Life On Guam
Coral Reef

by Richard H. Randall and L.G. Eldredge

art Terry Palumbo and L Hotaling

Life On Guam

...a project to produce relevant class, lab, and field materials in ecology and social studies for Guam junior and senior high schools. Funding is through a grant under ESEA Titles III and IV, U.S. Office of Education——HEW——whose policy, position, or endorsement is not necessarily reflected by the content herein.

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

The other units of this project and their authors:

Beach Strand	Margie Cushing Falanruw
Farm and Garden	Philip H. Moore
Freshwater	Lynn Raulerson
Geology	Gail Elkins Dave Hotaling Richard H. Randall
Human Impact	M. C. Falanruw
Limestone Forest	Larry Behrens
Mangrove Flat	Gaylord Diaz Dave Hotaling
Savanna, Old Fields, Roadsides	M. C. Falanruw
Schoolyard Ecology	Jeffrey E. Shafer
Schoolyard Surveys	Magdalena T. Flores

Prepared with the assistance of
L Hotaling, design and layout,
Jane Grobins, format,
special editors Tere Rios-Versace and Wayne Dapser,
and the Learning Resources Center

Junior/Senior Edition - 1977

Project Director and Editor: Dave Hotaling
Secretary: Bertha Tanaka
Consultants' Office - Department of Education - Guam

Life On Guam
Coral Reef

by Richard H. Randall and L.G. Eldredge

art Terry Palumbo and L Hotaling

R. H. RANDALL

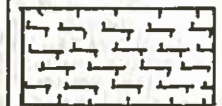
L. G. ELDREDGE

Contents

Key to Reef Profile Maps

VOLCANIC ROCK

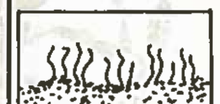
CORALS AND CALCAREOUS ALGAE



FRAMEWORK REEF DEVELOPMENT

DEPOSITIONAL REEF DEVELOPMENT

SEDIMENTS



SEAGRASS

RUBBLE

DIRECTION OF SEDIMENTS ERODED FROM REEFS

I - What's What

What is a coral reef—what's it made of, how are its parts arranged, how did it form?

We're still asking lots of questions about reefs, even though they've been explored and studied in depth. Here's one explanation, modified after John Wells of Cornell University, who has spent a good part of his life on coral reefs.

> *Coral reefs happen because of a long series of related events in warm shallow marine water. The warmth, light and food in the shallow water provide a perfect environment for reef building. In general, reefs are built by 2 kinds of organisms: corals, which are animals, and calcareous algae, calcium-containing plants. They take in seawater containing food and calcium. The organisms attach this calcium to the substrate (the bottom) and it interlocks and encrusts there with other material. This forms a framework on, in and around which sediments collect. The sediments come from organic and physical breakdown of organisms and the frame itself. The sediments can mass together in a volume a lot bigger than the frame.*

Sedentary marine animals usually have a small, weakly-swimming larval stage. The larvae can meander off from the stay-at-home parent and be carried into the open ocean. They may drift onto a reef many miles away. But when they metamorphose—change into adults—they attach to some reef surface and stay there for the rest of their lives.

Corals The eggs of most reef corals are fertilized inside the parent. There they hatch into larval planulas (plan = flat; ula = little). They swim away by waving their cilia, tiny hairs. Before settling down, a planula might wander a few hours to more than a month. Then it metamorphoses and becomes a permanent attachment.

Algae Some plants also are very important in reef building. Calcareous algae are seaweeds that take in calcium ions from seawater and secrete them as solid calcium. When they reproduce, parent algae release spores and/or gametes. Spores are small individuals that can become adults; gametes are male and female cells that can unite to make new individuals. (Look up spores and gametes in biology reference books.)

You can hardly get here from there. . .

To sum up, corals and calcareous algae and many other plants and animals of a reef community make hard mineral skeletons. Some skeletons are on the inside, some are on the outside. Many organisms live stuck to the reef surface, and their skeletons stay there when they die. New reef dwellers settle on and attach to old skeletons, overgrowing them by depositing their own minerals. Each new generation lives on the remains of the brothers gone before. That's how a reef is built.

Oceanic Transportation

Guam is isolated from large land areas. Our climate includes occasional typhoons. So, we don't have a very wide assortment of land plants and animals. The ocean prevents the migration of many terrestrial plants and animals, and typhoons often cut down the populations of local species.

In the marine environment, it's a different story. Ocean currents are a great transportation system. These currents carry marine plants and animals great distances. The organisms may come to an island like ours and become established as part of the coral reef flora and fauna. So we have a greater diversity of marine life around Guam than terrestrial life on the Island. Over 600 species of crustaceans are around Guam, more than all the species of native flowering plants on the Island.

Energy Flow

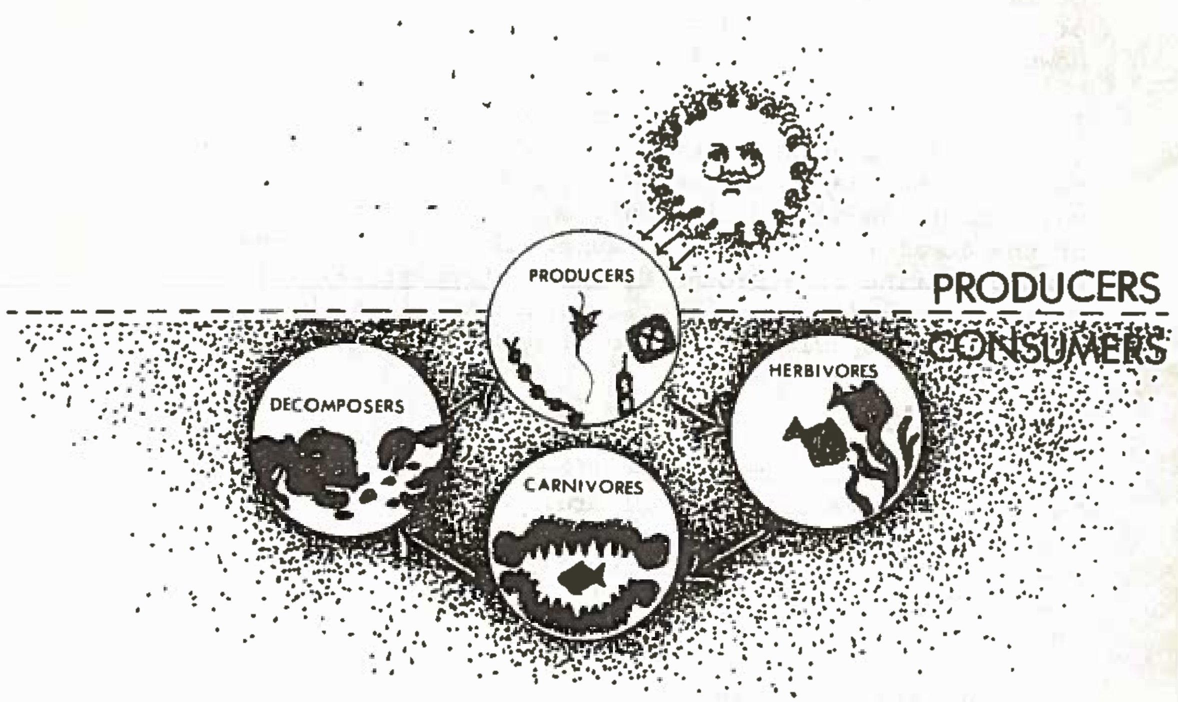
Energy flows many ways in a living system, but most energy comes originally from the Sun. In communities like the savanna, limestone forest, mangrove flat, schoolyard, coral reef and any others, organisms stay alive because they get this energy. Green plants capture the Sun's energy directly. Using it, they change CO_2 and H_2O into themselves, that is, plant tissue; and 'waste' product, O_2. In an energy system, the green plant is the producer. Algae——the seaweeds——are green plants and therefore producers, even if their green is hidden by yellow, brown, red or blue.

Lots of energy from the Sun goes into space. A little of it gets to Earth. A little of that gets to reefs. Still less is captured by reef plants, the producers. Producers are the link between the Sun and life in the reef system. When plants are eaten, a little of their stored energy is used to drive the life processes of animals that eat them.

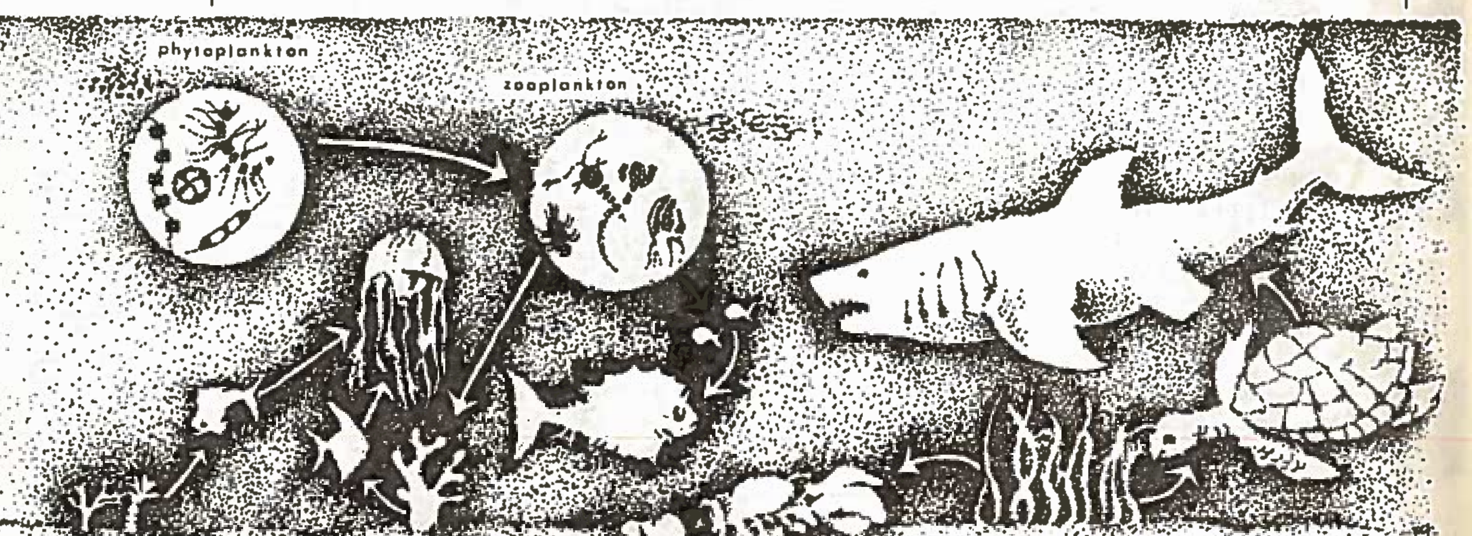
Goniopora - 1 cm long, .75 cm across

Animals can't make their own food. They are consumers. They depend on producers for food. Herbivores are primary consumers ——they eat plants. Carnivores are secondary consumers, eating herbivores, and each other. Organisms that eat dead producers and consumers are decomposers——the bacteria and fungi.

Without decomposers, energy flow stops. Producers and consumers leave leftovers, including their dead selves. Decomposers change leftovers into simple organic compounds. These are used by new producers to synthesize new food. Consumers eat the new food. So the cycle is completed, and it continues. Here you see energy flow on a reef:



Energy is transferred from organism to organism by feeding. A lot of these transfers together make a food web. Each organism in the reef community fits somewhere into the community food web.



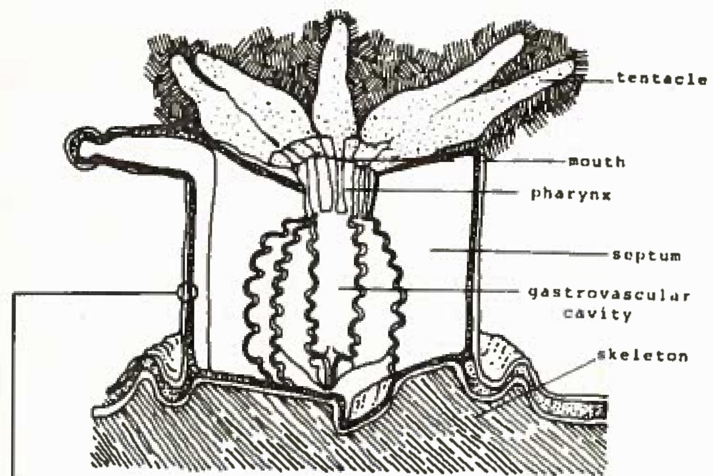
Recycling

Food is produced at a high rate in coral reefs. For a long time biologists compared a coral reef to a desert oasis, and wondered, 'How can coral reefs maintain their high rate of productivity?' The answer: Recycling. Even though the nearby ocean isn't rich in plankton and nutrients, it does supply some——in currents carrying water over the reef. Once the reef gets the nutrients, it recycles them quickly and efficiently, over and over, through the food web. (How can we apply this efficient system of recycling to our own communities?)

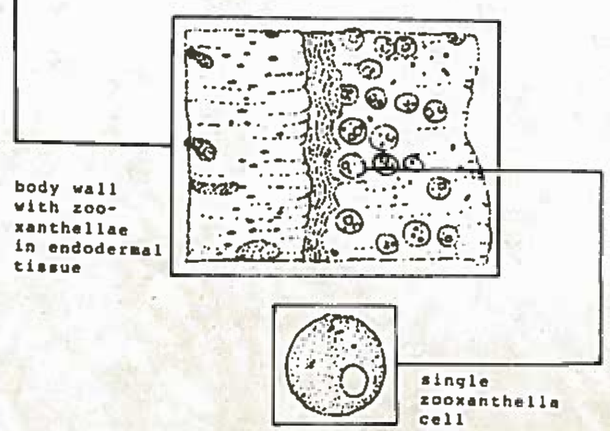
Where Reefs Are

Coral reefs develop best between 30°N and 25°S latitude, where the annual temperature range is between 25°C and 30°C. (What is Guam's latitude——what is the temperature range in our waters?)

Why Reefs Need Sunlight



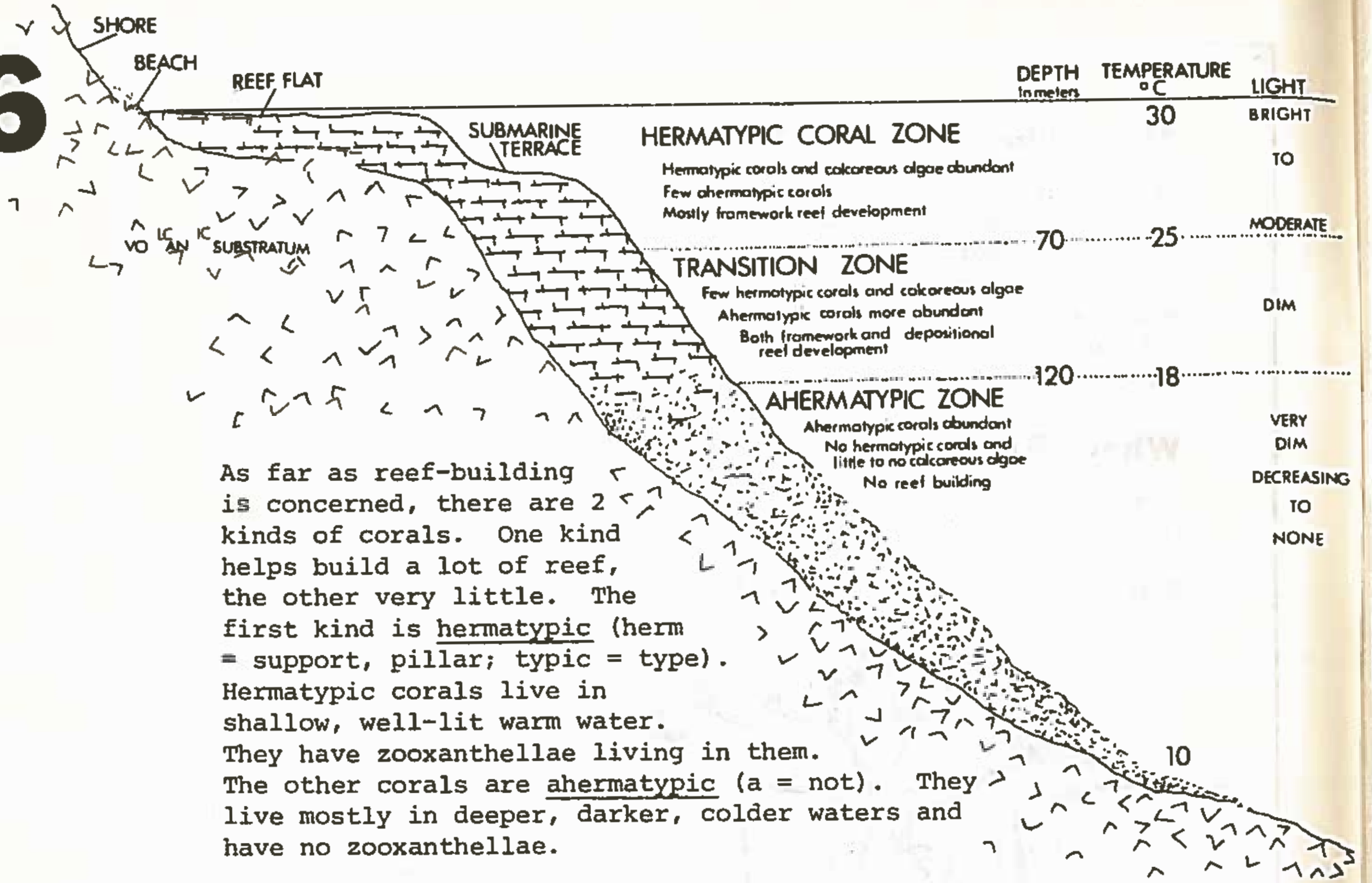
INDIVIDUAL CORAL POLYP WITH ZOOXANTHELLAE IN ENDODERMAL WALL



Water absorbs light. The deeper down you go, the less light there is and the fewer reef-building corals there are. To build reefs, the coral animal needs many single-celled plants ——algae——in its tissues. The algae need sunlight to photosynthesize.

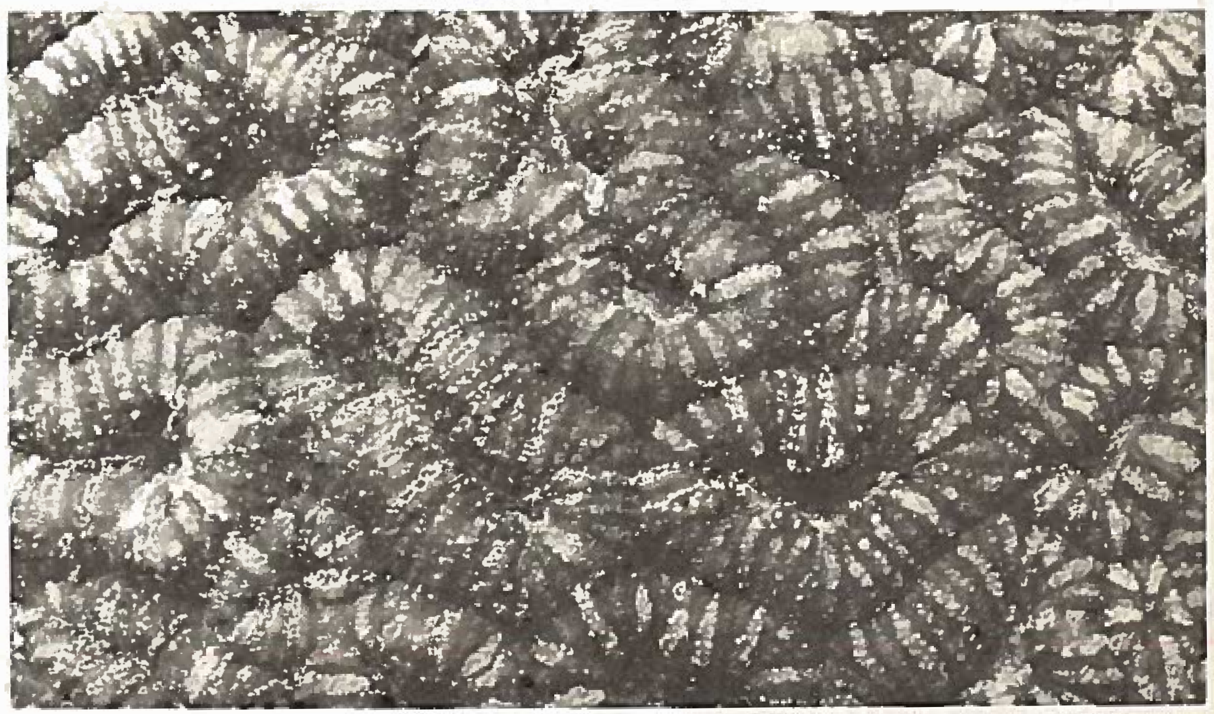
The tiny, brown, one-celled algae that live in various corals are zooxanthellae——zo-o-zan-thel'ee. (Some early biologist got confused, and called them 'little yellow animals'. He got 2 out of 3 on this: zo = animals, not o.k.; xanth = yellow or brown, o.k.; ellae = little ones, o.k.) They live only in the inside skin of coral. Their numbers can be very high: as many as 30,000/mm^3.

Zooxanthellae give much of the brown color to corals, although many corals have other pigments that can hide some or all of the brown. Above is a coral polyp with a few zooxanthellae.



As far as reef-building is concerned, there are 2 kinds of corals. One kind helps build a lot of reef, the other very little. The first kind is hermatypic (herm = support, pillar; typic = type). Hermatypic corals live in shallow, well-lit warm water. They have zooxanthellae living in them. The other corals are ahermatypic (a = not). They live mostly in deeper, darker, colder waters and have no zooxanthellae.

To make reefs, you have to put up framework fast. Hermatypic corals can do it. They grow fast and deposit hard skeletons rapidly. A single colony can have over 30 million polyps and be more than a meter across. Ahermatypic corals are small and many are solitary. They grow slowly. This diagram shows where hermatypic and ahermatypic corals live. How deep are they? How much light do they have? What temperatures do they live in?



Lobophyllia - life size

II - The Way It Was - History of Guam Reefs

60 - 25 Million Years Ago - Eocene and Oligocene Epochs

NOTE: Times are approximate (don't set your watch by them).

Mt. Alutom Most likely, Guam's first coral reefs grew around volcanic Mt. Alutom, in the central and oldest part of the Island. In the shallow waters around that Eocene-age mountain, small limestone reefs could have developed.

However, a live volcano and a growing coral reef don't mix well. To really get going, a reef needs a fairly stable shallow water platform and a time of little or no volcanic activity. With a volcano's periodic eruptions, a reef would get buried in hot lava and ash.

So, the newly-forming volcanic Guam didn't let reefs grow much. Later on, our volcano must have gone through a long dormant stage. Then the coral reef made up for lost time.

In the late Eocene and into the Oligocene, volcanoes exploded. Look at the lava flows in the Alutom rocks of central Guam——you can find irregular, angular limestone fragments jumbled up every which way. It means that eruptions broke up the reefs and ash and molten lava engulfed them.

