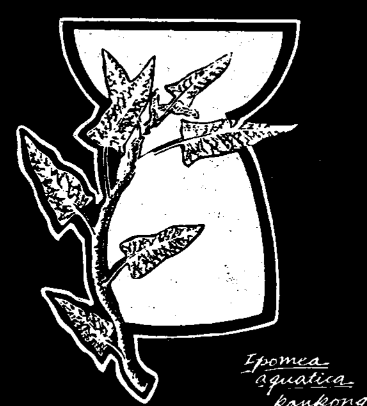
Life On Guam Freshwater



by Lynn Raulerson

art Terry Palumbo

Life On Guam

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"...to ultimately graduate citizens who are knowledgeable and conscientious about environmental concerns of Guam and the rest of the World."

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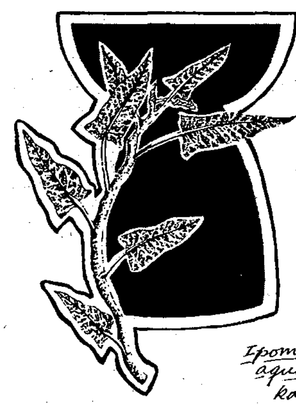

Ipomea aquatica kankong

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I - Introduction

This book is about freshwater on Guam. The study of freshwater is 'limnology'.

Limnology has many different points of interest. A freshwater biologist studies the living parts of a freshwater system: everything in the biotic community. Hydrologists, on the other hand, study temperature, light, currents and pressures, and the kinds of salts present in the water: the abiotic, non-living parts. Some people investigate entire systems of living and non-living components. These people are freshwater ecologists; they study ecosystems.

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We can study most systems by examining their parts separately. We can do the same thing with limnology, looking at a lake, a stream, or a spring; then we can try to put every part together. Or a limnologist can study an entire system all together——and then try to take it apart. Each method gives us valuable information.

For human beings and for everything else that lives on islands and continents, freshwater is essential. Living things are mostly water, and those on land require a source of freshwater to stay alive.

Like the ocean, freshwater bodies give us places for recreation——places to swim, to bathe, to go boating or canoeing, to fish, or merely to sit and daydream.

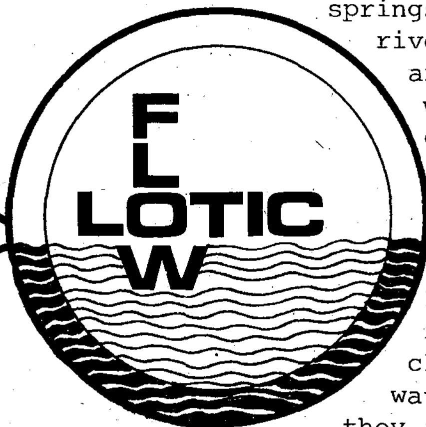
For a long time, freshwater (especially rivers and lakes) was considered a good place to dump sewage and other garbage. People also thought there would always be enough freshwater ——for people, for agriculture, for manufacturing and other industry.

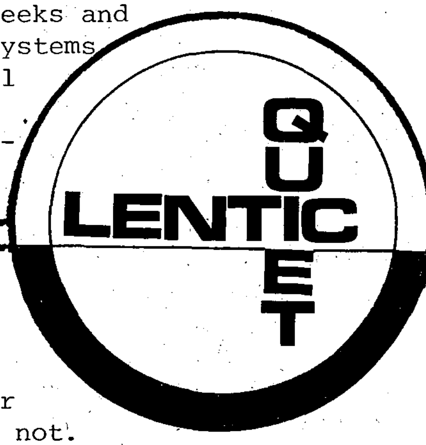
Through a lot of sad experiences, we are learning not to take freshwater for granted. We've found that freshwater systems are fragile. Like living things, they can't do everything we expect of them if they are abused. If we dump in too much sewage, we can't use the water for drinking. No one wants to swim——or go boating——with garbage floating in the water. Industrial wastes can poison the organisms in a stream. After that, no one can fish or use the water to drink. One large Ohio city dumped so much waste into a river that the river caught on fire, and burned a bridge up! Because of problems like these, public health officers and agencies and pollution ecologists also study freshwaters.

The next chapters give you general information and experiments you can do to add to it. We still have a lot to learn about freshwater, and you can help put some of the pieces together. These chapters deal with freshwater in general——and Guam in particular.

II - Types of Freshwater Systems

There are two basic types of natural freshwater systems, <u>lotic</u> and <u>lentic</u>. Lotic systems contain moving, flowing water, like springs, streams, creeks and rivers. Lentic systems are quiet, still waters with no current, including ponds, lakes, swamps and marshes. In most cases it is easy to classify fresh waters by whether they are flowing or not.





An ecologist will also classify ecosystems another way, asking 'Is this a major or a minor ecosystem?' A major ecosystem can exist by itself. It can feed itself and is independent. For example, a large lake is a major ecosystem. It has its own plants and animals——it makes its own food——it's independent. A minor ecosystem, on the other hand, needs help. It's dependent; it expects help from other nearby systems. A stream is a minor ecosystem. Its water is always leaving——running downhill. If it has plants in it, many of them wash downstream. If an animal doesn't swim well and forgets to hang on, it gets washed downstream. An old proverb says, 'You never walk twice in the same stream'——because the water and plants and animals don't stay in the same place. (Nor are you the same person!) Obviously, this system requires help from land communities it runs through. It gets fallen leaves and dirt. Its animal supply is maintained by flying insects and other animals which lay their eggs in water and have larvae that grow up in water.

Before we talk about each kind of system, let's consider how the water gets into it. Where does the water come from? Every kind of water on Earth is related to every other kind. In fact, if there is anything special about Earth in our whole solar system, it is the water we have. As far as we know, only Earth has liquid water. Other planets may have frozen water ——ice, or water in a gas state——vapor, but not liquid.

Materials can exist in three states: solid, liquid, and gas. (Actually, there is a fourth state of matter, called plasma. This is not like blood plasma, but more like the molecules of very hot bodies like our Sun. On Earth, plasmas may exist in someone's laboratory but aren't found naturally.) The state matter happens to be in at any one time depends on how close together are its molecules. If they're very far apart, they don't run into and react with one another very much: the matter is in the gaseous state. When the molecules are very close together—almost 'locked together'—the matter is in the solid phase; none of the molecules move very much at all. In the intermediate condition, the molecules run into each other a lot. They are sometimes stuck together and sometimes free to move. This is the liquid phase of matter.

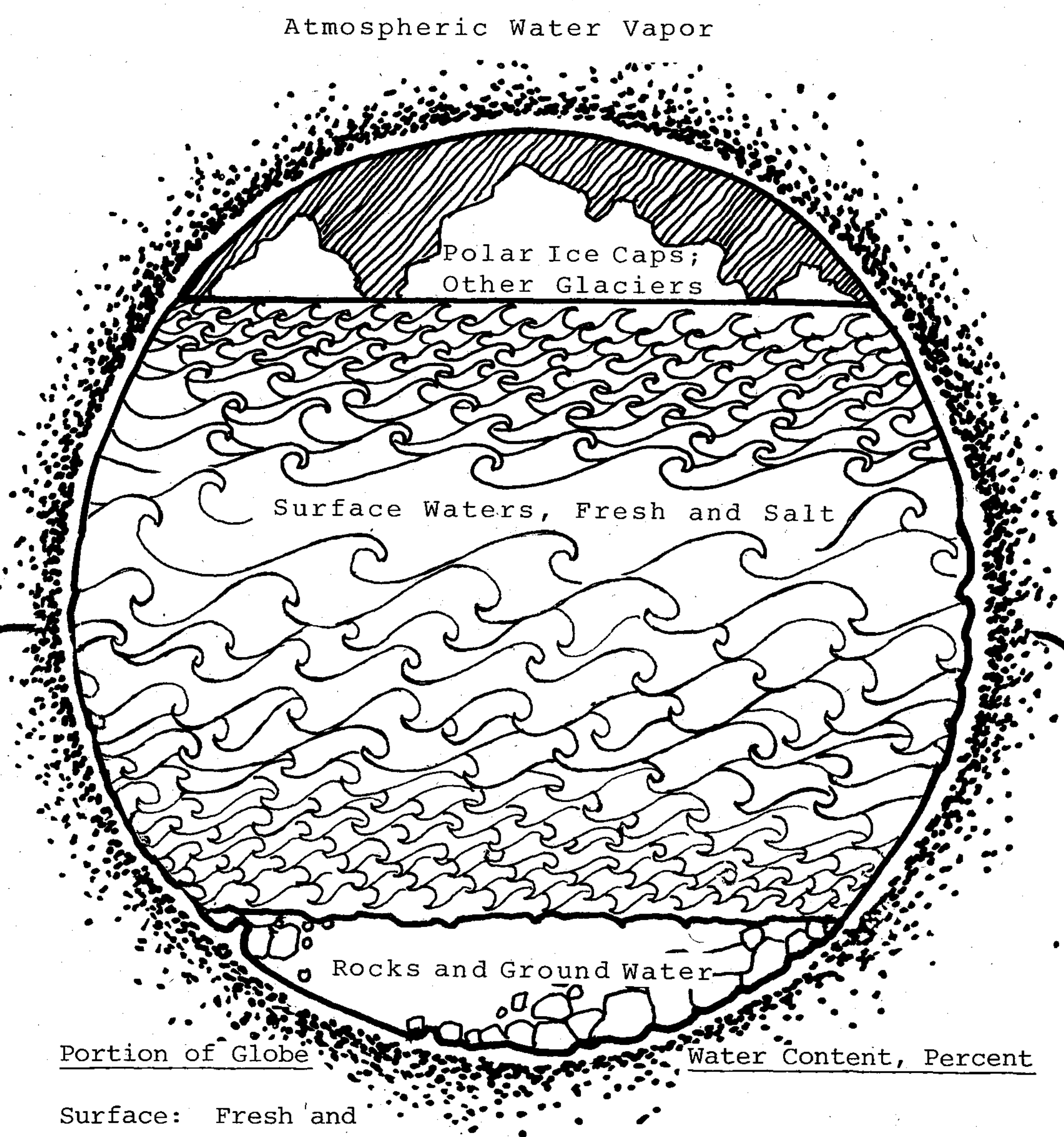
Three things influence the states of matter: temperature, pressure, and the number of molecules present. All these involve the energy that molecules in the matter have. Every time a molecule hits another molecule it loses some energy. If there are a lot of molecules in a small place, and no way to make the space larger, eventually the molecules will lose energy and 'settle down'. If every space is full of molecules, you have a solid. If you increase the pressure, the molecules will run into one another more frequently.

Temperature measures heat. Heat is one kind of energy. If you put energy into matter by heating, the molecules move around a lot more. So, if you want to change ice (water's solid state) to a liquid, you merely warm it up. Eventually the ice cube will be a liquid puddle of water. If you want to change the liquid to a gas, you warm it up some more. If you boil water, it becomes the gas we call steam. You know it has a lot of energy in it because you can burn yourself badly with steam. Just before liquid water becomes steam, it becomes water vapor. You can see this vapor just above a pot of boiling water, or above the road after a rain when the Sun comes out. Water vapor still has water molecules clumped together, so you can see vapor. You can't see steam.

On Earth water can be converted into all states of matter (except plasma) under natural conditions. This seems like a simple thing to say, but it isn't. Very few substances can be converted even into 3 states of matter under Earth conditions. Oxygen, for example, occurs in nature only as a gas. In the laboratory, liquid oxygen (LOX) can be manufactured. We use it for fuel in space programs. Even solid oxygen (SOX) might theoretically be possible under lab conditions! All molecules on Earth take part in cyclic processes. We call the cycles Bio-Geo-Chemical. 'Bio' means 'living'; 'Geo' means 'Earth'; and 'Chemical' refers to a molecule as it acts according to basic physical laws. So water is in a biogeochemical cycle, as are oxygen and nitrogen and most other molecules. (See Human Impact pp 5-10, Schoolyard Ecology p 26.)

Water's Biogeochemical Cycle

From this diagram and table, you can see that most of Earth's water is on the surface.



Portion of Globe	Water Content, Percent
Surface: Fresh and Salt Water	97.217
Polar Ice Caps; other Glaciers	2.15
Rocks and Ground Water	0.625
Atmospheric Water Vapor	0.001

Not much water is locked into polar ice caps and glaciers. This is solid water—ice—unusable by people or any other system until portions melt and become liquid water. The atmosphere holds the least water—water in the vapor stage. The air gets water from all the Earth's surfaces by evaporation and by transpiration from living plants. We call vapor in the air 'humidity'. If water vapor collects in an area (usually on microscopic dust particles), clouds form. If the vapor continues to collect, what happens? The water returns to earth and the oceans as rain or snow. Thus water runs in a great cycle, operated by two major forces: gravity, and energy provided by sunlight.

Gravity is the force exerted by a 'body' on another body. The more mass a body has, the more gravitational force it exerts. Gravity also depends on the relative closeness of objects. Jupiter is much larger than Earth, and has much more gravity. But when you jump up in the air, you come down on Earth, not on Jupiter! An astronaut jumping on the Moon would land on the Moon, not on Earth, even though Earth is far larger than the Moon. Because of gravity, rivers run downhill. Water vapor stays near the Earth. Earth's gravity holds its atmosphere close. The Moon once might have had an atmosphere, but not now. Because of its small size and low gravity, the Moon would have lost its atmosphere in 4 or 5 billion years.

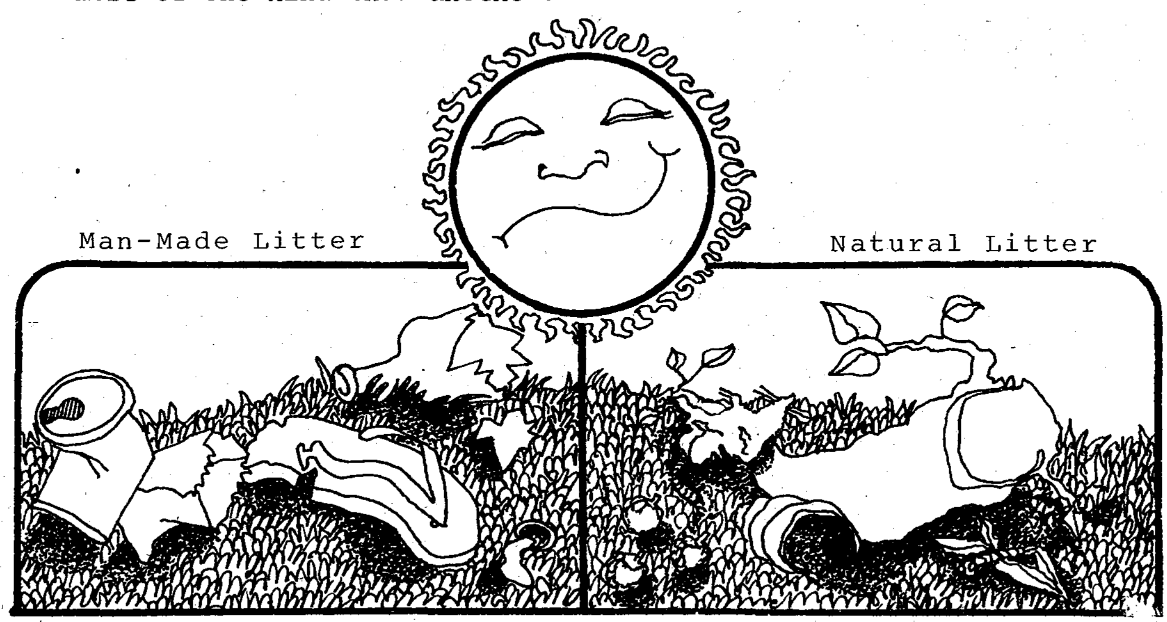
Why would would the Moon have lost its atmosphere? Shouldn't its gravity hold the small molecules which might have been in its atmosphere? Here is where the second force—energy provided by sunlight—comes in. Sunlight is *light energy*. You know energy is necessary to move molecules. Water molecules will stay with other water molecules until they acquire enough energy to get away. Sunlight provides the energy to release them. This is the main reason evaporation happens on Earth's surface. Earth's gravity prevents most molecules from leaving and going to outer space. But some molecules, especially the very smallest, do escape. This happens if they don't bump into others on their way out, losing their escape energy. With its smaller gravity, the Moon couldn't balance the 'escapees' with the 'captives'.

So, water on Earth cycles: Precipitation falls on Earth because of gravity; evaporation happens mainly because of the Sun's energy. This isn't the whole picture, but you can find out more in physics and chemistry.

On page 3 we said that the two kinds of freshwater systems, 'lotic' and 'lentic', are based on currents. Lotic systems include springs, streams and rivers. They have a current, and usually are minor ecosystems.

Springs are bodies of water formed when underground water comes to the land's surface. To talk about them, we should understand a little bit about the 'ground', the geology of an area. (Remember that 'geo' means 'Earth'——and any time you see the word part 'logy' it means 'study of': so geology means study of the Earth.) If you were to dig a hole, your shovel would first go through a layer of leaves and branches called 'litter' ——natural litter, not the same as cigarette butts, cans, plastic, or bottles. Then it would reach a layer of topsoil, earth mixed with decaying plants and animals. Eventually you would run into rocks of some kind. Rock is formed by pressure. Layer after layer of material is piled on top of one another. The lower layers become more and more squashed and harder and harder. This is *sedimentary* rock.

Or, rock can be formed by volcanic activity, by great pressure and high temperature deep inside the Earth. This kind is *igneous* rock. Great forces within the Earth can also mix up the two kinds——rolling them, tilting them and squashing them together until such a messy mixture is formed that you can't tell one from the other. This kind of rock is *metamorphic*. All surfaces of continents and islands on Earth have these three kinds of rock just below them. Sometimes they have much more of one kind than another.



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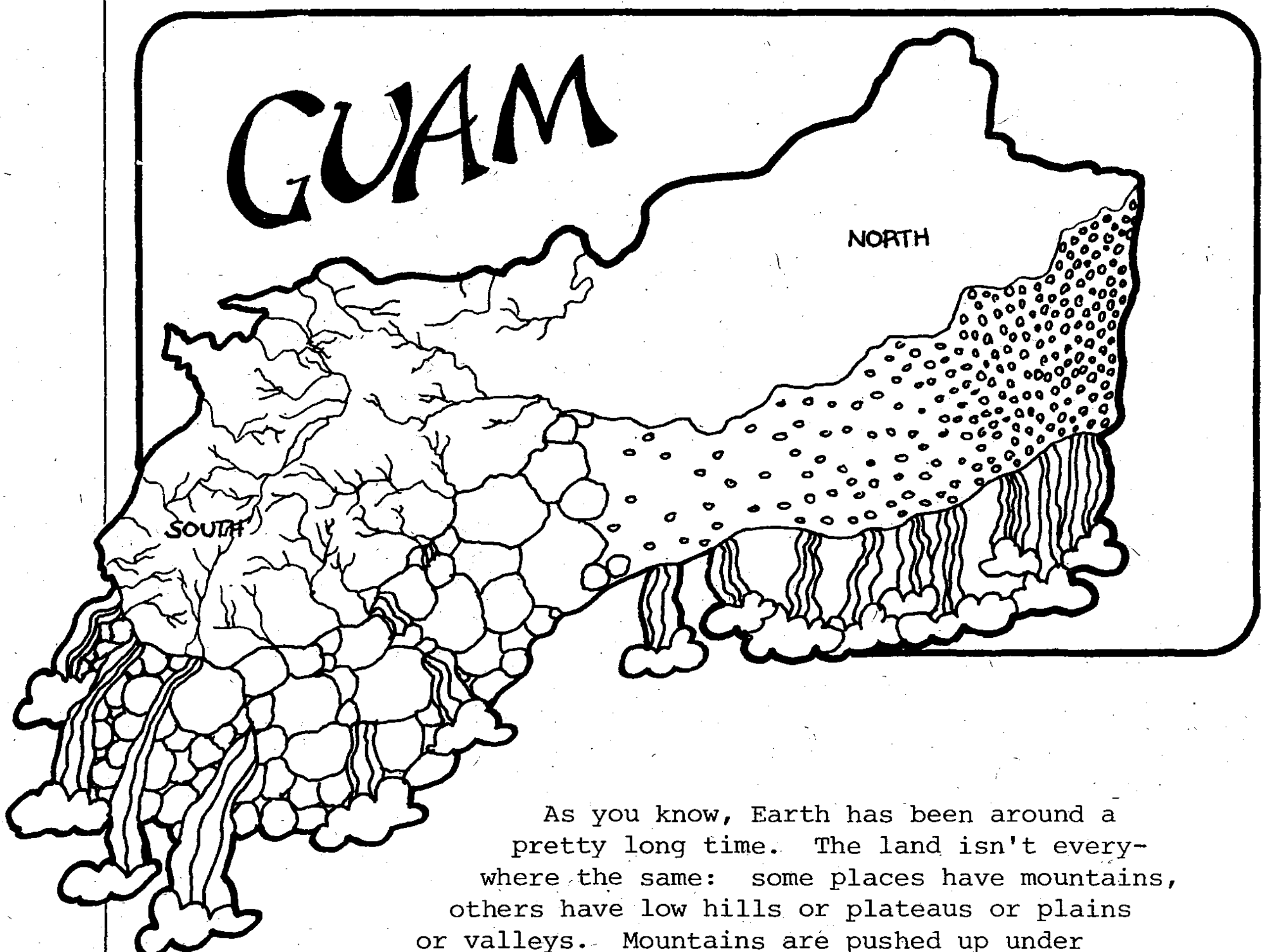
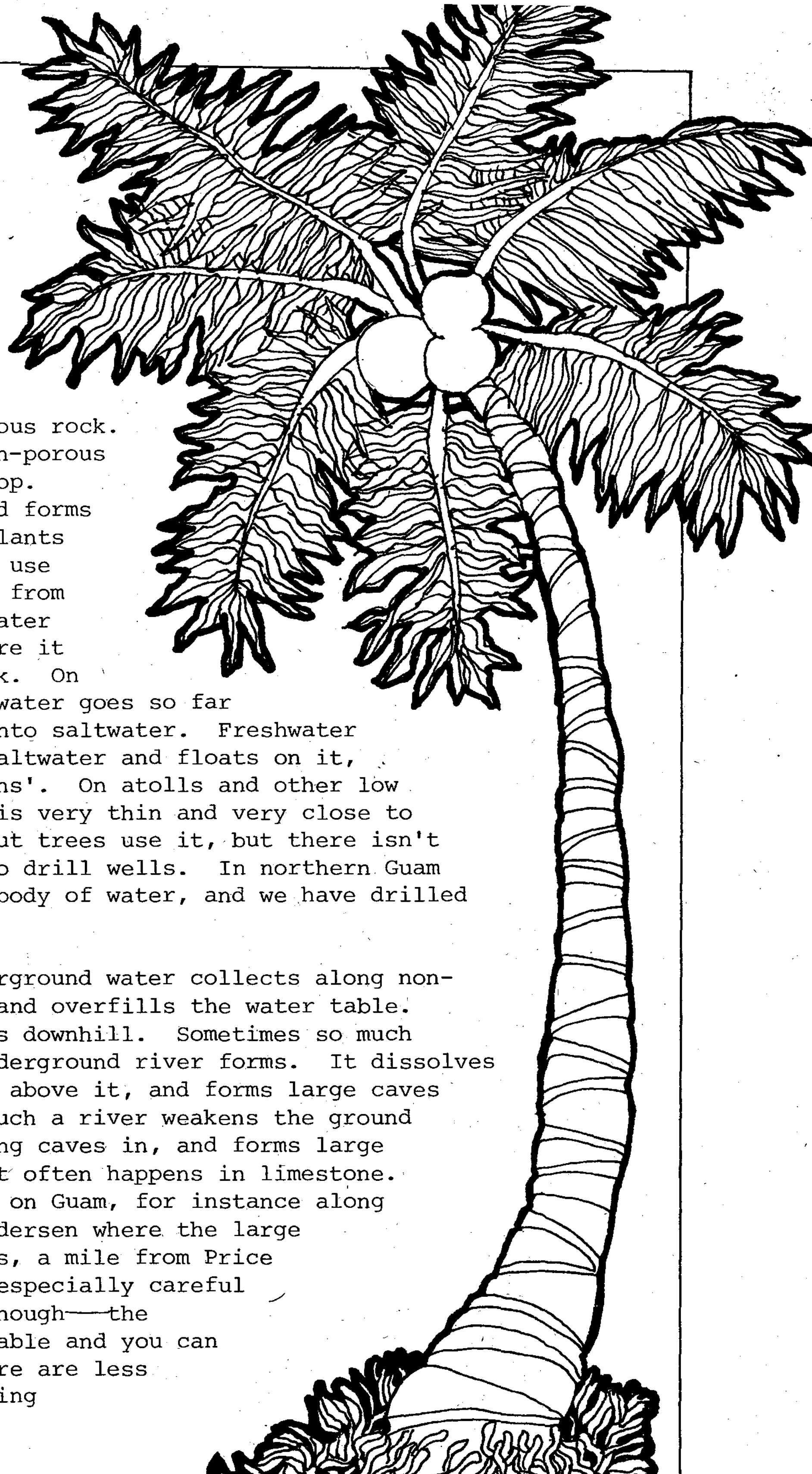
Some rocks let water through very easily. These are porous rocks——they have holes (pores) in them. Sometimes water dissolves away the rock and causes the pores to form. Limestone is a very porous sedimentary rock. It forms much of northern Guam. Other rock is non-porous and doesn't let much water pass through. Over a long time, water may wear this rock down by flowing over it. Water erodes it even if it has a hard time getting into it. Much of southern Guam is this kind of non-porous igneous rock.

