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ABSTRACT

This manual introduces teachers to the biological systems at work in a marine aquarium. It provides guidance in selection of the tanks, specifically discussing the effect of capacity on the well-being of the occupants. It guides the teacher in setting up aeration, filtering, lighting, and temperature control for the aquarium. It also advises on collection or treatment of water sources for the salt water aquarium. Instructions on the construction of home-made aquarium tanks are also provided. The selection of aquarium species is somewhat specific to those collectable in the coastal waters of Alaska. A glossary of terms is provided. (RE)

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MARINE ADVISORY PROGRAM
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CONSTRUCTION AND MAINTENANCE of CLASSROOM AQUARIA

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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by

Richard S. Lee

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INTRODUCTION

During much of the year the lower intertidal zone is out of reach for coastal Alaskan teachers and students. Inclement weather and poorly timed tides make this valuable teaching resource impractical except on rare occasions. However, when favorable low tides occur in good weather at a time when they can be utilized for teaching, the educational experience may be extended by maintaining small numbers of marine organisms in classroom aquaria for further study.

Animals taken from tidepools may generally be held for short periods of time in temperate aquaria. The use of temperate aquaria precludes the keeping of delicate marine tropicals, or those northern animals for which refrigeration is necessary. *It should be noted that animals taken for classroom observation should be returned to the ocean after study, and no attempt should be made for long-term maintenance or culture, except under unusual conditions.* Collecting of intertidal animals should be strictly limited for purposes of conservation.

This manual is concerned only with closed-system temperate marine aquaria. The information it contains does not apply to open systems, fresh water, or to most temperature controlled systems, since each of these systems has inherent problems which must be dealt with separately.

If you already have a satisfactory classroom aquarium, the following section is superfluous. If you are considering acquiring an aquarium, the following factors must be considered: type of construction, cost, availability, brand, and price. In view of some of the drawbacks of ready-made aquaria, you may decide that a classroom construction project is the most feasible way to get the type of tank most suitable for your purposes. Directions for construction are included in this manual.

PURCHASING A READY-MADE AQUARIUM

Type of construction

Without qualification, the most satisfactory type of construction is all glass, with a non-toxic silicone sealant. This last criterion is important to check since some tanks meant only for freshwater are sealed with a cement which leaches toxins when used with saltwater.

Many commercial tanks have stainless steel frames adequate for fresh-water tanks, but since such frames are usually made with low-grade steel, saltwater deterioration will become evident in a few months. At best this will be unsightly, at worst it could prove toxic to the animals in the aquarium.

Recently plexiglass has been used extensively for marine aquaria. These tanks are relatively expensive and are not completely satisfactory. In deeper tanks, water pressure causes the walls to bow outwards, creating some degree of optical distortion. Furthermore, plexiglass scratches very easily. Even careful periodic algae removal will mar the tank, and algal grazers, such as urchins, chitons, abalones or snails will scar the plastic as they graze on the algae that will inevitably grow on the walls of the tank.

Commonly, marine tanks are constructed of a wood (either marine plywood or redwood) and glass combination with the wood walls covered with fiberglass or resin. These tanks are suitable, but require periodic refinishing since some organisms, particularly urchins, are capable of eroding the fiberglass.

Brand and Price

As with many items, you get what you pay for. It makes little difference which brand you buy, as all major brands have a wide variety of types and quality. Perhaps the best criterion upon which to judge is the inclusion of a two to five year guarantee on the tank.

A 20 gallon all-glass tank, without accessories, ranges from $25 to $42 in price (in 1977). Air pumps, filters and fluorscent hoods are almost necessities and will add $20 to $35 to the base price.

Size

Generally speaking, the lower practical size limit is about 20 gallons, the most easily managed is 50 gallons, and the upper limit about 150 gallons.

Shapes

Aesthetics and oxygenation are the two factors to consider in determining the shape of the tank. Unfortunately, these two factors work in direct opposition to each other: a tall, narrow tank tends to be a more effective display tank, but its reduced surface area lowers the amount of oxygen which can be absorbed. On the other hand, a broad shallow tank has excellent oxygenation capacity, but leaves much to be desired for display purposes.

Tank shape must be considered when purchasing aquarium accessories such as hoods, lights and sub-sand filters, since the accessories must conform to the tank shape.

