ALL CLASSES of domestic animals are alike in that they eat forage in some form. They differ, though, in the extent of their use of grass and such crops. Dog foods may contain small amounts of alfalfa leaf meal; poultry diets include forage meals to supply vitamins, minerals, and proteins, and increasing emphasis is placed on pasturage for poultry flocks; swine consume much more herbage; and horses, goats, sheep, and dairy and beef cattle sometimes get all their feed from forage.

This difference rests on differences in their digestive systems and ability to handle the bulky forages, which have a relatively high content of celluloses, lignins, and other carbohydrate materials that are not readily attacked by the enzymes of the digestive tract. Micro-organisms in the digestive tracts of cattle, sheep, goats, and horses secrete enzymes that can break down celluloses, but the lignins seem to be left relatively untouched.

Also, quite apart from the matter of bulkiness, the cell walls in the plants resist digestion, and so affect the ability of swine and poultry, for example, to make full use of the proteins, fats, minerals, and even the vitamin factors within the cells. In other words, horses, cattle, and sheep have special advantages in utilization of forages not shared by single-stomach animals such as swine.

The first need of animal life is for heat and energy, and the central chemical element is carbon. Carbon occurs in starches, sugars, and other carbohydrates, fats and oils, proteins, and even in plant pigments and the vitamin compounds. Depending on the animal's digestive capacity, the forages are therefore prime sources of energy by which to maintain life, grow, secrete milk, perform work, and reproduce.

Protein is next. Growing animals, which are building their muscular structure, need more protein than mature, resting animals. Likewise the growth of wool, the formation of milk, and the development of the fetus call for a relatively high intake of protein. These varying requirements for protein (which cut across the varying percentages of proteins in forages) produce a situation in which the animal may sometimes fail to eat sufficient forage to obtain enough protein to meet the requirements. In such a case retardation must result, whether it be production of wool or of the muscle structure.

Proteins are complex substances that are built up from amino acids. The twenty-odd amino acids are the channels through which food protein
passes in the body in the transformation to the proteins formed by the animal and built into muscular framework, milk, eggs, wool, hair. About 10 of the amino acids known to science are essential to man, and probably to poultry and swine. Apparently the micro-organisms that grow in the rumen of cattle and sheep can build up these essential amino acids to the benefit of the host. Accordingly, the amino-acid make-up or quality of the protein in forages is not highly important to cattle and sheep. Poultry and swine, although quality of protein is important to them, do not subsist on forage to such an extent as to make the matter of much importance.

The mineral elements generally considered essential to animal life include calcium, phosphorus, magnesium, sodium, chlorine, iodine, iron, copper, manganese, sulfur, zinc, potassium, and cobalt. The actual needs of the several classes of farm animals for a number of the elements have not been demonstrated for a certainty, however, because of their occurrence in animal tissues and in feeds in very small amounts.

The content of the more common minerals in the body can be illustrated by data on steers. Expressed as percentages of the fat-free body, the approximate figures are: Calcium, 1.33; phosphorus, 0.74; potassium, 0.19; sodium, 0.16; sulfur, 0.15; chlorine, 0.11; magnesium, 0.41; iron, 0.013.

From the standpoint of forages and their supply of these eight mineral elements, the principal concern in animal feeding is in calcium, phosphorus, sodium, and chlorine. Skeletal growth depends largely on an adequate supply of calcium and phosphorus. Sodium and chlorine, which together form common salt, are constituent parts of body tissues and fluids. Iron, cobalt, and copper are generally associated because of their roles in blood formation. Iodine is needed in the normal functioning of the thyroid gland. Other than the needs of poultry for manganese, little is known about the functions and requirements for manganese and zinc in other livestock. On the other hand, too much of certain substances—selenium and fluorine, for instance, can have harmful effects.

Even greater extremes exist in the requirements of different classes of animals for particular vitamins. Problems also arise from the differences in the disappearance of the vitamins in successive stages of ripening of the forage and in the ways the harvested crop is preserved and stored.

