INTRODUCTION

TO PART III

PHYSIOLOGY AND METABOLISM OF WILD RUMINANTS

Physiology is an often-overlooked aspect of the ecology of an individual or a species. Yet, no behavioral act, no maintenance activity, or no productive process can occur without basic physiological processes.

The first two PARTS of this book have included descriptions of physical and chemical characteristics (PART I) and behavior (PART II). Both contained factual information based on observations on many different species. PART III is directed more toward the functional characteristics of various systems, emphasizing the processes rather than the products of life functions.

Understanding of the functions and metabolic processes described in the next five CHAPTERS is very important for an understanding of productivity. Energy metabolism, possible only with a supply of digestible nutrients, is a fundamental characteristic of life itself, as gastrointestinal functions convert range forage energy into chemical forms that can be metabolized for maintenance and production.

Various systems of the body perform specific functions; these are discussed in CHAPTER 6. SYSTEMS PHYSIOLOGY. Metabolic processes, including ENERGY METABOLISM (CHAPTER 7), PROTEIN METABOLISM (CHAPTER 8), and MINERAL, WATER, AND VITAMIN METABOLISM (CHAPTER 9) support the functions of the systems, providing the nutrients and enzymes necessary for tissue maintenance and production. Deviations from normal metabolic functions are discussed in CHAPTER 10: FACTORS AFFECTING THE PHYSIOLOGY AND METABOLISM OF WILD RUMINANTS.

Some of the topics in these CHAPTERS are discussed in only a general way because there are no specific data available for any species of wild ruminants. In some cases, domestic ruminants have been studied intensively and the basic principles applied to wild ruminants.

There is an emphasis, whenever possible, on mathematical expressions of basic measurements in order to relate these physiological characteristics to other ecological functions. The use of mathematics to evaluate interrelationships increases as more functions of ecological importance are evaluated together. <u>Ecological accounting</u> is very important, and physiological processes, especially metabolism, are very well suited for mathematical expressions and ecological accounting.

The necessary reference information, including a glossary of symbols used, glossary of code names for the serials, and list of publishers is given at the end of each chapter. A Julian Day Calender is provided at the ends of those chapters which include time-related calculations.

The lists of REFERENCES, PART III, that follow provide essential bibliographic information for books and articles containing general information on several biological characteristics. These general references will be helpful in many of the UNITS that follow, but they are not listed again after each UNIT as the UNIT lists are limited to more specific articles of direct application to the material discussed in each UNIT.

REFERENCES, PART III

PHYSIOLOGY AND METABOLISM OF WILD RUMINANTS

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS----------------	AUTHORS/EDITORS---	YEAR
aubo	repu	nyny	1023		bioenergetics and growth	brody.s	1945
aubo	mhbc	nyny	895		a text of general physiolo	mitchell,ph	1956
aubo	saco	phpa	1180		textbook of mediacl physio	guyton,ac	1961
aubo	moco	slmo	547		textbook of physiology	tuttle,ww; schotte	1961
aubo	jwis	nyny	468		textbook of comparat endoc	gorbman,a bern,ha	1962
aubo	saco	phpa	535		body cell mass, suppor env	moore,fd; oleson,/	1963
edbo	mhbc	nyny	1427		hawk's physiological chemi	oser,bl,ed	1965
edbo	saco	phpa	1308		clinical diagn, lab method	davidsohn,i; henry	1969
edbo	orpr	nute	522		energy metabol, farm anima	blaxter,kl; kielan	1969
edbo	lefe	phpa	402		animal growth and nutritio	hafez,ese;dyer,ia	1969
edbo	acpr	nyny	439		clinical biochem, dom anim	kaenko.jj; corneli	1970
edbo	coup	itny	1463		duke's physiol of dom anim	swenson,mj,ed	1970
edbo	acpr	nyny	352		clin bioch of dom anim, v2	kaenko,jj; corneli	1971
edbo	lefe	phpa	573		textbook of veterin physio	breazile,je,ed	1971
aubo	lmep	llca	648		review of physiolog chemis	harper,ha	1977
aubo	rokp	loen	597	cerv	deer of g. britain, irelan	whitehead,gk	1964
aubo	huho	nyny	426	od--	deer, antelope of america	caton,jd	1877
edbo	stac	hapa	668	od--	deer of north america	taylor,wp	1956
aubo	stac	hapa	128	od--	if deer are to survive	dasmann,w	1971
aubo	vipr	nyny	194	od--	deer of the world	whitehead,gk	1972
aubo	omcc	eail	107	odvi	the white-tailed deer	madson,j	1961
edbo	nhfg	conh	256	odvi	the white-tai deer, new ha	siegler,hr	1968
aubo	ucap	beca	567	odhe	a herd of mule deer	linsdale,jm; tomic	1953
aubo	oxup	loen	215	ceel	herd of red deer, behavior	darling,ff	1937
aubo	stac	hapa	386	ceel	elk of north america	murie,oj	1959
aubo	wiwe	eail	125	ceel	the elk	madson,j	1966
aubo	ucap	beca	209	ceel	tule elk	mccullough,dr	1971
aubo	utop	toon	280	alal	north american moose	peterson,rl	1955

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS----------------	AUTHORS/EDITORS---	YEAR
aubo	macm	nyny	300	rata	bar-gr car of north canada	pike,w	1892
aubo	ukap	laka		rata	bar-ground carib, keewatin	harper,f	1955
aubo	qupr	oton	339	rata	migratory, barren-ground c	kelsall,jp	1968
aubo	stac	hapa	238	anam	the pronghorn antelope	einarsen,as	1948
aubo	utop	toon	957	bibi	the north american buffalo	roe,fg	1951
aubo	thcr	nyny	242	bibi	the buffalo	haines,f	1970
aubo	aakn	nyny	339	bibi	time of the buffalo	mchugh,t	1972
aubo	swap	atoh	374	bibi	the buffalo book, saga ani	dary.d	1974
aubo	uchp	chil	383	ov--	mt sheep, behavior, evolut	geist,v	1971
aubo	coup	itny	248	ov--	mt sheep, man, norther wil	geist,v	1975
aubo	usgp	wadc	242	ovca	the bighorn of death valley	welles,re; welles	1961
aubo	qupr	oton	166	obmo	muskoxen in canada	tener,js	1965
aubo	dalt	laen	271	dada	fal de: histor, distr, bio	chapman,d; chapman	1975
aubo	doup	nyny	318	many	americ anim; popular guide	stone,w; cram,we	1902
aubo	cscs	nyny	347	many	our big game	huntington,d	1904
aubo	cscs	nyny	1267	many	life hist northern animals	seton,et	1909
aubo	ropr	nyny	129	many	wildlife in alaska, ecolog	leopold,as; darlin	1953
edbo	holt	nyny	264	many	records of n a big game an	boone & crockett c	1958
aubo	ropr	nyny	547	many	mammals of north america	hall,er; kelson,kr	1959
aubo	ucap	beca	586	many	wildlife of mexico	leopold,as	1959
aubo	vipr	nyny	304	many	wildlife in america	matthiessen,p	1959
aubo	repu	nyny	335	many	principals of mammalogy	davis,de; golley,f	1963
aubo	blsp	loen	308	many	guide, study of productivi	golley,fb; buechne	1968
aubo	jhpr	bamd	769	many	mammals of the world	walker,ep; paradis	1968
aubo	whfr	sfca	458	many	wildlife ecology	moen,an	1973
aubo	utop	toon	438	many	the mammals of canada	banfield, awf	1974
aubo	repu	nyny	1023	dome	bioenergetics and growth	brody,s	1945
edbo	coup	itny	1463	dome	duke's physiol domest anim	swenson,mj	1970

SERIALS

CODEN	VO-NU	BEPA	ENPA	GENS	SPEC KEWO-----------------	AUTHORS----------	YEAR
MDCBA	5----	1	64	odvi	w-tailed deer of minnesota	erickson,ab; gunv	1961
MDCRA	14---	1	80	odvi	michigan white-tailed deer	jenkins,dh; bartl	1959
WCDBA	14---	1	282	odvi	white-tailed deer, wiscons	dahlberg,bl; guet	1956

CODEN	VO-NU	BEPA	ENPA	GENS	SPEC KEWO-----------------	AUTHORS----------	YEAR
AZWBA	3----	1	109	odhe	in arizona chaparral	swank,wg	1958
CFGGA	8----	1	163	odhe	life hist, managemt, calif	taber,rd; dasmann	1958

CODEN	VO-NU	BEPA	ENPA	GENS	SPEC KEWO-----------------	AUTHORS----------	YEAR
UCPZA	88---	1	209	ceel	tule elk: hist, behav, eco	mccullough,dr	1969
WLMOA	16---	1	49	ceel	status, ecol, roosevel elk	harper,ja; harn/	1967
WLMOA	24---	1	66	ceel	the sun river elk herd	knight,rr	1970

CODEN	VO-NU	BEPA	ENPA	GENS	SPEC KEWO-----------------	AUTHORS----------	YEAR
NCANA	101--	1	436	alal	ecol, proc inter sym, pt 1	bedard,j	1974
NCANA	101--	437	735	alal	ecol, proc inter sym, pt 2	bedard,j	1974

CODEN	VO-NU	BEPA	ENPA	GENS	SPEC KEWO-----------------	AUTHORS----------	YEAR
BPURD	2----	1	215	rata	ecol, caribou, prudhoe bay	white,rg; thomso/	1975
CWRSB	38---	1	71	rata	biology, kaminuriak popula	dauphine,tc,jr	1976
UABPA	8----	1	82	rata	ecology, managment, sweden	skunke,f	1969

CODEN	VO-NU	BEPA	ENPA	GENS	SPEC KEWO-----------------	AUTHORS----------	YEAR
WMBAA	10A--	1	79	rata	prelim investigation, pt 1	banfield,awf	1954
WMBAA	10B--	1	112	rata	prelim investigation, pt 2	banfield,awf	1954
WMBAA	12---	1	148	rata	caribou, continued studies	kelsall,jp	1957
WMBAA	15---	1	145	rata	barrn gr carib, coop study	kelsall,jp	1960

CODEN	VO-NU	BEPA	ENPA	GENS SPEC	KEWO------------------	AUTHORS----------	YEAR
AMNAA	43--2	257	354	anam	life hist, ecology, texas	buechner,hk	1950
JOMAA	3----	82	105	anam	the prong-horn	skinner,mp	1922

CODEN	VO-NU	BEPA	ENPA	GENS SPEC	KEWO------------------	AUTHORS----------	YEAR
AMNAA	24--3	505	580	ov--	distribut, variat, no amer	cowan,imct	1940
AZWBA	1----	1	153	ov--	desert bighorn	russo,jp	1956
WLMOA	4----	1	174	ov--	united sta, past to future	buechner,hk	1960

CODEN	VO-NU	BEPA	ENPA	GENS SPEC	KEWO------------------	AUTHORS----------	YEAR
AMNAA	56--2	297	324	ovca	ecology of mountain sheep	mccann,lj	1956
WGFBA	1----	1	127	ovca	wyoming bighorn study	honess,rf; frost,	1942
XNFSA	6----	1	242	ovca	th bighorn of death valley	welles,re; welles	1961

CODEN	VO-NU	BEPA	ENPA	GENS SPEC	KEWO------------------	AUTHORS----------	YEAR
CAFNA	81--1	1	22	oram	observat, brit col, canada	holroyd,jc	1967
CGFPA	8----	1	23	oram	liter review on ecology of	hibbs,ld	1966

CODEN	VO-NU	BEPA	ENPA	GENS SPEC	KEWO------------------	AUTHORS----------	YEAR
NATUA	221--	59	60	dada	geographi var, fallow deer	chapman,di; chapm	1969

OTHER PUBLICATIONS

Proceedings of the White-tailed Deer in the Southern Forest Habitat Symposium
Transactions of the Annual Meeting of the Northeast Deer Study Group (Annual meeting beginning 1964)

Proceedings of the North American Moose Conference (Vol. 5, 1968)

Proceedings of the International Reindeer/Caribou Symposium (First meeting in 1977, second in 1980)

Proceedings of the Biennial Antelope States Workshop
Transactions of the Interstate Antelope Conference

Transactions of the North American Wild Sheep Conference- (Second meeting in 1976)

Transactions of the Desert Bighorn Council (Annual meeting beginning 1957)

Proceedings of the International Mountain Goat Symposium

Proceedings of the Annual Conference of Western Association of State Game & Fish Commissioners (Annual conference beginning 1921)

LIST OF PUBLISHERS - PART III

aakn	Alfred A. Knopf	New York	nyny
acpr	Academic Press	New York	nyny
blsp	Blackwell Scientific Publications	London	loen
coup	Cornell University Press	Ithaca, NY	itny
cscs	Charles Scribner's Sons	New York	nyny
dalt	Dalton	Lavenheim, England	laen
dipr	Dial Press, The	New York	nyny
dohr	Dowden, Hutchinson & Ross	Stroudsburg, PA	stpa
doup	Doubleday, Pace, & Co.	New York	nyny
hocl	Hollis & Carter Ltd.	London	loen
huho	Hurd Houghton	New York	nyny
holt	Holt	New York	nyny

Publishers continued on the next page

jhpr	John Hopkins Press	Baltimore, MD	bamd
jwis	John Wiley and Sons, Inc.	New York	nyny
lefe	Lea and Febiger	Philadelphia, PA	phpa
lmep	Lange Medical Publishers	Los Altos, CA	llca
macm	MacMillan Co.	New York	nyny
mhbc	McGraw-Hill Book Co., Inc.	New York	nyny
moco	C. V. Mosley Company	St. Louis, MO	salo
nhfg	New Hampshire Fish & Game Dept.	Concord, NH	conh
omcc	Olin Mathieson Chem. Corp.	E. Alton, IL	eail
orpr	Oriel Press	Newcastle Upon Tyne, Eng.	nute
oxup	Oxford University Press	London	loen
qupr	Queen's Printer	Ottowa, Canada	oton
ropr	Ronald Press	New York	nyny
repu	Reinhold Publishing	New York	nyny
rokp	Routledge & K. Paul	London	loen
saco	Saunders Publishing Company	Philadelphia, PA	phpa
stac	The Stackpole Company	Harrisburg, PA	hapa
swap	Swallow Press	Athens, OH	atoh
thcr	Thomas Crowell Co.	New York	nyny
ucap	University of California Press	Berkely, CA	beca
uchp	University of Chicago Press	Chicago, IL	chil
ukap	University of Kansas Press	Lawrence, KA	laka
utop	University of Toronto Press	Toronto, Ontario	toon
usgp	U. S. Government Printing Office	Washington D. C.	wadc
vipr	Viking Press	New York	nyny
wbsc	W. B. Saunders Co.	Philadelphia	phpa
whfr	W. H. Freeman Co.	San Francisco, CA	sfca
wiwe	Winchester-Western Press	East Alton, Il	eail

GLOSSARY OF CODE NAMES, PART III

Code names (CODEN) of Serials are defined in a GLOSSARY OF CODENS at the end of each CHAPTER. The GLOSSARY below includes the CODENS listed as Serials in this PART I. It is a miniature version of the lists given at the ends of CHAPTERS.

AMNAA	American Midland Naturalist
AZWBA	Arizona Game and Fish Department Wildlife Bulletin
BPURD	Biol. Pap. Univ. Alaska Spec. Rep.
CAFNA	Canadian Field Naturalist
CFGGA	California Department of Fish and Game, Game Bulletin
CGFPA	Colorado Division of Game, Fish, and Parks Special Report
CWRSB	Canadian Wildlife Service Report and Management Bull. Series
JOMAA	Journal of Mammalogy
MDCBA	Minnesota Deptartment of Conservation Technical Bulletin
MDCRA	Michigan Department of Conservation Game Division Report
NATUA	Nature
NCANA	Naturaliste Canadien, Le
UABPA	Proceedings of the Utah Academy of Sciences, Arts and Letters
UCPZA	University of California Publications in Zoology
WCDBA	Wisconsin Department of Natural Resources Technical Bulletin
WGFBA	Wyoming Game and Fish Commission Bulletin
WLMOA	Wildlife Monographs
WMBAA	Wildlife Management Bulletin
XNFSA	U S National Park Service Fauna of the National Parks of the United States, Fauna Series

THE BIOLOGY AND MANAGEMENT OF WILD RUMINANTS

CHAPTER SIX

SYSTEMS PHYSIOLOGY

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CONTENTS OF CHAPTER SIX

SYSTEMS PHYSIOLOGY

CHAPTER 6. SYSTEMS PHYSIOLOGY

Animals are complex biochemical entities, with specialized organs that perform particular functions. Organs have functional relationships with other body parts, and those with related functions are grouped together as systems.

The physiological functions of the systems of wild ruminants have not been studied very thoroughly. This is understandable because of the costs and difficulties involved. Their importance, however, is great, since physiological functions encompass all of the biochemistry of life. They have been given considerable attention by domestic animal scientists, and Duke's Physiology of Domestic Animals (Swenson 1970) is a classic text on this general subject.

A number of vital signs, including heart rates, respiration rates, and body temperatures are considered in this chapter. Signs indicate the status of the functions of some rather important body systems. Many of the functions are of direct importance to two or more systems. Cardiovascular and respiratory functions are interrelated, and these interact with the products of gastrointestinal functions. They also indicate the presence of internal responses that are not always accompanied by overt behavioral responses. Heart rates, for example, may accelerate as a fright response, even though the animal may not run away.

Vital signs also show diurnal and seasonal variations. Heart rates of deer, for example, are reduced when an animal is at rest each day, a short-term energy conservation adaptation, and they are reduced in winter when deer are less active, a long-term and very important energy conservation adaptation.

The organization of CHAPTER 6 is based on commonly-recognized systems of the body. The TOPICS describing the functions of each system are presented in the same order as the UNITS in CHAPTER 1 which contained descriptions of system characteristics.

LITERATURE CITED

Swenson, M. J., Ed. 1970. Dukes's physiology of domestic animals. Comstock Publishing Co., Cornell University, Ithaca, NY. 1463 pp.

REFERENCES, CHAPTER 6

SYSTEMS PHYSIOLOGY

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS------------------	AUTHORS/EDITORS--	YEAR
aubo	mhbc	nyny	895		a textbook of genl physiol	mitchell,ph	1956
aubo	jwwa	pome	194		introduc to mammal biology	avis,fr	1957
aubo	uchp	chil	642		basic physiology	d'amour,fe	1961
aubo	moco	salo	547		textbook of physiology	tuttle,ww; schott	1961
aubo	haro	nyny	619		genl physiol, molec apprch	dowben,rm	1969
aubo	wiwi	bama	1964		textbk genl physio, 4th ed	davson,h	1970
aubo	hrwi	nyny	231		structu and functn, 2nd ed	griffin,;dr; novi	1970
edbo	coup	itny	1463		duke's physiol of dom anim	swenson,mj,ed	1970
edbo	lefe	phpa	573		textbook of veterin physio	breazile,je,ed	1971
aubo	saco	phpa	422		vertebrate physiology	mccauley,wj	1971
aubo	vare	nyny	691		principles of physiology	hartenstein,r	1972
aubo	edar	loen	342		princ anim physiol, 2nd ed	wood,dw	1974
aubo	hein	loen	660		biology of mammals, 4th ed	clegg,pc; clegg,a	1975
aubo	grst	nyny			intro to physiolog, 5 vols	davson,h; segal,m	1975
aubo	prha	ecnj	848		gen & comp physiol, 2nd ed	hoar,ws	1975
aubo	haro	nyny	656		comp phy of anim, env appr	hill,rw	1976
aubo	hrwi	nyny	533		intro to comparatv physiol	goldstein,l	1977
aubo	macm	nyny	699		phys, princ, adapt, 3rd ed	gordon,ms	1977
aubo	whfr	sfca	558		animal physiology	eckert,r; randall	1978
aubo	cupr	nyny	560		phys, adapt, envir, 2nd ed	schmidt-nielsen,k	1979
aubo	macm	nyny	891		princ anim physiol, 2nd ed	wilson,ja	1979

TOPIC 1. GASTROINTESTINAL SYSTEM FUNCTIONS

The gastrointestinal system functions both mechanically and chemically as foods are ingested and broken down. The process of digestion involves the conversion of ingested food into forms that can be absorbed by the body and assimilated into body tissue. The preparation of ingested food for digestion begins with mechanical processes, and ends with biochemical processes.

Foods eaten "are merely the carriers of the nutrients and the potential energy . . . . in a satisfactory diet." (Crampton and Harris 1969:5). Nutritive analyses must include not only investigations of food habits but also the digestion and assimilation of nutrients at different times of the year and under different range conditions. Microorganisms are absoslutely essential in ruminant digestion as there are no glands in the lining of the rumen and reticulum to secrete digestive enzymes.

The four functional parts of the mature ruminant's stomach are, in order of food passage: rumen, reticulum, omasum, and abomasum. At birth, the abomasum, or "true stomach," is the most well-developed, and the neonates are essentially monogastric animals. Ingested milk goes directly into the omasum via the oral groove, a passage that opens to allow milk to go to the omasum but closes when forage is swallowed, diverting that to the rumen. As the amount of forage ingested increases, the rumen develops thick muscular walls that contract rhythmically, promoting the breakdown and sorting of the ingesta for additional mastication of the coarser particles and passage of the finer particles to the reticulum, omasum, and abomasum.

Saliva functions as a lubricant and has a part in maintaining the fluid volume in the rumen. It assists in digestion to a very limited extent as the microorganisms in the rumen are almost totally responsible for the chemical breakdown of food in the rumen and reticulum. Nitrogen in the saliva is a substrate for protein synthesis by the rumen microorganisms, and their protein is subsequently useful to the ruminant host (Annison and Lewis 1959).

The rumen is lined with very rudimentary papillae at birth, and their development is dependent on the presence of volatile fatty acids (VFA's), the end products of rumen fermentation (Flatt et al. 1958), which are an energy source for the host animal. The papillae lining the interior surface of the rumen elongate as the amount of rumen fermentation increases, greatly increasing the surface area inside the rumen and permiting more rapid absorption of the VFA'S.

The reticulum, the second stomach compartment, is not as muscular as the rumen, and the internal surface has only a few papillae and no glands. It is separated from the rumen by the rumenoreticular fold, which acts like a dam to retain the larger particles of ingesta in the rumen. The smaller particles of ingesta are washed into the reticulum, and then they move on to the third stomach compartment, the omasum.

The absorption of water from the ingesta seems to be the principal function of the omasum. The internal surface has many granular papillae that greatly increase the surface area for absorption. Since the omasum is relatively small, the processed ingesta must move on to the fourth compartment, the abomasum, rather quickly.

The abomasum has a muscular layer composed of thin fibers in small bundles, an outer serous layer, and an interepithelial lining that includes secretory glands (Short 1964). It is the only part of the stomach which secretes digestive juices (Phillipson 1970:454). He points out that the movement of ingesta into the abomasum from the omasum and from the omasum to the duodenum is influenced by the quantities of material in the recipient organ. It appears that both the amounts and chemical characteristics of ingested materials have become fairly uniform by the time the processed ingesta reaches the abomasum.

Ruminants have a small and nonsacrulated large intestine (Dukes 1955: 416). A diverticulum at the proximal end, called the cecum, does have some fermentation of food materials going on (Dukes 1955:428), but this is of little overall importance.

A series of mechanical actions keeps the ingesta moving through the gastrointestinal tract. Pressure or strain gauges are used to measure movement, especially in the rumen and reticulum. Both _in vivo_ and _in vitro_ techniques are used to study fermentation and digestion. Rumen fistulas, openings to the rumen through lateral incisions in the body walls, have been used extensively in studies on cattle and sheep, making it possible to suspend nylon mesh sacks of forage in the rumen for _in vivo_ fermentation analyses, and to collect rumen fluid with a minimum of disturbance to the animal for _in vitro_ measurements of fermentation. Several researchers have used fistulas on wild ruminants held in captivity as well.

The use of _in vitro_ fermentation techniques, with flasks of forage samples and rumen fluid maintained at rumen temperatures in a water bath, is an inexpensive way to study fermentation rates and processes. The products of fermentation can be conveniently analysed, but with caution since artificial rumens are not identical to natural (_in vivo_) ones. Additional information and photos of a fistulated deer and an _in vitro_ fermentation bath are in Moen (1973:149-159).

This topic contains three units describing the mechanical and chemical processes of digestion. Since gastrointestinal functions are an important and well-studied aspect of domestic animal science, several books which deal primarily with this topic are listed as references after the LITERATURE CITED. Serials describing gastrointestinal functions are listed after each of the units.

LITERATURE CITED

Annison, E. F., and D. Lewis. 1959. Metabolism in the rumen. Wiley, New York and Methuen, London. 184 pp.

Crampton, E. W., and L. E. Harris. 1969. Applied animal nutrition. 2nd ed. W. H. Freeman and Company, San Francisco. 753 pp.

Dukes, H. H. 1955. The physiology of domestic animals. 7th ed. Comstock, Ithaca, New York 1020 pp.

Flatt, W. P., R. G. Warner, and J. K. Loosli. 1958. Influence of purified materials on the development of the ruminant stomach. J. Dairy Sci. 41(11):1593-1600.

Moen, A. N. 1973. Wildlife ecology. W. H. Freeman and Co., San Francisco. 458 pp.

Phillipson, A. T. 1970. Physiology of digestion and metabolism in the ruminant. Proc. 3rd Intern. Symp., Cambridge, England. Oriel Press, Newcastle upon Tyne, England. 636 pp.

Short, H. L. 1964. Postnatal stomach development of white-tailed deer. J. Wildl. Manage. 28(3):445-458.

REFERENCES, TOPIC 1

GASTROINTESTINAL SYSTEM FUNCTIONS

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
aubo	edar	loen	252	rumi	reactions in the rumen	barnett,ajg; reid	1961
edbo	butt	loen	297	rumi	digestiv physiology of rum	lewis,d,ed	1961
edbo	butt	wadc	480	rumi	physiology of digesti, rum	dougherty,rw,ed	1965
edbo	libr	boma	261	many	recent advanc in anim nutr	abrams,jt,ed	1966
aubo	acpr	nyny	533	rumi	the rumen and its microbes	hungate,re	1966
edbo	acpr	nyny	427	many	comparativ nutrition, wild	crawford,ma,ed	1968
aubo	amph	wash		rumi	handbook of physiol: alime	code,cf,ed; heide	1968
aubo	moco	salo	262	many	physiol of gastroint tract	texter,ce,jr; ch/	1968
aubo	dcdh	coor	316	rumi	digest physiology, nutriti	church,dc	1969
aubo	whfr	sfca	753	many	applied animal nutrition	crampton,ew; harr	1969
edbo	orpr	nute	636	rumi	physiolog digest, metaboli	phillipson,at,ed	1970
aubo	orst	coor	801	rumi	dig physiol,nut of ruminan	church,dc	1971
edbo	dcch	coor	350	rumi	dig phys, nut of ruminants	church,dc,ed	1972
aubo	whfr	sfca	458	rumi	wildlife ecology: an analy	moen,an	1973
edbo	iepu	nyny	576	many	physiolog adapta to enviro	vernberg fj,ed	1974
edbo	unep	arau	602	rumi	digesti, metaboli, ruminan	mcdonald,iw; warn	1975
edbo	coup	itny	1020	rumi	physiolog domestic animals	dukes,hh	1955

UNIT 1.1: MECHANICAL FUNCTIONS

Mechanical functions keep the food materials moving through the alimentary canal. These begin with the prehension and ingestion of food, followed by mastication, swallowing, rumination (including regurgitation, mastication again, swallowing, and rumen contractions), passage to the omasum and abomasum, intestinal contractions, and the opening and closing of valves between the parts of the gastrointestinal tract. As the food passes through the alimentary canal, saliva and digestive juices are mixed with the food, and the enzymes in these secretions compliment the fermentations by rumen microorgaisms in the overall process of digestion in the ruminant. Food in the rumen and reticulum is actively moved and churned as it is metabolized by rumen microorganisms. The movement results in the separation of the ingesta into layers, with the finer particles moving from the rumen and reticulum onto the omasum and abomasum. Finally, defecation of undigested food materials occurs.

Prehension. Prehension is accomplished in different ways among wild ruminants. Browse is removed by grinding it off with the molars, and low herbaceous vegetation is ingested by seizing the plant material between the lower incisors and upper gum. Plant parts, such as flowers, can be carefully and selectively removed. Moose sometimes feed underwater, submerging their heads, blocking off the nasal passages, and grasping the vegetation in their mouths. The different abilities of wild ruminants in selective foraging contribute to differences in their food habits; Cervids are generally more selective feeders than Bovids.

Mastication. Ruminants chew the forage some when it is ingested and again after it has been regurgitated. Most of the mechanical reductions in particle size occurs when the animal chews the regurgitated bolus, usually while bedded between feedings. The vertical and lateral movements of the jaws result in a rotary motion centered on one side at a time. The teeth wear roughly, increasing their grinding efficiency as particle sizes are reduced and surface areas increased, resulting in greater efficiencies in fermentation.

Swallowing. Swallowing is a complex reflex act in the ruminant. Milk ingested by nursing young goes into the omasum via the closed esophageal groove. After weaning, the esophageal groove no longer functions and water goes directly to the rumen with the rest of the ingesta. The water content of the forage is important for ruminants as foods that are not sufficiently moist do not start the muscular contractions involved in swallowing. Salivation also occurs, and the saliva is mixed with the food during mastication until the bolus is swallowed. When swallowing occurs, respiration is inhibited and the glottis and posterior end of the nares are closed, preventing the possibility of food entering the respiratory tract via the trachea. The food swallowed enters the rumen where rumination adds to the mechanical treatment of the food, followed by chemical fermentation in the rumen and reticulum.

Rumination. Rumination includes regurgitation, mastication and salivation again, followed by swallowing. The frequencies and durations of these events are dependent on the characteristics of the diet. Rumination begins a few days after birth, and adult-type rumination rhythms occur within a few weeks. Regurgitation involves contraction of the skeletal muscles. Dzuik et al. (1963:782) observed that white-tailed deer sometimes regurgitated ingesta, swallowed without mastication and regurgitated again in less than ten seconds. The rapid reswallowing may have been associated with characteristics of the bolus. The contraction patterns of the rumen and reticulum of a showed that contractions of the musculature of the rumen and reticulum were very closely associated (Dziuk et al. 1963). The first or primary rumen contraction, involving all parts of the rumen, followed two successive contractions of the reticulum, or "reticular doublet." A secondary rumen contraction, involving the dorsal sac, posterior dorsal blind sac, and the ventral sac of the rumen, sometimes occurred. The duration of the ruminoreticulum cycle in the white-tailed deer was 20-30 seconds. The frequency of reticular and primary rumen contractions varied with the activity of the deer, with 1.8 contractions per minute when standing and 2.2 contractions per minute when bedded. Secondary rumen contractions varied from 0.6 to 0.8 contractions per minute while standing and 0.2 to 0.5 contractions per minute when bedded. Dzuik et al. concluded that similarity of the pressure events in deer, cattle, and sheep were marked.

Stomach and intestinal movements. In the omasum, contractions of the muscular walls compress and pulverize the food and much of the water is absorbed. The food materials are then passed on to the abomasum where gastric juice is secreted and the fluid content is restored to the approximate level in the omasum. The hydrochloric acid content of the gastric juice causes the pH to fall to 1.5 - 3.0. The protozoa disintegrate there and some of the bacteria are killed. The food materials pass through the abomasum quite rapidly and move on into the small and then the large intestine (Annison and Lewis 1959:18).

Defecation. When the food reaches the rectum it consists largely of undigestible materials and water. The fecal mass also includes tissue that has been removed from the lining of the alimentary canal, as well as the remains of rumen microorganisms that have escaped digestion in the small intestine. The water content is variable, depending on species, diets, and time of year. Defecation occurs several times a day, often but not necessarily shortly after the animal leaves its bed. The number of defecations per day have been used in estimating populations from pellet group counts.

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MECHANICAL FUNCTIONS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	20--1	70	74	odvi	eval pell gr count, census	eberhardt,l; van	1956
JWMAA	26--1	50	55	odvi	rain, count of pellet grou	wallmo,oc; jacks/	1962
JWMAA	26--3	341	342	odvi	use of rumen fistula in wh	short,hl	1962
JWMAA	28--3	4451	458	odvi	postnatal stomach developm	short,hl	1964
JWMAA	29--4	723	729	odvi	sourc of error, pell group	van etten,rc; ben	1965
JWMAA	39--3	596	600	odvi	rumen overld, rumenitis in	wobeser,g; runge	1975
JWIDA	13--3	281	285	odvi	rumenitis in suppl fed her	woolf,a; kradel,	1977
NAWTA	32---	420	429	odvi	use, chrom 51, digest stud	mautz,ww; petride	1967
NFGJA	7--1	80	82	odvi	perist, wint pelle grp, ny	patric,ef; bernha	1960

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	36--3	474	476	odhe	values, alimen canal ph	browman,lg; sears	1955
JOMAA	46--2	196	199	odhe	reminoreticular characteri	short,hl; medin,/	1965
JWMAA	28--3	435	444	odhe	defecation rates of mule d	smith,ad	1964
JWMAA	34--1	29	36	odhe	ceel, freq dist pellet grp	mcconnell,br;smit	1970
UASPA	32---	59	64	odhe	indices of carc fat, color	anderson,ae; med/	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	15---	253	268	ceel	relatio, age, size, poland	dzieciolowski,r	1970
JWMAA	24--4	429	429	ceel	dyes to mark ruminan feces	kindel,f	1960
JWMAA	29--2	406	407	ceel	determ defeca rate for elk	neff,dj; wallmo,/	1965
JWMAA	35--4	673	680	ceel	rumen characteristi, red d	prins,ra; geelen,	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	40--2	374	375	alal	dail wint pell gr, bed, al	franzmann,aw; ar/	1976
NCANA	95--5	1153	1157	alal	[numb pellet-gro each day]	desmeules,p	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AVSPA	57---	1	18	rata	topograph, internal organs	engebretsen,rh	1975
NJZOA	24--4	407	417	rata	morph,fat stor,org wt,wint	krog,j; wika,m; /	1976

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	13---	499	509	bibo	capac, weigh, walls, diges	gill,j	1968
ATRLA	14---	349	402	bibo	morphology digestive tract	pytel,sm	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
FEPRA	27--6	1361	1366	rumi	regulation of feed intake	baile,ca	1968

UNIT 1.2: FERMENTATION AND DIGESTION

Food materials are complex structures that must be broken down by rumen fermentation and digestion before the nutrients can be assimilated into new body tissue. Foods can be divided into two physical groups, water and dry matter, and the latter can be divided into chemical groups with similar characteristics as outlined below.

I. Water

II. Dry Matter

- A. Organic substances
  - 1. Nigrogenous compounds (crude protein)
    - a. True protein
    - b. Non-protein nitrogenous materials
  - 2. Non-nitrogenus substances
    - a. Carbohydrates
      - 1. Soluble carbohydrates (nitrogen free extract)
      - 2. Insoluble carbohydrates (crude fiber)
- B. Inorganic substances (ash)
  - 1. Salts
  - 2. Mineral matter

Rumen microorganisms break the food materials down into substrates that can be used for their own metabolism, and the metabolic by-products of the microorganisms and the microbes themselves are then chemically processed by the ruminant host for use in their own energy, protein, mineral, vitamin, and water metabolism. The ruminant host and the rumen microorganism represent a highly developed symbiotic relationship. Nearly 900 strains of bacteria and more than 100 species of protozoa have been identified in the anaerobic rumen environment of different ruminants (Moen 1973:151). No individual has this many kinds, of course; variations in the number present of each strain are primarily due to differences in diets.

The actual number of microorganisms in the rumen is very large. The mean number of protozoa may be 10^6 or one million in each milliliter of rumen contents (Pantelouris 1967:193), and of bacteria about 10^9 to 10^{10} in each milliliter (Annison and Lewis 1959:33). Expressed in longhand, the number is 10,000,000,000 (ten billion) bacteria in each milliliter of rumen contents.

The rumen is an open system that depends on the flow of food materials into it and the flow of microorganism metabolites and food residues out. When the supply of food in the rumen is maintained by frequent intake, conditions in the rumen remain quite constant as the microorganisms have a stable substrate for the maintenance of their own metabolic activities. If food remains undigested in the rumen, appetite and rumen movement stop. If the rumen is then filled with actively fermenting rumen fluid from other animals, both appetite and rumen movement begin again (Nagy et al. 1967:447).

The failure of deer to survive when fed artificially in the winter has been attributed to a lack of the types of rumen microorganisms necessary for breakdown of such things as alfalfa hay. Research by Nagy (1967:446) has shown that no major adjustments in the microbial spectrum were necessary when deer were fed alfalfa hay, and other factors appear to be more important when deer are found dead with their rumens full of nutritious hay and other artificial feeds. Nagy suggests that as the amount of forage ingested decreases under starvation conditions there is a concomitant loss in the number of properly functioning rumen microorganisms. When the rumen contains a relatively small number of active microorganisms, the food residues would, in normal passage through the intestinal tract, tend to remove these microorganisms at a faster rate than their population growth can sustain. A supply of new forage then becomes residual in the rumen as death occurs.

Digestion is also affected by oils in certain plant materials. Oils of big sage-brush, for example, had in inhibitory action on bacteria in the rumen of mule deer, with a subsequent decrease in the rate of cellulose digestion (Nagy et al. 1964:785). Appetite and rumen movement stopped completely when three 7-pound portions of sage brush were introduced into a steer through a rumen fistula. When range conditions deteriorate to the point where wild ruminants are forced to eat certain plants that might otherwise be avoided, reductions in the digestive efficiencies are inevitable.

It is clear that rumen fermentation continues only if the substrate is adequate for support of microorganism metabolism. Not only must there be an adequate quantity, but the balance between carbohydrates and nitrogen is also important. The use of starch is an important factor in maintaining a flourishing rumen flora, and the digestion of starch is influenced by the quantity and nature of the nitrogenous components of the diet. A minimal level of protein is essential for supplying the nitrogen requirements of the rumen nicroorganisms (Annison and Lewis 1959:79-83). Two main conclusions are usually drawn from experiments on carbohydrate and nitrogen effects. One, there is a more rapid attack by the rumen microorganisms upon the fibrous components of the ration as the protein intake is increased, and two, there is better use of protein in the presence of added carbohydrate (Annison and Lewis 1959:109).

The complex ecology of the rumen can be at least partially controlled when animals in captivity are fed known quantities of diets with selected nutritive characteristics. Wild ruminants are subject to natural changes in range conditions, resulting in a much more complex rumen ecology than that of penned domestic ruminants. This increase in complexity adds many problems to nutritive analyses of wild ruminants, but it also presents many new challenges to creative thinking. The opportunities for nutritive analyses beyond the food habits level are many in wild ruminant ecology.

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Pantelouris, E. M. 1967. Introduction to animal physiology and physiological genetics. 1st ed. Pergamon, Oxford and New York. 497 pp.

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FERMENTATION AND DIGESTION

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS------------------	AUTHORS/EDITORS--	YEAR
aubo	acpr	nyny	533	rumi	the rumen and its microbes	hungate,re	1966

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
CJZOA	48--6	1437	1442	cerv	varia, ruminal nitrog leve	klein,dr; schonhe	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
XAMPA	1147-	159	163	od	biol rel, rumen flor, faun	nagy,jg	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JPROA	8---1	33	41	odvi	ophryoscol fauna, ciliates	zielyk,mw	1961
JWMAA	26--3	341	342	odvi	use of rumen fistula in wh	short,hl	1962
JWMAA	27--2	184	195	odvi	rumen fermen, energy relat	short,hl	1963
JWMAA	28--4	791	797	odvi	digest cedar, aspen browse	ullrey,de; youat/	1964
JWMAA	29--3	493	496	odvi	rumen organis, south texas	pearson,ha	1965
JWMAA	33--1	187	191	odvi	vari, rumin-retic contents	short,hl; remmen/	1969
JWMAA	33--2	380	383	odvi	rumino-retic char, 2 foods	short,hl; segelq/	1969
JWMAA	35--4	732	743	odvi	limitat winte aspen browse	ullrey,de; youat/	1971
JWMAA	36--4	1052	1060	odvi	variation, digest capacity	mothershead,cl; /	1972
JWMAA	39--1	67	79	odvi	feed analyses, digestion	robbins,ct; vans/	1975
NAWTA	32---	420	429	odvi	use, chrom 51, digest stud	mautz,ww; petride	1967
VJSCA	23--3	116	116	odvi	dosh, chrm acid, feel otpt	sanders,ot;skeen/	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
APMBA	17--6	819	824	odhe	rumen microbial ecology	pearson,ha	1969
FOSCA	16--1	21	27	odhe	browsing, rumen fermentati	oh,jh; jones,mb;/	1970
JANSA	16--2	476	480	odhe	dosh, dig, liv oak, chamis	bissell,hd: weir,	1957
JANSA	31--1	235	235	odhe	infl pesticides rum bacter	barber,ta; schwa/	1970
JCOQA	6....	56		odhe	gastrointestinal ph values	olson,jc; nagy,j	1969
JOMAA	36--3	474	476	odhe	values, alimentar canal ph	browman,lg; sears	1955
JOMAA	46--2	196	199	odhe	ruminoreticular characteri	short,hl; medin,/	1965
JWMAA	16--3	309	312	odhe	digestibil, native forages	smith,ad	1952
JWMAA	28--4	785	790	odhe	eff essen oils,sagebr micr	nagy,jg; steinho/	1964
JWMAA	35--2	205	209	odhe	diarrhea, capt fawn, e col	kramer,tt; nagy,/	1971
JWMAA	38--4	815	822	odhe	effects starvat on rum bac	decalesta,ds; na/	1974
JWMAA	39- 4	663	669	odhe	starving, refeeding mule d	decalesta,ds; na/	1975
NAWTA	36---	153	161	odhe	eff, pesticid, rumen bacte	barber,ta; nagy,j	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BJNUA	24--3	843	855	ceel	dosh, digest, nitrogen met	maloiy,gmo; kay,/	1970
JWMAA	33--1	181	186	ceel	ruminal microorganisms	mcbee,rh; johnso/	1969
JWMAA	35--4	673	680	ceel	dada, rumen characteristic	prins,ra; geelen,	1971
JWMAA	40--2	371	373	ceel	exp w/rum cann, rum analys	staines,bw	1976
JWMAA	42--3	654	659	ceel	ruminoreticular characteri	church,dc; hines,	1978

ceel continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
QJEPA	56--4	257	266	ceel	dosh, compar dig, cont con	maloiy, mo; kay,/	1971
SZSLA	21---	101	108	ceel	physiol of diges, metaboli	maloiy,gmo; kay,/	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJBIA	49--1	119	126	alal	isoslat, enzym, chromotogr	stevenson,kj; lan	1971
CJBIA	52--7	637	644	alal	isolatio trypsin, elastase	lievaart,pa; stev	1974
JPROA	2---3	124	134	alal	morph, divisi cilia, stoma	krascheninnikow,	1955
NCANA	101--	227	262	alal	ener req rumen fermentati	gasaway,wc; coady	1974
PCBSA	16---	129	129	alal	serine proteases from	lindsay,rm; steve	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AZFEA	127--	1	76	rata	rumen ciliate fauna finla	westerling,b	1970
BJNUA	29--2	245	259	rata	seas variation, gluc metab	luick,jr; person/	1973
CJZOA	36--5	819	835	rata	rumen ciliates, canad arct	lubinsky,g	1958
CJZOA	36--6	937	959	rata	rumen ciliates, canad arct	lubinsky,g	1958
CJZOA	54--1	55	64	rata	gluc metab, lactating rein	white,rg; luick,j	1976
HLTPA	21--5	657	666	rata	radiocesium, lichen, alask	holleman,df; lui/	1971
LAANA	28---	175	180	rata	comp, reindeer, sheep dige	eriksson,s; schme	1962
SZSLA	21---	109	115	rata	wint nutr, wld reind, norw	gaare,e	1968
SZSLA	21---	117	128	rata	nutr semi-domestic reindee	steen,e	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	33--2	437	439	anam	ruminoreticular vfa conten	nagy,jg; williams	1969
TAMSA	72--3	248	252	anam	intestin amoeba from prong	noble,ga	1953
XARRA	148--	1	4	anam	starvation with stomach fu	pearson,ha	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
APMBA	15--6	1450	1451	bibi	rumen microorganisms, utah	pearson,ha	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
UCPZA	53--6	237	261	ovca	ciliates, sierra nev bigho	bush,m; kofoid,c	1948
JWMAA	36--3	924	932	ovca	env sour of var, physi val	franzmann,aw	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWIDA	7---3	139	141	ovda	physiologic values of ston	franzmann,aw	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	41--1	29	32	obmo	rumen ciliate, north canad	lubinsky,g	1963

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ZEJAA	8---3	97	111	caca	[topog organ, neck, chest]	hofmann,r	1962

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
EJBCA	63--2	441	448	many	carbohyd, pancre ribonucle	beintema,jj; gaa/	1976
FEPRA	27--6	1361	1366	rumi	regulation of feed intake	baile,ca	1968
JANSA	35--6	1271	1274	dosh	effect of watr, nutrnt dig	asplund,jm; pfand	1972
JONUA	86--3	281	288	rumi	blood urea, protein intake	preston,rl; schn/	1965
JPROA	21--1	26	32	wiru	rumen ciliate fauna, 3 wr	dehority,ba	1974
JWMAA	32--1	198	207		meth microb diges, pos mor	bruggemann,j; gi/	1968
JWMAA	38--4	948	949	wiru	differentiatio, pellet, ph	howard,vw,jr; del	1974
NARFA	29--2	511	511	rumi	fact, rumina dur developme	tulbaev,po	1959
NCANA	101-1	227	262	many	energy req rumen fermenta	gasaway, wc; coad	1974

UNIT 1.3: PRODUCTS OF FERMENTATION

Rumen microorganisms produce heat energy, gases, volatile fatty acids, nitrogen compounds, and vitamins as end-products of their metabolism. The heat energy given off is called the heat of fermentation, and contributes to the energy balance of the ruminant host. It is the result of exothermic metabolic reactions of the rumen microflora. Its role in the energy balance of free-ranging ruminants is discussed in PART V. The other products of rumen microorganism metabolism are discussed below.

GASES

Gases given off, primarily methane (CH_4) and carbon dioxide (CO_2) are either released directly into the atmosphere by eructation or absorbed by the blood and exhaled later as part of respiratory exchange. The composition of the rumen gases eructed do not vary much with rations. The total amount of gas formed is not affected much by the ration, but the quantity rises sharply after eating and then falls gradually (Dukes 1955: 382). The significance of eructation is in the loss of energy that it represents; about 8% of the digestible energy of the diet, varying with the digestibility of the food, is released in methane (Blaxter 1967:200; and Moen 1973:154).

VOLATILE FATTY ACIDS

Three volatile fatty acids (VFA's)--acetic, butyric, and proprionic--are invariably present in the active rumen as a result of microbial fermentation of carbohydrates (Annison and Lewis 1959:60). The total concentration and the amounts of individual acids are dependent on the composition of the ration and the feeding regime. Thus seasonal differences are expected in wild ruminants, and have been observed in mule deer (Short et al. 1966:466) and white-tailed deer (Short 1963).

Higher concentrations of VFA's are observed when easily fermented foods are ingested (Short 1963:186). There is an increased rate of rumen fermentation during the summer when the range forage is succulent, and a decrease in the fall and winter.

The concentration of volatile fatty acids in the rumen is not a simple and straight forward indication of the actual rate of VFA production, however. The concentration of VFA's at a given time depends not only on their rate of production in the rumen, but also on the rate of absorption from the rumen, rate of passage from the rumen to the omasum, dilution with saliva, use of VFA's by the rumen microorganisms, and conversion to other rumen metabolites (Annison and Lewis 1959:63).

The young ruminant has glucose and VFA concentrations like those of a monogastric animal in which most of the energy is absorbed in the form of glucose from the small intestine (Annison and Lewis 1959:73). As rumen fermentation increases, glucose concentrations fall to about one-half that of non-ruminants, and VFA concentrations increase. This change in carbohydrate metabolism is a physiological indication of the weaning process (Annison and Lewis 1959:20).

Volatile fatty acids are readily absorbed from the rumen and are a major source of energy for the ruminant animal. Moen (1973:154) cites references indicating that at least 600 to 1200 Kcal of energy are absorbed as VFA's from the sheep rumen every 24 hours, and 6000 to 12000 Kcal from the cattle rumen. The latter has a much greater physical capacity than the former, of course. VFA production by deer is discussed in Short (1963) who stresses the need for additional understanding of such nutritional energy relationships in deer management.

NITROGEN COMPOUNDS

Microbial protein synthesized from amino acids and non-protein nitrogen sources is digested in the omasum and abomasum as microbial populations are rapidly turned over (Pantelouris 1967:192). A considerable portion of the protein requirement of ruminants is supplied in this way (Annison and Lewis 1959:19) as non-protein nitrogen is converted to microbial protein and digested and absorbed by the host. Urea is an example of a non-protein nitrogen compound that may be converted by rumen microbes to microbial tissue. Deer ingest urea and other non-protein nitrogenous compounds by consuming water that has been accumulating in pools where feces and urine have been deposited, by lapping urine from other deer, and by the cleaning of the fawns by the doe. Fawns at the Wildlife Ecology Laboratory have shown varying degrees of interest in lapping the urine from their penmates, sometimes refusing milk in preference for urine.

The protein contents of the rumen are often higher than the protein contents of the forages being ingested. The terminal two to three inches of growth on browse sampled by Bissel (1959:57) had 6.9% crude protein, but the rumen contents of nine deer on that range averaged 17.6% crude protein. Fourteen deer studied when range plants were dormant had range and rumen protein contents of 7.1% and 17.2% respectively in January and 6.1% and 15.1% in February. Three deer fed alfalfa pellets had rumen protein contents of 21.0%, 16.2% and 14.7%. Such increases in the nitrogen contents of rumens over those of ingested food materials can be accounted for by nitrogen recycling. The percent of urea recycled by white-tailed deer ranged from 92.3% to 40.6% as dietary protein content increased from 5% to 26% (Robbins et al. 1974).

VITAMINS

The vitamin requirements of adult ruminants are satisfied in part by the rumen microorganisms. Water soluble vitamins of the B complex and fat-soluble vitamin K are synthesized in the rumen if appropriate foods are eaten (Annison and Lewis 1959:20, 155). Vitamins A, D, and E must be supplied in the diet. The provision of at least part of the adult's vitamin requirements by rumen microflora illustrates how important the symbiotic relationship between microflora and ruminant host is. All of the metabolic products of the microflora, except the gases, are used by the ruminant host as sources of different nutrients. When each individual microbe dies, the cell is then digested and nutrients, especially protein, extracted. The rumen is a closed, anaerobic system that represents the link between the animal and its range.

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Robbins. C. T., R. L. Prior, A. N. Moen and W. J. Visek. 1974. Nitrogen metabolism of white-tailed deer. J. Anim. Sci. 38(1):186-191.

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REFERENCES, UNIT 1.3

PRODUCTS OF FERMENTATION

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
edbo	nhfg	conh	256	odvi	w-tail deer of new hampshi	siegler,hr,ed	1968

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--6	1437	1442	cerv	rumen nitrog level, variat	klein,dr schonhe	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	38--1	186	191	odvi	nitrogen metabolism of whi	robbins,ct: prio/	1974
JWMAA	27--2	184	195	odvi	rumen ferment, energy rela	short,hl	1963
JWMAA	33--1	187	191	odvi	var ruminoreticul contents	short,hl; remmen/	1969
JWMAA	33--1	204	208	odvi	cage, metab, radioiso stud	cowan,rl; hartso/	1969
JWMAA	33--2	380	383	odvi	rumino-retic char, 2 foods	short,hl; segelq/	1969
JWMAA	36--3	885	891	odvi	digest, metaboli, aspen br	ullrey,de; youat/	1972
VJSCA	21--3	117	117	odvi	prod enrgy, comp rum diges	woodyard,gw; whel	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	39--1	236	236	odhe	effect starva on rumen bac	decalesta,ds; wa/	1974
JWMAA	14--3	285	289	odhe	sagebrush as a winter feed	smith,ad	1950
JWMAA	28--4	785	790	odhe	essen oils, sageb, rum mic	nagy,jg; steinho/	1964
JWMAA	30--3	466	470	odhe	seas varia, vol fatty acid	short,hl; medin,/	1966
JWMAA	37--3	312	326	odhe	effect nutr chan on captiv	robinette,wl; ba/	1973
JWMAA	39--3	601	604	odhe	reticulo rum char mal nour	dean,re; strickl/	1975
JWMAA	39--4	663	669	odhe	starving and re-feeding mu	decalesta,ds; na/	1975
NAWTA	36---	153	162	odhe	effects pestic, rumen bact	barber,ta; nagy,j	1971

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NCANA	101-1	227	262	alal	energy req, rumen fermenta	gassaway,wc; coad	1964

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BPURD	1----	290	296	rata	odvi, compar study rum met	bruggemann,j; dr/	1975
CJZOA	54--5	737	751	rata	dig energ in, glucos synth	mcewan,eh; white/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	33--2	437	439	anam	ruminoreticula VFA content	nagy,jg; williams	1969

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JASIA	60--3	393	398	doca	exper, nutri, dairy heifer	broster,wh tuck/	1963
JONUA	101--	1331	1342	doca	diet nonprot N, urea kinet	mugerwa,js; conra	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJBSA	20--5	967	973	dosh	transf nitr, blood to rume	weston,rh; hogan,	1967
BJNUA	21--2	353	371	dosh	metabolis of urea in sheep	cocimano,mr; leng	1967
BJNUA	27--1	177	194	dosh	ammonia and urea metabolis	nolan,jv; leng,ra	1972
JANSA	35--6	1271	1274	dosh	eff wat restric nutrnt dig	asplund,jm; pfand	1972
PAANA	VI---	378	383	dosh	urea metabolism in sheep	cocimano,mr; leng	1966

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJPHA	197-1	115	120	rumi	utilization of blood urea	houpt,tr	1959
JDSCA	51--2	265	275	rumi	nitrogen utiliz, metabolis	waldo,dr	1968
JONUA	22--2	167	182	rumi	value, urea, synth, protei	harris,le; mitche	1941

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJMEA	29---	832	848		design, anal, isotop exper	zilversmit,db	1960
CLCHA	17--9	921	925		singl reag meth, urea nitr	foster,lb; hochho	1971
ECOLA	52--5	935	939		model, absorp, ret ing ele	goldstein,ra; elw	1971
JANSA	25--2	593	593		dig prot est, nrc feed com	knight,ad; harris	1966
JANSA	26--1	119	128		develop, system, feed anal	van soest,pj	1967
JBCHA	58--3	873	904		meth, det biol value, prot	mitchell,hh	1924
JBCHA	58--3	905	922		biol val, prot dif int lev	mitchell,hh	1924

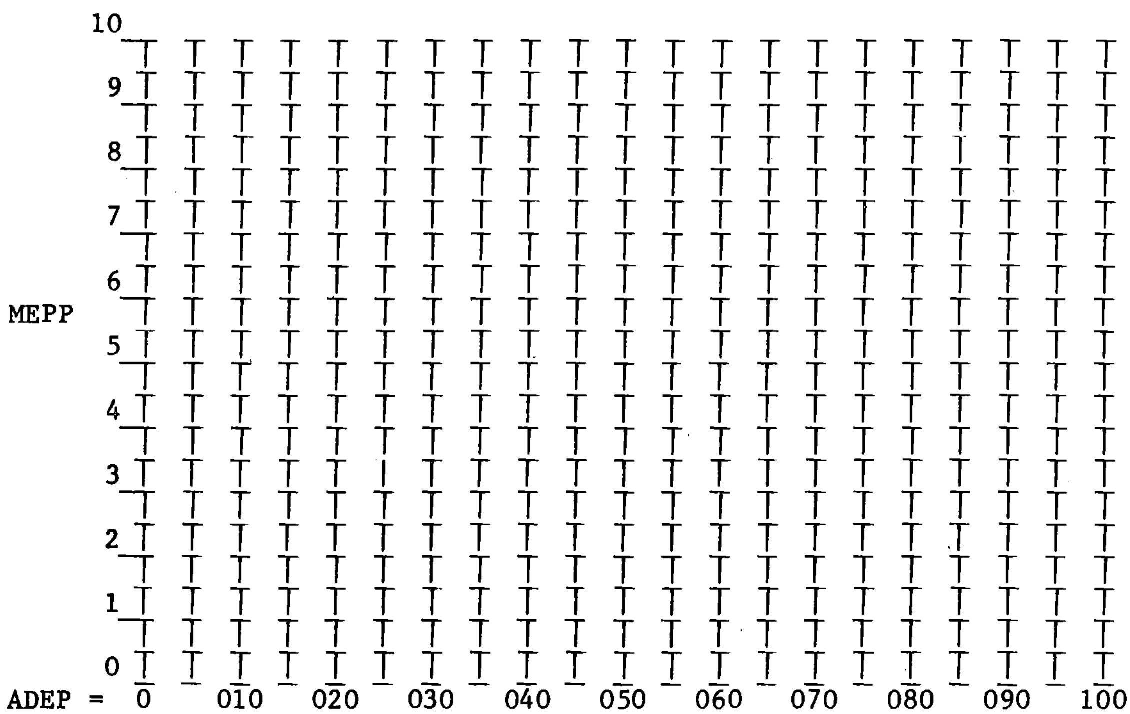
CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
SCIEA	130--	1192	1194	mamm	microbial fermentation in	hungate,re; phil/	1959

Estimates of methane energy

The food energy lost in the methane (CH_4) represents about 8% of the total food energy (Blaxter 1967:198-200). The amount of energy lost in methane can be estimated for animals on a roughage diet with the equation:

$$MEPP = 4.28 + 0.059\ ADEP$$

where MEPP = methane production as a percent of the gross energy of the forage ingested and ADEP is the apparent digestible energy of the forage expressed as a percent. Thus if ADEP = 50%, MEPP = 4.28 + (0.059)(50) = 72%. If ADEP = 80%, MEPP = 4.28 + (0.059)(80) = 9.0%. Note that these bracket the 8% figure given above.



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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

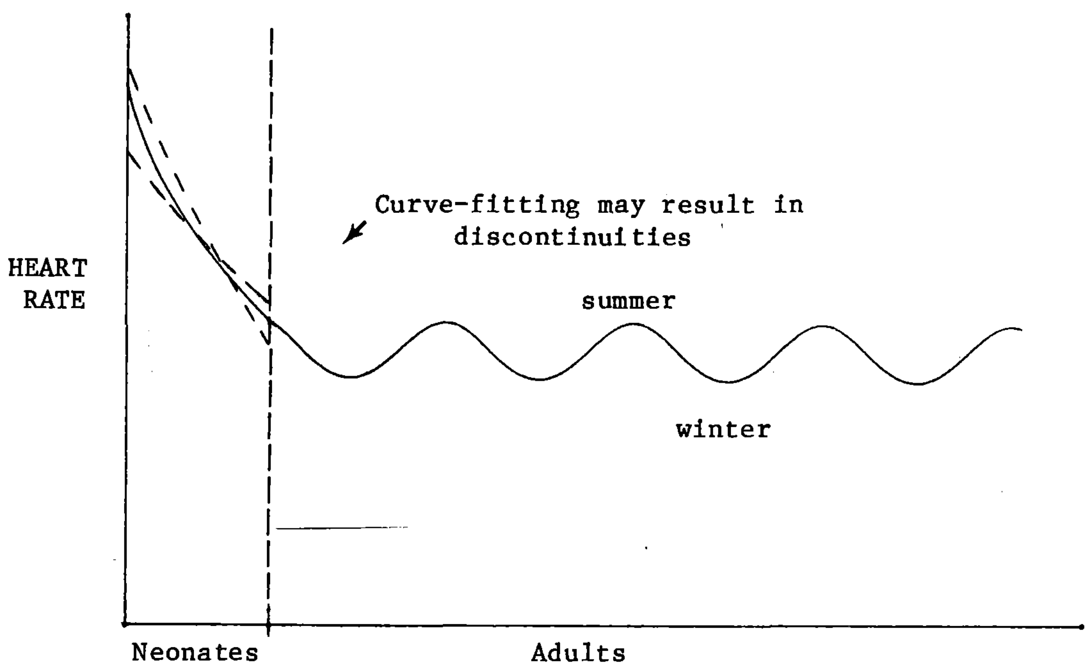
UNIT 2.1: HEART RATES

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

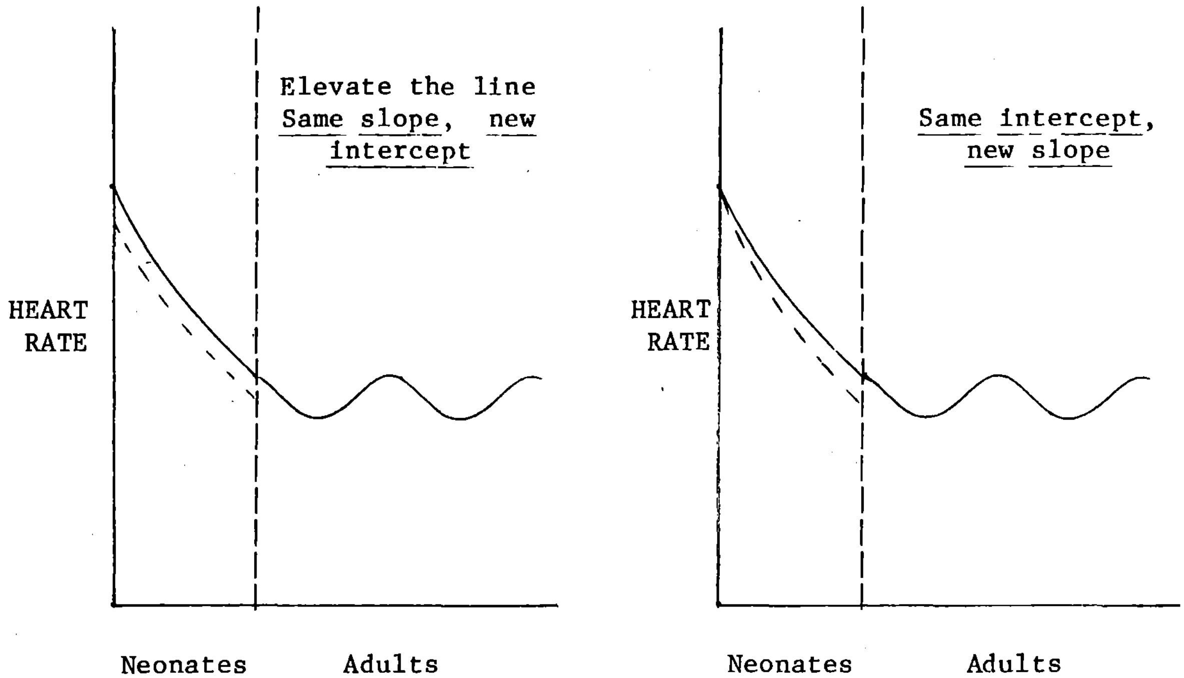
A heart rate pattern consistently observed in all species is that of a rapid decline in heart rates in the first few days or weeks or life. Heart rates of neonates are high, and they drop rapidly, logarithmically, until the rates characteristic of adults are reached. This shift from the high rates characteristic 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

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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

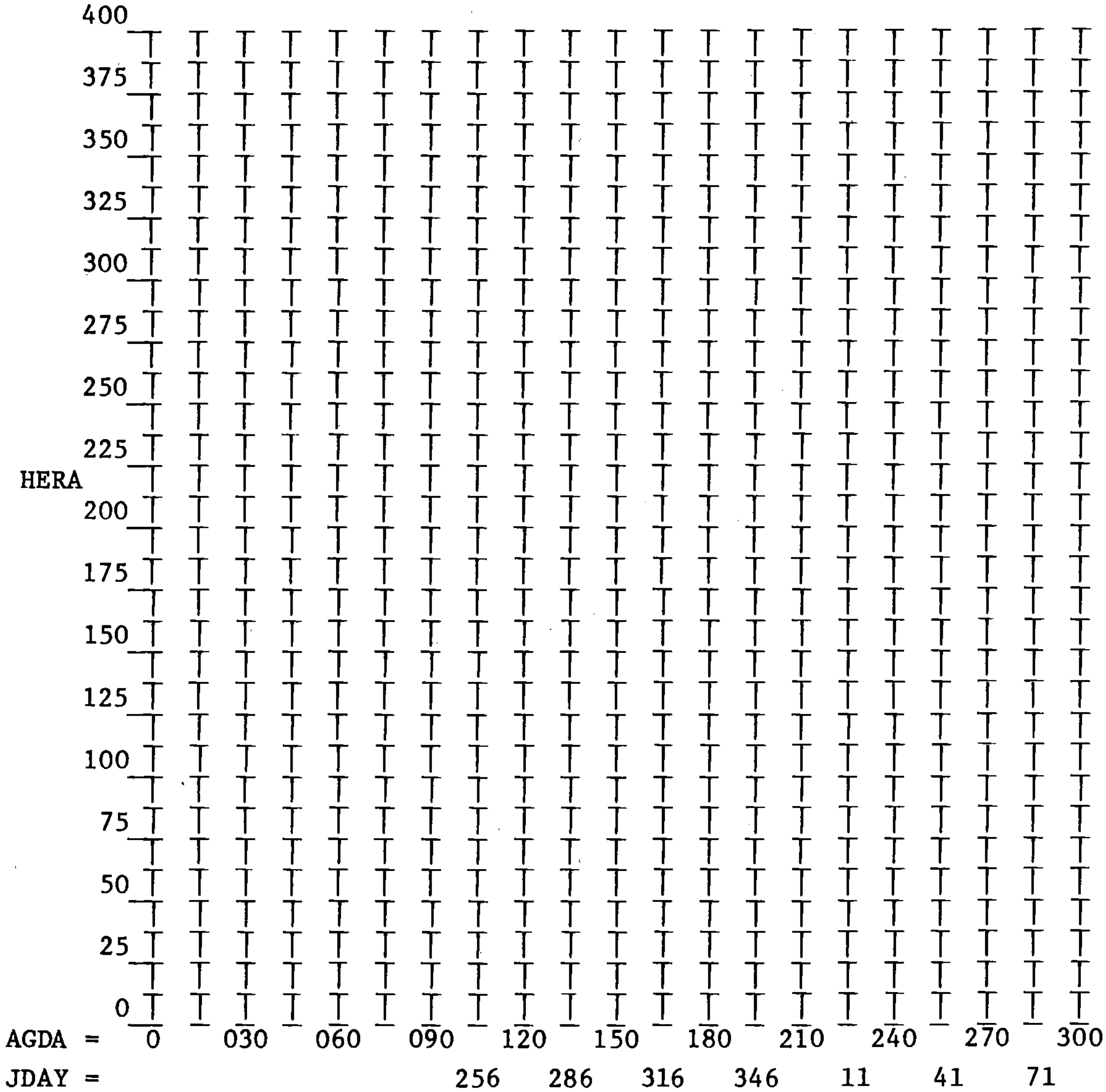
CHAPTER 6, WORKSHEET 2.1a

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:

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

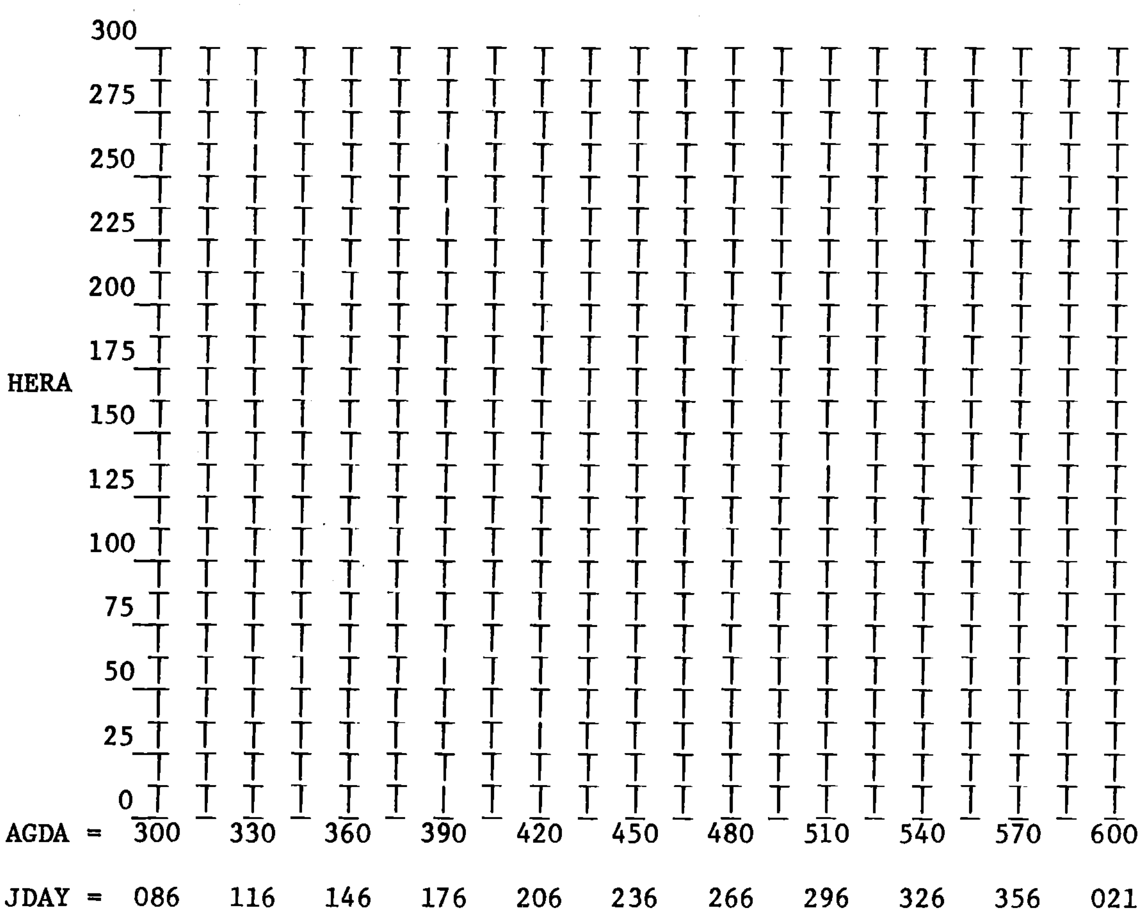
$$SHRM = \left[17.2907 \sin [(JDAY)(0.9863) + 226] + 0.4346\right] + 86$$

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

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

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

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

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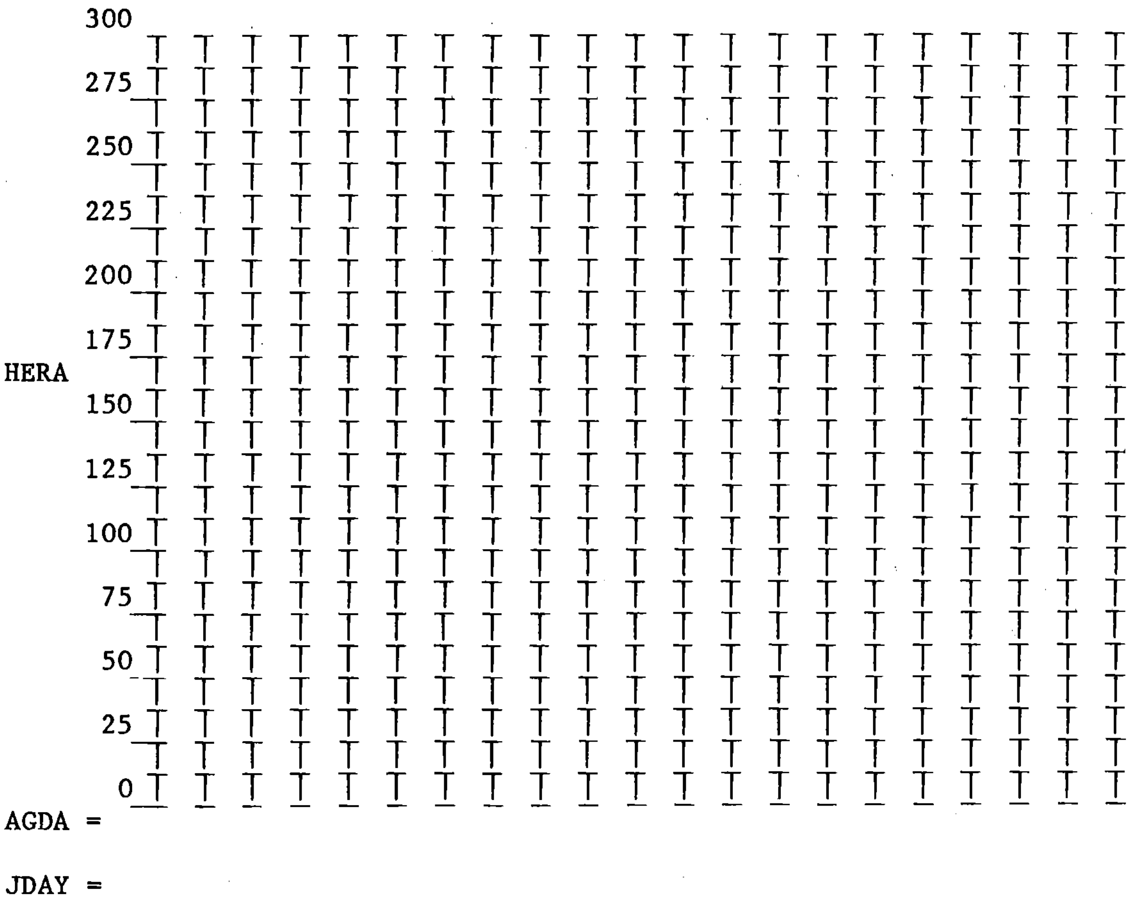

UNIT 2.2: STROKE VOLUME

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.

LITERATURE CITED

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; f1/	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

TOPIC 3. RESPIRATORY SYSTEM FUNCTIONS

Respiration includes both the physical exchange of oxygen and carbon dioxide between the lung surfaces and the atmosphere, called external respiration, and the chemical exchange of O_2 and CO_2 in cellular metabolism, called internal respiration. External respiration rates are rather easily measured, and changes in the gaseous composition of inhaled and exhaled air indicate the amounts of physical exchange of oxygen and carbon dioxide that has taken place. External respiration also includes changes in the vapor pressure of respired air which is part of the overall heat exchange and thermal energy balance of an organism. Internal respiration is necessary for tissue metabolism, and exothermic metabolic reactions are also involved in the thermal energy balance of an organism.

External respiration involves physical work, which can be accomplished only with the support of internal respiration and muscle contraction. Thus external and internal respiration are both essential and continuous functions for the maintenance of life itself, and both are part of the overall energy metabolism and heat exchange of organisms.

UNIT 3.1: EXTERNAL RESPIRATION

The mechanical movement of air from the atmosphere into the lungs and back to the atmosphere requires the expenditure of energy by the muscles involved in external respiration. The cost of breathing has been determined for man, and is 1.2% of the total oxygen consumption when at rest (Otis 1954). As activity and external respiration increase, the cost may double, and in very heavy respiration, may reach about four times the cost at rest, or nearly 5% of the total oxygen consumed. Margaria et al. (1960) determined a maximum of 3% of the total cost during exercise.

Respiration rates of wild ruminants are largely unknown. Generally younger animals have faster respiration rates than older animals of the same species. Larger animals, both of the same and different species, tend to have slower respiration rates than smaller ones. Respiration rates increase with increases in the amount of physical activity as more oxygen is needed to support higher rates of metabolism. The respiratory frequency of reindeer in lying posture was 23 and in standing posture 36 per minute (White and Yousef 1978).

Respiration rates are regulated by the CO_2 concentration in the blood; as the CO_2 concentration increases, the rate and volume of external respiration increases. It is interesting that, while increased activity results in an increased need for oxygen, it is not the need for oxygen but rather the increased CO_2 in the blood from increased internal resiration that stimulates pulmonary ventilation. This can be demonstated by increasing the CO_2 concentration of inhaled air, and observing an increase in the respiration rate and volume even without an actual increased energy expenditure.

A few measurements of external respiration rates have been made, usually as part of metabolism studies, and may be used to formulate a general pattern of changes in relation to age, size, and activity. Changes also occur with season as metabolic changes occur; measurements of external pulmonary ventilation rates should be made over the entire annual cycle. Superimposed on these predictable changes are the effects of transient stimuli. These changes occur in relation to fright responses, apprehension, etc. In general, transient changes in external respiration are expected to be related to changes in activity and metabolism due to overt responses.

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Otis, A. B. 1954. The work of breathing. Physiol. Rev. 34:449-458.

White, R. G. and M. K. Yousef. 1978. Energy expenditure of reindeer walking of roads and on tundra. Canadian J. Zool. 56(2):215-223.