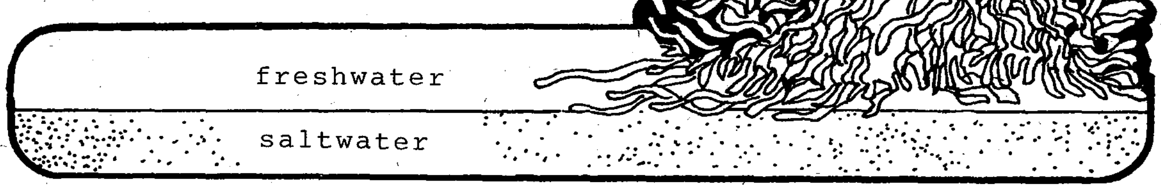


As you know, Earth has been around a pretty long time. The land isn't everywhere the same: some places have mountains, others have low hills or plateaus or plains or valleys. Mountains are pushed up under pressure, or formed by volcanic activity. They dwindle by erosion. Wind and water and vegetation, and our old friend gravity, work on the face of the land. New mountains rise——and more erosion happens. The rocks beneath the soil are tilted, put under pressure, jumbled up. Geologists look at more than just Earth's surface. If you really look——at a road cut, at a cliff by the sea——you can see the layers of rocks and read a little of the history of that part of our Earth. What you see on the surface depends very much on events below it. These events are still happening, even if so slowly we're not always aware of them. (Don't forget earthquakes!)

Water falling on Earth can land on non-porous rock and collect in pools or run off downhill. It can fall on soil where plants will use some of it, but most of it will continue on down through porous rock. At some places a non-porous layer is near the top. Water stops here and forms the water table. Plants with deep roots can use it. People pump it from wells. Sometimes water goes very deep before it hits non-porous rock. On some islands, freshwater goes so far down that it runs into saltwater. Freshwater is 'lighter' than saltwater and floats on it, forming a 'water lens'. On atolls and other low islands, this lens is very thin and very close to the surface. Coconut trees use it, but there isn't enough for people to drill wells. In northern Guam the lens is a huge body of water, and we have drilled many wells into it.



In many cases, underground water collects along non-porous rock layers and overfills the water table. This water then runs downhill. Sometimes so much collects that an underground river forms. It dissolves away rock below and above it, and forms large caves and channels. If such a river weakens the ground above it, the ceiling caves in, and forms large round sinkholes. It often happens in limestone. You can see several on Guam, for instance along the back road to Andersen where the large field of antennas is, a mile from Price School. Always be especially careful around sinkholes, though——the ground is very unstable and you can fall through. (There are less deadly ways of joining the 'underground'!)

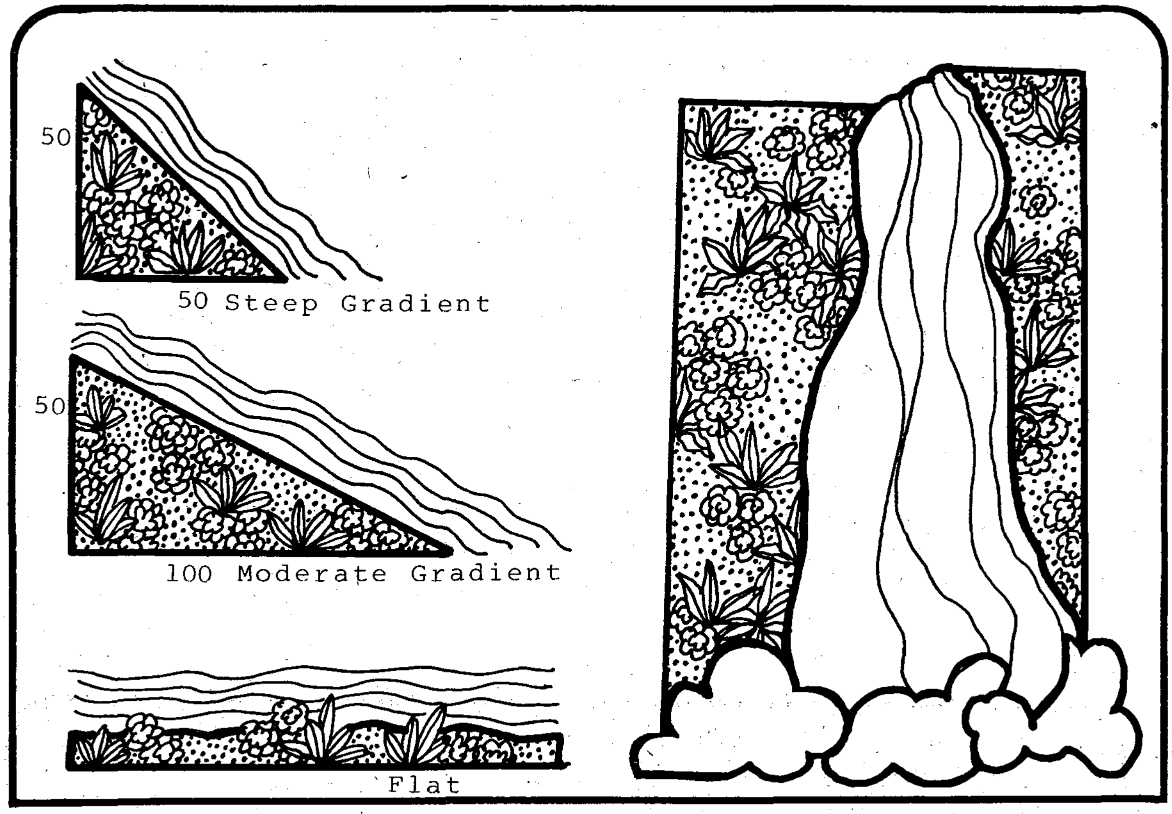


Often the river breaks through at the side or base of a hill; if it does, a spring is formed. The greater the amount of water in the river, the bigger the spring will be. If the breakthrough is in a hollow or depression, a spring lake will arise. Often the amount of water is not large; then a small spring like Agana Spring will form. Some springs, like the one at the War Memorial in Yigo, are even smaller. If the water flow is constant, the spring may overflow and make a small stream. (Such a stream is sometimes called a 'spring hook'.) When springs are very small they are called 'seeps'. You can find these anywhere near the upper parts of streams. On Guam they are also along beaches, especially at the water's edge. Northern Tumon Bay has several. Sometimes a spring is temporary; it exists only during the rainy season, or in very rainy years. No matter what size or kind, a spring always has water flowing from underground.

'Stream' is a hard word to define. One place's stream is another place's river! There are 'streams' in Malaysia three times as wide as our Pago River. Some 'streams' in Taiwan become 2 miles wide from shore to shore during the monsoon season! It's hard to tell streams from rivers, so we'll conveniently discuss them together. You can decide, when you meet one in the field, whether you have waded in a stream or a river.

Streams (creeks——better known as 'cricks'——branches and brooks) are tributaries of rivers. The name 'tributary' means that streams pay tribute. They donate water to rivers by dumping their contents into them. Streams get started in several ways: as overflow from springs, or ponds, or lakes; as glaciers or snowfields melting; and as runoff water from bare rock. Streams invariably cut channels, because flowing water has great erosive power. Not only can the water itself wear away rocks, but it carries minerals and acids from decaying vegetation. These react chemically with rocks. Water also carries larger materials——sand grains, pebbles, rocks and even boulders. These add to the 'scour power' of flowing water.

A young stream has several characteristics. One is a steep gradient. This means that water traveling in the stream goes down the shortest possible way. Let's look at an example:



What Gradient is a Waterfall?

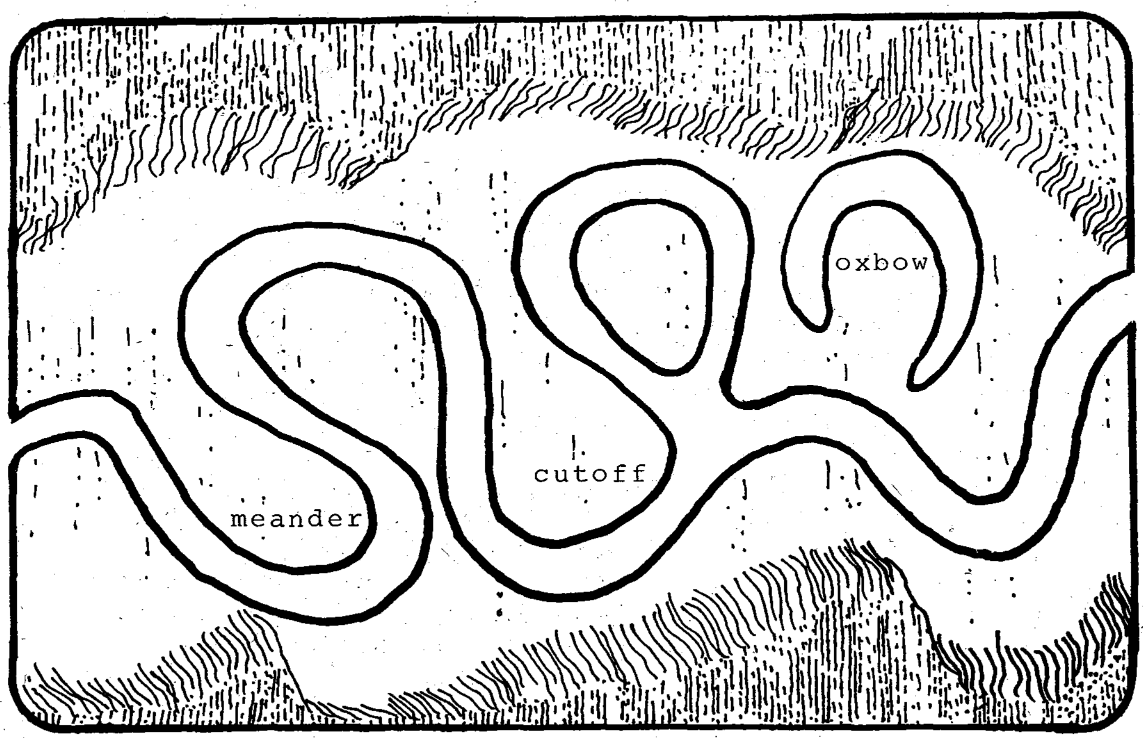
Diagram A shows water moving from a height of 50 meters to a height of zero meters in a distance of 50 meters. The gradient in A would be 50/50, a slope of 1 meter per meter. The water flows downhill 1 m for every horizontal m it travels. B shows water moving from a height of 50 m to a height of 0.0 m in a distance of 100 m. The gradient in B is 50/100, or 0.5 m per m. This water flows one-half of a downhill meter for each horizontal meter it travels.

Young streams look like example A. The water flows rapidly. A young stream tends to cut back up the hill, and downhill into the landscape. As it erodes materials away, its headwaters cut further upstream. Because of this, what was once the top of a young stream is now the middle of a middle-aged stream. A stream will continue to grow this way over millions of years, until it erodes away the entire landscape.

You can imagine some of this history when you travel down a young stream to the point where it enters—or becomes—a river. The travel will be downhill until you reach the flatter land the river occupies. The V-shaped valley cut by a young stream smooths out; erosion from tributary streams gentles the landscape and smooths it. The gradient more resembles C, above, and the water speed has decreased. The river still has considerable power. It is still quite capable of moving large boulders, but the boulders aren't so common. On their way downhill they have cracked and shattered, their rough edges worn away by water and collisions with other boulders. The volume of water has increased, as tributaries have paid their tributes.

A mature river wanders about in the flood plain it has created. Sand, dirt, rocks and pebbles have been scattered along the edge, where the water is shallow and the current slower. Rainy season floods are common and bring more topsoil down to the plain. A mature river often looks like a snake, turning one way and then another across its plain. The long curves are meanders, sometimes spectacular——especially when seen from the air.

Some meanders will be so close to each other that high water or a flood will join them. This shortens the main channel, and leaves disconnected lakes called oxbows on the flood plain. Big old rivers, like the Mississippi, the Amazon,



and the Mekong, have made many oxbows. While a river is shortening itself by cutting off meanders, however, it is often extending itself by building a delta.

As a river meets the sea, or a large lake, it is carrying clay, mud, sand and other things. At this point it slows enough to deposit its solids—the heaviest first, later and further out, the lighter stuff. As time goes by, sediments pile up and spill out and down into the ocean basin. The river often cuts additional channels through its sediments. This happens especially when the river is swollen with extra water and other materials in the rainy season, or in Spring when snows melt into the river. Eventually these alluvial (river-carried) deposits form a fan shape which the Greeks said looked like their letter △, 'delta'.

The Mississippi, Nile and Mekong deltas are some of the richest farming lands of the World; they contain an abundant supply of freshwater and much of the best topsoil from the lands upstream.

The other category of freshwater systems—the lentic—includes aquatic systems without currents: ponds, lakes, bogs, swamps and marshes. Let's review the basic differences between lotic and lentic systems:

Comparing Freshwater Systems

Characteristic	Lotic (Moving)	Lentic (Quiet)
Depth	Shallow	Deep
Width	Narrow	Wide
Current	Directional	None
Gradient	Changes, directional	None
Channel length, width and depth	Increase with time	Decrease
Transport of materials	Downstream	None
Stagnation	No	Yes
Influence of physical factors	More direct	Less direct
Food communities	Minor, depend on land	Major, self-sufficient

Lentic systems come in all sizes and shapes. A pond can be as small as a footprint that holds water when it rains. A lake can be as large as one of the smaller states of the United States. The largest body of freshwater on Earth is Lake Superior. (Is it superior for any other reason?) Its 82,000 sq km make it almost 150 times the size of Guam (560 km^2). Generally speaking, a pond is a very small, very shallow body of standing water with large aquatic plants and hardly any wave action. A lake is a body of standing water which occupies a basin not next to the ocean, and is larger than a pond. A marsh is always shallow, with rooted herbaceous (soft-stemmed) plants; a swamp is shallow and contains rooted woody vegetation. Depending on their size, both marshes and swamps could be considered either specialized ponds or specialized lakes. They all have similar origins, and similar fates. In geological time, all are fated to disappear.

Before we get to their disappearances, let's look at their origins. Lakes form in several different ways:

1. Glacial action. Glaciers are frozen rivers of ice. They can be many thousands of feet thick and many miles wide and long. They exert great pressure on the earth beneath them because of their tremendous mass. The pressure usually forces the lower layers of ice to flow——very slowly, but with great force.

Glaciers can easily dig out large basins, whereas streams can cut only small channels into rock. Rivers and streams cut V-shaped valleys; glaciers cut U-shaped valleys.

Glaciers also push along with them the materials they have dug out: dirt and boulders, tons of them. When glaciers melt and recede, they leave all of this stuff where they stopped; the mound of dirt, rocks and boulders is a glacial moraine.

Glaciers can create lake basins in four ways: by digging out a hole in the rock beneath them; by leaving moraines to block up a valley; by forming an ice wall at the lower end of a mountain valley; and by leaving in the moraine huge blocks of ice, which melt sooner or later. A region with many lakes was probably once covered with glaciers. Glaciers have covered much of Russia, Europe, Canada and the northern U. S.

2. Landslides block valleys and create lake basins.

3. Sinkholes connect with underground rivers and form spring lakes.

4. Earth's crust moves and creates basins and blocks valleys.

5. Extinct volcanoes have craters (calderas) holding lakes.

6. Rivers make oxbows by cutting off meanders.

7. Rivers get blocked up naturally: e.g. sediments, volcanoes, earthquakes.

8. People build dams and impound rivers, or bulldoze out depressions and make small lakes and ponds....or drop bombs....

Geologically, all lentic systems are temporary. All lakes become ponds; all ponds evolve into marshes or swamps; all marshes into dry land. This evolution is constant and orderly. Let's try to understand it: Start with an averaged-sized, glacier-formed basin. Rainfall, snowfall, and water from surrounding hills will fill the basin with water and materials dissolved in it, plus some sand, rocks and boulders. So we have a lake ——but no organisms in or around it. In time, bare rock around the lake starts to support living plants and animals. First come the primitive and tiny kinds, then larger and larger forms. (This is xeric succession—xer = dry—on dry land, and not a subject for this booklet.) There's a chance that some plant material—decaying leaves and dirt—will slowly begin to wash into the lake.

At the same time, the lake is slowly undergoing succession of its own. Microscopic algae are brought in by the wind. They reproduce slowly; many die and sink into the bottom. Eventually some insects lay eggs in the water, and their larval stages hatch and feed on the algae. Eggs of other animals —microscopic ones—fall in and hatch. Maybe even small fish are able to move in from older lakes below. At this time the lake is clear and clean and probably cold, especially in the deeper parts.

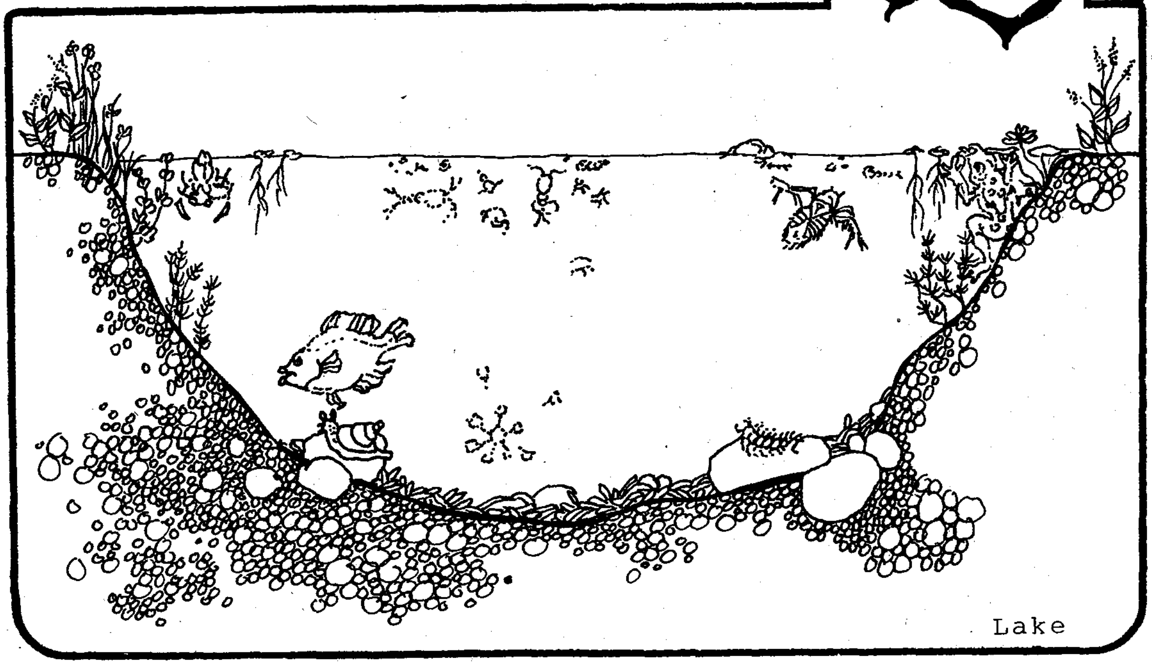
More and more sediments collect in the bottom, from runoff and from organisms dying and sinking. The shoreline has plants growing on it, and they hold mud with their roots. They die down adding soil to the edge of the lake, which gets shallower. The middle also gets shallower. The lake is filling in, but very slowly. The bigger the basin and the deeper it is, the longer this takes.

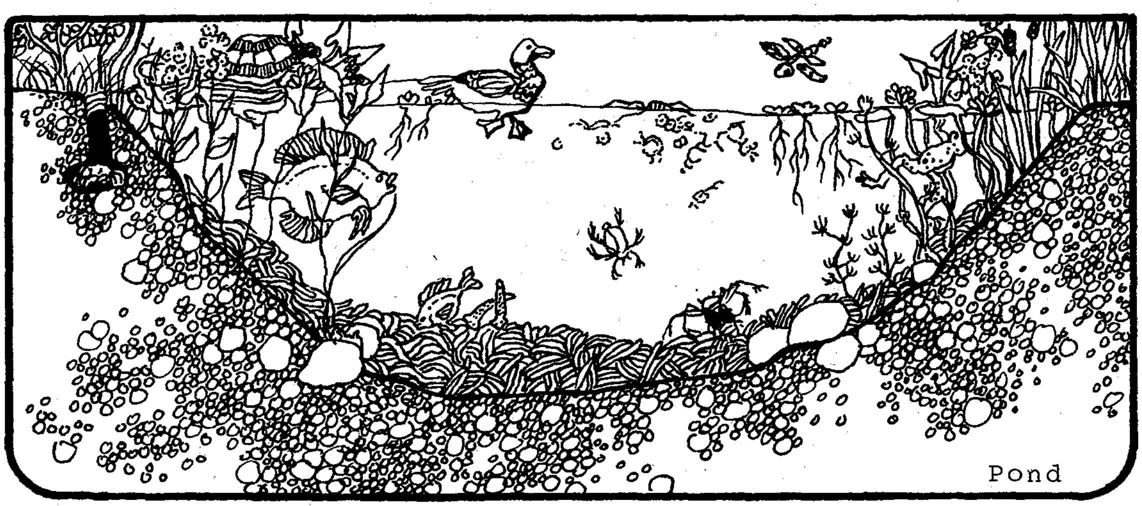
Algae and plants using sunlight to make food (what's the process called?) must live where they can get it. At first, algae live only at the shallow edges, where sunlight can get through. As the lake fills in and gets shallower, algae can live everywhere in the water. More algae living means more algae dying, providing more algae as food for animals. So more animals can live there, too. And plants with roots have more soil to put roots into. Now the lake is shallow, the water not so clear because it has lots of algae and animals and more mud. It's not quite so cold at the bottom, because more sunlight gets there.

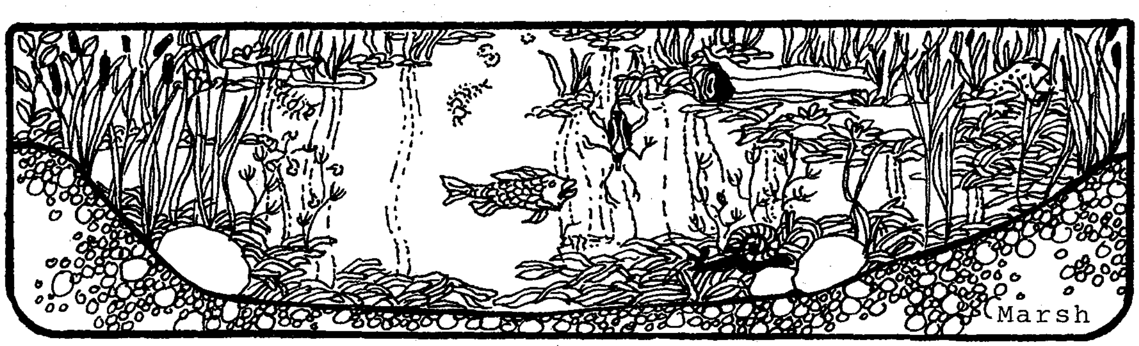
You can see what's coming—the lake will fill in more and more. Every year more things can live in it. More organisms can also die in it and add more decaying matter. The shoreline grows more and more into the lake. The lake gets smaller. Pretty soon our lake is as small as a pond.

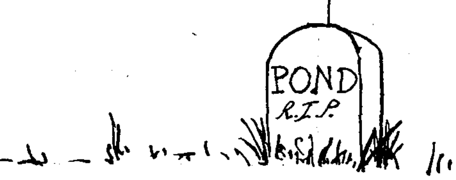
From being pond-sized, the next step is for the bottom to be covered with rooted plants—grass-like ones, maybe some water lilies. By this time the edge is dry and the center is a marsh. With more and more vegetation, even this marsh becomes filled in, and a grassy meadow grows where the lake—pond—marsh—had once been.

Life of a Pond









These steps are typical of the evolution of a lentic system. This is hydric succession (hydro = water). Even man-made lakes—ones with a river flowing through them and over or below a dam—go through these steps. It happens faster with man-made lakes. The river is blocked and slows down enough to drop its mud and rocks, often right at the dam. We could take the sediments out by dredging the lake, but we'd have to do it often, and usually it would cost too much.

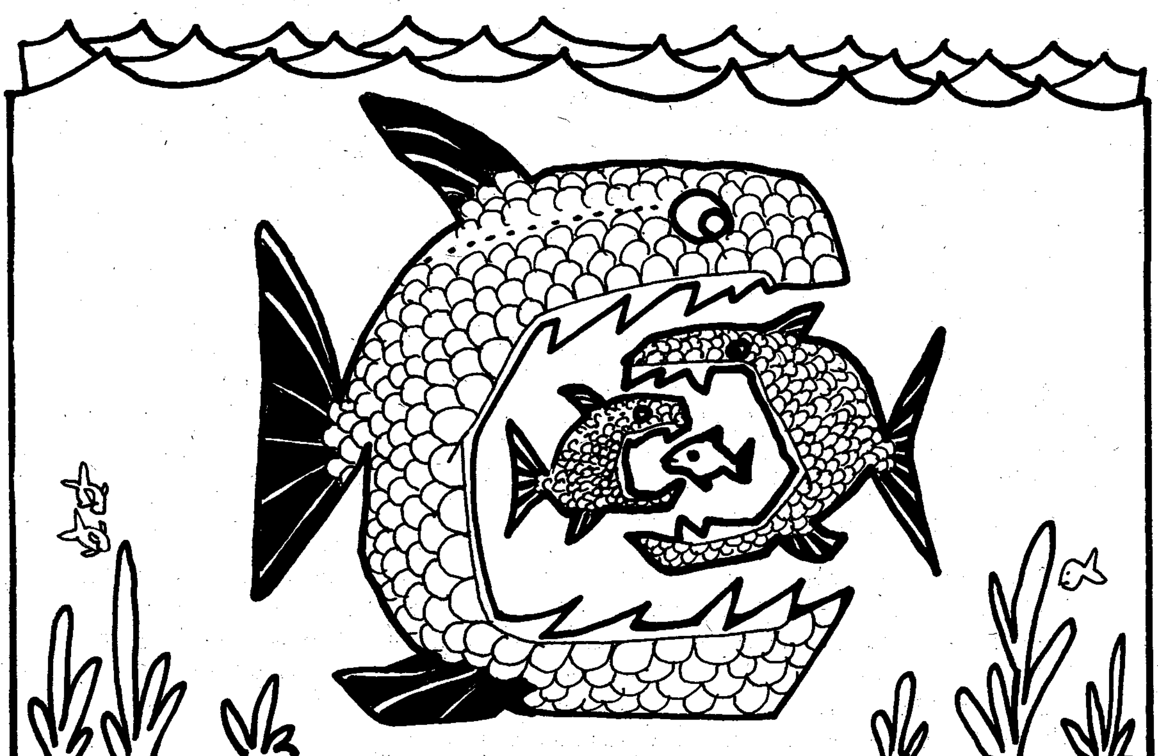
Ecologically, lakes have been studied longer than other bodies of water. Limnologists have described all kinds. A lake that fits the picture of our first one—clear, clean, few organisms—is *oligotrophic*. 'Oligo' means 'few', and 'trophic' means 'feeding'. This type of lake supports few feeding, living organisms. An easy way to know an oligotrophic lake is to visit it in the warmest part of the year. Take a water sample from the bottom; test it for dissolved oxygen. Warm weather is the time to find organisms, and most of them need oxygen. If you find oxygen at the bottom of the lake, there can't be many organisms because they would have 'breathed' it all up. Oxygen at the bottom in the warmest part of the year means an oligotrophic lake.

