Marine Life Book

Kingsborough Community College

M- 130 - James Goetz Aquarium

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COMMON NAME	Green Thread Algae
SCIENTIFIC NAME	*Enteromorpha sp.*
FAMILY	Ulvaceae
CLASS	Chlorophyceae (Green Algae)
PHYLUM	Algae

The Enteromorpha are fronds tubular, simple or branched and sometimes inflated. The tubes are different sizes in different species. Some being fine like a hair, flat or inflated. The genus is widely distributed and very abundant.

The enteromorpha grow on the bottom of ships and they are called grass. There are three different classes of the enteromorpha, clathrata, compressa, and intestinalis.

Enteromorpha clathrata. – Fronds are thread-like, tubular branched and branches beset with numerous fine branchlets; densely tufted, soft. They are common everywhere.

Enteromorpha compressa. - Fonds are long, slender, branched tufted; branches simple, compressed, extending from main central branches, obtuse at the ends but attenuated at the base. The species 1s very abundant everywhere, and is a useful plant for the aquarium.

Enteromorpha inteetinalis - Single long, inflated tubes or sacs, obtuse at the apex and very attenuated at the base. Fronds often crimped and twisted, resembling an intestine, hence the name.

COMMON NAME	Sea Lettuce
SCIENTIFIC NAME:	*Ulva latuca*
FAMILY	Ulvaceae
ORDER	Ulvales
PHYLUM	Chlorophyaceae

The plants of this order are, with few exceptions, formed of celled surfaces and show the earliest type of an expanded leaf. The cells form thin membranes, which sometimes are broad surfaces of no definite shape, sometimes are narrow and ribbon-like or they may be simple or branched tubes.

When the membrane consists of a single layer of cells it is *Monostroma* (one layer); when it consists of a double layer it is *Ulva;* when the layers separate, the thallus becomes hollow, and it is then *Enteromorpha.* These plants are mostly a brilliant grass-green in color, are silky in texture, and are attached by a small disk to rocks and stones. They abound everywhere, and are commonly known as *green laver*.

Frond a thin, silky, flat membrane, sometimes leaf-like, again an extended surface of no definite shape. These are the largest green algae. They are common everywhere.

U. lactuca, the sea-lettuce. Frond is a flat membrane of various shapes, sometimes orbicular, again deeply incised, often ribbon-like; margin always much waved or ruffled. In the variety *rigida* the frond is oval in outline not very large, and quite firm or rigid. The species is found on rocks exposed to the action of the waves.

U. latisslma. Frond is a fiat, expanded membrane of indefinite shape, but general outline oval, never ribbonlike; attains a size of twelve to twenty-four inches; often deeply lobed, very waved, often perforated with holes; membrane brilliant green, thin, smooth, glossy. It grows apart or in tufts, and is found everywhere, in all stages of growth. It. is the largest species of *Ulva* and is very common on muddy shores.

COMMON NAME	Kelp
SCIENTIFIC NAME	*Laminaia sp.*
ORDER	Laminariales
CLASS	Phaeophyceae
PHYLUM	Ocheophyta

The Kelp generally grows in large beds in cold, shallow parts of the ocean, attached to rocks by means at branched holdfasts. Steam-like stipes connect the holdfast with the broad. Leathery, leaflike blades which may grow to several feet in length. The blades are 10 to 15 feet long. The plant lives for several years but the blade dies each year. Growth occurs, as in all Kelp, at the meristematic region between the stipe and the blade. This plant has a brown color. It is peculiar that growth in some species occurs more actively in the winter and spring months.

There is an "epidermis·, a wide cortex which may appear as an inner and outer zone and a medulla. The cells in the three regions are quite distinctive in size and shape.
Some of the medullar filaments extended transversely or diagonally and serve as probable strengthening crevices.

The diocious condition of the sexual plants Indicates that meiosis two kinds at spores are produced. Small cells in the male filament produce a single spermatozoid. and a large *cell* at the female gametophyte elongates vertically and differentiate as an oogonium, the content being a single egg. The egg escapes just prior to union with a sperm, slipping through a break in the oogonial membrane. At least in culture it appears that the male gametophyte degenerates immediately, whereas the female persists tor some time. The large sporophyte immediately begins to develop from the zygote. First by putting out a rhizoid from the primary filamentous extension of the fertilized egg. About 15 species may be found In U.S.

The Kelp has many uses. In food as a vegetable (when dried} relist for beverage, and to flavor other foods. It is also put in ice cream before freezing to prevent crystallization. It is also used as a suspended and emulsifying agent.

