and left-coiled Foraminifera from open-sea sediments, the differences observed and the relative percentage of right- and left-coiled specimens indicate that the paleoclimatic conclusions should maintain, in a general way, their validity. However, in such a case, there is a factor of uncertainty of the measurements higher than the standard error.

This is due to the possibility that the percentages of right- and left-coiled specimens and the seasonal difference in the deposition of calcium carbonate by each vary in different species of the same fauna.

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Strontium-90 in Plants and Animals of Arctic Alaska, 1959–61

Abstract. *The strontium-90 content of the biota near Cape Thompson, Alaska, was related to environmental factors. In plants, perennials with persistent aerial parts had maximum and similar concentrations of strontium-90. The content of caribou muscle varied seasonally and was highest in winter when lichens were an important caribou food.*

Beginning in 1959, the U.S. Atomic Energy Commission sponsored a bioenvironmental study in the vicinity of Ogotoruk Creek (latitude 68°6′N, longitude 168°46′W) near Cape Thompson in northwestern Alaska. This study was made in conjunction with Project Chariot, a proposed test excavation employing nuclear energy. Project Chariot was part of the AEC's Plowshare Program for the development of peaceful uses of atomic energy (*1*).

The Chariot test site is located in a tundra region where the average annual precipitation is 20 cm. In this area of permafrost the ground is frozen to the surface during much of the year. Winds are strong and persistent, with average velocities of 36 km/hr during the winter and 22 km/hr in the summer (*1*). The vegetation is composed of sedges, mosses, willows, birches, lichens, and low-growing perennial herbaceous forbs. Much of the area is poorly drained and snow accumulates in the depressions during the winter. The exposed ridge tops are swept free of snow in winter by the strong winds.

Radionuclides originating from nuclear weapons testing were measured in the biota from 1959 through 1961 to determine distribution and concentration of radioelements in the environment before the test, and to aid in predicting the fate of radioactive materials which might be released to the environs by the excavation test.

Samples of plants and small animals were collected during the summers of 1959, 1960, and 1961 when no nuclear testing, except for the low-yield French Sahara Desert tests, were conducted. Most samples were collected within 24 km of the Project Chariot site. Caribou, however, were obtained in locations (Fig. 1) 160 km or more from the test site.

Vegetation was collected by clipping the tips of willow branches and the parts above ground of sedges, lupine, and the aquatic emergents *Arctophila* and *Hippurus*. Leaves and stems of heather (*Ledum*), *Dryas*, *Sphagnum* moss, and lichen were picked by hand. Samples were sealed in plastic bags in the field, weighed on the day of collection, transferred to cheesecloth bags, and dried.

Birds and small mammals were trapped or shot and were weighed and frozen on the day of collection. In most cases, wet-weight determinations were made on frozen caribou samples. Caribou muscle was taken from the hind leg and bone samples were obtained from the mid-shaft of the femur.

All Sr^{90} measurements were made at Hanford Laboratories. Before radioassay for Sr^{90}, all samples were ground, thoroughly mixed, and a portion was removed for determination of standard dry and ash weights (*2*). Samples were then dry ashed in a muffle furnace at 525°C for 12 hours or more. Usually the amounts used per sample were as follows: vegetation, 250 to 500 g air dry weight; entire animals, 100 to 500 g wet weight; muscle, 200 to 2000 g wet weight; bone and antler, 7 to 30 g air dry weight; and rumen contents, 500 to 1000 g wet weight. To obtain a countable amount of Sr^{90} in small birds and mammals, the tissues of several individuals were included in a single sample.

Strontium-90 was separated by a modification of the method described by Silker (*3*), and calcium determinations were made by a modification of the method of Yofe and Finkelstein (*4*).

Samples below 20 count/min were counted on low-background beta counters. Count rates twice that of the background and below were rejected. Samples with rates of 20 count/min or more were counted on a beta proportional counter having a counting error of about 2 percent.

There was surprisingly little difference, on a dry weight basis, in the Sr^{90} content (Table 1) of the plants examined with respect to species or time. Possible routes of entry of Sr^{90} in the vegetation are several, including uptake from the soil by way of the plant roots, foliar uptake from the water in which the plants were growing, and direct foliar sorption from the atmosphere. These routes are modified by environmental conditions such as exposure, chemical and physical properties of the substrate, and by variations in growth habits and specific mineral requirements of different plant species.

