HERE'S TO THE SANDY BEACH

BY
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Do you remember when you were going into the fourth grade? In third grade you had heard all these rumors about Ms. Gibson the fourth grade teacher. She was strict, you heard. She was hard and she wasn't friendly.

So you get to the fourth grade and Ms. Gibson turns out to be nothing like you were told. It was true she gave a lot of homework and she really did not smile much. If you had known the word, you would have called her *austere*, there was a sense of solemnity and dignity about her. Gradually, over the next few weeks you learned a lot about her and with time you began to respect that austerity. Looking back, she really was your favorite teacher in elementary school.

The sandy seashore has that same austerity, that same sparseness, about it. Take a blanket down there at sunrise and put it a bit above the high tide level, where the wet sand meets the dry. Just before dawn there isn't much to see, so listen to the sounds from the waves. If they are large and widely spaced, you will hear one, then a momentary silence, then a sound like Mylar being crinkled, then that crump as the next one hits the sand. Now watch the first light spill across the wet sand. At first glance, except for those early rising shorebirds, poking about in the sand, you will probably see very little living, for this is a world in hiding. You have to approach this habitat as you did your fourth grade teacher. Don't be fooled by first impressions, there are wonders here to be uncovered, some are easily found, and others require work.

THE BASICS

What Is A Beach?

A beach is an area of loose particles that cover part or all of a shore. At the landward side the beach might end with vegetation, a cliff or something constructed, such as a parking lot. Where does the beach end on the water side? A beach extends down into the water, until it reaches the level where the beach material (sand, gravel, cobblestones etc.) no longer moves toward the shore or is no longer moved deeper into the water. This varies with how much wave action there is, but the general rule is that the beach goes down to about

30 feet below the low tide line. The United States has about 11,000 miles of beaches, equal to about 30% of all its shoreline.

What Are Beaches Made Of?

Contrary to what most people might picture in their minds, beaches do not have to be made of nice, fine white sand. If the stuff is loose and can be moved by the water, it qualifies as beach material. So anything from boulders the size of a VW bug to extremely fine silt makes up our beaches. In particular, "sand" is defined as particles ranging in diameter from 0.062-2 mm (0.002-0.08 in.). And beach material varies widely. Throughout the world most beaches are composed primarily of ground-up rock, but many contain a lot of shells. Much of the continental U. S. has beaches made up of quartz and feldspar, the main minerals in granite. This makes for fairly steep, often soft beaches, with relatively large sand grains. On the other hand, the beaches of Oregon and Washington are formed from basalt and the sand is gray-green, fine in texture and quite hard. Much of the English coast is lined with small flat stones the British call "shingles". The black beaches of Hawaii and the Galapagos are composed of broken down lava and some of the beaches along the southwest African coast contain a surprisingly large number of diamonds.

My favorite beaches are those on small tropical islands, where there is no rock or lava at all. Where does all that nice, white "sand" come from? Actually, that nice white stuff is ground-up coral. When parrotfish eat living coral, they grind the hard parts up, digest the soft parts and pass the inedible material out into the water. This washes up on shore and creates the lovely beaches you saw in *South Pacific*.

How Are Beaches Made?

W*aves, tides and currents* are important factors in a beach's (and its inhabitants) birth, life and death.

Waves

Wave *size* has a profound impact on beach size, shape and composition. The size of waves depends on several factors and the most important is the size of the area a wave travels through without being hindered by islands or undersea ridges. The more wide open an area, the larger the waves that can be generated. If you stand anywhere from Cape Flattery, northwest Washington to Pt. Conception in central California, there is absolutely nothing between you and the Aleutian Islands. That is a long, long way and it allows for some fearsome waves to form. Wind velocity is also important, which explains why waves are higher during storms. On much of the Gulf Coast, waves tend to be small, and they are a factor only during hurricanes and other storms. Wave *frequency* also affects a beach. Wave frequency is the number of waves that pass a point (or hit a beach) per time period. It is often a reflection of wind velocity. The shape of the coastline has a large influence on wave action. Irregular coastlines, with bays, points and offshore reefs, will have a mixture of

wave activity. Offshore reefs and points will catch the full brunt of the waves. Coastlines inshore of reefs or in protected bays will be more protected.
How do waves influence beaches? First, wave action wears away coastlines, creating more sand for beaches and potentially enlarging the size of the established ones. Of course, the hardness of the cliffs also has a large influence.   Soft cliffs, combined with heavy wave action, can erode away very quickly. In an extreme case in 1724, more than 36 feet of shore cliffs along the English North Sea eroded during a severe 2-hour storm. On the other hand, coasts made of granite (such as the Maine coast) may retreat only a few inches per decade. In general, marine erosion is more rapid on high-energy coasts, those frequently battered by large waves. Typical high-energy coasts include much of the East Coast of the United States along North Carolina and Massachusetts, and northern and central California. Except for hurricane periods, the Gulf Coast is generally a low-energy region.

Wave size also influences a beaches composition and shape. The slope and the size of the beach material are controlled by the power of the waves that strike it. Steep slopes and coarse (large) grains mean big waves. Only big waves can pick up the large grains and toss them onto the beach, and as each wave recedes, the fast-moving water drags smaller grains offshore. Smaller surf (in more protected sites) creates wider, more gradually sloped beaches, with finer sand grains. It also has two other effects. The lower energy of this type of beach allows for more organic material to accumulate, and the finer grains hold more water at low tide. For these reasons, these beaches often contain more animals (there is more to eat and life is a bit easier), than high energy beaches with large-grained material. At the extreme, cobble beaches, where large rocks roll about continually, often have relatively few animals living on or in them. Beaches also change appearance with the seasons. Along the west coast, the bigger waves of winter storms may pull sand offshore to form *bars*, leaving behind only the larger gravel, cobble or bedrock. When the gentler seas of summer return, sand is redeposited and the offshore bars diminish.