REFERENCES, UNIT 3.1

EXTERNAL RESPIRATION

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAPYA	15--3	354	358		mecha work, breath, mus ex	margaria,r; mili/	1960
PHREA	34--3	449	458		the work of breathing	otis,ab	1954

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
CBCPA	61A--	43	48	ceel	oxygen util by elk calves	robbins,ct; cohe/	1977
JOMAA	49-4	762	764	ceel	physiolo studies, rocky mt	herin,ra	1968
JWMAA	43--2	445	453	ceel	energy expenditure, calves	robbins,ct; cohe/	1979
RSPYA	29--2	225	230	ceel	select oxygen transp param	mckean,t; staube/	1977

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

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
RSPYA	30--3	305	310	bibi	blood respirato properties	haines,h; chiche/	1977

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	12---	349	360	bibo	physiological properties	janusz,g	1967

UNIT 3.2: INTERNAL RESPIRATION

Internal respiration, or the exchange of gases between the lung surfaces and the blood is based on pressure differences between the blood and the lung surfaces, and the O_2 and CO_2 is exchanged by diffusion at rates dependent on the difference in pressure between capillary blood and the gas at the respiratory surface.

Blood increases in oxygen upon exposure to respiratory surfaces. Blood contains both plasma and cells, but the solubility of O_2 is low in plasma, so nearly all of the O_2 carried by the blood is associated with the red cells. These cells contain the pigment hemoglobin, which is chemically composed of a protein "globin" and four "heme" groups. The iron-containing heme groups function in oxygen transport, and oxygen molecules (4) unite with the four iron atoms to form a fully-saturated oxyhemoglobin molecule. This is the basis for very efficient oxygen transport in the vascular system.

Muscles are active sites of oxidative metabolism, and they contain a particular kind of hemoglobin called myoglobin which has a greater oxygen affinity than hemoglobin. It is likely that the pigment myoglobin facilitates oxygen diffusions to the mitochondria in muscle cells (White, p. 195 in Gordon 1977).

LITERATURE CITED

Gordon, M. S. 1977. Animal physiology: principles and adaptations. Macmillan Publishing Co., Inc., N.Y. 699 pp.

REFERENCES, UNIT 3.2

INTERNAL RESPIRATION

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
RSPYA	29--2	225	230	ceel	select oxygen transp param	mckean,t; staube/	1977

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

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
RSPYA	30--3	305	310	bibi	blood respirato properties	haines,h; chiche/	1977

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			

TOPIC 4. REPRODUCTIVE SYSTEM FUNCTIONS

Free-ranging animals exhibit definite reproductive cycles through each year of their lives. First, reproductive maturity is reached, which is dependent on both age and weight. Animals on poor range are expected to weigh les, and reproductive maturity is reached later. After reproductive maturity is reached, the period of breeding is regulated by the effects of light on the hormone balance, and the subsequent gestation and lactation periods are fixed in relation to the time of conception.

Spermatogenesis and ovulation are important functions of individual animals. The extent of differences in sperm and egg production between individual males and females, respectively, is not known because individuals cannot be evaluated under free-ranging conditions. A very high percentage of each sex is likely to be capable of breeding in wild ruminant populations.

After breeding, the male can be primarily concerned with maintenance while the female must meet the demands of gestation, parturition and lactation. These functions occupy about three-fourths of the year or more for the females, and include responsibilities not only for the production of a new individual but also must meet the high metaboliac cost of lactation and provide some measure of protection and behavioral security for the young. Further, the abundance of animals in a population depends on the sucessful completion of reproductive functions over successive annual cycles.

REFERENCES, TOPIC 4

REPRODUCTIVE SYSTEM FUNCTIONS

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS------------------	AUTHORS/EDITORS--	YEAR
aubo	meth	loen	321	mamm	ecol of reprod in wild, do	sadleir,rmfs	1969
edbo	caun	nyny	189	ovca	reproduct in mammal, bok 6	austun,cr short,	1976

UNIT 4.1: REPRODUCTIVE CYCLES

Reproduction by wild ruminants does not occur randomly throughout the year, but is part of a biological chronology characteristic of each species and, in some cases, the locations of populations. Males are non-productive for much of the year; sperm are not produced by the inactive testes. Females are non-reproductive for only a short time each year; they are pregnant or lactating most of the time. The timing of the reproductive and non-reproductive periods through the year is quite fixed, with not too much variation between years. This is apparently due to the association between metabolic demands for reproduction and the availability of forage resources on a seasonal basis.

The male reproductive cycle is often represented by the amount of testicular development. White-tailed deer in Texas showed the lowest testicular weights in February-May (Robinson et al. 1965). Pronghorn testes weights (Montana) were at an annual low in January and February (O'Gara et al. 1971). Maximum testes weights and sperm production occur in late summer in pronghorn, resulting in the breeding of pronghorn females earlier than the breeding of deer. Pronghorn have a gestation period of 240 days compared to 200 days for deer, so the earlier breeding results in parturition at about the same time for the two species. The time of breeding is an important consideration in describing the biochronology of a species because breeding commits the females to defined periods of gestation and lactation. The timing of these productive periods is an important consideration in relation to the phenology of the range, especially the last one-fourth of gestation and the first half of lactation because these are such critical periods in the life of both dam and offspring. Later fall breeding combined with a longer gestation period would result in too short a growing period for the young prior to the beginning of their first winter. The importance of the phenology of the range in relation to timing of the arrival of spring was discussed and illustrated in Moen (1978).

Peak breeding of deer in Texas occured in December, about one month later than in New York, which Robinson et al. (1965) consider a normal variation due to latitude effects. Differences in breeding times from north to south are not very large.

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Robinson, R. M., J. W. Thomas, and R. G. Marburger. 1965. The reproductive cycle of male white-tailed deer in central Texas. J. Wildl. Manage. 29(1)·53-59.

REFERENCES, UNIT 4.1

REPRODUCTIVE CYCLES

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
aubo	coup	itny	670	mamm	patterns mammalian reproduc	asdell,sa	1964

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	34--1	25	31	od--	br seas, produc, interstat	chattin,je	1948

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJVRA	39--6	1053	1056	odvi	antl, long bone mass, andr	brown,rd; cowan,/	1978
BIREB	16--3	340	343	odvi	repro ster, fema seas chan	plotka,ed; seal,/	1977
BIREB	17--1	78	83	odvi	repr, proges, estrog, preg	plotka,ed; seal,/	1977
CJZOA	44--1	59	62	odvi	breeding seasons, manitoba	ransom,ab	1966
CJZOA	56--1	121	127	odvi	seas var LH,FSH, tes, male	mirarchi,re; how/	1978
ENDOA	94--4	1034	1040	odvi	annual testos rhyth, adult	mcmillin,jm; sea/	1974
JANSA	31--1	225	225	odvi	sperm reserves of w-t deer	lambiase,jt,jr; a	1970
JANSA	40--1	185	186	odvi	andr lev, antl cy, bree se	mirarchi,re; sca/	1975
JANSA	42--1	271	272	odvi	seas var, gonad char, male	mirarchi,re; sca/	1976
JOMAA	32--4	411	421	odvi	analys reproduc pat, s tex	illege,d	1951
JOMAA	40--1	108	113	odvi	breed record, capt, alabam	haugen,ao	1959
JOMAA	47--2	266	280	odvi	endocrine glands,seas chan	hoffman,ra; robin	1966
JOMAA	53--4	760	773	odvi	ovar comp, repr phys,venez	brokx,pa	1972
JRPFA	47--1	161	163	odvi	chan estro, estradi, pregn	harder,jd; woolfl	1976
JWMAA	10--3	249	263	odvi	breeding season, new york	cheatum,el; morto	1946
JWMAA	14--3	290	295	odvi	breed rec, upper pen, mich	haugen,ao; davenp	1950
JWMAA	28--1	171	173	odvi	birth of white-tai d fawns	michael,ed	1964
JWMAA	29--1	53	59	odvi	reproduc cycle, male texas	robinson,rm; tho/	1965
JWMAA	29--1	74	79	odvi	reproducti studies, penned	verme,lj	1965

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JWMAA	30--4	843	845	odvi	regional diff, fawning tim	weber,aj	1966
JWMAA	31--1	114	123	odvi	reprodtive biolo, manitoba	ransom,ab	1967
JWMAA	33--3	708	711	odvi	fertility, male w-t fawns	follmann,eh; klim	1969
JWMAA	33--4	881	887	odvi	repro pattern, nutri plane	verme,lj	1969
JWMAA	36--3	868	875	odvi	reproductive physiol, male	lambiase,jt,jr; /	1972
JWMAA	38--2	183	196	odvi	eff diethylstilbes, reprod	harder,jd; peterl	1974
JWMAA	40--2	373	374	odvi	initia, preg, lactating de	scanlon,pf; murp/	1976
JWMAA	40--4	792	795	odvi	noneff, mechan birth contr	matschke,gh	1976
JWMAA	41--1	87	91	odvi	diethylstilbestr, contrace	matschke,gh	1977
JWMAA	41--1	92	99	odvi	ann chang, sperm prod org	mirarchi,re; sca/	1977
JWMAA	41--2	178	183	odvi	androg levels, antl develo	mirarchi,re; sca/	1977
JWMAA	41--2	194	196	odvi	antifertil act, syn proges	matschke,gh	1977
JWMAA	41--4	715	719	odvi	fact aff peak fawning, vir	mcginnes,bs; down	1977
NFGJA	16--2	261	261	odvi	twin fawns born 2 days apa	hesselton,wt; van	1969
NFGJA	20--1	40	47	odvi	breedi, parturit dates, ny	jackson,lw; hesse	1973
PCGFA	9----	128	131	odvi	birth dates of alabama dee	lueth,fx	1955
PCGFA	20---	123	130	odvi	breeding seas in louisiana	roberson,jh,jr; d	1966
PCGFA	20---	130	139	odvi	delin of rut, breedin seas	payne,rl; provos/	1966
PCFGA	29---	646	651	odvi	oral accep, eff, diethylst	matschke,gh	1975
PCGFA	32---	335	338	odvi	fawning dates, manag impli	butts,gl; harmel/	1978
POASA	56---	24	25	odvi	breeding season, e oklahom	dunbar,mr	1976
TJSCA	26...	417	420	odvi	breeding season in s texas	harwell,wf; barro	1975
TNWSD	27---	19	38	odvi	photoperiodism, breeding	mcdowell,rd	1970
VJSCA	24--3	112	112	odvi	spermatozoan reserves in d	lenker,dk; scanlo	1973
VJSCA	26--2	59	59	odvi	plas androg lev,repro char	mirarchi,re; sca/	1975
VJSCA	26--2	60	60	odvi	seas. age dif, male org wt	russell,md; wess/	1975
VJSCA	27--2	46	46	odvi	plas progest lev, estr cyc	kirkpatrick,rl; /	1976
WLSBA	3---4	152	156	odvi	hormon implan, contr repro	bell,rl; peterle,	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
APARD	1976-	208	215	odhe	environ eff on reproductio	sadleir,rmfs	1976
CAFGA	43--1	91	96	odhe	breedin seas, herds, calif	bischcoff,ai	1957
CJZOA	54-10	1617	1636	odhe	horm reg, repro, antl cycl	west,no; nordan,h	1976
CJZOA	54-10	1637	1656	odhe	eff methallibure,hormon tr	west,no; nordan,h	1976

odhe continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	54--1	302	303	odhe	reproductio, b-t deer fawn	thomas,dc; smith,	1973
JRPFA	44--2	261	272	odhe	reprod pattern, female b-t	thomas,dc; cowan,	1975
JWIDA	7---1	67	69	odhe	bilateral testicular degen	murphy,bd; clugst	1971
JWIDA	11--1	101	106	odhe	testicular atrophy, calif	demartini,jc; con	1975
JWMAA	14--4	457	469	odhe	bree seas, prod, faw, utah	robinette,wl; gas	1950
JWMAA	40--4	795	796	odhe	preg fawn, quintupl mule d	nellis,ch; prent/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BEHAA	16---	84	92	ceel	charact of estrous, captiv	morrison,ja	1960
JOENA	53-PR	48	49	ceel	thyr calci, seas repro cha	phillippo,m; lin/	1972
JOMAA	36--1	145	145	ceel	fetus in yearling cow elk	saunders,jk jr	1955
JOMAA	47--2	332	334	ceel	fetus resorption in elk	haugen,ao	1966
JOMAA	51--4	812	813	ceel	precoci antl dev, sex matu	moran,rj	1970
JRPFA	25--1	41	54	ceel	puberty, seas breedin male	lincoln,ga	1971
JRPFA	27--3	427	438	ceel	female reprodu cycl, scotl	guiness,f; linco/	1971
JWMAA	16--3	313	315	ceel	age at sex maturity, male	conoway,cf	1952
JWMAA	17--2	223	223	ceel	pregnant yearling cow elk	coffin,al; reming	1953
JWMAA	23--1	27	34	ceel	breed seas, known-age embr	morrison,ja; tra/	1959
JWMAA	32--2	368	376	ceel	exper studies, contr repro	greer,kr; hawkin/	1968
JZOOA	163-1	105	123	ceel	seas reprodu changes, stag	lincoln,ga	1971
JZOOA	172-3	363	367	ceel	timing, reproduc, latitude	fletcher,tj	1974
JZOOA	185-1	105	114	ceel	calving times, red d, scot	guiness,fe; gibs/	1978
MAMLA	35--2	204	219	ceel	ruru, season, births, n z	caughley,g	1971
NAWTA	21---	545	554	ceel	postconcept ovulation, elk	halazon,gc; buech	1956
NATUA	248--	616	618	ceel	restor lib, cast stag, est	fletcher,tj; shor	1974
ZEJAA	1---1	69	75	ceel	caca, dada [time of birth]	rieck,w	1955
ZEJAA	21--4	238	242	ceel	1 sided testicle shrinkage	wurster,k; hofma/	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AVSPA	14--1	81	91	alal	morph, ultrastr, spermatoz	andersen,k	1973
JOMAA	37--2	300	300	alal	late breeding, moose, alce	moisan,g	1956
JWMAA	26--4	360	365	alal	in gravelly, snowcrest mou	peek,jm	1962
VILTA	6---3	1	299	alal	reproductio, moose, sweden	markgren,g	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	90--4	449	463	rata	annual antler cycle, newfo	bergerud,at	1976
CJZOA	50--1	43	46	rata	reprodu, female reind, car	mcewan,eh; whiteh	1972
CJZOA	53--9	1213	1221	rata	repro seas, carib, newfoun	bergerud,at	1975
CJZOA	56--8	1684	1696	rata	morphol, b-g caribou ovary	dauphine,tc,jr	1978
JWMAA	35--1	175	177	rata	antl shedd, parturi, reind	espmark,y	1971
JWMAA	38--1	54	66	rata	synchronous mating, b gr c	dauphine,tc,jr; m	1974
NCANA	97--1	61	66	rata	calving dates, carib, queb	desmeules,p; sim	1970
PASCC	22---	17	17	rata	repro patter, reind, carib	mcewan,eh; whiteh	1971
ZOLZA	46-12	1837	1841	rata	[reproduc, wild, taimyr p]	michurin,ln	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
WMBAA	16---	17	23	bibi	biol, manage, national par	fuller,wa	1962

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	46--5	899	944	ovca	social, physical maturatio	geist,v	1968
SWNAA	22---	153		ovca	minimum breeding age, utah	mccutchen,he	1977

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
FUNAA	24...	96	100	obmo	early matur, fecund, norwa	alendal,e	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	19--4	417	429	oram	two-year study, crazy moun	lentfer,jw	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRPFA	21--1	1	8	dada	reproductive cycle, male	chapman,di; chapm	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	1----	333	376	bibo	reproduc of european bison	jaczewski,z	1958
ATRLA	12---	333	334	bibo	breeding, zool garden, pol	landowski,j; woli	1967
ATRLA	12---	407	444	bibo	reprod biol, reserve, free	krasinski,z; racz	1967
ZSAEA	33--4	193	214	many	[developm antlers, reprod]	lau,d	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	52--3	537	544	anam	ann test cycle, horn casti	ogara,bw; moy,rf/	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRPFA	12--2	337	351	caca	sexual cycle seas breed ma	short,rv; mann,t	1966

Testes development as percent of body weight in male white-tailed (odvi) through the annual cycle

The reproductive data in Robinson et al. (1965) on male deer collected through the year are ideal for representation as a sine wave through the annual cycle. The circle diagram shown in the Figure 2 in the published paper illustrates a pattern throughout the year that can be easily converted to a symmetric sine wave, with the maximum occurring in November and the minimum in May. Thus only a primary phase correction (see CHAPTER 1) is necessary.

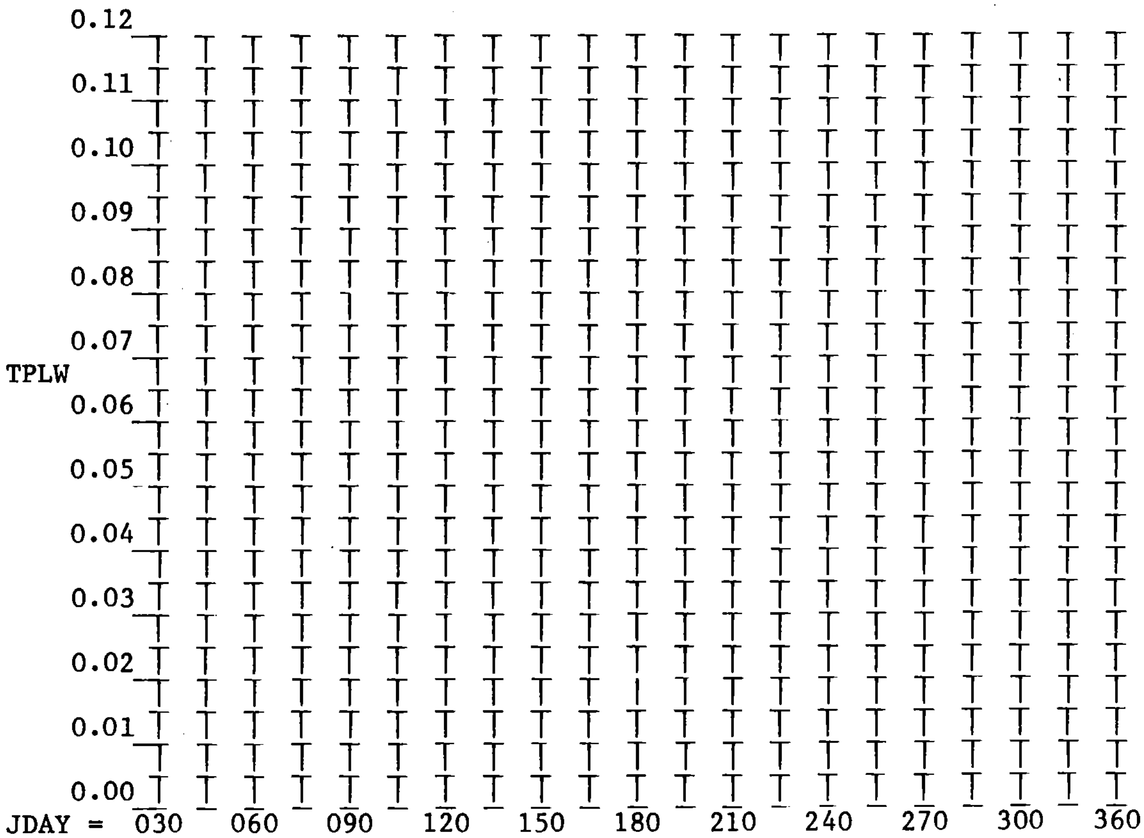
Complete the following table using data given by Robinson and adding the columns indicated by the underscore. The first line is an example.

Deer Number	Date Collected	Age (years)	JDAY	Total Weight (pounds)	LWKG	Testes Weight (gms)	Testes Percent of total Weight
N-4	9-22-62	3.5	264	88	40	31.5	0.078
N-97	_	_	_	_	_	_	_
_	_	_	_	_	_	_	_
_	_	_	_	_	_	_	_
_	_	_	_	_	_	_	_
_	_	_	_	_	_	_	_
_	_	_	_	_	_	_	_
_	_	_	_	_	_	_	_
_	_	_	_	_	_	_	_
_	_	_	_	_	_	_	_

Rewrite the procedures described in CHAPTER 1 for deriving sine wave equations with a primary phase correction, and derive an equation for testes weight as a percent of live weight (TPLW). Plot the results on the graph on the next page.

The primary phase correction is:

The equation is:



LITERATURE CITED

Robinson, R. M., J. W. Thomas, and R. G. Marburger. 1965. The reproductive cycle of male white-tailed deer in central Texas. J. Wildl. Manage. 29(1):53-59.

UNIT 4.2: SPERMATOGENESIS AND OVULATION

Testes are compact organs with specialized cells for the production of spermatozoa. Testicular weights, epididymal weights, testicular spermatozoa numbers, and epididymal spermatozoa numbers were all highly caculated with plasma endrogen levels in white-tailed deer (Mirachi et al. 1976). These reproductive characteristics of the male, are apparently related to the light regime, and coincide with the reproductive condition of the female, of course.

When spermatogenesis occurs, the spermatozoa arise from specialized sex cells called spermatogonia. They are released and move by way of the epididymis and vas deferens to the ejaculatory duct, from which they are expelled at the time of mating. Spermatogenesis occurs almost exclusively during the period of lowest body temperature (McCauley 1971:395). The testes of wild ruminants are suspended in the scrotum, which has a lower temperature than the abdominal cavity.

Ovulation occurs as undeveloped sex cells, or ova, mature and are released from the ovary, enter the fallopian tube and move through it to the uterus. If sperm are present, the ovum may be fertilized and then implanted in the uterine wall where it develops.

The female enters a period of estrus, or "heat," when ovulation occurs and she is ready to receive the male. Estrus occurs again in 3-4 weeks if conception has not occurred. The frequency of unsuccessful matings during the first estrus is not known for wild ruminants because of their secretiveness and daily behavior patterns. The general impression one gets from reproductive data on wild ruminants is that they reproduce very successfully and consistently when range conditions are favorable and herd health is good.

LITERATURE CITED

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

Mirachi, R. E., P. F. Scanlon, and R. L. Kirkpatrick. 1976. Seasonal variation in gonadal characteristics of male white-tailed deer. J. Anim. Sci. 42(1):271-272.

REFERENCES, UNIT 4.2

SPERMATOGENESIS AND OVULATION

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS------------------	AUTHORS/EDITORS--	YEAR
aubo	coup	itny	670	mamm	patterns mammalian reprodu	asdell,sa	1964

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
AJANA	132-2	189	205	odvi	ultrastr corpus lute, preg	sinha,aa' seal,u/	1971
BIREB	17--1	78	83	odvi	repr, proges, estrog, preg	plotka ed; seal,/	1977
CIRIB	6---2	1053	1056	odvi	collec semen, electro ejac	bierschwal,cj: m/	1968
COVEA	39--3	282	291	odvi	corpora lutea, ovul incide	cheatum,el	1949
JANSA	31--1	225	225	odvi	sperm reserves of w-t deer	lambiase,jt,jr; a	1970
JANSA	42--1	271	272	odvi	seas var, gonad char, male	mirarchi,re; sca/	1976
JAVMA	157-5	627	632	odvi	char semen coll, elec ejac	bierschwal,cj; m/	1970
JOMAA	32--3	267	280	odvi	notes on fecunidty, maine	palmer,rs	1951
JOMAA	40--1	108	113	odvi	breed record, capt, alabam	haugen,ao	1959
JOMAA	48--2	321	321	odvi	polyovulation in wt-tailed	hesselton,wt	1967
JOMAA	53--4	760	773	odvi	ovar comp, repr phys,venez	brokx,pa	1972
JWMAA	12--1	78	86	odvi	produc, yield, george rsrv	o'roke,ec; hamers	1948
JWMAA	15--2	73	80	odvi	produc, mortalit, coralled	severinghaus,cw	1951
JWMAA	29--1	74	79	odvi	reproducti studies, penned	verme,lj	1965
JWMAA	29--3	487	492	odvi	corpora lutea variation of	trauger,dl; hauge	1965
JWMAA	31--1	114	123	odvi	reprodtive biolo, manitoba	ransom,ab	1967
JWMAA	33--3	708	711	odvi	fertility, male w-t fawns	follmann,eh; klim	1969
JWMAA	33--4	881	887	odvi	repro pattern, nutri plane	verme,lj	1969
JWMAA	35--2	369	374	odvi	accessory corp lute, ovari	mansell,wd	1971
JWMAA	36--3	868	875	odvi	reproductive physiol, male	lambiase,jt,jr; /	1972
JWMAA	38--2	183	196	odvi	eff diethylstilbestrol rep	harder,jd; peterl	1974
JWMAA	41--1	92	99	odvi	ann chang, sperm prod, org	mirarchi,re; sca/	1977
JWMAA	41--2	87	91	odvi	microencapsulatd diethylst	matschke,gh	1977
JWMAA	41--2	194	196	odvi	antifertil act, syn proges	matschke,gh	1977
JWMAA	41--4	731	735	odvi	ferti control, steroi impl	matschke,gh	1977
NFGJA	11--1	13	27	odvi	product, growth, adirondac	severinghaus,cw;	1964

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PCFGA	29---	646	651	odvi	oral accep, eff, diethylst	matschke,gh	1975
VJSCA	24--3	112	112	odvi	ovula, pregnan, lactat dee	scanlon,pf; murp/	1973
VJSCA	24--3	112	112	odvi	spermatozoan reserves in d	lenker,dk; scanlo	1973
VJSCA	27--2	46	46	odvi	plas progest lev, estr cyc	kirkpatrick,rl; /	1976
WLSBA	3---4	152	156	odvi	hormon implan, contr repro	bell,rl; peterle,	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
APARD	1976-	208	215	odhe	environ eff on reproductio	sadleir,rmfs	1976
CAFGA	44--3	253	259	odhe	productiv, herds californi	bischoff,ai	1958
JOMAA	54--1	302	303	odhe	reproductio, b-t deer fawn	thomas,dc; smith,	1973
JWIDA	7---1	67	69	odhe	bilateral testicular degen	murphy,bd; clugst	1971
JWIDA	11--1	101	106	odhe	testicular atrophy, calif	demartini,jc; con	1975
JWMAA	19--1	115	136	odhe	fertility, utah mule deer	robinette,wl; ga/	1955
JWMAA	19--4	503	503	odhe	rocky mount, high repr rte	jensen,w; robinet	1955
JWMAA	21--1	62	65	odhe	ovarian anal, reprod perfo	golley,fb	1957
MRLTA	50--1	12	12	odhe	record, multiple ovulation	fowle,ke	1969
NAWTA	9----	156	161	odhe	productivity, central utah	robinette,wl; ols	1944
NAWTA	15---	589	596	odhe	productiv, mule d, colorad	tolman,cd	1950
THGNB	3---3	101	106	odhe	early pubert, female b-t d	mueller,cc; sadle	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BEHAA	16	84	92	ceel	charact of estrus, captive	morrison,ja	1960
CIRIB	8---4	994	997	ceel	freezi red d semen, polan	jaczewski,z; mor/	1976
JOMAA	47--1	152	153	ceel	occ of acces corpora lutea	douglas,mjw	1966
JRPFA	25--1	41	54	ceel	puberty, seas breedin male	lincoln,ga	1971
JRPFA	27--3	427	438	ceel	female reprodu cycl, scotl	guiness,f; linco/	1971
JWMAA	17--2	177	184	ceel	reproduction, yellowstone	kittans,wh	1953
JWMAA	24--3	297	307	ceel	ovarian char, breed histor	morrison,ja	1960
JWMAA	32--2	368	376	ceel	exper studies, contr repro	greer,kr; hawkin/	1968

ceel continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JZOOA	163-1	105	123	ceel	seas reprodu changes, stag	lincoln,ga	1971
NAWTA	20---	560	567	ceel	increas natal, lowered pop	buechner,hk; swan	1955
NAWTA	21---	545	554	ceel	postconcept ovulation, elk	halazon,gc; buech	1956
ZEJAA	4---3	105	130	ceel	[reproductive phenomena]	valentincic,si	1958
ZEJAA	21--4	238	242	ceel	1 sided testicle shrinkage	wurster,k; hofma/	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AVSPA	14--1	81	91	alal	morph, ultrastr, spermatoz	andersen,k	1973
JWMAA	22--3	261	268	alal	reproductn in a population	edwards,ry; ritce	1958
JWMAA	23--4	381	401	alal	reprod & produc, newfoundl	pimlott,dh	1959
VILTA	6---3	1	299	alal	reproductio, moose, sweden	markgren,g	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	56--8	1684	1696	rata	morphol, b-g caribou ovary	dauphine,tc,jr	1978
JOMAA	52--2	479	479	rata	twinning in caribou	mcewan,eh	1971
JOMAA	54--3	781	781	rata	twinning in reindeer, nwt	nowosad,rf	1973
JWMAA	38--1	54	66	rata	synchronous mating, b gr c	dauphine,tc,jr; m	1974
JZOOA	164-4	419	424	rata	collec, exam, reinde semen	dott,hm; utsi,mnp	1971
JZOOA	170-4	505	508	rata	artific insemina, reindeer	dott,hm; utsi,mnp	1973
PASCC	22---	17	17	rata	repro patter, reind, carib	mcewan,eh; whiteh	1971

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	9---2	155	156	ovca	non-breeding in bighorn sh	pulling, avs	1945
JWMAA	30--1	207	209	ovca	twinning in bighorn sheep	spalding,dj	1966

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
FUNAA	24...	96	100	obmo	early matur, fecund, norwa	alendal,e	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	19--4	417	429	oram	two-year study, crazy moun	lentfer,jw	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	1....	333	376	bibo	reproduc of european bison	jaczewski,z	1958
ATRLA	12---	407	444	bibo	reprod biol, reserve, free	krasinski,z· racz	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNTA	114-1	101	116	ungu	maternal reproductv effort	robbins,ct; robbi	1979

UNIT 4.3 GESTATION AND PARTURITION

Gestation occurs when the fertilized ovum, called a zygote, is implanted on the endometrium of the uterus. The zygote develops, becoming an embryo, and extraembryonic tissues develop to become the placenta. The placental membranes function in the exchange of nutrients, gases, and wastes between the fetal and maternal circulatory systems.

Fetal development is relatively slow in the first one-third, increases some in the second one-third, and increases rapidly in the final one-third of pregnancy; growth rates were discussed in CHAPTER 1.

Parturition in wild ruminants seems to be a rather routine event that is accomplished rather quickly, based on the few observations of parturition reported in the literature. Most wild ruminants tend to give birth at times and places that make observation difficult.

Breeding as a result of natural selection does not result in the physical mismatches that can occur through selective breeding of domestic ruminants. A large-breed ram and a small-breed ewe, for example, may result in difficulties during parturition due to fetal size. Difficulties at birth are probably quite infrequent in natural populations, although actual rates of mortality during parturition are unknown.

REFERENCES, UNIT 4.3

GESTATION AND PARTURITION

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JOANA	94--1	1	33	cerv	aspects of placentation	hamilton,wj; har/	1960

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
AJANA	126-2	201	241	odvi	morphogen, fetal membranes	sinha,aa; seal,u/	1969
AJANA	127-4	369	395	odvi	ultrastr amnion, amni plaq	sinha,aa; seal,u/	1970
AJANA	132-2	189	205	odvi	ultrastr corpus lute, preg	sinha,aa; seal,u/	1971
BIREB	17--1	78	83	odvi	repr, proges, estrog, preg	plotka,ed; seal,/	1977
CNJNA	54--2	259	259	odvi	doca, cotyled attach, uter	scanlon,pf	1974

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRPFA	47--1	161	163	odvi	chan estro, estradi, pregn	harder,jd; woolfl	1976
JWIDA	9---4	356	358	odvi	multipl anomali, w-t fetus	wobeser,g; runge,	1973
JWIDA	11--4	497	501	odvi	congen anom, neonat, alber	barrett,mw; chalm	1975
JWMAA	26--4	409	411	odvi	x-ray in determi pregnancy	verme,lk; fay,ld/	1962
JWMAA	27--1	142	143	odvi	technique for preser uteri	haugen,ao	1963
JWMAA	28--1	171	173	odvi	birth of white-tai d fawns	michael,ed	1964
JWMAA	29--1	53	59	odvi	reproduc cycle, male texas	robinson,rm; tho/	1965
JWMAA	29--3	487	492	odvi	corpora lutea variation of	trauger,dl; hauge	1965
JWMAA	30--2	414	417	odvi	sexing embryo by chromatin	segelquist,ca	1966
JWMAA	31--1	114	123	odvi	reprodtive biolo, manitoba	ransom,ag	1967
JWMAA	33--4	881	887	odvi	repro pattern, nutri plane	verme,lj	1969
JWMAA	37--3	423	424	odvi	support dev, field laparot	scanlon,pf; lenke	1973
JWMAA	39--4	684	691	odvi	uterin comp, growth, pregn	robbins,ct; moen,	1975
JWMAA	40--2	373	374	odvi	initia, preg, lactating de	scanlon,pf; murp/	1976
NFGJA	16--2	261	261	odvi	twin fawns born 2 days apa	hesselton,wt; van	1969
NFGJA	18--1	42	51	odvi	reprod anomali, female, ny	hesselton,wt; jac	1971
OJSCA	78-AP	14	14	odvi	possibl superfeta, spontan	lamvermeyer,bl; m	1978
PIAIA	71---	241	247	odvi	struc, cervic regi, uterus	morris,je	1964
VJSCA	23--3	116	116	odvi	a laparotomy technique w-t	scanlon,pf; lenke	1972
VJSCA	23--3	116	116	odvi	aspects of early pregnancy	scanlon,pf; murp/	1972
VJSCA	24--3	112	112	odvi	ovula, pregnan, lactat dee	scanlon,pf; murp/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ACATA	84--1	118	128	odhe	anam, morpho, cervix uteri	kanagawa,h; hafez	1973
ANREA	122--	335	340	odhe	quadruplets in mule deer	sears,hs browman	1955
CJZOA	48--1	123	132	odhe	odvi, develo, fetal period	ommundsen,p; cowa	1970
JOMAA	38--1	116	120	odhe	gesta per, breed, fawn beh	golley,fb	1957
JWMAA	37--3	312	326	odhe	effect nutr chan on captiv	robinette,wl; ba/	1973
JWMAA	40--4	795	796	odhe	preg fawn, quintupl mule d	nellis,ch; prent/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	47--6	1418	1419	ceel	sexual dimorphi in fetuses	retfalvi,l	1969
JOMAA	36--1	145	145	ceel	fetus in yearling cow elk	saunders,jk jr	1955
JOMAA	47--2	332	334	ceel	fetus resorption in elk	haugen,ao	1966
JWMAA	17--2	177	184	ceel	reproduction, yellowstone	kittans,wh	1953
JWMAA	17--2	223	223	ceel	pregnant yearling cow elk	coffin,al; reming	1953
JWMAA	23--1	27	34	ceel	breed seas, known-age embr	morrison,ja; tra/	1959
JWMAA	31--1	145	149	ceel	determ preg, rectal palpat	greer,kr; hawkins	1967
JWMAA	40--2	330	335	ceel	nutri, hesta, succes repro	thorne,et dean/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	26--4	360	365	alal	in gravelly, snowcrest mou	peek,jm	1962

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	90--4	498	499	rata	twin fetuses, woodland car	shoesmith,mw	1976
JOMAA	49--4	778	778	rata	placental remnants, rumens	miller,fl; parker	1968
JWMAA	25--2	205	205	rata	sex determination of calve	bergerud,at	1961
JWMAA	28--3	477	480	rata	field meth, parturiti rate	bergerud,at	1964

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	30--1	207	209	ovca	twinning in bighorn sheep	spalding,dj	1966
JWMAA	43--4	970	973	ovca	deter pregncy, progestin,	ramsay,ma; sadlei	1979

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
FUNAA	24...	101	103	obmo	gestation period of muskox	alendal,e	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	19--4	417	429	oram	two-year study, crazy moun	lentfer,jw	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBCPA	43A--	673	679	mamm	gestation period, body wt	kihlstrom,je	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNTA	114-1	101	116	ungu	matern repro effort, fetal	robbins,ct; robbi	1979

UNIT 4.4: LACTATION

The production of milk is a distinguishing feature of mammals. It is a very necessary process as the neonates are not able to either forage or digest forage; milk is the sole supply of nutrients immediately after birth. Further, colostrum, the first milk produced after parturition is highly nutritious and contains more dry matter, more protein, and more vitamins than milk produced a few days after parturition and through the rest of the lactation period. The colostrum of ruminants also contain antibodies essential for the young until they develop an active immunity to diseases. The low resistance due to a lack of antibodies at birth in ruminants is due to the lack of placental transmission from mother to fetus. The effects of these important mother-young relationships in the first few days of life may be realized in population dynamics as changing environmental conditions affect the successful establishment of both the nutritional and social relationships.

The amount of milk produced usually increases for a few weeks after parturition and then slowly decreases. The increase coincides with the increased demand for nutrients by the rapidly growing young before the rumen is developed well enough to be fully functional.

Milk is released in response to the nursing activities of the young. They may suckle several times a day, with a decline in the frequency of nursing in the last two-thirds of lactation. This decline coincides with increasing dependence on forage and decreasing milk production. Milk production ceases when the young no longer stimulate the dam by nursing, usually 3-5 months after parturition in wild ruminants.

REFERENCES, UNIT 4.4

LACTATION

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
aubo	isup	amia	291	doca	secretion of milk, 4th ed.	esped,w; smith,vr	1952
edbo	saco	phpa	584		handbook of biologica data	spector,ws,ed.	1956
aubo	coup	itny	670	mamm	patterns mammalian reprodu	asdell,sa	1964
edbo	acpr	nyny	516	mamm	mammary gland, dev & maint	larson,bl; smith,	1974
edbo	acpr	nyny	458	mamm	biosyn & secr milk;disease	larson,bl; smith,	1974
edbo	acpr	nyny	425	mamm	nutrit and biochem of milk	larson,bl; smith,	1974

REFERENCES, UNIT 4.4

LACTATION

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	39--2	355	360	odvi	milk consumpt, weight gain	robbins,ct; moen,	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	44--2	472	478	odhe	milk yield, black-tailed d	sadleir,rmfs	1980

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRPFA	37--1	67	84	ceel	comp, yield, milk, red dee	arman,p; kay,rnb/	1974
JWMAA	40--2	330	335	ceel	nutri, gesta, succes repro	thorne,et; dean,/	1976
SZSLA	41---	297	312	ceel	physiol effe lacta on moth	hanwell,a; peake	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ALLKA	55	23	28	alal	struc rib,thorax indic mil	anghi,c	1968
JWIDA	12--2	202	207	alal	milk, hair, element relati	franzmann,aw; fl/	1976
PNSUA	27--2	129	138	alal	compar nut in preg, lactat	payne,pr; wheele/	1968
VILTA	6---3	1	299	alal	reproductio, moose, sweden	markgren,g	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	49--4	443	447	rata	measu, milk intake, calves	mcewan,eh; whiteh	1971
CJZOA	54--1	55	64	rata	glucos metab, lactat reind	white,rg; luick,j	1976
SZSLA	41---	297	312	rata	physiol effe lacta on moth	hanwell,a; peake	1977

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JOANA	94--1	1	33	cerv	aspects of placentation	hamilton,wj; har/	1960

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
EVOLA	31--1	177	199	mamm	signif lacta, evol of mamm	pond,cm	1977

TOPIC 5. EXCRETORY SYSTEM FUNCTIONS

Excretion of unused forage components and waste products of metabolism is an important function since regularity is necessary to avoid build-up of potentially toxic substances.

Urine and feces are the two main kinds of materials excreted from the body of wild ruminants. Gas production also occurs, and waste materials are sloughed off the skin and hair. These waste products should be considered when evaluating the metabolic costs of maintenance; they are discussed in later chapters.

Urine and feces are discharged directly from the excretory system in measurable quantities that can be related to water and forage intake. The difference between ingestion and excretion represents some level of metabolic efficiency. There are many details to consider when evaluating efficiencies, however, since the components of excretory products come from both ingestion and metabolic sources.

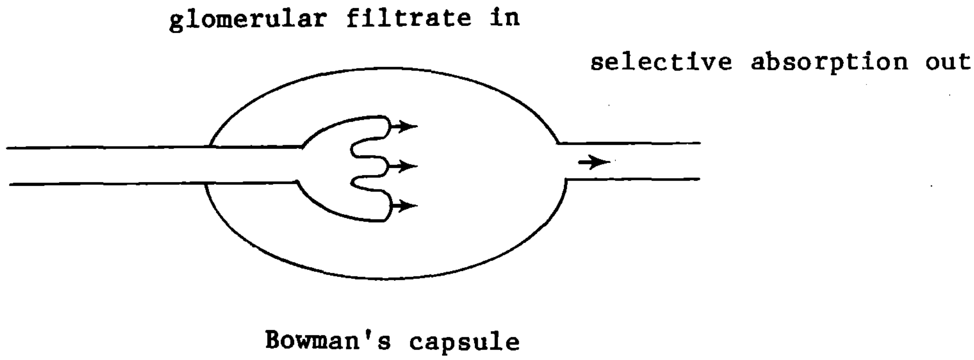
Few research studies have been completed in the excretory functions of wild ruminants. The basic functions behind urine and feces excretion are discussed in UNITS 5.1 and 5.2. Some of the more practical uses of fecal excretion characteristics is in estimating populations, but this is discussed in CHAPTER 19.

UNIT 5.1: URINARY FUNCTIONS

Water and salt balances are maintained as a result of the actions of the kidneys in regulating the amount and concentration of the urine. It is the only organ capable of regulating the movements of water and salts between the environmental medium and the fluid compartments of the body (McCauley 1971:158). Water loss also occurs in the feces, but this is quite constant, and through the skin. Neither of these two pathways are capable of regulating water balance, however, fecal water losses are fairly constant, and the losses through the skin vary in relation to thermal energy balance rather than water balance. Thus dehydration occurs when temperatures are excessive and water losses through the skin high.

The functional unit in the kidney is the nephron. It is richly supplied with blood, and differences in blood pressure within the glomerulus result in fluid, called glomerular filtrate, collecting in the cavity of Bowman's capsule. Reabsorption by active transport then occurs, resulting in the reclaiming of useful materials such as sugars and amino acids, and waste products are allowed to pass into the rumen. These and other details of renal function are described in McCauley (1971:153-168).

A schematic drawing of kidney function is shown below.



Note that urea may be reabsorbed rather than eliminated by the ruminant, resulting in the conservation of nitrogen as an aid in protein metabolism when the range is low in protein.

The recycling of urea is an example of resource conservation by free-ranging animals, illustrating how the resource economy may be maintained over time, thereby maintaining a higher level of productivity than would be the case if resource transactions were made on a short-term basis only.

LITERATURE CITED

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

REFERENCES, UNIT 5.1

URINARY FUNCTIONS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	38--1	186	191	odvi	nitrogen metabolis, whit-t	robbins,ct; prio/	1974
JWMAA	39--2	346	354	odvi	blood prot, gestatio, suck	harstook,ew; whe/	1975
JWMAA	39--4	692	698	odvi	ener, prot, blood urea nit	kirkpatrick,rl; /	1975
JWMAA	42--4	776	790	odvi	diet prot, energ fawn meta	verme,lj; ozoga,j	1978
JWMAA	43--2	454	460	odvi	season, nutri, serum nitro	bahnak,br; holla/	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAVMA	155-7	1085	1085	odhe	urine-collect device, male	richmond,m; pill/	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NZJSA	13--4	663	668	ceel	kidney wt, kidne fat index	batcheler,cl; cl/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BIJOA	155-3	549	566	alal	ceel, chymotrypsin, pancre	lindsay,rm; steve	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	39--2	379	386	rata	kidney wt fluct, fat index	dauphine,tc,jr	1975

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
ANREA	169-2	343	343	ovca	observ kidney, desert bigh	horst,r; langwort	1971

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			

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

UNIT 5.2: FECAL FUNCTIONS

The feces of ruminants contain water, undigested forage residues, cells that have been abraded from the gastrointestinal tract, bacteria, products of rumen fermentation, and other products of physiological processes such as bile acids, pigments, mucin, and inorganic salts. Large amounts of feces are defecated by ruminants because so much of the forage ingested is not digested. The more lignified the forage material is, the less it can be digested. Fecal samples may be used as a technique for estimating dietary composition by identifying fragments.

The water content of ruminant feces varies seasonally. Succulent spring forage is high in water content, and feces have little or no form. At other times, especially in the winter, the feces are quite dry and, in many species, formed into small pellets which are defected as pellet groups.

The excretion of rather dry pellet groups, composed largely of indigestible forage, has been used by biologists as a field method for estimating populations. If a known member of pellet groups are defecated per animal each day, then the number of pellet groups divided by the number defecated per day is an estimate of the number of animal-days of use. Such estimates may not be very precise due to sampling errors in counting pellet groups in the field and variations in the number of pellet groups defecated per day. This technique is discussed further in CHAPTER 19.

REFERENCES, UNIT 5.2

FECAL FUNCTIONS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	33--3	506	510	od	qual ident forage remnants	zyznar,e; urness,	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRMGA	30--1	61	63	odvi	chrom oxid indic fecal out	ruggiero,lf; whel	1977
JRMGA	32--2	93	97	odvi	infl brush control on diet	quinton,da; hore/	1979
JWMAA	26--1	50	55	odvi	rain, count of pellet grou	wallmo,oc; jacks/	1962
VJSCA	23--3	116	116	odvi	dosh chrmicoxide fecal out	sanders,ot skee/	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRMGA	30--2	116	118	odhe	food, wld hors, doca, colo	hansen,rm; clark/	1977

odhe continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	28--3	435	444	odhe	defecation rates of mule d	smith,ad	1964
JWMAA	31--1	190	191	odhe	anam, id fecal gr, pH anal	howard,vw,jr	1967
JWMAA	32--4	961	962	odhe	fecal ph values, dom sheep	nagy,jg; gilbert,	1968
JWMAA	43--2	563	564	odhe	number pellets per defecat	strong,ll; freddy	1979
JWMAA	32--4	961	962	odhe	fecal ph values, dom sheep	nagy jg; gilbert,	1968
SWNAA	13--2	159	166	odhe	food plants, habitat, okla	clark,tw	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	29--2	406	407	ceel	determinat defecation rate	neff,dj; wallmo,/	1965
JWMAA	41--1	76	80	ceel	foods of ungulates, colora	hansen,rm; clark,	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	40--2	374	375	alal	dail wint pell gr, bed, al	franzmann,aw; ar/	1976
NCANA	95--5	1153	1157	alal	[numb pellet-gro each day]	desmeules,p	1968

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
GRBNA	38--2	222	224	anam	sim bet prong, odhe fec pe	johnson,mk; maccr	1978
JRMGA	32--4	275	279	anam	fec, rum, util meths, diet	smith,ad; shandru	1979
JRMGA	32--5	365	368	anam	livest, foods, dese steppe	johnson,mk	1979
JWMAA	40--3	469	478	anam	diets, forag avail, colora	schwartz,cc; nagy	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	42--3	581	590	bibi	diet, sl rvr herd, nw terr	reynolds,hw; han/	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	37--3	363	366	ovca	food hab, plant frag, fece	todd,jw; hansen,r	1973
JWMAA	39--1	108	111	ovca	food of, southern colorado	todd,jw	1975

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CWOPA	35--1	1	19	obmo	rata, diets, canadi arctic	parker,gr	1978

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JZOOA	185--	270	273	dosh	caca, comparison wint diet	henry,bam	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	43--3	796	798	ungu	fecal ph compar, 3 species	peek,jm; keay,ja	1979

TOPIC 6. SKELETAL SYSTEM FUNCTIONS

The skeleton of vertebrates provides support for the entire body, more or less rigid places for the attachment of muscles, and protection for some of the vital organs. Joints or articulations are present in two main kinds: immovable joints, as in the skull, and movable ones, as in the limbs. The skeleton plus the musculature provides the basic form of the animal's body which results in animals of grace and beauty, attractive to nearly all persons.

The skeleton has important seasonal functions as it is a storage reservoir for animals for mobilization during periods of rapid antler growth. Skeletal remains are also useful for determining mortality of sex and age groups.

UNIT 6.1: THE SKELETON AS SUPPORT

One of the main functions of the skeleton is body support, which is attained as a result of the rigidity of the bones and the muscle tone and contractions that result in various postures. Skeletal support charcteristics are of importance when evaluating details of locomotion, and the anatomical characteristics that affect relationships between animal and range, such as the effects of snow and forage distributions and availability. Support functions themselves are not analyzed further in this UNIT; anatomical measurements were discussed in CHAPTER 1, and the effects of range conditions on animals in CHAPTER 17.

REFERENCES, UNIT 6.1

THE SKELETON AS SUPPORT

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CATRB	12--4	323	330	cerv	cyclic bone remodeling dee	hillman,jr; davi/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	50--2	302	310	odvi	alal, stuctur adapta, snow	kelsall,jp	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	41--4	629	636	odhe	age determ, ossif, long bo	lewall,ef; cowan,	1963
CAFGA	41--4	327	346	odhe	dosh, dogo, skeletal diffe	hildebrand,m	1955
CAFGA	42--1	15	21	odhe	odvi, pelv girdl, rel, sex	taber,rd	1956
JOMAA	45--2	226	235	odhe	rang-rel gro dif, sk ratio	klein,dr	1964

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	37--1	129	129	ceel	healing, fractured leg bon	gilbert,pf; hill,	1956
JWMAA	30--2	369	374	ceel	bone char assoc with aging	gilbert,pf; hill,	1956

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	50--2	302	310	alal	odvi,structur adapta, snow	kelsall,jp	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATICA	19--2	111	113	rata	functio brow tine, caribou	pruitt,wo	1967
UABPA	18---	1	41	rata	mechanics, energy, crateri	thing,h	1977

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNTA	113--	103	122	mamm	scal. skel mass, body mass	prange,hd: ander/	1979

UNIT 6.2: THE SKELETON AS A STORAGE RESERVOIR

The skeleton serves as an important storage reservoir of nutrients that can be mobilized when nutrient intake is not sufficient to meet current metabolic demands. Two particularly good examples of this situation are at the time of antler growth and when energy demands are higher than metabolizable energy intake in the diet.

Minerals. The accumulation of minerals in the skeletal system for mobilization during antler growth is probably necessary for such rapid rates to be possible. Phosphorous and calcium are mobilized from the ribs and long bones for deposition in the antlers of white-tailed deer and this basic physiological process is very likely characteristic of all of the ruminants that shed their antlers each year.

Marrow. Bone tissue is very much alive and active, though the calcified tissue is rigid and often encloses more active, spongy tissue. The marrow inside of the shafts of the long bones contains blood at all times, and a rather high fat content when range conditioNs are good enough to result in a positive energy balance by the animal. The fat contents of the femur is often used as an indicator of the physical condition of an animal, and its stability permits one to estimate the season of death when dead animals are found in the spring. Animals not found during the hunt can be distinguished from those that died as a result of poor nutrition in the winter.

REFERENCES, UNIT 6.2

THE SKELETON AS A STORAGE RESERVOIR

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JOMAA	31--2	5	17	odvi	weight relations, georg re	hamerstrom,fm,jr/	1950
JWMAA	9---4	319	322	odvi	symptoms of malnutrition	harris,d	1945
JWMAA	29--2	397	398	odvi	kidney, marrow fat, condit	ransom,ab	1965
NFGJA	21--1	67	72	odvi	physical condition of whit	monson,ra; stone/	1974
NYCOA	3---5	19	22	odvi	bone marrw index of malnut	cheatum,el	1949
PCGFA	26---	57	68	odvi	var fat levl, mandib cavit	nichols,rg; pelt	1972
PSEBA	129--	733	737	odvi	calcium strontium age antl	cowan,rl; hartso/	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	45--2	252	259	odhe	density studies, body fat	whicker,fw	1964
JOMAA	52--3	628	630	odhe	tiss, organ, tota body mas	hakonson,te; whic	1971
JWMAA	36--2	579	594	odhe	indice, carc fat, colo pop	anderson,ae; med/	1972
JWMAA	41--1	81	86	odhe	exp starva, recovery, does	decalesta,ds; na/	1977
WAEBA	589--	1	6	odhe	the mule deer carcass	field,ra; smith,/	1973
WLMOA	39---	1	122	odhe	carcas, bone, organ, gland	anderson,ae; med/	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JSFAA	22--1	29	33	ceel	fatty-acid compos, adipose	garton,ga; duncan	1971
JWMAA	30--1	135	140	ceel	measurements, weight relat	blood,da; lovaas,	1966
JWMAA	32--4	747	751	ceel	fat content, femur marrow	greer,kr	1968
MAMLA	35--3	369	383	ceel	demog, fat res, bod sz, nz	caughley,g	1971
WAEBA	594--	1	8	ceel	the elk carcass	field,ra; smith,/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AZOFA	12--2	148	155	alal	fatty-acid compos, org fat	tanhuanpaa,e; pul	1975
JWMAA	40--2	336	339	alal	marrow fat, mortali, alask	franzmann,aw; arn	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBCPA	30--1	187	191	rata	fatty acid comp bone marow	meng,ms; west,gc/	1969
CBPAB	56--3	337	341	rata	liver, bone, bone marrow	bjarghov,rs; jac/	1977
FUNAA	23...	106	107	rata	fat deposits, svalbard dee	oritsland,na	1971
JWMAA	34--4	904	907	rata	wt, dried marrow femur fat	neilans,ka	1970
NJZOA	24--4	407	417	rata	morph, fat stor, org weigh	krog,j; wika,m; /	1976
PASCC	22---	14	14	rata	water flux, climate, nutri	cameron,rd; luic/	1971
TNWSD	28---	91	108	rata	phys var, condit, b g cari	dauphine,tc,jr	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	33--1	309	309	anam	carbonyl analysis of fat	booren,a; field,/	1971
JDSCA	38---	1344	1344	anam	major chemi compos, bovine	reid,jt; wellin/	1955
JOMAA	56--3	583	589	anam	seas tren in fat lev, colo	bear,gd	1971
WAEBA	575--	1	6	anam	pronghorn antelope carcass	field,ra; smith,/	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	26--2	305	308	bibi	the lipids in bison bison	wilbur,dg; gorski	1955

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBCPA	50b-4	599	601	ovda	fatty acid comp bone marrw	west,gc; shaw,dl	1975

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	49--8	1159	1162	many	comp, adipose tiss triglyc	garton,ga; dunca/	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	18-11	209	222	caca	drssng %, body comp, calor	weiner,j	1973

TOPIC 7. MUSCULAR SYSTEM FUNCTIONS

Movements of vertebrate animals are made possible by the contraction of the muscles spanning skeletal articulations. Speedy locomotion is a very important attribute of wild ruminants as they often depend on short bursts of speed to escape danger.

Muscular contraction is an exothermic process, resulting in the release of heat energy. The heat energy must be dissipated or else the temperature of the body tissue will rise. Dissipation can become a problem on warm autumn days when the winter coat has grown enough to provide good insulation. Then, heat energy cannot escape efficiently, and warm autumn days can be thermally stressful for animals that must run as the emerging winter coat provides good insulation from heat loss. I have observed white-tailed deer with tongues out for cooling on several occasions under such conditions.

Muscles can also be a source of heat production without body movement; shivering is a form of thermogenesis that may be important for animals in extreme cold. Thus muscles function in more ways than for locomotion. Free-ranging animals, well adapted for their nautral environments, integrate all of their life functions into a way of being, a continuum in space and time, that is best understood by studying the animal as a whole in relation to the functions of its different parts or systems.

UNIT 7.1: LOCOMOTION

Locomotion occurs when muscles spanning skeletal articulations contract. The details of locomotion have been studied for several domestic and some wild species. The mechanics of locomotion by race horses, for example, is currently being studied in Sweden and at Cornell University, USA. Details of locomotion have not been critically evaluated for North American wild ruminants however.

One of the major characteristics of locomotion that has a distinct practical value is the mechanics of weight-loading when an animal is moving. Static weight loads, determined by relating body mass to hoof area, are of less value than dynamic weight loads when different species of animals are being compared, or different activities such as walking or running. More research in this rather specialized area of investigation would greatly increase our understanding of the effects of snow on animals in the northern regions.

REFERENCES, UNIT 7.1

LOCOMOTION

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ANANA	137-4	381	394	odvi	musculature of hip, thigh	bisaillon,a	1974

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

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
UABPA	18---	1	41	rata	behav, mechan energ, crate	thing h	1977

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
SCAMA	202-5	148	157	mamm	how animals run	hildebrand,	1960

UNIT 7.2: THERMOGENESIS

Thermogenesis is another term for heat production. It is a term applied to increases in heat production as a response to cold, implying that thermogenesis is a specific response in addition to the heat production that is a continuous characteristic of life.

Voluntary activity is a thermogenic response, and may be employed by ruminants to "keep warm." Severinghaus and Cheatum (1956:146) describe cases where white-tailed deer in the Adirondacks were observed to be walking slowly along heavily-used trails at midnight when temperatures approached -35°C, presumably to keep warm by excercising. While heat production increases will result from increased movement, it is not a good long-term adaptation because of the energy costs incurred at a time when food resources are declining in quality and may not be readily accessible, while body reserves are decreasing.

Muscular thermogenesis may occur as a result of shivering, without an increase in activity. Shivering is an involuntary muscular response, which includes an initial increase in muscle tone followed by several muscular tremors per second. Andersson (1970:1125-6) states that shivering may increase oxygen consumption by 400 percent, and that it is more effective from a thermodynamic point of view than voluntary muscle contractions. Thus thermogenics may be an important part of an animals' response to cold, but a difficult one to interpret in the field.

LITERATURE CITED

Andersson, B. E. 1970. Temperature regulation and environmental physiology. Chapter 49, Pages 1119-1134 In Dukes' physiology of domestic animals, M. J. Swenson, ed., Cornell Univ. Press, Ithaca. 1463 pp.

Severinghaus, C. W. and E. L. Cheatum. 1956. Life and times of the white-tailed deer. Pages 57-186 In The deer of North America, W. P. Taylor ed., The Stackpole Company, Harrisburg, PA. 668 pp.

REFERENCES, UNIT 7.2

THERMOGENESIS

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
				ceel			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JEBPA	13--2	133	136	alal	ceel, rata, compar myoglob	sukhomlinov,bf; /	1977

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

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 7.3: INVOLUNTARY MUSCULAR CONTRACTIONS

Involuntary muscular contractions occur continuously as a part of the maintenance of life. The heart beats without voluntary control, the diaphragm contracts and external respiration occurs, the rumen and rest of the gastrointestinal tract experience involuntary contractions that keep food materials moving, and there are other involuntary contractions of muscles associated with different system functions. All of these muscular contractions cost the animal something, but the costs are a part of maintenance. There is essentially no literature on this subject for wild ruminants, except that in references describing the functions of various body systems.

REFERENCES, UNIT 7.3

INVOLUNTARY MUSCULAR CONTRACTIONS

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

ceel

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

alal

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

rata

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

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obmo

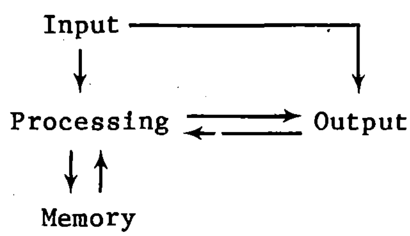
CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

oram

TOPIC 8. NERVOUS SYSTEM FUNCTIONS

The nervous system is a most elaborate and intricate control system that coordinates the maintenance, activity, and productive functions of each individual. Many other systems interact with the nervous system. The muscular system, for example, is coordinated to a high degree by the nervous system, resulting in smooth and graceful body movements. The endocrine system functions with the nervous system to a large extent. Klemm (1970:849) points out that the endocrine system is not only controlled by the nervous system but hormones also act on the nervous system in a feedback way.

The overall function of the nervous system is described by Klemm (1970:851) in a simplified way as an input -> output system mediated by the processing of the information, with the additional possibility of retention of some of the information in the memory. The functions can be illustrated like this.



Inputs may be processed in the brain before output responses are made. These are called voluntary responses. Some responses are made before the central nervous system has processed the input information. An animal may be startled, run a short distance without processing the reasons for running, and then stop to process the information provided by the input. The source of the input may be of no consequence--a branch may fall and scare a deer--or it may be of considerable importance to the individual--a twig may be snapped by an approaching predator. When incidents are processed and consistent biological responses formulated, the animal is exhibiting a memory that may be drawn on for later processing. Such information becomes part of the "historical environment" discussed in CHAPTER 3 of PART II.

Some responses do not include the nervous system; sensory receptors that signal distention of the rumen are part of the continuous system that causes the output--rumenoreticular contractions--to occur without conscious response by the organism. These are involuntary responses, and are part of the maintenance processes of life.

The sensory capabilities of an animal are of interest to ecologists because these functions link animal to environment. These functions are commonly referred to as the senses, and include sight, hearing, taste, touch, smell, thermal senses, and pain. These senses alone do not define the functional environment (See CHAPTER 3 in PART II), but they establish the perceived operational environment. If an individual cannot see, for example, then none of the wavelengths of the electromagnetic spectrum usually detected visually by an animal of that species affect that individual, and its environment is altered accordingly.

LITERATURE CITED

Klemm, W. R. 1970. Design of the nervous system. Chapter 40, Pages 849-879 In Duke's physiology of domestic animals, M. J Swenson, Ed. Cornell University Press, Ithaca. 1463 pp.

REFERENCES, TOPIC 8

NERVOUS SYSTEM FUNCTIONS

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS------------------	AUTHORS/EDITORS--	YEAR
aubo	anth	nyny	305	many	the sense of animals & men	milne,l; milne,mj	1962
edbo	else	nyny	933	many	acoustic behavior of anima	busnel,rg,ed	1963
aubo	phli	nyny	240	many	the senses of animals	matthews,lh· knig	1963
aubo	macm	nyny	113	many	sensory mechanisms	case,j	1966
aubo	hill	loen	760	many	the chemical senses	moncrieff.rw	1967
aubo	ccth	spil	200	many	molecular basis of odor	amoore,je	1970
aubo	tapl	nyny	183	many	animal senses	burton,r	1970
edbo	apcc	nyny	412	many	comm, chem sig: advan chem	johnston,jw,jr; /	1970
edbo	iucn	mosw	904	ungu	behav, relat to management	geist,v,ed; walth	1971
proc	acpr	nyny	231	rata	ecochemi studies, reindeer	bertmar,g	1975

UNIT 8.1: VISION

The eye, the organ of vision, is an extremely important part of the nervous system of diurnal animals. The eye of wild ruminants has but one lens, (it is a simple rather than a compound eye), and the lens focuses the image on the retina on the back of the eye where the stimuli are converted by the receptors to nerve impulses that are transmitted to the brain for processing.

Differences in visual functions of wild ruminant species have been observed but not evaluated physiologically. What structural and functional capabilities does the pronghorn have that enables it to see for great distances that other wild ruminants do not have? Comparative studies have not been done, so definitive answers to such questions are not available.

REFERENCES, UNIT 8.1

VISION

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS------------------	AUTHORS/EDITORS--	YEAR
aubo	ccth	spil	250	many	animal visi: what anim see	smythe,rh	1961
aubo	chha	loen	132	vert	vision in vertebrates	tansley,k	1965

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
AVCSA	18--2	152	158	cerv	the structure of cornea in	rehbinder,c; win/	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
AJVRA	39--4	699	702	odvi	cone, rod photo receptors	witzel,da; sprin/	1978

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

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

ceel

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

AVCSA 18--2 159 167 alal lens lesions, elk, sweden kronevi,t; holmb/ 1977

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

rata

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 8.2: HEARING

Most ruminants detect and interpret sounds in the natural environment with a high level of capability. Further, individuals emit sounds that have particular meanings to other members of the species. Elk, for example, use "bugling" as an integral part of breeding behavior. This sound is emitted by the vocal cords. White-tailed deer emit a snorting sound when they are uncertain of the kind of stimulus being received. This sound is made by forcing air out through the nostrils· vocal cords do not seem to be involved.

The organs of hearing are located in the inner ear. These organs convert vibrations of different frequencies and wave-lengths to nerve impluses that are transmitted to the brain for processing. The impulses received are interpreted according to pitch, which is dependent on the frequencies of the vibrations, and intensity, or loudness, which is dependent on the frequencies and amplitudes of the vibrations. Wild ruminants respond to differences in both of these as they process such information in the ecological context. Close but harmless sounds may cause a response, for example, while sounds that are distant but associated with potentially harmful events (distant gunshots, for example) may not cause a response .

Little is known about the actual sensitivity distributions of wild animals to different sound characteristics. Direct measurements of inner ear characteristics are difficult if not impossible to make in wild ruminants, and animals trained to respond in certain ways to different sound stimuli have not been used in wild ruminant research. Hearing capabilities must be guessed at or evaluated on the basis of limited observations made in the field.

One interesting bit of research was completed at the Wildlife Ecology Laboratory at Cornell when young whitetail fawns that were being trained for telemetry experiments were exposed to a systematic playing of recorded wolf howls (Moen et al. 1978). The fawns exhibited a patterned heart rate response to the frequencies and loudness of the howls, indicating some kind of genetically programmed response. Heart rate measurements in response to a series of snowmobile activities have also been made; the deer were very quick to detect the sound of the snowmobile. Further details are given in CHAPTER 17. Additional observations of heart rate responses to common sounds such as airplanes, tractors, and other noises of society have also been made while completing heart rate studies. Some of these transient responses are described in Moen and Chevalier (1977). The conclusion must be that deer, at least, are very sensitive to sounds and do a considerable amount of information processing without exhibiting overt behavioral responses.

LITERATURE CITED

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 8.2

HEARING

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	56--7	1207	1210	odvi	hrt rte resp to wolf howls	moen,an; dellafe/	1978

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

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMZOA	10--4	481	481	rata	ontogen, vocaliza, behavio	ericson,ca	1970
BEHAA	54--1	50	59	rata	indivi char, calls, calves	espmark,y	1975

rata continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BPURD	1----	387	397	rata	intrasp commu, mother-calf	ericson,ca	1975
BPURD	1----	398	408	rata	acoustic commun, review of	lent.pc	1975
BPURD	1----	423	435	rata	socializat, calving ground	miller,fl; ander/	1975
ZETIA	29--1	42	81	rata	mother-young rel, ontog be	espmark,y	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	50--3	647	648	anam	th blowsound of pronghorns	waring,gh	1969

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
SWNAA	9---3	118	145	anim	biol acoust, sound spectro	davis,li	1964

UNIT 8.3: OLFACTION

Olfaction, or the sense of smell, appears to be an important function associated with the selection of forage by at least some of the wild ruminants, and the avoidance of predators and in the reproductive behavior of all of the wild ruminants. Olfaction is made possible by specialized epithelial cells lining the nasal cavities. These specialized cells receive olfactory stimuli, and transmit information via olfactory nerves to the olfactory lobes of the brain for processing.

The olfactory areas are larger in the keen-scented animals than in those with a lesser sense of smell. The actual mechanism of olfactory perception is subject to further measurement and debate. Kare (1970:1173) briefly discusses theories of olfaction. Similarities in molecular configurations between the stimulus and the receptor may be one explanation. Molecular vibrations of the stimulus are thought to play a part in some olfactory relationships. Solubilities of adsorbed molecules may also play a part in olfaction, as well as enzyme effects and other chemical relations at the olfactory surface. Rather than seeking a single explanation for olfaction, the different contributions of all of these possible mechanisms under different ecological situations should be considered.

An interesting similarity exists between the apparent genetically programmed responses of young white-tailed deer to wolf howls using the sense of hearing described in the previous unit (UNIT 8.2) and the results of Muller-Schwarze (1972) on the responses of young black-tailed deer to predator odors. These black-tailed deer exhibited negative responses to the droppings of both North American and African predators, even though they had had no previous encounters with such predators. Muller-Schwarze concluded that the deer possessed a genetically determined negative response to odors of predators. Such conclusions, and those described in UNIT 8.2 on hearing responses to recorded wolf howls, are of real ecological interest and potentially of great significance in management. The role of odors in the behavior and ecology of wild ruminants is apparently great, and may be even greater than we humans, with our limited olfactory capabilities, consider it to be. The scent environment is very dynamic (see CHAPTER 3), and olfaction is very important in behavioral relationships (see CHAPTERS 4 and 5).

LITERATURE CITED

Kare, M. R. 1970. Taste, smell, and hearing. Chapter 51, Page 1160-1185 In Duke's physiology of domestic animals, M. J. Swenson, Ed. Cornell University Press, Ithaca. 1463 pp.

Muller-Schwarze, D. 1972. Responses of young black-tailed deer to predator odors. J. Mammal. 53(2):393-394.

REFERENCES, UNIT 8.3

OLFACTION

SERIALS

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ANBEA	19--1	141	152	odhe	pheromones in bl-tail deer	muller-schwarze,d	1971
JOMAA	53--2	393	394	odhe	respon, youn btd pred odor	muller-schwarze,d	1972

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JCECD	1---2	275	281	rata	volat comp fr tarsal sc gl	andersson,g; and/	1975
JCECD	3---5	591	601	rata	caudal gland, histol, chem	muller-schwarze,/	1977
JCECD	4---3	325	335	rata	resp to interdig secretion	muller-schwarze,/	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
MAMLA	37--1	25	33	anam	scent mark, territoriality	gilbert,bk	1973

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMZOA	7---3	421	429	mamm	olfaction in mammals	moulton,dg	1967

UNIT 8.4: TASTE

Taste is an important sensation associated with food. It is also closely associated with the sense of smell, and the two can hardly be separated except by experimental elimination of one of these senses.

The taste receptors are called taste buds, and are found in large numbers on the tongue. Cattle have large numbers on the tip of the tongue and even larger numbers on the back of the tongue (Kare 1970:1192). This distribution may also be characteristic of wild ruminants.

Taste and/or smell apparently function in food discrimination. Preference tests have shown that black-tailed deer have distinct preferences for different solutions (Crawford and Church 1971). Forage preferences of white-tailed deer discussed in PART IV indicate that they select the more digestible forages before the less digestible ones, showing that taste and smell have effects on the diet quality.

LITERATURE CITED

Crawford, J. C. and D. C. Church. 1971. Response of black-tailed deer to various chemical taste stimuli. J. Wildl. Manage. 35(2):210-215.

Kare, M. R. 1970. Taste, smell, and hearing. Chapter 51, Pages 1160-1185 In Duke's physiology of domestic animals, M. J. Swenson, Ed. Cornell University Press, Ithaca. 1463 pp.

REFERENCES, UNIT 8.4

TASTE

SERIALS

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	35--2	210	215	odhe	respon, chem taste stimuli	crawford,jc; chur	1971

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

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

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oram

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

NATUA 183-- 345 346 doca threshold val, tast, twins bell,fr; williams 1959

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JASIA	52--1	125	128	dogo	pref threshol, tast discri	bell,fr	1959

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	30--5	777	783	dosh	tas resp I. sug, sacc, sal	goatcher,wd; chur	1970
JANSA	30--5	784	790	dosh	II. acids, quin, urea, sod	goatcher,wd; chur	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	31--2	364	372	many	III. sucrose, sodium chlor	goatcher,wd; chur	1970
JANSA	31--2	373	382	many	IV. acetic acid, quin hydr	goatcher,wd; chur	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
SCIEA	161--	1349	1351		ecol chem, palatabi spectr	brower,lp; ryers/	1968
SCIEA	164--	1183	1185		tast nerv fib: rand distri	frank,m; pfaffman	1969
VETRA	71-45	1071	1079	anim	sense of taste, domest ani	bell,fr	1959

UNIT 8.5: TOUCH

No references to studies of the sense of touch in wild ruminants have been found. The role of touch in their daily lives may be quite important, however. The tongue of such selective browsers as deer appears to have a highly developed sense of touch, with the tongue and lips having important roles in prehension.

The sense of touch is also important in mother-young relationships. The licking of the newborn by the dam and the nursing responses of the young almost within minutes after birth likely involve the sense of touch to a high degree.

The roles of touch in the lives of wild ruminants should be considered when evaluating both physical and biological relationships to their environnments. Descriptions of these roles should be made, even if there is little or no experimental evidence of the functions or importances of the roles at this time.

REFERENCES, UNIT 8.5

TOUCH

SERIALS

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

odvi

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UNIT 8.6: THERMAL SENSES

Sensors that detect differences in the thermal energy at the skin surface or other sites of temperature sensitivity are important in the regulation of the thermal energy balance of free-ranging animals in their natural environments. These sensors function in thermoregulatory behavior, as well as in the internal thermogenic responses possible when heat energy must be dissipated or conserved.

The physiological functions of thermal sensors have not been reported on for wild ruminants. They presumably have a rather highly developed repertoire of possible responses as a result of thermal sensing since they are quite well-adapted to cold climates. The sensors in most direct contact with the environment must be located on the exposed skin surfaces. The nose, for example, seems to be sensitive to differences in thermal energy loads. Whitetail fawns at the Wildlife Ecology Laboratory, for example, have been observed to rest with their heads in the shade and their bodies exposed to the sun on hot days, suggesting that the head--most likely the nose--contains the sensors.

The roles of thermal sensors in relation to the transfer of heat energy from the skin to the environment are discussed in CHAPTER 16. Thermoregulatory behavior, piloerection, and other thermally-induced responses provide some clues to the functions of thermal sensors.

REFERENCES, UNIT 8.6

THERMAL SENSES

SERIALS

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

odvi

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

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oram

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

ARPHA 15--- 357 372 spec senses: therm recepto zotterman,y 1953

CLOSING COMMENTS

CHAPTER 6: SYSTEMS PHYSIOLOGY, contains descriptions, sometimes brief, of the functions of different systems of the body. These descriptions of system functions are in addition to descriptions of system characteristics in CHAPTER 1. There would be some advantages to discussing system characteristics and functions together, but then the discussions of a part of the animals body becomes so lengthy that relationships to other parts and the workings of the integrated whole cannot be easily worked into the overall discussion. The present organization of the material reflects a functional approach to the whole organism.

A limited number of WORKSHEETS have been included in CHAPTER 6. Many of the descriptions of system functions do not lend themselves well to mathematical representation, and data are lacking on many functions.

The next chapter (CHAPTER 7: ENERGY METABOLISM) describes one of the fundamental characteristic of life. All system functions are dependent on the metabolism of energy, and knowledge of the amounts of energy involved in ecological metabolism is absolutely essential when calculating the impacts of populations on range resources and carrying capacity.

