

FRENATAL VISCERAL GROWTH

by

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Study I
PRENATAL VISCERAL GROWTH
Introduction

Quantitative data on postnatal visceral growth have been documented for the human, cow, horse and dog by Brody (1945) and Altman and Dittmer (1962). With the exception of the human, such documentation on prenatal visceral growth is lacking.

Jackson (1909) described prenatal visceral growth in the human from approximately two to nine months gestation by expressing organ volumes as a per cent of body volume. On the average, Jackson (1909) found organs were heavier in females than in males. The organs reported included the brain, heart, liver, spleen, suprarenals, thymus, lungs and kidneys. The last three were heavier in the male.

Borovansky (1930) reported a tabulation of monthly averages of organ weights and their expression as a per cent of the body weight for the fourth through tenth months of the fetal period.

Noback (1925) described growth of the lungs during the fetal period as being steady and constant in linear dimensions.

The linear growth of the gastro-intestinal tract of the human fetus was described by Scammon and Kittelson (1927).

Wald and Scammon (1932) found the relationship between increase in testicular and body weights during the human fetal period to be comparable, but attempts to analyze ovary weights were inconclusive.

Cole et al. (1933) noted development of fetal gonads of the horse were parallel in both sexes and usually exceeded maternal ovary weight at approximately 180 days.

The presentation of normal prenatal visceral growth trends for the human, dog, cow and horse from accurately aged materials is of importance in teratological studies. The data also enables mathematical and statistical analyses of visceral growth.

MATERIALS AND METHODS

The fetuses from which visceral data were taken were obtained from the following sources:

Approximately 50% of the cow fetuses were obtained from the Kansas State University dairy herd containing cows of the Ayrshire, Guernsey, Jersey and Holstein breeds. Fetal age was determined to \pm 12 hours post ovulation by breeding records. Most of the remaining fetuses were obtained from Armour and Co. and Rodeo packing plants in Kansas City, Missouri. These fetuses were aged by growth charts developed at Kansas State University (Preston, 1969).

The horse fetuses were obtained from three sources: (1) Department of Veterinary Science, University of Kentucky, Lexington, Kentucky; (2) The Hill Packing Co., Topeka, Kansas; and (3) Veterinary Clinic, Kansas State University, Manhattan, Kansas. The majority of the fetuses were of known age and from mares weighing approximately 1,000 pounds. When the age of a fetus was not known, it was determined to \pm 5 days gestation by growth charts (Bergin, 1968).

Dog fetuses were obtained from a dog colony maintained for reproductive studies at Kansas State University. All fetuses were of known age determined by breeding records to ± 1 day post ovulation. Fetuses were removed by Ceaserean from bitches weighing between 20 and 40 pounds.

Human fetuses were obtained from a collection which had been accumulated in the Kansas State University Division of Biology over the past 25 years. The visceral data collected were supplemented by data reported by Jackson (1909) and Borovansky (1930). All fetuses from which these data were taken were aged according to adjusted versions of Streeter's (1921) growth curves. The adjustment was made by subtracting 2 weeks from the menstrual age given in order to approximate the conceptional age of the fetuses.

There were approximately 125 cow, 50 horse, 35 dog and 40 human fetuses used in this study.

The visceral data were collected by the following procedures. Most fetuses were dissected within 12 hours after being obtained and were refrigerated during that lapse of time. Others had been preserved in 10% buffered formalin prior to dissection.

Organs were removed from the fetuses, wiped free of excess fluid, and measured and weighed. Kilogramatic scales were used to determine weights greater than 2 grams, and a Mettler analytical balance determined weights less than 2 grams. The combined weight was recorded for the paired organs.

Measurements were taken by the use of vernier calipers calibrated to 0.1 mm. For larger organs a millimeter rule was used.

The liver was removed and the blood vessels were trimmed close to the surface. The spleen was excised and trimmed closely at the hilus. The stomach was dissected from the mesenteries and removed by cutting distal to the cardiac and pyloric sphincters. The intestinal mass included both the large and small intestines, dissected free from all mesenteries. The thymus was dissected free from surrounding adventitia and removed. The kidneys were removed and dissected free from surrounding fatty tissues. The arteries, veins and ureters were trimmed at the hilus. The adrenals were trimmed free of vascular and connective tissue after removal. The testes were severed from the vas deferentia and epididymides. The ovaries were freed from the oviducal funnel or bursa and excised at the hilus. The lungs were dissected free from the trachea and bronchi. The heart was removed by severing the blood vessels at their points of emergence. The pericardium and blood were then removed from the heart. The brain was removed from the cranium by severing at the spinal cord and freeing from the meninges.

Raw data plots of the visceral weights were made on semi-logarithmic paper (Figs. 1-4).

Points were determined by letting the vertical axis represent the organ weight at a given fetal age, represented on the horizontal axis. The free hand method of curve fitting was then employed.

RESULTS AND DISCUSSION

Organs of the four species studied exhibited characteristic

prenatal growth curves. Weight increased rather sharply at first but tapered off near parturition. The liver, brain, heart and kidneys were chosen to establish general characteristics of visceral growth trends in each species. Similarities and differences in trends between species will be indicated.

Before a discussion of growth trends can be meaningful, sources of variation in the data must be recognized. Preservation in formalin decreases weights and measurements of organs from their original condition (Schultz, 1919). For study, the data were collected from both preserved and unpreserved specimens. This source of variation was common to all species.

Breed differences in the dog, horse and cow were also a factor contributing to variation. Its effects were most apparent for body weight in later stages of the cow and horse and possibly a factor for a greater part of the gestation period of the dog. Pups in large litters are generally smaller than pups from small litters. Weight of the bitch also contributes variation to size of the pups. Although the bitches used in this study were between 20 and 40 pounds, a 40 pound bitch weighs 100% more than a 20 pound bitch, a difference reflected in the pup size and hence in organ weight. A 100 pound difference in weight between mares or cows is not nearly as critical as a 20 pound difference in bitches.

When making interspecies comparisons, one must also be aware of the differences between a chronologic time unit and a physiologic time unit, and their significance in the life of different organisms (Brody, 1937). Another factor which must be considered

is that the cow and horse are born at a later stage of development than the human and dog, making direct correlation and their growth trends difficult.

Growth data for the heart, brain, liver and kidneys are illustrated for the species studied (Figs. 1-4). All curves indicate a rather rapid growth rate at first with a general reduction during the last third of the gestation period.

The liver remained the heaviest organ throughout the period of study in the dog and horse. In the cow this was true only for the last three-fourths of gestation. In the human, however, the liver weight was less than the brain weight for the entire prenatal period. In dogs, cows and horses the brain was the second heaviest organ through most of gestation. For these species, the growth rate of the brain tapered off considerably near the end of gestation, but in the human its weight continues to increase steadily to birth. Through most of the fetal period, all species studied exhibited similarities in weight increase of the heart and kidneys. The growth curves of the heart and kidneys crossed once in the dog near the end of the fetal period with the kidneys attaining the greater final weight. A similar pattern existed in the cow but the heart weight and growth rate exceeded that of the kidneys near parturition. The heart and kidneys of the horse showed a similar trend to that of the cow near parturition, but the two growth curves had already crossed much earlier in gestation.

The results of this study indicated that the accumulated data exhibited normal growth curves. The results also indicated

that variations were not of such magnitude as to interfere with applicability of the derived growth curves to teratological studies, aging and mathematical analyses.

Study II
ANALYSIS OF PRENATAL VISCERAL GROWTH

Introduction

There have been many attempts to fit mathematical equations to pre- and postnatal growth data. Pearl and Reed (1920, 1923) were among the first to describe a biological application of the logistic equation in discussion of human population growth. Winsor (1932) discussed the properties of the logistic and Gompertz equations that make them useful in representing growth relationships.

A form of the Gompertz equation relevant to approximating embryonic and postnatal growth was reported by Laird et al. (1965). Application of this model is relative to the proportional decay with time of the specific growth rate. They also reported that the Gompertz equation offered a more economical description of the continuous exponential decay of the specific growth rate with time than does the logistic curve.

von Bertalanffy (1938) described a mathematical model for growth based on the concept that growth is the result of catabolic effects per unit of weight and time, which are less than anabolic effects per unit of surface and time. These entities are represented in his equation by constants which can be calculated. Fabens (1965) discussed the mathematical properties of the equation and presented a computer program for fitting the curve. Ricklef (1967) suggested a method by which transformed growth data could be fit to the von Bertalanffy, Gompertz and

logistic equations and a means of selecting one as best representing the specific growth process.

Roberts (1906) advanced the idea that a linear relationship exists between fetal age and the cube root of the fetal weight. Modifications and additions to the basic cube root model have improved its accuracy. Huggett and Widdas (1951) stated that the cube root relationship could not be made to fit when the age of the fetus was measured from conception. They suggested subtracting a constant from the fetal age to obtain a more precise representation of fetal growth throughout a substantial part of the gestation period. Spencer (1964) combined the relationships that fetal weight varies as the cube of the fetal length, and the linear correlation between fetal length and gestational age into a weight-age relationship. The resulting equation relates fetal weight to time of gestation. Spencer and Coulombe (1965) performed a transformation on fetal weight and gestational age, expressing each as a fraction of the maximum values for the purpose of interspecies comparisons.

Huxley (1932) demonstrated the wide applicability of the allometric equation in estimating relative growth rates of the parts of an organism. If a linear relationship exists between the \log_{10} of the parts or between the \log_{10} of a part and the \log_{10} of the whole organism, then an allometric relationship exists. This relationship implies that the specific growth rate ratio of any two parts being compared is constant for that growth period (Huxley, 1950). Laird et al. (1968) discussed allometry and its mathematical relation to the modified Gompertz equation.

They concluded that slope of the allometric line could be used to determine the age differential between two growth processes being compared. Bernardis and Skeleton (1964) employed allometric analysis to note differences in magnitude of the growth rate ratios (slope) between organs of weanling rats undergoing adrenal regeneration and controls.

MacDowell et al. (1927) stated that a linear relationship exists for the mouse, guinea pig and chick between the logarithms of weight and age only when age is taken from the appearance of the embryo proper. This age is known as embryo age as opposed to conceptional age.

The purposes of this present study are: (1) test the applicability of a few of the previously described growth models to prenatal visceral growth in the dog, human, horse and cow, and (2) present other mathematical models which have been found useful in analyzing and describing growth processes.

MATERIALS AND METHODS

Mathematical models were employed to estimate growth relationships between organs and gestational age and between two different organs of the same animal by the use of data collected on the viscera of the cow, horse, human and dog (Study I).

$$(1) \text{Log}_{10}Y = \alpha + \beta_1x + \beta_2x^2 + \dots + \beta_nx^n$$

was a model employed where Y is organ weight, x is fetal age in days and α and β are growth parameters to be estimated empirically by the method of least squares. This formula was employed through the fourth degree.

Of the four polynomial models used in fitting a set of viscus data, one was selected as the best on the basis of significant β coefficients ($p < .01$). For each of the polynomials the R^2 and variance ($S^2_{y,x}$) were calculated.

$$S^2_{y,x} = \frac{n}{n-k} \sum_{i=1}^n (Y_o - \hat{Y})^2$$

where Y_o is observed organ weight for a given fetal age, \hat{Y} is estimated organ weight by a given equation for that same fetal age, n is the total number of observations and k is the number of parameters estimated.

The non linear regression model (Huxley, 1932):

$$(2) Y = \alpha x^\beta$$

where Y is organ weight in grams, x is fetal age in days and α and β are parameters is mathematically equal to:

$$(3) \text{Log}_{10} Y = \text{Log}_{10} \alpha + \beta \text{Log}_{10} x$$

whose parameters can be estimated by linear regression least squares method.

Zar (1968) emphasized that although equations (2) and (3) are mathematically equivalent, they are not statistically equivalent for least squares solutions.

Both equations (2) and (3) along with the best fitting polynomial equation were tested in estimating growth and fetal age relationships on all sets of viscus data.

The R^2 and $S^2_{y,x}$ were calculated. One model was selected as best fitting a particular set of data on the basis of having the largest R^2 of all models considered.

The allometric equation described by Huxley (1932, 1950) was

used to gain insight into growth rate relationships between organs and between organs and the organism. A form of this equation: $\text{Log}_{10}Y = \text{Log}_{10}\alpha + \beta\text{Log}_{10}x$ where Y is the total body or an organ weight, x is any other organ weight of the same animal and α and β are constants was used for a series of allometric comparisons.

For each species a total of 66 comparisons of weight data were made between all possible combinations of organs, and organ and organism.

The equations were fit by the method of least squares. R^2 s were determined and their significance was tested ($p < .01$) to establish the existence of a linear relationship. If a linear relationship exists between the respective logs of the weights, the ratio of the two growth rates being compared is constant throughout the growth period (Lumer, 1937).

It has been documented (Laird et al., 1965 and Laird, 1965) that fetal growth rates are related to fetal age and undergo constant decrease throughout the gestation period.

Empirical estimates of visceral growth rates were made. Growth rates were estimated as follows:

The following relationship defines r, the growth rate:

$$dy/dx = rY,$$

where dy is the change in weight for a given change in time (dx), and Y is weight.

Solving for r, we obtain

$$r = dy/Ydx,$$

which is equivalent to

$$r = d\text{Log}_{e}y/dx.$$

We know that the data is fit by the model

$$\text{Log}_{10}Y = \alpha + \beta_1x + \beta_2x^2 + \beta_3x^3 + \dots + \beta_nx^n,$$

where Y is organ weight, x is fetal age in days, and α and β are constants. Therefore,

$$d\text{Log}_{e}y/dx = 0 + \beta_1 + 2\beta_2x + 3\beta_3x^2 + \dots + n\beta_nx^{n-1} / .434$$

so that

$$r = \beta_1 + 2\beta_2x + 3\beta_3x^2 + \dots + n\beta_nx^{n-1} / .434.$$

For each species and set of viscus data, previously calculated values for the best fitting polynomial equations were substituted into the above equation. Growth rates for human, dog, cow and horse organs were calculated for $2\frac{1}{2}\%$ intervals of their gestation.