The next lakes—shallower, and not so clear—are *eutrophic*. 'Eu' means 'true' (and trophic still means 'feeding')—so a eutrophic lake supports many organisms, all feeding like mad. You can check this lake in the same way—on the warmest days, sample the deepest water for oxygen. You'd expect that so many organisms would use up the oxygen. You don't find any. No oxygen at the bottom during the warmest part of the year means you have a eutrophic lake.

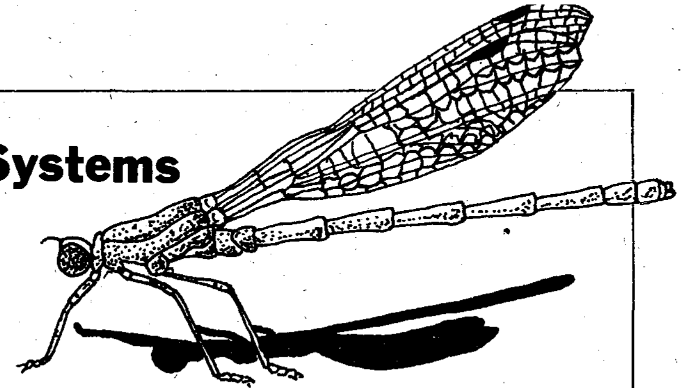
There's one more kind of lake, *dystrophic*. 'Dys' means 'bad', (maybe a bad choice of prefix because the lake isn't 'bad', nor are the organisms—for lakes, it's just that the trophic situation isn't like most). Many man-made lakes are dystrophic. When you sample them there are many organisms so you think 'Aha, it's eutrophic!' But when you check the bottom water, there's plenty of oxygen!

What happened? Check: A river probably runs through the bottom all the time bringing in fresh new water with minerals and nutrients. This doesn't fit the usual pattern.

Very salty lakes—like the Dead Sea and Great Salt Lake—are dystrophic too. All that salt messes up the pattern for critters living there. Lakes formed by hot springs are dystrophic. Many sinkhole lakes are dystrophic. Sometimes the bottom falls out of the sinkhole and the lake disappears—into an underground river. You've got to admit that a lake which isn't there is pretty different!



III - Life in Freshwater Systems



This section is about several different kinds of organisms living in freshwater.

A freshwater biologist is interested in classifying an organism by its residence, where it stays. A residence tells you a lot, even about people. People who live in large houses may be wealthy, eat expensive food, and may not have a vegetable garden. People living in smaller houses probably aren't wealthy, may have to get by on inadequate diets, and if they can, probably grow food for themselves. These are generalizations, but they often give useful information.

For a freshwater biologist, there are 5 basic 'places of residence'. Their inhabitants are plankton, nekton, neuston, benthos and aufwuchs.

Plankton live in open water but don't swim well, if at all. Most plankton are very small, even microscopic. Most are designed, evolutionally speaking, with high floatability. First, they're small. Water buoys them up. Many are able to hold air bubbles, or oil bubbles, in their cells. Others have very long appendages (like arms, legs and antennae) for their tiny bodies; by spreading out these appendages they float easily. Test this by trying to float with your hands and feet held very close, so your body forms a straight line. Then spread out your arms and feet. Which way keeps you floating more easily? Many plankton rely on water currents to move them up if they do start to sink; others do a sort of 'vertical breast stroke' and manage to stay off the bottom that way.

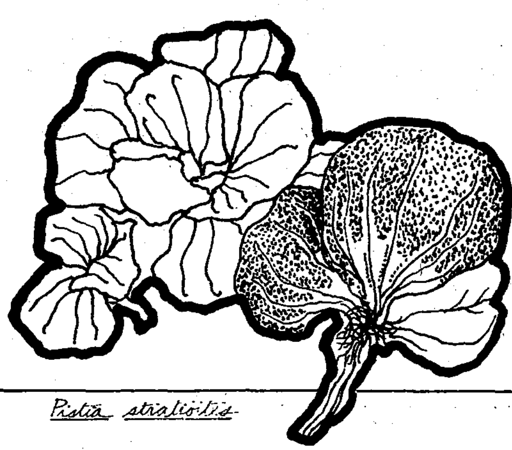
What organisms are planktonic?——many bluegreen algae, green algae and diatoms (goldenbrown algae); many, many protozoans, like Paramecium; small animals such as rotifers and microcrustaceans like Daphnia and Cyclops. Many adult animals that aren't planktonic have larval stages that are: sponges and mollusks and several arthropods. (Don't worry about their names now; we'll go into that later.)

Nekton are swimmers. They live in open water and can navigate against a current. They have well-developed muscles. They usually are fairly large and have streamlined bodies——narrow from side to side with pointed heads and tails. Obviously, fish are the major nekton of freshwaters. Turtles could be nekton——and some frogs and salamanders.

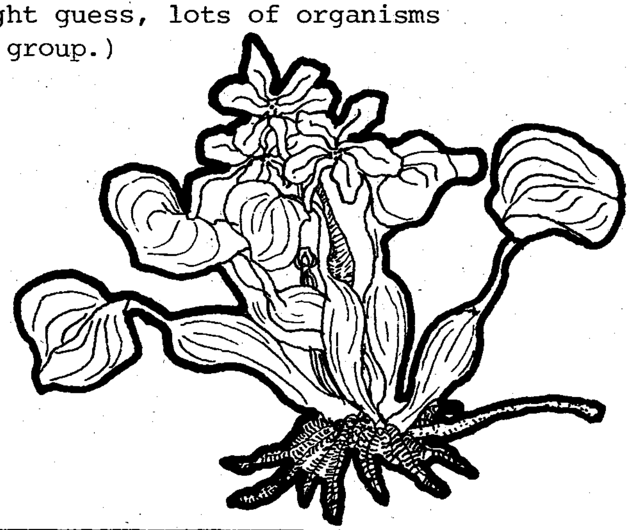
Neuston are floaters. They live on the surface, right where air and water meet. Some live mostly in the air, others mostly in the water. There aren't many true neuston, but they are noticeable in freshwater. Flowering plants like water hyacinth (Eichornia) and water lettuce (Pistia) often cover the surface of springs and rivers. Water striders, aquatic spiders and whirligig beetles seem to skate on surface tension, the 'skin' of water that air touches. A mosquito larva hangs below the surface film, with an air tube extending to the top. Neuston must be lightweight or able to spread body weight over a large area; they depend on surface tension. (By the way, there is always an argument about water lilies: The leaves float on the surface, but the stem and roots are anchored in the mud. Is a water lily neuston——or benthos?)

Benthos live on or burrow into the bottom sediments. Some benthic animals, like freshwater shrimp, are large and active, crawling along the bottom and searching for food. Other benthic animals burrow into the bottom and stay there. All sizes and shapes of organisms are benthos. The category includes bacteria and fungi, all sorts of protozoans, some algae and many rooted plants. Most of all, it includes worm-like creatures: flatworms and nematodes and aquatic earthworms and larval stages of many insects. It also includes mollusks (clams and snails), and crustaceans, and non-worm-like insect larvae like those of dragonflies.

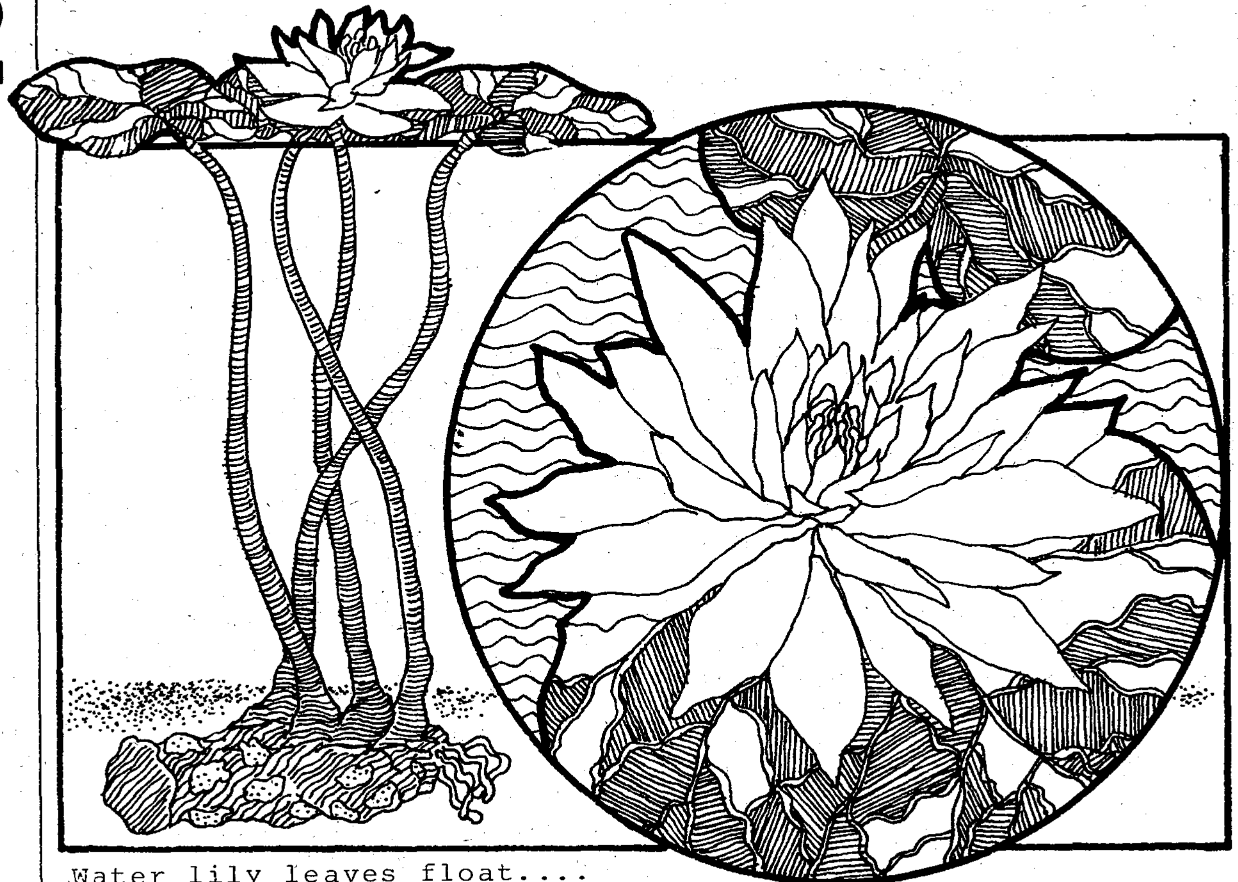
Aufwuchs (owf'vooks) is a German word referring to things that grow (wuchs) on or against (auf) other things, 'other things' being rocks, logs, plant stems and leaves. Some people look at this group narrowly: if the organism isn't firmly attached, it isn't aufwuchs. Most people take a broad view. They feel that if the organism stays in one place or moves but is definitely associated with materials attached to the environment, it is aufwuchs. (As you might guess, lots of organisms are going to be put in this group.)



Pistia stratiotis



Eichornia crassipes
water hyacinth



Water lily leaves float....

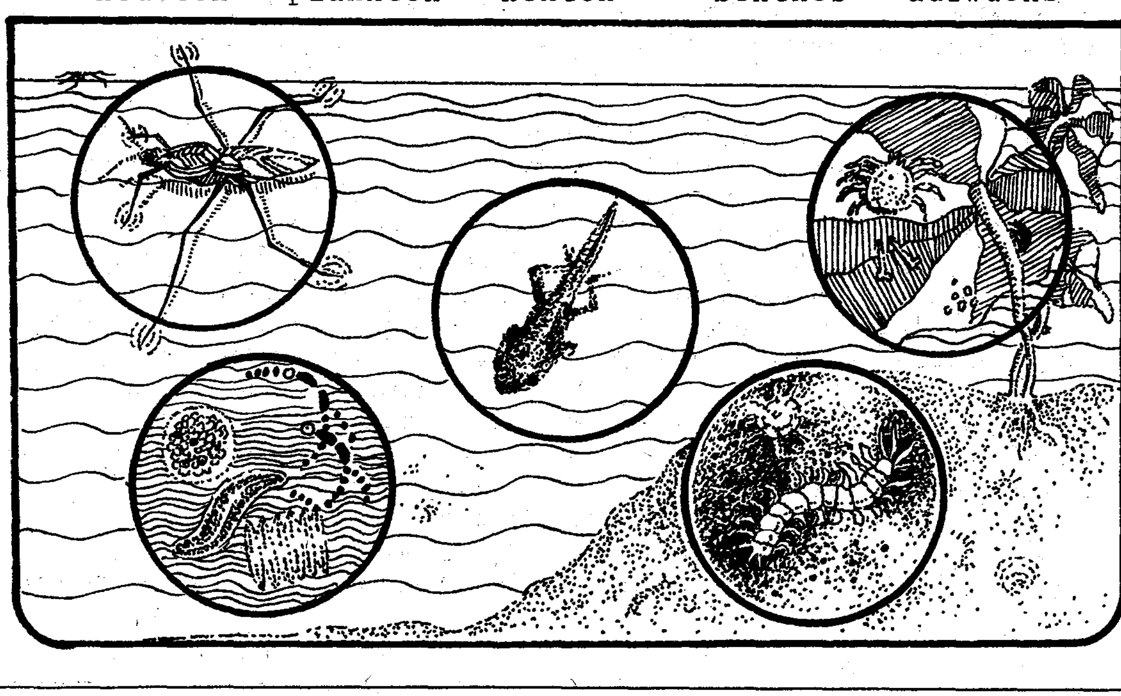
If you work in small fast-flowing streams, you'll have no difficulty with plankton. There won't be any——they keep leaving on the downstream current. There won't be many neuston, either——this water's a bit rough for these little critters. Benthos, like aquatic earthworms, have no chance. Anything that crawls out of the bottom gets a one-way ticket downstream——fast. Rocks you pick up will have dragonfly and damselfly larvae attached, but not permanently——they immediately crawl to the underside of the rocks. You'll see they're able to hang on to tiny crevices. They have flat bodies which they flatten even more against the rock. That way, the current doesn't wash them away. 'Aufwuchs' is a good place for them because they don't really fit any of the other categories.

Marine biologists have a good time with this group. The reef front where waves break is like a small mountain stream with fast-flowing, splashing water. Aufwuchs living on boat hulls, bridges, pilings and piers are called 'fouling organisms'. Why?

Aufwuchs include the same kinds of organisms as benthos: bacteria, fungi, bluegreen algae, protozoans, green and red algae, mosses, sponges, nematode worms, gastrotrichs, flatworms, bryozoans, and many kinds of aquatic larval stages of insects. Worms aren't so common in this group. Some vertebrates, for example salamanders, are part of the aufwuchs.

A freshwater biologist looks at organisms according to their residence. An ecologist looks at them as they relate to other organisms sharing their general system. Now, the name ecologist comes from two word parts: 'eco' which means 'home'——and our old buddy 'logy', which still means 'study of'. You probably know that a house isn't the same as a home. A house is merely a place to be (like the freshwater biology way of looking at things). A home is the people in the place, and the way they are with one another. So, an ecologist looks at more than just houses——he looks at living things in their homes. The term for these living arrangements is 'symbiosis'. 'Sym' means 'together' and 'bios' means 'life' or 'living'.

neuston   plankton   nekton   benthos   aufwuchs



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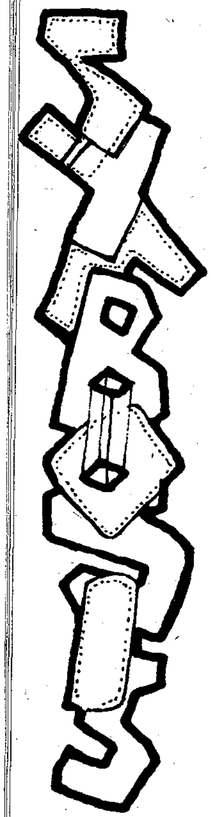
Symbiosis



Any 2 species relate to each other in 1 of 8 ways. This chart shows how.

Symbiotic Relationship	Species #1	Species #2	Examples
Neutralism	0	0	
Amensalism	0	–	
Parasitism	+	–	
Predation	+	–	
Competition	–	–	
Commensalism	0	+	
Protocooperation	+	+	
Mutualism	+	+	

The +, 0, - symbols show how one organism is affected by another. '+' means that the relationship is beneficial (helpful); '0' indicates that the organism is not affected; and '-' shows that the effects are harmful. The 'example' column was deliberately left blank, for you in your notebook.

Activity: Symbiosis

Make a table like this one in your notebook, using Guam examples from this book. Or come up with your own examples, based on your observations and reading.

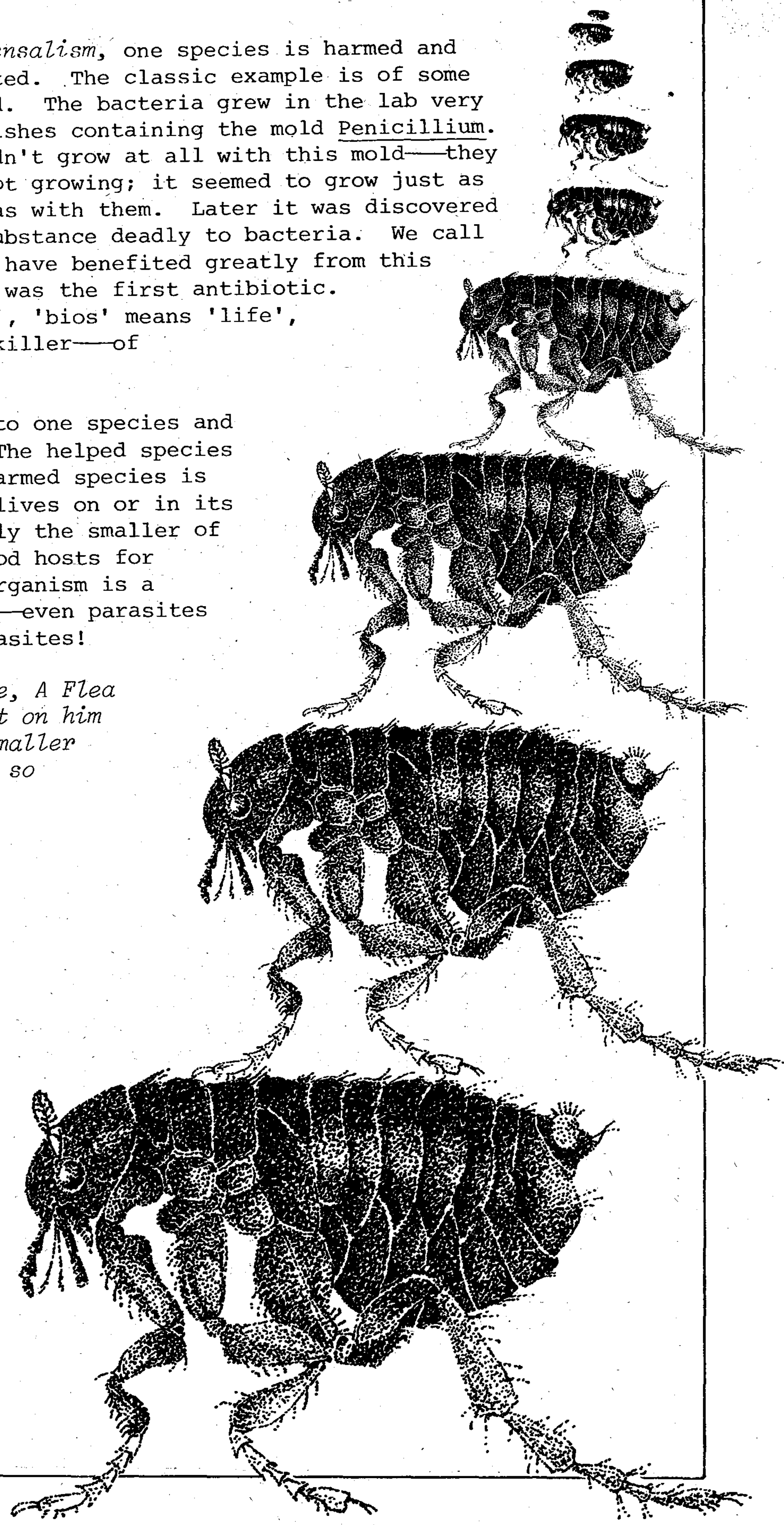
In the natural world, the relationship *neutralism* may not exist. It is hard to believe that two organisms living in the same area are not affected at all by each other—but it might be possible. An aquatic, benthic worm and an aquatic snail may show neutral behavior toward each other. Suppose that the snail crawls off some plant which it has just been eating. It heads across the bottom of the pond to look for another likely meal. Beneath the snail, in the mud, is the worm, munching away at the mud and dead materials. The snail reaches another plant and crawls up—the worm goes on eating. They were in the same area; they didn't try to eat each other; the worm didn't want to eat the live plant and the snail wasn't interested in chomping down on the mud; they didn't get in each other's way. Perhaps this is an example of neutralism, but it's a hard relationship to think of. Maybe you can think of a better example!

In the relationship *amensalism*, one species is harmed and the other is not affected. The classic example is of some lab bacteria and a mold. The bacteria grew in the lab very well except in petri dishes containing the mold Penicillium. The bacteria just couldn't grow at all with this mold——they all died. The mold kept growing; it seemed to grow just as fast without bacteria as with them. Later it was discovered that the mold made a substance deadly to bacteria. We call it penicillin. Humans have benefited greatly from this discovery. Penicillin was the first antibiotic. ('Anti' means 'against', 'bios' means 'life', so an antibiotic is a killer——of bacterial life!)

Parasitism is harmful to one species and helpful for another. The helped species is the parasite; the harmed species is the host. A parasite lives on or in its host, so it is generally the smaller of the two. Dogs make good hosts for fleas. Almost every organism is a host to some parasite——even parasites are hosts to other parasites!

So, Nat'ralists observe, A Flea
Hath smaller Fleas that on him
prey; And these have smaller
fleas to bite 'em, And so
proceed ad infinitum.
- Swift

One important thing about parasitism ——the best-adapted parasites harm their hosts, but don't generally kill them. Why is that a good idea?



The *predation* relationship also helps one species and harms another. The helped one is the predator, the harmed species is the prey. The predator is generally larger than the prey, and the prey is killed. In Nature, the predator of one relationship may very easily become the prey in the next. In a pond, a dragonfly larva may eat a mosquito larva—and then get eaten by a fish!

The relationship of *competition* results in harm for both species. Organisms can compete for space and/or food. If 2 species are so much alike that they compete for exactly the same things, they will both be harmed. Three results are possible from competition in Nature: one or both species will die; one or both species will move out and live in systems that can supply their needs; or one or both species will change their habits. Competition cannot be a long-term relationship.

Commensalism helps one species and doesn't affect the other. A good example is the relationship between cattle and certain birds. In pastures you can sometimes see birds on or around grazing cattle. The cows pull up grass and disturb insects which fly or hop away—into the mouth of a bird waiting for just such an opportunity. The cow is going to graze whether the birds are there or not; the birds don't eat grass, and cows don't eat insects. Thus the cow is unaffected, and the birds are helped. The word 'commensalism' is made of 2 parts that mean 'common table'—the name implies that 2 species eat at the same table—but not the same food!

Protocooperation helps both species involved. 'Proto' means 'primitive' and you know what 'cooperation' means. Generally, the relationship is accidental. In the example of cows and birds, you might imagine a time when insects were scarce in the grass. Birds have been seen to pick ticks and other parasites off cattle—probably because the birds were hungry and insects in short supply. This benefited the cattle, too; they got rid of some parasites. At a better season the birds might go back to catching insects, but for a while the relationship was one of protocooperation.

Mutualism also helps both species. This relationship is thought to be an obligation, and not an accident. The species not only benefit one another, but are essential for each other's well-being and survival. The leech, for example, has certain bacteria living inside its intestine. 'Aha,' you say—'it's a parasite-host relationship!' Well, these bacteria don't seem to be found anywhere but in leeches; if you remove them, they die, and so do the leeches.

And what good are bacteria for the leech? As you know, many leeches are bloodsuckers. Their food is blood. But there's one crazy thing wrong—the leeches don't have any way to digest blood! However, the bacteria do, and leeches thrive on the materials released by their bacteria. A leech without bacteria could eat, but couldn't digest what it ate. It would eventually starve to death. Those particular bacteria can't live outside a leech. For both species, therefore, the relationship is an obligation.

When you go into the field, or read about organisms, keep these relationships in mind. You will find more examples of each kind and increasingly understand how interconnected are all of the World's organisms. ('Todo y nilala y tano manuno'—motto of the Guam Environmental Protection Agency.)

Trophic Levels

Ecologists as well as freshwater biologists use many ways to classify organisms. One of the most useful things to know about a living thing is what it eats, and what eats it. Every organism has to feed to get energy for the rest of its life. We'll now get into classification based on food—energy sources—for organisms. Ecologists use the terms: producer, primary consumer, secondary consumer, tertiary consumer, decomposer.

Producers use simple chemicals, or the energy from sunlight, to make their own food. They are also called autotrophs (auto = self). Producers include all green plants, algae, and bluegreen algae. They manufacture their own food by photosynthesis. In this process, essential for life on Earth, energy in sunlight is captured and stored in roots, stems, leaves, flowers, and seeds. Producers also include those few species of bacteria which take in simple chemicals and convert them into molecules containing energy. This is chemosynthesis.

A *primary consumer* does not make its own food, but eats producers and uses the energy they have stored up. Primary consumers are also called herbivores (herb = plant; vore = to eat). In this group are large grazing animals like cattle and horses, vegetarians (people who eat no meat), and small animals which eat or suck plants—like some insects, snails, and microscopic protozoans and rotifers.

