CHAPTER VIII.

Conditions of Light, Water, Aeration, etc.

CONDITIONS OF LIGHT

As elsewhere stated, the best light for the aquarium is either a northern or northeastern exposure during the summer, and a position where it may receive a good, unobstructed light during the winter, when a few hours of the morning sun would be beneficial. A fine growth of plants is the best indication of favorable conditions, for when the light is excessive at noon or during the early afternoon, it will not only cause a loss of the suspended oxygen by a marked increase in the temperature of the water, but also affect the growth of the plants by a scorching and decay of the leaves, and arrestment of their growth. Too little light is also detrimental because plants require good light to grow.

When the admission of light is principally on the surface of the water, the conditions are nearest perfect. The plants will grow vigorously and the animal inmates be the most comfortable. For this reason aquaria exposed to very strong side light should be provided with a screen for use during the heated portion of the day. This may be constructed of one or more thicknesses of violet or greenish tissue paper or cheese cloth, attached to a light rod, to be hung over the front pane of glass. Window shades partly lowered or raised from below, or the setting of the aquarium back from the window are also effective measures.

Wooden tanks only admit light on the surface and should be placed where they will get the benefit of the morning sunlight or provided with awnings or other coverings that may be used when the heat of the sun is excessive. A fine growth of plants with floating leaves is the best screen to arrest the sunlight, and for this purpose lilies and water-poppies are used.

A little experience will teach the aquariist when the conditions are the most favorable, and his ingenuity will devise methods of reaching the best results.

WATER CONDITIONS

The oxygen necessary to sustain the life of fishes is not that which forms a chemical constituent of water (H_2O) but that contained in the air dissolved or held in suspension in the water. How considerable this is may be realized by looking through a glass of water heated near the boiling point.

In streams or ponds, aeration is maintained by the action of the wind on the surface, but in aquaria this condition is absent, and if air is not supplied as it is consumed all the living creatures suffer and the water deteriorates. Fishes transferred to water deficient in or devoid of air are speedily suffocated; but, as elsewhere stated, goldfishes are naturally of low vitality and their absorption of oxygen is small, compared with some other species whose habitat is running water. This is more or less characteristic of all stillwater fishes, notably the Carp family.

It is not chemically pure water that is required, as this does not exist in nature. Some saline, carbonaceous, sulphurous and nitrogenous combinations are always present, acquired from the atmosphere or from organic and inorganic or mineral substances by its absorbing and dissolving properties. River, brook, pond, spring, well and rain water all have different chemical composition due to these causes, and the proportion and nature of the substances present in solution vary with each locality. Rain water is usually the purest of the natural waters, containing only slight traces of ammonia, carbonic acid, and some inorganic particles taken from the air. Pond, brook and river waters usually contain mineral salts, inorganic substances, and contaminations of vegetal and animal origin. Spring and well waters usually contain mineral salts and other constituents in varying quantities and some organic contaminations.

Substances of a purely mineral nature are less injurious in character than those due to animal and vegetal decomposition, to sewage and to fungi. The presence of nitrates, nitrites, ammonia, and micro-organisms always indicate the oxidation and decomposition of organic matter. Inorganic and mineral substances are objectionable only when present in considerable quantity.

INORGANIC SUBSTANCES PRESENT IN WATER. The inorganic substances are usually the sulphates, carbonates and chlorates of calcium, magnesium, sodium and potassium; also iron, silica, traces of phosphoric acid, bromine, iodine and other mineral substances. The presence of these combinations with the hydrogen and oxygen affects the quality of the water and causes a change known as Hardness, which may be either temporary or permanent dependent upon the nature of the mineral salts present. Soft waters are those which contain the least substances in solution; temporary hardness is mainly due to the presence of the carbonates of lime and magnesium; and permanent hardness is caused by the sulphates, nitrates and chlorates of calcium, magnesium, sodium and potassium.