CONSTRUCTING A GLASS AQUARIUM

Aquarium construction is a reasonably simple, but somewhat delicate project. You should remember to build the tank around the dimensions of the accessories that you plan to use (i.e., sub-sand filter, reflector top, etc.). Also bear in mind that the ~~only~~ dimension with any bearing on pressure is that of depth. An aquarium with a surface area four square feet and a depth of one foot exerts the same number of pounds per square inch as one with a surface area of one square foot and a one foot depth, although the total weights will be vastly different.

Dimensions

For a first tank, a 20 gallon model would be the most appropriate. Twenty gallons of water occupies about 2.7 cubic feet, and weighs (water alone) almost 167 pounds. For best display purposes 18" (depth) x 24" (length) x 12" (width) would give you 3 cubic feet of space, allowing for gravel and sub-sand filters. By reversing the depth and width dimensions, better oxygenation would occur due to an increase in the area of water to air interface.

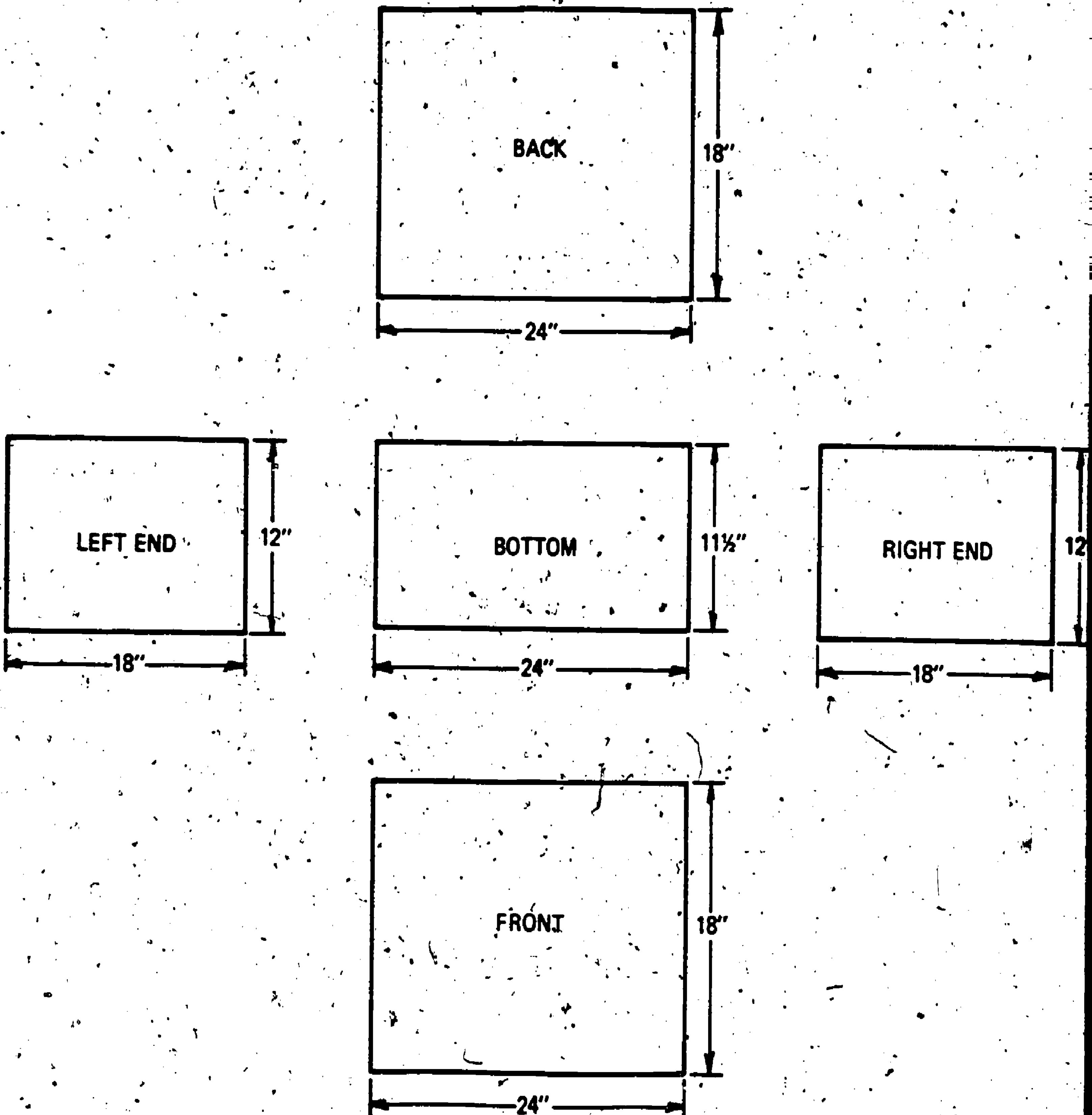
Constructing a 50 gallon tank presents a more ambitious project. In this case, a minimum of 6 cubic feet should be allowed, which allows the worker three combinations of dimensions: 24" x 24" x 21"; 48" x 12" x 21"; and 48" x 24" x 10.5". Again, remember that because depth alone accounts for the increase in pressure, there is less strain on the walls of a shallower tank. Also, bear in mind that 50 gallons of water weighs about 417 pounds, so support for your tank becomes critical.