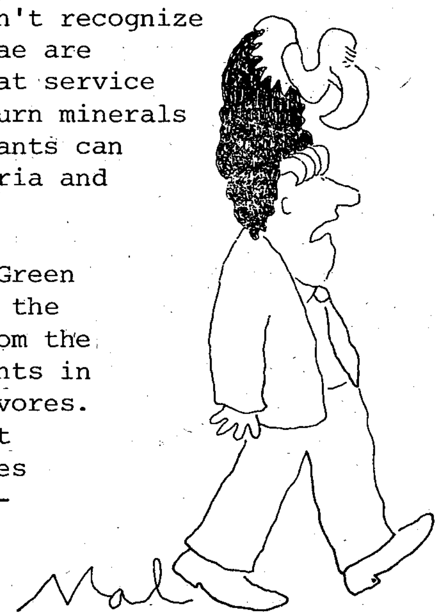
A *secondary consumer* doesn't make its own food, nor does it eat plants. It eats primary consumers. Another name is carnivore (carn = flesh). When you eat steak, you are a secondary consumer. A toad is a secondary consumer when it eats a grasshopper. It's customary to think of carnivores as predators, and of herbivores as prey (the predator-prey relationship we talked about on p 26). For some reason, primary consumers (which eat producers) are not called predators, and green plants (the producers) aren't called prey. Perhaps people think that 'prey' has to be an animal?

A *t*ertiary (third) *c*onsumer is a *t*op *c*arnivore; it is at the top of the heap, it eats other carnivores. Ecologists call these animals the TC's. Creatures like big fish, big cats, and spiders are typical TC's.

You are an omnivore (omni = all). Omnivores aren't particular ——they eat plants and animals (and strange things called TV dinners and cotton candy). Omnivores are pretty well situated: if meat is scarce or too expensive, they can manage quite well with vegetable foods. Many organisms are omnivores, for example, toads, some fish, birds. They don't care so long as it's food!

A *decomposer* gets its nourishment from dead and decaying organic matter: from the bodies of dead plants and animals. All organisms which help break down dead things into small pieces ——even to the molecules they are made of——are decomposers. Most animal-type decomposers are either 'scavengers' or 'detritivores'. A scavenger works on and feeds on dead things that are usually recognizable. (In lots of western movies there are vultures circling ominously——waiting for some man, or cow, or horse, to die in the desert. Dead fishes are eaten by freshwater crayfish. Detritivores eat detritus——material already so broken down you really can't recognize it. Earthworms and many insect larvae are typical detritivores. They do a great service to living creatures because they return minerals and other chemicals to the soil. Plants can then take them up again. Many bacteria and almost all fungi are decomposers.

Food follows an interesting cycle. Green plants absorb certain molecules from the soil and the air, add some energy from the Sun, and feed themselves. These plants in turn feed primary consumers and omnivores. Secondary consumers and omnivores eat the primary consumers. Top carnivores eat the secondary consumers and omnivores. All things that aren't eaten eventually die: decomposers get food from them.



"Shouldn't you be circling ominously?"

2 Omnivores

As they break down plant and animal bodies into smaller and smaller pieces, and finally into molecules, decomposers get their food. Green plants take these molecules from the soil and air, add in some energy from the Sun——and around we go again. Ecologists call this process a <u>food chain</u>, a linking of what eats what and what gets eaten by what. In Nature this chain is usually more complicated than simple because the only thing you can count on is that most plants will be producers. A fish which yesterday played detritivore and ate dead things on the bottom, just may decide that today it's going to eat a couple of mosquito larvae. Today it's a carnivore. A dragonfly larva that today ate 10 worms off the bottom may decide tomorrow to catch a small fish. Instead of simple food chains, Nature usually weaves complicated <u>food webs</u>.

The diagram on the next page shows a fairly simple food web.

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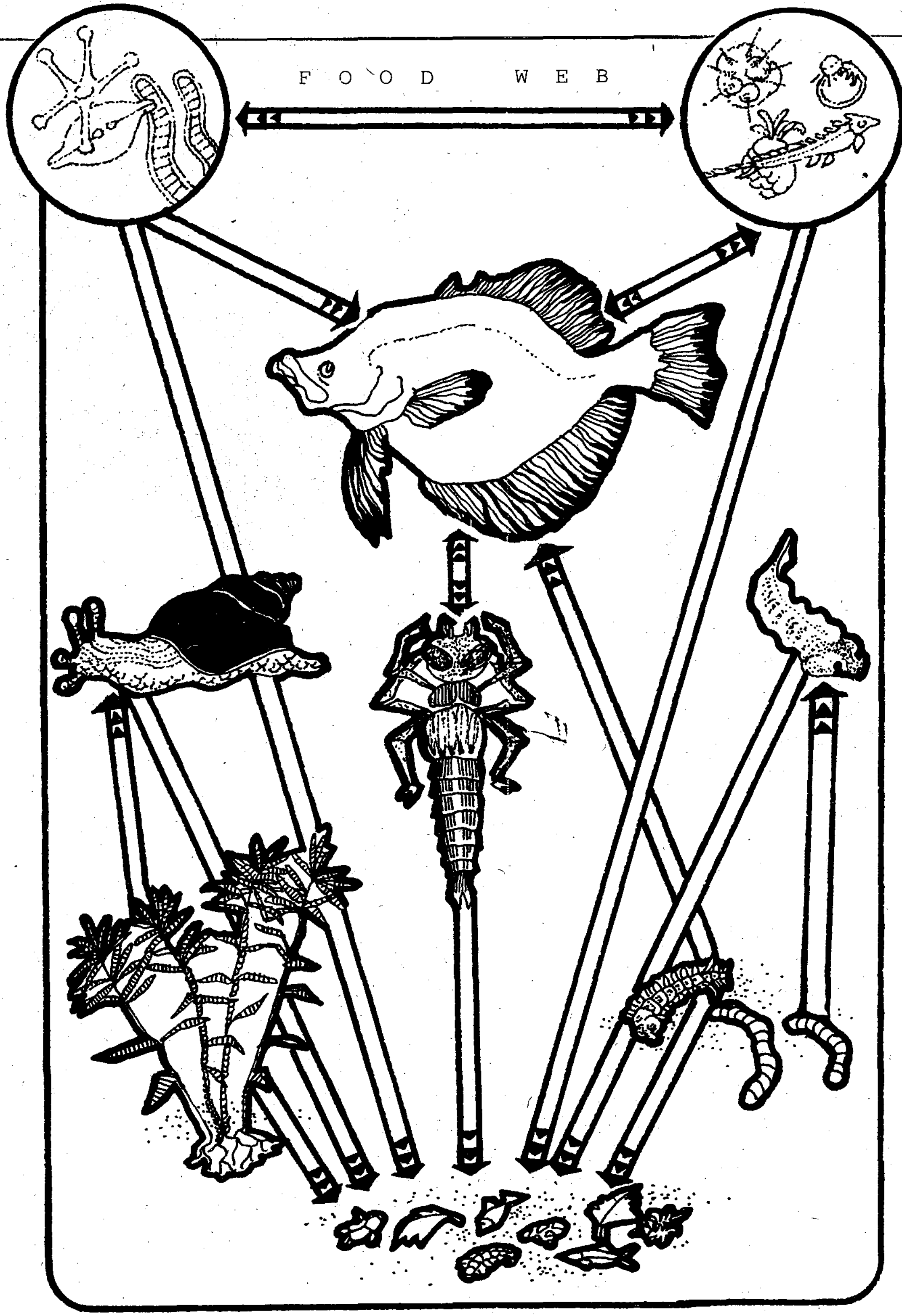


The arrows show what feeds on what, which way the food goes: fish eat plant plankton, but plant plankton don't eat fish.

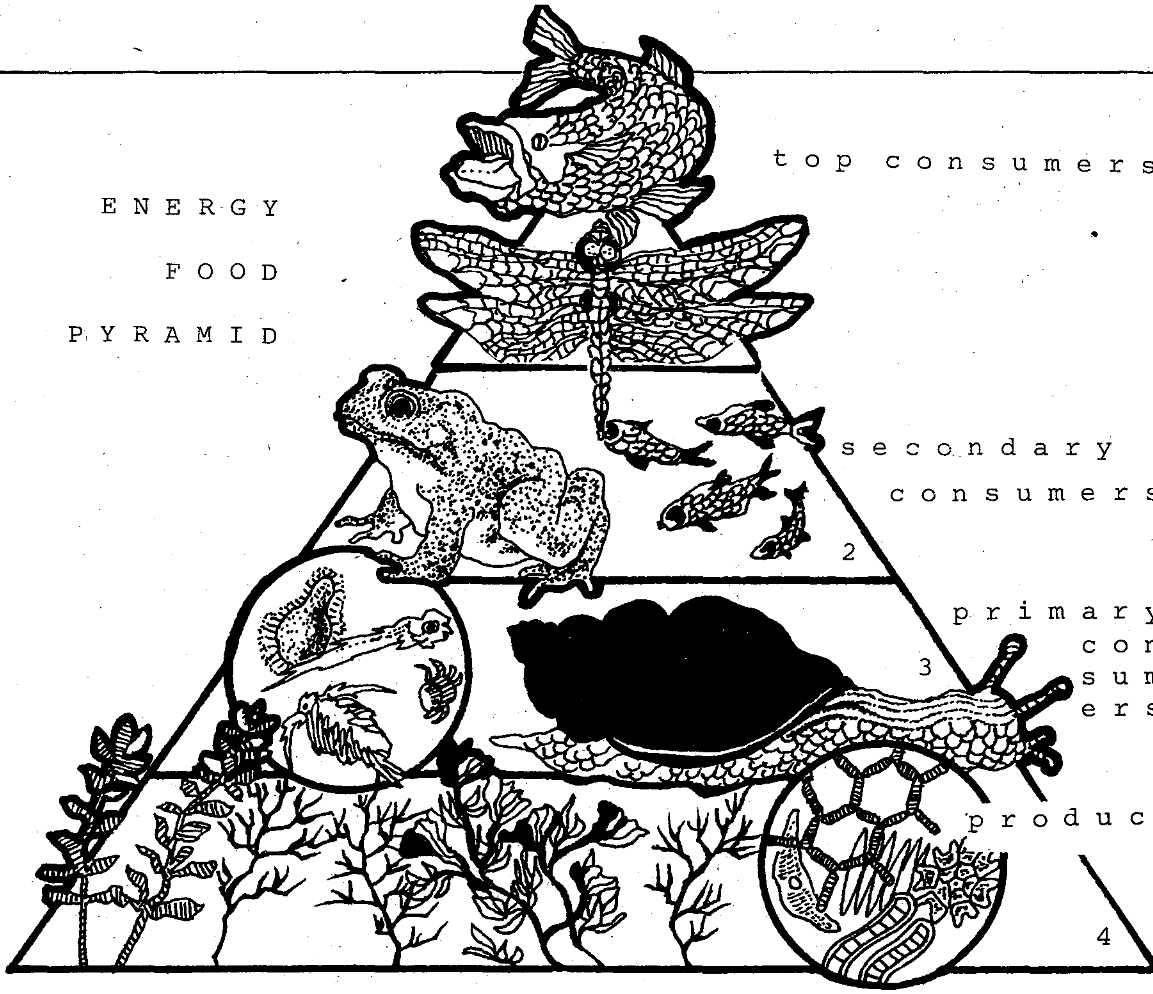
Energy

We've looked at the food and water cycles. Many parts of a natural system go through cycles. Energy, however, which all living things get from food, does not cycle. It isn't used up. It's changed to other forms of energy that can't be used again by organisms. Everything a living thing does takes energy; every time it moves, or grows, or produces flowers or seeds, it uses energy. Some of the energy is used to do work; some is used to make new parts or repair old ones. Some is given off as heat, and some just as random energy. If you're a typical person, some time after breakfast your body tells you it has 'spent' its energy supply. You get hungry for lunch. It's time to deposit a little more energy so you can survive until supper! (The next time you raid the refrigerator for a snack and your mother says 'Do you have to eat all the time?', you can tell her that your energy account is overdrawn and you've got to make a new deposit.)

Some energy does pass from producers to herbivores. Some passes to carnivores and top carnivores, and eventually to the decomposers. It doesn't just cycle back to the producers, who continually must receive energy from sunlight. At each step, the amount of energy available gets smaller and smaller. How much smaller? About 90% smaller, experiments show.

Here's an example: Energy is measured in calories. This is just as specific a measure as meters, or liters. (One thousand calories is a 'kilocalorie', kcal.) If you measured the calories in a field of grass, you might find 10,000 kcal of grass energy available. Now, let's bring in a bunch of grasshoppers—which eat up the whole field. The most energy they could pick up would be 1,000 kcal. 90% of the energy would go to the grasshoppers' moving—and jumping—and chewing—and what they couldn't digest of what they ate, and what's needed just to keep body activities of grasshoppers going. So, 10,000 kcal of grass is needed to produce 1,000 kcal of grasshoppers.

Now, fence in these grasshoppers and toss in some praying mantises. They're good carnivores; but that 1,000 kilocalories of grasshoppers will add only 100 kcal to the bodies of the praying mantises (10% stays, 90% goes). Next, toss a spider or two in with the praying mantises. If you're still with us, you'll expect the spiders to add only 10 kcal from those 100 kcal of praying mantises. And when the spiders die, decomposers will get only 1 kcal from the 10 kilocalories of spiders.



Here's an ENERGY FOOD PYRAMID built from a survey like the one with grass and grasshoppers.

Each block shows the number of kilocalories at each trophic level, as given by the example. Researchers have actually gone into a community and measured the amount of energy in each of the categories of living things. You may not have the equipment for measuring calories, but you can make other kinds of ecological pyramids.

For example, you might go into a community and count the *numbers* of organisms that are producers and in each of the other categories. This would be a lot of work, but if you did it, you could construct a NUMBERS PYRAMID. Usually, you will find fewer top carnivores than secondary consumers; fewer secondary consumers than primary consumers; and more producers than any other category.

Or, you might go into a community and get the *weight* of all the organisms in each category. They should be thoroughly dried before being weighed. (Why?) This would also be a lot of work, but at the end you would have a BIOMASS PYRAMID. In this case, biomass means the actual weight of what was living material, with the water removed.

When ecologists collect data to diagram such pyramids, they don't take every living thing in a community. That would ruin the community, and be too much work. Instead, they take a sample of small size—say, one meter square—and work with that. (You'll find out about special sampling techniques later on in this book). Sampling in this way means that you measure the standing crop of an area—the organisms there when you took the sample. In some places ecologists take samples several times during the year. At different times, the organisms will probably be different.

Major and Minor Communities

In major communities, able to feed themselves, pyramids like the ones we're discussing are usual. Major communities have their own producer organisms—enough plants to provide starting energy for the community. This kind of pyramid is based on an autotrophic food chain, one that starts with green plants as producers.

Minor communities can't feed themselves. They don't have the same kind of pyramid. Producers aren't present, or if so, only in small quantities. The only way a minor community can support its organisms is to get food from nearby communities. In a minor community, organisms at the bottom of the pyramid are not producers. They are detritivores (or scavengers, or decomposers). They use dead and decaying materials. These materials include leaves and plant and animal remains that wash in, fall in, or are carried by some other means to the community. This arrangement supports a heterotrophic food chain. The general term heterotroph (hetero = other) covers all kinds of consumers. You can figure out very quickly whether a community is a major or a minor one. Just note whether there are a lot of producers or very few.

We've seen that freshwater biologists and ecologists look at a living community differently. Freshwater biologists classify organisms by place of residence. Ecologists classify them by their eating habits and relationships with their community. Taxonomists have another set of ways for classifying. They are interested in how organisms are put together (their structure), and how one group relates to others during evolutionary history. Taxonomists classify organisms according to how they look and who their relatives are.

IV - Taxonomy (taxis - arrangement; nomos - law)

In the old days, long descriptions told how organisms were like other organisms and how they were different. Here's a coconut tree classified: 'A tall woody plant with a bare trunk and leaves clustered at the top of the trunk, bearing flowers and large seeds in a thick shell enclosed by a thick fibrous husk'. That's a pretty tough, long name to have to learn! Karl von Linné (better known as Linnaeus), changed this. He invented a two-name system for plants and animals. In his system, each kind of organism has 2 names——first the genus, then the species. The combination is the scientific name and it's in Latin. The big advantage is that the scientific name of any organism is always the same, in Japan, Russia, Guam, or any place else.

Another part of Linnaeus' plan was to group similar species into categories, and then to group these categories into larger groups. Our system today doesn't have the same categories that Linnaeus thought up, but the basic plan is the same.

The smallest category is the *species*. Members of the same species have offspring which can also produce offspring. We never call an organism by its species name alone; the species name is like a first name: Bertha, Jesus, Vicente, Maria.

Genus is the next larger category. A genus includes one to several species that are a lot alike. The genus and species names together are the organism's scientific name. Thus, a coconut palm is Cocos nucifera. Cocos is the genus, nucifera the species. 'Coconut palm' is the English name, 'niyok' the Chamorro. In other languages the common names will be different, but the scientific name will still be Cocos nucifera.

The next larger category is the *family*. A family consists of one to several genera (plural of 'genus') which have a lot of things in common. For example, the coconut palm is a member of the Palm family——Palmae——like other palms: betelnut, nipa, and oil-nut.

The *order* is the next larger category. An order includes families which share several characteristics. All the Palmae are in the order Monocotyledonae; so are lilies, grasses and orchids.

The next larger category is the *class*. In a class, one to several orders share traits. All Monocotyledonae belong to one class, Angiospermae. This includes all plants that produce flowers and seeds covered by a seed coat.

Phylum is the next larger category. In a phylum are classes with a few basic features in common. All Angiospermae belong to the phylum Pteridophyta, which also includes cycads (fadang) and other cone-bearing plants, and ferns.

The largest category is *kingdom*. A kingdom consists of one or more phyla (plural of phylum) which share a very few, very basic characteristics. To go back to our example, all Pteridophyta are members of the kingdom Plantae:

Kingdom	Plantae	
Phylum	Pteridophyta	
Class	Angiospermae	
Order	Monocotyledonae	
Family	Palmae	
Genus	Cocos	niyok
Species	nucifera	

To remember the groups, just memorize the saying, 'Kids play cards on fine Guam sands'. Or invent one of your own.

Taxonomy, the science of classification, hasn't yet settled down completely. Even the largest categories, kingdoms, are in dispute. Some taxonomists use only 2 kingdoms, others as many as five. In this booklet, we give you 5 kingdoms. In other publications, the number may be different. No way is 'right' or 'wrong'. Any author has very good reasons for the choice he made.

We seldom expect you to classify anything into a category smaller than Class. And we don't say much about groups that don't live in freshwater. This doesn't mean that classification isn't important. It's a specialized field you may not have much time for right now. We hope you will learn enough about it to make your work easier.

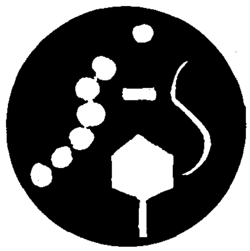
Coming up you will find 2 ways of classification. The classical, textbook way will give you basic information you can add to by looking in biology books.

The other way of classification is to be used in the field and lab, with the organisms in front of you. It's a 2-branched key. We've made 2 of these keys for you (pp 46-49). One is for large organisms. The other is for organisms that need magnifying for you to see.

A key is a way of eliminating characteristics one by one, until you find out which organism you're looking at. On this kind of key there are always 2 choices. The organisms you have will go to one branch or the other. Your teacher can help you work with the key (when you have organisms to look at).

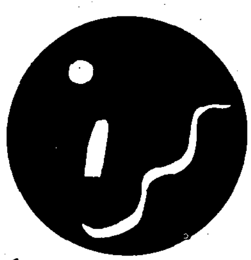
CLASSICAL TAXONOMY

KINGDOM Monera



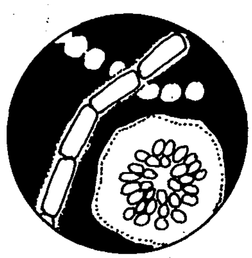
Small organisms. Most can be seen only if magnified. They have no internal membranes; the only membrane is the cell wall membrane. Because of it, you cannot see a nucleus inside the cell. Nuclear stuff——chromosomes and DNA——is there, but not wrapped in a neat package by a nuclear membrane. Also, mitosis (cell division) is an unorganized process in Monera, though in other kingdoms it is very orderly. Monera include viruses, rickettsiae, bacteria, and bluegreen algae. The first 2 are so small you can't see them with a standard microscope. The last 2 groups are in 2 separate phyla: Schizomycetes and Cyanophyta.

Phylum Schizomycetes



Bacteria. Monera without chlorophyll. They don't produce food by photosynthesis, although they may do it by chemosynthesis. Round bacteria are cocci (singular: coccus). For example, Staphylococcus; a common type here causes 'Guam sores'. Square or rectanglar bacteria are bacilli (singular: bacillus). Spiral-shaped ones are spirilla (singular: spirillum). Spirilla will be easiest for you to see in water samples. They are very active, and swim or twist. All bacteria are very small. You can see colonies of millions of bacteria together, but you need a lot of magnification to see single ones.

Phylum Cyanophyta



Bluegreen algae. Monera with chlorophyll. They produce their own food by photosynthesis. They grow everywhere, not just in freshwater. Some on Guam make the black or gray streaks on buildings where water comes down. Nostoc lives along road edges and in grass. It has a jelly coat, and absorbs rainwater. Many of us have slipped on it. Bluegreen algae are usually in colonies, with cells forming chains. Sometimes they are hard to tell apart from other algae. If you remember that Cyanophyta cells don't have nuclei, it'll be easy. To see cells, though, you need magnification.

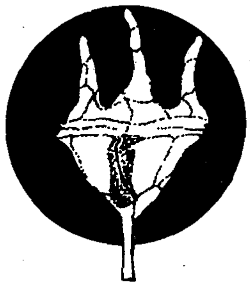
KINGDOM Protista

Lots of organisms are in this kingdom. They are grouped together because of small size, more than anything else. Many are plant-like and are called algae. Others are more like animals and are called protozoans. Protozoans are usually one-celled, but many algae form colonies which may be round or thread-like. All Protista have internal membranes, and you can see structures inside the cells——including a nucleus. Most are small and need to be magnified to be seen. However, they are not so small as the bacteria, viruses and bluegreen algae.

Phylum Chrysophyta

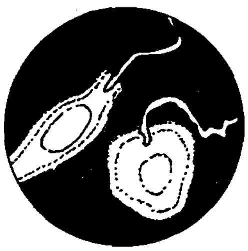
Diatoms, also known as goldenbrown algae. They are everywhere in water. In the open ocean they are the major producer organisms. Each cell has a clear cell wall around it, and this usually has fine lines in it. Each of these cell walls is in 2 parts ('di' of diatom means 2). Each cell is photosynthetic, and has chlorophyll. It also has other pigments which make the diatom look goldenbrown. Also, many diatoms move, looking like tiny boats gliding through the water.

Phylum Pyrrophyta



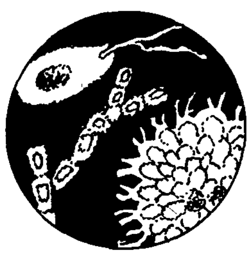
Dinoflagellates (dino = armored; flagellate = whip-bearer). They are single-celled algae which build themselves a 'shell' of clear plates. They usually have 2 flagella, one around the middle, and one hanging down. They are very common in the open ocean, and also inside animals like corals and giant clams. In fact, the colors of live corals are made by dinoflagellates. Dinoflagellates living inside other animals are called zooxanthellae (see in LOG unit <u>Coral Reef</u>). Many are in freshwater, too—but living free in the water. These are algae, and they photosynthesize, but they don't usually look green. This is because they also have other pigments in addition to chlorophyll.

Phylum Euglenophyta



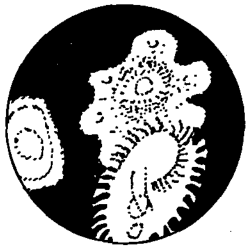
There is no common name. It's a small phylum, with just a few species. All are single cells. All have a flagellum or two. Some have chlorophyll, and some don't. All require an extra source of food, even those that photosynthesize. The cell doesn't have a rigid wall, and can change shape as the organism moves. Green ones look like green algae.

Phylum Chlorophyta



Green algae, a large and highly varied group. Some are single-celled, some are colonies of many cells. The colonies can be round, or in long strings. Many colonies are large enough to be seen easily. You do need magnification to see individual cells. All have chlorophyll and look green although other colors may be present. Some green algae have flagella. In freshwater, some are planktonic and others are aufwuchs.

Phylum Protozoa



Usually single-celled and animal-like (proto = primitive; zoa = animals). None have chlorophyll. Most move (but so do some algal protists with flagella). Protozoans are in 4 classes, not all of them living in freshwater.

Class Flagellata

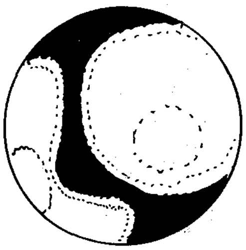
These have flagella, whip-like threads, usually one per cell. Some freshwater ones are in the phylum Pyrrophyta, some in Euglenophyta, and some in Chlorophyta. As you can see, there is a lot of confusion about this group! There are some animal-type flagellates—like trypanosomes, which cause sleeping sickness. They are not typically freshwater organisms.

Class Sarcodina

Move by flowing; they have flexible cell membranes and usually no flagella or cilia. Their flowing projections are pseudopods (pseudo = false; pod = foot). Some make shells with holes in them. To move, they stick their pseudopods out through the holes. Smarter ones like amoebas don't make shells. They just stick out their pseudopods without having to find holes to go through.

Class Sporozoa

All Sporozoans are parasites. They don't move much. They don't live in freshwater, but they're inside freshwater organisms.



Class Ciliata

Ciliates move with cilia, which look like many very short hairs. Ciliates are usually single-celled, and are very common in freshwater. In addition to cilia, they have 2 nuclei in each cell. Most are carnivores and have large mouths. They are so complicated inside that it's hard to believe they're single-celled.

