low blood level of vitamin A in dogs could not be considered a definite sign of depleted reserves. Meyer et al. (1942) compared vitamin A concentration

of liver biopsy specimens with plasma vitamin A levels in man and found no parallelism between liver and plasma vitamin A, except that subjects with high blood concentrations had at least average liver storage.

Several factors have been found to influence vitamin A and carotene concentration in the blood plasma and in the liver. The most obvious and important major source of variation appears to be dietary. Davis and Madsen (1941) found plasma content of carotene and vitamin A to be dependent upon intake and previous storage. Watkins and Knox (1950) studied the relation of the carotene content of range forage to the vitamin A requirements of range cows and concluded that, except in the case of prolonged drouth or other unusual conditions, southern New Mexico ranges provide adequate carotene to meet the requirements of beef cows. They found average concentrations of plasma carotene over a four and one-half year period ranging from 163 mcg./100 ml. of plasma in February to 727 mcg./100 ml. in May. Vitamin A concentrations tended to follow the same general trends but did not exhibit such severe fluctuation, ranging from 44 mcg./100 ml. plasma in January to 60 mcg./100 ml. in June. Wheeler et al. (1957) reported a direct relationship of plasma and liver concentrations of carotene and carotene intake. Plasma and liver levels of carotene and vitamin A tended to increase when the animals grazed green range forage and decrease when they grazed cured range forage. A delay in peak hepatic vitamin A reserves compared to plasma carotene and vitamin A and liver carotene was noted. Repp and Watkins (1958) noted a significant linear relationship between plasma vitamin A and the logarithm of forage carotene intake in a New Mexico study. Pope et al. (1958) found plasma carotene and vitamin A levels of cows reflected

directly the levels of carotene fed to them. Marsh et al. (1959) found large seasonal variation in plasma carotene with average values during the growing season ranging from 500 to 1000 mcg./100 ml. of plasma and values during winter months falling below 50 mcg./100 ml. of plasma. Vitamin A concentrations in the blood showed similar trends but over a much narrower range. Summer maximums were between 30 and 40 mcg./100 ml. of plasma and winter minimums were of the order of 18 to 25 mcg./100 ml. Other workers reporting seasonal influence on vitamin A and carotene concentrations of cattle include Ralston and Dyer (1960) and Long et al. (1952). Their results were in general agreement with those of other investigators. The seasonal influence may be a reflection of both dietary and temperature factors since Ralston and Dyer (1960) found significant correlations between mean temperature and blood and liver concentrations of carotene and vitamin A. Bohman and Wade (1958) reported dietary animal fat decreased plasma and liver carotene and vitamin A concentrations. These results were later partially contradicted and modified by the investigations of Bohman et al. (1959). Their findings were that dietary fat tended to increase plasma vitamin A and carotene, had no effect on liver storage of carotene, and decreased the liver storage of vitamin A during the winter period. During this same period supplementary protein also decreased plasma vitamin A. When extra protein was fed, less vitamin A and carotene was stored in the liver. Bohman et al. (1962) confirmed these findings reporting that during the winter, dietary fat increased plasma carotene and vitamin A, but that this effect was modified by different levels of dietary protein. The content of

vitamin A in the liver decreased with increasing amounts of alfalfa pellets in the diet with fat showing no apparent effect.

Studies dealing with the influence of sex on vitamin A metabolism have been reviewed by Moore (1957, pp. 501-513) and most reports seem to indicate a tendency for females to accumulate and retain greater stores of vitamin A than males although some workers found no significant differences between the sexes. None of the studies reported by Moore (1957) produced evidence of superiority of vitamin A storage in males, however. The studies of vitamin A concentration in the blood tend to show the reverse situation; i.e., higher average concentrations of vitamin A in the plasma of males than in that of females. Diven (1959) detected no important sex differences in vitamin A concentrations in the plasma and liver of range Herefords.

Information relative to genetic influence with respect to carotene and vitamin A concentrations is limited. Diven (1959) presented data estimating heritability of hepatic vitamin A at 72% for heifers and 44% for bulls at weaning age. However, as Diven (1959) points out, the extreme widths of his 95% confidence limits on his estimates indicates the need for further study to provide more reliable estimates. Diven (1959) also presents estimates of genetic influences over hepatic carotene and plasma carotene and vitamin A at four stages of maturity in range Herefords. Nelson et al. (1944) noted an appreciably greater vitamin A content in the plasma of beef calves than in dairy calves from birth to four months age. They hasten to point out this difference may have been due to vitamin A received in the milk since the beef calves were allowed to run with their dams. Long et al.

(1952) in an Oklahoma study of blood composition in normal beef cattle found no significant difference between three breeds in plasma carotene and vitamin A concentrations, though Shorthorns showed a tendency toward slightly lower plasma vitamin A and slightly higher plasma carotene levels when compared to Hereford and Angus.

With respect to effects of age on concentrations of carotene and vitamin A, Riggs (1940) noted that the accumulation of vitamin A in the body tends to increase with increasing age and is dependent on the character of the diet.

Hemoglobin

The function and importance of hemoglobin in the oxygen transport system has long been recognized. This function makes hemoglobin an integral part of the metabolic system in mammals and of interest in investigations dealing with the physiology of growth and development.

Normal values of hemoglobin concentration in the bovine have been estimated and reported by many workers. These estimates generally fall within the range from 10.7 gm./100 ml. of blood reported by Long et al. (1952) and Davis et al. (1958) to 13.2 gm./100 ml. of blood reported by Dollahon et al. (1959).

Environmental factors affecting the hemoglobin concentration in the blood of the bovine have been investigated by a number of researchers. The reports relative to the influence of sex of animal upon the hemoglobin concentration are not uniform. Byers et al. (1952) observed no difference between sexes in Holstein, Jersey, Guernsey or grade cattle. On the other hand, Oregon studies by Price et al. (1957) indicate male

calves had lower concentrations of hemoglobin than did female calves at both 500 and 800 pounds body weight.

A number of investigators have reported studies dealing with the effects of the dietary regime on hemoglobin concentration in the bovine. Rousseau et al. (1954) noted a decrease in blood hemoglobin of calves receiving a low level of a vitamin A-depletion ration while no change in concentration was observed in calves on a high level intake of the same ration. Bedrak et al. (1956, 1957) observed that decreasing the protein intake of beef heifers reduced blood hemoglobin concentration after 140 days on test. Meacham and coworkers (1964) also found low protein rations reduced hemoglobin concentration in Florida beef bulls. Bohman et al. (1959) reported that dietary fat had no influence on blood hemoglobin but cattle receiving no protein supplement decreased in hemoglobin concentration during the winter period. Byers et al. (1952) found high-fat rations produced nonsignificant elevation of hemoglobin concentration. In the same study they found no difference between barn feeding and pasture feeding with respect to effects on hemoglobin concentration. Claesson and Hansson (1957) noted that animals on a low plane of nutrition developed a more hypochromic erythropoiesis than animals on a high plane of nutrition. Hobbs et al. (1954) found that fluoride content up to 200 parts per million in the feed did not affect the hemoglobin content in the blood of cattle or sheep, but lots receiving 300 and 600 parts per million showed a drop in hemoglobin concentration during the later stages of their study. They point out that this may have been due to lower nutrient intake rather than a direct effect of the fluorine content of the feed. Nelson and coworkers (1952) in

an Oklahoma trace mineral study found hemoglobin concentrations unaffected by trace mineral feeding or by high manganese intake.

A number of investigators, Long et al. (1952) and Byers et al. (1952), were unable to relate age of animal to blood hemoglobin concentration within the age range studied. Rice and Nelms (1964) reported normal values of hemoglobin concentration in range calves to be: birth, 13.0 ±2.16 gm./100 ml.; one week age, 12.7 ±1.73 gm./100 ml.; one month age, 12.5 ±1.67 gm./100 ml.; five month age, 15.7 ±1.87 gm./100 ml. of blood. The magnitude of the standard errors prevents clean separation of the means, but a drop in hemoglobin concentration after birth with a subsequent rise is considered normal (see Hubbert and Wallace, 1959).

The effects of other environmental factors upon hemoglobin concentration have been reported by several investigators. Season of the year has been reported to have no effect on hemoglobin concentration by Long et al. (1952) and Davis et al. (1958). Increased ambient temperatures in the range from 50° to 100° F. had little or no effect on hemoglobin concentration according to Brody et al. (1949). Injection of 1.2 ml. of a 1:1000 solution of adrenaline per 100 pounds body weight into Holstein calves had no effect on hemoglobin concentration (Schultze, 1959). This finding would indicate little influence of short term stress upon hemoglobin levels.

Information with respect to genetic influences on hemoglobin concentration of the blood is meager. While some studies have concerned themselves with the genetic determination of hemoglobin type in cattle, Crockett et al. (1962, 1963) and Stormont et al. (1964), few, if any, have attempted to estimate the degree to which hemoglobin concentration

is influenced by genotype. From observations of several workers, however, a genetic influence may be indicated. Squibb et al. (1958) found native Guatemalan calves raised in tropical lowlands had greater hemoglobin concentrations than the dairy breeds. Oregon workers (Price et al., 1957; McDonald et al., 1956) observed lower hemoglobin levels in Hereford cattle than in Angus. Byers et al. (1952) noted significant hemoglobin concentration differences between Holstein and Jersey cattle. On the other hand, Long et al. (1952) reported hemoglobin concentration apparently unrelated to breed in an Oklahoma study involving Hereford, Angus and Shorthorn cattle. Brody and coworkers (1949) failed to establish differences between Holstein and Jersey cattle with respect to hemoglobin levels.

The relationship between hemoglobin concentration and growth has been investigated by a few researchers. Oregon studies by Price et al. (1957) and Alexander et al. (1959) have found hemoglobin concentration inversely related to rate and efficiency of gain at both 500 and 800 pound body weights in Hereford and Angus cattle. Luitingh (1962) reported a correlation of +.31 between hemoglobin concentration and live weight in steers, but no correlation between hemoglobin and rate of gain. None of the relationships reported have been of sufficient magnitude to be useful in prediction of growth potential.

Plasma Phosphorus

Phosphorus is vitally important in physiological and metabolic processes in that it is a component part of the skeletal system and the phosphatides of the nucleic acids. It is also indispensible in

phosphorylation and energy transfer systems. It is known to be functional in many enzyme systems.

Normal concentration of inorganic phosphorus in the blood of cattle has been estimated by many investigators. The estimates reported show considerable variation depending upon the environmental conditions under which the investigation was carried out.

As with a great majority of other blood constituents, dietary factors have been noted to have the greatest effect on plasma phosphorus concentrations. In Oregon studies Alexander, Kreuger and Bogart (1958) found the influence of sex on plasma phosphorus concentration unimportant. Knox et al. (1941) found that the inorganic phosphorus level in the blood appeared closely related to intake in New Mexico range cattle. The concentration was found to be lower than generally believed to be optimum, but cows appeared to be in excellent health and maintained quite satisfactory production performance. Subsequent work by Watkins (1943) and Watkins and Knox (1945, 1948) has further supported these observations. Reynolds et al. (1953) reported in a south Texas study that phosphorus supplementation increased the concentration of inorganic phosphorus in the blood of cows and the supplemented cows produced larger calf crops and heavier calves at weaning. Nelson et al. (1955) found phosphorus supplementation of cattle in southeastern Oklahoma effectively raised the inorganic phosphorus level in the blood. Average concentrations ranged from 2.3 to 3.4 mg./100 ml. of blood on low level intake, 3.5 to 5.9 mg./100 ml. on medium level, and 3.6 to 7.3 mg./100 ml. of blood on high phosphorus rations. Long et al. (1957) also reported plasma phosphorus increased in cattle with increased phosphorus

supplementation over the range from 0.07 to 0.19 percent total phosphorus in the ration. Plasma phosphorus concentration was especially sensitive to phosphorus intake but did show periodic variation. Marsh et al. (1959), on the other hand, reported monthly average plasma phosphorus concentrations ranging from 4.33 mg./100 ml. of plasma to 7.42 mg./100 ml. in Montana range cattle and observed that these levels were not increased by bonemeal supplementation. They also noted that cattle grazing most heavily stocked range tended to have the higher plasma phosphorus concentrations. This was attributed to the lack of older, more leached forage forcing the animals to eat a higher proportion of young phosphorus-rich green growth. Marsh and Swingle (1960) noted that highest average concentrations of phosphorus in the blood was observed for cattle on protein supplement. Johnson et al. (1952) reported that plasma phosphorus varied with the season, being lowest in winter and lower in dry than in wet years in South Dakota. Davis et al. (1958) detected no seasonal variation in blood phosphorus concentrations of Florida cattle over a ten year period. Rollinoon and Bredon (1960) found that water starvation caused a steady rise in the inorganic phosphorus concentration of whole blood in east African Zebu cattle. They reported a mean of 5.7 mg./100 ml. of whole blood with a range of 4.28 to 6.66 mg./100 ml. as being normal levels in these cattle. Neither trace mineral feeding nor high manganese intake had any significant effects on plasma phosphorus concentration in Oklahoma beef heifers (Nelson et al., 1952). Hobbs et al. (1954) reported that fluoride content up to 200 parts per million in the feed had no detectable effects on serum phosphorus concentration in Tennessee cattle. Lots receiving 600, 900 and 1200 parts

per million in the ration showed a slight drop in serum phosphorus levels but this may have been due to reduced nutrient intake rather than a direct effect. Nevada investigations by Bohman and Wade (1958) and Bohman, Wade and Torell (1959) have indicated that dietary fat temporarily depresses plasma phosphorus concentrations.