The carbonates of lime and magnesium which cause temporary hardness are soluble only in an excess of carbon dioxide (CO_2) and are only contained in water in which the CO_2 is present in such quantity as to hold it in solution as bicarbonate of lime and magnesium, as will be seen by the formulæ:—

$$\underset{\text{(Carbonate of lime)}}{CaCo_3} + \underset{\text{(Carbon dioxide and water)}}{H_2\,CO_3} = \underset{\text{(Structural formula)}}{CaCO_3 + CO_2 + H_2O} = \underset{\text{(Condensed formula)}}{Ca\,(HCO_3)_2}$$

$$\text{or}\quad \underset{\text{(Carbonate of magnesia)}}{MgCO_3} + \underset{\text{(Carbon dioxide and water)}}{H_2CO_3} = \underset{\text{(Structural formula)}}{MgCO_3 + CO_2 + H_2O} = \underset{\text{(Condensed formula)}}{Mg\,(HCO_3)_2}$$

The hardness produced by these causes is called temporary because it can be removed by boiling the water, the bicarbonates being thereby changed into the original simple carbonates by driving off the carbonic acid gas and precipitating the carbonates in insoluble form:—

$$\underset{\text{(Bicarbonate of lime)}}{Ca\,(HCO_3)_2} = \underset{\text{(Carbonate of lime)}}{CaCO_3} + \underset{\text{(Water)}}{H_2O} + \underset{\text{(Carbon dioxide)}}{CO_2}$$

The sulphates, nitrates and chlorates which cause permanent hardness are not affected by boiling and are retained by the water.

WATER ANALYSES. Some years past the author had occasion to make a number of analyses of Schuylkill and Croton river waters for manufacturing purposes, and collected considerable data which is of interest.

For drinking and manufacturing purposes the analytical determinations are usually ten in number, and these are, in their respective order, Total Solids, Mineral matter, Organic and Volatile matter, Organic Carbon, Ammonia both free and albuminoid, Nitrogen, in any or all the forms of nitrates and nitrites, combined nitrogen and organic nitrogen, Chlorine and Metallic salts; also the amount of Oxygen required to oxidize the water, usually by the permanganate of potassium color test, the degree of hardness, and a microscope examination. These are more than are required for the examination of aquarium water.

It is of interest to note that an analysis of the water of a balanced aquarium, which had not been changed for eight months, made for Mr. Mark Samuels by Prof. Leeds, should be of such remarkable purity. As may be naturally supposed the aquarium water contained the greatest proportion of solids, mineral matter, chlorine and the highest degree of hardness, due to easy explained causes. Rain water is the lowest in all of these constituents, while the very highest are Deep well and Spring waters. In point of purity as to ammonia, the aquarium water is as low as many of the city supply waters; and as to nitrogen, the proportion of nitrites is lower than Schuylkill water and the nitrates but two-tenths higher. The high percentage of chlorine is to be explained by the probable addition of table salt, from time to time, in the aquarium, and from the animal waste.

All natural waters are chemically impure, though they may be perfectly clear and free from suspended particles. They contain substances in solution, due to water being a natural universal solvent, which more than any other liquid dissolves and takes up solids, liquids and gaseous

Water Analyses

Source of Water	Analyst	Total Solids: Parts in 100,000	Total Solids: Grains per Gallon	Mineral Matter: Parts in 100,000	Mineral Matter: Grains per Gallon	Organic Carbon: Parts in 100,000	Organic Carbon: Grains per Gallon	Organic and Volatile Matter: Parts in 100,000	Organic and Volatile Matter: Grains per Gallon	Ammonia: Free Ammonia: Parts in 100,000	Ammonia: Free Ammonia: Grains per Gallon	Ammonia: Albuminoid Ammonia: Parts in 100,000	Ammonia: Albuminoid Ammonia: Grains per Gallon
Balanced Aquarium Water (8 months)	Prof. A. R. Leeds, Ph.D.*		25.21		21.36				3.85		0.007		0.0286
Rain Water.......	Prof. W. R. Nichols	2.95	1.65			0.07				0.029	0.0168		
Upland Surface Water	"	9.87	5.63			0.322				0.002	0.0012		
Deep Well Water....	"	43.78	25.54			0.061				0.012	0.0069		
Spring Water..........	"	28.20	16.45			0.056				0.001	0.0005		
Schuylkill River Water............	Prof. A. R. Leeds, Ph.D.		10.64		3.50				3.84		0.0085		0.0095
Hudson River Water	Prof. C. F. Chandler, Ph.D.		5.78		4.12				1.59		0.0215		0.0072
Croton River Water..	Prof. A. R. Leeds, Ph.D.		6.87		2.95				3.95		0.0019		0.0157

