SOME EFFECTS OF NUTRITIONAL LEVELS

by Paul E. Howe [1]

THE different parts of the body develop at quite different rates at different periods in an animal's life. By raising or lowering the general level of nutrition, it is apparently possible to vary these rates considerably, producing animals with very different characteristics. This explains the production of "bacon type" and "lard type" hogs from animals with the same genetic constitution. Here is a brief account of new experimental work on this line which is significant for livestock producers.

ADEQUATE nutrition is necessary to the full development of the inherited characteristics of animals (and man also, of course). Various factors other than accident or disease interfere with or modify the inherited possibilities of an individual. Development may be modified to a considerable degree by nutrition; hereditary defects may interfere with the utilization of food, although physical development may become normal when these defects are overcome; good nutrition may mask hereditary characteristics or defects; psychological, physiological, or pathological conditions may interfere with the taking of food or its utilization.

The kind and rate of feeding has such a marked influence on the physical development of animals that it is necessary to define normal growth and physique before attempting to discuss the modifying effects of nutrition. In man, the objective of good nutrition is a strong healthy body capable of meeting the vicissitudes of a long life. The requirements for domestic animals, on the other hand, vary according to the purposes for which they are kept. Long life and good reproductive ability are important factors in animals used to replenish their respective species. Such animals are also used for productive purposes—for example, cows and goats for milk production, sheep for wool production, and horses for work. For animals that are fattened for food, however, long life is not so important as is the rapid development of flesh—muscle and fat.

The growth and development of the body, as measured in terms of

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height and weight, is a fairly regular process, accelerated shortly before birth and at the time of puberty, with a gradual slight regression during adult life. The development, however, is a composite of changes that occur at different rates in different parts of the body. Certain parts develop earlier than others. The results of work in Cambridge, England,[2] indicate that the various tissues and anatomical parts of the body have a definite order and proportion in development. The limbs develop relatively early, with the fore limbs developing slightly earlier than the hind limbs. The latest development occurs in the middle of the back. There is a marked differential growth of the skeleton, muscle, and fat. The skeleton makes a greater proportion of its growth earlier in life than does muscle, and muscle earlier than fat. There are likewise differential growth relationships in these tissues. In the skeletal units the direction of development is from the head to the trunk. The bones of the limbs develop from the feet toward the body. Muscle and fat surrounding the various skeletal units show a similar type of differential growth, and develop latest over the loin. The body organs show a marked differential growth; the parts essential to life processes and body functions are relatively well developed at birth and make a smaller proportion of growth after birth than the less essential tissues. The organs that function primarily or largely as stores of nutrients, such as muscle and fat, show little development until the later stages of growth.

The nutritional status of the body determines to a considerable extent the rate of development. Abundant nutrition permits the maximum expression of inherited characteristics, while undernutrition results in retarded development. An interesting example of the effects of different rates of feeding is shown in some experiments of McMeekan and Hammond on the development of swine fed in different ways to the same final weight.

Young pigs of similar breeding were individually fed the same feed in such a way that they gained weight at predetermined rates until they weighed 200 pounds, as follows: (1) Rapidly throughout (high-high); (2) rapidly at first, then slowly (high-low); (3) slowly at first, then rapidly (low-high); and (4) slowly throughout. Up to 16 weeks of age there were 2 groups, low plane (3 and 4 above) and high plane (1 and 2 above), which were then divided to give a rapid and a slow rate of gain for animals selected for each group. The plan of experiment and rates of gain are given in figure 1. When the pigs were 16 weeks old a certain number of the animals were slaughtered and the weights of the organs, of various anatomical parts, and of the muscle, fat, and bone of the parts were determined. Similar observations were made when the remaining animals reached 200 pounds body weight.