Aaron N. Moen
February 23, 1981

GLOSSARY OF SYMBOLS USED - CHAPTER SIX

ADEP = Apparent digestible energy in percent

AGDA = Age in days

BHRM = Bedded heart rate per minute

FHRM = Foraging heart rate per minute

HERA = Heart rate

JDAY = Julian day

LWKG = Live weight in kilograms

MEPP = Methane production as percent of gross energy in the food

RHRM = Running herat rate per minute

SHRM = Standing heart rate per minute

TPLW = Testes weight as a percent of live weight

WHRM = Walking heart rate per minute

AABIA	Annals of Applied Biology
ABBIA	Archives of Biochemistry and Biophysics
ABBGB	Animal Blood Groups & Biochemical Genetics
ACATA	Acta Anatomica
AHEMA	Anatomia Histologia Embryologia
AJANA	American Journal of Anatomy
AJBSA	Australian Journal of Biological Sciences
AJMEA	American Journal of Medicine
AJPHA	American Journal of Physiology
AJVRA	American Journal of Veterinary Research
AKASA	Arkansas Academy of Science Proceedings
ALLKA	Allattani Kozlemenyek
AMNTA	American Naturalist
AMZOA	American Zoologist
ANANA	Anatomischer Anzieger
ANBEA	Animal Behaviour
ANIPA	Animal Production
ANREA	Anatomical Record
ANYAA	Annals of the New York Academy of Sciences
APARD	American Association Zoo Veterinarian Annual Proceedings
APMBA	Applied Microbiology
ARPHA	Annual Review of Physiology
APSSA	Acta Physiologica Scandinavica Supplementum
ATICA	Arctic
ATRLA	Acta Theriologica
AVCSA	Acta Veterinaria Scandinavica
AVSPA	Acta Veteinaria Scandinavica Supplementum
AZFEA	Acta Zoologica Fennica
AZOFA	Annales Zoologici Fennici
BEHAA	Behaviour
BIGEB	Biochemical Genetics
BIJOA	Biochemical Journal
BIREB	Biology of Reproduction
BJNUA	British Journal of Nutrition
BLOOA	Blood
BLUTA	Blut
BPURD	Biological Papers of the University of Alaska Special Report
BRHLA	Biorheology
BUCDA	Bulletin of the Georgia Academy of Sciences
CAFGA	California Fish and Game
CAFNA	Canadian Field Naturalist
CATRB	Calcified Tissue Research
CBCPA	Comparative Biochemistry and Physiology
CBPAB	Comparative Biochemistry and Physiology A Comparative Physiology
CIRIB	Proceedings International Congress on Animal Reproduction and Artificial Insemination

CJBIA Canadian Journal of Biochemistry
CJCMA Canadian Journal of Comparative Medicine
CJZOA Canadian Journal of Zoology
CLCHA Clinical Chemistry
CNJMA Canadian Journal of Comparative Medicine and Veterinary Science
CNJNA Canadian Journal of Animal Science
CNVJA Canadian Veterinary Journal
COVEA Cornell Veterinarian
CPSCA Chesapeake Science
CWOPA Canadian Wildlife Service Occassional Paper

ECOLA Ecology
EJBCA European Journal of Biochemistry
ENDOA Endocrinology
EVOLA Evolution

FEPRA Federation Proceedings
FOSCA Forest Science
FUNAA Fauna

GENTA Genetics
GNKAA Genetika
GRBNA Great Basin Naturalist

HEREA Hereditas
HLTPA Health Physics

JANSA Journal of Animal Science
JAPYA Journal of Applied Physiology
JASIA Journal of Agricultural Science
JAVMA Journal of the American Veterinary Medical Association
JBCHA Journal of Biological Chemistry
JCECD Journal of Chemical Ecology
JCOQA Journal of the Colorado-Wyoming Academy of Sciences
JDSCA Journal of Dairy Science
JEBPA Journal of Evolutionary Biochemistry and Physiology
JICRB Journal of Interdisciplinary Cycle Research
JOANA Journal of Anatomy
JOENA Journal of Endocrinology
JOMAA Journal of Mammalogy
JONUA Journal of Nutrition
JOPAA Journal of Parasitology
JPROA Journal of Protozoology
JRMGA Journal of Range Management
JRPFA Journal of Reproduction and Fertility
JSFAA Journal of the Science of Food and Agriculture
JWIDA Journal of Wildlife Diseases
JWMAA Journal of Wildlife Management
JZAMD Journal of Zoo Animal Medicine
JZOOA Journal of Zoology

KPSUA Khimiya Prirodnykh Soedinii

LAANA Lantbrukshogskolans annaler
LBANA Laboratory Animals
LBASA Laboratory Animal Science

MAMLA Mammalia
MGQPA Minnesota Department of Natural Resources Game Research Project Quarterly Progress Report
MRLTA Murrelet, The

NARFA Nutrition Abstracts and Reviews
NATUA Nature
NAWTA North American Wildlife and Natural Resources Conference, Transactions of the,
NCANA Naturaliste Canadien, Le
NFGJA New York Fish and Game Journal
NJZOA Norwegian Journal of Zoology
NYCOA New York State Conservationist
NZJSA New Zealand Journal of Science

OJSCA Ohio Journal of Science

PAANA Proceedings of the Australian Society of Animal Production
PAARA Pennsylvaina State University College of Agriculture Agricultural Experiment Station Progress Report
PASCC Proceedings of the Alaskan Scientific Conference
PCBSA Proceedings of the Canadian Federation of Biological Societies
PCGFA Proceedings of the Southeastern Association of Game and Fish Commissioners
PCZOA Proceedings of the International Congress of Zoology
PHREA Physiological Reviews
PIAIA Proceedings of the Iowa Academy of Science
PNSUA Proceedings of the Nutrition Society
POASA Proceedings of the Oklahoma Academy of Science
PSEBA Proceedings of the Society for Experimental Biology and Medicine

QJEPA Quarterly Journal of Experimental Physiology and Cognate Medical Sciences

RSPYA Respiration Physiology

SCAMA Scientific American
SCIEA Science
SOVEA Southwestern Veterinarian
SWNAA Southwestern Naturalist
SZSLA Symposia of the Zoological Society of London

TAMSA Transactions of the American Microscopical Society
THGNB Theriogenology
TJSCA Texas Journal of Science
TNWSD Transactions of the Northeast Section, The Wildlife Society

UABPA	Biological Papers of the University of Alaska
UASPA	Proceedings of the Utah Academy of Sciences, Arts and Letters
UCPZA	University of California Publications in Zoology
WAEBA	Wyoming Agricultural Experiment Station Bulletin
WDABB	Bulletin of the Wildlife Disease Association
WLDHA	Waldhygiene
WLMOA	Wildlife Monographs
WLSBA	Wildlife Society Bulletin
WMBAA	Wildlife Management Bulletin
XAARA	U S Department of Agriculture, Agricultural Research Service
XAMPA	U S D A Miscellaneous Publication
XARRA	U S Forest Service Research Note RM
ZEBFA	Zhurnal Evolyutsionnoi Biokhimii i Fiziologii
ZEJAA	Zeitschrift fuer Jagdwissenschaft
ZETIA	Zeitschrift fuer Tierpsychologie
ZOLZA	Zoologicheskii Zhurnal
ZOOLA	Zoologica
ZSAEA	Zeitschrift fuer Saeugetierkunde

LIST OF PUBLISHERS - CHAPTER SIX

acpr	Academic Press	New York	nyny
amph	American Physiolocial Society	Washington, D. C.	wadc
anth	Antheneum	New York	nyny
apcc	Appleton-Century-Crofts	New York	nyny
butt	Butterworth	London	loen
butt	Butterworth	Washington, D. C.	wadc
caun	Cambridge University Press	New York	nyny
ccth	Charles C. Thomas	Springfield, IL	spil
chha	Chapman & Hall	Appleton, WI	apwi
coup	Cornell University Press	Ithaca, NY	itny
cupr	Cambridge Univ. Press	Cambridge, England	caen
dcch	C. D. Church, Oregon State	Corvallis, OR	coor
edar	Edward Arnold	London	loen
else	Elsevier	New York	nyny
grst	Grune and Stratton	New York	nyny
haro	Harper and Row	New York	nyny
hein	Heinemann	London,England	loen
hill	Hill	London, England	loen
hrwi	Holt, Rhinehart & Winston, Inc.	New York	nyny
iepu	Intext Education Publishers	New York	nyny
isup	Iowa State University Press	Ames, IO	amia
iucn	IUCN	Morges, Switzerland	mosw
jwwa	J. W. Walsh	Portland, ME	pome
lefe	Lea and Febiger	Philadelphia, PA	phpa
libr	Little, Brown	Boston, MA	noms
macm	MacMillan Company	New York	nyny
meth	Methuen & Co., Ltd.	London	loen
mhbc	McGraw-Hill Book Co., Inc.	New York	nyny
moco	C. V. Mosley Co.	St. Louis, MO	salo
nhfg	New Hampshire Fish & Game Department	Concord, NH	conh
orpr	Oriel Press	Newcastle Upon Tyne, Eng.	nute
orst	Oregon State University	Corvallis, OR	coor

pepr	Pergamon Press	Oxford, England	oxen
phli	Philosophical Library	New York	nyny
prha	Prentice-Hall, Inc.	Englewood Cliffs, NJ	ecnj
saco	Saunders Publishing Co.	Philadelphia,PA	phpa
tapl	Taplinger	New York	nyny
uchp	Univ. of Chicago Press	Chicago, IL	chil
unep	University of New England Publishing Unit	Armidale, Australia	arau
vare	Van Nostrand-Reinhold	New York	nyny
wbsc	W. B. Saunders Company	Philadelphia	phpa
whfr	W. H. Freeman Company	San Francisco, CA	sfca
wiwi	Williams and Wilkins	Baltimore, MD	bama

LIST OF WORKSHEETS - CHAPTER SIX

THE BIOLOGY AND MANAGEMENT OF WILD RUMINANTS

CHAPTER SEVEN

ENERGY METABOLISM OF WILD RUMINANTS

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ENERGY METABOLISM OF WILD RUMINANTS

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CHAPTER 7. ENERGY METABOLISM

Metabolism, the biochemical processes characteristic of life, includes both assimilation (anabolism) and breakdown of protoplasm (catabolism). When the rate of assimilation equals the rate of breakdown, metabolism is at the maintenance level. If the rate of assimilation exceeds the rate of breakdown, growth or weight gains occur, and if breakdown exceeds assimilation, weight losses occur.

Anabolism occurs at different rates in different tissues, depending on the age, time of year, and activity of the animal. A young growing animal has a higher rate of metabolism per unit body weight than an older mature one. Young growing animals deposit more protein and skeletal tissue, and older, more mature animals deposit more fat tissue. Anabolism is greater in the summer and fall than in the winter and spring. In fact, weight losses usually occur in the winter as part of an adaptive survival strategy. Active animals have higher rates of metabolism than inactive ones, and activity levels are often reduced in the winter as another adaptive survival strategy.

Catabolism, the breakdown of tissue, is the reverse of anabolism. It is a part of maintenance. Some tissues are broken down and their energy, protein, and minerals become available to the animal. Body fat is an energy reserve that may be mobilized when ingested nutrients are not sufficient to meet the energy needs of the animal. Male Cervids partition resources into antlers in spring and summer, mobilizing minerals from some of their bones for deposition in the antlers. Pregnant females partition nutrients into their own maternal tissue and into fetal and reproductive tissue. Lactating females assimilate nutrients into milk, sometimes mobilizing their own tissues to do so. These are important capabilities when forage resources are depleted or unavailable.

Ruminants also have metabolic adaptations for the conservation of resources. Lower energy metabolism in the winter when range resources are more limited and higher metabolism in the summer when range resources are less limited is a seasonal conservation adaptation. This is an important metabolic adaptation for wild ruminants living on ranges with seasonally fluctuating resources, and may be critical for survival when range resources are especially limited, as in severe winters.

Measurements of energy metabolism have been made for many years. The French scientist, Lavoisier completed a very basic experiment in metabolism by placing mice in a container surrounded by ice and measuring the rate of ice-melt. He found that the energy required to melt the ice was related to the heat production of the mice, providing an early estimate of metabolism. Techniques have been refined considerably since that early experiment. While metabolic chambers are still used to directly measure the heat given off by an animal, indirect measurements and estimates are often made by gas analyses, and the amounts of oxygen consumed and carbon dioxide released used to estimate metabolic rates.

Several terms are used in the literature to describe metabolism measurements. Basal metabolism has been defined as the minimum energy cost when an animal is at rest in a thermoneutral environment and in a post-absorptive nutritive condition (Brody 1945). The definition of basal metabolism implies standard conditions for measurement rather than minimum metabolism for life. The resting animal is not active, nor is it sleeping. Thermoneutrality is the condition of being neither too hot nor too cold while in the metabolism chamber. Then, there are no thermogenic responses; the animal makes no attempt to keep from getting too hot (by panting, for example) or too cold (by shivering, for example). The post-absorptive condition eliminates the metabolic contributions of rumen microflora to the total heat production of the animal. These microflora produce their own metabolic heat as they break down the ingesta in the rumen. This heat is not a part of the host's metabolic heat production.

The energy required to maintain life during basal metabolism tests is used to meet the costs of circulation, excretion, secretion, respiration, and the maintenance of muscle tone. Basal metabolism is a laboratory measurement that is useful for comparative purposes, but it is not applicable to the field situation since free ranging animals seldom meet the conditions prescribed for a metabolism test.

The term fasting metabolism applies to metabolism tests conducted on animals in a post-absorptive condition and in a thermoneutral environment, but not corrected for activity. Results are given in this way when corrections for activity during the test cannot be made.

Ecological metabolism is an expression of the total cost of maintenance, activity, and production processes of free-ranging animals (Moen 1973:123-124). The cost varies because the rates of these processes vary. Some of the variability is rhythmic due to seasonal patterns in weather and thermal exchange, the timing or reproductive functions, activity patterns, and other biological functions. Some of the variability is due to the effects of transients, such as quick changes in the level of energy expenditure for activity due to a flight response from a predator. The metabolic expenditures for each of these processes accumulate over a 24-hour period, resulting in the ecological metabolism per day (ELMD).

One very useful expression for evaluating rates of energy metabolism is base-line metabolism. This expression is a mathematical base-line, a common denominator used when dividing ecological metabolism per day (ELMD) to determine a multiple of base-line metabolism (MBLM) for comparative purposes, numerically equal to (70)(MEWK) KCAL per day and (294)(MEWK) KJOU per day (MEWK = $W_{kg}^{0.75}$). While the numerical value approximates the average basal metabolism of a large number of species, base-line metabolism should be considered as a mathematical base-line only and not as an average basal metabolism value. Average basal metabolism of white-tailed deer varies seasonally (Moen 1973), and averages are not appropriate representations of metabolic rhythms that vary in a patterned way through the year. Time-related ecological metabolism should be expressed as a function of time; the use of averages for long time periods results in the loss of too much information of ecological significance.

The ratio of ELMD to BLMD is called the multiple of base-line metabolism (MBLM). This ratio is weight-independent; the effects of weight appear in both the numerator and the denominator (MBLM = ELMD/BLMD). MBLM is especially useful when comparing ELMD for different species. When ELMD is expressed as a multiple of base-line metabolism, interspecies comparisons can be easily made since differences in size have been eliminated by the use of weight in both the numerator and denominator. MBLM may be used to establish a reasonable biological framework for expressing ELMD for a variety of species; calculations indicate that MBLM values approaching 5 are unrealistically high, and below 1.3 or so, low. Details for different species are discussed next.

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Moen A. N. 1973. Wildlife ecology. W. H. Freeman and Co., San Francisco. 458 pp.

REFERENCES, CHAPTER 7

ENERGY METABOLISM

BOOKS

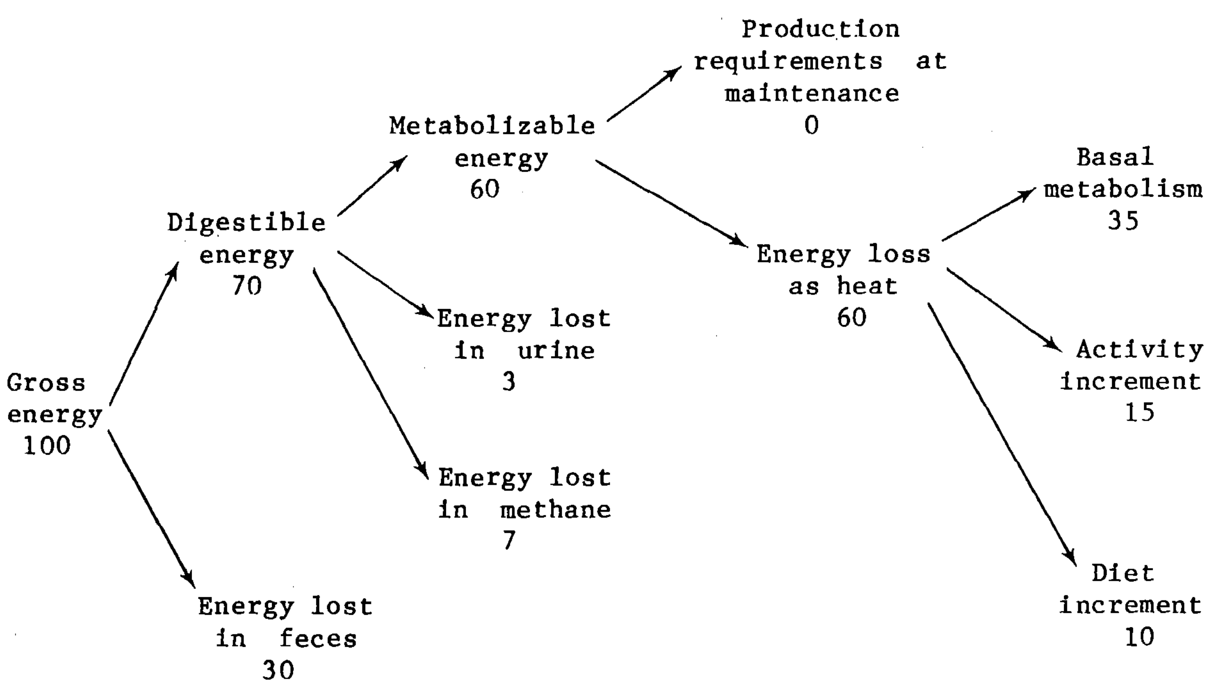
TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS------------------	AUTHORS/EDITORS--	YEAR
aubo	repu	nyny	1023	doan	bioenergetics and growth	brody,s	1945
aubo	mopc	itny	1207	rumi	feeds and feeding, 21st ed	morrison,fb	1948
aubo	coms	itny	1020	doan	physiology, domestic anima	dukes,hh	1955
aubo	wile	nyny	184	rumi	metabolism in the rumen	annison,ef; lewis	1959
aubo	saco	phpa	546	many	fundamntls of ecol, 2nd ed	odum,ep	1959
aubo	acpr	nyny	236		rhyth activ, physiol, beha	cloudsley-thompso	1961
aubo	wile	nyny	454	many	the fire of life	kleiber,m	1961
aubo	ccth	spil	329	rumi	energy metaboli, ruminants	blaxter,kl	1962
aubo	agrc	loen	37	rumi	nutr req farm livest, rumi	agricultural rese	1965
edbo	acpr	loen	450	doan	energy metabolism	blaxter,kl,ed	1965
aubo	prha	ecnj	815	many	gener, comparative physiol	hoar,ws	1966
aubo	hutc	loen	332	rumi	energy metabolism, ruminan	blaxter,kl	1967
edbo	fase	bemd	737		metabolism	altman,pl; dittme	1968
edbo	acpr	nyny	427	many	comprtv nutritn wild anims	crawford,ma ed	1968
aubo	whfr	sfca	753	doru	applied anim nutri, 2nd ed	crampton,ew; harr	1969
edbo	jdve	zusw		doca	5th symp energy metabolism		1971
aubo	whfr	sfca	458	wiru	wildlif ecol: analyt appro	moen,an	1973
aubo	acpr	nyny	545	vert	scale effects in locomotio	pedley,tj,ed	1977

TOPIC 1. FACTORS AFFECTING ENERGY METABOLISM

Nothing is free. The maintenance of basic life processes, the completion of activities, and the production of new tissues are all energy-requiring processes. The energy costs of these processes can be estimated because the energy transfers involved are predictible processes. Equations can be derived that provide good first approximations of the costs of these processes in different ecological circumstances.

Each individual must meet its own requirements for the basic life functions--respiration, circulation, daily activities that provide food necessary to support these functions, maintenance of body tissues, production of new tissues to replace that metabolized--that combine to establish a maintenance requirement of each individual. Since metabolism is an energy-using process, the energy used must be replaced each day in order to sustain life. If the energy requirement is not being met, the animal is in a negative energy balance, and if the amount of energy in ingested nutrients exceeds the energy required, the animal is in a positive energy balance.

The energy flow through an organism includes several pathways of use and dissipation illustrated below. The numbers below each of the terms are relative values illustrating the efficiencies of an animal given by Crampton and Harris (1969:145) at each step.



The efficiencies of energy use have a direct bearing on the amounts of food required. Further, the nutritional requirements are constantly changing as a result of physiological and environmental variables. Since so little is known about the metabolic efficiencies and maintenance, activity, and productive functions of wild ruminants, it is difficult to assess the effects of the different variables in the lives of free-ranging animals in their natural environments. Nevertheless, some patterns may be recognized from data on both domestic animals and wild ruminants, providing insights into relationships between wild ruminants and their natural environments.

LITERATURE CITED

Crampton, E. W. and L. E. Harris. 1969. Applied animal nutrition. 2nd Ed. W. H. Freeman and Co., San Francisco. 753 pp.

UNIT 1.1: BIOLOGICAL FACTORS AFFECTING ENERGY METABOLISM

Some of the biological factors affecting energy metabolism are historically determined, and some are variables due to circumstances. The former include factors that are determined by genetic and by "programmed" physiological changes. The latter include interspecies and intraspecies relationships present due to current circumstances.

GENETIC

It is well known that animals exhibit individual variation due to genetic differences. The more obvious characteristics, such as coat color, body size, etc., are often the only characteristics considered by field biologists when studying particular populations. Since energy metabolism is so vital to the survival of the individual, genetic factors which affect the energetic efficiencies of animals may have a significant bearing on their survival, especially when conditions of stress begin to appear.

SEX

The two sexes have different metabolic rates at different times of the year; differences in metabolic rates of the sexes are related to their different biological roles. Males are very active during the breeding season, spending a lot of energy for activity. Females are very active during the lactation period, especially in foraging activity when they must supply nutrients for milk production.

AGE

It is well known that the metabolism per unit weight of young animals is higher than that of adults; the metabolic rate of an adult, relative to weight, is usually less than one-half that of a newborn. Lambs reach summit metabolism, the maximum heat production possible without voluntary muscular activity, within one-half hour after birth, and maximum values may be 15 times greater than fetal levels and 5 times greater than "basal" levels (Alexander 1962a). He noted that there was no increase after ingestion of milk, and heat production declined slowly with advancing age, prolonged exposure to cold, and continued fasting.

The physiological capabilities of newborn wild ruminants are quite well-developed as the young are active shortly after birth. Some species, such as caribou, goats, sheep, and muskox, sometimes give birth to young in rather severe weather conditions, and only well-developed offspring can survive. Newborn caribou are able to follow their dam within hours after birth, indicating a high level of physiological development, with survival very much dependent on the nutritional ties between the neonate and the dam.

HAIR CHARACTERISTICS

Since warm-blooded animals maintain a specific internal body temperature (with some variation of course), hair coats with lower insulation values may necessitate higher levels of heat production by the animal. If two animals with equal surface areas were exposed to identical thermal environments, the one with the better insulation would lose less heat. If heat production were identical for the two animals, the one with the better coat would have a more positive heat balance. Brody (1954) attributed the ability of cattle to withstand temperatures to -40°F to their coat insulation and highly developed vascular control of the thermal conductivity of peripheral tissues. Wild ruminants are very dependent on hair characteristics for insulation from the cold, and have seasonal molts to accomodate seasonal changes in weather.

RELATION TO SURFACE AREA

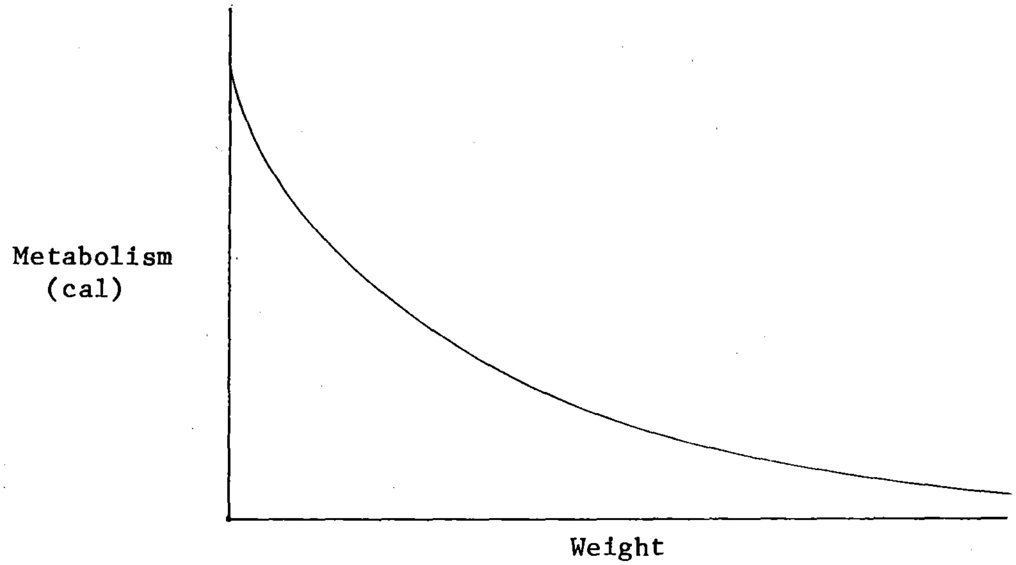
Interpretations of the basal metabolic rate have been made by physiologists for many years, and numerous disagreements have arisen over its relationship to surface area and body weight. The "surface area law" was formulated because it could be shown that heat loss from any object is proportional to surface area, and since heat production must be proportional to heat loss if homeothermy is to be maintained, it was concluded that heat production must be proportional to surface area. This was demonstrated for dogs and rabbits, and the concept was widely applied to other species as well (Brody 1964:356).

However, one factor in the relationship between surface area and heat production is the variability in the surface area of a single animal. A standing animal has a greater surface area than the same animal lying down and curled up. Thus the surface area of an individual is variable, and living organisms may be constantly changing their surface area, heat production, evaporative heat loss, muscular activity, diet, hair insulation through pilo-erection, and other characteristics to maintain a homeothermic condition. If one considers the complexity of heat exchange by radiation, conduction, convection, and evaporation, it becomes immediately obvious that surface area is only one of several important parameters operating in heat exchange. A simple relationship observed empirically between surface area and heat production can hardly be called a "law" in view of the many other associated variables.

If, however, one considers two animals of the same species with identical thermal characteristics of the coats and equal rates of heat production per unit of metabolic tissue, the larger animal with its more favorable surface area:weight ratio should be able to withstand more cold stress than a smaller one. It is possible to calculate the critical surface area (Moen 1968) of an animal. The critical surface area is the surface area:weight relationship which is just sufficient to result in a net thermal exchange of zero. Larger animals have relatively less surface area than smaller ones, and they also have more metabolic tissue and greater metabolic potentials. Heavier lambs were able to maintain homeothermy under conditions of higher heat loss than lighter ones (Alexander 1962b), and this may be due not only to their more favorable size and surface area ratio but also their larger amounts of metabolic resources.

RELATION TO BODY WEIGHT

A large animal has a higher absolute metabolism than a small one. The heat production per unit weight of a small animal is greater than the heat production per unit weight of a large animal, however. The relationship is illustrated below.



Benedict's mouse to elephant curve (Benedict 1938; see also Dukes 1955:625 and Moen 1973:116), widely known in physiological circles, is a quantified display of this relationship; variations between species were found to be quite low and the smooth and logical shape of the entire graph striking. Deviations from the curve may be real or they may be artifacts, and perhaps are a combination of the two.

The total mass of an animal includes some tissue that is not actively participating in the metabolic processes but is the final product of metabolic processes. The hair, horns, and antlers, once growth is completed, are examples. Ingesta in the gastro-intestinal tract is another example; it adds to body weight but is not part of the animal's metabolic tissue.

There has been considerable discussion of the mathematical relationship between heat production and body weight. The formula for this relationship is:

$$Q = k\ W^b$$

where Q is the heat production in calories per day, k is a constant, W is the weight in kilograms, and b is an exponent that has generated most of the controversy. Physiologists have been searching for an exponent which will result in a constant value of k. If this could be found, the basal heat production of any animal could be determined by simple multiplication after measuring the weight of the animal.

Published values of b have ranged from 0.66 to 0.75. Much of the controversy is in the rounding off of the value. Brody (1945) suggests that b should be 0.7 and Kleiber (1961) uses 0.75. The National Research Council (1966) adopted the exponent b = 0.75. Fasting homeotherms under standard conditions produce about 70 kcal of heat per $kg^{0.75}$ (Kleiber 1961). Measurements of four deer in winter coat resulted in an average of 75.6 Kcal per $kg^{0.75}$ per 24 hours, and measurements of three deer in summer coat had an average of 84.4 Kcal per $kg^{0.75}$ (recalculated from Silver 1968· see Moen 1973:117). Since winter and summer differences are part of the rhythmic seasonal variations in metabolism of deer, I no longer calculate an average basal metabolism for deer, choosing rather to use $70W_{Kg}^{0.75}$ as a mathematical base-line and representing ecological metabolism with time-dependent equations.

REPRODUCTIVE CONDITION

Three stages in the reproductive cycle--breeding, gestation, and lactation--have definite effects on the energy metabolism. It is well known that male wild ruminants expend large amounts of energy in increased activity during the breeding season and lose considerable weight. During gestation, the female must expend additional energy to maintain the uterus, to meet increased demands on the circulatory, respiratory, and excretory systems, to handle the endocrine influences on her own metabolism, and provide for fetal growth (Brody 1945). The energy metabolism per unit weight is not higher for pregnant females until the last 1/3 of pregnancy when fetal growth is much accelerated, however (Morrison 1948). During rapid fetal growth, elevated metabolism is expected since growth demands additional energy for synthesis of fetal tissue. The high rate of fetal metabolism is followed by a declining but still high neonate metabolism, after which metabolic rates decline to more stable and rhythmic adult levels.

Lactation places a high physiological demand on the female as milk is synthesized from the nutrients in ingested food. The heat production of cattle during heavy lactation is approximately 100% above the non-lactating level, with the increase directly proportional to milk production. The higher metabolic rate is associated with the higher food consumption and milk prodution rather than with muscular activity (Brody 1945:820). Calculations of the cost of lactation for white-tailed deer indicate that it is the most costly sustained biological process there is (Moen 1973 and Robbins and Moen 1975).

PATHOGENS AND PARASITES

Whenever one organism supports the life processes of another organism living upon or within it, the energy requirements of the host animal must go up unless the two species exhibit a kind of mutualism (Odum 1959) in which the growth and survival of both populations is benefited. The relationship between a ruminant and the rumen flora and fauna is an example of mutualism. Pathogens and parasites, however, increase the catabolic mechanisms of an animal (Jones 1963 _in_ Thayer), resulting in increased energy demands.

HEAT INCREMENTS

Heat production increases when an animal becomes more active since muscle contractions are exothermic. Digestion of food in the gastrointestinal tract also results in an increment in heat production of an animal. It is defined as an extra heat increment incident to the total nutritive process, including the energy cost of excretion of the end products (Brody 1945:59). It is sometimes called an energy waste associated with the use of food, but the extra heat energy may be of value during cold weather as it helps keep the animal warm.

What heat increments are characteristic of animals on different diets? Blaxter (1962:141) presents a table showing the differences in heat production of sheep and steers on fasting, maintenance, and full-feed diets. For sheep the ratio of the maintenance to the fasting diet is 1.47/1, and of the full feed diet to the fasting diet 1.88/1. The ratio for steers on a maintenance diet compared to a fasting diet was 1.38/1. Such increments are of interest to the field biologist when analyzing the energy balances of animals on ranges with different food supplies, topographies, and weather conditions.

ACTIVITY

Activity, or the movement of mass through distance, is work. Every animal must expend energy when moving its mass horizontally and vertically for whatever distances are involved. Range and wildlife managers ought to be interested in the amounts of energy required for these movements since topographic relief, distances to water and other range characteristics may have effects on the efficiencies of the animals and on population ecology.

The speed with which an animal moves also has an effect on the energy cost of movement. In sheep, the energy cost of horizontal locomotion increased but the cost of ascending vertical gradients decreased with increasing speed (Clapperton 1961). It is interesting to speculate on the energy costs involved in rapid bursts of speed exhibited by wild ruminants during escape behavior.

SOCIAL AND PSYCHOLOGICAL EFFECTS

Numerous sociological and psychological stressors influence energy requirements. Pfander (1963:117) lists such things as confinement vs. natural range, herd vs. individual response, numbers per group, space per animal, noise level, and other disturbances as factors that affect energy requirements of domestic species.

One unknown factor in basal metabolism measurements is the effect of confinement on the psychology and metabolism of the animal. Well-trained animals appear more calm, of course, but visible signs of excitement need not be present to have elevated metabolism. A male white-tailed deer that was rescued from an ice-covered lake (Moen 1967) showed body temperature variations that were not accompanied by visible signs of excitement when resting in the garage at the laboratory. The deer showed a steady increase in body temperature from a low of 26.4°C to a high of 39.5°C as it was warmed up, after which it returned to 38°C. My presence in the room, however, caused the temperature to rise quickly to 38.5°C, but the animal showed no signs of fear. When I left the room, body temperature declined to 38°C again. The docile nature of the deer when in the garage changed instantly when it saw the trees through the open garage door as we prepared to release him. After thrashing around in its nylon mesh cage, the deer was finally released and ran directly into the woods.

RHYTHMIC CHANGES IN THE BASAL METABOLIC RATE

Marked changes in the rates of metabolism during daily and seasonal periods have been observed. Nocturnal animals have a lower BMR during the daytime (Benedict 1938), and times of muscular activity and metabolic rates are related (Brody 1945). Seasonal variations also occur. A depressed winter metabolism in white-tailed deer was first reported by Silver (In Siegler 1968:191), but the number of deer studied was not sufficient to warrant a definite conclusion about seasonal lability. Several years of research at the Wildlife Ecology Laboratory have shown definite seasonal metabolic rhythms in ecological metabolism (Moen 1978).

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Silver, H. 1968. Deer nutrition studies. pp. 182-196 In The white-tailed deer of New Hampshire. H. R. Siegler, ed. Survey Report No. 10, New Hampshire Fish and Game Department, Concord. 256 pp.

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BIOLOGICAL FACTORS AFFECTING ENERGY METABOLISM

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	34--4	863	869	odvi	diges metab ener mich does	ullrey,de; youat/	1970
JWMAA	42--4	715	738	odvi	seas chan, heart rate, act	moen,an	1978
JWMAA	42--4	776	790	odvi	diet prot, engy effct fawn	seal,us; verme,l/	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--2	275	282	odhe	feed intake, heat producti	nordan,hc; cowan/	1970
JWMAA	35--3	461	468	odhe	radioiodine uptake, retent	gist,cs; whicker,	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
SZSLA	21---	101	108	ceel	physiol of diges and metab	maloiy,gmo; kay,/	1968

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	34--4	908	912	anam	ener flux, water kinet, yo	wesley,de; knox,/	1970
JWMAA	37--4	563	573	anam	energy metabolism, prongho	wesley,de; knox,/	1973

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJAEA	11--1	85	96	dosh	seas var wool gr, heat tol	wodzicka,m	1960
AJAEA	13--1	82	99	dosh	temp reg, metab, newborn l	alexander,g	1962
AJAEA	13--1	144	164	dosh	energ metab, starved newbo	alexander,g	1962
AJAEA	15--6	969	973	dosh	ener cost, expend, feed ac	graham,nmcc	1964
BJNUA	16--4	615	626	dosh	fasting metab, adult wethe	blaxter,kl	1962
COVEA	57--1	43	53	dosh	erythrocyte loss, restitut	georgi,jr; whitlo	1967
PAANA	5---1	138	140	dosh	effect lactat, wool growth	corbett,jl	1964
PNSUA	20-	xxxi	xxxii	dosh	energy expenditur, walking	clapperton,jl	1961
SCIEA	145--	1318		dosh	hematocr val, hemoglo type	evans,jv; whitloc	1964

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJPHA	219-4	1104	1107		scali, energ cost, running	taylor,cr; schmi/	1970
AMNTA	99---	373	376		nat mort, reprod, min meta	wilson,ta	1965
AMZOA	8---1	71	81		thermodynam consid, nutrit	wiegert,rg	1968
ATRLA	24-12	125	136		metab, body size, homeothe	poczopko,p	1979

continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CIWPA	503--	1	215		vital energ: comp bas meta	benedict,fg	1938
FEPRA	29--4	1524	1532		ener metab, bod size, scal	schmidt-nielsen,k	1970
JANSA	43--3	692	704		fasting heat prod, body wt	thonney,ml; touc/	1976
JCCPA	31---	281	291		oxyge consump, basal condi	morrison,pr	1948
NUMEB	21--1	88	104		energet fat metabo, growth	van es,ajh	1977
OJSCA	74--6	370	380		energetics of endotherms	mcnab,bk	1974
PECTD	1---2	85	101		bioenerg params, wild rumi	drozdz,a; weiner/	1975
PHREA	27--4	511	541		body size, metabolic rate	kleiber,m	1947

OTHER PUBLICATIONS

Davydov, A. F. On the processes of muscular activity in reindeer during procurement of feeds from under the snow. Russian original from Sbornik "opyt izucheniya regulyatsii fiziologicheskikh funkstii v estestvennykh uslovyakh sushchestvovania organizmov," Vol. 6:35-40. 1963. Translation available from U.S. Dept. Commerce, Clearinghouse for Federal Scientific and Technical Information, Springfield, Va.

CHAPTER 7, WORKSHEET 1.1a

Resting heat production of black-tailed deer

Measurements of the resting heat production of male and female black-tailed deer fawns have been made by Nordan et al. (1970). The weight and heat production measurements reported in TABLE II (p. 278) make it possible to calculate multiples of base-line metabolism (MBLM) at each weight. The data and calculations are given below.

	LWKG	REHP	$LWKG^{0.75}$	BLM	MBLM
Males:	5	382	3.34	234	1.63
	10	880	5.62	394	2.24
	15	1180	7.62	534	2.21
	20	1460	9.46	662	2.21
	25	1722	11.18	783	2.20
Females:	5	498	3.34	234	2.13
	10	837	5.62	394	2.12
	15	1076	7.62	534	2.01
	20	1408	9.46	662	2.13
	25	1669	11.18	783	2.13

Note how similar the MBLM values are throughout this range of body weights.

Keep in mind these are resting heat production values, and will be different from ecological metabolism. The MBLM for the ecological metabolism of a growing fawn will be higher (see CHAPTER 7, Page 2 and also TOPIC 6).

LITERATURE CITED

Nordan, H. C., I. McT. Cowan, and A. J. Wood. 1970. The feed intake and heat production of the young black-tailed deer (*Odocoileus hemionus columbianus*). Can. J. Zool. 48(2):275-282.

CHAPTER 7, WORKSHEET 1.1b

Energy metabolism of pronghorn

The total heat production and fasting heat production of female pronghorns from 2 months to 18 months are given by Wesley et al. (1973). Calculations of MBLM are easily made from the age, weight, and heat production data presented in Table 2 (p. 567). The following table is derived from their data.

Month of Year	Age Class (months)	LWKG	MEWK*	Total Heat Production	MBLM	Fasting Heat Production	MBLM
July	2.0	8.9	5.15	783	2.17	603	1.67
January	7.5	26.1	11.55	1316	1.63	843	1.04
May	12.0	26.8	11.78	1425	1.73	884	1.07
November	18.0	37.8	15.24	1707	1.60	1220	1.14

*MEWK = metabolic weight in kg = $LWKG^{0.75}$

Note how MBLM for total heat production varies from 1.60 to 2.17. Variations after the age of 2.0 months may be a reflection of a seasonal rhythm, but there are too few data through the annual cycle to confirm that.

Evaluate these MBLMS in relation to the seasonal rhythms of white-tailed deer discussed in TOPIC 6.

LITERATURE CITED

Wesley, D. E., K. L. Knox, and J. G. Nagy. 1973. Energy metabolism of pronghorn antelopes. J. Wildl. Manage. 37(4):563-573.

CHAPTER 7, WORKSHEET 1.1c

Behavioral effects on the energy expenditures of white-tailed deer

The effects of different amounts of physical activity in six different behavioral regimes on energy metabolism have been demonstrated in a sequence of calculations in Moen (1976). The least activity, with 75% of the time spent bedded, 10% standing, 10% foraging, 5% walking, and no running, resulted in graphed values of energy expenditure as low as 1700 kcal per day for a 60-kg deer. The most activity, with 25% of the time spent bedded, 30% standing, 12% walking, 30% foraging, and 3% running, resulted in graphed values approaching 3000 kcal per day for a 10-kg deer. These two expenses, and various combinations of effects between them, are plotted in Figure 3, page 198 of Moen (1976).

Determine multiples of base-line metabolism for the energy expenditures given in the paragraph above with the following formula:

$$\text{MBLM} = \text{Energy expenditure}/(70)(\text{MEWK})$$

where MBLM is the multiple of base-line metabolism, and MEWK is metabolic weight in kg, and (70)(MEWK) is base-line metabolism. Both of these are discussed on Chapter 7 - Page 2.

Other values of MBLM may be determined from Figure 3 in Moen (1976) also. Note that the 1976 publication includes discussions of multiples of <u>basal</u> metabolism rather than <u>base-line</u> metabolism. This change in terminology is due to clarification of concepts as a result of analyses described in Moen (1978).

LITERATURE CITED

Moen, A. N. 1976. Energy conservation by white-tailed deer in the winter. Ecology 57(1):192-198.

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.

UNIT 1.2: ENVIRONMENTAL FACTORS AFFECTING ENERGY METABOLISM

The concept of thermoneutrality--the thermal range in which an animal does not need to respond physiologically to maintain normal body temperature --is well known. The terms "upper critical temperature" and "lower critical temperature," deeply entrenched in the literature, are meant to represent the limits of the thermoneutral range on a thermometric scale. Many more parameters are involved in heat exchange in the natural world than temperature alone, however. Further, temperature measurements are on an ordinal scale, and do not represent the actual amount of energy exchanged in a particular system. I have suggested that the concept of a critical thermal environment (Moen 1968) replace the "critical temperature" idea used previously. Critical thermal environment is a much more appropriate term in view of the many factors involved in heat exchange.

A critical temperature may be determined if all thermal parameters except temperature are held constant in a particular system. In the same manner, however, a critical wind velocity can be determined if temperature and all other thermal parameters are held constant. Similarily, critical values for body weights, evaporation rates, postures, heat production, and many other parameters can also be calculated.

The concept of thermal neutrality is physiologically sound. The term critical thermal environment is comprehensive and applies to the concept of thermoneutrality.

Another environmental factor affefcting energy metabolism is snow. The depth and density characteristics of snow can have a major effect on energy metabolism as animals of different sizes and weights sink to different depths.

Surface characteristics also affect the metabolic cost of walking. Less energy expenditure was measured on reindeer walking on roads than on tundra (White and Yousef 1978), indicating that the more firm road surface was easier to walk on than the softer tundra surface.

The topography affects energy metabolism as the cost of walking on the level is less than the cost of walking upslope. The cost of walking downslope is less than the cost on an upslope (Robbins et al. 1977), but the compensation is not equal to the upslope costs.

Environmental stimuli, such as mechanical noises, wind, predators, and other stimuli, may get the attention of an animal and increase the energy metabolism. Many of these transients are of short duration, such as a jet plane passing overhead, and may contribute little to the total daily cost of living. Others, such as a predator, may demand a higah rate of energy metabolism for escape. Heart rate increases are discussed in Moen and Chevalier (1977); corresponding changes in energy metabolism are unknown, however.

LITERATURE CITED

Moen, A. N. 1968. The critical thermal environment: A new look at an old concept. BioScience 18(11):1041-1043.

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.

Robbins, C. T., Y. Cohen, and B. B. Davitt. 1979. Energy expenditure by elk calves. J. Wildl. Mange. 43(2):445-453.

White, R. G. and M. K. Yousef. 1978. Energy expenditure in reindeer walking on roads and on tundra. Can. J. Zool. 56(2):215-223.

REFERENCES, UNIT 1.2

ENVIRONMENTAL FACTORS AFFECTING ENERGY METABOLISM

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
BISNA	18-11	1041	1043	odvi	critical thermal environme	moen,an	1968
CJZOA	53--6	679	685	odvi	ambien temp effect, physio	holter,jb; urban/	1975
CJZOA	56--5	1207	1210	odvi	heart rates w-t-d wolf how	moen,an; dellaf/	1978
ECOLA	57--1	192	198	odvi	energy conservat in winter	moen,an	1976
JOMAA	48--4	655	656	odvi	hypotherm, water-chill dee	moen,an	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JWMAA	33--3	482	490	odvi	diges ener, win, mich does	ullrey,de; youat/	1969
JWMAA	34--4	863	869	odvi	diges metab ener mich does	ullrey,de; youat/	1970
JWMAA	35--1	37	46	odvi	effect falli temp, heat pr	silver,h; holter/	1971
JWMAA	42--4	715	738	odvi	seas chan, heart rate, act	moen,an	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
CJZOA	48--2	275	282	odhe	feed intake, heat producti	nordan,hc; cowan/	1970
ECMOA	2---1	1	46	odhe	seasonal migration, mule d	russel,cp	1932
JWMAA	43--1	162	169	odhe	energ requi, fawns, winter	baker,dl; johnso/	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBPAB	60A-3	251	256	ceel	energ, nitr metab, cold en	simpson,am; webs/	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	50--2	302	310	alal	od, structur adaptat, snow	kelsall,jp	1969
QSFRA	3----	51	73	alal	influence of snow on behav	des meules,p	1964

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
APSCA	105-3	268	273	rata	spitzberg, wint-dorman ung	ringberg,t	1979
CJZOA	39--7	845	856	rata	clima, metab, therm, infan	hart,js; heroux,/	1961
CJZOA	48--2	391	392	rata	energy metab, barren groun	mcewan,eh	1970
IJBMA	12--1	21	27	rata	act wint cari, snow, alask	henshaw,j	1968
PHZOA	30--2	93	105	rata	melt points, anim fat, col	irving,l; schmid/	1957

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	31--1	159	164	anam	mort, severe wint, montana	martinka,cj	1967
JWMAA	37--4	563	573	anam	energy metabolism, prongho	wesley,de; knox,/	1973

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	56-11	2388	2393	ovca	winter bioenerget, rocky m	chappel,rw; hudso	1978
JWMAA	35--3	488	494	ovca	variat of rectal temperatu	franzmann,aw; heb	1971

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JASIA	44--1	5	66	doca	wint nutr depres, grow, re	joubert,dm	1954
JASIA	58--1	109	120	doca	sig extremities, therm reg	whitton,gc	1962
RSPYA	4---3	353	362	doca	oxy cost, therm- hyperven	hales,jrs; findla	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJAEA	11--3	402	407	dosh	regula bod temp, hot envir	brook,ah; short,b	1960
AJAEA	13--1	82	99	dosh	wind, h2o, metab rate, lam	alexander,g	1961
AJAEA	13--1	122	143	dosh	heat excha, lamb.hot envir	alexander,g; will	1962
AJAEA	13--1	144	164	dosh	energ metab, starv newborn	alexander,g	1962
AJAEA	15--6	982	988	dosh	ambi temp, heat prod, preg	graham,nm	1964
BJNUA	21--3	769	785	dosh	conti meas, heart ra, ener	webster,ajf	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CNJNA	43--1	39	46	dosh	low envir temp, phys respo	hess,ea	1963
JASIA	52--1	13	24	dosh	ener metab, clos clipped s	graham,nm; wainm/	1959
JPHYA	198-2	251	276	dosh	shiv, nonshiv thermogenesi	alexander,g; will	1968
SCIEA	145--	1318	1318	dosh	hematocr val, hemoglo type	evans,jv; whitloc	1964

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ANYAA	53--3	600	607	mamm	role, piliary sys, therm e	herrington,lp	1951
BISNA	18-11	1041	1043		critical thermal environme	moen,an	1968
FEPRA	28--3	1053	1058		intersp diff, cold adaptat	jansky,l; bartun/	1969
FEPRA	29--4	1541	1552	many	rhythmic var in ener metab	aschoff,jj; pohl/	1970
JAPYA	7---4	355	364		skin temp, arcti, heat reg	irving,l; krog,j	1955
NATUA	234--	483	484		many hier watr, eng, desrt	macfarlane,wv; h/	1971
NUMEB	21--1	88	104		energet fat metabo, growth	van es,ajh	1977
SSEBA	18---	31	48	many	insulat, metab adapt, cold	hart,js	1964
ZOBIA	2---	887	899		calor val equiv, bod wt ch	dargol'ts,vg	1973

OTHER PUBLICATIONS

Davydov, A. F. On the processes of muscular activity in reindeer during procurement of feeds from under the snow. Russian original from Sbornik "opyt izucheniya regulyatsii fiziologicheskikh funkstii v estestvennykh uslovyakh sushchestvovania organizmov," Vol. 6:35-40. 1963. Translation available from U.S. Dept. Commerce, Clearinghouse for Federal Scientific and Technical Information, Springfield, Va.

CHAPTER 7, WORKSHEET 1.2a

Chamber temperature effects on MBLM of the white-tailed deer

The energy expenditure values for white-tailed deer in a temperature-controlled chamber given by Holter et al. (1975) may be converted to MBLM by dividing the y-axis values in Figure 3 (p. 682) by 70. In the summer, MBLM was about 3.0 as the ambient temperature in the chamber was lowered to near 0°C. This is a very high relative rate of metabolism as a response to cold; productive processes require MBLM's of 2.5 to 4.0 (Moen 1978). In the winter, MBLM reached a low of about 1.3 at about 10°C, and a high of about 1.8 at about -20°C. These values are within the range of values for the winter period in the annual metabolic cycle discussed in Moen (1978). No indications of a rise in energy metabolism have been observed in the deer at Cornell's Wildlife Ecology Laboratory when air temperatures have dropped from about 10°C to -20°C. These animals have been free to choose their options in response to natural weather patterns.

Air temperatures to -20°C and cooler have always been accompanied by further reductions in heart rates and energy conservation behavioral responses by these deer. Different results in the New Hampshire chamber are likely due to the fact that the number of options are very limited in a chamber, and that the freedom to select and move to locations of the deer's choice cannot be exercised.

Equations for energy expenditures during different seasons are not given in Holter et al. (1975), but values may be estimated from plotted data using a grid overlay. Complete the estimations and compare MBLM's determined with the seasonal rhythms in Moen (1978).

LITERATURE CITED

Holter, J. B., W. E. Urban, Jr., H. H. Hayes, H. Silver, and H. R. Skutt. 1975. Ambient temperature effects on physiological traits of white-tailed deer. Can. J. Zool. 53(6):679-685.

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.

CHAPTER 7, WORKSHEET 1.2b

The effects of walking speed, percent slope, and snow depths on the energy expenditures of white-tailed deer

The effects of various combinations of walking speed, percent slope, and snow depths on energy expenditures have been graphed in Moen (1976, Figure 3, p. 194). The energy costs of different combinations may be read on the y-axis and MBLM determined for a 60-kg deer. For example, a deer in Behavioral Regime 6, walking 90 cm per second on a 0% slope in about 18 cm of snow is predicted to have an energy expenditure of 2400 kcal per day. The multiple of base-line metabolism is:

$$\text{MBLM} = 2400/(70)(60^{0.75}) = 1.59$$

Determine the energy costs of different combinations and summarize in the space below. Note that the multiples of <u>basal</u> metabolism given in Moen (1976) are considered in this book to be multiples of <u>base-line</u> metabolism (see WORKSHEET 1.1c, Chapter 7 - Page 18c).

LITERATURE CITED

Moen, A. N. 1976. Energy conservation by white-tailed deer in the winter. Ecology 57(1):192-198.

CHAPTER 7, WORKSHEET 1.2c

Energy exchanges of red deer (ceel) at three chamber temperatures

Energy exchanges of young red deer at three air temperatures and three levels of feeding are given in Table 4 (p. 253) of Simpson et al. (1978). The values are presented in MJ per day, which can be converted to kcal with the following equation:

$$\text{kcal per day} = (\text{MJ}/4.184)1000$$

Multiples of base metabolism are determined by dividing kcal per day by (70)(MEWK). Using these equations, the following MBLMs have been determined:

		Level of Feeding	
	Low	Medium	High
Metabolizable energy intake (MBLM)	1.10	1.84	2.33
Heat production (MBLM) at 16°	1.57	1.58	1.70
8°	2.05	2.35	2.49
4°	1 86	2 38	2.20

These multiples indicate a rise in heat production at each level of feeding as the temperature dropped from 16 to 8°, and at only one level of feeding as the temperature dropped from 8 to 4°.

The MBLM calculations are illustrated here to call attention to the utility of MBLM as a parameter for comparisons between levels of feeding, chamber conditions, weights, and species. Verify these calculations based on the original data in Simpson et al. (1978) in order to become thoroughly familiar with the patterns of MBLM in different situations.

LITERATURE CITED

Simpson, A. M., A. J. F. Webster, J. S. Smith, and C. A. Simpson. 1978. Energy and nitrogen metabolism of red deer (Cervus elaphus) in cold environments: a comparison with cattle and sheep. Comp. Biochem. Physiol. 60:251-256.

CHAPTER 7, WORKSHEET 1.2d

Effects of weather on energy metabolism of infant caribou

The effects of different combinations of air temperature, wind and precipitation on the metabolism of infant-caribou was studied by Hart et al. (1961). Results are presented in Table III (p. 850), including a column for heat production in kcal per hour/kg$^{0.75}$. These data may be converted to MBLMs by simply multiplying the HP value by 24 and dividing by 70. Values of MBLM range from about 1.4 for a dry calf in the lab at 0°C to over 10 for a calf exposed to wind and precipitation.

Complete the calculations of MBLM for each of the test conditions given in the published paper and evaluate them in relation to the experimental variables. Examples are MBLM in relation to air temperature (the first five results in Table III) and MBLM in relation to wind velocity (the last six results in Table III). Multiple regression analyses may be useful here too, except that the effects of wind on MBLM may not be linear. This is discussed further in PART V.

Note that Hart et al. indicate that 25 kcal per hour/kg$^{0.75}$ is a "lethal level." This is (25)(24)/70 = 8.6 = MBLM, which is a higher rate of metabolism than that of very high producing dairy cows! Infant caribou can hardly be expected to maintain such a metabolic level for very long.

LITERATURE CITED

Hart, J. S., O. Heroux, W. H. Cattle and C. A. Mills. 1961. The influence of climate on metabolic and thermal responses of infant caribou. Can. J. Zool. 39(7):845-856.

TOPIC 2. MEASUREMENTS OF ENERGY METABOLISM

Measurements of the metabolic rates of several species of wild ruminants have been made with a variety of methods at different times of the year. The results show variations in relation to several parameters of ecological importance. The time of the year is an important consideration for evaluating seasonal rhythms, and the day, week, or at least the month of the year in which the tests were conducted should always be given in the results. If the time of year cannot be determined, the results are relatively worthless.

Weights of the animals should also be given, of course. Metabolic expenditures can then be determined per unit weight, or per unit metabolic weight. Sex, age, and reproductive characteristics are also important characteristics for interpreting the results of metabolism tests.

The topics and units that follow give the results of metabolism tests and calculations for a variety of wild ruminants. Short-term chamber measurements are included, though it is difficult to derive equations for ecological metabolism over the entire annual cycle from such studies. Calculations by summation, estimations from vital signs and in relation to base-line metabolism provide estimates throughout the year.

UNIT 2.1: CHAMBER MEASUREMENTS

Direct measurements of metabolism involve the measurement of the heat production of the animal after the manner of Lavoisier in the latter part of the eighteenth century. His early methods have been replaced by very refined calorimetry chambers, however. Professor Armsby built one early in the 20th century at the Pennsylvania State University; it is still in existence but not currently being used. The basic principle is the same as the crude ice-box calorimeter, but circulating water removes heat from the chamber and calculations are based on the flow rate, temperature changes, and other thermal parameters of the water. Direct calorimetry chambers are not used extensively now because of the high cost of construction and the availability of simpler and less expensive oxygen consumption methods.

The calculation of heat production from oxygen consumption is based on the relationship between the volumes of oxygen consumed and heat production. The relationship is illustrated by equation (1) from Brody (1945).

This equation shows that the oxidation of one mol of hexose ($C_6H_{12}O_6$) requires 6 mols of O_2, with the resulting production of six mols of CO_2, 6 mols of H_2O, and 678 calories of heat energy.

$$C_6H_{12}O_6 + 6\ O_2 = 6\ CO_2 + 6\ H_2O + 678\ \text{Cal} \qquad (1)$$

$$(180\ \text{g.})\ (134.4\ \text{lit.}) \qquad (134.4\ \text{lit.})$$

The heat production (678 calories) divided by the consumption of 134.4 liters of oxygen or the production of 134.4 liters CO_2 yields 5.047 calories (5.047 = 678/134.4). Thus 5.047 calories of heat are produced for each liter of O_2 consumed and each liter of CO_2 produced in carbohydrate oxidation. The oxidation of mixed fat results in the release of 4.69 calories per liter oxygen consumed, and 6.6 calories per liter carbon dioxide produced. For the oxidation of mixed protein, 4.82 calories are released per liter O_2 consumed, and 5.88 calories per liter CO_2 produced. The figures above indicate that the numbers of calories produced by oxidation varies with the carbohydrate, fat, and protein content of the food, so the proportion of carbohydrate, fat, and protein in the food should be known before calculating the heat production from either oxygen consumption or carbon dioxide production.

The amount of protein oxidized is determined from the urinary nitrogen excreted. This assumes that there is a constant quantity of nitrogen in the protein. If 16% of the protein is nitrogen, the protein catabolized is estimated by multiplying the urinary N by the ratio of total protein to nitrogen in the protein (100/16 = 6.25) (Equation 2)

$$\text{Urinary N} \times 6.25 = \text{protein catabolized} \qquad (2)$$

The example above is true for several animal proteins. Cereal proteins contain 17-18% N, so the conversion factor is 5.8 to 5.9. In practice, the assumption that protein contains 16% nitrogen is sufficient. The relative amounts of fat and carbohydrate oxidized are determined from the non-protein respiratory coefficient (R.Q.). The R.Q. is the ratio of mols or volumes of CO_2 produced to mols or volumes of O_2 consumed. Thus in equation (1), the R.Q. is equal to 1.0 because $6\ CO_2/6\ O_2 = 1.00$; only carbohydrates had been consumed.

The R.Q. for mixed fats is 0.71, and for mixed protein, 0.81. These are averages only, as fatty acids vary in their R.Q. (short-chain fatty acids have an R.Q. nearer 0.8) and each protein and amino acid has its distinctive R.Q. The relative amount of heat produced by the oxidation of carbohydrates and fats can be computed from the R.Q., and these are presented in tabular form in Brody (1945:308-310), the source of information for the material discussed in the previous paragraphs.

The respiratory quotient does not always have the simplicity of interpretation implied in the foregoing discussions. In ruminants, large quantities of CO_2 are produced by the rumen bacteria, and this cannot be distinguished from the CO_2 resulting from internal respiration. The measurement of oxygen consumption and its multiplication by the caloric equivalent of oxygen is a satisfactory method for estimating heat production by the ruminant. Note in Table 1 that the calories per liter of oxygen cosumed ranged from 4.686 to 5.047. The mean value is about 4.86, and this occurs at an R.Q. of 0.85. The R.Q. of protein is about 0.82, so if one is satisfied with an approximation of mean values, the rate of heat production can be calculated by multiplying the liters of oxygen consumed by 4.82 to 4.85 without correcting for protein metabolism. This method is often used by comparative physiologists (Hoar 1966).

BASAL METABOLISM

The tabular format shown below includes columns for the information necessary for interpreting published results of basal metabolism tests. The first three items identify the conditions for a basal test. Completion of the blanks results in KCAL and KJOU being expressed on an absolute basis, and MBLM provides for comparisons of the results on a relative basis.

FORMAT FOR COMPARING BASAL METABOLISM TESTS

				Time of	Weight in		24-hour basal metabolism		
Reference	Species	Sex	Age	Year	Kg	IFMW	KCAL	KJOU	MBLM
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-

Basal metabolism tests on white-tailed deer showed seasonal variations, with the lowest metabolism occurring when the deer were in winter coat and the highest when they were in summer coat (Silver 1968). Seasonal variations in basal metabolism may be expressed with a sine wave in the same manner that seasonal variations in weight were, showing seasonal metabolic rhythms as an animal goes from a winter low to a summer high in a gradual way. There is no general formula available yet for the expression of seasonal rhythms in metabolism. Results of curve fitting the data for white-tailed deer are given in the WORKSHEETS.

FASTING METABOLISM

Fasting metabolism measurements are expected to show seasonal variations, just as basal metabolism tests did. The differences between the two tests is that basal tests are for animals at rest, and fasting tests are uncorrected for activity. Both tests are conducted on post-absorptive animals in thermoneutral conditions.

A tabular format for comparing the results of fasting metabolism tests is shown on the next page.

FORMAT FOR COMPARING RESULTS OF FASTING METABOLISM TESTS

Reference	Species	Sex	Age	Time of Year	Weight in Kg	IFMW	24-hour fasting metabolism KCAL	KJOU	MBLM
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-

LITERATURE CITED

Brody, S. 1945. Bioenergetics and growth. Reinhold Publ. Co., New York. 1023 pp.

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

REFERENCES, UNIT 2.1

CHAMBER MEASUREMENTS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
CJZOA	53--6	679	685	odvi	ambien temp effect, physio	holter,jb; urban/	1975
JPHYA	194-1	22	24	odvi	energy metabolism, red dee	brockway,jm; mal/	1968
JWMAA	23--4	434	438	odvi	basal metab, a pilot study	silver,h; colovo/	1959
JWMAA	33--1	204	208	odvi	cage, metab, radioiso stud	cowan,rl hartso/	1969
JWMAA	33--3	490	498	odvi	fasting metabolism	silver,h; colovo/	1969
JWMAA	35--1	37	46	odvi	effect falli temp, heat pr	silver,h; holter/	1971

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JPHYA	194-1	22	24	ceel	energy metabolism, red dee	brockway,jm; malo	1968

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	39--7	845	856	rata	clima, metab, therm, infan	hart,js; heroux,/	1961
CJZOA	48--2	391	392	rata	energy metab, barren groun	mcewan.eh	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	34--4	908	912	anam	energ flux, water kinetics	welsey,de; knox,/	1970
JWMAA	37--4	563	573	anam	energy metabolism, prongho	wesley,de; knox,/	1973

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
AJPHA	178-3	515	516	oram	metabolism of mountai goat	krog,h; monson,m	1954

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJAEA	13--1	144	164	dosh	energy meta, new-born lamb	alexander,g	1962
AJAEA	18--1	127	136	dosh	fastng metab rate reln wt,	graham,nm	1967
BJNUA	16--4	615	626	dosh	fast metab, adul wether sh	blaxter,kl	1962

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	22--1	3	24	caca	energy metabolism, roe dee	weiner,j	1977

OTHER PUBLICATIONS

Davydov, A. F. On the processes of muscular activity in reindeer during procurement of feeds from under the snow. Russian original from Sbornik "opyt izucheniya regulyatsii fiziologicheskikh funkstii v estestvennykh uslovyakh sushchestvovania organizmov," Vol. 6:35-40. 1963. Translation available from U.S. Dept. Commerce, Clearinghouse for Federal Scientific and Technical Information, Springfield, Va.

Basal metabolism of white-tailed deer

Measured basal metabolic rates of white-tailed deer show differences between winter and summer coat. These are summarized in Moen (1973:117) based on data in Silver (1968). The average multiple of base-line metabolism for the winter coat is 75.6 and for the summer coat, 84.4.

How can these limited data be used to represent a seasonal rhythm in basal metabolism of deer? Suppose the summer peak was reached on August 15, which is JDAY 227, and the winter low six months later, which is JDAY 45. The sine wave is again employed to determine a smooth transition from maximum to minimum, and a phase correction is needed to make JDAY 227 equivalent to 90° when sin 90 = +1.

The primary phase correction is $90 - (227)(0.9863) = -134 = PRPC$. Therefore:

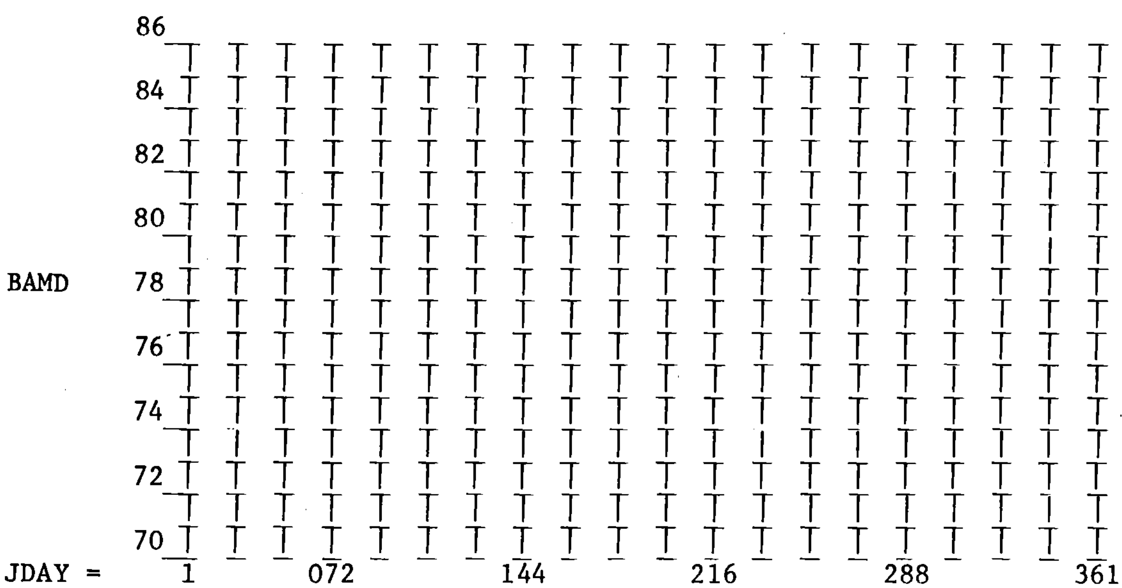
$$\sin[(227)(0.9863)]-134 = +1.0, \text{ and } \sin[(45)(0.9863)]-134 = -1.0$$

The equation for predicting the seasonal rhythm in basal metabolism per day (BAMD) is:

$$BAMD = [(84.4 + 75.6)/2] + \left\{\sin[(JDAY)(0.9863)]-134\right\} \left\{[84.4 - 75.6]/2\right\}$$

This simplified deviation of BAMD illustrates another use for the sine wave equation for smoothly correcting observed biological values over an annual cycle. The deviation is illustrative, and not meant to prove that basal metabolism values through the year are exactly these values.

Complete the calculations and plot the results below.



LITERATURE CITED

Moen, A. N. 1973. Wildlife ecology. W. H. Freeman & Co., San Francisco. 458 pp.

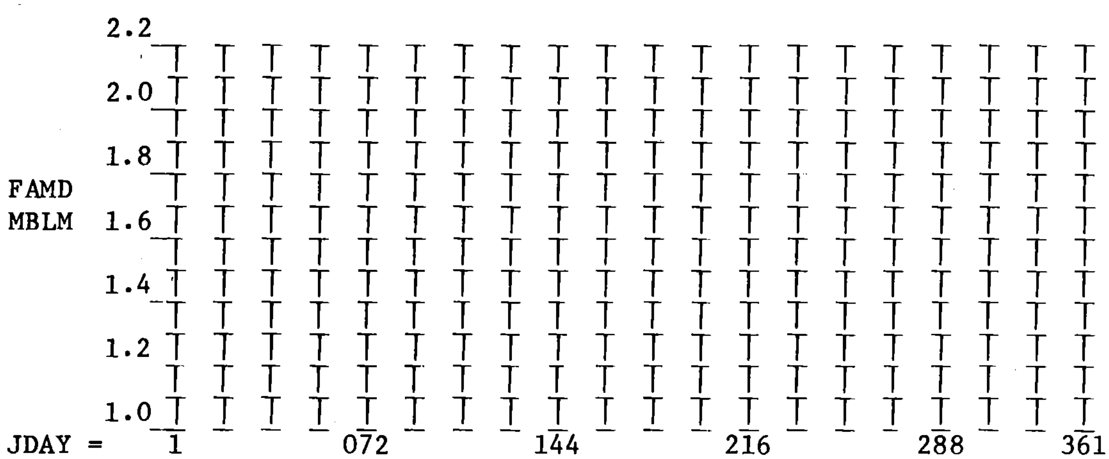
Silver, H. 1968. Deer nutrition studies. In The white-tailed deer of New Hampshire, ed. H. R. Siegler. Survey Report No. 10, Concord: New Hampshire Fish and Game Department, pp. 182-196.

Fasting metabolism of white-tailed deer

The fasting metabolism of white-tailed deer has been measured by Silver et al. (1969) and the data recalculated and compiled in Moen (1973:118). Average heat production values in kcal per $W_{kg}^{0.75}$ are as follows:

Age	Sex	Coat	Heat production	MBLM
Adult	male	winter	95.6	1.37
Adult	male	summer	141.4	2.02
Adult	female	winter	97.5	1.39
Adult	female	summer	146.3	2.09
	yearlings	summer	130.6	1.87
	fawns	winter	90.1	1.29

The differences in MBLM between sexes are very slight. The values 1.38 = MBLM in winter coat and 2.06 = MBLM in summer coat could be used for both sexes. Using the procedures described in WORKSHEET 2.1a, derive a sine wave equation for fasting metabolism expressed as a multiple of base-line metabolism and plot the results below.



LITERATURE CITED

Moen, A. N. 1973. Wildlife ecology. W. H. Freeman & Co., San Francisco. 458 pp.

Silver, H. 1968. Deer nutrition studies. In The white-tailed deer of New Hampshire, ed. H. R. Siegler. Survey Report No. 10, Concord: New Hampshire Fish and Game Department, pp. 182-196.

CHAPTER 7, WORKSHEET 2.1c

Metabolism of a mountain goat

The metabolism of a 1 1/2 year-old male mountain goat was measured in February and March in a temperature-controlled chamber by Krog and Monson (1954).

The measured values are:

Weight	Ambient Temperature	Total Heat Production (kcal per 24 hour)	Kcal per $LWKG^{0.75}$	MBLM
32 kg	20 to -20	1027	____	____
	-30	1304	____	____
	-50	2362	____	____

Complete the "kcal per $W_{kg}^{0.75}$" column by dividing total heat production by $32^{0.75}$, and the MBLM column by dividing the previous answer by $(70)(32^{0.75})$. Note the MBLM values for later comparisons with seasonal rhythms in different species discussed in TOPIC 6 of this CHAPTER.

LITERATURE CITED

Krog, H. and M. Monson. 1954. Notes on the metabolism of a mountain goat. Am. J. of Physiol. 178:515-516.

UNIT 2.2: OUTDOOR MEASUREMENTS

It is difficult to get good direct measurements of the heat production of wild ruminants in chambers because of the extensive training required and the potentials for psychological effects, and it is impossible to measure heat production directly when they are ranging freely of course. How may the "cost of living" of free-ranging animals be quantified? Since it is impossible to measure ecological metabolism directly over 24-hour periods throughout the annual cycle, it must be calculated based on biological evidence for general patterns and magnitudes of metabolic rates of specific activity and productive functions.

Outdoor measurements may be made in several ways, including the use of respiratory masks, tracheal cannulae, calculations of the cost of movement of mass over distance, and by converting vital signs to estimates of metabolic rates. Closed circuit spirographic-masks, consisting of an oxygen spirometer which measures the rate of oxygen consumption, are one of the least expensive methods for measuring enerby expenditures, although not all animals are willing to wear the masks. Closed-circuit systems involve rebreathing of the same air, except that CO_2 is absorbed by porous soda lime after passing through one-way valves. Open-circuit mask methods for larger animals involve the measurements of CO_2 increases and O_2 decreases of directly inspired air. Gas analyzers are used to determine the amounts of oxygen consumed, and these measurements are converted to estimates of heat production.

The basic equations for determining metabolism using heart rates and activity patterns and heart rate to metabolism conversions have been described, and can be assembled into a sequence of calculations throughout the year to predict ecological metabolism throughout the year. While these calculations can be repeated for every day, 365 times for a year, that is unnecessary as 15-day intervals are sufficiently close to result in a smooth curve over the annual cycle.

REFERENCES, UNIT 2.2

OUTDOOR MEASUREMENTS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	20--3	221	232	odvi	nutrient req, growth, antl	french,ce; mcewa/	1956
JWMAA	27--2	185	195	odvi	rumen ferment, ener relati	short,hl;	1963
JWMAA	33--3	482	490	odvi	diges ener, win, mich does	ullrey,de; youat/	1969
JWMAA	34--4	863	869	odvi	diges metab ener mich does	ullrey,de; youat/	1970
JWMAA	37--3	301	311	odvi	nutrition requiremen, fawn	thompson,cb; hol/	1973
JWMAA	42--4	715	738	odvi	seas rhyth, heart rat, met	moen,an	1978
JWMAA	43--4	880	888	odvi	predict energ, nitro reten	holter,jb; urban/	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--2	275	282	odhe	feed intake, heat prod, yo	nordan,hc; cowan/	1970
JWMAA	43--1	162	169	odhe	energ requirem fawn, winte	baker,dl; johnso/	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBPAB	59A-1	95	100	ceel	effic of utili diet energy	sipson,am; webst/	1978
CBPAB	61A--	43	48	ceel	oxyg use, calves, locomotn	cohen,y; robbins/	1978
JWMAA	43--2	445	453	ceel	energy expenditure, calves	robbins,ct; cohe/	1979

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BPURD	1----	335	339	rata	meth meas ener exp, unrstr	young,ba; mcewan,	1975
CJZOA	56--2	215	223	rata	energ expnd, walk, rd,tund	white,rg; yousef,	1978

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PAANA	7----	335	341	dosh	co2, index ener expen, lmb	white,rg; leng,ra	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PNUSA	37--1	13	19		altern meth, larg anim cal	brockway,jm	1978

CHAPTER 7, WORKSHEET 2.2a

Caloric value of oxygen at different respiratory quotients

Calculations of heat production based on oxygen consumed are made by multiplying the liters of oxygen consumed by the caloric value of O_2 at the respiratory quotient (R. Q. = REQO) characteristic of the diet of the animals at the time of measurement.

The abbreviated table below, based on data in Brody (1945:310) illustrates differences in the kcal per liter of oxygen at REQOs ranging from 0.70 to 1.00.

REQO	Kcal per liter O_2
0.70	4.686
0.75	4.729
0.80	4.801
0.85	4.863
0.90	4.924
0.95	4.985
1.00	5.047

The table in Brody gives the kcal per liter O_2 for R. Q. from 0.70 to 1.00 at 0.01 intervals. While the table covers more than half a page vertically, curve-fitting with linear regression reduces the tabular information to a simple equation. Thus, the kcal per liter of O_2 (KCLO) at different respiratory quotients (REQO) can be calculated:

$$KCLO = 3.818 + 1.229 \; REQO; \; R^2 = 1.00$$

LITERATURE CITED

Brody, S. 1964. Bioenergetics and growth. Hafner Publishing Co., Inc. New York. 1023 pp.

TOPIC 3. ESTIMATES OF ENERGY COSTS FOR PRODUCTION

Production results in the formation of new individuals (reproduction) and the deposition of new tissue by the individual (growth). Both of these productive functions are essential for the growth of the population. The growth rates of individuals often become indicators of the reproductive potentials of populations. Populations with smaller than average individuals will likely have lower than average reproductive rates because when requirements for a high rate of growth are not met, resources are not available for a high rate of reproduction. In white-tailed deer, for example, first conception becomes probable at a weight of about 40 kg. If a fawn does not attain this weight by its first winter, it is unlikely to reproduce until it is a yearling.

Inadequate nutrition during the gestation period may result in abortion, resorption of fetal tissue, or reduced fetal growth during the final stages of gestation. When fetal growth is reduced, the young weigh less at birth and have decreased chances of survival.

Inadequate maternal nutrition may impair lactation, possibly reducing the growth rate of the nursing young. Lactation is the single greatest sustained energy and protein requirement of mammals, and the major factor contributing to the high metabolic rate in the summer. The timing of this high cost is ecologically sound, however, as offspring are produced in late spring, just in time for the nursing dam to have access to a range with new growth as a source of nutrients for the costly process of lactogenesis.

While forage resources are more abundant and often quite digestible in the summer, this does not suggest that nutrients are unlimited on a green and growing range. Wild ruminants forage rather selectively, and will not consume any plant just because it is present. In fact, they often exhibit a high degree of selection not only for a particular plant species, but also for plant parts such as flowers. Ingestion of selected plant parts contributes to a higher quality diet (Whittemore and Moen 1980).

When nutrients are ingested in sufficient quantities to result in the production of new tissue, the nutrient balance is positive. The new tissue may be milk, which is made available to the dependent offspring whose growth may be at the expense of the body tissue of the lactating female. Weight curves have been calculated (CHAPTER 1) showing that annual minimum weights of lactating females occur at about the time of peak lactation.

LITERATURE CITED

Whittemore, S. and A. N. Moen. 1980. Composition and digestibilities of various forages of the white-tailed deer. Can. J. Anim. Sci. 60:189-192.

UNIT 3.1: THE ENERGY COST OF BODY GROWTH

Growth of wild ruminants that have not yet reached their full adult size occurs in the spring, summer and fall. Unbred yearlings may grow from spring through fall. Nursing young grow in the summer, and reproducing females will grow in late summer and fall as lactation demands are reduced. Antler and horn growth occurs in mature males from spring to early fall. The amount of growth is partially related to body weight and growth, so it is also related to range conditions, and partially related to the genetic potentials of the individual.

The cost of body growth is equal to the amounts of nutrients deposited plus the cost of synthesizing the tissue. These costs are directly dependent on tissue composition. Suppose that an animal gained 10 kg over a 100-day period. Suppose that 8 kg of this increase was water, 1.5 kg fat, and 0.5 kg protein. The energy increment in the animal's body is equal to 1.5 kg fat times 9,500 kcal per kg = 14,250 plus 0.5 kg protein times 5,500 kcal = 2750 kcal, totaling 17,000 kcal of tissue energy. This is 170 kcal per day.

One very important parameter must also be considered, and that is the efficiency of growth. If the efficiency were 50% in the example above, then the energy cost of tissue deposition would be equal to twice the energy in the tissue and the total cost would be 2 x 170 = 340 kcal. Efficiency of growth is related to physiologic age. But body composition is related to body weight and age, so the older and larger mammal, gaining less but depositing more fat, is depositing tissue with a higher caloric density. Thus while efficiency of growth goes down, changes in efficiency are reflected in changes in body composition. Examples illustrating how the cost of growth can be calculated on the basis of chemical composition and the cost of tissue synthesis are given in a WORKSHEET.

REFERENCES, UNIT 3.1

THE ENERGY COST OF BODY GROWTH

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JWMAA	20--3	221	232	odvi	nutrit req, growth, antler	french,ce; mcewe/	1956
JWMAA	37--3	301	311	odvi	energ requiremnts of fawns	thompson,cb; hol/	1973
JWMAA	39--2	355	360	odvi	milk consumpt, weight gain	robbins,ct; moen,	1975
JWMAA	39--4	684	691	odvi	uterin comp, grow, pregnan	robbins,ct; moen,	1975
NAWTA	22---	119	132	odvi	nutrient requirements of	mcewen,lc; frenc/	1957
PAARA	209-1	1	11	odvi	eff feed restric, antl dev	long,ta; cowan,rl	1959

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NAWTA	22---	179	186	odhe	feed requirem, grow, maint	cowan,imct; wood/	1957

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NATUA	215--	1134	1136	ceel	comparitive nutr, pregnanc	payne,pr; wheele/	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PNUSA	27--2	129	138	alal	compar nut in preg, lactat	payne,pr; wheele/	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--2	391	392	rata	energ metab, bar gro carib	mcewan,eh	1970
CJZOA	48--5	905	913	rata	seas chan, energ, nit inta	mcewan,eh; whiteh	1970

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

CODEN-VO-NU-BEPA-ENPA-ANIM-KEWO-----------------------AUTH--------------YEAR

WLMOA 14--- 1 78 pharm, physiol of restrain hartoorn,am 1965

CHAPTER 7, WORKSHEET 3.1a

The energy cost of body growth

Experiments designed to measure the cost of body growth are not as easily completed on wild ruminants as on domestic ruminants. Estimates of the cost of growth may be made by determining change in weight over a specified time period, changes in body composition in relation to weight, and the caloric equivalents of the tissue involved. The steps are:

1. Subtract final weight from initial weight.

2. Determine body composition at final and initial weights and the amounts of each of the following:

    a. Water
    b. Fat
    c. Protein
    d. Ash

3. Multiply the change in the fat and protein components by their approximate combustion values (Brody 1945:35).

    Fat = 9.5 kcal per gm
    Protein = 5.7 kcal per gm

4. Add the energy contents of the fat and protein gain together and divide by the number of days between the initial and final weight used in Step 1.