Source of Water	Nitrogen: As Nitrites and Nitrates: Parts in 100,000	Nitrogen: As Nitrites and Nitrates: Grains per Gallon	Nitrogen: Nitrites: Parts in 100,000	Nitrogen: Nitrites: Grains per Gallon	Nitrogen: Nitrates: Parts in 100,000	Nitrogen: Nitrates: Grains per Gallon	Nitrogen: Total Combined Nitrogen: Parts in 100,000	Nitrogen: Total Combined Nitrogen: Grains per Gallon	Nitrogen: Organic Nitrogen: Parts in 100,000	Nitrogen: Organic Nitrogen: Grains per Gallon	Chlorine: Parts in 100,000	Chlorine: Grains per Gallon	Microscope Examination	Oxygen Required to Oxidize	Degrees of Hardness: Temporary	Degrees of Hardness: Permanent	Degrees of Hardness: Total
Balanced Aquarium Water (8 months)				0.0023		0.544						4.89		0.452	9.04	3.26	12.3
Rain Water.......	0.003	0.0017					0.048	0.0271	0.015	0.0079	0.82	0.478			0.4	0.5	0.9
Upland Surface Water	0.009	0.0052					0.042	0.0349	0.032	0.0291	1.13	0.653			1.5	4.3	5.4
Deep Well Water....	0.495	0.2888					0.522	0.3045	0.018		5.11	2.972			15.8	9.2	25.0
Spring Water..........	0.383	0.2234					0.396	0.2312	0.013	0.00175	2.49	1.453			11.0	7.5	18.5
Schuylkill River Water............				0.0033		0.204						0.448		0.164			
Hudson River Water		0.0228										0.155		0.22	3.17	3.12	6.29
Croton River Water..				None		0.484						0.204		0.47			1.92

* Amateur Aquarist; Mark Samuels
Water Supply, Chemical and Sanitary; Prof. W. R. Nichols
Report on the Philadelphia Water Supply; Prof. A. R. Leeds, Ph.D.
Report on the Waters of the Hudson River; Prof. C. F. Chandler, Ph.D.

NOTE: The duplications of quantities (grains per gallon) are in some instances made by the author, to facilitate comparisons.

substances. So much is this the case that chemists distinguish substances as soluble or insoluble in water. Some which are not affected at ordinary temperatures dissolve in the superheated water of deep-lying strata, as is noticeable in geyser deposits; while other substances held in suspension are concentrated by evaporation and rendered insoluble by heat and precipitated; for instance the deposits in a teakettle or steam boiler.

When there is much vegetal or animal matter present, or when the hardness is due to salts of magnesia or to sulphate of lime, the water is not well suited for drinking purposes; and pollutions by the waste materials of factories and dwellings, by sewage or similar contaminations, are the cause of certain specific diseases which become epidemic; and injurious micro-organisms belonging to the class of fungi, algæ, bacteria and the large class of Schizomycetes, when present in drinking water, are the direct cause of typhoid and typhus fevers, diphtheria, dysentery and numerous other stomach and bowel complaints. To destroy these, thorough aeration is better than filtration, as most of the disease organisms are so small that mechanical filters will not remove them and their spores. Boiling is the best sterilization.

Any good drinking water is all that is required for the aquarium, though soft water is natural to the Carp family. Gradual changes in temperature also do not affect fishes if not too long sustained or excessive; but for those which naturally inhabit cold water streams, attention must not only be given to the character of the water but also to the required temperature, and what may be either excessively warm or cold avoided.

A constant danger in the aquarium is the fouling of the water by the decomposition of dead animals. This is indicated by a local cloudiness, a greasy surface, a foul odor, and later by the behavior of the fishes, and is followed by the death of all the inmates and the decay of the plants if the cause is not removed. This is more often due to dead scavengers than fishes.

Brook and river water abundantly contain the spores of algæ, which are beneficial in clearing the water and furnish food for the inmates, but if these are excessive or objectionable, the water should be filtered or spring water used which has been left standing to acquire oxygen and so assume the character of stillwater.

In a healthy aquarium the water must be clear and colorless though a faintly yellow or green tint is not objectionable, the one due to the decomposition of chlorophyll, the other to the presence of algæ. Comparison of condition is best made by taking a glassful and comparing it with a similar glassful of the water of a well-conditioned aquarium or with filtered water.

The odor of the water is also a means of determining its condition, as when this is strong, vitiation has advanced to a dangerous degree, and to keep the inmates alive it is not only necessary to entirely refill the aquarium but it should be cleaned, the plants reset, and after a few days the water again changed. Experienced aquariists can tell the condition of the water by its taste.

When the conditions are good there is no need of changing the water for long periods, as filling in what has evaporated is sufficient, or removing a part of the lower depth and adding a little fresh water, from time to time, especially when the weather has became warmer.