All calculations were done on an IBM 360/50 digital computer. The computer time was granted by the Division of Biology from allocations given to the College of Arts and Sciences, Kansas State University, Manhattan, Kansas. Computer programs were obtained from the IBM Scientific Subroutine Package for calculations dealing with equations (1) and (3). The program for equation (2) was obtained from correspondence with Dr. J. H. Zar, Department of Biological Science, Northern Illinois University, De Kalb, Illinois. The programs for the allometric comparisons and the viscus growth rate determination were developed in this laboratory.

RESULTS AND DISCUSSION

The equations (1) $\text{Log}_{10}Y = \alpha + \beta_1x + \beta_2x^2 + \dots + \beta_nx^n$, (2) $Y = \alpha x^\beta$ and (3) $\text{Log}_{10}Y = \text{Log}_{10}\alpha + \beta \text{Log}_{10}x$ have shown applicability in fitting prenatal visceral growth data. The four polynomial models, represented generally by equation (1), were fit to sets of viscus data. One was selected as the best on the basis of significant β coefficients. A summary of the polynomial models accepted for each species and organ are presented in Table I. The testes and ovaries data were fit individually and then pooled and fit as a group, labelled "gonads". The model $\text{Log}_{10}Y = \alpha + \beta_1x$ did not gain acceptance as best fitting for any organs of the bovids or equids. The quadratic model fit more organs of the canids than did any other. The cubic curve fit most organs in the human, horse and cow. The quartic curve fit more organs of the horse than it did other species organs and was not found best fitting for any organs of the dog. Without consideration of species, the cubic equation fit the greatest number of organs, followed by the quadratic. The model $\text{Log}_{10}Y = \alpha + \beta_1x$ fit the least number of organs.

The α and β parameter estimates for the four polynomial models fit to each organ of the four species are recorded in Appendix Table V. The R^2 and $S^2_{y,x}$ for the above have been noted in Appendix Table VI. In most cases, a high positive correlation existed between the best fitting calculated polynomial curve and the observed values. This is shown by R^2 values in Table II.

Plots of raw data and best fitting calculated polynomial curves were made for the heart and brain of the four species stud-

TABLE I. Summary of polynomials accepted.

	<u>Human</u>	<u>Horse</u>	<u>Cow</u>	<u>Dog</u>
$\text{Log}_{10} Y = \alpha + \beta_1 X$	testes	none	none	testes ovaries
$\text{Log}_{10} Y = \alpha + \beta_1 X + \beta_2 X^2$	stomach thymus ovaries gonads	thymus adrenals	thymus gonads heart	liver spleen intestine thymus kidneys lungs heart
$\text{Log}_{10} Y = \alpha + \beta_1 X + \beta_2 X^2 + \beta_3 X^3$	liver intestine adrenals heart brain	liver spleen stomach gonads testes ovaries heart	spleen stomach intestine kidneys adrenals testes ovaries lungs brain	stomach adrenals gonads brain
$\text{Log}_{10} Y = \alpha + \beta_1 X + \beta_2 X^2 + \beta_3 X^3 + \beta_4 X^4$	spleen kidneys lungs	intestine kidneys lungs brain	liver	none

TABLE II. R² and variance (S²y.x) and number of observations (N) for each of the equations.

	Accepted Polynomial		Log-Log Transformation		Power Function		
	R ²	S ² y.x	R ²	S ² y.x	R ²	S ² y.x	N
<u>LIVER</u>							
Dog	.906	1.46 x 10 ¹	.854	4.39 x 10 ¹	.734	4.20 x 10 ¹	28
Human	.965	1.02 x 10 ²	.934	5.35 x 10 ²			38
Horse	.979	1.91 x 10 ⁴	.961	7.42 x 10 ⁴	.869	1.98 x 10 ⁴	44
Cow	1.000	1.32 x 10 ⁴	.964	4.98 x 10 ⁴	.873	2.10 x 10 ⁴	127
<u>SPLEEN</u>							
Dog	.821	1.40 x 10 ⁻¹	.669	4.41 x 10 ⁻¹	.295	4.16 x 10 ⁻¹	25
Human	.941	2.24 x 10 ⁻¹	.908	3.80 x 10 ⁻¹			28
Horse	.989	1.88 x 10 ²	.986	5.65 x 10 ²			39
Cow	.972	2.33 x 10 ²	.940	4.75 x 10 ³	.000	2.35 x 10 ³	121
<u>STOMACH</u>							
Dog	.828	5.72 x 10 ⁰	.790	5.71 x 10 ⁰	.183	5.71 x 10 ⁰	29
Human	.883	8.46 x 10 ⁻¹	.871	2.19 x 10 ⁻¹	.669	1.23 x 10 ⁰	32
Horse	.977	4.92 x 10 ¹	.973	1.16 x 10 ²			43
Cow	.978	1.58 x 10 ⁵	.962	1.63 x 10 ³	.869	4.56 x 10 ³	122
<u>INTESTINE</u>							
Dog	.942	1.66 x 10 ⁰	.923	7.72 x 10 ⁰	.771	4.57 x 10 ⁰	29
Human	.957	1.33 x 10 ¹	.933	2.05 x 10 ²			34
Horse	.962	2.08 x 10 ³	.907	1.81 x 10 ⁴	.110	1.60 x 10 ⁴	42
Cow	.960	1.07 x 10 ⁴	.959	1.39 x 10 ⁴	.857	1.13 x 10 ⁴	106

TABLE II (continued).

	Accepted Polynomial		Log-Log Transformation		Power Function		
	R ²	S ² y.x	R ²	S ² y.x	R ²	S ² y.x	N
<u>THYMUS</u>							
Dog	.850	1.51 x 10 ⁻¹	.745	4.13 x 10 ⁻¹	.400	4.06 x 10 ⁻¹	27
Human	.928	4.95 x 10 ⁰	.921	6.04 x 10 ⁰	.714	5.88 x 10 ⁰	28
Horse	.976	2.85 x 10 ²	.966	2.20 x 10 ²	.889	2.19 x 10 ²	32
Cow	.956	2.40 x 10 ³	.936	1.39 x 10 ⁴			125
<u>KIDNEYS</u>							
Dog	.913	5.74 x 10 ⁻¹	.882	1.41 x 10 ⁰	.658	1.35 x 10 ⁰	27
Human	.972	2.30 x 10 ⁰	.889	5.43 x 10 ¹			36
Horse	.975	5.40 x 10 ²	.941	6.20 x 10 ³	.230	1.72 x 10 ³	123
Cow	.982	6.80 x 10 ²	.962	4.25 x 10 ³	.757	1.35 x 10 ⁰	27
<u>ADRENALS</u>							
Dog	.702	1.86 x 10 ⁻⁴	.654	2.45 x 10 ⁻⁴			11
Human	.930	2.17 x 10 ⁻¹	.848	2.58 x 10 ⁰	.444	2.30 x 10 ⁰	35
Horse	.941	4.68 x 10 ⁻¹	.939	4.78 x 10 ⁻¹			35
Cow	.948	2.59 x 10 ⁻¹	.928	3.88 x 10 ⁻¹			103
<u>GONADS</u>							
Dog	.477	1.45 x 10 ⁻⁴	.297	2.04 x 10 ⁻⁴	.800	1.79 x 10 ⁻⁴	25
Human	.602	2.87 x 10 ⁻¹	.607	2.83 x 10 ⁻¹			92
Horse	.968	2.89 x 10 ⁰	.891	4.00 x 10 ⁰	.000	1.66 x 10 ⁰	46
Cow	.865	2.56 x 10 ⁰	.864	2.67 x 10 ⁰	.706	2.67 x 10 ⁰	80

TABLE II (continued).

	Accepted Polynomial		Log-Log Transformation		Power Function		
	R ²	S ² y.x	R ²	S ² y.x	R ²	S ² y.x	N
<u>TESTES</u>							
Dog	.233	7.44 x 10 ⁻⁵	.206	8.00 x 10 ⁻⁵	.848	7.13 x 10 ⁻⁵	15
Human	.615	4.93 x 10 ⁻¹	.632	5.28 x 10 ⁻¹			52
Horse	.966	1.12 x 10 ²	.874	3.83 x 10 ³	.000	1.24 x 10 ³	18
Cow	.925	2.76 x 10 ⁰	.917	1.30 x 10 ¹			45
<u>OVARIES</u>							
Dog	.704	1.47 x 10 ⁻⁴	.711	1.40 x 10 ⁻⁴			10
Human	.612	7.67 x 10 ⁻³	.592	2.08 x 10 ⁻²			40
Horse	.970	4.52 x 10 ²	.876	4.35 x 10 ³	.000	2.21 x 10 ³	26
Cow	.908	2.78 x 10 ⁻³	.887	1.64 x 10 ⁰			35
<u>LUNGS</u>							
Dog	.918	2.36 x 10 ⁰	.867	1.16 x 10 ¹	.557	9.21 x 10 ⁰	31
Human	.971	6.40 x 10 ⁴	.896	3.10 x 10 ⁵	.010	1.88 x 10 ²	37
Horse	.983	1.59 x 10 ⁴	.959	1.84 x 10 ⁴	.261	1.41 x 10 ⁵	43
Cow	.982	2.17 x 10 ⁴	.971	7.54 x 10 ⁴	.795	3.21 x 10 ⁴	127
<u>HEART</u>							
Dog	.907	5.26 x 10 ⁻¹	.865	1.24 x 10 ⁰	.019	4.00 x 10 ⁰	31
Human	.963	3.50 x 10 ⁰	.936	5.37 x 10 ¹			40
Horse	.987	1.03 x 10 ³	.988	1.16 x 10 ³	.952	9.51 x 10 ²	45
Cow	.959	4.55 x 10 ²	.958	1.73 x 10 ³	.907	9.24 x 10 ²	126

TABLE II (concl.).

	Accepted Polynomial		Log-Log Transformation		Power Function		N
	R ²	S ² y.x	R ²	S ² y.x	R ²	S ² y.x	
<u>BRAIN</u>							
Dog	.932	5.68 x 10 ⁻¹	.916	1.50 x 10 ⁰	.866	1.49 x 10 ⁰	31
Human	.957	1.78 x 10 ³	.907	2.39 x 10 ⁴	.015	2.04 x 10 ⁴	36
Horse	.974	7.35 x 10 ²	.968	7.62 x 10 ³	.890	2.16 x 10 ³	44
Cow	.988	1.98 x 10 ²	.987	1.31 x 10 ³			119

ied (Figs. 5-12). The polynomial curves on Figures 5, 7, 8 and 9 represented the growth trends of organ weight to be continually increasing throughout the gestation period. In Figures 10, 11 and 12 the curves illustrate that the increase in weight becomes negative near the end of the gestation period. Whether this negative growth represents a biological growth phenomenon, or if it is the result of inherent properties of the polynomial equations to reach a peak value and then descend remains in question. The polynomial curve has been estimated for the horse brain, illustrated in Figure 10. The calculated curve reaches a peak value shortly after 290 days and begins to descend toward the average observed value of 327 grams at 330 days. The curve comes close to the maximum value observed for brain weight of 347 grams just prior to its descent. This indicated the calculated curve appeared to have incorporated an actual characteristic of the data into its parameters. It has not been determined whether this characteristic of the data represents normal growth trends of the organ or whether it is the effect of small sample size for this time of gestation. Similar situations appeared to have existed for the calculated polynomials illustrated on Figures 10, 11 and 12. The best fitting polynomial curve for the human brain data is illustrated on Figure 6. A sharp increase in the growth rate is apparent, beginning at 230 days. A reasonable explanation could not be given to attribute the calculated curve to the observed data for this time in gestation.

Parameter estimates for equations (2) and (3) have been noted in Appendix Table IV. Equation (2) was solved by the method of

least squares. Equation (3) was solved by supplying parameter estimates of equation (2) as starting estimates for an iterative method of solution. The R^2 s and variance of the regression of organ weight on days gestation ($S^2_{y.x}$) have been noted in Table II. Values were not recorded for the power function (3) when parameter estimations were not obtained using the method of solution described.

Calculated curves for equations (2) and (3) were plotted along with observed values for the heart and brain of the four species studied (Figs. 5-12).

It was observed that equation (2) consistently: 1) over-estimated the near terminal and terminal organ weights, 2) underestimated organ weights in the middle of the gestation period and 3) had relatively good estimations of organ weights in the early part of gestation.

Curves calculated from equation (3) are also illustrated on Figures 6-12. They exhibited a better capability for fitting terminal weight data than equation (2), but were less accurate in estimating organ weights in the middle of gestation. Equation (3) generally fit well in the early part of gestation. This equation occasionally gave very poor curve estimations (Fig. 5).

Selection of equations (1), (2) or (3) as best fitting for a set of viscus data was done on the basis of R^2 s (Table II). In most cases the polynomial equation had the greatest R^2 values for visceral data. The gonads and testes of the dog were best explained by equation (3). The horse heart data was best fit by equation (2). On the basis of results in Table II, it was con-

cluded that the polynomial equation was best suited to estimating normal growth curves for visceral growth data. Similar conclusions were drawn from inspection of Figures 5-12. The polynomial curve consistently gave the best appearing fit to the data. Table II further indicates that equation (2) and its method of solution is generally superior to equation (3) for estimation of visceral growth trends.

The results of a series of allometric comparisons between organs and between organs and body weights of the same species are presented in Table III. As previously stated, if a straight line exists between the \log_{10} of two specific growth rates being compared, their rates of decay are the same. The β values in Table III represent the slope of the line or the ratio of the two relative growth rates being compared. Laird *et al.* (1968) showed that when the slope is 1.0 the entities being compared simultaneously pass through corresponding points on their individual growth curves. When β differs from 1.0, the entities being compared have a different time scale and do not pass through corresponding points on their growth curves simultaneously. In other words, there is no synchronization with respect to time between growth rates being compared.

Inspection of Table III indicated the R^2 s for the majority of comparisons were significant, hence inferring the rates of decay of their specific growth rates to be the same. Further inspection reveals that for the majority, β values are close to 1.0. Possibly some of this difference in β from 1.0 is attributable to variation in the data and size of sample. The plot

TABLE III. β coefficients and R^2 s for the allometric comparisons of the dog and horse. Insignificant R^2 s are noted by *.