Tides

Tides dictate how high up on the beach waves will extend. Tides are rhythmic, predictable, periodic changes in the height of a body of water. The tides are caused by a combination of the gravitational pulls of the sun and moon and the motion of the Earth. Throughout the year, tides vary in their heights and the highest highs and lowest lows occur together during the new and full moons each month. These extreme tides are call *spring* tides, which comes from the Old English word *springen*, meaning to jump or move quickly. Spring tides occur every two weeks and alternate with less extreme *neap* tides.

Tidal *patterns* (how often highs and lows occur within 24 hours) and *ranges* (the difference between high tide and low tide water levels) differ in different parts of the world. Some areas, such as much of the east and west coasts of the United States, usually have two high and two low tides per 24 hours.

These are *semi-diurnal* tides. On the other hand, the Gulf Coast tends to have one high and one low tide (*diurnal* tides) during the same period. Tidal ranges vary dramatically, depending on the shape of the water basin the tides flow through. The narrow Bay of Fundy, in New Brunswick, Canada, has tides of about 50 ft. Remember, this does not mean that the water goes inshore 50 ft. It means that it rises in height by that amount. So if the land is pretty flat, the sea might flow inshore for miles before reaching the necessary elevation. Tidal ranges for much of the west and east coasts of the U. S. are 6-8 ft. The Gulf Coast tides are narrower, perhaps a foot or two.

Currents

While a beach may look about the same from day to day, it is composed of different sand grains each day. This is because currents carry individual grains along the coast; no grain stays in one place for long. Each breaker lifts millions of grains from one spot and the longshore current deposits them at another. Though each movement may be small, there are an average of 8,000 waves a day and a 1/4 inch lateral movement with one wave becomes a 100 foot transit in a day. Over the course of a year, sands may be moved considerable distances along a coast.

Where does the sand go? On the east and Gulf Coasts sand may travel hundreds of miles (from north to south on East Coast and west to east on the Gulf Coast). On these coasts, much of the sand eventually drifts below the reach of wave action and may migrate farther out on the continental shelf. However, on the West coast there are a number of deep underwater canyons (such as in Monterey Bay, off Port Hueneme, Redondo Beach, Newport Beach and La Jolla) that cut into the continental shelf and come very close to shore. In these areas, a large amount of the sand carried from north to south by currents falls over the edge of these canyons and is lost to the beaches. Given time, these submarine sands may be consolidated into rock and uplifted to form erodible mountains again.

Why are There Relatively Few Animals On A Sandy Beach?

Okay, no matter how we pretty it up, the plain truth is that sandy shores contain fewer organisms than rocky shores and wetlands, the two other intertidal habitats. Sandy shores are particularly unstable, making them difficult places for plants and animals to colonize. Keep in mind that beaches are extremely dynamic; the story of a beach is the story of change. Some parts of it change from second to second, some from tide to tide and some from season to season.

In contrast to the rocky intertidal, sandy beaches produce very little food. What productivity there is in the sand comes from two main sources. The first is the microscopic plants in the top few inches. On protected beaches, where the sand is finer, more compact and most important, more stable, diatoms and dinoflagellates migrate vertically through the upper few inches to capture sunlight at low tide. They serve as the base of the food web for such animals as sand crabs.

Another food source for those animals which live near the high water line is *wrack,* the debris cast ashore by waves. "Wrack" comes from the Old English word "Wrak" which means destruction. Indeed, wrack contains all that has died, been ripped up, discarded or lost in the ocean, both nearby and sometimes worldwide. On a typical beach, seaweed or other plant material from nearby kelp forests makes up much of the wrack, but dead animals (such as fishes, birds, mammals and jellyfish), logs, shells etc. are also common. On the Pacific Coast, giant kelp (*Macrocystis pyrifera*), feather boa kelp (*Egregia menziesii*) and bull kelp (*Nereocystis luetkeana*) make up much of the wrack. On the Gulf Coast various sea grasses are important, these include turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*) and widgeon grass (*Ruppia maritima*).

There are many living things which spend their entire lives in the wrack. The animals inhabiting the wrack and the decaying material itself provide food for other sandy shore dwellers. Soon after the material is cast up on the beach, a number of animals pay their respects. One of the first to arrive is the *kelp fly* (*Fucellia rufitibia* is an example), which swarms in to feed directly on the kelp or on the microorganisms which live on the plant material. Kelp flies deposit their eggs deep within the now decomposing wrack and the larvae feed on the moist, highly decayed plants. *Beach hoppers*, which we discuss below, soon gather under this moist, cool and yummy environment. Once the vegetarians take up residence, the predators are quick to follow. The *pseudoscorpion* (*Garypus californicus*), which bears a superficial resemblance to the real thing, pursues kelp flies, grabbing them with venomous pincers. *Pictured rove beetles* (*Thinopinus pictus*) burrow in the sand during the day and hunt at night. They and another voracious beetle, the *ground beetle* (*Dyschirius marinus*) feed on small crustaceans, such as beach hoppers. There is a little sharp-snouted weevil (*Elassoptes marinus*) which you can look for in driftwood. It spends its entire life within driftwood, chewing on the fibers.

Be sure to search the wrack for neat things—you may be pleasantly surprised. In particular, examine kelp holdfasts, the root-like structures which anchor kelp plants to the bottom. If the holdfast is relatively fresh (newly ripped off the bottom), it is a virtual cornucopia of goodies. Cut or pry open the tendrils (try to get down into the center) and you may find octopi, kelp crabs, brittle stars, worms and other beasts. Another organism that is quite common in some areas is the leaf barnacle (*Lepas*), a large creature which attaches to almost anything that floats, including logs, buoys and bottles.

