TOPIC 2. CARDIOVASCULAR SYSTEM FUNCTIONS

The cardiovascular system is responsible for the distribution of oxygen and nutrients to the cells throughout the body. The role of the heart in pumping blood has been known for a long time, and the exchange of O_2 and CO_2 at the respiratory surfaces of the lungs is an important function associated with the flow of blood. The number of beats per minute and the volume of blood pumped are both dependent on the level of activity and other factors affecting the oxygen and carbon dioxide concentrations in the blood.

The cardiac cycle may be described by beginning with ventricular systole, or contractions of the two ventricles. As these contractions occur, blood is forced out of the ventricles and into the pulmonary and systemic circiuts. The two atria, or receiving chambers of the heart, are in diastole, or a relaxed condition, and fill with blood that has been propelled through the arterial system to the venous system that leads to the atria. As the atria are filled with blood and ventricular diastole occurs, the ventricles are filled with blood from the atria in preparation for the next ventricular systole.

The amount of blood pumped with each cardiac cycle is dependent on the strength of ventricular systole. As the heart beats faster, stroke volumes may increase, but not necessarily in direct proportion to changes in heart rate. The total amount of blood present also affects the strength of the circulation pattern as decreased volumes will likely result in less flow from the atria to the ventricules and throughout the systemic circulation.

The circulating blood is an active nutrient and oxygen transport system. The chemistry of the blood is important because it determines how well the blood functions as a medium for the transport of oxygen and nutrients to the sites of metabolism. The red cell fraction of the circulating blood, for example, is important because oxygen is carried primarily by the chemical combination of oxygen with hemoglobin. Thus an anemic animal is as metabolically efficient as one with higher red cell and hemoglobin concentrations, and will consequently be less able to withstand the effects of cold weather, parasites, and other factors of metabolic and ecological importance.

Evaluations of heart rates when the animals are involved in different activities at different times of the year, the stroke volumes of each heart beat, the total amounts of blood present in the animal, red cell functions, chemical characteristics of the blood are all of potential importance when estimating the metabolic potentials of free-ranging animals.

LITERATURE CITED

McCauley, W. J. 1971. Vertebrate physiology. W. B. Saunders, Co., Philadelphia, PA. 422 pp.

REFERENCES, TOPIC 2

CARDIOVASCULAR SYSTEM FUNCTIONS

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS----------------	AUTHORS/EDITORS--	YEAR
aubo	wbsc	phpa	688		comparative animal physiol	prosser,cl; brown	1961
aubo	hrwi	nyny	120		animal structure & functio	griffin,dr	1962
aubo	wbsc	phpa	713		gen and comparat anim phys	florey,e	1966
aubo	prha	ecnj	815		general & comparat physiol	hoar,ws	1966
aubo	pepr	oxen	497		intro anim physiol, geneti	pantelouris,lm	1967
aubo	wbsc	phpa	422		vertebrate physiology	mccauley,wj	1971
edbo	blsp	oxen	...		comparitive clncl haematol	archer,rk; jeffco	1977
aubo	cupr	caen	560		anim phys: adapta, environ	schmidt-nielson,k	1979

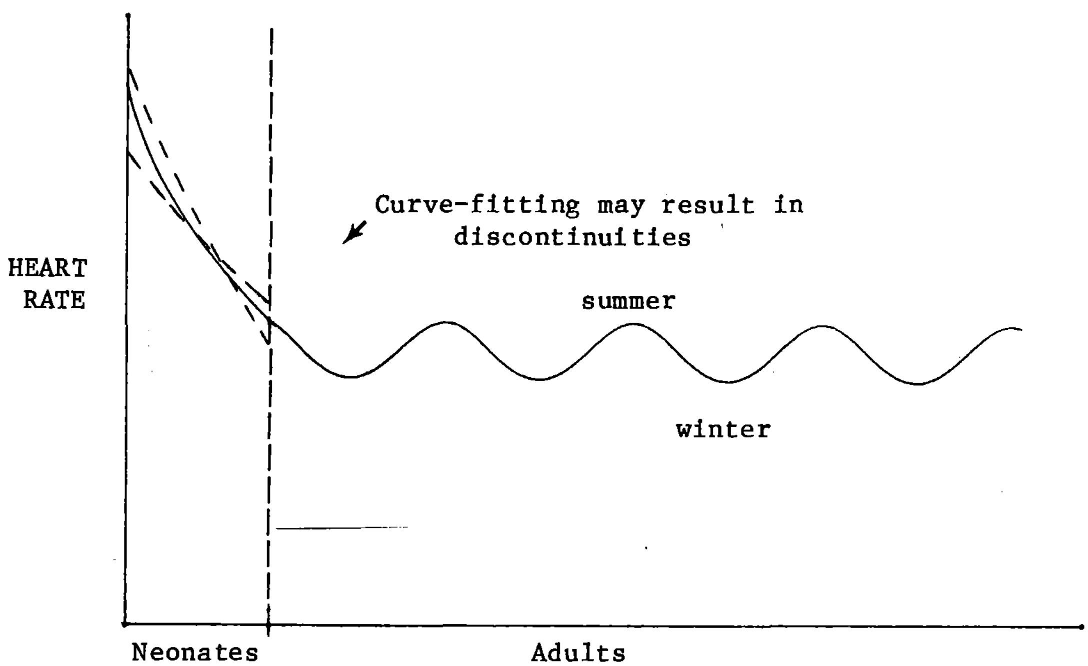
UNIT 2.1: HEART RATES

Electrocardiogram equipment, or even stethoscopes, are not standard equipment in the typical wildlife laboratory. Yet the heart rate is one of the first things to be checked when evaluating the health status of a person because it is a very important vital sign. Earlier societies considered the heart to be the center of life. Neglect of this very important organ and its vital signs in research on wild ruminants must be attributed to difficulties associated with cardiovascular research and not to a lack of importance of heart functions. Fortunately, radio telemetry now makes such research possible.