Dog

	Brain	Heart	Lung	Gonad	Adrn.	Kidn.	Thym.	Int.	Stom.	Spln.	Liver	Body Wgt.
Body Wgt.	.830	.627	1.088	1.382	.661	.579	.571	.603	.494	.791	1.219	Brain
Liver	.945	.937 *	.344	.834	.951	.858	.917	.883	.848	.917	.966	Heart
Spln.	.987	.968 *	.261	.876	.960	.897	.936	.871	.885	.951	.946	Lung
Stom.	.984	1.277	1.415	1.884	.917	.766	.875	.906	.636	1.249	.777	Gonad
Int.	1.052	1.113	*.293	.882	.939	.887	.955	.838	.859	.959	.937	Adrn.
Thym.	.985	.965	.877	.805	.220	.300	.178	.196	.250	.314	1.531	Kidn.
Kidn.	.936	1.236	.868	*.626	.434	*.467	*.317	*.333	*.379	*.379	*.416	Thym.
Adrn.	.939	.975	.898	1.031	.825	.366	.217	.296	.301	.551	1.645	Int.
Gonad	.711	1.697	1.107	1.349	1.470	.780	*.683	*.561	.729	.807	.800	Stom.
Lung	.955	.933	.936	.959	.911	.860	.848	.857	.706	1.365	.839	Spln.
Heart	.976	1.208	.868	1.025	.982	.893	.934	.864	.888	.959	.965	Liver
Body Wgt.	.974	.985	.931	.965	.978	.893	.899	.897	.790	1.457	.676	Body Wgt.
	1.058	1.046	.728	.820	.886	.837	.843	.866	.936	.869	.812	
	.945	.915	.929	.916	.892	.876		1.041	.707	1.378	.764	
	.970	1.157	.858	1.010	.948	.969	1.048	.888	.822	.937	.900	
	.916	.935	.887	.912	.919	.683	.802		.754	1.190	.739	
	.895	1.318	.984	1.139	1.055	.750	1.088	1.175	.814	.854	.865	
	.984	.994	.945	.966	.979	.948	.992	.907	1.073	1.798	.571	
	1.050	1.110	.892	.991	.899	.971	.941	.934		.857	.789	
	.990	.970	.929	.986	.924	.920	1.144	.890	.840	.993	.993	
	1.150	1.027	.783	.904	.821	.957	.941	.899	.968	.909	.941	
	.991	.985	.962	.984	.955	.852	.971	.828	.778	.909	.983	
						.978	.907	.920	.983	.983	.983	

Body Liver Spln. Stom. Int. Thym. Kidn. Adrn. Gonad Lung Heart Brain Wgt.

Horse

TABLE III (concl.). B coefficients and R²s for the allometric comparisons of the cow and human.

	Cow											
	Brain	Heart	Lung	Gonad	Adrn.	Kidn.	Thym.	Int.	Stom.	Spln.	Liver	Body Wgt.
Body Wgt.	.713	.666	.750	1.039	1.359	1.825	1.506	.691	.543	.754	.720	Brain
Liver	.956	.990	.836	.946	.979	.956	.978	.956	.972	.980	.987	Heart
	.924	.901	1.003	.716	.950	1.275	1.094	.952	.758	1.023	.985	
	.969	.953	.821	.906	.955	.942	.949	.920	.957	.959	.962	
Spln.	1.308	1.347	1.060	.705	.924	1.211	1.024	1.009	.800	1.113	1.068	Lung
	.943	.918	.846	.947	.981	.958	.978	.955	.972	.977	.990	
Stom.	1.028	1.082	.760	.745	1.001	1.285	1.133	.818	.633	.906	.805	Gonad
	.898	.896	.859	.820	.864	.790	.838	.853	.823	.877	.847	
Int.	1.159	1.214	.849	.820	1.225	.541	.675	.720	.566	.778	.735	Adrn.
	.970	.961	.849	.909	.937	.886	.919	.909	.921	.948	.944	
Thym.	1.322	1.436	1.014	1.028	1.045	.725	.896	.948	.742	1.017	.992	Kidn.
	.930	.936	.919	.769	.878	.966	.970	.955	.977	.980	.983	
Kidn.	1.106	1.167	.752	1.033	.971	.665	.793	1.255	.997	1.343	1.324	Thym.
	.965	.973	.948	.926	.967	.917	.942	.927	.958	.854	.966	
Adrn.	.958	1.025	.610	.877	.829	.543	.854	1.081	.806	1.154	1.068	Int.
	.925	.958	.845	.878	.920	.798	.968	.976	.957	.962	.975	
Gonad	.657	.656	.598	1.455	1.485	.550	.550	.571	.753	1.034	.993	Stom.
	.706	.667	.643	.889	.626	.799	.668	.598	.940	.955	.981	
Lung	.987	1.052	.634	.875	.839	.606	.851	.963	.946	1.339	1.309	Spln.
	.961	.956	.888	.858	.942	.914	.954	.919	.620	.968	.970	Liver
Heart	.959	1.050	.739	.916	.875	.680	1.003	1.053	.976	.960	.976	Body Wgt.
	.976	.974	.902	.897	.965	.882	.968	.948	.681	.949	.976	
Brain	1.036	1.171	.710	.870	.669	.913	1.046	1.022	1.113	1.090	.976	
	.960	.941	.913	.887	.988	.911	.974	.935	.668	.954	.949	

Human

Body Liver Spln. Stom. Int. Thym. Kidn. Adrn. Gonad Lung Heart Brain Wgt.

of an allometric comparison with a relatively high R^2 value and β close to 1.0 is presented in Figure 13. A linear trend is apparent for the data with little scatter about the line. An example of an allometric comparison with an insignificant R^2 value and a β value greatly different from 1.0 is illustrated in Figure 14. Scatter about the line is greater than in the previous example. There was no apparent organization to the scatter in its deviation from the line. The dog gonad consistently had insignificant R^2 values and β s greatly different from 1.0 when compared with other organs and body weights (Table III). This suggests that the dog gonad growth rate has a different rate of decay than other dog organs and its growth rate is not synchronized with respect to time with that of other dog organs. In certain comparisons a similar situation is suggested for the dog adrenal. Further inspection of Table III indicated the occurrence of a low R^2 value or β greatly different than 1.0 for other allometric comparisons. There was no apparent consistency in these occurrences and no meaningful conclusions were made.

Empirical estimates of visceral growth rates are illustrated for the liver and heart of the four species studied (Fig. 15). The growth rates for the dog heart and liver show a linear decrease throughout the gestation period. This was not the case for these organs in the human, horse and cow. Generally they showed a linear decrease in the first third, followed by a curvilinear decrease in the middle of the curve and finally a curvilinear increase in the last third of the gestation period. These observations give some support to the conclusions of Laird *et al.* (1965),

that the specific growth rates of organisms and their parts undergo constant decrease throughout the growth period.

However, if this conclusion is taken to be universal for all prenatal growth, contradiction arises with some of the findings illustrated in Figure 15. During the last one-third of the fetal period, the organ growth rates of the human and horse increased. There is no indication that the method of analysis is responsible for such an increase. Thus it is suggested that this growth rate increase near the end of the gestation period is the result of an inherent biological growth phenomenon.

An interesting relationship existed between organ growth rates when interspecies comparisons were made for the horse, human and cow. At certain near-equal fractions of their respective gestation periods, the growth rates of the hearts of these animals are similar. This relationship also existed between growth rates of other organs when compared interspecifically. The reasons for such growth rate similarities for the same organ between species is obscure. Perhaps histological examination or hormonal analysis of the organs of the different species at these periods of synchronization would provide the information.

The problem of making valid interspecies comparisons is difficult. One complication in expressing fetal age as a percent of gestation periods is that the four species studied are born at different stages of development. At birth the cow and the horse are developed more than the human and dog. Making comparisons between species could be done at comparable stages of development but this would be subject to one's individual

judgements.

It is also illustrated (Fig. 15) that similar relationships of growth rates existed between different organs of the same or different species. Without further examination of the organs and species involved, at their comparable periods of gestation, it is impossible to form meaningful conclusions.

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ILLUSTRATIONS

Figure 1. Liver, brain, heart and kidneys weights for cow fetuses.

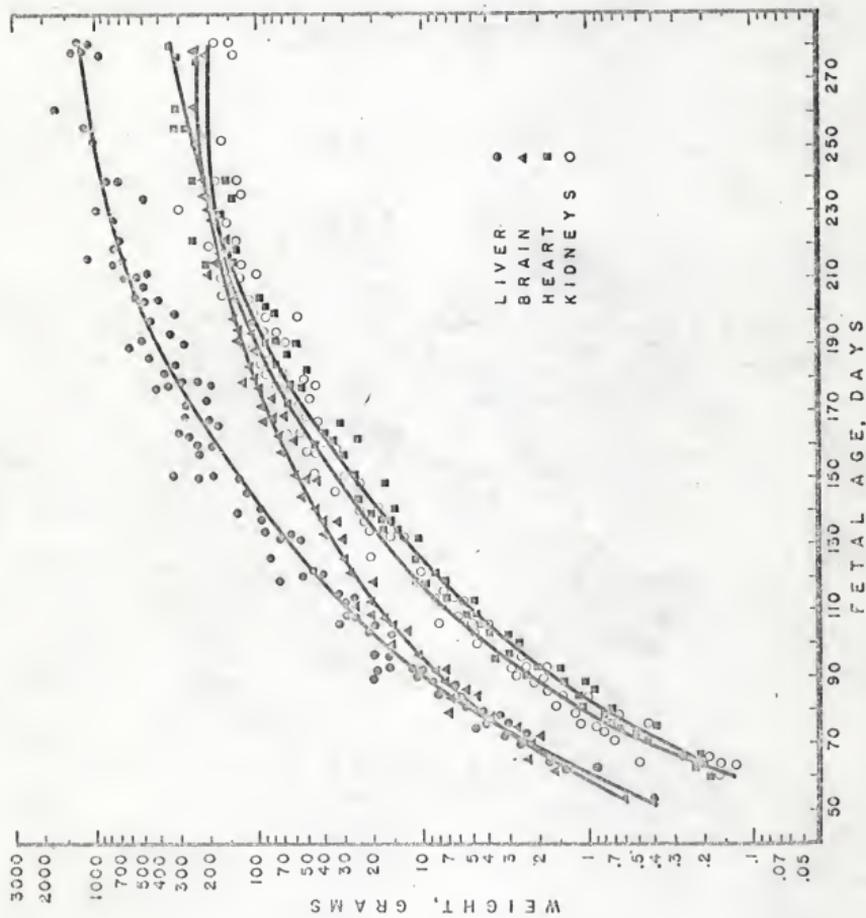


Figure 2. Liver, brain, heart and kidneys weights for dog fetuses.

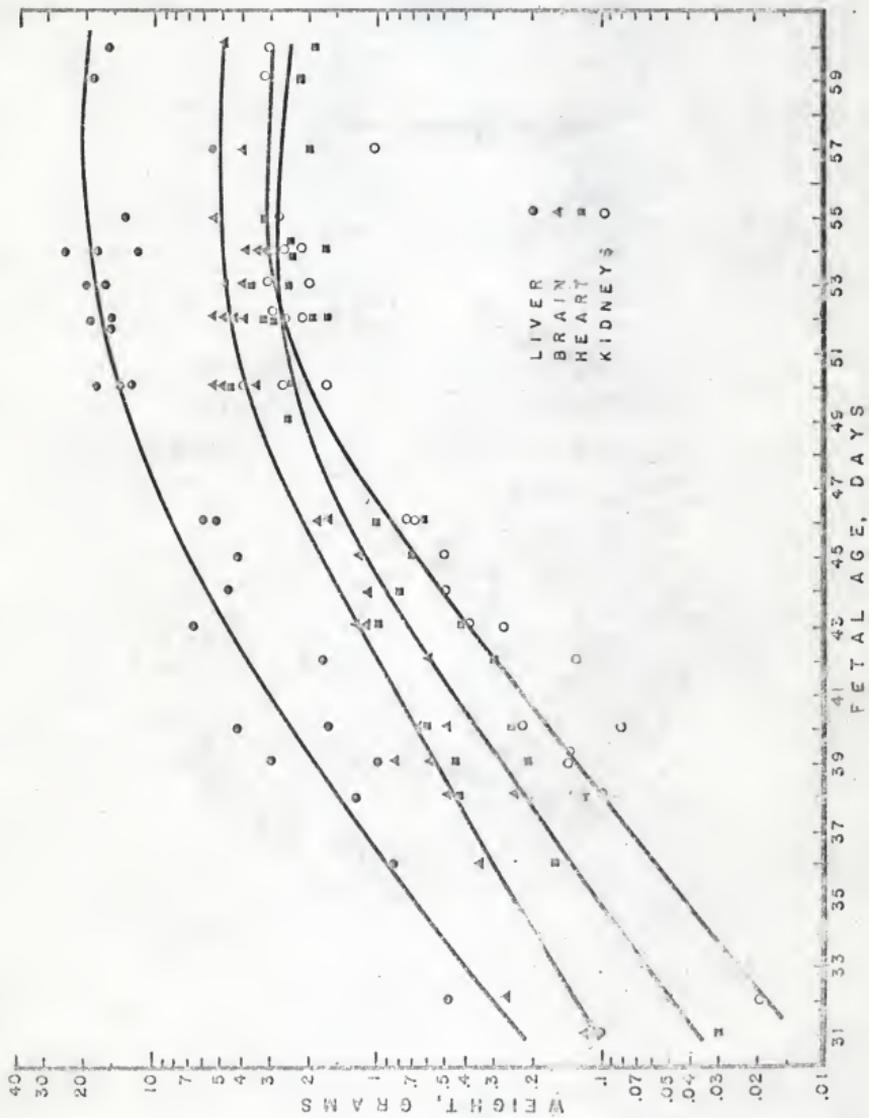


Figure 3. Liver, brain, heart and kidneys weights for human fetuses including data of Jackson (1909) and Borovansky (1930).

