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Growth and Development

With Special Reference to Domestic Animals

LXIII. Electrocardiograms of Mules, Horses, Cattle, Sheep, Swine and Goats

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A voluminous literature has developed on electrocardiography because of its potentiality for rapid diagnosis of heart disease. This literature is, for obvious reasons, concerned almost exclusively with man. While attempting to develop an index of "work capacity" in mules[5*], it occurred to us that electrocardiography might be helpful for this purpose. This report does not, however, attempt to correlate electrocardiographic configurations with indices of "work capacity", but presents some material which may perhaps be useful as "normals" for future explorations in this field.

The literature on electrocardiography of farm animals is rather small. There is the excellent report on dairy cattle by Alfredson and Sykes[9] who, however, did not give the duration of the P and R-S-T intervals. There are four reports on the EKG of the horse: Norr[10] and Kahn[11] first observed the notching of the P wave; Yocoel and Spitz[13] experimented on the position of placing the leads on the horse in relation to the axis of the human heart; and Waller[12] reported briefly on the possible correlation between the occurrence of ventricular systole with the R and T waves. No EKG literature was found on mules or asses and only brief mention of histological studies on sheep and swine heart[8].

ANIMALS

The observed subjects included a 15-year old jackass; four 5-year old mules; thirteen horses (ten Percheron mares 2 to 14 years old, an 8 to 9-year old Percheron stallion, and two 5 to 7-year old Belgian mares); ten dairy cows (seven 3 to 9-year old Holsteins, two 6 to 7-year old Jerseys, one 8-year old Guernsey); thirteen dairy calves

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*See list of references on page 2.

(ten 30 to 244-day old Holsteins, three 50 to 61-day old Jerseys); six 60 to 90-day old pigs; twelve 1 to 6-year old sheep; five normal goats and seven 4 to 8-year old experimental goats, each of which had received in their feed approximately 60 mg. per day of stilbestrol (dimethyl ether of diethylstilbestrol) and 75 gm. per day of thyroprotein for periods ranging from two to seven months.

PROCEDURES

The electrocardiograms were taken with the subject in the standing position. The instrument, the "Cardiotron", manufactured by the Electrophysical Laboratories, is an amplifying, direct-writing type, which records on a hard thermosensitive paper.

The standard Leads I, II, and III were obtained with the electrodes attached to shaved areas covered with electrode jelly on the inner side of the fore leg approximately in the center of the humerus, and on the left hind leg above the stifle about ⅓ the length of the femur. The electrodes used were generally those supplied with the instrument. For the horses and mules a large brass alloy thin metal plate 7½″ x 4″ was used on the left hind leg in order to obtain a firmer surface contact. Where evidence of grounding was visible on the record, dry burlap bags or rubber mats were placed under the animal's feet. Other base line interferences resulting from radiowaves, etc., were eliminated when possible by working in a grounded metal building.

The measurements obtained from the electrocardiograms were analyzed statistically. All leads were standardized so that one centimeter equals one millivolt.

The galvanometer stylus of the "Cardiotron" describes an arc with a radius of six inches. The arc, according to the manufacturer, does not distort the wave forms at points within one-half centimeter of the isoelectric line; only cases of high R voltage, such as appear in precordial leads, need correction. Inasmuch as most of the time measurements were made within the prescribed limits, the effects of this curvature were not considered significant.

The measurements and nomenclature are in accordance with standards of the American Heart Association[2].

THE HEART RATE

The heart rate was determined from the electrocardiogram by counting the number of complete heart cycles within an interval of 6 seconds and estimating the fraction of a cycle over the whole number to the nearest tenth of a cycle. This count was then multiplied by ten to obtain the rate per minute.

The mean heart rate per minute for each group of animals was as follows: cows, 61; calves, 92; horses, 40; mules, 44; swine, 182; sheep, 103; normal goats, 120; and the treated goats, 108. The high heart rates in the swine may be attributed to struggling.

