NUTRITIONAL REQUIREMENTS OF DOGS

by Imogene P. Earle [1]

HERE is a discussion of the nutrition of dogs from the theoretical standpoint. It deals with such questions as whether or not they must have an all-meat diet; whether or not they can digest carbohydrates; what are the proper proportions of protein, fat, and carbohydrate in the diet; what their energy needs are in terms of calories; and what are their quantitative needs for minerals and vitamins. The practical feeding of dogs is taken up in a later article.

THE DOG in his natural state was a carnivorous animal subsisting almost entirely on the flesh, bones, blood, and viscera of animal carcasses and living under conditions in which abundant exercise and free access to sunlight, soil, and green leaves played an important part. During the process of his domestication, however, he has had imposed on him a different set of conditions. Generally speaking, the amount of his exercise has been reduced, he has been restricted in his access to sunlight, and his dietary habits have for the most part become those of the omnivores, which live on both animal and vegetable foods.

Under these new and artificial conditions the dog is far more subject to nutritional-deficiency diseases than under natural conditions. Such diseases, in the light of present knowledge, can usually be easily recognized in their acute stages and may be prevented or cured by correcting the deficiency. However, deficiencies so marked and extreme as to produce acute disease undoubtedly occur much less often than partial and perhaps multiple deficiencies which result in lowered vitality, decreased appetite, dull coat, impaired reproductive functions, decreased rate of growth in the young, and other signs of general ill health. These symptoms are such as can be attributed either to infection or to malnutrition and their correlation with feeding practices is difficult.

The nutritive requirements of the dog have received an increasing amount of attention and interest within the past few years. Dog races and dog shows have grown in popularity, and as scientific

[1] Imogene P. Earle is Associate Biochemist, Division of Animal Nutrition, Bureau of Animal Industry.

knowledge of the fundamentals of nutrition has increased, the breeders and owners of racing and show dogs, and of pets and working dogs as well, have become more conscious of the importance of nutrition in the health and performance of their animals. In recent years the preparation of dog foods has grown to remarkable proportions as an industry. The manufacturers are concerned with knowing the composition of adequate rations on which a profit can be made, and in some instances they have carried out experimental work in testing the efficiency of their products in the nutrition of dogs. Veterinarians also have been interested in the proper nutrition of the dog, since they recognize that a large percentage of their canine patients are suffering from ills of nutritional origin.

Although the amount of scientific investigation concerned primarily with the food requirements of the dog has not been great, the dog has been used as a laboratory animal in fundamental nutrition studies more extensively than any other domestic animal. As a result a good deal is known about many aspects of his nutrition such as vitamin requirements, both qualitative and quantitative; bone and tooth formation; and ability to digest and utilize carbohydrates. His energy requirements can be calculated from the standards of Dechambre, as reported by Linton (*687*),[2] and of Brody, Procter, and Ashworth (*157*). While little that is specific is known about his mineral requirements, estimates of his needs for minerals are made on the basis of the requirements established for human nutrition. Information regarding his specific protein requirements is meager, and estimates of his protein needs and of the proportions in which protein, fat, and carbohydrate should be combined in his diet have been based for the most part on the composition of diets that have been found in practice to be satisfactory.

In spite of the results of many studies involving the nutrition of the dog, there is a great divergence of opinion among veterinarians and dog breeders concerning the feeding of dogs. For example, Quitman (*940*) after more than 40 years of veterinary practice in which he states he has treated approximately 50,000 dogs, 20 percent of which were suffering from ills of dietetic origin, has concluded that dogs do best on a meat diet exclusively and that they do not digest starchy or vegetable foods. Spaulding (*1092*), in his paper on the proper feeding of dogs, has stated that 75 percent of dogs have difficulty in digesting vegetables and has recommended a diet in which meat is used in large proportions but is supplemented by cooked cereals in the form of biscuit. He further advised against the use of any sloppy or mushy foods. There is ample support in the veterinary journals for these views regarding the indigestibility of vegetables from the point of view of supplying energy and protein needs. The function of vegetables in the diet as an important source of vitamins and minerals is fairly generally recognized. Some veterinarians agree with Quitman that no carbohydrates in the form of cereals or vegetables should be included in the dog's diet. Many others allow a limited amount of carbohydrate foods, but there is diversity of opinion as to kind and amount. There is, however, fair agreement among the veterinarians that meat is the essential basis of all successful diets.