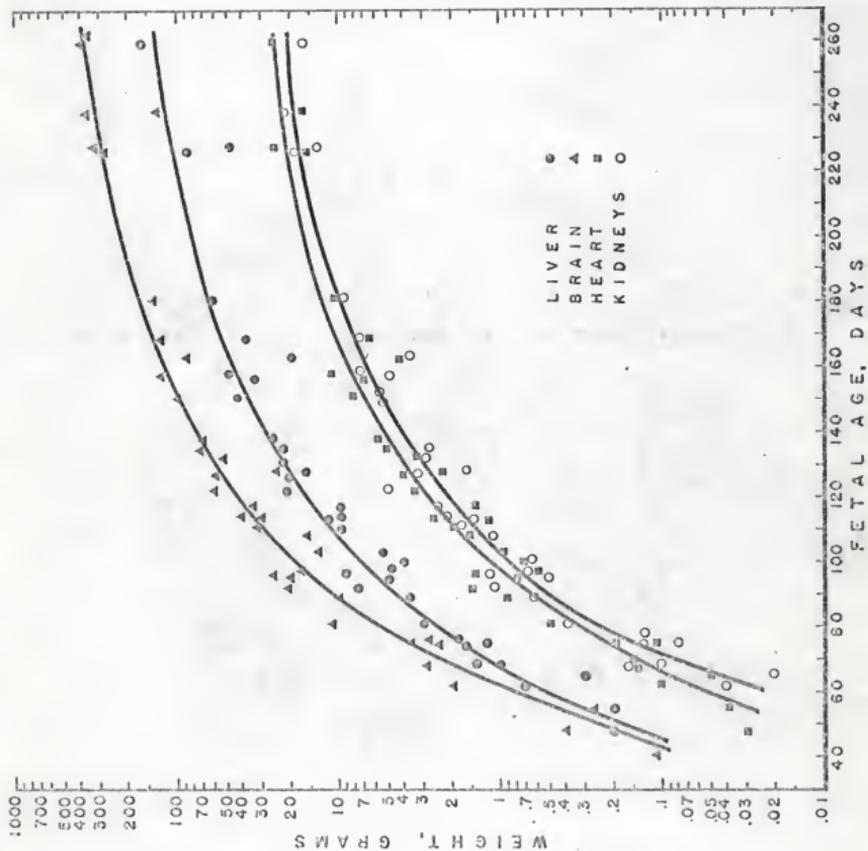


Figure 4. Liver, brain, heart and kidneys weights for horse fetuses.

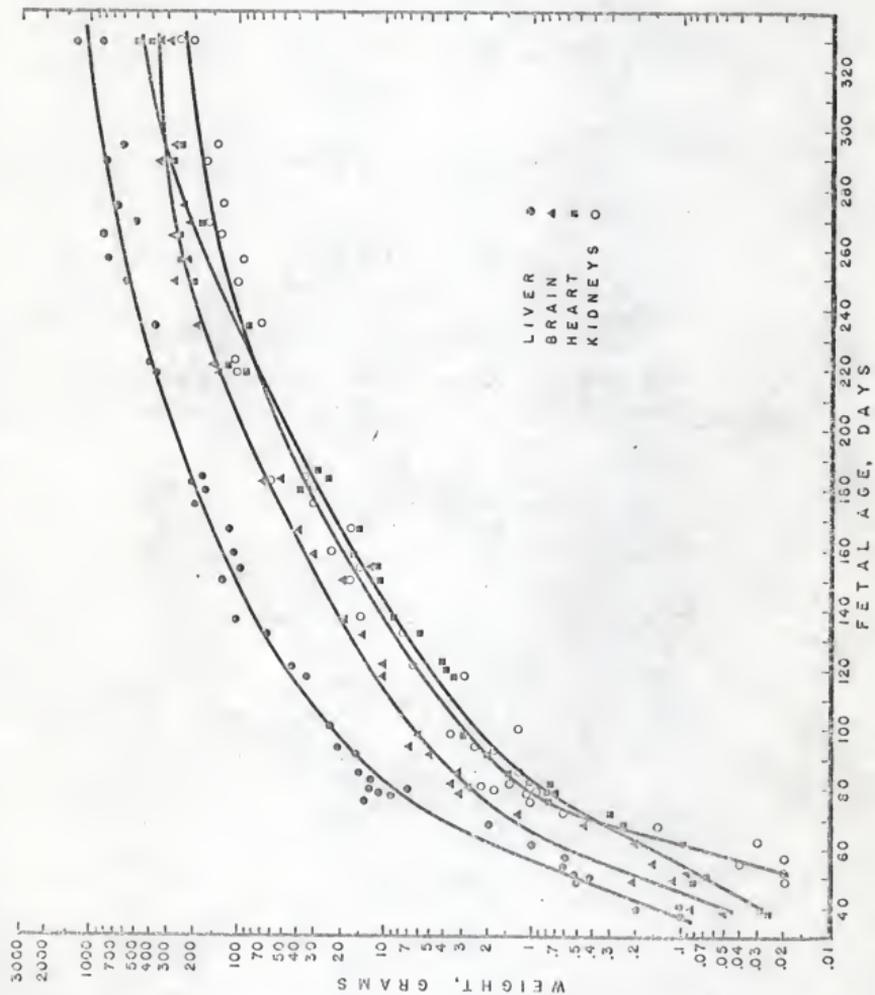


Figure 5. Human fetal heart weights and calculated curves of the polynomial, log-log transformation and power function.

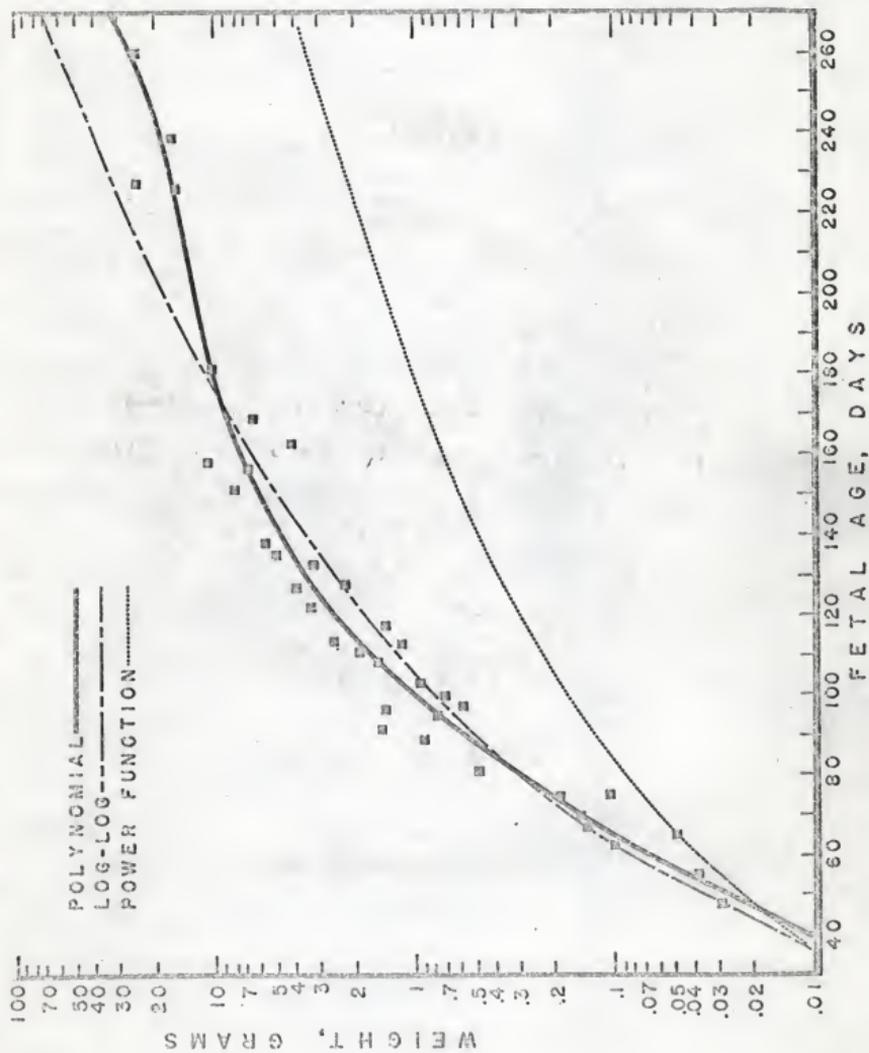


Figure 6. Human fetal brain weights and calculated curves of the polynomial and log-log transformation.

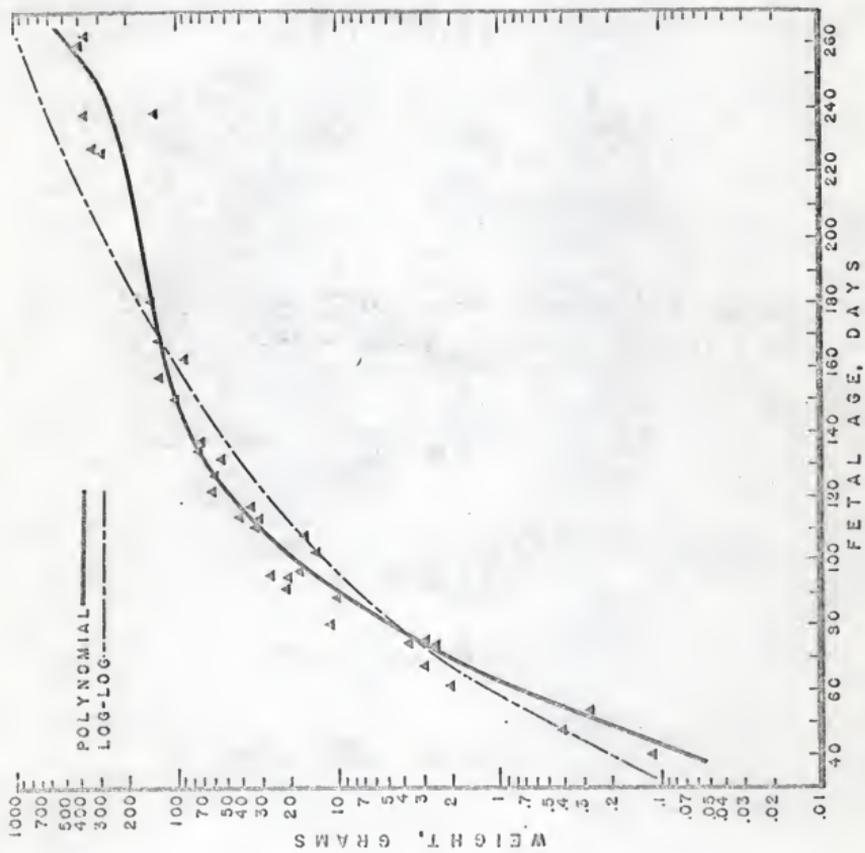


Figure 7. Cow fetal heart weights and calculated curves of the polynomial, log-log transformation and power function.

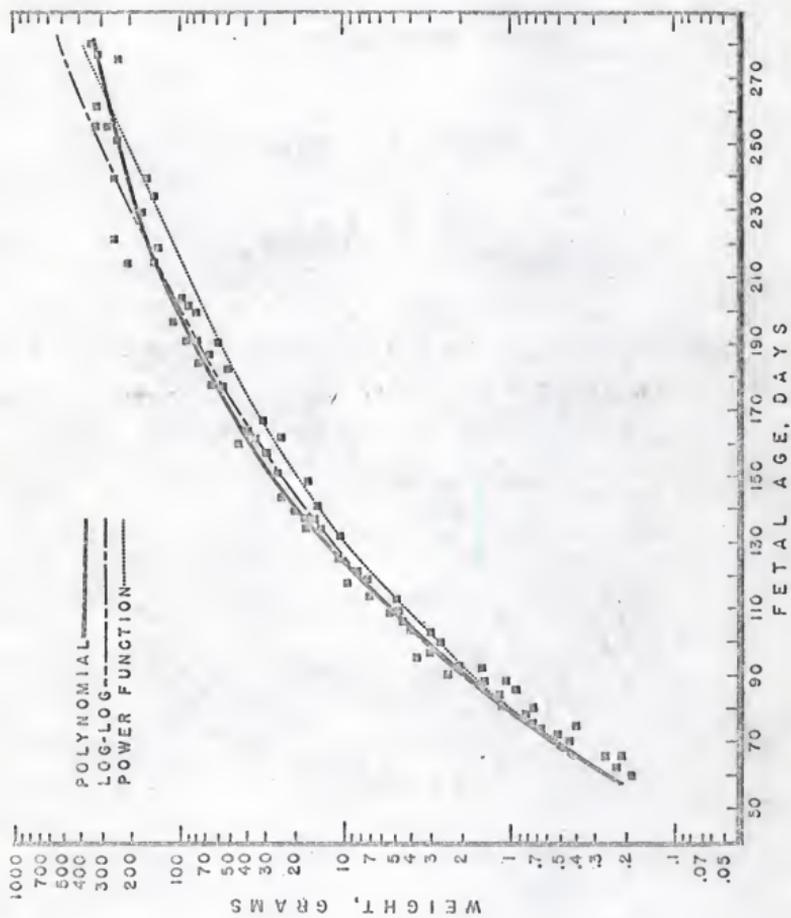


Figure 8. Cow fetal brain weight and calculated curves of the polynomial and log-log transformation.