HEART RATES IN RELATION TO AGE

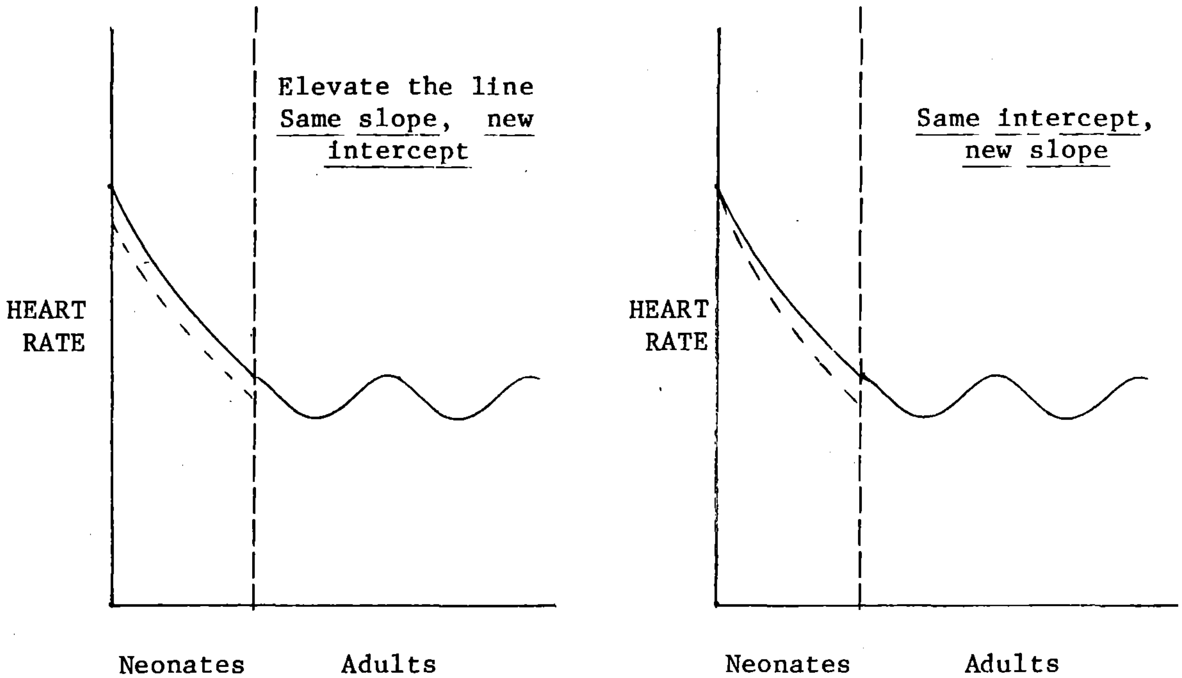
A heart rate pattern consistently observed in all species is that of a rapid decline in heart rates in the first few days or weeks or life. Heart rates of neonates are high, and they drop rapidly, logarithmically, until the rates characteristic of adults are reached. This shift from the high rates characteristic of neonates to the seasonally-variable characteristics of adult deer is observed by the end of the suckling period.

Curve-fitting of neonate and adult heart rates should be done without discontinuities where the two patterns merge, just as weight equations for different phases of growth were merged, as illustrated below.



Individual variations, experimental artifacts, and random errors contribute to mathematical discontinuities. Living animals exhibit a smooth transition in these functions from day to day, however, and mathematical representations must reflect that. The equations may have to be adjusted slightly to link directly with the equation for the other group.

Adjustments are easily made in the equation for the young by elevating the entire equation, or by curve-fitting just two points--the intercept, a, and the point where the equation for the young merges with the adult equation. The adjustments illustrated below show how the equations can be merged without discontinuities.



Heart rates of the adults of large species are slower than adult heart rates of smaller species. This is characteristic of a wide range of species; very high heart rates are observed in some small animals, such as shrews, and very slow rates in large animals, such as elephants. It is apparently true for wild ruminants too. Elk have slower heart rates than deer, and moose are expected to have slower rates than elk. Data are too limited to derive mathematical expressions of heart rates in relation to the weights of different species, however.

HEART RATES IN RELATION TO ACTIVITY LEVELS

There is a general pattern of increased heart rates with increased physical activity. Heart rates in five major activities increase in the following order: bedded, standing, foraging, walking, and running. It would be very surprising if a species or even an individual showed a different pattern. Accelerations due to fright responses may occur in any activity, however, and upset the patterns based on physical activity alone.

The use of radio telemetry techniques for transmitting heart rates of unrestrained animals in their chosen activities provides the best information when activity patterns, other animals, and other stimuli are monitored concurrently. This has been done during experiments on white-tailed deer at the Wildlife Ecology Laboratory. Insights gained in such carefully-controlled conditions are useful when interpreting variations observed in free-ranging animals.

HEART RATES IN RELATION TO TIME OF YEAR

Measurements of heart rates of wild ruminants must be made carefully over time. Heart rates of white-tailed deer varied during the year with the highest rates observed in the summer when metabolism was highest, and lowest in the winter when metabolism was lowest (Moen 1978). Sine wave variations in adult heart rates are illustrated on the previous page, showing highest heart rates in the summer and lowest in the winter.

The higher heart rate: higher metabolism pattern was evident in all activities, as heart rates were seasonally higher when the deer were walking than when they were standing, and higher when standing than bedded. The higher heart rates, and metabolism too, reflect a synchrony between range resources and animal requirements. When range resources are down, animal requirements are down, and when resources are up (during the growing season), productive functions rise to their highest levels. This is ecologically very reasonable, and represents a distinct energy conservation adaptation.

HEART RATES IN RELATION TO TRANSIENT STIMULI

While there are general heart-rate patterns in relation to age, weight, and time of year, there are also many variations due to transient stimuli. Many of these transients are very natural; the approach of a dam to its fawn may cause tachycardia, or a marked acceleration in the heart rate of the fawn. Rain and thunder also cause tachycardia; as do other animals and other natural noises. (Moen and Chevalier 1977). Sometimes heart rates are slowed; bradycardia is a characteristic fright response in neonates. Heart rate responses of whitetail fawns to recorded wolf howls included both tachycardia and bradycardia, as well as a patterned response to howl frequency and loudness (Moen et al. 1978).

The dynamics of the environment and their effects on heart rates are very great. Overall heart rate patterns in relation to both activity and time of year were observed at the Wildlife Ecology Laboratory because heart rates were recorded only when the experimental animals were being observed, relating behavior to heart rates. Further, deviations in the heart rates due to transient stimuli were also evaluated and the undisturbed heart rates in different activities determined. These kinds of data collections and analyses rather than strictly timed measurements at arbitrary intervals, were very important factors in recognizing the sine wave patterns described in Moen (1978). Another important factor in the successful recognition of patterns over the annual cycle was the careful observations and measurements on several animals for 24-hour or larger periods over several successive annual cycles. Attention to these details with animals that were treated as naturally as possible was very important in the synthesis of relationships into whole pictures, unencumbered by deviations due to experimental mathematical or statistical procedures.

