FOOD REQUIREMENTS OF DOGS ON ANTARCTIC EXPEDITIONS

By N. W. M. Orr

Abstract. The diets of sledge dogs were studied at the Hope Bay station of the British Antarctic Survey and during sledge journeys over a period of two years. Body weights were compared with calorie intakes and samples of the diets and the relevant faeces were analysed.

The natural diet of Antarctic sledge dogs is seal meat. It is highly calorific and very well absorbed. The artificial diets have varied from year to year but they have never been entirely satisfactory in that the routine ration did not supply sufficient calories to maintain the body weight or efficiency of the dogs. The artificial diets were also found to be uneconomical in that large quantities were passed in the faeces.

The calorific requirements of sledge dogs were found to vary considerably from dog to dog and depended on the activity in which the dogs were involved. While 2,500 kcal./dog/day was only just sufficient to maintain the body weight of a completely idle dog, 5,000 kcal./dog/day was barely sufficient to maintain the body weight of a dog pulling a heavy sledge over long distances.

The dogs of the British Antarctic Survey originally came from Labrador in 1945–46. They were supplemented by dogs from Canada and from Greenland, and formed the first permanent dog population resident in the Antarctic. The diets were based on those of the British Graham Land Expedition and have been little modified since, except temporarily by force of circumstance.

At the base station the diet has usually consisted of seal meat. James (1947) found that one Adélie penguin per dog was an adequate daily diet, as was 2 lb. (0·91 kg.) of biscuit together with 1 lb. (0·45 kg.) of "Pemmican",* but neither compared with seal meat when it was available (Fig. 1). Adie (1953) suggested 4 lb. (1·82 kg.) of lean seal meat on alternate days as a summer diet, with 6 lb. (2·72 kg.) of meat and blubber on alternate days in the winter. Taylor (1957) advocated 6–8 lb. (2·72–3·63 kg.) of seal meat on alternate days.

The present practice of the Survey is to feed 7 lb. (3·18 kg.) of seal with skin and blubber on alternate days in winter and to remove excess blubber during the summer. The size of the feeds is judged by experience and, as all personnel take turns with the dog feeding, the quantities vary enormously—mostly on the side of generosity.

From 1945 to 1956 the sledging ration of the Survey's dogs was dog Pemmican, which was made in 1 lb. (0·45 kg.) blocks by Bovril Ltd. The basic sledging ration has always been 1 lb. (0·45 kg.)/dog/day, though all authorities have agreed that this has not been enough to maintain body weight and full efficiency. Adie (1953) suggested that extra should be given if the dogs showed signs of fatigue. He suggested that ideally an extra 0·5 lb. (0·23 kg.) of Pemmican should be given on alternate days, with seal meat at least every ten days, and Mason (1950) reported that dogs fed on 1·25 lb. (0·57 kg.) of Pemmican a day supplemented by fresh seal meat returned to the base station in excellent condition after covering 1,200 miles (1,930 km.) in 99 days.

Taylor (1957), who studied the work output and nutritional requirements of sledge dogs, found that dogs fed on Pemmican in the field lost weight and condition. He estimated that on a diet of 1 lb. (0·45 kg.) of Pemmican per day a dog's work output fell 5 per cent in a week, quite apart from any loss of output due to psychological factors. He also drew attention to the distressing diarrhoea that accompanied Pemmican feeding and, finding that nearly 30 per cent of the diet was passed in the faeces, suggested that metabolic disturbances might be caused by the high ratio of protein to carbohydrate in the diet. On his recommendation, therefore, Pemmican was superseded by a new sledging ration, "Nutrican", made by Bob Martin Ltd. in 1 lb. (0·45 kg.) blocks. Dogs subsequently fed on this new diet were not troubled with diarrhoea and tended to fare better.

The dogs of the "Shackleton" party of the Commonwealth Trans-Antarctic Expedition (1956–58) were given Nutrican and Pemmican on alternate days. Sir Edmund Hillary, reporting on the dogs operating from "Scott" at the same time, stated that they lost condition when fed

* "Pemmican" consists of "lean meat, dried and pounded and mixed with melted fat, so as to form a paste and pressed into cakes containing much nutriment in little bulk and keeping for a long time" [O.E.D.].

Fig. 1. On sledging journeys seals are killed and fed to the dogs whenever possible. Note the thick layer of blubber.

on Pemmican but that an alternative diet* based on a formula made for Byrd in 1928 was an outstanding success (Bell, 1957; Hillary, 1960).

Wyatt of the British Antarctic Survey carried out controlled trials on dogs fed on the two diets, Pemmican and Nutrican, and collected faeces for analysis so that an estimate could be made of the comparative availability of their components. Nutrican apparently provided a more balanced diet than Pemmican and controlled the diarrhoea, but there was a very high fat excretion on the Nutrican diet as compared with the excessive protein excretion on the Pemmican diet. At the rate of 1 lb. (0·45 kg.)/dog/day neither diet was sufficient to maintain body weight even if the dogs remained idle. From measurements of body-weight loss he estimated that the energy expenditure of a working dog would be between 4,140 and 4,730 kcal./dog/day (personal communication from H. T. Wyatt).

The present series of experiments was similar to that carried out by Wyatt. Weight changes and performance of dogs on various quantities of a sledging diet and seal meat were compared over a period of two years and an estimate was made of their energy expenditure and nutritional requirements.

Experimental Methods

Selected dogs were segregated into comparable units of 3–8 dogs, and in the course of 11 experiments comparable units were subjected to the same conditions in everything but feeding. They were fed with various quantities of 4 diets—seal meat, Pemmican, "old" Nutrican and Nutrican—samples of which were analysed at the Department of Experimental Medicine, University of Cambridge. Faeces, collected in certain experiments, were also analysed and showed the digestibility and availability of the component parts of the diets. Weight changes of the dogs were taken as an indication of the calorific adequacy of the diets at various levels of activity.