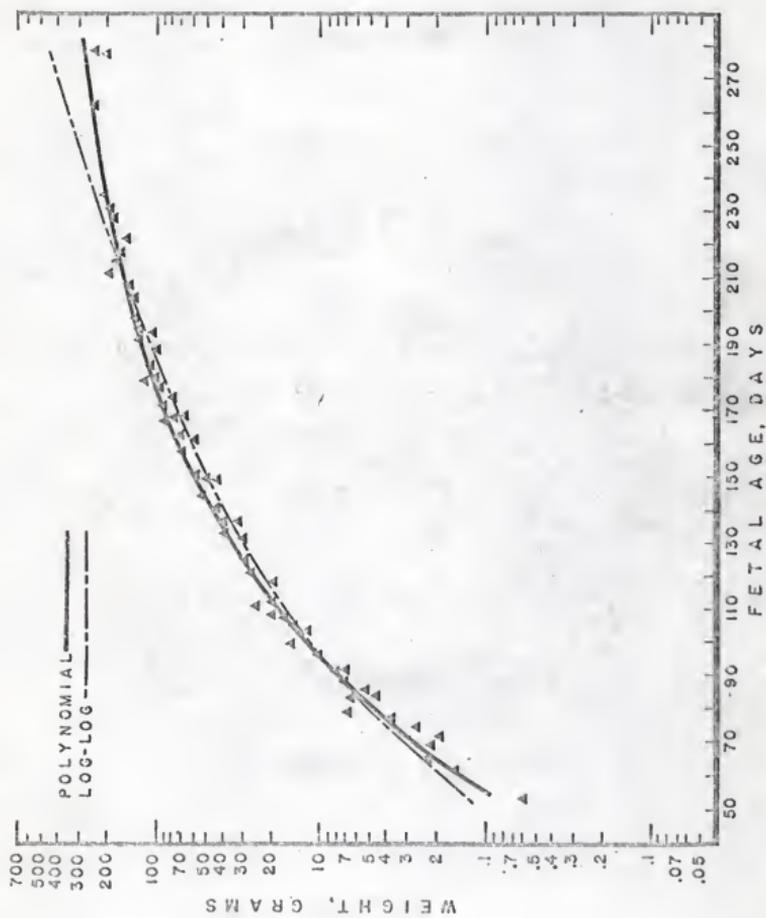


Figure 9. Horse fetal heart weight and calculated curves of the polynomial, log-log transformation and power function.

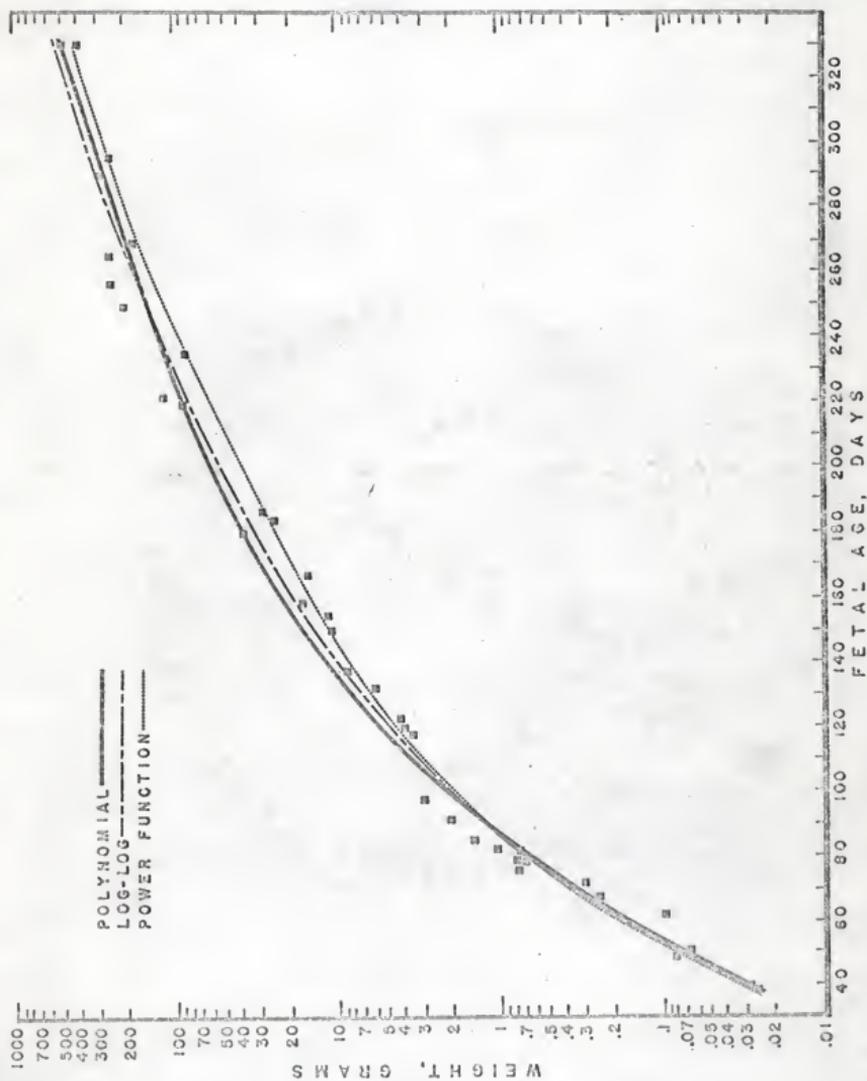


Figure 10. Horse fetal brain weights and calculated curves of the polynomial, log-log transformation and power function.

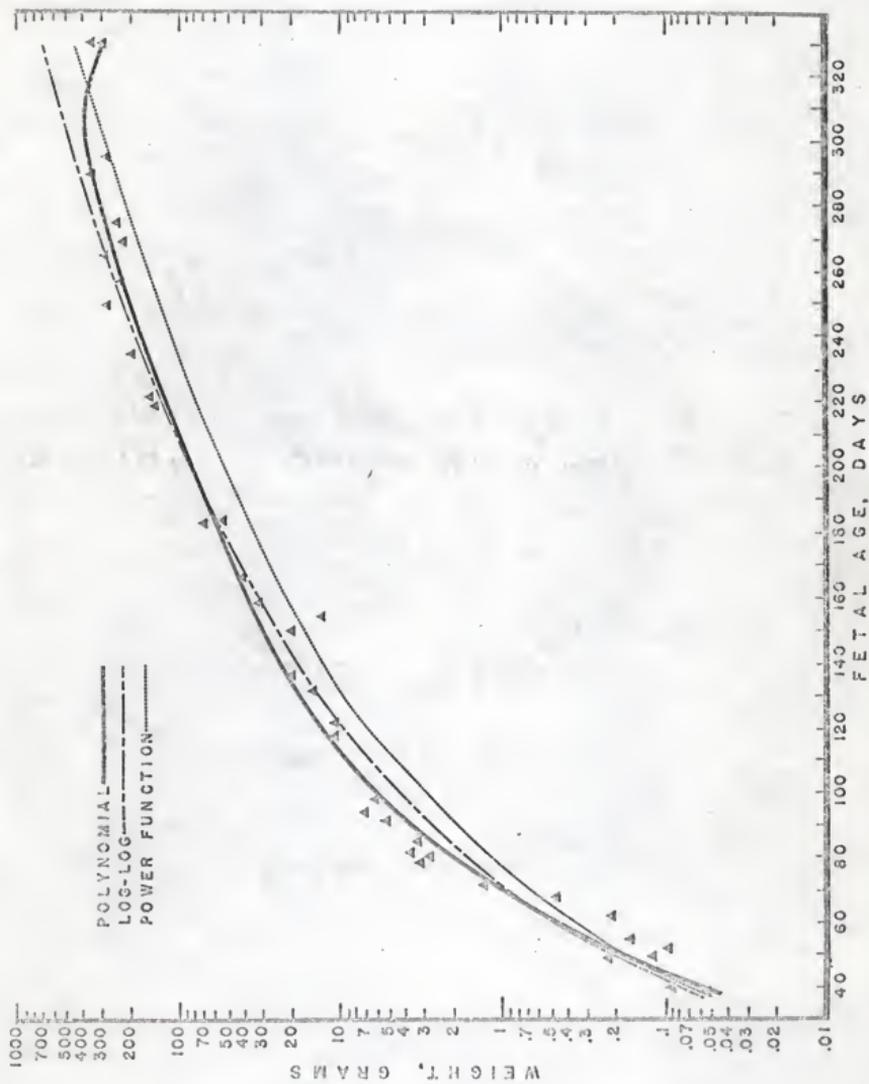


Figure 11. Dog fetal heart weights and calculated curves of the polynomial and log-log transformation.

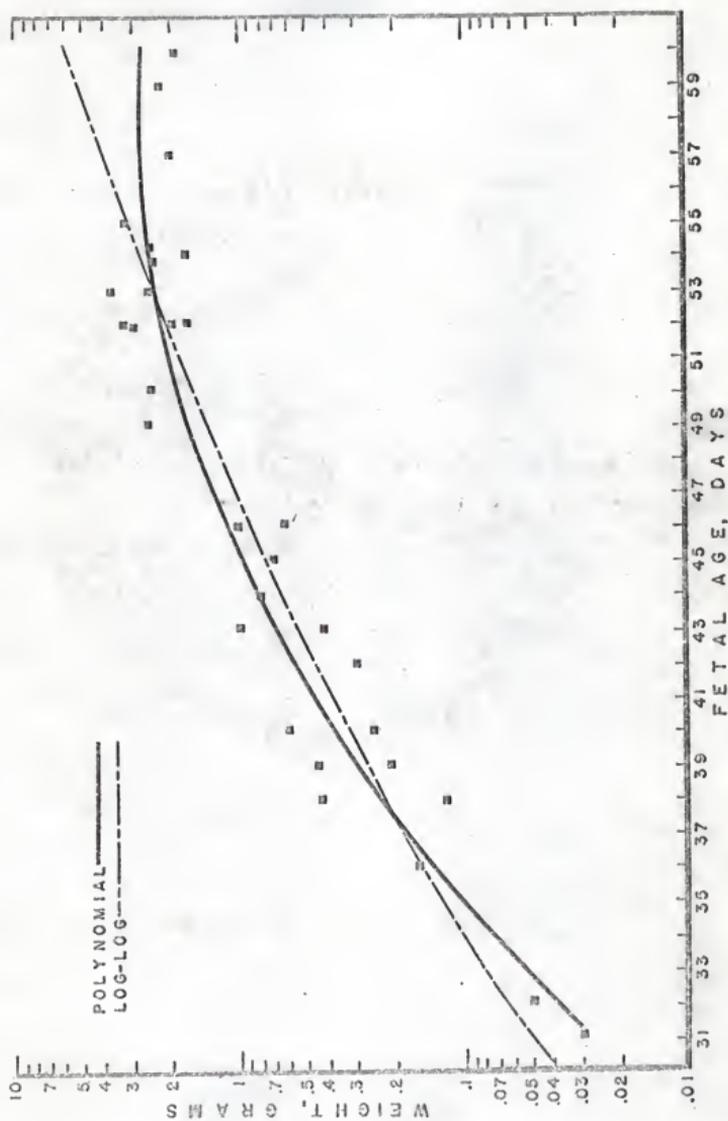


Figure 12. Dog fetal brain weights and calculated curves of the polynomial, log-log transformation and power function.

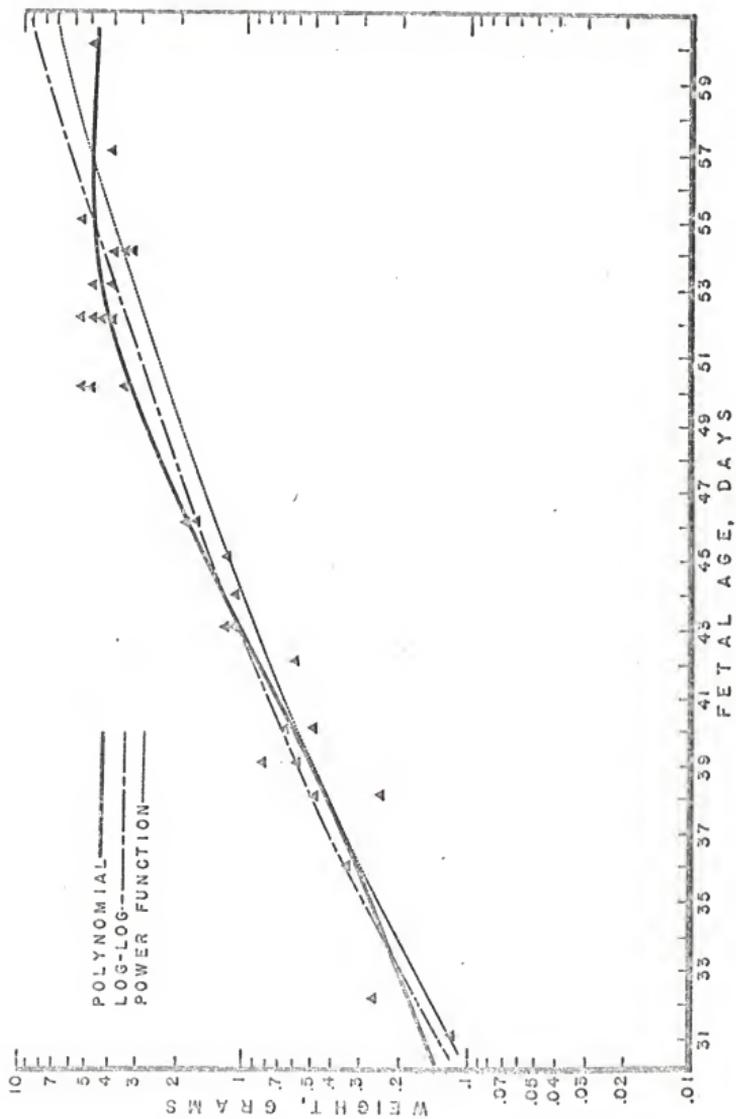


Figure 13. Allometric comparison between fetal cow body weight versus liver weight. $R^2 = .976$. $\beta = .960$.

Figure 14. Allometric comparison between fetal dog body weight and gonad weight. $R^2 = .416$. $\beta = 1.531$.