So, if you are a sand dweller this is a tough, unstable place to live. First, there is nothing to hold on to, as the surface of the sand is constantly pounded, stirred and shifted by waves, to a depth of at least several inches. Second, the sand that is your home is constantly shifting. At the extreme, a beach that has five feet of sand during the summer may only have bedrock in winter. Abrasion is also a constant problem; shells can be quickly worn away in the swirling sand.

How Do Animals Cope?

First, virtually all of the animals that live on sandy shores are quite *motile*; they move within their habitat in response to the ever-changing conditions. These changes might be predictable ones, such as the rhythmic wet and dry cycles of the tides or they might be unpredictable, as when larger than normal storm-generated waves hit the beach. Second, with the exception of birds and marine mammals, virtually all sandy beach animals live at least part of the time *in* the sand. This protects them from the pounding force of the waves and prevents their shells from being abraded by sand. Some organisms, such as beach hoppers and ghost crabs, live in distinct burrows. Others, such as clams, worms and sand crabs continually burrow through the sand. Third, all of the animals which spend at least part of their lives above the sand (such as beach hoppers, ghost crabs, sand crabs, various snails) have shells to protect them against wave damage. The few soft-bodied creatures, primarily worms, spend all of their lives well under the sand. Lastly, many of these organisms mature at an early age and have a short life span. If you are one of these animals, such as a worm, this is a very positive trait to have. Imagine how useful it would be if you could reproduce at 4 months of age, particularly if the broad sandy beach you settle on in spring only lasts nine months, and then it (*and you*) are swept out to sea with the winter storm waves. In the cases of sandy beach worms, if the beach completely disappears during winter, the worms are swept out to sea and die. Fortunately for the worm populations, not all beaches completely disappear in winter.

WHAT LIVES THERE?

Remember that on any given day and on any given beach, it is difficult to predict what animals you will find. Sandy beaches are much less predictable than the rocky intertidal. Most of the animals living around rocks are either attached to or living inside them, and massive boulders or ledges just do not move around much. On the other hand, beaches are very mobile and beach dwellers come and go. Moreover, the numbers of organisms on a beach may vary from season to season and from year to year. As an example, on the West Coast during warm water (El Niño) years, when the prevailing current flows northward from Mexico, sand crabs may be abundant all the way up to Canada. When the prevailing, cold, southflowing current returns, you may soon find no sand crabs anywhere along the Canadian coast. Also, sand crabs are much more abundant on beaches from spring through fall (they may go offshore in the winter, we don't know for sure). Some beaches lose a lot of sand during the winter and there just isn't any place for sand dwellers to live during these periods. However, do not despair, you will usually find some goodies in this habitat regardless of when you go.

As mentioned before, sandy beach organisms can be broadly divided into two categories, those which live *in* the sand and ones which live *on* it.

In-Sand Dwellers

Beach hoppers (also called sand fleas, but they *don't* bite), *Orchestoidea* spp., are the one animal you are most likely to find in huge numbers on the sandy beaches of the West Coast—up to 25,000 per square meter. These are small (a one-incher is a monster), shrimp-like invertebrates that live in the sand. Hoppers are well named because, considering how small they are, they can hop remarkably high, often up to three feet. Since they feed on decaying plants, such as the algae the sea brings in, or dead animals, the best place to find them is often under the piles of wrack near the high tide line. In fact, beach hoppers usually live where the sand is sort of fluffy and slightly moist on the surface and damp (but not wet) underneath. This allows them to easily dig their daytime burrows. Beach hoppers are active primarily at night, though if the day is really cloudy, you might find them hopping about. If you don't find these creatures immediately, don't give up hope! Beach hoppers are pretty particular about what stretch of beach they inhabit. Try looking in more protected areas, where the wave action is smaller.

There are three good ways to find these beasts. Probably the fastest and most spectacular is to lift up a clump of decaying algae from near the high tide line. If you hit the right pile, hundreds or thousands of aggravated beach hoppers will start bipping around, though they will quickly burrow into the sand. Most often these are the small juveniles, the larger ones may not be under vegetation. This is often a most exciting technique as 30 goal-oriented second graders try to catch these extremely fast creatures. The second way to find beach hoppers is with a shovel and screen. Again, find the piece of beach that has a covering of somewhat moist sand and dig down a half-foot or so. Spread the sand on a screen (you can make a simple sieve with a piece of screen surrounded by wooden sides) or a kitchen colander with small holes and shake it back and forth until the sand falls through the openings. For the third way, which requires more preparation but often catches a lot of beach hoppers, see our insert on making your own beach hopper trap.

On Gulf and east coasts (and along Baja and the Galapagos) the beach hopper job of nocturnal scavenger is carried out by ghost crabs (Ocypode), which patrol the beaches from dusk to a little after dawn. These 2-inch, sandy-colored crabs are really remarkable and rather endearing creatures. They have rather conspicuous burrows, but trying to dig one out can be a remarkably frustrating affair, as some of the burrows go as deep as 4 feet. The little grabbers may also have a second entrance through which they make their getaway. These are very fast and very active animals; when chased they usually win, even if they have to run into the waves to escape. While ghost crabs eat mostly sand crabs and small clams, they also consume almost anything organic the waves bring in. They even scoop sand into their mouths and separate out microscopic food particles from the grains. Animals that switch easily from one food to another are called opportunists or generalists, and are often typical of habitats where food availability is unpredictable. Despite spending nearly all their time in the air, ghost crabs are water breathers. They carry the salty stuff in their gill chambers and have to replenish their supplies often from the surf. If they can't make it to the water, these really resourceful animals can actually suck up water from wet sand to wet their gills. Ghost crabs prefer warm waters, and when the water cools off in winter, the crabs plug their burrows with packed sand and siesta until spring.