Only two vitamins, A and D, are known to be required by cattle, sheep, and goats. For horses, it appears that riboflavin and pantothenic acid need to be added to the list. For swine, thiamine, nicotinic acid, pyridoxine, and choline are certainly needed. The list for poultry must also include biotin, vitamin E, and vitamin K. These differences, as they concern the so-called vitamin-B-complex factors, are related largely or entirely to the activities of the micro-organisms in the digestive tracts of animals.

General Feeding Values

It follows from the long history of the reliance of different livestock on grassland crops for their food supply that forages in general must supply these necessary feed nutrients. In the unraveling of the details about individual items, it has become evident that the exceptions to this generalization account for much of the failure to obtain best performance in our livestock. In many parts of the world in many ages, people have learned to avoid troubles with their flocks by moving them from one area to another. Restrictions of feed supplies in one way or another have brought about conditions conducive to many of the nutritional deficiencies that confront us today. In the main, grassland crops do supply those nutrients that animals require—within the limits, of course, to which different kinds of livestock are naturally adapted to utilize forage.

The energy supply on which life so
heavily depends can be obtained readily enough from forages, providing a few conditions are met. These include an adequate supply, reasonable palatability and digestibility, and adequate quality. A cow that has to search over 40 acres of range for a few pounds of grass may not be able to obtain the needed energy to maintain weight. Likewise, consumption of 30 pounds of dry forage of low digestibility may not support life so well as 15 pounds of a highly digestible forage.

This difference in feeding value is determined markedly by seasonal and climatic factors. Furthermore, it is often more accentuated on ranges than in pastures. The growth of most range grasses in the South, for example, re- vives early in the spring, and the plants grow and mature comparatively rapidly. The peak in their feeding value is passed even by the beginning of summer. In the drier sections of the West, somewhat similar conditions exist with slower rates of growth and later maturity in the northern zones. Thus a wide difference in feeding value may exist on a given range at different times of the year.

On the average, cattle and sheep can digest and assimilate approximately 60 pounds of feed nutrients for every 1.00 pounds of dry matter in forages. In other words, 100 pounds of dry matter yield about 60 pounds of total digestible nutrients.

Some variations from this figure are of interest. For example, young plant growth generally yields more than older, more mature growth. Pasturage generally yields 3 or 4 pounds above the 60-pound average; hays and silages yield 2 or 3 pounds less. The approximate equality of hays and silages and the near 10-percent superiority of tender green material in total digestible nutrients is borne out, in the usual case, in actual production of livestock and livestock products.

A 600-pound steer that gains an average of 1.4 pounds daily needs about 8.5 pounds of total digestible nutrients. In terms of timothy hay with a dry-matter content of 90 percent, this is 16.3 pounds. On pasture, the steer must eat nearly 67 pounds when the dry matter is as low as 20 percent.

That is not to say, however, that wide differences in available energy or total digestible nutrients do not occur within classes of forages, whether pasture, silage, or hay. The studies of E. W. Crampton and others in eastern Canada give evidence that the digestibility of the dry matter of pasture herbage may drop from a high value of 80 percent in the early spring to 60 percent and less in midsummer. Significant changes occur in chemical composition, of course.

But Dr. Crampton's work, which discloses the lack of positive and high correlations between the data on composition and digestibility, shows that we cannot trust ordinary data on chemical composition as indices of digestibility and (still more important) of feeding value. From the practical, economic standpoint, the results emphasize the great need for further studies to find some constituent that can be determined chemically and that can give more reliable information on the digestibility of forages.

These studies on composition and feeding values suggest, however, that increasing the ratio of leaves to stems may be associated fairly well with increasing the digestibility. Possibly not enough attention has been given to the usefulness of forages with a maximum leaf content. We have realized for some time that leafy hays were much more valuable than those with a high content of stems. Much of this advantage has been attributed to the content of protein, minerals, and vitamins. Typical figures on the digestible nutrients of alfalfa leaves (dry-matter basis) may reach or surpass 65 percent and for alfalfa stems may fall to 46 percent or less. It thus appears that available energy may be the more important factor in many instances.