25-11 Million Years Ago - Miocene Epoch

Umatac Formation During the Miocene, volcanic activity again broke out. It left lava and rocks on southern Guam, producing the Umatac formation. History probably repeated itself——reefs grew again, only to be broken up by eruptions. At Agat Jr. High and as you go along the high-way from Agat to Merizo, look at remains of fringing coral reefs in the steep mountain slopes. There are the telltale angular limestone reef fragments mixed with lava flows and ash deposits.

Late in the Umatac formation, thin layers of limestone are streaked with volcanic deposits.

Bonya Limestone After the Island's volcanic activity stopped, wide Miocene reefs developed. You can see their remains in Bonya Limestone in Guam's central lowlands and along the east coast. As these reefs were being formed, the Island slowly began rising. With more land above the sea, there was also more erosion. More silt and freshwater washed to the coasts and streams. Reef building slowed down.

The rising Island gradually ended the formation of Bonya limestone. Erosion cut platforms in the volcanic slopes.

Alifan Limestone Then, about 14 million years ago, the Island began sinking. Reefs got new layers of coral which became Alifan limestone. Sinking continued and fringing reefs built up. Less and less of the Island was exposed to erosion above water. Reefs flourished.

With submergence, barrier reefs grew around the Mt. Alifan-Mt. Lamlam ridge. Maybe an atoll-like reef—a ring of reef around a lagoon—surrounded the ridge. Evidence from the time shows that Guam was then 3 island areas: the southern mountain ridge from Mt. Sasalaguan to Mt. Jumullong-Manglo, the Mt. Tenjo-Mt. Alutom ridge in central Guam, and in the north, a smaller island at Mt. Santa Rosa. Terraces had earlier been cut around these islands. Fringing reefs grew on them.

11-2 Million Years Ago - Pliocene Epoch

Barrigada Limestone Here and there south of Mt. Santa Rosa thick reef deposits collected. These formed the Barrigada Banks. By the early Pliocene—10,000,000 years ago—slight uplift made shallows of this broad submerged area. Reefs then grew, depositing Barrigada limestone.

Emergence of the Island continued in slow motion, thousands of years at a time. Alifan and Barrigada limestones stopped forming. Faulting happened at the same time as the Island's uplift and emergence. (For faulting, see the LOG unit, Geology, pp 11, 13.) Parts of the earlier limestone deposits and volcanic areas were again exposed to erosion.

Mariana Limestone In the late Pliocene, Guam started sinking again. Reefs flourished along the flanks of the southern and central volcanic mountains and on much of northern Guam. Reefs that grew at this time are Mariana limestone, our most extensive reef remains.

2,000,000 Years Ago - Start of the Pleistocene Epoch

Mariana reefs continued to grow well into the Pleistocene. They stopped when the Island rose again. During re-emergence, more faulting went on. The Mariana limestone area and probably the whole Island were tilted toward the southwest.

Pleistocene geology here is hard to figure out. The Island didn't rise evenly. It 'bounced' up and down. Faulting also shoved parts of Guam up and down.

Late Pleistocene geology became even more complicated with major shifts in the shoreline. In other parts of the World, glaciers and ice sheets forming and melting made sea levels everywhere fall and rise. The notches in the cliff face at Amantes Point were cut in periods of stable sea level during glacial or interglacial time. (See photo, Amantes Point, below, and nips, p 15.) During these ups and downs, reef building and erosion formed terraces all along the shoreline. Three terraces at Pauliluc Bay are shown below.

These activities went on hundreds of thousands of years ago, and happened very slowly. Now, all around us, in the waters off the Island, more reefs are building. They will change the shape and character of the Island some more. Hundreds of thousands of years from now it could be nothing like it is today.

Amantes Point, with at least 7 nips. These indicate former sea levels. The bottom 3 are probably the most recent. (Why?) The upper 4 (toward the left) are less distinct, because of erosion and dripstone deposits.

The fresh water of Pauliluc River and its sediments keep corals from growing in the shallow upper bay. Where the bay deepens, the fresh water is diluted. Corals can grow. They close in on each other across the mouth of the bay.

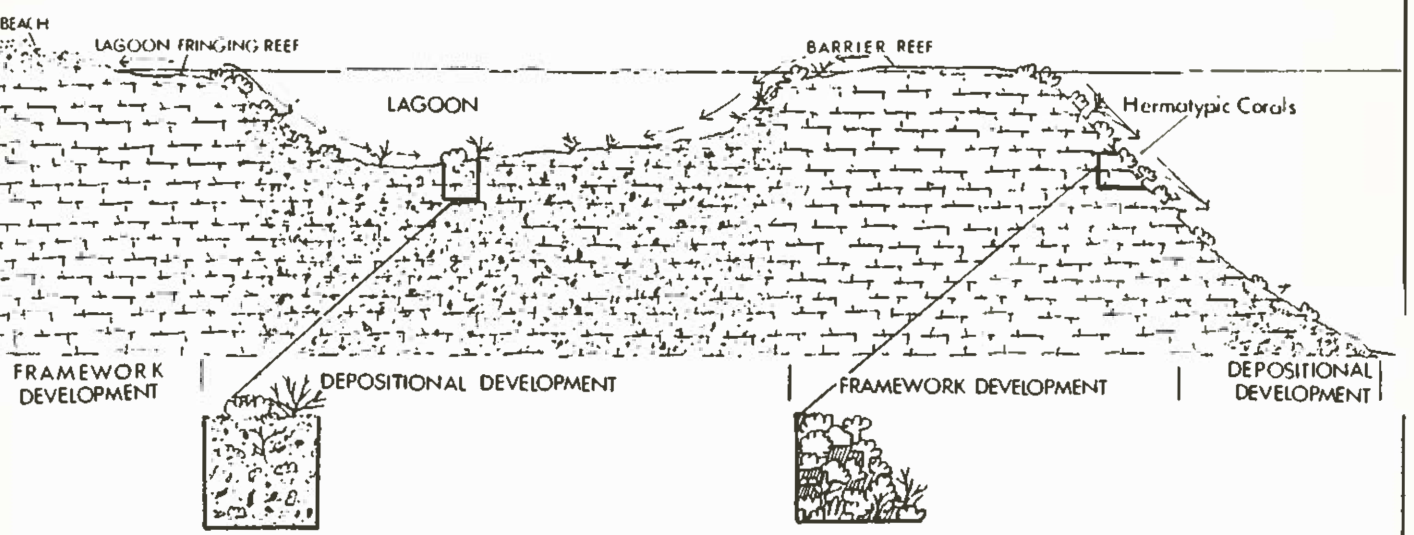
III - What's Going On Here - A Closer Look

Framework and Sediments

A reef has 2 main non-living parts: framework substrate and sediment. The framework is cemented together by living organisms. It is the reef's foundation, built layer by layer, mostly of reef corals and calcareous algae. Wherever these grow best, there you have good reef framework. Where strong currents and surf come together, the framework absorbs wave energy and the reef survives. Without the framework, there is no reef.

Erosion

As soon as the framework starts to form, erosion gets going. Waves break off pieces here and there. Like sandpaper, gravel and sand carried in the water wear the framework down. Organisms eat, bore, scrape and dissolve. All this removes pieces of the framework, and makes sediments. Sediments are loose sand, gravel and rubble from the eroding framework, and pieces of other residents in the area. Reef sediments can be deposited around the framework and built to a large mass. Or they can be carried away. The sea reclaims some of them in solution.



To stay the same size or grow larger, the reef framework has to beat erosion. It must grow back as much as or more than erosion wears away. What happens when reef framework growth is less than erosion? A typhoon, a disease, the Acanthaster starfish, sea level changes, man-made pollution——these might reverse the balance. Then erosion, gnawing away at its usual rate, would slowly let waves in on the sedimented places. Poorly cemented or loose sediments would quickly wash away. The reef would disappear. The shoreline would be exposed. The Island would lose ground.

Reef growth and erosion happen all the time, and erosion occurs everywhere on a reef. At the reef edge, where wave energy is strongest, a lot of coral sediments are made. More sediments come from the hard parts of other reef animals and plants——algae, Foraminifera, sponges, soft corals, mollusks, and sea cucumbers.

Sediment Sampling

When you visit a reef, dig into some sediments. They can tell you a lot about the reef. Measure the thickness. Collect samples to take back to school for analysis. Separate part of your sediment samples by size.

TABLE I SIZE OF REEF DIMENTS

Diameter in mm	Sediment Type	
more than 256	Boulders	
64 - 256	Cobbles and Rubble	
2 - 64	Pebbles or Gravel	
0.06 - 2	Sand (coarse to fine)	
0.004 - 0.06	Silt	(fine)
0.00024 - 0.004	Clay	
less than 0.00024	Colloids	

Use Table I to classify sediments by size. It takes greater wave energy to move a heavier particle than a lighter one. Does the size of sediments affect their distribution? If so, how?

Try to identify and tell what or where they came from. Maybe your sediment sample was collected near a river mouth——rivers carry eroded land to the reef. Sediments from the land on Guam are mostly volcanic and dark brown, black or green. You can tell them from the lighter-color reef sediments, but watch out for a few red fragments of Foraminifera! Use Table II as a guide to tell what your sediments are made of.

TABLE II SEDIMENT COMPOSITION

Origin of Sediment Materials

Land	Reef
Volcanic debris (clay silt, sand, gravel, cobbles)	Calcareous algae (solid sticks or flat sections, whitish)
	Corals (calcareous material, usually white to cream, sometimes blue with holes, radiating stars)
	Foraminifera (small discs or stars, most cream or tan, some red)
Organic debris (twigs, grass, bark, leaves, some shells)	Mollusk shells (whole or pieces)
	Sponge spicules (needle-like rods)
	Sea cucumber sclerites (warty rods, thicker and blunter than spicules)
	Soft coral sclerites (also warty rods)
	Organic debris (seagrass leaves and fleshy algae)
	Unidentifiable material

Questions to consider in sediment analysis:

1) Which organisms contributed the most to your samples? What did they contribute?

2) What is the percent of each sediment type in your sample—how many per 100? (You get percent by dividing the weight of one sample by the total weight of all the samples, and multiplying by 100. If you don't have a scale to weigh the samples, you can find percentage by measuring their volume. The total volume of one group, divided by the total volume of all groups, times 100 = percent.)

3) Using your percentages, graph each sediment sample. Then you can easily compare samples. Compare your graph with others. What do you think is the cause of any differences?

4) Graph the sediment samples by size. Compare their sizes. Compare graphs from different parts of the reef. What could make any differences?

5) Where do the different sizes come from?

Waves and surf are strong on the outer reef flat, carrying lightweight sediments shoreward. Storm waves can break off chunks of the reef framework and roll them across the reef margin onto the reef flat. Did you see any blocks like these on your reef flat? Storms can pack boulders and rubble into fields or make long lines of them. Islets start this way, like the one on the outer reef flat at Tumon Bay. (See map, p 14.)

Depositional Development

Since sediments are loose—neither cemented together nor anchored—currents and waves can easily carry them away from the reef framework and deposit them elsewhere. Behind and in front of the reef framework the sediments build up, layer by layer. They may be large, noticeable parts of the reef system. This is the second way that parts of a reef may form. We call it depositional development. (See diagram, p 10.) The amount of reef that develops by deposition may be many times larger than the framework itself.

Pleurogyra - each bubble 1-1.5 cm

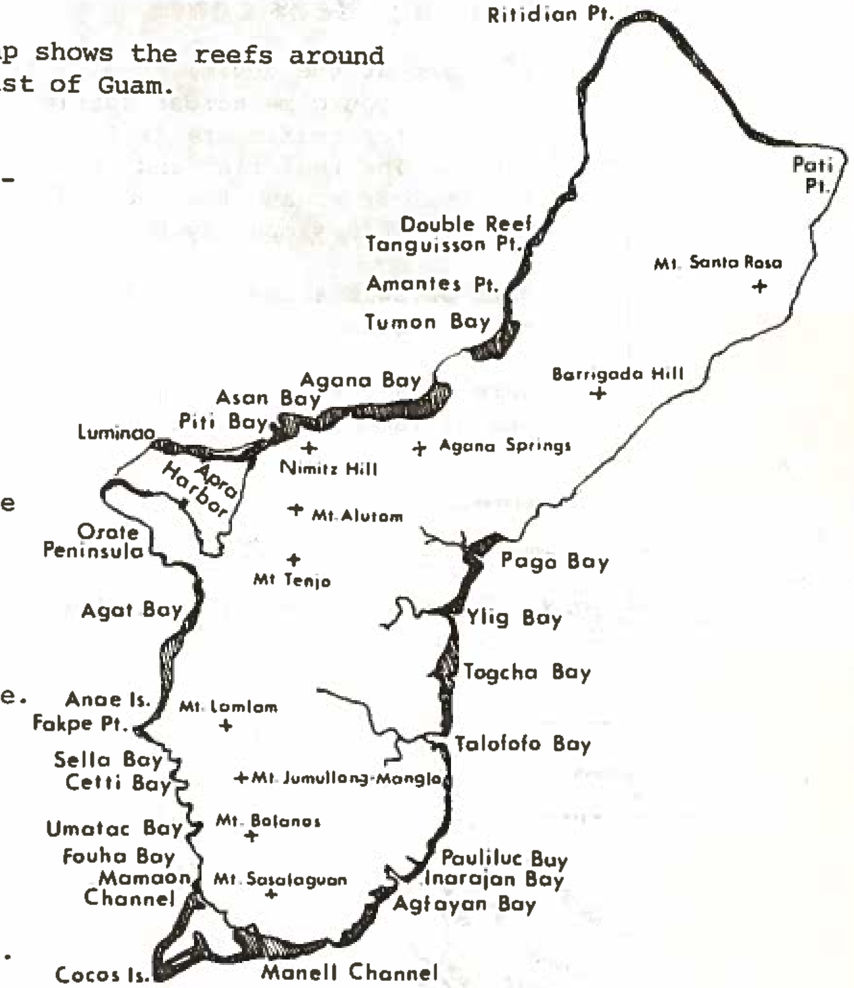
Acropora - branch, 1 cm diameter

IV - Where Is It?

Let's take different places on the reef and look at what's there. Let's see how Guam's reefs are made and shaped, and how the various shapes relate to their environments and the many different kinds of organisms that live on them.

Kinds of Reefs

This map shows the reefs around the coast of Guam.

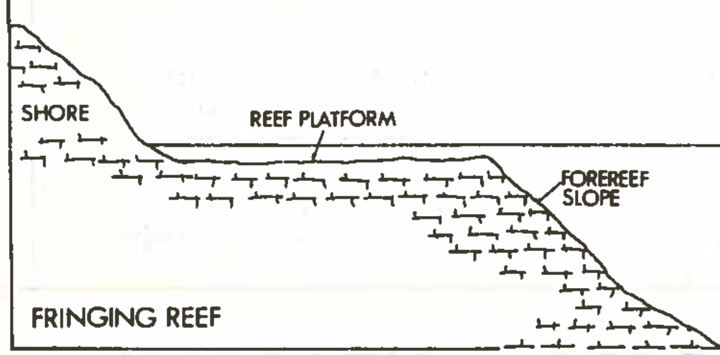


Several things stand out on the map: First, Guam isn't surrounded by reefs. The shore around Guam is half fringing reefs. These are shallow reefs not separated from the Island. A quarter of the shore is sea-level benches, and the rest is sea cliffs, mangrove swamps, offshore barrier reefs, or volcanic platforms partly covered by reef deposits. Algae and corals live all along the shore. Other reef organisms also live there.

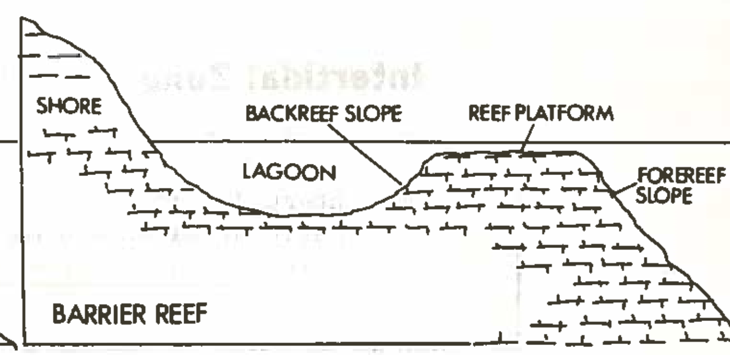
The shapes of fringing reefs vary; some are narrow, some wide. Some are split by rivers going through them. Find the differences on a map or in aerial photos of the Island.

Guam has 2 barrier reefs, Cocos and Luminao. Barrier reefs are separated from land by a lagoon.

Here are diagrams of fringing and barrier reefs and their 2 main divisions, reef platform, and at the seaward edge, the forereef slope. The backreef slope faces the land.



FRINGING REEF



BARRIER REEF

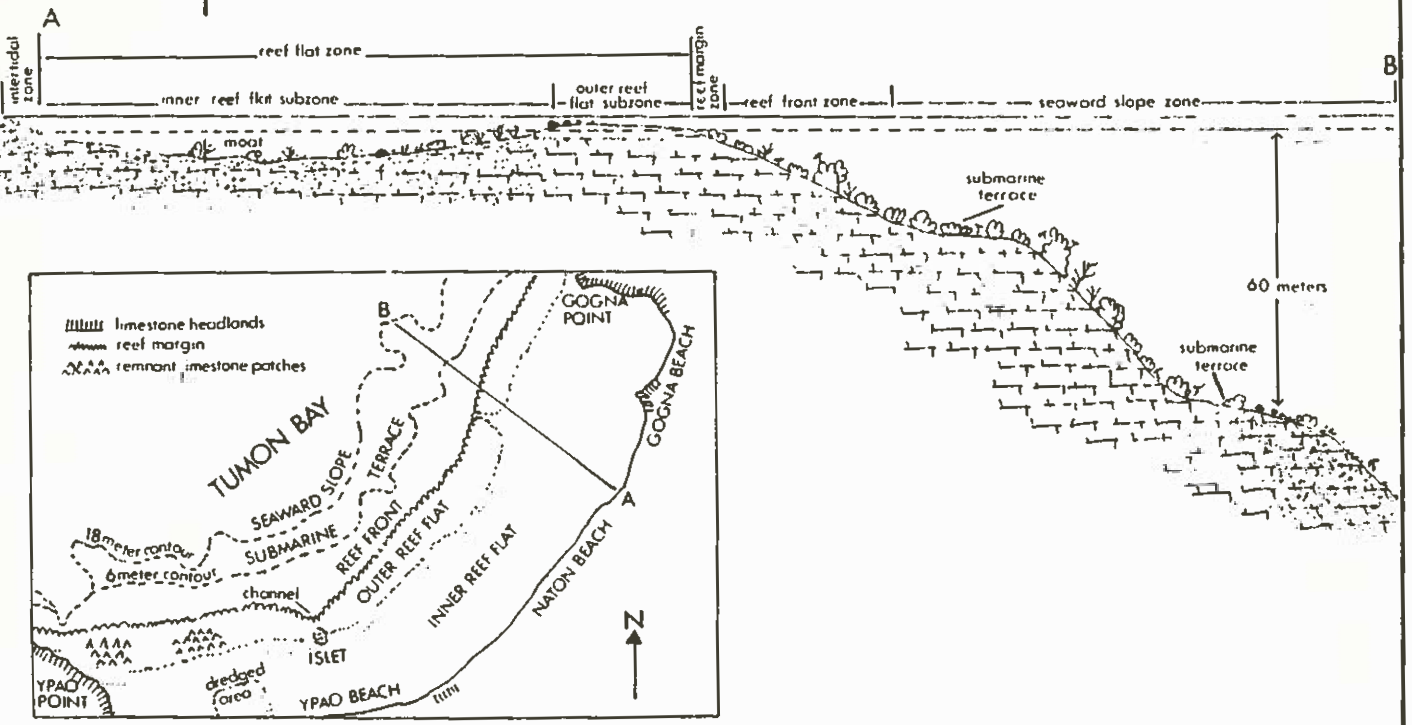
These divisions of the reefs have different, easily recognized zones. Each zone has different surface materials, topography, kinds and numbers of plants and animals, water depth and currents, and action of waves and surf.

Fringing Reef Zones

Starting at the shoreline of a fringing reef and exploring seaward, you come across the intertidal zone, the inner reef flat, outer reef flat, reef margin, reef front and seaward slope. The reef flat and reef margin are part of the platform. The reef front and the seaward slope are part of the forereef slope. This slope may have one or more horizontal terraces.

Walk or swim across a reef and notice the differences from zone to zone.

Here is a vertical profile of the fringing reef at the north end of Tumon Bay, and a map of the same region.



Intertidal Zone

At high tide, this part of the shore is covered by water. At low tide, it's uncovered. It can be wide or narrow, depending on the slope.

The intertidal zone is not really part of the living coral reef. It's built by water and marine organisms which sculpt and erode materials from nearby reef and shore.

Nips - Where the intertidal zone is steep or vertical, horizontal grooves called 'nips' are made.

Tumon Bay. Nips in the rocky shore. The lower one is being carved at roughly the same level as the bordering reef-flat. The upper nip was cut when sea level was about 2 m higher than now.

At first glance it may seem that waves alone cut nips. But there's more to it.

In a nip you find a gray surface above and a pinkish coating of encrusting algae lower down. Scattered all over are oval chitons (ky-tunz) of 8 plates, and smaller, one-shelled, hat-shaped limpets (pp 39, 40).

The gray layer is about 1 mm thick and has many microscopic threads of boring algae in it. Limpets and chitons eat them. During the day, limpets and chitons rest in pits they've made by dissolving the limestone. At night they move around. With their file-like tongues they scrape rock for the algae that have bored into it. As daylight comes, they return to their home pits. (If you cut a groove across their outbound track, will they cross it coming home?)

So, living algae, chitons, and limpets cause a good deal of biogenic erosion.

Freshwater on the Reef - Freshwater runs from the land into the sea; not just from the land surface and rivers, but also from the freshwater lens. (Look it up in Geology and Freshwater.) It seeps and flows from holes and cracks in rocky shores; it makes rills in sandy beaches. It so dilutes reef-flat water near shore that corals and some other marine organisms can't live there. It makes reef water look blurry. The nutrients it brings make some organisms, for example, Enteromorpha, grow fast. Lots of this bright green stringy alga in one place means that there's freshwater coming in nearby.

The Reef Flat

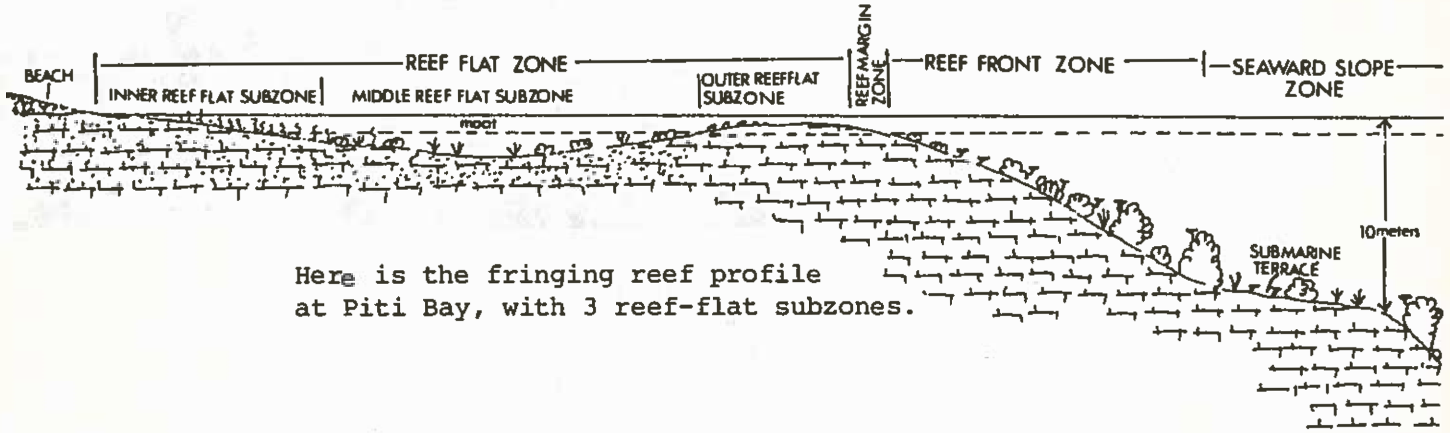
The reef flat is between the shore and the reef margin. At high tide, the water may be 2 m deep. At low tide, parts of the platform can be exposed. Guam reef flats differ in origins and topography.