Along the entire Pacific Coast, particularly in protected areas, lives the bl*oodworm* (*Euzonus*). You can find these little (1 1/2 - 2 inches) worms in the soft, but not mushy sand, from near the surface to about one foot down. They appear to have very specific requirements, because when you find one you find them all; they form a narrow band along the beach. Bloodworms get their rather graphic name from the bright red blood which is quite visible through their thin skin. One way to find the bloodworm zone is to dig a series of small holes from the beginning of the wet sand down toward the ocean. Space the holes about two feet apart. You'll know when you hit the right area, a shovelful of sand will have lots of worms. Sometimes it's possible to find the right area just by looking for masses of footprints and tiny holes, which mark the places where birds have been probing and feeding on the worms.

A variety of other worms, often called bristle worms (members of the very large group called po*lychaetes*) may be found a foot or two below the sand on some beaches. A greenish one called *Nephtys* is common along the California coast. It grows to 5 or 6 inches long and you often find it in the bloodworm zone, where we suspect it is nibbling on these smaller worms. Many of these worms are quite active hunters, feeding on other worms, with sharp, hard jaws. These are folded back into a balloon-like sac (a proboscis). A muscular contraction turns the proboscis inside out to expose the jaws and zap the prey. Having been nailed by several of these worms, I would heartily advise caution in handling them, lest you find yourself doing a peculiar little dance on the sand. Open coast beaches along much of North America are hot spots for the *sand* or *mole crab*, *Emerita*, a very common burrowing animal. These are very cute, sort of teardrop shaped crabs, often found in dense aggregations. Usually the largest individuals are found on the lowest part of the beach (you may have to get wet to find them) and the tiny ones are in the highest. Sand crabs always run and swim *backwards*; so what appears to be a rounded "head" is actually a rear end and what looks like a feathery "tail" is actually the antennae on their head. Sand crabs spend most of their lives entirely buried in the sand, with only their tiny, beady black eyes and fluffy antennae protruding. As each wave crashes, then recedes over it, the crab's antennae catch small particles, such as plankton. The crab then wipes its antennae through its mouth, and the plankton are scraped off and eaten. Many sand crabs move up and down the beach (that is toward and away from shore) with the tide, staying pretty much in the breakers. However, they can often be found in the wet sand above the water line, particularly when the tide is low. The bright orange stuff under the tail end of larger crabs is eggs and you are more likely to see these in the spring and summer. You may sometimes find so many sand crabs in an area that there is virtually no sand between individuals. On both sides of the continent, sand crab females are larger than males. On the West Coast, larger individuals are usually found nearer the ocean, so the sexes may sometimes be found on different parts of the beach.

It is often easy to find sand crabs, particularly the small ones, by looking for masses of tiny "bumps" in the sand, these mark an aggregation. Another way of spotting them is to dig a hole in the wet sand, near the wave line, allow the hole to fill up with water and see if you can spot any swimming individuals. You have to look fast, they quickly burrow into the sand.

Clams are common creatures in this habitat and these come in several basic shapes. Clams are bivalve (two-shelled) molluscs, closely related to oysters, scallops and mussels. However, while most of these latter animals must attach themselves to hard surfaces, many clams dig their way into soft surfaces. Clams feed and breathe by sucking in water through a tube (the *siphon*), which goes past the gills and is strained for small planktonic organisms and oxygen. Clams come in a wide variety of shapes and sizes; good examples are the *Pismo clam* (*Tivela*), *razor clam* (*Siliqua*) and *bean clam* (*Donax*).

Pismos are large (5+ inch); thick-shelled animals that have to live in areas of high surf, as they apparently require a high oxygen content. Pismos were at one time extremely common from central California to Baja California, but, because they are a favorite food of both humans and sea otters, their numbers have declined over the years. These clams resemble everyone's idea of a "clam", using their heavy, tough shells to withstand the pounding of the surf.

On the other hand, razor clams (found from Alaska to Mexico and all along the East Coast) have long (up to 6 inches) and quite fragile shells, an unexpected development in this high-energy habitat. However, razor clams depend on speed, not strength to survive. Like the few other species adapted to feed in the midst of the crashing surf, this animal if uncovered by the water, is able to burrow fast enough to reposition itself with the short time between one wave and the next (an average of 7 seconds). Its ability to dig fast comes from a truly heroic-sized foot, which is often 50% of the shell length. When digging for its life, the pointed tip of the foot is driven into the sand, blood is pumped into it and it expands like an anchor. Contracting the foot muscle quickly pulls the animal below the surface.

Bean clams are tiny critters, one inch long at the most, which occur from southern California southward and on the Gulf and east coasts. Like sand crabs, the abundance of bean clams varies greatly from year to year. As a kid in southern California, I can remember years with none and years with so many it was literally painful walking on the wet sand at low tide. On the West Coast, these clams tend to avoid the most turbulent surf and dig deep to wait for calm periods. However, on the east and Gulf coasts the species acts like a sand crab and actually emerges in the surf, allowing the waves to carry them along up and down the beaches. They are extremely active burrowers and reposition themselves between each breaker. Bean clams have two siphons, one for pumping water for respiration and the other for gathering food. The feeding siphon is long and mobile and curls across the sand surface groping for detritus, the minute bits of organic material drifting in the water. Food particles are pumped down into the gills, which act as a strainer (as is true of all clams) and transport the food to the stomach.

On-Sand Dwellers

Probably the most famous on-sand animal on the Pacific Coast is the grunion, a small smelt-like fish that spawns on shore from central California to Baja California. This is a very carefully scheduled event. It occurs from late February to early September, only on the 3 or 4 nights following each full or new moon (this is when the highest tides of the month occur) and then only for 1-3 hours immediately after the high tide. During spawning, a female swims on to the sand, usually with one or more males accompanying her. If no males are present, the female returns to the water, probably muttering some fairly unflattering things about guys. If males are present, the female swims as far up the beach as possible (this is real important) thrusts herself vertically in the sand, tail first, and wiggles her tail like crazy. When she has dug herself about two-thirds of the way into the sand, she lays her eggs and the males come over and emit sperm onto her, which travels down her body into the sand, fertilizing the eggs. After laying the eggs, the female thrusts herself out of the sand and hops the next wave out.