The following summary of McMeekan and Hammond's work indicates the effect of variation in rate of development on the characteristics of the pigs and the possibilities of modifying body characteristics by changes in nutrition:

By making the growth curve rise quickly (high plane) instead of slowly (low plane) certain parts and tissues of the body are made to develop more quickly

[2] Unpublished results of C. P. McMeekan and John Hammond. Presented in part by McMeekan in the Proceedings of the American Society of Animal Production, 1938. Data presented here with the permission of Professor Hammond.

than others. For example at 16 weeks old (fig. 2) the weight of the loin in the high-plane pigs was 450 percent of that in the low-plane pigs, while the weight of the head was only 209 percent. Similarly the weight of the fat in the high-

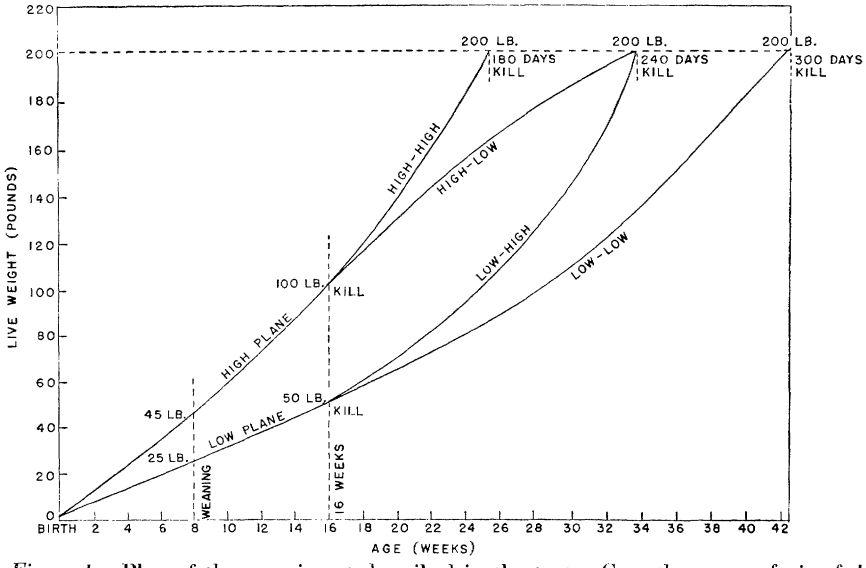

Figure 1.—Plan of the experiment described in the text. Growth curves of pigs fed at different nutritional levels to the same final body weight.

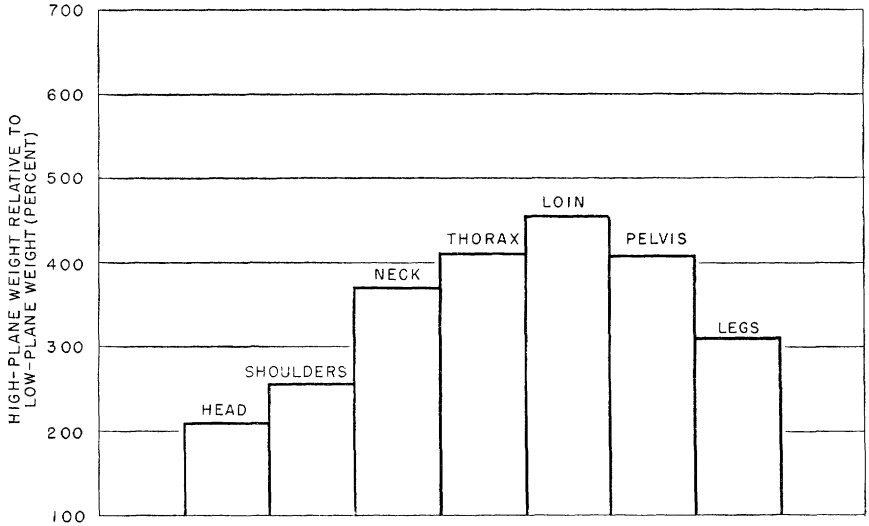

Figure 2.—How the body proportions of the pigs on the different levels of nutrition varied at 16 weeks of age. Taking low-plane weights as 100 percent, the weights of the different body parts of pigs on the high plane exceeded them as shown.

