length of life of the individuals stained. Further observations both on these jellyfishes and other forms will be reported at a later date.

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## AN ICHTHYOMETER

THIS apparatus was designed to make possible quantitative studies on the activity of fishes. It had been in use for some weeks in the laboratory of animal behavior of the zoology department of the Ohio State University when Magnan's description of a device for registering the speed of swimming in fishes was published.[1] Breder has described a dynamometer for recording the pull of fishes, which, however, he states was not very successful in operation.[2] While Breder's apparatus was made to register pull and that of Magnan to measure speed of swimming, this device records neither of these, but is constructed to show the total swimming movements of fishes over considerable periods of time and their position from time to time in the aquarium.

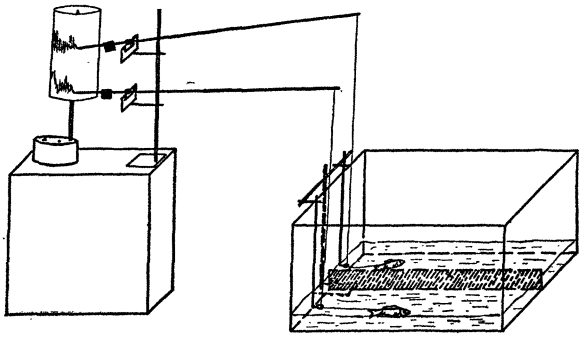

FIG. 1

The slow kymograph of the Harvard apparatus company, revolving once in approximately fourteen hours, is used. An aquarium which may vary in size with the size of the experimental fish is filled not more than four inches deep with water. An aquarium through which water is running may be used for species which do not thrive in still-water aquaria. The recording device consists of a long lever to the short arm of which the tracing point is attached. To the end of the long arm a fine thread is tied. This thread passes through an eye fixed rigidly about a half inch above the surface of the water at one end of the aquarium and directly below the point of attachment of the thread to the lever arm. This thread is attached to the tail of the experimental fish just anterior to the caudal fin. A sharp needle may be used and the thread passed through the skin and a little of the muscle in the dorsal part of the tail region. Such a wound is very slight, soon heals and apparently causes the fish little irritation. A sliding weight is fixed to the short arm of the lever and so adjusted that the short arm is slightly heavier than the long arm. When the fish swims away from the rigid eye the long arm of the lever is pulled down and the movement recorded by an upstroke of the recording point. As the fish swims back toward the eye the long arm of the lever swings up, taking up the slack in the thread, and the movement is recorded by a downstroke of the recording point. Thus every swimming movement is recorded and by the proper measurements the total distance covered by the fish in a given time can be computed. By placing an opaque partition down the center of the aquarium it can be divided into two long, narrow compartments and records of two individuals can be taken simultaneously. Such a long, narrow compartment results in movement almost entirely in a direction directly away from or directly toward the rigid eye. To secure activity records with the least possible disturbance to the fish the lever should be constructed of very light material, and should be balanced so that the fish pulls only a gram or two of weight. The long arm of the lever should be of such a length that when the fish swims from one end of the aquarium to the other the end of the arm describes an arc subtending an angle of between 30 and 45 degrees. The length of the short arm can be so adjusted as to give a record of convenient height. The lever can be constructed of soda straws. One end of a straw is split along one side for an inch and a half, the end rolled in and telescoped into the unsplit end of another straw. In this way four or five straws may be telescoped together, making a lever extremely light and at the same time sufficiently rigid for this work. The fulcrum consists of a needle passed through a small cork, and the lever is fixed rigidly to this. The ends of the needle fit into small metal sockets. The lower limit in the size of the fish is about two inches in length. A certain minimum weight is necessary to overcome surface tension and cohesion at the point where the thread is being drawn from the water in taking up slack. In fish of small size this weight becomes a disturbing influence in normal activity records.

As can readily be seen, the apparatus is applicable to problems where it is desirable to know the movements and changing positions of fish in a still-water or running-water aquarium. Such problems as the reactions of fish to light, temperature, oxygen supply and food supply can be studied quantitatively. The apparatus, by the addition of certain accessories, lends itself to the study of conditioned reflexes. It is being used at present in this laboratory in a study of

[1] A. Magnan, "Les Caractéristiques Géométriques et Physiques des Poissons. Avec Contribution a L'Etude de leur Equilibre Statique et Dynamique," *Annales des Sciences Naturelles, Zoologie*, T. XII, Fas. 1, Avril, 1929.

