looked like an old-fashioned coachman's cape. New World monkeys seem unhappy if the temperature goes below about 70°F., and like it much hotter.

Exercise

Of course, the more space monkeys can have the better, but healthy monkeys can take an astonishing amount of exercise in a very small space.

General considerations

We have often been told that our success with monkeys was due to detailed attention and fussing, but I do not think that is the whole truth. Monkeys hate to be alone and, if they have no monkey company, demand human company. After her mate died Olive became a pet, but our marmosets were not pets. They were a family group and provided their own society. They had clean cages, not at all large, food, drink, bed boxes and bedding and ultraviolet light; the rest they did themselves. I am sure other equally interesting and attractive family histories, with non-tame monkeys of other kinds, could be obtained by following the same methods.

REFERENCES

Anonymous (1951). *Zoo Life*, **6**, 1.
Hume, M. & Smith, H. H. (1951). *Zoo Life*, **6**, 3.
Lucas, N. S., Hume, E. M. & Smith, H. H. (1927). *Proc. zool. Soc. Lond.* p. 447.
Lucas, N. S., Hume, E. M. & Smith, H. H. (1937). *Proc. zool. Soc. Lond.* A, **107**, 205.
Marshall, F. H. A. (1936). *Phil. Trans.* B, **226**, 423.
Marshall, F. H. A. (1937). *Proc. roy. Soc.* B, **122**, 413.
Rewell, R. E. (1954). *J. Path. Bact.* **68**, 291.

EXPLANATION OF PLATE

X-ray photographs of the wrist of two monkeys.

1. African monkey, Tom, *Cercopithecus* sp. Florid rickets.
2. Congo mangabey, Freckles, *Cercocebus* sp. Severe rickets, 3.iii.1926.
3. Same as 2 but with rickets healed after treatment with ultraviolet light, 20.xi.1926, *post mortem*.

Some aspects of the feeding of dogs and other carnivora

By G. H. Bourne, *Department of Histology, London Hospital Medical College, London E.*1

There are about 20 million dogs in the United States and about 3½ million in this country. The American dogs consume about half a million tons a year of canned food and dry feed, and the importance of domestic animals in Britain's economy has

recently been emphasized by the fact that, for the first time, in this country, expenditure on pet foods has been placed on the cost-of-living index.

The dog was probably man's earliest animal associate and has in fact played a major part in medical discoveries. It is an important experimental subject in physiology departments and was used long ago by De Graaf (1664) for studies on salivary and pancreatic secretion; its use in Pavlov's classical work on conditioned reflexes is well known. From the dog came the first evidence that the pancreas was essential to life (von Mering & Minkowski, 1889). In nutrition the dog is probably best known for the parts that it played in the elucidation of pellagra and rickets.

In the past man probably adopted the dog as a hunting companion and as a camp scavenger. In both capacities the dog undoubtedly received a liberal allowance of entrails but probably very little lean meat. When it hunted itself for small mammals, it invariably ate the whole carcass. All hunting carnivora do so and when they kill a large animal such as a gazelle where it is impossible to eat everything they often rip open the body and devour entrails and organs leaving the rest of the carcass to vultures. It is organs such as the liver and kidney that provide stores of vitamins and accumulations of minerals, and calcium is obtained from the crunching and swallowing of bones.

So long as man remained a primitive hunter the diet of the dog remained adequate, but with the rise of civilization it underwent a progressive deterioration. A dog fed on table scraps and what it can pick up around a big city is never a properly nourished dog—nothing is more pathetic than the miserable *pi* dogs which haunt the villages and cities of the Middle and Far East, and many domesticated dogs in the West are little better. It has been said with a good deal of truth that the nutritional state of a family can be effectively assessed from the nutritional state of its dog.

Dogs and carnivora in general have short digestive tracts in comparison with herbivora; food passes through relatively rapidly, there is limited opportunity for bacterial synthesis of vitamins such as those of the B complex, and it is deficiency of this group and of vitamin D that seems most likely to occur.