Foliar sorption is the main route of Sr^{90} uptake in lichens. Maximum concentrations were found in lichens adhering to the rocky substrates of exposed ridges; there were lesser amounts in lichen in areas of winter-snow accumulation. The persistence of lichen aerial parts, their very slow growth rate of 5 mm or less per year (*5*), their long life span of up to 100 years (*6*), and the high ratio of surface area to mass all contribute to their relatively high levels of Sr^{90}. Their capacity to obtain most of their nutriment through absorbed moisture and the hypothesized property of the cell walls of the lichen thalli to behave as hydrophilic gels (*6*) also enchances aerial sorption of fallout Sr^{90}.

The calcium content in lichen samples was quite variable owing to the inclusion of different amounts of mineral material in the form of soil particles. The lichen communities sampled grew on stoney soils, making the possibility of incorporation of inorganic materials greater in these than in other plant samples. As a consequence, the measured ratio of Sr^{90} to calcium in lichen samples is exceedingly questionable.

Relatively high concentrations of Sr^{90} were found in *Dryas octopetala* and heather (*Ledum decumbens*), both of which grow on well drained slopes.

Table 1. Strontium-90 in Alaska plants.

Habitat	Date (mo.-yr.)	pc/g Wet Wt.	pc/g Dry Wt.	S. U.*
		Lichen-Cetraria, Cladonia		
1	8-59	(1) 1.1	3.3	59,400
1	8-60	(5) 0.93	2.0	43,900
		± 0.28**	± 0.53	
1	6-61	(5) 0.52	1.4	1,270
		± 0.11	± 0.30	
2	6-61	(1) 2.3	3.4	1,180
		Lichen-Cornicularia		
3	8-61	(4) 3.8	5.4	3,320
		± 0.27	± 0.31	
3	9-61	(4) 2.1	5.1	1,850
		± 0.099	± 0.21	
		Sphagnum		
4	8-59	(1) 0.16	2.4	568
5	9-60	(3) 1.1	2.3	
		± 0.26	± 0.52	276
		Heather-Ledum decumbens		
3	8-59	(1) 1.4	4.0	1,180
		Dryas octopetala		
3	9-60	(3) 1.8	2.9	323
		± 0.095	± 0.153	

Habitat	Date (mo.-yr.)	pc/g Wet Wt.	pc/g Dry Wt.	S. U.*
		Sedge-Carex aquatilus		
6	7-59	(3) 0.52	2.6	141
		± 0.16	± 0.80	
4	8-59	(8) 2.2	5.0	1,370
		± 0.19	± 0.41	
6	7-60	(3) 1.7	3.8	553
		± 0.12	± 0.21	
7	7-60	(2) 1.2	2.4	678
8	7-60	(3) 2.1	3.7	1,840
		± 0.021	± 0.048	
4	7-60	(1) 0.85	2.1	805
4	8-60	(2) 0.96	2.4	902
4	7-61	(8) 0.68	3.0	868
		± 0.065	± 0.33	
		Sedge-Eriophorum vaginatum		
2	7-59	(3) 1.6	3.1	1,380
		± 0.17	± 0.38	
2	8-60	(3) 0.54	1.8	1,280
		± 0.012	± 0.048	

Habitat	Date (mo.-yr.)	pc/g Wet Wt.	pc/g Dry Wt.	S. U.*
		Willow-Salix pulchra		
7	8-59	(4) 0.57	1.7	266
		± 0.082	± 0.24	
7	9-60	(3) 0.67	1.3	322
		± 0.23	± 0.46	
		Salix alaxensis		
5	9-60	(3) 0.24	0.58	43
		± 0.026	± 0.058	
		Lupine-Lupinus arcticus		
2	8-60	(2) 0.37	1.1	808
		Hippurus vulgaris		
8	8-59	(1) 0.13	2.3	564
8	9-60	(2) 0.51	8.9	12,400
8	8-61	(2) 0.18	9.5	
		Arctophila fulva		
8	8-59	(2) 0.040	0.37	570
8	9-60	(3) 0.039	0.28	147
		± 0.0039	± 0.042	

The number of samples is in parentheses. * Picocuries of Sr^{90} per gram of calcium. ** S.E. Habitat (unless otherwise indicated, all samples were collected near Ogotoruk Creek): *1*, snow accumulation area; *2*, rolling tundra; *3*, ridge; *4*, wet meadow; *5*, spruce forest (Noatak River); *6*, snow accumulation area, high calcium; *7*, streamside; *8*, tundra pond.