Now, here's the reason all of this has to be timed so perfectly. While buried in the sand, the fertilized eggs take about ten days to develop into larvae. This is about the length of time between major high tides. If the eggs are not buried at the highest tide of the cycle, one of the intermediate tides will uncover them too early and the larvae will die. You can see how a grunion's behavior must be in sync not only with other grunion, but just as importantly, with the tides. It is likely that grunions use a variety of cues to signal when to hit the beaches. They probably use day length, as well as changes in water temperature, to indicate seasons. It is likely they can also sense changes in moon phase using differences in nighttime light levels.

Five species of sea turtles have at one time or another been seen on Gulf Coast beaches. These are the loggerhead (*Cretta caretta*); green turtle (*Chelonia mydas*); Kemp's ridley turtle (*Lepidochelys kempi*); hawksbill (*Eretmochelys* *imbricata*) and leatherback (*Dermochelys coriacea*). Sea turtles are most commonly seen on sandy beaches when the females come ashore to lay their eggs. The loggerhead is the most common sea turtle in the United States and while nesting has been recorded from Virginia to Texas, most occurs in Florida. As estimated 20,000 loggerhead nests are made on the beaches of southeast Florida, representing one of the five major loggerhead nesting sites in the world. As with other sea turtle species, female loggerheads come ashore at night, usually on beaches with little light. The females may crawl more than 500 feet from the water; in general the more gentle the beach slope the farther inland they will travel. After digging a hole in the sand, females usually lay 110-125 eggs per nest. During the nesting season, females return to lay more eggs (in a new nest) about every two weeks, usually within 2-4 miles of the previous nesting site. Interestingly, the sex of the young are not genetically fixed, they are determined by the temperature of the surrounding sand. In loggerheads, cooler temperatures produce males, warmer ones, females. Assuming the eggs survive predation by such animals as raccoons and feral pigs, the young hatch out in two months (always at night), pop out of the sand and head for the water. It is likely that the young key in on the reflection of moonlight on the ocean to find their way to the sea.

In the United States, known nesting sites are protected by law and all sea turtle species are listed under the Endangered Species Act. Unfortunately, sea turtles are wide-ranging animals and they do not receive the same protection everywhere. Even within U. S. waters they face danger, particularly from shrimp fishermen in the Gulf of Mexico and along the Atlantic Coast. Shrimp trawlers regularly catch turtles (primarily loggerheads and Kemp's ridleys) by accident and they are often dead when landed on deck. While the exact number of sea turtles killed by shrimpers is not known, estimates just for loggerheads killed in the Gulf of Mexico range between 2,000 and 4,000 annually. Recently, various "turtle exclusion devices", or TEDs, have been tested in shrimp nets. These are designed to allow most turtles to escape the nets, while retaining the shrimp. While the use of TEDs is growing, they still face resistance from some fishermen, who believe the devices reduce shrimp catches.

In many places throughout the world, turtles are a major food source for people. This has led to massive over-harvesting (of eggs, juveniles and adults) and today virtually all sea turtle populations are in danger. In the face of this problem, many countries have passed laws ending or curtailing turtle harvests. However, many of these laws are poorly enforced and in many parts of the world turtle numbers continue to decrease. Eggs poaching is particularly easy, because of the accessibility of sandy beaches, the turtles' predictable appearances and the lack of funds (in most countries) to pay for beach patrols. Harvesting turtle eggs is also particularly deadly. Since an entire population of adults that ranges over hundreds of miles might lay its eggs on just one or two beaches, an entire generation of turtles can be wiped out before it even hatches, by a handful of industrious egg collectors.

The horseshoe crab, Li*mulus polyphemus*, is another interesting part-time shore dweller on the East and Gulf coasts. This very ancient animal (they haven't changed much in the past 200 million years), looks dangerous, but is completely harmless. Horseshoe crabs eat algae and soft-bodied animals such as worms, and their claw-like legs are extremely weak. While they spend much of their time offshore, adults make spring spawning migrations onto sand beaches and mudflats. Spawning occurs at night, when the smaller male climbs onto the back of the female, while she scoops out a series of depressions in the sand. She then deposits 200-300 eggs in each hole and these are fertilized by the male. The eggs are then covered and left to develop. By midsummer the young hatch out and swim off into deeper water.

Shorebirds are a most aesthetic part of this habitat and they can be roughly separated into two categories, those that stick their bills into the sand and those that don't. In the former category, my favorite birds are *sanderlings* (*Calidus alba*); their name comes from the Icelandic *sanderla*, referring to their sandy habitat. Found all along the coasts of North America, these are the little ones that dart back and forth at the edge of the crashing surf, always avoiding getting wet. With their bodies held motionless and their feet a blur, sanderlings look like wind-up toys gone berserk. Watching them blitz up and down the sand, it seems they are connected to the waves and moved by them. Equipped with stumpy little beaks, sanderlings can't probe deeply into the sand, so they find their prey (beach hoppers, worms, sand crabs) as it is stirred up by the waves, before it can reburrow. The larger, more stately, *willets* (*Catoptrophous semipalmatus*) have longer bills and legs and are less concerned about getting wet; they wade into the retreating surf to forage. And because they have longer bills, they are less restricted to finding loosened prey at the sand surface. In fact, their bills have sensitive tips able to detect tiny vibrations that indicate the present of animals deep in the sand. Willets eat worms, crabs, small clams, fishes and the tender shoots of plants. Willets and other long-billed probers like *godwits* (*Limosa* spp.) are actually "feeling" the sand for food.