The Kelp is used for medicine. It' s algenic acid is used in the drug Industries. lt is also used for fertilizers, to make soaps, paint, glass, tires, textiles, and hand lotion.

The Kelp plant is very rich in vitamins. like iodine, and potash, potassium. The ash (when burned) is rich in carbonates (polysaccharide), sulfates, Sodium, and potassium. ln Japan Kelp is harvested in great quantity for use in foods called KOMBU.

COMMON NAME Rockweed

SCIENTIFIC NAME *Fucus spp.*

FAMILY Fucaceae

ORDER Fucales

PHYLUM Phaeophyceae

The rockweeds. The plants of this genus grow in thick bunches and are found in great abundance between tidemarks. The plants are attached by sucker-like disks to the rocks, from which they hang like fringe when the tide recedes when it rises, they float and sway in the water in beautiful bouquet-like forms. In color they are brown or olive-green, in texture thick and leathery, but they sometimes expand into thin membranes. They are many times forked in the same plane, which produces a flat thallus. They often have a distinct midrib. The air-vessels, whose function it is to float the plant, are disposed along the midrib, usually in pairs.

The species are named according to the divisions of the frond, and the disposition, or presence, of the airbladders and the *conceptacles,* or spore-chambers.

The conceptacles congregate in particular portions of the frond and give its surface a roughness which is very perceptible; such portions are then known as the, receptacles, In *Fucus* this usually occurs on the bulbous extremities of the branches. Under the microscope a section of one of these little pointed spots shows a spherical cavity filled with a beautiful arrangement of *paraphyses,* or threads, some of which hold spores, while others protrude through a small opening in the outer mem brane. Conceptacles are peculiar to the order Fucacere. In them spore-production is carried on in a manner as complicated as is the formation of seeds in flowering plants. Although rockweeds are such a conspicuous feature of sea-shore vegetation, two species only, *Fucus vesiculous* and *Ascophyllum nodosum* (formerly called *Fucus nodosus),* are common on the Atlantic coast, and these do not occur south of New York, owing to the fact that a long stretch of sand-bench extends beyond that point.

COMMOM NAME	Irish Moss
SCIENTIFIC NAME	*Chondrus crispa*
CLASS	Rhodophyceae
PHYLIUM	Algae

Irish moss or Carrageen is the name of several kinds of seaweeds that grow in rocky places of Great Britain, Ireland, and the eastern coast of North America. The most common Irish moss has thick, forked fronds that are fan shaped. It has a reddish-brown or purple color. Merchants sell it commercially after it has been washed, bleached, and dried in the sun. Irish moss is not nutritious, but people use it in soups and deserts. Carrageen is used in making blancmange and other puddings, as well as in jellies.

Irish moss if about four-fifths water and one-tenth gelatinous matter, with smaller percentages of nitrogen. fats, calcium, sodium, bromine, potassium, magnesium, chlorine, iodine, and sulfur. The center of the Irish moss industry *in* America continues to be at Scituate, Massachusetts.

European consumption of algae as food is somewhat more than that in America. Irish moss is used for puddings; originally chewed when dried before the days of tobacco. It is also used as a condiment.

COMMON NAME	Glasswort
SCIENTIFIC NAME	*Sa1icornia sp.*
FAMILY	Chenopodiaceae
ORDER	Chenopodiales
CLASS	Dicotyledoneae
SUBPHYLUM	Angiospermae
PHYLUM	Spermatophytes

This Glasswort plant is shallow-rooted annual of North America, Europe. and Asia. It can be found in the salty deserts around the land-locked Caspian and Aral Seas. Here it is called an Halophyte because it can adapt to the sun when it concentrates common salt in an arid soil and can survive the blazing sun.

Glasswort is so-cal1ed because, its ash was used as a source of soda needed by medieval glassmakers. During droughts it stores water in its fleshy jointed stems, which nave waxy surfaces to check transpiration.

Pollination of the Glasswort is by wind, but ordinarily it does not release pollen in large enough quantities to be considered a hay-fever plant. Each flower produces a single brown seed covered with fine white hairs.

In autumn the stems turn red, yellow, or orange and are eaten by several species of waterfowl, especially the Canada Goose and Pintail Duck.

The young tender stems can be cooked as a vegetable, but a change of water may be necessary to reduce the saltiness. They may also be pickled in vinegar or added fresh to salads.

Glassworts are also found on tidal flats and in salt marshes along the Atlantic coast from Quebec to Florida, and inland areas of high salt concentration.