5. Multiply the answer in Step 4 by the reciprocal of the efficiency (50% efficiency: 1/0.50 = 2; 33% efficiency: 1/0.33 = 3).

Specific equations for the energy cost of growth may be compiled from the weight equations and chemical composition equations in PART I.

LITERATURE CITED

Brody, S. 1964. Bioenergetics and growth. Hafner Publishing Co., Inc., New York. 1023 pp.

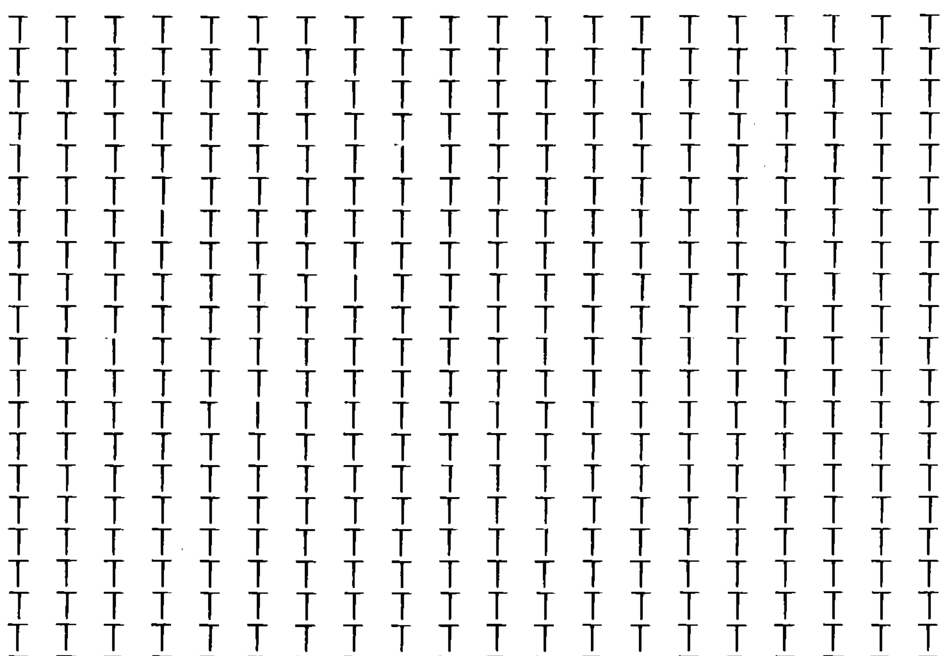
CHAPTER 7, WORKSHEET 3.1b

Total energy content of white-tailed deer as a function of ingesta-free weight

The total energy content of white-tailed deer in relation to ingesta-free weight has been determined by Robbins et al. (1974), simplifying calculations of the cost of growth. Only slight differences were observed in males and females so a single equation may be used to estimate total caloric content in kcal (TCCK).

$$TCCK = e^{1.3720 \ln IFWK - 0.5876}$$

Using this equation and the seasonal weight equations in CHAPTER 1, the caloric content can be quickly determined after initial and final weights have been determined. Set up some weight differences based on the calculations in CHAPTER 1, UNIT 1.4, determine the daily change in energy content, and estimate the energy cost of these changes. Label and plot the results below. Differences in efficiencies may be represented as a family of curves.



LITERATURE CITED

Robbins, C. T., A. N. Moen and J. T. Reid. 1974. Body composition of white-tailed deer. J. Anim. Sci. 38(4):871-876.

UNIT 3.2: THE ENERGY COST OF HAIR GROWTH

The cost of hair growth may be determined in a manner similar to that for body growth. Time-periods of hair growth, amounts of hair, and chemical composition of the hair need to be known when making these calculations. These parameters were discussed in CHAPTER 2; calculations are illustrated in the WORKSHEETS.

REFERENCES, TOPIC 3.2

THE ENERGY COST OF HAIR GROWTH

SERIALS

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

JWMAA 38--4 871 876 odvi body composition of white- robbins,ct; moen, 1974

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

odhe

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

ceel

CODEN-VO-NU-BEPA-ENPA-ANIM-KEWO-----------------------AUTH--------------YEAR

alal

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

rata

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

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

JANSA 45--4 826 831 doca hair indic calor-prot stat haaland,gl; mats/ 1977

CHAPTER 7, WORKSHEET 3.2a

The energy cost of hair growth of white-tailed deer

The energy cost of hair growth may be estimated by determining the weight of the hair coat, chemical composition, and caloric values of the hair to give the energy content of the hair coat. The daily cost may be estimated by multiplying the energy content by the reciprocal of the efficiency of hair growth and dividing by the numbers of days during which the hair growth occurred. The formula may be written as:

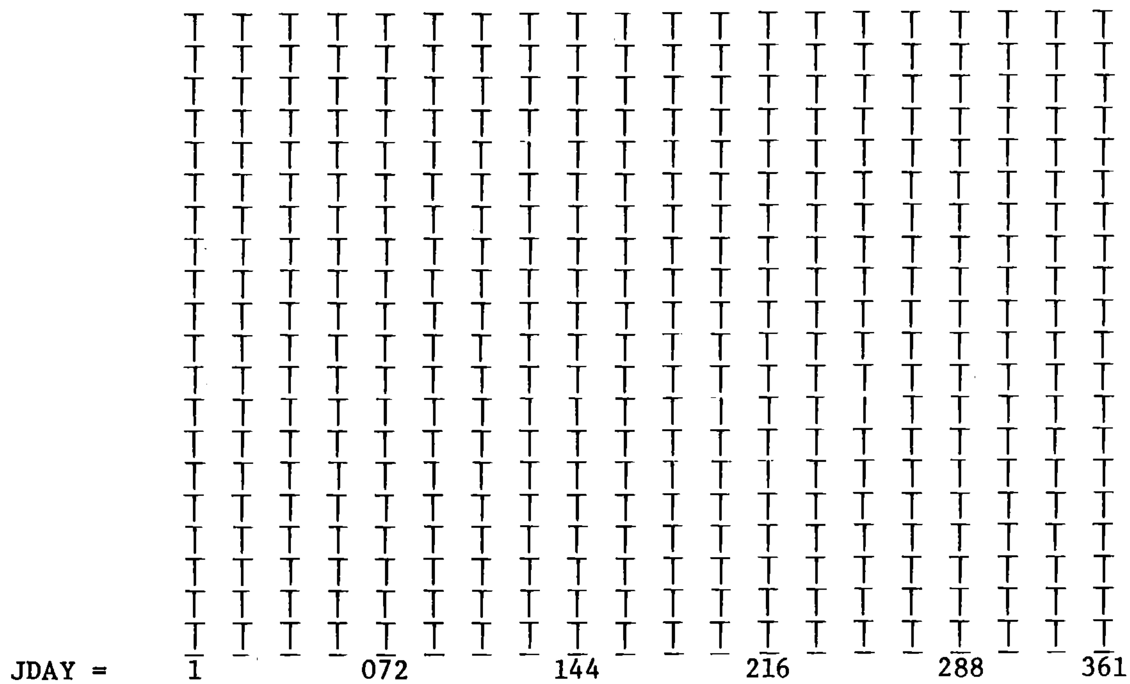
$$ECHD = \left\{[(HAWG)(FACO)(9.74) + (HAWG)(PRCO)(5.61)]\ 1/PEHG\right\} /DHGD$$

where ECHD = energy cost of hair growth per day
HAWG = hair weight in grams
FACO = fat content expressed as a decimal fraction = 0.098
PRCO = protein content expressed as a decimal fraction = 0.890
PEHG = physiological efficiency of hair growth expressed as a decimal fraction
DHGD = duration of hair growth in days

The caloric values and fat and protein contents are taken from Robbins et al. (1974). HAWG is determined from WORKSHEET 1.3b in CHAPTER 2. PEHG is a variable, and DHGD is dependent on the biochronology of the species or population group being considered.

Calculate and plot HAWG and ECHD on the next page, labeling the y-axis with the appropriate units of measurement. The effects of different physiological efficiencies of hair growth may be expressed with a family of curves.

How much does variation in PEHG contribute to variation in ecological metabolism? This question may be answered after all of the maintenance, activity, and production costs have been considered and ecological metabolism per day (ELMD) determined. Completion of the WORKSHEETS in this CHAPTER will enable the user to evaluate the cost of any process in relation to the total.



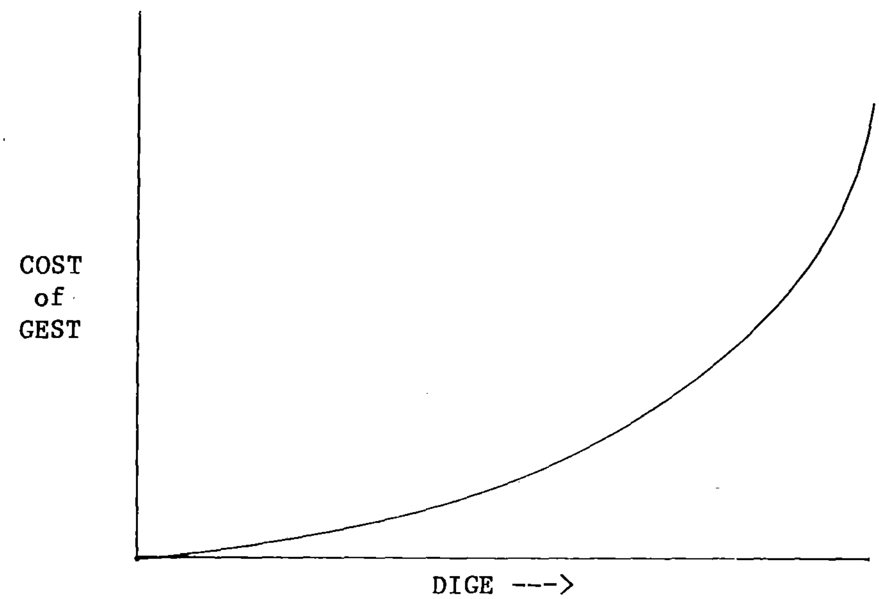
LITERATURE CITED

Robbins, C. T., A. N. Moen and J. T. Reid. 1974. Body composition of white-tailed deer. J. Anim. Sci. 38(4):871-876.

UNIT 3.3: THE ENERGY COST OF GESTATION

Accelerating requirements for gestation must be met in the last one-third of pregnancy. This acceleration generally coincides with the period of renewed plant growth, although differences in the lengths of winters result in different times of renewed plant growth from year to year. A late-arriving spring may have considerable effect on the condition of pregnant females during the last one-third of pregnancy (see Moen 1978). Conception occurs in the fall, and its timing is not related to the termination of winter several months later, of course. High conception rates may be followed by reduced birth rates if winter conditions are extended.

Increases in the requirements for gestation are related to increases in fetal growth and in the energy content of the uterus and associated reproductive tissues. The trends are illustrated below; curve-fitting of actual data may result in logarithmic, exponential, or power curves. Costs for associated uterine tissues increase in the same way, and are added to the costs of fetal growth to determine the total energy cost of gestation.



Calculations of the cost of gestation are made in the WORKSHEETS, with equations given for white-tailed deer and proportionalities described for other species.

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.

REFERENCES, UNIT 3.3

THE ENERGY COST OF GESTATION

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNAA	43--3	650	666	odvi	fetal develop, white-taile	armstrong,ra	1950
JOMAA	47--2	266	280	odvi	endoc glan, seas, sex, age	hoffman,ra; robin	1966
JWMAA	33--3	482	490	odvi	dig energ req, wintr, does	ullrey,de; youat/	1969
JWMAA	34--2	383	388	odvi	morphol develop, aging, fe	short,c	1970
JWMAA	34--4	863	869	odvi	dig, met ener, wintr, does	ullrey,de; youat/	1970
JWMAA	39--4	684	691	odvi	uterin comp, grow, pregnan	robbins,ct; moen,	1975
JWMAA	42--4	715	738	odvi	seas chan, heart rate, act	moen,an	1978
NAWTA	28---	431	443	odvi	nutrit, growth, fetal, faw	verme,lj	1963
NAWTA	22---	119	132	odvi	nutrient requirements of w	mcewen,lc; frenc/	1957
VJSCA	23--3	116	116	odvi	aspects of early pregnancy	scanlon,pf; murp/	1972
VJSCA	24--3	112	112	odvi	ovula, pregnan, lactat dee	scanlon,pf; murp/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--1	123	132	odhe	development, fetal period	ommundsen,p; cowa	1970
JWMAA	23--3	295	304	odhe	embryo, fetal development	hudson,p; browman	1959

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	47--6	1418	1419	ceel	sexual dimorphism, fetuses	retfalvi,l	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PNUSA	27--2	129	138	alal	compar nut in preg, lactat	payne,pr; wheele/	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--5	905	913	rata	seas chan, energ, nit inta	mcewan,eh; whiteh	1970

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
JOMAA	46--3	524	525	ovca	fetal measure, milk charac	forrester,dj; sen	1965

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNTA	114-1	101	116	ungu	matern repro effort, fetal	robbins,ct; robbi	1979

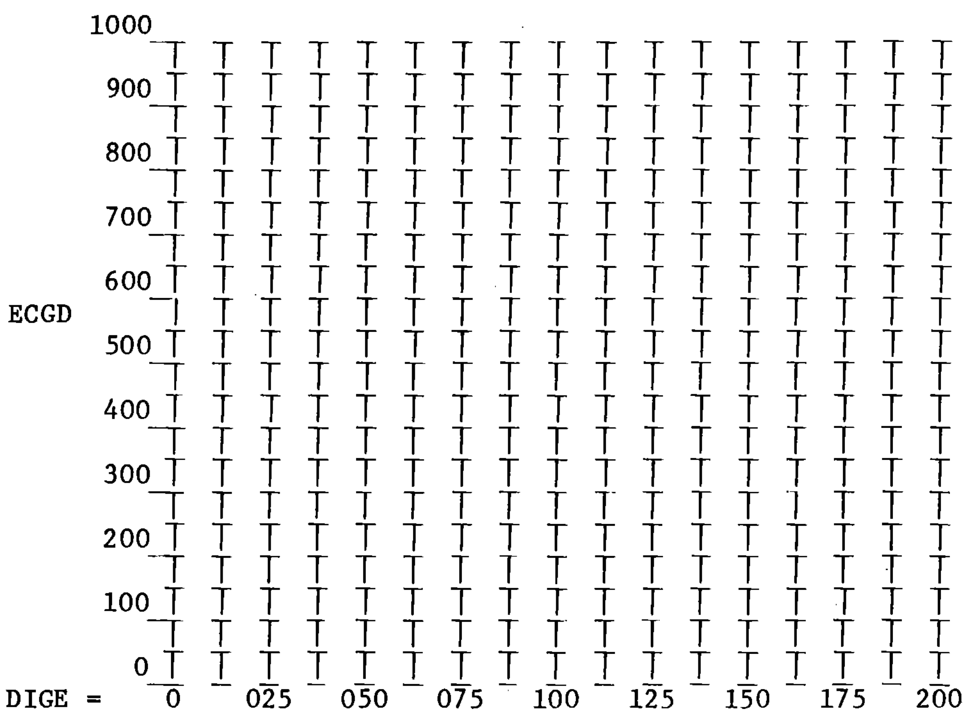
The energy cost of gestation in white-tailed deer

The energy cost of gestation is equal to the energy deposited in the gravid uterus each day times the efficiency of the physiologic processes involved. The energy content of the gravid uterus has been determined by Robbins and Moen (1975), and may be used to calculate the energy cost of gestation with the following equation.

$$ECGD = (e^{0.2803 + 0.0282\ DIGE})(1/PEGE)$$

where ECGD = energy cost of gestation per day,
DIGE = days into gestation, and
PEGE = physiological efficiency of gestation

Plot ECGD below, expressing PEGE as a family of curves again.



LITERATURE CITED

Robbins, C. T. and A. N. Moen. 1975. Uterine composition and growth in pregnant white-tailed deer. J. Wildl. Manage. 39(4):684-691.

CHAPTER 7, WORKSHEET 3.3b

The energy costs of gestation in several species of wild ruminants

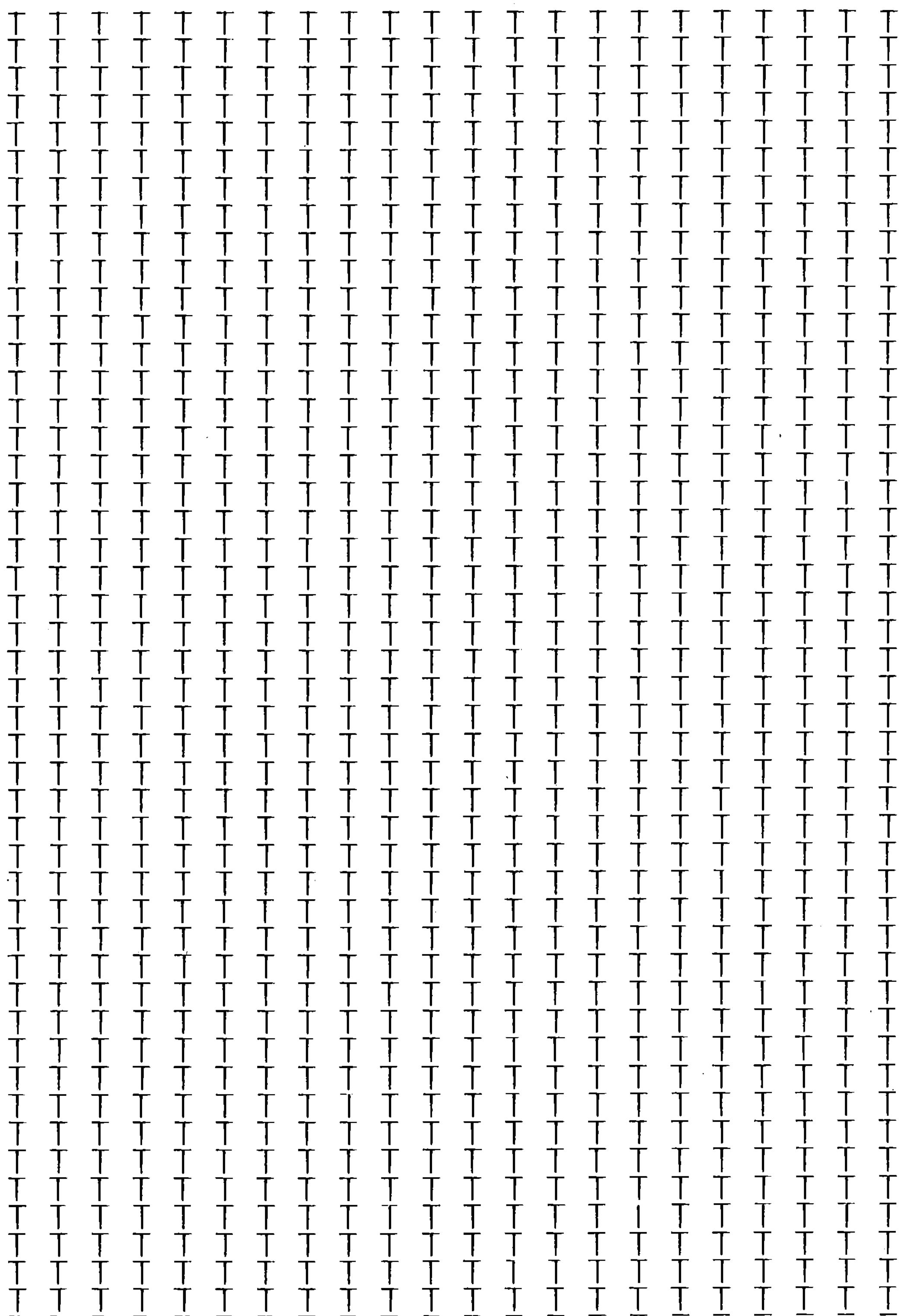
The energy costs of gestation have been estimated for several species of wild ruminants in Robbins and Moen (1975) by considering the costs for these species to be proportional to the costs for deer. Fetal weights and lengths of the gestation period vary, of course.

The equations for estimating ECGD for different species, modified modified from those in Robbins and Moen (1975), are listed below.

Species	Equation	LEGP
ceel:	ECGD = $(e^{0.0193\ \mathrm{DIGE}\ -\ 1.7938})(1/\mathrm{PEGE})$	260
alal:	ECGD = $(e^{0.0204\ \mathrm{DIGE}\ -\ 1.7358})(1/\mathrm{PEGE})$	245
rata:	ECGD = $(e^{0.0226\ \mathrm{DIGE}\ -\ 1.6198})(1/\mathrm{PEGE})$	220
anam:	ECGD = $(e^{0.0209\ \mathrm{DIGE}\ -\ 1.7140})(1/\mathrm{PEGE})$	240
bibi:	ECGD = $(e^{0.0173\ \mathrm{DIGE}\ -\ 1.9036})(1/\mathrm{PEGE})$	290
ovca:	ECGD = $(e^{0.0334\ \mathrm{DIGE}\ -\ 1.2443})(1/\mathrm{PEGE})$	150
oram:	ECGD = $(e^{0.0278\ \mathrm{DIGE}\ -\ 1.4281})(1/\mathrm{PEGE})$	180

Complete the numbering of the x and y axes and plot the energy costs of gestation on the grid on the next page. Note again that different physiological efficiencies may be expressed a a family of curves.

ECGD



DIGE =

LITERATURE CITED

Robbins, C. T. and A. N. Moen. 1975. Uterine composition and growth in pregnant white-tailed deer. J. Wildl. Manage. 39(4):684-691.

CHAPTER 7, WORKSHEET 3.3c

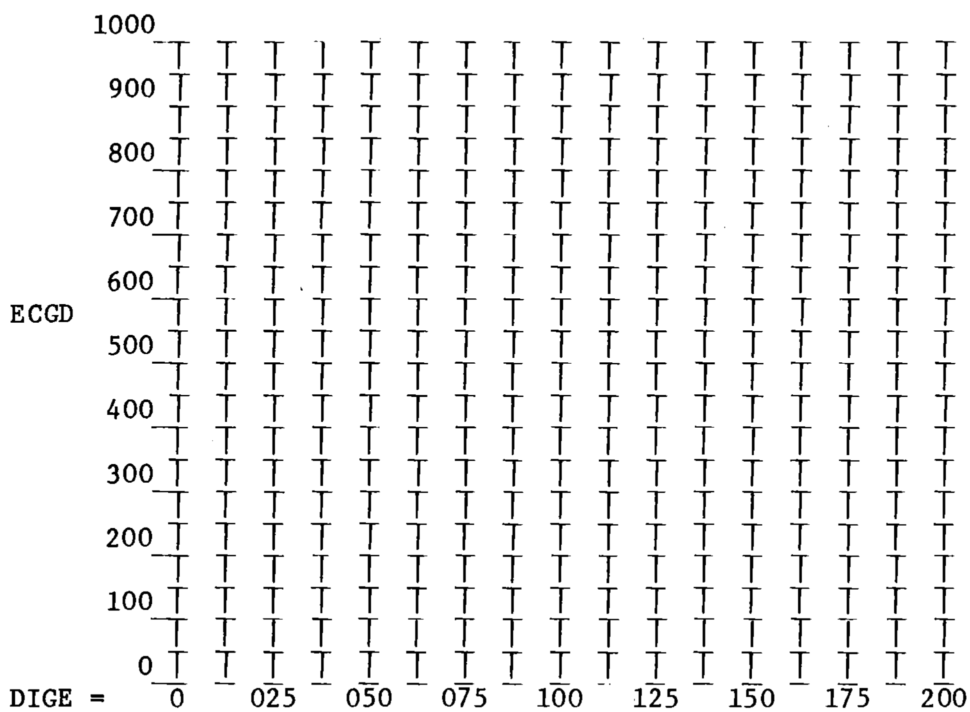
The energy costs of gestation in relation to days into gestation and fetal weight at birth

The two previous WORKSHEETS have included equations for selected species with averge fetal weights and gestation periods built into the equations. An alternative equation in Robbins and Moen (1975) may be used to provide the flexibility needed when applying the proportional costs to any species. The formula for calculating the energy contents of the uterus and contents (kcal) per fetal weight at parturition (kg) is:

$$\text{ECGD} = \Big\{ [e^{(2.1548 + 5.01\,(\text{HIGR DIGE/LEGP})}] - [e^{(2.1548 + 5.01(\text{LOWR DIGE/LEGP})} \Big\} (\text{BIWK}) / (\text{HIGR DIGE} - \text{LOWR DIGE})(1/\text{PEGE})$$

where ECGD = energy cost of gestation per day
HIGR DIGE = higher number of days into gestation
LOWR DIGE = lower number of days into gestation
LEGP = length of the gestation period
BIWK = birth weight in kg
PEGE = physiological efficiency of gestation

Make the calculations for selected species with different birth weights and evaluate the daily costs associated with gestation. The results may be plotted below.



LITERATURE CITED

Robbins, C. T. and A. N. Moen. 1975. Uterine composition and growth in pregnant white-tailed deer. J. Wildl. Manage. 39(4):684-691.

UNIT 3.4: THE ENERGY COST OF MILK PRODUCTION

Milk production has been mentioned several times already as a very costly biological process. One might come to this conclusion simply by observing the condition of lactating females; they are often in the worst condition of the year during the lactation period. The weight pattern shows minimum weights during the lactation period, and it is well known that if milk production of dairy cattle is to remain high, a high quality ration must be fed in large quantities.

If milk production is the most costly sustained biological process there is, then it is imperative that ways be found to quantify the cost. Direct measurements of milk production might be made by actually milking the animal, but this is difficult because wild ruminants are not inclined to stand while being milked. Further, milk production is partly dependent on the demand for milk, and this varies with the suckling young as they grow and their diet includes increasing amounts of forage. Since the demand of the young for milk cannot be duplicated by hand-milking the female, estimates of milk production obtained in this way will not be accurate.

Animals in captivity might be weighed before and after nursing, and either the dam's weight loss or the sucklings' weight gain measured. Scales sufficiently large to weigh the dam before and after nursing are not accurate enough to weigh the difference in her weights, however. The suckling animal often urinates and defecates while nursing--the dam usually licks the anal region to stimulate release--so accurate measurements of milk intake are difficult to make. Furthermore, it is difficult to be present to weigh the animals each time the young nurse, which could be several times a day.

The only practical way to determine milk production of wild ruminants is by mathematical means. There is a fundamental relationship that can be considered the basis for mathematical calculations, and that is that the milk production of the females of a species will be adequate to supply that portion of the nutrients derived from milk by the young of that species to meet their total metabolic costs for growth and activity. The amount of nutrients supplied by the milk varies as the rumen develops and the young become increasingly more dependent on forage for nutrients. This mathematical approach, then, requires a knowledge of three things, including the rate of rumen development so that the ratio of milk nutrients: forage nutrients is known, the chemical composition of the milk, and the ecological metabolism of the nursing young. These were discussed in earlier chapters, and they can be assembled here in WORKSHEETS to calculate the cost of milk production.

REFERENCES, UNIT 3.4

THE ENERGY COST OF MILK PRODUCTION

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRPFA	37--1	67	84	cerv	composi milk, cerv species	arman,p; kay,rnb/	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	24--4	439	441	odvi	rearing, breedi fawns, cap	murphy,da	1960
JWMAA	25--1	66	70	odvi	deer milk, substitute milk	silver,h	1961
JWMAA	29--1	79	84	odvi	comp milk,bld nursng doe,f	youatt,wg; verme/	1965
JWMAA	37--3	301	311	odvi	energ requiremnts of fawns	thompson,cb; hol/	1973
JWMAA	39--2	355	360	odvi	milk consumpt, weight gain	robbins,ct; moen,	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	37--2	217	218	odhe	composit, deer milk, calif	hagen,hl	1951
JOMAA	36--3	473	474	odhe	mule deer milk	browman,lg; sears	1955
JOMAA	58--3	420	423	odhe	changes nutri compos, milk	mueller,cc; sadle	1977
JWMAA	20--2	212	214	odhe	postnat grow, comp of milk	kitts,wd; cowan,/	1956
JWMAA	44--2	472	478	odhe	milk yield, black-tailed d	sadleir,rmfs	1980

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRPFA	37--1	67	84	ceel	comp, yield of milk, red d	arman,p; kay,rnb/	1974
JWMAA	40--2	330	335	ceel	nutrition, gestat, reprodu	thorne,et; dean,/	1976
ZTTFA	31--5	227	238	ceel	comp, milk, red deer, pt 1	brueggemann,j; d/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--2	213	215	alal	gros comp milk, fat, minrl	cook,hw; rausch,/	1970
JWIDA	12--2	202	207	alal	milk, hair, element relati	franzmann,aw; fl/	1976
NCANA	101-1	227	262	alal	review of energy requireme	gasaway,wc; coady	1974
PNUSA	27--2	129	138	alal	compar nut in preg, lactat	payne,pr; wheele/	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	45--6	1101	1106	rata	milk, gros comp, fat, prot	hatcher,vb; mcew/	1967
CJZOA	49--4	443	447	rata	measurement milk intake, r	mcewan,eh; white/	1971
JDSCA	57-11	1325	1333	rata	milk comp chang, grazing r	luick,jr; white,/	1974
ZOBIA	32--6	746	750	rata	alal, electroph, milk prot	shubin,pn; turub/	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	37--2	217	218	anam	odhe, compos milk, compars	hagen,hl	1951
JWMAA	34--4	908	912	anam	enrgy flux, water kinetics	wesley,de; knox,/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	36--2	305	308	bibi	the lipids in bison bison	wilbur,cg; gorski	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	41--2	131	143	ovca	rearing lambs in captivity	deming,ov	1955
CJZOA	43--5	885	888	ovca	milk, gross comp, fat cons	chen,ech; blood,/	1965

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--4	629	633	ovda	milk, stage lact, composit	cook,hw; perarso/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	34--6	569	571	obmo	gross composition of milk	tener,js	1956
CJZOA	48--6	1345	1347	obmo	gros comp,ftty acid, minrl	baker,be; cook,h/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	47--1	5	8	oram	gross compos, fat acid con	lauer,bh; blood,/	1969
CJZOA	47--2	185	187	oram	miner const, milk, arctic	luer,bh; baker,b	1969

CHAPTER 7, WORKSHEET 3.4a

The energy cost of milk production in white-tailed deer

The energy cost of milk production may be estimated if the quantity of milk being produced is known. Estimates of the latter may be made with an equation in Moen (1973:355), modified to include new terms and parameters. The formula is:

$$MPGD = [(MBLM)(70)(MEWK)]\ [(PNDM)(1/NECM)/GENM]$$

where MPGD = milk production in gms per day
MBLM = multiple of base-line metabolism
MEWK = metabolic weight in kg
PNDM = percent nutrients derived from milk = [1.136 - 0.045 LWKG]
NECM = net energy coefficient for milk
GENM = gross energy in the milk

The formula can be used only if numerical values for each of the paramaters are available. The first one needed, MBLM, has not been discussed in the ecological context yet (see TOPIC 6). The MBLM of resting fawns was usually between 2.10 and 2.25 (see CHAPTER 7, WORKSHEET 1.1a). The MBLM for ecological metabolism of suckling fawns is discussed in CHAPTER 7, UNIT 6.1. In the absence of a derived MBLM, MBLM = 2.5 may be used as a first approximation.

MEWK is the metabolic weight, or $IFWK^{0.75}$, where IFWK is the ingesta-free-weight of the fawns. Growth and weights were discussed in CHAPTER 1.

PNDM is an expression for determining the percent nutrients derived from milk, a function of rumen development. Derivation of this equation is discussed in Moen (1973:342).

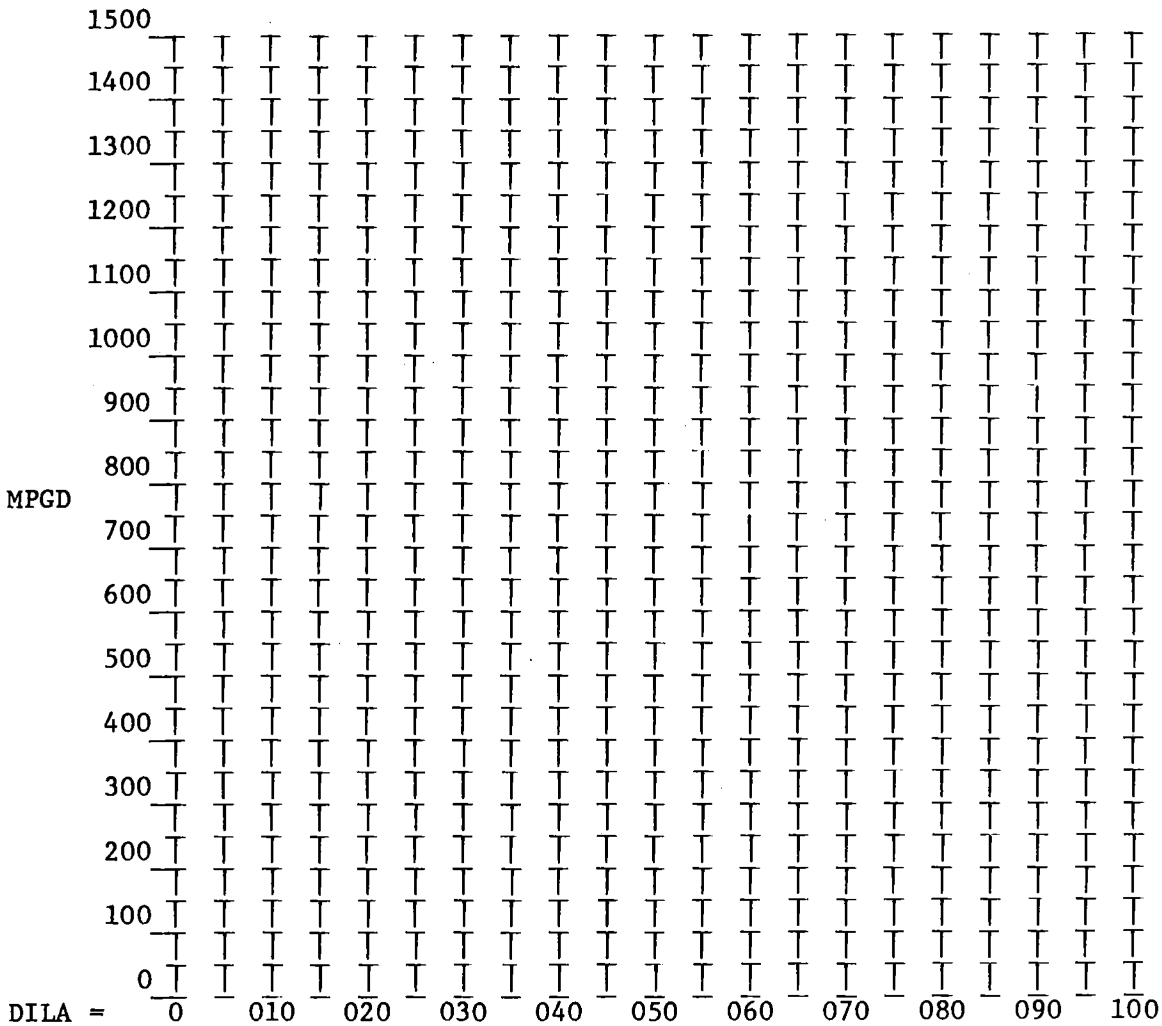
NECM is an expression of gross to net energy efficiency, including both the digestible energy and metabolizable energy coefficients.

GENM, the gross energy in the milk, may be measured directly or determined from the chemical composition of the milk, especially fat percent (FATP). FATP may be calculated with an equation derived from data in Youatt et al. (1965).

$$FATP = 1.036\ e^{(-1.0117)(DILA)};\ R^2 = 0.995$$

where FATP = fat percent and
DILA = days into lactation.

Using the equation in CHAPTER 2, WORKSHEET 2.2b, p. 46b, GENM may be estimated from FATP. MPGD may then be calculated by substituting these numbers and equations in the formula near the top of this WORKSHEET. A grid is provided on the next page for plotting the results.



LITERATURE CITED

Moen, A. N. 1973. Wildlife Ecology. W. H. Freeman and Co. San Francisco. 458 pp.

Youatt, W. G., L. J. Verme, and D. E. Ullrey. 1965. Composition of milk and blood in nursing white-tailed does and blood composition of their fawns. J. Wildl. Manage. 29(1):79-84.

TOPIC 4. ESTIMATES OF THE ENERGY COSTS OF ACTIVITIES

Every activity that an animal participates in has an energy cost associated with it. The movement of any mass for any distance involves work, and this is as true of wild ruminants as it is of man-made machines. Work is also involved in maintaining posture; muscles develop a tonus that permits animals to hold their heads erect, their ears in an alert position, stand, and other postures. While the holding of these postures my not involve motion, work is still being performed as the body is held in place against the force of gravity.

The energy costs of activities such as bedding, standing, walking, foraging, and running can be quantified with the use of the principles of physics involving the movement of mass over distance, and they may be calculated from oxygen consumption measurements. There are differences in efficiencies at different rates of movement, but such details have been analyzed for only two species of wild ruminants.

The energy costs of five different activities are discussed in the units that follow, with worksheets for calculating the costs for use in time and energy budget calculations.

REFERENCES, TOPIC 4

ESTIMATES OF THE ENERGY COSTS OF ACTIVITIES

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
aubo	acpr	loen	545	vert	scale effects in locomotio	pedley,tj,ed	1977

UNIT 4.1: THE ENERGY COST OF BEDDING

The energy costs of bedding may be approximated with the measurements of resting metabolism in relation to basal metabolism. This ratio provides a first approximation that can be conveniently applied to any animal, especially when evaluated in relation to base-line metabolism. There are differences due to posture, such as an erect head posture or a curled-up posture, but these details have not yet been discerned by experimentation.

The energy cost of bedding is a part of basal metabolism measurements. Animals then are at rest, and in a post-absorptive state in thermoneutral conditions. The measured heat production under basal conditions includes no heat of fermentation or heat of nutrient metabolism due to digestive processes, or extra heat production due to thermogenesis.

Resting metabolism of reindeer (rata) has been measured by White and Yousef (1978). Resting metabolism of two reindeer used in walking experiments varied markedly. A group of four adult females taken from late summer grazing had a resting metabolism of 125 $LWKG^{0.75}$ per day.

It is very important to realize that the resting metabolism of free-ranging animals also includes the costs of productive processes in progress. Thus the measured cost while resting is not the costs of resting alone.

Basal metabolism references and worksheets are given in UNIT 2.1, with WORKSHEET 4.1a in this UNIT illustrating how the activity costs of bedding can be calculated as a multiple of base-line metabolism.

LITERATURE CITED

White, R. G. and M. K. Yousef. 1978. Energy expenditure in reindeer walking on roads and on tundra. Can. J. Zool. 56(2):215-223.

REFERENCES, UNIT 4.1

THE ENERGY COST OF BEDDING

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	57--1	192	198	odvi	energy conservatio, winter	moen,an	1976

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JPHYA	194-1	22	248	ceel	energy metabolis, red deer	brockway,jm; malo	1967
JWMAA	43--2	445	453	ceel	energy expendi, elk calves	robbins,ct; cohe/	1979
JWMAA	43--2	564	567	ceel	postur, activ, metab, cold	gates,c; hudson,r	1979

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--2	391	392	rata	energ metab, jar gro carib	mcewan,eh	1970

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
AJPHA	178-3	515	516	oram	metabolism of mountai goat	krog,h; monson,m	1954

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JTBIA	49--2	345	362	mamm	model, est metab, rest, ac	wunder,ba	1975

Estimates of the energy cost of bedding

The energy cost of bedding may be considered equal to basal metabolism, because basal metabolism test results are expressed for animals at rest. The heat production of the free-ranging animal is expected to be higher, of course, since the heat of fermentation and heat of nutrient metabolism are present.

Calculations of the cost of bedding are easily made by multiplying base-line metabolism by the appropriate MBLM. If basal metabolism is considered equal to be the interspecific mean of 70 $W^{0.75}$, then the energy cost of bedding per day (ECBD) is:

$$ECBD = BMBL\ (70)(IFWK^{0.75})(FTBD)$$

where ECBD = energy cost of bedding per day,
BMBL = bedded multiple of base-line metabolism,
IFWK = ingesta-free weight in kg, and
FTBD = fraction of time bedded per day.

If basal metabolism is greater than the interspecific mean, it is still convenient to express ECBD as a multiple of base-line metabolism. Using the average value of basal/base-line ratio for deer, MBLM = 80/70 = 1.1 (see CHAPTER 7, UNIT 2.1). The equation for seasonal rhythms in basal metabolism expressed as MBLM may also be used; this is given in CHAPTER 7, UNIT 6.1.

Note that the fraction of time bedded per day (FTBD) is given in the equation above The intitial MBLM calculation is for a 24-hour period so FTBD, based on time budgets discussed in PART II, is used to allocate the portion of the day spent in bedded activity.

UNIT 4.2: THE ENERGY COST OF STANDING

The energy costs of standing have been measured for several species, both ruminants and non-ruminants. The cost of standing above lying is about 9% in man, cattle, and sheep (Crampton and Harris 1969:151). An increase of 9.7% in oxygen consumption was observed in a reindeer when standing compared to lying (White and Yousef 1978). Elk calves had standing metabolic rates of 137 to 161 $LWKG^{0.75}$ per day (Robbins et al. 1979). These are more than 9% higher than the expected basal rate, but it must be emphasized that the energy costs measured while standing also include the costs of productive processes. The total measured cost while standing is not only the cost of standing.

The energy costs of standing may be expressed as multiples of base-line metabolism. The multiple for man, cattle, and sheep (9% increase) would be 1.1. The costs of standing for domestic ruminants under controlled experimental conditions may be less than the costs for wild ruminants since standing by the latter may be accompanied by a state of alertness that contributes to the metabolic cost while standing. Some of the cost estimates for standing discussed by Robbins et al. (1979:451-452) seem unreasonably high; increase of more than 60% must be due to some experimental effects. The cost of standing should be considered as a physical cost, separate from the costs of alertness while standing.

LITERATURE CITED

Crampton, E. W. and L. E. Harris. 1969. Applied animal nutrition. W. H. Freeman and Co. San Francisco. 753 pp.

Robbins, C. T., Y. Cohen, and B. B. Davitt. 1979. Energy expenditure by elk calves. J. Wildl. Manage. 43(2):445-453.

White, R. G. and M. K. Yousef. 1978. Energy expenditure in reindeer walking on roads and on tundra. Can. J. Zool. 56(2):215-223.

REFERENCES, UNIT 4.2

THE ENERGY COST OF STANDING

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	57--1	192	198	odvi	energy conservatio, winter	moen,an	1976
JWMAA	34--2	431	439	odvi	wint feed patterns, penned	ozaga,jj; verme,l	1970
JWMAA	42--4	715	738	odvi	seas chan, heart rate, act	moen,an	1978

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JPHYA	194-1	22	248	ceel	energy metabolis, red deer	brockway,jm; malo	1967
JWMAA	43--2	445	453	ceel	energy expendi, elk calves	robbins,ct; cohe/	1979
JWMAA	43--2	564	567	ceel	postur, activ, metab, cold	gates,c; hudson,r	1979

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--2	391	392	rata	energ metab, bar gro carib	mcewan,eh	1970
CJZOA	56--2	215	223	rata	energy expend, walk, tundr	white,rg; yousef,	1978

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			

CHAPTER 7 - WORKSHEET 4.2a

Estimating the energy cost of or while standing

Estimates of the energy cost of standing may be made by using MBLM for standing as the measure of the cost of standing. If this MBLM is applied to free-ranging animals, it should either contain concomitant costs of production, or the value of MBLM should be supplemented by additional costs of production. The important point is that a distinction must be made when calculating the costs <u>of</u> standing or <u>while</u> standing.

The costs <u>of</u> standing may be expressed with MBLM = 1.1 or slightly higher. The costs <u>while</u> standing, based on measurements of wild ruminants on *ad libitum* diets, were as high as 2.3, based on data (161/70 = 2.3) in Robbins *et al.* (1979:447). If the former is used, production costs are to be added. If the latter, they are a part of the direct measurement.

Another necessary parameter when calculating the cost of standing is the fraction of time spent standing each day (FTSD). This is necessary because the base-line metabolism approach is on a 24-hour basis. Thus, the formula for determining the energy cost of standing per day is:

$$ECSD = (SMBL)(70)(IFWK^{0.75})(FTSD)$$

where ECSD = energy cost of standing per day,
SMBL = standing multiple of base-line,
IFWK = ingesta-free weight in kg, and
FTSD = fraction of time standing per day.

Since there are variables in the formula dependent on the species, weights, time of year, and other factors unique to the situation being evalauted, equations are left for you, the user, to derive. An unlabeled grid is provided for plotting results.

LITERATURE CITED

Robbins, C. T., Y. Cohen, and B. B. Davitt. 1979. Energy expenditure by elk calves. J. Wildl. Manage. 43(2):445-453.

UNIT 4.3: THE ENERGY COST OF WALKING

Walking, defined as locomotion resulting when no more than two of the hooves are off the ground at one time, involves the movement of mass over distance at a fairly slow rate of speed. Walking on the level is composed of movement in one plane (the horizontal), and walking uphill involves movement in two planes (horizontal and vertical).

Horizontal. The energy cost of walking may be calculated if the mass of the animal and the distance traveled are known. Equations for different species were evaluated and summarized in Moen (1973:356). More recently, direct measurements of oxygen consumption by adult reindeer and elk calves have been made by White and Yousef (1978) and Robbins et al. (1979), respectively. Oxygen consumption of reindeer walking on the horizontal was 14% higher than estimated for several smaller mammals by Taylor et al. (1970). Energy expenditures of elk calves were also higher than that predicted with equations in Taylor et al. (1970). The Taylor estimates should not be considered an interspecies mean, however, since too few animals and species were represented. Robbins also reported that the energy expenditure was a direct linear function of the speed of travel, as was oxygen consumption by adult female reindeer (White and Yousef 1978).

Vertical. The vertical component of the topography adds greatly to the cost of locomotion. Measurements have not been made on species which live on rugged topography, such as mountain goats, and those which live on more level terrain, such as pronghorn. The reindeer and elk experiments mentioned above also included measurements on different gradients. The energy cost of climbing was determined for reindeer by measuring oxygen consumption on the incline and subtracting the consumption measured on the horizontal. The energy cost of descent was determined in the same way, resulting in an estimate of locomotion downhill that was less than that on the horizontal. A similar relationship was observed for the elk calves.

The costs of locomotion at different speeds and on different gradients is of ecological interest because of potential energy costs associated with activities on different topographies. Patterns of energy conservation are discussed for white-tailed deer in Moen (1976). The extent of such differences may be estimated by calculating the costs of movements of different speeds and distances by species on different topographies, and by quantifying the behavior patterns of the species and calculating the daily costs of all activities. While the cost of movement may be more costly on rugged topography, it may be compensated for by adjustments in the time spent in different activities.

LITERATURE CITED

Moen, A. N. 1973. Wildlife ecology. W. H. Freeman and Co., San Francisco. 458 pp.

Moen, A. N. 1976. Energy conservation by white-tailed deer in the winter. Ecology 57(1):192-198.

Robbins, C. T., Y. Cohen, and B. B. Davitt. 1979. Energy expenditure by elk calves. J. Wildl. Manage. 43(2):445-453.

Taylor, C. R., K. Schmidt-Nielsen, and J. L. Raab. 1970. Scaling of energetic cost of running to body size in mammals. An. J. Physiol. 219:1104-1107.

White, R. G. and M. K. Yousef. 1978. Energy expenditure in reindeer walking on roads and on tundra. Can. J. Zool. 56(2):215-223.

REFERENCES, UNIT 4.3

THE ENERGY COST OF WALKING

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	57--1	192	198	odvi	energy conservatio, winter	moen,an	1976
JWMAA	42--4	715	738	odvi	seas chan, heart rate, act	moen,an	1978

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	23-22	365	370	ceel	energy cost of locomotion	gates,c; hudson,r	1978
CBPAB	61A-1	43	48	ceel	oxy util, horiz, vert loco	cohen,y; robbins/	1978
JWMAA	43--2	445	453	ceel	energy expendi, elk calves	robbins,ct; cohe/	1979
JWMAA	43--2	564	567	ceel	postur, activ, metab, cold	gates,c; hudson,r	1979
QJEPA	62--4	333	340	ceel	ener cost locom level, gra	brockway,jm; ges/	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	57-11	2153	2159	alal	morph param affec loco,sno	telfer,es; kelsa/	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	56--2	215	223	rata	energy expend, walk, tundr	white,rg; yousef,	1978

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BJNUA	18--1	47	54	dosh	ener metab, walk lev, grad	clapperton,jl	1964
PNUSA	20--	xxxi	xxxii	dosh	ener exp, walk, lev, gradi	clapperton,jl	1961

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRMGA	27--6	437	443	rumi	physiol, ener expen, pastu	osuji,po	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBPAB	34A-4	841	846	many	energetic cost, locomotion	tucker,va	1970

CHAPTER 7, WORKSHEET 4.3a

Estimates of the energy cost of walking based on weight and gradient

Estimates of the energy cost of walking may be made based on data for domestic sheep, where the costs are calculated as a function of weight, distance, and height. Equations given in Moen (1973:356), modified with different symbols here, are:

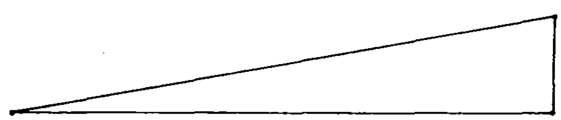
$$ECWL = (0.59)(LWKG)(DSTK)$$

$$ECVA = (6.45)(LWKG)(HGTK)$$

where ECWL = energy cost of walking on the level,
LWKG = live weight in kg,
DSTK = distance in kilometers,

ECVA = energy cost of vertical ascent and,
HGTK = height ascended in kilometers.

Suppose an animal weighed 60 kg and walked a distance of 4 horizontal km at 4 km per hour on a 10% gradient as indicated in the drawing below.



The equations are:

$$ECWL = (0.59)(60)(4.0) = 141.60$$

$$ECVA = (6.45)(60)(0.4) = 154.8,$$

and the total cost is 296.4 kcal.

How does this relate to MBLM? Multiply 296.4 by 24 to get the cost on a daily basis. The answer is 7113.6 kcal per day. Divide by base-line metabolism: $7113.6/(70)(60^{0.75}) = 4.71 = MBLM$. This is a rather high cost, and could not be sustained for long. If the rate of speed were cut in half (2 hours rather than 1 hour of walking time), then 148.2 kcal per hour 3556.8 and MBLM = 2.36. A further reduction in speed of travel at 1 km per hour would reduce the cost to 74.1 kcal per hour. Base-line metabolism is

62.9 kcal per hour, so the cost of walking 1 km per hour and ascending vertically a total of 10% of the horizontal distance plus the cost of base-line metabolism (or basal if you wish) is, in this case 74.1 + 62.9 = 137 kcal, 137/70 = 1.96 = MBLM.

Note how the example on the previous page allows for differences in the rate of speed. Variations in vertical ascent were not evaluated. New variables may be used and different combinations evaluated. The calculation of MBLM is always a good idea because of the large amount of evidence for upper limits to ecological metabolism as discussed in UNIT 6.1 of this CHAPTER.

LITERATURE CITED

Moen, A. N. 1973. Wildlife Ecology. W. H. Freeman and Co. San Francisco. 458 pp.

Estimates of energy expenditure of elk calves at different speeds on different upslopes

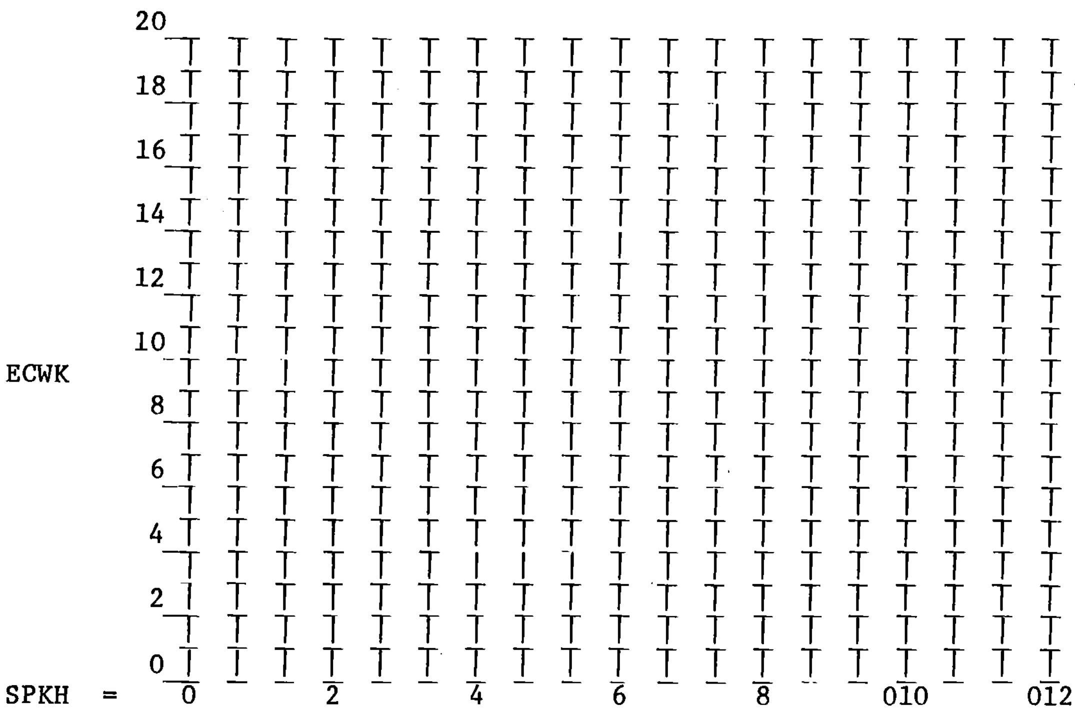
Measurements of the enegy expenditure of elk calves at different speeds on three diffferent slopes were made by Robbins et al. (1979). The energy expenditures per kg per hour on three different slopes were graphed in Figure 1, but no equations wer presented for these results. A single equation may be derived for locomotion upslope by first determining linear regression equations for each of the slopes (11.7, 4.2, 0°). The a and b values in these equations are then expressed with equations. The a values are best fit with exponential regression equations, and the b values with linear regression equations. The final, overall equations are:

$$ECWU = 3.28599\, e^{0.01660\,(SLPD)} + [0.97296 + 0.05722\,(SLPD)]\, SPKH$$

$$ECWD = 3.18453\, e^{0.01741\,(SLPD)} + [0.96953 + 0.02381\,(SLPD)]\, SPKH$$

where ECWU = energy cost of walking upslope in kcal per kg per hour,
SLPD = slope in degrees,
SPKH = speed in km per hour and,
ECWD = energy cost of walking downslope in kcal per kg per hour.

Calculate several combinations of speed and slope and plot below. Different slopes may be convienently represented as a family of curves.



LITERATURE CITED

Robbins, C. T., Y. Cohen, and B. B. Davitt. 1979. Energy expenditure by elk calves. J. Wildl. Manage. 43(2):445-453.

CHAPTER 7, WORKSHEET 4.3c

The energy cost of walking for reindeer (rata)

Measurements of oxygen and consumption by reindeer waling on roads or on tundra have been made by White and Yousef (1978). Their results are expressed as equations for oxygen consumption Table 1, p. 217. Using the energy equivalent of oxygen consumed in relation to the respiratory quotient (see CHAPTER 7, UNIT 2.2, WORKSHEET 2.2a, p. 32a), a respiratory quotient of 0.85 may be used if a specific REQO is not available, calculate the energy cost for each of the several experimental conditions. Body weights are also given in Table 1, so MBLM may be calculated.

Complete the calculations and compare these costs of walking calculated in WORKSHEETS 4.3a and 4.3b. Keep in mind that these direct measurements are for all of the metabolic processes of reindeer while walking.

LITERATURE CITED

White, R. G. and M. K. Yousef. 1978. Energy expenditure in reindeer walking on roads and on tundra. Can. J. Zool. 56(2):215-223.

UNIT 4.4: THE ENERGY COST OF FORAGING

The costs of foraging are quite variable due to the differences in the styles of foraging and in the terrain inhabited by different wild ruminants. Pronghorn, for example, live in a rather sparsely vegetated habitat and cover large land areas as their home range. Forage density is much less than one finds on white-tailed deer range in the northeastern states where deciduous forests are interspersed with farms. Sheep and goats live in rugged areas with rather sparse forage densities too, and foraging for these species may be more costly than for pronghorn or deer.

Measurements of the energy costs of foraging have not been made for free-ranging ruminants. The use of oxygen consumption masks, as for the measurements on reindeer and elk discussed in the two previous units, prohibits foraging, of course. Tracheal cannulae have apparently not been tried on wild ruminants.

A single value, for the cost of foraging, based on data for grazing domestic sheep and expressed as a multiple of base-line metabolism, is given in Moen (1973:356). Such approximations are often necessary because of the lack of measured data on free-ranging wild ruminants due to the technical difficulties involved in the measurements. A WORKSHEET provides opportunities to estimate the energy cost of foraging.

LITERATURE CITED

Moen, A. N. 1973. Wildlife ecology. W. H. Freeman and Co., San Francisco. 458 pp.

REFERENCES, UNIT 4.4

THE ENERGY COST OF FORAGING

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	57--1	192	198	odvi	energy conservatio, winter	moen,an	1976
JWMAA	34--2	431	439	odvi	wint feed patterns, penned	ozoga,jj; verme,l	1970
JWMAA	42--4	715	738	odvi	seas chan, heart rate, act	moen,an	1978

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	43--2	564	567	ceel	postur, activ, metab, cold	gates,c; hudson,r	1979

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--2	391	392	rata	energ metab, bar gro carib	mcewan,eh	1970
CJZOA	48--5	905	913	rata	seas chan, energ, nit inta	mcewan,eh; whiteh	1970

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
ATRLA	23-21	359	363	ovca	energ costs feedin, roc mt	chappel,rw; hudso	1978

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AFBUD	.....	38	39	doca	energy cost, ingestin feed	adam,i; young,ba/	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJAEA	15--6	969	973	dosh	energ cost, feed act, graz	graham,nc	1964
AJAEA	17--3	355	362	dosh	energy expend, resp, feedi	young,ba	1966
PAANA	7----	327	334	dosh	ener req, grazi, calorimet	young,ga; corbet	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRMGA	27--6	437	443	rumi	physiol, ener expen, pastu	osuji,po	1974

CHAPTER 7, WORKSHEET 4.4a

Estimating the energy cost of foraging

The energy cost of foraging may be estimated with a simple mathematical relationship given in Moen (1973:356). The equation given is $(0.54)(W_{kg})$ the rate per hour. Multiplying by 24 to convert to a 24-hour period and using 4-letter symbols, the equation is:

$$ECFD = (12.96)(LWKG)(FTFD)$$

where ECFD = energy cost of foraging per day,
LWKG = live weight in kg, and
FTFD = fraction of time foraging per day.

The result does not include maintenance costs; ECFD is for the cost of foraging alone and not the other concomitant productive processes.

Note that the fraction of time spent foraging per day is part of the calculation. These fractions were discussed in PART II, and need to be considered again here.

Convert the estimates to MBLMs again. Note that foraging costs less than walking at the rate of 1 km per hour. Foraging is intermittent standing and walking.

LITERATURE CITED

Moen, A. N. 1973. Wildlife Ecology. W. H. Freeman and Co. San Francisco. 458 pp.

UNIT 4.5: THE ENERGY COST OF RUNNING

Running is a highly variable cost due to the different velocities possible, but a small contributor to the daily energy expenditure of wild ruminants because only a small fraction of each day is spent running. The cost of running may be determined from estimates, or calculated with the heart rates or respiration rates and converted to estimates of metabolism, and expressed as multiples of base-line metabolism. Since muscle artifacts often interfere with the telemetered ECG signal, heart rates of running animals are difficult to obtain. It may be that multiples from 6 to 20 times base-line metabolism have to be chosen as estimates simply because measured values are unavailable.

REFERENCES, UNIT 4.5

THE ENERGY COST OF RUNNING

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	57--1	192	198	odvi	energy conservatio, winter	moen,an	1976
JWMAA	42--4	715	738	odvi	seas chan, heart rate, act	moen,an	1978

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	23-22	365	370	ceel	energy cost of locomotion	gates,c; hudson,r	1978
CBPAB	61A-1	43	48	ceel	oxy util, horiz, vert loco	cohen,y; robbins/	1978
JWMAA	43--2	445	453	ceel	energy expendi, elk calves	robbins,ct; cohe/	1979
JWMAA	43--2	564	567	ceel	postur, activ, metab, cold	gates,c; hudson,r	1979
QJEPA	62--4	333	340	ceel	ener cost locom level, gra	brockway,jm; ges/	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	57-11	2153	2159	alal	morph param affe loco, sno	telfer,es; kelsa/	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	56--2	215	223	rata	energy expend, walk, tundr	white,rg; yousef,	1978

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJPHA	219-4	1104	1107	mamm	energy cost run, body size	taylor,cr; schmi/	1970
CBPAB	34A-4	841	846	many	energetic cost, locomotion	tucker,va	1970
SCIEA	178--	1096	1097		runni up, down hills: size	taylor,cr; caldw/	1972

CHAPTER 7 - WORKSHEET 4.5a

Estimates of the energy costs of running

The cost of running is quite variable, depending on the speed. The cost of locomotion of elk calves at 12 km per hour on 0° slope (Robbins et al. 1979) has an MBLM of 13 to 14. The range of multiples--6 to 20--given on page 63 indicates wide possibilities for errors. Actual errors on a daily cost basis are small, however, since running can take up only a very small fraction of each day. Thus the suggested formula is:

$$ECRD = (RMBL)(70)(IFWK^{0.75})(FTRD)$$

where ECRD = energy cost of running per day,
RMBL = running multiple of base-line metabolism,
IFWK = ingesta-free weight in kg, and
FTRD = fraction of time spent running each day.

A running time of 10 minutes per day is less than 1% of the daily time budget, so larger variations in MBLM are offset by small possibilities for error in FTRD.

Complete calculations of ECRD for different combinations of RMBL and FTRD. Use data in PART II on time budgets to establish realistic limits to FTRD and evaluate the possible errors of estimation. Once the costs of all activities are added up, errors in ECRD will be found to be small.

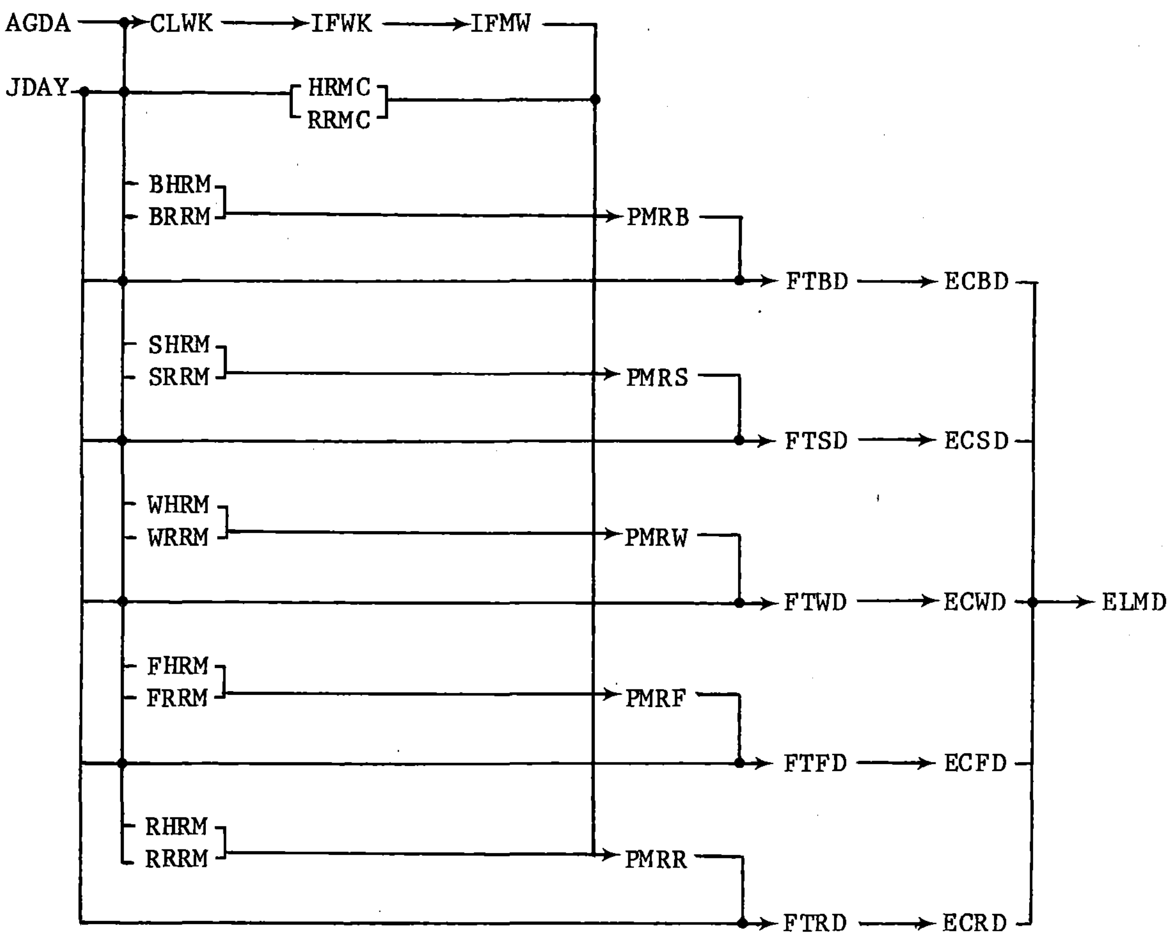
LITERATURE CITED

Robbins C. T., Y. Cohen, and B. B. Davitt. 1979. Energy expenditure by elk calves. J. Wildl. Manage. 43(2):445-453.

TOPIC 5. VITAL SIGN: METABOLISM RELATIONSHIPS

Vital signs of free-ranging animals are difficult enough to measure, but measurement of the metabolism of wild, free-ranging ruminants is essentially impossible. Estimates of the ecological costs of living are absolutely essential for calculating energy relationships within populations and systems, however, so methods for making such estimates must be found.

The use of equations to convert data on vital signs to estimates of metabolism is often criticized due to a lack of accuracy. It may, however, be the only practical way to get estimates for long time periods. The patterns of metabolism estimates based on vital signs may give one considerable insight into variations from one season to another through the annual cycle. Conversion of heart rates to estimates of the energy cost of activity follows the sequence of calculations illustrated in the figure below, based on Moen (1978). Respiration rates are added to the sequence to illustrate how heart rates and respiration rates may be used either alone or together. Definitions of the symbols are given on the next page.



DEFINITIONS OF SYMBOLS USED IN THE FLOW CHART ON THE PREVIOUS PAGE

AGDA = age in days

BHRM = bedded heart rate per minute
BRRM = bedded respiration rate per minute

CLWK = calculated live weight in kg

ECBD = energy cost of bedding per day
ECFD = energy cost of foraging per day
ECRD = energy cost of running per day
ECSD = energy cost of standing per day
ECWD = energy cost of walking per day
ELMD = ecological metabolism per day

FHRM = foraging heart rate per minute
FRRM = foraging respiration rate per minute
FTBD = fraction of time bedded per day
FTFD = fraction of time foraging per day
FTRD = fraction of time running per day
FTSD = fraction of time standing per day
FTWD = fraction of time walking per day

HRMC = heart rate to metabolism conversion factor

IFMW = ingesta-free metabolic weight
IFWK = ingesta-free weight in kg

JDAY = Julian day

PMRB = predicted metabolic rate bedded
PMRF = predicted metabolic rate foraging
PMRR = predicted metabolic rate running
PMRS = predicted metabolic rate standing
PMRW = predicted metabolic rate walking

RHRM = running heart rate per minute
RRRM = running respiration rate per minute

SHRM = standing heart rate per minute
SRRM = standing respiration rate per minute

WHRM = walking heart rate per minute
WRRM = walking respiration rate per minute

The energy costs of activities can be predicted with a sequence of equations that relate heart rate, metabolism, and behavior. Heart rates observed during specific activities (See CHAPTER 6, UNIT 2.1) are calculated first Then heart rate is converted to metabolism (See UNIT 5.2), and the results multiplied by the metabolic weight. This results in a 24-hour estimate of energy metabolism for a specific activity. Since an animal does not spend 24 hours a day in any one activity, the 24-hour cost is multiplied by the fraction of time spent in each activity per day (See CHAPTER 4). The daily costs of each activity are then added together to determine ecological metabolism per day (ELMD).

Two inputs--AGDA and JDAY--are necessary for the calculations. Both are used to calculate live weight (CLWK), which is converted to ingesta-free weight (IFWK) and ingesta-free metabolic weight (IFMW) = $IFWK^{0.75}$). The Julian day (JDAY) is then used to calculate the heart rates and respiration rates in each of the activities, followed by the heart rate-to-metabolism conversion factor, HRMC, discussed in the WORKSHEET that follows, and the respiration rate-to-metabolism conversions factor RRMC (See WORKSHEET that follows).

Metabolic body weight, heart beats per minute, and the heart rate-to-metabolism conversion factor are then combined to estimate the metabolism of the animal for a 24-hour period of time in each of the five activities listed. These 24-hour estimates are then multiplied by the fractions of time in each of the five activities (determined from JDAY) to determine the energy cost of bedding per day (ECBD), energy cost of standing per day (ECSD), energy cost of walking per day (ECWD), energy cost of foraging per day (ECFD), and the energy cost of running per day (ECRD) throughout the year. The sum of these costs is the ecological metabolism per day (ELMD). Maintenance costs are included, however, since heart beats during activities also support the biological functions that provide for tissue maintenance.

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.

REFERENCES, TOPIC 5

VITAL SIGN: METABOLISM RELATIONSHIPS

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS------------------	AUTHORS/EDITORS--	YEAR
edbo	acpr	nyny	427	many	comprtv nutritn wild anims	crawford,ma,ed	1968
aubo	hutc	loen	332	rumi	energy metabo of ruminants	blaxter,kl	1967
aubo	wile	nyny	184	rumi	metabolism in the ruminant	annison,ef; lewis	1959
edbo	jdve	zusw	259	doca	energ met farm anims; symp	schurch,a,ed; wen	1978

UNIT 5.1: BODY TEMPERATURES

Body temperatures are indicators of the metabolic rate in relation to that expected under current conditions. Low body temperatures indicate depressed metabolism and hypothermia. High body temperatures indicate either elevated metabolism or a breakdown of heat loss mechanisms. Elevated metabolism may be due to infections, or to prolonged activity. Body temperatures are useful indicators of general body condition, but not of the absolute levels of metabolism. Temperatures are the effect rather than the cause.

Measurements of body temperatures are most often made in the rectum, representing a deep body temperature. Variations in temperatures do occur over different parts of the body, and the locations of measurements should be noted, especially when sites other than the rectum are involved.

REFERENCES, UNIT 5.1

BODY TEMPERATURES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
APAVD	1976	185	194	odvi	succinylcholine in deer	kitchen,h	1976
JWMAA	40--4	626	629	odvi	predic metab rat, heart ra	holter,jb; urban/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	19--1	154	155	odhe	normal temperat, colum btd	cowan,im; wood,a	1955

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	39--3	634	636	alal	physiol effec, m-99 etorph	roussel,ye; paten	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	43--5	683	687	rata	body temp, barren ground c	mcewan,eh; wood,/	1965

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	56--3	697	698	anam	normal body temp, mule de	thorne,et	1975
JWMAA	35--4	747	751	anam	telemetry syst, body tempe	lonsdale,em; bra/	1971

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWIDA	7---2	105	108	ovca	comp phys vals, capt & wld	franzmann,aw;	1971
JWMAA	35--3	488	494	ovca	variation rectal temperatu	franzmann,aw; heb	1971
JWMAA	36--3	924	932	ovca	physiologc vals, env varia	franzmann,aw	1972

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BJNUA	21--3	769	785	dosh	cont measure heart rate in	webster,ajf	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	22--1	3	24	caca	energy metabolism, roe dee	weiner,j	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JPHYA	176--	136	144		deep bod temp 12-month per	bligh,j; ingram,/	1965
JWMAA	34--4	921	925	ungu	radio-telem, temp, unrestr	mcginnis,sm; fin/	1970

UNIT 5.2: HEART RATE-TO-METABOLISM CONVERSIONS

Relationships between heart rates and metabolic rates have been determined under controlled conditions for several species. The general pattern of increased heart rate: increased metabolism is clear, but the application of a general equation to individuals is not good due to wide variability between individuals. Some, for example, have larger hearts and greater stroke volumes than others, so their heart rates are less per unit metabolism. Some have higher overall rates of metabolism, and some have different ratios of heart rate: metabolism due to differences in vascular resistances and the efficiencies of gas exchange.

The most complete set of simultaneous measurements of heart rate and metabolic rate has been made by Holter et al. (1976) on white-tailed deer. Seasonal effects were statistically significant. No statistically significant effects on metabolic rate of sex or nutrition level, or of sex x season, nutrition level x season, or sex x nutrition level interactions were found. They presented four linear regression equations--for summer, fall, winter, and spring--for calculating metabolic rate from heart rate.

Seasonal differences in the heart rate:metabolic rate relationships for an animal must involve gradual shifts through the annual cycle. The use of four separate equations in data analyses would result in a discontinuity at the beginning of each season. Accordingly, the four separate equations were combined into a single eqution by expressing the a values and the b values as single equations for a and b rather than as seasonal constants. This is discussed in Moen (1978:723). The resulting equation is presented in WORKSHEET 5.2a.

Heart rate:energy expenditure relationships are discussed by Robbins et al. (1979) for elk calves, but an equation is not given for their data in Figure 5 (p. 451). They point out the large amount of variability in the relationship, but this variability may be due as much or even more to transient effects on heart rate of their animals while outside as to a fundamental physiological difference in the heart rate:metabolic rate relationships.

Careful interpretation of heart rates is necessary. Heart rate transients due to known stimuli may be pronounced (Moen et al. 1978 and Moen and Chevalier 1977), resulting in wide fluctuations in heart rates. The effects of such transients were eliminated in the measurements described in Moen (1978), resulting in distinct seasonal patterns to both heart rate and metabolism that would have been much more difficult to recognize if random samples of heart rates without behavioral observations had been made.

LITERATURE CITED

Holter, J. B., W. E. Urban, Jr., H. H. Hayes, and H. Silver. 1976. Predicting metabolic rate from telemetered heart rate in white-tailed deer. J. Wildl. Manage. 40(4):626-629.

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. 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., 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.

Robbins, C. T., Y. Cohen, and B. B. Davitt. 1979. Energy expenditure by elk calves. J. Wildl. Manage. 43(2):445-453.

REFERENCES, UNIT 5.2

HEART RATE-TO-METABOLISM CONVERSIONS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
APAVD	1976	185	194	odvi	succinylcholine in deer	kitchen,h	1976
JWMAA	40--4	626	629	odvi	predic metab rat, heart ra	holter,jb; urban/	1976
JWMAA	42--4	715	738	odvi	seas chan, heart rate, act	moen,an	1978

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

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	56--2	215	223	rata	energy expend, walk, tundr	white,rg; yousef,	1978

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BJNUA	21--3	769	785	dosh	cont meas heart rat indi e	webster,ajf	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	22--1	3	24	caca	energy metabolism, roe dee	weiner,j	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJCNA	22---	696	700	many	heart-rate tel, energ, man	bradfield,rb; hu/	1969
ATRLA	16--1	1	21		metabo levels, homeotherms	poczopko,p	1971
CJBIA	38-11	1301	1309		pulse rate, meta rate, man	booyens,j· hervey	1960
JAPYA	14--6	927	936		oxy inta, heart, work, man	wyndham,ch; stry/	1959
JAPYA	26--3	297	302		energy exp, work, hear rat	datta,sr; ramanat	1969

CHAPTER 7, WORKSHEET 5.2a

Heart rate to metabolism conversions for white-tailed deer

The heart rate to metabolism conversion equation in Moen (1978:723), modified to include four-letter symbols is given below.