Among other factors found to affect blood phosphorus in cattle is the observation by Brody et al. (1949) that increasing ambient temperature from 50° F. to 100° F. resulted in an increase of approximately 30% in blood inorganic phosphorus concentration. Very little is found in the literature with respect to genetic influences over blood phosphorus concentrations. Brody et al. (1949) did report significant breed difference in inorganic phosphorus concentrations between the Holstein and Jersey breeds.

Significant correlations between blood phosphorus concentration and growth characteristics have not been found in the literature. Marsh et al. (1959) found blood phosphorus concentration in Montana cows generally showing positive correlation with the weight gain of their calves, but significantly so in only a few cases. Reynolds et al. (1953) reported that phosphorus supplemented cows produced larger calf crops and heavier calves than unsupplemented cows in south Texas. Nelson and coworkers (1955) found phosphorus supplementation showed definite benefits in the growth, health and production of southeast Oklahoma calves and heifers.

MATERIALS AND METHODS

The essentially unselected bull and heifer progeny of a registered Hereford herd owned by the San Carlos Apache Indian tribe were used to furnish data for this study. This herd varied in size from approximately 280 to 435 cows with from 9 to 14 herd sires per year over the period covered by this study, which includes progeny born in the years 1957 through 1962.

This herd is maintained under ordinary range conditions prevailing over large areas of the semiarid Southwest. The range area is located approximately 60 miles east of Globe, Arizona, with an altitude of about 5000 feet above sea level. The range forage consists primarily of desert grassland vegetation as described by Nichol (1952). Mean temperatures range from approximately 45 degrees Fahrenheit in January to 85 degrees in July with the maximum temperatures seldom exceeding 95 degrees (Rice, 1956). With the exception of being furnished with salt and minerals, supplementation of these cattle has been held to a minimum. Only in some years have even the calves received a 1:2 mixture of salt and cottonseed meal from weaning until spring growth became available on the range.

Cows were randomly allotted, within age-of-dam groups, to breeding pastures for the calving seasons of 1958 and 1959. For the calving seasons 1957, 1960, 1961 and 1962, replacement heifers were randomly assigned to two (1957, 1960, 1961) or three (1962) breeding pastures instead of being randomly allotted among all breeding pastures.

For their second year of production these replacements were allotted at random over the rest of the pastures. Cows were allotted and placed in the breeding pastures prior to calving and remained there until the end of the breeding season. Bulls were placed in the breeding pastures about May 20th and removed about July 31st each year. This made the calving season begin around February 25th and last until about May 10th. At the end of the breeding season the cows and their calves were removed from the breeding pastures and run together until weaning time. All breeding and calving pastures were so arranged that they could be considered essentially equivalent with respect to forage and water availability so that all calves were subjected to an approximately equal environment within year up to the time of weaning. After weaning the two sexes were maintained separately and the environments for them could not be considered strictly comparable beyond this stage of development.

Throughout the calving season cowboys rode the calving pastures daily and as the new calves arrived they were identified by placing a tattoo in each ear. The date of birth and identification of the dam were recorded at this time.

Early in November, approximately at the end of the growing season for range forage, the cows and calves were driven to the corrals at Arsenic Tubs and separated. The calves were individually weighed on a set of Fairbanks-Morse platform scales graduated in two pound increments, run into a squeeze chute and restrained. Blood was withdrawn from the jugular vein of all animals for blood analyses and liver biopsies were performed according to procedures outlined by Erwin et al. (1956) on animals born in the years 1957 through 1959 for

studies of hepatic vitamin A and carotene. After being identified by means of the ear tattoo the animal was released from the squeeze chute and its condition appraised by a committee of three judges. An average score of the three evaluations was used in the analyses. A 15 point system of condition classification was used with the higher scores representing the higher degrees of condition. The male and female progeny were separated at this time and maintained separately from this time to maturity. During this collection period the male and female progeny of the previous year were also driven to the corral and the same data collected from them. In the early spring, usually late February, before the appearance of range forage in volume, data was collected on the one and two year old progeny so that four observations on each trait were available on each animal if that animal was available throughout the test period.

Hemoglobin concentration determinations were carried out at the time blood samples were drawn. The method of determination consisted of taking 0.05 milliliter of whole blood and adding distilled water to make 5.0 milliliters. The solution was placed in a colorimeter tube and 5.0 milliliters of 8% ammonia solution was added. Light transmittance at 540 millimicrons was read on a Bausch and Lomb Spectronic 20 colorimeter. This method was a slight modification of the direct photometric method outlined by Hawk, Oser and Summerson (1954, pp. 562-564).

Plasma filtrates were prepared and frozen in Dry Ice for the later determination of inorganic phosphorus. These filtrates were stored in a frozen state until analysis could be carried out at the Animal Science Department laboratory in Tucson. Plasma for vitamin A

and carotene determinations, physiological-saline washed liver samples for hepatic carotene and vitamin A determination were also frozen in Dry Ice and taken to the Animal Science laboratory in Tucson for subsequent analysis. Since freezing and differences in storage time might influence the results in the determination of concentrations of the liver and blood components, every practical precaution was taken to reduce these effects to a minimum and keep them essentially randomly distributed. Before laboratory analysis for a given component was begun, all required equipment and chemicals were prepared and procedures established. Samples were withdrawn from storage at random and analyzed as quickly as possible with the available personnel and equipment. By doing most of the individual component analyses in a single run, occasionally covering more than a 24 hour period, it was possible to keep laboratory procedures relatively uniform. The data obtained were recorded on IBM punch cards to facilitate numerical analysis.

Hepatic carotene and vitamin A determinations were made following the procedures of Gallup and Hoefer (1946). Plasma carotene and vitamin A concentrations were determined by the method outlined by Kimble (1939). Determination of plasma inorganic phosphorus concentration was essentially the method of Fiske and Subbarow as outlined by Hawk, Oser and Summerson (1954, pp. 630-633).

Selection of a statistical model appropriate to the analysis of the data was necessarily conditioned by a number of considerations. Since there were six individual hepatic and blood components included in the study and these were observed at four stages of development along with 11 observed growth traits, there were 35 separate least

squares analyses to be considered. If the sexes were to be treated separately for reasons to be presented later, the number of analyses doubled.

Another consideration of utmost practical importance was the availability of programming and computer capacity to carry out the necessary computations involved in complete least squares analyses where unequal and disproportionate subclass numbers exist. The inclusion of interactions and/or nesting of contributing effects would excessively complicate programming, coding of data and manipulation within the capacity of available computing equipment.

Some compromise was necessary in order to accomplish the stated objectives of the study within limitations imposed by time and available facilities. As a consequence a simple linear model assuming no important interactions was chosen to serve in both variance and covariance analyses. This model took the form:

$$Y_{ijkl} = \alpha + a_i + b_j + c_k + dX_{ijkl} + e_{ijkl}$$

where

Y_{ijkl} = the observation of the l^{th} animal by the k^{th} sire in the j^{th} age-of-dam class born in the i^{th} year.

α = the theoretical population mean with equal subclass numbers and with age equal to zero.

a_i = the effect of the i^{th} year of birth.

b_j = the effect of the j^{th} age-of-dam class.

c_k = the effect of the k^{th} sire.

d = the partial regression of the dependent variable on the continuous independent variable.

X_{ijkl} = weaning age in days of the observed animal, treated as an independent continuous variable.

e_{ijkl} = random variations associated with the individual observation, assumed to be normally and independently distributed with a mean of zero and common variance.

The age-of-dam factor was dropped from the model in all analyses subsequent to weaning. To the extent that interaction may be of importance in the various analyses, the estimates of the effects of the interacting factors will be biased and tests of significance will be approximate rather than exact.

Little information is available with respect to the importance of interactions of sex with other factors in the case of blood and liver components, but differential responses between sexes in growth data from beef cattle has been reported by a number of workers. Swiger (1961) reported a significant age of calf by sex interaction for weaning weight in beef cattle. Pahnish et al. (1961) reported significant sex by year interaction in a study of weaning weights of Arizona range calves. Blackmore, Marchello and Urick (1960) found highly significant sex by year interactions with respect to growth traits of cattle. In an evaluation of the importance of interactions affecting weaning weights of Hereford calves, Harwin, Brinks and Stonaker (1966) conclude that data for the two sexes should be analyzed separately to obtain most reliable estimates of effects. Because the sexes were maintained separately subsequent to weaning and also because it was felt that sex by other factor interactions would be the most likely to be important, it was decided to analyze the data for the two sexes separately. Also, in this way the complexities of interpretation or evaluation of interactions

involving disproportionate subclass numbers was avoided. It may have been possible to reduce the size of some confidence limits by the pooling of data but in view of the number of observations available, separate analyses were considered more desirable.

According to the assumptions of the statistical model where contributing factors act independently, the expectations of mean squares would be:

Source of variation	E(MS)
Year of birth	$\sigma_e^2 + k_3 \sigma_{yob}^2$
Age of dam	$\sigma_e^2 + k_2 \sigma_{aod}^2$
Sire	$\sigma_e^2 + k_1 \sigma_s^2$
Error	σ_e^2

and all effects would be tested by the error estimate of variance. As previously noted, these tests cannot be considered exact but should be far better than none.

More precise estimates of the effects of various environmental factors upon concentrations of hepatic and blood constituents are definitely needed. Further studies of individual components as affected by more precisely defined environment, perhaps utilizing more sophisticated statistical models when possible, should be carried out. However, the results of this study should provide basic information relative to mean concentrations and variability to be expected in these blood and liver components under this uncontrolled environment and subject to practical limitations of measurement and estimation.

Statistical analyses and estimation of variance and covariance components were carried out following least squares procedures as

outlined by Harvey (1960). Age of dam and weaning age were considered as fixed effects with year of birth and sires being considered random. Since the range of difference in weaning age was approximately 100 days, the partial regression coefficient obtained represented only the slope of a linear regression over this range in age rather than an effect of age *per se* on the dependent variable.

Heritability estimates were computed from the analyses of variance by the estimation of paternal half-sib correlations. Genetic correlations were estimated by partitioning the components of covariance in the same manner as was used in estimating sire variance from the analysis of variance. Approximate standard errors of heritability and genetic correlation estimates were computed using a slight modification by W. R. Harvey of the formulas derived and presented by Tallis (1959) and by Swiger *et al.* (1964). The estimates of standard error do not take into consideration adjustments being made for fixed effects, thus they probably represent minimum estimates of the standard errors. Because of limited numbers of sires and consequent fewer degrees of freedom, the estimates of heritability and genetic correlations are subject to considerable sampling error. Estimates of genetic correlations especially will have limited meaning and usefulness due to this factor. However, in the absence of information in this area, genetic correlation estimates which exceeded their standard error estimates are presented in appendices.

Where the detection of a significant difference between sample means of the sexes within sampling period, or between sampling period means within sex appeared possible from examination of mean and standard

error estimates for a given constituent, this significance was checked using a "t" test as indicated by Steel and Torrie (1960, chapter 5). Sample variance was estimated by the error mean square in each case. The estimated sample variances were checked for homogeneity and if found homogeneous were pooled in computing the standard error of the difference. If sample variance estimates were found to be heterogeneous they were not pooled in computing the standard error of the difference and a weighted value of "t" was computed with which to make the test. If it was apparent no difference could be detected, no test was applied.

RESULTS AND DISCUSSION

Hepatic Carotene and Vitamin A

In order to obtain maximum information from the available data, the concentrations of carotene and vitamin A in the liver and in the blood were studied separately. Since the literature indicates quite variable interrelationships between hepatic and plasma concentrations and because of a considerable loss of observations in trying to relate the blood and liver values from the available data, it was decided to omit these relationships from this investigation.

Arithmetic and least squares estimates of over-all mean hepatic carotene concentrations at four ages are presented in table 1 along with their associated standard errors. The over-all mean estimates obtained agree reasonably well with those reported by Diven (1959) which are the most comparable of any data found in the literature. Most other studies have been concerned with cattle either older or younger and under completely different environmental conditions. Hepatic concentrations of carotene reported by Ralston and Dyer (1960) tended to be somewhat higher than those found in this study while values reported by Wheeler et al. (1957) tended to be lower.

Female progeny had significantly higher concentrations of hepatic carotene than the males at weaning ($P \leq .01$) and at 20 months age ($P < .05$). While the differences are not statistically significant, it is interesting to note that the point estimates of female concentrations at 12 and 24 month ages are also somewhat greater than

estimates for the males at these ages. Comparison of sampling period means within sex reveals that hepatic carotene concentrations at weaning were considerably lower ($P<.01$) than concentrations at 12, 20 and 24 months age in both sexes. It might be expected that a decrease in hepatic carotene concentration would be found between weaning and the 12 month observations but such was not the case. In fact, a rather substantial increase ($P<.01$) is noted, probably indicating that some dietary carotenoids are available in this area throughout the winter and that at this stage of development there is a rather strong inherent ability and tendency to increase carotene storage in the liver. A significant ($P<.05$) decrease in hepatic carotene concentration between 20 and 24 months age is shown in the female data. A similar but smaller, non-significant decrease in concentration is indicated in the male data. This tendency toward lowered carotene concentrations over the winter period would seem more in line with usual expectations. None of the remaining comparisons between sampling period means were found significant.

Table 1. Arithmetic and Least Squares Estimates of Mean Hepatic Carotene Concentration[a] in Beef Cattle at Four Ages.

	Number		Arithmetic				Least Squares			
			Male		Female		Male		Female	
	M	F	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Weaning	240	226	5.00	0.10	5.38	0.12	4.82	0.10	5.28	0.14
12 Month	191	179	8.50	0.20	8.70	0.20	8.28	0.25	8.37	0.24
20 Month	159	149	7.92	0.23	8.47	0.33	8.15	0.24	8.73	0.25
24 Month	118	108	7.93	0.28	8.43	0.19	7.81	0.32	8.06	0.24

[a]Micrograms carotene per gram of fresh liver.