KINGDOM Fungi

There are lots of fungi, including mushrooms, molds, rusts, mildews, and yeasts. Yeasts are single-celled, but most of the others are many-celled. Fungi are usually saprophytes or decomposers; they eat decaying and dead organic matter. None are photosynthetic, but many have pigments and are brightly colored. There are some parasites in the kingdom, but they're not common in freshwater. There are 2 classes of fungi; the Myxomycophyta and the Eumycophyta.

Class Myxomycophyta

These are the 'slime molds' (myxo = slime, myco = fungus-mold; phyto = plant). They look like large, colored amoebas. They are not common in freshwater, but are often seen on damp logs and leaves in shady woods.

Class Eumycophyta

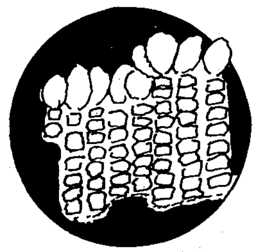
Bracket fungi and mushrooms, the true fungi (eu = true). The obvious part of mushrooms is in the open, but the main body of true fungi are mycelia (white threads) growing inside wood and under dead leaves. The mushroom you see is the part that reproduces sexually. Sexual reproduction happens only at certain times of the year. Mycelia live year-round. Fungi reproduce by budding, a kind of mitosis, and also produce spores. The spores fall to the ground and sprout to form mycelia. Many spores are found in freshwater. A spore is single-celled with a heavy black or brown wall. There are many water molds, fungi which don't produce a mushroom. They have thousands of mycelia which can also form spores. Some water fungi are parasitic. They infect fish with those white patches: These are clumps of fungal mycelia. Water fungi are very common, but you will need to magnify them to see them.

KINGDOM Plantae

These are plants. (Many people call all algae and fungi plants, but they can more easily be studied in other categories.) All plants are many-celled; very few are microscopic. All have chlorophyll and produce their own food by photosynthesis. (Some are totally parasitic and are not green, but these are not aquatic plants.)

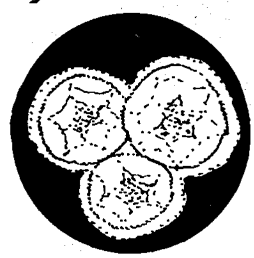
Phylum Phaeophyta

Brown algae. They are large and include Sargassum and the kelps. All brown algae are marine plants.



Phylum Rhodophyta

Red algae. Very complicated, multicellular. This is why they're better identified as plants, and not as protists. They are common in the ocean but rare in freshwaters of Guam.



Phylum Bryophyta

Mosses, liverworts and hornworts. Their life cycle has 3 stages. The gametophyte stage produces gametes (egg cells and sperm cells). In this phylum, the sporophyte stage is a sort of parasite on the gametophyte stage.

Class Musci

These are the mosses. Some are aquatic, but most grow in shaded, wet terrestrial habitats. Most have root-like structures for attaching the plant to the ground, logs, tree trunks, etc. Tiny leaf-like parts are carried on a short stem. The sporophyte is usually a brown stalk topped with a pointed brown capsule which holds spores.

Class Hepaticae

Liverworts. Most are aquatic, or grow in wet places along ponds and streams. The gametophyte grows flat on the ground, and looks like a small green piece of liver. The sporophyte stage looks like a little umbrella. It grows on top of the gametophyte. Spores are carried under the umbrella part.

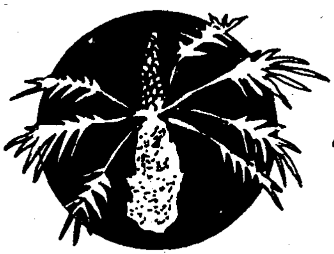
Phylum Pteridophyta

Plants of this phylum include all the higher, more complicated plants. All produce embryos and have true roots, stems and leaves.

Class Filicinae

Ferns. Most ferns are terrestrial, but some are aquatic. One species may be found floating in Agana Springs. Ferns do not produce flowers. On the bottom side of the fronds (leaves), they produce spores in clusters called 'sori'.

Class Gymnospermae



Cone-bearers. On Guam, there are native gymnosperms, fadang (Cycas circinalis), and introduced species like Norfolk Island pine (Araucaria). Cone-bearing trees like pines, firs, cypress and spruce are gymnosperms, but aren't native here. There are no aquatic gymnosperms.

Class Angiospermae

Flowering plants——lots of them live in freshwater. All produce flowers. Some root in the bottom mud, like kinds of taro, and grasses, sedges and rushes, even water lilies. Some stay mostly underwater——like Hydrilla. Others float on the surface——like water hyacinth (Eichornia) and water lettuce (Pistia). On Guam, nipa palms (Nypa) and mangroves (mangle, Rhizophora) are aquatic, but prefer slightly salty water, not freshwater.

KINGDOM Animalia

Two very large kingdoms are plants and animals. All animals have many cells, they are multi-cellular. No animal has chlorophyll; therefore no animal is a producer organism. All animals have nerves and muscles. There are several phyla in the animal kingdom. Some are more common in freshwater than others.

Phylum Porifera

Sponges. These are very simple animals, and very common in marine waters. Only one group of sponges——the one with skeletons made of fibers, is found in freshwater, but not in freshwaters of Guam.

Phylum Cnidaria

Hydras, jellyfish, corals, sea anemones, and sea fans. The ocean has a wonderful variety of these animals; freshwater almost none, but not quite——a few small jellyfish of one species have been found in Fena Lake.

Phylum Ctenophora

Comb jellies. They look like long jelly-fish with 2 tentacles. They're common where freshwaters and saltwaters mix, in 'brackish' water.

Phylum Platyhelminthes

Flatworms (platy = flat; helminth = worm). Three classes—2 of them completely parasitic. The class Trematoda consists of flukes—flatworms that live in the intestine, liver, or blood of other organisms. Tapeworms are in class Cestoda, long chains of sections living in the intestines of other organisms. They're not usually called 'freshwater organisms'. The third class of this phylum is Turbellaria. They are common in fresh and salt waters. They're small and very flat, with a mouth opening on the ventral side (belly) of the body. Most have eyespots and turn away from light. They're under rocks and leaves and other kinds of vegetation. Flatworms are typically carnivorous.

Phylum Aschelminthes

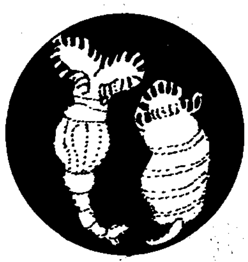
This is a large mixed-up group, so let's look at the separate classes in it:

Nematodes
Rotifers
Gastrotrichs
Nematomorphs

Class Nematoda

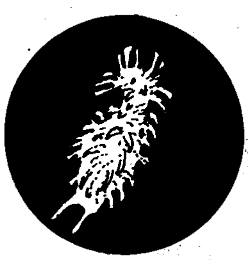
Roundworms. All nematodes look alike; they're skinny, whitish, round, and taper at the ends. Nature gave them but one set of muscles (see Annelida, next page). Live nematodes thrash from side to side when they move. They are free-living and parasitic, and common in freshwater and soil. Some, especially those in freshwater, are very small, and need magnification to be seen. Pinworms, heartworms and ascarid worms are parasitic nematodes.

Class Rotifera



Rotifera, 'wheel animals' (roti = wheel; fera = to bear). The 'wheel' is a row of cilia around the mouth. When these cilia move, they make a current of water that either brings food into the mouth or helps the animal move. Rotifers have both sets of muscles (again see Annelida, next page), and can also creep along the bottom. They are common in freshwater, but are small and need to be magnified to be seen. They are plentiful in stagnant water—water that has stood in one place for a while.

Class Gastrotricha



There's no common name for Gastrotrichs. They're so small, most people aren't even aware of them. It's easy to confuse them with ciliated protozoans, because both are about the same size and live in many of the same places. The name means 'stomach hairs'. The animals have bristles all over their bodies. Unlike protozoans, gastrotrichs are many-celled and have muscles. They are found in freshwater, and have been seen on Guam, but are not common.

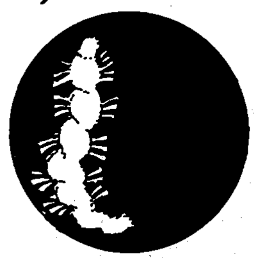
Class Nematomorpha

Horsehair worms. Adults look like very long, very thin nematodes; the young stages are parasites inside insects. So far, they have not been reported on Guam, but the adults live in freshwater in other places.

Phylum Nemertea

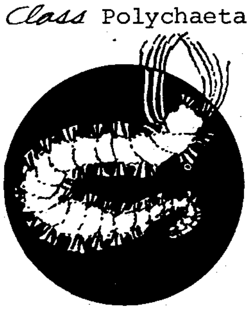
Ribbon worms. They're long, flat and marine. We haven't yet found any freshwater nemertines on Guam (and we've been looking pretty hard!).

Phylum Annelida



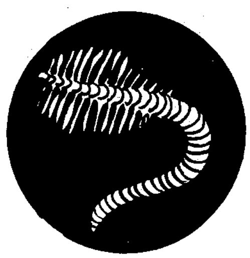
Annelida are the segmented worms, including everybody's friend, the earthworm. The body looks like a stack of rings. There are 2 sets of muscles: long and circular. The long ones go from one end of the body to the other. When they do what muscles do——contract, shorten and thicken——it makes the worm get shorter. Circular muscles contract and squeeze the rest of the body out long. Circular and long muscles work in turns. See how worms can move? Annelids come in 3 classes: Polychaeta, Oligochaeta, and Hirudinea.

Class Polychaeta



These have many bristles (poly = many; chaeta = bristles). Almost all are marine, and are common around Guam——not in our freshwaters.

Class Oligochaeta



Worms with a few bristles (oligo = few). Earthworms are the best known. There are many aquatic 'earthworms'. Many aquatic insect larvae look like oligochaetes but don't have bristles and do have leg stumps near the head. Aquatic oligochaetes do <u>not</u> have leg stumps.

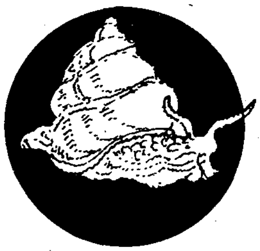
Class Hirudinea

Short, thick bodies. No bristles, but suckers to attach to other creatures and plants. Leeches are aquatic, but there are none reported from Guam.

Phylum Mollusca

Soft-bodied, but usually identified as animals with shells. Many don't have shells. Each has a body layer, the mantle. The mantle makes the shell if it is called for. This phylum has 6 classes, varied and large. A few terrestrial, more freshwater, and many marine species. Some gastropods and pelecypods live in freshwater.

Class Gastropoda



Snails and slugs. If there is a shell, it is usually in one part or coiled. All gastropods have a head with 1 or 2 pairs of tentacles. Snails are common herbivores in freshwater, and often are on aquatic plants or algae-covered rocks. All the freshwater snails on Guam have shells and are easy to identify.

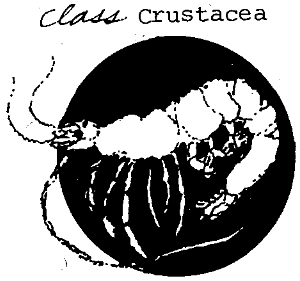
Class Pelecypoda

Clams and mussels (pelecy = hatchet; pod = foot). No freshwater mussels have been reported from Guam, but many marine kinds live on the reefs around the Island.

Phylum Arthropoda

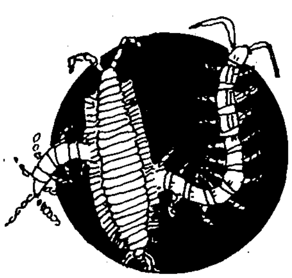
The largest phylum in the animal kingdom. Arthropods have external skeletons and jointed appendages (legs, arms, and antennae = feelers). They live everywhere and are man's toughest competitors.

Class Crustacea



Crayfish, lobsters, shrimp, crabs, etc. Almost all crustaceans live in water. They have 5 or more pairs of legs, and 2 pairs of antennae. Some have an external skeleton that looks like a clamshell, but the jointed legs that stick out tell you you have a crustacean. Most of you have seen freshwater shrimp. Dozens of species are microscopic. Most animal-type plankton (zooplankton) are crustaceans. Many crustaceans are benthic. The juvenile stages may not look like the adults they will grow up to be, but they also have jointed appendages.

Class Myriapoda

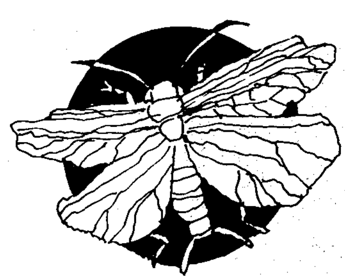


Millipedes and centipedes. These live on Guam, but are not aquatic.

Class Insecta

The largest class in the animal kingdom; we know over 1 million species! Insects have 3 pairs of legs or leg stumps, one pair of antennae, and wings or wing buds. They're usually terrestrial, but some are aquatic. Many have aquatic larval stages. There are about 26 orders of insects. We'll look only at 6 that live in aquatic habitats.

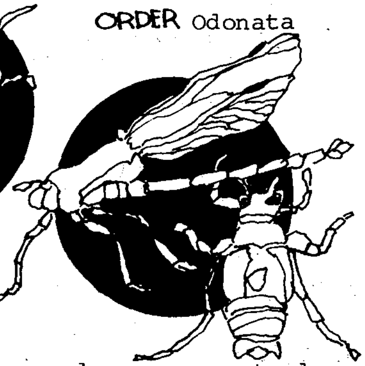
ORDER Plecoptera



Stoneflies. Only the larvae are aquatic. Adults fly, mate and then lay eggs in the water. Stoneflies are characteristic of cold water streams, and have not been reported from Guam.

ORDER Ephemeroptera — Mayflies. Like stoneflies because only the larvae are aquatic. They also live in cold water, and have not been seen in Guam.

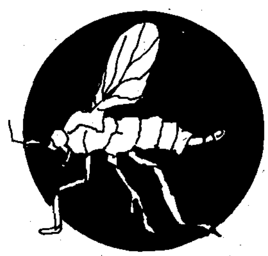
ORDER Odonata — Dragonflies and damselflies. They have aquatic larvae, and the adults fly over freshwater. Dragonflies have 2 sets of wings which they hold out sideways from the body. Their larvae are fat and rounded with no tails. The larvae have huge, shovel-shaped mouths. These larvae are carnivorous, and should <u>never</u> be put into collecting bottles with other specimens!



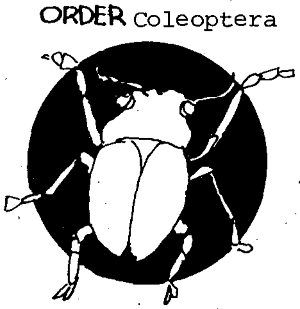
Damselflies have 2 sets of wings which they fold vertically together when feeding. Their larvae are slender with 3 tail projections. These larvae are also carnivores, but take smaller prey than do dragonfly larvae.

ORDER Hemiptera — True bugs. The name means half-wing (hemi = half; ptera = wing). The wings are thick and heavy at the top, and thin and fragile at the end. You can easily identify a hemipteran by the X-pattern of the wings. It is always a wise idea to identify insects of the order, because many of them have mouth parts like hypodermic needles, which can cause considerable pain to the ignorant collector! Aquatic hemipterans are usually the adult stage, not the larvae. Most common on Guam are the water striders, or 'Jesus bugs'. They are neuston, and can be seen in large groups walking on the surface tension.

ORDER Diptera — Flies, gnats, mosquitoes, and those 'giant mosquitoes'—craneflies. The adults are never aquatic, but many dipterans lay their eggs in water and have aquatic larvae and pupae. Dipteran larvae are worm-like, and are usually benthic organisms. If you look carefully, you can see a head with mouth parts, and usually 6 stumpy projections which eventually become legs. Most of you are familiar with mosquito larvae. They wriggle through the water and often hang down from the surface.



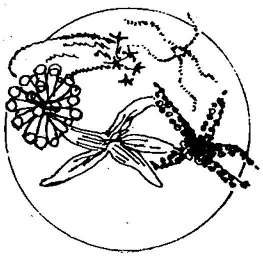
ORDER Coleoptera — Beetles and weevils. Their larvae and pupae are almost never aquatic, but there are aquatic adults. Some skate on the surface tension; others dive underwater for brief periods. All beetles have 2 sets of wings. The outer set is stiff and hard and is lifted up when the underwings are used for flying.



Phylum Ectoprocta (Bryozoa) — Moss animals. They form colonies either in jelly-like masses or as thin crusts on rocks or vegetation. Individual animals of the colony are microscopic, but you can easily see the colony. They're extremely common in marine environments. They also live in freshwater habitats but none of these have so far been reported from Guam.

Phylum Echinodermata

Starfish, sea urchins, sea cucumbers, etc. All echinoderms are marine. They are discussed in the LOG unit Coral Reef.



Phylum Chordata

All vertebrates (animals with backbones) and some small, near-vertebrate marine species. The following classes of this phylum have freshwater species: Osteichthyes, Amphibia, Reptilia, Aves and Mammalia. All these animals are vetebrates; they have jointed internal backbones and jointed appendages.

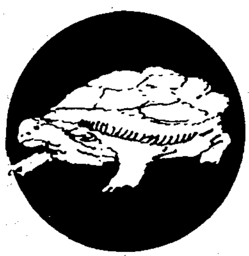
Class Osteichthyes

Osteo = bone; ichthus = fish——plain old fishes, marine and freshwater. Eels, too. Most freshwater species on Guam have been brought here from other places. This includes the commercial eel; the mosquito fish and Tilapia. Aquarium fishes like guppies and goldfish have also been introduced.

Class Amphibia

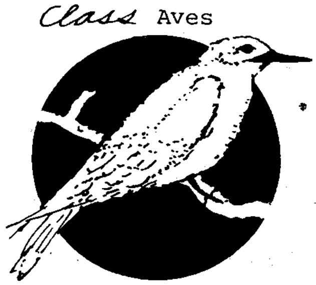
Amphi = both; bios = life. These live first in water, then on land. Amphibian eggs must hatch in a water habitat. There are several orders of amphibia. Only one lives on Guam ——Order Anura, including the frogs and toads. A tree frog was brought into Guam recently, but the toad, Bufo marinus, has been around for many years. The adult can be found in water and on land, but the larval tadpoles live only in water.

Class Reptilia



Crocodiles, alligators, snakes, lizards (e.g. geckoes and monitors), turtles. They breathe air. They live in water or on land, but all lay eggs. Many are aquatic, but only turtles are found in our freshwaters. These have been brought in recently and were probably turned loose by owners who bought them in a pet shop.

Class Aves



Birds. None actually live in the water, but many get their food from the water or float on its surface. Many ocean birds such as reef herons visit freshwaters, and ducks have been seen on lakes in the Marianas. Several small birds nest in the grasses and rushes of Guam swamps and marshes.

Class Mammalia

Mammals have hair and mammary (milk) glands. There are several aquatic mammals, such as the dugong, beaver, otter, water shrew, whale and porpoise. Whales, porpoises, and dugongs have been seen nearby.

Two-Branched Key to 'Large' Organisms

Each number offers 2 choices: a or b. Read BOTH and take your pick! (Don't use this key if your specimen needs magnification to be seen easily.)

1a Organism looks like a plant
- 2a Is not basically green
  - 3a Is a colony of animals, attached and growing together
    - 4a Colony not jelly-like; no skeleton—*Porifera* (sponges)*
    - 4b Colony has lace-like skeleton or is a jelly-like mass—*Ectoprocta* (moss animals)*
  - 3b Looks like a bunch of whitish roots; produces spores—*Fungi*
- 2b Is basically green with parts that look like stems.
  - 5a No true roots though may have root-like parts
    - 6a Body green, long, stem-like—*Chlorophyta* (green algae)
    - 6b Body with stem and parts sticking out like leaves
      - 7a Many short plants growing together, making carpet—*Bryophyta* (mosses)
      - 7b Plants separate, not forming a carpet —*Rhodophyta* (red algae)*
  - 5b True roots; plant is submerged or rooted or floating
    - 8a Makes spores, no flowers or seeds—*Filicinae* (ferns)
    - 8b Makes flowers and seeds—*Angiospermae* (flowering plants)

1b Not like a plant
- 9a Colonial animals, attached and growing together
  - 10a Colony shapeless but not jelly-like; no skeleton —*Porifera* (sponges)*
  - 10b Colony is a lace-like skeleton or is inside a jelly-like mass—*Ectoprocta* (moss animals)*
- 9b Not colonial; animals are separate
  - 11a Hard skeleton
    - 12a Skeleton outside
      - 13a Skeleton and appendages jointed—*Arthropoda*
        - 14a More than 4 pairs of legs—*Crustacea* (crabs, lobsters, crayfish, etc.)
        - 14b 4 pairs of legs or fewer
          - 15a 4 pairs of legs—*Arachnida* (spiders and mites)
          - 15b 3 pairs of legs or leg stumps—*Insecta* (insects)
      - 13b No joints—*Mollusca*
        - 16a Skeleton a one-part shell, may be coiled; —*Gastropoda* (snails)
        - 16b Skeleton 2 shells—*Pelecypoda* (clams, oysters, mussels, etc.)

12b Skeleton mostly or partly internal—*Chordata; Vertebrata*

17a Fins; no legs

18a Mouth a sucking disc—*Cyclostomata* (lamprey)*

18b No sucking disc—*Osteichythyes* (bony fish)

17b Fins lacking or along tail only; legs usually present

19a No scales

20a Mammary glands and hair—*Mammalia* (mammals)*

20b No hair; no mammary glands—*Amphibia*

21a Tail-less; hind legs bigger than front legs—*Anura*

22a Rough skin with 'warty' growths —toads

22b Skin smooth—frogs*

21b Tail; both pairs of legs about equal in young stage

23a Tail disappears as animal grows; legs develop unequally—Anuran tadpoles

23b Life-long tail; legs about equally developed—*Urodela* (salamanders)*

19b Scales on some part of body

24a Scales on feet; feathers—*Aves* (birds)

24b Scales on most of body; no feathers, no wings—*Reptilia*

25a Part of skeleton is a box-like case around the body—*Chelonia* (turtles)

25b Skeleton not partly box-like

26a Legs, scales heavy like armor —*Crocodilia* (alligators)*

26b Legs present or absent; scales light

27a No legs—*Squamata* (snakes)*

27b Legs—*Squamata* (lizards)*

11b No skeleton

28a Animal flat, body not segmented—*Platyhelminthes; Turbellaria* (planarians)

28b Body round and worm-like

29a Unsegmented, moves in a jerky, whip-like way—*Aschelminthes; Nematoda*

29b Animal segmented; movement coordinated—*Annelida* (segmented worms)

30a Sucking mouth parts—*Hirudinea* (leeches)*

30b No sucking mouth parts—*Oligochaeta* (earthworms), including aquatic ones)

*These may be found here—but not in natural freshwaters.

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Two-Branched Key to 'Small' Organisms

Each number offers 2 choices: a or b. Read BOTH and take your pick! Use this key if you need to magnify the critter to see it easily:

- 1a Independent, single cells, though they may be clumped in groups.
  - 2a Cell inside a heavy wall that you can't see through; see Note, opposite.
  - 2b Cell not inside a thick wall
    - 3a Cell moves itself (make certain it is moving, not just drifting)
      - 4a Cell very small; no insides visible
        - 5a Cell (or group of cells) greenish—*Cyanophyta* (bluegreen algae)
        - 5b Cell (or group of cells) not green—*Schizomycetes* (bacteria)
          - 6a Cell spiral—spirillus-type bacterium
          - 6b Cell not spiral
            - 7a Cell round—coccus-type bacterium
            - 7b Cell box-shaped—bacillus-type bacterium
      - 4b Cell larger; some insides visible
        - 8a Cell with special movement structures; cilia (lots of short hairs), flagellum, (one longer hair), pseudopods (foot-like part), etc.
          - 9a Cell with pseudopods (it oozes as it moves) —*Sarcodina*, amoebas
          - 9b Cell without pseudopods
            - 10a Cell with cilia—*Ciliata* (e.g. Paramecium)
            - 10b Cell with flagella (long hairs)
              - 11a Cell green
                - 12a Cell small; 1 flagellum; definitely changes shape—*Euglenophyta* (Euglena)
                - 12b Cell with 1 or more flagella, stays rigid —*Chlorophyta* (green algae)
              - 11b Cell not green
                - 13a Cell reddish, 2 flagella, 1 at end, 1 around the middle—*Pyrrophyta* (dinoflagellates)
                - 13b Cell colorless, relatively clear
                  - 14a Cell changes shape—*Euglenophyta* (Peranema-type)
                  - 14b Cell more rigid—*Pyrrophyta* (dinoflagellates)
        - 8b Cell without moving parts; lines on cell wall —*Chrysophyta* (diatoms)
    - 3b Cell not self-moving (but may drift; check carefully)
      - 15a Cell very small; no visible insides
        - 16a Cell (or group of cells) greenish—*Cyanophyta* (bluegreen algae)
        - 16b Cell (or group of cells) not green—*Schizomycetes* (bacteria)
          - 17a Cell round—coccus-type bacterium
          - 17b Cell box-shaped—bacillus-type bacterium

15b Cell larger; some insides visible
18a Cell in a case or shell
19a Case or shell with many holes or points—*Sarcodina* (shelled amoebas)
19b No holes or points; cilia on organism—*Ciliata*
18b Cell wall clear; no case, organism is a diatom and dead

1b Organism seems to have many cells
20a Cells very small; no visible insides
21a Organism green or bluegreen, probably with jelly-like coat—*Cyanophyta* (bluegreen algae)
21b Organism not green; cells in groups or chains —*Schizomycetes* (bacteria)
20b Cells larger with some insides visible
22a Organism colored; cells similar; colonial
23a Organism green, round or string-shaped—*Chlorophyta* (green algae)
23b Organism tan; cell walls with fine lines —*Chrysophyta* (diatoms)
22b Organism not colored
24a Like a mass of threads—*Fungi*
24b Not thread-like
25a Organism apparently not made in equal sections
26a Organism self-moving; not attached
27a Movement by cilia
28a Cilia on the ventral (belly) surface
29a Organism clear; mouth at head end —*Gastrotricha*
29b Some pigment present; mouth ventral —*Platyhelminthes* (flatworms)
28b Cilia around mouth—*Rotifera* (wheel animals)
27b No cilia, movement thrashing, apparently uncoordinated—*Nematoda*
26b Organisms attached and in colonies —*Ectoprocta* (moss animals)*
25b Organism segmented in more or less equal sections
30a Colonial; tentacles around mouth —*Ectoprocta* (moss animals)*
30b Organisms separate (not colonial); no tentacles
31a Like worms
32a Legs jointed or with leg-stumps —*Insecta* (larval stages)
32b Stiff bristles; no legs or leg-stumps —*Annelida* (worms)
31b Not like worms
33a 3 pairs of legs—*Insecta*
33b More or fewer than 3 pairs of legs —*Crustacea*

Note: Many organisms make special cells with heavy walls: flowering plants—*pollen;* ferns, mosses and fungi—*spores;* and some others —*eggs*. It may be difficult to tell these special cells apart.