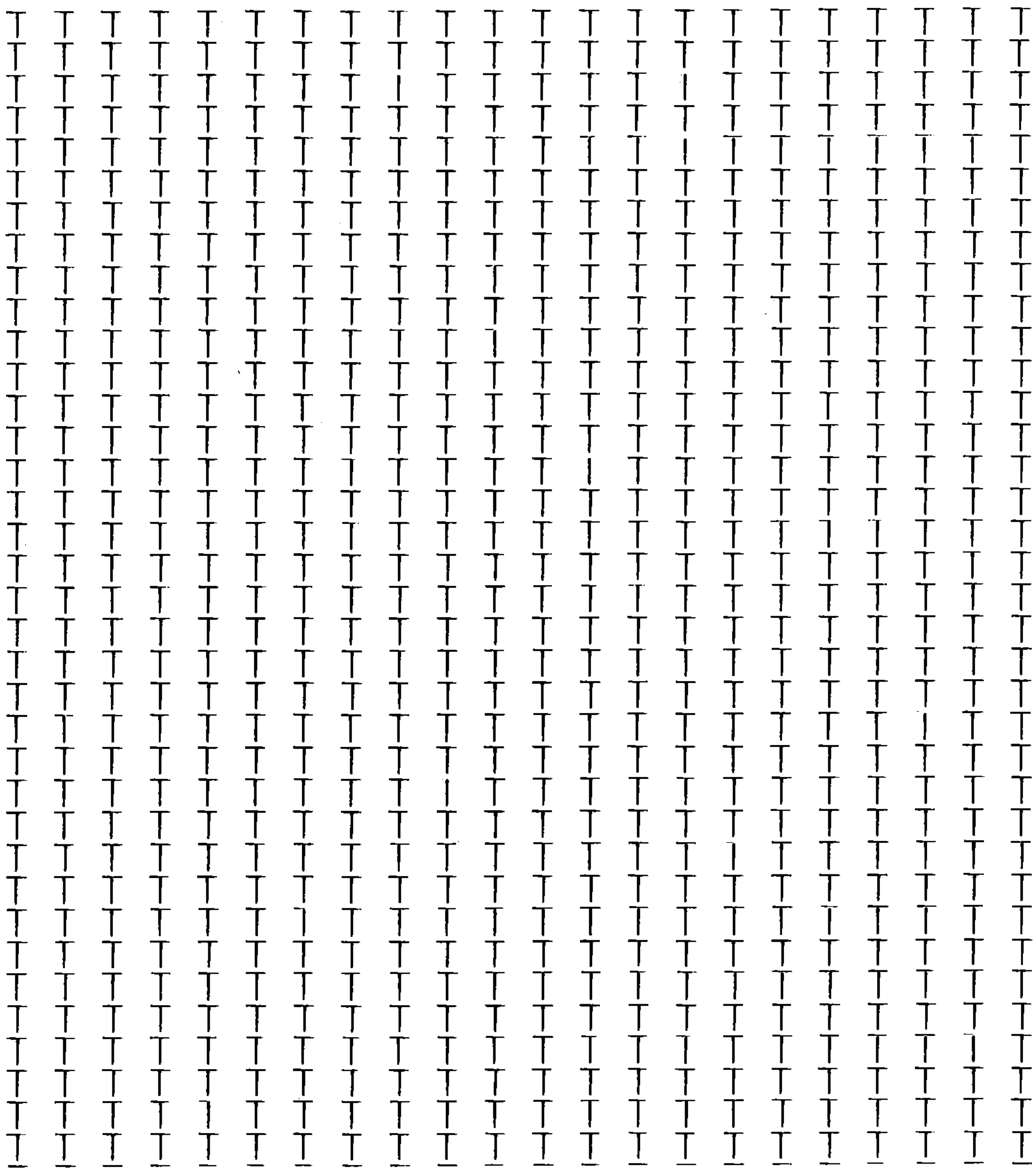
$$\text{MRMW} = \{-0.92 \sin[(\text{JDAY})(0.9863) + 74] - 0.005 + 2.3\} \text{ HRPM } + \{31.9 \sin[(\text{JDAY})(0.9863) + 74] + 0.087 + 0.55\}$$

where MRMW = metabolic rate per unit metabolic weight = metabolic rate in $\text{kcal}/W_{kg}^{0.75}$,
JDAY = Julian day, and
HRPM = heart rate per minute.

The 0.9863 is the day-to-degree conversion factor (360/365 = 0.9863).

A nomogram or a table of MRMW values would be useful for later reference and calculations. Verify the equation and complete a nomogram on the grid on the next page where JDAY is on the x-axis, MRMW is on the y-axis, and HRPM a family of curves (30, 40...100) for example, or set up a table as indicated below.

HRPM =	30	40	50	60	70	80	90	100	110	120	------->
	1										
	8										
JDAY =	15										
	22										
	29										
	.										
	.										
	.										
	365										
MRMW =											



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.

CHAPTER 7, WORKSHEET 5.2b

Heart rate-to-metabolism conversions for elk calves

The relationships between energy expenditures and heart rates of five elk calves were plotted by Robbins et al. (1979:451; Fig. 5). Four of the five were quite similar. Using a grid overlay, estimate the x-y pairs for these four and derive a linear regression equation for these data. Remember that such an equation can be easily derived with hand calculations described in CHAPTER 2, UNIT 1.2, WORKSHEET 1.2b, p. 10b).

Compare the results above with those calculated in the previous WORKSHEET. Keep in mind that these are for a different species, different ages and for only a 2-month experimental period (summer).

Comparisons like those suggested above help one understand both biological and mathematical concepts, and understanding is fundamental to syntheses of ecological pictures.

LITERATURE CITED

Robbins, C. T., Y. Cohen, and B. B. Davitt. 1979. Energy expenditure by elk calves. J. Wildl. Manage. 43(2):445-453.

UNIT 5.3: RESPIRATION RATE-TO-METABOLISM CONVERSIONS

Relationships between external respiration rates and metabolism are somewhat predictable since oxygen, supplied by external respiration, is necessary for metabolism. As activity levels increase, respiration rates increase, though not necessarily in direct proportion since volumes of air respired also change. Respiration and heart rates combined should be a better predictor of metabolism than either one alone.

Respiration rates have been measured by White and Yousef (1978) on reindeer and Robbins et al. (1979) on elk calves as oxygen consumption was being measured, permitting evaluations of the relationships between both respiration rate and volume and energy expenditures. results are presented graphically by Robbins et al (1979:450; Fig. 3 and 4), with equations. Variations in respiratory frequency during standing and the effects of panting are clearly illustrated in Figure 4. Respiratory frequency alone, including effects due to posture, locomotion, and panting could hardly be expected to be a good predictor of energy expenditure. Recognition of respiratory characteristics and frequencies will help when interpreting respiratory rate data.

LITERATURE CITED

Robbins, C. T., Y. Cohen, and B. B. Davitt. 1979. Energy expenditure by elk calves. J. Wildl. Manage. 43(2):445-453.

White, R. G. and M. K. Yousef. 1978. Energy expenditure in reindeer walking on roads and on tundra. Can. J. Zool. 56(2):215-223.

REFERENCES, TOPIC 5.3

RESPIRATION RATE-TO-METABOLISM CONVERSIONS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
APAVD	1976-	185	194	odvi	succinylcholine in deer	kitchen,h	1976
JWMAA	40--4	626	629	odvi	predic metab rat, heart ra	holter,jb; urban/	1976

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
ANREA	189-1	91	108	ceel	carotid, orbital retia, pr	carlton,c; mckean	1977

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

alal

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

rata

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	22--1	3	24	caca	energy metabolism, roe dee	weiner,j	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BJNUA	21--3	769	785	dosh	cont meas heart rat indi e	webster,ajf	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	22--1	3	24	caca	energy metabolism, roe dee	weiner,j	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJCNA	22---	696	700	many	heart-rate tel, energ, man	bradfield,rb; hu/	1969
ATRLA	16--1	1	21		metabo levels, homeotherms	poczopko,p	1971
CJBIA	38-11	1301	1309		pulse rate, meta rate, man	booyens,j; hervey	1960
JAPYA	26--3	297	302		energy exp, work, hear rat	datta,sr; ramanat	1969

TOPIC 6. ECOLOGICAL METABOLISM

Ecological metabolism is the term applied to the energy cost of living of free-ranging animals throughout the year, including all of the maintenance, activity, and productive functions as the animal goes through the annual cycle (Moen 1973).

Daily (24-hour) blocks of time are minimum for the expression of ecological metabolism because of diurnal rhythms in activity. Hourly rates of metabolism change during each 24-hour period because of activity periods. Changes in diurnal rhythms over the annual cycle are related to the light regime and to current weather conditions. The light regime changes in predictable ways through the annual cycle, and the pattern of daily ecological metabolism reflects these changes.

Ecological metabolism is very difficult to measure because the measurements must be made as the animals behave naturally over 24-hour periods throughout the annual cycle. Since direct measurements of metabolic expenditures or heat production of free-ranging animals are impossible, indirect measurements must be used. Gas exchange methods are difficult to use on wild ruminants, and they interfere with the animals' activities. Tracheal cannulae interfere less than face masks, but still are difficult to use on free-ranging animals. Calculations of metabolism made from vital signs, especially heart rates and respiration rates, do reflect metabolic patterns and provide insight into the overall role of metabolism in ecological considerations.

Absolute values of ecological metabolism per day (ELMD) may be estimated by vital sign to metabolism conversions, or by summations of maintenance, activity, and production costs as discussed in the previous units in the chapter. The ratio of ELMD to BLMD, called the multiple of base-line metabolism (MBLM) (See CHAPTER 7 - Pages 2-3) is a good way to express ecological metabolism on a relative basis. The ratio of ecological metabolism to base-line metabolism varies throughout the year because of seasonal rhythms in activity, growth, and reproduction. Transient changes in these functions contribute to a variable ratio, but long-term trends are approximated by a sine wave.

The use of the MBLM approach in calculating ELMD involves the use of live weights. Seasonal rhythms in weights (see CHAPTER 1, UNIT 1.4) are combined with seasonal rhythms in MBLM to estimate ELMD. This approach is applicable to different species of wild ruminants in northern areas of the United States and in Canada since a metabolic depression in the winter, summer metabolic highs, and an overall pattern similar to that of the white-tailed deer seems to exist in these ruminants.

One important use for the calculation of ecological metabolism, a dynamic variable so dependent on the activity and production levels of each individual, is in determining nutrient requirements in relation to age. Also forage ingested and fat reserves, both used as sources of energy by the animal to meet the cost of ELMD, are both important as their rates of depletion determine the forage and fat resources left, both of which are of critical importance to survival.

This unit is a place for the listing of metabolism references that do not fall clearly in previous units, or for references that should be included for use again in deriving equations for ecological metabolism for different species. WORKSHEETS that follow provide opportunities for estimating ELMD from available data, and first approximations, at least, are to be derived for different species.

LITERATURE CITED

Moen, A. N. 1973. Wildlife ecology. W. H. Freeman and Co., San Francisco. 458 pp.

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.

REFERENCES, TOPIC 6

ECOLOGICAL METABOLISM

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
edbo	acpr	nyny	427	many	comprtv nitritn, wild anim	crawford,ma,ed;	1968
aubo	hutc	loen	332	rumi	energ metabol of ruminants	blaxter,kl	1967
aubo	wile	nyny	184	rumi	metabolism in the ruminant	annison,ef; lewis,	1959
edbo	jdve	zusw	259	doca	energ met farm anims; symp	schurch,a,ed; wen	1970

UNIT 6.1: SEASONAL RHYTHMS IN ECOLOGICAL METABOLISM

Each individual must meet its own requirements for the basic life functions--respiration, circulation, daily activities, maintenance of body tissues, production of new tissues to replace those metabolized--that combine to establish the maintenance requirement of each individual. Productive members of a population must also synthesize new tissue, for both growth and reproduction. The timing of these productive functions results in marked changes in the rates of metabolism over the annual cycle. Highest metabolic rates occur in the summer when individuals are growing and females are lactating. In the winter, metabolism is depressed. Thus, ecological metabolism varies because maintenance, activity, and production costs vary due to seasonal patterns in growth, reproductive functions, activity patterns, weather and thermal exchange, and other biological functions. The timing of the productivity costs of ecological metabolism are dependent on the seasonal patterns of changes in range conditions.

The amount of direct information on seasonal metabolic rhythms of different species of free-ranging animals is very limited. There are clues in the literature, however. Deer are less able to withstand shock in the winter when they are in their period of metabolic depression. They also exhibit seasonal differences in their reactions to an immobilizing agent. Research at the Wildlife Ecology Laboratory has shown that there is seasonal response of white-tailed deer to succinylcholine immobilization that is apparently related to seasonal metabolic rhythms. Effective immobilization dosage rates varied from a low of 0.058 mg/kg in February to a high of 0.09 mg/kg in August (See Jacobsen et al. 1976). Stelfox and Robertson (1976) describe the seasonal reaction of bighorn sheep to succinylcholine chloride: "Lower dosage rates were required in late winter and spring compared to the fall." This suggests that bighorn sheep have a metabolic rhythm, too, and are energy conservers in the winter like white-tailed deer.

Seasonal rhythms in ecological metabolism of white-tailed deer have been described in detail in Moen (1978). It is interesting to compare the definitive pattern of high metabolism in the summer and low in the winter with supporting evidence published in earlier literature. Cyclic weight changes (Bandy et al. 1970), seasonal variations in hormone levels and reproductive functions (West and Nordon 1976), blood characteristics (Franzmann et al. 1976), thyroid activity (Hoffman and Robinson 1966), serum thyroxine levels (Seal et al. 1972), cementum annulus formation (Sauer 1973) and basal and fasting metabolic rates (Silver et al. 1969 and Holter et al. 1976) have all provided documented evidence for seasonal rhythms in metabolism. The WORKSHEETS that follow in this UNIT and UNIT 6.2 are very important for the verification of calculations of ecological metabolism.

LITERATURE CITED

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REFERENCES, UNIT 6.1

SEASONAL RHYTHMS IN ECOLOGICAL METABOLISM

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJPPA	56--6	945	949	odvi	thyroxine lev, male, femal	bubenik,ga; buben	1978
ECOLA	57--1	192	198	odvi	energy conservatio, winter	moen,an	1976
JOMAA	41--1	23	29	odvi	respon bucks, artifi light	french,ce; mcewe	1960
JOMAA	47--2	266	280	odvi	endocrine glands, sea chan	hoffman,ra robin/	1966
JWMAA	34--2	431	439	odvi	wint feed patterns, penned	ozoga,jj; verme,l	1970
JWMAA	34--4	863	869	odvi	dig, met ener, wintr, does	ullrey,de; youat/	1970
JWMAA	36--4	1041	1052	odvi	nutrit effec. thyroid acti	seal,us; verme/	1972
JWMAA	40--3	447	453	odvi	seas var succinylcho immob	jacobsen,nk; arm/	1976
JWMAA	42--4	715	738	odvi	seas chan, heart rate, act	moen,an	1978
JWMAA	42--4	791	798	odvi	thymus, nut status indicat	ozoga,jj; verme,l	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PNDAA	30--1	35	35	odhe	pituitary photoper, antlr	nicolls,ke	1976
PSEBA	93--1	161	162	odhe	cyclic var, thymus, mule d	browman,lg; sears	1956
ZZAHA	115-3	314	326	odhe	pituitar glnd photoperiod	nicolls,ke	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ACATA	63--4	580	590	ceel	caca, investigatn, thyroid	pantic,v; stosic,	1966
CBPAB	60a-3	251	256	ceel	doca, dosh enrg, nitro met	simpson,am; webs/	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NCANA	101-1	227	262	alal	energ req, rumen fermentat	gasaway,wc; coady	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
APSCA	105-3	268	273	rata	spitzbergen, winter dorman	ringberg,t	1979
BJNUA	29--2	245	259	rata	seasonal, glucose metaboli	luick.jr; person/	1973
CBPAB	40a	789	795	rata	thyroxine, sex, age seas	yousef,mk· luick,	1971
CBPAB	60A-2	123	126	rata	seas, growth hormon, thyro	ringberg,t; jaco/	1978

rata continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--2	391	392	rata	energ metab, bar gro carib	mcewan,eh	1970
CJZOA	48--5	905	913	rata	seas energy, nitrog intake	mcewan,lh; whiteh	1970
CJZOA	56--2	215	223	rata	energy expend, walk, tundr	white,rg; yousef,	1978
JANSA	33--1	260	260	rata	thyroxine secre rate, calv	luick,jr; white,/	1971
PASCC	19---	71	72	rata	thyroxine secretion rate	yousef,mk	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	37--4	563	573	anam	energy metab of yg prongho	wesley,de; knox,/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CNJNA	59--3	611	617	bibi	doca, seas enrg exp, thrmr	christopherson,r/	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	56-11	2388	2393	ovca	winter bioenergetics, rcky	chappel,rw; hudso	1978
JWMAA	40--1	174	176	ovca	immobiliz, succinyl, pheny	stelfox,jg; rober	1976

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	22--1	3	24	caca	energy metabolism, roe dee	weiner,j	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NCANA	101-1	227	262	alal	energ req, rumen fermentat	gasaway,wc; coady	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PZOOA	15--2	201	205	many	lipid metab, free fatty ac	felinski,l; kacz/	1971

CHAPTER 7, WORKSHEET 6.1a

Estimating ecological metabolism by summation

The estimation of ecological metabolism by summation involves the calculation of the costs of each of the biological processes occurring on a given day and adding up these costs to get a total for the day. the major cost items have been discussed in the units in this chapter. There are too many variables involved that it is impossible to summarize the costs for each of these items for a species. Weights vary between sex and age groups and throughout the year, reproductive rates vary, activity patterns vary, etc. The schematic below will be useful as a check list when identifying cost items for summations.

- Maintenance
- Activity
    - Bedding
    - Standing
    - Walking
        - level
        - uphill
        - downhill
    - Foraging
    - Running
- Production
    - Growth
        - body growth
        - hair growth
    - Reproduction
        - gestation
        - lactation

Establish a biochronology for the species of your choice, select the topography and behavioral regimes, estalish a reproductive rate, and identify every other maintenance, activity, and productive function that is part of that animal's life, and then complete the energy cost calculations discussed this CHAPTER 7. I suggest that you start with AGDA = 1, on the average JDAY for births. Follow that animal through its life, accounting for cost items characteristic of its life-style and events at 7 or 14 day intervals throughout the year. Such a calculation will call to your attention a great deal of natural history, behavior, and physiology, and will serve to acquaint you very well with the species.

The suggestion given on the previous page is a major assignment. Programmed computing will be very helpful. Programmed desk-top calculators are efficient enough to help with the calculations while yet being simple enough to operate easily and with enough manual steps to keep you oriented.

One last reminder. As the energy costs are added up for each day selected, be sure to convert the absolute energy costs to MBLM. This will allow you to compare between sex, age, season, and species. The results should be somewhat in line with the material discussed in UNIT 6.2.

CHAPTER 7, WORKSHEET 6.1b

Seasonal rhythms in ELMD; the MBLM approach

The calculation of energy costs at selected intervals of days to be summed through the year is a major assignment. The calculation of seasonal rhythms in ELMD using the MBLM approach described in Moen (1978) can be accomplished with a single, relatively short equation. Basically, energy expenditures of white-tailed deer are sinusoidal throughout the year, reaching a low in the winter and a high in the summer or early fall, depending on the reproductive rate. Lactation for two fawns shifts the maximum cost to mid-summer, for one fawn to late summer, and for no fawns to early fall.

The equation is:

$$MBLM = 2.56894\ e^{0.19602\ (NUFA)} \left(\left\{ [1.0285 \sin [(JDAY + 170.0536\ e^{0.15488\ (NUFA)})\ 0.9863 + 0.0281]\ [0.19 + 0.05\ (NUFA)] \right\} + [0.81 - 0.05\ (NUFA)] \right)$$

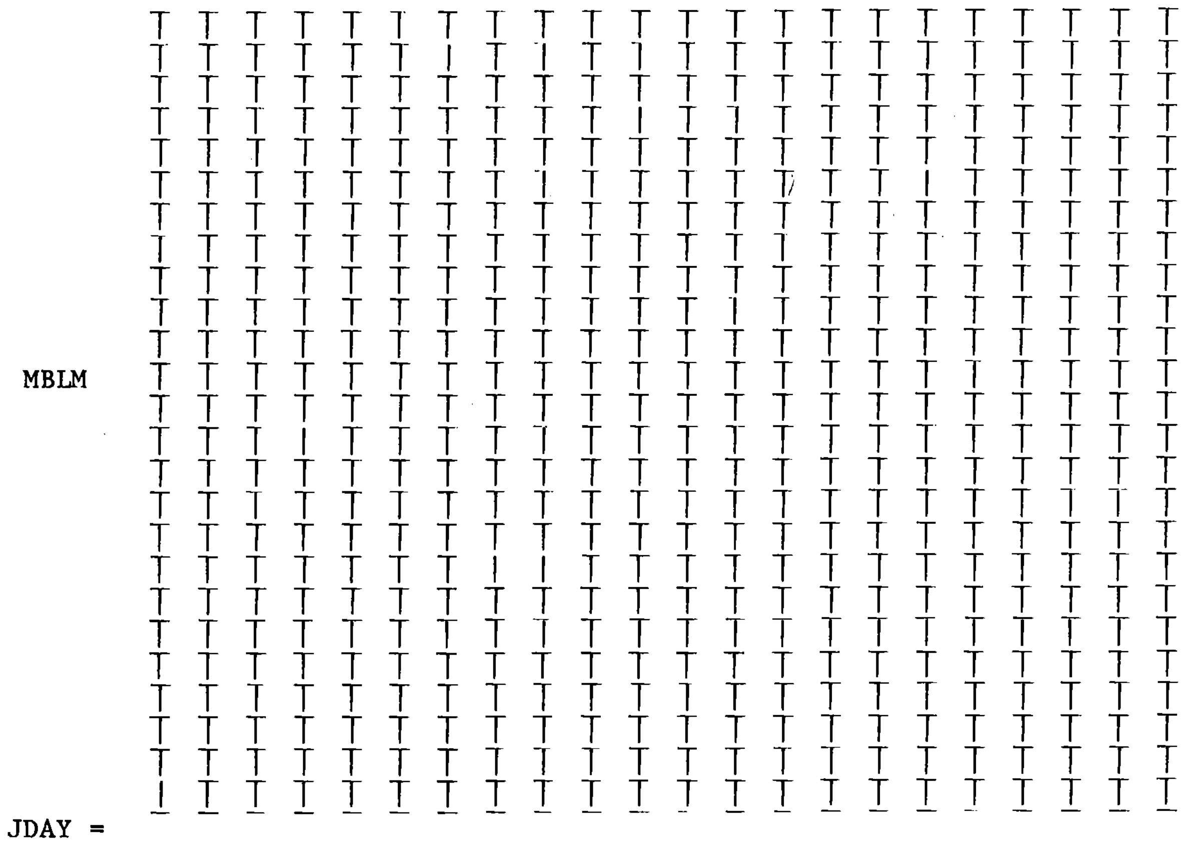
where MBLM = multiple of base-line metabolism,
NUFA = number of fawns, and
JDAY = Julian day.

ELMD is determined by multiplying MBLM by (70)(MEWK). MEWK is determined from the weight equations described in CHAPTER 1. Calculate MBLM and multiply by (70)(MEWK) through the annual cycle and plot the results on the grid on the back of this page.

Compare the MBLMs with those discussed on previous WORKSHEETS in this chapter, and compare with those discussed in UNIT 6.2.

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.


MBLM
JDAY =

UNIT 6.2: INTERSPECIES COMPARISONS

The use of base-line metabolism and multiples of base-line metabolism to express ecological metabolism is very conveniently applied to other species with different weights. Calculations have been made for caribou (Moen 1980) indicating similarities in the pattern of MBLM over the annual cycle. Detailed calculations by Gasaway and Coady (1974), summarized in Moen (NAS In press) indicate that moose have a lower metabolism in the winter (about 1.7 times the basal metabolic rate; BMR) and 3.0 to 4.0 times BMR in the summer. Both the metabolic patterns and the multiples of BMR (where BMR = $70\ W^{0.75}$ and is equivalent to base-line metabolism) of moose given by Gasaway and Coady (1974) are very similar to those determined for white-tailed deer by Moen (1978).

Interspecies comparisons using the multiple of base-line metabolism approach have been made for domestic animals; the following summary is from Moen (NAS In press). How does the use of MBLM apply to domestic cattle and sheep? First, the pattern of daily energy requirements of a 454 kg beef cow during her 12-month reproductive cycle is shown by Ensminger (1976:1083). Converting the graphed results to MBLM by dividing values on the (megacalories) Y-axis by base-line metabolism, $[70(454)^{3/4})]$, results in values of MBLM of 1.8, 2.3, 2.5, and 3.5 for maintenance, grazing, the addition of fetal development, and peak lactation, respectively. Both the general pattern and the values of MBLM are very similar to those discussed earlier for white-tailed deer and moose. The timing is different, as cows may be bred to calve in late winter and early spring, earlier than the time of parturition for wild ruminants.

The figure in Ensminger depicting metabolizable energy of a cow over a 12-month reproductive cycle is illustrative, and not designed for detailed expression of metabolizable energy and forage requirements of cows of different ages, weights, and breeds. The nutrient requirements of beef cattle and sheep have been summarized by subcommittees of the National Research Council (Nutrient Requirements of Beef Cattle, fifth revised edition, 1976 and Nutrient Requirements of Sheep, fifth revised edition, 1975). These publications include tables of metabolizable energy values in the forage consumed by animals of different weights, growth rates, and different stages of reproduction. The tables may be converted to MBLM by dividing the metabolizable energy in the daily feed allotment by base-line metabolism.

The values of MBLM for lactating beef cattle range from 3.1 to 3.7 (midpoint 3.4) for cows from 350 to 650 kg rated as "superior" producers, and from 2.5 to 2.8 (midpoint 2.65) for those rated "average." The calculated MBLM for cows in the middle third of gestation is 1.9, and in the last third, 2.35 to 2.15 (midpoint 2.25) for cows weighing 350 to 650 kg.

Metabolizable energy values for sheep, expressed as MBLM calculated from Table 1, page 42 in Nutrient Requirements of Sheep (NRC 1975), include a maintenance cost after lactation has ceased of MBLM = 1.45, the lowest of the year, to an MBLM during lactation of 3.5 for sheep suckling singles and 4.0 for sheep suckling twins.

An interesting and significant relationship emerges for these calculations of MBLM for cattle and sheep in relation to MBLM calculations for white-tailed deer. Maximum values of MBLM are 3.7, 4.0, and 3.9 for cattle, sheep, and deer, respectively. MBLM values for an average producing cow and sheep and deer nursing singles are 2.35, 3.5, and 3.2 respectively. Minimum MBLMs are 1.45 and 1.6 for sheep and deer, respectively, and 1.9 and 1.7 for cows and moose, respectively. Differences in ecological metabolism of free-ranging ruminants appear to be slight when compared on a relative basis using MBLM. On an absolute basis, differences between species in the amount of metabolism per day are caused by differences in their weights, especially of cattle and moose compared to sheep and deer.

Similarities in MBLM for the different four species suggest that MBLM can be estimated for free-ranging ruminants as well. A maximum of 4.0 and minimum of 1.5 likely include the expected values of MBLM of free-ranging ruminants over the annual cycle. References that contain weight and energy metabolism data on domestic cattle and sheep may be listed on the next page. WORKSHEETS that illustrate interspecies comparisions and evolutions within the 1.5 to 4.0 MBLM should also be added at the end of this UNIT.

LITERATURE CITED

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Gasaway, W. C. and J. W. Coady. 1974. Review of energy requirements and rumen fermentation in moose and other ruminants. Le Naturaliste Canadien 101:227-262.

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__________. [NAS In press]. Ecological efficiencies and forage intakes of free- ranging animals. In National Academy of Science Forage Allocation Workshop Publication.

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REFERENCES UNIT 6.2

INTERSPECIES COMPARISONS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AFBUD	.....	38	39	doca	energy cost, ingestin feed	adam,i; young,ba/	1979
BJNUA	20--1	103	111	doca	fasting metabolism, cattle	blaxter,kl; wainm	1966

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJAEA	15--6	969	973	dosh	energ cost. feed act, graz	graham,nm	1964
AJAEA	17--3	355	362	dosh	energy expend, resp, feedi	young, ba	1966
AJAEA	19--5	821	824	dosh	metab rate, bred wol prod	graham,nm	1968
BJNUA	18--1	47	54	dosh	ener metab, walk lev, grad	clapperton,jl	1964
PAANA	7----	327	334	dosh	ener req, grazi, calorimet	young,ga; corbet	1968
PAANA	7----	335	341	dosh	co2, index ener expen, lmb	white,rg; leng,ra	1968
PNUSA	20--	xxxi	xxxii	dosh	ener exp, walk levl, grdi	clapperton,jl	1961

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBPAB	34A-4	841	846		energetic cost, locomotion	tucker,va	1970
JRMGA	27--4	437	443		physiol, ener expen, pastu	osuji,po	1974
JTBIA	49--2	345	362		model, est metab, rest, ac	wunder,ba	1975
SCIEA	178--	1096	1097		runni up, down hills: size	taylor,cr; caldw/	1972
WLMOA	14---	1	78		pharma-physiol prin, restr	hartoorn,am	1965

CHAPTER 7, WORKSHEET 6.2a

Interspecies comparisons of MBLM and ELMD

Ecological metabolism per day, being a function of weight, varies widely betwen species, ELMD of white-tailed deer is much less than that of moose, and of domestic sheep, much less than that of cattle.

Similarities in MBLMs of different species are striking, however. MBLM is weight independent, calculated by dividing ELMD by base-line metabolism. Interspecies comparisons can be easily made when daily quantities of energy metabolism are given. Sometimes the metabolizable energy in the feed is given: this is the case for domestic cattle and sheep in the NRC publications. Consider the metabolizable energy in the daily ration to be the daily metabolizable energy and divide by BLMD.

The point to be made in this WORKSHEET is that MBLM is the expression to use for interspecies comparisons. It has been stressed throughout this CHAPTER, and will prove to be very useful in future calculations.

Mentally review MBLM, think of patterns through time, and sketch your thoughts in the space below.

CLOSING COMMENTS - CHAPTER SEVEN

CHAPTER 7 is a very important chapter in this book of seven parts. Calculations of the energy cost of living are as important to the resource manager as calculations of the dollar costs of goods are to the economist. Energy is the currency of the ecosystem, and an understanding of energy transactions helps one realize the potentials for and the limits to ecological processes in the natural world.

Aaron N. Moen
March 11, 1981

GLOSSARY OF SYMBOLS USED - CHAPTER SEVEN

AGDA = Age in days

BAMD = Basal metabolism per day
BIWK = Birth weight in kilograms
BHRM = Bedded heart rate per minute
BLM- = Base-line metabolism
BLMD = Base-line metabolism per day
BMR- = Basal metabolic rate
BRRM = Bedded respiration rate per minute

CLWK = Calculated live weight in kilograms

DHGD = Duration of hair growth per day
DIGE = Days into gestation
DILA = Days into lacation
DSTK = Distance in kilometers

ECBD = Energy cost of bedding per day
ECFD = Energy cost of foraging per day
ECGD = Energy cost of gestation per day
ECHD = Energy cost of hair growth per day
ECRD = Energy cost of running per day
ECSD = Energy cost of standing per day
ECVA = Energy cost of vertical ascent
ECWD = Energy cost of walking per day
ECWL = Energy cost of walking upslope
ELMD = Ecological metabolism per day

FACO = Fat content
FAMD = Fasting metabolism per day
FATP = Fat percent
FHRM = Foraging heart rate per minute
FRRM = Foraging respiration rate per minute
FTBD = Fraction of time spent bedded per day
FTFD = Fraction of time spent foraging per day
FTRD = Fraction of time spent running per day
FTSD = Fraction of time spent standing per day
FTWD = Fraction of time spent walking per day

GENM = Gross energy in the milk

HAWG = Hair weight in grams
HGTK = Height ascended in kilometers
HIGR DIGE = Higher number of days into gestation
HRMC = Heart rate to metabolism conversion factor
HRPM = Heart rate per minute

IFMW = Ingesta-free metabolic weight
IFWK = Ingesta-free weight in kilograms

JDAY = Julian day

KCAL = Kilocalories
KCLO = Kilocalories per liter of O_2
KJOU = Kilojoules

LOWR DIGE = Lower number of days into gestation
LWKG = Live weight in kilograms

MBLM = Multiple of base-line metabolism
MEWK = Metabolic weight in kilograms
MPGD = Milk production in grams per day
MRMW = Metabolic rate per metabolic weight

NECM = Net energy coefficient for milk
NUFA = Number of fawns

PEGE = Physiological efficiency of gestation
PEHG = Physiological efficiency of hair growth
PMRB = Predicted metabolic rate bedded
PMRF = Predicted metabolic rate foraging
PMRR = Predicted metabolic rate running
PMRS = Predicted metabolic rate standing
PMRW = Predicted metabolic rate walking
PNDM = Percent nutrients derived from milk
PRCO = Protein content
PRPC = Primary phase correction

REHP = Resting heat production
REQO = Respiratory quotient
RHRM = Running heart rate per minute
RMBL = Running multiple of base-line metabolism
RRRM = Running respiration rate per minute

SHRM = Standing heart rate per minute
SLPD = Slope in degrees
SMBL = Standing multiple of base-line
SPKH = Speed in kilometers per hour
SRRM = Standing respiration rate per minute

TCCK = Total caloric content in kilocalories

WHRM = Walking heart rate per minute
WRRM = Walking respiration rate per minute

GLOSSARY OF CODE NAMES - CHAPTER SEVEN

ACATA Acta Anatomica
AFBUD University of Alberta Agriculture and Forestry Bulletin
AJAEA Australian Journal of Agricultural Research
AJCNA American Journal of Clinical Nutrition
AJPHA American Journal of Physiology
AMNAA American Midland Naturalist
AMNTA American Naturalist
AMZOA American Zoologist
ANREA Anatomical Record
ANYAA Annals of the New York Academy of Sciences
APAVD American Association Zoo Veterinarian Annual Proceedings
APSCA Acta Physiologica Scandinavica
ATRLA Acta Theriologica

BISNA Bioscience
BJNUA British Journal of Nutrition
BPURD Biological Papers of the University of Alaska Special Report

CAFGA California Fish and Game
CBPAB Comparative Biochemistry and Physiology A Comparative Physiology
CIWPA Carnegie Institution of Washington Publication
CJBIA Canadian Journal of Biochemistry
CJZOA Canadian Journal of Zoology
CNJNA Canadian Journal of Animal Science
COVEA Cornell Veterinarian

ECMOA Ecological Monographs
ECOLA Ecology

FEPRA Federation Proceedings

IJBMA International Journal of Biometeorology

JANSA Journal of Animal Science
JAPYA Journal of Applied Physiology
JASIA Journal of Agricultural Science
JCCPA Journal of Cellular and Comparative Physiology
JDSCA Journal of Dairy Science
JOMAA Journal of Mammalogy
JPHYA Journal of Physiology
JRMGA Journal of Range Management
JRPFA Journal of Reproduction and Fertility
JTBIA Journal of Theoretical Biology
JWIDA Journal of Wildlife Diseases
JWMAA Journal of Wildlife Management

NATUA Nature
NAWTA North American Wildlife and Natural Resources Conference, Transactions of the,
NCANA Naturaliste Canadien, Le

NUMEB Nutrition and Metabolism

OJSCA Ohio Journal of Science

PAANA Proceedings of the Australian Society of Animal Production
PAARA Pennsylvania State University College of Agriculture Agricultural Experiment Station Progress Report
PASCC Proceedings of the Alaskan Scientific Conference
PECTD Polish Ecological Studies
PHREA Physiological Reviews
PHZOA Physiological Zoology
PNDAA Proceedings of the North Dakota Academy of Science
PNSUA Proceedings of the Nutrition Society
PNUSA Proceedings of the Nutrition Society
PSEBA Proceedings of the Society for Experimental Biology and Medicine
PZOOA Przeglad Zoologiczny

QJEPA Quarterly Journal of Experimental Physiology and Cognate Medical Sciences
QSFRA Quebec Service de la Faune Rapport

RSPYA Respiration Physiology

SCIEA Science
SSEBA Symposia of the Society for Experimental Biology
SZSLA Symposia of the Zoological Society of London

VJSCA Virginia Journal of Science

WLMOA Wildlife Monographs

ZOBIA Zhurnal Obshchei Biologii
ZTTFA Zeitschrift fuer Tierphysiologie Tierer naehrung und Futtermittelkunde
ZZAHA Zeitschrift fuer Zellforschung und Mikroskopisch Anatomie

LIST OF PUBLISHERS - CHAPTER SEVEN

acpr	Academic Press	New York	nyny
agrc	Agricultural Res. Council	London, England	loen
ccth	Charles C. Thomas	Springfield, IL	spil
coms	Comstock	Ithaca, NY	itny
fase	Federation of American Society for Experimental Biology	Bethesada, MD	bemd
hutc	Hutchinson	London, England	loen
jdve	Joris, Druck, and Verlag	Zurick, Switzerland	zusw
mopc	Morrison Publishing Co.	Ithaca, NY	itny
prha	Prentice-Hall, Inc.	Princeton, NJ	prnj
repu	Reinhold Publishing	New York	nyny
saco	Saunders Publishing Co.	Philadelphia, PA	phpa
whfr	W. H. Freeman Co.	San Francisco, CA	sfca
wile	Wiley	New York	nyny

LIST OF WORKSHEETS - CHAPTER SEVEN

JULIAN DAY: MONTH AND DAY EQUIVALENTS

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	1
2	002	033	061	092	122	153	183	214	245	275	306	336	2
3	003	034	062	093	123	154	184	215	246	276	307	337	3
4	004	035	063	094	124	155	185	216	247	277	308	338	4
5	005	036	064	095	125	156	186	217	248	278	309	339	5
6	006	037	065	096	126	157	187	218	249	279	310	340	6
7	007	038	066	097	127	158	188	219	250	280	311	341	7
8	008	039	067	098	128	159	189	220	251	281	312	342	8
9	009	040	068	099	129	160	190	221	252	282	313	343	9
10	010	041	069	100	130	161	191	222	253	283	314	344	10
11	011	042	070	101	131	162	192	223	254	284	315	345	11
12	012	043	071	102	132	163	193	224	255	285	316	346	12
13	013	044	072	103	133	164	194	225	256	286	317	347	13
14	014	045	073	104	134	165	195	226	257	287	318	348	14
15	015	046	074	105	135	166	196	227	258	288	319	349	15
16	016	047	075	106	136	167	197	228	259	289	320	350	16
17	017	048	076	107	137	168	198	229	260	290	321	351	17
18	018	049	077	108	138	169	199	230	261	291	322	352	18
19	019	050	078	109	139	170	200	231	262	292	323	353	19
20	020	051	079	110	140	171	201	232	263	293	324	354	20
21	021	052	080	111	141	172	202	233	264	294	325	355	21
22	022	053	081	112	142	173	203	234	265	295	326	356	22
23	023	054	082	113	143	174	204	235	266	296	327	357	23
24	024	055	083	114	144	175	205	236	267	297	328	358	24
25	025	056	084	115	145	176	206	237	268	298	329	359	25
26	026	057	085	116	146	177	207	238	269	299	330	360	26
27	027	058	086	117	147	178	208	239	270	300	331	361	27
28	028	059	087	118	148	179	209	240	271	301	332	362	28
29	029	[060]	088	119	149	180	210	241	272	302	333	363	29
30	030		089	120	150	181	211	242	273	303	334	364	30
31	031		090		151		212	243		304		365	31

* For leap year, February 29 = JDAY 60. Add 1 to all subsequent JDAYs.

THE BIOLOGY AND MANAGEMENT OF WILD RUMINANTS

CHAPTER EIGHT

PROTEIN METABOLISM OF WILD RUMINANTS

by

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PROTEIN METABOLISM OF WILD RUMINANTS

CHAPTER 8. PROTEIN METABOLISM

Protein metabolism involves the breakdown of the protein in food ingested into amino acids to be synthesized into new proteins that become part of different animal tissues. Muscle tissue is the main protein depot in the body as it is primarily protein and water.

The pathways and terms used to describe protein metabolism from ingestion to net use are listed below. The word nitrogen is used rather than protein because nitrogenous compounds are used by ruminants to synthesize protein-containing tissue.

Total nitrogen intake − fecal nitrogen = apparent digestible nitrogen

apparent digestible nitrogen − metabolic fecal nitrogen = true digestible nitrogen

true digestible nitrogen − urinary nitrogen = net nitrogen for maintenance and production

net nitrogen for maintenance and production → nitrogen for synthesis of protein-containing tissue

nitrogen for synthesis of protein-containing tissue → growth, enzyme production, other tissue anabolism

nitrogen for synthesis of protein-containing tissue → tissue catabolism → endogenous urinary nitrogen

The fundamental unit or building block of a protein molecule is the amino acid. Amino acids contain amino groups ($-NH_2$) and carboxyl groups ($-COOH$) which link together to form peptides. Many amino acids linked together form a polypeptide, and very long polypeptides are proteins.

The breakdown of or hydrolosis of natural proteins has yielded 26 different amino acids (McCauley 1971:190). Many of these are present in animal tissue, and can be produced by the process of transamination, or the interconversion from one to another. Some cannot be produced from other amino acids, so they must be present in the diet. These are called essential amino acids.

Amino acids not synthesized into protein are deaminated in the kidneys and liver and ammonia is produced (Pantelouris 1967). Ruminants convert ammonia to urea, which may then be used by rumen microflora in their own protein metabolism.

The ruminant animal has an advantage over the monogastric animal when meeting its protein needs because the intestinal microflora synthesize proteins which are, in turn, available to the ruminant host. Thus the ruminant does not need to have all of the essential amino acids supplied directly in the diet because the microflora synthesize these for the host. The total protein in the diet must be adequate in order to provide the necessary nourishment for the microflora (Crampton and Harris 1969:171). Ruminants also have a metabolic adaptation for the conservation of protein resources. The recycling of urea is a nitrogen conservation adaptation when protein intake goes down. This is characteristic of winter range conditions when many species of wild ruminants are on browse or highly lignified diets.

This chapter deals with the applied aspects rather than the biochemical aspects of protein metabolism. The TOPICS that follow include material on the factors affecting protein metabolism (TOPIC 1), measurements of protein metabolism (TOPIC 2), and estimates of protein costs for production (TOPIC 3). The equations presented will be used when evaluating range and diet characterics in PART IV.

LITERATURE CITED

Crampton, E. W. and L. E. Harris. 1969. Applied animal nutrition. W. H. Freeman and Co., San Francisco. 753 pp.

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

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

REFERENCES, CHAPTER 8

PROTEIN METABOLISM

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
edbo	butt	loen	297	rumi	dig phys & nutr, proc symp	lewis,d ed	1961
aubo	cfmo	code	154	rumi	gastro-intestinl prot loss	nielsen,k	1966
aubo	dcch	coor	400	rumi	dig physiol & nutri, vol 1	church,dc	1969
aubo	dcch	coor	400	rumi	dig physiol & nutri, vol 2	church,dc; smith/	1971

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
aubo	clpr	oxen	272		metab of prot, mammal body	bach,sj	1952
edbo	rupr	nbnj	80		prot met, hormones & grwth	bur biol research	1953
aubo	meth	loen	198		protein metabolism	fisher,rb	1954
aubo	ccth	spil	68		dynan equili body proteins	whipple,gh	1956
edbo	rupr	nbnj	119		serology, biochem, protein	cole,wh,ed	1958
edbo	blsp	oxen	402		role of g-i trct, prot met	munro,hn,ed	1964
edbo	acpr	nyny	566		mammal protein meta, vol 1	munro,hn,ed; alli	1964
edbo	acpr	nyny	642		mammal protein meta, vol 2	munro,hn,ed; alli	1964
edbo	acpr	nyny	...		mammal protein meta, vol 3	munro,hn,ed	1964
edbo	acpr	nyny	763		mammal protein meta, vol 4	munro,hn,ed; alli	1970
aubo	hein	loen	82		protein: basis of all life	mcdonagh,jer	1966
edbo	rupr	nbnj	303		protn met & biol functions	bianchi,cp,ed; hi	1970
edbo	acpr	nyny	560		plasma protn metab; regula	rothschild,ma,ed/	1970
edbo	butt	loen	515		prot met & nutr, proc symp	cole,dja,ed	1974
edbo	else	nyny	398		biochem evol & orig of lif	schoffenfiels,e,e	1977
aubo	nhpc	nyyn	804		prot trnovr in mamm body &	waterlow,jc; gar/	1978
edbo	base	nyny	260		N, elctroly, wat, ener met	rechcigl,m,jr,ed	1979

TOPIC 1. FACTORS AFFECTING PROTEIN METABOLISM

Protein metabolism of wild ruminants is affected by both biological and environmental factors. Like other mammals ruminants convert the ammonia released from the amino acids that are not used in protein synthesis into ammonia and then urea. Urea is a soluble compound that is excreted in the urine. Ruminants, however, have the ability to recycle urea, making it available to rumen microflora for synthesis into new protein tissue.

The amount of urea recycling is dependent on environmental conditions. More recycling occurs when the crude protein intake is less, and for wild ruminants, crude protein levels are a function of range condition.

Protein metabolism is also affected by the overall body condition of the animal, which is also affected by range conditions. Nutritional stress after fat reserves are depleted results in the breakdown of protein tissue, which means the animal is in a very critical situation. The interdependence of animal and range is illustrated again by these examples. Animal-range relationships of free-ranging ruminants are very dynamic, with feed-back mechanisms that eliminate direct proportions and simple equations when evaluating them mathematically.

UNIT 1.1: BIOLOGICAL FACTORS AFFECTING PROTEIN METABOLISM

Two factors affecting protein metabolism, the true biological value or metabolizable protein and urea recycling, will be discussed in this UNIT.

The true biological value of protein is a representation of the amount of protein that is actually used for metabolism, or true metabolizable protein. This is partly a function of the way the protein or nitrogenous compounds are packaged in the forage, and partly a function of the nitrogen balance of the animal.

The "packaging" of protein or nitrogenous compounds in the forage affects the digestibility of the forage. Those forages that contain nitrogen compounds that are easily broken down into amino acids are high digestible forages, and those that have cell structures which bind the nitrogen compounds or very complex proteins are low digestible forages.

The nitrogen balance of an animal affects the amount of true metabolizable protein by affecting the fate of nitrogen compounds in the forage. An animal on a high protein and low energy diet will use some of the nitrogen compounds as a source of energy. The caloric value per gram of proteins (5.7) is less than that of fats (9.5). There, is an additional inefficiency because animals do not completely oxidize proteins, but excrete portions of protein molecules in the form of ammonia and urea (Florey 1966:270). Thus the gross energy in a gram of protein oxidized in a bomb calorimeter is 5.7 kcal, and in a gram of protein metabolized in the animal, 4.8 kcal.

The nitrogen balance also affects the metabolic disposition of protein compounds. Urea recycling occurs when urea in the blood enters the gastrointestinal tract where it is broken down into ammonia and carbon dixoide. Some of the ammonia is then synthesized into protein by intestinal microflora, and the remainder is excreted in the feces.

Urea recycling represents a means of conserving nitrogen when ruminants are consuming poor quality forage (Robbins et al. 1974). When urea recycling is maximum due to very low crude protein in the forage, the only additional source of nitrogen is tissue nitrogen. Then, body condition may deteriorate rapidly. Short-term tissue nitrogen mobilization meets immediate and specific nitrogen requirements, but cannot continue for long periods of time, of course.

There are other factors affecting protein metabolism too, including requirements for maintenance and production; these are discussed in TOPICS 2 and 3. There are not many references available on protein or nitrogen metabolism of wild ruminants, so protein costs for various biological functions must be estimated from data on domestic ruminants.

LITERATURE CITED

Florey, E. 1966. An introduction to general and comparative physiology. W. B. Sanders Company, Philadelphia. 713 pp.

Robbins, C. T., R. L. Prior, A. N. Moen, and W. J. Visek. 1974. Nitrogen metabolism of white-tailed deer. J. Anim. Sci. 38(1):186-191.

REFERENCES, UNIT 1.1

BIOLOGICAL FACTORS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--6	437	1442	cerv	rumen nitrog level, variat	klein,dr; schonhe	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	38--1	186	191	odvi	nitrogn metabolism of wh-t	robbins,ct; prio/	1974
JWMAA	39--2	346	354	odvi	blood prot, gestatio, suck	harstook,ew; whe/	1975
JWMAA	39--4	692	698	odvi	ener, prot, blood urea nit	kirkpatrick,rl; /	1975
JWMAA	42--4	776	790	odvi	diet prot, energ fawn meta	verme,lj ozoga,j	1978
JWMAA	43--2	454	460	odvi	season, nutri, serum nitro	bahnak,br; holla/	1979

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BIJOA	155-3	549	566	alal	ceel, chymotrypsin, pancre	lindsay,rm; steve	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AVSCA	16--4	513	519	rata	renal excret urea, nutriti	hove,k; jacobsen,	1975
AZOFA	11--3	200	203	rata	seas chang renal urea conc	eriksson,l; valto	1974
MAAIA	51---	381	419	rata	renal resp, high, low prot	valtonen,m	1979

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NUMEB	21--2	105	118	doan	energet, prot depos, grwth	thorbek,g	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BJNUA	24---	983	988	anim	bloo urea, asses prot qual	eggum,bo	1970

CHAPTER 8, WORKSHEET 1.1a

Urea recycling and the biological value of protein
metabolized by white-tailed deer (odvi)

The amount of urea recycled by white-tailed deer is a function of the crude protein in the diet. The equation given by Robbins et al. (1974) is:

$$\mathrm{Log}_e\ Y = 5.3197 - 0.5007\ \mathrm{Log}_e\ X$$

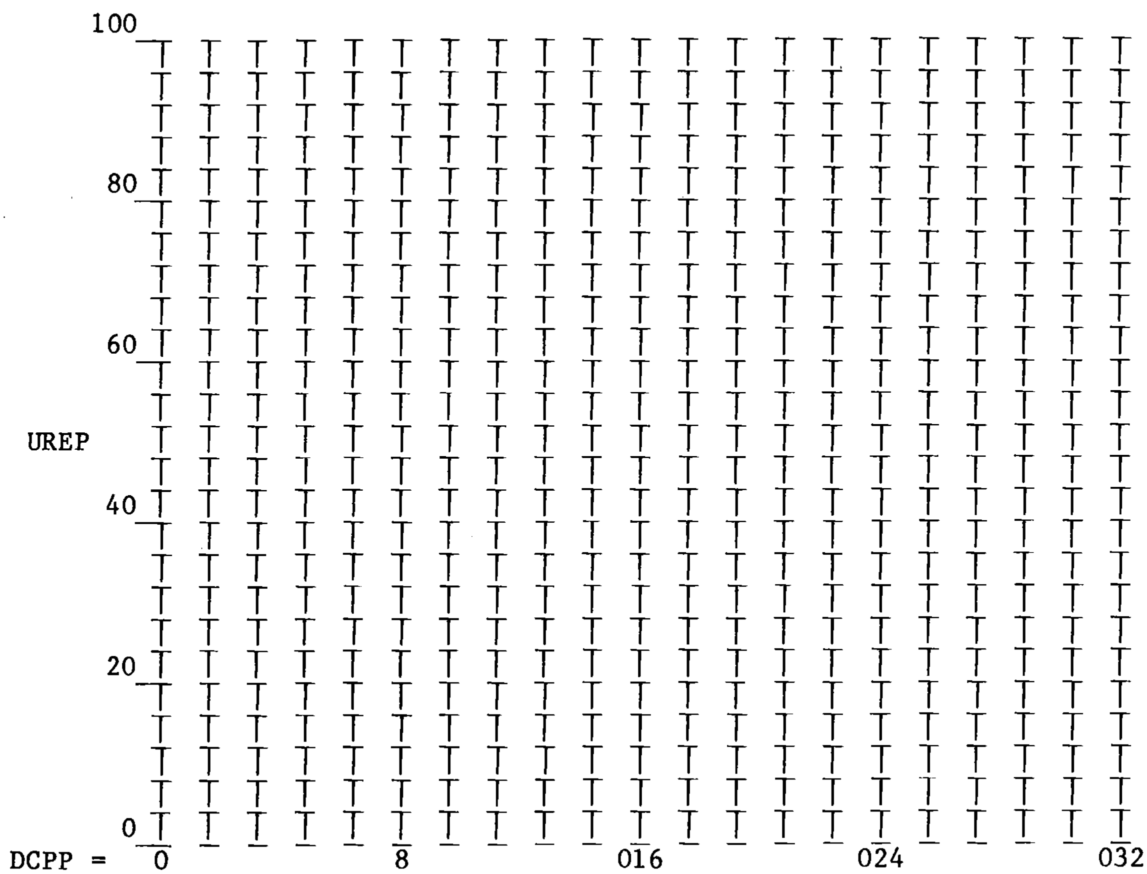
where X = dietary crude protein (%) and
Y = urea recycled (% entry rate).

Rewriting this equation and changing X and Y to DCPP and UREP, respectively, the new equation is:

$$\mathrm{UREP} = e^{5.3197}\ -\ 0.5007\ \ln \mathrm{DCPP}$$

where UREP = urea recycled in percent and
DCPP = dietary crude protein.

Complete the calculations and plot the values below. At what % dietary crude protein is 100% recycling reached?



The biological value of the protein increased as the crude protein decreased. The equation in Robbins et al. (1974) is:

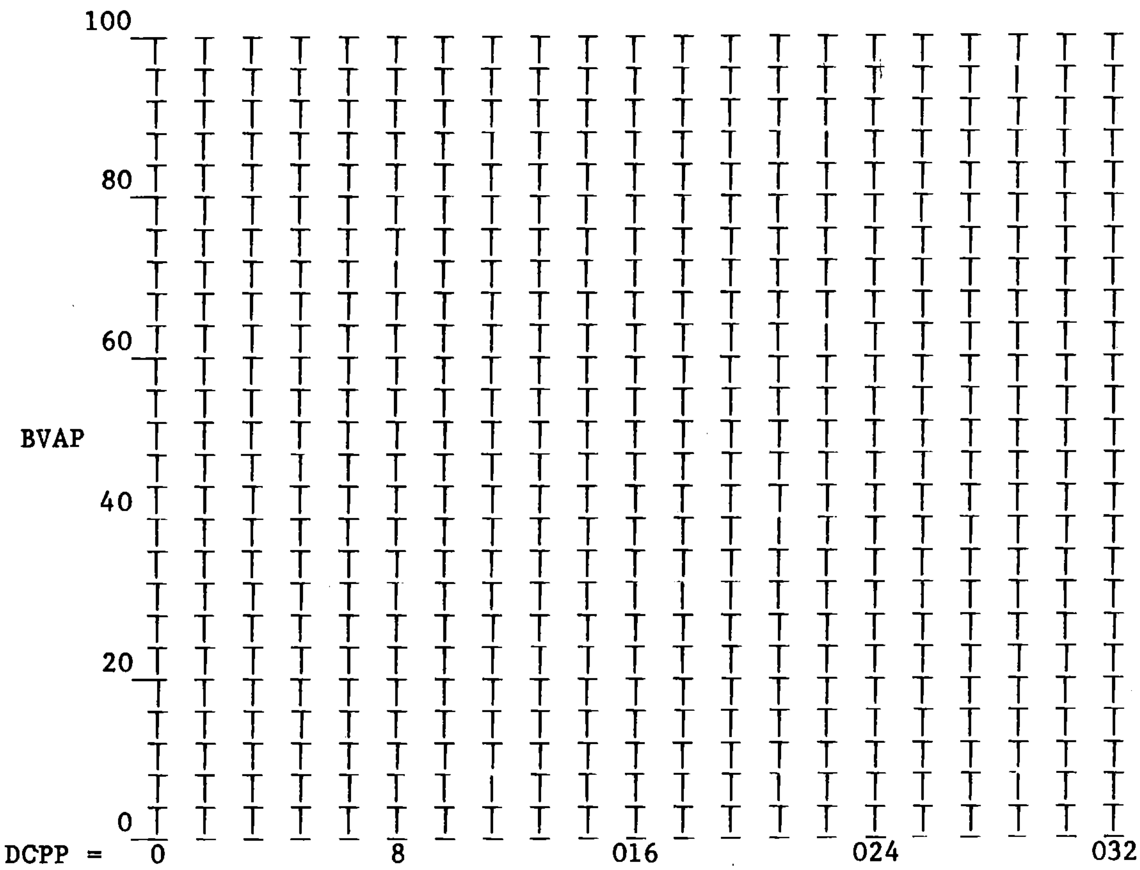
$$\text{Log}_e\ Y = 4.9825 - 0.3096\ \text{Log}_e\ X$$

where X = DCPP as defined before and
Y = biological value (%) = BVAP

Rewriting the equation:

$$\text{BVAP} = e^{4.9825 - 0.3096 \ln \text{DCPP}}$$

The relationship may be plotted below.



The decreasing biological value of the protein with increasing dietary protein may result from less efficient use of dietary protein due to more excretion and to less efficient urea recycling and use (Robbins et al. 1974).

LITERATURE CITED

Robbins, C. T., R. L. Prior, A. N. Moen, and W. J. Visek. 1974. Nitrogen metabolism of white-tailed deer. J. Anim. Sci. 38(1):186-191.

UNIT 1.2: ENVIRONMENTAL FACTORS

It is difficult to separate biological factors from environmental factors when evaluating protein metabolism. Crude protein in the diet is an environmental factor that causes changes in the efficiency of use by the biological organism. The stimulus is from the environment, the response is biological and internal.

Another enviromental stimulus that affects protein metabolism, catabolism in this case, is extreme cold that places the animal in a critical thermal environment (Moen 1968). An animal in good condition mobilizes fat if a thermogenic metabolic response is necessary. If the fat reserve is depleted, protein tissue is the only internal substrate for thermogenic responses.

Weight losses accelerate when protein tissue must be oxidized as a source of energy. The main reason for this is that the energy content of a gram of fat is about 9.5 kcal, and of a gram of protein, 5.7 kcal. Further, a gram of protein is not metabolized completely by animals; only 4.7 kcal of heat energy are released as part of the heat energy remains in waste products (ammonia and urea) that are excreted and lost to the animal (Florey 1966:270). Thus heat production per unit of protein tissue weight is only about half as much as heat production per unit of fat tissue. Accelerated weight losses and quick death must occur when depressed nutrition and cold stress are combined. The WORKSHEET that follows provides some insight into the relative effects of energy metabolism on fat and protein substrate.

LITERATURE CITED

Florey, E. 1966. An introduction to general and comparative physiology. W. B. Saunders Company, Philadelphia. 713 pp.

Moen, A. N. 1968. The critical thermal environment: A new look at an old concept. BioScience 18(11):1041-1043.

REFERENCES, UNIT 1.2

ENVIRONMENTAL FACTORS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JANSA	38--1	186	191	odvi	nitrog metab of white-tail	robbins,ct; prio/	1974
JWMAA	43--2	454	460	odvi	season, nutri, serum nitro	bahnak,br holla/	1979

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

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AZOFA	11--3	200	203	rata	seas chang renal urea conc	eriksson, l;valto	1974
BJNUA	33--1	63	72	rata	serum prot, urea, seas, nut	hyvarinen,h;hel/	1975

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			

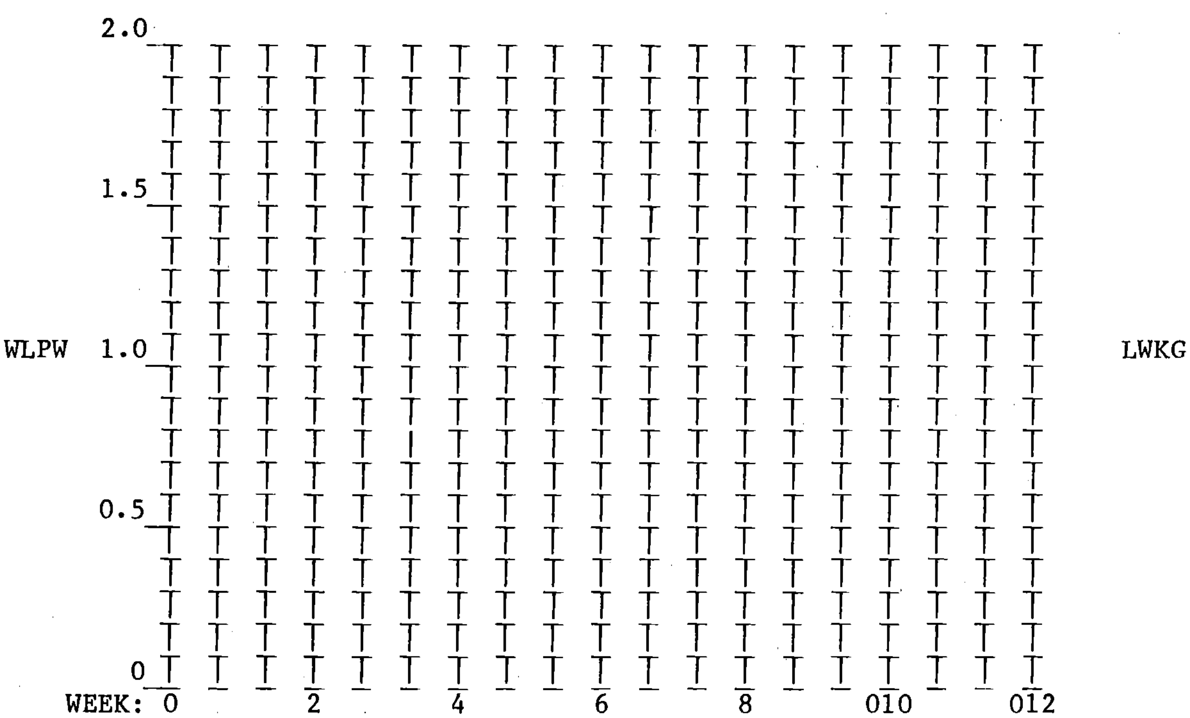
CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				oram			

CHAPTER 8, WORKSHEET 1.2a

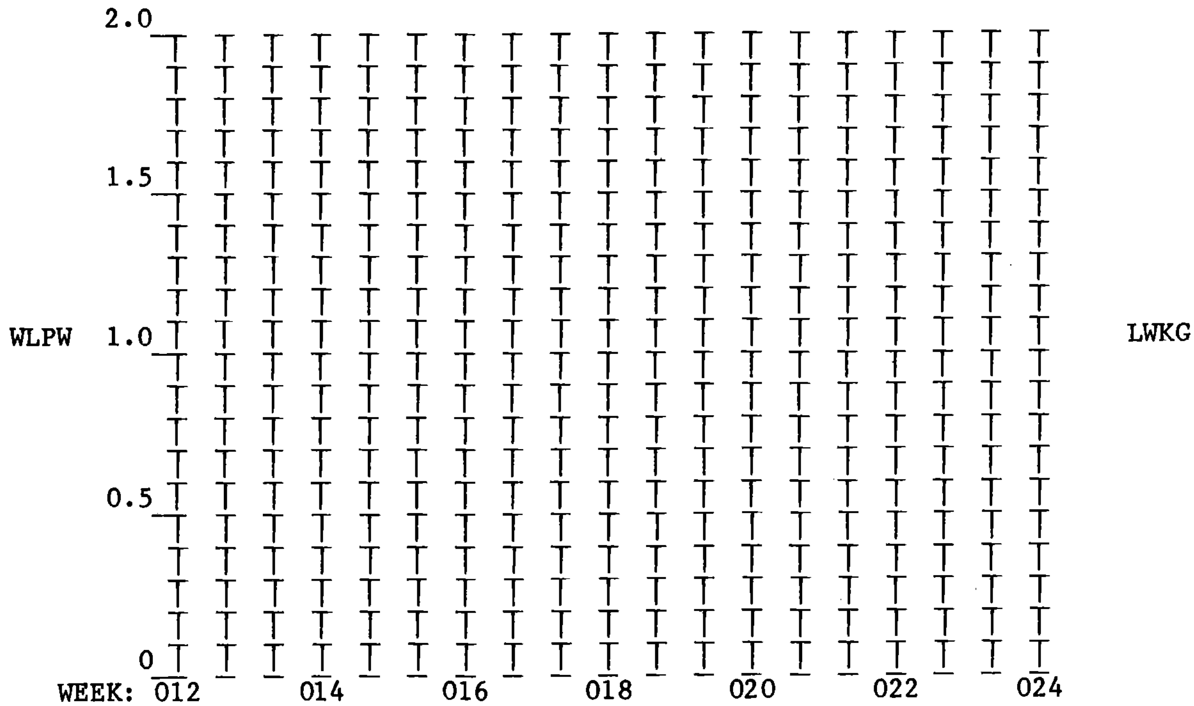
The effects of energy metabolism from fat and protein substrates on weight losses

About 9.5 kcal of heat energy are released when a gram of fat is metabolized. About 5.7 kcal are released when a gram of protein is oxidized in a bomb calorimeter, and 4.8 kcal when a gram of protein is metabolized. Demonstrate the effect of a change in substrate from fat to protein when one-half of the animals metabolic requirements are met by metabolized fat and protein tissue.

Begin with an animal weighing 100 kg with a 10 kg fat reserve and metabolism of MBLM = 1.5 so that ELMD = $(1.5)(70)(100^{0.75})$. The resulting ELMD is 3320 kcal. If one-half is met by daily intake and the other half by fat reserves, the first day weight loss is 0.17 kg. Making the calculations for one week at a time, weight loss after one week is 1.22 kg. The new weight is 100 -1.22 = 98.78. ELMD is then, $(1.5)(70)(98.78^{0.75}) = 2193$, and one-half of that is 1097 kcal of energy to be met by fat. At 9500 kcal per kg, the weight loss is 0.12 kg per day or 0.81 per week. The next week's weight is 97.94 and the calculations are cycled through again. Continue until the fat is gone, plotting the weight loss per week and the live weight in kg (LWKG) at weekly intervals below.



Continue the calculations after the fat is gone and protein must be the substrate metaboized. Continue plotting the results on the grid on the next page.


2.0
1.5
WLPW 1.0
0.5
0
WEEK: 012 014 016 018 020 022 024
LWKG

UNIT 1.3: INTERSPECIES COMPARISONS

General reviews of the literature indicate that protein metabolism processers are similar in both wild and domestic ruminants. Confined domestic animals are often given specific treatments to enhance growth, but such treatments do not alter basic metabolic processes. Urea and other non-protein nitrogen sources, for example, may be used as feed additives, even though domestic animals recycle urea naturally. Wild ruminants often do not not have access to foods high in protein or nitrogen, especially in the winter; urea recycling becomes a very important protein conservation adaptation then.

Endogenous urinary nitrogen has been measured in both domestic and wild ruminants. An equation for estimating endogenous urinary nitrogen in grams per day (EUNG) excreted, based on data in Crampton and Harris (1969:174) is:

$$EUNG = 0.002 \times 70\ (MEWK)$$

where EUNG = endogenous urinary nitrogen in gms per kg metabolic weight per day, and
MEWK = metabolic weight in kg = $LWKG^{0.75}$.

The constant 0.002 represents the average ratio of nitrogen in gms to kcal basal metabolism.

EUNG calculated with this equation is larger than that determined for white-tailed deer by Robbins et al. (1974). The equation for deer is given in UNIT 2.1.

The use of first approximations of metabolic costs for wild ruminants based on data for domestic ruminants is preferable to saying "I don't know" when faced with the need to determine total daily costs of living. This is necessary when estimating protein costs, and also when estimating mineral, water, and vitamin requirements in CHAPTER 9.

LITERATURE CITED

Crampton, E. W. and L. E. Harris. 1969. Applied animal nutrition. W. H. Freeman and Co., San Francisco. 753 pp.

Robbins, C. T., R. L. Prior, A. N. Moen, and W. J. Visek. 1974. Nitrogen metabolism of white-tailed deer. J. Anim. Science 38(1):186-191.

REFERENCES, UNIT 1.3

INTERSPECIES COMPARISONS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JASIA	60--3	393	398	doca	exper, nutri, dairy heifer	broster,wh; tuck/	1963
JONUA	101--	1331	1342	doca	non-prot nitr, urea kineti	mugerwa,js; conra	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJBSA	20--5	967	973	dosh	transf nit, blood to rumen	weston,rh; hogan,	1967
BJNUA	21--2	353	371	dosh	metabolism of urea in shee	cocimano,mr; leng	1967
BJNUA	27--1	177	194	dosh	ammonia and urea metabolis	nolan,jv; leng,ra	1972
JANSA	35--6	1271	1274	dosh	eff wat rstric nutrnt dig	asplund,jm; pfand	1972
JONUA	86--3	281	288	dosh	blood urea, protein intake	preston, rl;schn/	1965
PAANA	6----	378	383	dosh	urea metabolism in sheep	cocimano,mr; leng	1966

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJPHA	197-1	115	120	rumi	utiliz of blood urea, rumi	houpt,tr	1959
JDSCA	51--2	265	275	rumi	nitrogen metabolism of rum	waldo,dr	1968

TOPIC 2. MEASUREMENTS OF PROTEIN METABOLISM

Protein metabolism proceeds at orderly rates in relation to the biological functions involved. The basis for the requirement of protein traces back to the losses of nitrogenous end-products from the body (Crampton and Harris 1969:166). If an animal is to be in protein balance, intake must equal output. When an animal is in a positive protein or nitrogen balance, more is being ingested in and deposited in body tissue than is lost. When an animal is in a negative protein or nitrogen balance, more is lost from the body than is ingested.

Protein is necessary for the maintenance of basic life processes, including the synthesis of enzymes, replacement of catabolized body tissue, replacement of tissue abraded from internal surfaces of the gastrointestinal tract, and from the skin. Measurements of endogenous urinary nitrogen have been made on few wild species. Domestic cattle and sheep have been studied rather extensively, and the results are useful for estimating the protein costs for wild ruminants.

Protein balances are rather delicate. Protein is not stored in large quantities like fat is, nor is the protein stored passively like fat. Body composition measurements, for example, show rather constant protein fractions, while fat and water fractions are inversely proportional as weight increases (see CHAPTER 2).

The basic biological functions of domestic ruminants and wild ruminants should be similar, so the results of measurements of protein metabolism on domestic ruminants may be approximations for wild ruminants by expressing relationships per unit body weight, metabolic body weight, or to some some other baseline.

Two kinds of measurements are discussed in the two units that follow. UNIT 2.1 includes discussions of direct measurements under controlled chamber or pen conditions, and UNIT 2.2 of indirect measurements, made by evaluating the apparent effects of different levels of protein intake or productivity.

LITERATURE CITED

Crampton, E. W. and L. E. Harris. 1969. Applied animal nutrition. W. H. Freeman and Co., San Francisco. 753 pp.

UNIT 2.1: DIRECT MEASUREMENTS AND CALCULATIONS

Protein requirements may be estimated directly by measuring the amount of and evaluating the protein fraction of selected metabolic products. Such measurements involve captive animals and feces and urine collections. The amounts of feces and urine and the metabolic nitrogen fraction of each of these waste products provides an indication of how much protein has been catabolized. Measurements of the amounts and protein fractions of accumulated body tissues provide a basis for estimating the protein required for growth. Considerations that must be made when evaluating these protein or nitrogen fractions are discussed next.

ENDOGENOUS URINARY NITROGEN

Nitrogenous compounds are one of the by-products of protein metabolism. These compounds, such as ammonia and urea, must not be allowed to accumulate in the body as they can become very toxic. Urine is formed as a result of filtration, reabsorption, and secretion processes in the excretary system that result in the collection of nitrogen compounds that cannot be used (ammonia) or that are not recycled (urea).

The amount of urea recycled, a function of the crude protein in the diet, is variable and part of an adaptive strategy for nitrogen and protein conservation that has developed in free-ranging ruminants.

Endogenous urinary nitrogen, abbreviated EUNT, is derived from the catabolism of body tissue, and the quantity of EUNT is related to the metabolic body weight of the animal. An equation for calculating endogenous urinary nitrogen excreted by white-tailed deer, based on data in Robbins et al. (1974:189) is:

$$EUNG = 0.115 \times (MEWK)$$

where EUNG = endogenous urinary nitrogen in gms per kg per day, and
MEWK = metabolic body weight in kg = $LWKG^{0.75}$.

The calculated protein requirement in gms per day to meet this loss of EUNG is:

$$PRUN = (0.115)(MEWK)(6.25)$$

where PRUN = protein required for endogenous urinary nitrogen.

The equation for EUNG given above, based on measurements on white-tailed deer fawns that were about 6 months old, may not be the best estimation for other species of wild ruminants, and ruminants of different ages. Other estimations may be made with the equation given on page 11 of this chapter, and with values published by the Agricultural Research Council (1965). Slight differences in the estimates from these two sources are discussed in Moen (1973:335). Estimates with the equation in Crampton and Harris (see page 11) are less than estimates based on the ARC values at the lower weights and greater at the higher weights for both cattle and sheep.

FECAL NITROGEN

Nitrogen in the feces comes from four sources. One, ingested but undigested protein in the diet ends up in the feces. Such protein compounds pass through the gastrointestinal tract intact. Two, nitrogen residues originating in digestive enzymes; three, protein compounds and nitrogen residues from the metabolic activities of the intestinal microflora, and four, protein compounds and nitrogen residues from the metabolic activities of the cells lining the gastrointestinal tract all end up in the feces. These different origins are not discerned when simply analyzing the feces for protein or nitrogen. Further, the third source includes protein or nitrogen from the metabolic functions of the intestinal microflora. The second and fourth sources are of metabolic origin, and represent protein metabolized by the body and used for maintenance and productive functions.

Metabolic fecal nitrogen results from the abrasion of epithelial cells from the gastrointestinal tract as food passes through and from proteins used in the digestion of food. The quantity of metabolic fecal nitrogen is a function of both food intake and the quality of the ingested food.

The usefulness of ingested protein to the animal is expressed as the biological value of the protein. The true biological value is defined by Crampton and Harris (1969:89) as the "percentage of true absorbed nitrogen that is used for maintenance and production, or for maintenance only." It is related to the content of essential amino acids (those amino acids which must be ingested because they cannot be synthesized in the body).

Suppose the protein contained a perfect assortment of amino acids. Then, all of the protein could be used by the body and none would be deaminized and its nitrogen component excreted in the urine. The urine would contain only nitrogen of metabolic origin. Suppose that the protein in a food did not contain a perfect assortment of amino acids. Then, only a fraction of the protein could be used, with the rest deaminized and the nitrogen excreted. This fraction times the protein digestibilility results in a net protein coefficient (NPRC), which is a measure of the amount of protein that can be used for metabolic purposes. Calculations of net protein coefficients are illustrated below.

Protein characteristics of the food	Amino acid "index"		Protein digestibility		NPRC
Perfect amino acid distribution, high digestibility	1.00	x	0.95	=	0.95
Good amino acid distribution, medium digestibility	0.80	x	0.70	=	0.56
Poor amino acid distribution, low digestibility	0.50	x	0.50	=	0.25

These illustrations show how the amino acid distribution and digestibility interact (Oser 1951) to result in a net protein coefficient (NRPC). As NPRC decreases, food intake must increase if nitrogen requirements are to be met. The additional intake, however, raises MFNG requirements. Thus deteriorating protein quality of forage causes an increase in protein requirements, placing the animal in a negative feedback situation that results in low rates of ingestion and a negative protein balance.

GROWTH

Animals that are in a positive nitrogen balance are depositing more protein in body tissue than is being excreted. Protein is very important for body growth in young animals, it is deposited in hair as coat changes occur twice each year, and it is an important cost during reproduction as protein is an important component of fetal tissue and milk.

The protein costs associated with these productive processes may be estimated by determining the protein compositions and the quantities of the different tissues produced. Results of these "before and after" measurements may be expressed on a per day basis. Growth and chemical composition data were given in CHAPTERS 1 and 2. These data are needed when completing the WORKSHEETS in TOPIC 3.

LITERATURE CITED

Agricultural Research Council. 1965. The nutrient requirement of farm livestock. No. 2. Ruminants. Agricultural Research Council, London. 264 pp.

Crampton, E. W. and L. E. Harris. 1969. Applied animal nutrition. 2nd Ed. W. H. Freeman and Co., San Francisco. 753 pp.

Moen, A. N. 1973. Wildlife ecology. W. H. Freeman and Co., San Francisco. 458 pp.

Oser, B. L. 1951. Methods for integrating essential amino acid content in the nutritional evaluation of protein. J. Amer. Dietetic Assoc. 26:396.

REFERENCES, UNIT 2.1

DIRECT MEASUREMENTS AND CALCULATIONS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--6	1437	1442	cerv	variat, ruminal nitrog lev	klein, dr;schon	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	38--1	186	191	odvi	nitrogen metabolism, deer	robbins,ct; prio/	1974
JWMAA	39--3	582	589	odvi	protein requirement, fawns	smith,sh; holter/	1976
JWMAA	43--4	872	879	odvi	protein require, yearlings	holter,jb; hayes/	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAVMA	155-7	1085	1085	odhe	urine-collect device, male	richmond,m; pill/	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BJNUA	24--3	843	855	ceel	dosh, digest, nitrogen met	maloiy,gmo; kay,/	1970
CBPAB	60A-3	251	256	ceel	nitrogen metabolism, red d	simpson,am; webs/	1978

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

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

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

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

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

oram

UNIT 2.2: FEEDING TRIALS

Feeding trials which give indications of the levels of dietary protein necessary for different growth and reproductive responses may be completed for captive animals in order to get some estimate of the protein fraction of the forage required for different levels of productivity. These are "black box" type experiments; inputs are compared to outputs without evaluating the mechanisms within the animal that result in the partitioning of the nutrients. Further, interactions between different nutrients are difficult if not impossible to consider and control.