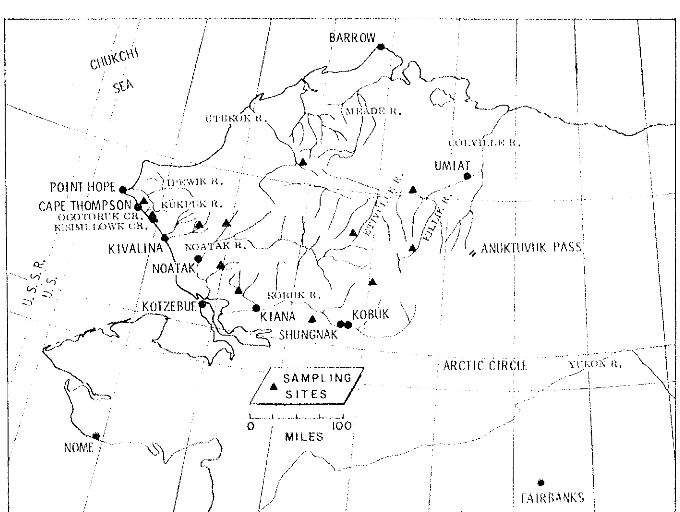
Their persistent aerial parts and year-around exposure to the atmosphere make foliar sorption of major importance in their accumulation of fallout strontium.

The sedges (*Carex aquatilus* and *Eriophorum vaginatum*) were collected, for the most part, in poorly drained acid soils (*p*H 4 to 5) (*1*). Both are herbaceous perennial plants whose foliar parts die each fall. The *Carex* sampled grew in dense stands on partially flooded, highly organic soil. The environment and growth habit of this plant suggest several important routes of Sr^{90} uptake. The high organic content of the soil would tend to reduce uptake of strontium by the roots (*8, 9*). Direct uptake from the water by submerged portions of the leaves and rhizomes could enhance uptake. Approximately 100 times as much radiostrontium is accumulated by plants from water solutions as from soil (*10*), and pasture grass in marsh areas contains more Sr^{90} than grass from the drier uplands (*11*). The *Carex* growth habit of forming rather dense stands would point to another route of uptake. Studies of permanent pastures showed that more than 80 percent of the Sr^{90} did not pass through the soil and that most of the uptake of radiostrontium was through foliar absorption and stem-base absorption, with the latter postulated as the more important route (*12, 13*).

To test the effect of plant litter on the uptake of Sr^{90}, three plots 1 m^2 in a *Carex* stand were clipped during the summer of 1960, and the leaves—both living and dead—and accumulated organic material from previous years' growth were removed. The following summer the new growth on these plots was harvested and compared with the crop from adjacent undisturbed plots in which both new growth and litter were included. The Sr^{90} content of the new growth and the new growth plus the litter was 1.7 ± 0.39 pc per gram of dry weight and 3.0 ± 0.33 pc per gram of dry weight, respectively. This suggests that accumulated litter is a possible source of Sr^{90} by way of the previously mentioned stem-base absorption. The Sr^{90} content of *Carex* from areas of high calcium was similar to that from acid soils, but the strontium to calcium ratio (pc Sr^{90}:g Ca) was much lower (Table 1).

Eriophorum grew in clumps or tussocks whose bases are compact masses of stems, roots, and accumulated litter. The interspaces between the tussocks are ideal places for the entrapment of water, drifting snow, organic debris, and air-borne particulates. As with *Carex*, the litter of past years' growth is a possible reservoir of Sr^{90} in this plant.