The dogs

There were between 80 and 90 dogs at Hope Bay in 1959 and 1960. These were trained as 9 teams which, during the two years, travelled a total of 20,000 miles (32,180 km.). 40 dogs, comprising 5 teams,† were involved in the present trials and as far as possible the experiments were arranged so as not to interfere with sledging and station routines, and so that the dogs could be observed under conditions as near normal as possible. Of the 40 dogs involved, 38 had been bred from dogs which had been in the Antarctic one or more generations (Fig. 2) and only two were newcomers to the Antarctic. Their ages ranged from 9 months to 9 years.

Body weights

The body weights of the dogs varied greatly with activity and feeding, but at the start of the first experiment the average weight was 94 lb. (42·7 kg.), with a range of 81 to 103 lb. (36·8 to 46·8 kg.). The 3 bitches each weighed 76 lb. (34·5 kg.).

The dogs were weighed at intervals during the course of the trials and daily when they were "recuperating" on a more liberal diet. They were weighed first thing in the morning, both at the base station and during sledge journeys, suspended by the shoulder straps on their harnesses from a balance hung from a tent-pole tripod (Fig. 3). In this way it was possible for one man to weigh the dogs unassisted if necessary, while the dogs remained secure and docile. Weights were taken to the nearest pound.

The diets

Seal meat with skin, blubber and bone was normally fed to dogs in lumps of 6–8 lb. (2·72–3·63 kg.) on alternate days. In summer, when the seals were fresh and the meat soft, the skin and part of the blubber were usually removed. In winter the seals froze log-hard and were

* This consisted of beef, tallow, meat meal, wheat germ, molasses, cod liver oil and mixed lemon, and was fed to the dogs in 1·5 lb. (0·68 kg.) blocks.

† "Terrors", "Huns", "Komats", "Gangsters" and "Players".

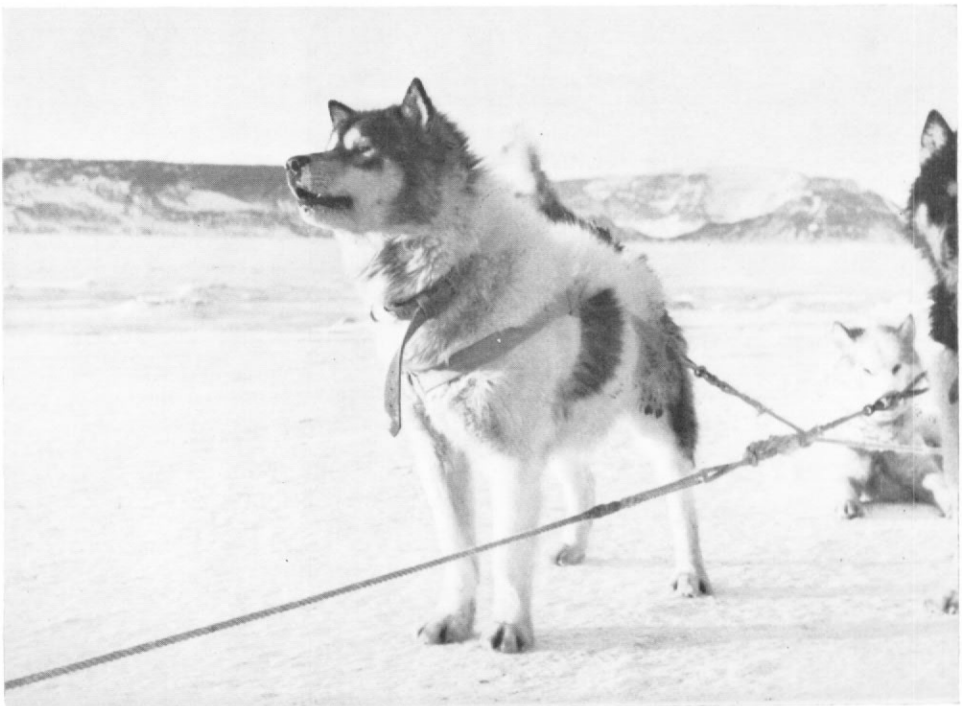

Fig. 2. A typical specimen of the husky dogs bred by the British Antarctic Survey. (Photograph by P. Thompson.)

Fig. 3. A dog being weighed in its harness during a sledge journey.

sawn into roundels with a cross-cut saw (Fig. 4) before being split with felling axes. Heads, flippers and selected offal were included, with a result that the composition of the individual feeds varied very widely.

An arbitrary section including skin, blubber and meat was analysed. The analysis showed that 1 lb. (0·45 kg.) of fat seal meat, of which about one-third was lean and two-thirds was blubber and skin, yielded nearly 2,000 kcal. 1 lb. (0·45 kg.) of lean seal meat, on the other hand, yielded about 500 kcal. (Table Ib).

Fig. 4. Sawing up a frozen seal for dog food. (Photograph by G. Brookfield.)

The sledging diets, Pemmican and Nutrican, were supplied in 1 lb. (0·45 kg.) blocks wrapped in paper, and the basic diet was 1 lb. (0·45 kg.)/day. It was usually possible to supplement this diet with an extra ration at intervals or, better still, with seal meat when travelling in coastal areas.

The analyses of the four diets, seal meat, Pemmican, "old" Nutrican and Nutrican, are given in Tables Ia, b and c. For comparison the analysis of lean seal meat has been included in Table Ib and figures for halibut and stockfish, the favourite sledging diets of the Arctic, have been taken from *Food Tables* (McCance and Widdowson, 1960).