It has been estimated that forages supply approximately 60 percent of the protein consumed by livestock. Of
that amount, pasturage and range supplies about two thirds; hays, silages, and other harvested forages supply the other third. The other 40 percent of protein consumed is obtained from the concentrate feeds.

**Protein Supply in Forages**

A point of great importance is the deficit between the protein an animal actually consumes and the amount it needs for most efficient production. Taken all in all, the estimated deficit is an imposing figure, but it is actually only about 10 percent of the total requirement. This interesting situation suggests the potentialities of forages in cutting down this country-wide deficit. The possibilities are greatest in the case of cattle, sheep, goats, and horses and least with poultry and swine.

Despite the large contribution made by forages as a group in furnishing protein, grasslands do not always supply the needed amounts to livestock. Grasses as a class generally contain adequate amounts during the early growing period, but the proportion declines as plants mature. The proteins in forages also vary considerably in digestibility. Average figures obtained in tests with cattle show 63 percent digestibility for the protein in green grasses, 75 percent in green legumes, 54 percent in grass silages, 66 percent in legume silages, 52 percent in grass hays, and 67 percent in legume hays. Later articles also treat this subject.

Using the example of a 600-pound steer with a requirement of 0.9 pound of digestible protein, we can estimate that 1.73 pounds of original grass hay protein must be consumed to meet the daily needs. In terms of timothy hay, 23 pounds may be required, compared to the 16.3 pounds calculated to meet the energy requirement. For a legume hay the situation is reversed, however. The same is true for pasture grasses where the amount needed for energy is more than sufficient to supply the protein. Indeed, young grasses may supply a considerable surplus of protein not only through high content in the dry matter but also through higher digestibility. Admixture of legumes, of course, accentuates the situation.

On pastures and ranges after the forages have matured or have passed into the dormant stage and weathering has leached out some of the nutrients, livestock often need supplementary protein feeds especially where legumes are absent. On Southern forest range, the protein and likewise the phosphorus content is adequate during the spring months but goes down during early summer. Accordingly, the most profitable use from the new growth is obtained during the spring. During much of the rest of the year, protein supplements can be used to advantage. Fortunately, cottonseed cake not only supplies protein but phosphorus as well. Sometimes supplementary pastures that contain grasses with different growth habits can be used to lessen or remove the needs for protein concentrates. In some places, legume silages and hays are used to good advantage as supplements, or the livestock are removed from the pasture or range and fed entirely on harvested crops.

**Mineral Supply**

The forages generally can meet the full needs of animals for the necessary mineral elements. Possible exceptions are sodium and chlorine. As with proteins, however, unhappy combinations of high demands of particular animals and low yields from some forages may be serious deterrents to maximum performance of the animal. For example, a low calcium content in a native range may lead to poor skeletal development with weak, easily broken bones or simply to a retardation in growth as a whole. Instances of low calcium content in forages are not common. The situation in the Southern forest range may be cited, however, where a moderate deficiency often exists during the winter months.

Recent research work has brought out the interesting situation of region-
PLUS AND MINUS: AN OVER-ALL VIEW

alized deficiencies and excesses of minerals in the forages (and other crops as well) that are due to soil and other closely related environmental factors. Thus certain areas of low feed phosphorus content predispose cattle and sheep to phosphorus deficiency. Other areas are associated with iodine, iron, copper, or cobalt starvation, as the case may be.

Under the leadership of the United States Plant, Soil, and Nutrition Laboratory in Ithaca, N. Y., this information on regional aspects of mineral nutrition has been brought up to date. Phosphorus deficiency is common in the Pacific Northwest and the Rocky Mountain States and the area extends eastward to northern Michigan. It is also common along the Gulf coast and in the Appalachian Mountain area. The States bordering on the Great Lakes and extending westward through the Northern Great Plains and Intermountain States are recognized as deficient in iodine in varying degrees.