Materials

As stated above, the most satisfactory aquaria are those of all glass construction. Emphasis on construction of a 20 gallon glass tank will be given here.

Plate glass is the most satisfactory, and 1/4 inch thickness is suggested. This can often be procured from glass companies by asking for scrap from broken sliding doors. It should be noted that it is difficult to cut this glass. The sealer (cement) should be one of the new silicone sealers, available in 12 ounce capacity for application with a caulking gun. Most brands of silicone cement come in clear, white, or black. The clear is most aesthetically pleasing, but it is harder to spot errors when using it.

One pint of acetone, masking tape, flat toothpicks, and rags are also needed.



LAYOUT DIAGRAM FOR AQUARIUM CONSTRUCTION
Figure 1

Assembly

(1) Dampen a rag with acetone and thoroughly clean all surfaces and edges of the glass. Oil from finger prints will inhibit the sealant, so this step is of the utmost importance.

(2) Lay the glass out on a clean, even surface as shown in Figure 1 (page 4).

(3) A neat cemented seam can be made with the help of carefully applied masking tape. A simple masking procedure follows:

> Place masking tape 1/4" in from the bottom edge of the front and back panels. Likewise, place masking tape 1/4" from the edge on the bottom and sides of the end panels. Mask all non-mating edges. See figure 2 below.

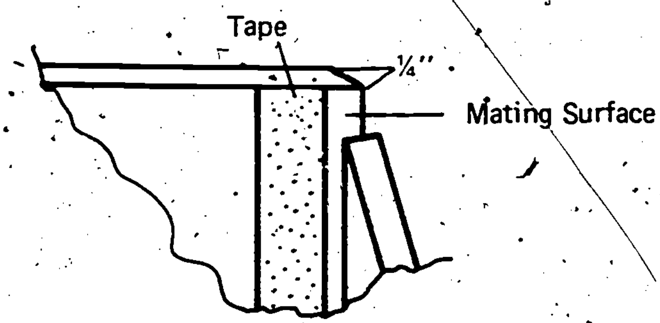


Figure 2

(4) Once taping is complete, put the aquarium together without sealant, making sure that all mating surfaces match. The side panels stand against (not on) the bottom plate.

(5) Then place toothpicks between these surfaces so that there is a slight gap. Masking tape may be used to keep the sides together.

(6) At this juncture, squirt the sealant into all the gaps provided by the toothpicks until the sealant emerges on the other side of the seam.

(7) When all seams are caulked, wait five minutes, then gently remove the toothpicks.

(8) Fill the holes with sealant.

(9) *The most important step is to let the tank sit undisturbed for twenty-four hours while the sealant cures.*

(10) For more support, small glass triangles (see Figure 3) can be set in the corners at the top of the tank where the side panels join the back and front panels.

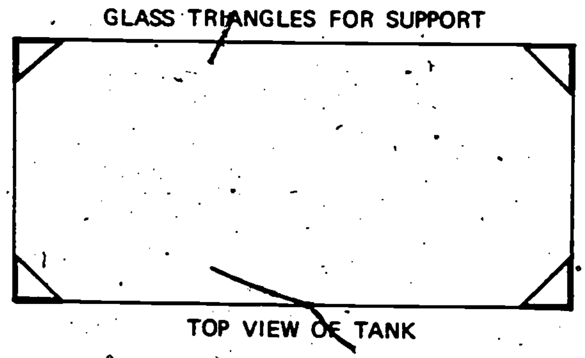


Figure 3.

(11) After twenty-four hours remove all tape.

(12) Excess sealant should be gently scraped off with a razor blade.

(13) Finally, the tank should be wiped off with a rag dampened in acetone. The results should be a very professional looking aquarium.

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CONSTRUCTION OF A PLEXIGLASS TANK

Although not as successful as glass, plexiglass tanks are easily constructed and suitable for small aquaria. As stated earlier, the ease of marring and warping the plexiglass is its most undesirable characteristic.