At the high end of the beach, elegant little *snowy plovers* (*Charadrius alexandrinus*) chase about in the dry sand and wrack snatching insects and beach hoppers from the surface. Snowys are abundant along the Gulf Coast from Texas to western Florida and along the Pacific Coast from southern Washington to southern Baja California. On gravelly beaches too coarse to probe into with beaks, or where there are thick wrack lines of kelp covering hordes of sand hoppers, there are shorebirds adapted to flipping over rocks and debris; these are the aptly-named *turnstones* (*Arenaria*). Besides using their bills to lift stones and other objects when searching for food, turnstones also root through wrack like pigs, searching for beach hoppers, worms, insects, etc. They are also common in winter among the breeding colonies of elephant seals in California and Baja California, where they make a temporary living picking flesh from the wounds of battling male seals. Along the U. S. coast, turnstones are found in California and from New Jersey to Texas.

Of course, the most noticeable birds on the beach, certainly the loudest by any measure, are the ubiquitous *gulls*. There are about 25 species of gulls in North America, ranging from the *great black-backed gull* (*Larus marinus*) which is 30 inches long and has a wingspan of 5 1/2 feet to the tiny *Bonaparte's gull* (*L. philadephia*), which measures only 14 inches long. The large *western gull* (*L. occidentalis*) dominates California beaches, while *laughing gulls* (*L. atricilla*) are the most common species on the Gulf Coast. Gulls are not particularly strong fliers. They depend on long narrow wings mostly for gliding. This is the reason you will often see them drifting upwards in long, stately spirals, riding updrafts of air created by cliffs, dunes, ocean waves, buildings or the warming of the land (these are called *thermals*). Once they spot food in the water, gulls descend and either hover or alight on the surface to feed. While they swim well, they do not dive completely under water, preferring to reach below the waterline with their heads and necks.

Most species of gulls are remarkably omnivorous; they will eat virtually anything organic. Along with fish (dead or alive), crabs and other aquatic animals, these birds also feed on the young or eggs of other birds as well as such items as rabbits, rats, worms, mice, insects, carrion, garbage, and peanut butter sandwiches from the schoolyard. Western gulls often force pelicans and cormorants to give up their fish catches, grabbing the dropped morsels in mid-flight. They are also famous for dropping sea urchins and other hard-shelled animals from great heights, in order to break the shells. Laughing gulls often feed on horseshoe crab eggs. Like westerns, laughing gulls sometimes steal food from other birds. They will light on the heads of brown pelicans and take fishes from the birds' pouches. In turn, such birds as jaegers and frigatebirds will force laughing gulls to disgorge food.

While some gull species are found well inland (the California gull, *L. californicus*, is very common over the Great Plains), western gulls stay very close to the coast. Westerns nest from May to July, usually on offshore islands, and usually produce 3 eggs. These take about one month to hatch and the young first fly about 49 days after hatching. Laughing gulls nest in large colonies, usually on the ground of coastal barrier islands or on tufts of grass or reeds in saltwater marshes. They nest from April to June and produce 3-4 eggs. These hatch in about 20 days, but their age at first flight is unknown.

True seals (e.g. harbor seals, elephant seals, monk seals) and ear*ed seals* (sea lions and fur seals) can often be seen off sandy beaches and use selected ones as *hauling out grounds* where they rest, mate and raise their young. Both, along with the walrus which will not be discussed here, are part of the group called p*innipeds*, which means “feather-” or “fin-footed”; they all have four flippers. While true seals and eared seals are closely related, there are significant differences between these animals. The most obvious difference is that eared seals have visible external earflaps, while true seals have only small holes on either side of their heads. Eared seals also have somewhat longer necks than true seals and bare flippers (without fur). But the most important difference is how these two groups of animals move on land. Eared seals have long front limbs, as much as one-third the length of their bodies, tipped with broad flippers and the hind flippers can be turned forward (under the body). Eared seals are quite agile on land; they can lift themselves off the ground with their front limbs and can move very quickly. True seals have smaller, furred flippers which cannot hold the animals up and their hind flippers cannot be turned far forward. When true seals travel on land they sort of squiggle their way around, like immense mammalian inchworms. On the other hand, true seals can generally dive deeper and spend less time breathing and resting at the surface.

All pinnipeds have whiskers and fur, which is kept lubricated with oils secreted by the skin. Only the fur seals have a dense layer of underfur, which traps air bubbles, keeping the skin dry and warm. Both true and eared seals are good divers, though some are better than others. Whereas the record for northern fur seals is 623 feet deep and 5.6 minutes underwater, that for the elephant seal is 5,280 feet and 120 minutes. True seals and eared seals eat a variety of sea creatures, most commonly fishes and squids, but also krill, octopi, and other marine life, including the occasional sea bird and other pinnipeds. Pinnipeds are eaten by a variety of larger animals. In temperate waters, orcas and white sharks eat large quantities. Orcas will attack pinnipeds right in the surf zone or even grab them when they are shuffling along the beach. In the Arctic, polar bears are a major predator. They spend much of their time around ice pack edges or seal breathing holes, waiting for seals to make an appearance. In more tropical areas, tiger sharks and probably other large sharks feed on them. A few species of true seals eat other true seals.

Historically, in areas like California, terrestrial predators, most commonly grizzly bears, also hunted those pinnipeds that hauled out onto mainland beaches. Now that humans have eliminated most large land predators, there is nothing to prevent pinnipeds from coming ashore more often and in greater numbers. Most hauling out areas are on remote beaches, such as around Año Nuevo, Big Sur and at Pt. Reyes. However, as pinniped populations increase, more animals are hauling out on beaches occupied by humans. As an example, elephant seals are becoming increasing common on the beaches around Santa Cruz, California. *These animals should be left strictly alone.* While they are not usually aggressive, pinnipeds will defend themselves if they are startled or feel attacked. Males during breeding season are particularly sensitive to encroachment.

