XXI.—THE AQUA-VIVARIUM AS AN AID TO BIOLOGICAL RESEARCH.

By WILLIAM P. SEAL.

The somewhat obsolete term "aqua-vivarium" is used in this article because it expresses shades of meaning not covered by any other word or term known to the writer. It is comprehensive, describing the establishment of methods, approximating to natural conditions, for the study of the varied forms of life which wholly or in part inhabit the waters. The word "aquarium" is properly restricted to a harmonious adjustment of the relations between animal and vegetable life wholly aquatic, while the term "aqua-vivarium" applies to this and also to receptacles arranged as homes for amphibious animals.

While rapid advance has been made in the methods of the study of life, while biological laboratories splendidly equipped with scientific appliances are rapidly becoming prominent features of our leading universities, but little attention has been paid to the establishment of means whereby the life histories of the lower forms of life may be studied in continuity. Apart from the embryological researches of the U. S. Fish Commission, through its embryologist, Mr. John A. Ryder, which are confined principally to a study of food-fishes; and the private biological laboratories of Professors Agassiz and Brooks, on the Atlantic coast, there seems to be no effort in this direction. The desirability of the establishment of practical propagating adjuncts to biological laboratories is universally acknowledged. No doubt the history of the great public aquariums of Europe, with their enormous expenditure of money and manifest lack of adequate scientific results, has much to do with the general apathy on this subject. It is not, however, by the expenditure of large sums of money that the ideal adjunct to the biological laboratory will be established. In fact, with the expensive and highly artificial methods in vogue better results than have been attained are not to be expected.

It is the desire of the writer to show how, at comparatively small expense, conditions which closely approximate those of nature, and afford the most gratifying results, may be established, under which conditions the lower forms of life will live contentedly, generate, and always be accessible to the investigator.

The grand requisite is that animals shall be furnished with places suited to their various requirements—light, temperature, and food be-

ing primary considerations. Any attempt at biological investigation which disregards the special requirements and natural habits of the forms of life under investigation must result in disappointment. A curious instance in illustration of this point is quoted from The Family Aquarium, written by Butler:

"There are plants, too, which will not thrive in tranquil waters. Sir John Paxton, knighted for his successful conception of the plan of erecting the novel building so renowned and imitated as the Crystal Palace, discovered this fact when he was a simple florist to the Duke of Devonshire. A gigantic South American water-lily, brought from the river Amazon, and well known at the present time as the *Victoria regia*, refused to flower under his care in the elegant tank he had prepared for it. Suspecting at length that the want of motion in the water might have something to do with its contumacy, he arranged a little paddle-wheel in such a manner that a mimic stream should roll over it, and thus in its fall into the tank continually agitate its contents. The ruse was successful. The lily imagined itself once more at home, and being perfectly at its ease expanded its giant flowers without further reluctance or solicitation."

The aquarium tank, while being indispensable for purposes of close observation in special cases of interest, is by reason of its great artificialty (that is, unnatural light, and injurious temperature in warm weather through exposure to the atmosphere on all sides), generally unfit for the generative development of fish, reptiles, crustaceans, &c., although they may be kept alive in such tanks for long periods. But for the purpose of close observation, such animals when at the proper stage of development, may be safely transferred to aquariums for short periods.

The necessity of imitating nature being kept in view, it is evident that the work is to be begun in the open air or outside of ordinary closed buildings, in order that there may be an abundance of light.

First, then, a piece of ground is needed proportioned to the magnitude of the operations. The proposed aqua-vivaria are simply excavations (trenches or basins) in the earth, of any desired size or shape. The excavations are to be lined with Portland cement to the thickness of a half inch or more, the cement being simply plastered against the earth walls without other backing. By excavating to but half the desired depth and banking up the removed earth around the outer edges of the basin, the aqua-vivaria will be raised above the reach of sudden and heavy rainfalls. They will be much strengthened by sodding the outside, though this is not necessary where they are permanently inclosed after the manner of hot-beds. It will be necessary that they be so inclosed during the winter months, and in some way heated during the prevalence of extremely cold weather. A small amount of heat will prevent the freezing of water under glass; and it may be done simply and inexpensively, after the manner of greenhouse heating.

Aside from the question of economy and the advantages gained in light and temperature, the capability of change or modification at trifling labor and expense, as experience may suggest, will prove a source of great satisfaction. While closely approximating natural conditions, the advantages gained over the conditions of nature are like those of a cultivated garden, in which everything is clean and orderly, over an uncultivated field.

Plate I represents the simplest and least expensive form of the aqua-vivaria here suggested, with section of front cut away to show the interior. There are many ways in which the interior may be arranged, affording equally satisfactory results. In fact, we may follow our individual fancy in this respect, so that we avoid artificiality as much as possible. The following suggestions, however, may be useful to some. The bottom may be made uniform and a bed of three or four inches of sand placed over it in which to root the plants which may be introduced; or it may be made of varying depths with hollows at intervals in which to put the sand and plants. Another and very satisfactory method is to root the plants in large dishes, or in rough receptacles made of Portland cement or suitable pieces of stone cemented together, as they can then be moved or taken out when searching for objects without disturbing the growth of the plants.