The duration in seconds of the intervals P-R and QRS are given in Table 1; and of the intervals P, Q-T and RST in Table 2. The mean interval was obtained and the standard error of the mean, which shows that the range in means of other similar sets of observations

TABLE 1. DURATION OF QRS WAVE AND P-R INTERVALS

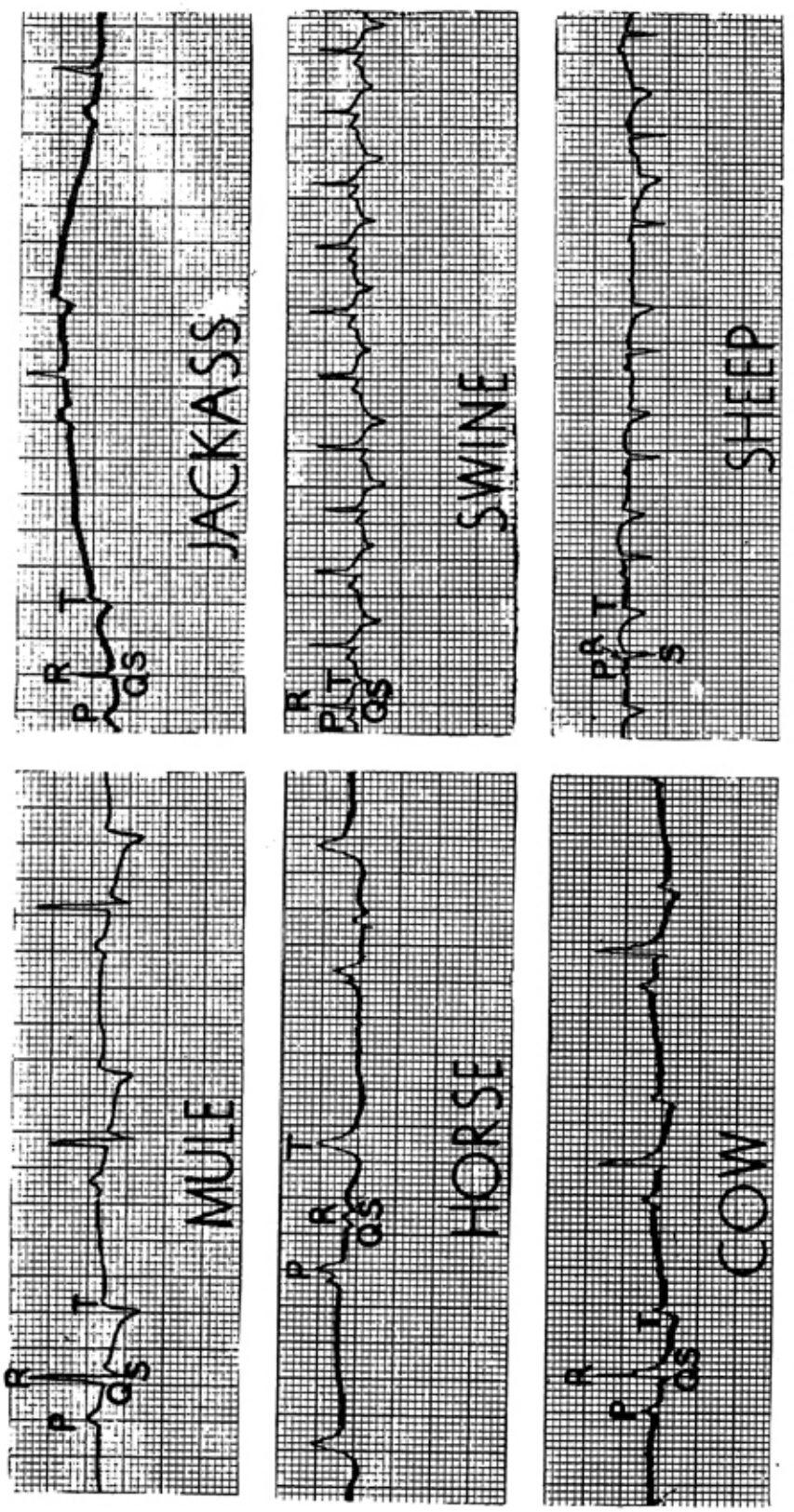
ANIMALS USED	NUMBER OF OBSERVATIONS	DURATION OF INTERVAL, SECONDS (AVERAGE OF 3 LEADS)					
		QRS			P-R		
		Mean interval	Standard error of mean[1]	Range in observation	Mean interval	Standard error of mean[1]	Range in observation
Dairy Cattle	10	0.090	0.0034	0.077 0.107	0.198	0.0096	0.250 0.160
Dairy Calves	13	0.073	0.0090	0.057 0.087	0.149	0.0033	0.133 0.167
Horses	13	0.073	0.0022	0.060 0.080	0.310	0.0082	0.280 0.360
Mules	4	0.087	0.0051	0.080 0.097	0.259	0.0157	0.227 0.293
Jackass	1	0.077			0.243		
Swine 60 to 90 days	6	0.044	0.0024	0.040 0.057	0.074	0.0023	0.067 0.080
Sheep	12	0.076	0.0027	0.060 0.087	0.115	0.0099	0.100 0.133
Goats	5	0.068	0.0017	0.063 0.077	0.107	0.0089	0.085 0.133
Experimental Goats	7	0.071	0.0025	0.060 0.080	0.119	0.0016	0.111 0.121

[1]The range in means of other similar sets of observations would not be expected to exceed twice the standard error more than one time out of three.

