A NEW AQUARIUM FOR BOSTON

by

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DISCLAIMER

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August 31, 1951
Cambridge, Mass.

Dean Pietro Belluschi
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Dear Sir:

As partial fulfillment of the requirements for the degree, Master of Architecture, I would like to submit my thesis entitled, "A New Aquarium for Boston."

Respectfully submitted

Henry A. Olko

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Thesis Abstract

It has been the aim of the Directors of Science Park to provide, in Boston, a complete museum of science. To this end Science Park was established. The building, located on the Charles River, will contain, when completed, a Planetarium, Museum of Science and an Aquarium.

The present Aquarium, located on Pleasure Bay , Boston, was built in 1912. The tanks now used are cracked, facilities antiquated and inadequate, and the location remote and difficult to reach except by car.

A site has been allocated by the directors of Science Park for the construction of an aquarium.

The purpose of the exhibitions shall be primarily as an educational medium as now carried forth by the institution. It is not the intention of the aquarium to compete with the aquariums of New York, Chicago or the like, but rather to present to the people as comprehensive and practical a building as possible within the alloted budget of 750 thousand dollars, showing aquatic life in all its manifestations.

The existing buildings provide a very strong tour de force. It was felt that any scheme produced should take cognizance of the fact, and should be such as to make the buildings compatible.

ACKNOWLEDGMENTS

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FOREWORD

From the beginning, men have recognized the sea as a supreme wonder and paradox of the natural world - at once a thing of beauty and terror, a barrier and a highroad dividing and uniting mankind, a source of life and a fearful and capricious destroyer. The sea poets of every land have sung in exaltation of its sunlit modes and in awe of its fury and fathomless deeps.

Today in the wider perspectives of man's awareness of the universe, it has become clear that the sea is in many ways a miracle. We know now that we are dependent upon the sea not only for certain accessories of existence, but for the very character of existence itself. The entity called life emerged from the sea; the basic fabric of all living things was initially determined by it; the entire system of nature composing man's "environment" is governed by it. More than any other physical feature of the planet, it is the sea that makes the earth unique.

If somewhere in space an extraterrestrial astronomer should examine our solar system, he might name our planet "Sea" rather than "Earth," a word connoting soil. For the characteristic that would impress itself most vividly, setting us apart from other satellites of the sun, is the great glistening sheath of water that permanently envelops nearly three quarters of the globe. No other world in range of man's vision has a sea. Mars discloses ice caps, some moisture, perhaps vegetation, but no sea. Mercury appears to have no water at all. Venus lies veiled behind dense clouds which, unlike the clouds of the earth, probably contain neither oxygen nor water. The outer planets are too cold to have a sea - the temperature of Jupiter rests at 216° F. below zero, that of Saturn at 240° below.

But our earth is nearly drowned in water. Only 29 per cent of its entire crust climbs above the great oceans that hide all the rest of the planetary surface under a liquid overlayer approximating two miles in depth. South of the Equator the seas engulf 81 per cent of the hemisphere. If all the land areas of earth - continents, islands, mountains - were somehow torn from their foundations and hurled into the sea, they would displace only one-eighteenth of the total volume of water in the ocean basins. And if all the irregularities in the earth's crust were somehow ironed out, reducing the planet to a perfectly smooth sphere, the seas would then completely submerge the globe beneath a uniform cover about 8,000 feet deep.

As he does with so many other aspects of his dependence on the manifold of nature, man takes for granted the abundance of water with which the earth is endowed. For, in a special sense, the miracle of the sea is the miracle of water. Only a few men of deep perception have ever realized this. St. Francis of Assisi, on his deathbed, composed a prayer containing the lines, "Praised be Thou, my Lord, for sister water, which is very useful and humble and precious and chaste," and thus, with the insight of saintly humility, affirmed his gratitude for a surpassing gift. Similarly, in desert regions or times of drought, men have acknowledged the worth of water. But the thought is always of fresh water - as if the salt sea, the ultimate source and reservoir of virtually all the earth's waters, fulfilled no function in the acquittal of man's needs. Yet, in the universe as a whole, liquid water of any dimension of man's own terrestrial existence, water stands as one of the most remarkable compounds in nature, upon whose unique properties most of the features and processes of his physical environment - the atmosphere, the weather, the soil, and all living things - ultimately depend.

"Miracle of the Sea"
by Lincoln Barnett

I. HISTORY

Fish have been kept in captivity for hundreds of years. The ancient Romans spared no expense to make their fish ponds as large and attractive as possible, and to obtain valuable and beautiful fish for stocking them.

The hobby of selective breeding of ornamental fish has long been in vogue with the Chinese since very early times. At least 400 years ago the Japanese began raising goldfish. Both Japanese and Chinese learned quite early that they could raise various types, and to the Chinese we owe the queer, bulging eyes or calico variety, while to the Japanese we owe the many beautiful long tail thin varieties. These were introduced into Europe in the seventeenth century, according to Pepys, who noted in his diary "fishes kept in a glass of water that will live forever - and finely marked they are being foreign."

Although ingenious and successful devices for holding fish alive have been in vogue for many centuries, the public aquarium - now a world-wide institution for the exhibition of aquatic life - has developed only within the past century.

About 1850, an Englishman, R. Warington, sent to the Chemical Society a letter about his experiences in keeping a freshwater aquarium. It was a simple affair, merely a glass globe of fresh water in which two goldfishes had been placed together with plants of Vallisneria. Soon

Warington introduced some pond snails to eat away the green algae which formed along the inner surface of the glass. Two years later, this investigator and another Englishman, Philip Gosse, experimented after a similar fashion with sea water. Tanks were constructed for the purpose, and marine animals and plants were introduced in such proportions as might be expected to neutralize each others' respiration.

The writings of Gosse aroused popular interest in aquatic life. Largely owing to this interest, the first public aquarium in the modern sense was opened in the Zoological Gardens at London in 1853. Because of its faulty construction, it had but a short life as a fresh water and marine aquarium; the building, however, is still in existence and is now being used for the exhibition of wading and diving birds. Soon other aquariums were constructed in many European cities. The first idea of presenting to the American public a display of live food and game fishes seems to have been suggested in 1872 by Spencer F. Vaird, who wrote, "I would respectfully call the attention of the commissioners of the Centennial Exposition to the propriety of taking steps for establishing an aquarium as part of the exhibit at the coming Centennial. You will observe the great success of these establishments which have been erected at Berlin, Hamburg, Naples...."

Excellent public response attended several temporary exhibitions of native fish at American expositions held after the 1876 Centennial. At the world's fairs at

Chicago, Atlanta, St. Louis, Buffalo, Omaha, Charlestown, Nashville and other cities, the aquarium attracted more visitors than any other single exhibit.

This response was influential in the establishment of a permanent aquarium at the Central Station in Washington in 1888 within the space available in the Fish Commission Building at 6th and B Streets. This first public aquarium in the National Capital was fitted out with a "Marine Grotto," which contained 24 tanks of salt-water fishes, as well as 25 tanks of fresh-water species. Its success was partly responsible for the establishment in 1893 of the famous aquarium at the Battery in New York City.

Today in the United States we have large permanent public aquariums at Boston, Chicago, Detroit (which is in the process of rehabilitation), Honolulu, New Orleans, Philadelphia, San Francisco, Washington. The New York aquarium, maintaining a small headquarters at the Zoological Gardens in the Bronx, is awaiting such time as construction can proceed. The success of aquariums is well attested by the fact that more visitors are attracted to them than to the zoological gardens or museums of natural history or art.

II. WHAT IS AN AQUARIUM?

Man's curiosity ever returns to the sea with awe and wonder at its vastness, its mystery and its countless and extraordinary forms of life.

To the layman, the aquarium offers deep satisfaction for this curiosity. Here he can see, in settings which accurately reproduce their habitats, a vast range of aquatic life - from the depths of the ocean to the mountain headwaters of the longest rivers - from invertebrates to fishes - amphibians and reptiles to birds and mammals. The lay visitor has a comprehensive panorama of the myriad life forms that exist entirely or principally in or near the water, a recreational and educational experience which cannot be so fully enjoyed in any other way.

The school child - and other students, too - find in the aquarium a boundless source of answers to the countless questions of life, with well-labeled exhibits of living aquatic animals constituting a powerful teaching source.

The scientist finds in the aquarium the place where he can pursue his research in many fields, working in an invaluable collaboration with his fellows. Daily the research of our scientists in the field of aquatic life brings nearer the answers to questions bearing great importance on human welfare. The sea and its inhabitants hold not only their own secrets and mysteries for man finds increasingly today that the key to many of his own puzzles may lie in the depths of the sea.

Today there are new aquariums in places all over the world, Shanghai, Ceylon, Jerusalem, Suez, Durban, Buenos Aires, Acapulco and Quebec. In the United States - Galveston, Miami, La Jolla, Indianapolis; and new ones are nearing completion in Bombay, India and Hermosa Beach, California. Some of these are the simplest type, in which the water is merely passed through a series of tanks exhibiting fish. Others are more ambitious with plans to exhibit fish from the various waters; and in these the water systems must be, of necessity, more elaborate.

III. WHAT DOES AN AQUARIUM EXHIBIT?

Fish, as well as aquatic invertebrates, i.e., sea anemones, snails, crabs, sea lions, porpoises and penguins; also amphibious reptiles, such as turtles, crocodiles; mosquitoes and toads that spend part of their developmental cycle in the water, even aquatic microscopic life. An aquarium, therefore, is not only a place to show marine life or exhibit backboned creatures, but an exhibition of all aquatic life in all its manifestations,

IV. PLANNING OF AN AQUARIUM

There are four different views to be considered in planning the public aquarium:

1. The public, for whom the place is being created;
2. The people who work in it;
3. The fish, mammals and plants that must live in it;
4. The feasibility and cost of construction.

A. Requirements of the Public

1. Easy access to all parts of the building, including the information desk.

2. Circulation that is simple to find, adequate in size and well worked.

3. Galleries that are effective for the display of the exhibits and that are designed in a scale that fits the material shown and size of attendance with clarity and orderliness.

4. Facilities for relaxation as a relief from the concentration which the gallery should induce.

5. Ready contact with the curator and staff.

6. Lighting and temperature conditions that will make the building physically restful as well as mentally stimulating.

7. Adequate arrangement for the comfort of visitors.

B. Requirements of Administration

1. Comfortable space to work.

2. Accessibility of staff to visitor by reasonable protection from casual intrusion.

3. Adequate provision for storage of material.

4. Facilities for repairing, preparing and labeling exhibits.

5. Planning of transportation of exhibits.

6. Facilities for physical care of building, cleaning, relamping, painting, etc. Protection against fire and theft.

7. Flexibility of plan exhibits and mechanical equipment.

C. Galleries

Minimum dimension requirements of galleries is that they shall provide adequate space for circulation and the comfortable viewing of the exhibits by the maximum number of people who will normally be present at one time.

In exhibitions it has been found that small objects can be viewed from distances up to six feet, while larger ones up to twenty feet. About eighteen feet has been found to be the minimum satisfactory width in public galleries.

Doorways for public use should be at least six feet wide. To avoid monotony, sizes can be varied by exaggeration in this respect might tend to give a jumpy effect.

1. Tanks

Fundamental to any aquarium are its tanks. They are the basic structural factor in the immobility of the exhibits. They must be solidly constructed for they are the waters on which the institution lives. Water is heavy. A small 15-gallon "home aquarium" weighs 125 pounds, enough to hold six goldfish comfortably. For larger fish, proportionately more. To maintain a five-foot shark, at least ten tons of water are needed. Some tanks in the new New York aquarium will hold as much as 6,000 tons of water.

Not only is water heavy, but it exerts pressure as well. This is intimately related to the weight of water but by no means identical. A vessel containing one ton of water may exert a pressure on the bottom and sides of the tank of several tons. For years aquarium tanks were made of concrete-lined wooden boxes or reinforced concrete. An empty concrete tank, 4 feet by 4 feet by 3 feet weighs about one-and-a-half tons. A slightly larger wooden tank at the New York aquarium weighed 3,700 pounds - moving it was next to impossible. A medium-sized tank holding 300 to 600 gallons of water can now be made much lighter. These tanks are made of pressed-wood, a composition board product - three-quarters or seven-eighths of an inch thickness - called die-stock, or more properly, Benaloid or Benalite. Three-inch angle irons welded at the corners are used for the supporting frames. The new tank is lighter and cheaper as compared with the old one; it holds more than twice as much water, costs one-fifth as much and, when empty, weighs one-twelfth as much.

Tanks are usually 5 feet high. The length varies however, small ones being 3.5 feet long, medium-sized ones about 7.5 feet and larger ones 15 feet. In the smaller tanks, the width between the glass and the back wall is about 3.5 feet - greater, in the larger ones. A small aquaria holds 445 gallons of water, other sizes in proportion. The medium- and large-sized tanks are the most useful. Instead of using small tanks, it has been found to be more advantageous to use a medium one capable of holding several species.

The shark aquarium in Chicago is 6 feet high, 10 feet wide, 30 feet long, has four windows and holds 13,800 gallons of water.

a. Number of Tanks

The Chicago aquarium (which cannot be used as a comparison) has 138 tanks, with a total capacity of 300,000 gallons. These tanks are arranged in six 90-foot galleries together with 60 balanced aquaria, with a 37,000 gallon pool in the center.

The Detroit aquarium, which is to be demolished and replaced by a larger one, has 50 small and medium-sized tanks, 20 home aquaria and two pools of about 10 feet by 15 feet.

Tank frames require a very high grade of workmanship in their welding. They must be absolutely true and must have no excrescences at their welds. A high grade of aquarium cement is absolutely essential, and although many kinds of cement can be used to make concrete tanks or lined wooden ones, there are only two kinds that are eminently satisfactory. The others all require a great deal of "curing" and some of them never seem to lose their capacity for giving off toxic chemicals into the water. These two suitable cements are Medusa Waterproof Cement and Saylor Cement. All aquarium cements must be thoroughly hand-worked and hand-mixed with whiting to the proper consistency just before using. Also, one edge of the plate glass should be chamfered by grinding - the one upon which it is set and rotated into place.

b. Lighting of Tanks

Visitors should be in semi-darkness with the light coming through from the tanks. Ordinary light bulbs are used at the Chicago aquarium.

In the workrooms, the electric conduits should be exposed as far as possible - not built in - as cables, because of dampness, must sometimes be changed.

c. Descriptive Labels

Formerly, labels were placed below the tanks. However, most of them today are placed above in plain sight, well lighted and easily read from a distance of three rows of spectators.

The labels should bear the Latin name, the principal common name, a color drawing of the fish, its geographical location, temperature and type of water and finally, an identification number corresponding to the classification guide.

2. Water - Pipes - Filtration and Pumping

Water is the lifeblood of the aquarium. The public is easy to please, as all it wants is clearness and clarity. Complete water control is necessary. With an open circulatory system this is impossible; i.e., water coming in from an outside source - unless that source is an absolutely dependable one, such as well water, or the ocean when it is removed from the influence of the polluting cities and diluting rivers. However, when the above is not possible, closed circulation must be depended upon. Thus water is stored, treated if necessary, and used over again by being recirculated through the tank filters, aerators and reservoirs.

A large number of water systems is essential for the control of infectious diseases and parasites, as well as the maintenance of the great variety of "types" of water required by different fish and invertebrates.

a. Piping

Piping carrying water to the exhibits should be non-metallic as it takes but a few parts per 11 million of some metals to kill fish quickly, and much less if exposed for a period of time. Only with completely non-metallic water systems can the aquarist hope to maintain the more sensitive fish and almost any of the invertebrates. The best alloy in piping is lead containing 8 per cent antimony. It presents an equal resistance to corrosion from both fresh and salt water.

Plastic piping, known commercially as Johnsonite, may be used along with a chemically inert pipe called Transite.

b. Filtration and Pumping

A closed unit must be freed from impurities acquired in the tanks. To this end, a fine filter performing the whole operation may be used, or a coarser one which would eliminate only the food particles and large débris, the balance being deposited by sedimentation. The Director of Chicago recommends the second. Each reservoir is divided into two sections, one serving as a sedimentation tank, the other as a supply tank; every two weeks their function is reversed.

From these large reservoirs in the basement, the water is pumped into the immediate supply tanks located above the floor of the galleries. From there it runs into the tanks, by gravity, and out again into the filters; thus the cycle is completed. Also, non-metallic, completely chemically inert water-conducting apparatus is essential.

In open circulations, where delicate invertebrates and fishes are not to be maintained, the ordinary kinds of plumbing - not containing copper in any form, or lead, if possible - can be used.

The old New York Aquarium used hard rubber pumps and plumbing almost exclusively in its closed water systems.

Glass-lined pumps as well as ceramic-lined pumps can be used. The only plastic besides some celluloids that should be used in closed water systems is Saran, a product manufactured by the Dow Chemical Company.

c. General

The only kind of paint or protective covering that will not eventually poison the fishes and invertebrates ih a closed system is Black Asphaltum Varnish.

In the New York Aquarium filters of a uniform-sized crushed quartz bed will be employed. Quartz which will not pass through a one-quarter-inch screen but will pass through a three-eighths-inch screen is the approximate size. With this in a three-inch layer, operating under at least eight inches of water, the filters will remove not only sediment but colloidal suspension as well. These filters will be employed in non-metallic systems, thus estimating a minimum of about ten gallons of water per mihute per square foot of surface.

d. Water Temperature

Fresh water is kept at three different temperatures: 50°, natural - varying with the season; 70° for tropical fish; and salt water, kept at temperatures between 60° and 70°. If possible, the various tanks should be grouped according to the temperatures of the water. A double set should be kept at contact places as it is not always possible to have the samespecies of fish. In the Chicago Aquarium, an excellent type of refrigerating machines is used which can lower the temperatures of the water to below 50°. It costs more than the other types of cooling machines, but the maintenancè expenses are lower, operation simple and no special license is required of the operator.

For heating the water, a coil is placed in the supply reservoirs.

e. Water Aeration

This is best achieved by spraying the water in fresh air. In Chicago this is done at four points of the circuit. As a precautionary measure, each supply tank is equipped with a pipe system feeding air at a 5-pound pressure.

f. Chemical Composition

Water must be tested regularly and corrected when necessary, so as to retain the brilliant hues of the fish which would be dulled in water either too acid or too alkaline.

g. Reservoirs

These must contain four times the quantity required for the fresh-water aquarium. In Chicago, the reserve water is taken directly from Lake Michigan and kept in two reservoirs having a total capacity of one million gallons. At Detroit, where the installation is not so modern, the water is changed every month.

h. Reserve Aquaria

These reservoirs, located in the workrooms behind the tanks, are used for new material and to hold the contents of the exhibits during cleaning and repairing and also for fish requiring special treatment. At the Chicago Aquarium, there are 95 such tanks of varying sizes, with a total capacity of 125,000 gallons. (According to the Director, half as many reserves as exhibition tanks are sufficient.)