Materials

The materials and tools needed for construction are: plexiglass sheets of the desired thickness (1/4" is suitable for very small tanks, 3/8" to 5/8" is necessary for larger tanks), plexiglass adhesive (dichloromethane, a solvent available through most scientific supply houses), a glass syringe, masking tape, a fine-toothed saw for cutting the plexiglass, and a small square for leveling the sides.

Assembly

(1) Cut the panels of the tank to the proper dimensions.

(2) Assemble the aquarium on a "dry run" since the adhesive solvent sets up very quickly.

(3) When it is time to start the final assembly, make sure that all corners are exactly 90°.

(4) Use masking tape to help steady the plates.

(5) Fill the glass syringe with dichloromethane and inject it directly into the crack between the two plates. The adhesive sets in about one minute leaving a very even seam. All four sides should be assembled.

(6) The assembled sides should be placed *on* the bottom. While the adhesive is being injected and is setting, pressure should be applied to the two plates involved.

(7) After the tank has been assembled, check carefully for leaks. Small leaks can be sealed with an injection of solvent. For large holes, a mixture of plexiglass shavings and dichloromethane should be applied.

The use of the glass syringe is not mandatory. The solvent can also be applied with an eye dropper, a spoon, or by dipping the mating edges into a shallow pan of solvent. The syringe, however, does provide the neatest seam. Extra dichloromethane is reusable; simply store it in an airtight glass or metal container.

Three main types of filtration must be considered - biological, mechanical, and chemical. Each of these is extremely important for the appearance and health of your aquarium ecosystem and will be discussed in detail.

Biological Filtration

This process constitutes a bacteriological removal of ammonia derived from waste products of the animals in your tank. Without biological filtration, the ammonia levels in the aquarium would rise rapidly to a toxic level. The most important site for this type of filtration is in the gravel lying on the subsand filter, and to a lesser extent on the charcoal in the external filter. The bacteria responsible for biological filtration occur naturally, entering the system with the animals, food, plants, and gravel. Only very small numbers of these bacteria are present initially; but during the period of conditioning the aquarium, they multiply very rapidly so within a week the tank will support a very high population.

The purpose of these bacteria is to convert the nitrogenous wastes (ammonia NH_3) into forms of nitrogen which are usable by plants. Several important steps are involved in this process and are outlined in Figure 4 below. Although the bacteria responsible for these processes can withstand gradual shifts in salinity, rapid changes can be lethal to them, thus slowing down the oxidation of ammonia. These populations recover within several days, but in the interim most aquarium animals would be killed by the increasing toxicity of the ammonia levels. *To avoid this, compensate for evaporation by adding small amounts of fresh water frequently. Since another major cause of mortality in bacterial populations is chlorine, the replacement waters should be aged.* To cure (age) water place it in an inert container for at least three days and aerated to rid it of all traces of chlorine.

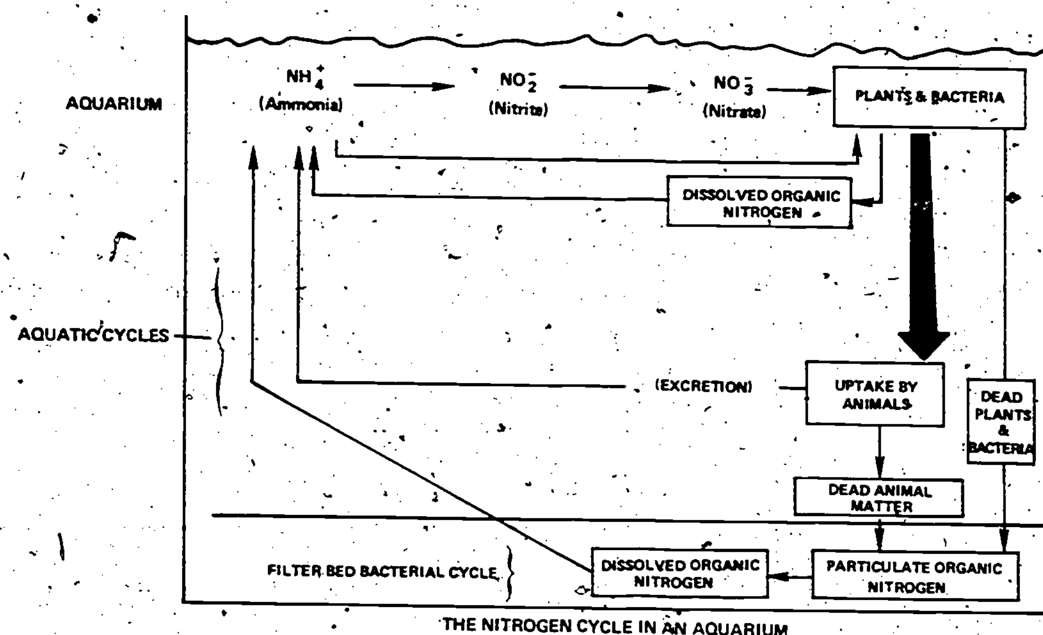

Figure 4.