TABLE 2. DURATION OF P, Q-T, AND RST INTERVALS

ANIMALS USED	NUMBER OF OBSERVATIONS	DURATION OF INTERVAL, SECONDS (AVERAGE OF 3 LEADS)								
		P			Q-T			RST		
		Mean interval	Standard error of mean[1]	Range in observation	Mean K	Standard error of mean[1]	Range of K values	Mean interval	Standard error of mean[1]	Range in observation
Dairy Cattle	10	0.087	0.0026	0.070 0.097	0.412	0.0109	0.335 0.449	0.197	0.0083	0.160 0.240
Dairy Calves	13	0.074	0.0019	0.060 0.080	0.402	0.0141	0.380 0.437	0.126	0.0091	0.110 0.153
Horses	13	0.142	0.0047	0.120 0.160	0.391	0.0125	0.273 0.455	0.326	0.0075	0.280 0.373
Mules	4	0.101	0.0145	0.083 0.143	0.440	0.0131	0.404 0.469	0.305	0.0165	0.268 0.347
Jackass	1	0.087			0.388			0.248		
Swine 60 to 90 days	6	0.047	0.0028	0.040 0.057	0.331	0.0120	0.303 0.386	0.090	0.0054	0.073 0.110
Sheep	12	0.068	0.0036	0.040 0.083	0.386	0.0079	0.327 0.427	0.124	0.0085	0.077 0.180
Goats	5	0.074	0.0056	0.050 0.087	0.408	0.0104	0.379 0.431	0.111	0.0068	0.093 0.137
Experimental Goats	7	0.048	0.0038	0.030 0.060	0.388	0.0239	0.253 0.441	0.139	0.0109	0.120 0.202

[1]The range in means of other similar sets of observations would not be expected to exceed twice the standard error more than one time out of three.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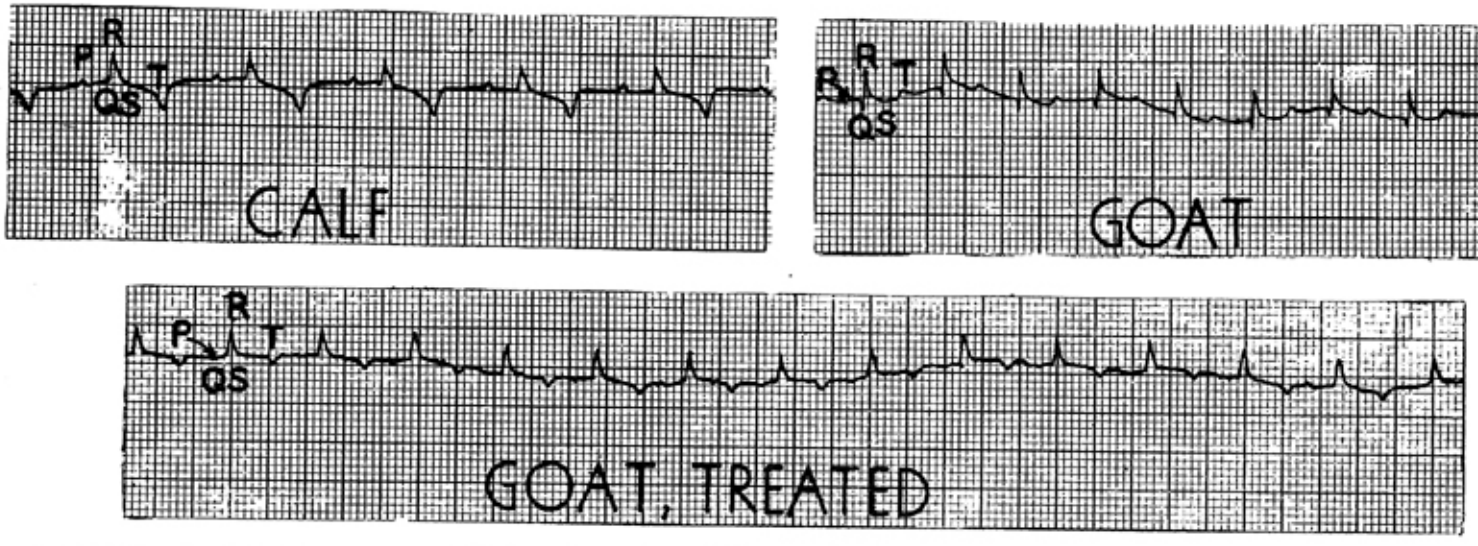