Salt water reservoirs should hold four times the quantity of the salt water aquaria. At Chicago, there is a reservoir of one million gallons divided between two reservoirs. The same water has been used for fifteen years. Evaporation is compensated by the addition of fresh water, and the saline content is maintained by adding synthetic salt water.

3. Lighting

The first obstacle to adequate lighting of an aquatic exhibit - one that is to be seen through water - is the reduction in amount of light that occurs through the reflection, absorption and scattering effect of the liquid itself. Although 90 per cent of the light from an inside-frosted incandescent bulb is transmitted through three feet of distilled water, only 74 per cent is transmitted through three feet of clear tap water, and 40 per cent through six feet of the latter substance. There is a 5 per cent total loss of daylight passing through some of our relatively clear coastal sea waters. The loss in aquarium tanks may be much greater because of a larger amount of suspended material.

When an electric lamp strong enough and placed close enough to punch through, say, three feet of water is used to light a tank, additional problems arise. If the light source is a single bulb, only part of the tank will be properly illuminated, and sharp, unnatural shadows will be cast. For this reason, several small lights are much more preferable than a single large one, even though the former arrangement requires greater wattage to produce the same amount of light. A considerable amount of heat is generated by incandescent lamps, and this additional complication must be taken into account, even for tropical fishes. During extremely hot weather, the heat generated by bulbs located close to the surface of a standing aquarium can be sufficient to race the surface water temperature about the lethal point. The location of a tank's lights within a few inches of the water means that the hot bulbs must be protected against splashing, if the fish are of the splashing kind or are among those that come to the surface and spit, as do the Cowfish and their relatives. Lights so located are also likely to interfere with the work of the tankmen.

It was these difficulties and others that led aquarium men like Dr. C. H. Townsend to declare that, "No artificial lighting of aquarium tanks can take the place of the light of day." In the construction of the aquarium building it is imperative that skylights be made large enough to admit diffused daylight in abundance. Unfortunately, the ideal of abundant, yet controlled, natural light can rarely be attained because skylights are heavy and require strong and very expensive roof construction and support. Moreover, they are hard to insulate against cold and heat. Thus, many aquariums are built so that they must always supplement their natural illumination with artificial. Of course, they all must do so on dark days or at night. If an adequate amount of daylight is available, provision should always be made for regulating the quantity that reaches the tanks. Too much daylight causes prolific growth of small aquatic plants and algae, making the task of keeping the glasses clean and water clear most difficult.

One way of reducing the amount of light necessary to show off the inhabitants of the tanks in an aquarium is to keep the exhibition halls in relative darkness. The visitor then sees each tank as a comparatively bright picture, framed in a hardly noticeable wall. Light transmitted through a tank of water can never successfully compete with that shining directly into a room. Another advantage is that reflections on the glass tank-fronts are minimized when the exhibition hall is rather dark. For these reasons, exhibition halls ideally should have no windows at all and should depend entirely upon artificial light, so placed as to give a minimum of reflections from the tanks' glasses.

Of great importance to both visitors and fishes is the location of the lights that illuminate the tank. The majority of fishes are more or less compressed; that is, flattened from side to side; and they therefore present one of two vertical planes (their sides) to anyone viewing them from below the water surface. Maximum illumination would be obtained by directing light at them from the front of the tank. This is, in fact, what a photographer must do. It is, however, impractical as a continuous arrangement, since the lights would project out into the exhibition hall and would give reflections off the viewing glasses unless most carefully set up. Numerous experiments have been performed with front lighting at the New York Aquarium. Although a technique was evolved that gave most satisfactory results as far as the appearance of many fishes was concerned, incorporating the rather cumbersome light-box that is required into the conventional type of building has not proved feasible.

In this setup, the source of light was located both at the front and top, and it did not seem to affect the fishes adversely. A somewhat similar lighting effect can be obtained by illuminating the tank, if it is not too large and has glass sides, with lamps that are located at both ends to the immediate right and left behind the wall of the exhibit hall. These lights shine through the water horizontally, directly on the fishes' sides. To the visitors, this is delightful; to the fishes it is disastrous. No species ever tested has thrived under such lighting, and most of them have died quite soon - seemingly from some nervous disturbance that manifests itself in extreme excitability and sensitivity to outside stimuli, in loss of appetite, in aggressive behavior toward tankmates and in failure to breed. In extreme cases, the fish may face the light and start to spin, revolving with increasing speed until apparently exhausted. Similar effects of abnormal lighting have been noted by other observers on a number of different species. It would seem that fishes' nervous and sensory systems are phylogenetically or ontogenetically conditioned to light coming only from above and that they are unable to cope with any drastic change in light direction.

Another bad feature of side-lighting is that it encourages the excessive growth of algae on the glass nearest the source of light, necessitating very frequent cleaning.

Since light, perforce, must come from the top, where above the water surface should its source be located? It has been found that the lamp or series of lamps should be placed as near the surface and also the front glass as is feasible. The former location gives maximum intensity and the latter eliminates silhouetting of the fish. If possible, some light should be directed down the water-glass interface at the front of the tank. Similar conclusions have been reached by other aquarists.

Keeping the light toward the front of the tank also makes it possible to subdue the background to any desirable extent - or to emphasize it with supplementary lights near the back of the tank. In the new type of tank, now in use at the "temporary" New York Aquarium, it has been found that, by painting the three opaque walls with black asphaltum varnish and by placing a small shadow board across the back of the tank, it is possible to "give an impression of infinite distance when viewed through as little as four feet of water. In such a bare tank, fishes seem to appear out of nowhere and to drift off into the unknown - all within the confines of their small microcosm."

The quality as well as the quantity and direction of light must be taken into consideration. One of the principal reasons why natural light was preferred by C. H. Townsend, among others, was that "natural colors are obscured and their values more or less altered by artificial light." It is now possible, however, to obtain a close semblance to natural coloration in fishes and other aquatic exhibits solely with artificial light.

Requirements from tank to tank, and each tank must be treated more or less as a case unto itself, but in general we have found that a variable mixture of regular frosted and daylight incandescent bulbs gives the best results. Using daylight bulbs alone produces a "cold" appearance in which the reds and oranges of the fish are quite subdued. With few exceptions, it has been found that better results are obtained if the light source is stronger in wave lengths towards the red end of the spectrum rather than towards the blue. The differential absorption and scattering of light rays is undoubtedly partly responsible for this, red light being transmitted through water with much less intensity than blue. Until recently this was the greatest objection to using fluorescent lighting for aquarium tanks. All the older types of fluorescent tubes gave an extremely "cold" effect - as if the tank were illuminated by moonlight. This was novel, almost eerie sometimes, but far from natural. Moreover, the vivid reds and warm oranges and yellows that play so important a part in piscine coloration were greatly dulled or obscured altogether.

Fluorescent lights have three definite advantages over incandescent ones:

1. A large, uniform light source,
2. Small heat production,
3. Low current consumption

A new cold color type called Warm Tint seems to be the answer. As its name implies, this fluorescent tube emits a more yellowish light, and the effect it gives in a tank is close to that of the best incandescent lighting.

Aquatic plants are dependent on the quality as well as the quantity of illumination that impinges on them. Although the common belief that plants are necessary to supply oxygen in standing aquaria - thus balancing the respiration of the fishes - is unfounded, no public aquarium can afford to neglect aquatic vegetation for its freshwater tanks.

Tanks without vegetation cannot compare in natural beauty to those that are well planted, and most fishes seem to thrive better when kept together with plants. There are many instances in which it is impractical to use them, but it behooves the aquarist to employ aquatics as much as possible. One of the desirable features of the new Warm Tint fluorescent lights is their good effect on plant growth. Although it had been well established that incandescent lighting alone would support plant life, it was at one time believed that fluorescent lighting would not.

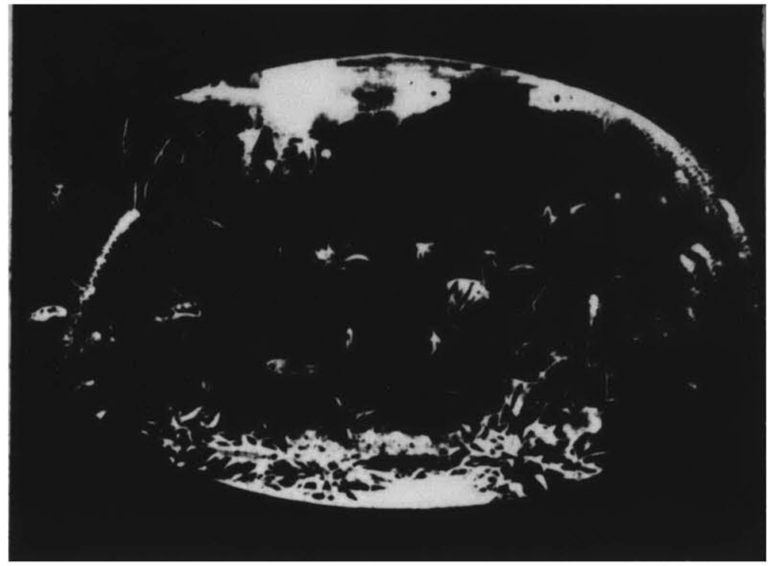
At the New York Aquarium, better response has been obtained from plants in the 300 gallon tanks with three opaque walls and containing thirty or more inches of water, by using Warm Tint fluorescent tubes together with a few frosted, incandescent bulbs, than with any other lighting arrangement thus far. Tubes are placed six inches from the water surface and about three inches behind the viewing glass.

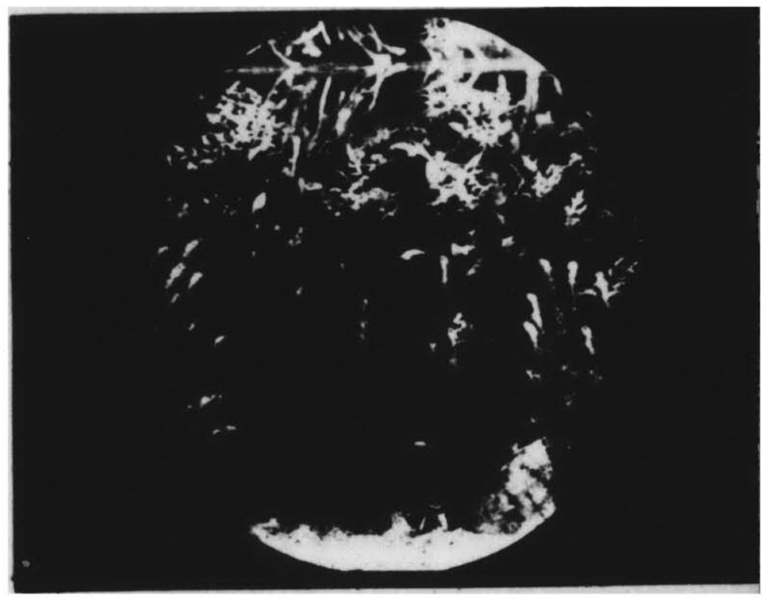
Were the only source of light thus located, all plants would tend to grow towards the top front of the tank. Additional lights, located further toward the rear, will offset this, but at the same time will cause a certain amount of undesirable silhouetting of the fishes when they swim to the front of the tank. As in most cases, a compromise between these two desirable, but incompatible, conditions must be struck. Only observation and experiment can provide the best possible adjustment.

The great value of mobility and flexibility within a public exhibition place has been previously stressed. This principle applies to lighting fixtures as well as to tanks and other apparatus. Since each exhibition tank contains living things, it cannot remain in one state for long. At best it will be in some kind of dynamic equilibrium - one that is easily upset or that periodically changes spontaneously. These changes often necessitate an alteration in the tank's lighting, and this is easily done only if mechanical facilities are available for rearrangement of the lights.

Lack of flexibility is perhaps the greatest single fault in the lighting systems of public aquariums today. In the new New York Aquarium, at present in the blueprint stage, it is hoped to achieve a large measure of the ideal of complete flexibility of lights by the construction of a catwalk above the tanks that, among other things, will provide a place from which a great variety of fixtures can be suspended over all parts of each tank. The lights should be so arranged that they can be quickly and easily moved aside, when a tankman wishes to work on any particular tank. In effect, this catwalk will be a grid for the stage (tank) below. Numerous reflectors have been experimented with, those constructed of polished metal or glass mirrors quickly become spotted or extensively corroded because of high humidity and salt water. Although white enamel may not be most efficient in reflecting list, it is the most satisfactory material for the reflectors of aquarium tank fixtures, since it resists corrosion and is easy to clean.

Lighting of Aquarium Tanks





4. Plants

Plants have been grown in home aquaria for more than a hundred years, yet their principal functions are often overlooked in favor of the usual concept of the oxygenation of tank water. The idea that fishes and plants of an aquarium balance each other in their production and consumption of carbon dioxide and oxygen is a false one.

In reality, the principal functions of plants in aquaria are:

a. To decorate the tank. This is put first even though it may seem the least itilitarian. To be sure, there are many who are interested in fish per se, but by and large, it is the beauty of a well-decorated tank that attracts people to the hobby.

b. To minimize the likelihood of excessive multiplication of algae. In general, tanks that are well planted suffer less frequently from green water or any other overabundance of algae. This phenomenon has also been noticed in outdoor ponds and pools and has been demonstrated experimentally out of doors. Several theories have been advanced to explain why it occurs. One is that the large plants shade the water sufficiently to prevent the growth of the small types, but it is unlikely that this could operate in a glass-sided tank. Another idea is that the large plants produce some substance inhibiting the growth of the small ones, but no one has yet detected such a material.

A third theory has been that plants are dependent upon a number of substances for growth; a well established stand of higher plants may use up one or more of the available growth-promoting materials as fast as they appear in an aquarium or keep them at so low a level that no large amount of algae can be formed. Johnstone's application of Liebig's Law of the Minimum to planktonic growth is perhaps pertinent here: "A plant requires a certain number of foodstuffs if it is to continue and grow, and each of these food substances must be present in a certain proportion. If one of them is absent the plant will die; if one is present in minimal proportion, the growth will also be minimal. This will be the case no matter how abundant the other foodstuffs may be. Thus the growth of a plant is dependent upon the amount of that foodstuff which is presented to it in minimal quantity."

Drs. F. W. Kavanagh and H. W. Rickett of the New York Botanical Garden have pointed out, however, that the amounts of nitrogenous and mineral substances used by plants in any ordinary aquarium are minute and unlikely to become a limiting factor. In fact, ordinary tap water is often a pretty good nutrient solution for plants, the very small amount of materials dissolved in it being sufficient for them. The reason why a good growth of higher plants tends to prevent excessive multiplication of algae is thus a mystery, and if the Law of the Minimum applies, it does not concern the fertilizing substances in fish wastes since these are present far in excess of the plants' needs.

Many aquarists have believed that plants help maintain a more nearly uniform water chemistry in an aquarium by utilizing appreciable quantities of the nitrogenous wastes of fishes. Because the amounts of these fertilizers necessary for aquatics' growth are insignificant compared to what the fishes are producing this effect does not operate to any extent. In this connection, it should be remembered that fishes have been known to live in unplanted tanks for years without any change of water. They have also lived for long periods in standing aquaria kept in total darkness, where not even algae can grow.

c. To provide food for the fishes, both directly and indirectly by promoting the growth of various microorganisms and other small animals. Fishes that eat leafy plants are not popular with the great majority of aquarists, so the use of higher plants directly as fish food is relatively unimportant. Only algae are regularly eaten by the common species of tropical fishes kept in aquaria. Indirectly, however, leafy plants and stoneworts may be quite important. The behavior of many fishes gives ample demonstration of this, for they spend much time picking or grazing on the leaves and stems of submerged aquatics. In nature a great variety of very small creatures live on aquatic plants. Undoubtedly fewer exist on the plants in aquaria, but, so far as we know, they help provide a more adequate and natural diet for captive fish. Nitella, one of the stoneworts or charales, is especially valuable in this regard.

d. To shelter less dominant fishes from attacks of their more aggressive neighbors:- A careful study of the behavior of practically any group of fishes in captivity reveals that certain individuals dominate others whenever there is competition for food, swimming space or potential mates. Sometimes this domination appears to border on persecution, and the only way a less aggressive fish may be able to escape harassment from its more domineering tankmate is by hiding. Nothing can provide more or better hiding places in an aquarium than a generous growth of plants. It has also been demonstrated that dividing a tank into partially separated compartments reduces the amount of aggressive behavior among territory-holding fish, apparently by enabling them to establish their domains securely with less fighting. It would seem quite probable that plants act in a similar way, providing fishes with niches, nooks or crannies that they can call their own, or use as refuges when hard pressed by some other fish.

e. To provide sites for the attachment of eggs and refuges for the protection of young fishes. These are well recognized functions of aquatic plants. A large number of different fishes place or scatter their eggs on plants. Among the better known genera that include species with such reproductive habits are: Hyphessobrycon, Hemigrammus, Nannostomus, Poecilobrycon, Barbus, Carassius, Rasbora, Corydoras, Rivulus, Epiplatys, Pachypanchax, Aplocheilus, Melanotaenia, Pterophyllum and Ambassis. For baby fishes, hiding places are life-or-death matters. Without a suitable sanctuary from hungry larger fish, few young would survive. A heavy growth of floating plants seems to be the best protection for tiny fish, and it also provides them with good feeding grounds for microscopic and near-microscopic prey.

f. To give the fishes a natural habitat, more conducive to their well being - in the broadest sense of the term. This somewhat intangible function of plants is placed last because it forms a sort of catch-all for any items not included in the first five - most of which it overlaps in several respects. It is quite reasonable to suppose that in general, captive fishes will behave more normally, be more healthy and live longer and more natural lives, the more closely their man-made environment approximates or betters their environment. Plants form an integral part of the natural habitat of most tropical fishes; for this reason, if no other, the aquarist should give them careful consideration.

Undoubtedly, some of the functions of plants in aquaria have been omitted from the above. It is nevertheless evident that fishes benefit greatly from the presence of plants in their aquaria. The benefits that accrue from keeping plants and fishes together do not extend only to the fishes, however; the plants, too, profit from the association. It is common experience that aquatic plants grow better when kept with fishes than when kept alone, provided, of course, that the fishes are not of the plant-molesting type, Aquatic plants need fertilizer just as terrestrial ones do, and fish wastes are evidently excellent fertilizer, although fishes produce far in excess of what the plants require. Of much greater importance is the carbon dioxide given off by the fishes. There is good evidence that this gas is usually a limiting factor in the growth of at least the higher aquatic plants. Without it, photosynthesis cannot take place and these plants apparently quickly exhaust the supply dissolved in water. Breder's measurements of carbon dioxide concentrations in aquaria lend support to this view, since he found that the carbon dioxide remained far below its equilibrium point with the atmosphere for long periods when the plants in an aquarium were actively photosynthesizing. A more adequate supply of carbon dioxide is undoubtedly the reason why plants kept with fishes grow better than those kept in old tanks rich in fish wastes but without any fish.

For both utilitarian and aesthetic reasons, aquatic plants should be an essential part of the home aquarium, and successful aquarists will continue to use them generously.