The most striking feature of the comparison is the very high calorific value of fat seal meat (2,000 kcal./lb.) and the surprisingly low value for lean seal meat (500 kcal./lb.). It is also significant that only the artificial diets, Nutrican and "old" Nutrican, contained any carbohydrates, while all the natural diets and Pemmican were composed solely of protein and fat. The very high figure for fat in seal meat with blubber no doubt accounts for its high calorific value and explains the emphasis that Arctic dog drivers have put on feeding blubber as a supplement to dried fish or a concentrated sledging diet.

From these figures it is possible to estimate and compare the calorific values of some of the more successful diets which have been used both in the Arctic and in the Antarctic. The base-station ration, advocated by Croft and used routinely by the Falkland Islands Dependencies

TABLE Ia. ANALYSES OF VARIOUS DIETS

	Pemmican	*"Old" Nutrican*	*Nutrican*
Basis	Lean seal meat and melted fat	Fish meal and margarine	Whale meat with beef dripping and suet
Protein (per cent)	66	30	25
Fat (per cent)	33	40	45
Carbohydrates (per cent)	—	10	21
kcal./lb.	2,400	2,500	2,500
Dates when used	1945–56	1956–58	1958–

TABLE Ib. ANALYSES OF VARIOUS DIETS

	Seal Meat (with Blubber)	*Lean Seal Meat*	*Pemmican*	*"Old" Nutrican*	*Nutrican*	*Halibut*	*Stockfish*
Composition (g./lb.)							
Moisture	203·6	325·1	26·7	39·0	23·1	321·9	294·6
Total nitrogen	13·1	19·3	45·4	21·4	15·0	16·5	23·2
Protein (N × 6·25)	81·7	120·6	284·0	133·9	93·7	103·3	145·3
Fat	176·2	1·7	127·7	189·4	181·3	18·2	4·8
Carbohydrate	0·0	0·0	0·0	50·2	103·3	0·0	0·0
Ash	3·0	5·6	7·5	32·3	34·9	—	—
Minerals (mg./lb.)							
Sodium	410	210	1,479	2,259	1,884	(504)	1,792
Potassium	85	2,152	56	2,799	2,075	112	144
Calcium	30	18	344	7,089	9,221	59·2	102·4
Magnesium	65	118	150	390	272	105·6	158·4
Iron	42	—	150	29	—	2·7	8·16
Chloride	382	199	1,935	2,670	2,624	363·2	3,040
Phosphorus	450	1,003	1,075	4,839	4,486	1,235	736
Calories (kcal./lb.)	1,973	510	2,352	2,520	2,456	590	640
Water (per cent)	45	72	6	9	5	70	65
kcal./lb. dry weight	3,587	1,821	2,502	2,769	2,585	1,967	1,829

Survey, of 6–8 lb. (2·72–3·63 kg.) for seal meat on alternate days would provide the equivalent of 6,000–8,000 kcal./dog/day. James's (1947) alternative of 1 lb. (0·45 kg.) of Pemmican and 2 lb. (0·91 kg.) of biscuit daily would have provided about 6,000 kcal./dog/day. Adie's (1953) summer ration of 4 lb. (1·82 kg.) of lean seal meat on alternate days would have provided only 1,000 kcal./dog/day and could possibly have accounted for the very low average weight (74 lb. (33·6 kg.)) of his dogs in January 1950 (Adie, 1950).

The values for sledging diets show greater variety. The 2–3 lb. (0·91–1·36 kg.) of dried fish recommended by Hadwen (1937) and Thomas (1939) would have provided between 4,000 and 6,000 kcal./dog/day. The addition of a 2 in. (5 cm.) cube of blubber, which Thomas suggested, would have given a total of between 5,000 and 7,000 kcal./dog/day. It is impossible to make an exact estimate of the calorie intake of Amundsen's dogs, but besides 0·5 kg. daily blocks of Pemmican, there were depots of more than a ton of seal meat for the initial stages of the 3 months' journey, while the slaughter of 31 dogs would have provided more than 2,000 lb. (908 kg.) of fresh meat for the latter part.

TABLE Ic. MANUFACTURERS' SPECIFICATIONS FOR SLEDGING DIETS

	Pemmican	*"Old" Nutrican*	*Nutrican*
Constituents (per cent)			
Beef meal	71	—	—
Whale meat	—	—	24
White-fish meal	—	25	—
Skimmed-milk powder	—	15	15
Pre-cooked maize	—	10	—
Kelloggs corn flakes	—	—	15
Debittered dried yeast	4	5	1
Suet (beef or mutton)	—	25	20
Beef dripping	22	—	25
Margarine (unsalted)	—	20	—
Bone meal	3	—	—
Vitamins			
A (i.u.)	0	1,000	1,000
D (i.u.)	0	600	600
B (mg./100 g.)	0	1·2	1·2
Nicotinic acid (mg./100 g.)	0	9·0	9·0
Riboflavine (mg./100 g.)	0	3·0	3·0
Ca pantothenate (mg./100 g.)	0	2·0	2·0
Pyridoxine (mg./100 g.)	0	0·4	0·4
Ethyl galate (anti-oxidant)	0	0·015	0·015

As Wyatt has pointed out "It is unlikely that the ideal of providing a 1 lb. (0·45 kg.) block of concentrated food which is nutritionally adequate in all respects can be realized". Few except the British have tried to realize it. The diet of Pemmican yielding only 2,400 kcal./dog/day has never been satisfactory but most researchers in the field have looked for faults in the quality of the diet rather than in its quantity.

If one accepts 25–30 per cent protein (dry weight) as the optimum for a dog's diet (Earle, 1939), the protein content of Pemmican (66 per cent) is relatively high and that of Nutrican (25 per cent) is relatively low. The value for fat seal meat (33 per cent dry weight) lies somewhere between, yet dogs fed on both artificial diets lost considerably more total solids and nitrogen in the faeces than did the dogs fed on seal meat (see below). This suggests that processing in some way diminishes the digestibility of the artificial diet and that the very high protein content of Pemmican is not directly to blame for metabolic disturbances.