LITERATURE CITED

Moen, A. N. 1978. Seasonal changes in heart rates, activity, metabolism, and forage intake of white-tailed deer. J. Wildl. Manage. 42(4):715-738.

Moen, A. N. and S. Chevalier. 1977. Analyses of telemetered ECG signals from white-tailed deer. Pages 118-125 in Proc. of Biotelemetry Conf., Univ. of Wyoming, Laramie.

Moen, A. N., M. A. DellaFera, A. L. Hiller, and B. A. Buxton. 1978. Heart rates of white-tailed deer fawns in response to recorded wolf howls. Can. J. Zool. 56(5):1207-1210.

REFERENCES, UNIT 2.1

HEART RATES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AHEMA	3----	250	261	odvi	maj arteries, shoulder,arm	bisaillon,a	1974
AJVRA	30--1	143	148	odvi	serum prot, normal, arthri	sikes,d: hayes,f/	1969
AJVRA	33-12	2545	2549	odvi	blood seru, arthrit reumat	sikes,d; kistner/	1972
AKASA	30---	50	51	odvi	electroph pattern, 2 subsp	jackman,gs; garne	1976
CBPAB	62a-4	885	888	odvi	chngs hrtrate, grwth, act	jacobsen,nk	1979
CJZOA	53--5	1207	1210	odvi	heart rate, fawn, wolf how	moen, an; dellafe/	1978
CJZOA	53--6	679	685	odvi	amb temp eff, physio trait	holter,jb; urban/	1975
JOMAA	60--2	343	349	odvi	alarm bradycardia in fawns	jacobsen, n	1979
JWMAA	37--3	413	417	odvi	seasonal heart rates, meta	moen, an	1978
SOVEA	26--1	51	58	odvi	electrocardiogram, wh-t de	szabuniewicz,m; /	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				odhe			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBCPA	61A--	43	48	ceel	oxygen utiliza elk calves	cohen,y:robbins,/	1977
JOMAA	49--4	790	791	ceel	electrocard, rocky mountai	herin,ra	1968
ZEJAA	4---4	171	177	ceel	[regulation of blood pres]	jaczewski,z; ja/	1958

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JEBPA	12--4	347	349	alal	rata, card comp emot stres	roshchevskii,mp/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
APSSA	396--	96	96	rata	blood circulation, finnish	hirvonen,l; jar/	1973
AVSPA	57---	1	18	rata	topograph, internal organs	engebretsen,rh	1975
LBANA	13--3	183	186	rata	electcardiogram, reindeer	timisjarvi,j; /	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				anam			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JZAMD	1---2	20	22	bibi	odvi, electrocrdgrph obsrv	jankus,ef; good,a	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
VETRA	97-12	230	231	ovca	electrocrdiogram, big-horn	rezakhani,a; edj/	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ovda			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	39--4	554	559	obmo	serologica evid, relations	moody,pa	1958

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				oram			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	12-32	1275	1276	bibo	electrocardi, experi death	nagorski,f; grodz	1967