The quantity of water included with *Sphagnum* moss samples affected their Sr^{90} content. In 1960, moss from which the water had been expressed by hand contained 0.28 pc of Sr^{90} per gram of dry weight as compared with 7.3 pc per gram of dry weight for a similar sample in which the water was retained. Moss from relatively dry hummock tops and from adjacent water-saturated depressions contained 1.6 and 3.2 pc of Sr^{90} per gram of dry weight, respectively. Direct sorption from surface water



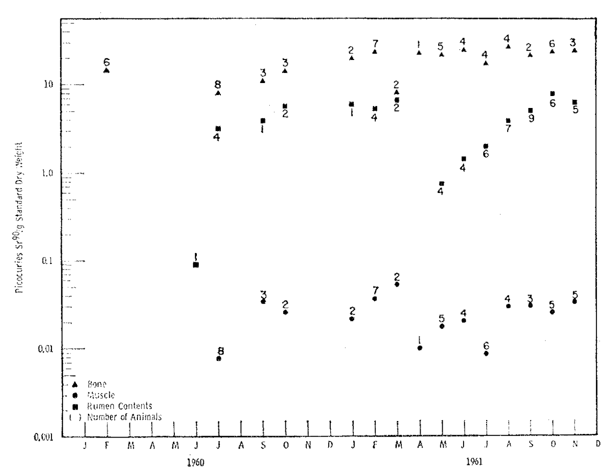


Fig. 1 (left). Caribou sampling sites. Fig. 2 (right above). Strontium-90 in Alaska caribou.

appears to be an important route of uptake by this plant.

Of the terrestrial plants, lupine and willow contained the lowest amounts of radiostrontium. Tissues from the lupine represented only the current year's growth and this was nearly so for willow. Main routes of Sr^{90} uptake for both species are probably foliar sorption and absorption from the soil by way of the roots.

The aquatic emergent plants exhibited the extremes in amounts of Sr^{90} measured. For the first part of the growing season, they are completely submerged in ponds and only the upper one-third to one-half of the shoots is exposed to the air during the later part of the summer. Consequently, direct foliar sorption from the atmosphere is of only minor importance as a route of Sr^{90} uptake. Their aquatic habitat provides for greater verticle distribution of fallout materials than does that of terrestrial plants. Most of the fallout on land is confined to the upper 10 cm of soil. Water depths up to 0.6 m or more were present for the dispersion of Sr^{90} in areas of emergent plant growth. Wind-induced currents also enhanced dispersion of fallout material in the ponds. Competition from the strontium by the abundant populations of planktonic and benthonic organisms would further reduce Sr^{90} available to the plants. The greater dilution of fallout strontium may explain the low amounts in *Arctophila* but reasons for the higher concentrations in *Hippurus* are not known.

Ingestion is the primary route of strontium uptake in animals; thus food habits are of major importance in Sr^{90} accumulation. The ground squirrel, vole, bear, ptarmigan, fish, and seal are permanent residents; the other animals sampled live in the Arctic only during the summer. A portion of the Sr^{90} burden of these summer residents was acquired prior to their northern migration. Their temporary residency, the slow turnover of Sr^{90} in bone, and the small size of the sample make the relating of body burden to local diet difficult and permit only general comparisons.

Herbivorous animals, such as the ground squirrels, voles, and ptarmigan, had more Sr^{90} than the carnivorous jaegers and marine birds (Table 2). The Sr^{90} concentration in ptarmigan bone was the maximum measured in any animal tissue. The relatively high body burden observed in a single sample of red phalarope may be due to a sampling mischance. An important food of these birds is aquatic invertebrates (*14*); in the vicinity of the Chariot site the invertebrates are low in Sr^{90} (Table 2). The relatively high values for hair seal, dominately a fish eater, may also be suspect on the basis of low concentrations of Sr^{90} found in fish taken at Chariot site (2.8 to 6.8 pc per kilogram of wet weight for muscle and 8.2 to 79 pc for bone) (*1*). Other analyses of seal tissues from the same area were 0.91 and 8.0 pc per kilogram of wet weight for muscle and bone, respectively (*1*).

The caribou, an important food source of the Eskimos of the Arctic, was sampled more extensively than other animals. General areas of caribou sample collection are shown in Fig. 1. Seasonal variations in the Sr^{90} content of caribou muscle, bone, and rumen contents are given in Fig. 2. Because no differences were evident in the amounts of radiostrontium with respect to age, sex, or area of collection, data from all animals were pooled by

Table 2. Strontium-90 in Alaska animals.