[2] Italic numbers in parentheses refer to Literature Cited, p. 10 5.7

Contrary to these opinions regarding the indigestibility of vegetables and the inadvisability of feeding sloppy food are the excellent results cited by Linton (*687*), obtained at the greyhound-racing establishments of England where the dogs are fed relatively large quantities of vegetables which are cooked and fed as slop. And in contradiction to the belief that meat is essential to a successful diet are the satisfactory results reported by Cowgill (*233*), Morgan (*813*), and many others from the use of meat-free diets in the laboratory.

An attempt is made here to correlate some established facts concerning the physiology and nutritive requirements of dogs with results of observations on practical feeding that are often seemingly contradictory.

PHYSIOLOGY OF DIGESTION IN THE DOG

The teeth of the dog are typical of those of the carnivores. Food is bolted without chewing and there is no digestion in the mouth.

The capacity of the stomach is quite large in relation to the size of the body and to the capacity of the intestines. The intestines have a little more than half (0.6) the capacity of the stomach in the dog, whereas in the pig they have 2.3 times the capacity of the stomach, and in the horse 11 times.

The stomach of the dog has a powerful muscle (the pyloric sphincter) which normally does not permit passage of partly digested food until gastric digestion is complete; hence digestion in the stomach is somewhat prolonged. The gastric juice is similar in composition to that of man except that it has a higher content of hydrochloric acid and of pepsin.

Gastric digestion concerns principally proteins, since the amounts of carbohydrates and of fat digested in the stomach are unimportant.

In the dog and in the carnivores in general, digestion of carbohydrates and of fats occurs for the most part only in the small intestine, and absorption of food materials is believed to take place largely from the small intestine. The enzymes necessary for completing the digestion of proteins and for the digestion of fats, starches, and sugars are present in the digestive juices from the pancreas and small intestine, but intestinal digestion is of relatively short duration because of the limited capacity of the small intestine. Apparently the chief functions of the large intestine are to permit absorption of water from the undigested food residue and to serve as a reservoir for the waste materials which constitute the feces.

The digestive canal of the carnivores differs from that of both the omnivores and the herbivores in the relative size and capacity of the different sections as well as in their functions. The differences in the relative capacities of different parts of the gastrointestinal tract of three species representing the herbivores, the omnivores, and the carnivores, respectively, are shown in table 1, which has been adapted from Dukes (*285, p. 225*).

The large intestine of the dog is short and of small capacity as compared with that of animals adapted by nature to subsist either wholly or largely on plant foods. The difference extends to function as well as to anatomy. In the dog, the large gut is designed to serve chiefly for storage of a limited and compact bulk of waste material;

it is not suited as a site for the prolonged action of bacterial enzymes, which are considered important factors in the digestion of cellulose and other fibrous constituents of plant foods; and there is probably relatively little, if any, absorption of products of digestion.

TABLE 1.—*Relative capacity of different parts of the gastrointestinal canal in herbivores, omnivores, and carnivores*

Animal and type	Part of canal	Relative capacity	Animal and type	Part of canal	Relative capacity	Animal and type	Part of canal	Relative capacity
		Percent			*Percent*			*Percent*
Horse (herbivore).	Stomach	8.5	Pig (omnivore).	Stomach	29.2	Dog (carvore).	Stomach	62.3
	Small intestine.	30.2		Small intestine.	33.5		Small intestine.	23.3
	Cecum	15.9		Cecum	5.6		Cecum	1.3
	Colon and rectum.	45.4		Colon and rectum.	31.7		Colon and rectum.	13.1
	Total	100.0		Total	100.0		Total	100.0

In the herbivorous animals the case is quite otherwise. The large intestine constitutes a large percentage of the total length and total capacity of the canal and serves an important function in the digestion and absorption of food. In the capacious large intestine of the herbivores with simple stomachs, fermentation and solution of the fibrous portion of food take place during a prolonged period of digestion; foods liberated by the solution of the cellulose membranes of plant cells are digested and products of this digestion are absorbed. The large cecum and colon accommodate a bulky diet and provide for the lengthened period required for the digestion of fibrous foods that leave a bulky residue.

The tract of the dog, being relatively short, is best adapted to a concentrated diet that can be digested comparatively quickly and will leave a nonbulky residue. Foods of animal origin are admirably suited to the digestive physiology of the dog because of the ease and completeness with which they are digested as compared with plant foods, which contain considerable amounts of indigestible structural material.