'Topography': look it up!

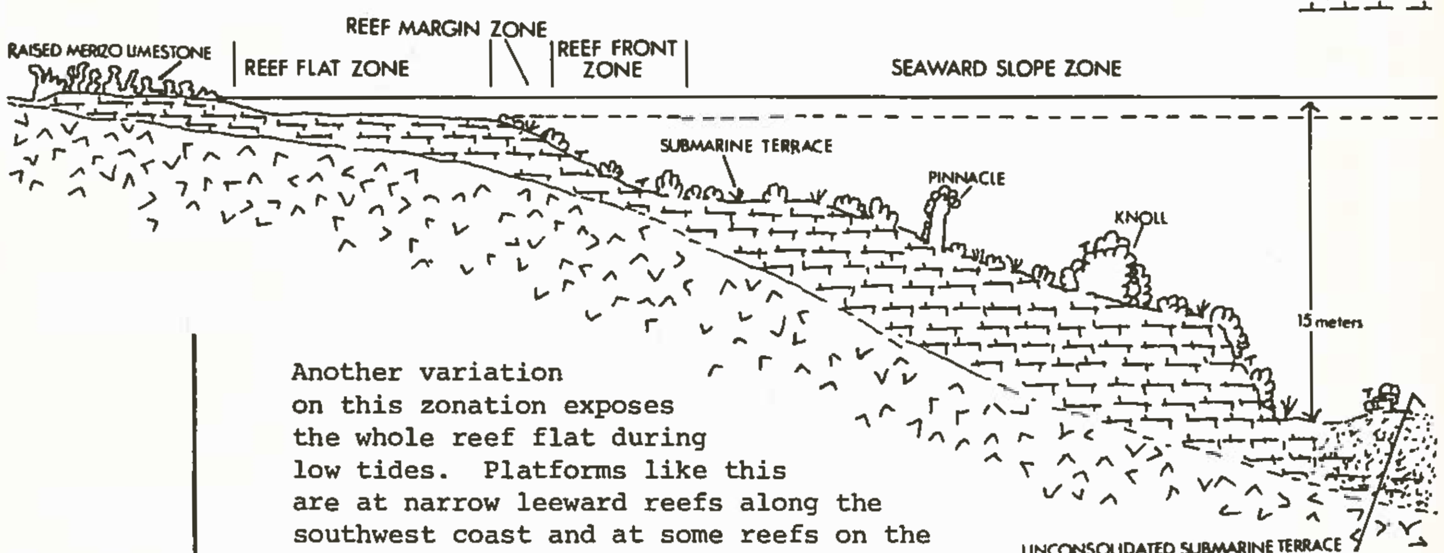
Limestone Flats - The most common reef-flat platforms here are of limestone formed during reef growth. Wide reef flats have developed from Tarague Beach in the north to Nimitz Beach in the south. Their outer parts are higher than the inner shoreward parts. Outer parts are often exposed at low tide.

This kind of reef-flat platform has 2 subzones—an outer reef flat, exposed during low tides, and an inner reef flat that stays covered at low tide. The water in it is the moat.

At a few places, especially along the southern coast, another kind of reef platform has 3 subzones: the above 2, both uncovered at low water, and between them a middle reef flat with a moat at low tide.



Here is the fringing reef profile at Piti Bay, with 3 reef-flat subzones.

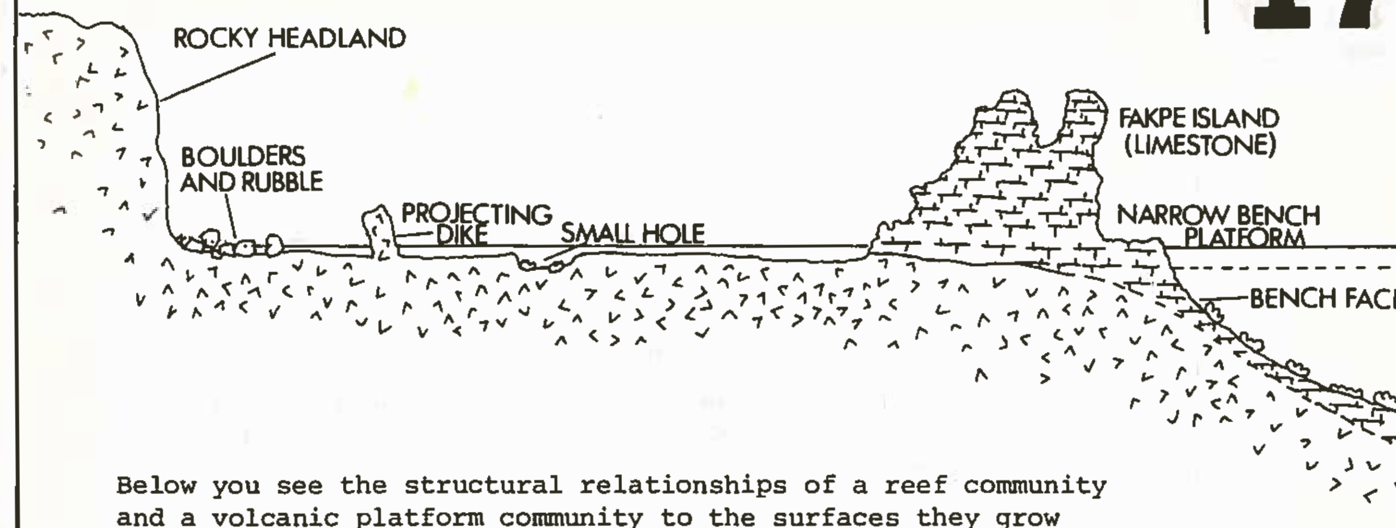


Another variation on this zonation exposes the whole reef flat during low tides. Platforms like this are at narrow leeward reefs along the southwest coast and at some reefs on the southeast. This is one example—a vertical profile of a fringing reef about 1 km north of Umatac Bay.

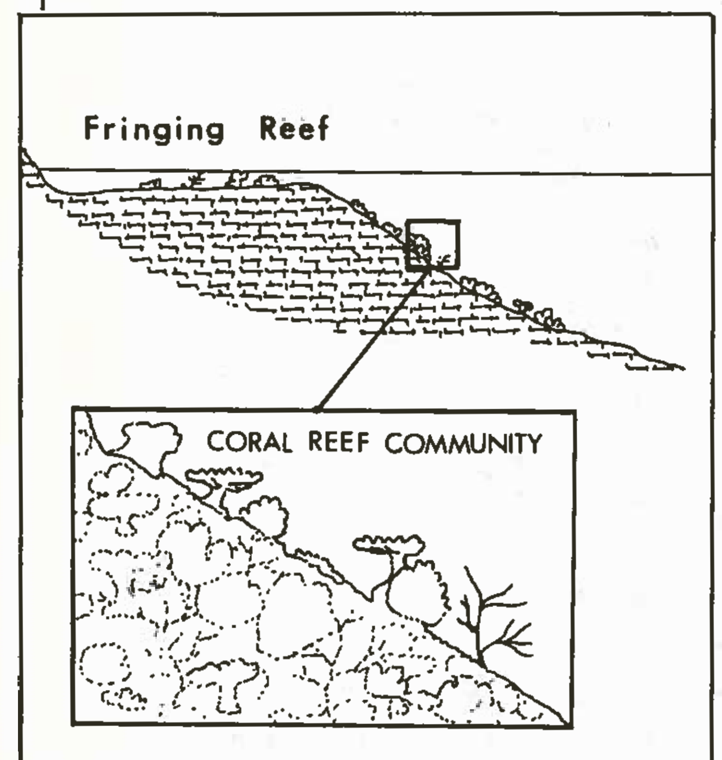
Sea Level Volcanic Platforms

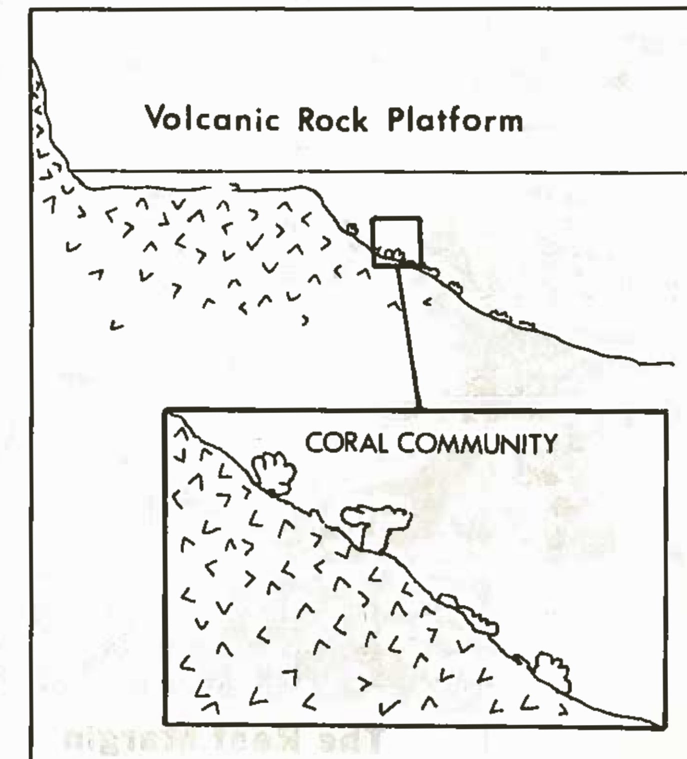
Where volcanic rocks have been cut to near sea level by marine erosion, they may look like fringing reefs, but don't be fooled! In some places, the inner parts are volcanic rock and the outer parts a thin layer of recent reef deposits. The southwestern and southern coasts have many platforms like this. One is about 1 km west of Adelup Point.

Another is at Fakpe Point, shown on the next page.



Below you see the structural relationships of a reef community and a volcanic platform community to the surfaces they grow on. The coral reef community grows on and contributes materials to its own recently produced surface. The coral community grows on an older erosional surface of volcanic rock.





Guam reefs are rich and varied. There are coral and algal colonies, several different kinds of communities, scattered depressions, low mounds, boulders thrown onto the platform by storm waves, and other things. Snorkeling or scuba diving will show you a lot more than wading.

<u>Living on the Reef Flat</u> - Visit a coral reef. Try to distinguish various zones. Draw them in profile. Which organisms live here at high tide? Which of them are still here at low tide? Where are they and where are the ones that aren't here?

Go to the reef at low tide and look at the exposed parts. Trapped pools of water are all around. Some are a few millimeters across, others a meter or more wide and just as deep. Some animals live in the pools all the time. Others stay there as the tide goes out. How do they do in a tide pool for several hours? How would they do exposed to the air?

Some fleshy algae survive low tides by forming a thick filamentous mat. The mat holds water like a sponge. Small worms, mollusks and crustaceans live among the wet algal filaments most of their lives. Other animals can survive being out of water for a little while. When they begin to heat or dry too much, they take shelter——in holes, under rocks, or in burrows in the sand. Reef structure is not completely solid, and some animals retreat into holes or burrow into sediments to a lower level. Here they find safety as well as water. How else do organisms adapt to low tide?

Three microatolls (<u>Porites</u> coral colonies) and boulders in foreground; dark reef blocks in background.

Coral larvae that settle on loose sediments get washed over and smothered by shifting particles. Survivors attach to solid substrate like reef framework. Even so, their upward growth is limited because most of them die if exposed to air. That happens at really low tides. So, they grow sideways, under water. They form 'microatolls', miniatures of true atolls. (What's an atoll?)

Continued growth this way gradually fills in the moat so that there's no space left. The algae and corals grow themselves out of a home. (Do people?)

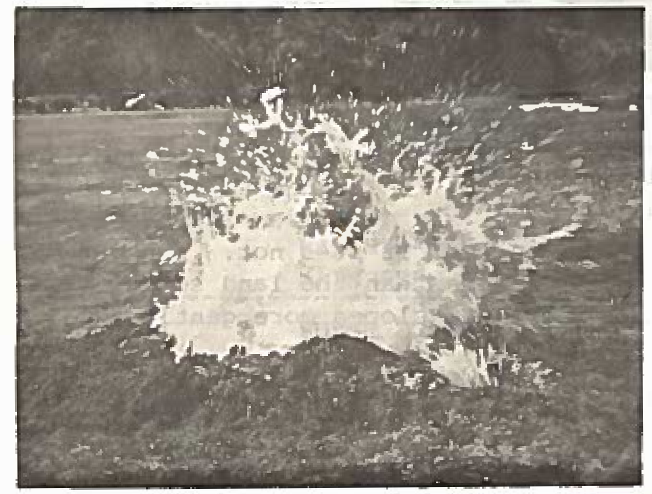
The Reef Margin

This is the reef flat's shallow seaward edge. Surf breaks here. Even at low tide, it's awash.

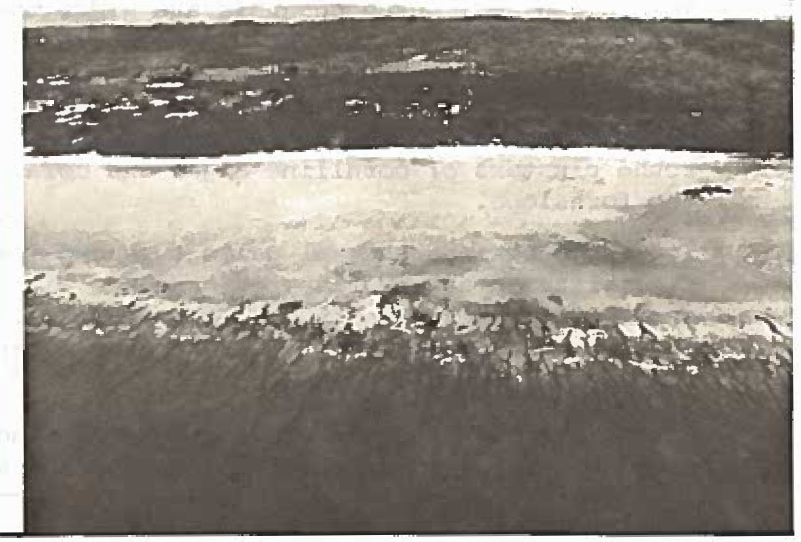
Here and on the reef front grows the richest assortment of the whole system. For instance, more than 200 species of corals grow on the forereef slopes; on the platform, fewer than forty.

<u>Surge Channels and Buttresses</u> - The margin's seaward edge is jagged. Between the buttresses are surge channels maybe 50 m long, 4 m deep and 3 m wide. A lot of reef growth is along channel walls. Corals and calcareous algae make shelves and grow toward each other from adjacent buttresses. They meet and make roofs for tunnels and caves.

Pago Bay. Rich growth of corals and calcareous algae at the upper edge of a reef margin surge channel.



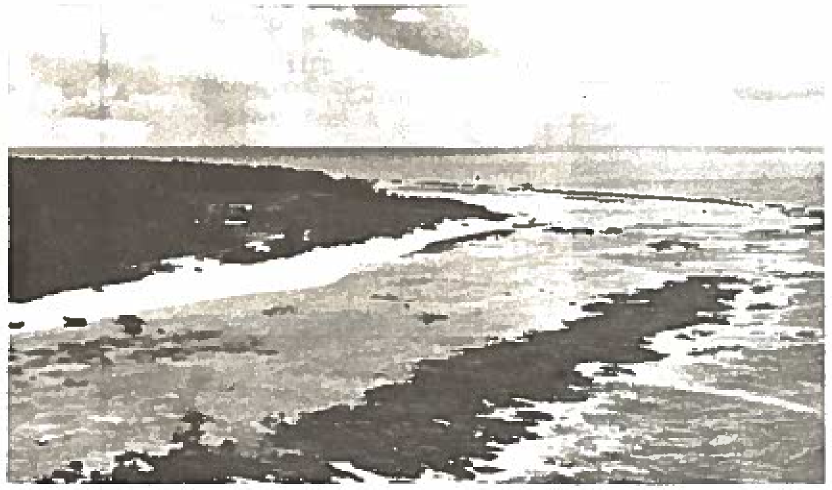
Water pushed through a cavernous surge channel by waves striking the reef margin is forced out through a blowhole.



Ypan. Wide fringing reef. Buttresses and surge channels make the outer edge jagged.

Most surge channels are wider at the bottom than the top. Shelves grow above. Currents roll boulders around below, eroding the bottom of the walls. Most boulders are encrusted with red algae, small corals, and other reef organisms. How does this show that the boulders aren't always on the go? (An old proverb may help you on this.)

Surge channels are separated by buttresses, walls that slope seaward from the reef front. In many places buttresses are irregular and honeycombed with holes. Algal ridges of encrusting coralline algae and some specialized corals grow in the reef margins exposed to constant battering.



Algal ridges, Ritidian Point——foreground, convex; background, cuestal

Algal Ridges - Along the seaward edge of some reef margins may be a long, low mound of algae and coral. This is an algal ridge. There are several around the Island. They grow mostly on exposed windward margins where waves are constant and vigorous.

Two kinds of algal ridge can develop here, convex if the reef margin is growing seaward, or cuestal if it's not. Both kinds of ridge are steeper on the sea side than the land side. The convex ridge is lower and wider, and slopes more gently than the cuestal one.

The *convex* ridge is the more common here. It has long surge channels. They are 2-4 m deep and 1-2 m wide, and cut across the ridge.

Toward the sea, surge channels are wider than they are toward the land. Buttress tops on opposite sides of a channel cantilever toward each other. They make some partial roofs, some tunnels, and some caves. The reef margin surface is honeycombed with holes connecting to the caves. Encrusting and many-branched round clusters of coralline algae and coral colonies grow on the foreslope.

Top and backslope channel walls fuse and form caves, or nearly fuse, leaving narrow fissures on top. With each advancing wave crest, water wells up through the fissures. As the following wave trough relieves the pressure, the water disappears into the cavernous regions below.

In the backslope, pools are common——roofing has eroded away, or hasn't happened. Corals and encrusting algae grow here.

A well-developed convex ridge may have a zone of dead reef behind the ridge crest, above high tide level. It is solution-sculptured by rainwater. Exposed to rain at low tide, it continues to erode. Probably it's the former location of the ridge crest which has since moved seaward to the zone of maximum wave wash.

The *cuestal* ridge grows where there is little or no seaward development of the reef flat platform. Its surface is fairly smooth and compact, with no extensive caves beneath.

It's narrow, up to 100 cm high, and steep——sometimes even concave on the foreslope.

Surge channels here are shallow. They seldom reach the reef platform. The foreslope grows encrusting algae. Soft, bottom-living algae cover much of the backslope.

Here is a table summarizing algal ridge characteristics. The sea is to your left, the reef flat to the right.

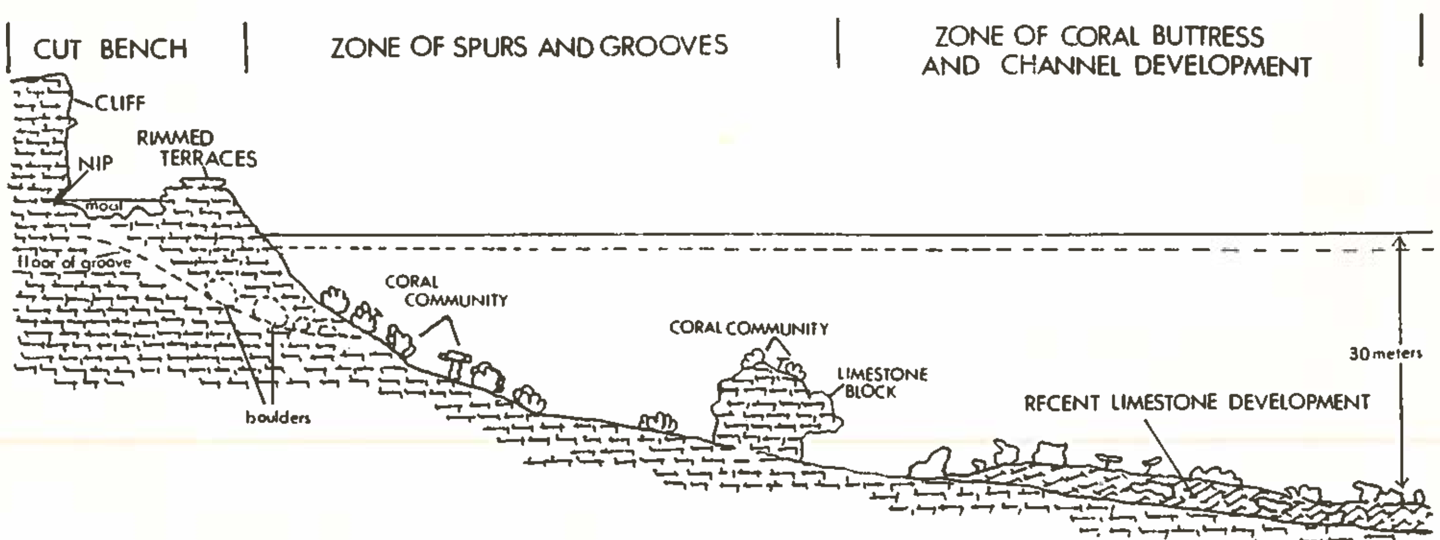
TABLE III

ALGAL RIDGE CHARACTERISTICS

Convex	TYPE	Cuestal
Seaward	REEF MARGIN GROWTH	Little or none seaward
Wide	CROSS-SECTION (Diagrammatic)	Narrow
15-50 cm	HEIGHT ABOVE THE MAIN REEF FLAT	100 cm
1-2 m wide 2-4 m deep Long, may penetrate to the reef flat platform	SURGE CHANNELS	Short, shallow, seldom reach the reef flat platform
	FORESLOPE	
Partly fissured	Surface	Smooth
Many-branched coralline algae Coral colonies	Organisms	Encrusting coralline algae
Honeycombed with holes connecting to caves below	BACKSLOPE	Solid and compact
Encrusting algae	Organisms	Soft, bottom-living algae cover the surface

Pago Bay. This reef margin is raised into a convex algal ridge about 30 cm high. Encrusting algae dominate the well-lit surface and dimly-lit outer galleries of the holes. In the dark inner regions live sponges, forams, and ahermatypic corals.

Narrow fringing reef at Ypao Point. A cuestal algal ridge at the surf line and a prominent spur-and-groove system at the reef margin and reef front.