Comparisons may be made between the results of feeding trials and the summation of different protein costs determined by measurements or calculations of the metabolic characteristics discussed in UNIT 2.1. The two independent approaches should have similar results, of course. Such comparisons are useful because they serve as checks on each other; "ecological accounting" is an important part of the many sequential calculations used to link animal to range in as many ways as possible.

REFERENCES, UNIT 2.2

FEEDING TRIALS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	31--4	679	685	odvi	protein requirement, fawns	ullrey,de; youat/	1967
JWMAA	43--4	872	879	odvi	protein require, yearlings	holter,jb; hayes/	1979

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

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

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

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

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

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

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

obmo

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

oram

TOPIC 3. ESTIMATES OF PROTEIN COSTS FOR MAINTENANCE AND PRODUCTION

Estimates of protein costs for production are made whenever new tissue is produced which contains protein. New body tissue resulting from growth, fetal tissue, hair, and milk are all protein-containing tissue, and the protein in these tissues must come from either the diet or from the catabolism of body protein. Since body protein stores are not extensive, the diet is the main source of protein for production.

A general rule to follow when estimating the protein costs for production is that the cost is at least equal to the amount of protein in the new tissue. Then, there is an additional cost associated with the assimilation of that tissue, an "overhead" that results from the less than 100% efficiency of metabolic processes.

The UNITS in this TOPIC include descriptions of the protein-requiring productive processes characteristic of wild ruminants. The equations given may be used for first approximations when evaluating the total protein requirements of individuals at different times during their annual cycles.

UNIT 3.1 ENDOGENOUS URINARY NITROGEN

Some of the nitrogen excreted in the urine is derived from the catabolism of body tissues, and has traditionally been called endogenous urinary nitrogen. Such nitrogen is of metabolic origin; it has been assimilated into body tissue from dietary nitrogen, and then released again when the body tissue is catabolized. This quantity of endogenous urinary nitrogen has been considered a minimum daily requirement. A formula for estimating endogenous urinary nitrogen (EUNG) based on data in NRC (1976) and Moen (1973:335) is:

$$EUNG = (a)(MEWK)$$

where EUNG = endogenous urinary nitrogen in gms and
MEWK = metabolic weight in kg.

The protein required to replace the endogenous urinary nitrogen excreted, PRUN, in gms per day, is:

$$PRUN = (a)(MEWK)(6.25)$$

The value of (a) in the formulas above is slightly different in different sources. In Crampton and Harris (1969:174) it is 0.140. In the NRC (1976:6) publication, it is 0.120. In Robbins et al. (1974:189) it is 0.115. The equations for calculating endogenous urinary nitrogen are, then:

$$\text{General: } EUNG = 0.140\ LWKG^{0.75}$$
$$\text{Beef cattle: } EUNG = 0.120\ LWKG^{0.75}$$
$$\text{White-tailed deer: } EUNG = 0.115\ LWKG^{0.75}$$

The differences in these three equations are in the value of a; the general equation results in a larger estimate than the beef cattle and white-tailed deer equations. Comparisons of absolute values are made in a WORKSHEET.

LITERATURE CITED

Crampton, E. W. and L. E. Harris. 1969. Applied animal nutrition. W. H. Freeman and Co., San Francisco. 753 pp.

Moen, A. N. 1973. Wildlife ecology. W. H. Freeman and Co., San Francisco. 458 pp.

National Research Council. 1976. Nutrient requirements of beef cattle. Number 4. National Academy of Sciences, Washington D. C. 56 pp.

Robbins, C. T., R. L. Prior, A. N. Moen, and W. J. Visek. 1974. Nitrogen metabolism of white-tailed deer. J. Anim. Science 38(1):186-191.

REFERENCES, UNIT 3.1

ENDOGENOUS URINARY NITROGEN

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	38--1	186	191	odvi	nitrogen metabolism of w-t	robbins,ct; prio/	1974

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

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

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

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

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CHAPTER 8, WORKSHEET 3.1a

Estimates of endogenous urinary nitrogen

Endogenous urinary nitrogen of white-tailed deer is dependent upon the weight of the deer and can be calculated from the ingesta-free weight with an equation from Robbins et al. (1974):

$$EUNG = 0.115\ (LWKG^{0.75})$$

where EUNG = endogenous urinary nitrogen in grams and
LWKG = live weight in kg.

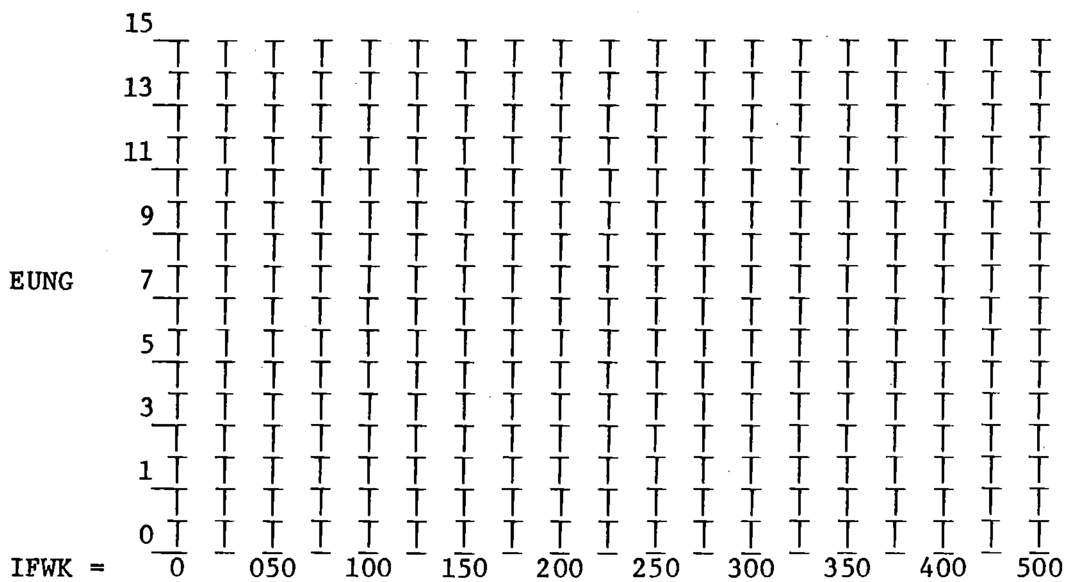
The NRC (1976:6) equation for beef cattle is:

$$EUNG = 0.120\ (LWKG^{0.75})$$

The general equation based on Crampton and Harris (1969:174) is:

$$EUNG = 0.140\ (LWKG^{0.75})$$

Plot the results using these equations below. Note that LWKG of deer is seldom over 100 kg. Beef cattle reach 500 kg or more at maturity.



LITERATURE CITED

Crampton, E. W. and L. E. Harris. 1969. Applied animal nutrition. W. H. Freeman and Co., San Francisco. 753 pp.

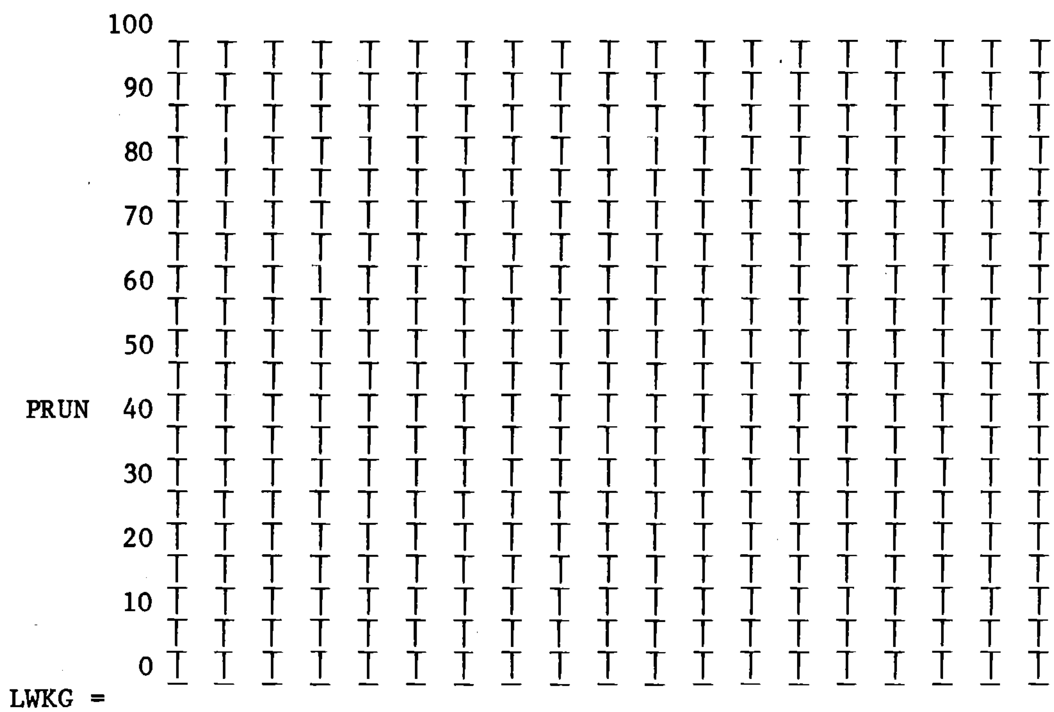
National Research Council. 1976. Nutritent requirements of beef cattle. Number 4. National Academy of Sciences, Washington, D. C. 56 pp.

Robbins, C. T., R. L. Prior, A. N. Moen, and W. J. Visek. 1974. Nitrogen metabolism of white-tailed deer. J. Anim. Sci. 38(1):186-191.

CHAPTER 8, WORKSHEET 3.1b

Protein required to meet EUNG losses

The protein equivalent of endogenous urinary nitrogen losses is determined by multiplying EUNG by 6.25, according to the formula on page 23. Select the weight range used, determine the amounts of protein required for endogenous urinary nitrogen losses using the 3 equations in the previous WORKSHEET, label the x axis (LWKG) and y axis (PRUN), and plot the protein required for endogenous urinary nitrogen in the grid below.



UNIT 3.2: METABOLIC FECAL NITROGEN

The nitrogen in the feces of dietary origin that has been assimilated into body tissue and then broken down again to appear in the feces is called metabolic fecal nitrogen. This category includes nitrogen from cells that have been absorbed from the linings of the gastrointestinal tract nitrogen from the protein compounds and nitrogen residues originating in secreted enzymes, and residual protein and nitrogen in intestinal microflora that ends up in the feces.

Metabolic fecal nitrogen in grams per day (MFNG) is related to food intake by the following formula modified from Moen (1973:366).

$$MFNG = k\ DWFK$$

where k = 5 and DWFK = dry weight forage in kg. DWFK necessary for maintenance is related to body weight, and has been calculated in previous UNITS in relation to energy metabolism. The calculated DWFK may be used as a starting point for calculating the protein requirements to meet quantities of metabolic fecal nitrogen excreted. If the calculated amount of food necessary to meet the energy requirements is low in protein, protein requirements may not be met by the predicted DWFK. This depends in part on the net protein coefficients of the forage ingested.

Metabolic fecal nitrogen for beef cattle given in the NRC publication (1976:6) is simply 4 g N/kg feed dry matter. Expressing this as an equation:

$$MFNG = (4)(DMIK)$$

where MFNG = metabolic fecal nitrogen in grams per day,
DMIK = dry matter intake in kg per day.

The value of "k" is variable in a formula in Moen (1973:336), based on the relative amounts of milk and forage in the diet. The values are:

on forage diets: $k = 5$

on milk diets: $k = 2.5$, and

forage and milk diets: $k = 5 - (PNDM)(2.5)$

where PNDM = percent nutrients derived from milk
$= 1.136 - 0.045\ LWKG$ (See CHAPTER 7, WORKSHEET 3.4a, Page 48a).

Note that the equations above relate metabolic fecal nitrogen to dry matter intake. As more forage is ingested, more nitrogen is released internally from the sources mentioned above to process the forage. MFNG is less when milk is ingested (c = 2.5) because fluid milk is more easily digested.

Actual calculations of MFNG are dependent on DMIK. Yet DMIK is dependent on energy and protein requirements, including MFNG. This feed-back mechanism suggests a need for an iteration procedure in final determinations of MFNG. Such a procedure is illustrated in a WORKSHEET.

LITERATURE CITED

Moen, A. N. 1973. Wildlife ecology. W. H. Freeman and Co., San Francisco. 458 pp.

National Research Council. 1976. Number 4. Nutrient requirements of beef cattle. 5th Rev. Ed. National Academy of Sciences, Washington, D. C. 56 p.

REFERENCES, UNIT 3.2

METABOLIC FECAL NITROGEN

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	38--1	186	191	odvi	nitrogen metabolism of whi	robbins,ct; prior/	1974

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

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

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

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

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

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CHAPTER 8, WORKSHEET 3.2a

Estimates of metabolic fecal nitrogen

Estimate the metabolic fecal nitrogen in grams with the following equation:

$$MFNG = (5)(DMIK)$$

Suppose 9 gms of nitrogen were required for all body processes <u>except</u> MFNG. Suppse that the crude protein content of the forage was 12%. Then, one kg of forage would contain 120 gms of protein. This is equal to 19.2 gms of nitrogen (120/6.25 or 120 x 0.16 = 19.2). Suppose the net protein coefficient of this forage is 0.70. The amount of forage needed to supply 9 gms of nitrogen is (9.0)(1/0.70)/19.2 = 0.67 kg = DMIK. MFNG = (5)(0.67) = 3.35. Thus the total nitrogen required, including MFNG , is now 9.0 + 3.35 = 12.35. Substituting 12.35 for 9.0, DMIK is now calculated by (12.35)(1/0.70)/19.2 = 0.92. MFNG = (5)(0.92) = 4.60, which is added to 9.0, and the total nitrogen requirement, including MFNG , is now 9.0 + 4.60 = 13.60. Substituting 13.60 for 9.0, DMIK is now calculated by (13.60)(1/0.70)/19.2 = 1.01. MFNG = (5)(1.01) = 5.05, and 9.0 + 5.05 = 14.05. Substituting 14.05 for 9.0, DMIK = (14.05)(1/0.70)/19.2 = 1.05.

Note how DMIK began at 0.67, and successive calculations of the MFNG resulted in successive approximations of DMIK = 0.92, 1.01, and 1.05. Note that DMIK is getting larger due to the addition of MFNG requirements, but that increments are getting smaller with each cycle. The last calculation resulted in an increment of less than 4%;the next calculation [(5)(1.05)...] results in an increment of less than 1%.

The protein required to meet this metabolic fecal nitrogen requirement may be calculated with the following equation, assuming that the protein contains 16% nitrogen:

$$PMFN = 6.25(MFNG)$$

where PMFN =protein required for metabolic fecal nitrogen.

Review this sequence so you understand it thoroughly. The iterations being completed result in the estimation of total nitrogen requirements, including the effects of metabolic fecal nitrogen on dry-matter intake, and the feed-back effects of dry matter intake on metablic fecal nitrogen.

Repeat these calculations with a forage that is low in crude protein say less than 5%. Depending on the value of NPRC, there is a level of crude protein at which ingestion rates must increase in order to keep up with the MFNG costs. Above that level, ingestion is counter-productive; metabolic processing costs more than is returned from the forage.

Urea recycling and changes in the biological value of the protein (hence NPRC) makes the biological process more complex than this mathematical process. The iterations described do help one understand a bit more about the balance between nutrient requirements and nutrient densities in the forage.

UNIT 3.3: PROTEIN REQUIRED FOR BODY GROWTH

The daily protein required for gain is a function of the amount of total gain per day and the composition, or fraction of the gain that is protein. Equations for body composition were given in CHAPTER 2, and the protein fraction equation is used here to calculate this requirement. The daily change in weight multiplied by the protein fraction of animals at this weight is the daily protein deposited, which is the minimum protein required for body growth. The efficiency of protein deposition affects the actual amount of protein required.

The protein composition of steers weighing 100 kg is 18 percent, and of those weighing 500 kg, 9%. Corresponding values for heifers are 18% and 7%, respectively. Note that the percent composition is higher for smaller and younger cattle that are still growing, and lower for the larger and older cattle that are more physically mature. The protein composition of white-tailed deer was much more constant for a wide range of ages and weights measured by Robbins et al. (1974). In fact, the protein content of males and females combined was 20% of the body weight at 6 and 60 kg body weight. Wild ruminants are expected to have a more constant protein fraction since they are neither bred nor raised for rapid gains which under confined conditions may result in a higher fat and lower protein content in the body.

LITERATURE CITED

Robbins, C. T., A. N. Moen, and J. T. Reid. 1974. Body composition of white-tailed deer. J. Anim. Sci. 38(4):871-876.

REFERENCES, UNIT 3.3

PROTEIN REQUIREMENTS FOR BODY GROWTH

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	38--4	871	876	odvi	body composition of white-	robbins,ct moen/	1974
JWMAA	31--4	679	681	odvi	protein requirements, fawn	ullrey,de; youat/	1967
JWMAA	39--3	582	589	odvi	protein requirements, fawn	smith,sh; holter/	1975
JWMAA	43--4	872	879	odvi	protein require, yearlings	holter,jg; hayes/	1979
NAWTA	31---	129	139	odvi	effects of dietary protein	murphy,da; coates	1966
PAABA	600--	1	50	odvi	nutr req growth, antlr dev	french,ce; mcewe/	1955
PAARA	209-1	1	11	odvi	eff feed restric, antl dev	long,ta; cowan,r/	1959

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

odhe

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

ceel

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

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

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oram

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

JONUA 86--3 281 289 rumi blood urea, protein intake preston,rl; schn/ 1965

Estimates of the protein requirements of white-tailed deer for body growth

The protein fraction of body growth is obviously the minimum protein required for body growth, with increases related to the efficiency of protein deposition during growth. The protein fractions of white-tailed deer of different weights from June through October were determined by Robbins et al. (1974). The equation for calculating the protein component of the body weight in kg (males and females combined), rearranged from the published paper, is:

$$PCBK = e^{1.0091 \ln IFWK - 1.6267}$$

where PCBK = protein component of the body in kg, and
IFWK = ingesta-free weight in kg.

The equation for the protein component of males and females combined, expressed as a fraction of ingesta-free weight, is:

$$PRFR = e^{1.0091 \ln IFWK - 1.6267}/IFWK$$

If IFWK = 6.0 and PCBK = 1.2, then PRFR = 1.2/6.0 = 0.20.
If IFWK = 34.0 and PCBK = 6.9, then PRFR = 6.9/34.0 = 0.20.
If IFWK = 68.0 and PCBK = 13.9, then PRFR = 13.9/68.0 = 0.20.

Thus the protein fraction is a constant 0.20 (or 20%) of the ingesta-free weight for a wide range of weights. The equation for the protein required for body growth is, then:

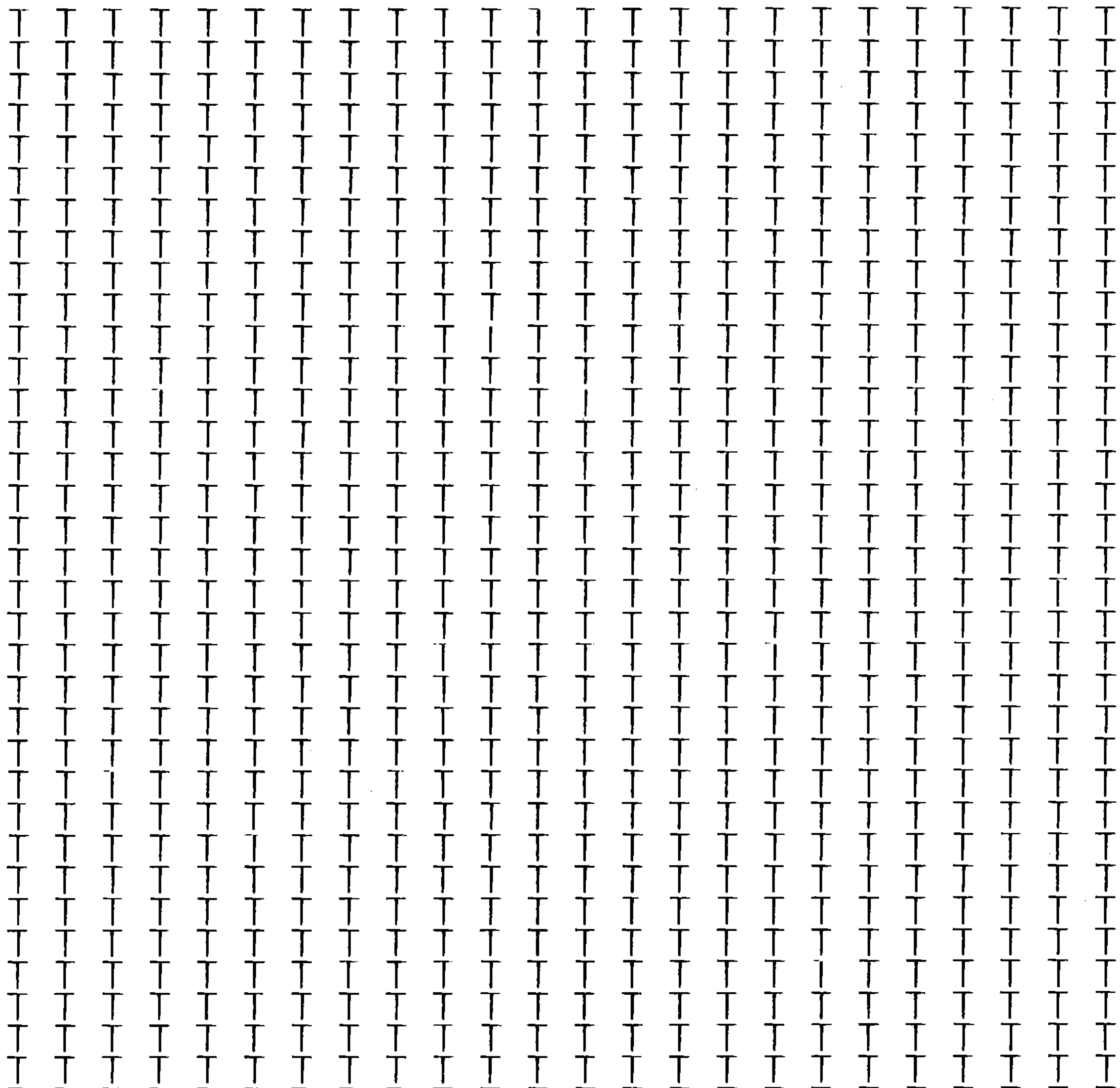
$$PRBG = (0.20)(DAGA)(1/PEFG)$$

where PRBG = protein required for body growth,
DAGA = daily gain, and
PEFG = protein efficiency of body growth.

The nitrogen component in kg (NTCK) is simply PRCK/6.25. Since the protein fraction is 0.20, the nitrogen fraction is 0.032, or 3.2% of the body. This is higher than the 2.5% estimate given in Moen (1973:336), based on data on domestic animals.

Protein and nitrogen components may be plotted on the grid on the next page for the range of ingesta-free weights selected. The axes are unlabeled since the 20% figure for white-tailed deer may be used as a first approximation for other wild ruminants of different weights. In other words, body composition of any wild ruminant may be estimated to include 20% protein, and this may be a better value than those based on domestic ruminants when none are available for particular wild species.

PRCK
or
NTCK



IFWK=

Literature Cited

Robbins, C. T., A. N. Moen, and J. T. Reid. 1974. Body composition of white-tailed deer. J. Anim. Sci. 38(4):871-876.

UNIT 3.4: PROTEIN REQUIRED FOR HAIR GROWTH

Wild ruminants have two coats per year as a heavy winter coat is replaced by a light summer coat. Some species show color changes that are associated with the coat changes too. Physical and chemical characteristics of the hair coats and molting were discussed in CHAPTER 2, and the data given there on protein content of hair of different species should be used to estimate the cost of hair growth.

The overall nitrogen loss through hair and surface cells is calculated for cattle as: grams N = $0.02\ W^{0.75}$ (NRC 1976:6). This expresses the grams of nitrogen required for hair and surface cells each day as a directy proportion of metabolic body weight. Rewritten with four-letter symbols:

$$NRHG = 0.02\ IFWK^{0.75}$$

where NRHG = nitrogen required for hair growth and
IFWK = ingesta-free weight in kg.

The protein required for hair growth (PRHG) is 6.25 times NRHG; therefore:

$$PRHG = 0.125\ IFWK^{0.75}$$

Both NRHG and PRHG are in grams.

These equations result in average costs over the entire year. Estimates of the cost of hair growth per day for wild ruminants must consider changes in the growth rate of hair from season to season. The winter coats of North American wild ruminants begin growing in August or September, and growth is completed by November or December. The summer coat begins growing in April and May, and growth is completed by June. After growth is completed, the protein is irreversibly present in the hair, and represents a cost that is met twice each year.

The protein required for hair growth may be calculated with rates of hair growth and composition of the hair, just as the cost of body growth was calculated. Daily changes in the amounts of hair times the protein fraction of the hair are necessary inputs when calculating the daily protein cost of hair growth, just as in calculations of the costs of body growth. These options are presented in WORKSHEETS.

LITERATURE CITED

National Research Council. 1976. Number 4. Nutrient requirements of beef cattle. 5th Rev. Ed. National Academy of Sciences, Washington, D. C. 56 pp.

REFERENCES, UNIT 3.4

PROTEIN REQUIRED FOR HAIR GROWTH

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	38--4	871	876	odvi	body composition of white-	robbins,ct; moen/	1974

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

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

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

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

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	45--4	826	831	doca	hair indic calor-prot stat	haaland,gl; mats/	1977

Chapter 8, Worksheet 3.4a

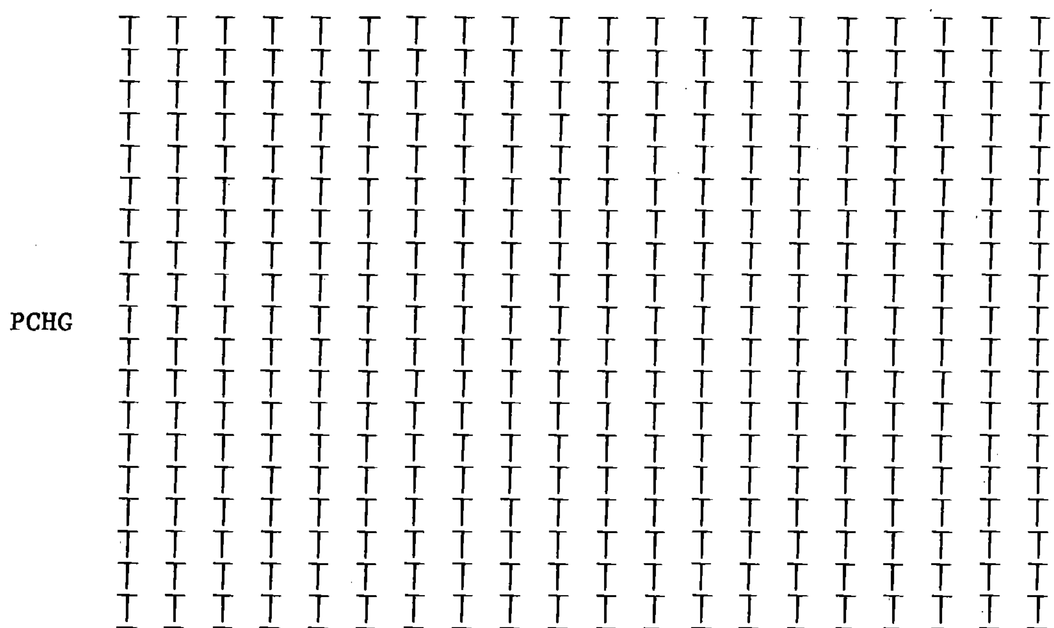
Estimates of the protein requirements for hair growth

The protein fraction of the hair is obviously the minimum protein required for hair growth, with increases related to the efficiency of protein deposition during hair growth. The protein fraction of hair of white-tailed deer was given by Robbins et al. (1974) and discussed in CHAPTER 2, UNIT 1.3, Pages 11-14. Knowing daily changes in hair weights, the protein composition of hair, and the physiological efficiency of hair growth, the protein cost of hair growth may be calculated with the formula:

$$PCHG = (DLTA\ HAWG)(PRFH)(1/PEHG)$$

where PCHG = protein cost of hair growth in gms per day,
DLTA = delta, or daily change,
HAWG = hair weight in gms,
PRFH = protein fraction of the hair, and
PEHG = physiological efficiency of hair growth.

Refer back to CHAPTER 2 for data on hair growth, and then calculate PCHG. Compare the results over the annual cycle with the protein costs estimated with the formula for cattle (see page 31). An unlabeled grid is provided for plotting the results for the species of your choice.



LITERATURE CITED

Robbins, C. T., A. N. Moen, and J. T. Reid. 1974. Body composition of white-tailed deer. J. Anim. Sci. 38(4):871-876.

UNIT 3.5: PROTEIN REQUIRED FOR GESTATION

The minimum protein required for gestation is equal to the amounts deposited in fetal and associated reproductive tissues, with increases in proportion to the rate of physiological efficiency of protein deposition for this purpose. Protein requirements increase rapidly in the last two-thirds of the gestation period.

The total nitrogen content of the gravid uterus of white-tailed deer has been determined by Robbins and Moen (1975). The published equation (page 688) is modified to:

$$\text{NCUG} = e^{0.2096 + 0.0275\ \text{DIGE}}$$

where NCUG = nitrogen content of the uterus in gms, and
DIGE = days into gestation.

Nitrogen retention may be calculated by subtracting NCUG for successive days. An equation has already been determined for this by Robbins and Moen (1975) for white-tailed deer, and another equation given that may be adapted to any species. The equation for estimating nitrogen retention for gestation per day (NRGD) in white-tailed deer, modified from Robbins and Moen (1975:688), is:

$$\text{NRGD} = e^{0.0275\ \text{DIGE} - 3.3856}$$

where NRGD = nitrogen required for gestation (gms per day), and
DIGE = days into gestation.

The equation for any species, modified from Robbins and Moen (1975:688), is:

$$\text{NRGD} = [e^{0.0512\ (\text{DIGE}/\text{LEGP})100\ -\ 1.7274}]\ [\text{BIWK}]$$

where NRGD = nitrogen required for gestation (gms per day),
DIGE = days into gestation,
LEGP = length of the gestation period, and
BIWK = birth weight in kg.

The above equation is particularly useful since it expresses a proportional nitrogen cost in relation to length of the gestation period and fetal weight at birth. Cattle, sheep, and deer were quite similar, and there is no reason to believe that the wild ruminants would be very different in this basic biological process.

WORKSHEETS provide opportunities to calculate the protein costs of gestation, expressed both as protein and nitrogen.

LITERATURE CITED

Robbins, C. T. and A. N. Moen. 1975. Uterine composition and growth in pregnant white-tailed deer. J. Wildl. Manage. 39(4):684-691.

REFERENCES, UNIT 3.5

PROTEIN REQUIRED FOR GESTATION

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	39--4	684	691	odvi	uterin comp, growth, pregn	robbins,ct; moen,	1975
NAWTA	31---	129	139	odvi	effects of dietary protein	murphy,da; coates	1966

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

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

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

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

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

CHAPTER 8, WORKSHEET 3.5a

Estimates of the protein required for gestation

Estimates of the daily protein required for gestation may be made with the equations in Robbins and Moen (1975). Since the protein required is 6.25 x nitrogen, the equations below include this conversion factor. The equations are:

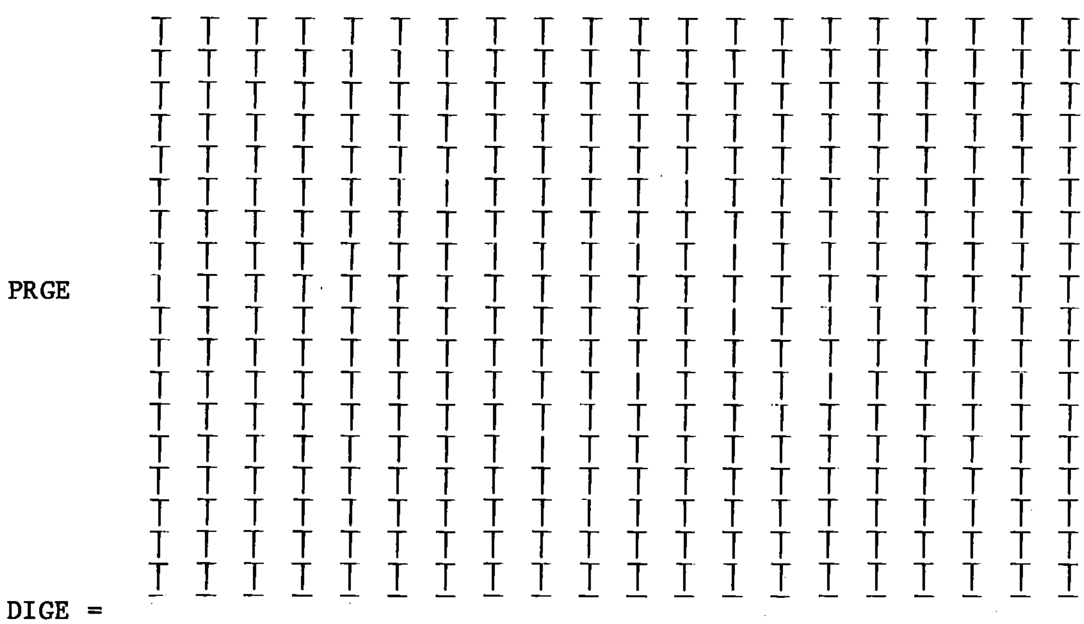
odvi $\quad PRGE = (e^{0.0275\ DIGE\ -\ 3.3856})\ (6.25)$

any species: $\quad PRGE = [e^{0.0512\ (DIGE/LEGP)100\ -\ 1.7274}]\ [BIWK]\ (6.25)$

where PRGE = protein required in for gestation in grams per day,
DIGE = days into gestation,
LEGP = length of the gestation period, and
BIWK = birth weight in kg.

The two reproductive system variables needed (LEGP and BIWK) to calculate PRGD were given in CHAPTERS 1 and 2.

Calculate PRGD for intervals of DIGE and plot in the grid below. The results are minimum values; physiological efficiencies less than 1.0 will increase the actual cost per day of nitrogen retention.



LITERATURE CITED

Robbins, C. T. and A. N. Moen. 1975. Uterine composition and growth in pregnant white-tailed deer. J. Wildl. Manage. 39(4):684-691.

UNIT 3.6: PROTEIN REQUIRED FOR MILK PRODUCTION

The protein required for milk production is a function of the amount of milk produced, the protein content of the milk, and the physiological efficiency of lactogenesis. Milk is relatively high in protein, a biological necessity for the rapid growth of the neonate.

Milk production was discussed in CHAPTER 7, UNIT 3.4, with calculations of milk production in gms per day given in WORKSHEET 3.4a (Chapter 7 - Page 48a). The chemical composition of milk was discussed in CHAPTER 2, UNIT 2.2. After data on these characteristics have been determined, the protein cost of lactation per day may be estimated as at least the amount of protein in the milk, with increases in the protein required due to the physiological efficiency of lactogenesis.

The WORKSHEET at the end of this UNIT provides opportunities to synthesize concepts, data, and equations from previous CHAPTERS while estimating protein required for lactation.

REFERENCES, UNIT 3.6

PROTEIN REQUIRED FOR MILK PRODUCTION

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	25--1	66	70	odvi	deer milk, substitute milk	silver,h	1961
JWMAA	29--1	79	84	odvi	comp milk,bld nursng doe,f	youatt,wg; verme/	1965
NAWTA	31---	129	139	odvi	effects of dietary protein	murphy,da; coates	1966

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	37--2	217	218	odhe	composit, deer milk, calif	hagen,hl	1951
JOMAA	36--3	473	474	odhe	mule deer milk	browman,lg; sears	1955
JOMAA	58--3	420	423	odhe	changes nutri compos, milk	mueller,cc; sadle	1977
JWMAA	20--2	212	214	odhe	postnat grow, comp of milk	kitts,wd; cowan,/	1956
JWMAA	44--2	472	478	odhe	milk yield, black-tailed d	sadleir,rmfs	1980

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BIJOA	153-3	647	655	ceel	whey proteins, red de milk	mcdougall,ei; ste	1976
JRPFA	37--1	67	84	ceel	comp, yield of milk, red d	arman,p; kay,rnb/	1974
ZTTFA	31--5	227	238	ceel	comp, milk, red deer, pt 1	brueggemann,j; d/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--2	213	215	alal	gros comp milk, fat, minrl	cook,hw; rausch,/	1970
JWIDA	12--2	202	207	alal	milk, hair, element relati	franzmann,aw; fl/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	45--6	1101	1106	rata	milk, gros comp, fat, prot	hatcher,vb; mcew/	1967
JDSCA	57-11	1325	1333	rata	milk comp chang, grazing r	luick,jr; white,/	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	37--2	217	218	anam	odhe, compos milk, compars	hagen,hl	1951

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	36--2	305	308	bibi	the lipids in bison bison	wilbur,cg; gorski	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	43--5	885	888	ovca	milk, gross comp, fat cons	chen,ech; blood,/	1965

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--4	629	633	ovda	milk, stage lact, composit	cook,hw; perarso/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	34--6	569	571	obmo	gross composition of milk	tener,js	1956
CJZOA	48--6	1345	1347	obmo	gros comp,ftty acid, minrl	baker,be; cook,h/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	47--1	5	8	oram	gross compos, fat acid con	lauer,bh; blood,/	1969
CJZOA	47--2	185	187	oram	miner const, milk, arctic	luer,bh; baker,b	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBCPA	42b-2	323	328	many	electrophesis milk caseins	lauer,bh; baker,b	1972
CJZOA	49--4	551	554	many	carbohydra content, casein	baker,be; lauer,b	1971
CJZOA	55--1	231	236	many	amin acid comp casein milk	lauer,bh; baker,b	1977
IZYBA	4----	333	342	many	composit milk wild animals	ben shaul,dm	1962

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRPFA	37--1	67	84	cerv	composi milk, cerv species	arman,p; kay,rnb/	1974

CHAPTER 8, WORKSHEET 3.6a

Estimating the protein required for milk production

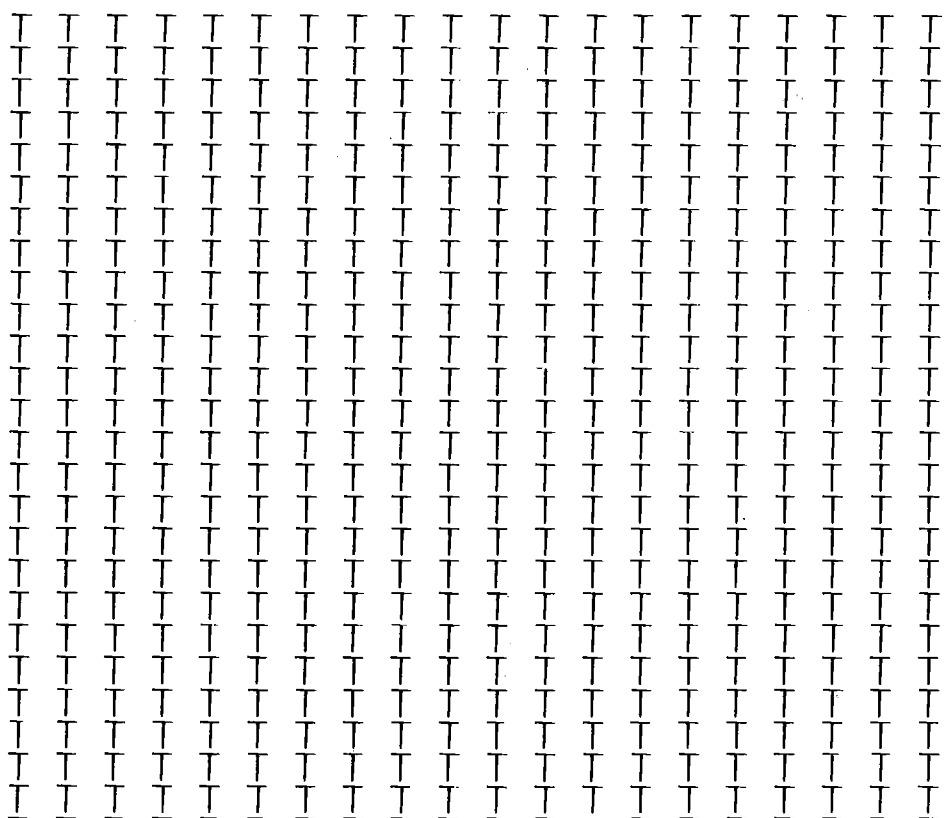
The protein required for milk production may be calculated by multiplying the amount of milk produced by the protein fraction of the milk by the reciprocal of the physiological efficiency of protein synthesis for milk production. In symbol form:

$$PRMP = (QMPK)(PRFM)(1/PEMP)(1000)$$

where PRMP = protein required for milk production in gms per day,
QMPK = quantity of milk produced in kg per day,
PRFM = protein fraction of milk,
PEMP = physiological efficiency of milk production, and
1000 = the conversion factor from kg to gms.

These parameters have all been discussed in previous chapters. For QMPK, refer to CHAPTER 7; for PRFM, refer to CHAPTER 2; and for PEMP, use 0.5 to 1.0. PRFM may change during the lactation period. Then, PRFM = f(DILA), where DILA is days into lactation, and an equation replaces a single value for PRFM.

Calculate PRMP and plot the results on the grid provided. The x-axis is PRFM or DILA, the y-axis PRMP, and PEMP effects a family of curves.



UNIT 3.7: SUMMATIONS OF PROTEIN REQUIRED

Equations for several different protein costs have been presented in this CHAPTER. If the concepts underlying each of these are understood and the costs calculated, then the total cost can be determined by summation. Addition of the separate costs is simple, with one main precaution.

The main precaution is that the maintenance costs must be either treated separately or as part of particular production costs, but not both. Some of the endogenous urinary nitrogen, for example, may come from metabolic transactions involved with gestation. If EUNG includes nitrogen from fetal metabolism, then the protein costs of fetal growth should include only the net costs. This is an important concept, and one that must be applied in each calculation from each published source. Procedures for expressing costs are not standardized, of course, so careful reading of each paper is necessary to determine just what is included in the results.

Summations may be made for protein costs throughout the year by developing the biochronology of each species and making the appropriate calculations through time. When these are plotted over the annual cycle, a pattern emerges that may be represented by a single equation as for energy metabolism (See Moen 1978 and CHAPTER 7). I must admit that at the time of this writing I have not made such comprehensive calculations for protein costs.

One WORKSHEET with reminders of the cost items to include in the summation of protein costs is included at the end of this unit.

REFERENCES, UNIT 3.7

SUMMATIONS OF PROTEIN REQUIRED

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	31--4	679	685	odvi	protein requirement, fawns	ullrey,de; youat/	1967
JWMAA	43--4	872	879	odvi	protein require, yearlings	holter,jb; hayes/	1979
PAABA	600--	1	50	odvi	nutr req growth, antl dev	french,ce; mcewa/	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NAWTA	22---	119	132	od--	nutrient requirements deer	mcewan,lc; frenc/	1957
NAWTA	22---	179	188	od--	feed req for growth, maint	cowan,i mct; woo/	1957

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

ceel

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

alal

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

CJZOA 48--5 905 913 rata seas chan, energ, nitr int mcewan,ch; wood,a 1970

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

CHAPTER 8, WORKSHEET 3.7a

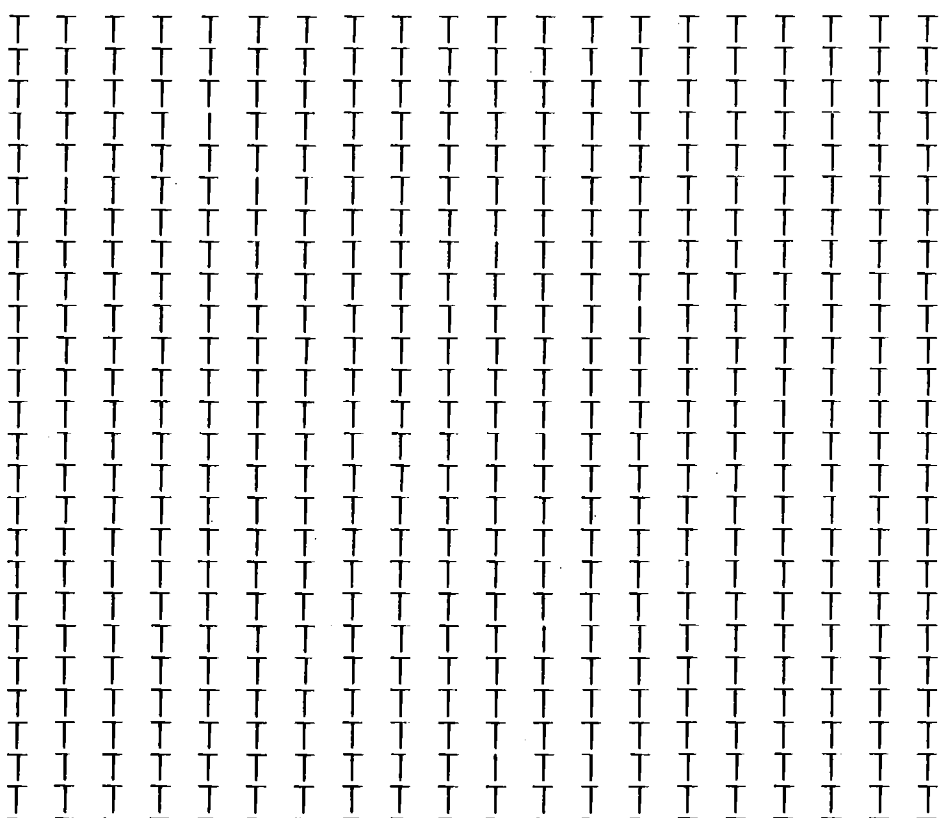
Estimates of total protein costs by summation

Total protein costs may be estimated by summing the costs for each of the maintenance and production processes. The costs to include are, in the order presented in this CHAPTER:

PRUN (WS 3.1b)
\+ PMFN (WS 3.2a)
\+ PRBG (WS 3.3a)
\+ PRHG (WS 3.4a)
\+ PRGE (WS 3.5a)
\+ PRMP (WS 3.6a)

TOTAL = ____ = PRGD

Calculations of the appropriate costs in relation to the biochronology at 7-day intervals will provide estimates of costs throughout the annual cycle. The patterns that emerge for different sex and age groups should be related to range characteristics and forage conposition discussed in PART IV. An unlabeled grid is provided for plotting results of the summations.



CLOSING COMMENTS

The basic format of CHAPTER 8 on protein metabolism is similar to that of CHAPTER 7 on energy metabolism. Estimates of protein costs have been described which provide first approximations at least. Some equations are based on well-designed experiments on wild ruminants. It is important to realize that biological costs to the animal go on whether we realize it or not. Therefore, first approximations are better than nothing, and students should not hesitate to include such estimates when necessary to maintain the integrity of the biological concepts. Concepts are fundamental; numbers and equations may be changed.

Aaron N. Moen
March 11, 1981

GLOSSARY OF SYMBOLS USED - CHAPTER EIGHT

BIWK = Birth weight in kilograms
BVAP = Biological value in percentage

DAGA = Daily gain
DCCP = Dietary crude protein
DIGE = Days into gestation
DILA = Days into lactation
DMIK = Dry matter intake in kilograms per day
DLTA = Delta
DWFK = Dry weight of forage in kilograms

ELMD = Ecological metabolism per day
EUNG = Endogenous urinary nitrogen in grams per day
EUNT = Endogenous urinary nitrogen

HAWG = Hair weight in grams
IFWK = Ingesta-free weight in kilograms

LEGP = Length of gestation period
LWKG = Live weight in kilograms

MBLM = Multiple of base-line metabolism
MEWK = Metabolic weight in kilograms
MFNG = Metabolic fecal nitrogen

NCUG = Nitrogen content of the uterus in grams
NRGD = Nitrogen required for gestation per day
NRHG = Nitrogen required for hair growth per day
NRPC = Net protein coefficient
NTCK = Nitrogen component in kilograms

PCBK = Protein component of the body in kilograms
PCHG = Protein cost of hair growth in grams per day
PEFG = Protein efficiency for body growth
PEHG = Physiological efficiency of hair growth
PEMP = Physiological efficiency of milk production
PNDM = Percent nutrients derived from milk
PRBG = Protein for body growth
PRCK = Protein component in kilograms
PRFH = Protein fraction of hair
PRFR = Protein fraction
PRFM = Protein fraction of milk
PRGD = Protein required in grams per day
PRGE = Protein required for gestation in grams per day
PRHG = Protein required for hair growth in grams per day
PRMP = Protein fraction for milk production in grams per day
PRUN = Protein required for endogenous urinary nitrogen

QMPK = Quantity of milk produced in kilograms per day
UREP = Urea recycled in percent

WLPW = Weight loss per week

GLOSSARY OF CODE NAMES - CHAPTER EIGHT

CODEN

AJBSA Australian Journal of Biological Sciences
AJPHA American Journal of Physiology
AZOFA Annales Zoologici Fennici

BIJOA Biochemical Journal
BJNUA British Journal of Nutrition

CAFGA California Fish and Game
CBCPA Comparative Biochemistry and Physiology
CJZOA Canadian Journal of Zoology

IZYBA International Zoo Year Book

JANSA Journal of Animal Science
JASIA Journal of Agricultural Science
JAVMA Journal of the American Veterinary Medical Association
JDSCA Journal of Dairy Science
JOMAA Journal of Mammalogy
JONUA Journal of Nutrition
JRPFA Journal of Reproduction and Fertility
JWIDA Journal of Wildlife Diseases
JWMAA Journal of Wildlife Management

MAAIA Journal of the Scientific Agricultural Society of Finland

NAWTA North American Wildlife and Natural Resources Conference, Transactions of the,
NUMEB Nutrition and Metabolism

PAABA Pennsylvania Agricultural Experiment Station Bulletin
PAANA Proceedings of the Australian Society of Animal Production
PAARA Pennsylvania State University College of Agriculture Agricultural Experiment Station Progress Report

ZTTFA Zeitschrift fuer Zellforschung und Mikroskopisch Anatomie

LIST OF PUBLISHERS - CHAPTER EIGHT

acpr	Academic Press	New York	nyny
base	Basel	New York	nyny
blsp	Blackwell Scientific Publications	Oxford, England	oxen
butt	Butterworth	London, England	loen
ccth	Charles C. Thomas	Springfield, IL	spil
cfmo	Carl Fr. Mortensen	Copenhagen Denmark	code
clpr	Clarendon Press	Oxford, England	oxen
dcch	D. C. Church, Oregon State	Corvallis, OR	coor
else	Elsevier	Springfield, VA	spva
hein	Heinemann	London, England	loen
meth	Methuen & Co., Ltd.	London, England	loen
nhpc	North-Holland Publishing	New York	nyny
rupr	Rutgers University Press	New Brunswick, NJ	nbnj

LIST OF WORKSHEETS - CHAPTER EIGHT

JULIAN DAY: MONTH AND DAY EQUIVALENTS

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	1
2	002	033	061	092	122	153	183	214	245	275	306	336	2
3	003	034	062	093	123	154	184	215	246	276	307	337	3
4	004	035	063	094	124	155	185	216	247	277	308	338	4
5	005	036	064	095	125	156	186	217	248	278	309	339	5
6	006	037	065	096	126	157	187	218	249	279	310	340	6
7	007	038	066	097	127	158	188	219	250	280	311	341	7
8	008	039	067	098	128	159	189	220	251	281	312	342	8
9	009	040	068	099	129	160	190	221	252	282	313	343	9
10	010	041	069	100	130	161	191	222	253	283	314	344	10
11	011	042	070	101	131	162	192	223	254	284	315	345	11
12	012	043	071	102	132	163	193	224	255	285	316	346	12
13	013	044	072	103	133	164	194	225	256	286	317	347	13
14	014	045	073	104	134	165	195	226	257	287	318	348	14
15	015	046	074	105	135	166	196	227	258	288	319	349	15
16	016	047	075	106	136	167	197	228	259	289	320	350	16
17	017	048	076	107	137	168	198	229	260	290	321	351	17
18	018	049	077	108	138	169	199	230	261	291	322	352	18
19	019	050	078	109	139	170	200	231	262	292	323	353	19
20	020	051	079	110	140	171	201	232	263	293	324	354	20
21	021	052	080	111	141	172	202	233	264	294	325	355	21
22	022	053	081	112	142	173	203	234	265	295	326	356	22
23	023	054	082	113	143	174	204	235	266	296	327	357	23
24	024	055	083	114	144	175	205	236	267	297	328	358	24
25	025	056	084	115	145	176	206	237	268	298	329	359	25
26	026	057	085	116	146	177	207	238	269	299	330	360	26
27	027	058	086	117	147	178	208	239	270	300	331	361	27
28	028	059	087	118	148	179	209	240	271	301	332	362	28
29	029	[060]	088	119	149	180	210	241	272	302	333	363	29
30	030		089	120	150	181	211	242	273	303	334	364	30
31	031		090		151		212	243		304		365	31

* For leap year, February 29 = JDAY 60. Add 1 to all subsequent JDAYs.

THE BIOLOGY AND MANAGEMENT OF WILD RUMINANTS

CHAPTER NINE

MINERAL, WATER, AND VITAMIN METABOLISM OF WILD RUMINANTS

by

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MINERAL, WATER, AND VITAMIN METABOLISM OF WILD RUMINANTS

CHAPTER 9. MINERAL WATER, AND VITAMIN METABOLISM

Minerals, water, and vitamins are essential components of life processes. The role of minerals in the growth and annual cycle of wild ruminants is obvious. Skeletal growth is extremely rapid, and antler growth in those species which grow a new set of antlers each year is truly remarkable. Water is the major component in body tissue. Vitamins have little identifiable mass in the body, but they have major roles in physiological processes.

The importance of mineral, water and vitamin balances is not reflected by the amount of literature available on these subjects. An understanding of basic life processes is such an important foundation for management, yet the literature on these subjects is very sparse. The explanation for this may likely include the tendency for management to be approached from the management end, and the difficulty in studying the interrelated roles of minerals and vitamins in free-ranging animals. Neat experiments are not easily done with minerals and vitamins. Much of the research in such areas is done with small laboratory animals, for several good reasons.

This chapter includes a few basic ideas on the three TOPICS--mineral, water, and vitamin metabolism--and lists of published literature. The requirements for each of these three categories of nutrients could be used to calculate carrying capacity in the same way as energy and protein were used, except that neither the requirements nor the chemical components of forage have been determined precisely enough to make such calculations possible. Think of the nutrient requirement: nutrient supply concept underlying the calculation of carrying capacity, even if precise calculations cannot be made.

TOPIC 1. MINERAL METABOLISM

Some specific minerals, or inorganic elements, are required for life processes. Other minerals appear to play functional roles in life processes, but their roles are not yet understood. Still others are present in animal tissue, but they may be inert and therefore not essential.

Lists of minerals required, those apparently functional, and minerals generally present in body tissue but without known physiological significance are given below (from Hays and Swenson 1970:663).

Those required, in alphabetical order, are:

calcium	iron	potassium
chlorine	magnesium	sodium
cobalt	manganese	sulfur
copper	phosphorous	zinc
iodine		

Those which are apparently functional are:

fluorine	molybdenum	selenium

Those present but without known physiological significance are:

aluminum	bromine	silicon
arsenic	cadmium	strontium
barium	chromium	

The functions of some of the minerals are well-defined. Calcium and phosphorous, for example, are important in the formation of bones and teeth. Iron is important in hemoglobin synthesis. Sodium and chlorine are important in the maintenance of body fluids. The roles of each of the minerals are discussed in Hays and Swenson (1970: Chapter 33); brief discussions are included here in UNIT 1.1.

Mineral deficiencies and excesses both result in abnormalities in physiological functions. Some deformities are caused by mineral deficiencies in the soil, resulting in inadequate intake by resident animals. Iodine is an example of such a mineral. Mineral excesses occur when too much of a specific mineral is present in the soil, absorbed by the plants, and eaten by primary consumers. Selenium is an example of such a mineral. References describing the effects of mineral deficiencies and excesses will be found in the reference lists in CHAPTER 10.

Wild ruminants usually ingest minerals as part of their daily forage diet. Wild ruminants also ingest soil, and rather deliberately so at times. Some local areas contain soils that are higher than average in mineral content, and these localities, known as mineral licks, become well-used by the resident population. Such mineral licks are not present everywhere, but they are definitely well-used when present. References on mineral licks are listed in UNIT 1.3.

The references listed below include books on mineral metabolism, and a list of OTHER PUBLICATIONS that include references not listed on the CODEN lists of serials. They are included here to supplement the limited literature on this TOPIC.

LITERATURE CITED

Hays, V. W. and M. J. Swenson. 1970. Minerals. p. 663-690 In M. J. Swenson, Ed., Dukes' physiology of domestic animals 8th Ed. Cornell University Press, Ithaca, N. Y. 1463 pp.

REFERENCES, TOPIC 1

MINERAL METABOLISM

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS------------------	AUTHORS/EDITORS--	YEAR
edbo	acpr	nyny	879		miner met, vol 1; princip,	comar,cl,ed; bron	1960
edbo	acpr	nyny	1272		miner met, vol 2; elements	comar,cl,ed	1962
edbo	acpr	nyny	....		mine met, vol 3; calc phys	comar,cl,ed	1969
edbo	cupr	caen	629		symp on hormones & environ	benson,gk,ed; phi	1970
edbo	coup	itny	1463	doan	duke's physiolog of domest	swenson,mj,ed	1970
edbo	umip	comi	457		trac substs, env, proc 8th	hemphill,dd,ed	1974
edbo	uppr	bama	775	anim	trace elem metab, proc 2nd	hoekstra,wg,ed; /	1974
edbo	dohr	stpa	401		radioecol & energy resourc	cushing,ce,jr,ed	1976

OTHER PUBLICATIONS

Beeman, R. D. 1957. Big game salting in Idaho. Idaho Wildlife Review 10(2):3-5.

Case, G. 1937. Game salting notes in the upper Selway. N. Region News May: 35-37.

Case, G. 1938. The use of salt in sparing winter range in the Selway. University of Idaho Bulletin 33(22):27-29.

Cooney, R. F. 1951. Salt as a management tool. Proc. Annual Conference of the Western Association of State Game & Fish Commissioners 31:99-105.

Gallaher, C. 1938. Some observations on game salting. N. Region News Oct.: 27-28.

Schneider, F. 1956. The use of supplemental salt as a big game management technique in Oregon. Proc. Annual Conference of the Western Association of State Game & Fish Commissioners 36:200-206.

Whelan, J. B., R. L. Cowan, E. W. Hartsook, and J. S. Lindzey. 1967. The uptake and distribution of 32P in male white-tailed deer. Pennsylvania Cooperative Wildlife Research Unit Paper 125. 21 pp.

Franzmann, A. W., J. L. Oldmeyer, and A. Flynn. 1975. Minerals and moose. Proc. North American Moose Conf. 11:114-140.

UNIT 1.1: MINERAL REQUIREMENTS

The mineral requirements of beef cattle and domestic sheep are discussed in two National Academy of Sciences publications: Nutrient Requirements of Sheep, Fifth Revised Edition, 1975, and Nutrient Requirements of Beef Cattle, Fifth Revised Edition, 1976. These publications include discussions of the requirements and how they are met by feed management, and signs of deficiencies, sometimes with photos of cattle or sheep exhibiting the symptoms.

Mineral deficiencies are much more likely to occur in confined domestic ruminants than in free-ranging wild ones because domestic animals are dependent on the food supplied rather than being able to choose from the variety naturally available. Wild ruminants on severely over-used ranges may tend toward the effects of confinement; options for choosing are gone. Seasonal variations in availability occur also; sodium dynamics in the diets of moose at Isle Royal may limit the moose population (Botkin et al. 1973) with requirements being met by ingestion for only two months of the year.

The mineral requirements of beef cattle and domestic sheep are listed below, based on sheep and beef cattle data in the NRC (1975 and 1976, respectively) publications. Requirements are given as percentage of diet dry matter or mg per kg of dry diet. These values may serve some useful purpose as base-line information for comparison with data on chemical composition of forages given in CHAPTER 11.

MACROMINERAL REQUIREMENTS (percentage of diet dry matter)

		Beef Cattle Requirements		
Mineral	Sheep Requirements	Growing & Finishing Steers & Heifers	Dry Pregnant Cows	Breeding Bulls and Lactating Cows
Sodium	0 04 - 0.10	0.06	0.06	0.06
Calcium	0.21 - 0.52	0.18 - 1.04	0.18	0.18 - 0.44
Phosphorus	0.16 - 0.37	0.18 - 0.70	0.18	0.18 - 0.39
Magnesium	0.04 - 0.08	0.04 - 0.10	0.04 - 0.10	0.18
Potassium	0.50	0.60 - 0.80	0.60 - 0.80	0.60 - 0.80
Sulfur	0.14 - 0.26	0.10	0.10	0.10

MICROMINERAL REQUIREMENTS (in mg per kg of dry diet)

Mineral	Sheep Requirements	Beef Cattle Requirements: Growing & Finishing Steers & Heifers	Beef Cattle Requirements: Dry Pregnant Cows	Beef Cattle Requirements: Breeding Bulls and Lactating Cows
Iodine	0.10 - 0.80		0.05 - 0.10	0.05 - 0.10
Iron	30 - 50	10.0	10.0	10.0
Copper	5	4.0	4.0	4.0
Molybdenum	> 0.5			
Cobalt	0.10	0.05 - 0.10	0.05 - 0.10	0.05 - 0.10
Manganese	20 - 40	1.00 - 10.0	20.0	1.00 - 10.0
Zinc	35 - 50	20.0 - 30 0	20.0 - 30.0	20.0 - 30.0
Selenium	0.10	0.10	0.05 - 0.10	0.05 - 0.10

Mineral excesses may occur as well as mineral deficiencies. Possible toxic levels of microminerals are listed below, based on data presented in the NRC (1975 and 1976) publications.

POSSIBLE TOXIC LEVELS OF MICROMINERALS (mg/kg diet)

Mineral	Sheep	Beef Cattle
Iodine	8+	100
Iron		400
Copper	8 - 25	115
Molybdenum	5 - 20	
Cobalt	100 - 200	10 - 15
Manganese		150
Zinc	1000	90p
Selenium	> 2	5
Fluorine	60 - 200	

LITERATURE CITED

Botkin, D., P. A. Jordan, A. S. Dominski, H. S. Lowendorf, and G. E. Hutchinson. 1974. Sodium dynamics in a northern ecosystem. Proc. Nat. Acd. Sci. 70(10):2745-2748.

National Research Council. 1975. Nutrient requirements of sheep. Fifth Revised Edition. National Academy of Sciences. Washington, D. C. 72 pp.

National Research Council. 1976. Nutrient requirements of beef cattle. Fifth Revised Edition. National Academy of Sciences. Washington, D. C. 56 pp.

REFERENCES, UNIT 1.1

MINERAL REQUIREMENTS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CORTB	69---	227	238	cerv	problems of antlerogenesis	goss,rj	1970
ZEJAA	2---3	119	123	cerv	mineral metab, radio isoto	rerabek,j; bubeni	1956

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NAWTA	22---	119	132	od--	nutrient requirements deer	mcewan,lc; frenc/	1957
NAWTA	22---	179	188	od--	feed req for growth, maint	cowan,imct; wood/	1957

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
FEPRA	26-51	416	416	odvi	uptake, distrib, P32, male	whelan,jb; cowan/	1967
JONUA	108-9	1439	1448	odvi	seleni, vit e, bioch, surv	brady,ps; brady,/	1978
JWMAA	36--3	996	998	odvi	salt vs brows-season baits	mattfeld gf; wil/	1972
JWMAA	37--2	187	194	odvi	calcium requi, weaned fawn	ullrey,de; youat/	1973
JWMAA	39--3	590	595	odvi	phospho requi weaned fawns	ullrey,de; youat/	1975
JWMAA	40--4	610	625	odvi	sodium deficiencies, adapt	weeks,hp,jr; kirk	1976
NFGJA	10--2	225	227	odvi	adequacy, cobalt nutri, ny	smith,se; gardne/	1963
PAABA	600--	1	50	odvi	nutr req growth, antlr dev	french,ce; mcewe/	1955
PAARA	209--	1	11	odvi	eff feed restric, antl dev	long,ta; cowan,r/	1959
PSEBA	129-3	733	737	odvi	calcium strontium age antl	cowan,rl; hartso/	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AZATA	75---	1	39	ofhr	experimental feeding of de	nichol,aa	1938
SWNAA	22--1	149	150	odhe	bone-chewing behav, desert	krausman,pr; biss	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBPAB	60A-3	251	256	ceel	energ, nitr metab cold env	simpson,am; webs/	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JONUA	107--	1182	1189	alal	copper deficiency, alaska	flynn,a; franzma/	1977
JWIDA	12--2	202	207	alal	moose milk, hair elem leve	franzmann,aw; fly	1976
JWMAA	23--3	356	358	alal	minera anal, liver, kidney	beeler,da; benso/	1959
JWMAA	39--2	374	378	alal	mineral elem, alaska, hair	franzmann,aw; fl/	1975
PNASA	70-10	2745	2748	alal	sodium dynam, north ecosys	botkin,db; jorda/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ALLKA	57...	23	30	rata	constitution of hair	anghi,c	1970
JOMAA	38--2	275	277	rata	disappearance shed antlers	mccabe,ra	1957

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
JRACB	37--1	473	481	oram	season, trace elemen, livr	turkstra,j; hart/	1977

UNIT 1.2: CALCULATIONS AND PREDICTIONS OF MINERAL REQUIREMENTS

The inclusion of selected minerals in the ratios suggested in the tables of requirements in UNIT 1.1 is a relatively simple matter when formulating feeds for domestic cattle and sheep. Feed of known composition is not provided wild ruminants, however. Estimates of the amount of forage needed to satisfy energy needs may be calculated with the data and procedures found in CHAPTERS 7-8 and 11-12. Calculations of the mineral compositions of these quantities may be made if the chemical data are available.

The daily costs of energy and protein were calculated by evaluating net gains from day to day (see CHAPTERS 7-8), and a similar approach may be taken for minerals, especially the more prominent ones deposited in such conspicuous tissues as antlers. If antler growth rates and chemical compositions are known (see CHAPTER 2), then "before and after" calculations may be made for estimating daily costs of minerals (calcuim and phosphorus, for example) for antler growth, and the results compared to calculated intakes based on forage ingested estimations and forage composition data. This approach provides some means of comparing first approximations of mineral requirements by wild ruminants with empirical data on domestic ruminants.

It is likely that negative mineral balances will be calculated for certain periods of the year, such as the time of rapid antler growth. This calls attention to possible mobilization mechanisms which very likely occur in wild ruminants.

The number of these calculations that can be made is limited by the availability of data on growth rates of the animals or selected tissues and chemical compostion of both animal and forage ingested. Students particularly interested in these processes should set up WORKSHEETS that result in first approximations of mineral requirements.

REFERENCES, UNIT 1.2

CALCULATIONS AND PREDICTIONS OF MINERAL REQUIREMENTS

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
				ceel			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
TLPBA	14--1	105	134	alal	diet optimizatn, genl herb	belovsky,ge	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	55--4	648	655	rata	min status, nutrit, season	hyvarinen,h; hel/	1977
MAAIA	51---	381	419	rata	renal respons, prot, sodiu	valtonen,m	1979

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			

CHAPTER 9, WORKSHEET 1.2a

Estimation of mineral intake based on predicted dry-weight forage intake

Mineral intake may be estimated if the mineral components and their fractions of the diet are known, and the amount of forage consumed is known or can be predicted. Calculate the predicted forage intake (See CHAPTER 12) based on energy (CHAPTER 7) and protein (CHAPTER 8) metabolism. Then, determine the intake per day of specific minerals in the forage ingested. The formula is:

$$SMID = (DWFK)(SMFR)$$

where SMID = specific minerals ingested per day,
DWFK = dry-weight forage ingested in kg per day, and
SMFR = specific mineral fractions of the forage.

These calculations are possible only if the mineral composition of the forage species is known (See CHAPTER 11). The mineral component is often given simply as "ash," with no differentiation beween the minerals involved.

Compare the results of these calculations with the requirements given in the tables in UNIT 1.1, and evaluate the literature further to see how these results compare with published values for specific mineral requirements.

UNIT 1.3: MINERAL LICKS

Mineral licks, also called salt licks, are moist areas or pools with an apparently higher concentration of minerals than usual. These areas are found by animals who then use them regularly.

The mineral lick at Cornell's Arnot Forest that has been used heavily by white-tailed deer for many years is about 10 meters in diameter. It has been walked in, stirred up, ingested, and eroded to the point where the level of the moist soil is up to 20 cm lower than the surrounding forest soils. Trails lead to this lick like spokes in a wheel. The easist way to find it, once in the vicinity, is by following the trails. Another much smaller lick (about 3 m diameter) has apparently been used for a much shorter time.

Deer use of these licks seems to fluctuate seasonally. Heaviest use is in the summer, which may be a response to high rates of mineral metabolism for both antler growth and lactation. Fall and winter use appears to be much less than in the summer, although the deer certainly do visit these licks then.

Maximum desire for salt by elk occurred in late May and early June (Dalke et al. 1965). The use of salt blocks as a management tool was tested, with no effects of salt distribution on the movements between seasonal ranges. If the elk were inclined to use the salt blocks, then local factors such as the vegetation, elevation, number of animals, and the amount of disturbance by livestock affected the use of artificial salt by elk.

Observations of female and yearling caribou on a lick about 23 meters in diameter on the Yukon Arctic Coastal Plain also included trails worn in the tundra vegetation approachig from several directions. Sixty shed antlers were counted in the lick, and animals were observed pawing, chewing, and licking the soil in the lick (Calef and Lortie 1975).

The role of mineral licks in the movement and ecology of wild ruminants is not known, except that the licks do attract the animals, and they do provide minerals that are of physiological importance. The nutritional benefits of mineral licks compared to dispersed minerals in the forage are unknown, although there may be some mineral implications in productivity.

LITERATURE CITED

Dalke, P. D., R. D. Beeman, F. J. Kindel, R. J. Robel, and T. R. Williams. 1965. Use of salt by elk in Idaho. J. Wildl. Manage. 29(2):319-332.

Calef, G. W. and G. M. Lortie. 1975. A mineral lick of the barren-ground caribou. J. Mammal. 56(1):240-242.

REFERENCES, UNIT 1.3

MINERAL LICKS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	4---1	21	25	od--	deer licks, natl for, cali	bryant,hc	1918
JOMAA	20--1	109	109	od--	biochem aspects, deer lick	dixon,js	1939

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNAA	100-2	384	395	odvi	chars of lick, behav, indi	weeks,hp,jr	1978
JWMAA	40--4	610	625	odvi	adap to natur occ sodi def	weeks,hp,jr; kirk	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	53--4	378	384	odhe	ceel, activity patterns at	carbyn,ln	1975
JRMGA	32--1	67	71	odhe	soil ingestion n centr col	arthur,wj,III; al	1979
JWMAA	2---3	79	81	odhe	ceel, salt, contrl distrib	case,gw	1938

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	29--2	319	332	ceel	use of salt by elk, idaho	dalke,pd; beeman/	1965
JWMAA	31--2	293	299	ceel	char, natural licks, monta	knight,rr; mudge,	1967

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	56--1	240	242	rata	mineral lick, barren groun	calef,gw; lortie,	1975

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
CJZOA	49--5	605	610	oram	natural salt licks, ecolog	hebert,d; cowan,i	1971
JWMAA	42--3	591	597	oram	behav in reln highwa, mont	singer,fj	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	30--4	379	387	wiru	natural game licks, canada	cowan,im; brink,v	1949
NAWTA	18---	247	258	wiru	chem charac, natural licks	stackstad,ds; mo/	1953

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BTROA	11--4	311	313		elemtl compo of lick, peru	emmons,lh; stark,	1979
JZOOA	158-3	293	310		chem proprties lick, eleph	weir,js	1969
OOKHA	3....	10	11		artificial salt licks	kotov,v	1964
ZEJAA	14--3	107	118	many	comp intk slt lcks, eur sp	ueckermann,e	1968

OTHER PUBLICATIONS

McBride, J. K. 1946. Deer lick improvements. Ohio Conservation Bulletin 10(10):20-21.

TOPIC 2. WATER METABOLISM

Water is not only an important but the major component of the body of ruminant animals. It is not the water as a compound composed of hydrogen and oxygen that is of significance, however, but rather its properties that allow the many physical-chemical processes to occur.

The water content of fetuses is very high--90% or more--and declines with advancing gestation. Adult cattle, however, still have water contents of 40 to 70% or more, and white-tailed deer have water contents of 60% of ingesta-free adult body weight (Robbins et al. 1974).

Body composition data given in CHAPTER 2 show that water and fat fractions are inversely proportional. This is because the water content of fat is only about 10% or less. Thus fat animals, such as wild ruminants in the fall at maximum weights during the annual cycle, have a lower water fraction than lean ones.

Water molecules can rapidly penetrate most cell membranes (Houpt 1970:745). If a pressure gradient exists, then water molecules are expected to move from the higher pressure to the lower pressure. The same should occur if there are differences in osmotic concentrations; water should move from the lower concentration to the higher one. Since water molecules are often more likely to penetrate through membranes than solute molecules, concentration differences may be equalized by the movement of water.

LITERATURE CITED

Houpt, T. R. 1970. Water, electrolytes and acid-base balance. Pages 743-766 In M. J. Swenson, Ed. Dukes' physiology of domestic animals. 8th Ed. Cornell University Press, Ithaca, N. Y. 1463 pp.

Robbins, C. T., A. N. Moen and J. T. Reid. 1974. Body composition of white-tailed deer. J. Anim. Science 38(4):871-876.

REFERENCES, TOPIC 2

WATER METABOLISM

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
edbo	nyha	nyny	255		symp on salt & water metab	fishman,ap,ed	1960
edbo	else	nyny	251		wat, elctrolyt met, 2nd ed	de graeff,j,ed; 1	1964
edbo	macm	nyny	570		symp, thirst, reg body wat	wayner,mj,ed	1964
aubo	moco	salo	169		wat, elect met, acd-ba bal	muntwyler,e	1968
edbo	base	nyny	260		n, electro, wat & ener met	rechcigl,m,jr ed	1970

OTHER PUBLICATIONS

Johnson, C. E. 1940. Waterholes for wildlife. National Park Service, Region Three Quart. 2(2):9-11.

Smith, A. D. 1954. How much water does a deer drink? Utah Fish & Game Bulletin 10(9):1,8.

Talbot, M. W. 1926. Range watering places in the southwest. U. S. Department of Agriculture Department Bulletin No. 1358. pp. 1-43.

UNIT 2.1: WATER COMPARTMENTS

Body water may be divided into two compartments: intracellular and extracellular. These terms refer to the fluid inside the cells and outside the cells, respectively. Extracellular fluid is further divided into interstitial fluid and plasma (Houpt 1970:744). The plasma is part of the vascular system, of course, and interstitial fluid is within tissues but not in cells.

LITERATURE CITED

Houpt, T. R. 1970. Water, electrolytes, and acid-base balance. pp. 743-766 In M. J. Swenson, Ed. Dukes' physiology of domestic animals. 8th Ed. Cornell University Press, Ithaca, N. Y. 1463 pp.

REFERENCES, UNIT 2.1

WATER COMPARTMENTS

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

ceel

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

alal

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

CJZOA 50--1 107 116 rata chang body water extracell cameron,rd; luick 1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	34--4	908	912	anam	energ flux, water kinetics	wesley,de; knox,/	1970
XIBPA	1....	250	250	anam	water kinetics in pronghor	wesley,de; knox,/	1971

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PNUSA	16--2	108	112		functions of water in body	robinson,jr	1957
SZSLA	31---	261	296	mamm	comprtv watr & energ econo	macfarlane,wv; ho	1972

UNIT 2.2: REQUIREMENTS AND TURNOVER RATES

The water balance is obviously an important part of the physiology of wild ruminants since water is such a major component of animal tissue. Water consumption is very difficult to determine, however, because the sources of water include forage (often 50% or more water), dew on the vegetation (sometimes twice a day), snow (often present in large quantities), and open water. A unique experimental set-up is described by Elder (1954) who was able to measure the water consumption of individuals and groups of mule deer that drank from tubs and barrels in which water levels could be measured. Six to seven quarts were consumed in an average of three minutes of drinking time.

Wild ruminants are not as dependent on open water as domestic ones are. Many species do not seem to frequent open water at all, except perhaps in the heat of summer when water losses are high. The vegetation and snow seem to be adequate sources under most natural conditions. Nevertheless, white-tailed deer, a species that can get along well in a frozen habitat, will use open water when available. There are reports in published literature of a lack of interest in open water (see Hosley 1956), yet whitetails do use open water in otherwise frozen habitat. I have observed large amounts of deer activity in a seeepage area below an earth dam in west-central Minnesota, and in natural seepage areas at Cornell's Arnot Forest in New York State.