Sample	Site[a]	(mo.-yr.)	pc/g Wet Wt.	S.U.[b]
Arctic Ground Squirrel - Citellus parryii				
Entire[c]	1	7-59	(2) 0.37	43
Entire	2	8-59	(1) 0.17	18
Entire	1	8-60	(3) 0.14 ± 0.021[d]	15
Bone	1	7-60	(1) 4.8	
Tundra Vole - Microtus oeconomus				
Entire	2	8-59	(7) 0.35 ± 0.10	35
Grizzly Bear - Ursus arctos				
Muscle	3	5-61	(1) 0.0014	
Hair Seal - Phoca vitulina				
Muscle	4	6-60	(1) 0.49	
Bone	4	6-60	(1) 3.1	
Ptarmigan - Lagopus spp.				
Entire	2	7-59	(1) 0.74	80
Entire	2	8-60	(4) 0.46 ± 0.35	43
Bone	2	8-59	(1) 64	375
Bone	2	6-60	(1) 19	
Lapland Longspur - Calcarius lapponicus				
Entire	1	7-59	(1) 0.20	26
Golden Plover - Pluvialis dominica				
Entire	1	7-59	(2) 0.054	4.3
Red Phalarope - Phalaropus fulicarius				
Entire	2	8-59	(1) 1.2	130
Sandpiper - Ereunetes mauri				
Entire	2	7-59	(1) 0.29	26
Lesser Sandhill Crane - Grus canadensis				
Muscle	2	8-59	(1) N.D.	
Long-tailed Jaeger - Stercorarius longicaudus				
Entire	2	7-59	(3) 0.087 ± 0.013	14
Muscle	1	7-60	(2) N.D.	
Parasitic Jaeger - Stercorarius parasiticus				
Entire	2	7-59	(1) 0.11	6.1
Muscle	1	7-60	(1) N.D.	
Oldsquaw Duck - Clangula hyemalis				
Entire	2	7-59	(6) 0.32 ± 0.15	43
Red-Throated Loon - Gavia stellata				
Entire	2	7-59	(1) N.D.	
Common Murre - Uria aalge				
Entire	4	9-59	(1) N.D.	
Horned Puffin - Fratercula corniculata				
Entire	4	8-59	(2) 0.064	7.8
Grayling - Thymallus arcticus				
Entire	5	9-60	(2) 0.012	1.1
Dolly Varden Char - Salvelinus malma				
Entire	2	8-59	(1) 0.16	60
Zooplankton				
	6	8-59	(1) N.D.	

The number of samples is in parentheses. (*a*) *1*, Kisimulowk Creek; *2*, Ogotoruk Creek; *3*, Utukok River; *4*, Cape Thompson; *5*, Noatak River; *6*, Ogotoruk-tundra pond. (*b*) Picocuries of Sr^{90} per gram of calcium. (*c*) Entire animals sampled minus gut contents. (*d*) S.E. N.D., not detected.

Table 3. Strontium-90 in Alaska caribou and reindeer.