5. Parasitic Fungi and Algae

Fungi presents no problem when the water is alkaline. Artificial lighting and alkaline water do not encourage the growth of blue algae, but when they do appear, they can be wiped off with a brush.

6. Heating

Presents no problem from conventional type heating in public buildings.

7. Personnel

In Detroit, two persons are entrusted with the care of the fish and other aquatic animals while heating and refrigerating are in the hands of a mechanic

In Boston, in addition to the Director, there are seven employees; three who care for the fish, three for the heating and one attendant.

8. Visiting Hours

In most aquariums visiting hours are during the day, from 9 to 5 daily, with some entrance fee charged. In Chicago the entrance fee is twenty-five cents, children free. In New York, the entrance fee is ten cents for adults, five cents for children ages 5 to 12.

9. Procuring of Animals

Animals are obtained by donations, exchange and from fees.

10. Exhibit Animals

The prime requisite for animals in captivity is a plentiful supply of their natural element to which everything is subordinate. The water supply must be pure and abundant, both for the marine and fresh water exhibits. Lack of food can be endured by aquatic animals, but the impairment to their natural element is immediately fatal, whether from actual fouling or mere lack of oxygen. They may long survive over-crowding if the supply of water is abundant.

11. Collection of Fish

The fish fauna of the world includes 20,000 species of which approximately 4,000 belong to North and Central America. Of this number, about 800 species, not counting home aquaria fish, can live fairly well in aquaria. Three-quarters of the fish are salt water varieties which keep better in aquariums than fish from cold fresh water. The Chicago collection numbers about 10,000 specimens, representing 250 species.

12. Main Attractions

Sea horses, electric eels, sharks, sea lions and seals are among the most popular. Game fish are of special interest to anglers.

13. Aquatic Animals

Collections of these may be made from the following groups:- Marine mammals; seals and sea lions; reptiles, amphibians, turtles, frogs, salamanders; crustaceans, crayfish, hermit crabs; lobsters, crabs, king crabs; insects and worms; mollusks:- oysters, snails, octopuses; echinoderms:-

sea urchins and star fish; coelenterates:- jelly fish, sea anemones, corals.

14. Outdoor Ponds

In the Detroit Zoological Gardens at Quebec, a stream divided into several sections holds fresh water fish in its pools. It would be desirable to have outdoor pools for seals and sea lions.

15. Home Aquaria

Detroit has 20, Chicago 65, to which must be added 80 reserve aquaria. The capacity varies from 5 to 200 gallons of water. In the large Montreal Botanical Gardens, provision has been made for about 100 balanced aquaria, not counting the reserve Victoria Regai pool and in the service greenhouses 27 other aquaria of 45 gallons and several pools (can. gal.).

V. NATIONAL AQUARIUM

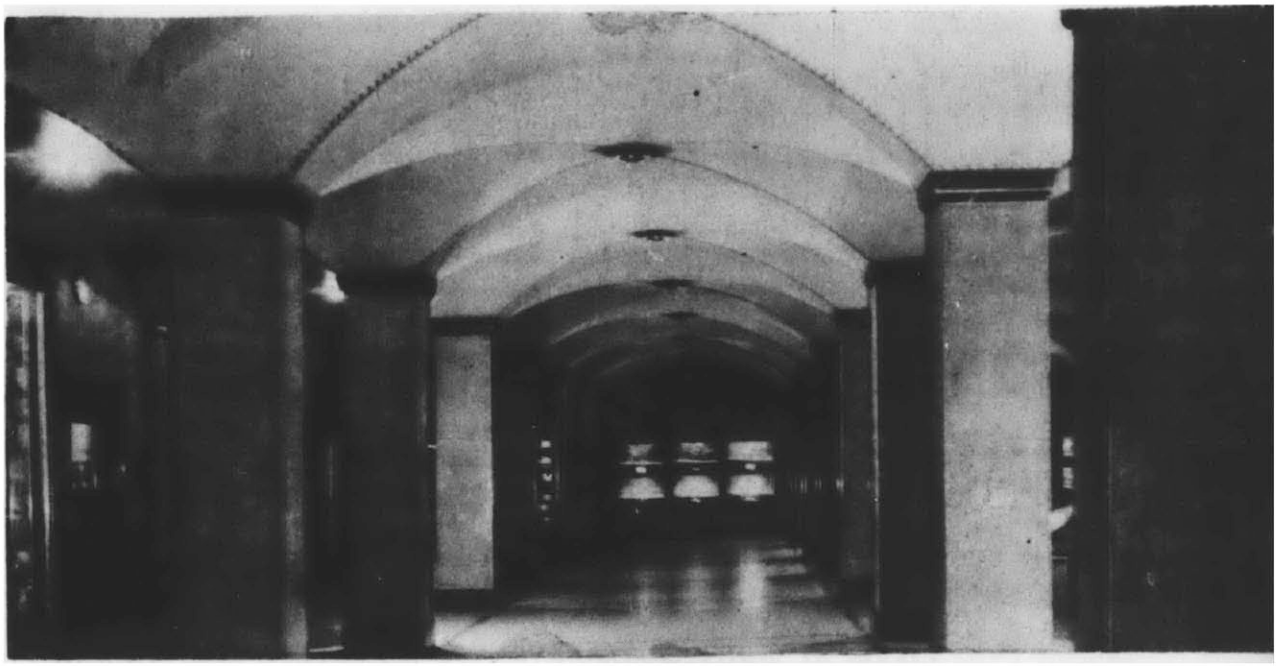
The National Aquarium, the oldest public aquarium in the United States, was established at the Central Station in Washington in 1888 within the space available in the Fish Commission Building at 6th and B Streets. This aquarium was fitted out with a marine grotto which contained 24 tanks of salt water fishes as well as 25 tanks of fresh water species. Its success was partly responsible for the establishment in 1893 of the New York Aquarium at the Battery in New York City.

For nearly fifty years, the aquarium was maintained here and eventually this aquarium occupied about 5,700 square feet in the main building and about 2,100 square feet in an annex. There were 27 tanks which held from 70 to 700 gallons of water each and a floor pool of 13,000 gallons. As time went by, the displays were arranged to present only fresh-water species and other aquatic life of interior waters. In spite of limitations of funds and space, this aquarium served well to show the public the principal game fish reared and distributed by the Federal and State Governments in their efforts to prevent depletion of a natural resource. In 1932 when construction was begun on the new Department of Commerce building which included the Bureau of Fisheries at that time, there arose an opportunity to build a more modern aquarium in Washington. In the basement floor of the building, the present aquarium came to occupy a space

148 feet long and 48 feet wide. The aquarium has 47 exhibition tanks, three of which have a capacity of 2,000 gallons; 20 of 1,000 gallons and 24 of 50 gallons. Three small floor pools and some large display cases complete the exhibition facilities.

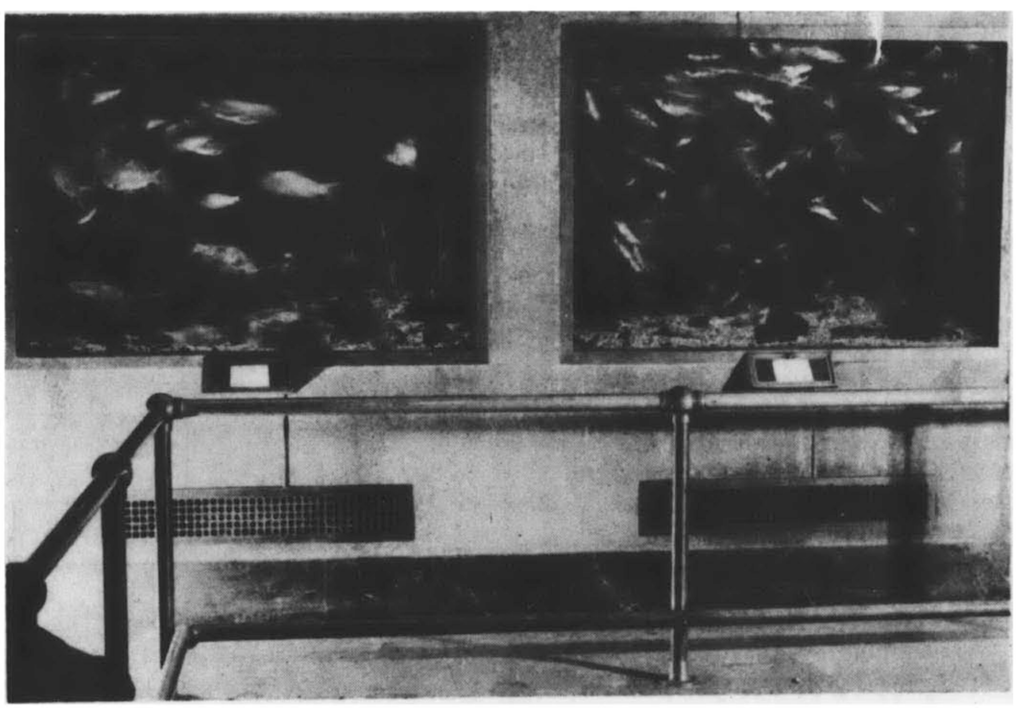
Water is supplied to the aquarium each day from the city water to supply its 100 tons of tank water. This chlorinated city water must first be passed through carbon filters to remove the chlorine and render the water useful and, in most cases, must be refrigerated for the tanks of the northern fishes.

Within this space the fish and wild-life service is capable of presenting a collection of the principal fresh-water game fish of the country; collections of miscellaneous native fish, tropical toy fish and the larger aquatic reptiles and amphibians, as well as fulfill certain secondary objectives:- to develop better methods of maintaining native fishes under artificial conditions of confinement, to stimulate such research in aquatic biology as can best be advanced by observing animals at all times in a large aquarium, and to give advice to the American public on the care of a home aquarium and the outdoor display of ornamental pond fishes.



NATIONAL AQUARIUM

View of Galleries



VI. THE JOHN G. SHEDD AQUARIUM

The John G. Shedd Aquarium in Chicago was completed in the Fall of 1929 with the last section of the exhibits being opened to the public in June of the following year.

The building is of white Georgia marble and simple Doric architecture and is today the largest and finest equipped institution of its kind in the world. The building is octagonal and measures three hundred feet in diameter, exclusive of a thirty-foot terrace which surrounds it.

In the entrance foyer hall are held fishes, turtles, shells and invertebrates, all modeled from life. On either side of the foyer are two smaller archways leading directly to the exhibition galleries. The large center archway opens into the rotunda, where there is a forty-foot pool. Half of this pool is occupied by a rockery planted with ferns and other suitable plants. The balance of the pool is arranged as a swamp, where live various specimens of turtles, frogs and other typical swamp fauna.

Radiating from the rotunda are the six main galleries, each ninety feet long and thirty feet wide, which contain a total of 132 exhibition tanks. The largest tanks are 30 feet long, 10 feet between the glass and the back wall and the water is six feet deep. They each hold approximately 13,500 gallons of water. The smallest tanks are 3½ by 3½ by 5 feet and hold about 445 gallons each.

In addition, there are ninety-five reserve tanks graded in size to correspond with the front tanks. These are used to hold reserve stock and to accommodate the show specimens when their exhibition quarters are being cleaned. The total capacity of all the tanks is about 450,000 gallons. In the basement of the building are situated four reservoirs with a combined capacity of 2,000,000 gallons. Half of this is fresh and half salt water. The fresh water is pumped directly out of Lake Michigan, through the aquarium's own intake situated just east of the building. The salt water was brought in railroad tank cars to Chicago from Key West, Florida.

The tanks, constructed of concrete, are divided into five separate systems; heated and chilled salt water, and heated, chilled and natural freshwater. Some of the tanks are double piped so that each system may be expanded or contracted as the character of the exhibits on hand requires. Each system has a separate reservoir, with the exception of the heated fresh water, which is auxiliary to the natural fresh-water system. Each reservoir is partitioned into two equal parts and half of the water is allowed to remain idle while the other half is working. This arrangement is reversed on the first and fifteenth of every month, and the benefit of this settling period is apparent in the clarity of the water in the exhibition tanks.

In all the systems water flows by gravity from the reservoirs to a pump sump in the basement. From here it is pumped to a pressure tank near the roof. It then flows by gravity to the fish tanks. From the fish tanks it flows to filters over the reservoirs and after filtering returns to the reservoirs. It is aerated by spraying at four different points in the circuit. The heated systems are maintained at the proper temperature in winter by steam coils situated in the gravity tanks. In summer they do not require heating. In the case of the cold water systems, all the water in the "working" half of the reservoir is lowered in temperature by means of hyge refrigerating machines. These machines operate about one-third of the time and hold the temperature within a margin of 2° F. The chemical constituency of the water is constantly watched and, when necessary, it is treated in order to maintain, as far as possible, its original condition. All of the aquarium water is handled in antimonial lead pipe throughout the building. Experience has shown that this material combines good tensile strength with excellent resistance to corrosion. This is particularly important in an aquarium with a closed system, where corrosion not only destroys equipment but also introduces into the water chemicals which often prove fatal to the exhibits.

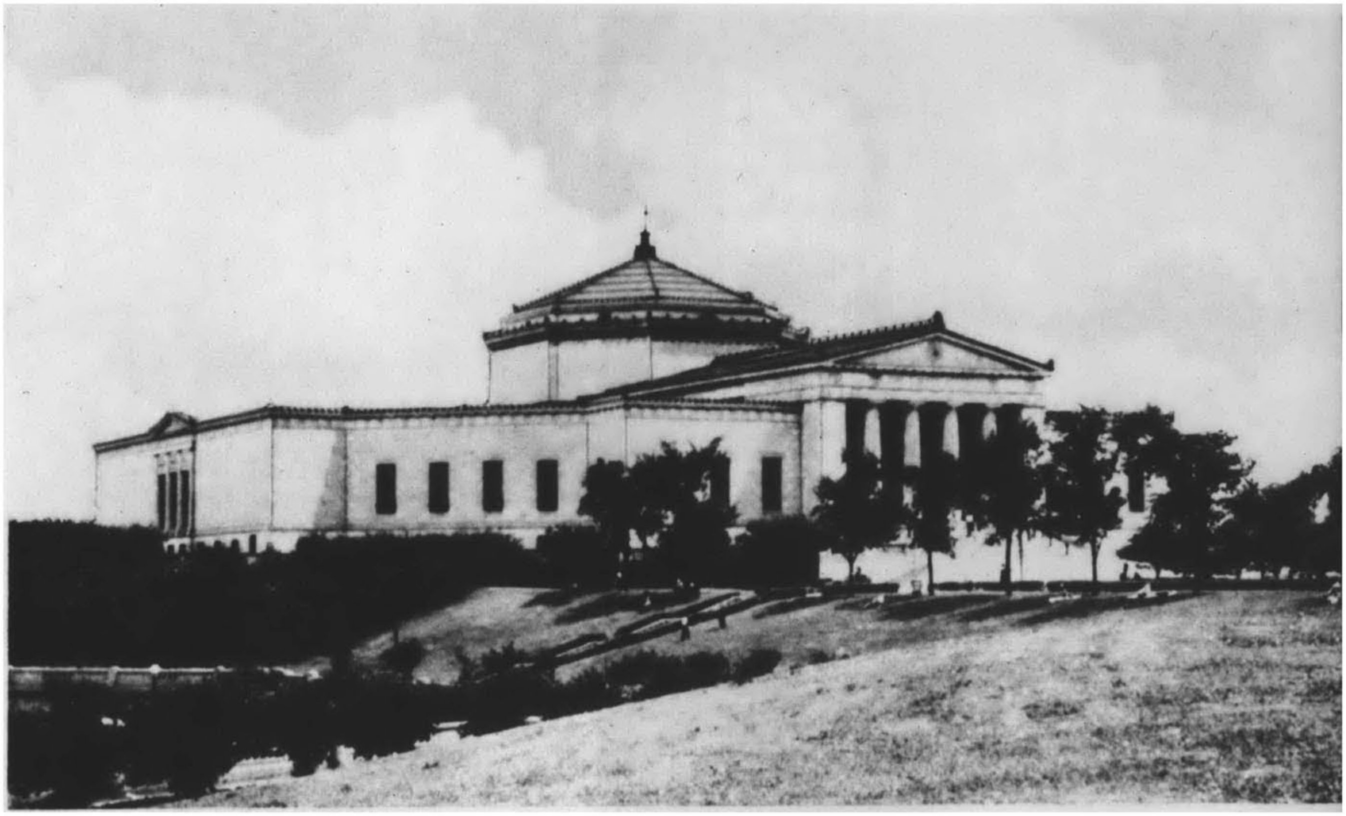
All of the machinery at the aquarium is electrically operated, steam being used only to heat the building. As everything is in duplicate to obviate the possibility of interrupted service, nineteen pumps are required to handle the water for the fishes alone. In addition, there are two air compressors that deliver air at a pressure of five pounds to every tank in the building, including those in the Balanced Aquarium Room, three 150-ton refrigerating machines and various pumps and other machines associated with the regular operation of a large public building.

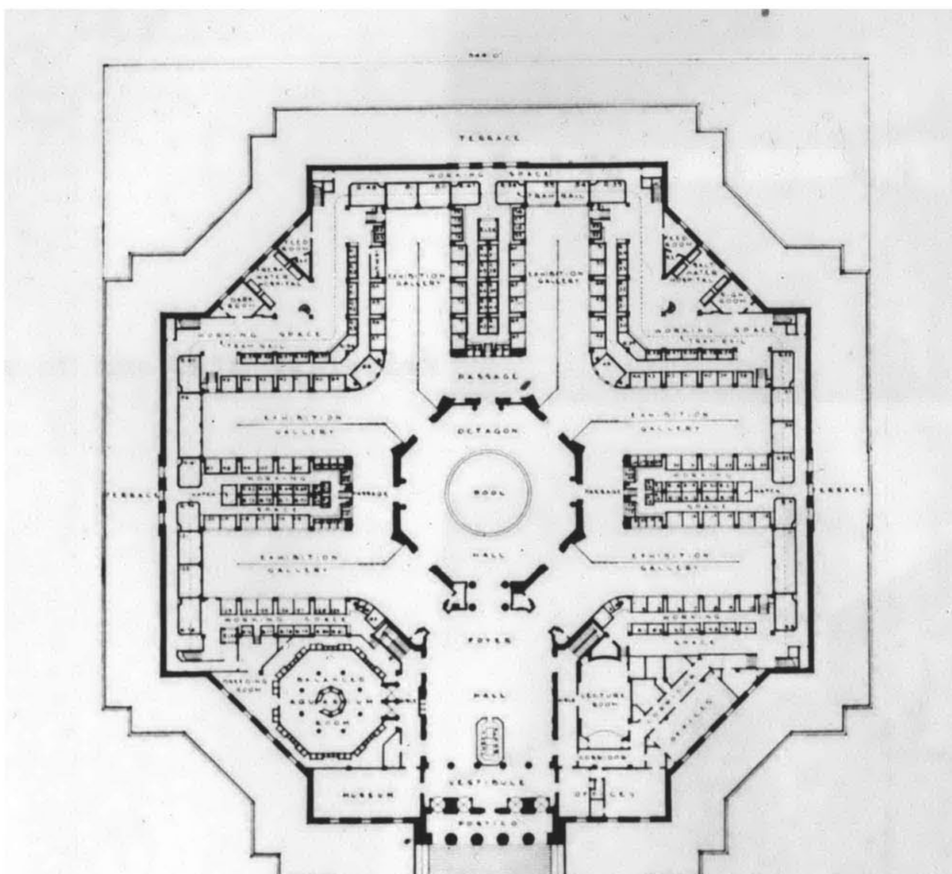
To the right of the foyer hall, is the entrance to the Balanced Aquarium Room. This room is decorated in an Oriental style to represent an open courtyard and is illuminated with eight large lanterns placed on bamboo poles. In the center is a kiosk with seven large aquariums. Around the wall of the room are sixty-five balanced aquariums ranging in size from nine to sixty-five gallons. The water in these tanks does not circulate. The fishes exhibited in the tanks of this room are comparatively small and depend for their oxygen on the growing plants with which each tank is provided. These fishes come from warm climates, and the Balanced Aquarium Room is maintained at a temperature of 80° F. by steam heaters which are thermostatically controlled.