The importance of fat in the diet, or as an addition to the diet, has been stressed time and again. Amundsen added "fatty substances" to his dried fish; Thomas added tallow, butter or seal oil to meal when fresh meat was not available; and modern sledgers have taken pieces of blubber or margarine to supplement both their own and their dogs' diet. It would seem, both from the present experiments and from previous work (Butson, 1950; Masterton, Lewis and Widdowson, 1957) that fat is appreciated by the individual, whether dog or man, and tolerated by the digestive system in response to hard work in the cold. That dogs travelling hard in winter will need larger quantities of fat and calories than idle dogs in the summer was confirmed by the seasonal variation in the dogs' appreciation of seal blubber, though it has not been possible to demonstrate any selective fat absorption under different conditions during the present experiments.

Carbohydrate has been incorporated into the sledging ration Nutrican. Its value has not been assessed during the present trials, but consideration of the natural diets suggests that protein and fat should form the basis of the ideal diet.

Although Consolazio and Forbes (1946) were unable to show any thiamine (B_1) deficiency in men fed solely on Pemmican, Taylor (1957) found an incipient thiamine deficiency in dogs fed on Pemmican for more than 2 weeks, but there was no evidence to suggest that husky dogs could not synthesize their own requirements of Vitamin C. Massey (1956) has suggested that various deformities in husky pups may have been caused by a deficiency in Vitamin D, and

Bell (1957) wondered if muscular dystrophies, often reported in sledge dogs, may not be the result of the destruction of Vitamin E during the production of sledging diets. Vitamins are now added to the diets of pups and to Nutrican (Table Ic) in quantities which should fulfil a dog's requirements (Earle, 1939), and no evidence of vitamin shortage has been recorded in sledge dogs fed either on modern sledging diets or on seal meat. Ample calcium and potassium are supplied in both the base station and sledging diets, and there is no suggestion that either diet is short of other minerals.

Faecal collection and analysis

24 hr. samples were collected from each dog in certain of the experiments (Table II, Nos. 1, 2, 10 and 11; p. 61). The faeces were preserved and later analysed for total solids, nitrogen and fat.

In these experiments the teams were divided into comparable units in such a way that dogs of the same family and similar initial body weight were fed different diets. In each experiment one unit was fed on Nutrican, while a comparable unit was fed on seal meat, Pemmican or "old" Nutrican.

At the base station and in the field the faeces were collected in labelled polythene bags. While still frozen, each 24 hr. sample was weighed to the nearest gram on a dietary scale, then thawed and thoroughly mixed. A 30 g. aliquot was next dried over a water bath for 10 hr., 10 $cm.^3$ of 90 per cent alcohol being added at intervals to aid evaporation. After re-weighing, part of the sample was stored in an air-tight glass tube for further analysis at Cambridge, where the faeces were dried to constant weight and the total dry weight of the 24 hr. sample was calculated.

Faecal nitrogen was estimated by the micro-Kjeldahl method, at least two estimations being carried out on each specimen. Faecal fat was estimated by digestion with concentrated hydrochloric acid and ether extraction (King, 1946). This estimation was also repeated on all samples.

Variables

Conditions at an Antarctic station or on a sledging journey are not ideal for accurate controlled observations, but during the course of the experiments it was possible to eliminate most of the possible sources of error.

The physical exertion of the dogs varied enormously and depended on whether they were kept static at the base station, exercised in the normal course of station duties, or were travelling hard in the field. Distances, temperatures, snow surfaces, loads, terrain, and the morale of dogs and drivers all added to the variability, but in each experiment comparable dogs were exposed to virtually the same conditions. Some indication of the work done has been derived from the daily distances travelled and the weight of the relevant sledge. Loads comprising more than 140 lb. (63·6 kg.)/dog are termed heavy, those between 90 and 140 lb. (40·9 and 63·6 kg.) are termed moderate, and those under 90 lb. (40·9 kg.) light. The average daily temperature was recorded during each experiment.

When the dogs were weighed certain conditions were liable to falsify the readings on the balance. An excited dog in inexperienced hands tended to struggle, and this made accurate reading very difficult, but most of the dogs became used to the procedure and remained very docile when hung in their harnesses. Drift snow in the dogs' coats and high winds could cause inaccurate readings but these conditions were avoided and readings to the nearest pound were possible on all occasions. Daily weight changes and re-weighings were used as checks and remained remarkably uniform.

The fitness of the dogs varied considerably and it depended on how consistently they had been worked before the start of an experimental period. An initial drop in weight was noticed in each experiment, and so it became the practice to start the experiment after three to four travelling days, during which time the dogs were liberally fed.

Uniform feeding presented no problems when the artificial diets were being used. The feeds were supplied in 1 lb. (0·45 kg.) blocks wrapped in paper. The blocks were normally fed to the dogs with the paper on and the paper was passed unchanged in the faeces. In those experiments where faeces were collected the paper was removed before feeding. In one experiment a dog got off his span and put on 7 lb. (3·18 kg.) overnight at the refuse bucket, but the intakes of the artificial diets were otherwise adequately controlled.

