with $W^{2/3}$; mechanically viewed, the pull of gravity varies with $W^{1.0}$ while the strength of the supporting structures tends to vary with $W^{2/3}$ (that is, with the cross-section areas of the supporting structures); hence, to retain stability the supporting structures must grow more rapidly than the visceral organs, or the visceral organs must grow less rapidly than the body as a whole, approximately in proportion to $W^{2/3}$; and it is the metabolism-supporting visceral organs and nutritive and excretory surfaces that con-

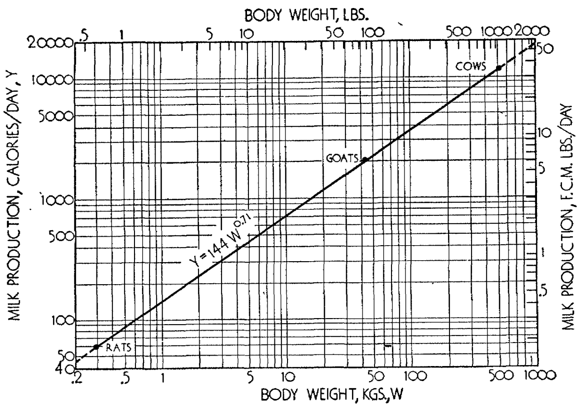

FIG. 1

dition and limit the functional rates: basal metabolism, apparently milk-production, and perhaps all vital and productive processes. If the small and large animals were similar and if the body did not develop devices for partial compensation of these geometric and mechanical limitations, the slopes of the curves relating these structures and functions to total body weight could be predicted precisely from geometric and mechanical considerations; since, however, small and large animals are not similar geometrically, mechanically or temporally, the value of the slope b in Fig. 1 for lactation, and for related structures and functions, can not be predicted precisely, but it may be said to be of the order of 0.7 ± 0.1.

The observation that *minimum* maintenance cost (basal metabolism) and milk production follow a parallel percentage course with increasing body weight suggests an economic application. If the *total* maintenance cost likewise parallels milk production with increasing body weight, the gross energetic efficiency of milk production (ratio of milk-energy produced to digestible feed-energy consumed) should be independent of body weight[2]; and if it is, the monetary profit of milk production should rise with increasing body weight because a major part of the expense of commercial milk production is for the labor of milking, feeding, cleaning, bookkeeping, housing, and so on; and such labor per animal is, within the species at any rate, practically the same whether it be relatively large or small. Hence, *within a given gross energetic-efficiency class,* the larger the animal the less the labor cost per unit milk-energy produced and, *if other conditions are equal,* the greater the profit per unit milk produced, and still greater per animal and per herd.

Unfortunately, it is not known how total maintenance cost varies with increasing body weight. It may rise more steeply than basal metabolism because the energy cost of moving the body is directly proportional to $W^{1.0}$ rather than to $W^{2/3}$. However, the voluntary movements may decline with increasing weight in such manner that the total maintenance-energy cost parallels the basal metabolism cost. Thus large animals appear to make fewer and slower movements than small, and the energy expenditure at approximately physiologically-equivalent work levels parallels the basal-metabolism energy in 1,500-pound horses, 700-pound ponies, and 150-pound men.[3] The data in Fig. 1 do not throw convincing light on the maintenance problem. The gross energetic efficiencies of milk production in the small animals in Fig. 1 were higher than in the large[4]: cows 31 per cent., goats 35 per cent., and rats 44 per cent. These differences may be fortuitous, but they may also indicate that total maintenance-energy cost rises more steeply with increasing body weight than milk-energy production, due either to selection factors or to physico-chemical inter-relations having a similar effect.

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EFFECTS OF Ca AND OTHER DIVALENT IONS ON THE ACCUMULATION OF MONOVALENT IONS BY BARLEY ROOT CELLS

THE concept of antagonism holds that Ca and other divalent cations retard the entrance of monovalent ions like K and Na into the plant cell. The experiments upon which this theory is based were, in general, performed with high and often toxic concentrations of salt on cells or roots with little regard to their metabolic status.

[2] There is no reason for assuming that it takes different amounts of feed-energy to produce unit milk-energy in, for example, 800- and 1,600-pound cows if the maintenance cost is excluded from the computations (*net* efficiency). If the maintenance item is included, the ratio of milk-energy produced to total feed-energy consumed (*gross* efficiency) is the same if the ratio of milk-energy produced to maintenance-energy is the same in large and small animals. If, however, the maintenance-energy rises more rapidly than milk production with increasing body weight, the gross efficiency decreases with increasing body weight.