While in the aquarium tank but few kinds of aquatic plants can be grown without great care and under the most favorable conditions, any water-plant whatever may, by means of these aqua-vivaria, be propagated successfully. The writer maintains, on the test of sufficient experience, that all the conditions favorable to life, animal and vegetable, of the largest pond may be had in this manner at trifling cost, and that undoubtedly many of the vexed questions of biology might readily be solved in this way. The great obstacle in the way of biological research is generally the limited amount of material obtainable, while rare forms are often unattainable for long periods.

One barrel of Portland cement and two bushels of sand, mixed, costing less than $5, will line a trench at least 4 by 20 feet, and from 6 to 18 inches in depth. The water supply may be had from hydrant, spring, raceway, or any available source. All the water needed, after filling, is to supply the loss by evaporation and the small amount which may at first percolate through the cement. Instead of a large basin a series of smaller ones of varying dimensions might prove better adapted to animals of different natures which might prey upon one another. In constructing homes for animals of widely divergent habits there is no plan other than that here proposed, which allows of such diversity of arrangement. The aquarium tank is costly, and, by reason of its too great and unvarying depth, and its perpendicular sides, is really unsuited for much else than ornament. It is difficult of arrangement for various forms of life, and is too subject to changes of temperature. In some experiments in fish culture the writer found that in a trench, such

as here described, of a depth of from 10 to 18 inches, and in which were growing *nymphæa* and other aquatic plants, although exposed all day to the heat of the summer sun, the temperature of the water never rose above 50° to 60°, except to from 2 to 3 inches from the surface. And while the water was swarming with young fish there was no sign of oppression to their respiratory organs, while in an aquarium tank, out in the open air in the shade, with a much smaller number of fish proportionately, the temperature of the water was always about that of the atmosphere, and the fish showed signs of more or less oppression throughout the day.

Many of the lower forms of life, such as the chelonians, batrachians, ophidians, &c., require sand patches or mossy rockeries, in which to deposit their ova and in which their natural food may propagate and be sought for by them. It is these conditions, so easily obtainable, which produce contentment and the normal discharge of the natural functions which are the subject of the biologist's investigations.

Fronts of glass might be of advantage in these aqua-vivaria in some cases, but are not generally necessary; the only objection to them, however, is the extra expense entailed without adequate advantages. With the graduated depths of water, the natural and healthy growth of plants, the natural distribution of light and temperature, and the pure and clear water obtainable by these methods, there is no difficulty in observing the habits of animals, as they soon lose their timidity when accustomed to the presence of man.

Plates II and III will serve sufficiently well to illustrate more elaborate forms of aqua-vivaria or combinations of such as the greenhouse plan, showing adaptations absolutely impossible with the aquarium tank for diverse forms of life. Rockeries properly constructed to prevent the escape of animals, mimic waterfalls, beds of mosses, or grasses and ferns, combine in such close imitation of nature that the animals readily accept them as habitats. Water may be supplied by running a pipe above with a cock for each basin, thus making each basin independent of the others. It may be introduced without agitation, or made to tumble over rock-work, or it may be supplied at one end and made to circulate through an entire series of basins by making a trough-like connection between the basins with wire-gauze guards. A pipe may be inserted in the bottom of each basin, with a stop-cock outside for emptying the basin speedily when desired. With an elevated reservoir, and windmill or other power to pump back the waste water, an economical aqua-vivarium might be had. These methods are alike adapted to the simple wants of the individual specialist or to the multifarious requirements of the greatest university.

The question of food is fully as important as are those of light and temperature. Many fish and reptiles will refuse all food which they do not kill themselves. Others will feed readily on dead animal food. Others, again, will thrive upon prepared vegetable or farinaceous food.

The young of animals inhabiting the water seem, in a greater degree, to require living objects as food. These they find in the myriads of animalcules, crustaceans, larvæ, &c., inhabiting quiet waters or the quiet parts of waters. Many of these, in their turn, prey upon the young fish, reptiles, &c. These minute forms of life may be propagated in incalculable numbers in basins such as are herein described. A basin, for instance, adjoining one in which fish are being propagated, might be used as a propagating basin for their food. These animalcules, &c., could be transferred to the fish-basin by means of a fine net, or the two basins might be separated for an inch or two from the surface by a bed of moss through which the animalcules could find their way to the fish-basin.

A row of tables and shelves with aquariums, jars, microscopes, &c., for purposes of special investigation, could be placed opposite the propagating and storage basins. There would thus be an economical and practically perfect adjunct to the biological laboratory, subject, of course, to the eternal sway of progressive development.

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