In the Fall, at the end of the collecting season, there is in the aquarium an average of 10,000 specimens, representing about 250 distinct species. This does not include a young hatchery fish too small to exhibit. Fish are brought by a railroad car specially built by the Pullman Company from plans drawn by the Director of the Aquarium.

The Aquarium is operated and controlled by the Shedd Aquarium Society which is composed of prominent business men. Funds for maintenance are obtained in three ways: from admission fees collected on pay days, from a small tax levied by the Chicago Park District, and from funds raised by the Society.

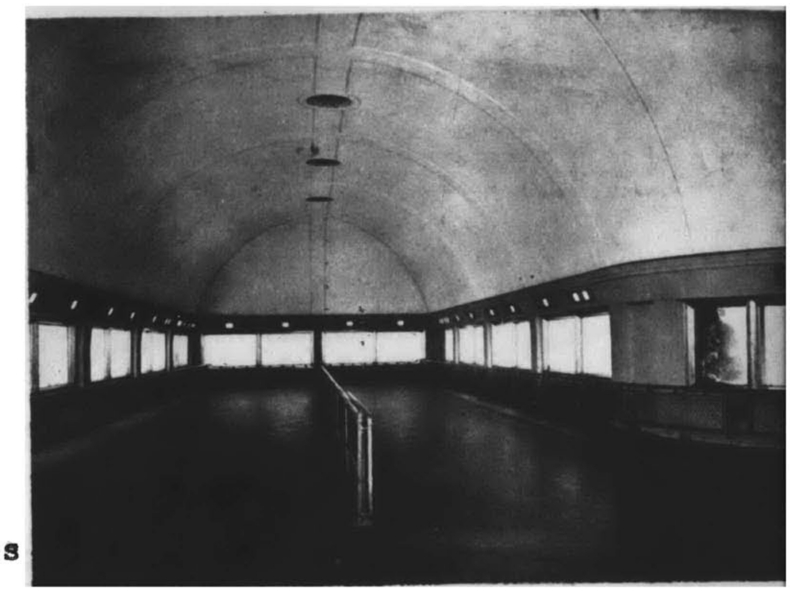
The popularity of the institution is attested by the fact that during the calendar year of 1931, there were 4,689,730 visitors.



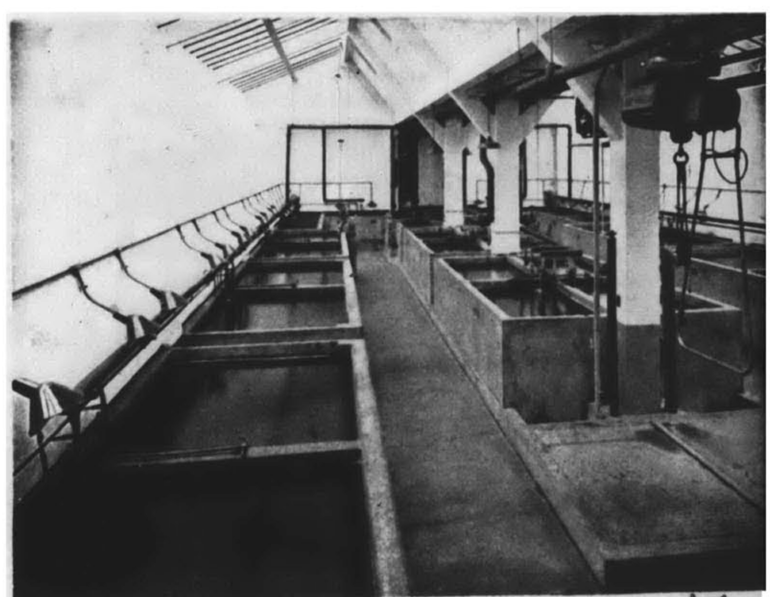


TERRACE
WORKING SPACE
EXHIBITION GALLERY
PASSAGE
OCTAGON
POOL
HALL
FOYER
VESTIBULE
PORTICO
MUSEUM
FIRST FLOOR PLAN
JOHN · G. SHEDD AQUARIUM
CHICAGO ILLINOIS
GRAHAM ANDERSON PROBST & WHITE · ARCHITECTS

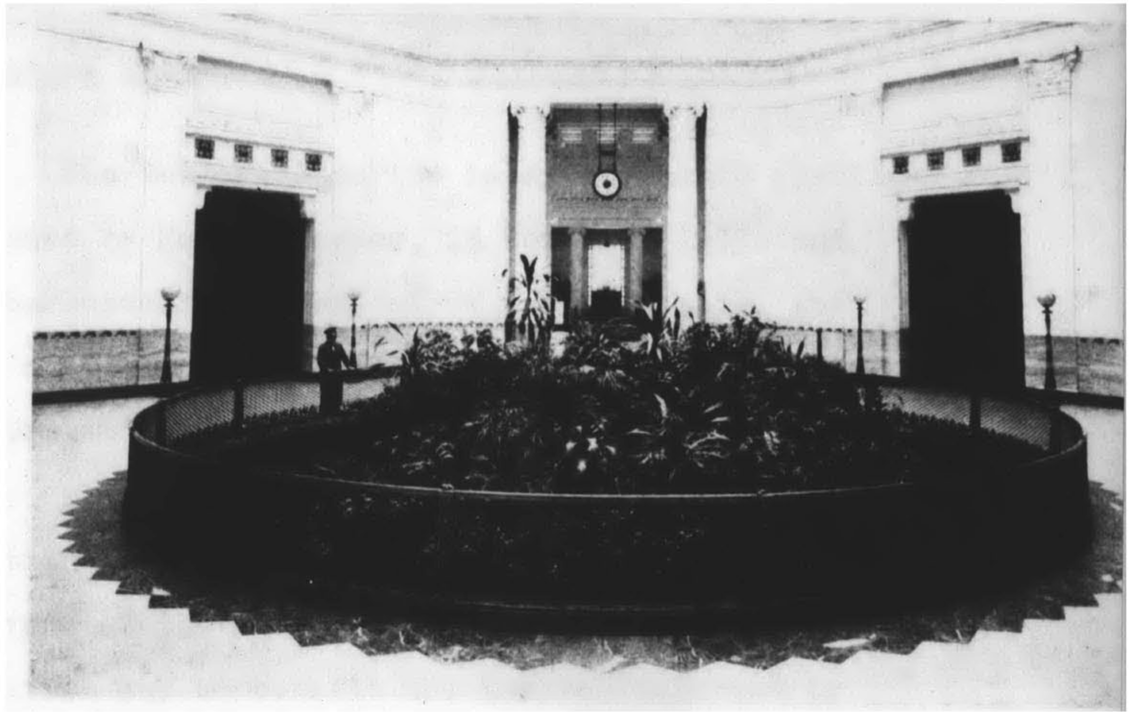
A Corner of the Foyer Hall



One of the Main Galleries



View of Work Space



Rotunda and Pool

Balanced Aquarium Room

VII. THE DENMARK AQUARIUM

The Denmark Aquarium is an autonomic institution established by Royal Charter, 15 November 1937, and erected in Charlottenlund Park, close to the castle, the headquarters of the International Council for the Exploration of the Sea.

Its object is twofold: To exhibit an appropriate selection of fish and other organisms from the seas, lakes and rivers of the world for the pleasure and education of the population and to benefit the Danish fisheries by placing, without charge, a special department for scientific experiments at the disposal of scientists and biologists connected with the International Council for the Exploration of the Sea.

The Aquarium is run by a committee of three; one appointed by the Minister by whom the Danish explorations of the sea are administered, one appointed by the Royal Danish Academy of Sciences, and one by Mr. Knud Hojgaard.

The Aquarium building was designed by the architect Gjerlov Knudsen, the technical installations planned and partly carried out by the civil engineer S. A. Andersen of Nordisk Koleteknik, and the decorations were done by Mr. Kay Simmelhag, the painter, all in cooperation with the Director of the Aquarium, Mr. Mogens Hojgaard.

The structure consists of a main building containing the section open to the public, a side wing comprising offices, laboratory, etc., a tower, and a hothouse for breeding small fishes and plants. It covers an area of about 3,900 square feet. Except for cleaning purposes, there is no light in the Public Hall other than that coming from the exhibition tanks. These receive their illumination through large skylights and only when it is very dark are they lighted artificially by lamps fixed on the wall just above the front-glasses of the tanks so that the light is cast diagonally downward across to the back wall of the tank.

In the basement of the main building there are, besides the public lavatories, a store room, an engine room, a workshop, the furnace room, and reservoirs in addition to a biological laboratory for the use of the scientists attached to the International Council for the Exploration of the Sea. There are four reservoirs which hold altogether about 3,650 cubic feet of water, salt and fresh in equal quantities. The fresh water comes from the Copenhagen Waterworks, the two fresh-water reservoirs being filled and maintained with city water; whereas the salt water comes from the North Sea. Both the fresh and the salt water is regularly tested by chemical analyses. The Aquarium has four separate systems of water supply in addition to the ordinary hot and cold tap water. They are cold fresh water, heated fresh water, heated salt water, and cold salt water, and each system has its own reservoir. From each reservoir, the water is pumped up to a gravity tank on one or the other of the two top floors of the tower, where the cooling and heating respectively takes place. On the top floor are the gravity tanks for cold fresh water and cold salt water. The cold fresh water is for the native fresh-water animals and is neither refrigerated nor heated, so that it is always at room temperature, namely between 60 and 70 degrees, according to the time of the year. The cold salt water is cooled in summer by means of an automatic refrigerating plant using methyl chloride. The refrigerating machines, two in number, are in the engine room, and from there the methyl chloride is driven through copper pipes up to the refrigerating coils in the gravity tank. The coils are one-inch iron pipes coated outside with lead, and painted. In order for the cooling to be sufficiently effective, it is necessary for the coils to have a large surface, and this is ensured by their being no less than 700 feet long. In winter the low outdoor temperature is sufficient to keep the salt water in the cold tanks down to about 50 degrees.

On the next to the top floor are the gravity tanks for the heated fresh and salt water. They are heated by pipes from the central heating system to about 90 degrees, this being sufficient to maintain the temperature in the exhibition tanks at about 82 degrees. The four large tanks are filled automatically by different pumps, which are activated through switches operated by floats in each of the individual tanks. From the gravity tanks in the tower the water runs down by gravity into the pipes feeding the exhibition tanks and the quantity flowing into the individual tanks can be regulated by valves or, in the case of salt water, by stop-cocks.

The supply of water passes down to the bottom of the tanks through celluloid pipes placed in one of the front corners. The water overflows through a funnel at the back of each tank and down the return pipes which all lead into a main pipe conducting the water into a mud precipitator in the basement. From here the water passes down through a pre-filter of rather coarse gravel with underlying stones, from which it passes through a sluice to the sand filter and finally through another sluice out into the reservoir. The surface of each of the eight filters is about 10 square feet, and their height about 9 feet.

All the fresh water pipes are iron, coated inside and out with lead, while all the salt-water pipes and their fittings are of ebonite, and this has proved to be entirely satisfactory. The salt-water pumps are also lined with ebonite, and the shaft is of stainless steel. In addition to the two ordinary pumps, both the fresh and salt-water systems have a reserve pump that can be connected up to replace either the cold or the heated water pump during repairs. The water in the individual tanks is renewed on an average of three times in twenty-four hours.

All the tanks in both the fresh- and salt-water sections are furnished with cocks for both heated and cold water so that it is possible to increase or decrease the size of a particular section according to the number of live stock at the moment.

Finally, by means of a fork in the pipes leading from the heated salt-water pump, it is possible to send the heated salt water directly to the tanks, instead of first to the tank in the tower and to have salt water in the tanks at 67 to 70 degrees when necessary, as is the case for various animals from the Mediterranean.

The engine room has two air compressors, one of which is always in reserve, for one is quite sufficient to supply the necessary amount of air pressure. Besides serving for the aeration of the water in a number of the tanks, air pressure is also used to control the valves that regulate the flow of heat to the heated fresh-water and the heated salt-water tanks in the tower. The air compressors are worked automatically by means of a pressostat that is controlled by the pressure in the air chambers and acts on the relay of the motor in question. All the fixed tanks have one or, in the case of the large ones, two air valves through which the air can be conducted to the bottom of the tank.

In the working space are six concrete aquaria in reserve, and three large iron-framed aquaria. These are used for keeping the small fishes used for feeding purposes or for the exhibition fishes while their tanks are being cleaned. In certain cases, sick fishes are treated in these reserve tanks. On the ground floor of the side wing, there is a special acclimatization department with 15 concrete tanks of various sizes.

The hothouse is 65 feet long and 18 feet wide, divided into three sections maintained at different temperatures. In the floor of each section are two basins about 9 feet long, 5½ feet wide and 2½ feet deep. These are furnished with heating pipes and used for propagation of aquarium plants. On each of the long walls of the hothouse are three concrete shelves for small iron-framed aquaria used for breeding small fish. Finally, along the south wall outside the hothouse are six open-air basins, which are used for breeding and keeping Daphnia and mosquito larvae and for breeding various cold-water animals and plants for exhibition. The outdoor basins are furnished with hot pipes so that they can be kept free of ice in winter.

The biological laboratory of the Denmark Aquarium is an independent part of the aquarium. It is at the disposal of scientists attached to the International Council for the Exploration of the Sea, but its facilities are also available to those who work in the field covered by the laboratory. It is situated in the southern half of the basement of the main building and occupies an area of 400 square feet. The laboratory is supplied with the same four kinds of water as the Aquarium and has, in addition, a separate sea-water system with its own reservoir.

Originally, the movable aquaria were iron-framed, but as they are quickly attacked by rust, various sizes of eternite aquaria were cast in one piece leaving an opening at one end for a glass plate. These aquaria are excellent for salt water. There is also a large salt-water hatching apparatus. In the fresh-water section there are three fixed concrete tanks, a considerable number of movable aquaria, and a hatching apparatus. The laboratory also has an extra refrigerating plant for cooling the water in the hatching apparatus and the circular tanks when desirable for the experiments.

As regards instruments and apparatus, the laboratory is modern and well-equipped, and since it was opened several series of experiments of scientific and practical importance have been carried out. Since the war, the laboratory has also been used by foreign scientists for shorter or longer periods. An assistaht looks after the daily work of the laboratory.

On account of the war and the difficulties connected therewith, the livestock has not been very extensive and representative. Since it opened, the aquarium has exhibited the following aquaria.

Invertebrates	about	200	species
Fresh water fishes	"	193	"
Salt water fishes	"	121	"
Amphibia	"	14	"
Turtles	"	21	"

Among them are still to be found several which have lived in the Aquarium since its opening in 1939.

Since the opening of the Aquarium, much research work has been done in the treatment of the diseases of fishes, and successful means have been found of combating diseases in the face of which one had previously been powerless.

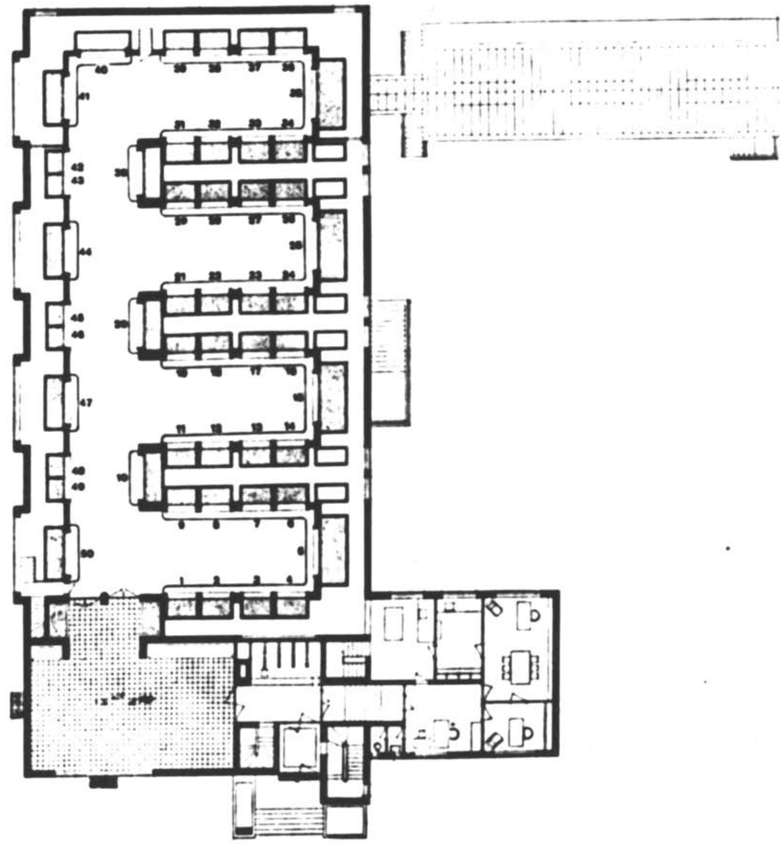
As a rule there is a sign in front of each exhibit giving a picture of the animal with its Danish name and, if known, the English name in parentheses in the bottom left corner as well as the geographical distribution of the exhibit. The figure in the top left corner indicates the group to which the exhibit belongs and corresponds to the grouping in the Danish catalogue.

From the start the Aquarium was very popular; no less than 311,741 visited it in 1939 between April 22 and the end of the year. In the years that followed, the number of visitors fell somewhat on account of the war and the German occupation and the minimum was reached in 1944 after which the figures rose again.

1940...126,507	visitors	1944...87,614	visitors
1941...104,701	"	1945...94,521	"
1942...105,356	"	1946..184,728	"
1943... 93,893	"	1947..179,594	"

The Aquarium is open daily all year round from 10 a.m. Closing time varies according to the season. In winter it never closes before 4 p.m., and in summer never later than 9 p.m. Admission fees are charged.

The staff of the Aquarium consists of: A director, an inspector, a secretary, an engineer, a keeper, one or two assistants, a night watchman, a charwoman, and a ticket seller.