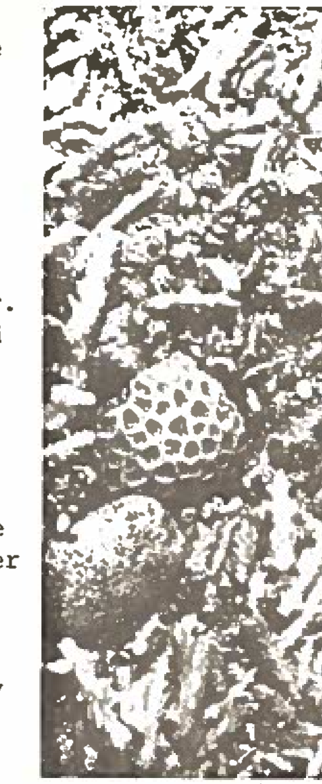


Buttresses grow, but channels, spurs and grooves form by erosion. Grooves are gouged by currents sweeping sediments back and forth, leaving remnant spurs. The toothed appearance of the reef margin and reef front zones is caused by both erosion and reef growth along the length of the buttresses. Corals and algae can grow well here because light is good and water currents keep reef sediments swept away.

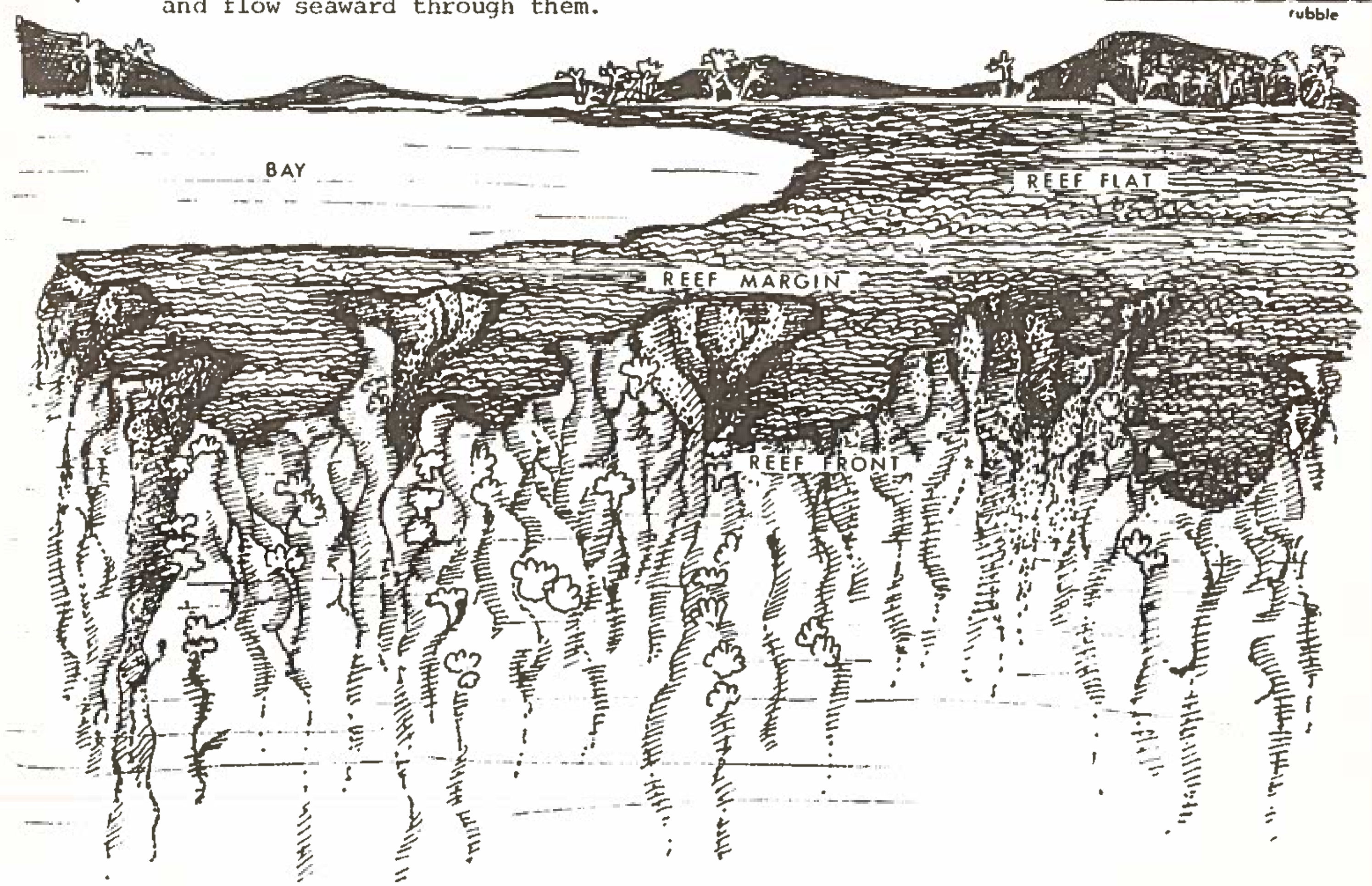
The Reef Front

The reef front is at the top of the forereef slope, constantly covered by water. It's the place where the reef abruptly gets steeper. The reef front is an extension of the reef margin buttress and surge channel system. These features end at the reef front boundary, about 4-8 m below the surface.

The greatest reef growth is in the reef margin and reef front zones. Erosion is high because of the breaking waves, surges and strong currents. Small bits and pieces are swept down the forereef slope or up onto the reef-flat platform to still-water areas. Constantly moving finer sediments like sand, gravel, and rubble slow down coral growth in the low places between ridges. At the reef front, channels and grooves are wider at the base than at the top. Their flat sandy floors are heavily peppered with gravel and boulders, rounded by water currents. They may be widened even more where longshore currents turn and flow seaward through them.



rubble



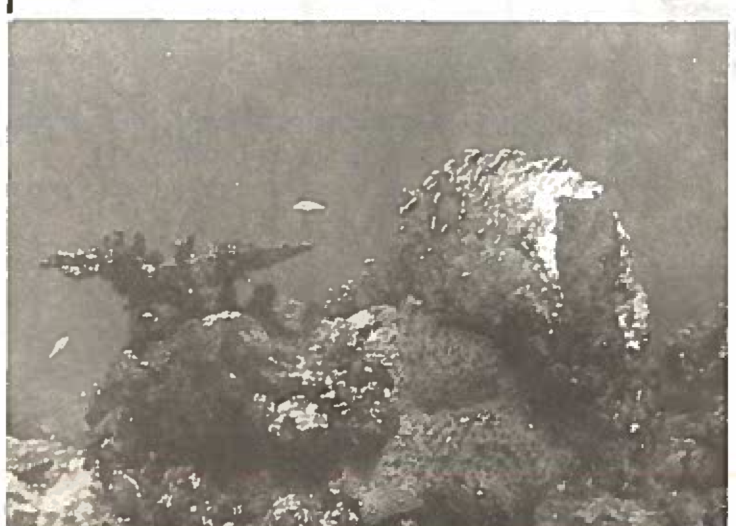
Tumon Bay. Submarine channels in the reef front. Rounded boulders along the floor and little coral growth on the lower walls show that the channel is eroding. The faster-growing coral along the upper walls makes shelves that narrow the space between them. (What will happen here?)

Fringing reef at Agat Bay. Relatively low relief. No spur-and-groove or buttress-and-channel systems here.

The Submarine Terrace

Nearly horizontal submarine terraces often separate the reef front slope and the deeper seaward slope. Two submarine terraces are shown in the vertical profile of Tumon Bay, p 14.

There are 4 distinct submarine terraces on the offshore slopes around Guam. They're at depths of 12 m, 35 m, 65 m, and 105 m. There is another off the southwest coast, 3-8 m deep.



Where active reef growth is taking place, the upper terrace is rich in coral. The surface is irregular with local coral clusters forming mounds, pinnacles and ridges.

Where the terrace is an older erosional rock surface, coral growth is less, giving the surface a smoother relief. Fleshy algae grow well on smooth erosional terraces. Other terraces have sediments from mud and sand, rubble and boulders. This is unfavorable for coral settlement and growth. Occasionally, however, corals gain a foothold on a boulder or a high unsilted place. There they can grow upward to form island-like knobs, mounds, and ridges in a sea of unstable sandy sediments.

The Seaward Slope

The top of the seaward slope is bordered either by the reef front or the edge of a submarine terrace. It continues down to the dwindle-point of reef coral growth. Where it breaks from the reef front or from the first submarine terrace, the seaward slope is steep. Near-vertical slopes are common and there are some sea-cliffs. Most upper slopes are interrupted by a second terrace 15 to 55 m down at the shoreward edge. The steep upper slopes are rich in coral.

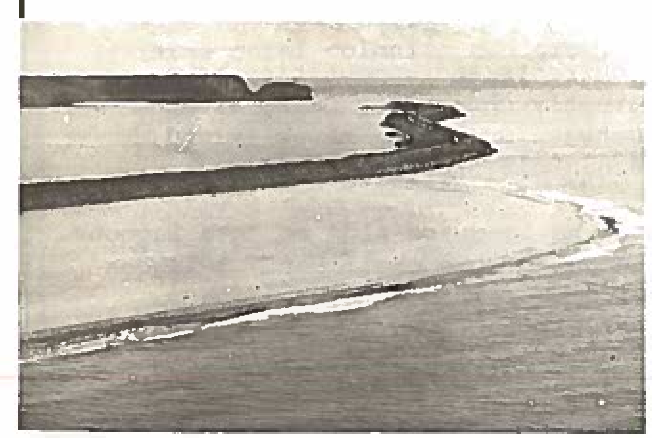
Before the crown-of-thorns starfish (*Acanthaster planci*) ate up a lot of the reef polyps, 50% of the substrate was covered with living corals in this zone at Tumon Bay. Here there are coral ridges, pinnacles and mounds generally more widely scattered than on the first terrace.

Where a second submarine terrace develops, sediments accumulate among the coral mounds, ridges, and pinnacles. Scuba divers notice distinct sediment trails from the upper reef front and first submarine terrace to the lower terraces.

Barrier Reefs and Lagoons

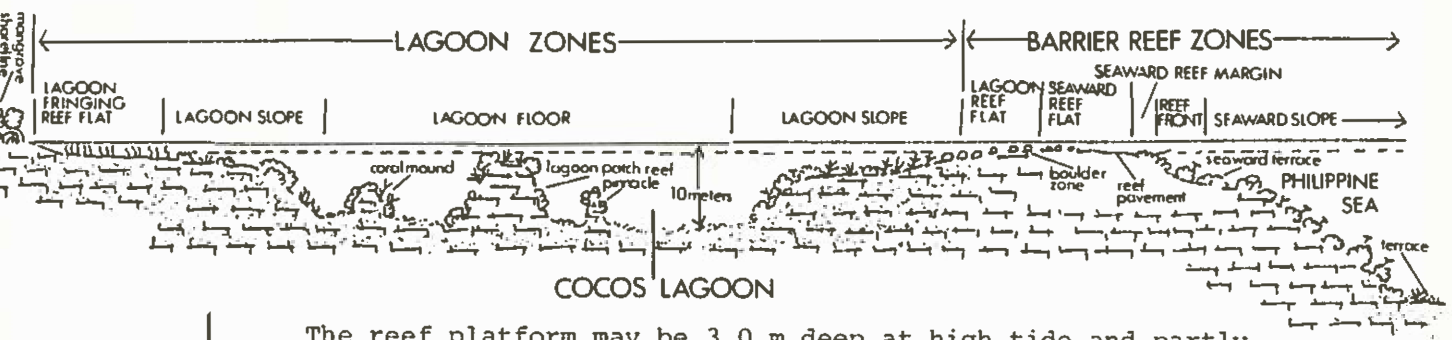
A barrier reef lies offshore, protecting a calm body of sea-water, the lagoon.

Guam has 2 barrier reefs, Luminao and Cocos. Luminao Reef, (with Cabras Island and Calalan Bank) encloses a 50-m deep lagoon at Apra Harbor. Dredging, landfill and construction have torn up and rearranged the lagoon. Even so, it's still rich in coral and has some unique species.



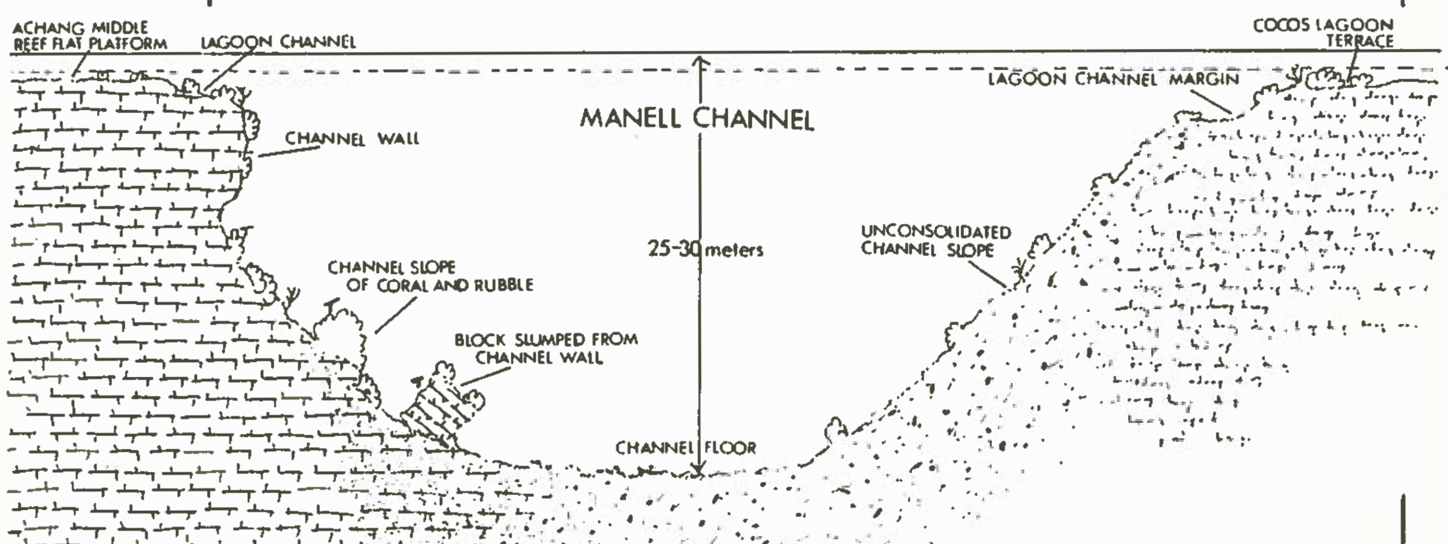
Luminao Barrier Reef partly encloses a lagoon at Apra Harbor. Waves break on the reef margin. Glass Breakwater was built on the lagoon side of the barrier reef and beyond that on the deeper Calalan Bank. Orote Peninsula in background.

Cocos barrier reef is at the southwest corner of the Island. Here a triangular reef encloses the shallow Cocos Lagoon (15 m deep).



The reef platform may be 3.0 m deep at high tide and partly exposed during low spring tides. The forereef slope drops abruptly to the dwindle-point of hermatypic corals.

Lagoon Reefs - Here and there on the lagoon floor are small patches of growing reef, and knolls, pinnacles, mounds and ridges (deeper reef structures). Channels connect barrier reef lagoons to open sea. Good examples are Mamaon Channel at the north and Manell Channel at the eastern corner of Cocos Lagoon. Another is the deep shipping channel at Apra Harbor.



In Apra Harbor Lagoon, natural currents and communities have been altered. They have been greatly changed by Glass Breakwater, dredging, the causeway between Guam and Cabras Island, and landfill to make Dry Dock Peninsula and Polaris Point.

Lagoon fringing reefs grow along the landward side of both lagoons. With time, a lagoon will fill in and become shallower. A lagoon has 3 major zones: landward fringing reef platform, slope landward and seaward, and central floor.

Lagoon Fringing Reef Platform

A lagoon fringing reef is less exposed to the open sea than barrier and other fringing reefs. The Cocos Lagoon fringing reef is mostly sand and rubble. A lot of seagrasses live on it, and mangroves grow nearby. The flat that fringes eastern Apra Lagoon is silt-covered rocky platform at places, and loose mud and sand at others. The lagoon fringing reef along Orote Peninsula is like fringing reefs facing the open sea. (It too was once exposed.) During low spring tides, much of this lagoon reef flat is exposed. Coral grows only in the low water-retaining areas.

Lagoon Floor

~ The deeper, uneven parts of the lagoon.

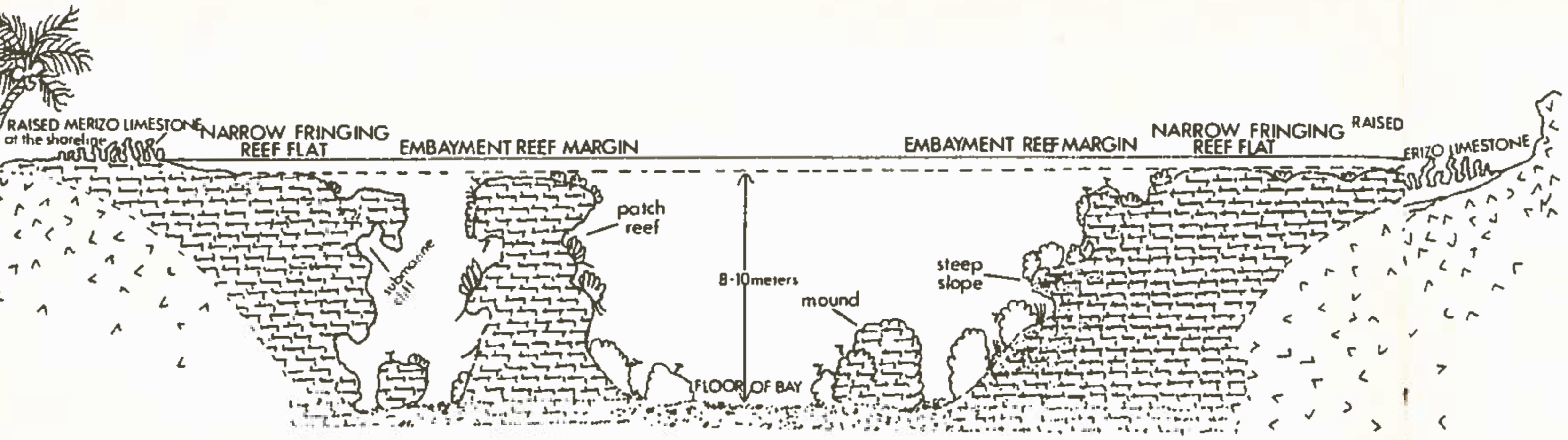
Small cone-shaped hills and funnel-shaped holes made by burrowing worms that take in water and sediments through the funnel and pump them out through the cone. Cone-and-funnel topography happens where sediments are in quiet marine waters.

Sediment on the lagoon floor is fine and loose. Burrowing worms like it, but it makes an unfavorable environment for corals and other sedentary reef organisms. They sink in and get buried. Sometimes a piece of rubble or a bit of rock sticks up through the sediment. This gives corals and other reef-building organisms a solid place to live on. They land, attach, grow, and add solids to the substrate. After they die, their skeletons offer a settling mound for more reef organisms. Eventually this small mound can grow into a knoll or pinnacle. If it grows up near the surface, it becomes a patch reef.

Hundreds of mounds, knolls, pinnacles and patch reefs have formed in Cocos and Apra Lagoons. These lagoons now are mostly too thick with sediments for much coral growth.

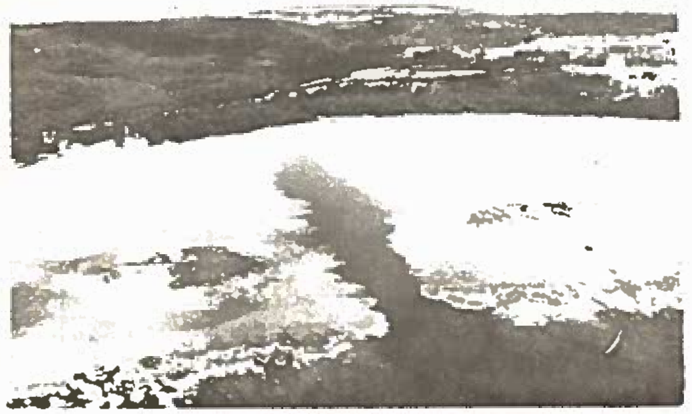
Lagoon Slope

Where slopes are steep and border deeper parts of the lagoon floor, large coral colonies can grow. A cluster of similar ones can make a nearly solid cover from upper slope to lagoon floor. They commonly slump downslope. Sediments move from the barrier reef platforms down slopes to the lagoon floor. Finer sediments don't settle quickly; they make the water murky. Some sessile organisms can avoid being covered by sediments—branching coral gives them space to drift through to the bottom; other organisms release mucus that drifts away and traps them; the cilia of others beat rhythmically, making currents that carry them off. A lagoon's turbidity keeps clear-water organisms from living in it.



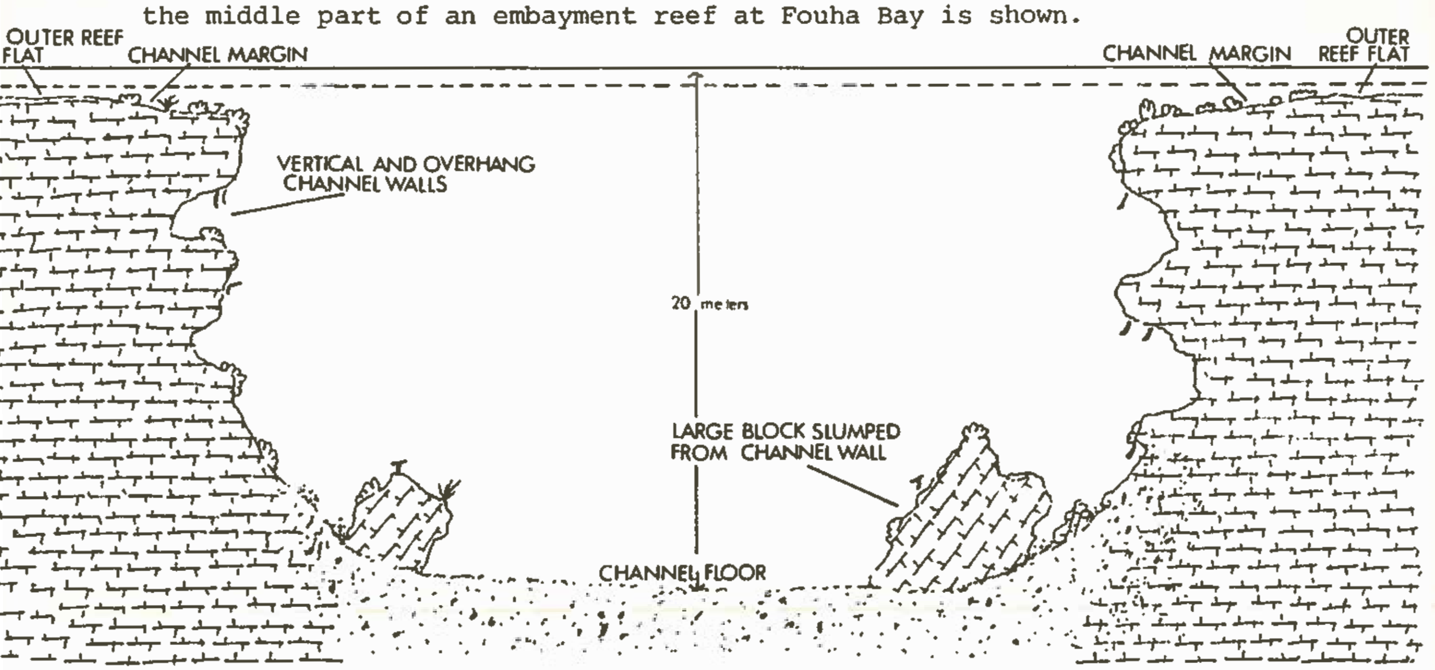
Reefs Along Coastal Bays · Fringing Reef Channels

Many rivers on the southern half of Guam form bays and channels. Bay reefs connect with fringing reefs, but they're built differently and have different communities. Waves hit fringing reefs all the time, sometimes very hard. Bays are protected from waves most of the time, but then, rivers cloud and cover them with silt. Ya hafa un cho'gue?