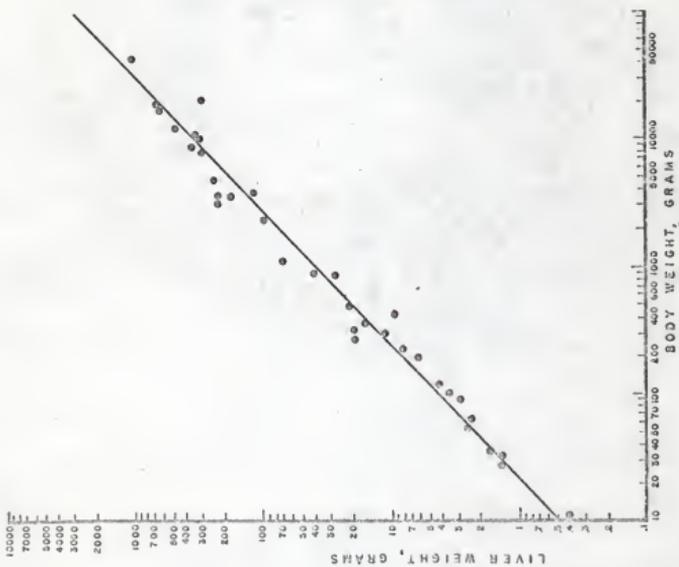


Figure 13

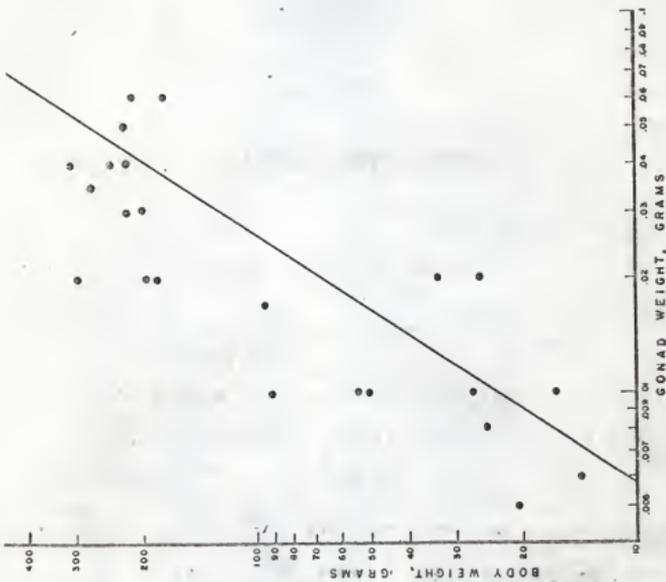
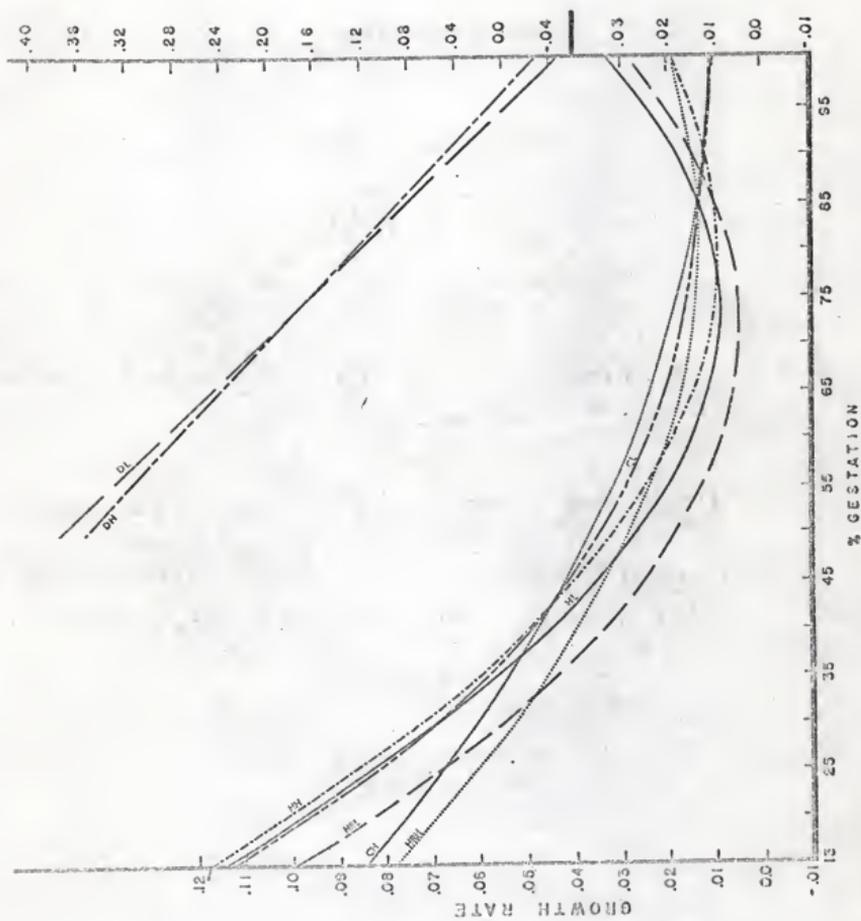


Figure 14

Figure 15. Heart and liver growth rates for dog, horse, human and cow fetuses. Fetal age is expressed as a per cent of the gestation period. Growth rate curves were plotted only for periods which data was available.

The guide letters used for identification of growth curves are:

HH-human heart, HL-human liver, HHH-horse heart, HHL-horse liver,
CH-cow heart, CL-cow liver, DH-dog heart, DL-dog liver.



APPENDIX

APPENDIX TABLE IV. α and β parameter estimates for the two methods of solution of the growth model $Y = \alpha x^\beta$.

<u>Log Y = Log $\alpha + \beta$ Log X</u>		<u>Y = αx^β</u>	
α	β	α	β
<u>LIVER</u>			
Human - 7.25	3.98 \pm .18		
Horse - 7.27	4.21 \pm .13 (1.41 \pm .91) $\times 10^{-7}$	3.90 \pm .30	
Cow - 8.21	4.71 \pm .08 (3.90 \pm 4.85) $\times 10^{-8}$	4.30 \pm .26	
Dog -11.24	7.20 \pm .59 (1.29 \pm 3.13) $\times 10^{-11}$	6.89 \pm 1.3	
<u>SPLEEN</u>			
Human -10.38	4.68 \pm .29		
Horse -10.75	5.28 \pm .10		
Cow -12.77	6.30 \pm .15 (2.27 \pm .41) $\times 10^{-12}$	3.98 \pm .43	
Dog -18.76	10.78 \pm 1.58 (6.08 \pm 20.4) $\times 10^{-19}$	10.24 \pm 2.9	
<u>STOMACH</u>			
Human - 9.84	4.64 \pm .33 (4.16 \pm 3.58) $\times 10^{-10}$	4.27 \pm .46	
Horse - 9.75	4.71 \pm .12		
Cow - 8.94	4.89 \pm .09 (2.69 \pm 1.17) $\times 10^{-9}$	4.63 \pm 1.1	
Dog -15.13	8.78 \pm .87 (.75 \pm 21.4) $\times 10^{-15}$	8.78 \pm 7.1	
<u>INTESTINE</u>			
Human -10.03	5.20 \pm .25		
Horse - 9.33	4.88 \pm .25 (2.70 \pm 1.98) $\times 10^{-9}$	3.96 \pm .74	
Cow -10.15	5.51 \pm .11 (2.73 \pm 5.35) $\times 10^{-10}$	5.23 \pm .41	
Dog -17.18	10.39 \pm .58 (1.54 \pm 3.23) $\times 10^{-17}$	10.10 \pm 1.2	
<u>THYMUS</u>			
Human -10.04	4.61 \pm .27 (1.56 \pm 5.64) $\times 10^{-10}$	4.48 \pm 1.1	
Horse -12.98	6.00 \pm .20 (1.29 \pm 4.52) $\times 10^{-13}$	5.96 \pm .75	
Cow -12.86	6.42 \pm .15		
Dog -16.59	9.57 \pm .12 (.80 \pm 2.51) $\times 10^{-16}$	9.04 \pm 2.4	
<u>KIDNEY</u>			
Human - 9.40	4.61 \pm .26		
Horse - 9.64	4.91 \pm .19 (1.15 \pm .93) $\times 10^{-9}$	4.17 \pm .71	
Cow - 9.16	4.85 \pm .09 (1.70 \pm .91) $\times 10^{-9}$	4.57 \pm .24	
Dog -15.12	8.96 \pm .66 (1.89 \pm 5.14) $\times 10^{-15}$	8.60 \pm 1.7	

APPENDIX TABLE IV (concl.).

<u>LOG Y = LOG $\alpha + \beta \text{LOG X}$</u>		<u>Y = αx^β</u>	
α	β	α	β
<u>ADRENAL</u>			
Human - 8.48	4.01 ± .30	(1.31 ± 1.04) x 10 ⁻⁸	3.42 ± .58
Horse - 9.00	3.88 ± .17		
Cow - 8.17	3.65 ± .10		
Dog - 8.52	4.08 ± .99		
<u>GONADS</u>			
Human - 5.79	2.26 ± .19		
Horse - 9.44	4.72 ± .25	(5.72 ± 1.49) x 10 ⁻⁹	2.01 ± .72
Cow - 9.59	4.31 ± .19	(2.58 ± 8.19) x 10 ⁻¹⁰	4.31 ± .58
Dog - 5.35	2.20 ± .71	(.65 ± 2.27) x 10 ⁻⁵	2.13 ± .90
<u>TESTES</u>			
Human - 6.22	2.47 ± .27		
Horse - 9.52	4.74 ± .45	(4.68 ± 2.07) x 10 ⁻⁹	2.07 ± 1.2
Cow - 9.96	4.55 ± .21		
Dog - 3.90	1.26 ± .69	(2.90 ± 9.40) x 10 ⁻⁵	1.66 ± .84
<u>OVARIES</u>			
Human - 4.76	1.77 ± .24		
Horse - 9.28	4.67 ± .36	(8.22 ± 2.88) x 10 ⁻⁹	1.96 ± .97
Cow - 6.78	2.83 ± .18		
Dog - 8.55	4.18 ± .94		
<u>LUNG</u>			
Human - 8.12	4.23 ± .24	(.76 ± 2.38) x 10 ⁻⁸	2.74 ± .58
Horse -10.28	5.50 ± .18	(2.56 ± 2.08) x 10 ⁻¹⁰	4.77 ± .70
Cow - 9.40	5.21 ± .08	(9.38 ± 5.40) x 10 ⁻¹⁰	4.63 ± .19
Dog -15.59	9.47 ± .69	(.74 ± 1.73) x 10 ⁻¹⁵	9.01 ± 1.6
<u>HEART</u>			
Human - 9.08	4.49 ± .19		
Horse - 9.11	4.71 ± .08	(1.39 ± 1.25) x 10 ⁻⁹	4.56 ± .28
Cow - 9.38	4.94 ± .09	(8.25 ± 4.06) x 10 ⁻¹⁰	4.75 ± .18
Dog -11.82	7.08 ± .52	(5.90 ± 3.34) x 10 ⁻¹⁰	4.44 ± 1.1
<u>BRAIN</u>			
Human - 7.94	4.52 ± .24	(9.41 ± 5.35) x 10 ⁻⁸	3.12 ± .84
Horse - 8.01	4.31 ± .12	(2.22 ± 1.68) x 10 ⁻⁸	4.08 ± .30
Cow - 6.17	3.60 ± .05		
Dog -10.28	6.32 ± .35	(.93 ± 1.84) x 10 ⁻¹⁰	6.12 ± .88

APPENDIX TABLE V. α coefficients, β parameter estimates and their standard of error the four polynomial regression models.

LIVER

	a	$b_1 \times 10^{-2}$	$b_2 \times 10^{-4}$	$b_3 \times 10^{-7}$	$b_4 \times 10^{-9}$
Dog	-2.48 -8.61 -3.21 -4.50	6.89 ± .65 34.70 ± 5.57 -2.57 ± 40.34 11.74 ± 80.68	-30.66 ± 6.11 53.59 ± 90.53 -.16 ± 257.73	-623.77 ± 667.84 239.95 ± 3819.90	-518.80 ± 2209.90
Human	-.64 -2.17 -3.72 -3.63	1.27 ± .10 3.74 ± .28 7.70 ± .89 7.36 ± 2.52	.84 ± .09 3.83 ± .66 3.42 ± 2.88	6.72 ± 1.46 4.73 ± 13.59	.33 ± 2.26
Horse	-.34 -1.73 -2.99 -4.32	1.24 ± .09 3.50 ± .22 6.67 ± .45 11.25 ± 1.21	.66 ± .06 2.75 ± .28 7.61 ± 1.22	3.91 ± .52 23.74 ± 4.86	- 2.73 ± .66
Cow	-.22 -1.80 -2.98 -3.40	1.40 ± .05 3.72 ± .13 6.34 ± .45 7.51 ± .16	.73 ± .04 2.44 ± .28 3.65 ± .16	3.40 ± .56 8.62 ± .70	- .78 ± .10

APPENDIX TABLE V (continued).

SPLEEN

	a	b ₁ x 10 ⁻²	b ₂ x 10 ⁻⁴	b ₃ x 10 ⁻⁷	b ₄ x 10 ⁻⁹
Dog	- 5.24	9.51 ± 1.51	-91.89 ± 19.08		
	-26.41	98.37 ± 18.48	93.42 ± 445.04	-1260.20 ± 3005.90	
	-11.50	7.39 ± 2.18	69.87 ± 566.19	- 837.95 ± 7569.60	-255.29 ± 4352.10
	-12.16	13.13 ± 2.14			
Human	- 2.27	1.30 ± .11			
	- 3.88	3.50 ± .56	- .67 ± .17		
	- 6.22	8.46 ± 2.84	- 3.92 ± 1.84	6.63 ± 3.73	
	- 9.87	18.71 ± 8.96	-14.19 ± 8.76	49.94 ± 36.49	6.51 ± 5.49
Horse	- 1.94	1.53 ± .08			
	- 3.31	3.60 ± .17	- .58 ± .05		
	- 4.11	5.44 ± .44	- 1.75 ± .26	2.12 ± .48	
	- 4.20	5.76 ± 1.38	- 2.07 ± 1.35	3.41 ± 5.25	.18 ± .70
Cow	- 2.02	1.83 ± .07			
	- 4.60	5.59 ± .20	- 1.18 ± .06		
	- 6.85	10.48 ± .68	- 4.35 ± .43	6.24 ± .84	
	- 9.50	18.57 ± 3.89	-12.67 ± 3.92	41.35 ± 16.40	- 5.22 ± 2.43

APPENDIX TABLE V (continued).