Analyses of variance from hepatic carotene concentrations in males and females are presented in tables 2 and 3, respectively. Least squares constant estimates for effects on hepatic carotene are presented in Appendix 1. While, as previously noted, little average difference in concentration is found between sexes, factors showing more or less influence on these concentrations do appear to differ appreciably between the two sexes. In general, year of birth accounted for by far the greater portion of variation in hepatic carotene concentration. Since year of birth includes such a wide multitude of environmental and other variables which might be expected to influence carotene concentrations, this factor would be expected to exert considerable effect. The failure of the selected model to account for a significant amount of the variation by any of the independent variables in the 24 month female data is difficult to explain except to conclude that the model is completely inadequate to describe the biological situation in this case.

The reason for a highly significant influence of age of dam on male hepatic carotene concentration at weaning while showing quite insignificant effects on female concentrations can only be speculated upon. Inspection of the least squares constant estimates (Appendix 1) does not reveal any apparent pattern of relationship between age of dam and hepatic carotene concentration in either sex, but does indicate considerably more variation in the case of male progeny. No satisfactory physiological explanation of this phenomenon is apparent at the moment.

Another noteworthy difference between the analyses of variance for the separate sexes is the fact that the "F" ratio for sire effects

Table 2. Analyses of Variance - Male Hepatic Carotene.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
		Weaning		
Year of birth	2	79.91	39.95	26.18**
Age of dam	7	29.73	4.25	2.78**
Sire	16	36.12	2.26	1.48
Weaning age	1	0.94	0.94	<1
Error	213	325.06	1.53	
		12 Months		
Year of birth	2	133.72	66.86	10.75**
Sire	16	103.51	6.47	1.04
Weaning age	1	27.63	27.63	4.44*
Error	171	1063.92	6.22	
		20 Months		
Year of birth	2	256.31	128.16	22.60**
Sire	15	110.19	7.35	1.30
Weaning age	1	2.90	2.90	<1
Error	140	793.72	5.67	
		24 Months		
Year of birth	2	187.23	93.62	13.88**
Sire	15	136.72	9.11	1.35
Weaning age	1	0.02	0.02	<1
Error	99	667.81	6.75	

*Probability less than .05.

**Probability less than .01.

Table 3. Analyses of Variance - Female Hepatic Carotene.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
		Weaning		
Year of birth	2	175.63	87.82	39.90**
Age of dam	7	16.90	2.41	1.10
Sire	16	82.15	5.13	2.33**
Weaning age	1	3.18	3.18	1.44
Error	199	437.96	2.20	
		12 Months		
Year of birth	2	86.90	43.45	8.50**
Sire	16	251.75	15.73	3.08**
Weaning age	1	2.53	2.53	<1
Error	159	812.40	5.11	
		20 Months		
Year of birth	2	901.80	450.90	96.31**
Sire	16	165.59	10.35	2.21**
Weaning age	1	10.24	10.24	2.19
Error	129	603.95	4.68	
		24 Months		
Year of birth	2	14.36	7.18	1.96
Sire	15	79.29	5.29	1.44
Weaning age	1	0.30	0.30	<1
Error	89	326.68	3.67	

*Probability less than .05.

**Probability less than .01.

in the analyses of the male progeny data, while consistently greater than one, never reached the usual levels accepted for significance. In the analyses of the female progeny data, however, three of the four analyses show highly significant sire effects. This, along with the heritability estimates presented in table 4, would seem to indicate that female concentrations of hepatic carotene may be more responsive to genetic influence than male concentrations.

Table 4. Heritability Estimates for Hepatic Carotene Concentration in Beef Cattle at Four Ages.

	Male			Female		
	h^2	SE[a]	"k"[b]	h^2	SE	"k"
Weaning	0.14	0.15	12.85	0.40	0.22	11.96
12 Month	0.02	0.14	10.45	0.70	0.31	9.81
20 Month	0.12	0.20	9.23	0.52	0.30	8.18
24 Month	0.20	0.27	6.81	0.26	0.31	6.26

[a]SE = standard error.

[b]"k" = effective number of progeny per sire.

Only in the case of male animals at 12 months of age did differences in age show a significant effect on hepatic carotene concentration. The negative partial regression coefficient of -0.024 would indicate younger animals tended to have slightly higher concentrations than older animals. The corresponding coefficient for the female progeny was -0.007 possibly indicating a like tendency but the estimate is not significant. Even though differences in age did show significance in the male data, the size of the regression coefficient appears too small to be of practical importance.

Estimates of over-all mean concentrations of hepatic vitamin A at the four stages of development are shown in table 5. These estimates of the mean concentrations are reasonably consistent with those of Diven (1959) and are well within the range of estimated means quoted in the literature (Ralston and Dyer, 1960; Wheeler, et al., 1957).

In contrast to estimated hepatic carotene storage where point estimates of carotene concentrations were consistently larger for females, hepatic vitamin A storage was greater ($P<.01$) in the females at weaning but male concentrations exceeded ($P<.05$) female levels at 20 months age. Concentrations of hepatic vitamin A at 12 and 24 months age were not significantly different for the two sexes. Within-sex comparisons between sampling period mean concentrations of hepatic vitamin A indicate male progeny were able to consistently increase ($P<.01$) storage between sampling periods up to 20 months age. The point estimate of 24 month concentration exceeded that at 20 months, but the difference lacked statistical significance. The female progeny failed to significantly increase their hepatic storage of vitamin A between weaning and 12 months age. Between 12 and 20 months age hepatic storage increased ($P<.01$) but not as much as in the case of male progeny. As in the male data, the estimate of 24 month concentrations slightly exceeded the 20 month estimate but the difference was not significant. There were no known environmental differences in management practices between the sexes which would contribute to these trends. However, since the sexes were maintained separately from weaning, direct comparison of the estimates is not warranted.

Table 5. Arithmetic and Least Squares Estimates of Mean Hepatic Vitamin A Concentrations[a] in Beef Cattle at Four Ages.

	Number		Arithmetic				Least Squares			
			Male		Female		Male		Female	
	M	F	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Weaning	240	226	108	2.12	118	2.47	104	2.39	116	2.91
12 Month	191	179	121	4.41	130	4.84	114	3.95	119	4.57
20 Month	159	149	176	6.01	167	4.17	181	5.95	168	4.79
24 Month	118	108	180	6.84	181	5.79	188	5.41	177	5.55

[a]Micrograms vitamin A per gram of fresh liver.

Analyses of variance for hepatic vitamin A concentrations for male and female progeny are shown in tables 6 and 7. These analyses show somewhat greater uniformity between the sexes with respect to factors contributing to variation in hepatic vitamin A concentrations than was the case with hepatic carotene storage. The least squares constant estimates for effects are to be found in Appendix 2. Average effects of the various factors considered as sources of variation in hepatic vitamin A concentration appear not to differ greatly between the sexes.

Effects attributed to year of birth contributed a substantial share of the variation found in hepatic vitamin A concentrations in all analyses. As previously noted in the case of hepatic carotene, this result would ordinarily be expected because of the wide scope of environmental variation which exists from one year to another.

There appears to be no evidence of any influence of age of dam on hepatic vitamin A concentration at weaning in either sex.

Table 6. Analyses of Variance - Male Hepatic Vitamin A.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
		Weaning		
Year of birth	2	17812	8906	11.23**
Age of dam	7	5578	797	1.01
Sire	16	28630	1789	2.26**
Weaning age	1	5964	5964	7.52**
Error	213	168915	793	
		12 Months		
Year of birth	2	201984	100992	67.97**
Sire	16	25750	1609	1.08
Weaning age	1	66	66	<1
Error	171	254067	1486	
		20 Months		
Year of birth	2	131075	65537	18.29**
Sire	15	175605	11707	3.27**
Weaning age	1	7497	7497	2.09
Error	140	501593	3583	
		24 Months		
Year of birth	2	263283	131642	68.53**
Sire	15	55618	3708	1.93*
Weaning age	1	938	938	<1
Error	99	190179	1921	

*Probability less than .05.

**Probability less than .01.

Table 7. Analyses of Variance - Female Hepatic Vitamin A.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
		Weaning		
Year of birth	2	21621	10811	11.78**
Age of dam	7	6806	972	1.06
Sire	16	56806	3550	3.87**
Weaning age	1	23640	23640	25.77**
Error	199	182560	917	
		12 Months		
Year of birth	2	241151	120575	66.17**
Sire	16	59171	3698	2.03*
Weaning age	1	163	163	<1
Error	159	289744	1822	
		20 Months		
Year of birth	2	39514	19757	11.21**
Sire	16	82750	5172	2.94**
Weaning age	1	2242	2242	1.27
Error	129	227295	1762	
		24 Months		
Year of birth	2	79339	39670	19.35**
Sire	15	45854	3057	1.49
Weaning age	1	2284	2284	1.11
Error	89	182426	2050	

*Probability less than .05.

**Probability less than .01.

The highly significant effects of sire on hepatic vitamin A concentration in both sexes at weaning and 20 months of age with significant effects at 12 months age in the heifer progeny and at 24 months age in the bull progeny indicate that genetic influences are of some importance in hepatic vitamin A storage. These results tend to substantiate to some degree the extent of genetic influence reported by Diven (1959). Heritability estimates for hepatic vitamin A concentration at four ages in beef cattle are shown in table 8.

Table 8. Heritability Estimates for Hepatic Vitamin A Concentration in Beef Cattle at Four Ages.

	Male			Female		
	h^2	SE[a]	"k"[b]	h^2	SE	"k"
Weaning	0.36	0.21	12.85	0.77	0.30	11.96
12 Month	0.03	0.15	10.45	0.38	0.24	9.81
20 Month	0.79	0.34	9.23	0.76	0.34	8.18
24 Month	0.48	0.34	6.81	0.29	0.32	5.26

[a]SE = standard error.

[b]"k" = effective number of progeny per sire.

Differences in age at weaning show highly significant effect on weaning hepatic vitamin A concentration in both the male and female data. Partial regression coefficients of 0.30 for the males and 0.63 for females indicate considerably more storage by the older animals of both sex groups. This effect might be accounted for primarily by an increased length of time for vitamin A storage along with an increased dependence upon forage as opposed to milk by the older animals.

Simple correlations among hepatic concentrations of carotene and vitamin A at the four stages of development are shown in Appendix 3. As noted in the literature, the correlations tend to show a great deal of variability. The strongest positive relationships between concentrations appear to be between hepatic vitamin A concentrations at weaning and 12 month ages ($r=0.56$ for males and $r=0.55$ for females) and between hepatic vitamin A concentrations at 20 and 24 month ages ($r=0.69$ for males and $r=0.66$ for females). This apparent relationship could be due, in part, to the relatively shorter time span between these sampling dates as compared to elapsed time between other periods. It would tend to indicate stored vitamin A is reasonably stable over this shorter period of time. This would be in agreement with the findings of Diven (1959) who developed a linear equation for the purpose of adjusting hepatic vitamin A concentrations for previous storage. With a few exceptions there is reasonable agreement between the sexes in the signs and magnitude of the estimated correlations among concentrations of hepatic carotene and vitamin A.

Simple correlations of hepatic carotene and vitamin A at the four stages of development with contemporary and subsequent growth traits are presented in Appendix 4. In general the correlations tend to be low and of little or no predictive value. This set of correlations shows a considerable amount of inconsistency of estimates between the two sexes. In a number of instances, some of the larger estimates of correlation obtained in the data for the individual sexes are opposite in sign. No explanation for this result is apparent unless it is due

to chance variation or to differences in response to environmental influences.

In the absence of previous investigations into the genetic relationships between hepatic carotene and vitamin A concentrations and between these concentrations and growth traits, it was considered worthwhile to compute estimates of genetic correlations. While many estimates of genetic correlation failed to exceed their standard error estimates, those which did are presented in Appendix 5. Of the estimates of genetic correlation shown, those relating to hepatic concentrations of carotene and vitamin A at various stages of development are predominantly positive in sign and usually fairly large in magnitude. The only two exceptions to this was in the male data correlating weaning hepatic carotene with 20 and 24 month vitamin A. Estimates of genetic relationships between hepatic concentrations of carotene or vitamin A and contemporary or subsequent growth were highly variable in both sign and size, being predominantly positive in male data and negative in female data.

Plasma Carotene and Vitamin A

Estimates of over-all mean concentrations of plasma carotene from the male and female progeny data are shown in table 9. The estimates of over-all mean concentrations fall well within the range of values reported in the literature (Watkins and Knox, 1950; Marsh et al., 1959; Diven, 1959; Marsh and Swingle, 1960). The range of mean estimates found in this study does not approach that reported by Marsh and Swingle (1960) in size.

Comparison of mean concentrations of plasma carotene for the two sexes show female progeny consistently having higher concentrations than males ($P<.01$) at all four stages of development. This difference is particularly striking in the 24 month data. Male plasma carotene concentrations decreased from a high of 422 mcg./100 ml. at weaning to 393 mcg./100 ml. of plasma at 12 months age. There were no significant differences in the 12, 20 and 24 month estimates from the male data. Female plasma carotene concentration also showed a highly significant decrease from 475 mcg./100 ml. at weaning to 423 mcg./100 ml. plasma at 12 months age. No significant difference was found in female concentrations at 12 and 20 months age but, in sharp contrast to the males, female progeny had a substantial increase ($P<.01$) in plasma carotene concentration between 20 and 24 months age. No explanation of the large increase in heifer plasma carotene concentration between 20 and 24 months age is known. Laboratory analysis of concentrations was made without consideration of sex so that sex of animal should have been essentially random in order with respect to laboratory analyses.

Table 9. Arithmetic and Least Squares Estimates of Mean Plasma Carotene Concentration[a] in Beef Cattle at Four Ages.