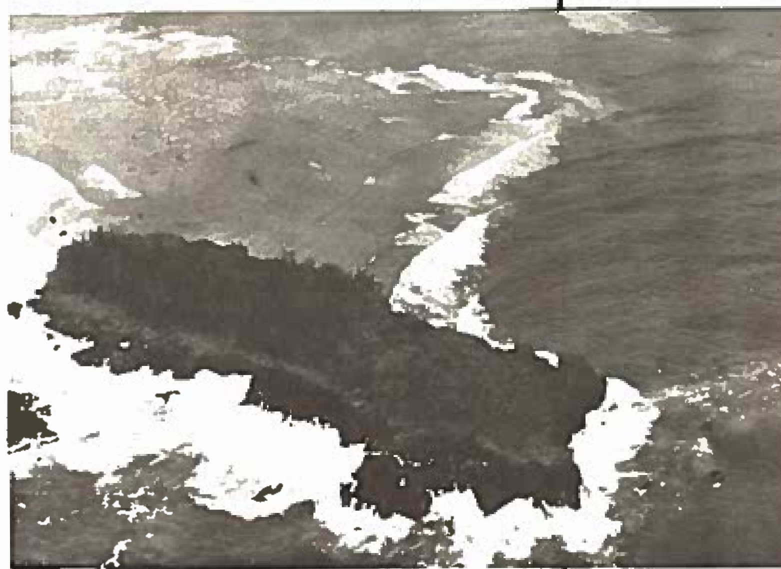
Togcha Channel.

This fringing reef channel was formed by the Togcha River emptying freshwater and sediments at the shoreline. This retards reef development from the river mouth to the reef edge. Some corals and calcareous algae grow along the upper walls of the channel, producing overhanging ledges that make the channel sides irregular. The islets on each side of the channel are patches of Merizo limestone from a former higher sea level. Below is a vertical profile across the channel. At the top of the page the middle part of an embayment reef at Fouha Bay is shown.



Offshore Patch Reefs

There are several patch reefs around Guam. The largest is Anae, on the southwest coast between Fakpe Point and Taleyfac Channel.

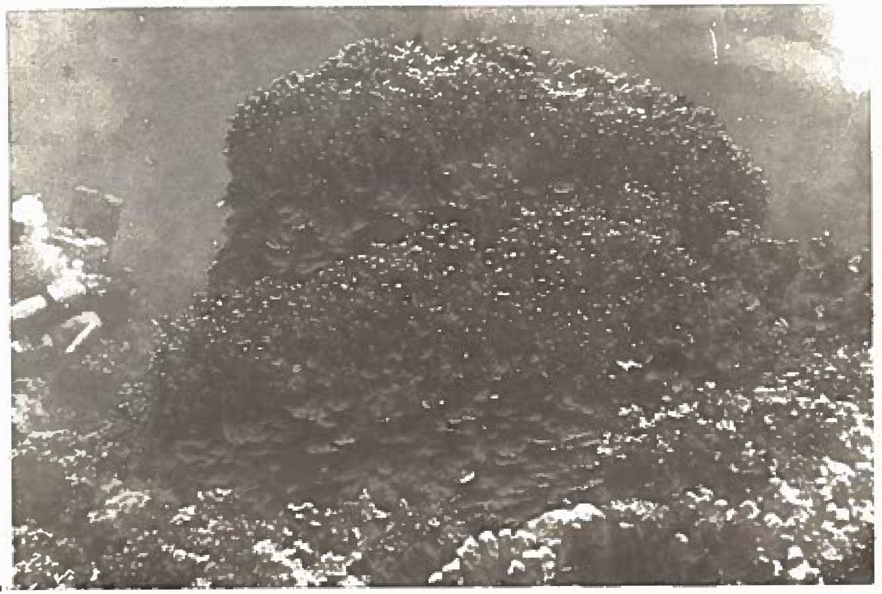


Anae Island and patch reef. A narrow erosional bench is on the seaward side of the small island.

Anae patch reef has a flat upper surface, partly exposed during low spring tides. A raised limestone mass, Anae Island, is part of that surface. This island was probably an offshore patch reef in other times, when the sea level was much higher. Right now it is eroding and has an irregular surface of sharp pinnacles.

The reef-flat platform of a patch reef is like the outer reef flat for fringing reefs. The few corals grow in small depressions.

A community-type coral development lives on the seaward patch reef slopes. The reef is still growing landward. Between Anae patch reef and fringing reefs along shore, a terrace 3 to 20 m deep supports some very active reef construction. Coral colonies here are many meters across and several meters high.



Large coral colony on a submarine terrace off Anae Island.

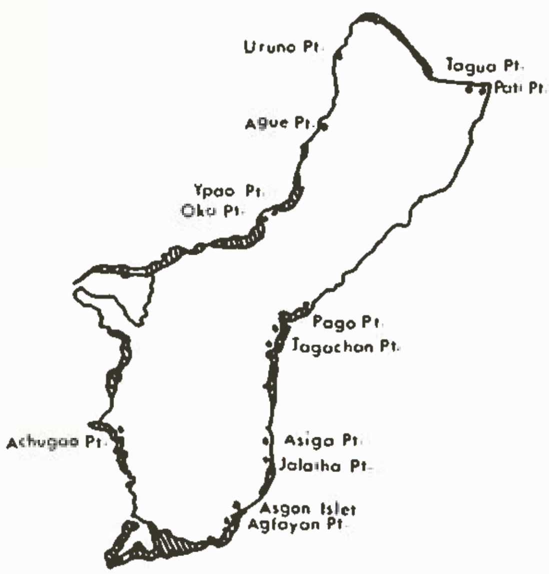
Erosional Sea Level Benches

Shoreline erosion has gnawed away the base of some rocky slopes and cliffs, making benches.

Benches are kept constantly wet by wave wash and spray, even at low tide. Elevated sea level benches on Guam form where there are no fringing-reef platforms. The seaward margin is usually higher than the shoreward part and contains a series of rimmed pools. The inner part of these benches usually holds a moat of impounded water.

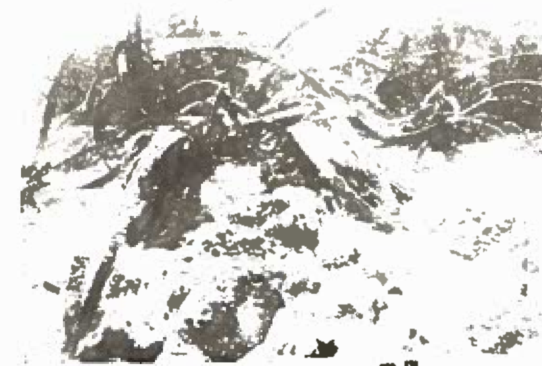
Benches line the shore from Tagua Point to Pago Bay; at Pago, Tagachan, Asiga, and Jalaiha Points along the southwest coast; at Inarajan Bay, the seaward side of Asgon Islet, and Agfayan Point along the southern coast; at Achugao Point along the southwest coast; and between Oka and Ypao Points; and from Uruno to Ague Points along the northwest coast. Along these benches are spur-and-groove systems. (See pp 22-23.)

Near Pati Point. Sea-level bench cut into the rocky limestone coast.



Sea Level Benches

V - Marine Plants



Seven kinds of plants live in the sea: all 6 kinds of algae (bluegreens, greens, browns, reds, golden-browns, dinoflagellates and marine flowering plants, the seagrasses. (See Beach Strand pp 16-19. For the salt-tolerant mangrove trees and nipa palms of estuaries and bays, see Mangrove Flat.)

Seagrasses

Three kinds of flowering seagrasses grow around Guam. Large beds of turtlegrass (the strap-like *Enhalus*) live on reef flats in Inarajan, Merizo, Agat, and Piti Bays. Turtlegrass flowers periodically, especially during low tides around April and October. A distinct community lives in the turtlegrass beds, including mañahak, snails, crabs, and mollusks. Round-leafed *Halodule* and the bladed *Halophila* grow low over the sand.

Algae

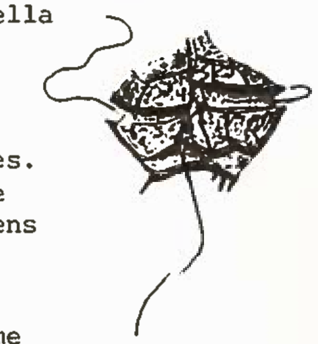
Whatever color they look, algae have chlorophyll (green) and make food.

Bluegreen algae are single-celled or in strings of cells in a gelatinous cover.

Some green algae have hard calcium in their bodies; others are soft and fleshy. Brown algae can grow fairly large, and some of them are calcareous, too. Red algae include the ones that help build the algal ridge at the reef margin. Some red algae look outwardly like corals, but have reddish hard parts. Corals don't.

We make a lot of our ice cream and packaged puddings today from seaweed gelatin.

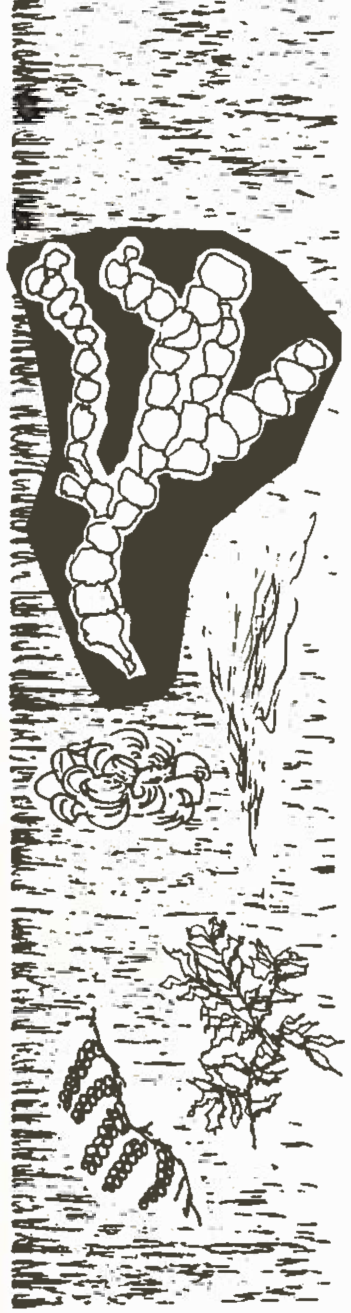
The silica skeleton of golden-brown diatoms looks like a box with a lid. Diatoms are one-celled and microscopic. Because of their photosynthesizing and uncountable numbers, they're the basic unit of the sea's food-energy web.



Dinoflagellates, also one-celled, use their 2 whip-like flagella for moving. One flagellum is in a groove around the middle of the cell. The other comes out of the bottom.

Ecologically, algae do several things besides making oxygen. They are a major food source for many invertebrates and fishes. Tataga' and guili eat the large brown sargassum weed. In the low-growing turf algae there are many kinds of short bluegreens and browns eaten by fishes grazing over the bottom.

Algae shelter many animals. Some fishes have become very selective; they live only with certain species of algae. Some snails and small crustaceans live only among the blades of specific seaweeds.



Some gastropods and extremely small snails without shells are found only on Caulerpa, ado'. New algal growth around artificial reefs, like the one made of old car tires in Cocos Lagoon, encourages fishes and lobsters to take up residence among the tires. There they can find neat places to hide and increase their numbers.

Red coralline algae cement loose rubble together, building the flaky reef substrate into solid pavement. These same algae cement themselves together and contribute to algal ridges like the ones at Ritidian Point (see p 20). A small algal ridge at Pago Bay is exposed to the surf and makes a good barrier against high waves and storm seas.

Halimeda, a calcareous green alga, is a terrific sand producer. It generates a calcium network inside its body. Every once in a while, it releases spores at its edges. After that, the whole plant disintegrates, leaving behind the 'sand' it became. Halimeda-produced sands are abundant at Pago Bay.

Bluegreen algae take free nitrogen from the water and convert it to nitrate and ammonia compounds. All marine organisms need these in metabolism. Lots of marine researchers are interested in this process.

Algae are either attached to the bottom (benthic), or they're free-floating (planktonic). Phytoplankton (phyto = plant) are drifters. Bluegreen, green, red and brown algae are benthic, although they do break off and float to the surface. If they drift ashore, they die.

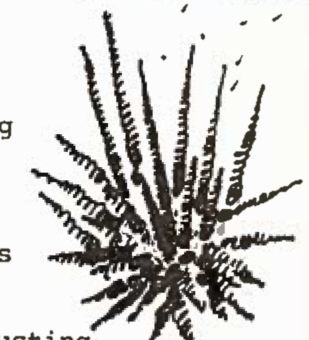
Algae stay in distinct zones of the reef: Long green strings of Enteromorpha may grow where freshwater runs into bays. You can see it in Tumon and at the NAS storm runoff into Agana Bay. In the moat, Padina, Halimeda, Sargassum, and Avrainvillea are most common.

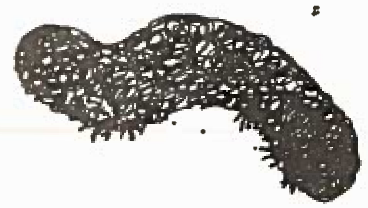
Guam marine plants have 2 major seasons, reflecting the wet and dry seasons on land. Large growths of Sargassum and Caulerpa, common at one time of the year, won't be seen at other times. Caulerpa usually is abundant only during the Spring and early Summer months.

Tidal fluctuations affect algae. During the Spring and Fall, mid-day 'minus' tides kill many algae by drying them out. Night low tides have less effect. (For tides, see Beach Strand, ch 4.)

Flooding from rivers can dilute the surrounding saltwater enough to kill algae and the animals living with them. Silt brought down by rivers can cover algae and smother them. After rainfall in the southern mountains, there is usually an offshore fan of red mud at the river mouths. The fans show that there's an excess of silt and freshwater runoff from the land.

VI - High Rise





The Coral Condominium

Thousands of coral polyps living together make a colony. Each polyp is a cement machine, building its own floor on the foundations left by the preceding generations. The one-room apartments grow into huge condominiums.

Sometimes the apartments are low-rise, encrusting on the surface of anything in their way. The high-rise kinds grow and branch out like trees, in the different style of each kind of coral. All kinds of tenants live in both kinds of condominium. They earn their living in different ways. Sometimes the always-growing condominium permanently encloses them.

Among the tenants in the upper stories are some small shrimps, worms and mollusks. They are plankton eaters. They're usually attached, or move around only slightly.

Small fishes live in the upper branches, darting out to feed. Other fishes hide among the branches. They may live alone or in large schools.

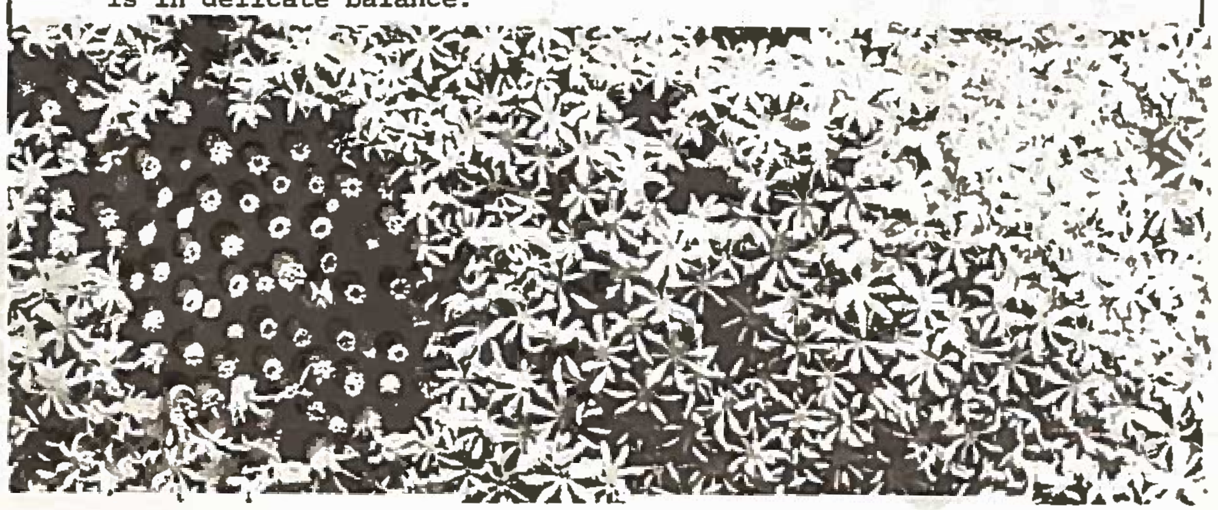
Parrotfish and some triggerfish bite off pieces of coral, some eating seaweeds or animals living on or within the coral.

One kind of gall crab settles on certain coral branch tips. When the female crab's breathing currents affect the coral's growth, the coral forms a chamber around her. It becomes her prison. The male crab is very small. He can freely enter and leave his wife's lockup.

One kind of barnacle lives inside the coral. Other small predators, including crabs, live among the branches. Some crabs live only in certain corals, others live in any kind. We don't yet know why. Snapping shrimps and other shrimps are common. Brittle stars, sea urchins and sea cucumbers feed on stuff that drifts down from above. Many worms and predator snails live here too.

Large predators like moray eels sometimes live on the ground floor. Many large fishes hide out there during the day or sleep there at night.

All these organisms are the coral community. You won't see them all at once—it takes a lot of patience and watching to get to know them. Each one has its place. If any is disturbed, the whole community may be changed. The reef is in delicate balance.



__Tubipora__
life size

VII - Who's Who - Reef Animals

Each of the World's major animal groups has a delegation living near you, on the reefs around Guam. In their Kingdom, Animalia, are various phyla, classes, orders, families, genera and species.

(To remember this, just say '__K__ids __P__lay __C__ards __O__n __F__ine __G__uam __S__ands.')

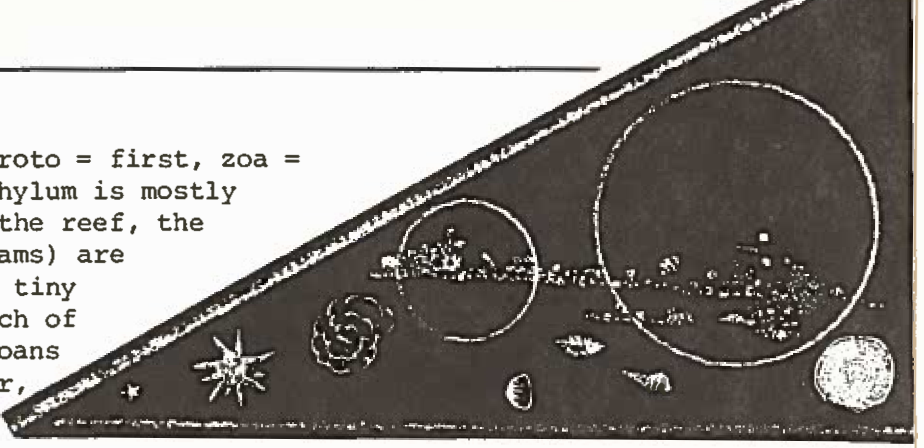
The groups are arranged and named according to who their relatives are. The Kingdom is the largest group of relatives. In each Kingdom are phyla; in each Phylum are classes; each Class has orders; each Order includes families; in the Family are genera; and each Genus has one or more species. From Kingdom down to species, the animals are more closely related and more and more alike. Only at the species level are they alike enough to mate and produce offspring that can again produce offspring. For example, here's how the mangrove crab goes:

Kingdom .	Animalia
Phylum .	Arthropoda (jointed legs)
Class .	Crustacea (crusty ones)
Order .	Decapoda (10 legs)
Family .	Portunidae (harbor crabs)
Genus .	Scylla (monster)
Species .	serrata (saw-edge)

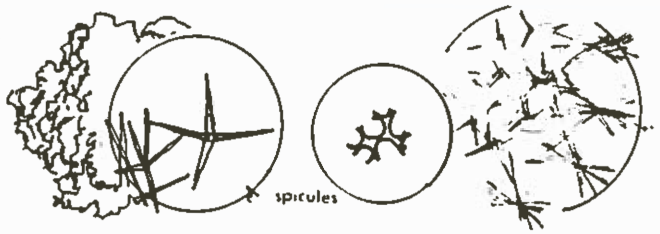
The scientific name, __Scylla serrata__, is a way for anyone in the World to identify a mangrove crab. A Guamanian might say, 'Aha, akmangao!' In Hawaii they call it 'Samoan crab' because it was introduced there from Samoa. A German would say 'Krebs von Mangrovenpflanze' and a Spaniard 'cangrejo de manglar'. But when they all get together, they say '__Scylla serrata__' and they know what they're talking about. That way you can't go wrong—Latin is used for scientific names because it's a language that doesn't change any more. After the name of the species may come the name of the person who first described it—would you like to have a snail or a hippopotamus named after you? Just find a new kind and tell all about it.

Guam's common reef animals are in 14 phyla. Here, we give you the major characteristics of each phylum and some common examples. Branches of a 'tree' show how we think animals have grown from each other.

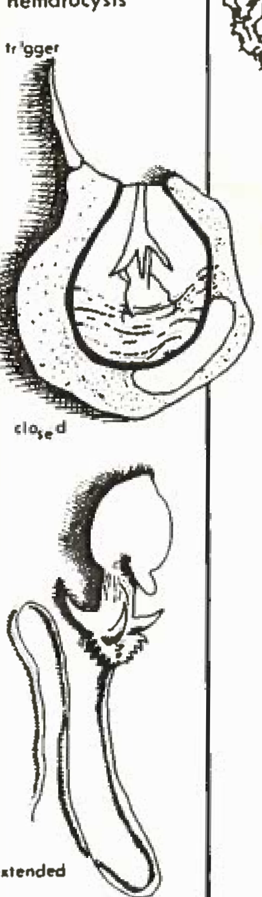
evolutionary 'TREE'



Protozoans (Proto = first, zoa = animals) - This phylum is mostly microscopic. On the reef, the Foraminifera (forams) are everywhere; their tiny shells make up much of our sand. Protozoans are eaten by other, larger animals.



Sponges - Porifera (pore = pore, fera = carrying). Sponges usually live where there's a solid bottom. They're the brilliant green, blue, purple, red and yellow blobs on the undersides of the reef. Sponges have lots of hard spicules (spic = spike, ule = little). Spicules are made of calcium or silicon.