TABLE II. THE EXPERIMENTS

Experiment	*Distance* miles	km.	*Duration* (days)	*Average Temperature* (°C)	*Team*	*Diet* (1 lb. (0·45 kg.)/dog/day unless otherwise stated)	*kcal./dog/day*	*Weighing Frequency* (days)	*No. of 24 hr. Samples of Faeces*	*Notes*
1 (field)	300	483	29	−16	"Huns": 2 groups (*a* and *b*) of 4 dogs	*a*. Nutrican for 17 days Pemmican for 12 days	2,400–2,500	3–6	4	Group *b* initially averaged 2 lb. (0·91 kg.) lighter than group *a*. Travel over difficult surfaces with heavy load
						b. Pemmican for 17 days Nutrican for 12 days	2,400–2,500	3–6	4	
2 (field)	60	97	14	−19	"Terrors": 2 groups (*a* and *b*) of 3 dogs	*a*. Nutrican for 14 days	2,500	3–5	2	Initial average weight of dogs 94 lb. (42·7 kg.). Moderate loads over sea ice and glaciers
						b. "Old" Nutrican for 14 days	2,500	3–5	2	
3 (field)	300	483	14	− 6	"Terrors": 2 groups (*a* and *b*) of 3 dogs	*a*. "Old" Nutrican for 14 days	2,500	—	2	Initial average weight of dogs 84 lb. (38·1 kg.). Faecal specimens lost in thaw. Moderate sledge loads
						b. Nutrican for 14 days	2,500	—	2	
4 (field)	100	161	25	−16	"Komats"	Nutrican + 8 lb. (3·63 kg.) seal on 22nd day, then unlimited seal	2,500	3–4	—	Weighed daily during recuperation. Moderate exertion with moderate loads
					"Terrors"	Nutrican + extra 1 lb. (0·45 kg.) of Nutrican every 3rd day + 8 lb. (3·63 kg.) seal on 22nd day, then unlimited seal	3,500	3–4	—	
5 (field)	90	145	27	−10	"Terrors" and "Komats"	Both groups Nutrican but "Komats" given extra 1 lb. (0·45 kg.) Nutrican every 3rd day. Both given 3 lb. (1·36 kg.) Pemmican (7,200 kcal.) on 23rd day, and extra 1 lb. (0·45 kg.) Nutrican (extra 2,500 kcal.) on 24th and subsequent days	"Terrors": 2,500 basic "Komats": 3,330 basic	Daily on days 1–3 and 24–27, and twice in between	—	Teams travelled together over sea ice and glaciers. Minimum activity with moderate loads
6 (field)	200	322	28	*c*. 0	"Huns"	2 lb. (0·91 kg.) Nutrican for 6 days; 1 lb. (0·45 kg.) Nutrican for 13 days; 2 lb. (0·91 kg.) Nutrican for 9 days; then seal meat	Initially 5,000	3–4	—	Travel over difficult steep surfaces with moderate loads. Weighed daily at beginning and end
					"Terrors"	2 lb. (0·91 kg.) Nutrican for 6 days; 2 lb. (0·91 kg.) Nutrican for 13 days; 1 lb. (0·45 kg.) Nutrican for 9 days; then seal meat				
7 (field)	440	708	22	− 8	"Terrors"	1·5 lb. (0·67 kg.) Nutrican for 17 days; then seal meat	Initially 3,750	—	—	On sea ice and ice shelf. Heavy loads on outward journey, light loads homeward. Travel impossible on 15th-18th days
					"Gangsters"	1 lb. (0·45 kg.) Nutrican for 17 days; then seal meat	Initially 2,500	—	—	
					"Players"	2 lb. (0·91 kg.) Nutrican for 17 days; then seal meat	Initially 5,000	—	—	
8 (field)	400	644	23	−10	"Terrors"	1 lb. (0·45 kg.) Nutrican for 15 days	2,500	Daily	—	
						2 lb. (0·91 kg.) Nutrican for 5 days; seal for 3 days	5,000			
9 (base station)	—		12		"Huns" and "Terrors": 4 groups (*a-d*) of 3–4 dogs	*a* and *b*. 1 lb. (0·45 kg.) Nutrican	2,500	4–6	2	Dogs on tethers or in pens; not exercised
						c. 1 lb. (0·45 kg.) "old" Nutrican	2,500			
						d. 1 lb. (0·45 kg.) Pemmican	2,400			
10 (base station)	—		12	−10 to −23	"Terrors": 2 groups (*a* and *b*) of 4 dogs	*a*. 2 lb. (0·91 kg.) Nutrican on alternate days	2,500	2–4	2	Dogs tethered on clean snow; not exercised
						b. 6 lb. (2·72 kg.) seal meat on alternate days	2,500			
11 (base station)	—		12	*c*. 0	"Terrors": 2 groups (*a* and *b*) of 3 dogs	*a*. 1 lb. (0·45 kg.) Nutrican	2,500	Daily	2	Dogs tethered on clean snow or concrete, but exercised regularly
						b. 3 lb. (1·36 kg.) lean seal meat	1,500			

[*face page 61*

Seal meat was more difficult to feed uniformly. Previously cut lean seal meat in 3 lb. (1·36 kg.) pieces could be fed at the base station easily enough, but it was impossible to cut uniform pieces of meat and blubber from a freshly killed seal at the end of a day's hard sledging while two or three teams waited impatiently. Under these conditions it became the practice to kill and cut up the seal in the usual way, weigh each piece, skin, blubber, bones and all, before it was given to the dog and weigh what little remained the following day. A head or a flipper might migrate mysteriously along the line during the night but as the total weight of seal eaten by the team was averaged this was not considered relevant.

The proportion of seal meat to blubber was very difficult to estimate. It varied with the type and condition of the seal and with the part of the carcass from which the feed was taken, and as fat seal meat yields 2,000 kcal./lb. and lean seal meat only 500 kcal./lb., the calorific value of the feeds could vary greatly.

Faecal collection was possibly the main source of error in the study. Hot faeces melted the snow before freezing and the total sample contained a variable amount of extraneous water and the total dry weight was therefore of more interest than the wet weight. It was easy to collect a well-formed stool from hard frozen snow but the projectile diarrhoea of a Pemmican-fed dog would melt and discolour the snow in as many as 60 patches over a distance of 2–3 ft. (0·6–0·9 m.), each component being little more than a dirty piece of snow. At the base station the dogs could be tethered in pens, so that the faeces could be collected off clean concrete, but the unusual confinement tended to constipate them.