In attempting to assess the nutritional requirements of dogs one is faced with the problem of the great variation in size and activity of these animals. In addition the environment will affect at least the calorie requirements, e.g. a dog that has to keep itself warm in an outside kennel, particularly in the winter will burn up more energy than a house dog. A Scottish sheep-dog running up hill and down dale for 100 miles a day has different requirements from a Mayfair lap-dog. The sheep-dog (usually a Border Collie) might be expected to be in robust health, but according to Greig (1956) it often is not. Its principal diet of porridge, usually without milk, is deficient in calcium, nicotinic acid, probably riboflavin and vitamin D (see also Greig, 1953). The wiping out of the rabbit population has probably had a serious effect on the nutrition of these dogs and there seems to have been in recent years an increase, in, for example, the incidence of black-tongue amongst farm dogs. It is of interest that their life-span is short (see Edwards, 1955; Worden, 1955; Burgess, 1956).

No proper survey seems to have been made of the inadequacies of the diet of the laboratory-kept dog although it probably suffers from similar deficiencies.

Calorie requirement

The basal metabolism of a 13·5 kg (33 lb.)* dog consumes about 48 Cal./kg/day (Williams, Riche & Lusk, 1912). Its total energy requirements are, however, about 80 Cal./kg/day, but if given food *ad lib* a dog will tend to eat about 100 Cal./kg/day, which results in the accumulation of fat, so that such intake is in excess of the day's needs. According to Michaud & Elvehjem (1943–4) these figures are similar to those for man. Calorie requirements are of course proportional to the size (see Brady, Procter & Ashworth, 1934), so that, whereas an adult dog weighing 1 kg (2½ lb.) should receive 141 Cal. daily, one weighing 50 kg (125 lb.) requires 49 Cal./kg/day. There is an increased requirement of course for growth, gestation and lactation. Whitney (1949) gives a graph of calorie requirements of dogs (Fig. 1) which gives higher figures than those quoted. Part of the difference may be, however, that the graph refers to 'total' not 'digestible' calories in the food supplied.

Carbohydrate requirement

Although in the wild state dogs consume little carbohydrate, they can be maintained quite well on diets containing 66% sucrose (Michaud & Elvehjem, 1943–4), have no difficulty in digesting cooked starch and will do well on a diet which includes as

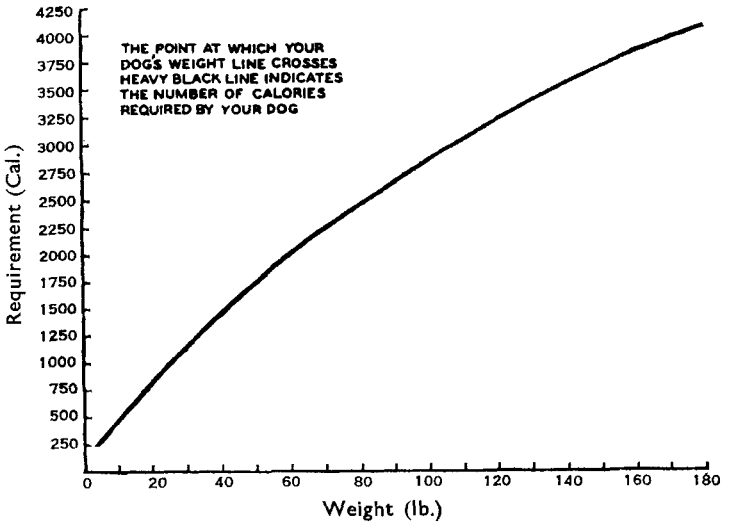

Fig. 2. Calorie requirements of dogs (Whitney, 1949).

much as 50% of it. Since dogs have been maintained for long periods on diets containing only milk powder and minerals it is obvious that they can digest lactose, although if much more than about 5% of it is present in the diet, it will cause diarrhoea (McCay, 1949). It is of interest that McCay has reported that in Florida the feeding of meat and sugar (sucrose) to greyhounds before racing is claimed to have good results.

* Values in lb. are rough approximations.

https://doi.org/10.1079/PNS19570021 Published online by Cambridge University Press

Fat requirement

There is no evidence that dogs require any particular quantity of fat in the diet although some is obviously necessary if only to purvey unsaturated fatty acids and fat-soluble vitamins. There is no evidence, apart from the requirements for these nutrients that either animal or vegetable fat is essential. It is of interest, however, that the amount of fat in the diet affects the hair. With low-fat diets for instance a dog tends to have coarse, dry hair and with high-fat diets the hairs of the coat appear finer and glossier (Michaud & Elvehjem, 1943–4). Whitney (1949) claims that dogs do better if a certain proportion of fat is included in the diet. He suggests chopped or minced suet as a way of adding it.