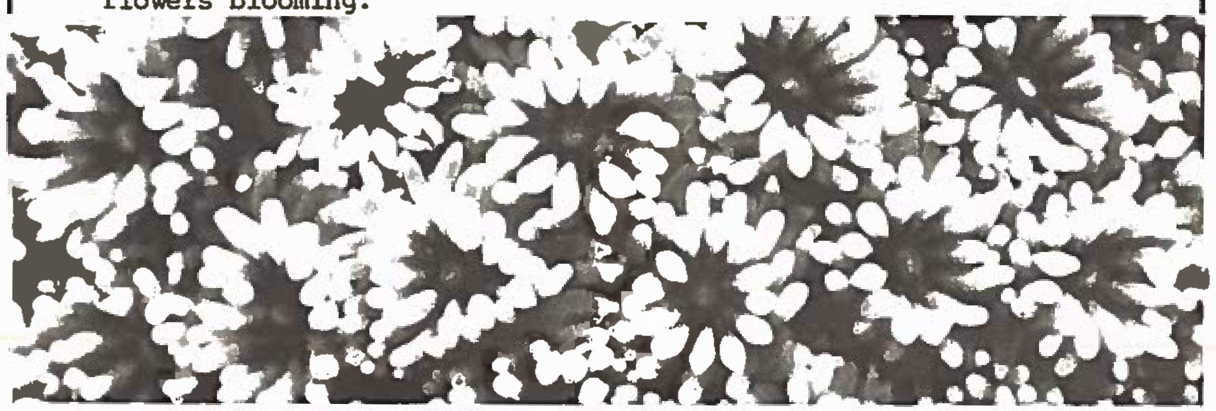
Cnidarians (cnid = nettle) - The phylum is named for its microscopic stinging nematocysts (= thread cells). They shoot out poisonous needles when touched. Corals, jellyfish and Portuguese man-o'-war are cnidarians.

Stony corals are the most common cnidarians on our reefs. We have more than 350 species. Almost all shallow-water ones are colonial; they begin as one individual and add new ones, making large colonies.

Some corals live in deeper water and don't form colonies.

Most corals have one-celled algae living inside them. (See zooxanthellae, p 5.) We don't know exactly what's going on between the corals and the algae, but we think it's good for both of them. The alga feeds on the coral's waste products, and the coral gets food and oxygen from the alga. The many algal cells give the coral its brown color.

Many soft corals have scattered spicules and no hard skeleton. Soft corals look pretty much like stony ones, but they feel soft. Both types live together in the shallows of the inner reef flat. The individual animals expand at night like millions of tiny flowers blooming.



Galaxea
8-10 mm
polyp
diameter

Several other kinds of cnidarians live on the reefs. One is the blue coral. Upright and branched, in the water it looks gray with white polyps. When taken from the ocean and dried, it's blue.

Fire corals live at the reef margin and in low places on the reef flat. Most of them are yellow-green with a brilliant yellow upper edge. Fire corals deserve their name: their stinging cells are poisonous and a touch causes burning pain. Fire coral bodies are quite different from stony corals even though their skeletons look similar.

Sea anemones are cnidarians without solid skeletons. A companion clownfish lives with some of them. The fish is immune to anemone poison. Its motion and colors may lure predators to the anemone. The predators get stung, the anemone eats, and the clownfish gets the scraps.

Most adult sea anemones are immobile—they stay in one place, they're sessile (= sitting, attached). Others can get their tentacles into motion and swim.

Portuguese
man o' war

All jellyfish are cnidarians. They don't like the reef but can float into harbors and lagoons. Some of the deep-sea types have tentacles 15 m long, but not around here. Ours seldom reach more than 2 or 3 m at most. The Portuguese man-o'-war, not a typical jellyfish, is often washed inside the reef, where its sting can cause discomfort to swimmers. If you get stung, keep your cool and don't thrash around.

Hydroids are small, feather-like, branching animals that attach to rocks, pilings or boat hulls.

hydroid

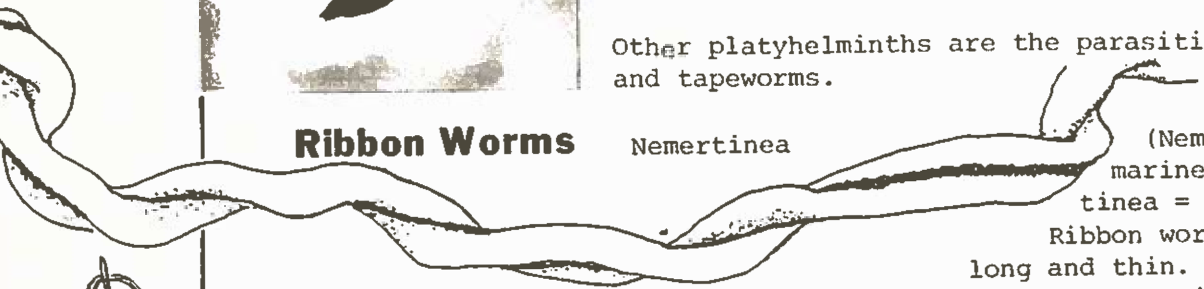
All the remaining reef animals we'll discuss are bilateral. Each side of the animal is a mirror image of the other, and it has a definite head and tail. (This leads to more complexity—in nervous systems, behavior, physiology, and reproduction.)

Lots of elongated animals are called 'worms'. Many of them live around Guam. They come in many different sizes, colors, and shapes. Flat ones are:

Flatworms

Flatworms - Platyhelminthes (plat = flat, helminth = worm). Free-living ones are bright colors. When they swim they look like silk scarves fluttering gently in the wind.

Other platyhelminths are the parasitic flukes and tapeworms.



Ribbon Worms

Nemertinea (Nemertes = marine worm, tinea = worm.) Ribbon worms are long and thin. They're multicolored, with contrasting bands and bars. A nemertine has a flat head. It may get to be 2 m long. It can make itself even longer by sticking out the proboscis, a kind of food-gathering tongue with hooks.

Aschelminths

(asc = bag, helminth = worm) - This group includes several worms that look alike. Only the round worms in this phylum—long, skinny animals—are found on the reef. Often they live in sponges or with other kinds of animals.

Annelids

(annulus = ring, segment) - These worms have a series of rings along the body. An earthworm is a typical annelid. A few earthworms live near the beach in sand mixed with seawater, but they are rare.

Most marine annelids are polychaetes (poly = many, chaet = bristle). All polychaetes have small pointed spines along the body. Some have a few spines in each segment, others have many. Most of these worms are small and hide in sand or under boulders. Fireworms leave lots of spines in your fingers if you touch them.

Many annelids build tubes to live in. The feather-duster worm lives in a soft tube and has a large ring of tentacles for breathing and catching food. They are retracted suddenly if a shadow falls on them. Some worms build a hard tube of calcium, like a shell. They have smaller tentacles, and an operculum (door) which they can pull shut to keep out predators.

Ectoprocts

(ect = outside, proct = anus) - These animals usually are small and colonial. We don't have many around here. They have a ring of tentacles which can be withdrawn into their 'house'. You can find them on sunken things like tires, concrete, and ships.

Most of the remaining phyla are large enough to see easily.

Sipunculans

(sipunc = siphon, ule = little) burrow in sand and in coral boulders. Sipunculans bore into and break down limestone to smaller and smaller pieces. Eventually this makes sand or beach rock.

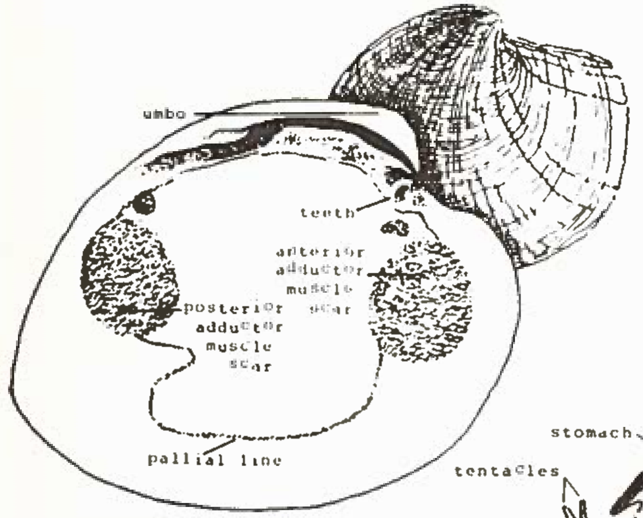

peanut worm

Echiurans

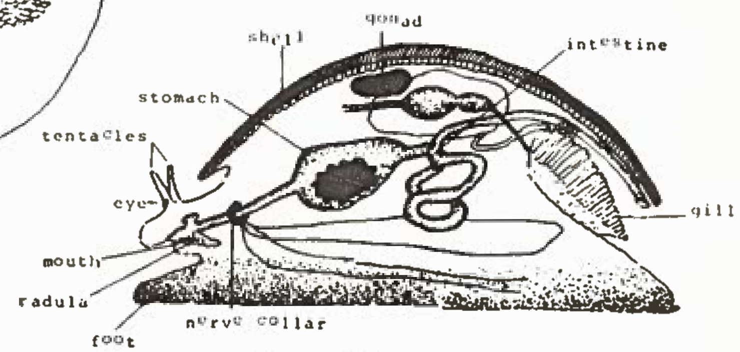
(ech = serpent, ura = tail) live on the sand bottom or in coral branches. Often, they're brilliantly colored. Their mouths are below the shovel-shaped, nonretractable proboscis.

Mollusks

(mollis = soft) - Many have a single foot which they stick out to move themselves along or to attach with. They may have a shell, or two, or more. The radula, a kind of sandpaper tongue, gathers food.



GENERALIZED BIVALVE



HYPOTHETICAL ANCESTRAL MOLLUSK

CHITONS live on the exposed coral boulders or the wave-washed shoreline. They have 8 overlapping plates. The body edge has short soft bristles. These mollusks are grazers—they stay in one spot during most of the day but at night move around eating low-growing algae. At least 2 species of chitons live on the reefs around Guam.

GASTROPODS (gaster = stomach, pod = foot) are snails. The single shell is a spiral and often has algae growing on it. The young stage has a small shell and a foot used for swimming. The limpets on rocky shores are snails, even though their shells look like Asian peasant hats. Limpets leave home at night and chomp their way through the low-growing algae.

One of the largest reef gastropods is <u>Trochus</u>, the top shell. It's high-spired with red and white bands. A soft operculum covers its opening.

limpet

Trochus

<u>Trochus</u> was introduced to Guam and the other southern Marianas from the Marshall Islands in the 1930's. It used to be a popular food, and mother-of-pearl buttons were cut from the shell. Turban shells are related to <u>Trochus</u>.

nerite

littorine

Nerites and littorines thrive along the shore on hard surfaces. One nerite is globe-shaped with ridges on the outer side.

Strombids are common and may be 10 cm long.

Some small, dark, high-spired gastropods are in the Cerithiidae family. Hermit crabs often move into their shells. The cerithiids live on sandy bottom parts of the reef flat.

Vermetids are snails which burrow into coral colonies and microatolls. You can tell them from worms living in the same areas by their flat disk. It's never extended beyond the end of the tube they live in.

Around seagrass thickets the small tan or white naticid carnivorous snail drills holes in and kills 2-shelled clam-like mollusks.

'Sand collars', the egg cases of similar snails, look like a stack of pancakes with a hole in the middle. These are made of mucus and sand. They hold thousands of eggs.

cerithiid

vermetid

strombid

naticid

There are over 50 species of cowries around Guam. Plenty of money cowries live on the reef flat. The mantle keeps their shells polished but can be withdrawn when the animal wishes.

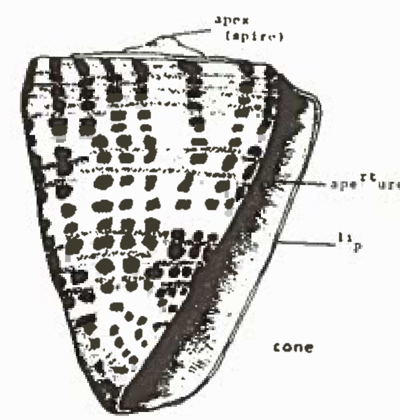
Muricid gastropods are common. Some live at the reef margin. Reef muricids are small and have an ornamented and sculptured shell. Larger ones in deeper water have many long spines.

muricid

Miters and olives are medium-size snails, high-spired and highly colored. The olives are shiny. Miters are duller and look like a bishop's hat, with ridges.

Augers have long, pointed shells and live in sandy places on the reef flat and reef front.

Closely related, but with low or flat spires, are the deadly poisonous cone shells. Their 'spears' are modified teeth that shoot out from the pointed end and can inflict a fatal wound. The marble cone is mottled black and white. Textile, geographic, and tulip cones have mixed colors in fine and distinctive patterns.

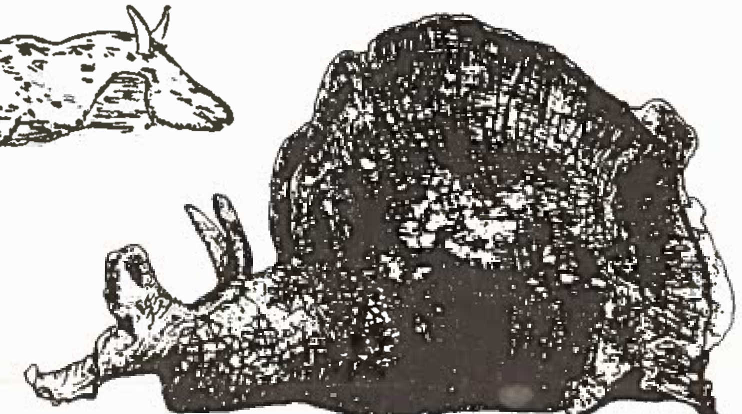


cone

Some snails don't even have shells. Many are brightly colored and have flamboyant shapes. Among those living on the reef flat are sea hares, aeolids, and dorids.

aeolid

dorid



sea hare

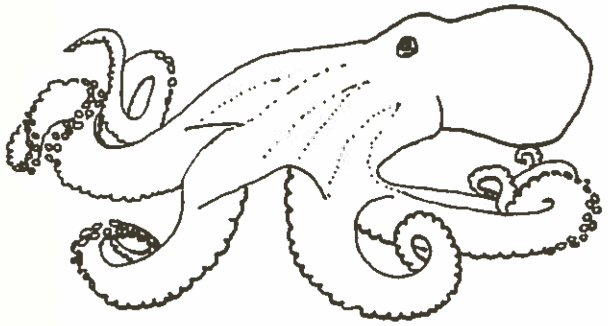
The second group of mollusks, BIVALVES, have 2 shells. Giant clams are the largest. They can grow to 120 cm long, but not on our reefs.

Other bivalves are oysters, mussels, arcs, and heart shells. One scallop-like clam can repeatedly snap its shells shut and swim away by jet propulsion.

Shipworms cause tremendous damage to wood. They drill holes and line them with calcium. The pholodid, closely related to shipworms, bores holes in coral boulders, using his shell as a drill.

Our last mollusk group is the CEPHALOPODS (cephalo = head, pod = foot). These include nosnos, the squid, with 8 short and 2 long tentacles. They spurt themselves around by jet propulsion. Small ones are plentiful here. Elsewhere the rare giant squid, the largest invertebrate, gets up to 16 m long.

Octopods (octo = 8), gamson, stay close to the bottom. They swim just above it and live in crevices in the rocks. Several species are here, but collections are scanty because gamson are usually eaten before they can be preserved for lab study.



giant clam

Crustaceans are arthropods (arthr = joint). More arthropods are around than any other kind of animals. Insects, spiders, centipedes and millipedes also are arthropods.

Almost all insects live on land, but most crustaceans live in water——mainly seawater. All arthropods are covered with a hard exoskeleton (exo = outside), with jointed appendages at each segment. Arthropods grow between moults when they shed the tough old skeleton. The new skeleton is soft and takes awhile to harden.

Since there are so many crustaceans, the classification is detailed and based on microscopic features. Small crustaceans are of great importance to ocean and reef. Many are at the bottom of the food web and are eaten by other small animals.

COPEPODS (cope = oar) are small, have long antennae, and a carapace covering most of the body. Copepods live in the plankton, along the bottom, or with other animals. They clan up in great numbers. Some parasitic kinds have lopsided, elongated, lumpy shapes.

AMPHIPODS (amphi = both sides) are very small and thin from side to side. They have large compound eyes with many facets. These animals may build tubes.

Another group of crustaceans is the ISOPODS (iso = equal). They're flattened from top to bottom.

These 3 kinds of crustaceans——copepods, amphipods and isopods—— often live together on the reef, in clumps of seaweed or among coral boulders. Collect some seaweed in a plastic bag. Let it sit for a time. Then stir the seaweed around and look at what falls to the bottom. You'll see copepods, amphipods, isopods, and maybe other animals too.

BARNACLES, unlike other crustaceans, cling to something hard throughout their adult life. The larvae drift with other plankton. Later they settle down head first and metamorphose into an animal with a number of hard shells. Barnacles cluster on the edges of the rimmed terraces, along the base of cliffs, or on boulders which are often exposed.

On floating objects like glass fishing floats, goose barnacles grow. A number of barnacle species are parasitic and not easily recognizable as barnacles.

Mantis shrimps are STOMATOPODS (stoma = mouth, pod = foot). Long and narrow, each one has 2 claws that look like those of praying mantises, but turned upside down. By snapping these claws, strong enough to cut your finger, the shrimp can rapidly kill its prey. The last segment of the animal's body is highly decorated and can be a plug against predators trying to get into the animal's burrow.

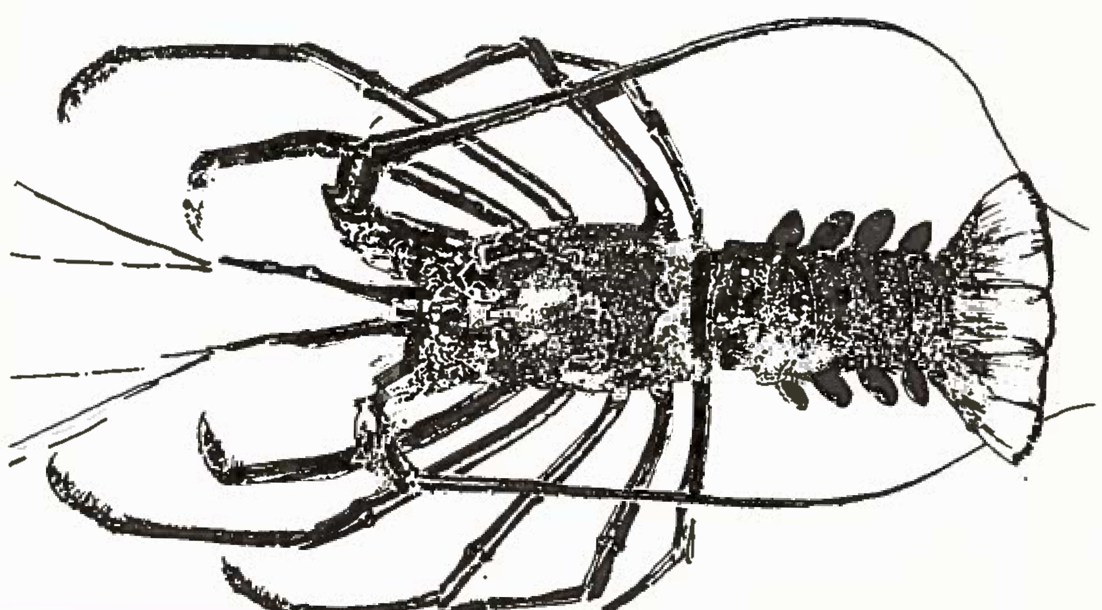
The rest of the crustaceans are larger and more easily seen.

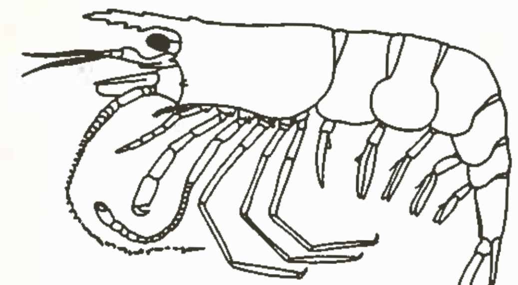
Most typical shrimp-like crustaceans are the CARIDEANS. Carideans are small and live with other invertebrates. All have a carapace covering the head and thorax. Typical carideans live at the bases of coral heads, in microatolls, among blades of turtlegrass, or along the shore. Some even live inside other animals—in the giant clam or in gills of other large mollusks. Shrimps have a wide range of colors and variously shaped claws and abdomens.

A large red-and-white banded shrimp lives in rock and coral crevices in shallow water. A cleaning shrimp, he picks parasites from fish which may wait in line to be cleaned. This shrimp usually lives in pairs. The smaller one is the male. Their antennae are long and usually white.

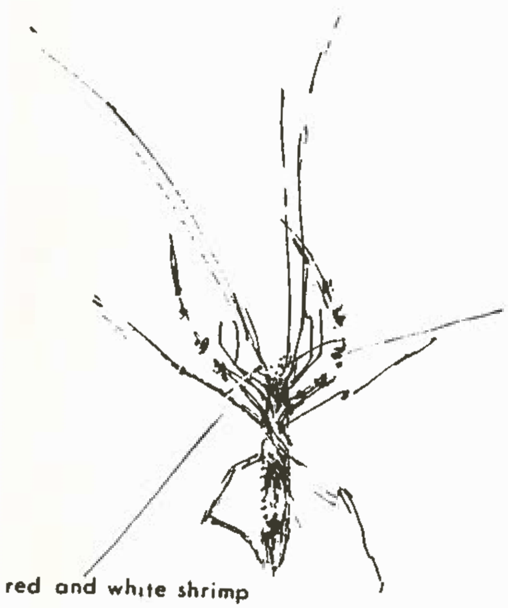
Lobsters, including the brilliantly colored spiny langusta, mahongang, live in deep reef waters or shallow bays. They have spines over all their bodies, even on their long, pale antennae.

Papangpang, slipper or butterfly lobsters, are flattish and usually kind of brown. Only a few species are on Guam reefs.