A deficiency of calcium, as we said, is the exception rather than the rule in the forages of continental United States. Iron, copper, and cobalt deficiencies occur at various places in the Atlantic Coastal Plain. Investigators in Florida have given the subject special attention. Cobalt is low in forages grown in certain districts of New Hampshire, Wisconsin, and Michigan. Selenium excesses occur in various places in the Northern Great Plains and Rocky Mountain States. In many instances these abnormal areas are relatively small. Much remains to be done in determining the relation of forage composition to animal health and the mapping of the entire country as to its importance in animal feeding. But one should not get the idea that the country as a whole or forages as a class offer any special hazard to livestock farmers. On the whole, forages, especially where there is variety in species composition, provide the mineral elements needed by most livestock most of the time.

In connection with species, composition, and the desirability of using grass mixtures, a recent contribution from the Plant, Soil, and Nutrition Laboratory in Ithaca illustrates some of the characteristic differences which can be expected to occur in mineral content of different grasses. Analyses for phosphorus, cobalt, manganese, and copper on 17 species of grasses grown under similar conditions on the same kind of soil showed a marked trend for certain ones to be high and others low in this group of mineral elements. Kentucky bluegrass was in the high group, Dallisgrass, orchardgrass, Johnsongrass, and redtop were in the intermediate class, and timothy was in the low class.

Vitamin Supply

Green forages in the form of pasture provide a very reliable source of the known vitamins with the possible exception of vitamin D. Since this factor is supplied through sunshine, animals on pasture are not likely to suffer any shortage. Carotene is so abundant in succulent green grass that as little as a pound of Kentucky bluegrass will supply the requirements of a 600-pound steer.

The main difficulty arises when the forage matures and becomes brown and weathered. A point may be reached in late winter when a full feed of this dry and weathered grass does not supply sufficient carotene for cattle and sheep. The better hays while they deteriorate progressively are fully adequate for a year and sometimes more. Hays, along with silages, provide the most dependable source of vitamin A for fattening cattle and sheep in the feedlot. Some feeders have tended to rely too much on yellow corn and too little on reasonable-quality forage, with resulting cases of vitamin A deficiency in their cattle.

Forages supply significant amounts of the various B vitamins in livestock rations. They are not so important to cattle and sheep as to swine and poultry because of the apparent synthesis
either in the body tissues or in the rumen by micro-organisms. Recent evidence appears to show that calves do need certain factors, biotin for one, in their feed supply, and forages, especially pasture, certainly supplement the milk supply for suckling calves.

The thiamine content of the dry matter in green grass or well-cured hay is equivalent to that in cereal grains and legume seeds. The riboflavin content is definitely higher and nearly equal to that in milk byproducts.

The nicotinic acid content is comparable to that in seeds and milk by-products. Pantothenic acid, like riboflavin, is higher in forages. The tocopherols (vitamin E) are also abundant in green forages. Other known vitamins and other unidentified nutrient factors are likewise present.

Many of these factors decline in content as the plants mature or are partially destroyed during the making of hay. Nevertheless, ordinary hay is generally a valuable and dependable source of such factors as riboflavin, thiamine, and nicotinic acid.

**Classes of Forages**

The livestock man has appreciated some of the differences as reflected in feeding value for many years. From the standpoint of energy or over-all feed value, grasses and legumes yield up their constituents about equally well. In other words, an animal obtains about as many pounds of total digestible nutrients from 100 pounds of grass as from legume.

There is a considerable difference in protein, however, as already mentioned. The protein content of legumes is normally the higher and more digestible thus making this class of forage much the more valuable from the standpoint of protein. The composition of the proteins with respect to amounts of essential amino acids has not been studied in much detail as yet. The available data do not suggest much difference between grasses and legumes. As compared to corn, the forages appear to have the advantage in content of arginine, lysine, and tryptophane, at least.

The legumes have another advantage in their relatively high content of calcium. The forbs are often well supplied with calcium also. There is not much choice between the several classes of plants with respect to phosphorus. There are some individual species of both grasses and legumes which appear to possess the power to take up and build into their cellular structure more of certain specific elements than do others. The diverse nature of grass and legume species offers many points of contrast fully as important within the class as between. Especially important are the contrasts in plants growing in cool versus hot weather and dry versus humid climate.

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