Figure 1.—Electrocardiograms of different species of farm animals. (Lead II). The letters indicate the relative positions of the various wave forms.

would not be expected to exceed twice the standard error more than one time out of three.

The P-R interval was measured in all three leads making allowance for an absent or isoelectric Q wave as recommended by Graybiel and White[6].

The Q-T time was measured from the beginning of the QRS complex to the end of the T wave. Table 2 shows the average duration in the different animals groups. These values have been corrected for heart rate (see discussion).

The following analysis (see Tables 1 and 2, and Fig. 1) of the wave forms of the electrocardiogram of the jackass shows certain resemblance to that of the mules.

The P wave was upright in all three leads. In Lead I and III it was occasionally diphasic and/or notched. These instances, however, were few in any one lead. The Q wave was absent in all three leads,

TABLE 3: DISTRIBUTION OF WAVE FORMS IN LEADS I, II, AND III IN ELECTROCARDIOGRAMS OF FARM ANIMALS

(The number of animals measured is shown by the number in parentheses. In a few instances, records were not obtained on individual animals for one or two leads.)

Wave forms	Mules (4)			Horses (13)			Dairy Cows (10)			Dairy Calves (13)			Swine (6)			Sheep (12)			Goats (5)		
Leads	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
P Wave																					
Upright	3	3	3		2	2	2	8	7	1	8	11	5	5	3	8	10	7			2
Upright; notched	1	1	1	12	9	8			1												
Inverted						1			1	4			1		1						
Diphasic				1	2		7	2	1	4	4	1				1				1	
Isoelectric or small										4	1	1		1	2	3	2	5	5	4	3
Q Wave																					
Present				1	6	2	5	4	4	4	5	1	3	5	2	2	6	5	3	3	1
Absent	4	4	4	12	2	4	4	3	3	8	6	5	3	1	3	2	2	6		1	4
QS					5	5		3	2	1	1	7			1	7	4	1	2	1	
Bizarre									1							1					
R Wave																					
Present	4	4	4	13	8	6	9	7	7	12	11	6	6	6	5	4	8	11	3	4	5
QS					5	5		3	2	1	1	7			1	7	4	1	2	1	
Bizarre									1							1					
S Wave																					
Present		4	4	1	2	4	2	2	1		2	3		1	1	1	1	1			1
Absent	4			8	4	2	7	5	6	12	9	3	6	5	4	3	7	10	3	4	4
Splintered					2																
QS				4	5	5		3	2	1	1	7			1	7	4	1	2	1	
Bizarre									1							1					
T Wave																					
Upright	1	2	3		4	9		2	4	2	9	8	1		2	2	1	8	5	5	5
Inverted	3	2		12	2		5	6		6	4	4	5	4	3	10	11	4			
Diphasic			1	1	6	2	4	2	5	3		1		2	1						
Notched (upright)					1																
Isoelectric									1	2											
S-T Segment																					
Flat	4	3	4	13	9	9	9	9	9	11	8	10	2		2	6	6	10	5	1	1
Depressed		1										1				1	2	1			1
Elevated						1								1						2	1
Convex					4	1							1	1		4	2				
Concave											1	1	1							2	2
Ascending															1						
Descending								1	1	2	3		2	4	2						
Concave & elevated											1	1			1						
Convex & depressed																1	2	1			

TABLE 4. DISTRIBUTION OF AMPLITUDES IN LEADS I, II, AND III IN ELECTROCARDIOGRAMS OF FARM ANIMALS

(The number of animals measured is shown by the number in parentheses. In a few instances, records were not obtained on individual animals for one or two leads. All amplitudes are given in millimeters.)