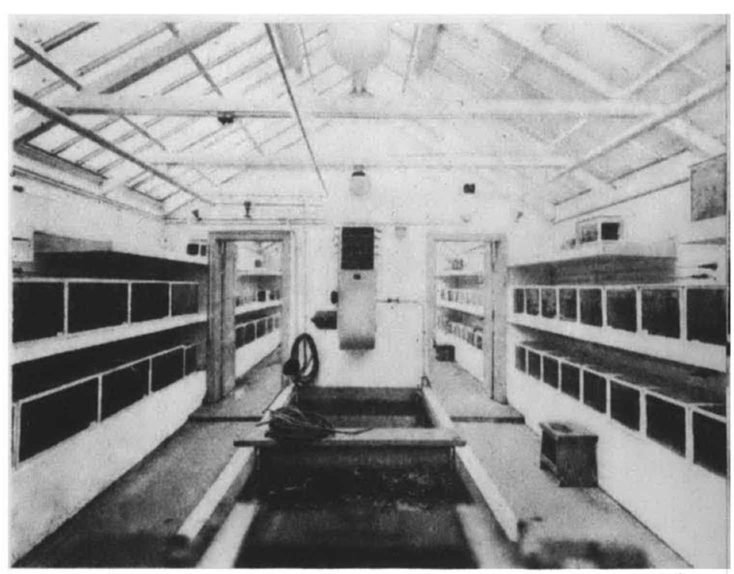


Denmark Aquarium

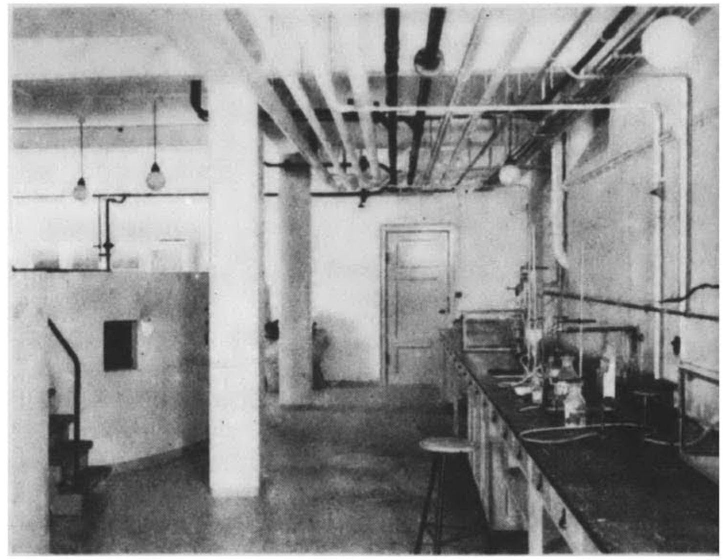
Plan Showing entrance hall,offices,exhibition hall and greenhouse.

Exterior view of Aquarium

View of Gallery



Greenhouse Work Area



Labratory and Resevoir tank

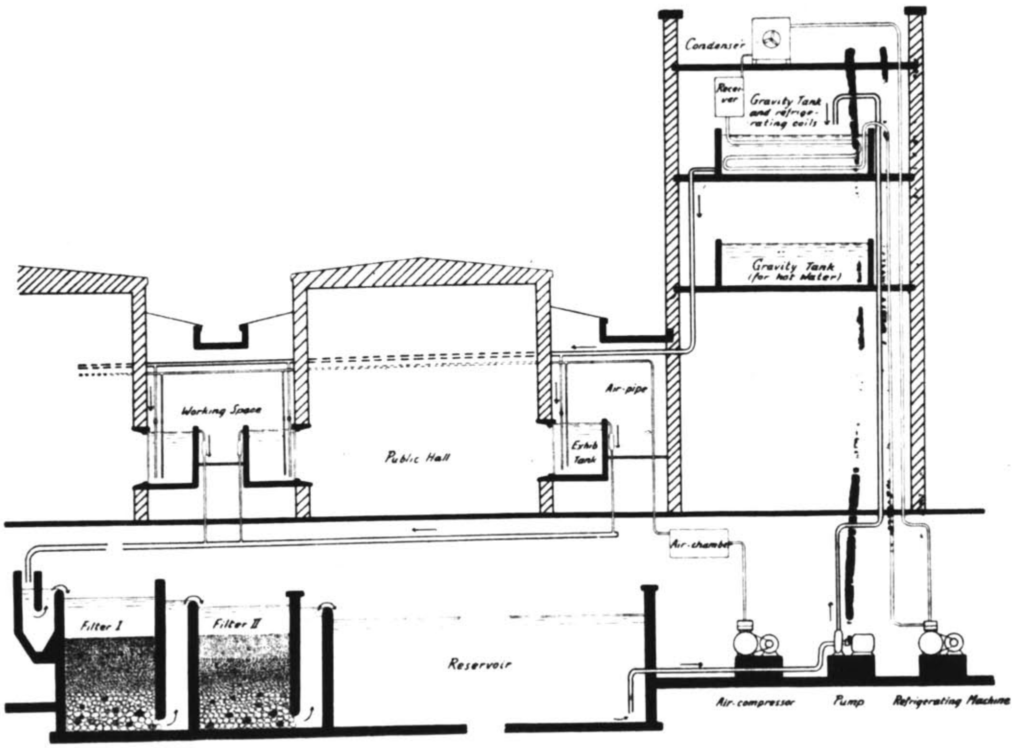
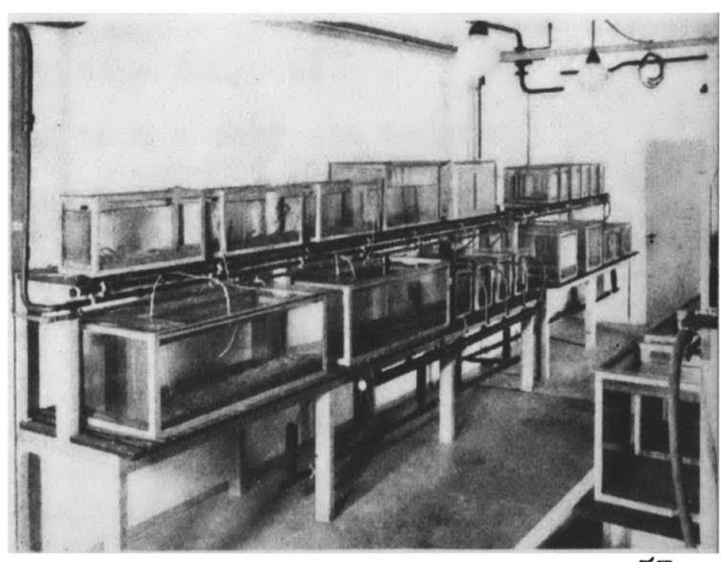


Diagram of flow of Water



Labratory Aquaria Tanks

VIII. EAST LONDON AQUARIUM, LONDON, ENGLAND

This aquarium consists of the old sea-water hall, new sea-water hall, sea lion tank and penguin tank.

The old sea-water hall has tanks furnished with artificial rockeries which serve not only as an artistic frame and background for the exhibits, but also imitate the natural environment of the animals kept in these tanks.

There are 28 tanks holding the various sea anemones, cat-fish or octopus; moray; crabs; crawfish and others.

The new sea-water hall contains four large tanks with a capacity of over 32 tons of sea water. Here a collection of sharks and skates are exhibited along with aquatic reptiles. In addition, there are seven tanks equipped with electric heating apparatus for fish imported from warmer seas.

The sea lions are kept in a large open tank on the sea front. The tanks require from 12 to 15,000 gallons of clean water each day. Exhibited along with the sea lions are three green turtles. The penguin tank shelters a number of the South African Jackass or Cape Penguins.

In the center of the tank a concrete island has been constructed in place of the usual rockeries. Its smooth surface prevents an accumulation of dirt and ensures a fine background for its inhabitants.

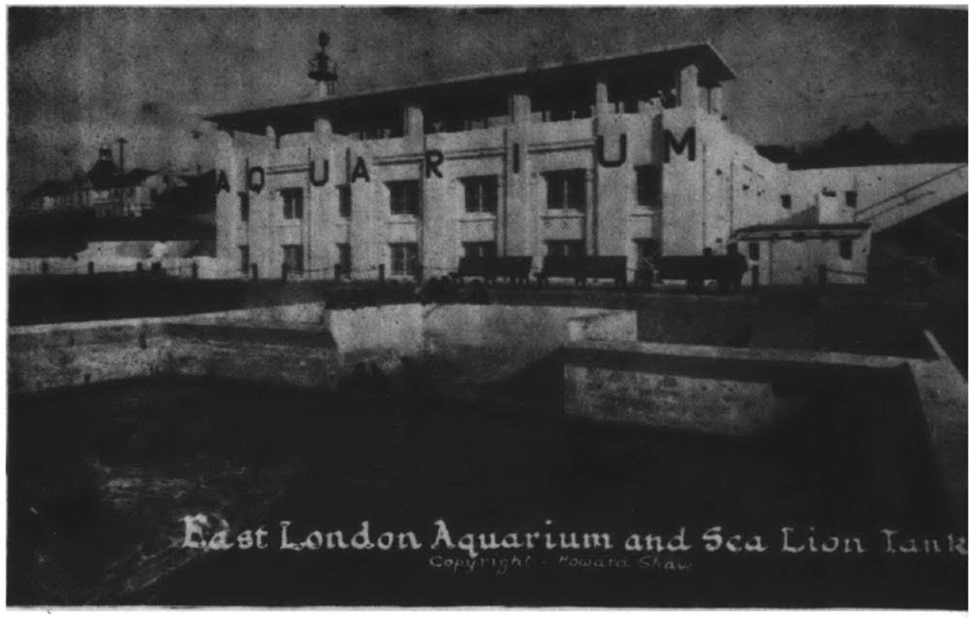
A. Water Circulation

In order to keep the specimens alive, a continual stream of fresh sea water must be pumped into the tanks. The sea water used for this purpose is pumped by two electrically driven centrifugal pumps from the sea into the low-level tank, where the fine sand settles to the bottom. From here the water is raised by two other pumps to the filter. By soaking through sand, the water is cleared and gravitates into a storage tank. From here the water is distributed to all tanks and thence flows mainly into the low-level reservoir. Part of the water goes into the sea lion tank and thence to the sea.

The daily requirements amount to 20,000 to 24,000 gallons of water.

B. Aeration

In order to supply the necessary oxygen for the animals, the water has to be artificially aerated. Two automatic pumps supply the compressed air which enters the water by means of porous materials in the form of fine bubbles, causing the white "smoke" rising in the tank corners.



East London Aquarium and Sea Lion Tank

Penguin Pool

IX. THE WOODS HOLE OCEANOGRAPHIC INSTITUTION

The Woods Hole Oceanographic Institution was founded in 1930 at the recommendation of the National Academy of Sciences, to provide facilities for the neglected study of the seas. Endowment from the Rockefeller Foundation, the Carnegie Corporation and other donors made it possible to erect a laboratory at Woods Hole, to design and build a research vessel and to employ a professional staff.

The Institution is incorporated under the laws of Massachusetts as a non-profit scientific organization. Its affairs are managed by a Board of Trustees which appoints the Director and the members of the scientific staff.

A. The Scientific Staff

The staff consists of approximately 50 scientists, about half of whom are in full residence, while the remainder return to the universities for a part of the year. They are assisted by a total of nearly 200 technical assistants, artisans, ships' officers and crews.

Fellowships are provided annually which enable about ten graduate students and younger instructors from the universities to work on oceanographic problems during short periods.

Visiting investigators are welcomed if facilities for their work are available. Since 1930 several hundred scholars have come in contact with oceanography by visiting the Institution for periods of several months.

The scientific staff has aided in the training and establishment of other oceanographic facilities in the United States. The Institution also has aided in the establishment of courses at about ten universities and colleges.

In association with the Massachusetts Institute of Technology, the Woods Hole Oceanographic Institution publishes a periodical entitled, "Papers in Physical Oceanography and Meteorology." Other contributions in scientific journals now number more than 500. The published contributions are distributed annually as a bound volume to scientific libraries and to oceanographic and marine biological laboratories throughout the world.

B. Aims

The Institution is dedicated to the study of the ocean in all its aspects: the physical and chemical characteristics of sea water, the geology of the bottom and margins of the seas, the interaction between ocean and atmosphere, the plant and animal life and their relation to the marine environment.

These aims bring together many sciences. Although the Woods Hole Oceanographic Institution is an independent organization, it operates closely with the universities. Its facilities are available to qualified scholars when needed for appropriate investigations. Many members of the scientific staff hold joint appointments in universities.

C. Facilities

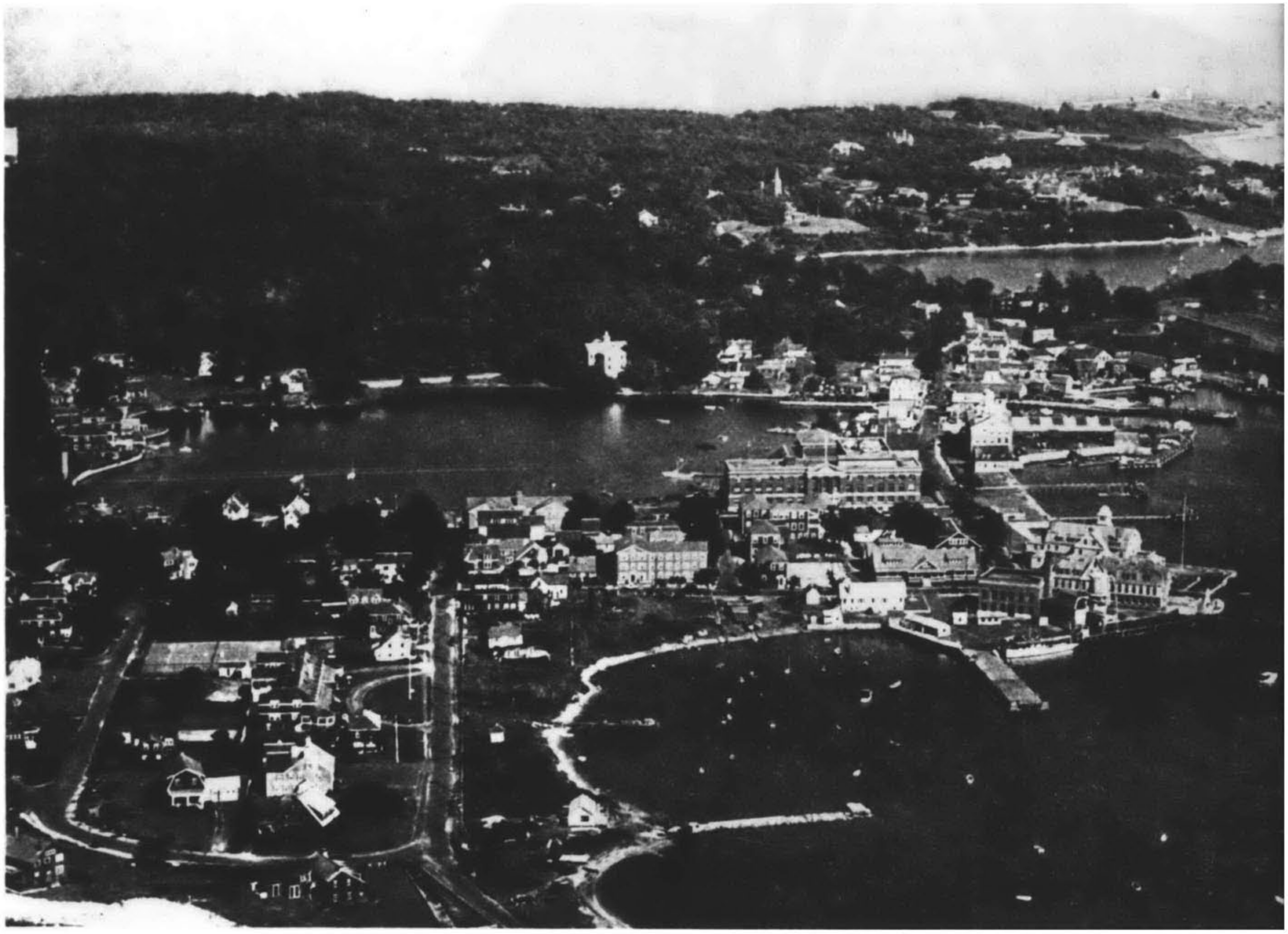
The main laboratory stands on the waterfront at Woods Hole on Cape Cod, Massachusetts. The building contains laboratories for physical, chemical, biological and geological investigations and also shops for the development of oceanographic instruments.

Two sea-going research vessels, the 142-foot steel ketch Atlantis, built in 1930 and the 97-foot ketch Caryn, acquired in 1948, can be moored at the whark in front of the laboratory building. The ships are equipped with deep-sea winches and the latest instruments for navigation. A boat basin harbors three smaller vessels used for inshore work.

D. Program

The Woods Hole Oceanographic Institution seeks to obtain a thorough knowledge of what takes place in the ocean and to understand the principles involved. Its work at sea has much in common with expeditions of the past which explored unknown regions - although the cruises of its ships by contrast are systematic surveys in which conditions of interest are examined in ever-increasing detail.

In addition to the institute, Woods Hole maintains a small aquarium. The building is a converted dwelling unit containing two large exhibition areas. One for the keeping of aquaria life containing 24 tanks, and the other of the same size for the exhibition of other aquatic manifestations; i.e., effects of tides, microscopic organisms, nets used to catch sea life and the like.



Woods Hole Oceanographic Institution

Woods Hole Aquarium

View of Gallery

X. THE NEW YORK AQUARIUM

The new aquarium was long the determination of the city and the New York Zoological Society. The Association dates back to the year 1895, and together the New York Zoological Park was built. Together again, through the Department of Parks, the City and the Society guided the career of the old aquarium at the Battery from 1902 to 1941.

The new aquarium will be built at Seaside Park, Coney Island, New York. An area of twelve acres was purchased by the City, providing ideal needs for the aquarium, as well as ample parking facilities.

The aquarium will call for the handling of 1,200,000 gallons of water of the many types needed for the exhibition of marine life and specimens. It will serve the city of New York with a television, radio and motion picture exchange, and also serve the teachers with in-service courses on how to use the aquarium as a teaching source.

The building will be approximately five city blocks in length, stretching along the open sea. Its façade will include an outdoor promenade skirting two large outdoor pools with stairs leading down into a marine garden as long as the main body of the building. The outdoor pools will approximate the huge tank at Marineland Florida measuring 40 by 60. The building itself will consist of five major halls connected at the floor level by a sixth exhibition area that is also a corridor running the greater part of the building's length. These halls will be linked again by an overhead

passage with stair cases leading down into each hall.

In the halls, there will be located hundreds of species of marine, fresh water, tropical, temperate and arctic life. In the connecting gallery space will be provided for reptiles and amphibians.