UTILIZATION OF CARBOHYDRATES

The common belief that dogs do not tolerate a diet containing a high percentage of carbohydrate must be based on some other factor than the inability of the dog to digest starch, for it has been clearly shown experimentally (*579*, *987*) that dogs can digest large quantities of cornstarch either raw or cooked. Starches in the form of cooked rice fed to mature dogs for a period of 15 days in amounts up to 33 calories a day per pound of body weight—an amount sufficient to satisfy total energy requirements—have been found to be 95-percent digested. Further, the dogs so fed suffered no noticeable ill effects from the starch feeding.

Such results as these lead to the conclusion that if dogs do poorly on high-starch diets it is due to some other factor than any effect of the starch itself. In practice, the unfavorable results obtained are probably due to an imbalance of or deficiency in vitamins, minerals,

or proteins, or to the presence of too large amounts of indigestible crude fiber along with the digestible starch and sugar.

In cereals and vegetables the digestible carbohydrates and proteins are contained within cell walls of cellulose and can be acted upon by digestive enzymes only after the cell contents are liberated by the rupture of the enclosing membranes. These cellulose membranes may be ruptured by mechanical means such as grinding, chewing, or application of pressure, by cooking, and by cellulose-splitting enzymes of certain micro-organisms. The delicacy of the cellulose membranes and the ease with which they are broken down vary widely in different plant products and with age, hardness, and the part of the plant used.

The investigations of the digestibility of crude fiber or cellulose by the dog have been reviewed by Mangold (*744*). Some workers have found crude fiber to be almost wholly indigestible, while others have found a considerable degree of digestibility. This variability has been explained by Thomas and Pringsheim (cited by Mangold) as being due to variations in intestinal flora. The dog by nature is without cellulose-splitting bacteria, but under some conditions, after having been fed large amounts of plant foods, he may develop an intestinal flora capable of digesting the more delicate vegetable celluloses.

Mangold (*744*) has quoted some figures obtained by Lössl on the digestibility of fiber of potatoes and of cereals by Fox Terriers. These dogs digested fiber prepared from different sources as follows:

Fiber from—	*Percent digested*
Barley meal	7. 67–33. 53
Potato flakes	15. 37–23. 07
Boiled potatoes	3. 27–86. 83
Rye meal	14. 54–24. 28
Wheat meal	2. 92–87. 52
Rice	25. 24–80. 05

Such wide individual variations with a given carbohydrate can be best explained only on the basis of differences in individual dogs in intestinal flora and in adaptability of the digestive system to an omnivorous diet. Fingerling and Schoeneman (*361*) have suggested that different carbohydrates also differ in the extent to which they are utilized independently of digestibility. Their conclusions were based on results from a group of dogs kept on a maintenance diet of horse meat, which was supplemented by equivalent amounts of several carbohydrates. Different sugars were utilized with equal efficiency but starch they thought was used with greater efficiency than the sugars.

The influence that carbohydrate foods may have on certain phases of mineral metabolism demands attention in a consideration of the place of carbohydrates in the diet of the dog. It has been shown by Mellanby (*778*) that a diet containing just enough calcium and vitamin D to allow normal bone building (calcification) in growing puppies produced rickets when it included a large proportion of cereals. This action of cereals has been explained as the result of a disturbance in calcium absorption due to formation of an insoluble calcium compound in the presence of a high proportion of a compound, phytin, furnished by the cereals. The combination of calcium with phytin (or its split products) apparently occurs, however, only in the

absence of fat, since it has been found that the addition of as much as 11 percent of lard or olive oil will counteract the anticalcifying action of the cereals (*727*).

The advantages of including carbohydrates in the diet of the dog are that carbohydrates are a cheap source of energy, both in initial cost and in the work required of the organism for metabolism; and easily digested carbohydrates reduce the break-down of body proteins. Further, some carbohydrate is required for the metabolism of fat.

Since there is ample experimental evidence that the dog has no difficulty in digesting and using starch and sugar for the production of energy, it may be concluded that the presence of a high percentage of these carbohydrates in the diet is innocuous if the diet is otherwise well balanced as to protein, minerals, and vitamins, and contains sufficient fat, and if there is no excessive amount of indigestible and possibly irritating cellulose.