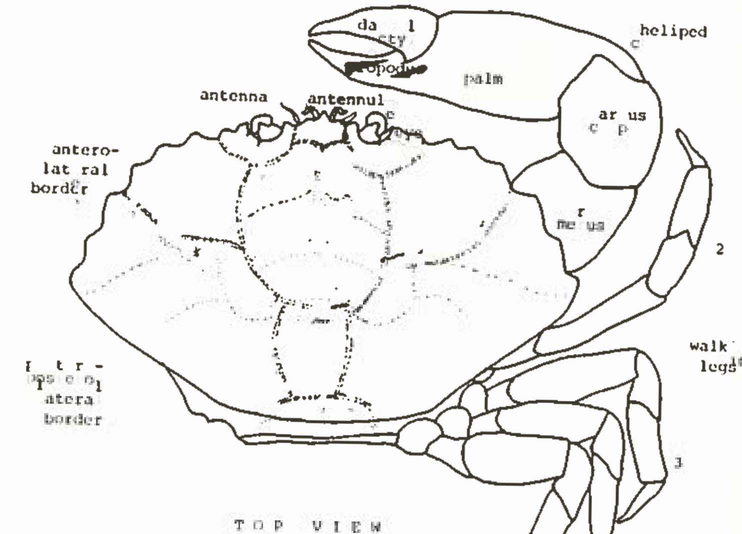


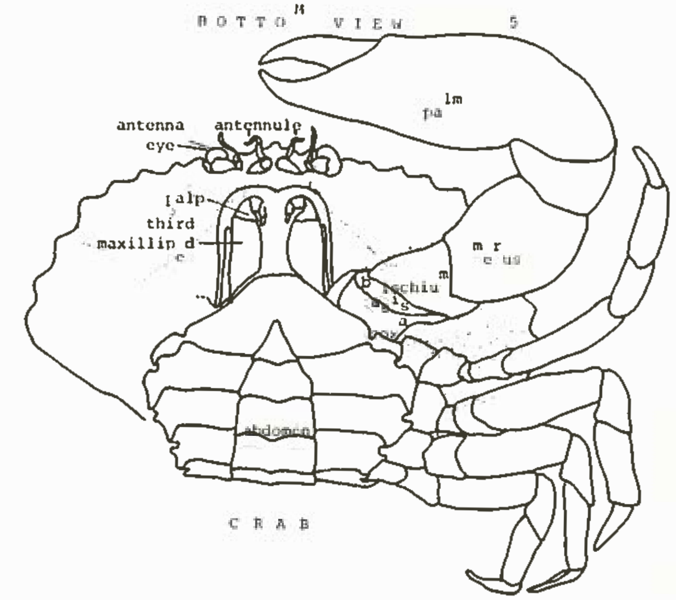
ENERALIZE MARINE SHRIMP



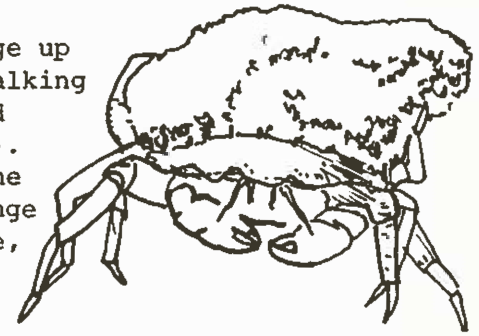
red and white shrimp

papangpang





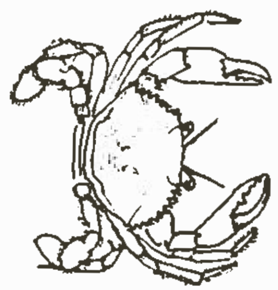
Typical CRABS are flat, wide, and short compared to lobsters. Several kinds of crabs live on the reef.



A sponge crab holds a protective sponge up over his body with his last pair of walking legs. The crab and sponge make a good example of symbiosis (living together). The sponge gets to move around, and the crab is nicely camouflaged. Some sponge crabs think a zori is a kind of sponge, and run around carrying a zori on their back.

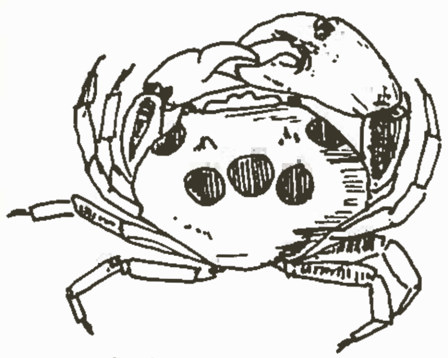
Look closely at any swollen branch tips on corals. You may find a female gall crab inside (see p 34). Other gall crabs make small tunnels in large rounded corals.

Box crabs scurry around on sand. If they're disturbed, they wriggle into it and leave only their eyes sticking out. They're hard to see because they're the same color as sand.



Swimming crabs are about the largest on the reef. They use their last pair of legs for paddles. There are many species around Guam.

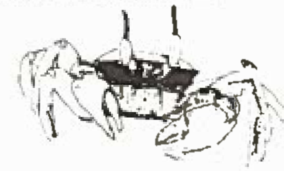
In shallow waters the commonest crabs are xanthids. Most are pretty large. Panglao tunas, the 7-11 crab, one of the biggest, can be 12 cm wide. Xanthids have rounded carapaces and heavy claws. An overturned boulder should yield several different kinds. (Remember to turn the boulder back again.)



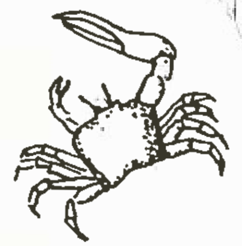
panglao tunas

Small smooth-shelled crabs live at the base of living coral colonies. These xanthids stay with specific corals. One specialized xanthid carries sea anemones in its claws and uses them like boxing gloves to keep off possible predators. In some places of the western Pacific, a few xanthids may be poisonous.

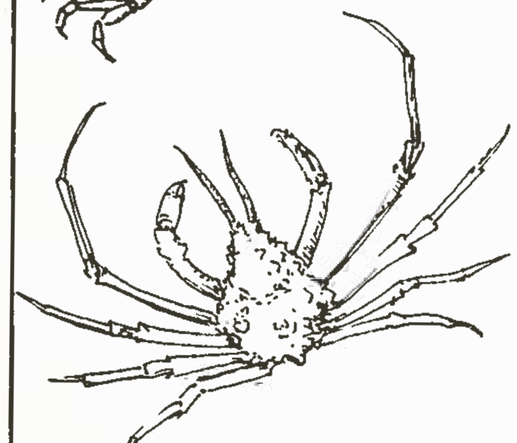
Hagahaf, red crabs of the grapsid family, live along the beach and on shore boulders. They have squarish, smooth carapaces. Two other grapsids are very flat, have spiny legs, and live in rivers.



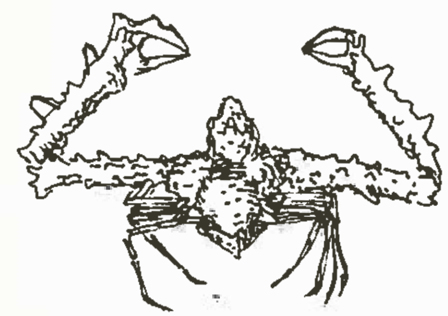
Haguihi, ghost crabs, run around in the intertidal zone. Their carapaces are squarish and smooth. They have long eyestalks and large eyes. Ghost crabs are light and sand-colored, but if they're put on black sand, they turn dark.



Fiddler crabs are close relatives of ghost crabs. Each male fiddler has one large claw used to signal with. (See <u>Mangrove Flat</u>.)



Some spider crabs are rough-bodied, small, and can carry other animals or seaweeds on their backs. These crabs are often well camouflaged and very hard to find.

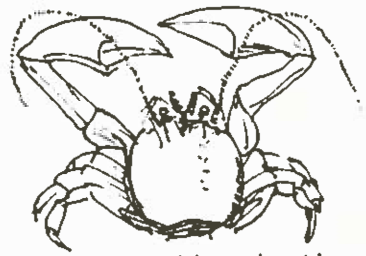


Parthenopid crabs may seem odd because of unusual sculpturing on the carapace and the extremely long first pair of legs. The body form lets them hide very well.

Hermit crabs have soft abdomens and back into abandoned snail shells for protection. Guam has more than 20 kinds of hermit crabs. Sometimes sea anemones live on the snail shell. When the hermit crab outgrows the snail shell, it moves into a bigger one and transfers the sea anemones to the new shell.

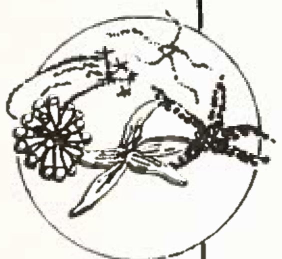
At least 4 kinds of hermit crabs on Guam are land-dwellers. Even so, in order to hatch, their eggs must be laid in the water around the Island. Three kinds hang around houses or roadsides and live in African snail shells. They will eat almost anything.

Ayuyu, the large coconut crab, whose adult abdomen is so hard it doesn't need an extra shell, is a hermit crab. As a juvenile, it does use a mollusk shell for protection.



Small flat porcelain crabs stick to the bottoms of boulders. They're closely related to hermit crabs.

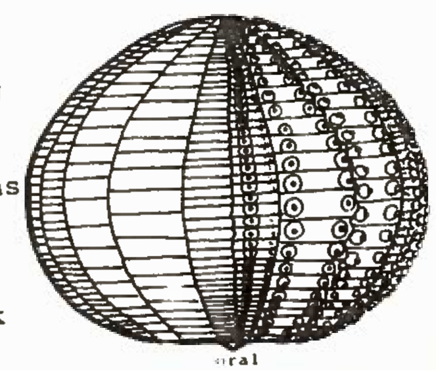
Crabs and other crustaceans are a large and influential part of the reef population. More than 600 crustacean species live in the shallow waters around Guam. They live in lots of different places and do lots of different things on the reef.



Echinoderms (echin = spiny, derm = skin) - This diverse group has a spiny skin and tube feet. They get around by pumping water into the tube feet and extending them. Some echinoderms have short spines, others long. On the skin around the base of the spines are neat little 3-piece jaws. They cut debris that lands on them into little bits. The bits then drift off in the current, leaving the skin free and clean.

CRINOIDEA (crin = lily, oid = like) - sea lilies. Most live in deep water, but a few brightly-colored ones grow on the reef. Crinoids have a central body with the mouth on top, 5 arms, and maybe a lot of 'fingers'. Their attached stalks with the 'arms and fingers' make them look sort of like flowers.

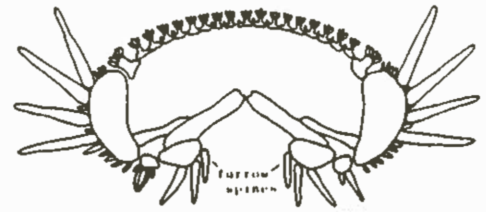
ECHINOIDEA (echin = spiny) - sea urchins. They have a globular skeleton of calcareous plates with many spines sticking out. The plates are a 'test', not a shell. The mouth is on the underside, and so the urchins can scrape up food from the substrate. Some sea urchins have brittle, sharp-pointed spines. Tips of these can break off in a person's skin, and be quite painful.



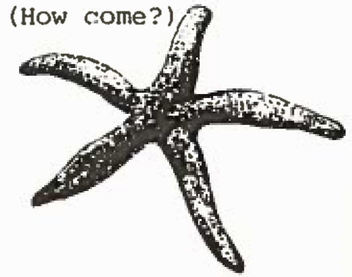
GENERALIZED SEA URCHIN TEST, SIDE VIEW

ASTEROIDEA (aster = star) - starfish, sea stars. Most have 5 arms, made of loosely connected plates. The mouth is underneath, in the center. A starfish eats by pushing its stomach outside its body, digesting its food there, and sucking it in. The bright blue Linckia of our leeward western flat has not been recorded from Guam's windward side. (How come?)

Linckia



TRANSVERSE SECTION OF STARFISH ARM



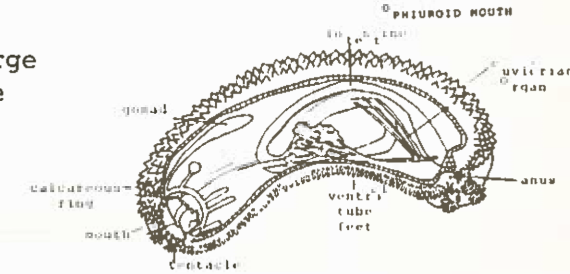
Guam has more than 20 different kinds of starfish. Years ago, the crown-of-thorns starfish, Acanthaster planci, was thought to be a relatively rare reef animal. Then, in the 60's, its population exploded, and Acanthaster ate up lots of live reef corals. The whole reef was changed. Colorful fishes disappeared. Filamentous algae grew on dead coral skeletons. Burrowing organisms attacked the dead coral, weakening it. We still argue about why the crown-of-thorns population increased so rapidly. We blame pesticides, dredging, and over-collecting of the triton snail, which eats crown-of-thorns. Trying to 'save the reef', people did different things to get rid of crown-of-thorns, injecting them with poison under water, dredging them up to be killed by drying. After awhile, the Acanthaster population declined. We think we caused the decline. But the crown-of-thorns numbers dropped where there was no attempt to control them at all. We still don't know; suddenly, they were killing the reef——just as suddenly, they weren't.

Serpent stars (brittle stars), Class OPHIUROIDEA (ophi = serpent), also have 5 arms. Calcareous plates on the mobile arms give them a spiny look. Black or gray, they live in shallow water, usually in crevices, with 2 or 3 arms extended. These break easily——that's why they're 'brittle stars'. If you try to pull one out of its hiding place it may come loose minus a couple of arms. Or you may find yourself holding a lonesome arm, whose body is still back in the hole, beginning to grow another.

OPHIUROID MOUTH

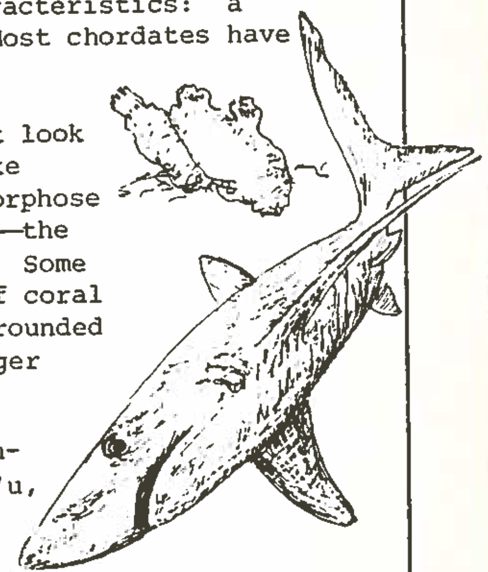
Sea cucumbers, Class HOLOTHUROIDEA, lie around on the bottom in shallow bays. Some live on sand and others on boulders or among corals. There are 30 species in Guam waters. One long brown-and-white striped sea cucumber here has mistakenly been called a sea snake and a giant worm.

One deep water sea cucumber is covered with large pointed papillae. Most sea cucumbers have tube feet; one group doesn't have any. They feel sticky because of sharp, anchor-like spicules that stick out of their skin.



GENERALIZED HOLOTHURIAN SEA CUCUMBER

Chordates (chord = rod) - At some time while they're growing up, all chordates, you included, have 3 characteristics: a 'backbone', a nerve cord, and gill slits. Most chordates have a hard skeleton. Our first 2 groups don't.

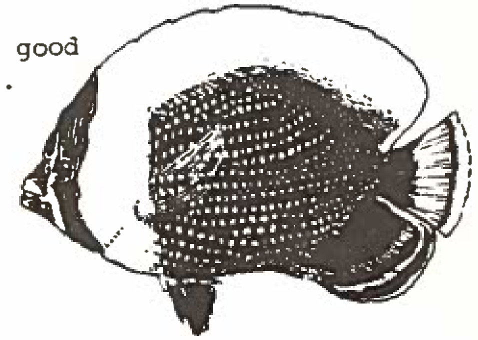


ASCIDIANS (sea squirts) are chordates that look like invertebrates. As larvae they look like tadpoles. When they settle down they metamorphose into attached animals with 2 body openings—the water flows into one end and out the other. Some colonial ascidians live on the undersides of coral boulders in shallow water; they are small, rounded lumps, orange, white, or pinkish. Some larger ones live alone like hermits.

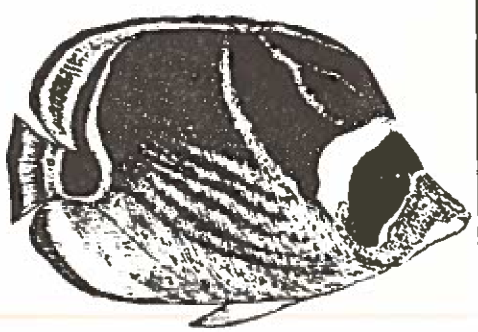
CHONDRICHTHYES (chondros = cartilage, ichthyes = fish). Sharks—halu'on unai, halu'u, and katsunesitu—have cartilage skeletons.

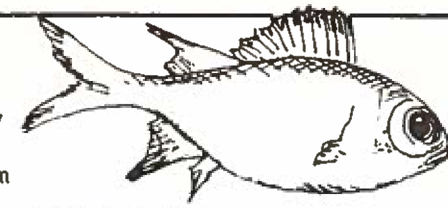
Typical reef fishes have bony skeletons. They are OSTEICHTHYES (ost = bone). Six hundred different kinds of fishes swim around Guam. This section should help to identify several of our reef fish families.

A snorkel across the reef flat will show you many kinds of flatfishes (tampat), with both eyes on one side; small gobies (macheng) darting across the bottom and into burrows; cruising angels, damsels, wrasses and butterflies. Most 'reef fishes' are among the corals in deeper water, including the butterfly fish (ababang) that has a black line on the yellow body. Many of them have a large 'eye' near the tail fin.



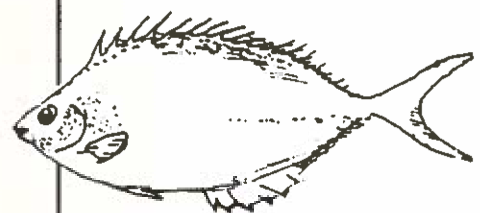
Butterfly fishes (Chaetodontidae) are good examples of diversity within a family. Some are plankton feeders. Others eat a variety of different foods. Among the butterflies, the bright angelfishes can even change their design as they grow. A baby angel is basically black with a blue and white target on its body. By the time it's grown to full size, the markings have changed to wavy yellow squiggles on burnt orange. A bandit angel has a 'mask' across the eyes running all the way back to the tail. A butterfly fish dorsal fin can look like a ruffle or a crown of spikes. Some have long noses or buck teeth. One has a blue body with pink stripes and a yellow face with black stripes.





Squirrelfishes (Holocentridae—cha'lak, sisi'ok, sagamilon) are usually small and red with light and dark stripes from head to tail. They hang around ledges and caves and run in small schools.

Goatfishes (Mugilidae—pi'os) have a pair of barbels, long whiskers, under the chin. They use them to sense small crustaceans in the sand.



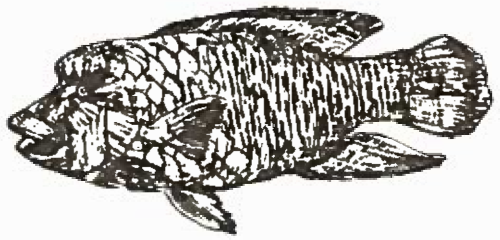
Three similar groups can be found together on the reef flat: siganids, surgeonfishes, and the Moorish idols. Most common are the Siganidae—rabbitfishes. During the Spring, and again in the Fall, small juveniles—mañahak—swarm over the reef margin into shallow water. They grow up inside the reef. During their 'run', you can catch them by the thousands. People pickle them and eat them whole. The ones that escape may mature into sesyon, the middle-size fish among the blades of turtlegrass.

Surgeonfishes (Acanthuridae—tataga') have single movable or double immovable 'blades' on each side of the base of the tail. These blades can cause a nasty wound if you don't handle the fish properly.

Surgeonfishes are herbivores; they eat algae. You can use sargassum weed that floats near the shore for bait. Surgeonfishes are generally thin from side to side and are quite high. Their colors range from dull to brilliant, with highly patterned markings.

Moorish idols (Zanclidae—ababang gupalao). We have only one species here. The body is very thin from side to side with alternating black and yellow bars. The dorsal fin has a long extension. The snout is long, too, with an orange mark on top. Moorish idols usually swim in pairs. When disturbed, they gracefully swoop under the overhang of a boulder.

Damselfishes (Pomacentridae——fomho') inhabit coral beds in the outer reef flat. They live only with particular species of corals. Black and white spotted damselfish live around upright branching corals. Damsels also come in peach, blue, green and gold, each to its own kind of coral.

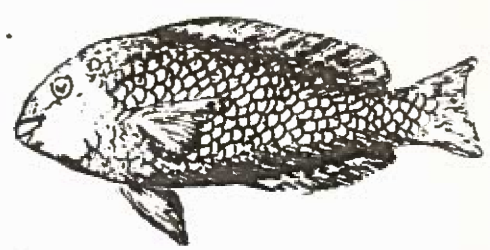


Wrasses (Labridae——a'aga, gatdas, palaksi, tangison). Wrasses can change color markings as they grow older. They can switch personalities and even change sex. Ichthyologists and other wrasses are about the only ones who can sort wrasses out.

A young yellowtail wrasse is scarlet with black-framed white splotches, and white tail. By adulthood, he's orange in the face, red on his blue-dotted fins; his black body has electric blue spots, and his tail has turned yellow. These fishes may come with vertical/horizontal/zigzag stripes in many shades.

The cleaner wrasse eats parasites off larger fishes, which obligingly hold still while the cleaner cleans them up. Some, like tangison, the humphead wrasse, grow to enormous size.

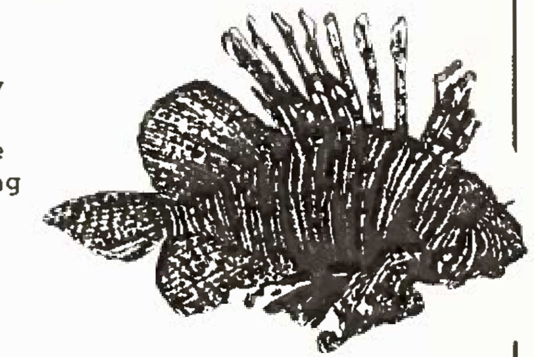
Parrotfishes (Scaridae——laggua) are brilliant with blues, greens and reds. With their large teeth they scrape coral for the algae living inside it. At night they blow themselves a sleeping bag——a mucus cocoon which keeps predators like eels from attacking. Each morning, the parrotfish swallows its cocoon and swims away.



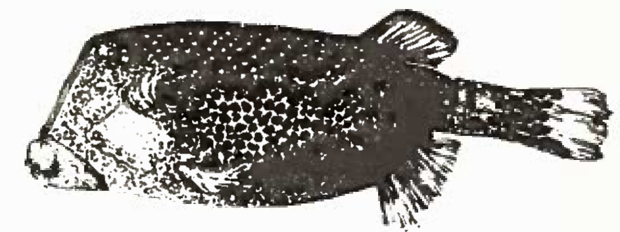

nufo'

Scorpionfishes (Scorpaenidae) live close to the sand. They're usually dark and well camouflaged. Nufo', the poisonous stonefish, is in this group. Scorpionfishes hide in rubble and algae.

Nufo' pabu, the turkeyfish, looks like a rust, brown and white feather fan as he swims slowly and gracefully above the coral. The 'feathers' are poisonous, but if you keep your place he'll just hover at the bottom, waving them and looking remarkable.



Boxfish and cowfish (Ostraciontidae) have hard plate-like coverings. They're fun to watch. The cowfish has 2 horns aimed forward above the eyes. The boxfish is black with small white spots and looks like a clown.

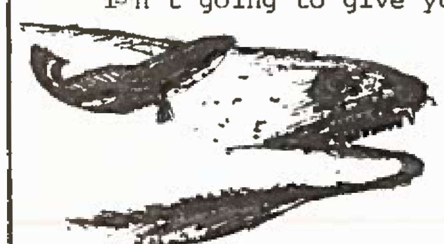


Pulonon, a triggerfish (Balistidae), has eyes well back and a long, painted-on mouth running to below the eye. His real mouth is only about a centimeter wide. He spends hours building his nest. He digs a hole in the reef, brings rocks, and prods and nudges them until the arrangement suits him. Then he shoves sand up around the decor. He'll fight like a tiger if anyone tries to rearrange it. Otherwise he's a peaceable fellow.