	Number		Arithmetic				Least Squares			
			Male		Female		Male		Female	
	M	F	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Weaning	520	520	467	8.2	501	9.1	422	12.4	475	12.8
12 Month	305	461	410	9.6	438	7.0	393	14.0	423	10.2
20 Month	262	389	358	8.8	421	7.7	396	9.6	417	9.5
24 Month	237	350	412	11.3	678	15.2	385	12.1	687	15.5

[a]Micrograms carotene per 100 milliliters of plasma.

Analyses of variance for male and female plasma carotene concentrations are shown in tables 10 and 11, respectively. Constant estimates for the effects of the independent variables are presented in Appendix 6. The highly significant effect of year of birth found in all analyses would usually be anticipated. Inspection of the constant estimates for year of birth effects shows this factor exerting large influence in both sexes but not of the same magnitude. This is quite noticeable in the 24 month data where the range of differences between sexes in estimated concentrations was from 61 micrograms per 100 milliliters of plasma in the 1958 progeny to 506 micrograms per 100 milliliters of plasma in the 1960 progeny. In this case the female progeny consistently had the higher estimated concentrations.

There is no apparent reason for the significant age of dam effect on plasma carotene concentration in males at weaning but little evidence of effect on concentration in females at weaning. One possible speculation might be that those male calves receiving less milk consume more grass and browse, thus tending to increase the general level of their plasma carotene. The female calves, not having as great a growth potential or feed requirement, may not have been so subject to this influence. The constant estimates for age of dam effects (Appendix 6) show male calves from cows 5, 6, 7 and 10+ years of age having plasma carotene concentration estimates below the mean. The usual expectation is that cows in the 5, 6 and 7 year old age group would be at the peak of their milk producing capacity.

Sire effects are highly significant in five of the eight analyses, significant in two, and fail to reach the 0.05 level of

Table 10. Analyses of Variance - Male Plasma Carotene.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
		Weaning		
Year of birth	4	6057534	1514383	78.24**
Age of dam	7	296156	42308	2.19*
Sire	23	1511155	65702	3.39**
Weaning age	1	118570	118570	6.13*
Error	484	9368091	19356	
		12 Months		
Year of birth	4	2671341	667835	37.83**
Sire	21	525475	25023	1.42
Weaning age	1	28129	28129	1.59
Error	278	4907129	17652	
		20 Months		
Year of birth	4	2462659	615665	91.03**
Sire	21	708618	33744	4.99**
Weaning age	1	17528	17528	2.59
Error	235	1589421	6763	
		24 Months		
Year of birth	4	1031879	257970	24.89**
Sire	21	532129	25339	2.44**
Weaning age	1	23205	23205	2.24
Error	210	2176865	10366	

*Probability less than .05.

**Probability less than .01.

Table 11. Analyses of Variance - Female Plasma Carotene.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
		Weaning		
Year of birth	4	6534417	1633604	65.86**
Age of dam	7	221643	31663	1.28
Sire	23	1414178	61486	2.48**
Weaning age	1	227304	227304	9.16**
Error	484	12004902	24804	
		12 Months		
Year of birth	4	2197841	549460	43.25**
Sire	23	518124	22527	1.77*
Weaning age	1	5280	5280	<1
Error	432	5488135	12704	
		20 Months		
Year of birth	4	4179426	1044856	106.87**
Sire	23	470035	20436	2.09**
Weaning age	1	8057	8057	<1
Error	360	3519757	9777	
		24 Months		
Year of birth	4	8113714	2028428	86.56**
Sire	23	972879	42299	1.80*
Weaning age	1	2347	2347	<1
Error	321	7522262	23434	

*Probability less than .05.

**Probability less than .01.

significance in only one analysis (male data at 12 months age). This would indicate that plasma carotene concentrations may be influenced, even under highly variable environmental influences, by genetic factors. The degree of genetic influence over plasma carotene concentrations may be indicated by the heritability estimates presented in table 12. Whereas hepatic concentration of carotene in females appeared more subject to genetic influence as indicated by heritability estimates, male plasma concentrations appear generally to be the more highly heritable.

Table 12. Heritability Estimates for Plasma Carotene Concentration in Beef Cattle at Four Ages.

	Male			Female		
	h^2	SE[a]	"k"[b]	h^2	SE	"k"
Weaning	0.43	0.16	19.71	0.28	0.13	19.70
12 Month	0.13	0.13	12.97	0.16	0.11	18.04
20 Month	1.06	0.30	11.10	0.27	0.14	15.23
24 Month	0.50	0.24	10.04	0.22	0.14	13.66

[a] SE = standard error.

[b] "k" = effective number of progeny per sire.

Differences in age accounted for a significant amount of the variability in plasma carotene concentrations only at weaning. Significant and highly significant negative partial regressions on age at weaning for the males and females, respectively, indicate younger animals tend to have greater plasma concentrations of carotene than older animals at this stage of development under the conditions of the study.

Over-all estimates of mean plasma vitamin A concentrations in beef cattle at the four ages under consideration are shown in table 13. These estimates of mean concentrations tend to be slightly higher than most of the means estimated for mature animals presented by other workers (Watkins and Knox, 1950; Ralston and Dyer, 1960; Marsh and Swingle, 1960).

Female progeny had significantly ($P<.01$) greater concentrations of plasma vitamin A at all four stages of development. In contrast to the case of plasma carotene concentrations where mean levels dropped between weaning and 12 months age in both sexes, plasma vitamin A increased significantly ($P<.01$) in both sexes during the same period. Bull plasma vitamin A remained relatively constant with no significant differences between estimated concentrations at 12, 20 and 24 months age. Heifer concentrations showed a slight drop ($P<.01$) between 12 and 20 months age, but underwent a rather sharp increase ($P<.01$) between 20 and 24 months age. This fluctuation is not so great as that found in the plasma carotene concentrations of heifers during the same period, but does parallel it. Watkins and Knox (1950) and Marsh *et al.* (1959) also reported that plasma vitamin A concentration fluctuated seasonally but not over so wide a range as did plasma carotene concentration.

Analyses of variance for male and female plasma vitamin A concentration in beef cattle at four ages are presented in tables 14 and 15, respectively. Least squares constant estimates for effects of the independent variables on plasma vitamin A concentration may be found in Appendix 7. As is to be usually expected, year of birth

Table 13. Arithmetic and Least Squares Estimates of Mean Plasma Vitamin A Concentration[a] in Beef Cattle at Four Ages.

	Number		Arithmetic				Least Squares			
			Male		Female		Male		Female	
	M	F	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Weaning	520	520	49.7	0.76	52.2	0.78	47.9	1.12	51.4	0.95
12 Month	305	461	50.6	1.01	59.2	0.95	50.0	1.56	58.1	1.26
20 Month	262	389	49.4	1.11	57.2	1.12	50.5	1.51	55.8	1.58
24 Month	237	350	51.6	0.99	75.3	1.48	51.9	1.46	70.8	2.07

[a]Micrograms vitamin A per 100 milliliters of plasma.

effects show the greatest influence over plasma vitamin A concentration at all ages. As was the case with plasma carotene concentration, year of birth effects (Appendix 7) at 24 months age were highly significant in both sexes, but were not consistent between the sexes. The range of differences in estimated plasma vitamin A concentrations at this age was from 1.4 micrograms per 100 milliliters of plasma in the 1958 progeny to 42.4 micrograms per 100 milliliters in the 1962 progeny.

Age of dam shows no indication of influence on plasma vitamin A concentration in either sex. This is in slight contrast to the age of dam effects indicated in the plasma carotene concentration of the male progeny at weaning.

Sire effects on plasma vitamin A concentrations are significant only at weaning ($P<.01$) in the male progeny and at weaning ($P<.05$) and 12 month ages ($P<.05$) in females. While these analyses indicate a degree of genetic influence on plasma vitamin A levels, they are in rather distinct contrast to the degree of genetic influence indicated in the case of plasma carotene concentrations. Estimates of heritability

Table 14. Analyses of Variance - Male Plasma Vitamin A.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
		Weaning		
Year of birth	4	31771	7943	49.79**
Age of dam	7	1215	174	1.09
Sire	23	7206	313	1.96**
Weaning age	1	887	887	5.56*
Error	484	77214	160	
		12 Months		
Year of birth	4	19936	4984	22.91**
Sire	21	4288	204	<1
Weaning age	1	572	572	2.63
Error	278	60491	218	
		20 Months		
Year of birth	4	14833	3708	22.33**
Sire	21	5211	248	1.49
Weaning age	1	4160	4160	25.05**
Error	235	39019	166	
		24 Months		
Year of birth	4	15975	3994	26.66**
Sire	21	1699	81	<1
Weaning age	1	94	94	<1
Error	210	31456	150	

*Probability less than .05.

**Probability less than .01.

Table 15. Analyses of Variance - Female Plasma Vitamin A.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
		Weaning		
Year of birth	4	28674	7168	52.81**
Age of dam	7	944	135	<1
Sire	23	5604	244	1.80*
Weaning age	1	1131	1131	8.33**
Error	484	65694	136	
		12 Months		
Year of birth	4	36246	9062	46.97**
Sire	23	7049	306	1.59*
Weaning age	1	592	592	3.07
Error	432	83339	193	
		20 Months		
Year of birth	4	56023	14006	51.99**
Sire	23	4851	211	<1
Weaning age	1	3737	3737	13.87**
Error	360	96978	269	
		24 Months		
Year of birth	4	94237	23559	55.93**
Sire	23	11197	487	1.16
Weaning age	1	0	0	<1
Error	321	135211	421	

*Probability less than .05.

**Probability less than .01.

of plasma vitamin A concentrations in beef cattle at four ages are presented in table 16. The heritability estimates tend to be low with fairly large standard errors. In three cases negative estimates of sire variance were obtained and no estimates are given for heritability.

Table 16. Heritability Estimates for Plasma Vitamin A Concentration in Beef Cattle at Four Ages.

	Male			Female		
	h^2	SE[a]	"k"[b]	h^2	SE	"k"
Weaning	0.19	0.10	19.71	0.16	0.10	19.70
12 Month	c	-	-	0.13	0.10	18.04
20 Month	0.17	0.16	11.10	c	-	-
24 Month	c	-	-	0.04	0.10	13.66

[a]SE = standard error.

[b]"k" = effective number of progeny per sire.

[c]Negative estimate of sire variance.

Differences in age over the range considered within the analyses appear to exert considerable influence over plasma vitamin A concentration at certain times or stages of development. Negative partial regression coefficients at weaning were -0.07 ($P<.05$) for the male progeny and -0.08 ($P<.01$) for the females (Appendix 7). This would indicate a tendency for younger animals to have higher concentrations of plasma vitamin A than older animals. Whether this may be due to greater ability of younger animals to retain previously attained levels of vitamin A in the blood or to some unrecognized environmental conditions of the study is not clear. Positive partial regression coefficients of 0.26 ($P<.01$) for the male progeny and 0.18 ($P<.01$) for

females at about 20 months age indicate that older animals within this age range tend to have higher concentrations than younger animals at this stage of development. Age differences at the other two stages of development show little or no evidence of effect of plasma concentration of vitamin A.

Simple correlations among plasma carotene and vitamin A concentrations at four stages of development are shown in Appendix 8. Reasonable agreement is found between the sexes in the sign and size of most of the estimated relationships, though there are some exceptions. Within period correlations between plasma concentrations of carotene and vitamin A are among the larger estimates with the exception of the 24 month data when the female data indicated a correlation of only 0.10 between these traits. The simple correlations of plasma carotene and vitamin A concentrations at four ages with contemporary and subsequent growth traits shown in Appendix 9 are highly variable and tend generally to be small. As was the case with hepatic concentrations of carotene and vitamin A, some instances of opposite signs between the two sexes for some of the larger estimated correlations are noted.

Estimates of genetic correlations among plasma concentrations of carotene and vitamin A at the various ages and between these concentrations and contemporary and subsequent growth traits are shown in Appendix 10. Only those estimates of genetic correlations which exceeded their estimated standard errors are shown. The remainder were assumed to equal zero.

Hemoglobin

Table 17 shows the arithmetic and least squares estimates of over-all mean concentrations of hemoglobin in range beef cattle at four stages of development. These estimates are in the range of estimates previously reported for beef cattle by other workers (Byers, Jones and Haag, 1952; Long et al., 1952; Luitingh, 1962).

Table 17. Arithmetic and Least Squares Estimates of Mean Hemoglobin Concentrations[a] in Beef Cattle at Four Ages.

	Number		Arithmetic				Least Squares			
			Male		Female		Male		Female	
	M	F	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Weaning	539	539	14.3	0.06	14.8	0.06	14.2	0.10	14.6	0.10
12 Month	330	484	12.1	0.12	12.1	0.10	11.7	0.17	12.1	0.15
20 Month	296	440	13.0	0.09	14.3	0.08	13.0	0.15	14.2	0.13
24 Month	253	385	12.2	0.16	13.6	0.16	11.7	0.17	14.1	0.15

[a]Grams of hemoglobin per 100 milliliters of blood.

Female progeny consistently had higher ($P<.01$) concentrations of hemoglobin at all sampling periods than did the males. This is not in agreement with the findings of Byers, Jones and Haag (1952) who failed to detect any sex difference in hemoglobin concentrations. Within-sex comparison of sampling period means reveals that in both sexes, hemoglobin concentrations were significantly ($P<.01$) greater at weaning than at any other period. A significant ($P<.01$) reduction in concentration was observed in both sexes from weaning to 12 months age. This was followed by an increase ($P<.01$) in concentration at 20 months age. The male progeny had another decrease in concentration ($P<.01$) between 20 and 24 months age while female hemoglobin concentrations

remained relatively constant. One possible cause of a decline in hemoglobin levels over the winter period could be severely reduced protein and energy intake through this season. Low levels of protein in the ration and low plane of nutrition have been noted by a number of workers to lower hemoglobin concentrations (Claesson and Hansson, 1957; Bohman, Wade and Torell, 1959; Bedrak et al., 1956, 1957). Another factor which could be of importance in this respect would be a build-up of internal and external parasite infestation over the winter season with a consequent decrease in concentrations of hemoglobin.