Wave forms	Leads	Mules (4)	Horses (13)	Dairy Cows (10)	Dairy Calves (13)	Swine (6)	Sheep (12)	Goats (5)
P Wave Amplitudes								
Monophasic	I	0.1 to 0.5	0.1 to 0.5	0.6 to 1.0	0.3 to 0.5	0.5 to 1.0	0.2 to 0.5	0.0 to 0.1
	II	1.2 to 2.5	0.6 to 3.0	0.4 to 1.2	0.4 to 1.2	0.6 to 1.2	0.2 to 0.6	0.0 to 0.2
	III	1.0 to 2.0	2.2 to 2.7	0.5 to 1.0	0.2 to 1.0	0.3 to 0.8	0.1 to 0.5	0.0 to 0.3
Diphasic	I		2.0	0.4 to 1.5	0.3 to 0.5		0.2	0.5
	II		3.0 to 4.0	0.3, 1.2	0.8 to 1.2			
	III			0.3	8.0			
Q Wave Amplitudes								
	I		1.0	0.3 to 2.3	0.6 to 1.2	1.0 to 1.4	0.7 to 3.0	0.5 to 1.2
	II		0.2 to 1.5	0.4 to 1.9	1.0 to 5.2	0.3 to 1.5	0.5 to 4.0	0.4 to 1.2
	III		0.5 to 1.0	1.2 to 2.7	1.0	0.5 to 0.8	0.3 to 3.0	1.0
R Wave Amplitudes								
	I	1.0 to 4.0	0.2 to 5.0	0.4 to 2.5	0.2 to 5.5	1.5 to 4.5	1.2 to 4.5	0.5 to 2.2
	II	8.0 to 12.2	1.0 to 9.0	0.7 to 8.0	0.8 to 4.2	3.2 to 6.0	0.7 to 5.0	1.3 to 3.0
	III	6.0 to 9.0	2.0 to 8.0	0.5 to 9.0	0.8 to 4.0	0.5 to 4.0	0.5 to 4.0	1.0 to 5.3
S Wave Amplitudes								
	I		0.5	0.2, 5.0			6.0	
	II	0.5 to 3.0	0.2 to 1.5	0.2, 1.5	0.2 to 1.5	1.0	4.0	
	III	2.5 to 4.0	1.5 to 3.0	5.0	1.4 to 1.5	2.5	2.0	0.9
T Wave Amplitudes								
Monophasic	I	-3.0 to 4.5	-3.5 to-1.2	-2.0 to-1.0	-1.5 to 1.5	-2.5 to 1.0	-3.0 to 2.0	0.5 to 1.5
	II	-3.0 to 2.5	-5.5 to 5.0	-3.0 to 4.0	-3.0 to 3.2	-4.0 to-2.0	-4.0 to 0.5	0.7 to 3.0
	III	1.5 to 4.0	1.5 to 4.5	0.0 to 3.0	1.2 to 2.5	2.0 to 3.7	-2.0 to 2.0	0.5 to 2.0
Diphasic	I		2.0	0.5 to 3.0	0.5 to 1.0			
	II		1.5 to 4.0	2.0 to 3.5		1.2 to 4.0		
	III	2.8	2.5 to 5.0	1.2 to 2.0	1.5	0.7		

resembling that in the mules. The R wave was upright in all three leads being highest in Lead II with a mean height of 5.0 mm. The S wave was slurred from R in Lead I and II but absent in Lead III. The T wave was inverted in all three leads. The S-T segment was principally flat with no measureable displacement.

The wave forms were classified very simply, retaining only the essential characteristics. The direction and range of amplitudes are given in Tables 3 and 4 respectively.

DISCUSSION

Statistical treatment of the amplitudes of the various waves would have added little to the understanding or interpretation of the results because of the limited number of animals on which records were taken. However the trend of the various complexes can be ascertained. For instance, a notched P wave characterized the horse. This resulted in an unusually long P interval. In one instance where the P wave was not notched the duration was 0.08 seconds. Only one of the 4 mules showed a notched P wave. It is difficult to estimate the significance of this deviation because of the small number of animals involved. The jackass also lacked a notched P wave. Prac-

tically, a notched P wave or a prolonged P-R or Q-T interval is almost certainly associated with a larger heart, slow pulse, and therefore probably with greater "work capacity". Species difference in heart size (in relation to body size) is instructive in indicating that "athletic species", such as the horse, have larger hearts than non-athletic species, such as the domestic pig and guinea pig[15] (see Fig. 2). The P-R and Q-T interval may well be correlated with heart size and "work capacity".