It is difficult to separate requirements from preferences. Water requirements are met in several different ways; preferences for meeting those water requirements vary through the year and from place to place. The water consumption of pronghorn varied inversely with the quantity and succulence of the preferred forage species (Beale and Smith 1970). Succulent spring vegetation has a high water content and excess water is excreted not only in urine but also in feces.

References on water consumption follow. The WORKSHEET is included which relates to forage intake calculations and the water content of the forage.

LITERATURE CITED

Beale, D. M. and A. D. Smith. 1970. Forage use, water consumption, and productivity of pronghorn antelope in western Utah. J. Wildl. Manage. 34(3):570-582.

Elder, J. B. 1957. Notes on summer water consumption by desert mule deer. J. Wildl. Manage. 18(4):540-541.

Hosley, N. W. 1956. Management of white-tailed deer in its environment. Pages 187-259 In W. P. Taylor, Ed., The Deer of North America. The Stackpole Company. Harrisburg, PA 668 pp.

REFERENCES, UNIT 2.2

REQUIREMENTS AND TURNOVER RATES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	39--2	355	360	odvi	milk consumpti weight gain	robbins,ct; moen,	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJVRA	31--4	673	677	odhe	dosh, tot body watr turnov	longhurst,wm; ba/	1970
JWMAA	18--4	540	541	odhe	summer wate consumpt deser	elder,jb	1951
JWMAA	33--2	389	393	odhe	water turnover in mule dee	knox,kl; nagy,jg/	1969

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	54--6	857	862	rata	tritium wat dilu, wat flux	cameron,rd; whit/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	34--3	570	582	anam	forag, watr consum, produc	beale,dm; smith,a	1970
UTSCB	29--1	3	6	anam	seasonal forage use, utah	beale,dm; scotter	1968
				anam	continued on the next page		

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
WGFBA	12---	1	61	anam	food hab, abundan, distrib	sundstrom,c; hep/	1973
XIBPA	1....	250	250	anam	water kinetics in pronghor	wesley,de; knox,/	1971

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	54--4	289	296	ovca	summer water requirements	blong,b; pollard,	1968

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJAEA	19--4	655	672	doca	eff wat restrc & exer, dig	thornton,rf; yate	1968

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
PNUSA	16--2	108	112		functions of water in body	robinson,jr	1957
SZSLA	31---	261	296	mamm	comprtv watr & energ econo	macfarlane,wv; ho	1972
YAXAA	1955-	14	18		animals and fowl and water	sykes,jf	1955

CHAPTER 9, WORKSHEET 2.2a

Water consumption as part of forage ingested

The amount of water ingested with the forage may be determined if the amounts of forage ingested are determined based on energy or protein requirements as discussed in CHAPTER 12. The calculations of forage ingested are made on a dry weight basis, so the water fraction of field-weight forage must be known.

Determine the water fraction of field-weight forage, calculate dry-weight forage required to meet energy and protein requirements, and estimate the water component of the diet. Compare this to the limited data on water consumption.

TOPIC 3. VITAMIN METABOLISM

Vitamins are organic compounds that function as metabolic catalysts, usually in the form of coenzymes (Smith 1970:634). Vitamins may be divided into a fat-soluble group (A, D, E, and K) and a water-soluble group (the B complex and C).

Vitamins have essential roles in metabolic processes. Vitamin requirements are met both by ingesting foods that contain the vitamins, and by synthesis in the body. Rumen bacteria synthesize vitamins in the B-complex and vitamin K, so ruminant animals are not dependent on a dietary source for these vitamins. Neonates, however, do not have a functional rumen, so they are dependent on dietary vitamins in the first few weeks of life. Solar radiation, especially the ultraviolet wavelengths, is an important factor affecting the amount of vitamin D in the body. Sunlight is not the "source," but the stimulus for the formation of vitamin D at the skin surface to be absorbed by the body.

A deficiency of vitamins is called avitaminoses. An excess is called hypervitaminoses. Vitamin imbalances cause malfunctions in different body functions, especially metabolic pathways, as they function as metabolic catalysts. The vitamin metabolism of wild ruminants is largely unknown, except a inferred from studies on domestic ruminants. A few measurements of vitamin levels in the tissue of Odocoileus have been made, but that is the extent of published literature found for wild ruminants.

Vitamin requirements of beef cattle are listed below, from a table in the NRC (1976) publication.

VITAMIN REQUIREMENTS OF BEEF CATTLE (in amount per kg of dry diet;IU)

		Beef Cattle Requirements		
Vitamin	Sheep Requirements	Growing & Finishing Steers & Heifers	Dry Pregnant Cows	Breeding Bulls and Lactating Cows
A	IU	2,200	2,800	3,900
D	IU	275	275	275
E	IU	15-60	—	15-60

This TOPIC 3 is not divided into UNITS because of the lack of information, and there are no worksheets. The paucity of information may stimulate someone who specializes in vitamins to review the pertinent literature on wild and domestic animals, and to write a good review of the concepts and principles involved in vitamin nutrition and metabolism.

LITERATURE CITED

National Research Council. 1976. Nutrient requirements of beef cattle. Fifth Revised Edition. National Academy of Sciences. Washington, D. C. 56 pp.

Smith, S. E. 1970. Vitamins. Pages 634-659 In M. J. Swenson, Ed. Dukes' physiology of domestic animals. 8th Ed. Cornell Univ. Press, Ithaca, NY 1463 pp.

REFERENCES, TOPIC 3

VITAMIN METABOLISM

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
edbo	nvif	nyny	118		symp on vitamin metabolism	brown,gm,ed; /	1956
aubo	acpr	nyny	366		biosyn vitami & rel compds	goodwin,tw	1963
aubo	hein	loen	148		vitamins in endocrine meta	jennings,iw	1970
aubo	vare	nyny	278		hndbk of vitamins & hormon	kutsky,rj	1973
edbo	nasc	wadc	72	dosh	nutrient requirem of sheep	natl research cou	1975
edbo	nasc	wadc	56	doca	nutrient req of beef cattl	natl research cou	1976

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAPRA	9---3	130	131	odvi	avitaminosis e, white-tail	indianapolis zoo	1968
JOMAA	36--4	553	557	odvi	vitamin excretion by deer	teeri,ad; pomera/	1955
JOMAA	41--3	410	411	odvi	vitamins a and e in blood	haugen,ao; hove,e	1960
JONUA	108-9	1439	1448	odvi	seleni, vit e, bioch, surv	brady,ps; brady,/	1978
JWMAA	40--1	172	173	odvi	vitam a concentr in livers	youatt,wg; ullre/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBPAB	41B-4	745	758	odhe	carote, vit a, liver, seru	anderson,ae; med/	1972

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

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

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

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AASNA	19---	22	28	rumi	aspects of vit e deficienc	oksanen,he	1973
JAVMA	151-4	430	436	rumi	vit a nutition of ruminant	mitchell,ge	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AASNA	19---	87	96		chemistry of vitamin e	hjarde,w; leerbe/	1973

CLOSING COMMENTS

This chapter has included a few basic ideas and lists of references in the areas of mineral, water, and vitamin metabolism. The amount of material in the chapter is limited by both the lack of published information on these nutrients and my own limited knowledge of the roles of these nutrients. This chapter is a good example of an opportunity for someone specializing in these nutrients to particiapte as an author in future revisions.

Aaron N. Moen
March 12, 1981

GLOSSARY OF SYMBOLS USED - CHAPTER NINE

DWFK = Dry-weight forage ingested in kilograms per day

SMFR = Specific mineral fraction of the forage
SMID = Specific minerals ingested per day

GLOSSARY OF CODE NAMES - CHAPTER NINE

CODEN

AASNA Acta Agriculturae Scandinavica Supplementum
AJAEA Australian Journal of Agricultural Research
AJVRA American Journal of Veterinary Research
ALLKA Allattani Kozlemenyek (Hungary)
AMNAA American Midland Naturalist
AZATA Arizona Agricultural Experiment Station Technical Bulletin

BTROA Biotropica

CAFGA California Fish and Game
CBPAB Comparative Biochemistry and Physiology A Comparative Physiology
CJZOA Canadian Journal of Zoology
CORTB Clinical Orthopaedics and Related Research

FEPRA Federation Proceedings

JANSA Journal of Animal Science
JAPRA Journal of Small Animal Practice
JAVMA Journal of the American Veterinary Medical Association
JOMAA Journal of Mammalogy
JONUA Journal of Nutrition
JRACB Journal of Radioanalytical Chemistry
JRMGA Journal of Range Management
JWIDA Journal of Wildlife Diseases
JWMAA Journal of Wildlife Management
JZOOA Journal of Zoology

MAAIA Journal of the Scientific Agricultural Society of Finalnd

NAWTA North American Wildlife and Natural Resources Conference, Transactions of the,
NFGJA New York Fish and Game Journal

OOKHA Okhota i Okhotnich'e Khozyaistvo

PAABA Pennsylvania Agricultural Experiment Station Bulletin
PAARA Pennsylvania State University College of Agriculture Agricultural Experiment Station Progress Report
PNASA Proceedings of the National Academy of Sciences of the United States
PNUSA Proceedings of the Nutrition Society
PSEBA Proceedings of the Society for Experimental Biology and Medicine

SWNAA Southwestern Naturalist
SZSLA Symposia of the Zoological Society of London

TLPBA Theoretical Population Biology

UTSCB Utah Science

WGFBA Wyoming Game and Fish Commission Bulletin

XIBPA US-IBP (International Biological Program) Analysis of Ecosystems Program Interbiome Abstracts

YAXAA U S D A Yearbook of Agriculture

ZEJAA Zeitschrift fuer Jagdwissenschaft

LIST OF PUBLISHERS - CHAPTER NINE

acpr	Academic Press	New York	nyny
base	Basel	New York	nyny
coup	Cornell University Press	Ithaca, NY	itny
cupr	Cambridge Univ. Press	Cambridge, England	caen
dohr	Dowden, Hutchinson, & Ross	Stroudsburg, PA	stpa
else	Elsevier	New York	nyny
hein	Heinemann	London, England	loen
macm	MacMillan Company	New York	nyny
moco	C. V. Mosley Company	St. Louis, MO	salo
nasc	National Academy of Science	Washington, D. C.	wadc
nvif	National Vitamin Foundation	New York	nyny
nyha	New York Heart Association	New York	nyny
umip	Univ. of Missouri Press	Columbia, MO	comi
uppr	University Park Press	Baltimore, MD	bama
vare	Van Nostrand - Reinhold	New York	nyny

LIST OF WORKSHEETS - CHAPTER NINE

JULIAN DAY: MONTH AND DAY EQUIVALENTS

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	1
2	002	033	061	092	122	153	183	214	245	275	306	336	2
3	003	034	062	093	123	154	184	215	246	276	307	337	3
4	004	035	063	094	124	155	185	216	247	277	308	338	4
5	005	036	064	095	125	156	186	217	248	278	309	339	5
6	006	037	065	096	126	157	187	218	249	279	310	340	6
7	007	038	066	097	127	158	188	219	250	280	311	341	7
8	008	039	067	098	128	159	189	220	251	281	312	342	8
9	009	040	068	099	129	160	190	221	252	282	313	343	9
10	010	041	069	100	130	161	191	222	253	283	314	344	10
11	011	042	070	101	131	162	192	223	254	284	315	345	11
12	012	043	071	102	132	163	193	224	255	285	316	346	12
13	013	044	072	103	133	164	194	225	256	286	317	347	13
14	014	045	073	104	134	165	195	226	257	287	318	348	14
15	015	046	074	105	135	166	196	227	258	288	319	349	15
16	016	047	075	106	136	167	197	228	259	289	320	350	16
17	017	048	076	107	137	168	198	229	260	290	321	351	17
18	018	049	077	108	138	169	199	230	261	291	322	352	18
19	019	050	078	109	139	170	200	231	262	292	323	353	19
20	020	051	079	110	140	171	201	232	263	293	324	354	20
21	021	052	080	111	141	172	202	233	264	294	325	355	21
22	022	053	081	112	142	173	203	234	265	295	326	356	22
23	023	054	082	113	143	174	204	235	266	296	327	357	23
24	024	055	083	114	144	175	205	236	267	297	328	358	24
25	025	056	084	115	145	176	206	237	268	298	329	359	25
26	026	057	085	116	146	177	207	238	269	299	330	360	26
27	027	058	086	117	147	178	208	239	270	300	331	361	27
28	028	059	087	118	148	179	209	240	271	301	332	362	28
29	029	[060]	088	119	149	180	210	241	272	302	333	363	29
30	030		089	120	150	181	211	242	273	303	334	364	30
31	031		090		151		212	243		304		365	31

* For leap year, February 29 = JDAY 60. Add 1 to all subsequent JDAYs.

THE BIOLOGY AND MANAGEMENT OF WILD RUMINANTS

CHAPTER TEN

FACTORS AFFECTING THE PHYSIOLOGY AND METABOLISM OF WILD RUMINANTS

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CONTENTS OF CHAPTER TEN

FACTORS AFFECTING THE PHYSIOLOGY AND METABOLISM OF WILD RUMINANTS

CHAPTER 10. FACTORS AFFECTING THE PHYSIOLOGY AND METABOLISM OF WILD RUMINANTS

The physiology and metabolism of wild ruminants has been discussed in CHAPTER 6 - 9, with discussions of measured results and equations that permit calculations of rates and quantities. The discussions have centered about presumably normal conditions and functions. Rates of energy metabolism, for example, have been discussed in CHAPTER 7. The general equation for calculating ecological metabolism per day as a function of weight, reproductive rate, and JDAY gives an expected metabolism, unencumbered by unusual circumstances. The effects of cold weather, for example, are built into the equation as part of the winter metabolic depression.

There are a number of factors that affect the physiology and metabolism of wild ruminants, causing deviations from the norm. It is these deviations that cause much of the drama in ecology as the struggle for survival proceeds from day to day. Many, if not most of these factors are ordinary components of daily existence, with the effects becoming pronounced only when unusually high levels of the effector are encountered, or the effects of several factors are combined and the accumulated effect is great.

Parasites, for example, are part of the daily life of all wild ruminants. Unusually large numbers of parasites, however, may have a pronounced detrimental effect on the productivity of the host. Lesser parasite loads may have an impact when other factors, such as deteriorating range conditions during an exceptionally long winter, exist and act together to depress overall ecological efficiency.

This chapter includes extensive reference lists in three TOPICS. These three topics and the units in each are not discussed at length, however, because ecological analyses--the evaluation of relationships in the ecological context between primary consumer and range, parasite and host--have not been made. The extensive and organized reference lists may increase the efficiency of literature reviews to the point where persons interested in these factors will be more ecologically comprehensive in the approach to understanding the roles of these factors.

TOPIC 1. PARASITES, DISEASES, AND ABNORMALITIES

Parasites, diseases and abnormalities are an extensive array of factors that affect the physiology and metabolism of wild ruminants. They are also a normal part of life; parasites and diseases are expected to be present, and the responses necessary to cope with their effects serve to strengthen the species' ability to withstand future impacts. It must be assumed that a natural balance exists between parasite and host, with short-term fluctuations in favor of one or the other.

The impacts of parasites and diseases may be greatest when a ruminant species is moved into suitable but unoccupied areas. Then, the additional stresses due to the moving plus the possibility of encounters with new parasites and disease may make the transplants more susceptible. Generations may build up a resistance to the effects, resulting in increased productivity in later years.

It is conceivable that a species could be moved into a new area and experience less environmental resistance, including lesser effects of parasites and diseases, than in the previous range. Initial productivity may be higher than normal in the previous range for a time. An initially high rate of productivity may be followed by depressed productivity as factors affecting physiology and metabolism begin to take effect.

The effects of parasites and diseases tend to increase and decrease through the year and over the years. Abnormalities are more of an either-or effector; either an animal is abnormal or it isn't. The degree to which the abnormality affects physiological functions may vary, of course, resulting in a gradient-type effect on the animals productivity.

There are rich opportunities for exploring the effects of parasites, diseases, and abnormalities on ecological productivity, but the rich opportunities are also very challenging. The effects are hard to measure because productivity is hard to measure. The results of different levels of effects, providing they can be quantified, are often not available for two or more years when working with large animals such as wild ruminants because of the time needed to reach reproductive maturity. Nevertheless, the opportunities exist, and it is my hope that the organized reference lists in the units that follow will make study and work in these areas not only more efficient but also more appealing.

REFERENCES, TOPIC 1

PARASITES, DISEASES, AND ABNORMALITIES

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS------------------	AUTHORS/EDITORS--	YEAR
aubo	faog	roit	119	anim	diseases free-liv wild ani	mcdiarmid,a	1962
edbo	ccth	spil	967	anim	diseases trans anim to man	hull,tg, ed	1963
aubo	hein	loen	136		ecology of parasites	croll,na	1966
aubo	wbsc	phpa	462		veterinary clinical pathol	coles,eh	1980
edbo	acpr	nyny	332	anim	diseases free-liv wild ani	mcdiarmid,a,ed	1969
aubo	isup	amia	421	mamm	infectious dise, wild mamm	davis,jw; karsta/	1970
edbo	isup	amia	364	mamm	parasitic disea, wild mamm	davis,jw; anders/	1971
aubo	lefe	phpa	1521	anim	veterinary pathology,4th e	smith,ha; jones,	1972
edbo	plpr	nyny	686	many	wildlife diseases	page,la	1976

OTHER PUBLICATIONS

Fyvie, A. 1969. Manual of Common Parasites, Diseases and Anomalies of Wildlife in Ontario, 2nd ed. Dept. of Lands and Forests, Ontario. 102 p.

McDiarmid, A. 1960. Diseases of Free-Living Wild Animals. Animal Health Monograph #1, FAO Working Document. FAO, Rome. 91 p.

Reed, D. and H. Shane. 1976. Deer Diseases in South Dakota, 1972-76. Department of Game, Fish and Parks, Pierre, S. D. 32 p. [parasites and diseases, odvi, odhe]

Worley, D. E. and K. R. Greer. 1976. Parasites and Diseases of North American Elk (Cervus spp.) - An annotated bibliography. 52 p. Montana Dept. of Fish and Game in Cooperation with Montana Agricultural Experiment Station, Montana State Univ., Bozeman, Montana.

UNIT 1.1: PARASITES

Parasites inhabit wild ruminants, living off the ruminant host as the ruminant lives off the range. The effects may not be limited to resource use, however (anemia, for example, in the case of a blood-sucking parasite) but may also include effects on behavior as well as physiology. "Moose sickness" is such a case; moose infected with Pneumostrongylus tenuis exhibit aberrant behavior as a result of the effects of the parasite in the central nervous system. It is interesting to note that this parasite may be resident in white-tailed deer without the effects observed in moose. The prevalence of white-tailed deer carrying the parasite is great enough to cause problems in moose populations when their habitats overlap.

The larval stages of parasites often do more harm than the adult stages. Further, the different stages in the life cycles of different parasites result in different levels of susceptibility under different habitat conditions. Range conditions, buth vegetative and physical, may be very important factors affecting levels of parasite infections. This is well-known in the treatment of domestic livestock; the development of clinical parasitism depends not only upon the number and activity of the parasites, but also on the age, resistance, and nutritional status of the host, climatic conditions and management practices (Siegmund 1967: 699-700). Putting it another way, range conditions, weather conditions, and the age, resistance and nutritional status of wild ruminants affect the number and the effects of parasites on their hosts.

One example of differences in the abilities of individual animals to withstand parasites and in the ecological effects of different parasites on host populations is given by researchers on domestic sheep. Georgi and Whitlock (1967) established a direct cause and effect relationship between exposure of sheep to infection by Haemonchus contortus (twisted stomach worm), a helminth parasite of ruminants usually found in the abomasum, and the onset of erythrocyte loss. The number of erythrocytes is important in determining the efficiency of the oxygen transport system, which is fundamental to efficient tissue metabolism. Georgi (1964) clearly shows that the rate of iron loss from sheep infected with H. contortus was greater than that from non-infected sheep. Evans and Whitlock (1964) concluded that, other things being equal, an animal (sheep) with a low erythrocyte volume has a smaller chance of surviving a natural challenge with this parasite than an animal having a greater erythrocyte volume. Such experimental evidence in sheep indicates that responses to parasites by the host are important determinants of metabolic efficiencies.

Basic research on the reactions of wild ruminants to pathogens and parasites should be made along with studies on apparently healthy animals in frder to evaluate the ecological importance of these interactions. Such research is especially difficult on wild ruminants because the results of such research are not necessarily important at clinical levels established for domestic animals, but could be rather important, in relation to ecological metabolism and its relation to productivity. These relationships are not only hard to evaluate; they are hard to identify. Van Volkenburg and Nicholson (1943) found 11 specific parasites in the nasal passages, skin, abomasum, and small intestines of dead deer in the Edwards Plateau, Texas. They concluded that parasites were unimportant among deer on ranges with sufficient food but made no efforts to quantify metabolic relationships between host and parasite.

The next several pages contain lists of references with information on parasites in relation to the different species of wild ruminants. The lists should prove to be convenient when reviewing this area of the biology of wild ruminants.

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PARASITES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
APRPA	13-44	445	481	cerv	helminths, helminthiases	drozdz,j	1965
APRPA	14--1	1	13	cerv	helminth fauna in poland	drozdz,j	1966
APRPA	21-34	475	479	cerv	trichostr nematode, mongol	drodz,j; namzyl,g	1973
CJZOA	44--5	851	861	cerv	exper stud, pneumostrongyl	anderson,rc; mur/	1966
JOPAA	13--1	25	28	cerv	nematod, stomach, cervidae	schwartz,b	1926
JOPAA	39--2	119	134	cerv	fluke in america ruminants	price,ew	1953
JOPAA	59--3	569	578	cerv	haemaphysalis magesh, japn	saito,y; hoogstra	1973
NAWTA	30---	156	167	cerv	cerebrospinal nematodiasis	anderson,rc	1965
PPPAA	6---4	439	458	cerv	ecology of dermacentor alb	howell,de	1939
WDABB	8---4	304	310	cerv	ecol relation, mening worm	anderson,rc	1972
ZOANA	110--	202	208	cerv	nematodes, n amer ruminant	wehr,ee; dikmans/	1935

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
AZATA	75---	1	39	od--	experiment feeding of deer	nichol,aa	1938
AJVRA	2---3	199	201	od--	new record, nematod, calif	annereaux,rf	1941
AJVRA	23--1	21	23	od--	doca, transm anaplas, tick	osebold,jw; doug/	1962

od-- continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	15--4	309	315	od--	parasitism in deer	vanroekel,h	1929
CAFGA	30--1	58	59	od--	eye worm infection, califo	herman,cm	1944
CAFGA	31--4	201	208	od--	some worm parasites, calif	herman,cm	1945
CAFGA	32--1	17	18	od--	the nose bot fly of deer	herman,cm	1946
CAFGA	32--4	182	189	od--	foot worm parasite, califo	herman,cm; bischo	1946
CAFGA	33--1	54	54	od--	deer foot worm infect, cal	herman,cm	1947
CAFGA	51--3	208	210	od--	tick paralysis, california	brunetti,oa	1965
CAFGA	55--4	307	316	od--	parelaphostrongylus, calif	brunetti,oa	1969
CNVJA	3---3	71	78	od--	cul, ser evi, lepto, ontar	abdulla,pk; kars/	1961
COVEA	40--3	315	323	od--	experim transmis, lungworm	o'roke,ec; cheatu	1950
FPARA	20--1	41	48	od--	yearly cycle, helminthoses	erhardova-kotrla/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JFUSA	40--8	540	543	od--	foot-wor dis, n rocky mt r	denio,rm; west,rm	1942
JOPAA	19--3	246	246	od--	onchocerca, subcut abscess	dikmans,g	1933
JOPAA	29--1	80	80	od--	corynebacterium, louse fly	steinhaus,ea	1943
JOPAA	55--4	720	725	od--	dist, meningi worm, se u s	prestwood,ak; smi	1969
JWIDA	8---2	109	111	od--	devic, aid exam brain, men	smith,jf	1972
JWIDA	8---2	163	164	od--	devic, aid exam sm intesti	doster,gl	1972
JWIDA	10--3	225	227	od--	trans echinoc gran, coyote	romano,mn; brune/	1974
JWMAA	7---2	220	223	od--	parasitism, malnutrit, tex	van volkenberg,h/	1943
JWMAA	30--1	202	203	od--	deer, cattle fever ticks	park,rl; skov,o;/	1966
JWMAA	31--3	595	597	od--	endoparasites, welder refu	glazener,wc; know	1967
NAWTA	3----	882	885	od--	deer, fever tick erad, flo	shillinger,je	1938
NAWTA	10---	242	246	od--	dee, domes livest par, dis	herman,cm	1945
NAWTA	16---	135	143	od--	effec, screw-worm, southea	allen,gw	1951
NYCOA	8---3	32	32	od--	deer fly, mechan dee repel	lee,j	1953
PARAA	36---	199	208	od--	nematod lungworms, no amer	dougherty,ec	1945
PCGFA	8----	1	19	od--	screw-worm problem, florid	strode,dd	1954
PMASA	18---	33	33	od--	ecto, endoparasites, monta	senger,cm	1958
PPASA	39--2	73	77	od--	id nemato eggs, larv, penn	samuel,wm; beaudo	1965
WDABB	1---4	44	48	od--	microfilar, wehrdikm, ariz	hibler,cp	1965
WDABB	5---1	27	30	od--	elaeophorosis, new mexico	hibler,cp; adcoc/	1969
WIDIA	10---	1	5	od--	the foot worm, northe utah	yuill,tm; low,jb/	1961

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS----------------	AUTHORS----------	YEAR
AESAA	62--5	1208	1210	odvi	pharyngeal bot in oklahoma	hair,ja; howell,/	1969
AJVRA	31--5	879	883	odvi	antigen, serodiag, theiler	gadir,fa; hidalg/	1970
AJVRA	39-12	1901	1903	odvi	anthelmint activ, albendaz	foreyt,wj; drawe,	1978
AMNAA	79--2	528	530	odvi	rate, tick attachmen, fawn	montgomery,gg	1968
AMNAA	85--2	507	513	odvi	seas fluc tricholipeur,tex	samuel,wm; traine	1971
AMNAA	86--2	506	508	odvi	new sp. trichostrongylus	maples,wp; englan	1971
APRPA	19-11	141	145	odvi	2 nematode species, poland	drozdz,j	1971
CJCMA	33--4	280	286	odvi	eff pneumostrongyl on kids	anderson,rc; stre	1969
CJCMA	38--3	271	279	odvi	path chang, fasciola infec	presidente,pja; /	1974
CJCMA	39--2	155	165	odvi	exp fasciola-hepati infect	presidente,pja; /	1975
CJCMA	39--2	166	177	odvi	fasciola infec, path featu	presidente,pja; /	1975
CJZOA	34--3	167	173	odvi	elaphostrongyl, cranial ca	anderson,rc	1956
CJZOA	41--5	755	792	odvi	inci, dev, tr, pneumostron	anderson,rc	1963
CJZOA	45--3	285	289	odvi	penetrat, pneumostrongylus	anderson,rc; stre	1967
CJZOA	46--3	373	383	odvi	gastropods, pneumostrogylu	lankester,mw; and	1968
CJZOA	47--6	1411	1411	odvi	host recor, nematodirus sp	webster,wa; macka	1969
CJZOA	52--6	785	789	odvi	demodex odocoilei, new spp	desch,ce; nutting	1974
CJZOA	53--1	87	96	odvi	seas cha, aboma worms, ont	baker,mr; anderso	1975
CJZOA	53--8	1047	1054	odvi	seas change, louse populat	watson,tg; anders	1975
CNJMA	31-12	354	357	odvi	antibodies, theileria infe	kutler,kl; robin/	1967
CNVJA	5--11	287	296	odvi	elaphostrongylosis, moose,	smith,hj; archib/	1964
COVEA	40--2	211	212	odvi	new host, dicrocoelium, ny	mapes,cr; baker,d	1950
COVEA	51--3	431	441	odvi	cerebra nematodiasis, penn	alibasoglu,m; kr/	1961
COVEA	68--2	139	149	odvi	demodex canis, redescripti	nutting,wb; desch	1978
DABBB	34B--	5002	5002	odvi	lone star tick, fawn survi	hoch,al	1974
DABBB	35B-6	3114	3114	odvi	survey helminth parasites	owen,wb,jr	1974
DABBB	36B-8	3806	3807	odvi	epizoot larg amer liver fl	foreyt.wj	1976
EVETB	6---2	263	269	odvi	seas abund, lonestar ticks	patrick,cd; hair,	1977
GRLEA	8---1	1	29	odvi	the deer flies of indiana	burton,jjs	1975
JAVMA	96---	607	608	odvi	tropic var cattle-fev tick	knapp,jv	1940
JAVMA	163-6	556	561	odvi	abomas helmin, tex,virg is	prestwood,ak; ha/	1973
JAVMA	166-8	787	789	odvi	helmin w-t deer, cattle, s	prestwood,ak; ke/	1975
JAVMA	169-9	896	900	odvi	intest nema, w-t deer, s e	pursglove,sr; pr/	1976
JAVMA	171-9	933	935	odvi	prev, distr, setaria se us	prestwood,ak; pur	1977
JAVMA	171-9	936	938	odvi	fascioloides infect, se us	purseglove,sr; p/	1977
JAVMA	173-9	1242	1243	odvi	otitis media caused by pso	rollor,ea: nettl/	1978

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CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JMENA	7---5	567	574	odvi	amblyomma, s texas, theile	samuel,wm; traine	1970
JMENA	8---5	495	498	odvi	arthropod parasites, w-t d	kellogg,fe; kist/	1971
JMENA	9---1	104	106	odvi	lipoptena mazamae dip, tex	samuel,wm; traine	1972
JNYEA	85--4	217	220	odvi	epizo, bovin babesias, tex	hourrigan,jl	1977
JOMAA	16--1	70	71	odvi	onchocerciasis, montana	rush,wm	1935
JOPAA	29--2	158	158	odvi	protostrongylus, lungs, ny	goble,fc	1943
JOPAA	45--4	32	32	odvi	odhe louse-flies, w montan	senger,cm; capell	1959
JOPAA	53--4	691	691	odvi	oesophagostomum, se u s	payne,rl; maples/	1967
JOPAA	54--3	441	444	odvi	ostertagia, med stom worms	becklund,ww; walk	1968
JOPAA	54--6	1091	1091	odvi	trichostrongylus axei	samuel,wm; traine	1968
JOPAA	55--4	720	725	odvi	distr meninge worm, se usa	prestwood,ak; smi	1969
JOPAA	56--1	123	127	odvi	geog dist, gongylonem, par	prestwood,ak; sm/	1970
JOPAA	56--4	6	7	odvi	ecol menigea worm, cervids	anderson,rc	1970
JOPAA	56--4	299	300	odvi	parasites,relat epizoo fac	samuel,wm	1970
JOPAA	56--5	1038	1038	odvi	new host for psoroptes sp	strickland,rk; g/	1970
JOPAA	57--3	468	493	odvi	spiculosteragia nematoda	doster,gl; friend	1971
JOPAA	57--3	657	659	odvi	fail boophil, trans anapla	kuttler,kl; grah/	1971
JOPAA	57--6	1292	1292	odvi	cestodes of w-t de, se usa	prestwood,ak	1971
JOPAA	58--5	897	902	odvi	parelaphostrongylus,new sp	prestwood,ak	1972
JOPAA	58--5	1010	1011	odvi	occuren, fascioloides, tex	foreyt,wj; todd,	1972
JOPAA	59--1	208	209	odvi	oxyclozanide, fascioloides	forety,wj; todd,a	1973
JOPAA	59--6	1091	1098	odvi	lone star tick, hemat chan	barker,rw; hoch,/	1973
JOPAA	60--4	573	573	odvi	leptostrongyl, georgia,lou	prestwood,ak; pur	1974
JOPAA	60--6	1059	1060	odvi	trichostrongylus, ostertag	pursglove,sr,jr;/	1974
JOPAA	61--1	145	146	odvi	trypanosomes, new york	krinsky,wl	1975
JOPAA	62--1	26	32	odvi	devel large amer liv fluke	foreyt,wj; todd,a	1976
JOPAA	62--1	144	145	odvi	parenteral infec, fasciola	foreyt,wj; todd,a	1976
JOPAA	62--1	166	168	odvi	oesophagostomum in w-t dee	baker,mr; pursglo	1976
JOPAA	62--4	574	578	odvi	eucyathostomum webbi,new s	pursglov,sr,jr	1976
JOPAA	62--5	824	825	odvi	trypanosomes from oklahoma	krinsky,wl; burgd	1976
JOPAA	62--6	1000	1002	odvi	tech det amblyomma infecti	durham,ka; corst/	1976
JOPAA	63--5	938	939	odvi	mamm hosts fasciola, washi	lang,bz	1977
JOPAA	63--6	974	978	odvi	low lev infec parelaphostr	prestwood,ak; net	1977
JOPAA	63--6	1050	1052	odvi	fascioloides magna, w-t de	foreyt,wj; samue/	1977
JOPAA	64--1	14	16	odvi	2 sp of entamoeba, georgia	kingston,n: stabl	1978
JOPAA	64--3	567	568	odvi	filariasis, w-t d, missour	robbins,dj; clark	1978
JPROA	8---1	33	41	odvi	ophryoscolecid fauna, w-t	zielyk,mw	1961
JPROA	18--2	306	308	odvi	ecol factors influ eimeria	samuel,wm; traine	1971
JWIDA	6---1	35	42	odvi	experimental haemonchosis	foreyt,w; trainer	1970
JWIDA	6---1	56	63	odvi	compar, parasit, 2 populat	beaudoin,rl; sam/	1970
JWIDA	6---1	84	86	odvi	neurol dis, meningeal worm	prestwood,ak	1970
JWIDA	6---3	182	183	odvi	pulex porcinus, s texas	samuel,wm; traine	1970
JWIDA	6---4	430	436	odvi	mening worm invas of brain	eckroade,rj; rhe/	1970

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CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWIDA	6---4	437	440	odvi	hosts, cattle fever ticks	kistner,tp; hayes	1970
JWIDA	7---2	133	134	odvi	natural occur haemonchosis	prestwood,ak; kel	1971
JWIDA	7---3	142	146	odvi	pharyngeal bot fly larvae	samuel,wm;train/	1971
JWIDA	7---3	149	154	odvi	lungworms in w-t d, se usa	prestwood,ak sm/	1971
JWIDA	8---1	63	66	odvi	fail establ babesia infect	kuttler,kl; grah/	1972
JWIDA	8---2	109	111	odvi	device exam brain, helmint	smith,jf	1972
JWIDA	8---2	112	114	odvi	occurrence demodex, oklaho	carpenter,jw; fr/	1972
JWIDA	8---2	163	164	odvi	devi, exam sm intes, helmi	doster,gl	1972
JWIDA	8---3	233	236	odvi	elaeophoros, distri se usa	prestwood,ak; rid	1972
JWIDA	8---4	304	310	odvi	ecol rela mening wor, cerv	anderson,rc	1972
JWIDA	8---4	381	383	odvi	mening worm pareleaph, okla	carpenter,jw; jo/	1972
JWIDA	9---2	136	143	odvi	parelaphostrongylus, maine	gilbert,ff	1973
JWIDA	9---2	182	193	odvi	hepatozoon procyonis, texa	clark,ka; robins/	1973
JWIDA	10--1	11	17	odvi	strongyloidosis, captiv de	forrester,dj; ta/	1974
JWIDA	10--2	146	148	odvi	strongyloid, fawns, florid	forrester,dj; ta/	1974
JWIDA	10--4	404	409	odvi	distrib muscleworm, se usa	prestwood,ak; ne/	1974
JWIDA	11--2	256	262	odvi	ceel, morph trypanos, mich	stuht,jn	1975
JWIDA	12--1	65	71	odvi	ixodes scapularis, ontario	watson,tg; anders	1976
JWIDA	12--3	361	366	odvi	eff 6 fasciolicides, fasci	foreyt,wj; todd,a	1976
JWIDA	12--3	380	385	odvi	dosh, parasit, common rang	prestwood,a; pur/	1976
JWIDA	13--1	2	8	odvi	culicoid vector hemorr, ky	jones,rh; rought/	1977
JWIDA	13--1	9	16	odvi	trans hemorrhag dis, culic	foster,nm; breck/	1977
JWIDA	14--1	89	96	odvi	mening worm parelaphos, nh	thurston,dr; stro	1978
JWIDA	15--1	51	56	odvi	sarcocystis, herbi, nat bi	pond,db; speer,ca	1979
JWIDA	15--1	55	56	odvi	elaeophora schneideri, tex	forent,wj; forent	1979
JWIDA	15--1	83	89	odvi	clin-path change, fasciolo	forent, wj; todda	1979
JWIDA	15--2	273	280	odvi	exp infect, elaeophora sch	titche,ar; prestw	1979
JWIDA	15--3	405	408	odvi	gast-intest helminths, ill	cook,tw; ridgewa/	1979
JWMAA	5---2	141	158	odvi	tissue chan, lungworm infe	goble,fc	1941
JWMAA	15--2	216	220	odvi	disease, winter mortality	cheatum,el	1951
JWMAA	31--2	299	303	odvi	alal, pneumostrongyl, minn	karns,pd	1967
JWMAA	31--3	455	459	odvi	theileriasis in texas wtd	robinson,rm; kut/	1967
JWMAA	32--4	963	966	odvi	pneumostrongylus, maine	behrend,df; witte	1968
JWMAA	33--4	888	894	odvi	tech, surv, helmin, protoz	samuel,wm; traine	1969
JWMAA	34--3	546	552	odvi	mort, tissue destr, ticks	bolte,jr; hair,j/	1970
JWMAA	36--4	1349	1353	odvi	dist meningeal worm, canad	bindernagel,ja; a	1972
JWMAA	37--2	183	186	odvi	deer ked infestatio, texas	davis,jw	1973
JWMAA	37--3	327	330	odvi	mening worm, moose pop,ont	saunders,bp	1973
JWMAA	40--3	579	581	odvi	protozo, helmnth, key deer	schulte,jw; klim/	1976
JWMAA	41--2	169	177	odvi	manage impl abomasal paras	eve,jh; kellogg,f	1977
MUATA	159--	1	20	odvi	helminths of deer, minneso	olsen,ow; fenster	1943
NAWTA	1----	473	478	odvi	lungworm situation, michig	o'roke,ec	1936
NAWTA	4----	244	249	odvi	prevalenc, dis, para, mich	whitlock,sc	1939
NAWTA	28---	225	232	odvi	tropical cattle fever tick	marshall,cm; sea/	1963
NAWTA	33---	364	372	odvi	domes rumin, endoparasites	samuel,wm	1968

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CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NFGJA	17--1	45	49	odvi	nematode, pneumostrong, ny	behrend,df	1970
NFGJA	20--2	158	161	odvi	liver flukes, adironda, ny	behrend,df; matt/	1973
PAVEA	2----	360	379	odvi	develop pneumostrongy, cns	anderson,rc	1965
PCGFA	12---	224	227	odvi	liver flukes, southeast de	holland,jb	1958
PCGFA	19---	128	141	odvi	incid, pneumostrongyl, vir	dudak,d; cornwel/	1965
PCGFA	29---	651	655	odvi	nasal bots,w-t dee, se usa	nettles,vf doste	1975
PHSWA	6---2	102	104	odvi	helminth parasites, florid	dinaburg,ag	1939
PHSWA	42--2	141	143	odvi	range exten rec, helmin,ky	heuer,de; philli/	1975
PHSWA	44--1	107	108	odvi	helminth paras, nj, oklaha	pursglove,sr,jr	1977
PHSWA	44--2	179	184	odvi	trypanosoma cervi, se usa	kingston,n; crum,	1977
PRLBA	206--	395	402	odvi	malaria paras, rel plasmod	garnham,pcc; kutt	1980
PSDAA	48---	47	57	odvi	odhe, parasites, so dakota	boddicker,ml; hug	1969
PUNMA	79-18	1	6	odvi	nema, ostertagia, vir deer	dikmans,g	1931
SENTD	4---3	192	194	odvi	tick survey, sou tex count	garnett,wh; ahren	1979
TAMSA	54--2	138	144	odvi	lungworms from w-t deer, m	dikmans,g	1935
TISAA	60--2	203	203	odvi	lone star ticks, illinois	montgomery,gg; ha	1967
TRCIA	34...	57	92	odvi	helminth, arthro parasites	anderson,rc	1962
VTPHA	13--5	381	393	odvi	exp parelaphostrongy infec	nettles,vf; prest	1976
WDABB	2---4	100	107	odvi	2 surv meth, helminth infe	samuel,wm; beaudo	1966
WDABB	3---4	182	183	odvi	tick transm, theileriasis	kuttler,kl; robi/	1967
WDABB	4---4	142	143	odvi	isolation of a babesia	emerson,hr; wrigh	1968
WDABB	5---1	25	26	odvi	sarcocystis in w-tail deer	karstad,l; traine	1969
WDABB	5---2	108	108	odvi	new host, amblyommainornat	cook,rs; glazene/	1969
WDABB	5---3	137	139	odvi	comp, parasit, cent, e tex	emerson,hr	1969
WDABB	5---3	351	356	odvi	eimeria, penn, tex, wiscon	anderson,dr; samu	1969
WDABB	5---4	398	399	odvi	trypanosomiasis in w-t dee	kistner,tp; hanso	1969
WIDIA	63---	1	59	odvi	path, exp fasciola hep inf	presidente,pja; /	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AESAA	68--1	63	67	odhe	dermacentor alb hydridizat	ernst,se; gladney	1975
AJVRA	38--8	1205	1209	odhe	hist study, exp sarcoc hem	koller,ld; kistn/	1977
CAFGA	20--3	181	282	odhe	life hist, food hab, calif	dixon,js	1934
CAFGA	56--1	71	71	odhe	jay feeding on ectoparasit	schulz,ta; budwis	1970

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CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
CJZOA	53--7	977	992	odhe	behavior of nose bot flies	anderson,jr	1975
CNRDA	21--6	171	187	odhe	2 dipterous paras, lif his	cowan,i mct	1943
CNRDA	24--3	71	103	odhe	parasites, dis, injur, b c	cowan,i mct	1946
GRBNA	37--3	407	410	odhe	occur ticks, mule de, utah	pederson,jc	1977
IZSPB	1----	1	45	odhe	odvi, checklist, parasites	walker,ml; becklu	1970
JAVMA	96---	542	542	odhe	host, nemato eye wor, cali	oberhansley,fr	1940
JMENA	10--2	225	226	odhe	euschoengastia sp, oregon	easton,er; krantz	1973
JMENA	13--2	169	173	odhe	dada, transf bovicola, cal	westrom,dr; nels/	1976
JMENA	13--3	375	377	odhe	hematophag acti, hybomitra	clark,gg; hibler/	1976
JMENA	16--5	448	449	odhe	barbary sh, ectoparas, tex	gray,gg; pence,db	1979
JOPAA	45--4	32	32	odhe	louse flies, w montana	senger,cm; capell	1959
JOPAA	45--4	32	32	odhe	cephenemyia jellisoni, mon	capelle,kj; senge	1959
JOPAA	53--2	392	394	odhe	nematodirus odocoilei	becklund,ww; walk	1967
JOPAA	56--5	1039	1040	odhe	ear scab mites, psoroptes	roberts,ih; mele/	1970
JOPAA	60--6	972	975	odhe	prev eye worm, 3 pop, oreg	beitel,rj; knapp/	1974
JWIDA	6---2	110	111	odhe	experim infect, elaeophora	hibler,cp; adcoc/	1970
JWIDA	8---4	325	326	odhe	trypanosomes, n mex, color	clark,gg	1972
JWIDA	9---1	34	40	odhe	treat, dictyocaulus, capti	presidente,pja; /	1973
JWIDA	9---1	41	43	odhe	doca suscep dictyocaul iso	presidente,pja; k	1973
JWIDA	9---3	213	220	odhe	host,filarial worms, calif	weinmann,cj; and/	1973
JWIDA	10--1	44	46	odhe	exp infect elaeophora schn	hibler,cp; gates/	1974
JWIDA	10--4	361	369	odhe	morph larv stag elaeophora	hibler,cp; metzge	1974
JWIDA	11--2	214	220	odhe	exp induc fasciola infect	kistner,tp; kolle	1975
JWIDA	11--4	519	521	odhe	trypanosomes, mule d, wyom	kingston,n; mort/	1975
JWIDA	12--1	86	87	odhe	doca, sp diff, sarcocystis	hudkins-vivion,g/	1976
JWIDA	13--1	33	39	odhe	trypanosoma cervi, wyoming	matthews,mj; kin/	1977
JWIDA	13--1	80	84	odhe	sarcocystis hemionilatrani	hudkins,g; kistne	1977
JWIDA	13--2	137	143	odhe	mening worm indu neuro dis	nettles,vf; pres/	1977
JWIDA	15--1	51	53	odhe	sarcocystis, herbi, nat bi	pond,db; speer,c	1979
JWMAA	12--1	105	106	odhe	granular tapeworm, echinoc	cowan,im	1948
JWMAA	23--1	119	122	odhe	cysticerci of taenia, colo	olsen,ow; william	1959
NAWTA	18---	168	188	odhe	dosh, parasite interrelati	longhurst,wm; dou	1953
NAWTA	22---	160	166	odhe	dosh, exp trans, nematodes	baker1nf; longhu/	1957
PHSWA	18--2	120	122	odhe	porcupine nematode, colora	olsen,ow; tolman,	1951
PHSWA	39--1	135	138	odhe	prev helminth paras, monta	worley,de; eustac	1972
PHSWA	45--1	139	141	odhe	helmin, sympat barbary she	gray,gg; simpson/	1978
PHSWA	47--2	266	267	odhe	gongylonema, n. w. califor	botzler,rg; fanto	1980

odhe continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PPETA	19--4	139	147	odhe	ixodes sp, mule dee, skunk	cooley,ra; kohls,	1943
PPETA	21--2	48	57	odhe	deer lousefly calif	hare,je	1945
PPETA	21--3	120	120	odhe	cephenemyia, nasal bot	herman,cm	1945
TAMSA	88--4	589	591	odhe	new, eimeria ivensae, mont	todd,ks,jr; ogara	1969
WGFBA	8---3	13	22	odhe	internal parasites, wyomin	landram,jf; hones	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ACVTB	41--1	117	124	ceel	subcutaneous filariases in	dykova,i; blazek,	1972
ACVTB	41--2	197	201	ceel	microfilariae, tiss reacti	dykova,i	1972
APMIA	65--4	613	620	ceel	tick, encephal virus, swed	svedmyr,a; zeipe/	1965
APRPA	8--21	345	350	ceel	paramphistomum cervi, dise	zadura,j	1960
CAFNA	63--5	204	205	ceel	echinococcus granulo, banf	green,hu	1949
CJZOA	47--5	795	803	ceel	incidenc, abund, parasites	flook,dr; stenton	1969
FPARA	16--1	74	74	ceel	elaphostron, cent nerv sys	dykova,i	1969
JAVMA	140-7	689	690	ceel	transfer, psoroptic mites	hepworth,wg; thom	1962
JOPAA	59--6	1132	1133	ceel	trypanosomes from elk, wyo	kingston,n; morto	1973
JOPAA	61--1	17	23	ceel	trypanosom cerv sp. n. wyo	kingston,n; morto	1975
JPROA	21--3	448	448	ceel	babesia sp. in sc red deer	blewett,da; adam/	1974
JWIDA	5---3	348	350	ceel	reserv host, domest parasi	worley,de; barre/	1969
JWIDA	8---1	57	62	ceel	doca, cross-transmis exper	presidente,pja; /	1972
JWIDA	9---2	148	153	ceel	neurol dis, meningeal worm	carpenter,jw; jo/	1973
JWIDA	10--1	63	65	ceel	trypanosomes, horse flies	davies,rb; clark,	1974
JWIDA	11--1	40	44	ceel	preval dictyoc vivp infect	bergstrom,rc	1975
JWIDA	11--1	66	67	ceel	psoroptic mange in wapiti	colwell,da; dunla	1975
JWIDA	13--2	149	154	ceel	prev, parelaphostr, capt p	woolf,a; mason,c/	1977
JWIDA	14--2	263	268	ceel	neurolog diseas, capt herd	olsen,a; woolf,a	1978
JWIDA	15--1	33	36	ceel	prev, parelaphostron, capt	olsen,a; woolf,a	1979
JWIDA	15--1	51	53	ceel	sarcocystis, herbi, nat bi	pond,db; speer,c	1979
KLVBA	1962.	49	61	ceel	dada endoparasites, denmar	gui'dal,ja	1962
NEZTA	24--1	22	23	ceel	elaphostrongylus cervi in	mason,pc; kiddey/	1976
NEZTA	24--1	23	23	ceel	dicty viv, elaph cer, wapi	mason,pc; mcallum	1976
NEZTA	24-11	263	266	ceel	elaph cer, gross hist lesi	sutherland,rj	1976
NZASA	11--4	182	183	ceel	gastrointest parasitism in	mason,pc	1977

ceel continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NZJSA	11--4	686	692	ceel	ophryoscolecid ciliat, n z	clarke,rtj	1968
PAHUA	9----	73	84	ceel	seasonal incidence larvae	sugar,l	1976
PAHUA	10...	95	96	ceel	occur elaphostron, hungary	sugar,l; kavai,a	1977
PARAA	73--1	1	11	ceel	isola, char, babesia from	adam,kmg; blewet/	1976
PAVEA	6----	185	213	ceel	path-elaeophorosis	adcock,jl; hible/	1969
PHSWA	42--2	179	181	ceel	mult stag tryp cerv, splee	kingston,n; morto	1975
PHSWA	47--2	266	267	ceel	gongylonema, n. w. calif	botzler,rg; fanto	1980
TMPRA	26--1	60	69	ceel	onchocera flexuosa, germny	schulz-key,h	1975
TMPRA	26--3	348	358	ceel	filariidae of, germany	schulz-key,h	1975
VETRA	100--	252	252	ceel	warble fly in red deer (co	dear,jp	1977
VETRA	100--	346	346	ceel	warble fly in red deer (co	ray,rj	1977
WDABB	1---4	48	48	ceel	elaeophoriasis in elk	adcock,jl; hibler	1965
WDABB	2---1	5	6	ceel	dictyocaulus, s-cent monta	barrett,re worley	1966
WDABB	5---1	23	24	ceel	some parasites, new mexico	wilson,gi	1969
WDABB	5---1	27	30	ceel	elaeophorosis, new mexico	hibler,cp; adcoc/	1969
WDABB	5---2	95	98	ceel	fringed tapeworm, yellowst	jacobson,rh; wor/	1969
WGFBA	8---4	25	28	ceel	eimeria of elk, new specie	honess,rf	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AESAA	67---	204	214	alal	tax, lif hist moos fly, wy	burgerr,jf; ander	1974
AJVRA	3---9	403	408	alal	parasites, northern minnes	olsen,ow; fenster	1942
AJVRA	27---	548	558	alal	cerebro nema, minn,pneummo	kurtz,hj; loken,/	1966
ATMPA	58...	307	314	alal	intro reindee, hydatid dis	sweatman,gl	1964
BEREA	17---	249	249	alal	moose-tick in saskatchewan	cameron,ae; fulto	1927
CAENA	102--	1461	1473	alal	od, tabanid, distr, ontar	smith,sm; davies/	1970
CJZOA	43--4	635	639	alal	neurologic signs, ontario	anderson,rc	1965
CJZOA	52--2	235	245	alal	nematode,trematod, manitob	lankester,mw	1974
CJZOA	52--3	401	403	alal	od, elaphostrongy, alberta	samuel,wm; holmes	1974
CJZOA	54--3	307	312	alal	helminths in moose, albert	samuel,wm; barre/	1976

alal continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CNVJA	5--11	287	296	alal	elaphostrongylosis, deer,	smith,hj; archib/	1964
CNVJA	12--2	56	56	alal	infect dictyocaulus calv	gupta,rp; gibbs,h	1971
JAVMA	37--5	770	775	alal	parasites, moose, minnesot	wallace,fg	1934
JAVMA	171-9	987	988	alal	cerebr nematodiasi, n hamp	stackhouse,ll	1977
JEBCA	67---	24	29	alal	odhe, dermacen tick, paral	wilkinson,pr	1970
JOMAA	39--1	139	145	alal	paras, dis, wells gray her	ritcey,rw; edward	1958
JOMAA	39--3	449	450	alal	onchocerca in an alaska mo	williams,rb; babe	1958
JOMAA	48--4	668	669	alal	parasites, newfoundland	threlfall,w	1967
JOPAA	18--4	219	231	alal	new disease in moose, minn	thomas,lj; cahn,a	1932
JOPAA	18--4	303	303	alal	hematodirella, moose, minn	dikmans,g	1932
JWIDA	8---3	242	244	alal	elaeophorosis, montana	worley,de; ander/	1972
JWIDA	15--2	281	284	alal	dermacentor, ontario	addison,em; john/	1979
JWMAA	23--1	122	123	alal	preva, hydatid dis, alaska	rausch,ra	1959
JWMAA	31--2	299	303	alal	pneumostrong, deer, minnes	karns,pd	1967
JWMAA	33--2	431	433	alal	pneumost, deer-free island	karns,pd; jordan	1969
JWMAA	37--1	327	330	alal	odvi, mening worm, ontario	saunders,bp	1973
JWMAA	38--1	42	46	alal	parelaphostrongylus, maine	gilbert,ff	1974
NCANA	101--	23	50	alal	infect, parasi dis, n amer	anderson,rc; lan	1974
PAVEA	1----	289	322	alal	neuro dis, exp pneumostron	anderson,rc	1964
PAVEA	2----	360	376	alal	motor ataxia, paral, pneum	anderson,rc	1964
XENOB	6....	168	169	alal	deer louse fly, se finland	brander,t	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AEHLA	25--4	246	252	rata	obs on some nat-foc zoonos	rausch,rl	1972
AGBOB	12--1	23	28	rata	warble-fly problem in alas	washburn,rh; kle/	1980
AVCSA	3---3	201	225	rata	cereb, muscu nematod, swed	roneus,o; nordkvi	1962
AVCSA	6---4	353	359	rata	experim babesia infections	nilsson,o; nordk/	1965
AVCSA	14--4	642	644	rata	onchocercosis in swedish r	rehbinder,c	1973
AVCSA	16--1	14	23	rata	giant cell reac, echinococ	roneus,o	1975
AVCSA	17--3	359	362	rata	echinococcosis, slaughtere	kummeneje,k; waag	1976
AVCSA	18--1	75	85	rata	keratitis in reindeer	rehbinder,c	1977
AVCSA	18--1	86	90	rata	dictyocaulus viviparus inf	kummeneje,k	1977
ATMPA	58...	307	314	rata	intro reindee, hydatid dis	sweatman,gl	1964

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CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BPURD	1----	509	517	rata	warble fly distrib, canada	kelsall,jp	1975
CAFNA	90--2	189	191	rata	paras, woodland caribo, bc	low,wa	1976
CJZOA	49--2	159	166	rata	odvi, neurolog dis, ontari	anderson,rc	1971
CJZOA	49--2	280	281	rata	fascioloides magna tremato	chouquette,lpe; /	1971
CJZOA	54--5	680	684	rata	protostrongylid nematode	lankester,mw; cr/	1976
CNJMA	21--6	199	203	rata	parasites, reindee, canada	choquette,lpe; w/	1957
CNRDA	10---	527	531	rata	skrjabinema oreamni, canad	swales,we	1934
DOBTA	119-3	621	621	rata	life cycle, nematode, rein	mitskevich,v iu	1958
FPWTA	33---	30	39	rata	dis condit, parasi, bar gr	broughton,e; chou	1969
JOPAA	9---1	38	39	rata	parasites, alaska	hadwen,s	1922
JOPAA	9---1	48	48	rata	nematodirus tarandi, reind	hadwen,s	1922
JOPAA	28--5	423	423	rata	parasites, woodland caribo	erickson,ab; high	1942
JOPAA	46--5	624	628	rata	redescri, avitellina arcti	gibbs,hc	1960
JWIDA	7---4	242	245	rata	occure setaria in reindeer	dieterich,ra; lui	1971
JWIDA	9---4	376	378	rata	mort due to meningeal worm	trainer,dd	1973
JWIDA	12--4	566	571	rata	besnoitiosis in woodla car	wobeser,g	1976
NOVDA	16--4	390	395	rata	hist stud, parasit nodule	lisitzin,p	1964
NOVDA	25--6	203	210	rata	elaphostrongylosis, reind	bakken,g; sparboe	1973
NOVTA	30--4	214	216	rata	gastric para, winter slau	rehbinder,c; szo/	1978
NOVTA	31--6	282	283	rata	parasit visceral granuloma	rehbinder,c; chr/	1979
PARAA	66--1	123	132	rata	solenopotes-tarandi, ba-gr	weisser,cf; kim,k	1973
ZEVMA	25B-1	81	87	rata	antiparas eff, tetramisolu	kurkela,p; kaante	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOPAA	19--3	246	246	anam	onchocerca, subcut tissue	dikmans,g	1933
JOPAA	28--2	167	168	anam	a new coccidium from anam	huizinga,h	1942
JOPAA	40--6	637	648	anam	internal parasites, n dako	goldsby,ai; evele	1954
JOPAA	44--5	514	514	anam	ornithodoros (otobins) meg	schad,ga	1958
JOPAA	46--5	671	671	anam	thysanosoma actinioides	allen,rw; samson,	1960
JOPAA	56--4	759	767	anam	dosh, immun, haemonch isol	allen,rw; samson/	1970
JOPAA	56--5	917	917	anam	otobius-megni, ears, n mex	meleney,wp; rober	1970
JWIDA	8---4	332	334	anam	capillaria-hepatica, alber	barrett,mw; chalm	1972
JWIDA	10--1	60	62	anam	infect podo dermati, alber	chalmers,ga; barr	1974
JWIDA	10--1	70	73	anam	protostr-macrotis nem, wyo	greiner,ec; worl/	1974

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CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PHSWA	12--1	2	4	anam	distribut, pseudostertagia	lucker,jt; dikman	1945
PHSWA	20--2	96	97	anam	thysanosoma, pronghorn ant	allen,rw; kyles,p	1953
PHSWA	27--1	69	73	anam	helminth parasites, ne mex	gilmore,re; allen	1960
PHSWA	42--1	61	63	anam	dosh, marshallagia, wyomin	bergstrom,rc	1975
PNDAA	6----	25	25	anam	coll, ident parasit. nd an	goldsby,ai	1955
PNDAA	17---	70	71	anam	od epizootic, n dak badlan	richards,sh	1963
TRSTA	66--2	335	335	anam	trypanosome infection, cap	roberts,cj; gray,	1972
WDABB	3---2	71	73	anam	inci, eimeria antelocaprae	todd,ks jr; hamm/	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AESAA	63--3	635	639	bibi	associati face fly, n amer	burger,jf; anders	1970
CNVJA	2---5	168	174	bibi	parasites, disease, canada	chouquette,lpe; /	1961
COVEA	69--2	198	205	bibi	ostertagiosis, case rep, n	wade,se; haschek/	1979
JAVMA	119--	386	387	bibi	parasitism in bison	frick,ej	1951
JOPAA	22--5	517	518	bibi	arthropod, helminth parasi	roudabush,rl	1936
JOPAA	39--1	58	59	bibi	parasites, bibi, nw u s	locker,b	1953
JOPAA	50--5	655	655	bibi	speleognathus australis, b	drummond,ro; mad/	1964
JOPAA	53--4	724	724	bibi	sheep liver fluke, wyoming	bergstrom,rc	1967
JWIDA	11--3	412	414	bibi	bovine coccidia, wyoming	ryff,kl; bergstro	1975
JWIDA	15--1	51	53	bibi	sarcociptis, herbi, nat bi	pond,db; speer,ca	1979
NAWTA	28---	233	239	bibi	paras, dis, anthrax, canad	novakowski,ns; c/	1963
NOSCA	26--2	61	64	bibi	tick paralysis, amer bison	kohls,gm; kramis,	1952
NPSMD	1....	...	...	bibi	bison, yellowstone natl pk	meagher,mm	1973
VETRA	100--	406	406	bibi	redwater in, babesia major	findlay,cr; begg,	1977
WMBAA	16---	1	52	bibi	biol, mngt, wood buf na pk	fuller,wa	1966

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ARMIA	25---	231	254	ovca	pathogenicit, soil amoebas	culbertson,cg	1971
CEXIA	8---2	345	354	ovca	lungw infec, homocytotr an	hudson,rj; bandy/	1971
CJCMA	36--1	69	73	ovca	cell adher, lungworm infec	hudson,rj; bandy/	1972

ovca continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS----------------	AUTHORS----------	YEAR
CJZOA	41--6	913	918	ovca	parasi, calif bigh, sou bc	blood,da	1963
CJZOA	49--4	507	512	ovca	helminths, rocky mt, canad	uhazy,ls; holmes,	1971
CJZOA	49-11	1461	1464	ovca	coccidia, rocky mt, canada	uhazy,ls; mahrt,/	1971
CJZOA	51--8	817	824	ovca	lungworms, rocky mt, canad	uhazy,ls; holmes/	1973
CJZOA	53--4	391	394	ovca	lymp cell adher, protostro	hudson,rj	1975
DABBB	40B-4	1640	1640	ovca	pathogenesis pulm protostr	spraker,tr	1979
JKESA	35--4	369	370	ovca	a new species, mallophaga	emerson,kc	1962
JOPAA	41--6	583	587	ovca	parasites, new mexico	allen,rw	1955
JOPAA	52--3	618	621	ovca	oestrus ovis, wyom, montan	capelle,kj	1966
JOPAA	53--1	157	165	ovca	parasi, checklist, rocky m	becklund,ww; seng	1967
JOPAA	58--1	29	33	ovca	moufflon hybri, protostron	monson,ra; post,g	1972
JOPAA	59--1	136	140	ovca	redescr trichuris-schumako	knight,ra; uhazy,	1973
JWIDA	6---3	169	170	ovca	mycoplas, pneumo, rocky mt	woolf,a; kradel,/	1970
JWIDA	8---4	389	389	ovca	transplac trans, protostro	hibler,cp; lange/	1972
JWIDA	10--1	39	41	ovca	trans placen, protostr inf	hibler,cp; metzg/	1974
JWIDA	11--2	193	194	ovca	wyominia-tetoni, washingto	colwell,da; dunl/	1975
JWIDA	12--1	48	51	ovca	influ rain, lungworm infec	forrester,dj; li/	1976
JWIDA	13--2	117	124	ovca	pneumon, muelleri sp, capt	demartini,jc; dav	1977
JWIDA	13--2	125	130	ovca	helminth parasites, oregon	kistner,tp; matl/	1977
JWIDA	13--3	248	250	ovca	prenat infec, lungw, alber	gates,cc; samuel,	1977
JWIDA	15--4	561	561	ovca	transplacental trans, prot	kistner,tp; wyse/	1979
JWIDA	16--1	77	82	ovca	psoroptic scabils, new mex	lange,re; sandov/	1980
JWMAA	28--3	481	491	ovca	surv, lungworm infect, mon	forrester,dj; sen	1964
JWMAA	38--4	771	774	ovca	lamb prod, surv, mort, col	woodard,tn; guti/	1974
JWMAA	43--2	461	467	ovca	eval drug treatment, lungw	schmidt,rl; hibl/	1979
PHSWA	10--1	8	9	ovca	lungwor, protostron, yello	dikmans,g	1943
PHSWA	19--1	39	39	ovca	parasites, new mexico	allen,rw; kennedy	1952
PHSWA	23--1	68	69	ovca	lungworms, montana	marquardt,wc; sen	1956
PMASA	22---	82	92	ovca	land mollusca, protostrong	forrester,dj	1962
WDABB	3---2	74	76	ovca	virus isola, lung, nemato	forrester,dj; wad	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JPROA	21--2	197	199	ovda	new spec protozoa, eimeria	clark,gw; colwell	1974
JWIDA	13--4	427	428	ovda	popula, bovicola jellisoni	kim,kc	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	36--4	529	532	obmo	helminth parasit, nwt, can	gibbs,hc; tener,j	1958
CJZOA	55--6	990	999	obmo	ovca, new eimeria species	duszynski,dw; sa/	1977
CNVJA	17--5	138	139	obmo	haemonchosis, captive calf	macdonald,dw; sa/	1976
ETBRA	30---	222	224	obmo	hypodermatid larvae dipter	jansen,j,jr	1970
JAVMA	131-3	195	196	obmo	parasitosis in a musk ox	durrell,wb; bolto	1957
JWMAA	38--4	775	782	obmo	parasitic infection in mus	samuel,wm; gray,d	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CNRDA	10---	527	531	oram	skrjabinema oreamni, canad	swales,we	1933
JOPAA	51--6	945	947	oram	nematodirus maculosus	becklund,ww	1965
JWMAA	30--4	786	790	oram	parasites, w centr alberta	kerr,gr; holmes,j	1966
JWMAA	35--1	94	103	oram	parasite, pestic, so dakot	boddicker,ml; hu/	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ACVTB	43--4	411	416	many	treatment fasciola hepatic	chroustova,e	1974
DKBSA	199--	505	506		dev caus agent, setariosis	shol,va; drobisch	1972
ENAMA	21--1	1	220	many	melophaginae (diptera)	bequaert,j	1942
FPARA	19--3	253	256	many	studies, toxoplasmosis, na	catar,g	1972
FPARA	24--1	35	40	many	helmint, wiru, intro czech	kotrla,b; kotrly,	1977
IJLAA	43-10	944	947	mamm	species composit, coccidia	bhatia,bb; chauh/	1974

continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JMENA	13--1	115	118		repellency of n,n-diethyl-	schreck,ce; smit/	1976
JMENA	13--3	225	275	many	anim dis agent tran, flies	krinsky,wl	1976
JMENA	13--3	375	377		hematophag, hybomitra spec	clark,gg; hibler/	1976
JOHLA	40---	suppl	1	mamm	bibliography, lung nematod	forrester,dj; fo/	1966
JOPAA	56--4	6	7	many	ecol relation, meningea wo	anderson,rc	1970
JOPAA	55--2	359	368	many	tax, host, dist sefaria, u	becklund,wm; wal/	1969
JOPAA	55--5	1067	1074	many	helminths, big game, s.d.	boddickey,ml; hu/	1969
JOPAA	56--4	408	408	many	furthr toxoplasma isolatns	catar,g	1970
JOPAA	57--1	191	192	many	prev, geog distr, cooperia	burtner,rh; beckl	1971
JWIDA	6---4	194	204		ecol approach, zoonoti dis	johnson,hn	1970
JWIDA	9---1	21	25	many	horse fli, elaephor, n mex	clark,gg; hibler,	1973
JWIDA	9---2	160	162		parasites of blackbuck ant	thornton,je; gal/	1973
JWIDA	11--4	486	488	many	elaleophora-schneid, monta	worley,de	1975
JWIDA	12--2	233	236	many	trypanoso, game anim, wyom	morton,jk; kingst	1976
JWIDA	12--3	322	325	mamm	prev antibod,toxoplas, ont	tizard,ir; bille/	1976
JWIDA	12--4	550	551		cerebral coenurosis, wild	toofanian,f; ivog	1976
JWIDA	14--2	157	162	many	toxoplasmosis, norway, swe	kapperud,g	1978
JWIDA	15--1	51	54		sarcocystis, herbivor, mon	pond,db; speer,ca	1979
NEZTA	21--3	43	47	many	host paras checklist n zea	andrews,jrh	1973
OUOKA	24-11	2	7		ticks can kill!	hair,ja	1968
PARAA	59--3	649	661		anal, host-parasi interact	ractliffe,lh; ta/	1969
PHSWA	1---2	63	64	many	helminth parasites	dikmans,g	1934
PHSWA	6---2	97	101	many	helminths, n.a., wild rumi	dikmans,g	1939
POASA	55---	101	102	many	prevale marshallagia, wyom	bergstrom,rc	1975
SEHEA	8---3	267	...		hematolog manif, paras inf	conrad,me	1971
WGFBA	9----	1	279	many	wildlife wyoming, disease	honess,rf; winter	1956
ZTMPA	24--4	457	466	many	studies on stephanofilaria	patnaik,b	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ACVTB	45--1	133	140	rumi	dynamics of cocc, helminth	tilc,k; hanuskova	1976
JOPAA	32--1	7	16	rumi	hosts, protostron sp, key	dougherty,ec; gob	1946
TGMEA	30...	156	...	rumi	doca, theileriidae sporozo	uilenberg,g	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ASISA	29---	536	536	wiru	parasitic bronchopneumonia	julini,m; peracin	1976
NEZTA	21--3	43	47	wiru	host-parasite checklist, h	andrews,jrh	1973
PAHUA	7---7	181	189	wiru	occ of nasal throat bot fl	sugar,l	1974
ZTMPA	24--4	467	478	wiru	species of haemonchus, dom	sachs,r; gibbons/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWIDA	15--1	51	53	herb	sarcocystis in free-rangin	pond,db; speer,ca	1979
PAHUA	9----	85	96	biga	incidence larvae of hypode	sugar,l	1976
TMPRA	29--2	223	233	ungu	invest, trypanosome carrie	drager,n; mehlitz	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
IVEJA	49--2	133	135	axax	obser on fascioliasis, zoo	rao,at; acharjyo,	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ACVTB	43--1	65	77	caca	helminths, coccidia, ecolo	dyk,v; chroust,k	1974
NATUA	200-2	490	490	caca	host, muellerius capillari	fairlie,g	1963
NATWA	65---	395	395	caca	intermediate host, coccidi	entzeroth,r; sch/	1978
PAHUA	9----	67	71	caca	dipetalonema rugosicauda n	meszaros,f; sugar	1976
PARAA	55--4	739	475	caca	gastro-int helminths, brit	dunn,am	1965
RSZOA	81--1	13	24	caca	endoparasites of roe deer	andrews,jrh; hor/	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAASA	42---	133	133	dada	surv, intrnl paras, alabam	brugh,th,jr	1971
JWIDA	13--1	55	58	dada	nat occur neurologic disea	kistner,tp; john/	1977
JWIDA	13--4	440	444	dada	cerebrospnl parelaphostron	netties vf: pres/	1977

dada continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JZOOA	177-4	494	496	dada	occurrence certain ectopar	jackson,j	1975
PHSWA	41--2	250	250	dada	new host rec, setaria yehi	phillips,jh; har/	1974
TMPRA	26--4	494	498	dada	caca, filariidae, germany	schulz-key,h	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BSKBA	31---	153	154	ceni	pathol studi, fascioliasis	tomimura,t; hira/	1979
JWIDA	14--1	137	141	ceni	elaeophorosis, texas	robinson,rm; jon/	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	12-26	377	384	bibo	helminthofauna, euro bison	drozdz,j	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWIDA	15--2	263	265	ovli	gast-intest helminths, ira	eslami,a; meydan/	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ACVTB	43--2	123	131	ovmu	caca, helminths, coccidia	dyk,v; chroust,k	1974
FPARA	15--2	178	178	ovmu	neostrongylus linearis	chroust,k; dyk,v	1968
VPARD	1---2	145	150	ovmu	caca, incid, trans, coccid	dyk,v; chroust,k	1975

UNIT 1.2: DISEASES

The word disease can be loosely interpreted to include any departure from health, or more strictly interpreted as a response to a pathogenic microorganism. The Merck Veterinary Manual tends toward the first interpretation, as references are made to parasitic diseases, or malfunctions caused by parasites. The sorting of large numbers of references in this area was done on the basis of the second definition. Thus the reference lists in this UNIT 1.2 includes those departures from normal health that can be attributed to infectious diseases, or microscopic organisms that upset normal physiological functions and metabolic pathways.

Since extra energy demands result from infections, adequate quantities of good quality food help prevent or alleviate the effects of pathogens. While there are large amounts of information on the nutrient requirements of healthy domestic ruminants, there is very little on their requirements when exposed to infections and metabolic disorders, and even less information on wild ruminants. The general principle stated with reference to the effects of parasites also applies to diseases; animals on good range will very likely be affected less than those on poor range. Prevention of problems is better than having to cure them, and wild ruminant ranges in good condition, not suffering from overgrazing or overbrowsing, will likely not harbor an unusually large number of pathogens.

The next several pages of reference lists on diseases have been sorted according to the criteria explained above. Such sorting cannot be perfect, so there may be important papers in both UNITS 1.1 and 1.2 that should be consulted when reviewing the literature. The arrangement should greatly facilitate finding of the literature.

