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.