An indication of Q-T time with heart rate was worked out on all

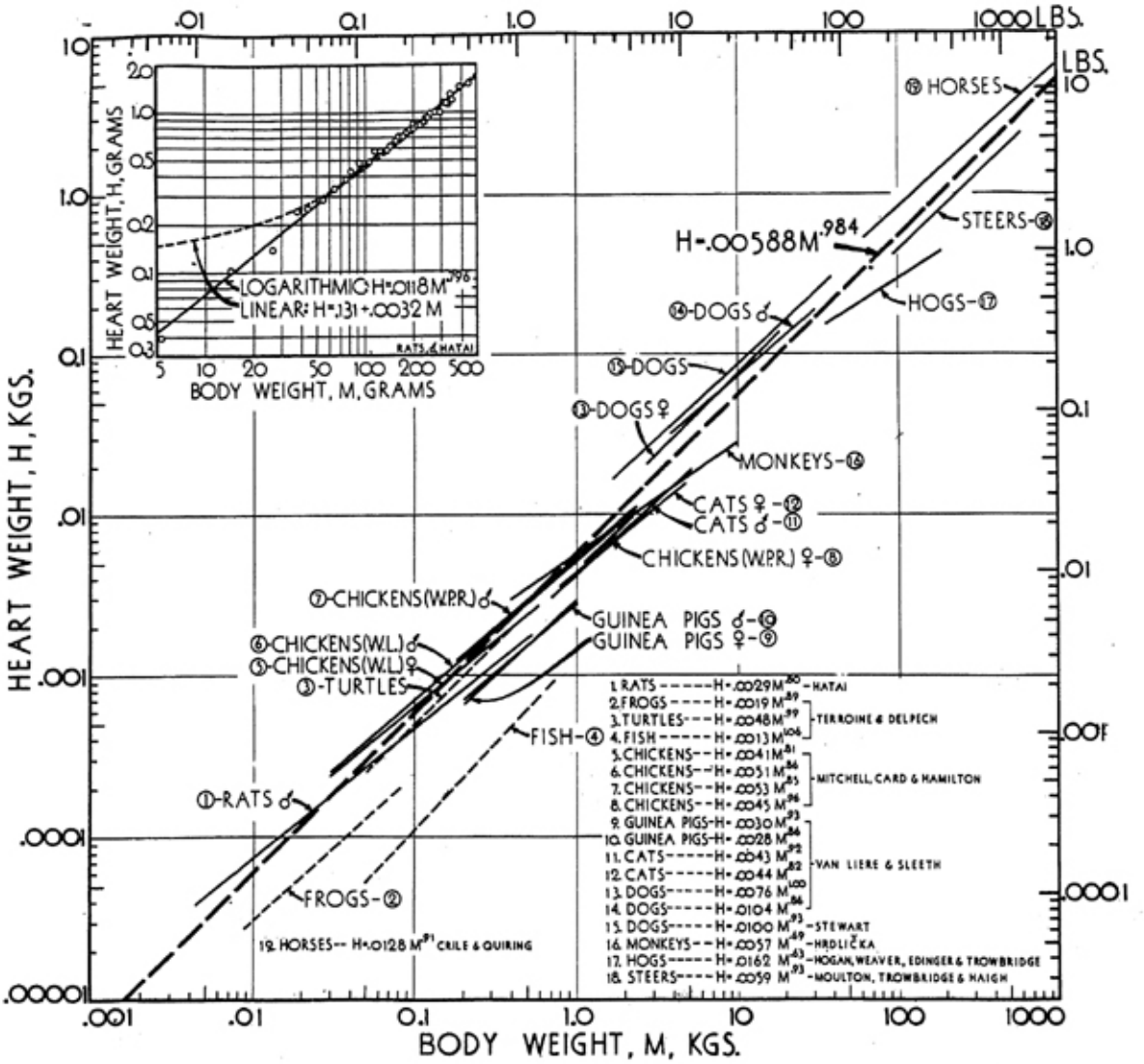

Figure 2.—The relation of heart weight to total body weight plotted on a log-log grid. Note that frogs and fishes (which do not work against gravity in locomotion) have the smallest hearts; followed by such "non-athletic" land species as guinea pigs and domesticated (fat) swine; while "athletic" species such as race horses and dogs have the largest hearts.

animals using the expression recommended by Bazett[3]. He reported that the K (corrected Q-T interval) can be increased after exercise, which is probably due to the slow rate of conduction in the ventricles. Furthermore, K may be reduced as a result of increase in vagal inhibition versus sympathetic acceleration. Alternation in K may also be due to dilatation, as during exercise. Such criteria might be valuable aids in evaluating "work-capacity". Robb[4] reported, on the basis of a study of eleven species, that the Q-T interval not only varies according to metabolic rate within one species but also with metabolic rate from one species to another. If this be the case, then the Q-T parameter would have to be determined from a very large number of animals under carefully standardized conditions.