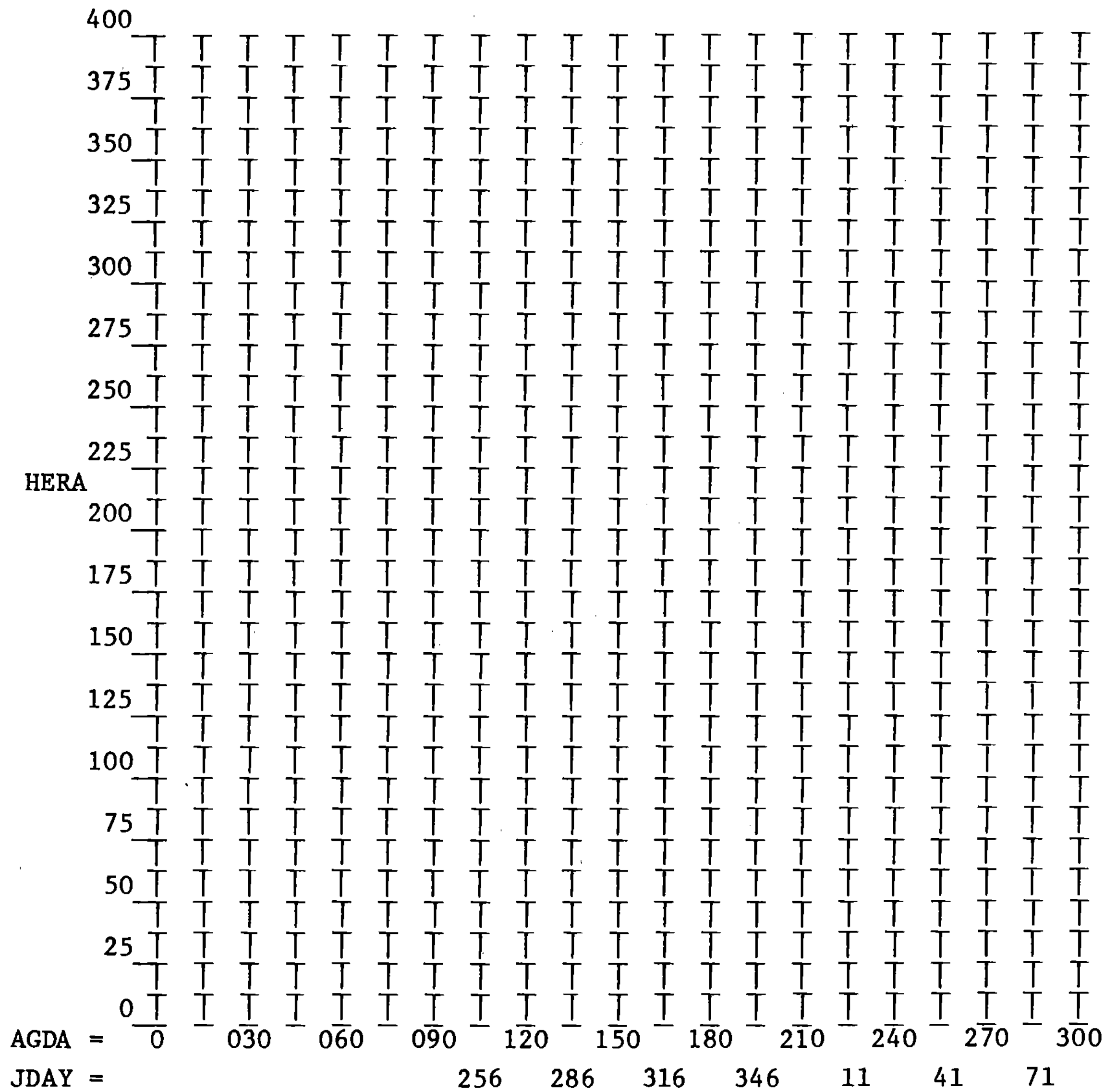
CHAPTER 6, WORKSHEET 2.1a

Heart rates of white-tailed deer fawns (odvi) in relation to age and activity

Heart rates of whitetail fawns, measured at the Wildlife Ecology Laboratory with a radio telemetry system, are related to activities and the age of the fawn. There is a rapid decline in the heart rates in different activities shortly after birth, and the rates continue to decline until 105 days of age. After this age, the heart rates vary seasonally, without regard to the age of the deer, and the equations for adult deer apply. Equations for predicting heart rates for fawns from 1-105 AGDA in five activities are listed below.

Activity	Equation
Bedded	BHRM = 250 - 35.5 ln AGDA
Standing	SHRM = 306 - 43.8 ln AGDA
Walking	WHRM = 390 - 59.1 ln AGDA
Foraging	FHRM = 321 - 45.9 ln AGDA
Running	RHRM = 383 - 40.0 ln AGDA

Plot and label the heart rates (HERA) for each of the activities on the next page. Note especially the heart rates at AGDA = 105 (JDAY = 256 if birth date = 151) comparing them to rates calculated in WORKSHEET 2.1b for adult deer on JDAY 256.


400
375
350
325
300
275
250
225
HERA
200
175
150
125
100
75
50
25
0
AGDA = 0 030 060 090 120 150 180 210 240 270 300
JDAY = 256 286 316 346 11 41 71

CHAPTER 6, WORKSHEET 2.1b

Heart rates of adult white-tailed deer (odvi) in relation to activity and time of year

Heart rates of adult white-tailed deer have been studied for several years at the Wildlife Ecology Laboratory, Cornell University. Equations for bedding, (BHRM), standing, (SHRM), walking, (WHRM), foraging (FHRM), and running (RHRM) heart rates per minute given in Moen (1978:722) are:

$$BHRM = \left[14.6878 \sin [(JDAY)(0.9863) + 226] - 0.1640\right] + 72$$

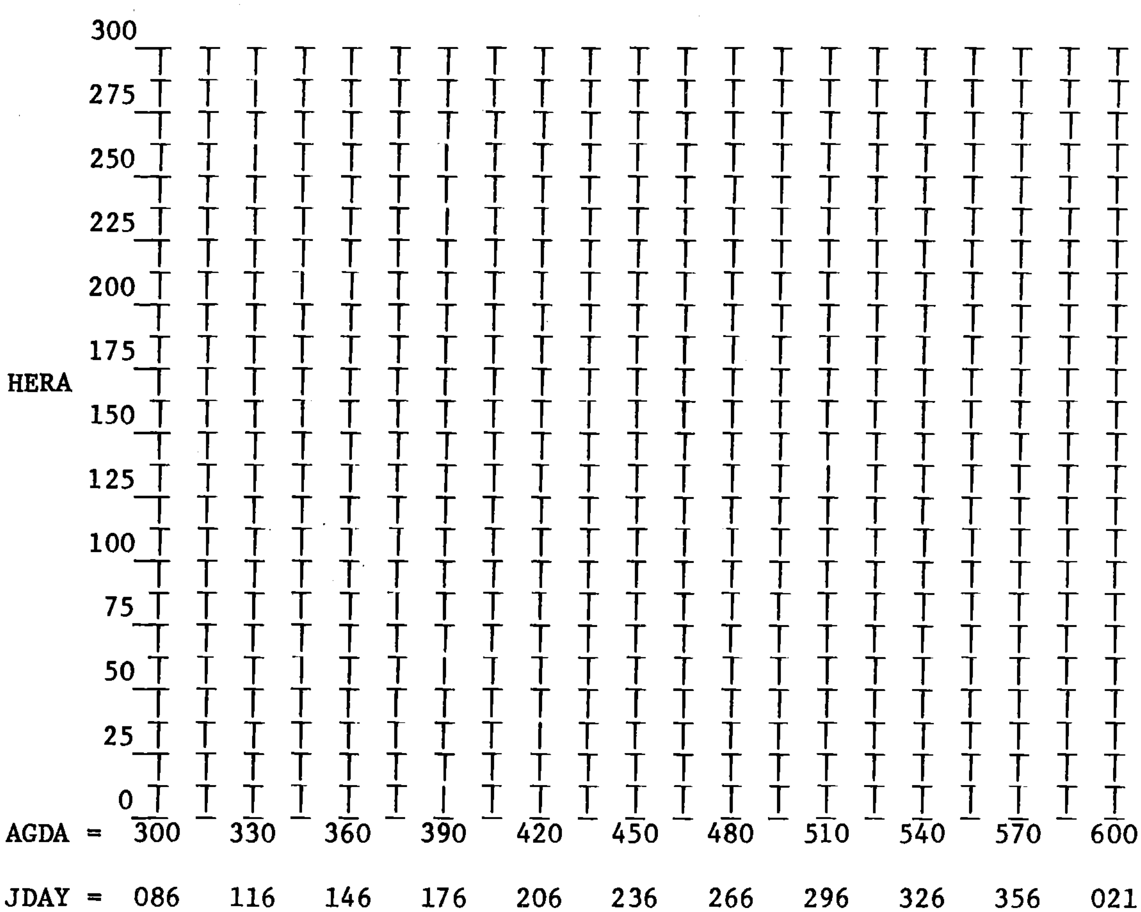
$$SHRM = \left[17.2907 \sin [(JDAY)(0.9863) + 226] + 0.4346\right] + 86$$