PROPORTIONS OF CARBOHYDRATE AND FAT

Apparently the ratio between fat and carbohydrate may be varied within wide limits as long as the requirements for proteins, minerals, and vitamins are met. Ivy (*578*) has stated that, if the amount of fat is increased gradually, as much as 40 percent of fat in the diet of the dog seems to be well tolerated. Morgan (*814*) reported excellent results from the use over a period of 2 years of a stock ration containing approximately 24 percent of fat. The ration she used later for puppies contained 11 percent of fat. However, in Linton's (*687*) recommendations for an average diet for adult dogs, 5 percent of fat and 70 percent of carbohydrate are suggested. It has already been pointed out that a certain amount of fat in the diet is important in the absorption and utilization of calcium and phosphorus, especially where the percentage of cereals is high and the calcium and vitamin D content no more than just sufficient. In the light of the findings of MacDougall (*727*) in this respect it seems advisable that the amount of fat, especially for the growing dog, should be not less than 11 percent if the proportion of cereal is high, and less than 40 percent in any case; though many rations containing less than 11 percent of fat are apparently adequate for adult dogs. In rations low in fat it is particularly important that a good source of the fat-soluble vitamins be included.

PROTEIN REQUIREMENTS

The view that meat is the essential basis for all successful dog diets receives its chief support from two facts: (1) Meat is in general easily and almost completely digested, leaving little residue; in this respect it is better adapted to the digestive physiology of the dog than the plant products in which the protein may be enclosed in supporting structures of the plant tissues, which are digested with more difficulty and leave a bulky residue. (2) Proteins of animal origin as a class are undoubtedly superior in biological value to those obtained from plants. There remains to be considered, however, the fact that meat is probably less important in the dietary of the dog than popular opinion indicates.

Proteins are required by any animal body (1) for the replacement

of the tissue proteins, which are broken down in the metabolic processes involved in body maintenance, and (2) for building new tissues in growth and reproduction. Proteins digested and absorbed in excess of these requirements are for the most part used for the production of energy—either stored as carbohydrate or fat, or expended in heat or work. As sources of energy, however, proteins are less efficient than carbohydrates and fats since they require more energy for their metabolism.

The question whether protein in excess of the two requirements mentioned is advantageous or disadvantageous has long been debated. It is believed by some that the metabolism of excess protein places an unnecessary burden on the body as a whole and on the kidneys in particular. At least direct evidence of definite beneficial effects from any large excess of protein seems to be lacking. However, during the growth period an increase of protein intake above the minimum requirements has a beneficial effect under normal conditions.

Studies of the amount of body protein used by the adult animal in maintaining the metabolic processes essential to life have indicated that the amount of protein required for maintenance is the same for all species per unit of surface area and hence increases with body size. The theoretical requirements for growth, on the other hand, are the amounts of protein actually stored as new tissue, and these decrease in proportion to size of the body as the rate of growth slows down. Likewise the protein requirements for lactation and reproduction are determined by the amounts of protein laid down in milk or deposited in the fetus and the tissues associated with gestation.

A measure of the amounts of protein deposited in the animal body as repaired tissues and as new tissues is not a measure of the amount of food protein that will satisfy these requirements, since food protein varies according to its digestibility and its amino acid make-up. The amino acids are the building blocks of which all proteins are different combinations. Proteins from different sources vary in their value to the body—their biological value—according to their efficiency in supplying all the amino acids required for repair and tissue growth in the proportions needed. Thus there can be no fixed minimum protein requirement for any body function except in terms of a specific food protein or combination of food proteins. No protein has a biological value of 100 percent, but the proteins of whole milk and whole eggs occupy the highest rank, and the proteins of liver and kidney are superior to those of muscle meats, which in turn are superior to those of connective tissue. The plant proteins in general are apt to be deficient in one or more of the essential amino acids. Some of these deficient proteins have been found to maintain adult animals when fed in sufficiently large amounts but not to allow growth in the young animals regardless of the amounts fed. Some of the cereal proteins will support both maintenance and growth, but larger amounts are required to accomplish the same results than in the case of animal proteins.

There is evidence that the biological value of proteins is decreased by the application of heat, particularly very high temperatures. This is an important consideration in estimating the value of protein in commercial dog food.

Lössl (*693*) has reported that good growth of puppies can be obtained when the entire protein in the diet after weaning is supplied by either wheat or rye, but still better growth results from the use of meat protein.