While sledging, the 24 hr. samples of faeces quickly froze in their polythene bags and generally remained in good condition for weighing and drying at the base station. One complete series which had been buried in a snow drift was, however, ruined by a sudden thaw, and another series was discovered and mutilated by marauding pups. In one experiment, problems of travelling over difficult country made it impossible to collect a full 24 hr. sample and one specimen only was collected from each dog.

Coprophagia is a well-known weakness of sledge dogs and the re-digestion of the components of their own or each other's faeces could have made a difference to the more detailed qualitative trials. To avoid this, the dogs were spanned well apart at the base station, and the faeces collected at frequent intervals. During field trials the faeces were collected instantaneously. Defaecation was usually stimulated either by food or by exercise and the dogs rarely defaecated during the night.

The analysis of the faeces under laboratory conditions emphasized the inaccuracies that could arise when working in the field. Paper, gravel and hair were found in a few stools but they did not affect the final results significantly.

Together, the sources of error were rather formidable and because of them some of the experiments had to be abandoned, but 11 experiments, involving 40 dogs and 4 diets, were nevertheless completed; these are listed in Table II. They included over 1,000 weighings and 68 faecal collections.

Results and Conclusions

Weight changes

Dogs travelling 10 miles (16 km.) per day with heavy loads lost weight steadily when fed on routine rations yielding 2,400–2,500 kcal./dog/day (experiment 1).

Group *a* lost 10 lb. (4·54 kg.) on Nutrican then 6 lb. (2·72 kg.) on Pemmican.

Group *b* lost 12 lb. (5·45 kg.) on Pemmican then 6 lb. (2·72 kg.) on Nutrican.

Dogs fed on any ration yielding 2,500 kcal./dog/day lost weight steadily when pulling moderate loads over short distances (experiments 2, 4 and 5) or long distances (experiment 3). Dramatic weight gains followed a more liberal diet (experiments 4 and 5).

Experiment 2: Dogs lost 13 lb. (5·90 kg.) on Nutrican and 12 lb. (5·45 kg.) on "old" Nutrican.

Experiment 3: Dogs lost 10 lb. (4·54 kg.) on "old" Nutrican and 11 lb. (4·99 kg.) on Nutrican, but the rate of loss slowed down when exertion reduced.

Experiment 4: "Komats" lost weight steadily on Nutrican, but gained 3–8 lb. (1·36–3·63 kg.) after a feed of seal (Table III). After 2 days of seal feed they had regained 98 per cent of their initial weight.

TABLE III. EXAMPLE OF WEIGHT CHANGES: THE "KOMATS" DURING EXPERIMENT 4

Day	1	4	7	10	17	22	23	25
Dogs	*Weights* (lb.)							
Flush	78	75	72	72	69	72	79	76
Sleek	92	85	85	81	78	81	86	90
Rover	90	86	85	81	80	81	88	86
Rufus	103	90	94	97	87	90	95	102
Till	98	95	90	88	85	90	93	97
Ranter	97	93	88	90	84	85	93	94
Ringwood	93	86	84	87	79	82	89	93
Average weight	93	87	85	85	80	83	89	91
Average (per cent)	100	94	91	91	86	89	96	98
Feeds	1 lb. (0·45 kg.) Nutrican daily					8 lb. (3·63 kg.) seal meat	Seal meat *ad lib.*	

Experiment 5: "Terrors" lost weight steadily. 5 lb. (2·27 kg.) increase overnight followed a Pemmican feed and 96 per cent of the initial weight was regained. (A 5 lb. (2·27 kg.) weight increase was recorded after an extra 3 lb. (1·36 kg.) of dehydrated food is probably accounted for by an increased intake of snow.)

Dogs pulling moderate loads over short distances maintained body weight on a diet yielding 3,330 kcal./dog/day and gained weight dramatically when fed on large quantities of seal meal (experiments 4 and 5).

Experiment 4: "Terrors" lost weight until the fourth day then became steady. Gained 3–8 lb. (1·36–3·63 kg.) after the first seal feed. After 2 days' seal feed the initial weight was exceeded.

Experiment 5: "Komats" lost weight initially but gained 1 lb. (0·45 kg.) from the sixth to twenty-third day in enforced rest due to bad weather. 5 lb. (2·27 kg.) increase overnight following a Pemmican feed, exceeding initial weight. Weight maintained on extra Nutrican.

For dogs involved in moderate sledging activity, 1·5 lb. (0·67 kg.) Nutrican (3,750 kcal./dog/day) is probably adequate to maintain body weight (experiment 6).

Experiment 6: Teams lost weight on a 1 lb. (0·45 kg.) diet (2,500 kcal.) but gained on a 2 lb. (0·91 kg.) diet (5,000 kcal.). "Huns" were 2 lb. (0·91 kg.) over initial weight on the twenty-ninth day. "Terrors" regained weight by the twenty-ninth day. Little change when teams were fed on seal meat.

For dogs travelling hard (20 miles (32 km.) per day) with heavy loads, 5,000 kcal. was barely sufficient to maintain body weight. As dogs became increasingly undernourished they became more difficult to drive and control (experiments 7 and 8).

Experiment 7: "Players" lost weight until the eighth day. ("Gangsters" on 2,500 kcal. lost 18 lb. (8·17 kg.) in 18 days and "Terrors" on 3,700 kcal. lost weight until the fourteenth day.)

Experiment 8: "Terrors" lost weight steadily on 2,500 kcal. but maintained weight on 5,000 kcal. There was some increase of weight when lying up and on easier surfaces. 96 per cent of the initial weight was regained on a seal diet.