The Nitrogen Cycle

Aeration

The functions of aeration (oxygenation) and circulation of water through the filter bed are best combined by use of an airlift system, rather than with a standard water circulation pump. The advantages of the airlift system are in lower cost, ease of maintenance, portability, simplicity, and higher efficiency.

The principle of an airlift is a very simple one: it is merely a vertical standpipe with the lower portion extending through the filter plate and the upper portion raised above the surface of the water. Air is injected into the pipe at or near the bottom. This upsets the equilibrium and causes the aerated water in the pipe to flow up and out of the pipe. The aerated water is replaced by water being drawn down through the filter bed (see Figure 5). For maximum efficiency, the volume of air flowing through this system should be adjusted so that the water flows smoothly and steadily out of the standpipe.

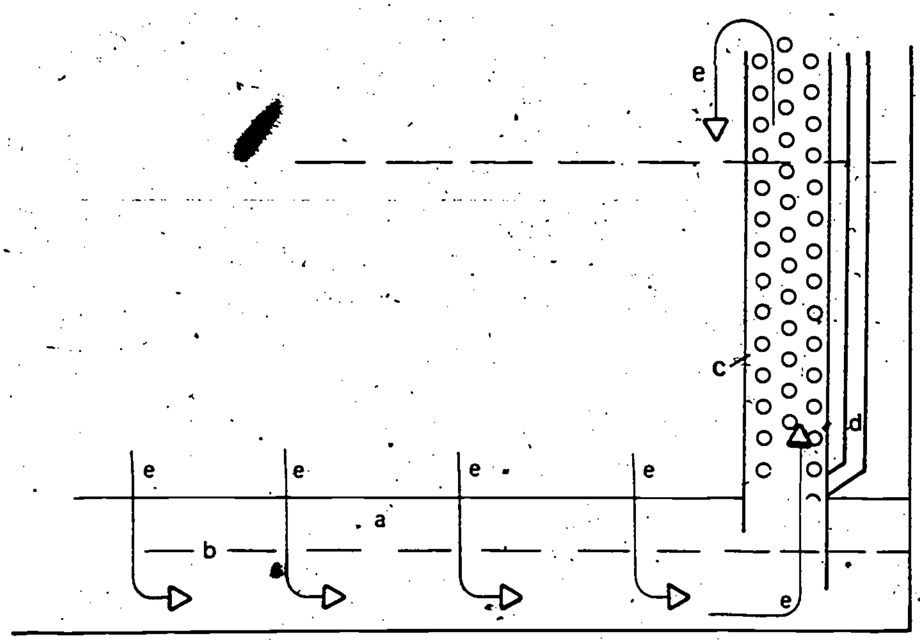

Figure 5

SUBSAND AIRLIFT SYSTEM

a. Gravel filter bed
b. Filter plate
c. Airlift standpipe
d. Air inlet
e. Path of water

(After Spotte, 1970)

Gravel

Gravel is important to the filtration process because it vastly increases the surface area as a substrate for the necessary bacteria. Studies have shown that nitrifying bacteria are100 times more plentiful in the filter bed than suspended in the water. Other studies have shown that the majority of the biological filtration takes place in the top five centimeters of the gravel; so in planning your filtration system, surface area, rather than volume, should be the main criterion. The size of the gravel grains is also important, with small grains providing more surface area. This, however, is self-limiting, since circulation throughout the bed is impaired when the grain size becomes to small. Angular gravel grains provide more surface area than do spherical, polished ones.

Temperature

Temperature changes do not greatly affect the nitrifying bacteria in the biological filtration system. It has been noted by various studies that warmer aquaria provide more efficient filter beds, thus permitting a larger total biomass than an aquarium with cooler water.

Toxic Materials

The bacteria are highly susceptible to toxins that may be introduced into the system in various ways. For example, treating a sick animal with any sort of chemicals designed to eliminate a pathogen may well eliminate the entire filter bed bacterial culture. Therefore, any treatment of diseases or parasites should be done in a separate tank. Aerosols used in the vicinity of the tank can prove lethal to the bacteria. Tobacco smoke and insecticides have often been indicted in this regard. For most purposes, animals should be released before problems of disease set in.