plane pigs was 1,007 percent of that of the low-plane pigs, while the weight of the bone was only 224 percent (fig. 3). This is equally true when the pigs are compared at the same body weight (200 pounds; high-high and low-low groups)

as well as at the same age. If the degree to which the different parts and tissues of the body are affected by the quick rise is compared with that resulting from the slow rise in the live-weight growth curve, it is found that these correspond to the order in which the parts and tissues develop as the pig grows. Thus, those parts and tissues which, like the loin and the fat, develop late in life are increased to a much greater degree by a high plane of nutrition (quickly rising growth curve) than are those parts and tissues that develop early in life, such as the head and the bone. The reason for this is probably that the latter have the

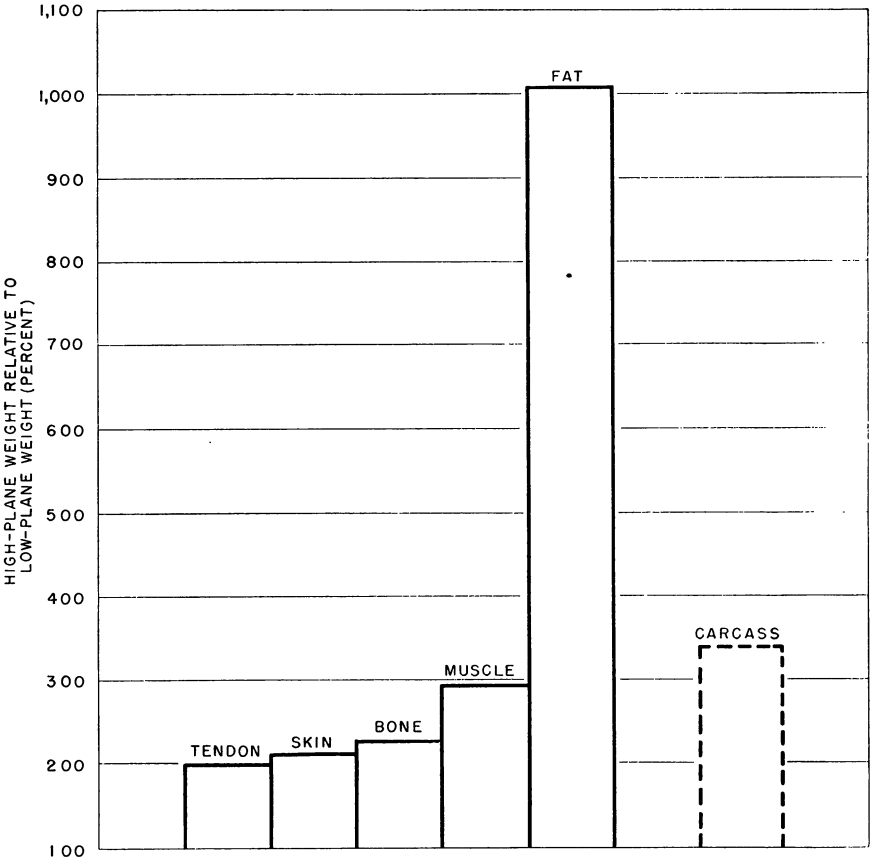

Figure 3.—How the carcass composition of the pigs varied at different levels of nutrition at 16 weeks of age. Low-plane weight taken as 100 percent.

greatest metabolic rate and so have priority over the later developing tissues when the supplies of nutrition are low.

By making growth rapid early in life and slowing it down later (high-low group) the early developing parts and tissues of the body are accentuated and the later developing parts and tissues are reduced. Conversely, by slowing growth early in life and speeding it up later (low-high group), the later developing parts and tissues of the body are accentuated and the early developing parts and tissues are reduced. Thus one can produce experimentally at the same age and same body weight, by controlling the shape of the growth curve, a bacon type (high-low) or pork type (low-high) from the same strain of pig (figs. 4, 5, and 6).

The results of the four differently shaped growth curves on the composition of the carcass at 200 pounds are summarized in table 1.