The aquarium should have a considerable change of water, more than half, when hot weather sets in, and it may be advisable to change part of the water occasionally, say once a month, if not perfectly clear. The new water also brings into the aquarium some of the mineral salts necessary for the plants and animals, which may become exhausted by long standing. Culturists of the food fishes recognize the benefit of occasionally turbid water, as the precipitation of the particles of soil act as a disinfectant, and the mineral substances are required by the fishes to digest their food. In ponds and streams, rainstorms will supply this requirement, but at the beginning of the feeding period of the alevin, breeders of the trout and other food fishes make the water of indoor hatching basins thoroughly turbid twice a day by pouring into it a mixture of water and rich sod soil, after which the young fishes take their food with particular readiness. The breeder of the goldfish supplies the required mineral constituents by placing dishes of turf in the rearing tanks, which is especially necessary to furnish soil artificially in wooden tanks and cement basins, as otherwise the health and growth of the fishes will be impaired. Muddy water is a favorable remedy for some of the illnesses of goldfishes and is frequently used. A small piece of plaster of paris is also beneficial, as it furnishes lime to the animal inmates.

Dr. W. Koch demonstrated that the addition of like quantities of nitrate of ammonia and biphosphate of potassium with a minute quantity of iron to calciferous wellwater, in which a number of water plants were placed, soon produced very green and turbid water rich in plant life consisting principally of algæ, voucheria and wolffia, when kept at a temperature of 50° to 54° F. This admixture produced conditions favorable to the development of the ever present spores of these low plant forms, which are beneficial to the animals in the aquarium.

When much animal life is present in proportion to the size of the aquarium and the plant growth is insufficient, frequent changes of water are necessary. In overstocked aquaria this must be done daily, but such conditions should be avoided. Frequent aeration will then also be necessary as the vitiating carbonaceous constituents combine with oxygen and form CO_2, the form in which the plants can best assimulate it, but which in excess is fatal to animal life. Oxygen is one of the best anticeptics and for this reason some of the water should be dipped out and slowly poured back into the aquarium that it may absorb air.

If the plants do not develop new shoots and leaves at all seasons, something is wrong with the water, if the light is sufficient but not excessive. When the roots are affected, indicated by their black appearance, the ease with which the plants are uprooted and the unsatisfactory general appearance of the leaves, the aquarium should be cleaned and refilled with clean water.

One very important consideration for success is the condition of the water when the fishes are transferred from an out-of-door to an aquarium existence. At this time many of the mishaps occur, and at no other period are the fishes more likely to contract fungus diseases. It is always better to fill the aquarium with the water in which the fishes have been kept, when this is in good condition, as they will not then be subjected to differences in temperature and composition of the water, will continue in the same conditions to which they have been accustomed, and not subjected to sudden changes, as they will be acclimated to household conditions in water which will gradually assume the temperature of the room. Experienced aquariists always employ this method of transfer.

AERATION

All animals require oxygen to maintain their existence, and have organs by which it is brought into the blood. In breathing, a part of this oxygen is taken from the air, distributed to every part of the organism and consumed in the functions of life. In exhalation and surface expulsion CO_2 or carbonic acid gas is given off, for which reason the air becomes poorer in oxygen and richer in carbon with every breath, as every 100 parts of inhaled air contains 20 parts of oxygen and approximately .04 parts of carbon, and the exhaled air 16 parts of oxygen and 4.38 parts of carbonic acid gas. This would indicate a consumption of one-fifth of the oxygen and an addition of one hundred times as much carbonic acid gas. Hence a constant breathing of normally constituted air is necessary or suffocation will result, not only from the consumption and consequent lack of oxygen but also from the poisonous effect of the exhaled carbonic acid gas.

Nature, however, has provided for the maintenance of an equilibrium by the breathing of plants which require the carbonic acid gas exhaled by animals, taking up the carbon and liberating the purified oxygen. What occurs in the air also takes place in the water, though it contains less free or suspended oxygen, an average of only 2 to 3 percent, and considerably more suspended carbonic acid gas. The animals consume oxygen, give off carbonic acid gas, and the plants consume carbonic acid gas and liberate oxygen. Therefore, unless oxygen is added to the water, either by plants or furnished by aeration, animal life must cease. In the properly established aquarium the plant life should be in excess, and only as much animal life present as will exist comfortably under the conditions. But as plants are only active in producing this interchange when growing, and as their growth is entirely dependent upon sufficient light, when this is not abundantly obtained artificial aeration is necessary or a frequent change of water required, surface aeration alone being insufficient.