Around Guam there are several families of eels. The moray (Muraenidae——hakmang) is about 2 m of angry muscle and sharp teeth. He doesn't go looking for trouble, but don't put your hand near him or try to start anything.

The 'white' or conger eel (Congridae——hakmang palus) is really gray or tan with a black line on the dorsal fin edge. He's not dangerous.

At first glance, sand eels (Ophichthidae——hakmang lisayu) look like Palauan sea snakes, but eels don't have scales and they breathe with gills, not lungs. Besides that, hakmang lisayu isn't going to give you any trouble.



VIII - You Scratch My Back...

Animals often live together with other kinds of animals—they are associated.

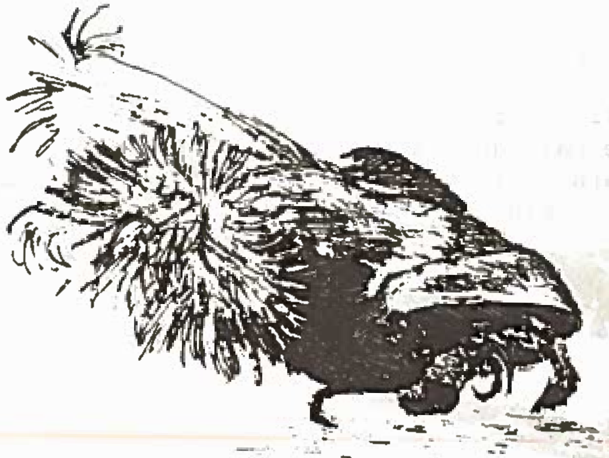
In parasitism, one animal gets food from its host, the animal it lives on. Ectoparasites (ecto = outside) live on the surface of the host. Many kinds of crustaceans with long, piercing mouth parts live on the gills or other parts of a fish. To be a successful parasite, the parasite shouldn't kill the host. Why not?

Endoparasites (endo = inside) live inside the host's body and get their food there. Many worms live in intestinal tracts, blood systems, or body cavities of invertebrates, fishes, and other animals.

Sometimes, animals that live in another animal aren't parasites. They may be there for shelter or protection, and don't harm the host. Boring animals find good protection inside what they bore into. The most common borers are worms. A peanut worm has a head that looks like a drill. It grinds its way through live and dead corals with the help of an acid it secretes. Some 2-shelled mollusks swivel back and forth and slowly drill holes in rocks. One sponge grows through the middle of a coral. Look at broken pieces of coral, and you'll see that the fuzzy yellowish stuff in the middle is sponge.

Some small fishes and shrimps clean up big fishes by eating their parasites. (See cleaner wrasse, p 52, and shrimp, p 44.)

Sometimes, several animals live together. In one hermit crab-sea anemone arrangement, a hermit crab carries sea anemones around on a borrowed snail shell. The mutual advantage is clear. The hermit crab is concealed by a poisonous animal. The sea anemones get to move around with the crab and eat food particles that the crab spills. As the hermit crab grows larger and changes shells, it moves its sea anemones from the old shell to the new one.



This isn't the whole story, though. Two kinds of sea anemones are involved—the larger one on top and a small one on the underside of the crab. If you collect these hermit crabs (cover with a plastic bag when you move them, even under water), still other animals show up. A small amphipod crustacean swims around the sea anemones and eats small leftover food particles.

Two kinds of worm share the shell with the crab. They steal food from it while it's eating. A small stalked barnacle attaches to the shell under the base of the sea anemone.

There goes an entire zoo, nonchalantly strolling around in the shallow water!

In another crab-sea anemone association, the crab holds an anemone in each claw. When the crab wants to eat, it sets the anemones down and uses the claws. Threatened, the crab will use the sea anemones as 'boxing gloves' to ward off attackers.

Around low mounds in shallow places, a fish and a snapping shrimp will share a burrow. The shrimp keeps the burrow free of pebbles while the fish swims above scouting for food and protecting the home.

A small black and white swimming crab crawls on sea cucumbers. If the crab is disturbed, it quickly crawls into the sea cucumber's mouth or anus for protection. In this case, only the crab benefits. The sea cucumber doesn't care one way or another. Sea cucumbers also play host to pearlfish, which look like tiny eels. The pearlfish may actually eat some of the inner parts of the sea cucumber, but the sea cucumber grows them back again anyway.

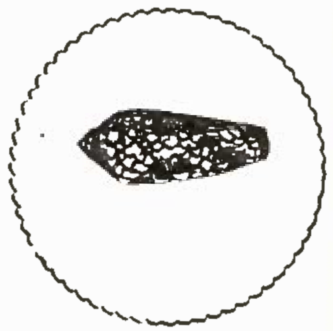
Snails have lots of associations: They can be parasites or have casual relationships. Many of them eat other reef animals. Some feed only on coral polyps. Others live only at the bases of specific corals. One spends its entire life imprisoned in large soft corals.

So, animals may depend on other animals for more than food. Where there's a living-space vacancy, somebody will move in. In many cases, the association is coincidental. Sometimes it's a necessity for both animals, and is vital to their survival. (See Freshwater, pp 24-27, for details on symbiosis.)

IX - Don't Tread On Me

Some coral reef animals are dangerous. Some sting or are venomous, some are poisonous to eat, some bite. Some have ways of self-defense that can also kill prey.

With its glass-like splinters, even the 'harmless' fireworm can make your fingers sore. The hollow spines of the long-spined sea urchin carry poison. They break off easily in fingers, knees and toes. You can get serious puncture wounds if you step on a crown-of-thorns starfish. The well camouflaged stone-fish has 13 long, hollow spines in its dorsal fin. If you touch them these spines can inject poison. Fire corals burn and cause a nasty rash after being touched.



The sting of cone shells can cause death. The teeth of these snails are long, pointed radulas connected to a poison gland. As the radula sticks into prey, it injects the poison. Use tongs or thick gloves to handle them. Never pick them up with your bare hands.

Some fish are poisonous and cause the disease ciguatera. Usually the large carnivorous fish are the most toxic—barracuda (alu, alon laiguan), moray eels (hakmang), and snappers (tagafi). We think that ciguatera poison is first produced by an alga; the alga is eaten by a herbivore. The herbivore is eaten by a carnivore. The food chain keeps the poison moving along.

The buteten malulas (pufferfish, blowfish) of Guam is poison. In Japan this fish is called fugu. There, special chefs are trained to clean and cook the fish very carefully. They must taste it themselves before serving it.

Many fishes, like sharks, barracudas, and moray eels, can slash with their sharp teeth. Sharks (halu'u) and barracuda (alu) are dangerous because they can bite off an arm or a leg—and if they're big enough, more than that.

Be cautious around large predatory fishes.

Beware the Jabberwock, my son!
The jaws that bite, the claws that catch!
Beware the Jubjub bird, and shun
The frumious Bandersnatch!
L. Carroll

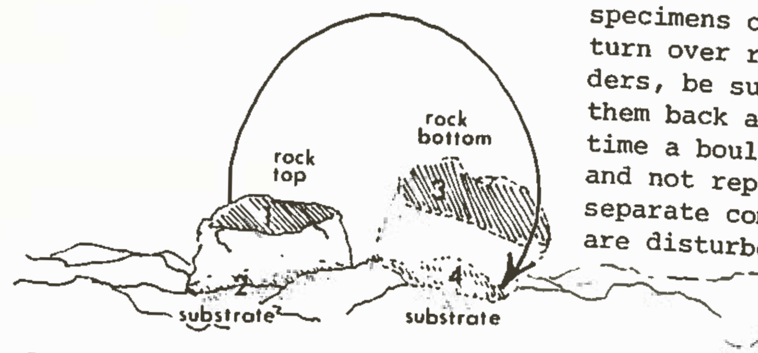
X - Off We Go

Most of the time at Guam, the ocean is a real friend. It sends cooling winds to the land. Boats and ships travel on it. Fishes and lobsters live in it. People play in it. The reefs are breakwaters and also give us some spectacular surf.

Coral reefs keep the ocean from getting too friendly and eating up the shore. They keep sharks out and people in.

The reef is there to enjoy. The surf pounding on it is a reminder that it keeps the land from washing away.

Turtlegrass beds on the inner reef are nursery grounds for plants and young fishes. Here the small fishes are safe among the long grass blades. People who live nearly surrounded by reefs fish on them, or talk about them, and should know something of what's going on out there.



Reef organisms are delicate. Be careful. If you walk or collect specimens on the reef and turn over rocks or boulders, be sure to turn them back again. Each time a boulder is moved and not replaced, 4 separate communities are disturbed.

Put back any natural things you move. Walk carefully and disturb the corals and other organisms as little as you can.

Don't over collect. Follow the Sheller's Creed of the Hawaiian Malacological Society. Here's part of it:

> *"The wildlife and natural resources of these islands have been entrusted to me for protection and preservation. . .I must account to the future for my handling of this wealth today."*

Suppose there are 3 cowries and you take 2. Can one cowry reproduce itself? If it could sing, you'd hear: 'I'm a lone cowry. . .'

You know what pollution is. You hear about it, read about it and talk about it yourself. Let's think about it some more. The oceans can be polluted in many ways—with freshwater runoff, heated wastewater, sewage, and industrial waste.

Rivers and streams carry silt and fine-grained sand. They smother animals and plants on the reefs. Every time it rains inland, river water carries silt. Planting grass and trees can prevent some of that runoff.

When people get into the act and disturb the land near rivers, trouble begins. Rain sloshes dirt from bulldozed hillsides into the river. The river dumps it on the reefs.

Some animals living at river mouths or on adjacent reef flats are adapted to daily tidal changes. But reef organisms can't 'breathe' in freshwater. A storm drain can drown the life where it empties.

Power plants like those at Piti, Cabras Island, and Tanguisson Point cause thermal (hot-water) pollution. Ocean water is taken into the plant to cool the power-making machinery. Cooling the hot machinery, the water heats up. The hot water pumped back onto the reef kills algae, corals and other organisms. How hot is this discharge? A band of coral outside the Tanguisson power plant has been killed by hot water.

At the University Marine Lab, experiments were done on live corals to find out how hot water affects them. After 5 days at a temperature 6°C above normal, all the corals were killed. After 2 weeks at a temperature 4° above normal, all in another group were dead. Even with a 2°C increase, most corals had not grown at the same time as those living in regular seawater (28°C).

Several spots around Guam are polluted with sewage. Each time you empty the sink, flush the toilet, or drain the washing machine, water flows into the sewer system. Sewage will be dumped into the bays and the ocean. In deep waters sewage is diluted. Shallow bays are soon polluted. Does Guam have any bays like that?

Guam doesn't get much industrial waste——we don't get much smoke or spillage from factories, refineries and other businesses. Why not? What pollution do we get?

During many centuries past, people learned to take advantage of the water and the reefs. Boats were built to sail among the islands. Different fishing techniques were developed to catch many different kinds of fish. The Chamorros were experts in building and sailing outrigger canoes——European navigator-explorers called Guam the 'island of swimmers' and the 'island of lateen sails'.

Today, not many commercial fishermen work out of Guam. Many years ago, Islanders depended on the sea to provide food for their families. Now, only a few people still fish on the reefs, with nets and spears. Some collect snails and seaweeds to eat. Some dig clams and use fish traps in Cocos Lagoon and Apra Harbor and some of the windward bays.

Laws have been passed to keep enough food in the waters. Agents of the Department of Agriculture's Division of Fish and Wildlife are responsible for enforcing fishing rules and regulations. They issue licenses and often stop people and count their catch. They take censuses of fish populations and are beginning an aquaculture program, to grow fish for food.

Aquaculture grows water plants and animals in ponds or tanks——not in their natural habitats. Mariculture grows marine organisms in fenced-off areas of seawater. At the University Marine Lab, successful work has been done with mañahak (rabbitfish). These small fish were collected on reefs and grown in seawater tanks. They were fed special food, and grew faster than those living on the reef flats.

We've built artificial ponds along the Talofofo River to grow eels and shrimp. Those ponds have been quite successful, too. On Guam, the shrimp grow very fast.

The reefs contribute to our daily life, providing food, space to swim, snorkel, dive, and a place to sail boats.

Take care of the reefs and enjoy them. Good reefing!

T H E   J E L L Y F I S H

(after the English of
Marianne Moore)

Annok, malingu
i lamlam na alahas,
i amariyu na alahas
sumasaga gi sanhalom-ña.

Umarima i kodo-mu,
ya ha baba,
ya ha huchom.

Hinasso-mu na un kone' gue',
lao lumaolao.

Maleffa-hao nu i intension-mu.

free translation
by V. Olson and
Mrs. Huxel's Chamorro class,
University of Guam,
Spring 1971

An Aquarium

Get one of the different-sized fishtanks sold in stores, or make your own from any transparent container.

Scrub your aquarium clean and keep it clean. Rinse it thoroughly with running water.

One of the best systems has a filter on the bottom. If you have this kind, there should be an air space between the bottom of the filter and the aquarium floor. Attach the air hoses, making sure they fit tightly.

Put well-rinsed, coarse gravel or sand over the bottom and the filter. Use a reasonable amount, depending on the size of your tank (and whether or not you want to put a box crab in it).

Fill the aquarium with water. On the gravel or sand, put a small dish to deflect the water and keep the bottom from getting washed around as you pour water on it. Let the cloudy water settle before you put anything into it. Arrange small coral boulders on the bottom.

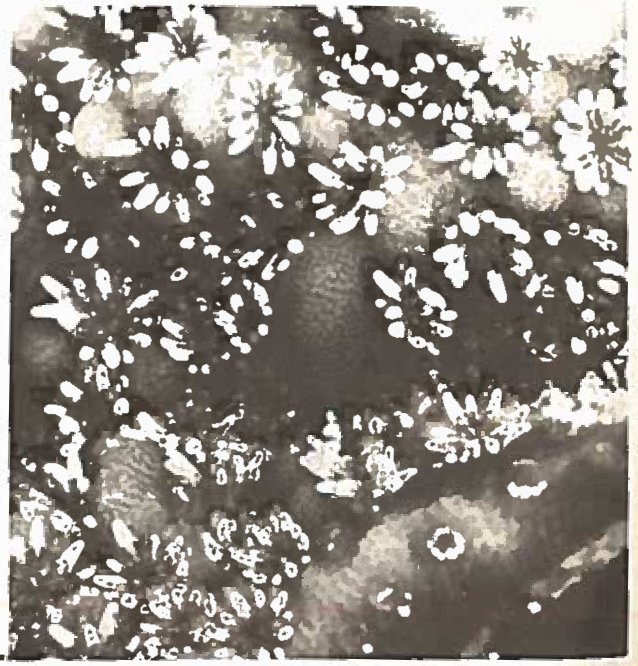
With the air hoses running to pump and filter, adjust the air flows until there are only 3 or 4 bubbles at a time in the upright tubes. This forces the water slowly through the hoses to the filter, from where it returns through a larger tube.

All sorts of different organisms can be put in your tank—but not at once! First, put in a few living things you collect on a field trip. Invertebrates crawling along the bottom help keep the sand clean. Mollusks can climb on the boulders or glass. Fishes can swim in the upper water.

Feed carnivores bits of fish or meat. You can grow brine shrimp for some animals to feed on.

For herbivores, a growth of seaweed is good eating.

If the aquarium is near direct sunlight, seaweeds will grow too quickly. Better to put it away from the sunlight—this helps control the algae.



Montipora
polyp diameter 1 mm

Index

P l a n t s

A n i m a l s

References

Clark, A. M., and F. W. E. Rowe. 1971. Monograph of Shallow-water Indo-West Pacific Echinoderms. British Museum (Natural History), London. 238 p.

DiSalvo, L. H., and H. T. Odum. 1974. Coral reefs. Coastal Ecologial Systems of the United States 1:372-441.

Patton, W. K. 1974. Community Structure Among the Animals Inhabiting the Coral Pocillopora damicornis at Heron Island, Australia. *In* Symbiosis in the Sea 2:219-243.

Wells, J. W. 1957. Coral Reefs. *In* Treatise on Marine Ecology and Paleoecology 1:609-630.

Williams, A. B. 1965. Marine Decapod Crustaceans of the Carolinas. Fishery Bulletin 65(1):1-298.

Acknowledgements

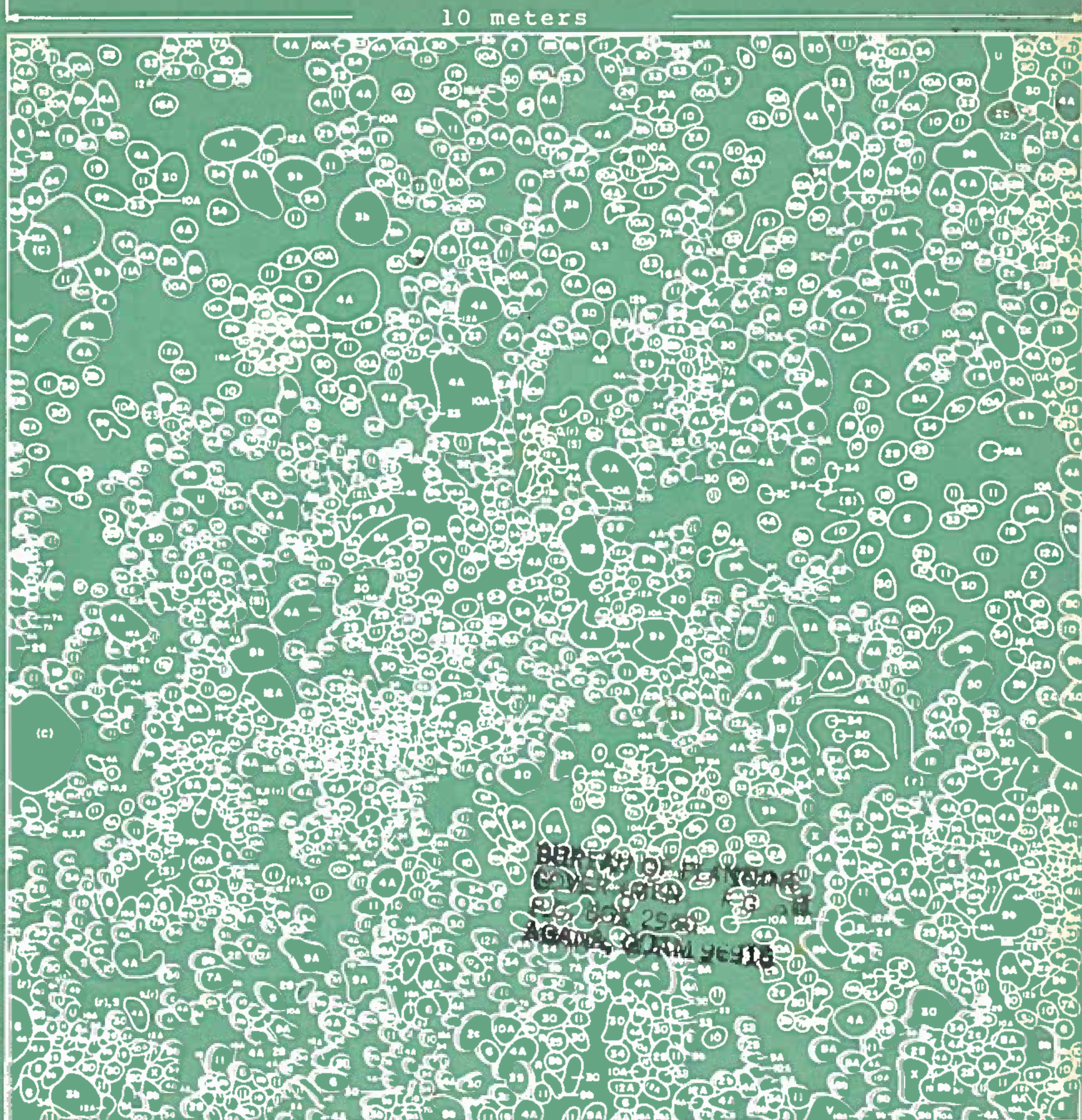
Photo credit pages; photos numbered (in parentheses) left to right and top to bottom as they appear on their pages: R. H. Randall 12 (2), 15, 18, 19 (1 & 2), 22 (1), 23, 24 (1 & 3), 27, 29 (1), 36, 37, 47, 48, 49 (1), 52, 60; T. L. Tansy 3, 6, 12, 34, 38, 49 (2 & 3); D. Hotaling/R. H. Randall 9, 19 (3), 20, 22 (2), 28, 29 (2), 30; H. T. Kami 25; U. S. Navy inside back cover. Back cover from a study of Guam's west shore currents and coral ecology, Special Publication 259, U. S. Naval Oceanographic Office, 1974.

Our thanks to Joseph A. Quitugua and the Learning Resources Center for photo-reducing many drawings.

As the final volume in the LOG series goes to press, the general editor again wishes to acknowledge, albeit inadequately, the generous and gifted contribution of L Hotaling. For more than a year she has volunteered her skills, working all hours and in all matters of production. Without her, Life On Guam would have been incomplete.

COCOS LAGOON

THE MANY REEF ORGANISMS OF A QUADRAT AT SELLA BAY



KEY

1A. Millepora platyphylla
1b. M. tenera
2 . Pocillopora sp.
2A. cf. P. cespitosa
2b. cf. P. meandrina
2c. cf. P. damicornis
2d. cf. P. verrucosa
3 . Acropora sp.
3A. cf. A. palifera
3b. cf. A. hyacinthus
3c. cf. A. hebes
3d. cf. A. corymbosa
3e. cf. A. leptocyathus
4A. Porites lobata
4b. P. (Synaraea)
5 . Galaxea sp.
5A. G. fascicularis
6 . Lobophyllia corymbosa
7A. Fungia scutaria
7b. F. echinata
8 . Herpolitha limax
9 . Montipora sp.
9A. M. verrucosa
9b. M. marshallensis
10 . Favia sp.
10A. F. speciosa
10b. F. pallida
10c. F. hombroni
10d. F. hawaiiensis
11 . Favites sp.
11A. F. abdita
11b. F. halicora
12 . Goniastrea sp.
12A. G. parvistella
12b. G. pectinata
12c. G. retiformis
13 . Platygyra rustica
14 . Leptoria tenuis
15 . Leptoseris sp.
16A. Pavona decussata
16b. P. frondifera
17 . Euphyllia glabrescens
18 . Pachyseris speciosa
19 . Stylopora mordax
20 . Polyphyllia talpina
21 . Oulophyllia crispa
22 . Echinophyllia aspera
23 . Alveopora sp.
24 . Polyastra sp.
25 . Cyphastrea sp.
26 . Hydnophora sp.
27 . Goniopora sp.
28 . Coscinaraea sp.
29 . Diploastrea sp.
30 . Psammocora sp.
31 . Heliopora coerulea
32 . Tubipora sp.
33 . Seriatopora angulata
34 . Astreopora myriophthalm
35 . Merulina sp.
E . Sea urchin
G . Sponge
H . Holothurian
P . Turbinaria sp.
Q . Halimeda sp.
R . Soft green algae
S . Soft gray algae
T . Fleshy Alcyonarian
U . Gonolithon sp.
V . Porolithon sp.
X . Unidentified hard coral
Y . Anemone (C). Dead coral
(r). Rock (S). Sand