Date	pc/g Wet Wt.	pc/g Dry Wt.	S.U.*
1960	Caribou - Muscle		
Aug.	(8) 0.0021** ± 0.00069	0.0078 ± 0.0026	51
Oct.	(3) 0.0086 ± 0.0030	0.035 ± 0.013	209
Nov.	(3) 0.0068 ± 0.0011	0.026 ± 0.0047	145
1961			
Feb.	(2) 0.0060	0.022	230
Mar.	(7) 0.0086 ± 0.0011	0.037 ± 0.0061	244
April	(2) 0.014	0.055	234
May	(1) 0.0027	0.010	68
June	(5) 0.0040 ± 0.0012	0.018 ± 0.0054	79
July	(4) 0.0051 ± 0.0031	0.021 ± 0.013	131
Aug.	(6) 0.0023 ± 0.00086	0.0086 ± 0.0032	109
Sept.	(4) 0.0075 ± 0.0021	0.030 ± 0.0088	148
Oct.	(3) 0.0078 ± 0.00026	0.031 ± 0.0058	234
Nov.	(5) 0.0068 ± 0.0017	0.026 ± 0.0067	233
Dec.	(5) 0.0087 ± 0.0021	0.034 ± 0.0063	303
1960	Caribou - Bone (femur)		
Mar.	(6) 13 ± 2.3	15 ± 2.5	53
Aug.	(8) 6.8 ± 1.2	7.8 ± 1.4	29
Oct.	(4) 9.8 ± 2.9	11 ± 3.4	40
Nov.	(3) 12 ± 3.4	14 ± 3.9	53
1961			
Feb.	(2) 17	20	78
Mar.	(7) 20 ± 3.3	24 ± 4.1	75
April	(2) 7.0	8.2	30
May	(1) 20	23	80
June	(5) 19 ± 3.5	22 ± 4.2	86
July	(4) 21 ± 6.8	25 ± 8.3	93
Aug.	(4) 15 ± 4.5	18 ± 5.2	65
Sept.	(4) 23 ± 6.3	27 ± 7.9	106
Oct.	(2) 19	22	79
Nov.	(6) 20 ± 3.6	24 ± 4.7	86
Dec.	(3) 22 ± 2.6	25 ± 2.9	94
1960	Caribou - Rumen Contents		
July	(1) 0.13	0.93	
Aug.	(4) 0.62 ± 0.22	3.2 ± 1.1	
Oct.	(1) 0.86	3.9	
1961			
Feb.	(1) 1.6	6.0	1880
Mar.	(4) 1.0 ± 0.13	5.4 ± 0.62	1210
April	(2) 1.3	6.7	1740
June	(4) 0.12 ± 0.026	0.74 ± 0.15	141
1961			
July	(4) 0.21 ± 0.046	1.5 ± 0.48	192
Aug.	(6) 0.33 ± 0.057	1.9 ± 0.27	575
Sept.	(7) 0.73 ± 0.060	3.9 ± 0.037	329
Oct.	(9) 0.93 ± 0.069	5.1 ± 0.38	1600
Nov.	(6) 1.5 ± 0.11	8.0 ± 0.52	4840
Dec.	(5) 1.2 ± 0.091	6.4 ± 0.13	2540
1961	Reindeer - Muscle (Nunivak Is.)		
Aug.	(5) 0.017 ± 0.0080	0.058 ± 0.027	213
Oct.	(5) 0.011 ± 0.0067	0.036 ± 0.023	110
1961	Reindeer - Bone (femur)		
Aug.	(5) 37 ± 3.9	42 ± 4.7	145
Oct.	(5) 29 ± 2.3	35 ± 2.7	126

The number of animals is in parentheses. * Picocuries of Sr^{90} per gram of calcium. ** S.E.

Table 4. Strontium-90 in ruminant bone (values from the literature).

Date	Location	pc/g Wet Wt.	S. U.*	Ref.
		Cow		
1957				
Fall	Nevada	(2) 3.5 a	16	18
1958				
Spring	Nevada	(3) 4.0 a	18	18
1958				
Fall	Nevada	(3) 4.6 a	21	18
1959				
Mar.	Germany	(1) 2.0 b	8.4	19
		(1) 0.32 b	1.5	19
		(1) 0.32 b	1.4	19
1959-60	France	2-3 a	9.2-14	20
1960				
May	Nevada	(5) 15 b	66	17
		Sheep		
1956	Norway	4.1 c	17	21
1956				
Mar.	B. C., Can.	7.7 c	32	18
	Chile	1.7 c	7	18
	England	48 c	200	18
1959				
Mar.	Germany	5.9 b	25	19
		Roe		
1959				
Mar.	Germany	1.3 b	5.4	19
		Gams		
1959				
Oct.	Alps	20 b	79	19
		Caribou		
1956				
May	Alaska	12-27 c	50-112	18
1961				
Feb.	Alaska	43 b	175	22
	Alaska	51 b	180	22
		Reindeer		
1956				
Fall	Norway	24 c	100	21
1958				
Fall	Norway	36 c	150	21
		Mule Deer		
1961				
July	Colorado	(4) 5.3 b	15 d	23
Aug.	Colorado	(3) 6.4 b	18 d	23
Sept.	Colorado	(3) 7.2 b	21 d	23
Oct.	Colorado	(3) 4.7 b	13 d	23
Nov.	Colorado	(2) 6.7 b	19 d	23
Dec.	Colorado	(1) 1.5 b	4.3 d	23

The number of samples is in parentheses. * Picocuries of Sr^{90} per gram. *a*, Calculated on assumed ash wt/wet wt = 0.63, and 35 percent Ca/g ash. *b*, Calculated on assumed ash wt/wet wt = 0.63. *c*, Calculated on assumed ash wt/wet wt = 0.63, and 38 percent Ca/g ash. *d*, Calculated on assumed 35 percent Ca/g ash.

months. These differences may exist in the caribou populations, but could have been obscured in our data by the small number of observations and discontinuity in the sampling. Age-dependent differences in Sr^{90} content of caribou probably exist, as they have been reported for man and other mammals (*15–17*). The concentration of cesium-137 in caribou varied with the area of collection (*1*). Caribou muscle from the Colville–Noatak River drainages contained more Cs^{137} than that from the vicinity of Cape Thompson.