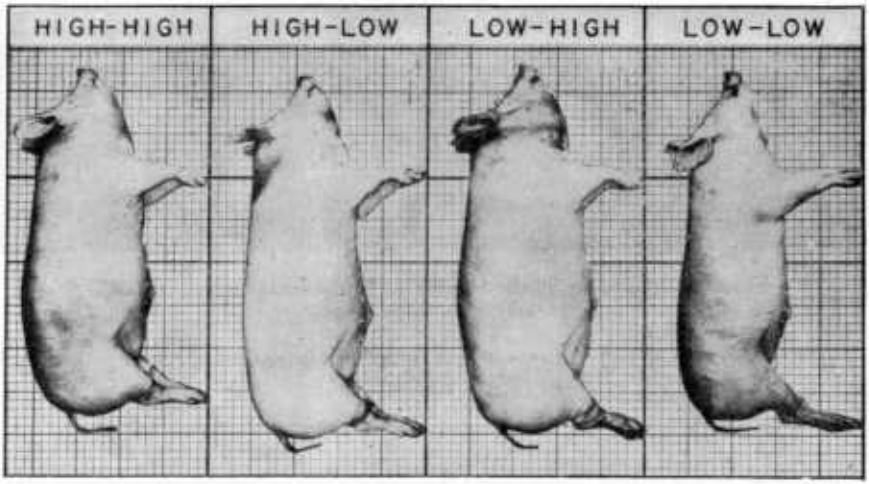

Figure 4.—Body proportions at 200 pounds, arranged at the same shoulder height.

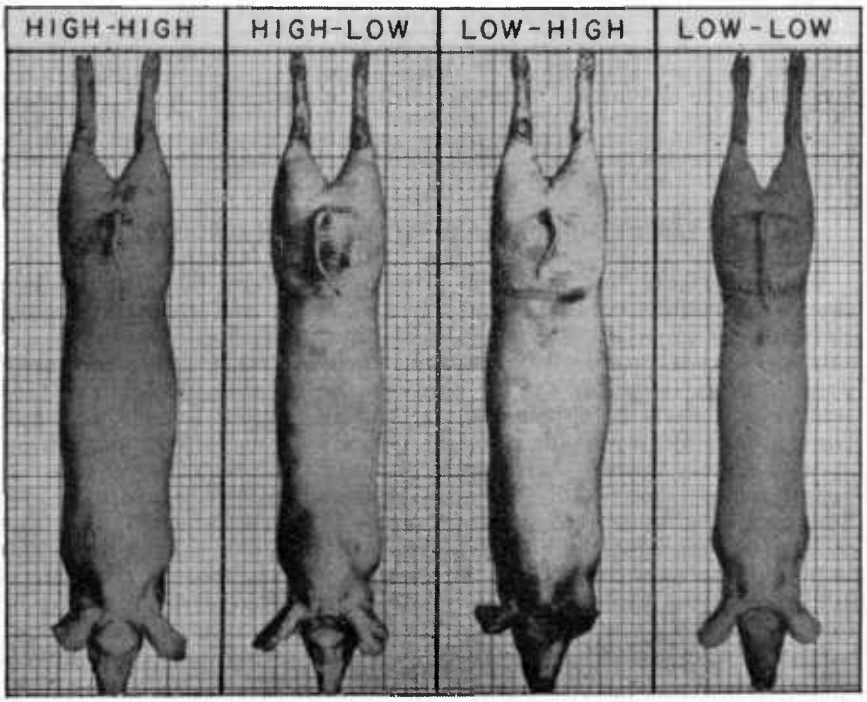

Figure 5.—Body proportions at 200 pounds, arranged at the same total length.

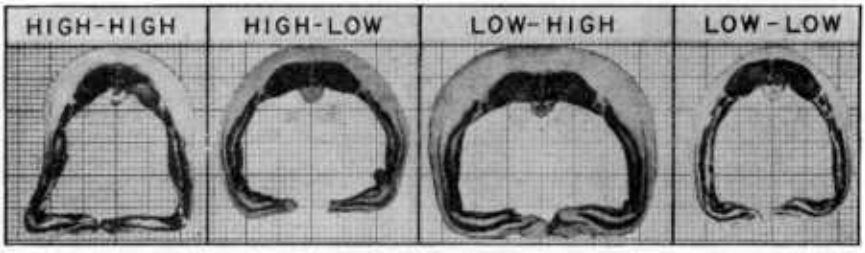

Figure 6.—Loin cut at the last rib at 200 pounds, arranged at the same eye-muscle length.