2,500 kcal./dog/day, whatever its source, is barely sufficient to maintain the body weights of idle dogs. An initial drop in weight occurs when the bulky natural diet is replaced by a concentrated diet (experiments 9 and 10).

Experiment 9: Groups *a–c* lost weight initially on a sledging diet but remained fairly steady after the third day. Group *d* lost weight slowly after the third day.

Experiment 10: Both groups lost weight in the first 2 days, then were steady until the ninth day when group *b* resumed loss.

Experiment 11 substantiated previous findings and emphasized the low calorific value of lean seal meat. It also demonstrated that there are dramatic weight gains when a dog rationed on a concentrated diet has access to unlimited food.

Experiment 11: Both groups (on 2,500 and 1,500 kcal.) lost weight sharply in the first two days, then lost steadily. Further results were invalidated by a dog who escaped and gorged at the refuse bucket.

The faeces

The dogs produced faeces characteristic of the diets on which they were fed.

A synopsis of the faecal analyses is given in Table IV. The mean of the components, wet weight, dry weight, faecal nitrogen and faecal fat, have been presented for the different diets.

TABLE IV. MEAN VALUES OF ANALYSES OF DOG FAECES

Food	*Faecal Dry Weight* (g./24 hr.)	*Faecal Nitrogen*		*Faecal Fat*	
		(g. per cent)	(g./24 hr.)	(g. per cent)	(g./24 hr.)
Nutrican (1 lb. (0·45 kg.) daily)	67	5	4	37	25
Pemmican (1 lb. (0·45 kg.) daily)	106	13	14	4	4
Seal meat (6 lb. (2·72 kg.) with blubber *alte die*)	47	6	3	9	5
Seal meat (3 lb. (1·36 kg.) lean daily)	27	6	1	12	3

Nutrican has been used as a control in each of the experiments. Table V shows the intakes, excretions and percentage availability of total dry matter, nitrogen and fat on diets of Pemmican, Nutrican and lean seal meat.

The total wet weight of the faeces varies greatly, the percentage of water largely depending on the amount of snow collected with each specimen.

It is generally agreed that the composition of faeces is not necessarily dependent on the composition of the food eaten. Much faecal matter is the product of bacteria, intestinal secretions and the sheddings from the intestinal mucosa. However, when considering the component parts of the diet, an indication of their availability for metabolism can be gained from the difference between total intake and total faecal excretion. This forms a useful index for the comparison of various diets.

Dogs fed on lean seal meat and fat seal meat passed remarkably little dry matter (27 and 47 g./day) in their faeces, and the total availability was 93–94 per cent. The dry weights of faeces of dogs fed on Nutrican were remarkably uniform (average 67 g./day) and the total availability of dry matter was 85 per cent. The dogs who were fed on Pemmican passed very much more (102 g./day), so that the availability was only 76 per cent dry weight. Taylor's figures for Pemmican-fed dogs give an absorption of 72 per cent (Taylor, Worden and Waterhouse, 1959).

TABLE V. MEAN VALUES FOR INTAKE AND ABSORPTION OF DRY MATTER, NITROGEN AND FAT FOR DOGS FED ON PEMMICAN, NUTRICAN AND LEAN SEAL MEAT

	Pemmican	*Nutrican*	*Lean Seal*
Total dry intake/24 hr. (g.)	427	431	387
Total dry faeces/24 hr. (g.)	106	67	27
Available (per cent)*	76	85	93
Total N intake/24 hr. (g.)	45	15	58
Total faecal N/24 hr. (g.)	14	4	1
Available (per cent)*	70	75	98
Total fat intake/24 hr. (g.)	128	181	5
Total faecal fat/24 hr. (g.)	4	25	3
Available (per cent)	97	87	—†

* Percentage loss in urine is not known, therefore the percentage absorbed will be lower than this figure.
† No estimate for the percentage availability of fat in lean seal meat has been made as it is felt the small amount of faecal fat is probably the product of intestinal sheddings, which as a percentage of the negligible intake would give a false picture.

Estimates for the availabilities of the components of *fat seal meat* have not been made, because it was impossible to estimate the proportion of blubber to lean meat in each feed.

Wyatt's (personal communcation) figures for total excretion are rather lower, especially during the field trials, but he attributed this to coprophagia.

Nitrogen is mainly lost in the urine and only to a minor extent in the faeces. Nevertheless, dogs fed on Pemmican and Nutrican passed 30 and 25 per cent of the ingested nitrogen, respectively. The very striking figure for nitrogen excretion by Pemmican-fed dogs corresponds very closely with Taylor's (i.e. 33 per cent). Dogs fed on seal meat passed only 2 per cent of the ingested nitrogen, although their total protein intake was considerably higher than that of dogs fed on either of the artificial diets. Therefore, it appears that processing in some way renders the protein of the artificial diets less digestible.

The figures for fat excretion are very much more variable. The faeces of dogs fed on either lean seal meat or fat seal meat contained little fat (12 and 9 per cent, respectively), suggesting a high rate of absorption. However, as measurements of the total fat intake with the natural diets are not uniform, a figure for fat availability has not been given.

Pemmican-fed dogs produced faeces containing only 4 per cent of fat. Only 3 per cent of the total fat ingested was excreted, and the availability was therefore 97 per cent. This is identical with Taylor's finding. Dogs fed on Nutrican produced faeces containing 37 per cent fat. 13 per cent of the ingested fat was excreted and the availability was 87 per cent.

DISCUSSION

The problems of dog feeding and dog handling are so closely related that the two must be considered together. Two essentials are needed to get the best out of sledge dogs: good drivers and adequate diets, and if one considers the conquest of the South and North Poles one sees well-fed dogs in expert hands. The South Polar party rode on their sledges for much of the way and the dogs, bursting with energy, were covering 25 miles (40 km.) a day for the last 460 miles (740 km.) of the return journey. The North Polar party made the journey with so little trouble that one of the Eskimos said "the Devil is asleep or having trouble with his wife or we should never have come back so easily". At the other extreme Nansen found his dogs attacking the Pemmican boxes and remarked "hunger is becoming too much for them and Nature is stronger than discipline".