There are many methods of furnishing air to the aquarium or larger tank. The following have been given thorough trial and have proven satisfactory when arranged that the air enters in minute bubbles for ready absorption by the water. Good results may be had by either direct admission of the air, or by means of a stream of water under the pressure of a considerable elevation, through a very finely perforated nozzle fixed close to the surface of the water on the opposite side to the overflow pipe, so that the force of the water carries with it a large amount of minutely divided air. This also permits of warming or cooling the water supply by coiling the pipe in a water-tight chamber, if desired, and may be installed on a larger or smaller scale to suit the requirements.

Direct aeration, without the necessity of the overflow pipe, is arranged by the use of a pressure tank and bicycle pump, placed at any convenient location, and the compressed air admitted into the aquarium by a small block tin pipe buried under the pebbles. Several petcocks are necessary to hold the pressure and to check the amount of flow, and tiny pin holes blocked with pieces of porous wood will best serve to admit the air in the required minute bubbles. When properly installed, a pressure of 35 pounds in an air chamber 28 inches high and 12 inches in diameter, produced in three minutes by a bicycle foot-pump, will furnish a 50 gallon aquarium with air for two or three days. This system of aeration is in successful use with a number of aquariists in Philadelphia. Care must however be taken not to over-oxygenate the water.

The simplest fountain device, when the aquarium is placed at a window and is as broad as the opening, is the following. A block tin pipe may be led under the bottom of the aquarium through the base and screened by rockwork. This should have a small stopcock at the end and a rubber hose to connect with a water can outside the window or screened by the window curtains; and arranged on a cord and pulley for raising to the desired height. If the pipe is closed to a very small opening above the water level, five gallons of water should be sufficient to cause a fine fountain play for probably an hour. The overflow may be carried out of the aquarium in the corner, and a half-inch rubber tube through the trim of the window would lead it outside, or it may be collected in a vessel under the aquarium. This device was successfully used in swamp-aquaria.

Many other ingenious aerating devices have been produced, but the simplest and most efficient are those here given.

SOIL FOR AQUATIC PLANTS

Experts in the maintenance of the freshwater aquarium favor the use of soil in shallow pots under the pebbles into which to root the aquatic plants, the result being always satisfactory. For this purpose clean turf, directly from under the roots of lawn grass, is the best, not garden earth or potting soil. Aquatic plants rooted in turf grow with vigor and there is less likelihood of its fermenting or decomposing, to cause disturbances in the aquarium, as may be the case with the rich potting soil, when used in considerable quantity. For plants required as oxygenators, the turf may be used in pots, but for those with floating leaves in out-of-door tanks a richer compost is necessary, as both the lilies and water-poppies are rank feeders and require a large quantity of rich soil, frequently renewed. The compost prepared by gardeners for this use consists of turf and some well-rotted cow manure, a little ground bone and about a quart each of pond soil and clean sand, the whole to about fill a bushel measure. This should be packed about the roots of the lilies and poppies, covered with clean turf and a thin layer of pebbles and set into pails of water for a few days, that it may "set" and expel the generating gases before introduction into the tanks. Water-poppies, water-clover and the potamogetons will thrive in the aquarium in turf, but experience has taught the aquariist that *Sagittaria natans* and *Anacharis canadensis gigantea*, the best oxygenators, will grow more vigorously when set directly into the pebbles and sand; for when the roots do not have much nutrition they serve principally to anchor the plants and consume the humus. The leaf blades will perform the functions of roots, grow more rapidly and assume a finer pale-green color. The plants are less likely to develop blossoms and seeds and will not as soon exhaust themselves or deteriorate, the propagation of Sagittaria then being by rhizomes or offshoots, the desired "runners" of the aquariist. It is also advisable to remove their floating floral leaves and the flower stalk, as the plants usually die after ripening the seeds.

ROCKWORK FOR THE AQUARIUM

Picturesque effects in the aquarium may be produced by the introduction of rockwork and other natural objects. Pomice adapts itself well for this purpose and is easily worked. Odd pieces fastened together to form a grotto or rockery may have the surfaces hollowed out to contain soil and sand in which plants may be grown, or form a screen behind which brackets for small flower pots may be constructed. Tuftstone is also to be recommended, as very handsome odd pieces may be obtained and natural effects produced by their tasteful arrangement. Selinite or gypsum may be introduced, as it is not only handsome in appearance but dissolving slowly in the water, it furnishes lime, necessary to the molluscs and other animal life. Small pieces of plaster of paris will also serve for this purpose. Mica schist, quartz, feldspar, agate, rock crystals and other minerals are effective, or water-worn stones to which aquatic plants are attached may be introduced, but all other objects not natural to a water garden are in questionable taste. All objects should be clean, and soaked for some time in water before they are put into the aquarium.