*May be found on Guam but not in freshwater.

V - Abiotic Factors

The organisms in a natural system are only part of the story. The other part is non-living, abiotic (a = not; bios = living). Abiotic factors directly and indirectly affect organisms in the system. Some abiotic factors have already been discussed. Let's mention them again:

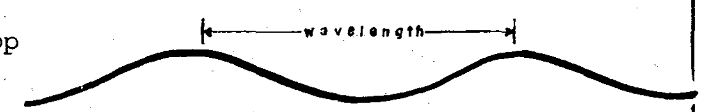
- light
- temperature
- precipitation: rain, snow, humidity, etc.
- currents and pressures
- gases
- minerals, particularly trace elements
- topography
- fire

They vary in importance, depending on the system they're in.

Light in natural systems on Earth is one of the many forms of energy produced by our nearest star, the Sun. It can be considered from 3 points of view: 1) the quality of the light (its wavelength), 2) its quantity (the amount of energy provided, measured in calories, foot candles, or lumens), and 3) its periodicity (its duration: how long it lasts each day, or each season). The periodicity of light is easiest to measure; you can always find the time of sunrise and sunset from the newspaper, radio, TV, or by calling the weather bureau.

The other measures of light are harder to come by; you have to assume certain things. For instance, you must assume that the Sun's whole range of wavelengths is available on Earth. Now, you need to know what a wavelength is!

Imagine that you are standing at the ocean side of a bay, watching the waves, or the water swells, as they go past. You would see something like this:



The distance between the top of one wave and the top of the next one is one wave length. Surfers know all about 'waiting for the next good one': they measure that length all the time! Light also travels in wavelengths. Not all wavelengths are the same. You probably have watched the ocean and have seen waves come in very fast——while at other times, the times between waves is longer.

In example A, the wavelength is long; in C it is short. B shows a wavelength that's in between. The neat thing is that you can think of wave 'lengths' as related either to distance or to time. In example C, there is not only a short distance between the waves, but also a short time. Measuring wavelengths gives you 'frequency'. The waves of C have high frequency—they come more frequently. The waves of A have low frequency—they don't come so often! Musicians know about frequency: When you tune a guitar, or any other stringed instrument, you're really playing around with the frequency of the strings' vibration. Bass strings have low frequency; they don't vibrate so often. The high sounds have higher frequency, and the strings vibrate faster.

But you don't hear light wavelengths—you see them. In fact, the wavelengths you see are what we call light. Wavelengths you hear are called sound. There are a lot of wavelengths you don't see or hear, probably a good thing. For example, radio waves, which are very long, and inaudible, travel through the air. They are 'picked up' by gadgets we call radios. Radios turn these wavelengths into sounds we can hear. It would be terrible if your body 'picked up' radio waves—you wouldn't have a moment's peace all day long!

Light comes in wavelengths. Short ones have high frequency and high energy; long ones have low frequency and low energy. The shortest wavelength you can see is violet; the longest you can see is red. The range of colors you can see is called the light spectrum: red-orange-yellow-green-blue-indigo-violet—the colors of a rainbow (ROY G BIV for easy remembering).

Another thing: light can be absorbed, or reflected. Light rays (wavelengths) that are absorbed in a substance are taken up by it. If they aren't absorbed, they get through; or bounce back, they're reflected. If light is absorbed by something you can't see it. If it's reflected, or goes through something, then it will be there for you to see. All the colors of light together are seen as 'white'. If all the colors are absorbed, you don't see any light, and we call this color 'black'.

This causes some crazy things. For example, you see that the leaf of a plant is green. OK—the green wavelength must be reflected—or you wouldn't see it, right? So you can figure that the leaf absorbs all the other wavelengths, and reflects green! A plant may have a red flower. Since you see the red, it must be reflected, and the other colors of light must be absorbed. Now, it's not so very important that the <u>color</u> is absorbed or reflected, but that the wavelengths of light, and the energies that go with those wavelengths, are absorbed or reflected. We said that a plant requires light energy to make its food. So, a leaf must use the energy of violet-indigo blue-yellow-orange and red wavelengths, but not the energy of green.

Many of you are active in sports. What color clothes do you wear to stay as cool as possible in the heat? If you wear black, you're in trouble. Remember, you see black when all light is absorbed, and none is reflected. Black absorbs all the visible light and all the energy that goes with it. And you aren't a plant, so that energy is wasted as heat energy. Obviously, white clothes reflect all light rays (or you wouldn't see them as 'white'). White clothes reflect the energy, too——so you'll stay much cooler. If you have a chance to get a car, or paint one, you might think about it. Do your own test: At the same time, put one hand on the fender of a black car and the other on the fender of a white car. What happens?

So far, we've been talking about light in air. What about light in aquatic habitats? You know that molecules in a liquid are closer together than molecules in a gas. Whatever can move through a gas can move more rapidly through it than through water. Why?——because it doesn't run into as many molecules and doesn't get bumped around as much as in water. Light is no exception. More light is absorbed by more molecules. So, in water, the wavelengths of light that have the most energy penetrate deepest. If you have been diving you know that in deep water, things look bluish. Blue wavelengths are on the short, high energy end of the light spectrum. Red wavelengths don't have much energy: they are absorbed, even in shallow water. If they are absorbed, they can't be reflected. (Ask a diver what color blood is, 10 m down.) Why is the ocean, or a lake, blue?

The amount of light in water habitats is critical (very important). If there isn't enough light, green plants and algae can't make their food. If plants can't live below a certain depth, then herbivores there are in for trouble. Light——the wavelength, the energy, and the duration——has a great effect on living organisms, and especially on aquatic ones.

It's hard to measure light intensity. Weather stations have machines called 'pyrheliometers' to do it. The University has one. You realize that sunlight falling on one place may be absorbed by clouds at another place close by. Also, trees and other objects absorb light. Pocket light meters are, alas, about 50% off——even the best of them! It's unfortunate, but the measurement of light intensity is a real problem.

Temperature is a measure of heat energy. The temperature of the biosphere (the part of Earth where life exists) varies between -60°C and +100°C. Temperature is directly related to the chemical activities (metabolism) inside a cell or an organism. If temperatures get too high——about 40°C (human body temperature = 37°C), reactions get out of control, and the chemicals inside most organisms break down. If the temperature gets too low, reactions occur so slowly that the organism doesn't get enough energy to live. Mammals and birds regulate their body temperatures. They have a built-in thermostat, a temperature-regulating system. Most other animals take on the temperatures of their environments. They can regulate temperature some by changing environments; if it gets too hot, they move into the shade; if it gets too cold, they move around, or into the sunshine.

Precipitation is water from the atmosphere. A water cycle has already been discussed, and you know that all living things need water. When you talk about precipitation, consider 2 things: evaporation and seasonal distribution. Think about a desert. It may receive 25 cm of rain a year—but all that rain may come down in one torrential storm! Also, with no clouds above and plenty of sunlight, a lot of the rain may evaporate before doing desert organisms any good.

On Guam there are 2 seasons. Most of our 150 cm of rain falls between April and November, our rainy season. Enough usually falls during the 'dry' season, however, to keep plants and animals alive—even if the plants do turn brown and lose leaves. Aquatic environments always have water; even so, they lose it by evaporation, and by runoff. It is very important that a water supply exist to replace what is lost.

Currents and pressures develop in air and water. They have force; they mean movement. Air currents can be breezes, or tradewinds, or the tremendous force of typhoons. Water currents develop in a mountain stream, or in a broad river moving slowly between its banks. They can be huge ocean currents like the Kuroshio (Japan) Current which carries tropical water northward. Air pressure is made by gravity pulling the air toward Earth. It is lower on high mountains. Air up there has fewer molecules than at sea level. Divers care about water pressure: it's much greater than air pressure because water has more molecules. They're closer together than air molecules, and exert more force in response to gravity. In freshwater systems where the water isn't deep, currents probably have more influence than pressure.

Gases of the environment are important too. Most species need oxygen which is about 20% of the air. It is also dissolved in the waters of aquatic systems. [NOTE: This oxygen is <u>not</u> the O in the HOH (= H_2O) molecules. Dissolved oxygen in water is the molecule O_2, the same O_2 molecule which makes up 20% of our air.] Oxygen dissolved in water behaves sort of like CO_2 dissolved in soft drinks—the fizz in soft drinks is groups of CO_2 molecules. When most of them escape into the air, the drinks go 'flat'. You can remove dissolved oxygen from water by boiling it. The bubbles you see when boiling begins are groups of oxygen molecules. If you drink boiled water (after it has cooled, of course), it too will probably taste 'flat'.

Once, we said that air was 79% nitrogen, 20% oxygen, 0.4% CO_2, plus tiny amounts of a few other gases. Today, however, air is polluted, not so much here as in other places, but even on Guam it's polluted. We now have sulfur dioxide (SO_2) and nitrous oxide (NO_2) and other sorts of new hazardous gases. These are 'unnatural'. Today's organisms did not evolve with them and may respond to them in strange and unpredictable ways.

Minerals are elements in a more or less solid state, in soil and water. Some are required in very small amounts by organisms and are called 'trace' elements. Iron, for instance, is a trace element in man. The body uses it to make hemoglobin, the stuff in red blood cells that carries oxygen. (That's why the ads mention "Get plenty of iron for tired blood!"——this is rather silly, because your blood isn't 'tired'——it's just low in hemoglobin.) Plants use magnesium to make chlorophyll, needed for photosynthesis. Of course, you haven't yet seen any ads: "Plants! Feel blah? Look pale and yellow, instead of glossy and green? Photosynthesis on the blink? Tsk, tsk! Try our enriched magnesium——good for what ails you! Only $4.95 at greenhouses and tree surgeons everywhere!"

Topography is the mapping of surfaces (topo = surface; graph = draw, write). It shows the physical features of Earth's surface: mountains, rivers, ocean basins. These change over time, and provide either barriers that keep organisms from migrating, or pathways by which they can move to new locations. Look up 'plate tectonics' in the LOG Geology unit, and elsewhere. Ask your teacher about it. Some excellent movies on the subject are available.

Review formation of lakes and rivers, pp 10-19.

Fire is a physical factor extremely important for terrestrial communities, but of limited interest for aquatic habitats (except, of course, for that infamous Ohio river, the Cuyahoga, which caught fire and burned a bridge!). Fire ecology is a new and controversial subject which your teacher can probably discuss with you. (See the Savanna unit in this LOG series.)

VI - Equipment and Methods

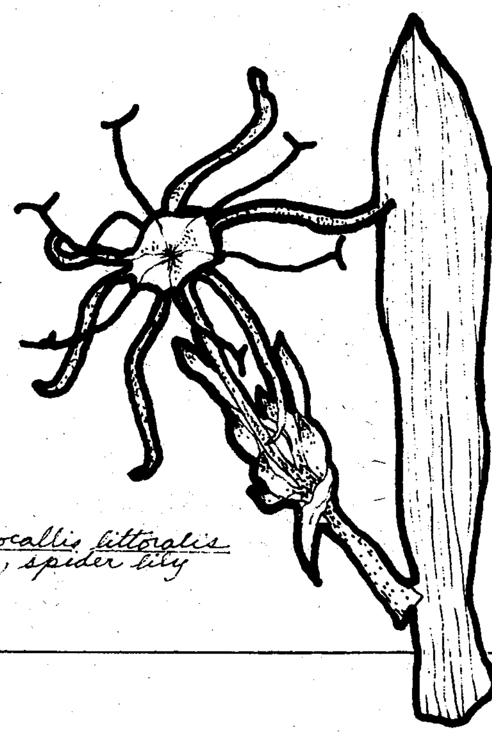
Getting good scientific information involves doing 2 things: observing and experimenting. Each of these activities is difficult to do well, but practice helps. Observing and experimenting give different results, and different kinds of information.

Observing lets you stay out of the system being observed. Natural events take time to start, and to finish. Most observers simply don't have that much time, so information gained by observation alone is likely to be incomplete.

Information that comes only from experiment is also inadequate, because the experimenter gets into the system. He is not a natural part of it, and his being there disturbs it. On the other hand, by working with the system, you can make things happen that you want to study——without waiting for the system to do them. So, each activity has its positive and its negative side.

It's always a good idea to look at a system before starting to mess with it. It may take a lot of practice to be a good observer. People need to learn the patience that goes with good observing. Many of them get excited and careless when they go into the field. They may disturb the system before having a chance to observe it as it is, *naturally.* If you start to observe a quiet pond, and 10 people rush into the water, the pond is disturbed. Clear water gets muddy. Bottom organisms (benthos) end up floating. Swimming organisms (nekton) leave the scene as fast as they can. Nature's organization has been disorganized.

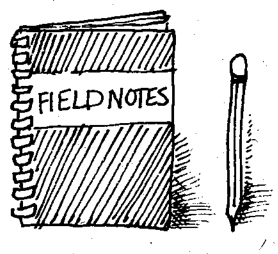
The following pages show some tools suggested for looking at freshwater systems. Take appropriate items when you go on a field trip. Our list has 2 types of equipment: general, and quantitative. General equipment helps you find and collect many things. Quantitative equipment lets you know exactly how much you've got of whatever you're counting. If you want to note down a food web, for example, you use general equipment; if you want to note an ecological pyramid, you use quantitative equipment.



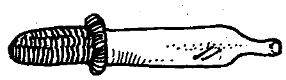
Hymenocallis littoralis
lirio, spider lily

EQUIPMENT FOR FRESHWATER SAMPLING

I. General Equipment

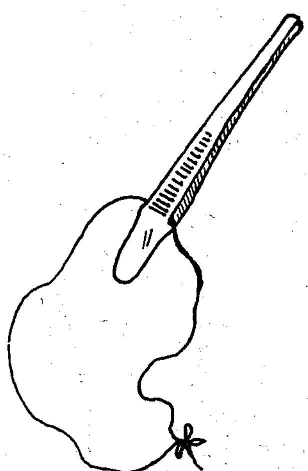


A. Have a field notebook, for instructions, observations, and data. Use pencil. It's going to get wet, and ink runs when wet. A science notebook should not be beautiful—it should be useful. Don't write on loose pieces of paper or towels or your lunch bag, because they get lost. Your notebook should have a waterproof cover or a plastic bag. On aquatic field trips it can get wet, even if it doesn't rain. If the book gets muddy streaks—or sweaty handprints—or bits of fina'denne' sauce, that's okay. If the organisms you draw look a little weird, or the temperature you read the first time is a little off—don't worry, and <u>don't</u> erase. Lightly cross out what's wrong—but leave it so you can read it later. Maybe it wasn't wrong! If you want to re-do something, use new pages in your notebook, and <u>don't</u> tear out old ones.



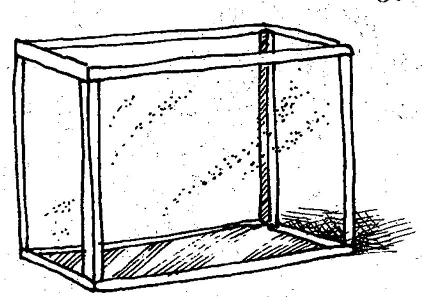
B. Collectors

1. Pipet (eyedropper): This is for moving small organisms off rocks or out of one water sample into another.



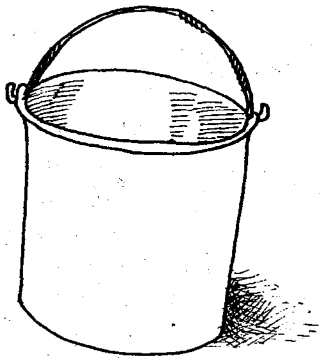
2. Forceps (tweezers): With these you can pick small critters out of tea strainers or other nets. Be careful not to squeeze too hard or you might squash them. Tweezers are easy to lose, so consider tying a long string around them and wearing it around your neck.

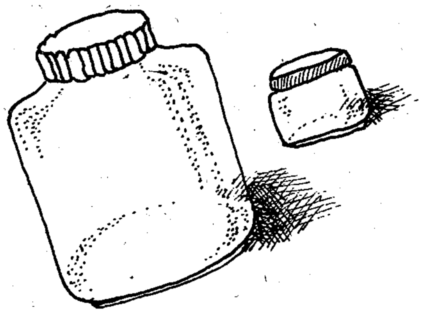
C. Containers



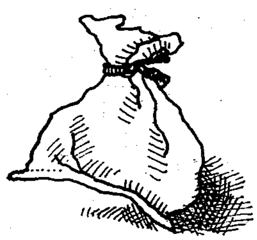
1. Aquarium: A container of plastic or glass. Put organisms from the field into aquaria for easy observation. You can use them for laboratory experiments without going into the field. An aquarium often has a pump which circulates the water and puts oxygen into it.

2. Buckets, pails, bowls, jars: Use 'em to bring in large organisms and water to refill aquaria. Sometimes you want to watch the critters awhile before putting them back in the water. You may want to take some back to the classroom for study. See what everyone has collected before you leave the field, and return duplicates to the system. Remember that other people will visit the place, and they expect to find organisms. Don't be greedy. If you want to keep the animals alive in the classroom, either collect water and bring it back—or let tap water from the sink sit awhile so the chlorine escapes. (Tap water is chlorinated to kill organisms that live in water. Set it out a day before the trip.) Plastic buckets are best for Guam —they won't rust. Every liter of water weighs 1 kg, so don't try to carry too much. If open containers are too full, they'll slop over in the bus.



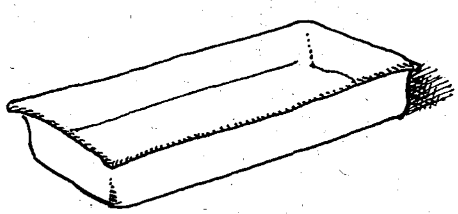


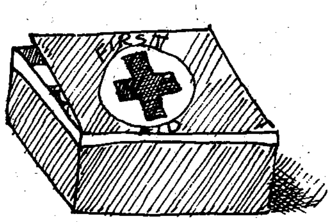
Wide-mouthed jars and baby food jars are easy to find and cheap. Large bottles make good aquaria. Baby food jars with lids are ideal for the field. Don't put too many organisms in jars—and don't mix carnivores (animals that eat animals) with other animals. You may get back to the lab and find only one fat carnivore!



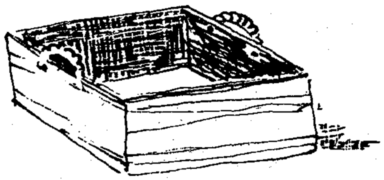
3. Plastic bags and 'ties'.

4. Pans: Use white enamel pans for sorting. You can easily see small organisms against the white bottom. Aluminum pans are okay to use. If you put waterproof white paint on them, it makes seeing easier. Never put live organisms in pans which had formaldehyde or alcohol or preserved organisms in them.





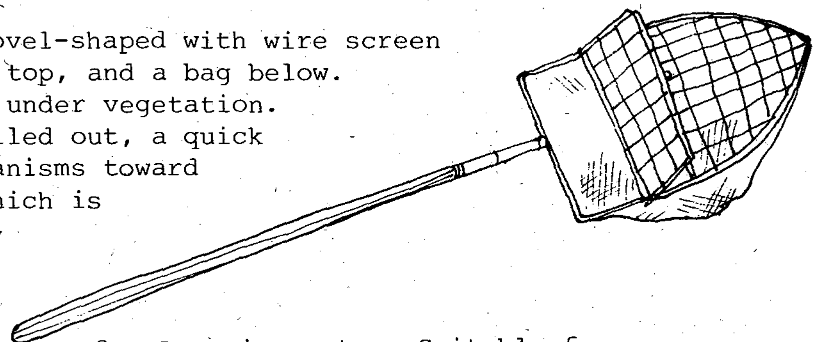
D. First Aid Kits: Every field trip should have a first aid kit, and someone who knows how to use it and when to get a doctor. Large kits and small kits are available.

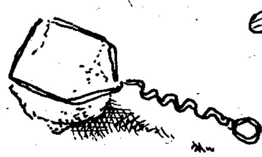


E. Look boxes ('sea' boxes): For waders. Boxes with open top and a bottom of (plate) glass. Like a face mask, they flatten the water surface so you can see through it.

F. Nets: Different kinds are good for benthos (bottom-dwellers), plankton (drifters), aufwuchs (clingers), and nekton (swimmers):

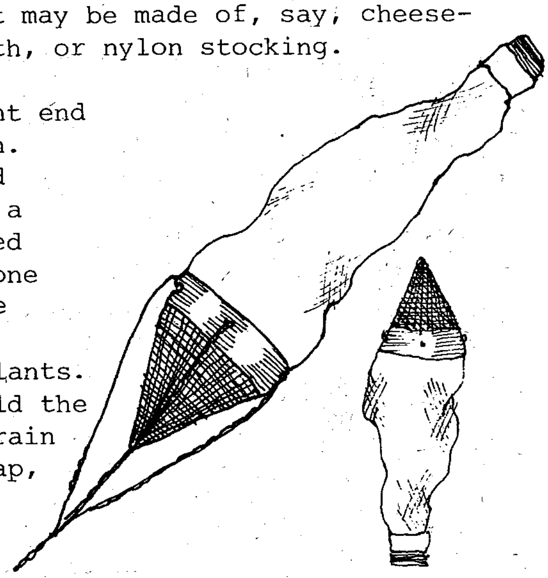
1. Apron Net: Shovel-shaped with wire screen halfway across the top, and a bag below. You shove this net under vegetation. When the net is pulled out, a quick jerk sends the organisms toward the pointed end, which is covered. Thus they can't escape.



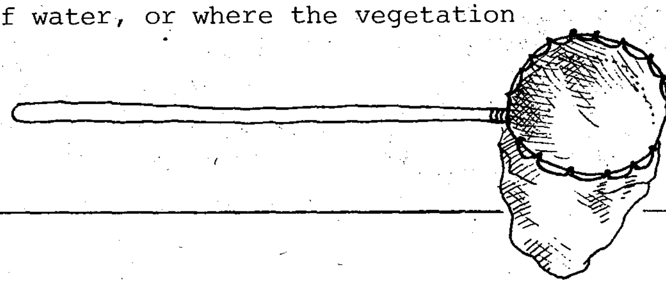


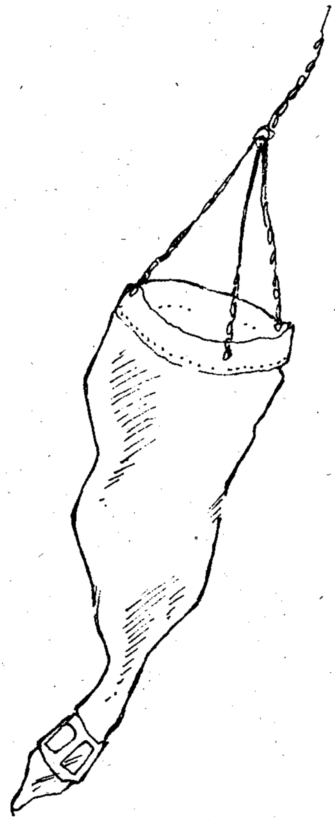
2. Aquarium nets: Suitable for use in small containers. The bag part may be made of, say, cheese-cloth, or nylon stocking.

3. Birge Cone Net: The front end is a cone-shaped brass screen. Behind it is a nylon net, and behind that a small cup with a screw cap. The net is dragged through the water with the cone toward the dragger. The cone lets small organisms in, but keeps out large leaves and plants. When you pull in the net, hold the cone up, and the organisms drain into the cup. Unscrew the cap, and put the contents into a container.

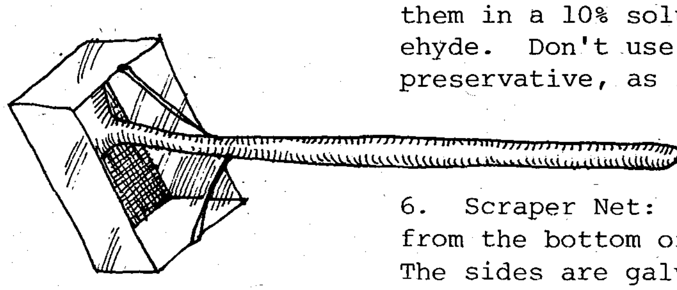


4. Dip Nets: These are like butterfly nets—a long pole with a bag at the end. They can be made easily with a clothes hanger bent into a circle, and a mop handle. The bag material can be very tight mesh (small holes) if you wish to trap protozoa—or a loose mesh that will trap only larger organisms. Dip nets are not heavy enough for dragging the bottom of a body of water, or where the vegetation is thick.

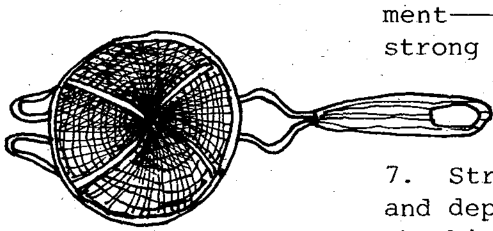




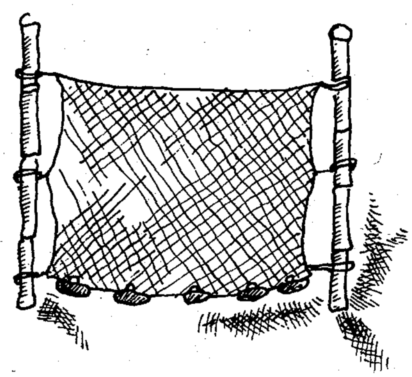
5. Plankton Net: Plankton are small drifters living in water. They're mostly not visible unless you magnify them. This net is a cone-shaped nylon cloth with a stiff wire holding the large end open. A container like a bottle or test tube is tied at the small end. The net is fragile so use it only in open water, not near the bottom or other obstructions. The cloth is a very fine strainer. You either drag the net through water or pour water into it. The cloth lets water out, and even some very very small organisms. Other ones slide down into the container. This helps you collect and also concentrates them so they're easier to find. Plankton are little and delicate. Keep them cool. Look at them soon after you collect, or they will either run out of oxygen or eat each other up! They are much more fun to see alive. But if you won't be able to look at them as soon as you get back to school, preserve them in a 10% solution of formaldehyde. Don't use alcohol for a preservative, as it makes them brittle.