In horses the T wave was inverted in 90% of the cases in Lead I and predominantly diphasic in Lead II; in mules most of the inversions were in Leads I and II and only one diphasic T appeared in Lead III. The Q wave was absent in all leads. In horses the Q wave was predominantly absent in Lead I, present as a QS in about 50% of the instances in Lead II and III. An upright R wave was present in every instance in mules but the horses showed an upright R wave mostly in Lead I, and in about 50% of the instances in Leads II and III.

In dairy cattle the P wave was predominantly diphasic in Lead I and in only one instance was there an inversion in Lead III. The calves, on the other hand, showed a variable P wave, being diphasic or inverted in Lead I in an equal number of instances but no inversions occurred in Leads II and III.

A study of 97 normal dairy cattle by Alfredson and Sykes[9] showed the mean duration of the QRS to be 0.09 seconds which has been confirmed in this report.

The majority of the calves reported here were less than one year old. The short QRS interval of 0.073 seconds may be attributed to age and faster heart rate. Barnes, Davis and McKay[14], who studied normal calves ranging from 12 to 589 days of age, reported QRS intervals similar in length to those observed here.

Slurring of the S wave from the down stroke of R appeared to be more prevalent in calves than in cows in Lead I and II but no difference between the two ages appeared in Lead III.

The sheep did not show inversion of the P wave in any of the three leads although in one instance a diphasic P wave occurred in Lead I. In 7 out of 12 instances the R wave was inverted (as QS) in Lead I and Q was only rarely present in Lead I but occurred frequently in Lead II. The S wave was usually absent in Lead III. The T wave was inverted in the majority of the cases in Leads I and II and upright in 8 out of 12 instances in Lead III.

The experimental goats treated with stilbestrol and thyroprotein were characterized by extra auricular systoles and exhibited in Lead II, a higher amplitude of the P wave with a mean of 0.32 mm. in contrast to an isoelectric, notched or diphasic P wave in normal goats. The negative deflection of Q preceding an upright R wave in Lead II was, however, greater for normal goats than for the medicated goats. But when considering the amplitude of Q when formed as a QS wave, the medicated goats had a greater mean amplitude, being 4.6 mm. as contrasted with the normal of 0.5 mm. The R wave in Lead II was also higher in the treated than in the normal goats, the mean amplitude being 3.7 and 3.5 respectively. The T wave in Lead II, however, was lower in amplitude in the treated goats with a mean of 1.38 mm. as contrasted with 1.72 mm. for normal goats.

These results corroborate those of Ralston *et al*[7], that thyroxine administration increases the amplitudes of the P and Q waves in Lead II and markedly decreases the T wave. However, the present conditions were not like those of Ralston *et al* because stilbestrol was given with the thyroxine. The amplitudes of the waves in Lead I were greatly reduced indicating a diminished force of the heart, and therefore a smaller output per beat. In terms of "work capacity" therefore, this treatment in normal animals would not be advantageous since "work capacity" depends on an initial slow pulse and a large output per beat to maintain the increased metabolic rate of the active tissues.

In swine the T wave was inverted in about 80% of the instances in all leads. The electrocardiograms of swine, normal goats, and experimental goats, showed waves which varied in amplitude considerably in the same lead. In the goat records the P waves continually changed in amplitude from negative to positive.

SUMMARY

1. Electrocardiographic data and their analysis have been presented for 13 horses, 4 mules, 1 jackass, 10 dairy cows, 13 calves, 6 swine, 12 sheep, 5 normal goats, and 7 goats that were fed thyroprotein and stilbestrol.

2. The various time measurements as obtained from the tracings were analyzed statistically to obtain the means and the measures of variability for each species, and the results presented in a table.

3. A correlation of P-R and QT intervals with "work capacity" in horses and mules is suggested.