$$WHRM = \left[15.5409 \sin [(JDAY)(0.9863) + 226] - 0.3256\right] + 102$$

$$FHRM = \left[18.7914 \sin [(JDAY)(0.9863) + 226] + 0.1934\right] + 90$$

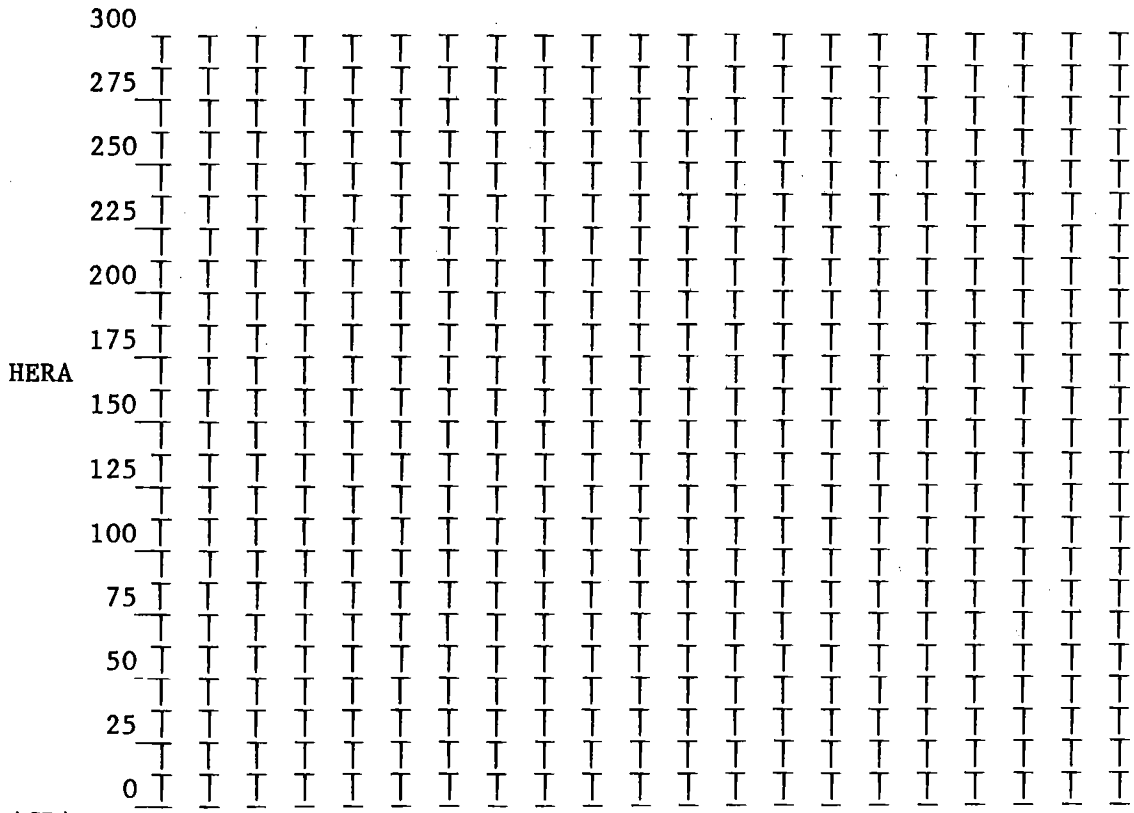
$$RHRM = \left[32.0023 \sin [(JDAY)(0.9863) + 226] + 14.7795\right] + 155$$

Plot the heart rates for AGDA 105 to 300 on the grid in WORKSHEET 2.1a, demonstrating how they merge with the results of the calculations in WORKSHEET 2.1a. Continue plotting heart rates below for each of these activities through AGDA = 600 and JDAY = 21. Plotting may be continued on the back of this page in the grid provided.



LITERATURE CITED

Moen, A. N. 1978. Seasonal changes in heart rates, activity, metabolism, and forage intake of white-tailed deer. J. Wildl. Manage. 42(4):715-738.



AGDA =

JDAY =

UNIT 2.2: STROKE VOLUME

The stroke voume is a characteristic of ventricular systole, but it is influenced by more factors than the heart itself. The amount of blood circulating depends on three major factors: the cardiac output, the general activity of the animal, and the peripheral resistance to blood flow (Hoar 1966:168-169). The cardiac output, or blood pumped per unit time, is a function of the ventricular volume, the force of the contraction, and the total blood volume in the body. The amount of blood in the heart, up to the limit of ventricular volume, is affected by the amount of venous blood returned. Muscular exercise results in an increase in the venous blood returned to the heart because of the pumping effects on the veins.

Ventricular contraction does not result in complete emptying of the ventricles; varying amounts of blood remain after each contraction. The force of ventricular contraction is limited by the muscle tissue itself, but modified up to the maximum possible by the amount of blood in the heart--it contracts more forcibly if it is full--and the effect of the hormone adrenaline, which causes an increase in the strength of cardiac muscle contraction (Schmidt-Nielson 1979:103). Total blood volume obviously affects the amount of blood in the heart and the subsequent force of the contraction.

The control of stroke volume or cardiac output is self-regulated due to the feedback effects of the return of venous blood to the heart, by hormonal regulation as adrenalin affects the strength of the contraction, and by the blood volume and venous system, all acting within the physical framework of heart size. Undisturbed animals in different activities likely have stroke volumes that are proportional to heart rates. Disturbed animals, responding to noises, by elevating heart rate, for example, likely have stroke volumes that are not in proportion to rate. Their heart rate increases are not accompanied by concommitant increases in stroke volume and metabolism is not elevated in direct proportion to heart rate increases. This is an important consideration when using heart rate as an independent variable when calculating energy metabolism.

Heart volume and heart weights in relation to body weights that were discussed in CHAPTER 1 are good starting points for further analyses of the effects of these functional effects on the realized stroke volumes in different cirumstances.

LITERATURE CITED

Hoar, W. S. 1966. General and comparative physiology. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 815 pp.

Schmidt-Nielson, K. 1979. Animal physiology: adaptation and environment. Cambridge University, Press, Cambridge. 560 pp.

REFERENCES, UNIT 2.2

STROKE VOLUME

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				odvi			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				odhe			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ZEJAA	4---4	171	177	ceel	[regula of blood pressure]	jaczewski,z; janu	1958

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JEBPA	12--4	347	349	alal	rata, card comp emot stres	roshchevskii,mp/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
APSSA	396--	396	96	rata	blood circulation, finnish	hirvonen,l; jar/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				anam			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				bibi			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ovca			

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

ovda

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

obmo

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

oram

UNIT 2.3: BLOOD VOLUMES

Blood volumes are dependent on the mass of the animal and on the time of year. Larger animals are expected to contain more blood than smaller animals, and higher blood volumes are observed during seasons of the year when metabolic functions are highest.

Total blood volume includes of both the plasma, or fluid portion, and blood cells which are suspended in the plasma. Red cells make up a greater portion of the packed cell volume than white cells.