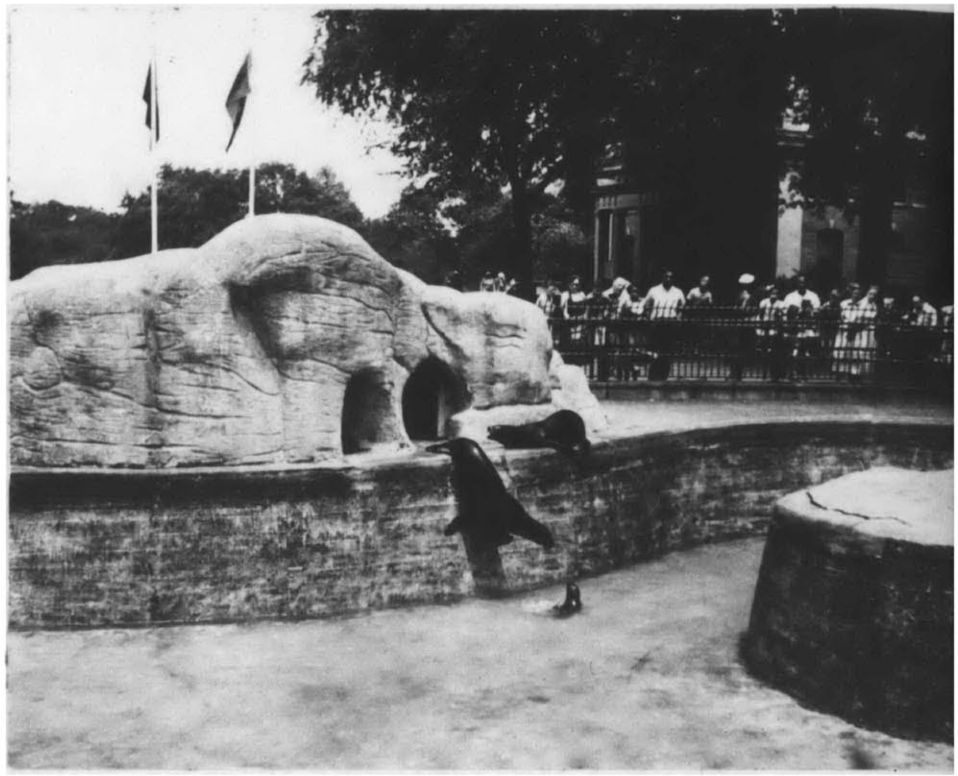
Aquatic birds will be seen in planned enclosures as well as in the gardens between the building and boardwalk. In the outdoor tanks there will be sea elephants, seals, sea lions, porpoises, walruses and sea otter.

The keynote of the exhibitions will be a forty-foot dioramic demonstration of the water cycle and its essential importance to life.

In general, the exhibition in the New York Aquarium will represent all the major fish families of the fresh and salt waters from pole to pole, with the exception of those which cannot survive at the surface. Invertebrates and insects will be shown, as well as the range of aquatic reptiles, amphibians, water birds and aquatic mammals.

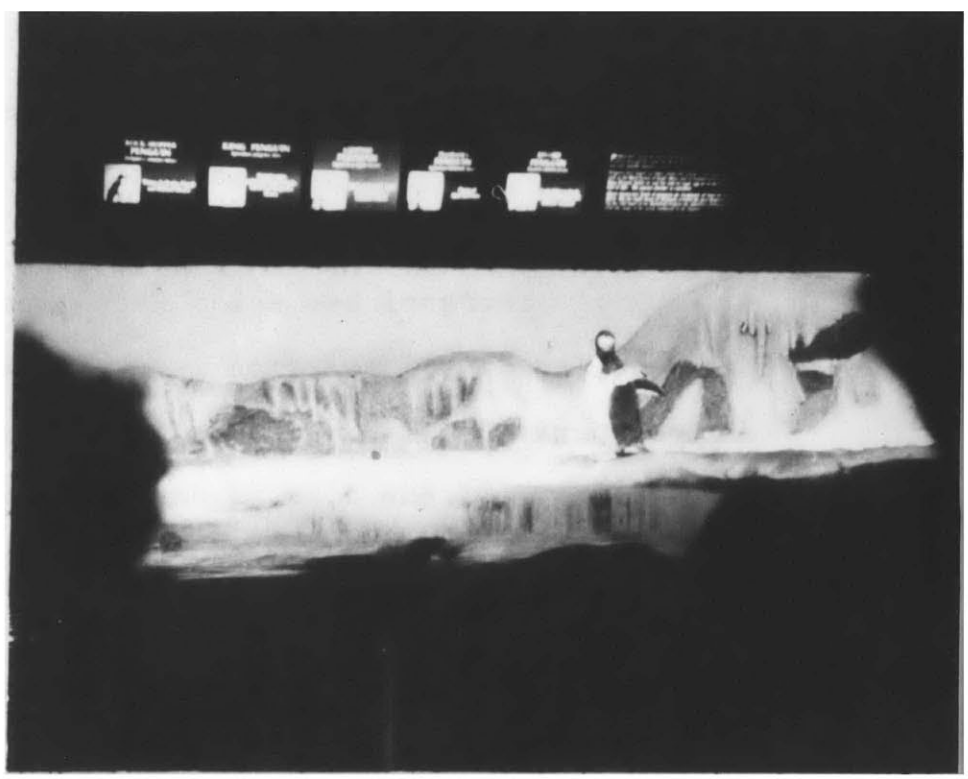
In addition to the exhibition areas, there will be an auditorium for scientific meetings and school groups, laboratories for the technical staff and a large restaurant. The cost of the structure, excluding the cost of the land, is estimated at 8 million dollars.

1 — Main Entrance and Colonnade
2 — Library
3 — Entrance Waterfall
4 — Clouds-to-Earth
5 — Three Banks of Tropical Marine Tanks
6 — Coral Reef and Moray Tanks
7 — Shark Tank
8 — Ten Research Laboratories
9 — Two Banks of Marine Tanks
10 — Eight Large Marine Tanks
11 — Oceanic Tank
12 — Electric Eel Exhibit
13 — Fifty Tropical Freshwater Tanks
14 — Four Large Tanks (Crocodiles, etc.)
15 — Swamp Corridor
16 — Four Temperate Freshwater Tanks
17 — Eighteen Temperate Freshwater Tanks
18 — Four Trout Tanks
19 — Crystal Column
20 — Sixteen Small Freshwater Tanks
21 — Seven Large Freshwater Tanks
22 — Twenty-four Temperate Tanks
23 — Antarctic Penguin Exhibit
24 — Temperate Zone Penguin Exhibit
25 — Oceanic Tank
26 — Auditorium
27 — Gardens



Sea Lion Pool

New York Zoological Park



Penguin Tank

XI. BOSTON AQUARIUM

The Boston Aquarium, located on Pleasure Bay, Boston, was opened to the public on November 12, 1912, at a cost of 150,000 dollars. It is owned by the city and controlled by the Park Commission, from where it derives its funds. The building is L-shaped with a dome over the center, and measures 150 by 100 feet. Along the side walls are 63 tanks having a linear glass area of 165 feet and containing from 45 to 1500 gallons. In the center is a large seal pool of 4500 gallons. Between the side walls there are 80 linear feet of floor tanks holding turtles, reptiles, and a collection of shells. A balanced aquaria area is located in the basement; it consists of 25 tanks with a total capacity of 500 gallons.

The large aquaria tanks are constructed of reinforced concrete with thicknesses varying from three to five and one-half inches, depending upon the volume of water. At present, some of these tanks are in complete disrepair, with cracks forcing their abandonment.

Along the side walls and behind the tanks the reserve aquaria and some work space are located.

The water system contains 17,400 gallons in salt and 15,600 gallons in fresh water. The daily consumption of water is 99,200 gallons in salt and 100,700 in fresh.

The purifying of water is accomplished in two ways, by sedimentation and aeration, at two points. The sedimentation taking place at the reserve tanks along with a water-fall drop aeration; the nozzles of the pipes flowing into the tanks bring about the additional aeration.

The basement, besides holding the balanced aquaria, has in it the mechanical equipment, including heating, along with the filter tanks for the large reservoirs located outside the building and to the rear. They hold 128,000 gallons.

Lighting at first was done through the use of skylights, but through the years was found to be unsatisfactory and has since been replaced by standard incandescent bulbs.

Since 1929 there have been some 2,688 exhibits, comprising some 2,528 fishes, two mammals, 32 reptiles, 29 amphibians, 63 invertrals and 34 mounted exhibits.

There are, in spite of its remote location, some 700 visitors daily, making a yearly total of between 400 and 500 thousand.

The aquarium employs eight poeple, three as attendants for the fish, three for heating, one guard and the director. No admission is charged.

XII. MUSEUM OF SCIENCE AQUARIUM REPORT

Prepared by J. Moir for
The Museum of Science

The following suggestions are based on interviews with O'Brien of the Boston Aquarium, Coates and Atz of the N.Y. Aquarium, and Pfau of the Boston Aquarium Society. In addition, most of the articles in the attached bibliography were consulted, plus whatever additional material could be found in Widener and the M.C.Z. Library. Many of these sources were not in agreement on some details: in general I would be inclined to accept the statements of the N.Y. Aquarium staff as most valuable. They have been planning their new aquarium for ten years and have carried out a great deal of research trying to solve the problems of aquarium operation.

However, everyone agreed on one thing: <u>All aquariums should be designed from the inside out</u>. First, the number of tanks and their layout should be decided on and then, the building planned around this arrangement. The main principle to remember is that water is heavy. In general, it was agreed that our building shouls include as many large tanks as we could afford, but the general ratio of tanks would probably be as follows: One big tank (14' x 10' x 4' deep) for every eight medium-size tank (300-600 gallons) and five to ten small tanks (even 2-3 gallon tanks are not too small). 1 : 8 : 5-10.

The service area should be greater than the exhibit area, have at least six feet of work space behind tanks, and, ideally, it should be all linked together. All tanks must be accessible from the service area, except the balanced aquariums.

Traffic flow will be a problem especially on weekends; this and the service area requirement can probably best be solved by an L-shaped or a square building with the service area along the walls. If the building is oblong, the wall area could be increased by extending tapered standing walls alternately from either long wall toward the center with tanks on each side of the wall and a narrow service area between them.

Due to the cost of driving piles our aquarium should have at least two floors in addition to a basement. On the second floor a space should be provided for an office and a laboratory. The latter is considered almost essential since the water in the systems must be analyzed at frequent intervals and treated to reduce acidity. Also, if fish diseases get started in a closed system, the whole population of the tanks can be wiped out unless the disease agent is identified and eliminated.

If the reservoir tanks are not buried outside the walls of the building, there will probably be very little room for a lab in the basement amid the filter beds, pumps, heaters, cooling coils, etc. If there is to be a second floor, any large number of tanks there would require a good deal of planning to provide the necessary floor strength without filling the lower hall with columns. However, a few columns might be built into the standing walls without disturbing the traffic flow.

As for what the aquarium should house; several sources have suggested that anything, plant or animal, that lives wholly or partly in the water can be fittingly displayed.

In the new Coney Island Aquarium they plan to have a "Clouds to Earth" keynote exhibit illustrating the water cycle. Another thought that occurred to me was an exhibit showing the plankton-to-fish-to-man progression. As far as I know, our Blaschka glass models do not include any specimens of plankton or small coelenterates, but we might trade some of our models to the M.C.Z. for a few of their glass plankton and jellyfishes or get Rieber or Marchaud to make some for us. These might be combined with some collecting nets and oceanographic equipment from Woods Hole.

Exhibits such as these and others which do not include actual tanks of water (perhaps one on sea birds like the Whitney Hall in the American Museum) might be set up on the second floor. Small tanks for a trout hatchery might be placed here too.

If there are to be tanks for seals and porpoises, these should be outside or at least isolated to reduce the odor and noise.

Open floor tanks were not recommended except for saurians, turtles, and amphibians. All these animals benefit from some direct sunlight, a point to remember in designing the building as a whole. Amphibians and saurians may or may not be included in the general plan but, as Mr. Coates pointed out, it is far easier to find good herpetologists than good aquarium curators.

A gift and book shop was considered a valuable addition; it might well be eliminated in our case if our present shop is expanded. Benches and rest areas should be provided where space allows.

In general, the fresh and salt water fish should be in separate areas for both educational and maintenance reasons, but it is suggested that, since refrigeration is very expensive, all the fish requiring fresh or salt cold water i.e. salmon, trout, cod, haddock, etc., should be displayed along the walls of a cold-room. In this way the cost of cooling could be reduced since only one side of each tank would be exposed to warm air.

Again for reasons of economy, all the balanced aquariums containing fresh water tropicals should be in one room where the temperature could be maintained at 75°. This avoids the use of electric heaters which are unreliable. Different species that normally school together can be kept in the same tank but labelling becomes a problem.

It was generally agreed that the public area should be lighted primarily by light from the displays - this reduces reflections and enhances the beauty of the fish and plants. In New York they have found that Warm-Tone fluorescents supply pleasing color without too much ultra-violet which damages the plants and fish. (See reprint "Lighting the Tank in a Public Aquarium in file.) The tanks <u>must</u> be lighted from the top, research has shown that many fish suffer fatal nervous breakdowns when exposed solely to front or side lighting! In connection with the lighting, all wires should be over the tanks and easily accessible, <u>never</u> buried in the walls. In general the less electrical wiring in an aquarium the less trouble is experienced. All wiring should be color coded.

In the new Coney Island Aquarium, the display areas are designed along the module principle. That is, the openings in the walls between the service area and public area are all the same size. This provides a very flexible arrangement because one large tank can be replaced by two medium size tanks or several small tanks without any construction work. All that is needed for the change is suitable plumbing, supports for the tanks, and a mask to cover the unused area.

None of the tanks, even the large ones of concrete, should be integral with the building. Only by keeping them separate can the glass and concrete be kept from cracking as the foundations settle.

Although reinforced concrete is not ideal for big tanks, nothing better has been found. However, Coates and Atz have developed a method of constructing tanks as big as 600 gallons capacity out of heavy Masonite and steel angle irons. (See article "New Tanks for Old" in bibliography.) These tanks are cheap and light enough to be moved easily.

The reinforcing rods in the large concrete tanks should run up to the top and be at least three inches below surface to prevent internal rusting and cracking. Perhaps some sort of plastic coating for these rods can be found to prevent rusting if ordinary steel rods are used. Only a few brands of cement have been found suitable for concrete tanks and it should be noted that sea water causes building brick and mortar to crumble after long exposure.

The glass fronts of the large tanks should mount on the front of the tank, being set in aquarium cement and held in place by a metal frame bolted to studs set in the concrete. Monel is probably the best material for the frame and studs. All glass should be plate glass which cracks and wedges when it fails rather than shattering as tempered glass will. One edge of the sheet should be chamfered; this is the edge that is set in first then the whole sheet pivots on this as the glass is moved into place. Almost all cracked glass in aquariums is the result of faulty setting. Great care is required in fitting and the tank should be filled gradually over a period of several days.

The smaller tanks should involve fewer construction problems but all exposed metal should be painted with black asphaltum varnish. (See list of materials and sources of supply.) The dimensions of the various tanks may vary considerably but even the large ones need not be very deep; for instance: a tank 14 feet long and 10 feet wide need only be 4 feet deep. The number of fish in a tank is determined by its surface area not its volume. Most of the medium and large-size tanks in the aquariums which were visited were raised about 3 feet off the floor. Small tanks of course can be set higher and at various levels to produce attractive designs.

As indicated above, the larger tanks should be as big as we can afford and 2- or 3-gallon tanks are not too small for display purposes. However, even these small tanks will require a plumbing system unless they are set up as balanced aquariums. All circulating tanks should have an outlet working on the siphon principle with the other end of the outlet pipe placed as low as possible to ensure good siphoning action. The inlet pipes should end above the surface of the water, the jet of air and water produced by this system results in better circulation.

Although the Shedd and the Boston Aquariums have no plants in their tanks due to the care and trouble involved, the New York Aquarium curators felt that the beauty of careful planting far outweighed the work involved. (Some of their tanks had plants set in terraced steps covering the back wall.)

In general it was agreed that round white gravel provided the best bottom cover; sand gets roiled up and a bare surface is unattractive. Some fish, however, require sand or shell bottom. The New York Aquarium is going to decorate its tanks with coral, sea fans, and other scenery - these will not be built in but moveable so changes can be made.

There should be a railing in front of all the displays and Mr. O'Brien recommended that one rail with screening below was better than a two-rail fence which is often used for gymnastic exercises. Depending on the floor plan, a railing down the middle of the hall may be found necessary for proper traffic control, but it should be avoided if possible.

Before going further into tanks and water systems the distinction between storage tanks and reserve tanks should be made. Storage tanks are the large tanks located in the basement or underground where the larger volume of circulating water is allowed to settle in the dark; reserve tanks on the other hand are smaller and usually located on the same level as the displays. In these reserve tanks are kept surplus display fish; minnows, shrimp, etc., for food; and fish in quarantine or under treatment. These last mentioned should have an entirely separate water supply to prevent the spread of disease. The capacity of these reserve tanks should at least equal that of the display tanks and a ratio approaching 2:1 is better.

The storage reservoirs should be much larger. Their capacity <u>must</u> be at least twice that of the displays and reserves combined and a ratio of 10:1 is preferred. These reservoirs need not be huge single tanks; there are several valid reasons for having many small storage tanks instead. More separate reservoirs mean more separate water systems; this, although more expensive, reduces the losses of fish in the event of a breakdown or an epidemic. Smaller reservoirs can be emptied for cleaning and repair without much trouble. Lastly, since the circulating water should be heated, cooled and treated in the reservoirs, more storage tanks will allow us to satisfy the environmental requirements of more different species of fish. The value of many separate systems is verified by the plans for the new Coney Island Aquarium which will have forty entirely separate water systems.

Whatever the size of the reservoirs, they should be easy to clean. Drains should be installed in the bottom of each one so the sludge can be removed. If the large reservoirs were built in the form of a cylinder with a deep sump and a dump valve in the center, then a rotary swirl could be produced by water jets set in the walls. When the detritus had collected in the center it could be dumped with a minimum loss of water.

If the large reservoirs are to be buried, and they could be, under the parking lot, it is recommended that at least half of each tank extend into the basement so the plumbing and heating or cooling coils can be serviced. There should be no broken connections and no wiring inside the tanks.

Although several of the older authorities suggest the use of lead piping and pumps, research has shown that less than 3 parts of lead in <u>ten million</u> parts of water is fatal to many fish. The New York curators feel that nothing but certain kinds of plastic or hard rubber plumbing should be considered. (A list of hard rubber and plastic materials is given separately.) All pipes ought to be color coded.

There should be enough stand-by pumps to handle the circulation should any breakdown occur and a gasoline powered emergency generator should be installed, if the pumps are to be driven electrically. Air-lift pumps which have no moving parts could be used for small volume circulations; these would need an air compressor which could also supply aeration for the balanced aquariums. A stand-by compressor should be provided unless the Museum's portable compressor would serve.