Analyses of variance for hemoglobin concentration in beef cattle at four ages are presented in tables 18 and 19 for the male and female progeny, respectively. Constant estimates for effects of factors considered in the least squares analyses are presented for reference in Appendix 11.

Apparently due to wide variations between years in many contributing factors, year of birth accounts for by far the greater portion of the variation in hemoglobin concentrations for both sexes. As with the estimates of the over-all means at the various ages, these differences between years may be largely nutritional in nature though undoubtedly other factors also contribute to the effect.

Age of the dam shows no indication of having any influence upon hemoglobin concentrations at weaning in either sex.

Sire contributions to the variation in hemoglobin concentrations indicate genetic influence at weaning and 20 months of age in the male progeny and at weaning, 20 months and 24 months age in the female progeny. In general the sire influence was greatest in the fall

Table 18. Analyses of Variance - Male Hemoglobin.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
		Weaning		
Year of birth	4	403.90	100.98	85.75**
Age of dam	7	7.69	1.10	<1
Sire	23	59.91	2.60	2.21**
Weaning age	1	7.98	7.98	6.78**
Error	503	592.32	1.18	
		12 Months		
Year of birth	4	393.86	98.46	34.41**
Sire	21	67.89	3.23	1.13
Weaning age	1	0.01	0.01	<1
Error	303	867.17	2.86	
		20 Months		
Year of birth	4	164.46	41.12	22.49**
Sire	21	71.16	3.39	1.85*
Weaning age	1	1.77	1.77	<1
Error	269	491.74	1.83	
		24 Months		
Year of birth	4	797.39	199.35	86.72**
Sire	21	69.75	3.32	1.44
Weaning age	1	0.00	0.00	<1
Error	226	519.49	2.30	

*Probability less than .05.

**Probability less than .01.

Table 19. Analyses of Variance - Female Hemoglobin.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
		Weaning		
Year of birth	4	257.42	64.36	43.10**
Age of dam	7	4.44	0.63	<1
Sire	23	84.30	3.67	2.45**
Weaning age	1	0.14	0.14	<1
Error	503	751.09	1.49	
		12 Months		
Year of birth	4	347.63	86.91	28.67**
Sire	23	102.04	4.44	1.46
Weaning age	1	8.64	8.64	2.85
Error	455	1379.44	3.03	
		20 Months		
Year of birth	4	282.77	70.69	37.50**
Sire	23	104.22	4.53	2.40**
Weaning age	1	5.44	5.44	2.89
Error	411	774.89	1.89	
		24 Months		
Year of birth	4	2191.38	547.85	228.76**
Sire	23	99.30	4.32	1.80*
Weaning age	1	0.03	0.03	<1
Error	356	852.58	2.39	

*Probability less than .05.

**Probability less than .01.

season for both sexes. The stress of cold weather and poorer nutritional regimes during the winter may tend to increase the environmental effects and mask genetic influences in the early spring data. Further indications of the degree of genetic influence on hemoglobin concentrations are shown in table 20 in the form of heritability estimates. In general the range of these estimates would indicate hemoglobin concentration to be low to moderately heritable under the uncontrolled range environment of this study.

Table 20. Heritability Estimates for Hemoglobin Concentration in Beef Cattle at Four Ages.

	Male			Female		
	h^2	SE[a]	"k"[b]	h^2	SE	"k"
Weaning	0.22	0.11	20.47	0.27	0.12	20.42
12 Month	0.04	0.10	14.07	0.10	0.09	18.98
20 Month	0.25	0.16	12.58	0.30	0.14	17.26
24 Month	0.16	0.16	10.75	0.20	0.13	15.07

[a]SE = standard error.

[b]"k" = effective number of progeny per sire.

Age differences within analysis had no effect on hemoglobin concentration except in the bull progeny at weaning. In this instance a negative partial regression coefficient of -0.007 exerted highly significant effects. Even if this effect is real, the magnitude of the regression would indicate the differences would be relatively unimportant.

Simple correlations among hemoglobin concentrations at four ages in beef cattle are presented in Appendix 12. These estimates

indicate that under the conditions of this investigation, there is relatively little relationship between hemoglobin concentration at one period and that at another. This is somewhat in contrast with the observations of Byers, Jones and Haag (1952) in dairy cattle who noted that animals with high or low hemoglobin values tended to maintain these values over extended periods.

The simple correlations presented in Appendix 13 of hemoglobin concentrations in beef cattle at four ages with contemporary and subsequent growth traits show a great deal of inconsistency in size and sign. None of the estimates show any indication of being useful for predictive purposes. Because of these inconsistencies of the estimates, comparisons with the rather varied reports in the literature do not appear to be worthwhile.

Estimated genetic correlations among hemoglobin concentrations at the four stages of development and between hemoglobin concentration and contemporary and subsequent growth traits are presented in Appendix 14 for comparison purposes. Only those estimates which exceeded their estimated standard errors are presented.

Plasma Phosphorus

Over-all estimates of mean concentrations of plasma phosphorus in beef cattle at four ages are presented in table 21. These estimated means are within the range of values estimated by other workers (Marsh et al., 1959; Long et al., 1952). Estimates of plasma phosphorus concentration found in the literature show a considerable range of values

depending upon experimental conditions, indicating large environmental influences which makes comparisons between studies difficult.

Table 21. Arithmetic and Least Squares Estimates of Mean Plasma Phosphorus Concentration[a] in Beef Cattle at Four Ages.

	Number		Arithmetic				Least Squares			
			Male		Female		Male		Female	
	M	F	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Weaning	398	391	6.43	0.07	6.53	0.08	6.31	0.10	6.52	0.11
12 Month	258	348	6.89	0.09	7.20	0.11	6.85	0.14	6.99	0.13
20 Month	237	328	5.75	0.09	5.59	0.10	5.62	0.14	5.55	0.16
24 Month	209	296	5.49	0.11	6.00	0.09	5.62	0.14	5.79	0.13

[a]Milligrams phosphorus per 100 milliliters plasma

No significant differences in plasma phosphorus concentrations were found between the sexes except at weaning when female concentrations were significantly ($P<.05$) greater than male concentrations. This is in general agreement with the findings of Alexander, Krueger and Bogart (1958) in which they concluded that blood phosphorus varied in a manner unrelated to sex. In both sexes plasma phosphorus levels were significantly ($P<.01$) higher at 12 months age than at any other sampling period. Weaning levels were higher ($P<.01$) than 20 and 24 month concentrations and female progeny had greater concentrations at 24 months than at 20 months age ($P<.05$). There were no differences between 20 and 24 month plasma phosphorus concentrations in the males. The tendency toward higher concentrations at weaning and 12 months age would seem to agree somewhat with the observations of Long and his coworkers (1952) on Oklahoma beef heifers except they detected peak levels at about six months age. The estimates of mean plasma phosphorus

concentrations found in this study exceed slightly most of the estimates reported for mature animals (Marsh and Swingle, 1960; Watkins and Knox, 1948). They agree more closely with the mean concentrations reported by Rollinoon and Bredon (1960) for East African Zebu cattle.

Tables 22 and 23 present the analyses of variance in plasma phosphorus concentrations for the bull and heifer progeny, respectively. Least squares constant estimates for the effects of factors considered in the statistical model are reported in Appendix 15. The failure of the selected statistical model to account for a significant amount of the variation in plasma phosphorus concentration in the case of the 12 month old male progeny indicates an inadequacy of the model to fit the biological situation.

While, as previously noted in the discussion of the over-all estimates of mean plasma phosphorus concentrations, there appears to be little or no differences between the sexes, inspection of the least squares constant estimates for the effect of year of birth (Appendix 15) indicates considerable difference between the sexes, particularly at 12 and 24 month ages. Since the sexes were maintained separately from weaning, precise interpretation of this difference is not possible from this study. The effects of year of birth would be due to nutritional and other environmental factors which have been noted by other workers to influence plasma phosphorus concentration (Long et al., 1952; Marsh and Swingle, 1960).

Age of dam gives no indication of having any influence on plasma phosphorus concentration from this study. Apparently there

Table 22. Analyses of Variance - Male Plasma Phosphorus.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
		Weaning		
Year of birth	3	85.20	28.40	14.79**
Age of dam	7	19.12	2.73	1.42
Sire	14	31.50	2.25	1.17
Weaning age	1	13.90	13.90	7.24**
Error	372	714.25	1.92	
		12 Months		
Year of birth	3	11.65	3.88	1.99
Sire	14	38.78	2.77	1.42
Weaning age	1	0.72	0.72	<1
Error	239	466.36	1.95	
		20 Months		
Year of birth	3	46.64	15.55	8.82**
Sire	14	37.36	2.67	1.51
Weaning age	1	2.61	2.61	1.48
Error	218	384.25	1.76	
		24 Months		
Year of birth	3	72.80	24.27	13.46**
Sire	14	54.36	3.88	2.15**
Weaning age	1	1.15	1.15	<1
Error	190	342.57	1.80	

*Probability less than .05.

**Probability less than .01.

Table 23. Analyses of Variance - Female Plasma Phosphorus.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
		Weaning		
Year of birth	3	53.11	17.70	7.20**
Age of dam	7	10.26	1.47	<1
Sire	14	43.10	3.08	1.25
Weaning age	1	36.10	36.10	14.69**
Error	365	897.16	2.46	
		12 Months		
Year of birth	3	424.16	141.39	72.26**
Sire	14	39.12	2.79	1.43
Weaning age	1	4.76	4.76	2.43
Error	329	643.76	1.96	
		20 Months		
Year of birth	3	50.10	16.70	5.79*
Sire	14	34.84	2.49	<1
Weaning age	1	4.03	4.03	1.40
Error	309	891.57	2.89	
		24 Months		
Year of birth	3	115.50	38.50	21.24**
Sire	14	29.24	2.09	1.15
Weaning age	1	1.23	1.23	<1
Error	277	501.99	1.81	

*Probability less than .05.

**Probability less than .01.

was not enough variation in phosphorus intake due to this factor to influence the plasma phosphorus level of the calf detectably.

In only one case, the male progeny at 24 months age, did the effect of sire show significance. This, along with the heritability estimates presented in table 24, indicates very minor genetic differences in plasma phosphorus concentrations. This would be in general agreement with the variable indications of possible genetic influence found in the literature where Brody et al. (1949) noted significant breed differences in the plasma phosphorus concentrations of Holstein and Jersey cows. Long and his coworkers (1952) found no obvious relation to breed in plasma phosphorus concentrations of Oklahoma beef cattle.

Table 24. Heritability Estimates for Plasma Phosphorus Concentration in Beef Cattle at Four Ages.

	Male			Female		
	h^2	SE[a]	"k"[b]	h^2	SE	"k"
Weaning	0.03	0.07	24.51	0.04	0.08	24.14
12 Month	0.10	0.13	16.48	0.08	0.09	22.32
20 Month	0.13	0.14	15.11	c	-	-
24 Month	0.32	0.21	13.34	0.03	0.09	18.89

[a]SE = standard error.

[b]"k" = effective number of progeny per sire.

[c]Negative estimate of sire variance.

Age differences within sampling period apparently had little or no effect upon plasma phosphorus concentration in either sex except at weaning. At weaning negative partial regression coefficients of -0.010

for the male progeny and -0.018 for the female progeny were highly significant and indicated a tendency for the older animals to have lower concentrations of plasma phosphorus. Since the average age at weaning for these animals was approximately eight months, this observation could be in agreement with the findings of Long et al. (1952) of peak concentrations occurring at approximately six months age. The older animals may already have lowered concentrations by the time of weaning.

Simple correlations among plasma phosphorus concentrations in beef cattle at four ages, presented in Appendix 16, show very little relationship between concentrations of plasma phosphorus from one period to another. Likewise, the simple correlations of plasma phosphorus concentration to contemporary and subsequent growth traits, shown in Appendix 17, also indicate very low or no relationship between the level of plasma phosphorus and growth traits. Phosphorus levels appear to have been fully adequate for growth and to meet the needs of the animals, thus there was not enough variation in growth due to differences in phosphorus levels to cause correlations of any consequence with the growth traits.

Estimates of genetic correlations among plasma phosphorus concentrations at four ages and between these concentrations and contemporary and subsequent growth traits are shown in Appendix 18. Only those correlations exceeding their standard errors were tabulated.

SUMMARY AND CONCLUSIONS

Estimated mean concentrations of all blood and hepatic components covered in this investigation fall within the range of reported normal values from other studies. In general the estimates tended to indicate no severe depletion of any of the components under the rather rigorous range conditions encountered. None of the hepatic or blood components appeared sufficiently low on the average to have an appreciable effect upon growth traits under the range conditions. Under essentially unsupplemented range conditions protein and energy intake is severely limited at times, especially during the winter and summer dry spells. This limited intake of energy and protein prevents full expression of growth potential and tends to mask any effect of variations in individual hepatic or blood components on growth. Under higher intake levels of energy it is possible greater relationships between some hepatic or blood constituents and growth might be found.

