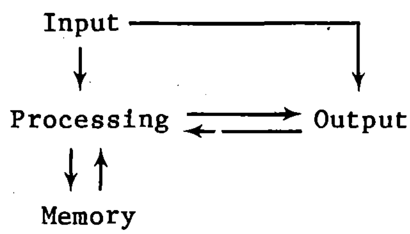
TOPIC 8. NERVOUS SYSTEM FUNCTIONS

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

alal

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

rata

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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

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

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

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ovda

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

obmo

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

oram

UNIT 8.6: 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

odhe

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

ceel

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
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