SOME HUMAN IMPACTS ON SANDY SEASHORES
Probably the greatest impact humans have on beaches is building something (a house, marina, road) on them. Remember, beaches are not forever (often they are not even for a year), they come and then they go. When beaches start to go, say from a hurricane, the owners of beachfront structures start to get nervous and start to look for solutions. Often the solution is a breakwater or some sort of structure to keep the sand on the beach. In the long run, these cause as many problems as they solve. As an example, a breakwater was built to protect Santa Barbara Harbor in 1928. This retarded the along-shore drift of sand and the harbor promptly began to fill up. The City of Santa Barbara built an addition to the breakwater, and the problem just got worse. Without the breakwaters, sand would have continued on to the beach below the Harbor. That beach was losing its sand in a normal manner. However, the sand that should have been its replacement was now filling up the Harbor, so that beach began to disappear. Since 1935, the Harbor has had to be annually dredged and the dredged sand pumped over to the denuded beach. Whenever a structure is built or placed near shore it dampens wave action and causes sand to settle out and build up. If the structure impedes the long-shore transport of sand, the beach will expand "upstream" of the structure and contract "downstream". So if one part of a beach is protected, someone must supply other sand for the rest.

Marine debris or trash is now a worldwide problem of considerable magnitude and it originates from everyone who uses the sea: shipping, construction, commercial and sport fishermen and beachgoers. No part of the globe is immune to this problem. A sad commentary on this situation comes from a study on the aptly named Inaccessible Island, a remote, uninhabited and almost-never-visited island located in the South Atlantic. From 1984 to 1990, surveys were conducted there on the amount of litter per kilometer of beach. Every year the amount increased, from 500 pieces per kilometer in 1984 to almost 2,500 pieces in 1990! Closer to home, in Los Angeles County beachgoers leave behind 75 tons of trash each summer weekend. A lot of that garbage is carried out to sea by wind and tide. It has been estimated that 14 billion pounds of refuse finds it way into the ocean each year and much of it is plastic. Plastics are virtually immune to rotting, and once at sea they can drift for decades or centuries.

Not only is this stuff aesthetically yucky, it is a potential and real health hazard for both humans and marine organisms. Certainly syringes and other medical wastes pose a real threat to beach patrons on many urban beaches. Worldwide, marine organisms may be injured or killed by many forms of marine debris, particularly various types of plastic. As an example, 20% of the loggerhead turtles around the island of Malta in the Mediterranean are damaged from either discarded plastic or metal. A South African scientist recently pulled enough plastic from the gut of a starving leatherback turtle to make a ball several feet in diameter. And this is not an isolated occurrence.

There is good evidence that many marine mammals, birds and turtles die after either choking or starving to death, following the ingestion of plastic bags and other material. Refuse may also damage creatures in other ways. Many sea birds become ensnared and strangled in six-pack yokes and discarded fishing line.

In response to this ever-growing problem, an amendment to the International Marpol (Marine Pollution) Treaty went into effect in 1989, making it illegal for any vessel to dump plastics into the ocean. With fines of up to $50,000 and five years in jail, this amendment may be more effective than past laws, but only time will tell if it can be enforced. On a local level beach cleanup efforts have been organized in many shore communities around the country. In California, the success of these events and the need for year-round efforts led to the establishment of the Adopt-A-Beach program. Organizations all along our nation's coast are being encouraged to "adopt" a local beach, through beach cleanups, recycling and community awareness. Nearby schools often incorporate this activity into their marine science or environmental education curriculum. Students tackle the issue of marine pollution and get a chance to make a difference by creating positive change. In California, your class can become part of the solution by contacting the California Coastal Commission in San Francisco.

Oil is a natural part of the marine environment; oil seeps have been leaking large quantities of oil into the sea and up onto beaches for millions of years. However, in recent years, much more oil has entered the ocean because of offshore oil drilling and the vast amount of petroleum transported by ship and pipeline. In 1985, about 3.5 million tons of oil entered the ocean, only about 8% of that came from natural seeps. A lot of the rest was spilled accidentally, in tanker crashes, drilling platform blowouts, etc. However, a considerable amount came from the intentional, but illegal, dumping during loading and discharging of oil and the flushing of tanker ship holds. It is estimated that between 150,000 and 450,000 marine birds are killed every year by the routine release of oil from tankers.

Not all spills are equally hazardous. Actually, crude oil spills (such as the *Exxon Valdez* in 1989, the Santa Barbara oil platform blowout in 1969, and the oil released during the 1991 Gulf War) are less harmful than spills of refined petroleum. Crude oil looks terrible and does kill many animals, particularly birds and marine mammals. Refined oil products, such as gasoline or aviation fuel, contains poisonous chemicals in far greater concentrations than in crude oil. The effects of refined oil spills seem to last longer, probably because the poisonous molecules of refined products are small and can get into the sediment easier than the tar balls that crude oil becomes. Any nearshore spill, such as those mentioned above, end up washed by the tides onto our beaches, rocky shores and wetlands. With each tidal cycle the oil works its way deeper and deeper into the sand and becomes more difficult to remove.

SO YOU WANT TO MAKE YOUR OWN SANDY SEASHORE?

If you are going to create your own sandy seashore in the classroom and want to make it as accurate to your area as possible, here are a few tips. First, sandy seashores are extremely variable. Low turbulence shorelines near bays or estuaries, for instance, often have very fine sand. Just a few miles away there may be an open coast beach, which is exposed to continuous wave action. Here the sand grains may be large or may even be the size of cobblestones. In fact, there is so much variability along even a few miles of coastline that a “typical” West Coast sandy seashore can’t be distinguished from a “typical” Gulf Coast, east coast or even a South American or African one.