When two proteins of unlike amino acid composition are fed, one may supplement the deficiency of the other, provided, of course, that both proteins are not deficient in the same amino acids. Thus good results can often be obtained from a mixture of proteins each of which is deficient or incomplete. It has been shown that rice bran and corn, tankage and corn, lactalbumin and corn, beef and wheat flour, oatmeal and rice, peas and wheat or rye supplement each other. Kidney, liver, and muscle proteins are more highly effective supplements to cereal proteins than to leguminous proteins. In general, mixtures of plant proteins are improved by the addition of some meat protein.

Casein and dried milk have been utilized as protein sources with entire success by many investigators in meat-free diets for laboratory dogs.

It must be pointed out in any discussion of the relative values of animal and plant proteins that a diet in which proteins are supplied largely by plant products is more likely to be deficient in certain of the B vitamins. The feeding of meat and milk products is the simplest way to supply both the protein and vitamin B requirements of dogs, but it is entirely possible with careful planning that the same results may be obtained with a combination of plant foods and their concentrates.

Little study has been made of the effects in the dog of various levels of protein feeding. Results of observations regarding the amount of protein required for maintenance or for growth are usually expressed in terms of percentage of total calories or as the ratio of calories furnished by protein to calories furnished by fat and carbohydrate.

The total amount of protein required, as has been pointed out above, varies with the kind of protein. Melnick and Cowgill (*782*) used a synthetic ration furnishing 70 calories per kilogram of body weight and fed different kinds of protein to determine the minimum amount of each required to maintain a protein balance in the dog's body. The amounts required, as a percentage of the total calories of the diet, were: Lactalbumin 6.9 percent, serum protein 8.6, casein 9.4, gliadin 21.0 percent. Attention is called to the fact that when the wheat protein gliadin was fed as the sole protein three times as much was required as of the milk protein lactalbumin.

Lössl's (*694*) observations indicated that a nutritive ratio of 1:4 (1 calorie of protein to 4 of carbohydrate and fat) is sufficient for growth in small breeds but that larger breeds utilize to advantage a larger proportion of protein (1 calorie of protein to 2.5 calories of carbohydrate and fat). Morgan (*814*) provided approximately 36.3 calories, of which one-fourth were furnished by protein, per pound of body weight a day to adult dogs, and found it adequate for maintenance; for growing puppies the same proportions were used but approximately three times the amount per pound of body weight. From her studies she has concluded that the optimum protein concentration for all dogs probably lies between 25 and 50 percent of the dry weight of the

ration. This protein may be supplied by casein, meats of all kinds, fish, and even cereal proteins.

The protein requirements for reproduction, lactation, and growth are of course much greater than those for maintenance.

Daggs (*247*) has studied the production of milk in the dog as influenced by different kinds of food protein. He has pointed out that relatively high protein diets are beneficial to milk production and that animal proteins are better suited to the synthesis of milk than plant proteins. He used diets constructed according to Cowgill's (*232*) suggestions, which, on a dry-weight basis, contained within a 2- or 3-percent variation for each factor, 25 percent of fat, 40 of carbohydrate, 6 of ash, and 30 of protein. These were supplied to the dogs at the rate of approximately 36 calories per pound of body weight. The protein was supplied from different sources. He concluded that liver was a better source of protein for lactation than eggs or round steak.

Linton has suggested that the average diet for a dog should contain, on a basis of dry weight, 22 percent of protein, 5 of fat, 70 of carbohydrate, 0.5 of fiber, and 2.5 of ash.

ENERGY REQUIREMENTS

The energy requirements of the dog vary widely with size, age, activity, and nutritive condition. It has been shown (*157*) that the maintenance requirements of adult animals for both protein and total energy vary directly with surface area or with the two-thirds to three-fourths power of the body weight. Thus the smaller the dog the greater the maintenance requirements per unit of body weight—assuming energy, external temperature, and nutritive condition to be the same. Young, growing dogs, however, require more food for maintenance, aside from the requirements for growth, than adult dogs. The puppy requires two or three times as much energy-producing food as an adult dog of the same weight.