Mechanical Filtration

In addition to acting as a biological filtration unit, the gravel filter bed, in combination with a sub-sand filter plate and airlift pump, also functions as a mechanical filter. In this capacity it acts to reduce turbidity which is caused by suspended particulate materials in the water. The efficiency of the gravel bed depends, as stated, on the size and shape of the gravel used (smaller and more angular grains being the more effective), and on the accumulation of detritus on the top of the filter bed. As the detritus accumulates the pores between the grains are reduced, thus straining out finer particles. For this reason, filter systems with finer pore spaces provide water of greater clarity.

External filters utilizing a densly packed polyester fiber (rather than spun or fiberglass) and activated charcoal are also useful in trapping suspended particles. For further mechanical filtration diatomaceous earth filter sleeves are sometimes employed, and yield water of exceptional clarity. These devices are often marketed in pet stores as "water polishers."

Chemical Filtration

Chemical filtration takes place mainly in an external filter using well-rinsed activated charcoal. Dissolved organic compounds which are not affected by the biological filtration are adsorbed to the charcoal particles. Often this type of filtration will clear up the yellow staining of the water resulting from dissolved organic compounds.

Other methods of chemical filtration are frequently used. These include ozonization, irradiation, and airstripping. Of these, only airstripping shall be considered here since the other two techniques are costly and sometimes detrimental to the system.

Airstripping devices are often referred to as protein skimmers because they concentrate proteinaceous wastes in surface foam in a special cup. The underlying principles of airstripping involve the tendency of active organic compounds either to react with surface-active solutes or to be adsorbed at a gas-liquid interface. In each case, a foam is produced which can be removed. The mechanical principle involves a simple airlift pump with a two-story cup above the water surface, the upper cup being removable for cleaning (see Figure 6). As the bubbles are formed, the proteinaceous compounds are adsorbed to the bubble surface and are carried into the cups. The water, being heavier, falls into the lower cup, while the lighter foam is carried up into the upper one.

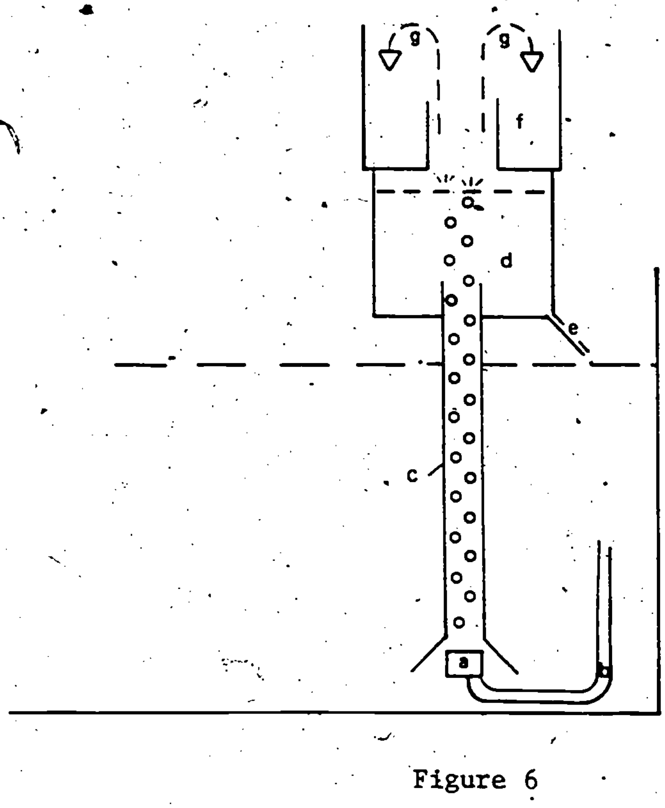

Figure 6

AIRSTRIPPER

a. Air stone b. Air inlet c. Airlift standpipe d. Lower cup
e. Water return port f. Foam collector cup g. Foam path

(After Spotte, 1970)

ACCESSORIES

Pumps

The most important accessory for your aquarium is the air pump. Without it the sub-sand filters are inoperative, and the water rapidly becomes depleted of its vital oxygen supply. Therefore, only a pump sold with a lifetime guarantee is worth considering. For tanks under 50 gallons, a single high capacity air pump is sufficient.