[2] C. M. Breder, Jr., "The Locomotion of Fishes," *Zoologica*, Vol. IV, No. 5, September, 1926.

periodicity and rhythm in activity in various species of fishes. This work will be reported fully at a later time.

It is with the hope that the apparatus may be found useful to students of animal behavior that it has been described.

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# SPECIAL ARTICLES

## POTASSIUM IN RELATION TO THE SHAPE OF THE SWEET POTATO[1]

FERTILIZER experiments in the field by Schermerhorn[2] have shown that good yields of Yellow Jersey sweet potatoes of desirable chunky shape can not be consistently secured unless a fertilizer is used containing considerable potassium in relation to nitrogen.

During the past three years sweet potatoes of the same variety were grown under controlled nutrient conditions in sand culture in the greenhouse. The triangle system was employed and the growth responses and chemical composition of the plants were recorded. Many of these solutions produced excellent growth of tops and roots. The entire vine growth of one of the largest plants was nearly 150 meters in total length, and the yield of potatoes of another was over one kilogram.

It was found as a result of this work that those plants supplied with ample nitrate nitrogen in the nutrient solution produced potatoes which were comparatively high in organic nitrogen and relatively low in carbohydrates. These potatoes were distinctly chunky, whereas other plants supplied with a smaller proportion of nitrates produced potatoes with a low percentage of organic nitrogen and higher percentage of carbohydrates. These potatoes were distinctly long.

An experiment was devised to determine the effect of limiting the supply of potassium on growth of the sweet potato. One of the nutrient solutions of the triangle was selected which had been found to support good top growth but did not produce the maximum yield of potatoes. This solution contained abundant nitrate nitrogen. Plants were grown a month or longer with this nutrient solution after which some of them received the same solution lacking potassium but otherwise complete. Sodium was substituted for potassium.

Leaves, petioles and stems of plants which received no further supply of potassium after the first month grew more slowly than others receiving potassium continuously. The low potassium plants were apparently healthy in every respect, although the foliage was not quite so dark green as that of the high potassium plants and exhibited a condition like that of others grown with a slightly limited nitrogen supply. The sweet potato plants which received no external supply of potassium after the first month formed potatoes relatively early as the result of carbohydrate accumulation in the roots, whereas the plants grown continuously with abundant potassium in the nutrient solution formed potatoes later and there were fewer of them.

It appears probable that potassium may be necessary at some stage for the change of nitrates and carbohydrates to proteins which can be used for the production of embryonic tissue. If this process is checked by limiting the potassium supply available to the plant, carbohydrates must necessarily accumulate provided photosynthesis is not greatly checked. As already noted, the low potassium plants of this experiment were not chlorotic.

In addition, study of the structure of chunky sweet potatoes[3] shows that these low carbohydrate and high protein roots have a larger and more active cambium than long thin potatoes, which are relatively low in protein and high in carbohydrates. The cambium of the sweet potato gives rise to cells which are later used for starch storage. If the major amount of cell division is principally at or near the tip of the root, as when potassium is low, there will result a greater increase in length than in diameter, and the potatoes will, therefore, be long and thin. But, if the increase in diameter takes place nearly as rapidly as increase in length the potato will be chunky. Cell division can take place only if there is an ample supply of organic nitrogen. If potassium is necessary for the formation of organic nitrogen and the potassium supply is limited, cell division in the direction of the diameter of the potato will be retarded and the potatoes will be long even though there may be an abundance of nitrate nitrogen and carbohydrates in the plant tissue and nitrates in the nutrient solution.

An adequate supply of potassium, therefore, appears to be essential for the production of chunky potatoes in order that there may be formed proteins of quality and quantity necessary for the rapid development of cambium, the tissue of the sweet potato root chiefly responsible for increasing the number of cells and therefore the thickness or chunkiness.

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[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Division of Horticulture.

[2] "Sweet Potato Studies in New Jersey," Bulletin 398, N. J. Agri. Exp. Sta.

[3] "How Potassium Affects Sweet Potatoes," N. J. Agriculture, Vol. 11, No. 6, June, 1929.