The effects of gross environmental factors and additive genetic effects on the various hepatic and blood constituents tended to differ appreciably between the sexes in many cases. At weaning female concentrations of all hepatic and blood constituents studied were found significantly greater than male concentrations. At 12 months age female concentrations of plasma carotene and vitamin A and hemoglobin were significantly above those of the males. Non-significant differences were found between the sexes in concentrations of the remaining components at 12 months age. Female levels of hepatic carotene, plasma

carotene and vitamin A as well as hemoglobin were above those of the males at 20 months age. Male concentrations of hepatic vitamin A at this age was greater than that of the females. No significant differences were found between the plasma phosphorus levels of the two sexes at this stage of development. At 24 months age female progeny had significantly higher levels of plasma carotene and vitamin A and hemoglobin than the males. No significant differences between sexes were detected in concentrations of hepatic carotene and vitamin A or plasma phosphorus at 24 months age. Within-sex comparisons of sampling period means indicated some period to period variation in all hepatic and blood components, but these variations were not uniform for both sexes.

Year of birth effects were generally by far the most important source of variation considered. This is not a well defined factor and includes under one classification many factors known to influence concentrations of blood and liver components so it would normally be expected to contribute greatly to their variation. In two instances in this study year of birth failed to account for a significant amount of variation. This was in the case of female hepatic carotene concentration at 24 month age and in male plasma phosphorus concentration at 12 month age. In both these cases none of the factors considered accounted for significant amounts of variation in concentration, thus the statistical model failed completely in describing the biological situation.

In most cases age of dam exerted no detectable influence on concentrations of blood and liver constituents at weaning. Exceptions

to this were found in male concentrations of hepatic and plasma carotene where age of dam contributed significantly to the variation.

Estimates of genetic or sire influences upon hepatic and blood constituent concentrations were highly variable and differed appreciably between the sexes in a number of instances. Hepatic vitamin A and plasma carotene appear to show greatest over-all response to genetic influence of the constituents studied. Hepatic carotene concentration in the female progeny appeared to show moderate heritability except at 24 months age. Plasma vitamin A concentration showed evidence of genetic influence only at weaning in both sexes and at 12 months age in the heifer progeny. Hemoglobin concentration was indicated to be under moderate genetic influence at weaning and 20 months age in both sexes, but showed little or no genetic effect at 12 and 24 months age in the males or at 12 months age in the females. Plasma phosphorus showed little indication of genetic influence except in male concentrations at 24 months age. In general, the genetic influence upon the constituent concentrations appeared to be most expressed at weaning and 20 month ages though there were exceptions to this.

Differences in age within sampling period showed their greatest amount of influence at weaning. Weaning concentrations of hepatic vitamin A, plasma carotene, plasma vitamin A, and plasma phosphorus were all influenced in both sexes by age differences. Also hemoglobin concentration at weaning in the male progeny showed a response to age. At 12 months age only male hepatic carotene concentrations were affected by regression on age. Plasma vitamin A concentration showed highly significant effects of age differences in both sexes at 20 months

while none of the other constituents were detectably affected at this age. None of the constituents showed an effect of age differences in either sex at 24 months age.

Simple correlation estimates among hepatic and blood concentrations at the four stages of development for the constituents considered and between these concentrations and contemporary and subsequent growth traits ranged from moderate to low, seldom exceeding 0.60. None appear to have value for predictive purposes. While some of the estimates of genetic correlation exceeded the theoretical maximum correlation of 1.00, the effects of sampling variation and the magnitude of standard error estimates stresses the importance of using extreme caution in their interpretation.

Appendix 1. Least Squares Constant Estimates for Hepatic Carotene.[a]

	Weaning		12 Month		20 Month		24 Month	
Effect	Male	Female	Male	Female	Male	Female	Male	Female
Mean								
	4.82	5.28	8.28	8.37	8.15	8.73	7.81	8.06
Year								
1957	0.31	0.26	1.43	1.12	2.77	5.65	0.64	-0.89
1958	0.65	1.05	0.10	0.06	-1.49	-3.19	1.50	0.52
1959	-0.96	-1.31	-1.53	-1.18	-1.28	-2.46	-2.14	0.37
Age of dam								
3 years	-0.39	-0.14	-	-	-	-	-	-
4 years	0.38	0.13	-	-	-	-	-	-
5 years	0.46	-0.38	-	-	-	-	-	-
6 years	0.24	-0.04	-	-	-	-	-	-
7 years	-0.21	-0.11	-	-	-	-	-	-
8 years	0.26	-0.42	-	-	-	-	-	-
9 years	-0.78	0.56	-	-	-	-	-	-
10+ years	0.04	0.40	-	-	-	-	-	-
Sire								
1	0.82	1.01	-0.69	0.96	-0.75	-1.36	-1.44	-1.30
2	-0.24	-0.27	-0.32	-0.16	-1.24	0.70	-1.18	-0.02
3	-0.10	0.30	0.61	1.02	0.55	1.38	1.19	1.34
4	0.14	0.72	0.40	0.86	-0.18	0.39	-0.97	1.14
5	-0.36	-0.27	0.77	-0.09	-0.24	0.89	-0.71	0.76
6	0.56	1.00	1.65	2.76	0.73	3.01	0.80	0.95
7	0.68	1.98	-0.75	-1.35	1.64	0.77	1.92	1.37
8	0.10	-0.01	-3.03	-2.48	-	-2.76	-	0.63
9	-0.24	-2.00	-0.88	-0.24	-0.16	-3.48	0.55	-
10	-0.35	-0.65	-0.47	-0.34	-1.76	0.21	-2.19	-0.79
11	0.04	0.76	0.42	0.11	0.23	0.69	1.64	-0.28
12	0.34	-0.33	0.85	-1.00	1.35	0.33	1.18	-0.04
13	0.49	0.32	1.08	1.77	0.77	1.12	0.30	0.15
14	-0.19	-0.48	0.74	0.54	-0.31	-0.55	1.03	-2.49
15	-0.29	-0.88	-0.84	-2.16	0.51	-0.39	-0.67	-1.14
16	-0.52	-0.74	1.13	0.04	-0.92	-0.22	-0.26	-0.29
17	-0.88	-0.46	-0.66	-0.23	-0.22	-0.75	-1.20	0.02
Regression on age								
	0.00	0.01	-0.02	-0.01	0.01	0.02	0.00	0.00

[a]Means and deviations expressed as micrograms of carotene per gram of fresh liver.

Appendix 2. Least Squares Constant Estimates for Hepatic Vitamin A.[a]

	Weaning		12 Month		20 Month		24 Month	
Effect	Male	Female	Male	Female	Male	Female	Male	Female
Mean								
	104	116	114	119	181	168	188	177
Year of birth								
1957	-12.8	-9.5	-62.1	-79.9	57.3	0.0	87.5	15.0
1958	14.8	16.5	50.1	50.1	-8.0	21.3	0.9	29.3
1959	-2.1	-7.0	12.0	29.8	-49.3	-21.3	-88.4	-44.3
Age of dam								
3 years	0.7	6.9	-	-	-	-	-	-
4 years	6.4	-2.0	-	-	-	-	-	-
5 years	3.2	3.2	-	-	-	-	-	-
6 years	-3.5	-10.2	-	-	-	-	-	-
7 years	-5.3	-5.2	-	-	-	-	-	-
8 years	6.3	-5.0	-	-	-	-	-	-
9 years	0.4	1.5	-	-	-	-	-	-
10+ years	-8.2	10.8	-	-	-	-	-	-
Sire								
1	-10.7	-10.8	-9.1	8.5	-73.2	-13.8	-80.5	-3.5
2	-11.7	-16.8	-13.4	-26.5	-35.6	-12.4	-28.3	-18.6
3	10.5	8.7	8.9	26.7	14.1	15.2	-1.9	14.8
4	14.7	13.6	6.5	28.4	15.6	15.9	-5.2	26.6
5	-1.6	-0.2	10.5	6.8	-14.9	12.8	-1.0	35.6
6	15.6	32.6	21.6	17.6	19.0	47.3	15.7	12.3
7	-2.7	-4.0	4.9	2.9	-7.7	15.6	-22.7	28.1
8	6.7	-9.6	1.4	-1.3	-	-1.6	-	26.8
9	23.1	31.7	6.9	30.7	110.6	92.8	23.9	-
10	-8.7	-16.0	-2.3	-23.7	-39.3	-19.2	14.0	-14.8
11	5.5	22.7	10.1	-2.6	7.6	-30.5	19.3	17.7
12	3.4	-25.3	1.4	-21.1	6.1	-3.1	8.5	-18.4
13	-2.2	-3.3	15.3	-5.2	-10.9	-26.2	9.4	1.8
14	-16.1	-10.6	-22.0	2.2	-3.2	-35.8	25.7	-46.8
15	5.7	-9.3	3.1	-26.9	-5.9	-38.6	22.7	-14.7
16	-13.1	0.7	-23.6	-9.0	-6.1	-12.6	-2.1	-11.9
17	-18.4	-4.1	-20.2	-7.5	23.8	-5.8	2.1	-35.0
Regression on age								
	0.31	0.63	-0.04	-0.05	0.43	-0.23	-0.17	-0.27

[a]Means and deviations expressed as micrograms of vitamin A per gram of fresh liver.

Appendix 3. Simple Correlations Among Hepatic Carotene and Vitamin A Concentrations in Beef Cattle at Four Ages.[a]

	Weaning		12 Month		20 Month		24 Month	
	Carotene	Vitamin A	Carotene	Vitamin A	Carotene	Vitamin A	Carotene	Vitamin A
Weaning								
Carotene	--	0.29	0.29	0.13	0.32	0.30	0.44	0.37
Vitamin A	0.32	--	0.03	0.56	-0.04	0.25	0.21	0.20
12 Month								
Carotene	0.40	0.15	--	-0.02	0.41	0.23	0.37	0.36
Vitamin A	0.11	0.55	-0.02	--	-0.31	-0.11	0.26	-0.16
20 Month								
Carotene	0.22	-0.15	0.37	-0.52	--	0.49	0.36	0.50
Vitamin A	0.38	0.47	0.34	0.21	0.25	--	0.40	0.69
24 Month								
Carotene	0.24	0.32	0.29	0.33	0.05	0.22	--	0.51
Vitamin A	0.49	0.46	0.36	0.16	0.22	0.66	0.30	--

[a]Correlations for males above diagonal; for females below diagonal.

Appendix 4. Simple Correlations of Hepatic Carotene and Vitamin A Concentrations in Beef Cattle at Four Ages With Contemporary and Subsequent Growth Traits.

	Sex	Weaning		12 Month		20 Month		24 Month	
		Carotene	Vitamin A	Carotene	Vitamin A	Carotene	Vitamin A	Carotene	Vitamin A
Weaning Weight	M	-0.08	0.22	--	--	--	--	--	--
	F	-0.09	0.22	--	--	--	--	--	--
Condition	M	0.24	0.30	--	--	--	--	--	--
	F	0.32	0.22	--	--	--	--	--	--
12 Month Weight	M	0.26	0.20	-0.09	0.16	--	--	--	--
	F	0.17	0.14	0.07	-0.14	--	--	--	--
Condition	M	0.44	0.37	0.13	0.36	--	--	--	--
	F	0.30	0.03	0.11	-0.08	--	--	--	--
Daily Gain Wn-12 mo.	M	0.41	-0.01	0.33	-0.21	--	--	--	--
	F	0.30	-0.11	0.27	-0.48	--	--	--	--
20 Month Weight	M	-0.16	-0.11	-0.20	-0.20	-0.07	-0.11	--	--
	F	0.00	0.13	-0.13	0.28	-0.31	-0.09	--	--
Condition	M	-0.26	-0.28	-0.07	-0.44	0.17	-0.01	--	--
	F	-0.43	-0.17	-0.16	-0.07	0.00	-0.31	--	--
Daily Gain 12-20 mo.	M	-0.25	-0.37	-0.07	-0.56	0.21	0.01	--	--
	F	-0.13	-0.08	-0.07	0.17	-0.25	-0.09	--	--
24 Month Weight	M	0.02	-0.01	-0.14	-0.33	0.14	0.04	-0.12	0.02
	F	-0.39	-0.21	-0.17	-0.16	0.11	-0.32	-0.20	-0.43
Condition	M	0.22	-0.10	0.22	-0.32	0.33	0.31	0.22	0.55
	F	-0.50	-0.32	-0.11	-0.20	0.12	-0.36	-0.11	-0.47
Daily Gain 20-24 mo.	M	0.19	0.11	0.10	-0.13	0.15	0.20	0.18	0.44
	F	-0.47	-0.37	-0.05	-0.36	0.38	-0.33	-0.20	-0.46

Appendix 5. Genetic Correlations Among Hepatic Carotene and Vitamin A Concentrations in Beef Cattle at Four Ages and Between These Concentrations and Contemporary and Subsequent Growth Traits.[a]

	Male		Female	
	Genetic Correlation	Standard Error	Genetic Correlation	Standard Error
Weaning hepatic carotene with				
12 month hepatic carotene	--	--	0.967	0.222
20 month hepatic carotene	0.977	0.670	1.125	0.342
Weaning hepatic vitamin A	--	--	0.756	0.238
12 month hepatic vitamin A	--	--	0.862	0.327
20 month hepatic vitamin A	-0.560	0.456	0.611	0.415
24 month hepatic vitamin A	-0.936	0.548	--	--
12 month weight	1.301	0.521	--	--
20 month weight	0.780	0.472	--	--
24 month weight	0.608	0.524	--	--
12 month condition	--	--	-0.640	0.492
Daily gain - weaning to 12 mo.	0.994	0.552	--	--
12 month hepatic carotene with				
20 month hepatic carotene	--	--	1.068	0.224
24 month hepatic carotene	--	--	0.565	0.474
Weaning hepatic vitamin A	--	--	0.733	0.230
12 month hepatic vitamin A	--	--	0.771	0.263
20 month hepatic vitamin A	--	--	0.598	0.307
12 month weight	--	--	-0.676	0.410
24 month weight	--	--	-0.415	0.398
12 month condition	--	--	-0.678	0.430
24 month condition	--	--	-0.638	0.585
20 month hepatic carotene with				
24 month hepatic carotene	--	--	1.373	0.468
Weaning hepatic vitamin A	1.599	1.126	0.619	0.323
12 month hepatic vitamin A	--	--	0.704	0.497
20 month hepatic vitamin A	0.629	0.548	0.729	0.281
24 month hepatic vitamin A	--	--	0.876	0.548
24 month weight	--	--	-1.281	0.414
24 month condition	--	--	-1.250	0.790
Daily gain - 20 to 24 months	--	--	-0.713	0.465
24 month hepatic carotene with				
Weaning hepatic vitamin A	--	--	0.911	0.469
20 month hepatic vitamin A	--	--	2.008	0.980
24 month hepatic vitamin A	0.961	0.484	1.538	0.685
24 month weight	--	--	-0.777	0.627
24 month condition	--	--	-1.379	1.023