Blood plasma volumes are regulated by the exchange of water through the capillary wall. Two factors are given by Pantelouris (1967:252) as the cause of such exchange. One, water tends to move by osmosis from the tissue spaces (interstitial fluid) into the capillaries because of the higher protein content within the capillaries, and two, the greater hydrostatic pressure inside the blood vessels tends to force water out, counteracting the movement of water in by osmosis. Thus total blood volume is maintained properly in the healthy animal by fluid exchange through the walls of the capillary network.

LITERATURE CITED

Pantelouris, L. M. 1967. Introduction to animal physiology and physiological genetics. Pergamon Press, Oxford. 497 pp.

REFERENCES, UNIT 2.3

BLOOD VOLUMES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
CBCPA	19--2	471	473	odvi	red cell life span, w-t de	noyes,wd; kitchen	1966
CPSCA	7---4	217	218	odvi	organ:body weight relation	robinson,pf	1966
JOMAA	31--1	5	17	odvi	weight relations, georg re	hamerstrom,fm,jr/	1950
JOMAA	49--4	749	754	odvi	hematologica volumes, mich	johnson,he; youa/	1968
VJSCA	26--2	61	61	odvi	immobi drug, pack cell vol	wesson,ja III; s	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	38--6	1331	1332	odhe	blood compon, seas, wt, fe	o'brien,jm; les/	1974
JOMAA	36--3	474	476	odhe	erythrocyte val, mule deer	browman, lg; sear	1955
JOMAA	52--3	628	630	odhe	tiss, organs, tota body ma	hakonson, te; whi	1971
JOMAA	53--2	384	387	odhe	total serum protein in pop	anderson,ae; med/	1972
JWMAA	34--2	389	406	odhe	erythrocyte, leukocy, colo	anderson,ae; med/	1970
PCZOA	2--10	46	46	odhe	chang, plas lipid thr year	stewart,sf; nor/	1974
WLMOA	39---	1	122	odhe	carcas, bone, organ, gland	anderson,ae; med/	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	15---	253	268	ceel	relat age and size, poland	dziecioloski,r	1970
ZEJAA	4---4	171	177	ceel	[regulation of blood pres]	jaczewski,z; ja/	1958

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	27--1	90	91	alal	weights of minnesota moose	brechinridge,wj	1946
JOMAA	50--4	826		alal	blood chemis, shiras moose	houston,db	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
APSSA	396--	96	96	rata	blood circulation, finnish	hirvonen,l; jarv/	1973
CJZOA	47--4	557	562	rata	hematologi studies, bar-gr	mcewan,eh	1968
CJZOA	50--1	107	116	rata	seas chang, blood vol, wat	cameron,rd; luick	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
RSPYA	21-3	365	370	anam	doga, cardiopulmonary para	mckean,t; walker,	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				bibi			

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

ovca

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

ovda

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

obmo

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

oram

UNIT 2.4: BLOOD CHARACTERISTICS

Blood characteristics may be divided into two major categories: hematology and blood chemistry. Hematology involves analyses of the cellular components of the blood. Blood chemistry involves analyses of the chemical components of the blood. Hematology is a physical approach, blood-chemical determinations a chemical one.

HEMATOLOGY

Counting the cellular elements in the blood of animals is valuable in assessing conditions of health and disease (Siegmund and Eaton 1967:1461). They point out, however, that variations between animals of the same species (they are discussing domestic animals) are considerable and depend on age, sex, nutrition, diurnal and sexual cycles, and stresses such as strenous exercise and excessive heat and cold. Since these variations are very much part of the lives of wild ruminants in their natural habitats, large variations should be expected in this group. Further, collections cannot be made conveniently, regularly, and without immediate stress on the free-ranging ruminant, so a very incomplete hematology picture can be obtained at best. Captive animals provide some base-line values and patterns, of course, but their relationship to free-ranging ruminants will also be variable.

A "normal hemogram" table is given in Siegmund and Eaton (1967:1462) for the ox, sheep, and goat. Categories include hematocrit, erythrocytes, hemoglobin, leukocytes, neutrophils, and lymphocytes.

Hematocrit is the packed cell volume, expressed as a percent of the total blood volume. It is determined by centrifuging the blood sample. The red blood cell or erythrocyte count is made as a check for anemia. Malnutrition, iron deficiency, or chronic disease may result in a reduction in the number of circulating red blood cells. The hemoglobin content of each red blood cell is also variable; a reduction indicates an anemic condition.

The leukocyte count usually rises in response to an acute bacterial infrection, and declines in response to acute viral infections. Neutrophils increase markedly in response to pus-forming organisms, and an increase in lymphocytes usually indicates a more chronic process, or the end stage of an acute infection. Additional details and instructions for analyzing these blood characteristics are given in Siegmund and Eaton (1967).

BLOOD CHEMISTRY

Blood chemical determinations may be made for such things as blood sugar, blood urea nitrogen, blood creatinine, and minerals such as calcium and phosphorous.

Uniform handling and collection procedures were suggested by Seal et al. (1972a) as white-tailed deer showed effects of handling (with no drugs) for up to 24 hours later. Comparisons were made for restraint and drug groups, and another paper by the same authors describes nutritional effects on thyroid activity and blood of white-tailed deer (1972b). One important result is that serum thyroxine decreases in the winter, indicating a state of hypothyrodism and decrease metabolic rate as an energy conservation adaptation. This is discussed further in CHAPTER 7.

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Seal, U. S., J. J. Ozoga, A. W. Erickson, and L. J. Verme. 1972a. Effects of immobilization on blood analyses of white-tailed deer. J. Wildl. Manage. 36(4):1034-1040.

Seal, U. S., L. J. Verme, J. J. Ozoga, and A. W. Erickson. 1972b. Nutritional effects on thyroid activity and blood of white-tailed deer. J. Wildl. Manage. 36(4):1041-1052.

Siegmund, O. H. and L. G. Eaton, Ed. 1967. The Merck Veterinary Manual. Merck & Co., Inc., Rahway, N. J. 1686 pp.