Temperature Control

Many intertidal animals can withstand temperatures up to 65°F, but most prefer somewhat cooler temperatures. For tropical species (available at great expense from any metropolitan pet store), special immersion heaters may be purchased which will hold the temperature at 75° - 85° F. For sub-tidal fishes, especially Alaskan species, a cooling system is desirable. Several varieties of refrigeration systems can be built by the school craftsman.

The easiest system to work with depends on the availability of an old-fashioned soft-drink immersion cooler. The best type has the refrigeration coils wrapped around a metal tank which holds water. All metal surfaces of the tank exposed to water should be completely sealed with fiberglass and resin. With the aquarium set in place directly above the cooling tank, water may be exchanged between the two by means of a siphon and an airlift system. The water running from the tank to the cooler should be filtered through a bed of filter floss encased in a cartridge (Figure 7) to prevent any animals, particularly in planktonic forms, from reaching the cooling tank where they might settle and abrade the fiberglass lining. See Figure 7 (page 13) for details.

Lighting

Some exposure to light is necessary to promote algal growth. In most cases, indirect natural sunlight supplemented by fluorescent lights is desirable. Incandescent lighting should be avoided, as it contributes too much heat. Tinted fluorescent tubes, such as those used for indoor gardening, yield the best results as they enhance the color of the animals. The amount of light should be controlled to limit the algal production.

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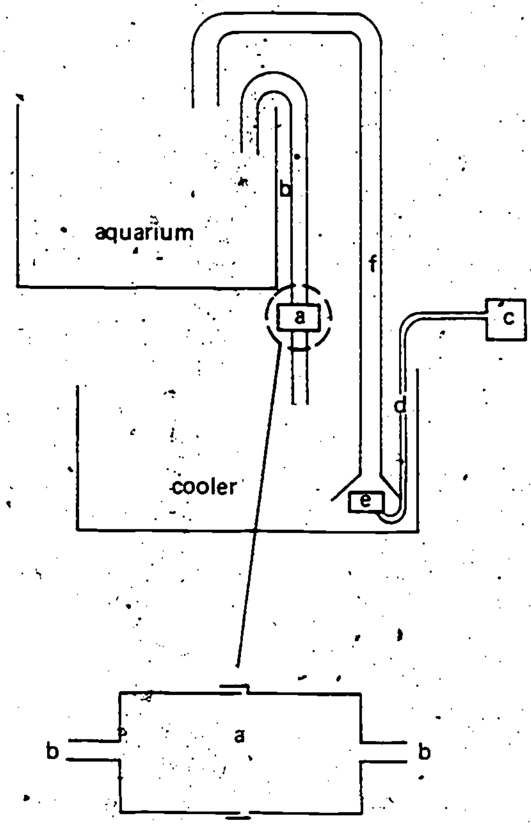

Figure 7

FILTER SYSTEM

a. Filter cartridge
b. Siphon
c. Air pump
d. Air line
e. Air stone
f. Airlift standpipe

SEA WATER

If natural sea water is available from a clean and unpolluted source, it is the best alternative. Most people have access to sea water only in harbors, which are not likely to be good sources of aquarium water. Natural water should be filtered before use. The other alternative is artificial sea water which can be made from any one of several commercial salt mixes available from pet supply houses. Its disadvantage lies in the fact that artificial sea water may lack some trace elements that may be important to the maintenance of a healthy system.

The water should be cured in an inert clean container. Note that the curing container should also be cured before use. It is important not to expose the water to light while curing in order to prevent algal growth. The curing period should be between three and four weeks, after which the water should be carefully siphoned into the tank without disturbing the sediment which has settled during the curing process.

SETTING UP

1. The aquarium should be placed in its permanent location before being filled. Moving aquaria of any size when full will likely cause the seams to rupture, or fracture one or more walls.

2. Once the tank is in place it should be filled with water in order to check for leaks before placing the gravel or filter component in place.

3. If no leaks are found, drain the tank with a siphon.

4. Before filling the tank the sub-sand filter plates and airlift should be installed and connected to the air pump.

5. Cover the filter plate with at least three inches of gravel.

6. Rocks and other shelter for animals should be put in place at this time. Be sure that they are clean and free of any contaminants.

7. If any outside filter is to be used, it should be installed at at this time using well-rinsed activated charcoal and polyester resin floss.

8. Before filling the tank, make sure that your air pump is placed above the maximum tank water level to prevent possible backflow into it.

9. A refrigeration unit, if one is to be used, should be installed before the tank is filled.

10. Filling the tank should be done gently to prevent displacing the filter parts. The easiest method is to place an enamel or glass pan directly on the gravel and pour the water into it allowing it to overflow. Do not fill the tank to the brim. Instead, leave two or three inches air space.