Appendix 5. (continued)

	Male		Female	
	Genetic Correlation	Standard Error	Genetic Correlation	Standard Error
Weaning hepatic vitamin A with				
12 month hepatic vitamin A	--	--	0.912	0.155
20 month hepatic vitamin A	1.325	0.487	0.493	0.281
24 month hepatic vitamin A	--	--	1.093	0.309
12 month condition	0.782	0.739	-0.829	0.416
20 month condition	0.680	0.606	--	--
Daily gain - 12 to 20 months	--	--	-0.613	0.576
12 month hepatic vitamin A with				
20 month hepatic vitamin A	--	--	0.972	0.300
Daily gain - 12 to 20 months	--	--	-0.877	0.831
20 month hepatic vitamin A with				
24 month hepatic vitamin A	1.022	0.143	--	--
20 month weight	-0.570	0.323	--	--
24 month weight	-0.468	0.412	--	--
24 month condition	1.225	0.502	--	--
Daily gain - 12 to 20 months	-0.598	0.321	--	--
Daily gain - 20 to 24 months	0.452	0.437	--	--
24 month hepatic vitamin A with				
24 month weight	-0.711	0.455	--	--
24 month condition	1.275	0.574	--	--

[a]Only correlation estimates which exceeded their estimated standard errors are tabulated; others assumed to equal zero.

Appendix 6. Least Squares Constant Estimates for Plasma Carotene.[a]

	Weaning		12 Month		20 Month		24 Month	
Effect	Male	Female	Male	Female	Male	Female	Male	Female
Mean								
	422	475	393	423	396	417	385	687
Year of birth								
1958	10	33	124	-71	-196	-199	141	-100
1959	-197	-220	-158	-4	55	18	54	101
1960	109	82	-8	8	-8	24	-10	194
1961	-94	-95	-67	-118	104	176	48	191
1962	172	200	109	185	45	-19	-233	-386
Age of dam								
3 years	51	24	-	-	-	-	-	-
4 years	5	20	-	-	-	-	-	-
5 years	-1	-2	-	-	-	-	-	-
6 years	-15	22	-	-	-	-	-	-
7 years	-3	9	-	-	-	-	-	-
8 years	8	-27	-	-	-	-	-	-
9 years	26	8	-	-	-	-	-	-
10+ years	-71	-54	-	-	-	-	-	-
Sire								
2	-34	3	-28	8	-67	-39	-43	-8
3	51	27	30	23	-34	-30	4	-66
4	46	24	24	33	-14	13	23	27
5	78	58	12	41	27	16	47	62
6	131	123	26	22	37	57	27	43
10	-14	10	-94	61	-58	6	-49	-1
11	79	-44	18	11	20	16	42	41
12	31	35	106	8	28	13	105	-51
13	22	36	55	34	-11	-18	13	-19
14	11	-30	-43	-13	-94	-27	18	-103
15	28	4	44	-26	-108	-57	-77	-72
16	0	-12	50	38	-34	-30	44	-24
17	-51	-74	-23	-12	-62	-63	-76	-71
50	9	70	29	-105	274	275	167	503
51	71	23	-16	34	116	-16	-28	-11
52	-47	35	-29	21	-5	-16	-23	5
53	-64	-162	-31	-85	-31	-27	-35	-45
54	65	36	-7	-64	142	8	10	3
55	-188	-106	-29	-90	-39	-13	-71	-79
56	-208	-56	-	53	-	38	-	-25
57	-58	-62	-27	-66	-73	-28	-31	-48
58	-8	-42	-	118	-	-13	-	-43
59	49	146	-37	-28	-39	-117	-7	3
60	1	-42	-30	-16	25	52	-60	-21
Regression on Age								
	-0.8	-1.2	-0.6	-0.2	-0.5	-0.3	-0.7	-0.1

[a]Means and deviations expressed as micrograms of carotene per 100 milliliters of plasma.

Appendix 7. Least Squares Constant Estimates for Plasma Vitamin A.[a]

	Weaning		12 Month		20 Month		24 Month	
Effect	Male	Female	Male	Female	Male	Female	Male	Female
Mean								
	47.9	51.4	50.0	58.1	50.5	55.8	51.9	70.8
Year of birth								
1958	-6.12	-4.83	3.95	-9.88	-9.16	-7.13	-1.78	-22,14
1959	-5.58	-9.69	-4.64	-2.67	-11.50	-14.49	-3.56	-8.86
1960	-7.60	-7.35	2.67	2.02	-1.68	-6.73	-3.06	-11.04
1961	-6.05	-4.83	-16.76	-14.20	13.77	23.28	19.83	29.97
1962	25.35	26.70	14.78	24.73	8.57	5.07	-11.43	12.07
Age of dam								
3 years	1.31	-0.43	-	-	-	-	-	-
4 years	-0.18	1.70	-	-	-	-	-	-
5 years	1.07	0.18	-	-	-	-	-	-
6 years	-1.60	1.18	-	-	-	-	-	-
7 years	-2.34	-0.43	-	-	-	-	-	-
8 years	3.24	-3.28	-	-	-	-	-	-
9 years	-1.28	1.59	-	-	-	-	-	-
10+ years	-0.22	-0.51	-	-	-	-	-	-
Sire								
2	0.06	-0.57	-1.86	2.37	-1.76	1.19	-2.08	5.56
3	2.55	4.56	7.29	4.25	4.64	-1.78	1.86	-5.04
4	4.66	0.98	2.94	1.61	4.94	0.16	2.79	2.93
5	7.12	-0.01	4.39	0.07	6.36	4.12	0.01	9.08
6	1.80	-1.41	-3.85	4.89	-1.27	2.74	-3.35	7.50
10	4.05	6.53	-3.56	7.26	-3.09	7.71	3.37	13.15
11	-0.95	-1.39	-0.19	-1.74	2.65	1.51	-4.00	-0.90
12	2.64	-0.33	2.86	-0.65	-1.91	1.25	3.22	9.53
13	0.08	-0.81	0.24	-0.66	-1.36	-2.56	-2.81	6.32
14	4.38	-0.16	-4.49	-2.91	-4.71	-5.42	-0.37	0.69
15	0.02	-1.86	4.49	-8.17	1.56	-0.18	-2.69	2.75
16	-2.06	-3.97	-4.25	1.33	-0.27	-3.59	3.53	5.26
17	-4.85	-0.68	-4.42	-5.74	-2.02	-3.14	-1.55	-10.47
50	0.38	-0.92	-9.91	-15.70	3.60	-0.36	-7.96	4.21
51	6.06	3.00	-1.84	0.69	2.91	-1.68	-2.23	2.85
52	-7.52	2.94	1.97	-0.63	-11.23	-1.06	2.80	-1.17
53	6.17	-2.63	-1.37	1.19	-15.12	-2.50	8.54	-0.18
54	-4.03	-6.48	3.34	0.64	-6.78	-12.75	-0.35	-12.29
55	-12.27	-12.47	-3.17	-11.42	-0.33	1.87	3.58	-3.89
56	-7.22	-2.39	-	-5.49	-	-4.91	-	-11.90
57	-4.85	-6.00	-1.99	1.74	3.61	11.95	-4.93	-0.75
58	2.55	7.79	-	12.05	-	3.51	-	-12.05
59	-0.81	9.22	3.87	8.97	22.17	0.68	-0.86	-13.63
60	2.04	7.06	9.51	6.05	-2.59	3.24	3.48	2.44
Regression on age								
	-0.07	-0.08	0.09	0.06	0.26	0.18	-0.04	0.00

[a]Means and deviations expressed as micrograms of vitamin A per 100 millliliters of plasma.

Appendix 8. Simple Correlations Among Plasma Carotene and Vitamin A Concentrations in Beef Cattle at Four Ages.[a]

	Weaning		12 Month		20 Month		24 Month	
	Carotene	Vitamin A	Carotene	Vitamin A	Carotene	Vitamin A	Carotene	Vitamin A
Weaning								
Carotene	--	0.44	0.40	0.30	-0.06	0.10	-0.07	-0.16
Vitamin A	0.50	--	0.13	0.25	0.09	0.20	-0.28	-0.10
12 Month								
Carotene	0.43	0.50	--	0.50	-0.30	-0.04	0.10	-0.14
Vitamin A	0.35	0.58	0.66	--	-0.16	0.02	-0.23	-0.32
20 Month								
Carotene	-0.09	-0.11	-0.03	-0.09	--	0.32	-0.17	0.14
Vitamin A	0.03	0.13	-0.06	0.04	0.40	--	-0.28	0.17
24 Month								
Carotene	-0.20	-0.57	-0.38	-0.47	0.43	0.05	--	0.32
Vitamin A	-0.08	0.11	-0.08	-0.05	0.48	0.46	0.11	--

[a]Correlations for males above diagonal; for females below diagonal.

Appendix 9. Simple Correlations of Plasma Carotene and Vitamin A Concentrations in Beef Cattle at Four Ages With Contemporary and Subsequent Growth Traits.

		Weaning		12 Month		20 Month		24 Month	
	Sex	Carotene	Vitamin A	Carotene	Vitamin A	Carotene	Vitamin A	Carotene	Vitamin A
Weaning									
Weight	M	0.13	-0.07	--	--	--	--	--	--
	F	0.04	-0.14	--	--	--	--	--	--
Condition	M	0.23	-0.11	--	--	--	--	--	--
	F	0.22	-0.07	--	--	--	--	--	--
12 Month									
Weight	M	0.36	0.05	0.19	0.26	--	--	--	--
	F	0.22	0.01	0.04	0.10	--	--	--	--
Condition	M	0.15	0.00	0.39	0.20	--	--	--	--
	F	0.08	-0.11	0.03	-0.05	--	--	--	--
Daily Gain									
Wn-12 mo.	M	0.32	0.12	0.57	0.27	--	--	--	--
	F	0.32	0.27	0.25	0.24	--	--	--	--
20 Month									
Weight	M	-0.16	0.02	-0.34	-0.20	0.44	0.36	--	--
	F	0.00	0.03	-0.04	-0.02	0.09	0.24	--	--
Condition	M	-0.15	-0.07	-0.42	-0.21	0.62	0.28	--	--
	F	-0.16	-0.12	0.04	0.01	0.37	0.01	--	--
Daily Gain									
12-20 mo.	M	-0.42	0.01	-0.49	-0.36	0.56	0.26	--	--
	F	-0.17	0.12	-0.01	-0.03	0.14	0.25	--	--
24 Month									
Weight	M	-0.21	-0.02	-0.23	-0.14	0.18	0.13	0.03	0.17
	F	-0.15	0.00	-0.08	-0.02	0.40	0.25	0.14	0.35
Condition	M	-0.23	-0.35	-0.05	-0.33	-0.23	-0.14	0.63	0.31
	F	-0.46	-0.32	-0.37	-0.35	0.34	0.16	0.41	0.25
Daily Gain									
20-24 mo.	M	0.03	0.06	0.27	0.18	-0.47	-0.41	0.29	-0.20
	F	-0.19	-0.03	0.00	0.03	0.47	0.08	0.25	0.26

Appendix 10. Genetic Correlations Among Plasma Carotene and Vitamin A Concentrations in Beef Cattle at Four Ages and Between These Concentrations and Contemporary and Subsequent Growth Traits.[a]

	Male		Female	
	Genetic Correlation	Standard Error	Genetic Correlation	Standard Error
Weaning plasma carotene with				
12 month plasma carotene	0.689	0.413	0.626	0.317
20 month plasma carotene	0.969	0.161	--	--
24 month plasma carotene	0.580	0.293	0.785	0.359
Weaning plasma vitamin A	0.764	0.206	--	--
12 month plasma vitamin A	--	--	0.864	0.364
20 month weight	-0.403	0.380	--	--
Weaning condition	0.403	0.295	--	--
20 month condition	0.629	0.513	--	--
24 month condition	1.249	0.636	0.511	0.375
Daily gain - 20 to 24 months	1.151	0.959	--	--
12 month plasma carotene with				
20 month plasma carotene	0.490	0.467	--	--
24 month plasma carotene	--	--	0.491	0.357
Weaning plasma vitamin A	--	--	0.888	0.352
12 month plasma vitamin A	--	--	0.826	0.325
Daily gain - weaning to 12 mo.	--	--	0.948	0.452
Daily gain - 20 to 24 months	--	--	-0.720	0.327
20 month plasma carotene with				
24 month plasma carotene	0.898	0.152	1.178	0.232
Weaning plasma vitamin A	0.764	0.538	-0.542	0.494
24 month plasma vitamin A	--	--	1.419	1.283
20 month weight	-0.561	0.275	--	--
24 month weight	-0.372	0.262	--	--
20 month condition	--	--	0.417	0.372
24 month condition	0.957	0.529	--	--
Daily gain - 12 to 20 months	-0.503	0.324	--	--
24 month plasma carotene with				
24 month weight	-0.547	0.283	0.680	0.291
24 month condition	--	--	0.405	0.376

Appendix 10. (continued)

	Male		Female	
	Genetic Correlation	Standard Error	Genetic Correlation	Standard Error
Weaning plasma vitamin A with				
12 month plasma vitamin A	--	--	1.170	0.366
Daily gain - weaning to 12 mo.	--	--	0.762	0.483
12 month plasma vitamin A with				
12 month weight	--	--	-0.546	0.396
24 month condition	--	--	0.475	0.471
Daily gain - weaning to 12 mo.	--	--	-0.560	0.539
20 month plasma vitamin A with				
24 month weight	-0.395	0.380	--	--
24 month condition	-0.849	0.666	--	--
24 month plasma vitamin A with				
24 month condition	--	--	1.331	1.262

[a]Only correlation estimates which exceeded their estimated standard errors are tabulated; others assumed to equal zero.