Protein requirement

According to Rose & Rice (1939) a dog develops and grows normally if the diet provides the following amino-acids: tryptophan, lysine, histidine, phenylalanine, leucine, isoleucine, threonine, methionine and valine. Recent work has added arginine to this list (Madden, Carter, Kattus, Miller & Whipple, 1943).

It is of interest that foxes have been raised in Quebec on a diet containing only vegetable proteins and have produced furs equal in quality to those produced by foxes receiving liberal amounts of animal protein (Michaud, 1940). It has been estimated (McCay, 1949) that a dog needs a minimum of 12–14% of good protein in its diet but Michaud & Elvehjem give a figure of 24% for total protein.

Vitamin requirements

With the exception of vitamin C, most of the known vitamins seem to be required by dogs. Bone deformities, deafness and ophthalmia result from deficiency of vitamin A. The following members of the vitamin B complex are necessary: thiamine, riboflavin, nicotinic acid, pyridoxine, pantothenic acid, biotin and folic acid (Michaud & Elvehjem, 1943–4). Vitamin B_{12}, *p*-aminobenzoic acid, inositol and choline are probably also required, but experimental evidence for this need is

Table 1. *Calorie, protein, vitamin and mineral requirements of dogs*

(Values*/kg body-weight/day, derived from Michaud & Elvehjem, 1943–4)

Calories (Cal.):		Pyridoxine (μg)	10–60
Small dogs	141 (adult)	Pantothenic acid (μg)	100
	282 (pup)	Choline (mg)	10–50
Big dogs	49 (adult)	Calcium (g)	0·02
Protein (percentage of diet)	24	Phosphorus (g)	0·07–0·04
Vitamin A (μg)	20	NaCl (g)	0·03
Vitamin D (i.u.)	10–20	Potassium (g)	0·08
Vitamin E (mg)	1	Magnesium (g)	0·01
Vitamin K	None	Iron (g)	0·0004
Vitamin C	None	Copper (g)	0·00006
Thiamine (μg)	10–25	Manganese (g)	0·00004
Riboflavin (μg)	15–30	Zinc (g)	0·00006
Nicotinic acid (mg)	0·20–0·25	Iodine (g)	0·000001

* Except for protein.

https://doi.org/10.1079/PNS19570021 Published online by Cambridge University Press

lacking. In addition, dogs have been shown to develop signs of deficiency when fed on a purified diet supplemented by a mixture of known synthetic B-vitamins (Schaefer, McKibbin & Elvehjem, 1942; Fouts, 1943; Frost & Dann, 1944). This finding suggests that other unidentified factors, probably members of the vitamin B complex, are required for the adequate nutrition of dogs, particularly since these signs did not occur if the diet was supplemented by dried yeast. Dogs require vitamin D (Mellanby, 1921). The amount necessary is dependent upon age, sex, breed and the calcium: phosphorus ratio; an average value is about 10–20 i.u. vitamin D/kg body-weight/day. The requirement for other vitamins and for minerals can be seen from Table 1.

We have no evidence that the figures quoted for vitamins are optimal. I have seen many dogs fed on meat (beef containing about 25% fat and connective tissue) which seemed in reasonable health, but which when their diets were supplemented with dried brewer's yeast* greatly improved in appearance and vitality. A diet of meat, which is the standard one given in laboratories and many homes and kennels, may be estimated to supply probably an adequate quantity of thiamine, riboflavin and nicotinic acid, but to provide only half the requirements for pyridoxine and pantothenic acid, and it may well supply less than the requirements for other members of the vitamin B complex. One should remember the conception of Williams (Williams, 1942; Williams, Beerstecher & Berry, 1950) of genetotrophic disease which is based on the evidence that there exist through any normal population variations in metabolic efficiency. A functional deficiency may call for an increased supply of a particular nutrient or nutrients. The pattern appears to be highly individual and the amount of any particular nutrient required by one individual may exceed many times that required by others, and since such amounts are rarely present in ordinary diets deficiencies of some nutrients may occur. Such deficiencies may be latent for the greater part of an individual's life and become manifest under conditions of stress, e.g. infection. The striking improvement in some dogs when their diet is supplemented with B-vitamins may be an example of this mechanism in operation.