STOMACH

	a	b ₁ x 10 ⁻²	b ₂ x 10 ⁻⁴	b ₃ x 10 ⁻⁷	b ₄ x 10 ⁻⁹
Dog	-4.49	8.51 ± .90	-24.73 ± 10.99	-2246.50 ± 1100.80	-1279.90 ± 3445.20
	-9.43	30.93 ± 10.00	279.13 ± 149.30	-69.65 ± 6011.90	
	10.00	-1.04 ± 66.58	142.44 ± 406.97		
	6.51	-66.65 ± 12.68			
Human	-2.31	1.67 ± .16	-1.13 ± .23	8.14 ± 4.57	4.66 ± 17.66
	-3.97	4.56 ± .59	-4.51 ± 1.91	-17.79 ± 98.08	
	-5.61	8.85 ± 2.48	.48 ± 19.25		
	-4.38	4.77 ± 15.78			
Horse	-1.95	1.39 ± .08	-.57 ± .06	2.34 ± .60	.90 ± .76
	-3.24	3.38 ± .20	-1.84 ± .33	8.94 ± 5.59	
	-4.05	5.35 ± .53	-3.47 ± 1.42		
	-4.52	6.91 ± 1.42			
Cow	-.67	1.47 ± .05	-.78 ± .05	5.26 ± 8.46	2.53 ± 1.27
	-2.31	3.90 ± .15	-3.40 ± .29	22.03 ± 8.46	
	-4.09	7.87 ± .45	-7.31 ± 2.00		
	-5.31	11.61 ± 1.96			

APPENDIX TABLE V (continued).

INTESTINE

	a	b ₁ x 10 ⁻²	b ₂ x 10 ⁻⁴	b ₃ x 10 ⁻⁷	b ₄ x 10 ⁻⁹
Dog	- 4.59	10.04 ± .66	-29.75 ± 6.59	-916.25 ± 762.94	-509.41 ± 2294.40
	-10.53	37.01 ± 6.00	93.98 ± 103.49	-38.40 ± 4016.60	
	- 2.59	-17.77 ± 46.15	38.61 ± 271.49		
	- 4.04	- 2.78 ± 84.08			
Human	- 1.60	1.87 ± .14	- 1.19 ± .18	12.04 ± 3.03	- 12.56 ± 11.03
	- 3.34	4.91 ± .47	- 6.19 ± 1.27	81.46 ± 61.16	
	- 5.78	11.25 ± 1.65	-19.72 ± 11.99		
	- 8.83	22.17 ± 9.83			
Horse	- 1.09	1.35 ± .12	- .80 ± .11	6.08 ± .96	- 4.87 ± 1.12
	- 2.95	4.17 ± .38	- 4.13 ± .53	42.26 ± 8.34	
	- 5.19	9.42 ± .87	-13.25 ± 2.14		
	- 8.00	18.40 ± 2.20			
Cow	- .98	1.77 ± .06	- .88 ± .08	4.17 ± 1.46	- 6.18 ± 4.65
	- 2.60	4.34 ± .24	- 2.76 ± .66	41.23 ± 28.07	
	- 3.68	6.94 ± .94	-10.67 ± 6.04		
	- 5.72	13.88 ± 5.44			

APPENDIX TABLE V (continued).

THYMUS

	a	$b_1 \times 10^{-2}$	$b_2 \times 10^{-4}$	$b_3 \times 10^{-7}$	$b_4 \times 10^{-9}$
Dog	- 4.71	8.68 ± 1.11	-65.19 ± 13.76		
	-19.05	70.42 ± 13.05	89.04 ± 292.83	-1074.10 ± 2028.70	
	- 7.42	-3.10 ± 1.40	112.72 ± 704.29	-1437.60 ± 9777.10	189.10 ± 5336.50
	- 6.74	-9.58 ± 2.37			
Human	- 1.96	1.23 ± .09	- .63 ± .14		
	- 3.62	3.40 ± .50	- .98 ± 1.90	.69 ± 3.71	
	- 3.90	3.95 ± 3.06	-40.87 ± 21.12	160.82 ± 84.39	-23.16 ± 12.16
	-19.93	46.22 ± 22.53			
Horse	- 2.54	1.56 ± .06	- .33 ± .06		
	- 3.53	2.81 ± .25	.68 ± .51	- 1.71 ± .86	
	- 2.63	1.05 ± .92	- 4.52 ± 6.13	16.81 ± 21.70	- 2.31 ± 2.70
	- 4.78	6.92 ± 7.08			
Cow	- 1.85	1.84 ± .07	- 1.06 ± .06		
	- 4.28	5.27 ± .21	- 1.37 ± .58	.62 ± 1.13	
	- 4.51	5.76 ± .94	- 7.12 ± 5.53	24.29 ± 22.74	- 3.46 ± 3.32
	- 6.32	11.44 ± 5.65			

APPENDIX TABLE V (continued).

KIDNEY

	a	$b_1 \times 10^{-2}$	$b_2 \times 10^{-4}$	$b_3 \times 10^{-7}$	$b_4 \times 10^{-9}$
Dog	- 4.12	8.39 ± .69	-30.37 ± 7.50	-1666.00 ± 761.14	-1168.50 ± 2625.10
	-10.00	36.67 ± 7.00	198.96 ± 105.16	298.13 ± 4547.90	
	4.85	-67.06 ± 47.94	77.44 ± 309.60		
	2.00	-35.13 ± 98.85			
Human	- 1.67	1.41 ± .14	- 1.11 ± .12	9.13 ± 2.11	8.30 ± 2.91
	3.80	4.74 ± .38	- 5.26 ± .96	59.90 ± 17.93	
	6.08	10.38 ± 1.34	-16.15 ± 3.91		
	9.04	20.03 ± 3.55			
Horse	- 1.41	1.40 ± .11	- .76 ± .08	4.39 ± .82	3.17 ± .85
	3.13	4.05 ± .30	- 3.15 ± .45	27.77 ± 6.33	
	4.70	7.79 ± .73	- 9.00 ± 1.62		
	6.47	13.48 ± 1.65			
Cow	- .94	1.43 ± .05	- .86 ± .04	2.96 ± .53	3.19 ± .95
	2.78	4.15 ± .12	- 2.34 ± .27	24.16 ± 6.35	
	3.80	6.39 ± .41	- 7.28 ± 1.50		
	5.37	11.15 ± 1.47			

APPENDIX TABLE V (continued).

ADRENAL

	a	b ₁ x 10 ⁻²	b ₂ x 10 ⁻⁴	b ₃ x 10 ⁻⁷	b ₄ x 10 ⁻⁹
Dog	- 3.50	3.81 ± .94	- 11.19 ± 19.50		
	- 5.91	14.29 ± 18.30	1468.60 ± 694.84	-10308.00 ± 4837.60	
	104.08	-6.88 ± 3.30	214.49 ± 701.75	3089.30 ± 9857.00	-4848.70 ± 4079.60
	35.49	-1.98 ± 1.72			
Human	- 1.81	1.28 ± .14			
	- 3.72	4.39 ± .47	- 1.10 ± .16		
	- 6.89	12.47 ± 1.77	- 7.27 ± 1.32	14.22 ± 3.04	
	- 6.54	11.37 ± 9.05	- 5.96 ± 10.77	7.52 ± 53.59	1.20 ± 9.42
Horse	- 2.31	1.03 ± .07			
	- 3.41	2.52 ± .25	- .40 ± .07		
	- 4.00	3.75 ± .95	- 1.12 ± .54	1.24 ± .92	
	- 3.62	2.71 ± 3.44	- .17 ± 3.06	2.25 ± 11.08	.44 ± 1.41
Cow	- 1.94	1.06 ± .04			
	- 3.20	2.89 ± .17	- .57 ± .05		
	- 4.76	6.25 ± .64	- 2.73 ± .41	4.25 ± .79	
	- 6.11	10.22 ± 2.40	- 6.75 ± 2.38	21.05 ± 9.87	- 2.48 ± 1.45

APPENDIX TABLE V (continued).

GONAD

	a	b ₁ x 10 ⁻²	b ₂ x 10 ⁻⁴	b ₃ x 10 ⁻⁷	b ₄ x 10 ⁻⁹
Dog	-2.69	2.12 ± .67	-	.37 ± 9.35	
	-2.77	2.47 ± 8.71	-	304.53 ± 115.25	-2207.00 ± 831.92
	17.72	-1.36 ± 52.65	128.72 ± 235.90	650.49 ± 3426.50	-1696.60 ± 1968.30
	13.31	-89.16 ± 76.43			
Human	-1.85	.61 ± .05	-		
	-2.32	1.22 ± .34	-	.17 ± .10	
	-3.09	2.80 ± 1.52	-	1.16 ± .93	1.91 ± 1.78
	-6.79	13.37 ± 7.80	-	11.55 ± 7.58	44.41 ± 30.82
Horse	-1.58	1.35 ± .13	-		
	-3.78	4.91 ± .25	-	1.04 ± .07	
	-4.88	7.65 ± .63	-	2.84 ± .40	3.38 ± .74
	-4.02	4.74 ± 1.75	-	.26 ± 1.78	9.32 ± 7.09
Cow	-2.39	1.35 ± .07	-		
	-3.18	2.56 ± .34	-	.39 ± .11	
	-3.28	2.78 ± 1.24	-	.54 ± .80	.30 ± 1.61
	-4.14	5.43 ± 4.63	-	3.37 ± 4.84	12.66 ± 20.92
					- 1.89 ± 3.17
					1.75 ± .97

APPENDIX TABLE V (continued).

TESTES

	a	b ₁ x 10 ⁻²	b ₂ x 10 ⁻⁴	b ₃ x 10 ⁻⁷	b ₄ x 10 ⁻⁹
Dog	- 2.40	1.28 ± .65			
	- .62	-6.61 ± 7.69	8.49 ± 8.24		
	13.40	-1.02 ± 56.31	220.76 ± 124.40	-1542.40 ± 902.19	
	-14.65	1.46 ± 1.38	-602.56 ± 461.21	10437.00 ± 6727.00	-6401.40 ± 3609.30
Human	- 1.93	.67 ± .08			
	- 2.38	1.27 ± .49	.17 ± .14		
	- 3.18	2.93 ± 2.15	1.21 ± 1.31	1.99 ± 2.50	
	- 7.33	14.86 ± 8.42	- 13.08 ± 8.22	50.75 ± 33.48	- 7.06 ± 4.85
Horse	- 1.44	1.24 ± .20			
	- 3.88	4.93 ± .47	1.02 ± .13		
	- 5.64	8.97 ± 1.37	3.56 ± .83	4.61 ± 1.50	
	- 7.16	13.47 ± 4.07	- 7.87 ± 3.77	20.93 ± 14.05	- 2.12 ± 1.82
Cow	- 2.19	1.32 ± .08			
	- 3.56	3.27 ± .34	.60 ± .10		
	- 3.66	3.47 ± 1.46	.72 ± .90	.25 ± 1.71	
	- 2.56	.46 ± 7.57	2.32 ± 7.52	- 12.64 ± 31.15	1.88 ± 4.56

APPENDIX TABLE V (continued).

OVARIES

	a	b ₁ x 10 ⁻²	b ₂ x 10 ⁻⁴	b ₃ x 10 ⁻⁷	b ₄ x 10 ⁻⁹
Dog	- 3.40	3.89 ± .89	- 18.37 ± 26.16		
	- 7.36	21.08 ± 24.49	5526.80 ± 6311.00	-39072.00 ± 44376.00	
	402.50	-.26 ± .30	672.57 ± 574.98	450.77 ± 12748.00	-5587.40 ± 3412.50
	70.93	-4.22 ± 3.52			
Human	- 1.64	.46 ± .07			
	- 2.48	1.53 ± .41	.31 ± .12		
	- 2.20	.96 ± 2.01	1.24 -	.69 ± 2.40	2.40
	- 4.54	7.50 ± 9.26	6.41 ± 9.00	26.12 ± 37.03	3.97 ± 5.47
Horse	- 1.45	1.32 ± .18			
	- 3.77	4.98 ± .36	1.08 ± .10		
	- 5.06	8.12 ± .82	3.11 ± .51	3.78 ± .93	
	- 3.65	3.37 ± 2.28	1.91 ± 2.31	16.63 ± 9.22	2.79 ± 1.26
Cow	- 2.18	.99 ± .08			
	- 2.98	2.36 ± .37	.51 ± .14		
	- 4.51	6.35 ± 1.20	3.67 ± .93	7.60 ± 2.21	9.66 ± 6.16
	- 7.14	15.56 ± 6.01	14.79 ± 7.16	62.92 ± 35.35	

APPENDIX TABLE V (continued).

LUNG

	a	$b_1 \times 10^{-2}$	$b_2 \times 10^{-4}$	$b_3 \times 10^{-7}$	$b_4 \times 10^{-9}$
Dog	- 4.06	9.06 ± .77	-39.69 ± 7.19	-1388.00 ± 733.82	-1266.00 ± 1112.60
	-12.01	45.10 ± 6.55	147.82 ± 99.39	795.59 ± 1943.10	
	- .03	-37.82 ± 44.28	11.15 ± 130.49		
	- 3.84	- .58 ± 40.05			
Human	- 1.09	1.35 ± .14	- 1.07 ± .12	8.46 ± 1.70	- 7.71 ± 2.47
	- 2.98	4.43 ± .34	- 4.84 ± .76	54.52 ± 14.82	
	- 4.93	9.43 ± 1.04	-14.40 ± 3.13		
	- 7.27	17.52 ± 2.73			
Horse	- 1.20	1.63 ± .12	- .88 ± .09	5.33 ± .81	- 4.24 ± .83
	- 3.02	4.60 ± .32	- 3.67 ± .43	35.85 ± 6.00	
	- 4.70	8.77 ± .67	-11.10 ± 1.50		
	- 6.78	15.77 ± 1.48			
Cow	- .55	1.54 ± .05	- .81 ± .04	3.11 ± .54	- 3.91 ± 1.13
	- 2.32	4.13 ± .12	- 2.38 ± .27	29.10 ± 7.55	
	- 3.41	6.52 ± .43	- 8.45 ± 1.79		
	- 5.33	12.36 ± 1.76			

APPENDIX TABLE V (continued).