In addition to maintenance and growth, food must supply the energy used in exercise or work. It is commonly said that the dog should be fed just sufficient to be kept healthy but not fat, since his normal condition is lean. Linton (*687*) has stated that the appetite of the dog cannot be trusted as a guide to the amount of food he requires, and has suggested the use of a table compiled by Dechambre as a suitable guide in estimating the amounts of energy required by adult dogs under different conditions of activity. Table 2 is an adaptation of Dechambre's table as cited by Linton.

TABLE 2.—*Energy requirements of dogs of different weights for maintenance, moderate activity, and great activity*

Weight of dog		Total calories for—			Weight of dog		Total calories for—		
		Maintenance	Moderate activity	Great activity			Maintenance	Moderate activity	Great activity
Kilograms	*Pounds*	*Calories*	*Calories*	*Calories*	*Kilograms*	*Pounds*	*Calories*	*Calories*	*Calories*
5	11	520	680	860	27	59.4	1,550	2,060	2,620
10	22	855	1,140	1,440	40	88	2,020	2,670	3,400
15	33	1,080	1,360	1,680	50	110	2,330	3,085	3,930
20	44	1,265	1,665	2,120	60	132	2,640	3,490	4,450

Contrary to the usual opinion in regard to the unreliability of the dog's appetite as an index of his requirements, Cowgill (*234*) concluded from some experiments that, when all dietary essentials are offered in sufficient quantity and there are no pronounced mental influences operating, dogs will voluntarily adjust their food to their energy needs. The amounts of food consumed by the experimental dogs during periods of nutritive adjustment under the conditions of his experiments were such as to furnish 64 calories per square meter (1.196 square yards) of body surface per hour. This corresponds roughly to 32 to 36 calories per pound of body weight per day for dogs weighing approximately 15½ pounds.

Slightly higher values for maintenance requirements have been reported by Giuliani (*448*), who concluded from his experiments that 22-pound dogs need 40 calories per pound per day, while dogs weighing 110 pounds require only 22 calories.

MINERAL REQUIREMENTS

The mineral requirements of the dog are usually estimated on the basis of requirements established for human nutrition. Arnold and Elvehjem (*35*) have suggested the following amounts as the probable requirements of the adult dog for the 11 minerals that are at present considered essential:

Minimum suggested requirement per pound of body weight per day

Mineral	*Gram*	Mineral	*Gram*
Calcium	0.009	Phosphorus	.018
Sodium chloride	.136	Zinc	.000027
Copper	.000027	Potassium	.036
Iron	.00018		
Magnesium	.0045		*Microgram*
Manganese	.000018	Iodine	.45

Aside from the added salt (sodium chloride) required for rations containing a large proportion of plant products, if natural plant and animal foods are fed, probably the only minerals that require special consideration are calcium and phosphorus. These two make up about 14 percent of the total weight of the bony skeleton, and this 14 percent contains approximately 99 percent of all the calcium and 80 percent of all the phosphorus in the body. It is readily seen that during the growing period when bone is being laid down rapidly there is a greatly increased requirement for these structural elements.

A deficient supply of calcium or phosphorus in the diet of the growing animal, or an interference in their absorption and metabolism, results in malformation and poor development of bones and teeth. Any disturbance in mineral metabolism that results in abnormal calcification of the growing bones is usually termed rickets. This condition may occur as the result of low calcium, low phosphorus, or a deficiency of vitamin D.

Morgan's (*814*) observations have indicated that rickets in dogs is usually of the low-phosphorus type. This is probably related to a faulty utilization of phosphorus rather than to a deficiency in the phosphorus content of the diet, since, when natural foods are used, low-phosphorus diets are less likely to be encountered than low-calcium diets. A ration consisting of a large proportion of muscle meat

alone or of muscle meat and cereals is apt to be deficient in calcium. This deficiency may best be compensated for by the addition of bonemeal, ground bone, milk, or calcium phosphate.

VITAMIN REQUIREMENTS

Vitamins have been largely described in the past by the diseases resulting from their absence. It is being recognized more and more that many of the subacute symptoms of general unfitness in dogs may be attributable to an inadequate supply of one or more of these essential food factors.

VITAMIN A

Symptoms of advanced deficiency of vitamin A in dogs are an eye disease with resulting impaired vision, inflammation of the conjunctiva, or mucous membrane which lines the eyelid, and injury to the mucous linings of the body. Less easily recognized symptoms are an apparent lowered resistance to bacterial infection, especially of the upper respiratory tract, retarded growth, and loss of weight.