REFERENCES, UNIT 2.4

BLOOD CHARACTERISTICS

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
aubo	lefe	phpa	807		veteri hematology, 3rd ed	schalm,ow; jaina/	1975
aubo	lefe	phpa	1287		clinical hematology	wintrobe,mm	1967
edbo	coup	itny	1463		duke's physiol of dom anim	swenson,mj	1970

REFERENCES, UNIT 2.4

BLOOD CHARACTERISTICS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ZOOLA	27--4	17	23	arti	qauntita serolog relations	baier,jg jr; wolf	1942

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBPAB	23--1	149	157	cerv	serum proteins, transferri	nadler,cf; hughe/	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CNJMA	31-12	317	319	od--	erythr infec, splenec, tex	kuttler,kl; robi/	1967
JWMAA	39--2	346	354	od--	blood protn chng, gestatio	hartsook,ew; whe/	1975
NATUA	187--	333	334	od--	sickling phenomenon in dee	undritz,e; betke/	1960
PSEBA	34--5	738	739	od--	sickle cell anemia in deer	o'roke,ec	1936
PSEBA	117-1	276	280	od--	sickling, heteroge, hemogl	weisberger,as	1964

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ABBIA	127--	711	717	odvi	hemoglobin heterogeneity	huisman,thj; doz/	1968
ABBIA	151-2	540	548	odvi	struct, hemogl alph chains	harris,mj; wilso/	1972
AJPHA	199--	190	192	odvi	tactoid forma, hemoglobin	moon,jh	1960

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJVRA	30--1	143	148	odvi	serum prot, normal, arthri	sikes,d; hayes,f/	1969
AJVRA	33-12	2545	2549	odvi	blood seru, arthrit reumat	sikes,d; kistner/	1972
AKASA	30---	50	51	odvi	electroph pattern, 2 subsp	jackman,gs; garne	1976
ANYAA	241--	653	671	odvi	dome,embryo, fetal hemoglo	kitchen,h; brett,	1974
BLOOA	29--6	867	877	odvi	hemoglobin polymorphism in	kitchen,h; putna/	1967
BUCDA	29--2	105	105	odvi	geogr dist, hemoglo compon	harris mjw	1971
CBPAB	30--4	695	713	odvi	hemat, bloo chem prot poly	seal,us; erickson	1969
CBPAB	58a-4	387	391	odvi	short-term chan, corti, in	bubenik,ga; bube/	1977
CBPAB	62a-4	869	872	odvi	circannl rhythm, estradiol	bubenik,ga; buke/	1979
CJCMA	34--1	66	71	odvi	ser biochem, hemat par cap	tumbleson,me; cu/	1970
CJZOA	44--4	631	647	odvi	odhe var, blood ser, elect	van tets,p; cowan	1966
CJZOA	53--6	679	685	odvi	amb temp eff, physio trait	holter,jb; urban/	1975
CJZOA	57--4	777	780	odvi	death, sampling, blood mea	wesson,ja; scanl/	1979
CNJMA	34--1	66	71	odvi	serum biochem, hemat fawns	tumbleson,me; cu/	1970
CNVJA	14-12	299	300	odvi	chloramphenicol in blood	sisodia,cs; gupt/	1973
JBCHA	247--	7320	7324	odvi	heterog, hemogl alpha chai	taylor,wj; easle/	1972
JICRB	9---3	179	193	odvi	seas, body cond. plas vol	jacobsen,nk	1978
JOMAA	31--1	5	17	odvi	weight relations, georg re	hamerstrom,fm,jr/	1950
JOMAA	39--2	269	274	odvi	blood composition of w-t d	teeri,ae; vircho/	1958
JOMAA	39--2	309	311	odvi	aspects of blood chemistry	wilbur,cg; robin/	1958
JOMAA	41--3	410	411	odvi	vitamins a and e in blood	haugen,ao; hove,e	1960
JOMAA	49--4	749	754	odvi	hematologica volumes, mich	johnson,he; youa/	1968
JOMAA	54--1	270	274	odvi	geograph dist, hemoglo var	harris,mj; huism/	1973
JOPAA	59--6	1091	1098	odvi	hematol chan, fawns, ticks	barker,rw; hoch,/	1973
JWIDA	9---4	342	348	odvi	combin etorphine, xylazine	presidente,pja;/	1973
JWIDA	10---	18	24	odvi	blood char, free-rang, tex	white,m; cook,rs	1974
JWMAA	3---1	14	16	odvi	studies on the blood of wt	whitlock.sc	1939
JWMAA	29--1	79	84	odvi	comp milk, blood, doe,fawn	youatt,wg; verme/	1965
JWMAA	29--4	717	723	odvi	natural var blood proteins	miller,wj; hauge/	1965
JWMAA	31--4	679	685	odvi	protein requirement, fawns	ullrey,de; youat/	1967
JWMAA	34--4	1034	1040	odvi	effec immobil on blood ana	seal,us; ozoga,j/	1972
JWMAA	36--4	1041	1052	odvi	nutrition, thyroid, blood	seal,us; verme,l/	1971
JWMAA	38--4	845	847	odvi	restrain appar, blood samp	mautz,ww davis/	1974