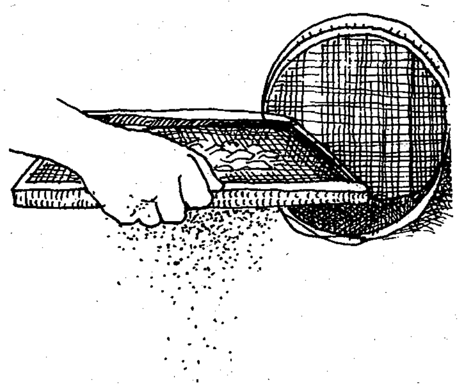
6. Scraper Net: Scrapes organisms from the bottom of ponds and streams. The sides are galvanized sheet metal, the floor is brass screening. This is a piece of heavy-duty equipment——to use when dip nets aren't strong enough.



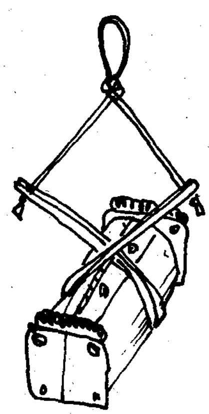
7. Strainer (tea strainer): Grocery and department stores sell them. Get the biggest one. This is heavy enough to use on rocks and vegetation. The mesh is a little large for smaller organisms which will slip through. Because the handle is short, it's suitable for shallow-water work.



G. Seine: Many throw-nets that Guam fishermen use are a kind of seine. Standard ones have a pole along each end. The bottom edge of the net may be weighted with lead sinkers. Usually a person holds each pole. A small seine can be handled by one person. It helps if a number of people start upstream and turn over rocks, or kick the mud, and move toward the net——a sort of 'fish round-up'. To use a seine now, you need permission from Fish and Wildlife Division of the Department of Agriculture.

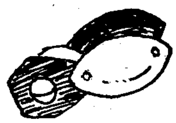


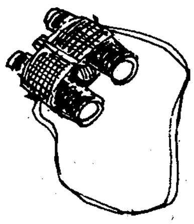
H. Dredges and Screens: A dredge is a metal scoop that often works like a set of jaws. Most are dropped with a rope. When they hit bottom (and they're made heavy so they hit hard) the 2 sides close like jaws and take a 'bite' out of it. The substrate stays inside as the dredge is raised. It's usually dumped onto a stack of boxes with horizontal screens. The top screen has the largest mesh and the bottom screen the smallest. The catch is often washed down through the screens. The largest things stay in the top boxes. Smaller ones wash down until they reach a screen small enough to hold them.



Screens come in many shapes, sizes, and materials. The best and most expensive are brass, but hardware cloth in a wood frame makes good ones, too.

Dredges are used in sampling river, lake, and ocean bottoms. Your school should have a small one for use in Life On Guam.

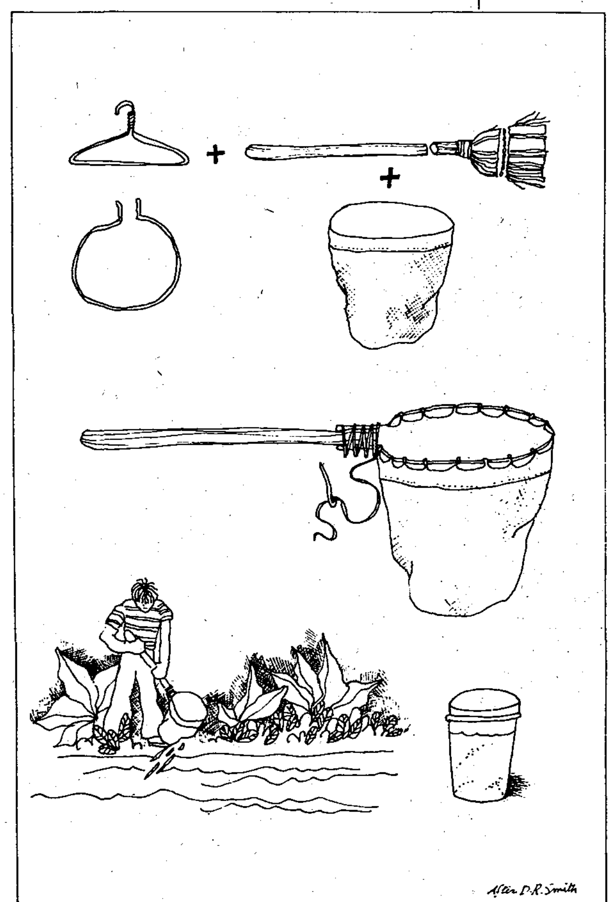




I. Magnifying equipment: This includes microscopes, binoculars and magnifying lenses. Magnifying equipment is necessary for many plankton and benthic organisms. It's useful for looking at small parts of large organisms——or looking for parasites on or in large organisms. Microscopes can be used in the field if they have mirrors instead of built-in lights. You will probably use them when you get back to school. Binoculars are good in large habitats where there are plants you see but can't get to. And for birds, which you should not collect but want to see. Magnifying lenses can be carried by you; some are small and can be worn on a string around the neck. Others have a handle and are to be hand-held. They are useful in the field, especially if you don't have a microscope.

II. Quantitative Equipment

Thermometers, metersticks, light-measuring devices, marked string, float (stick, twig, leaf), stopwatch or watch with second hand, water testing kit, scale, hand counter.



VII - In the Field

Observation

Whatever you can learn by observing should be done before you do anything else. You make things unnatural just by being there. They will be more natural if you at first stay out of the water, stay quiet, and just watch.

Things to observe:

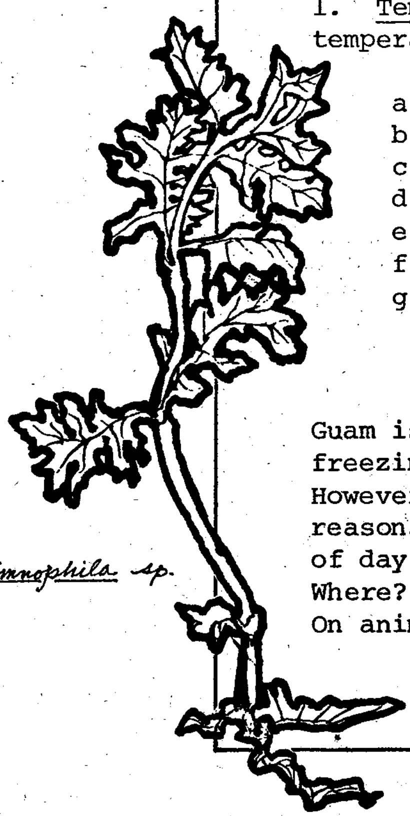
a. What organisms can you see in the habitat? What are they doing?
b. What kind of aquatic habitat are you studying?
c. Draw a map of the habitat.
d. Is the water clear or cloudy? How fast does it move?
e. Does sunlight go to the bottom? Why is this important?
f. Are there plants? Are they floating—rooted—totally underwater?
g. Is the habitat shaded (by what?)—or in the open? Will the Sun shine on it all day or only part of the time? How can you tell?
h. When you finish your experiments, do you think your answers to any of the other questions will change? Which answers may be different? Why?

The Non-Living Part of Habitats

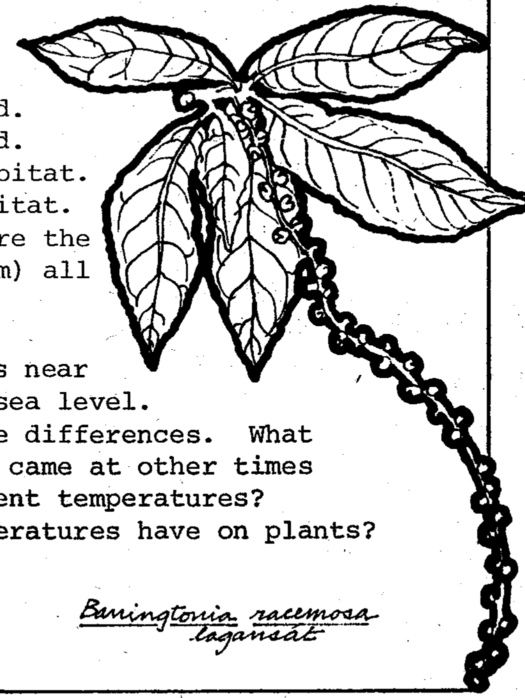
1. Temperature. Using a thermometer, measure and record the temperature of the following places in the habitat:

a. a shady area on the ground.
b. a sunny area on the ground.
c. a shady area, 2 m above ground.
d. a sunny area, 2 m above ground.
e. the surface of the aquatic habitat.
f. the bottom of the aquatic habitat.
g. If the habitat is deep, measure the temperature each meter (100 cm) all the way down.

Guam is in the tropics, so temperatures near freezing don't occur, especially near sea level. However, you probably found temperature differences. What reasons can you give for them? If you came at other times of day, would you expect to get different temperatures? Where? Why? What effects do the temperatures have on plants? On animals? Why?



Limnophila sp.



Barringtonia racemosa
lagansat

2. Measurements

Using a meterstick, or a marked piece of string, measure the aquatic habitat and record the following information:

a. the width of the habitat at the widest part, and at the narrowest part.
b. the length of the habitat at the longest part, and at the deepest part.
c. the depth of the habitat at its deepest part.
d. the depth every 0.5 m from the shore to the deepest part.

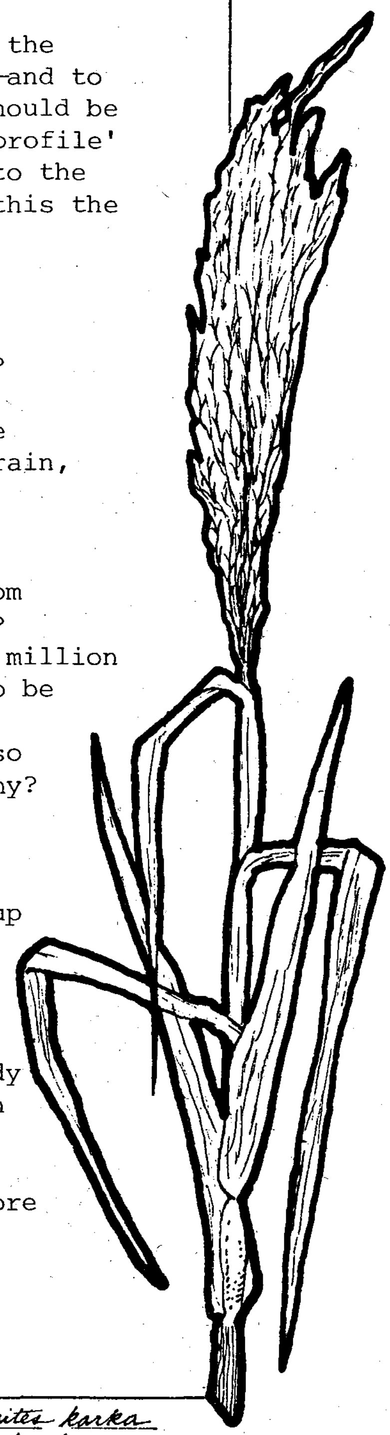
With this information, construct 2 maps. Let one show the surface features——the size and shape of the habitat——and to proper 'scale'. That is, the side that was shortest should be the shortest on your map. The other should show the 'profile' of your habitat——how the bottom slopes from the edge to the deepest part. We aquatic biologists, you and I, call this the 'basin profile' (like those on page 17).

Answer the questions:

a. Will this habitat look the same all year long? Why, or why not?
b. Did you have trouble telling exactly where the 'shore' was? Would a dry season, or a heavy rain, make any difference?
c. Was the bottom solid, rocky, sandy or muddy? (Anything else?)
d. Do you expect that after a long time the bottom will be rockier, or sandier, or muddier? Why?
e. If you had the chance to visit this habitat a million or so years from now, what would you expect to be different? In what way? Why?
f. If you had visited this habitat a million or so years ago, what would have been different? Why?

3. Substrate

The substrate of a habitat is the material that makes up the bottom. There are two ways to study it. You can take a piece of pipe and hammer it into the bottom. When you pull it up, all the layers of the bottom are inside the pipe, in order. This is called 'coring', and the material in the pipe is a core. Often, on muddy bottoms, the pipe used is a clear plastic, so that when you pull it up, you can see layers of the core. Other times the substrate is very tough and a plastic pipe would break. Then you use a metal pipe and push the core out to look at it. If you mess up the core getting it out of the pipe, don't worry. Just put it in water, shake it, and look at it later. The usual layers are rock, organic material, clay, and sand.



Phragmites karka karisu

A second technique is to use a dredge or shovel, and scoop up the substrate. Put some in a container with water (a bottle is best). Shake the container and wait for it to settle. This may take a day or two.

Draw a picture of your settled substrate.

a. Are there layers in your sample? How many?
b. What are they?
c. By measuring the thickness of each layer (and using a little math) you can tell about what percent of the total each layer is. What percent is organic? Rocky? Sand? Clay?
d. Which layer has the heaviest material? The lightest? Explain.
e. Where do these substrate materials come from?
f. By looking at the sample, estimate how much life the habitat produces. Explain.

4. Gradient

Review the section on gradients (pp 10 ff); remember they're important in lotic aquatic habitats. This activity requires two people: a starter and a timer. You also need a float: plastic, or a cork, or even a twig; a meterstick, and a stopwatch or a watch with a second hand.

a. Measure a 10-m length along the stream or river. This length is the 'course' of the experiment.
b. The timer, with the watch, goes to the downstream end of the course.
c. The starter places the float at the start of the course (preferably near the middle of the stream) and yells 'Ready, go!' The timer starts timing.
d. When the float reaches the end of the course, the timer stops timing and picks it up.
e. The time is recorded.
f. Run the experiment at least 3 times on the same course, with the same float. Average the times for your final result.

The float 'should' travel at the same rate (speed) that the water is moving. By the formula $r = d/t$, rate equals distance divided by time, you can calculate the rate. (You yourself set the distance, 10 m, and measured the time.)

The data you get don't directly tell you the gradient (slope) of the stream or river. Generally, a steeper gradient will give a higher velocity. To check this, sample several streams, or one stream at several places, and compare results.

a. Without doing the experiment, what would you guess the results would be? Why?
b. Where do you expect velocity (and gradient) of a stream to be greatest? Least? Do your data agree with your expectations?
c. What do data on velocity (and gradient) tell you about the age of streams or of parts of one stream?

5. Water Quality

A water testing kit (Limnology Test Kit, LaMotte Chemical Co., Chestertown, MD 21620) should be available with this course. The kit has self-contained tests for pH, dissolved O_2, CO_2, nitrates and phosphates, calcium, magnesium, hardness, and silica. They have their own instructions. Copy them in your notebook so they won't get lost. Each test is easy if you follow directions. In this booklet our purpose is not to repeat instructions but to give information about what the tests do. You then interpret your own data.

a. pH - The pH of a solution is the number of H^+ and OH^-, hydrogen and hydroxide ions, present. (An ion is an atom or molecule that has gained or lost one or more electrons, and thus has lost or gained one or more electrical charges.) The pH scale goes from 0 to 14. A pH of 7, right in the middle, means that the solution is neutral (the H^+ = the OH^-, and they cancel each other out, as in distilled water). Below 7 there are more and more H^+, and the solution is more and more acidic. Each number going down the scale has 10 times more hydrogen ions than the number above it. Loosely speaking, you can say "pH means the *power* of the hydrogen ion". The pH of a strong acid (hydrochloric acid, or sulfuric acid) is close to 0. A weak acid like acetic acid (vinegar) has a pH closer to 7. The pH of a strong base like sodium hydroxide, or potassium hydroxide (= Drano) is close to 14.

The pH of water is crucial for its organisms. Essential supplies like O_2, CO_2, and nitrates aren't available in water with the pH too high or too low. (Also, chemicals with pH's near 0 or 14 burn or dissolve tissues.) The pH of natural water also tells about the substrate. Decaying organic matter (leaves, etc.) makes water acidic. Water flowing over or through acidic or basic rocks will pick up acidic or basic ions. Farmers have pH tests done on their soils, and agriculture departments treat soils to make them more neutral.

Things to do and information to record:

1. Make solutions (use distilled water——why?) of common things like toothpaste, shampoo, mouthwash, soap, fina' denne' sauce. Measure the pH's. Discuss your results.

2. Test soils by shaking them with distilled water, and letting the mixture settle. Then check the pH.

Use soils from different parts of the Island. Are the pH's different? What might cause differences? Get a guest speaker or other information from the Agriculture Department. Find out what to add to soils to make them better for crops.

3. Measure the pH of different bodies of water—e.g. puddles, rainbarrels... Check their soil, rocks, vegetation. What are the effects on pH?

4. Measure pH of rainwater from different places. (Try to collect samples soon after rain, because algae start to grow—bugs fall in—things happen when water 'sits' for a while.) In the States, farmers and foresters are worried about 'acid rain'. Look that up. Find out what causes it and why people are concerned. Does Guam have acid rain? Explain.

b. <u>Dissolved Oxygen</u> (O_2) - Oxygen doesn't dissolve easily in water. It does go into solution slowly from the air. If the pH is too high or too low, oxygen has an even harder time dissolving. If water is moving, it takes in O_2 more easily. The more the water flows or splashes, the more it bounces into the air and the more O_2 it captures. Water plants also add O_2 by photosynthesis. Aquatic organisms can use O_2 dissolved in water. They are *aerobes*, meaning 'living with oxygen'.

Oxygen is removed from water in several ways: 1) At the bottom of lakes or other quiet waters it is used by aerobes and isn't replaced from the air. If a great many aerobes are in the water, they may use up O_2 faster than it's replaced. 2) Heating the water. This makes the O_2 molecules move more rapidly, and a lot of them just jump out of the water into the air. 3) O_2 combines chemically with some substances, iron, for instance. The rust you see on metals left in water is probably iron oxide, FeO_2, the O_2 effectively removed from the water so organisms can't use it.

A few kinds of simple living things (some bacteria and some fungi) can live without oxygen. They are *anaerobes*. Most organisms need oxygen to live. Look up reasons for this in biology books under 'cell respiration'. Oxygen is needed to get energy out of food. This energy is used for movement —of and in an organism, for making new cells and molecules and repairing others, and for keeping the organism alive. The more complex a living thing is the more energy it needs.

Things to do and record:

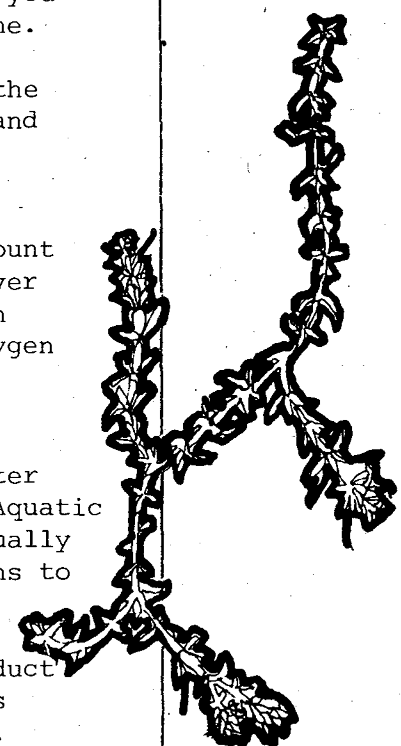
1. Measure the O_2 in water from a rapids area and a quiet pool of a stream. Explain any differences.

2. Measure the oxygen in water at the surface of a pond, and at the bottom. Explain any differences.

3. Fill 2 containers with water whose oxygen content you already know. Put fish or other aquatic animals in one. Close them tightly. At the end of 4 hours (or a convenient length of time longer than 4 hours), measure the oxygen in the 2 containers. What differences occur, and how can you explain them?

4. Fill 2 transparent or translucent containers with water of known oxygen content. Add about the same amount of Hydrilla (an aquatic plant) to each container. Cover them tightly. Place one in the light and the other in the dark for 24 hours. Then measure the amount of oxygen in each. What differences are there? Explain.

5. Water pollution occurs when water is poisoned by heavy metals, or detergents, or pesticides. Other water pollution happens when sewage or wood pulp gets in. Aquatic organisms eat these and multiply rapidly. What eventually happens to the oxygen in water like this? What happens to the organisms? Why?



Hydrilla verticillata

c. Carbon dioxide (CO_2) - Carbon dioxide is a by-product of cell respiration (breathing). Any organism which breaks down food molecules to get energy gives off carbon dioxide. Plants use CO_2 in photosynthesis, but they also respire and give it off. Like oxygen, CO_2 is a gas. Unlike oxygen, it dissolves easily and quickly in water.

When carbon dioxide is dissolved in water, especially under pressure, it can do different things. It can stay as carbon dioxide—or it can combine with water to form either carbonate or bicarbonate ions. The way CO_2 behaves in water depends pretty much on the pH of the solution.

1. Test natural waters of Guam for CO_2 and pH. Record and discuss your results.

2. Now, using acids and bases, change the pH of the waters and again test for CO_2. What is the effect of the pH?

d. Nitrates and Phosphates - These are important in body metabolism. Nitrates are used in building proteins. Phosphates are needed in energy reactions and as parts of large molecules. Both are used in fertilizers. They do the same jobs in plants as in other organisms. Organisms absorb them wherever they are. If an organism dies in its home territory, the 2 compounds are returned to the system when decay occurs. They are immediately taken up by other organisms. But if crops are harvested and shipped off, nitrates and phosphates are not returned to the ecosystem they came from. That's why farmers have to re-apply them every year as fertilizers.

Nitrates and phosphates aren't often 'loose' in natural systems. When one organism releases them, another picks them up. In the past, when organisms were fewer, these compounds accumulated, and packed down hard and became rock. Some have been raised by mountain-building or volcanoes. There are some large phosphate and nitrate deposits. Most of the island of Nauru is phosphate rock, and brings a good price. Most places, especially near the Equator, are low in nitrate and phosphate. These minerals are water soluble. In tropical places like Guam it rains a lot. Nitrates and phosphates are dissolved out of soil by rain and carried away to sea.

Finding a lot of nitrates or phosphates in an aquatic habitat is unusual. It's so unusual you can be sure one of three things is going on: 1) the water is polluted by runoff from fertilized farms or sewage, 2) phosphate- or nitrate-bearing rocks are near, or 3) the system has few or no live organisms.

Things to do and write down:

1. Test for nitrates and phosphates in natural aquatic habitats. Discuss your findings.

2. Test home products for these chemicals—see if the 'low phosphate' detergents really are low in phosphates.

3. Test for nitrates and phosphates in water from several spots on the south end of Guam, and from several places in the north. Discuss your results.

e. <u>Calcium, Magnesium and Hardness</u> - Both calcium and magnesium occur as ions (electrically charged particles —Ca^{++} and Mg^{++}) scattered in water. Calcium is essential to some living cells—it's part of muscle, nerve and bone. Things like clam shells and coral skeletons contain a lot of calcium. Magnesium is in all chlorophyll molecules in plants and algae. It is also found in cells of most organisms. Water is 'hard' when it has Ca^{++} and Mg^{++} ions in it. It's very hard to get up a lather of soapsuds in hard water. 'Soft' water doesn't have these ions. Rainwater is very soft, and in it a tiny bit of soap or shampoo makes mountains of suds.

Both of these ions are taken in by living things. Animals don't need as much magnesium as plants and algae. Organisms that build heavy skeletons—animals like corals, mollusks and vertebrates, and some reef algae—take up lots of calcium ions. A skeleton, if not surrounded and protected by living tissue, gives away calcium to solutions, especially watery ones. Water filling the lens system goes down through limestone that once was a reef. A reef is a mass of coral and algal skeletons.

So, water from the lens system will have many calcium ions and will be 'hard' water.

Things to do and write down:

1. Collect a sample of rainwater and a sample of tap water. Test both for calcium, magnesium and hardness. Explain any differences.

2. Collect a freshwater sample from the north end of the Island and one from the south end. Remember, many southern rivers are tidal and are influenced by saltwater. (See Mangrove Flat.) Try to collect from above the estuary. Test each for calcium, magnesium and hardness. What differences occur? Comment on the nature of rocks making up these 2 parts of the Island.

f. Silica (- SiO_2, silicon dioxide) - Silicon is an interesting element. In the way it chemically attaches to other molecules, it is very much like carbon. Carbon is the basic 'organic' element of Earth——it's in all living things. A lot of science fiction writers dream up 'life' on our planets and in other galaxies, and make silicon the basic element to that form of life!

Here on good old Earth, silicon is in rocks and sand. Glass is mostly silicon. (If you can get the temperature high enough and remove other minerals, you can make glass by melting sand.) When you find silica in water, the water is probably near sand or sandstone rocks, or rocks that have silica in another form. You should be able to measure the silica in water even if lots of organisms are there. A few protista build skeletons with it. Few other living things use it in metabolism or for body parts.


Chinese least bittern
Ixobrychus sinensis

Things to do and note down:

1. Test for silica in natural waters of Guam. Record your results, and comment on what these tell you about the geology of the Island.