Hunger and a rather savage discipline may account for many of the tales of the husky dog's ferocity which originate in the Arctic. Eskimo methods of feeding and training are very different from those employed by the Europeans: one hears of dogs returning from sledge journeys having to be destroyed because the skin was whipped from their backs; of whip handles being broken over dogs' skulls; and of dogs being hanged until senseless while their back teeth have been filed or knocked out (Bird and Bird, 1939). It is common practice for trappers and Eskimos to turn their dogs loose to fend for themselves in the summer during which time they hunt in packs and become wild, independent and fierce, and they have been known to attack and devour women and children.

On the other hand, British Antarctic Survey dogs are affectionate to man and though fights do occur among the dogs themselves they can usually be attributed to nervousness or bad handling. The security of strong spans and regular feeding may account for some of their relative docility though Bingham commented that the weakening of the wolf strain, so much prized in the north, may account for much of this lessening in fierceness.

The present strain of Antarctic sledge dog, as well as being milder, is also slightly larger than its Arctic forebears. This again could be the product of adequate and regular feeding together with controlled breeding. The Eskimo husky is widely distributed from Alaska to Greenland and local breeds differ in weight, speed and stamina. Though dogs weighing up to 125 lb. (56·8 kg.) have been recorded, the average weight would appear to range between 75 and 85 lb. (34·1 and 38·6 kg.). It was dogs such as these that Peary and Amundsen took on their polar journeys, while Nansen, Borchgrevink, Scott and Shackleton used Samoyed dogs. These little cream and white dogs were bred by the Siberian Sayantsi people and weighed only 35 to 55 lb. (15·9 to 25·0 kg.). Though reports from expeditions suggest otherwise, they have the reputation of being the gentlest of sledge dogs. Taylor gave the average weight of Survey dogs as 95 lb. (43·1 kg.). The 40 dogs used in the present study weighed an average of 94 lb. (42·7 kg.). Weights over 100 lb. (45·4 kg.) usually suggested that the dogs were not getting enough exercise, while weights under 80 lb. (36·3 kg.), except of course in bitches, suggested that the dogs were not getting enough to eat.

Laboratory experiments on the work that may be expected from a dog running on a treadmill showed that a supply of adequate nutrition increased a dog's work output by as much as three times (Dill, Edwards and Talbot, 1932). In one case a dog ran for 17 hr. with 5 min. rest periods during each hour; during this time he covered the equivalent of 82 miles (132 km.) and climbed the equivalent of 14 miles (22·4 km.). The experiments showed that with low external temperatures and an adequate supply of oxygen, water and "fuel" (in the form of glucose) the performance of a dog was virtually tireless.

The present study suggests that a 90 lb. (40·9 kg.) dog will need about 5,000 kcal./day, if it is to maintain its body weight when it is involved in strenuous sledging activity and that, though other factors may play their part, weight loss under these conditions is usually due to a calorie deficit.

For a sledge dog a diet of fresh meat has always been considered the most suitable. With a little forethought this can usually be supplied to the dogs at an Antarctic station in almost unlimited quantities.

The composition of the ideal sledging diet is rather more uncertain and the deficiencies of dogs as a means of transport have often been blamed on to the ration on which they were fed. Thomas (1939), giving details of his own very liberal sledging diet, was not surprised that many Arctic explorers who were feeding their dogs on Pemmican, without the addition of some "oily substance" such as blubber or seal oil, should find them sluggish. Lindsay (1935), talking of long journeys on the Greenland Ice Sheet, said that "there is no great difficulty in driving trained teams 300 and 400 miles [483 and 644 km.] in 3–4 weeks. But after that, when the dogs lose interest and their only desire is for fresh surroundings and more food, then it is the experienced dog driver comes into his own . . . the difficulty is to get the front team to pull ahead." A number of expeditions have had to send a man in front of the dogs to encourage and lead them.

In the present series of experiments it was noticeable that as the dogs lost weight so they became more and more difficult to drive. The "Huns" in experiment 1 and the "Terrors" in experiment 8 deteriorated rapidly; they lay exhausted at halts, were difficult to rouse in the

morning, and only showed signs of animation when they snarled over the possession of a freshly dropped stool. In experiment 7 the "Gangsters", usually a very lively team, became progressively slower and more cussed, while the "Players" and the "Terrors", on a more liberal diet, remained willing and cheerful. Even as a following team the "Gangsters" dropped far behind the other two. These experiences suggest that what has forced men to lead their dogs, or to use the whip as a goad rather than as a guide has been undernourishment. There must be remarkably few times when a well-trained, well-fed team cannot be driven single-handed from behind the sledge.

Successful expeditions in polar regions have always taken great pains to lay depots and arrange support parties in such a way that their dogs have been adequately fed throughout, and this has been facilitated by the use of aircraft and mechanical transport. Nevertheless, the modern ration supplies only sufficient calories to maintain a static dog and barely half the calories needed to maintain a dog working hard. Faecal analyses show that this is uneconomical, since up to 25 per cent of the diet is wasted in the faeces, but Nutrican is better than Pemmican and does not cause the diarrhoea which has been one of the disadvantages of the Pemmican diet. There is, therefore, still scope for research into the production of a ration that is both economical and nutritious.

Figures can be presented to substantiate theories of work output, calorie requirements, intestinal absorption and faecal loss, but no objective criteria are available to standardize the variables which affect a sledge dog's performance. Ultimately, the dogs' performance depends on a sense of security which can only be brought about by consistent discipline, genuine affection as well as adequate feeding.

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