11. The level of the water should be marked so that evaporation can be noted and compensated for frequently.

12. The cover (transparent or translucent glass or plastic) should now be put in place and the air pump turned on to activate the filter and aerator systems.

13. If a light is to be used, it should be installed at this time.

MAINTENANCE

For the first two or three weeks the aquarium should house only a very few hardy animals, such as hermit crabs, in order to condition the water and filters. This period of conditioning is necessary to build up the bacterial populations responsible for the biological filtration.

Periodic maintenance is necessary for your aquarium system to insure its success. Usually this maintenance may be done on a weekly basis.

Checklist

1. Always make sure that there is a constant air supply to the tank.

2. Always make sure that the temperature does not exceed 65°F.

3. After every feeding be sure to remove any excess food.

4. Be sure that dead or sick animals are removed promptly.

5. The pH should be maintained at about 7.5 to 8.3. If it declines it is indicative of several possible problems, among them being overcrowding, inefficiency of the filter bed, or not enough calcareous material in the gravel. Most pet stores carry a very simple pH test kit.

6. Evaporation should be frequently checked by adding *fresh* water (distilled if available) to restore the water to its original level. Another means of checking the salinity and evaporation is by the use of a hydrometer (also inexpensively purchased from most pet stores). This instrument measures the specific gravity of water. Fresh water has a specific gravity of 0.99913 at 60°F (15°C). Standard sea water has a specific gravity of 1.025 at that temperature, but a range of 1.023 to 1.027 is tolerable by almost all animals. Intertidal animals are usually slightly more tolerant of salinity (and thus specific gravity) fluctuations than most marine animals from deeper habitats.

7. To prevent toxic conditions from building up in the filter bed, the gravel should be gently stirred periodically. This procedure is unnecessary if you have burrowing animals such as snails or sand dollars in your tank.

8. Occasionally all the viewing surfaces should be wiped free of the algal growth that is certain to accumulate. Use only a clean, boiled sponge, since razor blades or other scrapers will mar the surface of the glass. Remove algae only from those surfaces used for viewing, since this growth is generally beneficial.

9. Water should be changed periodically in gradual increments. A quarter of the total volume (or less) of the tank should be replaced with cured sea water about once every one or two months.

10. A properly maintained aquarium very seldom needs total cleaning. If a situation develops in which cleaning is unavoidable, use a dilute bleach solution, never soap or detergent. Rinse the tank thoroughly before using it again.

STOCKING

In stocking your tank remember that overcrowding can be a principal cause of mortality. Another cause is temperature shock. To avoid this, float the specimens in plastic bags until the water in the bag and the water in the tank are of equal temperature. Then perforate the bag to allow gradual mixing of the water before finally releasing the animals.

Among the common intertidal animals that live well in properly regulated classroom aquaria are sea anemones, which have lived in tanks for many decades, tidepool sculpins, hermit crabs, and other scavengers. Very active species (such as schooling fishes, larger crabs, and shrimps) should be kept only after you have gained a considerable amount of experience with the hardier animals. Kelps and other algae are often unsuccessful.

Finally, in the interests of conservation, do not over-collect in any one area and only keep animals for a short period of time. Return them to the sea after students have had a chance to observe them.

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GLOSSARY

activated charcoal -- a form of highly porous charcoal that can easily adsorb gases, vapors, and colloidal products

adsorb -- cause molecules to adhere to a solid surface

aeration -- bubbling air through water

airstripping -- the use of air bubbles to remove (strip) nitrogenous materials from the water

biomass -- total weight of all organisms in tank or habitat

calcareous -- composed largely of calcium carbonate ($CaCO_3$)

closed system -- an aquarium system totally dependent on constantly recirculating routes

detritus -- fine particulate debris - either organic or inorganic in origin

diatomaceous earth -- a filter medium composed of a deposit of diatom shells

hydrometer -- an instrument to determine the specific gravity of a liquid

inert -- will not react with water

irradiation -- the use of ultraviolet rays as a chemical treatment of water

intertidal zone -- the marine province located between low and high tide levels

oxygenation -- the process of absorbing oxygen

ozonation -- bubbling ozone (O_3) through the water

pathogen -- a disease-causing organism

pH -- hydrogren-ion concentration - a measure of the acidity or alkalinity of the water

proteinaceous -- made up of protein

protein skimmer -- a device for removing protein matter from the water

substrate -- attaching surface for plants, animals or bacteria

turbidity -- amount of suspended material in the water