[3] *Univ. Missouri Agric. Exp. Sta. Res. Bull.* 222 and 244.

[4] *Id., Res. Bull.* 285 and 291.

Recent investigations on the absorption of K and Br by actively metabolizing excised root systems of barley like those used by Hoagland and Broyer[1] showed that Ca and other cations appreciably increased the rate of absorption of K and Br as shown by analysis of sap expressed from previously frozen roots. Data from a typical experiment of 10 hours duration are shown in Table I.

TABLE I

Solution	Absorption in milliequivalents per liter of sap	
	K	Br
.005N KBr	24.7	15.9
.005N KBr + .001N $CaSO_4$	28.6	23.5
.005N KBr + .005N $CaSO_4$	30.9	24.8
.005N KBr + .025N $CaSO_4$	37.2	30.1

Potassium absorption from KNO_3 and K_2SO_4 solutions was also increased by Ca.

In several experiments it has been found that Ca may increase K absorption by 80 and Br by 100 per cent. without affecting the rate of CO_2 production.

Barley roots responded to Ca during simultaneous K and Br absorption regardless of their initial Ca content. Roots grown in the preliminary period in nutrient solutions saturated with $CaSO_4$ responded fundamentally the same as roots grown at lower Ca levels when subjected to study over a subsequent experimental period. Pretreatment of roots for 4 hours in saturated $CaSO_4$ solution produced no change in the rate of K and Br influx from dilute KBr solutions as compared with control roots kept in distilled water during the pretreatment period.

Roots maintained at several controlled temperatures from 10° C to 30° C all responded to the presence of Ca in the solution by increased rates of K and Br absorption.

Calcium was always more effective than Mg and Mg more effective than Sr of like concentration in increasing the absorption of K and Br. Ba produced effects which depended upon the concentrations used, dilute solutions producing increases in K and Br absorption and more concentrated solutions producing decreases. Mixtures of Ca and Mg sulfates produced increases in salt absorption of the same general magnitude as did these salts used singly. This indicates that Ca and Mg are not performing independent functions but are performing some common function, Ca being more efficient than Mg.

These results suggest the possibility that Ca and kindred cations can increase the permeability of the plasma membrane to K and Br during concurrent salt accumulation.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

USE OF COMPLETE FERTILIZERS IN CULTIVATION OF MICROORGANISMS

SOMETIMES experimental work requires the use of very large quantities of a culture containing microorganisms. For example, in the studies conducted by the authors on the physiology of feeding of oysters as much as 90 gallons of a rich culture of plankton were needed every day for a period of several weeks. Obviously it was impractical and virtually impossible to grow such large quantities of microorganisms by employing standard laboratory technic and using a culture medium such as Miquel's. Therefore, a different method was sought. A large number of commercial fertilizing mixtures were tried, and several of them gave excellent results.

The use of various fertilizing substances in fish ponds and small lakes has long been practiced in Europe. Recently a number of American workers, notably Wiebe[1] and Swingle and Smith,[2] contributed to our knowledge on the use of fertilizers in increasing the fish production of small bodies of fresh water. As a rule, after the addition of fertilizers, a significant increase in phytoplankton occurred. This in turn was followed by a prolific growth of zooplankton.

The fertilizing mixtures used in our studies are known as complete fertilizers. They are usually designated by a formula such as 5–3–5; 6–3–6; 10–6–4, etc., which indicates percentages of compounds of nitrogen, phosphorus and potash. Many of these fertilizers contain large quantities of organic components such as cottonseed meal, castor pomace, soyabean meal and steamed bone meal. There are also traces of copper, zinc, manganese, boron, iron and some of the other elements. Of the numerous mixtures tried the fertilizers 5–3–5 and 6–3–6 gave the best results. Both these fertilizers are used by tobacco growers. The relative value of each fertilizer was determined in a series of controlled laboratory experiments of growing cultures of *Chlorella* and *Nitzschia* in media prepared from each fertilizer.

For laboratory work a medium containing 1 gram of fertilizer in 1,000 cc of filtered sea water always gave excellent results. In growing *Nitzschia* and

[1] D. R. Hoagland and T. C. Broyer, *Plant Phys.*, 11: 471–507, 1936.

[1] A. H. Wiebe, *Bull. Texas Game Fish and Oyster Comm.*, 8: 1, 1935.

[2] H. S. Swingle and E. V. Smith, *Trans. American Fish Soc.*, 68: 126, 1939.