Conclusion

It appears that the nutrients most likely to be short in the diets of domesticated or laboratory-fed dogs, and this applies to other carnivora in captivity or in a domesticated state, are vitamins A and D, various members of the vitamin B complex, calcium and possibly iron. It is essential therefore that certain supplements be added to the diet of such dogs: these should be cod-liver oil and either liver or dried brewer's yeast. Of the two latter dried yeast is by far the cheaper.

* It will be noticed that I refer throughout to 'dried brewer's yeast' as a dietary supplement. I do so because, contrary to older beliefs, it has now been established that the mammalian digestive tract cannot digest the 'live' yeast obtained, for example, direct from a brewery (Parsons, Williamson & Johnson, 1945; Parsons, Foeste & Gilberg, 1945).

REFERENCES

Brady, S., Procter, R. C. & Ashworth, U. S. (1934). *Bull. Mo. agric. Exp. Sta.* no. 220.
Burgess, H. M. (1956). *Dog World*, 17 August, p. 1341.
De Graaf, R. (1664.) *Disputatio medica de natura et resu succi pancreatii.* Leyden.
Edwards, F. B. (1955). *Vet. Rec.* **67**, 105.
Fouts, P. J. (1943). *J. Nutr.* **25**, 217.
Frost, D. V. & Dann, F. P. (1944). *J. Nutr.* **27**, 355.
Greig, J. R. (1953). *Brit. vet. J.* **109**, 14.
Greig, J. R. (1956). *The Sheep Dog. Management and Feeding.* London: H.M. Stationery Office.
Madden, S. C., Carter, J. R., Kattus, A. A. Jr., Miller, L. L. & Whipple, J. H. (1943). *J. exp. Med.* **77**, 277.
McCay, C. M. (1949). *Nutrition of the Dog.* New York: Comstock Publishing Corp.
Mellanby, E. (1921). *Spec. Rep. Ser. med. Res. Coun., Lond.*, no. 61.
Mellanby, E. (1946). *Brit. med. J.* ii, 885.
Michaud, L. (1940) (quoted by Michaud & Elvehjem, 1943–4).
Michaud, L. & Elvehjem, C. A. (1943–4). *Nutr. Abstr. Rev.* **13**, 323.
Parsons, H. T., Foeste, A. & Gilberg, N. (1945). *J. Nutr.* **29**, 383.
Parsons, H. T., Williamson, A. & Johnson, M. L. (1945). *J. Nutr.* **29**, 373.
Phillips, P. H. & Hart, E. B. (1939). *Science*, **90**, 186.
Rose, W. C. & Rice, E. E. (1939). *Science*, **90**, 186.
Schaefer, A. E., McKibbin, J. M. & Elvehjem, C. A. (1942). *J. Nutr.* **23**, 491.
von Mering, J. & Minkowski, O. (1889). *Arch. exp. Path. Pharmak.* **26**, 3.
Whitney, L. F. (1949). *Feeding our Dogs.* New York: Van Nostrand.
Williams, H. B., Riche, J. A. & Lusk, G. (1912). *J. biol. Chem.* **12**, 349.
Williams, R. J. (1942). *Univ. Tex. Publ.* **4237**, 84.
Williams, R. J., Beerstecher, E. Jr. & Berry, L. T. (1950). *Lancet*, **258**, 287.
Worden, A. N. (1955). *Vet. Rec.* **67**, 173.

Some problems in the nutrition of the baby pig

By D. B. BELLIS, *Unilever Ltd, Food Research Department, Sharnbrook, Beds*

The young pig is almost unique because of its rapid rate of growth, which is comparable to that of the laboratory rat. At birth, the average piglet weighs $2\frac{1}{2}$–3 lb.; this initial weight is doubled within a week and quadrupled in 3 weeks. At the traditional weaning age of 8 weeks, the young animal often weighs about 50 lb. The birth weight is increased about one-hundredfold at 7 months and mature animals may weigh about 600 lb. Such rapid growth makes exacting demands on nutrition and environment and inevitably presents many problems in the artificial rearing of baby pigs.

Composition of colostrum and milk

Perrin (1955) has shown that in the colostrum of the sow, like in that of other mammals, total solids and protein decrease rapidly and lactose increases during the first few hours after parturition (Table 1). Comparison with the milk of other farm animals shows that sow's milk is high in energy and protein, and its ash content is among the highest of those of all mammals (Table 2). As regards the composition of the ash, the transition from colostrum to milk differs from that in other animals, since calcium and phosphorus are low in sow's colostrum and increase steadily