REFERENCES, UNIT 1.2

DISEASES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBCPA	57A-4	391	398	arti	haemoglobins, erthro sickl	butcher,pd; hawke	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWIDA	6---4	376	383	cerv	maligna catarrhal fev, tex	clark,ka robins/	1970
NAWTA	28---	199	206	cerv	leptospirosis, ontario dee	mcgowan,je; kars/	1963
WDABB	5---1	12	15	cerv	4 cases, systemati mycosis	fletch,al; anders	1969
WIDIA	43---	1	233	cerv	diseases of, bibliography	karstad,l, ed	1964
WIDIA	52---	1	114	cerv	dis, bibliogr supplement 1	karstad,l	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AGVIA	41--3	259	266	od--	mult epizoo haemorr diseas	boorman,j; gibbs,	1973
AJHEA	51--5	717	722	od--	brucellosis, leptospirosis	ferris,dh; hanso/	1961
AJPAA	70--3	379	400	od--	pathogenesis, epizoo hemor	tsai,k-s; karstad	1973
AJVRA	18-66	162	166	od--	vesicular stomatitis in de	karstad,l; hanson	1957
AJVRA	22-86	109	116	od--	electr micros, anaplasma m	ristic,m; watrach	1961
AJVRA	23-92	21	23	od--	doca, transm anaplas, tick	osebold,jw; doug/	1962
AJVRA	28---	599	600	od--	anaplasma, sier nevad, cal	christensen,jf· m	1967
AJVRA	35--6	817	819	od--	propagat epiz hem dis, avi	hoff,gl; spalati/	1974
ANYAA	241--	594	604	od--	sickling phenomena of deer	taylor,wj; easley	1974
ASMAC	72---	209	209	od--	quant, neutraliz, epi hemo	stim,tb; debbie,/	1972
ASMAC	74---	213	213	od--	dosh, isol blueton vir, ep	bando,bm	1974
AZATA	75---	1	39	od--	experiment feeding of deer	nichol,aa	1938
CAFGA	36--1	19	20	od--	papilloma, skin tumors, de	herman,cm; bischo	1950
CAFGA	47--3	293	300	od--	abscess, corynebacterium p	rosen,mn; holden,	1961
CAFGA	58--2	141	144	od--	rabies in a deer	cappucci,dt,jr; l	1972
CJCMA	35--3	187	191	od--	bluetongue virus, comparas	thomas,fc; traine	1971
CNREA	31-10	1373	1375	od--	pulmonary fibroblastomas i	koller,ld; olson,	1971
CNVJA	3---3	71	78	od--	cul, ser evi, lepto, ontar	abdulla,pk; kars/	1961
COVEA	49--1	97	115	od--	latent anaplasma infection	osebold,jw; chri/	1959
CVTJA	24--1	42	42	od--	traumatic splenitis in a d	kapur,mp; sadana,	1976
DABBB	33B-3	1165	1165	od--	cell-virus inter, char epi	tsai,k-s	1972
DABBB	36B-8	3806	3806	od--	study vasc lesions catarrh	clark,ka	1976
DABBB	39B--	5250	5250	od--	characteriz, virus epiz he	willis,ng	1979
IJAHA	14--2	135	136	od--	tuberculosis in captive de	basak,dk; chatte/	1975
INFIB	8---3	463	474	od--	ultrast char genome epizoo	tsai,k-s; karstad	1973
IVEJA	54--5	409	410	od--	pasteurella multocida infe	srinivasan,va; v/	1977
				od--	continued on the next page		

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAVMA	91---2186		192	od--	pseudotuberculosis of deer	hammersland,h; jo	1937
JAVMA	98---	129	131	od--	caseous lymphadenitis	seghetti,l· mcken	1941
JAVMA	99---	54	54	od--	paratyphoid, fawn, n carol	gauger,hc; gordon	1941
JAVMA	112--	337	337	od--	foot-mouth dis, wildl, cal	anonymous	1948
JAVMA	130--	513	514	od--	leptospir, brucello titers	wedman,ee; driver	1957
JAVMA	132-7	289	292	od--	infect, antibody, anaplasm	christensen,jf; /	1958
JAVMA	132-7	293	296	od--	serol surv, leptospi, mass	reynolds,im; smit	1958
JAVMA	136-9	426	427	od--	latent anaplasma marg infe	christensen,jf; /	1960
JAVMA	139-8	892	896	od--	inves, brucel, lepto, illi	ferris,dh; hanso/	1961
JAVMA	147--	1096	1098	od--	brain tumors (ependymomas)	kradel,dc; dunne,	1965
JAVMA	167-7	565	568	od--	surv, toxoplasma antibodie	franti,ce; conno/	1975
JAVMA	169-9	975	979	od--	necropsy, lab findin, free	reed,de; shave,h/	1976
JAVMA	175-9	914	915	od--	obs on diag test, paratube	temple,rms; musc/	1979
JCVPA	87--3	345	352	od--	epiz haemorr dis, tis cult	lawman,mjp; gibb/	1977
JIDEA	58--5	366	368	od--	doca, trans of warts, host	koller,ld; olson,	1972
JOPAA	29--1	80	80	od--	corynebacterium, louse fly	steinhaus,ea	1943
JWIDA	6---4	479	482	od--	sero ev, arbovir, wis, tex	issel,cj; hoff,g/	1970
JWIDA	8---1	72	74	od--	obs on malignant catarrhal	clark,ka; robins/	1972
JWIDA	13--2	184	190	od--	dermatoph-congol enzoo, ny	gordon,ma; salki/	1977
JWMAA	8---3	247	250	od--	contag panophthalmitis, wy	rosenfeld,i; beat	1944
JWMAA	15--2	216	220	od--	disease, winter mortal, ny	cheatum,el	1951
JWMAA	24--1	44	52	od--	leptos, bruc ser reac, wis	trainer,do; hanso	1960
JWMAA	28--2	377	381	od--	epizootic hemorrhagic dise	trainer,do	1964
JWMAA	30--4	777	780	od--	serol stud, epiz hemorra d	wilhelm,ar; train	1966
LANCA	2----	1374	1375	od--	ruptured psoas in deer	thrower,wr	1972
MMLRA	4---3	75	78	od--	mortality in deer	mcdiarmid,a	1974
NAWTA	3----	886	889	od--	malignant edema in deer	mckenney,fd	1938
NAWTA	10---	242	246	od--	dee, domes livest par, dis	herman,cm	1945
NAWTA	16---	164	178	od--	epizootic, foot rot, calif	rosen,mn;/	1951
NAWTA	21---	173	184	od--	epizootic in deer in michi	fay,ld; boyce,ap/	1956
NAWTA	23---	133	136	od--	southeast coop diseas stud	hayes,fa; greer,/	1958
NAWTA	29---	196	201	od--	virus, epizo hemorrhag dis	ditchfield,j; de/	1964
NAWTA	30---	196	205	od--	pathogen, viral hemorrhagi	debbie,jg; rowse/	1965
NAWTA	32---	381	386	od--	epizootiology, hemorrhagic	shope,re	1967
NEZTA	27--3	55	55	od--	diseases of deer	mcallum.h	1979
NEZTA	27--8	151	151	od--	tuberculosis in deer	hellstrom,j	1979
PCGFA	11---	1	18	od--	se cooperative od dis stud	greer,we; shotts/	1957
PIAIA	74---	78	86	od--	incid, dis antibodie, iowa	haugen,ao	1968

od-- continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
PSEBA	88--4	533	535	od--	an infectious fibroma of d	shope,re	1955
SAGCA	25--1	2	2	od--	fall deaths, acorn toxin	kradel,dc	1977
VETRA	93--4	98	100	od--	low incid leptospirosis, b	twigg,gi; hughes/	1973
VIWIA	7---1	15	18	od--	tumors of deer	quortrup,er	1946
VTPHA	14--6	643	647	od--	glioma, rhabdomyosa, brain	holscher,ma; pag/	1977
WDABB	1---3	31	32	od--	anitibod, myxovirus parasi	shah,kv; schalle/	1965
WDABB	5---1	3	7	od--	exper expos, calif encepha	cook,rs; trainer,	1969
WDABB	5---3	174	181	od--	leptospiros, illinois herd	andrews,r	1969
WDABB	5---3	295	296	od--	chronic tox hepatit, louis	seger,cl; newsom/	1969
WSCBA	4---2	31	32	od--	epithelial papillomas in d	chaddock,tt	1939

CODEN	VO-NU	BEPA	ENPA	ANIM	KEWO----------------------	AUTHORS----------	YEAR
AJEPA	96--5	379	382	odvi	exp infect venez equine en	hoff,gl; trainer,	1972
AJHEA	63--3	201	203	odvi	wildlife, monitors, diseas	trainer,dd	1973
AJPAA	66---	30A	31A	odvi	vascul chang, epizo hemorr	tsai,ks; karstad,	1972
AJTHA	22--3	414	417	odvi	isol jamestown canyon viru	issel,cj	1973
AJVRA	20-78	925	926	odvi	experimental brucellosis	youatt,wg; fay,ld	1959
AJVRA	22-86	104	108	odvi	epizoo hemorrag dis, s dak	pirtle,ec; layton	1961
AJVRA	31--2	271	278	odvi	bluetongue virus, w-t deer	thomas,fc; traine	1970
AJVRA	33-12	2545	2549	odvi	blood serum, erysipelothri	sikes,d; kistner/	1972
AJVRA	37--7	837	840	odvi	viral particl, malig catar	clark,ka; adams,l	1976
AJVRA	38--3	361	364	odvi	isola, hemorrhag dis virus	fosberg,sa; stau/	1977
APAVD	1978	169	169	odvi	vit e, selen, white muscle	ullrey,de; brady,	1979
AUVJA	51--4	174	177	odvi	bluetongue-like disease of	frank,jf; willis,	1975
CJCMA	35--3	224	229	odvi	pathogen, exp epizo hemorr	fletch,al; karsta	1971
CNJMA	32--1	382	387	odvi	experim bluetongue disease	vosdingh,ra; tra/	1968
CNJMA	32--1	388	391	odvi	staphylococcal arthritis	sikes,d; hayes,f/	1968
CNVJA	8--11	247	254	odvi	histopath, exp bluetongue	karstad,l; traine	1968
CNVJA	14--5	106	109	odvi	dis resemblin catarr fever	wobeser,g; majka/	1973
CNVJA	20-11	323	325	odvi	polioencephalomalacia in w	wobeser,g; runge,	1979

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CNREA	31-10	1373	1375	odvi	pulmonary fibroblastomas	koller,ld; olson,	1971
CNSVA	16--2	15	15	odvi	streptothricosis, dee, man	dean,dj	1961
COVEA	33--4	323	332	odvi	some diseases, minnesota	fenstermacher,r;/	1943
COVEA	45--4	538	547	odvi	degenerative myopathy	hadlow,wj	1955
COVEA	50--3	236	250	odvi	experim infect, leptospira	ferris,dh; hanso/	1960
COVEA	52--1	94	98	odvi	leptospirosis in the w-t d	reilly,jr; muras/	1962
DABBB	31B--	6785	6785	odvi	blue tongue virus, pt 1, 2	thomas,fc	1971
DABBB	34B-6	3000	3001	odvi	studies with arboviruses,	issel,cj	1973
JANSA	32--5	1037	1041	odvi	rata, atherosclerosis in r	wiggers,kd; jaco/	1971
JAVMA	133-7	359	361	odvi	surv, brucel, leptosp, sou	shotts,eb; greer/	1958
JAVMA	137-3	190	191	odvi	serol stud, brucel, southe	hayes,fa' gerard/	1960
JAVMA	140-1	53	57	odvi	experim leptospiros infect	reilly,jr; muras/	1962
JAVMA	157-5	633	635	odvi	cutaneous streptothricosis	kistner,tp; shot/	1970
JAVMA	159-5	605	610	odvi	malignant catarrhal fever	wyand,ds; helmbo/	1971
JAVMA	167-7	571	573	odvi	dermatophilus, alternaria	salkin,if; gordo/	1975
JAVMA	169-9	971	974	odvi	myopathy, myoglobinuria in	wobeser,g; bella/	1976
JEMEA	108-6	797	802	odvi	infectious cutaneo fibroma	shope,re; mangol/	1958
JEMEA	111-2	155	170	odvi	virus-indu epizo hemor dis	shope,re; macnam/	1960
JIDIA	108-3	278	286	odvi	experimental leptospirosis	trainer,do,jr; k/	1961
JNYEA	85--4	217	220	odvi	epizo, bovin babesias, tex	hourrigan,jl	1977
JOMAA	37--4	552	554	odvi	lymphangioma, w-tailed dee	chute,hl; chamber	1956
JOPAA	57--3	657	659	odvi	fail boophil, trans anapla	kuttler,kl; grah/	1971
JWIDA	6---4	226	228	odvi	anthrax epizootic, w-t dee	kellogg,fe; pres/	1970
JWIDA	6---4	295	298	odvi	leptospiral antibo, se usa	shotts,eb,jr; hay	1970
JWIDA	6---4	384	388	odvi	bluetongue vir 1, preg dee	thomas,fc; traine	1970
JWIDA	6---4	389	396	odvi	salmonellosis, w-t d fawns	robinson,rm; hid/	1970
JWIDA	6---4	397	401	odvi	use wildl, monitor zoonose	trainer,dd	1970
JWIDA	6---4	488	493	odvi	surv, stomatitis vir antib	jenney,ew; hayes/	1970
JWIDA	7---1	52	56	odvi	aspergillos, renal oxalosi	wyand,ds· langhe/	1971
JWIDA	9---1	56	57	odvi	caseous lymph adenitis	stauber,e; armst/	1973
JWIDA	9---3	245	248	odvi	infec calif arbovir, texas	issel,cj; hoff,g/	1973
JWIDA	10--1	25	31	odvi	bluetongue, epizoo hemorrh	hoff,gl; trainer,	1974
JWIDA	10--1	34	38	odvi	subcutaneous mycotic infec	salkin,if; stone,	1974
JWIDA	10--2	158	163	odvi	blueton vir, enzootic, tex	hoff,gl; trainer/	1974
JWIDA	10--3	187	189	odvi	id virus, 1971 hemorrag di	thomas,fc; willi/	1974
JWIDA	10--3	217	224	odvi	1971 hemorrhag dis, se u s	prestwood,a; /	1974

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWIDA	11--1	62	65	odvi	ossifying fibroma, ear tag	roscoe,de; veikl/	1975
JWIDA	11--1	116	121	odvi	alal, arthropathy in white	wobeser,g; runge,	1975
JWIDA	11--2	177	186	odvi	hemorrhagic dis, kentucky	roughton,rd	1975
JWIDA	11--2	195	200	odvi	serol,venez eq enceph, tex	smart,dl traine/	1975
JWIDA	11--3	398	401	odvi	dermatophilosi, twin fawns	roscoe,de; lund,/	1975
JWIDA	11--4	508	515	odvi	exp infect, rinderpest vir	hamdy,fm; dardir/	1975
JWIDA	11--4	552	553	odvi	presumpti paratuberculosis	libke,kg; walton,	1975
JWIDA	12--2	143	147	odvi	visual defcts, 6 case rpts	howard,dr; krehb/	1976
JWIDA	12--3	306	309	odvi	prev renal urolithias, cap	woolf,a; kradel,/	1976
JWIDA	12--3	396	401	odvi	hepatic fatty cirrhos, tex	blankenship,lh; /	1976
JWIDA	12--4	516	522	odvi	infec peste-des-petits rum	hamdy,fm; dardiri	1976
JWIDA	13--1	9	16	odvi	trans hemorrhag dis, culic	foster,nm; breck/	1977
JWIDA	13--2	184	190	odvi	dermatophilus dermatit, ny	gordon,ma; salki/	1977
JWIDA	13--3	281	285	odvi	occur rumenitis in sup fed	woolf,a; kradel,d	1977
JWIDA	13--3	297	299	odvi	fibro sarcoma in a w-t dee	elwell,mr; burge/	1977
JWIDA	16--1	19	24	odvi	w-t deer reservior brucell	boeer,wj; crawfo/	1980
JWMAA	11--1	91	94	odvi	actinomycosis, minnesota	cass,js	1947
JWMAA	11--4	317	323	odvi	die-offs, edwards pla, tex		
JWMAA	15--2	216	220	odvi	disease, winter mortal, ny	cheatum,el	1951
JWMAA	19--2	320	321	odvi	surv, brucellosis, missour	steen,mo; brohn,/	1955
JWMAA	22--2	203	204	odvi	granular venereal disease	helmboldt,cf; mcd	1958
JWMAA	23--3	345	348	odvi	brucellosis, leptosp, mich	youatt,wg; fay,l/	1959
JWMAA	26--1	27	31	odvi	experim stud, brucellosis	baker,mf; dills,/	1962
JWMAA	28--1	35	41	odvi	leptosp reac rates, illino	ferris,dh; verts,	1964
JWMAA	35--4	850	852	odvi	sarcoma in an aged w-t dee	kistner,tp; hayes	1971
JWMAA	37--3	331	335	odvi	epizo hemorrhag dis, n dak	hoff,gl; richard/	1973
NAWTA	4----	244	249	odvi	prevalenc, dis, para, mich	whitlock,sc	1939
NAWTA	26---	203	211	odvi	odhe, curr status, brucell	fay,ld	1961
NEZTA	20-10	194	195	odvi	pleurisy, pericarditis in	andrews,jrh	1972
NFGJA	10--1	118	123	odvi	tuberculosis in a wild dee	friend,m; kroll,/	1963
NFGJA	19--1	92	97	odvi	dermatoph cutane streptoth	stone,wb	1972
NFGJA	19--2	184	184	odvi	anoth case, dermatophilosi	stone,wb	1972
NFGJA	25--1	1	15	odvi	mortility, fawns, seneca a	opezio,jp	1978
PAVEA	5----	164	173	odvi	spontane bluetongue, texas	stair,el; robins/	1968
PCGFA	12---	206	208	odvi	surv brucell, leptospi, se	shotts,eb; greer/	1958
SABOA	13--3	329	333	odvi	phoma peyronellae,zoo path	gordon,ma; salki/	1975
SBJOD	1---2	61	61	odvi	fibroma skin tumors,kentuc	heuer,de; harley/	1975
TNWSD	33---	35	44	odvi	1975, hemorrhagic dise, nj	mcconnell,pa; lu/	1976
VTPHA	15--1	133	135	odvi	thalamic ependymoma in a w	nettles,vf; vande	1978

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
WDABB	1---3	35	35	odvi	mastitis, wild w-tail deer	evans,w; friend,	1965
WDABB	3---1	38	39	odvi	lymphosarcoma in a w-t dee	debie.jg; friend,	1967
WDABB	3---3	98	101	odvi	listeria monocytoge, feces	mccrum,mw; evela/	1967
WDABB	3---3	102	104	odvi	skin tumors, new york deer	friend,m	1967
WDABB	3---4	152	155	odvi	chlamydia antibody study	debbie,jg	1967
WDABB	4---1	12	12	odvi	salmonella, captive fawns	debbie,jg	1968
WDABB	5---2	68	72	odvi	meth, leptospi surv, ontar	kingscote,bf	1969
WDABB	6---4	226	228	odvi	anthrax epizootic, w-t dee	kellog,fe; prest/	1970
WDABB	6---4	295	298	odvi	leptospiral antibodies, us	shotts,eb,jr; hay	1970
WDABB	6---4	384	388	odvi	bluetongue vir, pregnan de	thomas,fc; traine	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJVRA	35--4	523	525	odhe	exp trans malig catarr,col	pierson,re; stor/	1974
AJVRA	38--3	411	412	odhe	nonleth exp inocu, hemorrh	stauber,eh; farr/	1977
CAFGA	20--3	181	282	odhe	life hist, food hab, calif	dixon,js	1934
CAFGA	58--2	141	144	odhe	rabies in a deer, californ	cappucci,dt,jr; 1	1972
CELLB	9---3	489	494	odhe	endogenou type c rna virus	aaronson,sa; tro/	1976
JAVMA	169-9	937	938	odhe	fetal macer, suppur metrit	stauber,eh; olso/	1976
JAVMA	170-3	334	339	odhe	eval, anaplas carrier, uta	renshaw,hw; vaug/	1977
JOMAA	36--2	308	310	odhe	"parrot mouth", rocky mt	robinette,wl; ald	1955
JWIDA	9---4	314	319	odhe	epizoo studies anaplasm, o	peterson,kj; kis/	1973
JWIDA	10--1	74	76	odhe	dermato mycosis, alberta	chalmers,ga; barr	1974
JWIDA	10--2	166	169	odhe	investigation, tansy ragwo	dean,re; winward,	1974
JWIDA	11--1	101	106	odhe	testicular atrophy in cali	demartini,jc; con	1975
JWIDA	12--3	427	434	odhe	card agglut test, anaplasm	howarth,ja; hoka/	1976
JWIDA	12--3	459	463	odhe	tularemia in a mule deer	emmons,rw; ruski/	1976
JWIDA	16--1	89	98	odhe	wasting disease, encephalo	williams,es; youn	1980
JWMAA	3---4	360	360	odhe	large fibroma, head, neck	honess,rf	1939
JWMAA	35--2	205	209	odhe	diarrhea capt fawns, esche	kramer,tt; nagy,/	1971
NAVEA	23--1	34	36	odhe	hemorrhagic septicem, utah	quortrup,er	1942
SCIEA	91---	168	168	odhe	anaplasmosis, deer, calif	boynton,wh; woods	1940
WDABB	4---4	143	143	odhe	phenylketonuria, mule deer	studier,eh; ewing	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJVRA	37--5	615	617	ceel	survey of anaplasmosis, id	vaughn,hw; rensh/	1976
APAVD	1977-	166	176	ceel	capture myopathy in elk	haigh,jc	1977
AVCSA	18--2	159	167	ceel	lens lesions in the elk	kronevi,t; holmb/	1977
BVJOA	116-6	284	287	ceel	louping ill, virus, scotla	dunn,am	1960
BVJOA	120-7	311	321	ceel	enzootic ataxia of red dee	terlecki,s: done/	1964
BVJOA	129-1	73	78	ceel	enzyme change, cns, ataxic	robinson,n	1973
COVEA	69--4	402	410	ceel	eval anaplas card agg test	magonigle,ra; eck	1979
JAVMA	171-9	927	932	ceel	capture myopathy in elk in	lewis,rj; chalme/	1977
JOMAA	13--4	371	372	ceel	bang's disease, yellowston	rush,wm	1932
JWIDA	6---2	144	48	ceel	bluetongue virus, nor amer	murray,jo; traine	1970
JWIDA	9---2	129	132	ceel	exp infect, epizoo hemorrh	hoff,gl; trainer,	1973
JWIDA	9---4	296	301	ceel	reprod, dis, physiol blood	vaughn,hw; knigh/	1973
JWIDA	11--3	330	334	ceel	listeria-monocytog, roosev	martyny,jw; botzl	1975
JWIDA	12--3	386	389	ceel	yersiniae, roosevlt, calif	martyny,jw; botzl	1976
JWIDA	14--1	74	81	ceel	brucellosis in elk, part 1	thorne,et; morto/	1978
JWIDA	14--3	280	291	ceel	brucellosis, effects, tran	thorne,et; morton	1978
JWIDA	15--2	303	306	ceel	embryonal nephroma	snyder,sp; davie/	1979
JWIDA	15--2	307	308	ceel	myxosarcoma in a wapiti	snyder,sp; davies	1979
JWIDA	15--3	379	386	ceel	eval anaplas card agg test	renshaw,hw; mago/	1979
JWIDA	15--4	529	532	ceel	yersiniae, soil, infec ran	botzler,rg	1979
JWMAA	15--3	284	287	ceel	actino, osteogenic sarcomo	drake,ch	1951
NEZTA	26--5	130	131	ceel	salmonellosis, dee, calves	mcallum,hjf; fam/	1978
NZJSA	9---2	399	408	ceel	brucel, lepto, salmo, n ze	daniel,mj	1966
VETRA	88-23	616	617	ceel	tuberculos, atypic mycobac	hime,jm; keymer,/	1971
VETRA	100-9	187	187	ceel	bovine viru diarr antibody	mcmartin,da; sno/	1977
VETRA	102--	484	485	ceel	exper challenge, mycobacte	orr,mb; hunter,a/	1978
VETRA	104-6	120	123	ceel	outbreak mal catarrhal fev	reid,hw; buxton,/	1979
VETRA	105--	574	576	ceel	exper pneumonia, ovine chl	mcmartin,da; hun/	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJPAA	15--4	445	454	alal	encephalitis, maine, minne	king,ls	1939
AJTHA	22--5	654	661	alal	rata, arbovi, serol,finlnd	brummer-korvenkon	1973
AVCSA	18--2	287	289	alal	"inclusion-body-like" conf	villar,ja; rehbin	1977
CAFNA	91--1	94	95	alal	trauma induc paralys, calf	chalmers,ga; barr	1977

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CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CNJMA	22--1	9	20	alal	brucellos, elk isl, albert	corner,ah; connel	1958
CNJMA	22--7	244	248	alal	moose "sickness", nov scot	benson,da	1958
CNJMA	22--8	282	286	alal	moose "sickness" n scot II	benson,da	1958
COVEA	32--3	241	254	alal	further stud, disease, III	fenstermacher,r;	1942
JAVMA	171-9	924	926	alal	capture myopathy in a moos	haigh,jc; stewar/	1977
JIDIA	136-2	312	316	alal	rata, brucel, 1965-74, usa	fox,md; kaufmann,	1977
JOMAA	39--1	139	145	alal	paras, dis, wells gray her	ritcey,rw; edward	1958
JWIDA	8---1	95	98	alal	fatality, range overextens	miller,fl; broug/	1972
JWIDA	11--2	116	121	alal	odvi, arthropathy	wobeser,g; runge,	1975
JWMAA	17--2	217	218	alal	brucellosis in a moose	jellison,wl; fis/	1953
JWMAA	24--1	44	52	alal	narcosis, moose, nicotine	rausch,ra; ritcey	1961
JWMAA	38--1	42	46	alal	parelaphostrongylus tenuis	gilbert,ff	1974
NCANA	101--	23	50	alal	infect, parasi dis, n amer	anderson,rc; lank	1974
WDABB	3---4	183	184	alal	johne's disease in a moose	soltys,ma; andre/	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AEHLA	25--4	246	252	rata	obser, natural-focal zoono	rausch,rl	1972
AJTHA	22--3	400	403	rata	doca, arboviruses in finla	saikku,p	1973
APAVD	1976.	40	44	rata	systemic mycosis, rein her	kennedy,s; monta/	1976
AVCSA	14--2	292	300	rata	struc reind cornea, kerati	winqvist,g; rehbi	1973
AVCSA	17--1	107	108	rata	isolation of neisseria ovi	kummeneje,k	1976
AVCSA	17--4	488	494	rata	pasteurellosis in reindeer	kummeneje,k	1976
AVCSA	18--1	54	64	rata	keratitis in reindeer, bac	rehbinder,c; glat	1977
AVCSA	18--1	65	74	rata	keratitis in reindeer, myc	rehbinder,c	1977
AVCSA	19--1	129	132	rata	cutan malig lymphome, immu	kummeneje,k; popp	1978
AVSPA	66--1	1	27	rata	clin epizoot studies kerat	rehbinder,c	1977
BJDEA	99--6	647	654	rata	obmo, parapoxvir infection	falk,es	1978
BPURD	1----	498	506	rata	q fever and alaska caribou	hopla,ce	1975
CJMIA	24--2	129	135	rata	brucellosis, inoc experime	rausch,rl; huntle	1978
CJPEA	64--1	82	82	rata	clin lab, epidem brucellos	brazeau,m; kien,/	1973

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CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	36--5	819	835	rata	entodiiniinae, canad arcti	lubinsky,g	1958
CJZOA	36--6	937	959	rata	diplodiniinae, canad arcti	lubinsky,g	1958
CJZOA	48--5	1023	1027	rata	brucellos, reinde, ba gr c	broughton,e; cho/	1970
FPWTA	33---	30	39	rata	dis condit, parasi, bar gr	broughton,e; chou	1969
JAVMA	175-9	996	998	rata	osteomyelitis, arthritis i	haigh,jc; pharr,/	1979
JWIDA	6---3	136	139	rata	rangif brucell, alask cani	neiland,ka	1970
JWIDA	6---4	483	487	rata	isol bunyamwera group arbo	hoff,gl; stalati/	1970
JWIDA	8---2	138	140	rata	cutan fibr papill, bg cari	broughton,e; mil/	1972
JWIDA	11--1	45	53	rata	rangiferine brucell, alask	neiland,ka	1975
JWIDA	11--4	465	470	rata	radiog exam, mandib lesion	miller,fl; cawle/	1975
JWIDA	15--2	309	318	rata	mandibular lesions, alaska	doerr,jg; dieteri	1979
JWIDA	15--3	433	435	rata	arterial disease, alaska	dieterich,ra; lui	1979
JZAMD	10--1	31	34	rata	clostridial myositis	herron,aj; garma/	1979
NOVTA	25--4	196	202	rata	clostrid perfringens enter	kummeneje,k; bakk	1973
NOVTA	26--7	456	458	rata	encephal, neuritis, calves	kummeneje,k	1974
VETRA	105-3	60	61	rata	contagious ecthyma, reinde	kummeneje,k; krog	1979
WDABB	4---4	227	236	rata	brucellos, caribou, alaska	neiland,ka; king/	1968
WDABB	6---4	483	487	rata	isolatio, arbovirus, carib	hoff,gl; spalati/	1970
ZEVMA	25A-1	48	56	rata	keratitis, proced sim sola	offosson,a; rehb/	1978
ZEVMA	25A-2	89	109	rata	keratitis, induced in mice	rehbinder,c; moe/	1978
ZEVMA	25A-2	110	128	rata	keratitis, experim induced	rehbinder,c; glat	1978
ZOGAA	37...	134	142	rata	reticulo sarcoma, reindeer	beyer,j; kronberg	19

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJVRA	33--5	1013	1016	anam	bluetongue virus, pronghor	hoff,gl; trainer,	1972
APAVD	1972-	15	16	anam	frostbite in antelope horn	simmons,lg	1972
CNVJA	16--1	3	9	anam	odvi, necrobacillosis, sas	wobeser,g; runge/	1975
JAVMA	171-9	918	923	anam	capture myopathy in canada	chalmers,ga; barr	1977
JWIDA	8---1	67	71	anam	caseous lymph adenitis, pr	clark,ka; robins/	1972
JWIDA	10--1	60	62	anam	infectious pododermatitis	chalmers,ga; barr	1974
JWIDA	12--3	347	348	anam	rabies in a pronghorn ante	wempe,jm	1976
JWIDA	12--4	488	491	anam	reovirus, neo-nat diarrhea	reed,de; daley,c/	1976
JWIDA	13--3	323	326	anam	anaplasmo reservio, mantan	jacobson,rh; wor/	1977

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CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	30--3	488	496	anam	pronghorn die-off, texas	hailey,tl; thoma/	1966
JWMAA	33--4	1032	1033	anam	clostridium, hand-rear ant	nagy,jg barber,/	1969
TAEPA	3011-	1	15	anam	hard yellow liver dis, rum	dollahite,jw; oh/	1971
TAEPA	3460-	1	57	anam	hard yel liv fatty cirrhos	bailey,em,,jr; u/	1977
TAMSA	63--1	27	29	anam	selenomonas, new, calif an	chattin,je; herm/	1944
XAGCA	154--	1	10	anam	bibi, doca, anaplasmosis	stiles,gw	1939
ZTMPA	24--2	192	197	anam	game anaplasmosis: isolati	lohr,kf; meyer,h	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJVRA	38--8	1183	1185	bibi	demo of bacteriocin activi	chengappa,mm; car	1977
CAFNA	86--2	127	132	bibi	parasites, diseases, canad	choquette,lpe; b/	1972
CNJMA	22--1	9	20	bibi	brucellos, elk isl, albert	corner,ah; connel	1958
CNVJA	2---5	168	174	bibi	tubercul, wood buf nat'l,	choquette,lpe; g/	1961
JAVMA	100--	19	22	bibi	tuberculosis in the buffal	hadwen,s	1942
JAVMA	171-9	913	917	bibi	malignant catarrhal fever	ruth,gr; reed,de/	1977
JOMAA	13--4	371	372	bibi	bang's disease, yellowston	rush,wm	1932
JWIDA	11--3	395	397	bibi	absence, anaplasma infecti	peterson,kj; roby	1975
JWIDA	14--3	329	332	bibi	serol surv brucell, canada	choquette,lpe; b/	1978
NAWTA	28---	233	239	bibi	paras, dis, anthrax, canad	novakowski,ns; c/	1963
WDABB	5---3	206	207	bibi	septicemic pasteurellosis	heddleston,kl; ga	1969
WMBAA	16---	1	52	bibi	biol, mngt, wood buf na pk	fuller,wa	1966

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAVMA	157--	1507	1511	ov	selenium-responsive diseas	muth,oh	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
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CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJVRA	33--1	87	90	ovca	id, char, mycoplasma-argin	al-aubaidi,jm; t/	1972
CJZOA	51--5	479	482	ovca	stress, lympho stim, phyto	hudson,rj	1973
JAVMA	161-6	669	672	ovca	parainflu 3 virus, rocky m	parks,jb; post,g/	1972
JAVMA	173-9	1178	1180	ovca	chronic frontal sinus, ost	paul,sr; bunch.td	1978
JNCIA	59--1	185	198	ovca	neoplasia captive mammals	effron,m; griner/	1977
JOMAA	18--1	105	106	ovca	hemorrag septice, rocky mt	potts,mk	1937
JWIDA	6---3	169	170	ovca	mycoplas, pneumo, rocky mt	woolf,a; kradel,/	1970
JWIDA	9---1	7	11	ovca	electrophor, chron pneumon	woolf,a; nadler,/	1973
JWIDA	9---1	12	17	ovca	mortality, captive bighorn	woolf,a; kradel,d	1973
JWIDA	10--2	107	110	ovca	serol survey, viral infect	parks,jb; england	1974
JWIDA	10--3	228	231	ovca	vaccina trials, bluetongue	robinson,rm; hai/	1974
JWIDA	11--1	26	31	ovca	oram, contag ecthyma, can	samuel,wm; chalm/	1975
JWIDA	15--2	221	227	ovca	johne's disease, colorado	williams,es; spr/	1979
JWIDA	15--4	499	503	ovca	isolation, chlamydial agen	pearson,hj; engla	1979
JWMAA	31--1	165	168	ovca	bluetongue, desert bighorn	robinson,rm; hai/	1967
JWMAA	35--2	270	274	ovca	contagiou ecthyma, rocky m	blood,da	1971
NAWTA	3---3	893	897	ovca	diseases, rocky mt nati pk	potts,mk	1938
WDABB	2---2	34	37	ovca	myxovirus parainfluenza-3	howe,dl; woods,g/	1966
WDABB	3---2	74	76	ovca	virus isola, lung, nemato	forrester,dj; wad	1967
WIDIA	23---	1	14	ovca	pasteurellosis, rocky mt	post,g	1962

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AVCSA	19--3	461	462	obmo	contagious ecthyma (orf) i	kummeneje,k; krog	1978
VTYMA	65-11	1063	1067	obmo	corynebacter infect, domes	beckley,jc; diete	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWIDA	13--2	135	136	oram	contagious ecthyma, britis	herbert,dm; samu/	1977
JWIDA	15--2	221	227	oram	johne's disease, colorado	williams,es; spr/	1979
JWMAA	35--4	752	756	oram	white muscle disease	herbert,dm; cowan	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
APAVD	1977-	136	145	many	avian tuberc, cerv tub tes	kollias,gv,jr	1977
AUVJA	51--4	203	208	many	epizootiology of bluetongu	hourrigan,jl; kli	1975
CNJMA	22--1	9	20	many	brucellos, elk isl, albert	corner,ah; connel	1958
JANSA	32--5	1037	1041	many	atherosclerosis in ruminan	wiggers,kd; jaco/	1971
JIDIA	124-2	217	222		pathogen epiz hemorr disea	debbie,jg; abelse	1971
JIDIA	136-2	312	316	many	brucellosis in usa 1965-74	fox,md· kaufmann,	1977
JMENA	13--3	225	275	many	diseas agents trans, flies	krinsky,wl	1976
JWIDA	13--1	74	79	many	viruses, capt, free, alber	thorsen,j; karst/	1977
JZAMD	7---4	5	7	many	symp on mycobac infec, zoo	montali,rj	1976
NZJSA	10--4	949	963	many	survey of diseases, new ze	daniel,jm	1967
SABOA	13--3	329	333		phoma (peyronellaea), zoop	gordon,ma; salki/	1975
TAMSA	70--2	185	187	many	selenomonas, calif mammals	herman,cm; sayama	1951
VETRA	94-24	559	559	many	brucellosis in wildlife	mcdiarmid,a; matt	1974
VETRA	96-23	503	506	many	manag deer, exp stud, foot	gibbs,epj; mcdia/	1975
VETRA	99-20	398	398	many	isolation rotavirus fr dee	tzipori,s; caple/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBCPA	64A-3	411	418	dosh	nature of erythro sickling	butcher,pd; hawkl	1979
JANSA	17--1	224	236	dosh	doca, white muscle disease	blinko,c; dye,wb	1958
JONUA	99--3	331	337	dosh	selenium def myopathic lam	whanger,po; wesw/	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJTHA	21--1	100	109	wldl	buttonwillow virus, califo	hardy,jl; lyness/	1972
AMFOA	52...	24	26	biga	when animals get sick	rush,wm	1946
CNVJA	19--5	139	139	wldl	brucellosis and wildlife	hudson,m	1978
DABBB	33B-7	3378	3379	wiru	epizootiological study, vi	hoff,gl	1973
JNCIA	59--1	185	198	mamm	nature, rate of neoplasia	effron,m; griner/	1977

continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOHYA	81--2	189	196		windbrne bluetng, portugal	sellers,rf; pedg/	1978
JWIDA	13---	74	79	wiru	viruses from captive, free	thorsen,j; karst/	1977
JWIDA	14--3	351	354	rumi	rotavirus infect, neonatal	eugster,ak; stro/	1978
NAWTA	12---	520	523	biga	the hoof and mouth disease	broughton,ib	1947
WIDIA	42---	1	6	ungu	epizo hemorrhag dis, alber	chalmers,ga; van/	1964

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAVMA	165-8	735	735	axax	mycobacterium bovis infect	sawa,tr; thoen,c/	1974
JAVMA	165--	998	999	axax	mycobac bovis infec, hawai	sawa.tr; thoen,c/	1974
JAVMA	174-8	841	843	axax	doca, dada, paratuberculos	riemann,h; zaman/	1979
RVETA	29--3	126	130	axax	polyarterit nodosa-like le	neumann,f; nobel/	1972
VETRA	98-26	525	526	axax	tuberculosis, whipsnade pa	jones,dm; manton/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AVCSA	7---4	330	363	caca	dis resemb paratuberculosi	hillermark,k	1966
JCVPA	84--2	215	220	caca	ceel, dada, foot-and-mouth	forman,aj; gibbs,	1974
NOVTA	28-11	539	546	caca	mycobacteriosis, caus pige	joergensen,jb; cl	1976
VETRA	98--6	116	116	caca	isolatio louping-ill virus	reid,hw; barlow,/	1976
VETRA	104--	214	215	caca	adenoma in british roe dee	craig,wa	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJVRA	36--6	749	752	ceni	in vivo erythrocy sickling	parshall,cj,jr; /	1975
AJVRA	36--6	753	756	ceni	ophthalmic manif, induc si	vainisi,sj; pars/	1975
JCVPA	85--3	361	366	ceni	stud, foot-and-mouth disea	gibbs,epj; herni/	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAVMA	173-9	1243	1243	dada	malig hyperthermia, etorpi	pertz,c; sundberg	1978
JWIDA	15--2	299	301	dada	adrenal cortical adenoma	schmidt,re; flet/	1979
VETRA	98--4	74	74	dada	case of bovine tuberculosi	wilson,p; harring	1976
VETRA	104--	450	453	dada	4 cases of chondrodystroph	baker,jr; ashton/	1979
VETRA	105--	573	574	dada	yersiniosis in free-living	chapman,di; chap/	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEWO----------------------	AUTHORS----------	YEAR
PZSLA	136-3	477	483	elda	malig catarrh,pere david d	tong,eh; senior,/	1961

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	12-30	445	452	bibo	foot-and-mouth dis, poland	podgurniak,z	1967
RVTSA	26--2	165	171	bibo	isol mal catarrhal fever v	straver,pj; bekk/	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ASISA	29---	535	535	ruru	coronary arterioscl, free-	guarda,f; cornagl	1976

UNIT 1.3: ABNORMALITIES

Abnormalities occur in wild species, but the frequencies of abnormal characteristics are not known. The basic principle that must operate is that abnormal individuals are less likely to live and reproduce than normal ones. This statement is based on the assumption that abnormalities are detrimental.

Some abnormalities are physical and easily recognized, such as abnormal antlers and dental anomalies. Some are physical but internal; fetal abnormalities are an example. Some are metabolic; a whitetail fawn at Cornell's Wildlife Ecology Laboratory had a severe calcium metabolism problem, mobilizing from the bones and excreting calcium with a concomittant loss of bone structure. The fawn died in a few days. Such a case would never survive in the wild, of course.

The number of references on abnormalities is small. Some of the cases described are curious instances, while others have physiological or genetic implications. The vast majority of abnormalities in wild ruminants go unnoticed.

REFERENCES, UNIT 1.3

ABNORMALITIES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PCGFA	13...	174	177	od--	poisonous plants, s e dise	hayes,fa; jenkins	1959

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
COVEA	45--4	538	547	odvi	degenerative myopathy	hadlow,wj	1955
JCVPA	82--2	219	221	odvi	intraocular lacrimal gland	wyand,ds; lehav,/	1972
JCVPA	87--4	557	568	odvi	anophthalmia, microphthalm	fulton,ab; alber/	1977
JOMAA	48--4	674	676	odvi	genital hypoplasia, w-t de	marburger,rg; ro/	1967
JWIDA	7---1	1	2	odvi	ventral hernia in a w-t de	wobeser,g; maclen	1971
JWIDA	8---4	311	314	odvi	antler malform, leg injury	marburger,rg; ro/	1972
JWIDA	8---4	320	320	odvi	scrotal hernia in a w-t de	schlegel,mw; lee/	1972
JWIDA	9---4	356	358	odvi	multiple anomalies, fetus	wobeser,g; runge,	1973
JWIDA	11--2	237	240	odvi	male pseudoherma, antl doe	scanlon,pf; urbs/	1975
JWIDA	11--4	497	501	odvi	congenital anomalies, neon	barrett,mw; chalm	1975
JWIDA	12--2	143	147	odvi	6 repor visual defec, mich	howard,dr; krehb/	1976
NFGJA	19--1	32	46	odvi	mandibul, dental anomalies	free,sl; bergstr/	1972

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BAPBA	22--1	67	72	ceel	induc antler grow, pedicle	jaczewski,z; krzy	1974
JEZOA	195-2	247	250	ceel	induc antler growt, polled	lincoln,ga; fletc	1976
JWIDA	8---4	319	319	ceel	injurious antler anomaly i	schlegel,mw; lee/	1972
JWIDA	15--2	303	306	ceel	embryonal nephroma, wapiti	snyder,sp; davie/	1979

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	91--1	94	95	alal	trauma induc paralys, calf	chalmers,ga; barr	1977
JWIDA	11--2	116	121	alal	odvi, arthropathy	wobeser,g; runge,	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJVRA	25---	1783	1785	rata	immunity study, reind herd	bolton,wd; murray	1964
JRPFA	57--1	127	130	rata	abnormal testes in reindee	leader-williams,n	1979
JWIDA	7---4	307	309	rata	polydactylism. nw manitoba	miller,fl; brough	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAVMA	171-9	918	923	anam	capture, myopathy, alberta	chalmers,ga; bare	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAVMA	171-9	988	989	bibi	atresia ani,recto vag fist	marler,rj; leipo/	1977

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

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

IVEJA 56--2 153 153 wiru trichobezobe, phytotrichob acharjyo,ln; naya 1979

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

JZOOA 180-4 518 523 dada mandib, maxill dental abno jackson,je 1976

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

JZAMD 6---2 28 28 axax ventricular septal defect gendron,ap 1975

TOPIC 2. NATURAL AND INTRODUCED TOXINS

Toxins are poisonous substances. Many toxins are produced by microorganisms, and many by plants and animals. There are natural toxins, a part of the natural world, and problem-causing only when local concentrations are great enough to upset the physiology and metaoblism of an individual.

Introduced toxins may be for specific target organisms, or they may be compounds introduced into the environment that have side effects. Examples of the former are herbicides and pesticides and of the latter, inorganic fertilizers that may reach unexpected concentrations in water.

Brief comments and fairly short lists of references are included in UNITS 2.1 and 2.2.

REFERENCES, TOPIC 2

NATURAL AND INTRODUCED TOXINS

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
edbo	tcpc	rege	380	anim	(p. 131-151) magnesium, en	jones,jb,jr;bloun	1972
edbo	tcpc	rege	380	anim	(p. 153-175) magnesium, en	jones,jb,jr;bloun	1972
edbo	acpr	nyny	270	many	fate of pestic in lg anims	ivie,gw; dorough,	1977

UNIT 2.1: NATURAL TOXINS

The definition of a natural toxin is based not on the presence of an element or compound in the diet of an animal, but on the quantity of the element or compound in the diet. Thus even minerals required in the diet, for example, may become toxic and cause metabolic disorders when present in too large quantities. Selenium is such a mineral. Several different naturallymoccurring elements and compounds are described as poisonous substances in PART II, TOXICOLOGY in the Merck Veterinary Manual (1967).

Natural toxins usually do not become a problem for wild ruminants unless range conditions are poor and the animals are in stressful conditions. As in the case of parasites and diseases, prevention of a problem is better than having to cure it. Good management practices which result in productive animals on a productive range will eliminate any potential harmful effects of natural toxins almost entirely. If animals are forced to consume potentially toxic plants on overused range, the danger of plant poisoning increases. Over 50 different plants found in the United State are listed in the Merck Veterinary Manual as poisonous. The list includes such common plants as Quercus (oaks) and Prunus (cherries). It may be that wild ruminants have a higher tolerance to the effects of such species than domestic ones, or it may be simply a matter of conditioning and adaptation.

The reference lists include a number of papers that may be of interest, as well as some that are on both the poisonous plant list and the nutrition lists in CHAPTER 11.

LITERATURE CITED

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

REFERENCES, UNIT 2.1

NATURAL TOXINS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AZATA	75---	1	39	od--	experimental feeding of de	nichol,aa	1938

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	12--2	323	333	odvi	mt laurel, rhododen, foods	forbes,eb; bechde	1931
WDABB	3---2	42	46	odvi	fluorosis in deer	karstad,l	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
FLUOA	8---4	182	191	odhe	odvi, industrial fluorosis	kay,ce; tourange/	1975
JANSA	41--1	412	412	odhe	eff high molybdenum intake	nagy,jg; chappel/	1975
JWIDA	12--1	39	41	odhe	fluorosis in black-ta deer	newman,jr; yu,m	1976
PYTCA	17--4	803	803	odhe	prunasin, amelanchier alni	majak,w; bose,rj/	1978

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

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	36--1	146	146	anam	chokecherry toxic to antel	ogilvie,sl	1955

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAVMA	157--	1507	1511	ov	selenium-responsive diseas	muth,oh	1970

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JONUA	99--3	331	337	dosh	selenium def myopathic lam	whanger,po; wesw/	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRMGA	28--4	252	256	anim	areas molybden tox, grazin	kubota,j	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	52-5	935	939	anim/model,	absorp, ret ing ele	goldstein.ra; elw	1971
JRMGA	29--5	356	363	rumi	majr plant toxic, west u s	james,lf; johnson	1976
JRMGA	30--3	237	238	rumi	toxicity, larkspur extract	olsen,jd	1977

UNIT 2.2: INTRODUCED TOXINS

Pesticides, herbicides, air pollutants, solid wastes, radioactive fallout... all represent toxins introduced by the activities of man that may affect the physiology and metabolism of wild ruminants. The toxicity to animals is often a secondary effect that, at least a few years ago, was given little thought. Now, after seeing some of the effects on a variety of wild species, more care is given to the handling of introduced compounds that are potentially toxic. Short-term financial advantages may still be gained by rapid dumping of waste products, but these can never be justified if the long-term functions of the ecosystem are disrupted.

The effects of introduced toxins must not be measured only in terms of dead animals, but also in relation to the health of the entire ecosystem. The health of the ecosystem can hardly be known or understood if the normal physiological functions of its components are not known and understood. Thus the need for courses in physiology in wildlife curricula is clear to those of us who think about the functions of individuals and populations rather than of populations alone. Population responses to introduced toxins will ultimately be understood only by having a knowledge of the physiology and metabolism of the productive members of the population.

REFERENCES, UNIT 2.2

INTRODUCED TOXINS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NATUA	182--	1294	1294	cerv	fall-out radioact, antlers	hawthorn,j: duckw	1958

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
HLTPA	34--6	691	696	od--	iodin-129 in man, cow, dee	ballad,rv; tan,s/	1978
HLTPA	36--4	516	519	od--	pluton conc, nucl plnt dee	kirkham,mb; adri/	1979
JWMAA	17---	33	36	od--	ammate in the diet of deer	haugen,ao	1953
PAAZA	21--6	16	17	od--	DDT in man, anim, soil ari	roan,cc; laubsch/	1969
PCGFA	5....	1	7	od--	ammate in the diet of deer	haugen,ao	1951

CODEN	VO-NU	BEPA	ENPA	ANIM	OEY WORDS-----------------	AUTHORS----------	YEAR
BMSCB	1----	39	56	odvi	ecol, physiol eff insectic	morris,je	1972
FLUOA	8....	182	919	odvi	odhe, industr fluorosis in	day,ce; touragne/	1975
HLTPA	25--5	515	516	odvi	rapid field-mon cesium-137	rabon,ew; johnson	1973
JWMAA	28--1	45	49	odvi	sampl antler for stront-90	schultz,v	1964
JWMAA	29--1	33	38	odvi	stron-90 lev in antle, man	schultz,v	1965
JWMAA	29--1	39	43	odvi	sex, age, stront-90 accumu	schultz,v; flyge,	1965
JWMAA	34--4	887	903	odvi	repro, grow, tis res diel	murphy,da; korsch	1970
MISTB	6----	166	166	odvi	ecol, physiol eff insectic	morris,je	1972
PSEBA	129-3	733	737	odvi	calcium, stront, age, antl	cowan,rl; hartso/	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BECTA	8---1	1	9	odhe	pesticide levels in deer	benson,ww; smith,	1972
BECTA	13--3	316	323	odhe	metabo, oral dose DDT, DDE	watson,m; pharao/	1975
FLUOA	8....	182	191	odhe	odvi, industr fluorosis in	kay,ce; touragne/	1975
HLTPA	11---	1407	1414	odhe	accum fallout cs 137, colo	whicker,fw; farr/	1965
HLTPA	21--6	864	866	odhe	tissue distri radio cesium	hakonson,te; whic	1971
JANSA	31-1	235	235	odhe	infl pesticides rum bacter	barber,ta; schwa/	1970
JWMAA	32--3	621	623	odhe	accumu stront-90, yearling	longhurst,wm; sc/	1978
NATUA	214--	511	513	odhe	radionuclides, liver, colo	whicker,fw; walt/	1967
NAWTA	36---	153	162	odhe	eff pesti on rumen bacteri	barber,ta; nagy,j	1971

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AUMGA	65--5	284	287	rata	lichen, cari, high radiati	pruitt,wo	1963
BPURD	1---	64	70	rata	radiocesiu cycl, reind/car	holleman,df; luic	1975
CATRB	4---1	1	12	rata	osteocytic osteolysis	belanger,lf	1969
CJZOA	54--6	857	862	rata	tritium wat dilut wat flux	cameron,rd; whit/	1976
ESTHA	1--11	932	939	rata	radioacti, 137 CS, alaskan	blanchard,rl; kea	1967
HLTPA	18--2	127	134	rata	lead-210, polonium-210,ala	blanchard,rl; moo	1970
HLTPA	20--4	393	402	rata	stront-90, annu vari, swed	persson,br	1971
HLTPA	20--6	585	591	rata	cesium-137, seas pat, alas	hanson,wc	1971
HLTPA	21--5	657	666	rata	radiocesium, lichen, alask	holleman,df; lui/	1971
HLTPA	29--1	27	41	rata	radioactiv in lichns, swed	mattsson,ljs	1975
JEENA	69...	260	262	rata	famphur, oxy analog, resid	ivey,mc; palmer,/	1976
RHDRA	11...	487	509	rata	radioactiv, sweden, nuc	magi,a; snihs,jo/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BECTA	3---5	269	273	anam	insecti residues, s dakota	moore,gl; greich/	1970
CJZOA	50--2	213	216	anam	accumul stront-90, females	mitchell,gj; hon/	1972

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BECTA	19--1	23	31	ovca	chlor hydroc residu in fat	turner,jc	1978
BECTA	21...	116	124	ovca	trnsplac mvmt pestic resid	turner,jc	1979

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CNJNA	45--3	197	202	doca	selenium, hair, malnutriti	hidiroglou,m; ca/	1965

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
WIDIA	37---	1	11	ceni	sika deer, potassium defic	christian,jj	1964

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	52--5	935	939	anim	model, absorp, ret ing ele	goldstein,ra; elw	1971
FLUOA	9....	73	90	ungu	pop var of fluor param, wi	kay,e; tourangea/	1976
HLTPA	29--1	43	51		fall-out pluton, swed lich	holm,e; persson,r	1975

TOPIC 3. DRUG EFECTS, SEROLOGY, AND PHYSICAL RESTRAINING DEVICES

This TOPIC 3 contains referrences to three areas of activity that are related to studies of both healthy and diseased animals. Drugs are used to immobilize and tranquilize, serology is important in diagnosis and in the treatment of disorders, and physical restraining devices are used when working with animals. The reference lists will be useful to someone considering different techniques, providing efficient access to the published literature.

UNIT 3.1: DRUG EFFECTS

Drugs are used for two main purposes when working with wild ruminants: immobilization and tranquilizing. An immobilizing agent does just that and nothing more; drugs that immobilize make it impossible for an animal to move, but the animal is fully conscious and presumably receiving environmental stimuli without being able to exhibit a behavioral response. A tranquilizer reduces the level of awareness of an animal. A tranquilized animal may still be mobile, but not as excitable. Heavy doses of a tranquilizer will also immobilize an animal.

Wild animals, being alert, excitable, elusive, and very hard to handle are prime candidates for immobilizing and tranquilizing drugs during research work. The effects of drugs on the physiology and metabolism are generally not well-known. The importance of several metabolic rhythms in relation to dosage levels is being understood (see CHAPTER 7).

The number of references that follow indicate a fairly large amount of activity in this area, all confined to the last 20 years.

REFERENCES, UNIT 3.1

DRUG EFFECTS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	31--4	686	692	cerv	diazepam, capture handlin	thomas,jw; robin/	1967
NOVTA	22---	385	400	cerv	capt, immob with neurolept	eriksen,e	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CNJMA	26--3	57	61	od--	tranquiliz, immobilization	cowan,i mct; woo/	1962
JAVMA	147--	1099	1101	od--	chlor hydra-halo-nitr-oxi	wolff,wa; davis,	1965
JWMAA	41--2	313	315	od--	transm syr to recov imm de	lovett,jw; hill,e	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
APAVD	1976-	185	194	odvi	succinylcholine in deer	kitchen.h	1976
CJZOA	57--4	756	767	odvi	infl chem imm blood charac	wesson,ja; scanl/	1979
CJZOA	57--4	768	776	odvi	infl chem imm ster hor lev	wesson,ja, scanl/	1979
COVEA	40---	275	282	odvi	anesthetization white-t de	severinghaus,cw	1950
CPSCA	3....	236	243	odvi	trauma, secondary shock in	flyger,vf; ridge/	1962
JAVMA	157-5	636	640	odvi	immob cap, free, etor hy c	woolf,a	1970
JAVMA	167-7	574	576	odvi	xylazine immob agent, capt	roughton,rd	1975
JWIDA	9---4	336	341	odvi	seda immobil etorph & xyla	presnell,kr; pre/	1973
JWIDA	9---4	342	348	odvi	combin etorphine, xylazine	presidente,pja; /	1973
JWIDA	15--4	537	541	odvi	blow-gun syring, captiv de	warren,rj; schau/	1979
JWMAA	17--4	516	520	odvi	flaxedil, paralysis, w-t d	hall,tc; taft,eb/	1953
JWMAA	21--2	213	220	odvi	nicotine salicylate, captu	crockford,ja; ha/	1957
JWMAA	28--1	173	175	odvi	mort, thor area, cap-chur	thomas,jw; marbur	1964
JWMAA	29--4	889	890	odvi	nicotine, field immobiliza	behrend,df	1965
JWMAA	31--4	844	845	odvi	device for immob trapped d	white,cm	1967
JWMAA	34--1	207	209	odvi	succin chlor, hyaluronidas	allen,tj	1970
JWMAA	36--4	1034	1040	odvi	effe immobil on blood anal	seal,us; ozoga,j/	1972
JWMAA	40--3	447	453	odvi	seas var, succ chol immobi	jacobsen,nk; arm/	1976

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JZAMD	5---2	18	18	odvi	ceel, m99, recov w/ m50-50	woolf,a	1974
PCGFA	28---	500	506	odvi	succinylcho, react, physi	wesson,ja,III; s/	1974
WLSBA	5---4	193	194	odvi	aggress toward immobi deer	scanlon,pf; mira/	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAVMA	155-7	1080	1084	odhe	new tech, restr antlerless	sauer,bw; gorman/	1969
JAVMA	171-9	987	987	odhe	odvi, ketamine xylazine im	richter,ag	1977
JWIDA	14--4	519	522	odhe	methoxyfluran anesth, fawn	trindle,bd; lewis	1978
JWMAA	25--2	202	203	odhe	anesthetizin deer by arrow	anderson,cf	1961
JWMAA	26--3	332	333	odhe	succinylcho chloride, colo	foyd,rj	1962
JWMAA	27--2	297	299	odhe	effects of succinyl chlori	pearson,ha; smit/	1963
JWMAA	32--1	195	197	odhe	succinyl chlor, immobiliza	miller,fl	1968
JWMAA	33--4	1037	1038	odhe	new dev for inject powdere	liscinsky,sa; ho/	1969
JWMAA	37--1	82	86	odhe	immob, phencyc hydro chlor	dean,r; hines,ww/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
IABLA	6....	45	50	ceel	immob of marals by ditilin	ushakov,kp; shol/	1971
JAVMA	169-9	888	889	ceel	yg eff, etor hydroc in dam	farnsworth,rj; st	1976
JWIDA	13--3	258	261	ceel	immob, etorphine hydchlori	magonigle,ra; st/	1977
JWMAA	23--3	365	366	ceel	curare, curare-like drugs	post,g	1959
JWMAA	26--3	334	336	ceel	succinylcholine chloride	flook,dr; robert/	1962
JWMAA	29--2	339	345	ceel	roosevelt elk, succin chlo	harper,ja	1965
JWMAA	39--4	814	816	ceel	m99, immobili rocky mt elk	coggins,vl	1975
VETRA	93--3	86	87	ceel	caca, ceni, immobilon,deer	low,rj	1973
VETRA	93--4	113	114	ceel	caca, dada, immobilon,deer	chapman,d	1973
VETRA	93--4	114	115	ceel	immobilon in deer, scotlnd	sharman,gam	1973
VETRA	94--5	85	86	ceel	hypersen isol pop to xylaz	fletcher,j	1974
VETRA	99-21	424	424	ceel	anaesthesia in red deer	whitelaw,a; fawce	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAVMA	175-9	916	917	alal	hyaluronidase in immob mix	haigh,jc	1979
JOMAA	51--2	396	399	alal	M99 etorphine, immobilizat	houston,db	1970
JWMAA	25--3	326	328	alal	narcosis, moose, nicotine	rausch,ra; ritcey	1961
JWMAA	33--3	534	537	alal	shiras moose, immobilizatn	houston,db	1969
JWMAA	39--3	634	636	alal	physiologic effect, m-99 e	roussel,ye; pate/	1975
JWMAA	42--3	686	690	alal	etorp & xylaz hydroc, immo	gasaway,wc, fran/	1978
JZAMD	5---2	26	31	alal	immobiliz of alaskan moose	franzmann,aw; arn	1974
JZAMD	8---3	22	29	alal	fentanyl & xylazine, captu	haigh,jc, stewar/	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	28--1	49	53	rata	newfoundl, succinyl, moose	bergerud,at; but/	1964

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	31--4	840	842	anam	succin chlor, immobilizati	beale,dm; smith,a	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PIAIA	83--2	67	70	bibi	immob adult bull, etorphin	haugen,ao; swens/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	40--1	174	176	ovca	succ chlor, phencyc hydroc	stelfox,jg; rober	1976

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	39--1	112	117	obmo	immob, marking, arct canad	jonkel,cj; gray,/	1975
ZOGAA	40...	138	142	obmo	sedation of a bull muskox	jones,dm	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
APAVD	1975-	40	42	many	xylazine, exotic anim prac	hertzog,re	1975
VTYMA	69--5	548	551	many	injectab anesth, wld rumin	boever,wj; paluch	1974
ZOGAA	35...	149	155	anim	eff tranq, anesth, wild an	nouvel,j; rinjar/	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
APAVD	1975-	16	39	ungu	clin use rompun, toron zoo	rapley,wa; mehren	1975
ZOOAA	1---1	231	238	ungu	use of (ROCHE), tranquiliz	hirst,sm; kett	1965
ZOOAA	1....	239	247	ungu	experim immobili ungulates	bigalke,rc	1965
ZOGAA	33...	182	185	ungu	immobil ungula catsk ga fa	heck,h; douigh,f	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAVMA	130--	479	482	dogo	nicotine, immobiliz, goats	hayes,fa; jenkin/	1957
JWMAA	27--2	292	296		new tech using cap-chur gu	green,h	1963
JWMAA	33--4	1037	1038		device, inject powdered dr	liscinsky,sa; ho/	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BVJOA	131..	545	548	dada	diazepam, sedat & restrain	done,sh; lees,p;/	1975
JZAMD	4---2	21	21	dada	restrain 2 dee w/ xylazine	klide,am; klein,l	1973
VETRA	93--1	26	27	dada	immobilon in fallow deer	jones,dm; manton,	1973
VETRA	93-16	454	455	dada	immobilisation, fallow dee	low,rj	1973
VETRA	93-16	455	455	dada	immobilisation fallow dee	lees,p; done,sh	1973
VETRA	94-16	362	363	dada	immobilon-rompun fallow de	harrington,r; wil	1974
VETRA	94-17	396	398	dada	powd succ chlo in dart, im	scanlon,pf	1973
VETRA	100--	386	387	dada	fentanyl & neuroleptic, im	haigh,jc	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
VETRA	95--3	71	71	axax	tranquilising deer	sutherland,c; hod	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAVMA	169-9	890	893	elda	immobiliz pere davids deer	smeller,j; bush,/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	12-32	467	470	bibo	narcos, chlor hydra, eth a	piwowarczyk,s	1967
ATRLA	12-32	471	472	bibo	use of palmer gun, immobil	starzynski,w	1967
ATRLA	12-32	473	475	bibo	eu bis hybrid, suxamethoni	zaniewski,l	1967
ZOPOA	25--2	85	98	bibo	etorphine hydrochlo, immob	kania,bf; teuchma	1975

UNIT 3.2: SEROLOGY

Serology is the science dealing with the properties and use of serum, or body fluids. Blood serum is the fluid considered most; it is important for its agents of agents of immunity and its role as an antitoxin. References to serology follow, providing access to the published literature on the wild ruminants.

REFERENCES, UNIT 3.2

SEROLOGY

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AGVIA	37--2	282	284	od--	antigenic rel, epiz, bluet	moore,dl; lee,vh	1972
AJVRA	35-12	1529	1531	od--	appendage-related antigen	carson,ca; weisi/	1974
AJVRA	36--9	1367	1370	od--	leptospiral antibodies in	harrington,r,jr	1975
AUVJA	51--4	185	189	od--	doca, dosh, serolog method	boulanger,p; fran	1975
JAVMA	132-7	289	292	od--	infect, antibody, anaplasm	christensen,jf; /	1958
JAVMA	132-7	293	296	od--	serol surv, leptospi, mass	reynolds,im; smit	1958
JAVMA	167-7	565	568	od--	surv, toxoplas-gondii anti	franti,ce; conno/	1975
JAVMA	175-9	911	913	od--	serologic profile of exoti	riemann,hp; rupp/	1979
JWIDA	6---4	479	482	od--	sero ev, arbovir, wis, tex	issel,cj; hoff,g/	1970
JWMAA	30--4	777	780	od--	serol stud, epiz hemorra d	wilhelm,ar; train	1966
PCGFA	13...	174	177	od--	poisonous plants, s e dise	hayes,fa; jenkins	1959
PIAIA	74---	78	86	od--	incid, dis antibodie, iowa	haugen,ao	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJTHA	21--6	979	988	odvi	experimental studies with	issel,cj; traine/	1972
AJTHA	23--2	242	245	odvi	maternal antibod, jamestow	issel,cj	1974
AJVRA	31--5	879	883	odvi	serodiognosis, theileriasi	gadir,fa; hidalg/	1970
AJVRA	33-12	2545	2549	odvi	elect dist, serol ch, arth	sikes,d; kistner/	1972
CNVJA	3---3	71	78	odvi	cul, ser evi, lepto, ontar	abdulla,pk; kars/	1961

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWIDA	9---3	245	248	odvi	infection in texas, califo	issel,cj; hoff,g/	1973
JWIDA	9---4	291	295	odvi	odhe, arbovir serol, n dak	hoff,gl; issel,c/	1973
JWIDA	11--2	195	200	odvi	serol.venez eq enceph, tex	smart,dl· traine/	1975
JWIDA	12--3	322	325	odvi	antibo toxoplasm gond, ont	tizard,ir; bille/	1976
JWIDA	13--1	9	16	odvi	transm 2 strains epizootic	foster.nm; breck/	1977
WDABB	3---4	152	155	odvi	chlamydia antibody study	debbie,jg	1967
WDABB	5---4	392	397	odvi	serolo surv, arbovirus, ny	whitney,e; roz,a/	1969
WDABB	6---4	295	298	odvi	leptospiral antibodies, us	shotts,eb,jr; hay	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWIDA	12--3	427	434	odhe	card agglut test, anaplasm	howarth,ja; hoka/	1976
JWIDA	13--4	429	431	odhe	ceel, anam, survey, titers	adrian.wj; keiss,	1977
JWIDA	14--2	193	202	odhe	hemaglut test, epidem, lep	cirone,sm; riema/	1978
JWIDA	14--4	523	527	odhe	stress, immune system	trindle,bd; lewi/	1978
JWIDA	15--1	25	31	odhe	tech eval immunity	brindle,bd; lewis	1979
JWIDA	15--3	443	446	odhe	serol sympatric sheep, mul	hampy,b; pence,d/	1979
JWMAA	41--3	515	519	odhe	preval reactor, lives path	stauber,eh; nell/	1977
WDABB	4---3	78	80	odhe	serol surv, arbovir, calif	emmons,rw	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
COVEA	69--4	402	410	ceel	eval anaplas rapid card ag	magonigle,ra; ec/	1979
FPARA	23--1	25	31	ceel	caca, leptospiral an, wild	sebek,z; kaasere/	1976
JOMAA	17--3	250	253	ceel	oservat on yellowstone elk	mills,hb	1936
JWIDA	14--1	74	81	ceel	brucell, serol, bacti, wyo	thorne,et; morto/	1978
JWIDA	14--4	471	478	ceel	odhe, serologi study, utah	merrell,cl; wrigh	1978
JWIDA	15--3	379	386	ceel	eval anaplams card agglut	renshaw,hw; mago/	1979
NATUA	241--	476	477	ceel	antibody to babesia, red d	latif,bma; adam,k	1973
RVTSA	23--2	133	138	ceel	occur antib to babesia, lo	adam,kmg; beasle/	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJTHA	22--5	654	661	alal	rata, arbovi, serol,finlnd	brummer-korvenkon	1973
JWIDA	7---2	93	95	alal	surv, antibod, bovin virus	thorsen,j; hender	1971
JWIDA	7---2	118	119	alal	evid, arbovir activ, alber	trainer,dd· hoff,	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJTHA	22--3	400	403	rata	doca, arboviruses in finla	saikku,p	1973
AVCSA	17--3	363	369	rata	doca, occur antib, chlamdi	neuvonen,e	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOPAA	56--4	759	767	anam	dosh, immun, haemonch isol	allen,rw; samson/	1970
JWIDA	11--2	157	163	anam	serol surv, albert, saskat	barrett.mw; chalm	1975
JWIDA	16--1	109	109	anam	seroepidem survey, idaho	stauber,eh; aute/	1980
TMPRA	25--2	217	226	anam	doca, detect fluor agg ant	lohr,kf; ross,jp/	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWIDA	9---4	306	310	bibi	vaccination against pasteu	heddleston,kl; we	1973
JWIDA	14--3	329	332	bibi	serol surv brucell, canada	choquette,lpe; b/	1978
JWIDA	14--4	493	500	bibi	serol, hemato values, colo	keith,eo; ellis,/	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CEXIA	8---2	345	354	ovca	in vitro detect, homocytot	hudson,rj; bandy/	1971
CJCMA	36--1	69	73	ovca	cell adherence react, lung	hudson,rj; bandy/	1972
DABBB	33B-8	3819	3820	ovca	devel pasteurella bacterin	nash,p	1973
JWIDA	6---2	105	106	ovca	electrophoresis, monitorin	hudson,r; kitts,/	1970
JWIDA	7---3	171	174	ovca	immuno globulin ressponse	hudson,r; kitts,/	1971
JWIDA	9---1	7	11	ovca	electrophor, chron pneumon	woolf,a; nadler,/	1973
JWIDA	9---1	12	17	ovca	mort, clin, hema, path obs	woolf,a; kradel,d	1973
JWIDA	10--2	107	110	ovca	serol survey, viral infect	parks,jb; england	1974

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
JWMAA	35--4	752	756	oram	white muscle dis, br colum	herbert,dm; cowan	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJEPA	90--4	354	358	many	serol evid arbovi, wild ru	trainer,do; hanso	1969
AJVRA	30-11	2007	2011	many	ser evi,blue tongue,n amer	trainer,dd; jochi	1969
JANSA	17--1	224	236	doan	ser trans, white muscl dis	blinko,c; dye,wb	1958
JWIDA	12--3	322	325	mamm	prev toxoplas antibod, ont	tizard,ir; bille/	1976
JWIDA	12--3	326	334	many	prev, dist, 4 serotyp smsv	smith,aw; akers,/	1976
JWIDA	13--4	429	431	many	brucello, leptospiro, colo	adrian,wj; keiss,	1977
TMPRA	29--2	223	233	ungu	preva trypanosome carriers	drager,n; mehlitz	1978
VETRA	92--5	119	119	mamm	antib to leptospira grippo	twigg,gi; hughes/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWIDA	15--2	339	341	dada	antigen, herpes virus, alb	kinyili,jh; thors	1979

UNIT 3.3: PHYSICAL RESTRAINING DEVICES

Any device used to restrain a wild ruminant has a potential effect on its physiology and metabolism. Restraint devices are necessary for some kinds of studies. A few references with descriptions of restraining devices, cages, etc. are listed. The philosophy of handling of wild ruminants in captivity is very important. I personally believe that they should be treated as naturally and with as little restraint as possible, and not as domestic cattle or sheep that are penned, tied, and herded around at will.

REFERENCES, UNIT 3.3

PHYSICAL RESTRAINING DEVICES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	57--4	756	767	odvi	blood char, inf phys res &	wesson,ja,III; s/	1979
CJZOA	57--4	768	776	odvi	ster hor lev, inf phy re &	wesson,ja,III: s/	1979
JWMAA	31--2	359	361	odvi	rope truss for restraining	thomas,jw; robin/	1967
JWMAA	38--4	845	847	odvi	restr appar, blood samplin	mautz,ww; daviso/	1974

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

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	42--4	904	908	rata	ef han, restr, blood param	karns,pd; crichto	1978

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	12-32	477	479	bibi	immobilizing cage for biso	krasinska,m	1967

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			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
WLMOA	14---	1	78	many	pharm, physio princ, restr	hartoorn,am	1965

CLOSING COMMENTS

CHAPTER 10 includes a large number of references to literature that has not yet been synthesized into ecological considerations. The factors affecting physiology and metabolism must in turn affect productivity, and productivity, in turn, affects population dynamics. The discussions in CHAPTERS 18 and 19 will relate to the literature listed here in CHAPTER 10, especially for mortality data.

Special thanks are due Dr. Susan Wade, College of Veterinary Medicine at Cornell, for sorting the long lists of references into the units in this chapter. We hope that the readily available lists for each wild ruminant species will be of value to those reviewing this literature.

Aaron N. Moen
March 20,1981

GLOSSARY OF CODENS - CHAPTER TEN

CODEN

ACVTB Acta Veterinaria Brno
AEHLA Archives of Environmental Health
AESAA Annals of the Entomological Society of America
AGBOB Agroborealis
AGVIA Archiv fur die Gestamte Virusforschung
AJEPA American Journal of Epidemiology
AJHEA American Journal of Public Health
AJPAA American Journal of Pathology
AJTHA American Journal of Tropical Medicine and Hygiene
AJVRA American Journal of Veterinary Research
AMFOA American Forests
AMNAA American Midland Naturalist
ANYAA Annals of the New York Academy of Sciences
APAVD American Association Zoo Veterinarian Annual Proceedings
APMIA Acta Pathologica et Microbiologica Scandinavica
APRPA Acta Parasitologica Polonica
ASISA Atti della Societa Italiana delle Scienze Veterinarie
ASMAC Abstracts of the Annual Meeting of the American Society for Microbiology
ATMPA Annals of Tropical Medicine and Parasitology
ATRLA Acta Theriologica (Poland)
AUMGA Audubon Magazina
AUVJA Australian Veterinary Journal
AVCSA Acta Veterinaria Scandinavica (Denmark)
AVSPA Acta Veteinaria Scandinavica Supplementum (Denmark)
AZATA Arizona Agricultural Experiment Station Technical Bulletin

BAPBA Bulletin de l'Academie Polonaise des Sciences Serie de Sciences Biologiques
BECTA Bulletin of Environmental Contamination and Toxicology
BEREA Bulletin of Entomological Research
BJDEA British Journal of Dermatology
BMSCB Bulletin of the Missouri Academy of Science Supplement
BPURD Biological Papers of the University of Alaska Special Report
BSKBA Bulletin of the University of Osaka Prefecture Series B Agriculture and Biology
BVJOA British Veterinary Journal

CAENA Canadian Entomologist
CAFGA California Fish and Game
CAFNA Canadian Field Naturalist
CATRB Calcified Tissue Research
CBCPA Comparative Biochemistry and Physiology
CELLB Cell
CEXIA Clinical and Experimental Immunology
CJCMA Canadian Journal of Comparative Medicine
CJMIA Canadian Journal of Microbiology

CJPEA Canadian Journal of Public Health
CJZOA Canadian Journal of Zoology
CNDRA Condor
CNJMA Canadian Journal of Comparative Medicine and Veterinary Science
CNJNA Canadian Journal of Animal Science
CNRDA Canadian Journal of Research, Section D, Zoological Sciences
CNREA Cancer Research
CNSVA Conservationist
CNVJA Canadian Veterinary Journal
COVEA Cornell Veterinarian
CPSCA Chesapeake Science
CVTJA Ceylon Veterinary Journal

DABBB Dissertation Abstracts International
DKBSA Doklady (Biological Sciences, Proceedings of the Academy of Sciences of the USSR) (English translation of DOBTA)
DOBTA Doklady Akademii Nauk SSSR Biological Science Section (for English translation see DKBSA)

ECOLA Ecology
ENAMA Entomologica Americana
ESTHA Environmental Science and Technology
ETBRA Entomologische Berichten (Amsterdam)
EVETB Environmental Entomology

FLUOA Fluoride
FPARA Folia Parasitologica
FPWTA Transactions of the Federal-Provincial Wildlife Conference

GRBNA Great Basin Naturalist
GRLEA Great Lakes Entomologist

HLTPA Health Physics

IABLA Izvestiya Akademii Nauk Azerbaidzhanskoi SSR, Seriya Biologicheskikh Nauk
IJAHA Indian Journal of Animal Health
IJLAA Indian Journal of Animal Sciences
INFIB Infection and Immunity
IVEJA Indian Veterinary Journal
IZSPB USDA Index Catalogue of Medical and Veterinary Zoology Special Publication

JAASA Journal of the Alabama Academy of Science
JANSA Journal of Animal Science
JAVMA Journal of the American Veterinary Medical Association
JCVPA Journal of Comparative Pathology
JEBCA Journal of Entomological Society of British Columbia
JEENA Journal of Economic Entomology
JEMEA Journal of Experimental Medicine
JEZOA Journal of Experimental Zoology
JFUSA Journal of Forestry

JIDEA Journal of Investigative Dermatology
JIDIA Journal of Infectious Diseases
JKESA Journal of the Kansas Entomological Society
JMENA Journal of Medical Entomology
JNCIA Journal of the National Cancer Institute
JNYEA Journal of the New York Entomological Society
JOHLA Journal of Helminthology
JOHYA Journal of Hygiene
JOMAA Journal of Mammalogy
JONUA Journal of Nutrition
JOPAA Journal of Parasitology
JPROA Journal of Protozoology
JRMGA Journal of Range Management
JRPFA Journal of Reproduction and Fertility
JWIDA Journal of Wildlife Diseases
JWMAA Journal of Wildlife Management
JZAMD Journal of Zoo Animal Medicine
JZOOA Journal of Zoology

KLVBA Kongelige Veterinaer-og Landbohojskole Arsskrift

LANCA Lancet

MISTB Transactions Missouri Academy of Science
MMLRA Mammal Review
MUATA Minnesota Agricultural Experiment Station Technical Bulletin

NATUA Nature (England)
NATWA (Die) Naturwissenschaften
NAVEA North American Veterinarian
NAWTA North American Wildlife and Natural Resources Conference, Transactions of the,
NCANA Naturaliste Canadien, Le
NEZTA New Zealand Veterinary Journal
NFGJA New York Fish and Game Journal
NOSCA Northwest Science
NOVDA Norsk Veterinaertidsskrift
NOVTA Nordisk Veterinaermedicin
NPSMD United States National Park Service Scientific Monograph Series
NYCOA New York State Conservationist
NZASA New Zealand Agricultural Science
NZJSA New Zealand Journal of Science

OUOKA Outdoor Oklahoma

PAAZA Progressive Agriculture in Arizona
PAHUA Parasitologia Hungarica
PARAA Parasitology
PAVEA Pathologia Veterinaria
PCGFA Proceedings of the Southeastern Association of Game and Fish Commissioners

PHSWA Proceedings Helminthological Society of Washington
PIAIA Proceedings of the Iowa Academy of Science
PMASA Proceedings of the Montana Academy of Sciences
PNDAA Proceedings of the North Dakota Academy of Science
POASA Proceedings of the Oklahoma Academy of Science
PPASA Proceedings of the Pennsylvania Academy of Science
PPETA Pan-Pacific Entomologist
PPPAA Pacific Science Congress Proceedings
PRLBA Proceedings of the Royal Society of London B Biological Sciences
PSDAA Proceedings of the South Dakota Academy of Science
PSEBA Proceedings of the Society for Experimental Biology and Medicine
PUNMA Proceedings of the United States National Museum
PYTCA Phytochemistry
PZSLA Proceedings of the Zoological Society of London

RHDRA Radiological Health Data and Reports
RSZOA Revue Suisse de Zoologie
RVETA Refuah Veterinarith
RVTSA Research in Veterinary Science

SABOA Sabouraudia
SAGCA Science in Agriculture
SBJOD Science of Biology Journal
SCIEA Science
SEHEA Seminars in Hematology
SENTD Southwestern Entomologist

TAEPA Texas Agricultural Experiment Station Progress Report
TAMSA Transactions of the American Microscopical Society
TGMEA Tropical and Geographical Medicine
TISAA Transactions of the Illinois State Academy of Science
TMPRA Tropenmedizin und Parasitologie
TNWSD Transactions of the Northeast Section, The Wildlife Society
TRCIA Transactions Royal Canadian Institute
TRSTA Transactions of the Royal Society of Tropical Medicine and Hygiene

VETRA Veterinary Record
VIWIA Virginia Wildlife
VPARD Veterinary Parasitology
VTPHA Veterinary Pathology
VTYMA Veterinary Medicine and Small Animal Clinician

WDABB Bulletin of the Wildlife Disease Association
WGFBA Wyoming Game and Fish Commission Bulletin
WIDIA Wildlife Disease
WLMOA Wildlife Monographs
WLSBA Wildlife Society Bulletin
WMBAA Wildlife Management Bulletin
WSCBA Wisconsin Conservation Bulletin

XAGCA	U S D A Circular
XENOB	Xenobiotica
ZEVMA	Zentralblatt fuer Veterinaermedizin
ZOANA	Zoologischer Anzeiger
ZOGAA	Zoologische Garten
ZOOAA	Zoologica Africana
ZOPOA	Zoologica Poloniae
ZTMPA	Zeitschrift fuer Tropenmedizin und Parasitologie

LIST OF PUBLISHERS - CHAPTER TEN

acpr	Academic Press	New York	nyny
ccth	Charles C. Thomas	Springfield, IL	spil
faog	Food & Agriculture Organization of U. N.	Rome, Italy	roit
hein	Heinemann	London, England	loen
isup	Iowa State University	Ames, IO	amia
lefe	Lea and Febiger	Philadelphia, PA	phpa
plpr	Plenam Press	New York	nyny
tcpc	Taylor County Printing Co.	Reynolds, GA	rege
wbsc	W. B. Saunders Company	Philadelphia, PA	phpa