All circulating water should be filtered before entering the reservoirs. A layer three inches deep of crushed quartz between 1/4" and 3/82 mesh in size provides a suitable filter for removing most sediment, even that in suspension. The filter tanks should be non-metallic of course and maintain the water level at least eight inches deep over the quartz layer. Such a filter will handle a minimum flow of ten gallons a minute per square foot of filtering surface.

If we are to have, as we should, a collection of fishes which is small in size but broad in coverage, we will have to provide at least five "kinds" of water: warm salt (70o - 75°), cold salt (55° - 60°), warm fresh (76° - 79°), cold fresh (42° - 48°), and "natural" fresh (varying according to the season between 55° and 80°). These kinds of water provide problems in heating and cooling some of which have been discussed above; it should be kept in mind when the exhibits are being planned that cooling water is more troublesome and many, many times more expensive than heating it.

In spite of this, we should have in our aquarium the local food and game fish of New England. Most of these (cod, haddock, halibut, pollack, and members of the salmon and trout family) will require cold water. The lake dwelling game fish can be kept in "natural" fresh water, as can the sturgeon and gars that always draw crowds.

However, experience has shown that public interest will be concentrated on the warm fresh and warm salt water tanks where the large and/or colorful tropical varieties will be displayed. Upsidedown catfish, piranhas, hatchet fish, sea horses, Siamese fighting fish, any weird or colorful tropical fish were guaranteed to attract attention. Large sharks, rays, moray eels, sea turtles and the like are very spectacular and, except for the morays, do not bother other fish too much.

Octopus and squid are always asked for by visitors. However, they are delicate and their sepia is poisonous to fish so they require a separate water system. Another marine invertebrate which produces a fish poison is the sea cucumber.

Seals and porpoises are very popular with all visitors. Seals are easily kept in fairly small open tanks but porpoises need a good supply of clean warm salt water to thrive. These sea mammals produce much more waste material than fish do, so a large-volume circulating system is required.

The small Bronx Zoo Aquarium had, among others, three exhibits which should be mentioned here. One was an electric eel in a special tank; when it was handled with rubber gloves the current produced lit up several light bulbs and a neon sign. Another exhibit told the life story of the common eel. It consisted of a tank of live mature eels, preserved specimens of elvers and leptocephali, plus a man showing the breeding area in the Sargasso Sea. The third exhibit was on "How a Salt Water Aquarium Works" complete with several tanks, pumps and a filter bed.

There are, unfortunately, many kinds of fish that are unsuitable for aquariums. Among these are: deep-water fish, some open-sea fish, nervous or delicate fish and most huge fish. Fish caught below a depth of thirty fathoms are usually killed by the pressure change when brought up.

Mackerel, spanish mackerel and other members of this family, such as the tuna, are unable to adjust to a confined area and swim head-on into walls. However, mackerel kept in a cylindrical tank will school and swim in circles without trouble; tuna apparently will not do this. Hammerhead sharks also have this bad habit and quickly injure their exposed eyes.

Very delicate fish which usually die when captured include the river-herring, flying fish, half-beaks and some gars. The difficulty with huge specimens, such as the ocean sunfish, big sharks, and rays, is that their bodies cannot stand being unsupported by water. When hoisted into a collecting vessel, these fish soon die of internal hemorrhages.

Collecting and transporting live specimens is a serious problem, often very expensive and sometimes disastrously unsuccessful. Nevertheless, we should be able to get fish from the New York Aquarium as soon as they are in operation and local collecting boats could come through the locks to deliver directly. It is during the transfer from one form of transport to another that most losses occur. The Massachusetts Fish and Wildlife Service has indicated that it will supply quantities of fresh water game fish and the Woods Hole Biological Laboratory should be able to provide local saltwater varieties.

The feeding of specimens should present few problems, especially since Boston is a seaport. Most ocean fish will thrive on smelt, herring, chopped haddock, clams, etc.; there are many commercial tropical fish foods available, and this diet can be supplemented with worms, Daphnia and other live food. Cooked mussel spawn was recommended as food for trout hatchlings and is available locally. Sharks and saurians need roughage and should be fed whole fresh fish.

It was generally agreed that each curator should prepare the food for the tanks he is assigned to. The number of tanks each man could handle would have to be determined by experience. In addition to the curators, enthusiastic docents (members of the Education Department) were considered a valuable adjunct.

Admission should be charged; this should be commensurate with our present system of charges. <u>It is thought that the seven-million dollar Coney Island Aquarium will be entirely self-supporting through admissions</u>.

Before any actual designing is undertaken, it is strongly suggested that the architects' plans of this Coney Island Aquarium be consulted. We have been offered free access to them by the Curator, Mr. Coates.

Despite the headaches and problems outlined in this report, the value of a modern, small, but excellent aquarium in Boston far outweighs any foreseeable difficulties.

XIII. SITE

The site has been allocated by Science Park for the construction of an aquarium. It is southeast of the proposed building and measures approximately 136' x 230', with the 230-foot side facing the Charles River. The land slope, about 5 feet, is towards the river. Parking facilities will be located to the northwest of the site, along Route 1.

Other sites were examined in particular the East Bank of the Charles River between the Harvard Bridge and Science Park. However, it was felt that the advantages of a contained Science Park far outweighed the separation of buildings to achieve some architectural effect.

Parking facilities will be directly to the north and northeast of the site serving the entire ensemble.

The ground is part fill along the water's edge with a rock strata coming about three feet below the ground level, making any basement excavation relatively expensive.

XIV. BUILDINGS

The existing buildings are built of salmon-colored brick and limestone and present a formal classical appearance. The mass disposition being so great, it was felt that any scheme made should be such that the buildings be compatible, necessitating the use of like or similar materials, and general feeling of order and rectilinearity, so as to conform to the composition as set forth by the existing structures. The Museum of Science building is a two-storey structure approximately 34 feet high and will have, when complete, a large central tower. The planetarium is 18 feet high with its dome adding an additional 14 feet. The mass, when complete, will be approximately 500 feet long.

XV. EXHIBITS

The purpose of the exhibitions shall be primarily as an educational medium. Therefore, a small, complete and practical aquarium is desirable, with emphasis placed on the aquaria of the northeast and as found around Boston. It is not the intention of the aquarium to compete with the aquariums at Chicago or New York in size and scope.

It has been found that certain exhibits have constituted the major attraction at all zoological parks and aquariums, such as sea lions, penguins, sharks and porpoises. Of these, the sea lions may be kept outdoors.

The aquarium will exhibit, including the normal aquaria life, a shell collection (which is an excellent attraction at the present aquarium); provision for aquaria life, i.e., larvae, mosquitoes; collection of turtles, salamanders and lizards, along with a small fish hatchery to show the development from eggs to fish, along with a balanced aquaria space to house the tropical fish collection.

This exhibition is always of interest to home aquarists.

Together with this, two large floor tanks for the viewing of sharks and porpoises are needed.

Space is also to be provided for the Director, Secretary, sale of tickets, small laboratory, reserve and storage tanks, toilets and general mechanical facilities, and services.

It is not intended that the aquarium will be a research center. Facilities for research will be drawn upon from the Woods Hole Institution, and other aquariums.

Transportation of fish will be relatively a simple problem as local collecting boats could come through the locks to deliver directly.

An admission charge will be made, enabling the aquarium to be self-supporting

The aquarium at Woods Hole offers an excellent parallel to the new aquarium. In it, one finds equal amounts of space devoted to aquaria and to exhibits relating thereto. One room contains the tanks normally associated with aquariums, while the other is devoted to the showing of tidal effects, ocean bottoms, fish procuring devices, microscopic life; each constitutes an excellent draw and represents for its small size a complete view of all manifestations of aquaria life.

XVI. PROGRAM

Public Spaces

Lobby:

The lobby is to accomodate at least people at

Entrance Desk:

For the sale of tickets and sale of books, photographs, prints and small aquaria objects.

Lounge Area:

Space for conversation and resting with bathroom facilities.

Exhibitions

Temporary exhibition area:

Balanced aquaria:

Space provided for the exhibition of 30 tanks containing approximately 600 gallons of water. Only service required is occasional feeding, heating and aeration of water.

Display cases:

For the exhibition of stuffed animals, birds and small aquaria life. Approximately 100 linear feet will be required.

Small floor tanks:

1. For the exhibition of small turtles, salamanders, aquatic reptiles. Approximately 40 linear feet will be required.

2. Small tank of approximately 80 square feet are needed. The above tanks require an available continuous water supply.

Floor tanks:

Two large floor tanks for the exhibition of sharks and porpoises holding at least 3,500 gallons, minimum diameter being 15 feet.

Penguin tank:

An area of at least 200 square feet is required. The unit must have air conditioning facilities.

Aquaria tanks:

170 linear feet of tanks with corresponding reserve tanks behind.

Number	Length	Depth	Width
3	8	5	5
34	4	4	4

All tanks are to be divisible.with the exception of the reserve.

Outdoor pool:

The outdoor pool is for keeping sea lions, which constitute a major attraction, Space to be provided for the housing of the mammals. A feeding platform shall also be provided.

Staff Areas

Office:

For the Director and one secretary.

Laboratory:

A small laboratory for two people for the examination of aquaria and the testing of water. It shall contain the following:

1. Work space
2. Tanks for the holding of specimens
3. Small refrigerator
4. Heating facilities
5. Storage of necessary materials and equipment.

Services

Mechanical Equipment:

In addition to the standard equipment necessary in all building, the following is required.

1. Refrigerator for the storage of food.
2. Pump space.
3. Filter beds for the reservoirs.
4. Food elevator.

Locker Room:

It shall provide the following:

1. Ten lockers.
2. Bathroom with shower facilities.

Janitors' Work Closet:

Area to be provided on the main exhibition floor.

Reservoirs:

There shall be two for both fresh and salt water with a storage capacity of 140,000.

Repair Shop:

The shop is used daily for the repairing of exhibits and the making of signs. The shop should have the following items:

1. Work bench
2. Preparation of sign material
3. Small paint sprayer
4. Welder
5. Drill press
6. Circular saw
7. Storage of materials.

Parking:

Space to be provided to the north and northeast of the site.

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Pamphlets

20. East London Aquarium.

21. Denmark Aquarium.

22. John G. Shedd Aquarium.

23. New York Aquarium.

24. National Aquarium.

25. Bulletin of the Woods Hole Oceanographic Institution.

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
WASHINGTON 25, D. C. June 24, 1953

Mr. Henry Olko,
Mass. Institute of Technology,
Graduate House Room 608,
Cambridge 39, Mass.

Dear Mr. Olko:

We are in receipt of your letters of June 22nd addressed to the Bureau of Fisheries and the Fish and Wildlife Service.

We regret that we do not have any printed material or pictures which we feel would of any benefit on the subject which you mentioned. Our only suggestion would be one of the larger aquariums listed below which you, no doubt, have already contacted:

Philadelphia Aquarium, Fairmont Park, Philadelphia, Pa.
Dallas Aquarium, Dallas Texas
John C. Shedd Aquarium, Grant Park, Chicago, Ill.
Steinhart Aquarium, San Francisco, Calif.
Detroit Aquarium, Belle Isle Park, Detroit, Michigan

We are referring your letter to the director of our aquarium located in the Commerce Building, Washington, D. C., with the hopes that he will possibly have some information which will be of benefit to you.

Yours very truly,

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
WASHINGTON 25, D. C.

The Aquarium, Commerce Blg. June 30, 1953

Mr. Henry Olko,
Graduate House R. 608,
M.I.T. Cambridge, Massachusetts

Dear Mr. Olko:

I regret that we have no detailed plans or suitable data on the Aquarium for your specific uses in architectural planning. The Aquarium is incorporated into the sub-basement of the large Com. merce Building and does not form a complete unit in itself.

I enclose abrief popular description, however, and trust you may find something of value in your proposed thesis.

Yours sincerely,

Aquarium Director

COMMISSIONERS
HOWARD C. BALDWIN
W. T. BARBOUR
JAMES S. HOLDEN
IVAN LUDINGTON
JOHN T. MILLEN, *Consultant*

FRANK G. MCINNIS, *Director*

City of Detroit

ZOOLOGICAL PARK COMMISSION
TEN MILE AND WOODWARD AVENUE
ROYAL OAK, MICHIGAN

TELEPHONES
JORDAN 4-6427
LINCOLN 1-0223

July 1, 1953

Mr. Henry Olko
Graduate House
Room 608
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Dear Mr. Olko:

Your letter of June 26 has been received. We are now in the process of rehabilating our old Aquarium, and regret that we do not have any literature to assist you.

Very truly yours,

ZOOLOGICAL PARK COMMISSION

DIRECTOR

FGM:kg

Municipality of the City of East London

TELEPHONES
Office - - 4629
Residence 3045

CURATOR:
~~J. NANNI, M.~~Sc., Ph.D.
A. E. Parkin, ~~B.Sc.~~

AQUARIUM,
ESPLANADE
~~QUEEN'S PARK ZOO~~
~~QUEEN'S PARK~~
EAST LONDON

8th, July, 1953.

Mr. Henry A. Olko,
Graduate House Room 608,
M. I. T.,
Massachusetts.

Dear Sir,

Enclosed please find a small booklet on our Aquarium, which I am afraid, is all I can offer you. I hope you will find some--thing of interest therein.

If your proposed Aquarium is to house marine specimens, may I suggest that all piping concerned be of asbestos-cement or plastic.

Lead, so commonly used, is too soft from the point of view of strength, and, where plumber's metal is used for joints, electrolytic action causes many headaches.

Wishing you every success,

Yours faithfully,

CURATOR OF AQUARIUM AND ZOO.

75 JAHRE Zoologischer Garten

RAT DER STADT LEIPZIG, ABTEILUNG VOLKSBILDUNG

Ruf 21001 und 21002. Bankkonto: Deutsche Notenbank Leipzig 5325345. Telegramm-Anschrift: Zoologischer Leipzig
Gerichtsstand Leipzig

Postanschrift: Zoologischer Garten, Leipzig C1, Dr.-Kurt-Fischer-Str. 29

Herrn

Henry A. O l k o,

Graduate House RM 608
M.I.T.
Cambridge 39 Mass. U.S.A.

Ihr Zeichen | Ihre Nachricht vom | Unser Zeichen Dr.D/H | Tag 11.7.53.

Bei Antwort und Geldsendungen angeben

Betrifft:

Sehr geehrter Herr Olko!

Besten Dank für Ihre Zuschrift vom 22.6.1953. So-bald unser Führer, der im Augenblick neu aufgelegt wird, ausgedruckt ist, werden wir uns erlauben, Ihnen ein Exemplar zuzusenden. Sie finden darin Bilder aus unserem Aquarium, von denen wir annehmen, daß sie Ihnen nützlich sein können.

Hochachtungsvoll

Zoologischer Garten * Leipzig *

(Prof.Dr.Schneider)
Direktor

III-18-123 Lp 7725-53

ÜBERSEE-MUSEUM

BREMEN 1, den 10. 7. 53
Bahnhofsplatz
Fernsprecher: 21331

Mr. Henry A. Olko
Graduate House Rm. 608
M.I.T.
C a m b r i d g e 39, Mass. U.S.A.
=====================

Dear Mr. Olko:

We received your letter from June 22, 1953. I'm very sorry, but we are not able to give you pictures etc., because we don't have anything in our Museum.

Very truly yours

Telegrams: "Zoological, Phone, London."
Telephone No.: Primrose 3333.

THE ZOOLOGICAL SOCIETY OF LONDON,
REGENT'S PARK, LONDON, N.W.~~8~~, ENGLAND.
1.

OUR REF. FAS/JS.

YOUR REF.

30th June 1953.

Mr. Henry A. Olko,
Graduate House, Rm. 608,
M.I.T.,
Cambridge 39 Mass.,
U.S.A.

Dear Sir,

Your letter of the 22nd instant has been passed to me for attention but I am afraid that we have no information readily available that could be of use to you for your thesis work.

I should like to point out that this is a very extensive subject and the only method of obtaining the information required is to visit a local aquarium and study the problems on the spot.

Yours truly,

(F. A. Stengelhofen).
Architect to the Society.

Tél. 021-54

INSTITVT OCÉANOGRAPHIQVE

RECONNV D'VTILITÉ PVBLIQVE

FONDATION ALBERT Ier, PRINCE DE MONACO

MVSÉE DE MONACO

MONACO-Ville, le 29 Juin 1953

Monsieur,

Le Directeur du Musée a bien reçu votre lettre du 22 Juin et me charge d'y répondre.

Il est bien difficile de vous donner, à distance, des indications valables et un court séjour dans un aquarium serait plus profitable; à la condition que ne soient pas refusées des méthodes que je considère comme périmées et qui sont néanmoins appliquées dans des Aquariums public assez récents, en vertu d'un conformisme tenace....

D'autre part, nous éditons plus spécialement des travaux scientifiques et non pas des articles techniques.... Cependant, j'ai obtenu que soient publiés certains principes nouveaux d'aquariologie et je vous envoie, par pli séparé, ce texte qui peut vous aider, bien qu'il soit très sommaire.

Des aquariums de cette conception sont en cours de construction dans le musée, selon les plans qui me sont personnels.

J'ai eu l'occasion, l'année dernière, de renseigner et de conseiller M. Delfante, de Lyon, (Rhône France) dont la thèse d'architecte a été reçue avec mention Bien. Il était assez facile de le renseigner, d'autant plus qu'il est venu se rendre compte sur place.

Si un jour ce projet devenait une réalité, voudrez-vous vous souvenir que j'irais volontiers à Boston, établir les plans modernes de toute la partie technique. Je me ferais aider de ma fille, licenciée ès lettres, qui parle parfaitement l'anglais.

Je regrette fort de ne pas pouvoir faire plus,

et je vous prie, Monsieur, de croire à mes sentiments distingués.