HEART

	a	$b_1 \times 10^{-2}$	$b_2 \times 10^{-4}$	$b_3 \times 10^{-7}$	$b_4 \times 10^{-9}$
Dog	-3.22	6.78 ± .57	-27.92 ± 5.71		
	-8.81	32.13 ± 5.20	87.24 ± 81.86	-852.29 ± 604.39	
	-1.43	-18.84 ± 36.47	9.62 ± 274.71	677.45 ± 4091.10	-892.73 ± 2342.20
Human	-3.92	7.45 ± 84.26			
	-1.75	1.51 ± .12	-1.02 ± .09		
	-3.48	4.43 ± .28	3.41 ± .70	5.49 ± 1.59	
Horse	-4.59	7.46 ± .91	-4.03 ± 3.52	8.58 ± 17.26	.54 ± 2.96
	-4.72	7.96 ± 2.94			
	-1.40	1.44 ± .07			
Cow	-2.52	3.22 ± .15	.52 ± .04		
	-3.16	4.80 ± .37	-1.55 ± .23	1.94 ± .43	
	-3.91	7.44 ± 1.37	-4.37 ± 1.38	13.47 ± 5.53	-1.59 ± .76
Cow	-1.00	1.47 ± .04			
	-2.38	3.47 ± .16	.63 ± .05	1.74 ± .84	
	-3.00	4.83 ± .67	-1.51 ± 4.32	21.35 ± 18.10	-2.93 ± 2.69
	-4.43	9.35 ± 4.32	6.18 ± 4.32		

APPENDIX TABLE V (concl.).

BRAIN

	a	$b_1 \times 10^{-2}$	$b_2 \times 10^{-4}$	$b_3 \times 10^{-7}$	$b_4 \times 10^{-9}$
Dog	-2.64	6.13 ± .38	-13.30 ± 4.46	-1256.70 ± 445.93	-1050.90 ± 1958.10
	-5.30	18.21 ± 4.06	156.42 ± 60.40	540.29 ± 3419.60	
	5.55	-56.85 ± 26.91	42.87 ± 229.66		
	2.61	-26.00 ± 70.47			
Human	-.41	1.40 ± .14	-1.07 ± .12	8.42 ± 1.67	5.96 ± 2.64
	-2.46	4.65 ± .36	-4.83 ± .75	43.80 ± 15.76	
	-4.30	9.55 ± 1.01	-12.06 ± 3.28		
	-5.90	15.47 ± 2.80			
Horse	-.88	1.27 ± .08	-.60 ± .06	2.46 ± .61	2.34 ± .73
	-2.19	3.34 ± .20	-1.92 ± .33	19.60 ± 5.38	
	-3.03	5.38 ± .53	-6.16 ± 1.36		
	-4.23	9.42 ± 1.36			
Cow	-.10	1.09 ± .35	-.61 ± .03	2.58 ± .35	2.43 ± 1.23
	-1.35	2.97 ± .08	-1.87 ± .17	18.47 ± 8.10	
	-2.18	4.85 ± .26	-5.53 ± 1.88		
	-3.26	8.29 ± 1.82			

APPENDIX TABLE VI. R^2 , variance ($S^2_{y.x}$) and number of observations (N) for polynomials, one through four.

	R^2	$S^2_{y.x}$	N
<u>LIVER</u>			
Human	.810	3.92×10^3	38
	.944	3.68×10^2	
	.965	1.02×10^2	
	.970	1.06×10^2	
Horse	.820	1.15×10^6	44
	.950	3.14×10^4	
	.979	1.91×10^4	
	.978	1.11×10^4	
Cow	.885	6.52×10^5	126
	.970	1.90×10^4	
	.977	1.33×10^4	
	1.000	1.32×10^4	
Dog	.812	6.53×10^1	28
	.906	1.46×10^1	
	.901	1.34×10^1	
	.835	1.65×10^1	
<u>SPLEEN</u>			
Human	.851	2.08×10^0	28
	.908	4.04×10^{-1}	
	.915	3.99×10^{-1}	
	.941	3.24×10^{-1}	
Horse	.913	5.27×10^4	39
	.984	1.10×10^3	
	.989	1.88×10^2	
	.986	2.19×10^2	
Cow	.839	4.83×10^4	121
	.960	3.31×10^2	
	.972	2.32×10^2	
	.938	2.97×10^2	
Dog	.632	5.41×10^6	25
	.821	1.40×10^6	
	.758	1.48×10^6	
	.822	1.53×10^6	

APPENDIX TABLE VI (continued).

	R^2	$S^2_{y,x}$	N
<u>STOMACH</u>			
Human	.783	2.20×10^1	32
	.883	8.46×10^{-1}	
	.894	6.27×10^{-1}	
	.823	1.04×10^0	
Horse	.885	5.84×10^3	43
	.968	1.44×10^2	
	.977	4.92×10^1	
	.976	5.15×10^1	
Cow	.880	3.21×10^5	122
	.963	1.61×10^5	
	.978	1.58×10^5	
	.970	1.60×10^5	
Dog	.770	5.91×10^0	29
	.807	5.69×10^0	
	.828	5.72×10^0	
	.768	6.04×10^0	
<u>INTESTINE</u>			
Human	.841	4.21×10^3	34
	.935	8.52×10^1	
	.957	1.33×10^1	
	.931	3.46×10^1	
Horse	.754	1.87×10^5	42
	.900	7.23×10^3	
	.951	4.00×10^3	
	.962	2.08×10^3	
Cow	.909	1.03×10^5	105
	.958	1.17×10^4	
	.960	1.07×10^4	
	.896	1.84×10^4	
Dog	.896	1.74×10^1	29
	.942	1.66×10^0	
	.931	1.59×10^0	
	.922	1.70×10^0	

APPENDIX TABLE VI (continued).

	R^2	$S^2_{y,x}$	N
<u>THYMUS</u>			
Human	.872	1.08×10^1	28
	.928	4.95×10^0	
	.930	5.31×10^0	
	.906	4.25×10^0	
Horse	.955	5.94×10^3	32
	.976	2.85×10^2	
	.978	1.89×10^2	
	.927	4.45×10^2	
Cow	.859	1.22×10^5	124
	.956	2.40×10^3	
	.955	2.49×10^3	
	.879	3.15×10^3	
Dog	.709	5.28×10^{-1}	27
	.850	1.51×10^{-1}	
	.809	1.59×10^{-1}	
	.775	1.67×10^{-1}	
<u>KIDNEY</u>			
Human	.760	2.43×10^2	36
	.931	5.55×10^0	
	.956	6.38×10^0	
	.972	2.30×10^0	
Horse	.807	9.12×10^4	44
	.936	1.62×10^3	
	.963	8.12×10^2	
	.975	5.40×10^2	
Cow	.873	3.14×10^4	123
	.977	6.82×10^2	
	.982	6.80×10^2	
	.981	6.97×10^2	
Dog	.854	2.18×10^0	27
	.913	5.74×10^{-1}	
	.912	5.04×10^{-1}	
	.829	5.92×10^{-1}	

APPENDIX TABLE VI (continued).

	R^2	$S^2_{y.x}$	N
<u>ADRENAL</u>			
Human	.715	8.68×10^0	35
	.882	1.02×10^0	
	.930	2.19×10^{-1}	
	.904	2.65×10^{-1}	
Horse	.875	3.90×10^0	35
	.941	4.68×10^{-1}	
	.943	3.72×10^{-1}	
	.940	3.86×10^{-1}	
Cow	.849	2.14×10^0	103
	.933	3.00×10^{-1}	
	.948	2.59×10^{-1}	
	.952	2.19×10^{-1}	
Dog	.648	2.00×10^{-4}	11
	.661	1.88×10^{-4}	
	.702	1.87×10^{-4}	
	.671	2.04×10^{-4}	
<u>GONAD</u>			
Human	.587	2.83×10^{-1}	92
	.602	2.87×10^{-1}	
	.607	2.91×10^{-1}	
	.587	2.95×10^{-1}	
Horse	.716	2.48×10^4	46
	.951	5.16×10^2	
	.968	2.88×10^2	
	.963	2.42×10^2	
Cow	.842	1.05×10^1	80
	.865	2.56×10^0	
	.864	2.61×10^0	
	.862	1.69×10^0	
Dog	.304	2.11×10^{-4}	25
	.304	2.19×10^{-4}	
	.477	1.73×10^{-4}	
	.473	1.81×10^{-4}	

APPENDIX TABLE VI (continued).

	R^2	$S^2_{y,x}$	N
<u>TESTES</u>			
Human	.615	4.93×10^{-1}	52
	.627	5.03×10^{-1}	
	.631	5.15×10^{-1}	
	.680	5.24×10^{-1}	
Horse	.708	1.16×10^4	18
	.944	4.27×10^2	
	.966	1.12×10^2	
	.971	1.56×10^2	
Cow	.863	3.23×10^1	45
	.925	2.76×10^0	
	.925	2.82×10^0	
	.863	3.82×10^0	
Dog	.233	7.44×10^{-5}	15
	.295	7.99×10^{-5}	
	.441	7.37×10^{-5}	
	.892	2.24×10^{-4}	
<u>OVARIES</u>			
Human	.540	8.72×10^{-3}	40
	.612	7.67×10^{-3}	
	.612	7.86×10^{-3}	
	.622	7.85×10^{-3}	
Horse	.693	2.59×10^4	26
	.947	6.27×10^2	
	.970	4.52×10^2	
	.973	3.37×10^2	
Cow	.817	8.85×10^{-3}	35
	.873	9.30×10^{-3}	
	.908	2.78×10^{-3}	
	.896	4.43×10^{-3}	
Dog	.704	1.47×10^{-4}	10
	.723	1.46×10^{-4}	
	.741	3.52×10^{-3}	
	.691	1.35×10^{-5}	

APPENDIX TABLE VI (continued).

	R^2	$S^2_{y.x}$	N
<u>LUNG</u>			
Human	.736	1.73×10^3	37
	.925	2.33×10^1	
	.957	1.85×10^1	
	.971	6.40×10^0	
Horse	.828	5.43×10^6	43
	.947	4.55×10^4	
	.975	8.78×10^4	
	.983	1.59×10^4	
Cow	.888	1.05×10^6	126
	.978	2.13×10^4	
	.982	2.17×10^4	
	.974	1.33×10^4	
Dog	.828	2.16×10^1	31
	.918	2.36×10^0	
	.922	1.71×10^0	
	.979	1.89×10^0	
<u>HEART</u>			
Human	.797	5.31×10^2	40
	.952	8.10×10^0	
	.963	3.50×10^0	
	.957	3.65×10^0	
Horse	.914	1.45×10^5	45
	.981	1.53×10^3	
	.987	1.03×10^3	
	.976	1.07×10^3	
Cow	.905	3.18×10^4	125
	.959	4.54×10^2	
	.959	4.56×10^2	
	.884	3.89×10^2	
Dog	.828	1.78×10^0	31
	.907	5.26×10^{-1}	
	.906	4.60×10^{-1}	
	.838	5.26×10^{-1}	

APPENDIX TABLE VI (concl.).

	R^2	$S^2_{y.x}$	N
<u>BRAIN</u>			
Human	.736	1.23×10^4	37
	.924	2.80×10^3	
	.957	1.78×10^3	
	.960	1.45×10^2	
Horse	.855	1.49×10^5	44
	.961	1.25×10^3	
	.972	1.26×10^3	
	.974	7.34×10^2	
Cow	.895	1.22×10^4	118
	.982	2.46×10^2	
	.988	1.98×10^2	
	.948	1.20×10^2	
Dog	.901	2.47×10^0	31
	.925	8.95×10^{-1}	
	.932	5.68×10^{-1}	
	.848	7.09×10^{-1}	

PRENATAL VISCERAL GROWTH

by

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Prenatal visceral growth was studied in the horse, human, cow and dog. The data were collected from approximately 125 cow, 50 horse, 40 human and 35 dog fetuses. The observed variation in the data for each species was attributed to differences in breed, weight of the mother, the use of both preserved and non-preserved specimens, and in the case of the dog, size of litter.

Plots of the raw data for the heart, liver, brain and kidneys of each species exhibited normal growth curves. The results indicated that variations were not of such magnitude as to interfere with applicability of the derived growth curves to teratological studies, aging and mathematical analyses.

Mathematical models were employed to test their usefulness in describing prenatal visceral growth trends. In most cases varying degrees of the polynomial model (1) $\text{Log}_{10}Y = \alpha + \beta_1x + \beta_2x^2 + \dots + \beta_nx^n$, where Y is organ weight, x is fetal age and α and β are constants, provided the best fits to the data.

The mathematically equal equations (2) $Y = \alpha x^\beta$ and (3) $\text{Log}_{10}Y = \text{Log}_{10}\alpha + \beta \text{Log}_{10}x$ have different methods of solution. Both equations and solution methods were employed to estimate parameters of prenatal visceral growth. It was found that equation (3) and its method of solution was superior to equation (2) in describing fetal visceral growth. However, it did not provide as good a fit to the data as did equation (1).

A series of allometric comparisons between organs and between organ and body weight for each species indicated generally that the ratio of the growth rates of the organs being compared remained constant throughout the fetal period.

Empirical estimates of growth rates were made. Comparable organs of different species had similar growth rates for the horse, cow and human at near equal fractions of their respective gestation periods. No conclusions were made as to the reason for such organ growth rate synchronizations between species. Further investigation is warranted.

The literature provides many equations for pre- and post-natal growth. The logistic, Gompertz, Laird modified Gompertz and von Bertalanffy are a few of those commonly employed. The polynomial model has been used in the physical and ecological sciences for curve estimations. The results of this study indicated that polynomial models provided a simple and accurate means for approximating prenatal organism growth.