Diseases due to vitamin A deficiency may be well established while the animal is still gaining in weight. In recent years Mellanby and others have drawn attention to the occurrence of nerve lesions in animals receiving diets deficient in vitamin A. Lack of muscular coordination and paralysis have been observed in dogs, and in many cases degeneration has been demonstrated in the central and peripheral nervous systems. Mellanby has suggested that local infection may be the result of such nerve lesions. Recently Mellanby (*779*) has found that young dogs kept for some months on diets deficient in vitamin A become deaf.

The daily requirements of the dog for vitamin A have been estimated at various figures between 10 and 36 International Units per pound of body weight per day.

Good sources of vitamin A are fish-liver oil, liver, green leaves and other green vegetables, kidney, heart, tomatoes, carrots, cheese, eggs, butter, and milk.

VITAMIN B_1 (THIAMIN)

Vitamin B_1 deficiency in the dog is characterized in its early stages by retarded growth or loss of weight and decreased fertility. There are also loss of appetite and impaired digestion. In advanced stages the animal is paralyzed, there is an accumulation of fluid in the tissues, and death eventually occurs apparently from heart failure.

Vitamin B_1 is partly destroyed by heat at temperatures beyond 100° C. (212° F.), especially in the presence of alkali. Canine daily requirements have been estimated at approximately 3 micrograms of the crystalline vitamin B_1 per pound of body weight.

Important sources of thiamin are yeast, the germ and outer husks of grain, liver, milk, eggs, carrots, and tomatoes.

RIBOFLAVIN

The water-soluble, heat-stable vitamin, riboflavin, of the vitamin B complex, is essential to the dog for growth and for the maintenance of a healthy skin. Street and Cowgill (*1107*) have estimated that 11.3 micrograms a day per pound of body weight will maintain a dog

in health for an extended period. Early deficiency symptoms are a variable dermatitis; advanced cases are terminated by death following collapse.

Liver, kidney, yeast, and milk, particularly the whey, are rich sources of riboflavin. This vitamin has a wide distribution in plant as well as in animal foods.

NICOTINIC ACID

This water-soluble, heat-stable factor is widely distributed in animal tissues and occurs in much lower concentrations in plant foods. A deficiency of the factor in the diet of the dog results, in its milder forms, in a loss of appetite and of weight; in acute stages, in the canine disease called blacktongue, followed by death. Sebrell and his associates (*1022*) found that a semiweekly dose of 10 milligrams of nicotinic acid is ample to prevent blacktongue for at least 6 months, the duration of the experiment. A daily allowance of 2.2 milligrams per pound of body weight has been estimated as more than sufficient to supply all requirements.

Good food sources are meat, yeast, fresh or canned milk, eggs, and peanut meal. Experimental work with canine blacktongue, which is analogous to human pellagra, has shown that canned mustard greens, canned turnip greens, and canned spinach are fair sources of nicotinic acid; and 6½ ounces of cooked rabbit meat, 6¾ ounces of smoked pork shoulder (cooked), or 11½ ounces of canned chicken fed daily in 2,400 calories of an otherwise blacktongue-producing diet protected the dog from the disease (*1024*).

VITAMIN C

Although there are some reports of spontaneously occurring cases of scurvy in dogs that have been cured by the feeding of good sources of vitamin C, it is believed that the normal dog can synthesize this vitamin in his own body.

VITAMIN D

An adequate supply of vitamin D is essential for the proper development of bones and teeth. This factor serves as a necessary regulator of the absorption and metabolism of calcium and phosphorus. A deficiency of it results in rickets or osteomalacia (late rickets) even though the diet contains adequate amounts of calcium and phosphorus. In the presence of adequate amounts of calcium and phosphorus, ½ to 1 International Unit per pound of body weight per day is sufficient to protect a dog from rickets. The best sources are sunshine, fish-liver oils, irradiated ergosterol, and egg yolk.

Experiments with very large doses of irradiated ergosterol have shown that a condition of "hypervitaminosis" characterized by the deposition of calcium in the arteries and organs can be induced. The range between the body requirements and the harmful dose is wide, but the possibilities of overdosage should be kept in mind.

Morgan has recommended for young pups and pregnant bitches ½ to 1 tablespoonful per day of cod-liver oil or other vitamin D-containing oil. Adult dogs living out of doors probably do not need extra vitamin D except in pregnancy.