J. Garnaud

J. GARNAUD

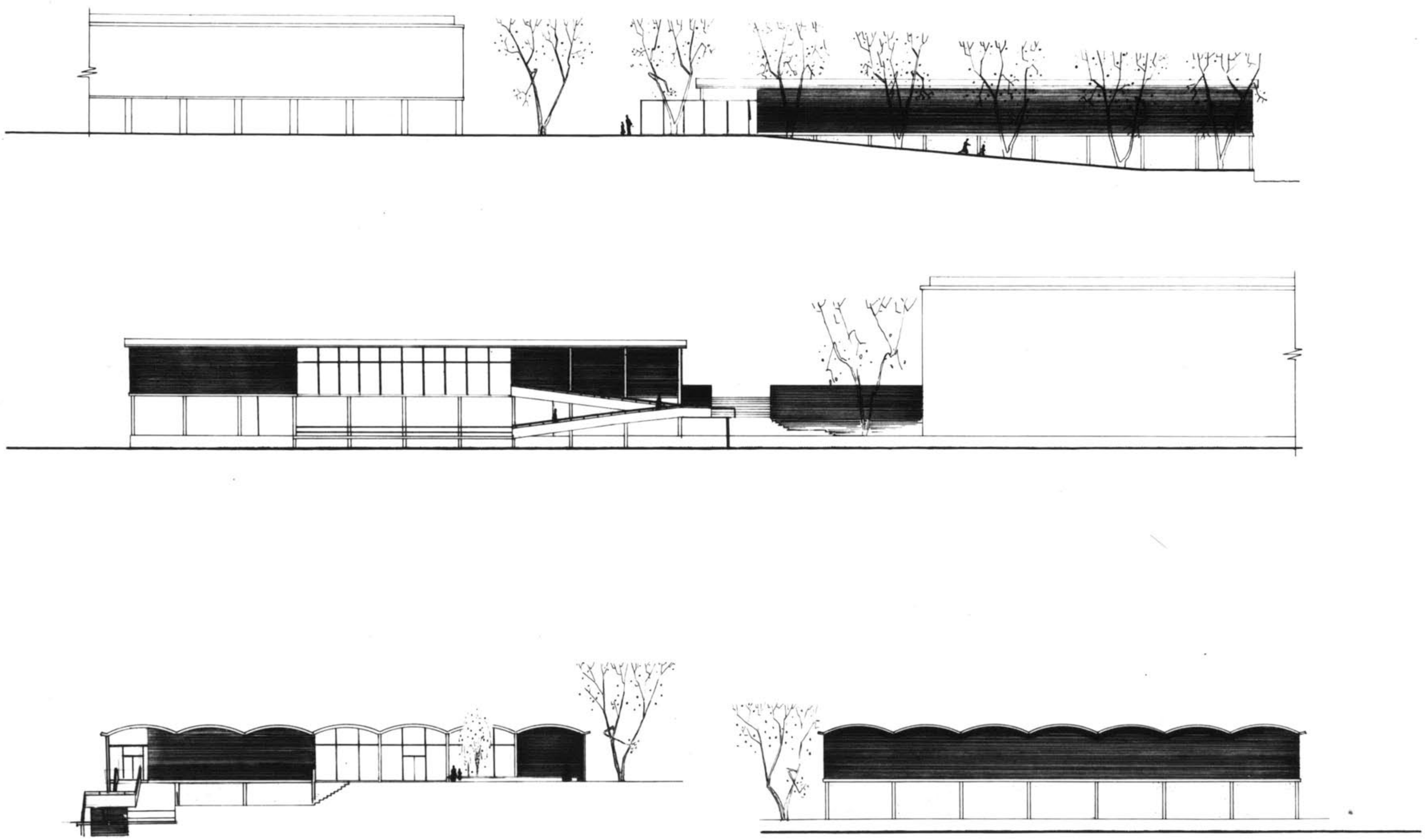
Assistant-Chargé de l'Aquarium

3rd July, 1953

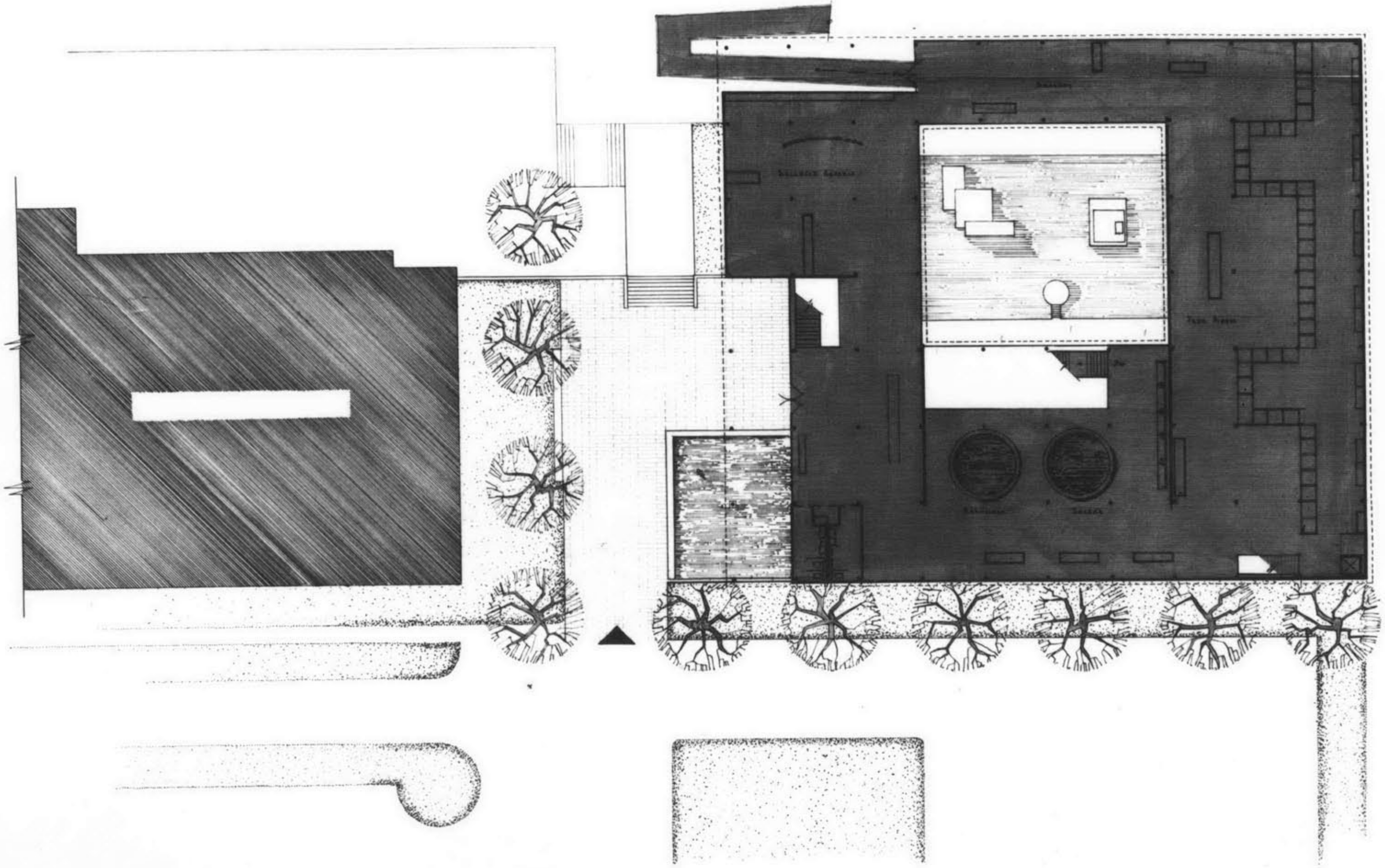
Dear Sir,

Your letter of June 22nd, 1953 to the Director of the Amsterdam Aquarium has been handed over to us, and we are sending you by the same post (as printed matters) a copy of a small booklet on Danmarks Akvarium and hope that this will help you in your work.

Yours truly.
for Danmarks Akvarium



1 HENRY OLKO
GRADE 4
M.I.T.



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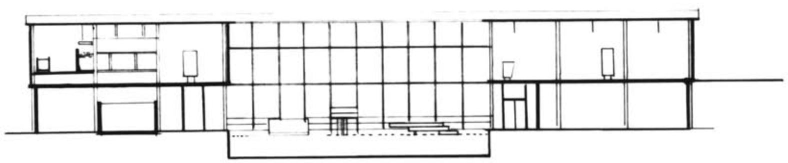
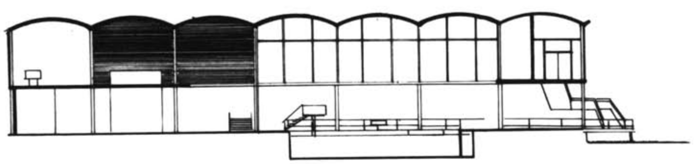
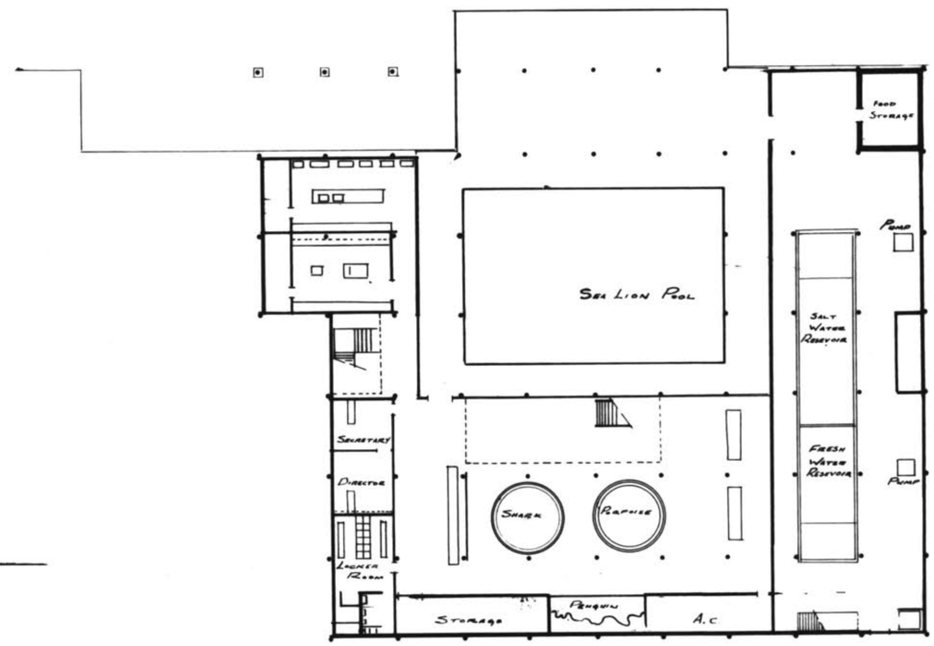
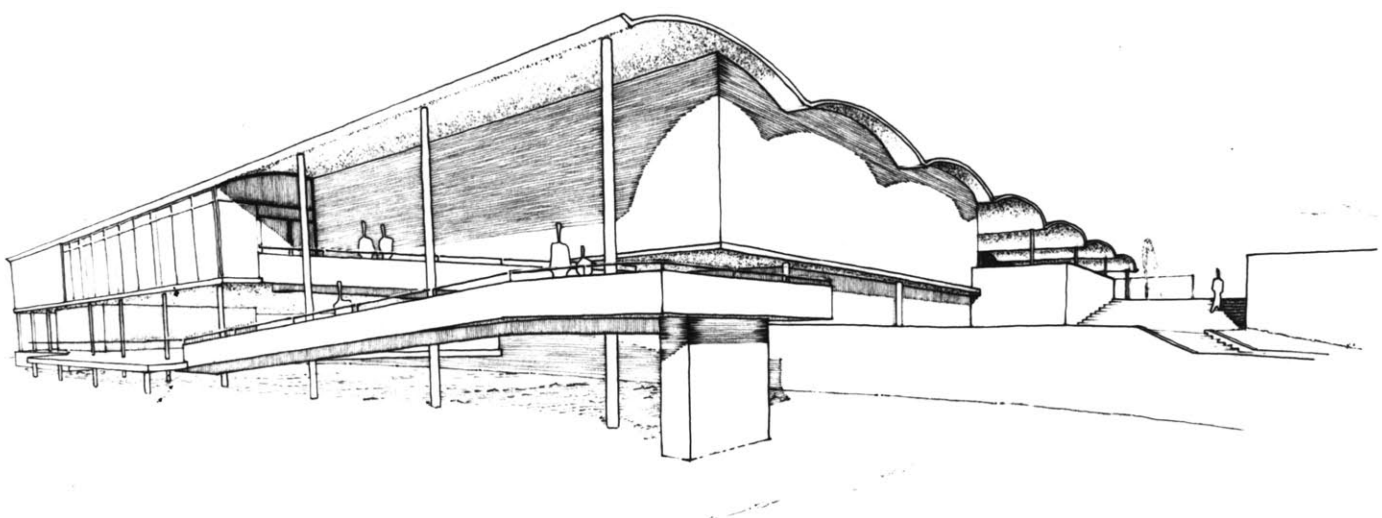
GRADE 4
M.I.T.







3 Henry Olko
Grade 4
M.I.T.



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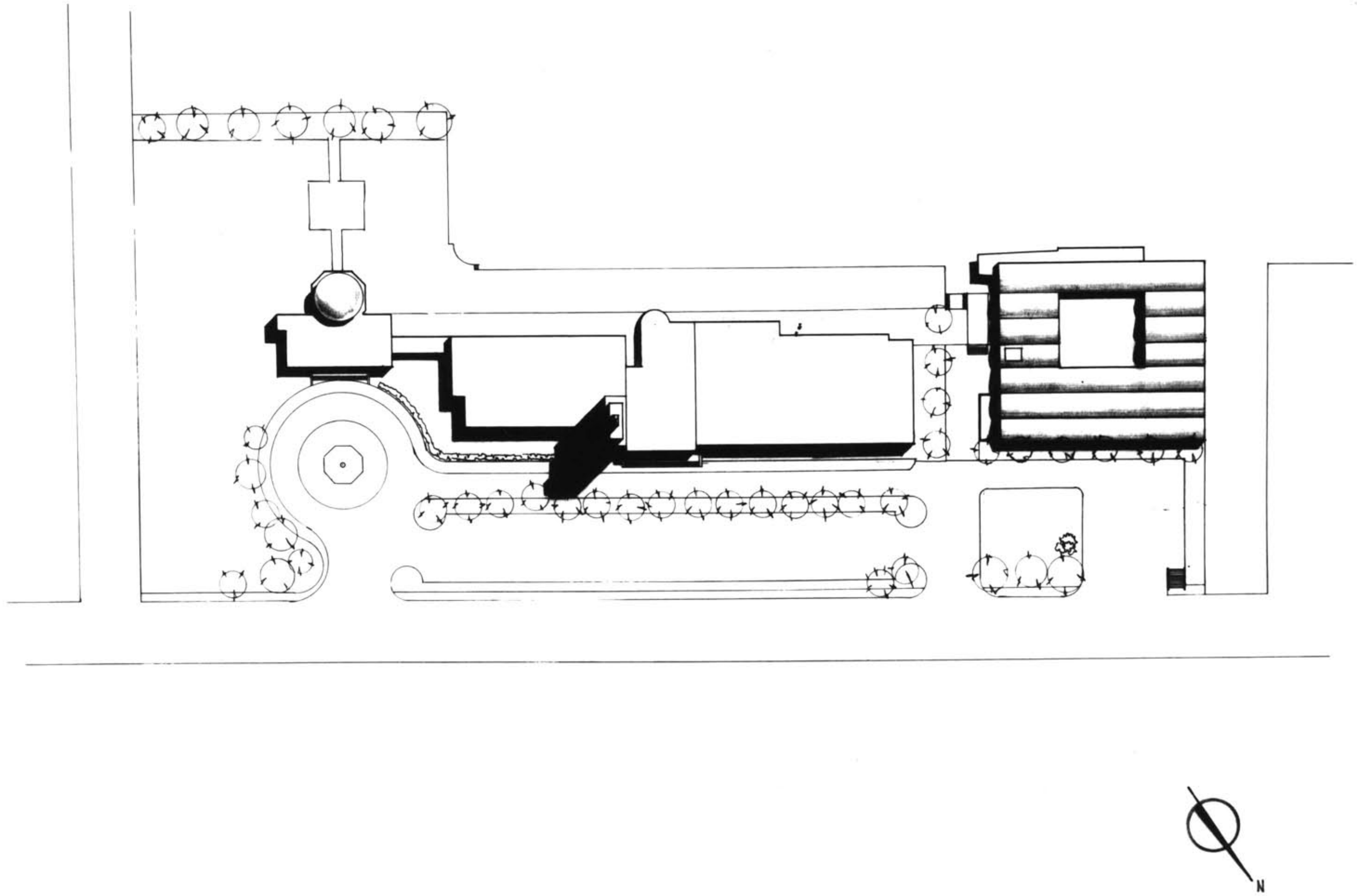
HENRY OLKO
GRADE 4
M.I.T.

A NEW AQUARIUM FOR BOSTON



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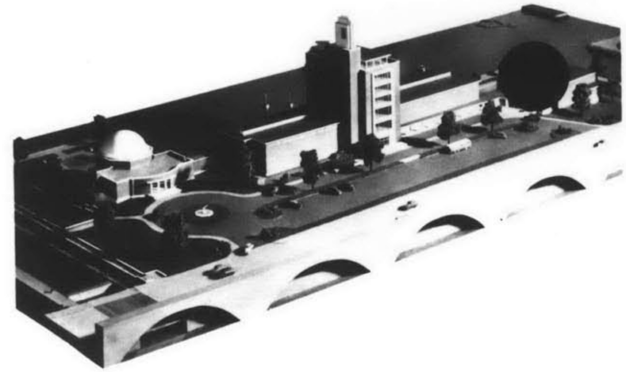
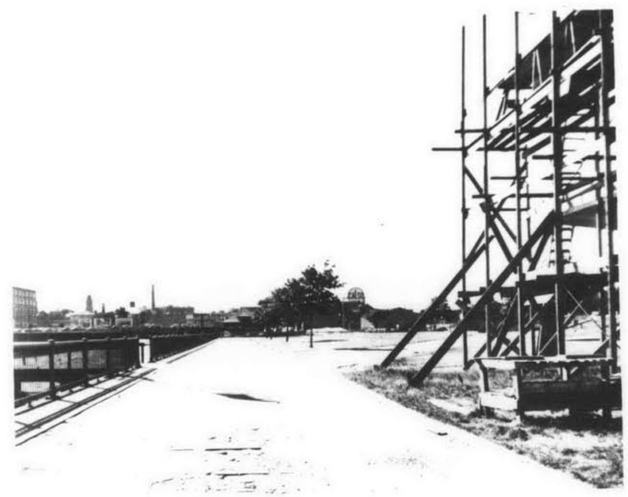
PRESENT DEVELOPMENT



FUTURE DEVELOPMENT

LOOKING WEST



LOOKING NORTHWEST

G

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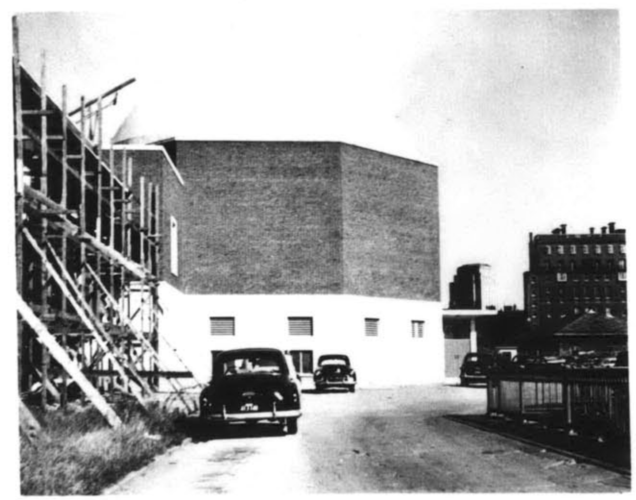
GRADE 4
M.I.T.

AERIAL VIEW OF SITE

UNDEVELOPED SITE

LOOKING NORTHWEST



LOOKING SOUTHEAST

7

HENRY OLKO
GRADE-1
M.I.T.