In Table 3 measurements of Sr^{90} in caribou from the mainland and a few reindeer from the managed reindeer herd on Nunivak Island (latitude 60°N, longitude 166°31′W) are given. There was a marked seasonal variation in the Sr^{90} content of caribou rumen contents. From June through September 1961 the concentration was about one-fifth that of the remainder of the year. This difference was probably caused by a seasonal change in type of forage eaten by caribou. Lichens are a major food of caribou, particularly during winter (*1, 5*). Studies on the closely related reindeer of Siberia show that choice of forage is governed to a large extent by plant availability (*5*). Lichens were dominant in the winter diet because most other food plants were either covered with snow or had died back to ground level. In spring and summer, the new growth of other plants were eaten as they became available. During the period from February through April more than 75 percent of the caribou in Ogotoruk Valley grazed in the *Dryas* fellfield vegetation where the percentage of lichen was higher than in any other plant community in the area (*1*). However, in May and June, the new buds of the sedge (*Eriophorum vaginatum*) were the most important food (*24*).

The Sr^{90} concentration in caribou rumen contents in winter was similar to that of lichen collected in Ogotoruk Valley during late summer, but the strontium content of rumen in summer appears to be slightly less than that of the leafy plants. The higher levels of Sr^{90} in Nunivak Island reindeer as compared to the mainland caribou may be due to different food habits or greater precipitation.

Strontium-90 in caribou muscle and rumen contents appeared to decrease during the summer, indicating that the biological half-time of strontium in muscle is short and directly related to the rate of intake. Strontium-90 content in muscle was similar to that previously reported for Alaska (*22*). In 1961, average values for meat in the human diet in New York City, Chicago, and San Francisco ranged from 0.0004 to 0.0006 pc of Sr^{90} per gram of fresh weight (*25*), which is approximately a factor of 10 lower than that observed in the caribou. Differences of the same magnitude have been reported between bone of temperate zone cattle and Alaska caribou (*22*).

The calcium content of caribou flesh is appreciably lower than that of domestic livestock. Cattle muscle contains 0.11 mg of calcium per gram of wet weight, sheep 0.10 to 0.20 mg of calcium per gram of wet weight (*26*), but caribou muscle has only 0.04 mg of calcium per gram of wet weight. The lower calcium content along with the higher Sr^{90} content of caribou flesh increases the Sr^{90}:Ca ratio compared to that of domestic food mammals.

The average concentration of Sr^{90} in caribou bone for 1961 was approximately 18 pc per gram of wet weight, about 3000 times the mean concentration in muscle. Strontium-90 content of bone did not vary seasonally as it did in muscle and rumen. A comparison of data for similar months of 1960 and 1961 shows that the Sr^{90} concentration in bone approximately doubled in a year. Although an increase in the amount in bone was expected, a twofold rise seems too large. Some of the difference may derive from different areas of migration and forage used by the sampled animals during the 2 years. A marked rise in the Sr^{90} concentration in vegetation was not evident, and values in muscle for the same months for the 2 years were nearly identical.

In general, the Sr^{90} in caribou bone was higher than that reported for most other ruminants (Table 4). The value of 200 pc of Sr^{90} per gram of calcium reported for English sheep in 1956 (*18*) was greater than that in caribou, and the 66 pc per gram of calcium in Nevada cattle in 1960 (*17*) was comparable to that observed in caribou for the same year. Colorado mule deer, a wild ruminant that feeds primarily by browsing instead of grazing, had only about one-third as much Sr^{90} in their bones (*23*).

The factor Sr^{90} per gram of Ca in diet/Sr^{90} per gram of Ca in bone varied in caribou with the time of year because of the large seasonal difference in the Sr^{90} content of the diet. By using the Sr^{90} concentration in rumen content as representative of that in the animals' forage, this factor ranged from 1.8 in June 1961 to 58 in November 1961. The yearly mean was 21. For caribou, this ratio should be used with caution because of its wide seasonal variation.