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	39--2	342	345	odvi	ser cholesterol level chng	coblenz,be	1975
JWMAA	39--2	346	354	odvi	blood prot, gestatn, suckl	hartsook,ew; whe/	1975
JWMAA	39--4	692	698	odvi	ener, prot, blood urea nit	kirkpatrick,rl;b/	1975
JWMAA	40--3	442	446	odvi	plasma progest, puber, faw	abler,wa; buckla/	1976
JWMAA	43--2	454	460	odvi	season, nutri, serum nitro	bahnak,br; holla/	1979
MGQPA	32	113	138	odvi	physiol baselines, hematol	karns,pd	1972
NAWTA	3----	890	892	odvi	glac nat par, enlar spleen	aiton,jf	1938
PAARA	209--	1	11	odvi	feed restr, seas, antl dev	long,ta; cowan,r/	1959
SCIEA	144--	1237	1239	odvi	hemoglob polymor, sickling	kitchen,h; putn/	1964
SOVEA	28--1	25	26	odvi	blood, glucose, urolog par	hoff,gl; trainer,	1975
WDABB	3---1	32	34	odvi	serolog surv, 2 herds n y	friend,j; halter	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	34--5	477	484	odhe	age, nutrition, blood chem	kitts,wd; bandy/	1956
CJZOA	35--2	283	289	odhe	age, nutrition, blood chem	bandy, pj; kitt/	1957
CJZOA	47--5	1021	1024	odhe	observa haematology, races	cowan,imct; band	1969
JANSA	33--1	244	244	odhe	plasma mineral indexes,nev	rohwer,gl; lesp/	1971
JANSA	34--5	896	896	odhe	lipid, plas comp lev, neva	lesperance,al; /	1972
JANSA	36--6	1201	1201	odhe	wt, plasma minrl indx, fem	lesperance,al; h/	1973
JANSA	38--6	1331	1332	odhe	blood compon, seas, wt, fe	o'brien,jm; les/	1974
JANSA	41--1	273	273	odhe	effect temp on blood compo	obrien,jm; alldr/	1975
JOMAA	36--3	474	476	odhe	erythr valu, alim canal ph	browman,lg; sears	1955
JOMAA	52--3	628	630	odhe	tiss, organs, tota body ma	hakonson,te; whic	1971
JOMAA	53--2	384	387	odhe	total serum prot, populati	anderson,ae; med/	1972
JWIDA	8---2	183	190	odhe	blood serum electrol, colo	anderson,ae; med	1972
JWMAA	34--2	389	406	odhe	erythrocytes, leukocy, col	anderson,ae; med/	1970
NAWTA	17---	482	496	odhe	rela hematology to conditi	rosen,mn; bischof	1952
NAWTA	33---	359	364	odhe	blood parasites, texas dee	robinson,rm; kut/	1968
WDABB	4---3	78	80	odhe	seriol surv, arbovir infec	emmons,rw	1968
WLMOA	39---	1	122	odhe	carcas, bone, organ, gland	anderson,ae; med/	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBPAB	43a-3	649	653	ceel	blood chemis roosevelt elk	weber,yb; bliss,	1972
JOMAA	49--4	762	764	ceel	physiologic stud, rocky mt	herin,ra	1968
JWMAA	39--3	617	620	ceel	blood chemistry & hematolo	pedersen,rj; pede	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ANYAA	97--1	296	305	alal	stud on blood, serum group	braend,m	1962
CJZOA	53-10	1424	1426	alal	serum corticoid, handl str	franzmann,aw; fl/	1975
HEREA	85--2	157	162	alal	var, red cell enzy, scandi	ryman,n; beckma/	1977
JOMAA	51--2	403	405	alal	charact, captive mich moos	verme,lj	1970
JZAMD	8---1	27	37	alal	serial bl chem, hemat	franzmann,aw; bai	1977
NCANA	101--	263	290	alal	cerv, blood chem, nutritio	leresche,re; sea/	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ANIPA	22--1	105	114	rata	effect hndlng, blood comp	hyvarinen,h; hel/	1976
BLUTA	32--6	439	442	rata	hematol val, finnish reind	timisjarvi j; re/	1976
BRHLA	9---2	105	114	rata	cryorheology of rein blood	halikas,gc	1972
CBPAB	41a-2	437	438	rata	fibrinogen concentration i	halikas,gc; bower	1972
CBPAB	55a-2	187	193	rata	serum enz, calves, nut eff	bjarghov,rs; fje/	1976
CBPAB	60a-4	383	386	rata	seas chng ser levels, ions	lund-larsen,tr /	1978
CJZOA	44--2	235	240	rata	electroly, red cells, plas	manery,jf; barlo/	1966
CJZOA	46--5	1031	1036	rata	hematologi studies, bar-gr	mcewan,eh	1968
CJZOA	47--4	557	562	rata	chan, blood const with age	mcewan,eg; white/	1969
CJZOA	50--1	107	116	rata	seas chang, blood vol, wat	cameron,rd; luick	1972
CNJMA	24--5	150	152	rata	hematol val, barren gr car	gibbs,hc	1960
GNKAA	12--1	56	65	rata	[blood ser, gene poly tra]	zhurkevich,nm; fo	1976
JOMAA	33--1	105	105	rata	notes on lipids, wild mamm	wilber,cg	1952
LBASA	21--6	817	824	rata	biomedical research, reind	dieterich,ra; lui	1971
ZEBFA	9---4	341	345	rata	[hemoglobin types, ontoge]	irzhak,li	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	55--2	448	455	anam	hematol val, adult free-ra	barrett,mw; chalm	1977
CJZOA	55--8	1252	1260	anam	clinicochem val, adu free-	barrett,mw; chalm	1977
RSPYA	21--3	297	306	anam	resp functions, mamm blood	dhindsa,ds; metc/	1974
RSPYA	21--3	365	370	anam	doga, cardiopulmonary para	mckean,t; walker,	1974
WAEBA	575--	1	6	anam	pronghorn antelope carcass	field,ra; smith,/	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ABBGB	9---3	175	179	bibi	doca, isozyme chr, cell cu	carleer,j; pasto/	1978
BIGEB	9---1	1	11	bibi	two hemoglobin phenotypes	harris,mj; wils/	1973
CJZOA	57--9	1778	1784	bibi	comp blood char plain, woo	peden,dg; kraay,g	1979
EVOLA	12--1	102	110	bibi	blood groups in amer bison	owen,rd; stormon/	1958
GENTA	61--4	823	831	bibi	doca, red cells, carb anhy	sartore,g; storm/	1969
JWIDA	11--1	97	100	bibi	hematol, blood chem values	marler,rj	1975
JWIDA	12--1	7	13	bibi	hematol valu, 5 areas, u s	mehrer,cf	1976
JWIDA	14--4	493	500	bibi	serolog, hematol val, colo	keith,eo; ellis,/	1978
RSPYA	30--3	305	310	bibi	blood respirato properties	haines,h; chiche/	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBPAB	40b-2	567	570	ovca	ovca, ovmu transfe, hemogl	nadler,cf; woolf/	1971
CJZOA	51--5	479	482	ovca	stress, lymphocyte stimula	hudson,rj	1973
JAVWA	157-5	647	650	ovca	physiol valu, cap, handlng	franzmann,aw; tho	1970
JRMGA	25--4	292	296	ovca	serum phospho valu, forage	hebert,dm	1972
JWIDA	6---1	67	68	ovca	hematologic values, captiv	woolf,a; kradel,d	1970
JWIDA	7---2	105	108	ovca	physiol values, capti, wil	franzmann,aw	1971
JWMAA	36--3	924	932	ovca	envir sour, varia, phy val	franzmann,aw	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ovda			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
FEPRA	35--3	480	480	oram	ovca, angiotensi, conv enz	zakheim,r; matti/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	39--4	554	559	obmo	serologica evid, relations	moody,pa	1958

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	35--6	1271	1274	dosh	eff wat restric nutrnt dig	asplund,jm; pfand	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	37--4	584	585		serol tech, ident blo prot	tempelis,ch; rod/	1973
JWMAA	40--3	517	522	ungl	id hemoglobins, law enforc	bunch,td; meadows	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBPAB	51a-1	21	26	ceni	oxyg trnsport, phosphoryla	ochiai,t; encki,y	1975