2. Read about the elements silicon and carbon. Report on why they are alike, and how they are different.

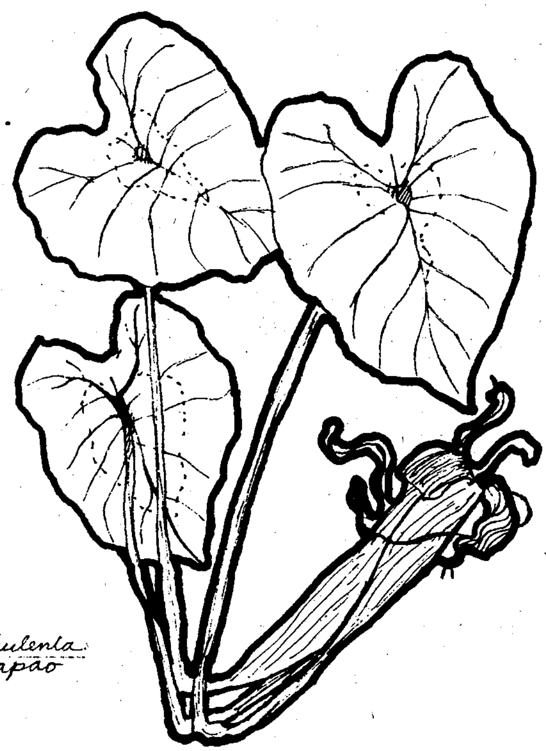
3. As a special project, look up the protists called Radiolaria. (You may have to use a zoology text if encyclopedias don't have enough information.) Report on the connection between these organisms and silica.

The Living Aspect of Habitats

You'll remember that water organisms can be classified in several ways. We need to find out what organisms are in an aquatic habitat, and then classify them in every way possible. Finding organisms can be very difficult in some cases——and very simple in others. Try all the techniques listed, so that you will get the whole picture of what's there.

Finding the Organisms

Observation - Most large plants, and animals like birds and fishes, can be seen by observation. Some plants, like water lilies, can be seen and identified from a distance. They don't need to be collected. Many things that you see have to be collected for identification. Always check with your teacher so that you don't collect organisms that someone else has collected or ones that are rare or endangered.



Colocasia esculenta
suni, papao

Polygonum minus var. *procerum*
mamaka

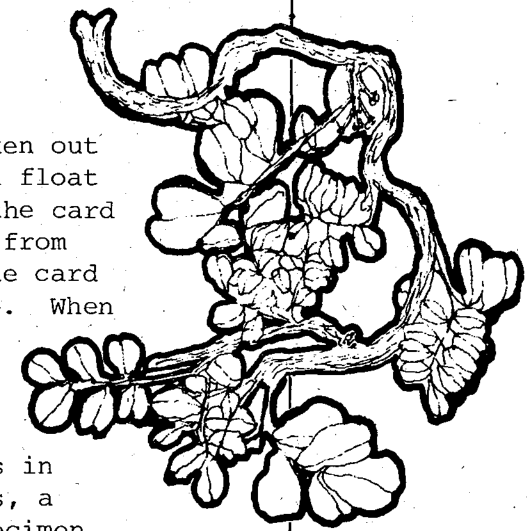
Hibiscus tiliaceus
pago

VIII - Back in School

Preparing Permanent Collections

A. Filamentous algae.

These are small algae that usually go limp when taken out of water. To prepare them, leave them in water and float them onto a card about 20 x 25 cm. Leave room on the card for a label! Then pick up the card very carefully from the water. The algae should stick to it. Press the card the way you press large plant specimens (see below). When it is dry, label it according to the directions.



Dalbergia candenatensis

B. Large algae and plants.

1. Collect a specimen with a minimum of holes in the leaves and little dirt on the roots. For trees, a small branch is enough. If possible, collect a specimen with flowers, if it's a flowering plant.

2. Press the specimen carefully between 2 pieces of newspaper. Turn one leaf over (if the specimen has leaves) so an underside will be upward.

3. Label the newspaper with the name of the plant, the date and place of collection, and the collector's name.

4. Place the newspaper between 2 blotters, if you have them. This isn't absolutely necessary, but is useful.

5. Place the blotters (with the newspapers between), or just the newspaper, between 2 pieces of corrugated cardboard. You can get the cardboard by cutting up old boxes.

6. Place all the specimens in a stack between 2 pieces of plywood. Using a rope, or straps, or even 2 old belts, press the stack firmly. Stand on it, if necessary, to tighten it securely.

7. Place the press in a drying place—a dryer if your school has one, or a cabinet heated with a light bulb—or a dryer you can make yourself. Build a frame with 4 sides and a chicken-wire bottom. Wire and secure 2 light bulb sockets (or 3—however big the frame is) on a piece of wood and rest this above the chicken wire. Then place several boards across the box so that the presses will rest above the bulbs. Cover the frame with a lid and you have a safe drying box. The heat from the bulbs will rise to dry your plants, but the wire bottom will let out excess heat so there is no chance of a fire.

Coix lacryma-jobi
bilen

Note: In the tropics it is <u>very</u> important to dry pressed plants thoroughly if you want to keep them! Otherwise molds grow on the plants and ruin them. Do <u>not</u> try to press fleshy fruits, roots or stems. If the stems or roots are thick, slice them thin before pressing them. If you wish to preserve fruits, bottle them in a solution of FAA (formaldehyde-alcohol-acetic acid—your teacher can help you make it). Also, place the presses so that the open edges (not the top and bottom wood or slots) are down—warm air goes through spaces better than through boards!

8. When the plants are dry mount them on paper. If you've gotten small plants or cut or folded larger ones, cards are handy for this. Small algae are already mounted as you press them! For the plants, use a thin solution of Elmer's Glue-All (mix it with water) and put it in a pan. If you float the plants on the glue-water, then move them carefully to the paper and press them down a little with a rag (that removes the extra glue, too), they should stick to your cards. Again remember to leave space for the label! If you want these to dry fast, put a piece of wax paper on top of the specimen, put it back in its newspaper (so you still have the information that was on the paper), put the whole thing between corrugated boards in a press, tighten the straps (but not <u>too</u> tightly—don't stand on the press) and let it dry overnight.

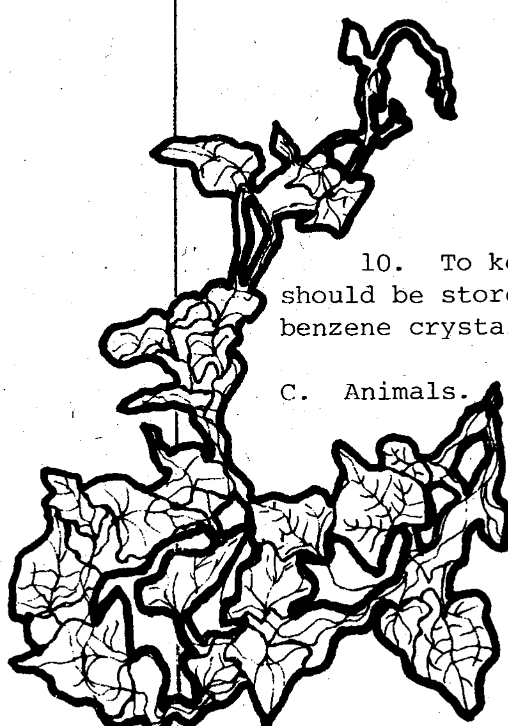
9. The last step is to label the specimen. Here is a sample so you will know what to include. The fruit you preserved should also have a label tied to it—usually written in pencil or India ink so the FAA doesn't dissolve it!

Scientific Name:
Family:
Common Name:
Where Found:
Date: Collector:
Other Information:

10. To keep bugs from eating plants <u>and</u> glue, specimens should be stored in containers with mothballs (para-dichloro-benzene crystals).

C. Animals.

Most animals should be preserved with either 10% formalin or 70% ethyl alcohol, in bottles. Insects can be pinned, but here in the tropics insect-eating pests are <u>very</u> common, so moth crystals (PDB-see above) must be used and constantly replaced. Try the liquid preservation technique!



Mikania scandens

Again, all animal specimens should be labelled with the same information shown on plant labels (p 72). If you aren't going to label what you collect, don't collect, because no one else can use unlabelled specimens. Also, if your school already has specimens like yours—don't collect them. There is no reason to ruin ecosystems by over-collecting organisms.

Projects with Living Organisms

1. Using the keys (pp 46-49), classify the organisms to as small a group as you can.

2. List each organism as a member of the plankton, nekton, neuston, aufwuchs or benthos.

3. Decide the trophic level of each. Some of this can be done by observation, but you may have to read further. Or run an experiment by placing 2 different organisms in a small jar to see if one feeds on the other. You can dissect some larger organisms and list the stomach contents.

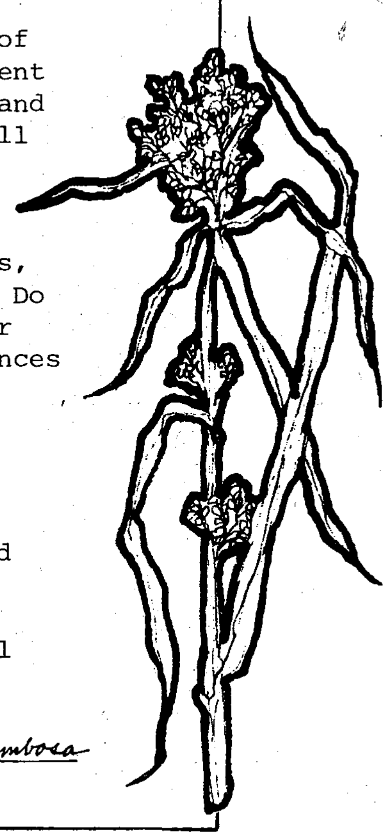
4. Draw a food web for the aquatic habitat you visited.

5. Record the numbers of each kind of organism you found, including the ones you didn't keep. See if you can construct an ecological pyramid of numbers, as on p 32.

6. As a class project, collect one of each kind of organism and fix them with help from 'Preparing Permanent Collections' (p 71). If you do this for one habitat, and other classes do it for other habitats, your school will have a nice reference collection. It can be looked at before a class goes on a trip.

7. Find out the amount of water in aquatic plants, plants of medium-wet places and plants of dry places. Do this by weighing the plants fresh, then drying them for several days, and reweighing them. Record any differences among plants from the 3 places. List reasons why such differences might occur.

8. Look at stomates on plant leaves (you can see them easily with 100x magnification, especially on the lower leaf side). Compare the number of stomates—and their locations on the leaf—on leaves from aquatic places, medium-wet places, and dry places. Record the differences, and look up information on stomates. Tell what makes these differences possible.



Rhynchospora corymbosa

9. Choose any aquatic animal and learn all you can about it by studying the animal and by reading about it. Try to study it through its complete life cycle.

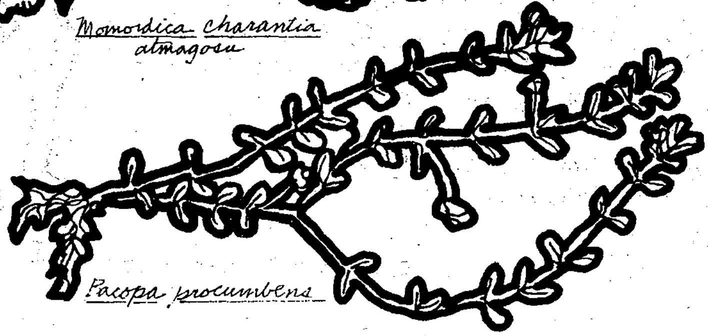
10. For the habitat you study, list the organisms that visit only temporarily. List reasons why they visit but do not live in the habitat.

11. A 'balanced' ecosystem is one that appears to stay the same for a long time. Of course, things in it live and grow and change and die, but the over-all system stays the same. Try to build a 'balanced' aquarium using organisms from an outdoor ecosystem. Just remember: if it's balanced, it will take care of itself; you won't have to feed anything in it! Keep a record of this experiment from the time you start until it seems balanced——or gets so unbalanced that it changes a lot. You should especially note which organisms grow and increase——and which have a lot of trouble surviving.

12. Visit a temporary pond; or build your own——dig a pit in the ground and line it with a large piece of plastic. Either way, make several visits, starting after a heavy rain and quitting when the pond dries up. Each time, collect a water sample and identify the organisms. Record the names and the relative numbers each time you check the sample. If you have trouble with the names, draw pictures of them. Identify your drawings using reference books.

13. As a class project, collect all the materials students have put together from one particular site. Prepare a report for the reference section of the school library. This report should include any photographs available.

Momordica charantia
atmagosu



Bacopa procumbens

Cyperus kyllingia
buton sugu,
cha'guan lemmai

IX - Some Field Trip Sites

1. Agana Springs - Turn downhill off Rte. 4 (Chalan Pago) at the top of Sinajana hill (directly across from the back driveway of a restaurant, in May 1977, 'The Brig'). The Springs are to the right in an open area. They are natural, but enclosed in concrete. Plenty of room for a class to work, easily accessible.

2. Agana Swamp - This large, mostly freshwater marsh occupies the entire depression inland behind Agana and between Rtes. 4 and 8 (NAS-Barrigada). There are 3 access points: Agana Springs area; the dirt road that concrete poles are built on, which gives the 'most' marsh; and a dirt road that turns off O'Brien Drive between the swimming pool and the tennis courts. This last site gives access to the Agana River, which is tidal in that area and has steep banks.

3. 'Straggler's Spring' - Reconnoiter this first. Check on the need for Navy permission. Leave vehicles at NCS beach (Tanguisson power plant). Walk north along the beach or along a dirt road that eventually leads to the beach. Continue on a well-marked trail until you reach the last beach (about 1.5 km; north of here cliffs drop to the sea; the reef here has a large, sand-bottom depression called 'Shark's Hole', though I've never seen a shark in or near it). From this beach a trail leads inland and eventually up the cliff. <u>This trail is hard to find</u>! Follow it until it starts up - at that point a less-traveled trail leads left. This left trail goes to a natural spring, probably a fallen-in sinkhole. It's safe to swim in, but a lot of sediment makes things murky very rapidly. <u>Many voracious mosquitoes at this site</u>! This is a particularly good place for reef, beach and limestone forest also.

4. Ritidian Cave - You will need Andersen permission to cross Northwest Field, and Navy permission to go through the Naval Facility below Ritidian Point. The trail was obliterated by Typhoon Pamela. Even when it was good, people who had used it 4 times got lost the fifth time. The cave has some good formations, does not require ropes, extends into the lens system (or vice versa), but doesn't have much life. If you aren't dissuaded <u>yet</u>, take some sensible adults with you and 5 or 6 Coleman lanterns. Each student should have a flashlight, extra (<u>new</u>) batteries - and a buddy. This is a spelunking trip. If you students can't control yourselves, forget it! Go northwest from Potts Junction (between NCS and Andersen AFB) and drive down to the Naval Facility. Park there and walk east; the cave is in the headland bluff, and the trail leading up from the beach may be the easiest to try to find.

5. Japanese War Memorial Spring - Located just below the memorial, it produces a small stream leading down a ravine. The memorial is north of Marine Drive between Dededo and Yigo, but the roads in can change, so you should ask locally - or ask a tour bus driver. It's one of the few springs of the northern plateau. Suitable for small classes.

6. 'Lake Barrigada' - This waterhole resulted from a change in drainage and is currently confined within a chain-link fence. It's on the Barrigada Junior High side of Rte 10 near Rte 8. The Highway Division of Public Works will open the gate for fieldtrips. The lake is unnatural and full of debris. But EPA and Andersen environmental health people say the water is clean as far as coliform counts are concerned.

7. Mangilao Little League Field - Next to the Commissioner's Office. It becomes a temporary pond during any week that has 2 or more heavy rains. Do not go during a ball game, rain or no rain!

8. Pago River - A mature, tidal river at access points, either the bridge on the Chalan Pago-Yona Road (Rte 4) or a farm road south of the bridge (inland) which follows the flood plain. Just now it's great for pollution ecology, courtesy of the sewage non-treatment plant.

9. Talofofo River - Several opportunities on this extensive site. The river is tidal at the bridge. Leave vehicles at the small store there. At the store, ask permission to walk in on the dirt road (not required, but shows good manners). You'll pass the remains of an eel farm on your left - behind this (walk the dike road) is a backwater of the main river. It's relatively currentless and is bordered by a nice swamp forest. Further on, the road curves left and crosses the flood plain. It usually has standing water pools and both swamp and marsh vegetation.

10. Talofofo Falls - Careful! The easiest way in is off the main highway onto the Dandan (NASA) station. Go until a dirt road leads off to the right. A fence may be across it - if so, you'll have to walk from Dandan. Otherwise you can drive to within 150 m of the Talofofo River. On the way there is a nice depression which makes a good rainy season temporary pond. The part of the river you reach is <u>above</u> the falls, and is a nice young stream study area. Getting a class down the falls without casualties is enough of a problem to make you consider quite a while whether you want to 'do' this site or not. A rope and some responsible adults are recommended. The falls are lovely. The garbage is not. Make it a clean-up trip on the way out - take garbage bags.

11. Malojloj (Bali Hai) - Leave vehicles by the roadside near Flores Egg Farm (south of the farm and north of Inarajan on the inland side of the road). Take a well-defined trail for a 10-minute stroll. The site consists of a small stream with rapids and a deeper swimming hole. As it is easily accessible, the site will also have a lot of garbage. Make noise as you walk in - skinny-dipping is usual here.

12. Inarajan River - Leave vehicles by the small store at the bottom of the road to Inarajan Jr. High. Walk to the bridge at the entrance to Inarajan. Inland it's fairly open farmland. The river has steep banks, but there are some interesting backwaters and marshy places.

13. Padre Pools - Leave the main road and go uphill toward the Merizo Elementary School. Turn left into a housing area and leave vehicles there. You are aiming for a ravine which leads down behind the school.

There should be the remains of a jeep road which you can follow, though the land was torn up recently and you may have to do some looking. The stream that cut this ravine has cut pot-hole pools all the way down, and it's the only easily-accessible young stream site in a volcanic area. Steep incline. Everyone go slowly!

14. Umatac River - Leave vehicles by the bridge south of Umatac. Walk upstream on a road (north or east side of the river) which turns into a path at the water-monitoring station. A weir there creates a small waterfall. Ask the house nearest the weir for permission (manners again) and continue upriver to the fork. Up the north (east?) fork is a ranch with a large boggy (spring-fed) meadow which is great for broken ankles and surprise encounters with dripping carabao. They rise ponderously from mudholes you didn't notice. The river is shallow, rocky and always registers a high coliform count, so don't drink. This is probably the 'freshest' river water on Guam, as tidal influence is never great and stops at the weir.

15. Namo River - Can be reached from the bridge between Naval Station and Agat. The floodplain is huge and the mud is pretty thick.

16. Rizal Beach - At the back gate to Naval Station. Turn off toward the ocean and park at the beach. Cross the stream that empties across the beach and turn inland. A small but amazingly diverse marsh is here. The mud has enough sand to make getting around fairly easy.

17. Naval Station - Just before the main gate at Big Navy on the inland side of the road, are two large sites that join quite a distance back from the road. The first can be reached by scrambling down at the bridge; it's tidal for a short distance but has both swamp and marsh. The mud is deep. The other site can be reached on an overgrown roadway. It runs between a small, horrible-looking-and-smelling creek and the chain-link fence that is the Naval Station boundary. This is a freshwater marsh which has some open water but is deceptively covered with tall wetlands grasses. You won't be able to tell where the water begins - but it's sooner than you think!

18. Atantano River - The Atantano goes under Marine Drive near the motorcycle shop. A good trail leads to a mature mangrove stand at Apra Harbor. Since it's near Polaris Point you might ask Navy permission. The inland flood plain is huge and has marshes, swamps and mud. Access, except along the roadside, is difficult.

19. Laguas River - South of the Piti power plant (USO, etc.) Marine Drive passes over the Laguas. The harbor side is a young mangrove stand, the inland side is a brackish-to-freshwater marsh that is as well-zoned vegetationally as any site on Guam. Access, except from Marine Drive, is difficult. The mud is extensive and slippery where it's shallow.

20. Fena Lake - This is an artificial reservoir at Naval Magazine. It is not accessible to classes, a shame since it's the only lake community on Guam. It wouldn't hurt to ask for permission from the Navy, but don't be surprised by a 'no' answer. You can probably go there on a USO Boonie Stomp!

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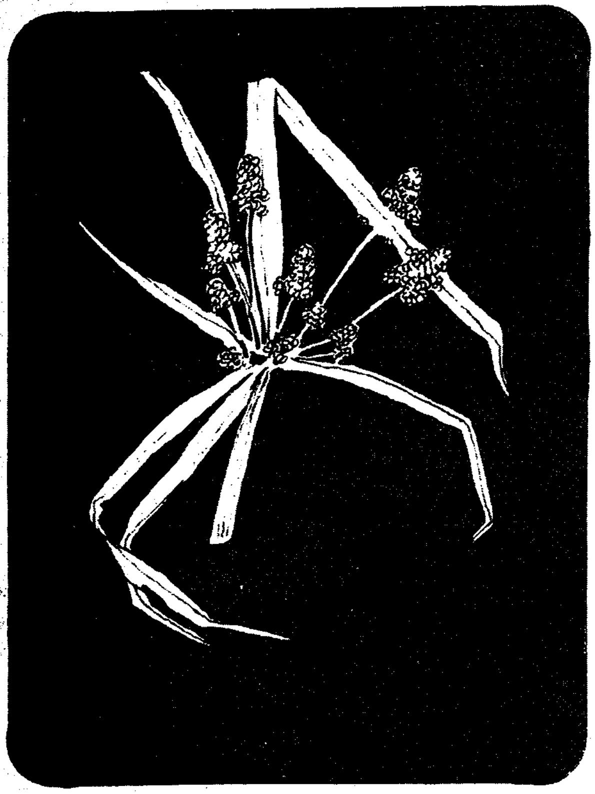
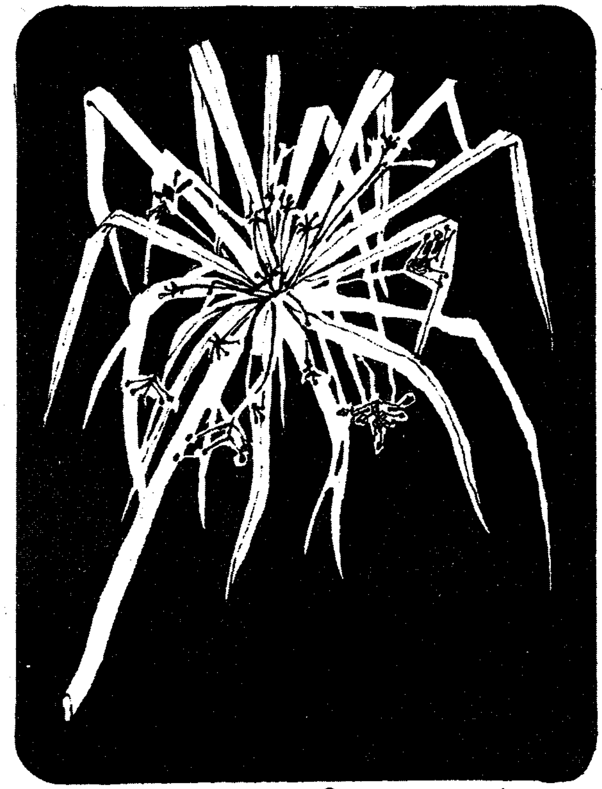
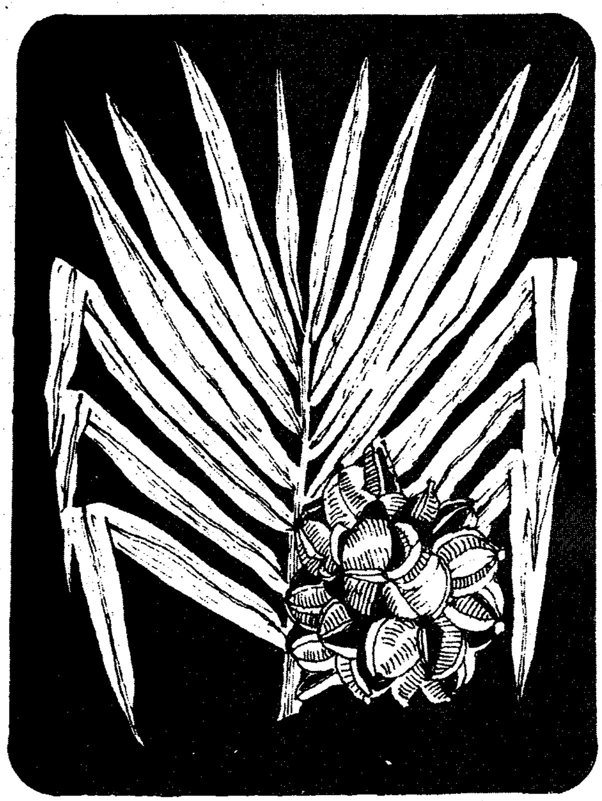


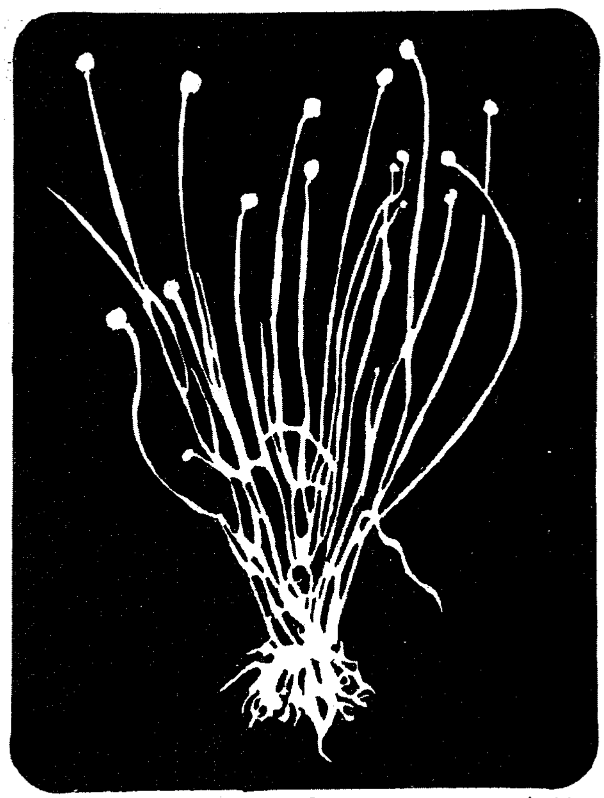
Cyperus sp.
rocket sedge



Cyperus alternifolius
umbrella sedge



Nypa fruticans
nipa



Eleocharis geniculata
spikerush