Caribou has been suggested as the primary source of Sr^{90} in the diet of the Eskimo population of Alaska (*22*). In a study of the body burden of Cs^{137} in the Alaskan Eskimos and research on their deitary habits conducted in 1962, it was found that the natives of Anaktuvuk Pass had the highest amounts of Cs^{137} and also ate the most caribou (*27*). Their average daily consumption of caribou flesh was about 770 g/day, or approximately 38 percent of their total diet. By use of this value and the mean concentration of 0.0067 pc of Sr^{90} per gram of wet weight measured in caribou meat in 1961, a daily ingestion rate of about 5 pc/day is obtained. This is within the Range I (2 to 20 pc/day) rate of Sr^{90}

ingestion set forth as an acceptable risk for lifetime exposure in the Federal Radiation Council's radiation protection guides for populations at large (*28*).

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Quantasome: Size and Composition

Abstract. *The quantasome as seen in a two-dimensional crystalline array is 185 Å long, 155 Å wide, and 100 Å thick. The surface of the quantasome appears to contain four or more subunits. The molecular weight, determined from volume and density measurements, is 2×10^6. This is twice the minimum molecular weight calculated from the manganese content and corresponds to a chlorophyll content of 230 chlorophyll molecules per quantasome.*

Both light and dark reactions of photosynthesis in higher plants are localized within the chloroplast (*1*). Electron microscopy and biochemical studies of chloroplast fragments show that the photosynthetic light reactions and associated electron-transport reactions are localized within the chlorophyll-containing lamellae of the plastid, while the carbon cycle or dark reactions are localized in the embedding matrix or stroma. The isolated chloroplast lamellae when illuminated perform electron transport from water to ferredoxin, yielding oxygen gas and reduced ferredoxin. Phosphorylation accompanies electron transport through the lamellae.

The chloroplast lamellar system, seen in cross section by electron microscopy, assumes many configurations. In oxygen-evolving photosynthetic organisms the lamellae exist as double unit membrane systems. The lamella in cross section appears as a flattened vesicle surrounded by a unit membrane. The lamellae are completely separated from one another in blue green (*2*) and red algae (*3*), probably because space is needed between the lamellae for the soluble accessory pigment systems present in these organisms. Stacking of the lamellae commonly occurs in the green algae (*3*) and bryophytes (*4*), and a mixture of stacked lamellae (grana lamellae) and single lamellae (stroma lamellae) is found in higher plants. The intimate morphology of these lamellae undergoes wide variations in response to the environment (*5*). Apparently the conversion of light energy to chemical potential in the lamellae is a consequence of the arrangement of substances within a single lamella and is not related to the detailed lamellar arrangement since all the organisms mentioned are capable of efficient photosynthesis.

Since the light reactions of photosynthesis are localized within the chloroplast lamella, we have been concerned with the morphological, chemical, and enzymological description of the lamella and its components (*6–8*). Morphologically, the chloroplast lamella is a specialized unit membrane. Though the membrane thickness (100 Å) and to some extent its staining characteristics are typical of a unit membrane, its chemical composition is unique (*8*). Most of the lipids, as can be seen from the tabulation below, are, with the exception of the phospholipids, found only in the photosynthetically specialized membrane. This uniqueness will probably also hold for the lamellar proteins when they are fully characterized. In thin section the chloroplast lamella appears smooth when observed by electron microscopy. However, shadowed preparations of isolated lamellae show a repeating structure on the inner surface of the unit membrane. This structure was first observed by Steinmann (*9*) and later described by Frey-Wyssling and Steinmann (*10*). Work in this laboratory has suggested that these repeating structures may be the morphological expression of the physiological photosynthetic unit as formulated by Emerson and Arnold (*11*). For this reason we termed these lamellar units quantasomes.

The quantasome was initially described as an oblate sphere 200 Å in diameter and 100 Å thick (*6*). We have now recognized quantasomes in spinach lamellae as existing in at least three types of packing (Fig. 1). The most crystalline type of packing is shown in Fig. 1*c*. This extended array of quantasomes allows a more accurate determination of quantasome dimensions than was possible previously. The quantasomes in Fig. 1*c* average 185 by 155 Å with a thickness of 100 Å. The crystalline packing of Fig. 1*c* is the least common quantasome-packing arrangement, but the easiest from which to get accurate dimensions. A more