TABLE 1.—*Results of four different growth curves on composition of the carcass of hogs weighing 200 pounds*

Treatment	Proportion of carcass weight				
	Fat	Muscle	Bone	Skin	Tendon, gland, etc.
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
High-high	38.3	40.3	11.0	5.3	5.1
High-low	33.4	44.9	11.2	5.4	5.1
Low-high	44.1	36.3	9.7	4.8	5.1
Low-low	27.5	49.1	12.4	5.8	5.2

Under the practical conditions of animal production, meat-producing animals are reared under all the four systems of nutrition represented by the growth curves described. Thus the lard type of pig is reared under a low-high system and yields a high proportion of fat and a low proportion of muscle in the carcass, while the bacon type is reared on a high-high or high-low system and yields a carcass with more muscle and less fat.

EFFECTS OF UNDERNUTRITION AND EXERCISE

Undernutrition has its most pronounced effect first on the less essential portions of the body. The skeleton and essential organs continue to grow at the expense of muscular tissue and fat. A similar effect is produced by fasting, when the body draws primarily upon muscle tissue and fat to maintain the functional organs. This reserve of material, represented particularly by the muscle, fat, and bones, plays an important role in a period of undernutrition or drain upon the body tissues. Examples of the utilization of body reserves during certain periods of the year are found in the case of wild and hibernating animals or domestic animals in winter or drought. The ability to draw upon the body reserves is often shown during reproduction and lactation, especially the latter. Even though the diet is inadequate, the fetus grows and milk is produced at the expense of the mother. In the case of the modern high-producing dairy cow, careful feeding is necessary to keep her from drawing upon her reserves. In fact, it has been suggested that many animals are unable to meet their calcium requirements during the period of lactation even though well fed, but that these reserves are restored between lactations.

The occasional moderate utilization of body reserves is not detrimental, since they are readily replenished when food is again available or the temporary drain is removed. An interesting example of periodical drain and replenishment is seen on the range, where cattle go through the winter like wild animals, reproducing and often beginning lactation on restricted feed and replenishing these losses during the remainder of the year.

The results of Hammond's experiments on the effect of different planes of nutrition on the development of pigs also apply to other animals that are relatively inactive. With man or with active animals such as the horse and dog, exercise modifies the potential effect of a liberal diet in that the activity diverts the energy contained in the food away from the formation of fat. Under such conditions the body tends to develop muscle and bone without excessive fattening. The quantity of food required to cover exercise was illustrated in an experiment planned to show the effect of exercise on the quality of meat produced by steers. To remove the effect of fattening on the quality of the meat, it was necessary to feed the two groups so that the weight of pairs of exercised and unexercised animals would be the same. At one stage of the experiment the exercised cattle required roughly 8 pounds of grain a day more than the unexercised cattle to maintain the same body weight.

NUTRITION AND LONGEVITY

Recent experiments have raised the question of the best level of nutrition for a long life, compatible with health. Length of life and maximum rate of growth are not necessarily related. Certain experimental results with rats indicate that the reverse may be true. Rats fed a diet adequate in proteins, vitamins, inorganic salts, and fats but restricted in calories lived longer on the average than those fed the same basal diet with an unlimited intake of calories. The males on the restricted diet lived roughly one-third longer than the well-fed rats, while the females lived a little longer than the female controls. About one-third of the rats on the restricted diets lived to the age of 1,200 days, which is equivalent to approximately 120 years in man. In these experiments the females were not allowed to reproduce. While the rats on the restricted diet lived longer, they did not attain as great a body weight as the full-fed rats and the bones were lighter and more fragile. Animals on restricted diets had adequate amounts of the protective foods.

Other experiments on the influence of diet on longevity indicate that a diet that has given satisfactory results with regard to growth, reproduction, and lactation may be improved by enrichment in certain factors, including vitamin A.