COMMON NAME	Salt Marsh Cord Grass
SCIENTIFIC NAME	*Spatina alterniflora*
FAMILY	Gramminae
ORDER	Geaninae
CLASS	Monocotyledon
SUBPHYLUM	Angiospermae
PHYLUM	Spermatophytes

Spartina patens (salt hay) grows at high-tide level in salt marshes that are covered with species of grass in eastern North America.

Marshes and swamps are wetlands that grows on mineral soils. An area is a swamp if it contains principally trees and a marsh if it contains principally trees and principally grasses.

Marshes; wet soil communities of grasses or glasslike plants. Salt marshes are covered with species of grass. Ir. eastern North America, coarse-leaned *Spatina alterniflora* grows at mid-tide level. On the Atlantic coast of the United States, salt marshes began to form about 4,000 to 5,OOO years ago when the rapid postglacial rise in sea level slowed.

Spatina alterniflora began to grow at mid-tide levels in sheltered areas. The grass stems retarded water movement. Sediment accumulated along with roots, which raised the level of the marsh. By this means, coupled with the addition of new sediments from land erosion, marshes grew out into the water and up to high-tide level.

To the South a dwarf from of *Spatina alternitlor*. Marshes have been noted as the structure of the land being a factor that restricts the drainage of freshwaters, thus causing a wetland to be formed by seawater flooding and draining, which exposes flat area of intertidal land. Where flooding is irregular, such areas may become too salty for higher plants to grow.

The growing tips of grasses, sedges, and rushes are at or just under the soil level. In this position they are protected from certain kinds of damage. This environment is a factor for trees and glasslike plants in both fresh and salt swamps and marshes. The grasses can be bent or even broken off at the top of the grasses without permanent damage to the whole plant.

Fire is an event that may damage grasses, but fires are relatively rare on wetlands. Water movement may damage plants by breaking their upper parts. Trees and shrubs will suffer more from such damage than grasses that have flexible upper parts. Grassy plants also have an advantage in regions where large masses of ice form in winter, especially if the ice is moved by currents or tides. Moving ice can completely destroy seedlings and even large trees. Winter ice prevents the evolution of a tree that could from salt swamps.

COMMON NAME	Beach Grass
SCIENTIFIC NAME	*Ammophila breviligulata*
FAMILY	Gramminae
ORDER	Graminales
CLASS	Monocotyledon
PHYLUM	Spermatophytes

Beach grass is a name derived from two Greek words, ammos meaning sand and philos meaning loving. They provide protection for inland farms by stilling the restless sands. Once firmly entrenched they build topsoil in which higher plants and even trees can grow. They are tough coarse perennials with stems about five feet tall, deep extensive root systems, and masses of tough basal leaves. Though they produce a spiky panicle of flowers nearly a foot long, the seeds which result are seldom fertile. The plants spread mainly by rhizomes. Beachgrasses grow very fast, often two feet or more in a season, and spread very rapidly. They are the most important of all known plants for anchoring sand dunes which, unless opposed by vegetation, move inland a few feet each year, covering arable lands and threatening buildings.

American beachgrass is found along the Atlantic coast from Newfoundland to North Carolina and on stretches of the Pacific shore.

The coarse sterns of the beachgrass forms a mechanical barrier that protects themselves from the scouring action of wind-driven sand. They force the wind to drop its sand, the thick clumps of leaves entangle it, and the roots bind and hold it. It pushes up upward through the sand no matter how deep the deposits become. They sprout new roots as they grow, while the sterns multiply rapidly from underground buds to form large clumps and extensive, root systems.

Decayed foliage and roots add organic matter to the developing soil. These grasses, established by nature along the shores of lakes and oceans, point the way to protecting valuable farmland against the dune that seeks to bury and destroy it. They also provide a means of converting the dunes themselves to productive agricultural uses.

COMMON NAME	RED BEARD SPONGE
SCIENTIFIC NAME	*Microciona prolifera*
FAMILY	Microcionidae
ORDER	Monaxonida
CLASS	Demospongiae
PHYLUM	Porifera

When young, this species forms bright-red incrustations over shells and stones; later it rises into irregular lobes and tubular prominences. When fully developed it is profusely branched in a forking manner. The branches are more or less flattened, and often are palmate at the ends. It grows in clusters six inches in diameter, of a dark orange-red color. When dry it is grayish-brown, brittle, and bristly.

They take in and digest food and eject excrement from the area enclosed by the collar. The cilia, by their constant movement, create currents which keep the water in motion. Water, then, is taken through the pores into the first or incurrent canals; then it is passed into the ciliated chambers, and then into the excurrent canals, and out through large passages terminating in large openings called oscula, or craters. The canal systems vary. In some species they become quite complex.