Appendix 11. Least Squares Constant Estimates for Hemoglobin.[a]

	Weaning		12 Month		20 Month		24 Month	
Effect	Male	Female	Male	Female	Male	Female	Male	Female
Mean								
	14.2	14.6	11.7	12.2	13.0	14.2	11.7	14.1
Year of birth								
1958	0.98	0.70	0.81	2.00	0.49	0.93	-0.26	-1.18
1959	-0.90	-0.33	-0.65	0.26	-1.10	-1.26	3.92	6.15
1960	-0.66	-0.81	2.22	0.31	0.90	0.99	-1.11	-0.07
1961	1.35	1.11	-0.65	-0.13	-0.74	-0.59	-2.04	-2.46
1962	-0.77	-0.66	-1.73	-2.44	0.45	-0.07	-0.51	-2.44
Age of dam								
3 years	-0.12	-0.06	-	-	-	-	-	-
4 years	-0.10	0.01	-	-	-	-	-	-
5 years	-0.01	0.14	-	-	-	-	-	-
6 years	-0.09	-0.07	-	-	-	-	-	-
7 years	-0.18	-0.16	-	-	-	-	-	-
8 years	0.24	0.12	-	-	-	-	-	-
9 years	0.21	-0.07	-	-	-	-	-	-
10+ years	0.05	0.08	-	-	-	-	-	-
Sire								
2	-0.17	0.48	-0.28	-0.13	-0.25	-0.09	0.59	-0.13
3	0.39	0.44	1.14	0.49	-0.72	0.31	0.81	0.47
4	-0.14	-0.31	0.48	-0.79	-0.19	0.18	0.59	0.22
5	0.34	0.20	0.62	0.54	0.65	0.27	0.65	0.96
6	-0.24	-0.37	0.20	-0.19	-0.11	0.17	0.49	0.46
10	0.29	-0.08	0.17	-0.13	0.20	-0.01	1.02	0.30
11	0.60	0.67	0.38	0.60	0.73	0.17	1.11	0.32
12	0.40	0.39	0.41	0.19	-0.27	-0.13	1.39	0.16
13	0.37	0.19	0.03	0.27	0.35	0.01	0.44	-0.32
14	0.11	0.39	-0.49	-0.27	0.02	0.55	0.78	0.10
15	0.33	0.14	0.54	0.78	-0.34	0.09	1.36	0.22
16	-0.57	-0.16	-1.05	-0.26	-0.37	-0.49	-0.34	-0.85
17	0.03	0.33	0.42	-0.20	-0.11	0.27	-0.54	0.55
50	-0.59	-0.92	-0.64	-0.82	-0.05	-0.83	-3.00	0.53
51	-0.43	-0.49	-0.26	-0.16	-0.97	-0.42	-1.09	-0.65
52	0.32	-0.41	-0.75	0.20	0.57	-1.42	-1.70	0.16
53	0.01	0.69	0.10	0.78	1.63	0.85	-0.23	1.03
54	-0.04	-0.04	-0.67	0.10	-0.02	0.19	-0.18	-0.14
55	1.00	-1.07	-0.26	-0.11	0.20	-2.00	-0.65	0.23
56	-1.10	-0.32	-	0.23	-	1.16	-	-0.99
57	-0.44	0.57	0.45	0.14	0.28	-1.05	-0.99	-1.46
58	-0.06	-0.36	-	-0.71	-	0.45	-	-0.13
59	0.17	0.57	0.06	0.64	0.13	1.55	-0.70	0.05
60	-0.59	-0.53	-0.60	-1.19	-1.36	0.04	0.19	-1.09
Regression on age								
	-0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00

[a]Means and deviations expressed as grams of hemoglobin per 100 milliliters of blood.

Appendix 12. Simple Correlations Among Hemoglobin Concentrations in Beef Cattle at Four Ages.[a]

	Weaning	12 Month	20 Month	24 Month
Weaning	--	0.16	0.08	-0.14
12 Month	0.29	--	0.27	0.01
20 Month	0.09	0.21	--	-0.04
24 Month	-0.03	0.22	-0.01	--

[a]Correlations for males above diagonal; for females below diagonal.

Appendix 13. Simple Correlations of Hemoglobin Concentrations in Beef Cattle at Four Ages with Contemporary and Subsequent Growth Traits.

	Weaning		12 Months		20 Months		24 Months	
	Male	Female	Male	Female	Male	Female	Male	Female
Weaning								
Weight	-0.20	0.03	--	--	--	--	--	--
Condition	0.17	0.11	--	--	--	--	--	--
12 Month								
Weight	-0.08	-0.04	0.18	0.06	--	--	--	--
Condition	0.20	0.09	0.16	0.30	--	--	--	--
Daily Gain								
Wn.-12 mo.	0.21	-0.11	0.23	0.04	--	--	--	--
20 Month								
Weight	-0.01	0.06	-0.21	-0.02	-0.17	0.04	--	--
Condition	-0.23	-0.07	-0.11	-0.08	-0.14	-0.12	--	--
Daily Gain								
12-20 mo.	0.04	0.10	-0.34	-0.15	-0.34	-0.12	--	--
24 Month								
Weight	0.11	0.03	-0.16	-0.15	-0.16	-0.14	0.09	0.10
Condition	0.44	0.30	0.21	0.14	-0.09	-0.20	0.10	0.47
Daily Gain								
20-24 mo.	0.09	-0.07	0.10	-0.24	0.10	-0.28	0.30	0.26

Appendix 14. Genetic Correlations Among Hemoglobin Concentrations in Beef Cattle at Four Ages and Between These Concentrations and Contemporary and Subsequent Growth Traits.[a]

	Male		Female	
	Genetic Correlation	Standard Error	Genetic Correlation	Standard Error
Weaning hemoglobin with				
12 month hemoglobin	--	--	1.368	0.478
20 month hemoglobin	--	--	0.811	0.323
24 month hemoglobin	1.497	0.749	--	--
Weaning weight	--	--	-0.532	0.301
12 month weight	-0.794	0.718	-0.391	0.353
20 month weight	--	--	-0.686	0.335
24 month weight	--	--	-0.532	0.313
Weaning condition	0.549	0.318	--	--
20 month condition	1.056	0.680	--	--
Daily gain - 12 to 20 months	--	--	-0.845	0.339
Daily gain - 20 to 24 months	1.348	0.997	--	--
12 month hemoglobin with				
24 month hemoglobin	1.399	0.795	0.703	0.455
20 month weight	-0.718	0.604	--	--
24 month weight	-0.761	0.480	--	--
Daily gain - 12 to 20 months	-0.731	0.658	-0.550	0.360
20 month hemoglobin with				
24 month hemoglobin	--	--	0.570	0.316
24 month weight	-0.435	0.342	--	--
Daily gain - 20 to 24 months	-1.238	0.815	0.413	0.365
24 month condition	--	--	0.339	0.332
24 month hemoglobin with				
24 month condition	-0.910	0.753	0.748	0.280
Daily gain - 20 to 24 months	1.163	0.791	0.520	0.393

[a]Only correlation estimates which exceeded their estimated standard errors are tabulated; others assumed to equal zero.

Appendix 15. Least Squares Constant Estimates for Plasma Phosphorus.[a]

	Weaning		12 Month		20 Month		24 Month	
Effect	Male	Female	Male	Female	Male	Female	Male	Female
Mean								
	6.31	6.52	6.85	6.99	5.62	5.55	5.62	5.79
Year of birth								
1958	0.86	0.65	-0.33	-1.16	-0.48	0.13	-0.55	-1.14
1959	-0.71	-0.50	0.25	-1.10	-0.26	-0.27	0.97	-0.07
1960	-0.17	-0.29	0.19	0.33	0.76	0.56	-0.58	0.67
1961	0.02	0.14	-0.11	1.93	-0.02	-0.42	0.16	0.54
Age of dam								
3 years	-0.12	-0.07	-	-	-	-	-	-
4 years	0.37	0.00	-	-	-	-	-	-
5 years	-0.14	-0.15	-	-	-	-	-	-
6 years	0.06	-0.06	-	-	-	-	-	-
7 years	0.35	0.14	-	-	-	-	-	-
8 years	0.05	-0.16	-	-	-	-	-	-
9 years	-0.27	0.46	-	-	-	-	-	-
10+ years	-0.30	-0.16	-	-	-	-	-	-
Sire								
2	-0.36	-0.37	0.06	-0.63	-0.02	0.32	-0.35	-0.29
3	0.07	0.27	0.09	0.08	-0.25	0.07	-0.25	-0.19
4	0.05	-0.08	-0.49	0.19	-0.02	-0.62	-0.46	0.14
5	0.13	-0.26	-0.19	0.00	-0.18	0.40	0.12	-0.32
6	-0.19	-0.37	0.48	-0.25	0.68	-0.11	-0.25	0.04
10	-0.81	-0.37	-0.95	-0.32	-0.25	0.05	0.81	-0.23
11	-0.20	0.01	-0.31	-0.48	-0.24	-0.51	-0.30	-0.35
12	0.28	0.55	0.26	-0.18	0.26	0.18	0.12	0.33
13	0.56	0.54	0.17	0.57	0.91	0.14	-0.59	0.63
14	-0.05	0.11	-0.20	0.23	0.37	0.17	1.09	0.15
15	0.03	0.11	0.51	-0.13	0.13	-0.17	0.36	0.67
16	0.03	-0.13	-0.27	-0.28	-0.50	-0.41	0.67	0.01
17	0.31	-0.36	0.87	-0.03	0.04	0.33	-0.60	0.12
50	-0.23	-0.33	-1.21	0.39	-1.14	-0.35	-1.78	-0.84
51	0.38	0.68	1.19	0.85	0.21	0.51	1.41	0.13
Regression on age								
	-0.01	-0.02	0.00	0.01	0.01	-0.01	0.00	0.00

[a]Means and deviations expressed as milligrams of phosphorus per 100 milliliters of plasma.

Appendix 16. Simple Correlations Among Plasma Phosphorus Concentration in Beef Cattle at Four Ages.[a]

	Weaning	12 Month	20 Month	24 Month
Weaning	--	0.03	-0.02	-0.13
12 Month	0.01	--	0.19	0.13
20 Month	0.04	-0.05	--	0.00
24 Month	0.02	0.31	0.10	--

[a]Correlations for males above diagonal; for females below diagonal.

Appendix 17. Simple Correlations of Plasma Phosphorus Concentrations in Beef Cattle at Four Ages With Contemporary and Subsequent Growth Traits.

	Weaning		12 Month		20 Month		24 Month	
	Male	Female	Male	Female	Male	Female	Male	Female
Weaning								
Weight	-0.11	-0.13	--	--	--	--	--	--
Condition	0.07	0.00	--	--	--	--	--	--
12 Month								
Weight	0.07	-0.07	-0.02	0.04	--	--	--	--
Condition	0.29	0.09	-0.13	-0.41	--	--	--	--
Daily Gain								
Wn.-12 mo.	0.28	0.08	-0.04	-0.33	--	--	--	--
20 Month								
Weight	-0.07	-0.02	0.05	0.16	0.13	0.01	--	--
Condition	-0.18	-0.15	0.15	0.16	0.16	0.05	--	--
Daily Gain								
12-20 mo.	-0.11	0.02	0.04	0.13	-0.01	-0.02	--	--
24 Month								
Weight	-0.05	-0.13	0.05	0.39	-0.05	-0.05	0.25	0.22
Condition	0.23	-0.01	0.01	0.22	-0.17	-0.13	0.06	0.10
Daily Gain								
20-24 mo.	0.10	-0.19	-0.15	0.29	-0.31	-0.06	-0.10	0.36

Appendix 18. Genetic Correlations Among Plasma Phosphorus Concentrations in Beef Cattle at Four Ages and Between These Concentrations and Contemporary and Subsequent Growth Traits.

	Male		Female	
	Genetic Correlation	Standard Error	Genetic Correlation	Standard Error
Weaning plasma phosphorus with				
12 month plasma phosphorus	1.171	0.628	--	--
20 month plasma phosphorus	1.219	0.605	--	--
20 month weight	0.481	0.441	--	--
Weaning condition	--	--	1.267	0.952
20 month condition	0.972	0.377	--	--
Daily gain - weaning to 12 mo.	0.985	0.677	--	--
12 month plasma phosphorus with				
20 month plasma phosphorus	0.744	0.607	--	--
20 month weight	0.606	0.461	--	--
24 month weight	1.462	1.179	--	--
20 month condition	0.609	0.537	0.725	0.669
24 month condition	--	--	-0.606	0.498
Daily gain - weaning to 12 mo.	0.833	0.778	--	--
Daily gain - 12 to 20 months	0.731	0.506	--	--
Daily gain - 20 to 24 months	--	--	-1.098	0.527
20 month plasma phosphorus with				
20 month condition	0.813	0.584	--	--
24 month plasma phosphorus with				
24 month weight	0.753	0.274	--	--

[a]Only correlation estimates which exceeded their estimated standard errors are tabulated; others assumed to equal zero.

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