What does define our seashores are the organisms which inhabit them. On the West Coast, you might consider including the western gull, harbor seal and northern elephant seal (Mirounga *angustirostris*), grunion in central and southern California, sand crab, pismo clam, beach hopper and bristle worm among the inhabitants. On the Gulf Coast, include the horseshoe crab, ghost crab, bean clam, sand (mole) crab, laughing gull and loggerhead turtle. Sanderlings and willets are common sandy seashore inhabitants all along the coast of the United States. For all seashores, be sure to include a healthy amount of “wrack”, that matter which the sea has cast up and which rests on the high tide line. On the west coast, much of this material is composed of algae, such as giant kelp or bull kelp. The Gulf Coast does not have these great stands of kelp, and here wrack is composed mostly of such seagrasses as turtle grass, shoal grass and widgeon grass.

WHAT IS SAND?

Everyone talks about sand, but what is it? Sand is composed of four very different kinds of particles. First, there is ***abiotic*** or ***Earth-based*** material. This is the stuff worn away from continents or islands, by rain, rivers, wind or waves. The sand on most of the beaches around continents is composed of quartz and clay. Quartz is hard, durable material (the major component of granite) and is very common on wave-swept beaches. Where wave action is low, particularly in back bays or river deltas (such as around the Gulf Coast), sand often contains a lot of clay. Clay particles are light and tiny and are not found on beaches with heavy wave action, because these particles are easily swept out to sea. Any mineral can become sand, if it is exposed to moving water and/or wind. ***Biotic*** or ***Life-based*** sands are the next most abundant type. These are bits of calcium or silicon that were the shells and skeletons of various creatures, such as coral, molluscs (clams, mussels etc.) or such planktonic creatures as diatoms. ***Water-based*** sands are composed of minerals that were dissolved in water, but have precipitated out. The most common material is manganese, which forms large nodules on the bottom, often around such things as shark teeth, whale bones and fish ear bones (*otoliths*). No one has figured out why manganese concentrates around these structures, but it may be that particular bacteria which live on these materials also concentrate manganese. ***Space-based*** sands come from outside the Earth and are the remnants of meteors or dust that hit our atmosphere. A surprising amount of space debris falls into our world's oceans, with estimates ranging between 2 million and 110 million pounds *per day*. However, space-based sands are not particularly common, rarely even 1% of any shovel full.

Where does sand come from? Though sands may be produced right at the shore, where waves crash against headlands and reefs, most beach sand around the world comes from the interior of the continents. As mountains weather, their fragments are brought down rivers, and eventually deposited where the river currents abruptly slow down after emptying into the ocean. Once at a beach, the sand may migrate hundreds or thousands of miles down the shore due to the longshore current. Seasonally, sand migrates onshore and offshore in response to storm-driven waves.

BUILD YOUR OWN BEACH HOPPER TRAP

A good way to study where beach hoppers live on a beach is to set out traps for them up and down the tide line. A beach hopper trap is wonderfully simple, just a tall cup (the higher the better) buried to its rim in the sand. Beach hoppers are active at night and they will fall into the trap as they walk along. The taller the cup, the less likely they will hop out. Because most hoppers will not be out during the day (when you are most likely to take your class), this technique only works if you go out to the beach the day before your field trip. Try to get down there in the late afternoon or in the evening. Starting very high up in the dry sand, place the cups every few feet as you work your way toward the ocean. Because these animals feed on rotting kelp and other plants, try to place some of the traps next to this material. Remember that beach hoppers are rarely found in completely wet sand and that if you put the traps too close to the ocean they may be washed away at the next high tide.

A FEW GOOD WORDS ON REPLACING ANIMALS

If you dig an animal out of the sand, it is your responsibility to put it back where you found it. In some cases, such as with sand crabs, this is easy, because both you and the crab are in agreement on how this is to be done. You put the animal on really wet sand and in about 3 seconds it has reburied itself. But for many other animals, such as the Pismo clam, this is not the case. With all the good will in the world, a Pismo clam cannot dig its way into the sand fast enough. Undoubtedly, a wave will hit it before it buries itself and it will wind up hurled up on to the beach, soon to become a Blue Plate Special for some gull. So, to assure their survival, it is best to rebury most of these species, particularly clams and worms. Worms can be returned just by digging a hole, putting them in and covering them over with sand. The best way to return a clam is to push the shell into the sand (about where you found it) with the hinge side up. The hinge is the place on the clam where the two shell are held together.

MALES GRUNIONS WILL MATE WITH A STICK
My all-time favorite grunion story is about the researchers that convinced male grunion to mate with, well, a stick. First, remember that during spawning, female grunions thrust themselves vertically in the sand and wiggle around. Researchers theorized that male grunion key in on females by looking for the only vertical things on the entire sandy beach, which would be these wiggling females. During the spawning runs, the researchers placed two-foot-long wooden dowels in the sand near individual males. While stationary sticks were not too effective, wiggled sticks, which created a soft, puddled sand, did the trick. Apparently, the sight of a thin, two-foot high “female grunion” was more than the males could resist.

DO-IT-YOURSELF BEACH DEBRIS SURVEY
If you would like your class to conduct its own marine debris survey, there are now two manuals available that tell you how to do it. One is Ma*rine Debris Survey Manual*, by C. A Ribic, T. R. Dixon and I. Vining. Included are chapters detailing almost every aspect of a survey you might want to know. The manual is labeled NOAA Technical Report NMFS 108 and is available from the U. S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. The second is a curriculum guide called Save Our Seas from the Center for Marine Conservation and the California Coastal Commission. Directions and data sheets for beach cleanups are included. To order the curriculum or to find out about training workshops, call the California Coastal Commission at (415) 904-5400.