Sponges vary greatly in shape, size, color, surface, rigidity, canal systems, and skeleton. They are cake shaped, tubular, digitate, palmate, cup-shaped, vase shaped, cone-shaped, spherical, hemispherical, pedunculate, etc., their shapes depending upon whether their growth is uniform or is excessive in a horizontal or in a vertical direction. When they grow evenly in both directions,
massive uniform shapes arise. If lateral growth predominates, broad, low, and incrusting shapes result. When there is an excess of vertical growth, the forms are digitate.

The Red Beard Sponge can be found from Cape Cod to South Carolina, and is abundant in Long Island Sound.

COMMON NAME	Sea Star
SCIENTIFIC NAME	*Asterias vulgaris*
FAMILY	Asteridae
ORDER	Cryptozonia
CLASS	Asteroidea
PHYLUM	Echinodermata

Sea Star are free moving and live mouth downward. The name sea star usually includes many different forms, the most familiar are the asteroidea of the North Pacific. These animals consist of a central body radiating out into five tapering arms. The flattened upper surface is covered with a leathery skin of small lobed plates of carbonate of lime.

They can crawl over any surface and squeeze its supple body through very narrow crevices and travel about six inches a minute. It is very destructive to mussels and oysters, which are its favorite food.

When they attack oysters and similar bivalves, they fix the suckers of one or two arms to one valve and those of the opposite arms, to the other. It then begins to straighten out its rays. The oysters cannot withstand a continued pull of the pressure that is being put on them, eventually it opens its shell, and the Sea Star then extrudes its stomach through its mouth, digests the oyster, after the meal it withdraws its stomach.

They begin to eat voraciously when very young. One less than 3/8 inches across ate over fifty young clams in six days. It may become sexually mature in less than a year, then produce many thousands of young.

Sea Stars are eaten by gulls, crows, ravens, foxes and various fishes. Their chief parasites are crustaceans.

COMMON NAME	Eastern Sea Star
SCIENTIFIC NAME	*Asterias forbesi*
FAMILY	Asteroids
ORDER	Cryptozonia
CLASS	Asteriidea
PHYLUM	Echinodermata

When moving, asteroids use their tube feet in the same direction. As it makes a step, it bends slightly and exert a push. Usually, one arm takes the lead in a specific direction. When he wants to change direction, another arm facing that new direction makes the first step. Generally, asteroids move when searching for food, during intense sunlight and increase in temperature.

Their speed depends on where they usually live, either in shallow coastal zones or inhabit the sand they can cover long distances. *Asterias forbesi* moves while in the ocean and unthreatened. Asteroids can turn on their back then attacked. They are considered to be predators, plant-eaters and detritus feeders.

The majority of asteroids are carnivorous, preying mainly on bivalves, gastropods, crustaceans, echinoids and ophiuroids. Among the carnivorous asteroids there are many forms that do not devour the entire prey, but rather digest their prey in front of their mouth.

Asteriidae have evolved four rows of tube-feet on each arm, increasing their efficiency in overpowering the prey animal. Asteroids perceive prey that is freely exposed, even animals buried in substratum. Asteroid species inhabit cold and polar waters which are deep-sea forms, and they produce several thousand of eggs. The fertilization takes place in the open water.

COMMON NAME	Sand Dollar
SCIENTIFIC NAME	*Echinarchnius parma*
FAMILY	Scutellidae
ORDER	Exocycloida
CLASS	Echinoidea
PHYLUM	Echinodermata

Sand dollar is a marine animal related to the sea urchins However, it is distinguished from the sea urchins by its flat shape and a striking pattern of five petal shaped marks. Sand dollar feeds on shellfish and other animals and on plants. It *is* purple mottled with gray and about 3 in. (8cm) in diameter.

The intact animal is covered with soft spies about 1/16 in. long and with soft locomotory tube feet by which it can creeps and burry itself. The mouth is located in the center of the flat lower and the anus on the oral surface near the edge. The sand dollar has an internal skeleton, and it releases eggs and sperms into the water where fertilization takes place.

The common sand dollar, *Echinarachnius parma*, is found mainly in warm waters. It lives in sandy shores and tidal flats where they are not exposed to surf. They orientate themselves so that the body is held at right angle to the flow of water.

COMMON NAME	Sea Urchin
SCIENTIFIC NAME	*Arbacia punctulata*
FAMILY	Arbaciadoe
ORDER	Desmosticha
CLASS	Echinoidea
PHYLUM	Echinodermata

Sea Urchins are any of large group of marine animals that have a globular shape and many projecting spines. Sea urchins are found in shallow and deep water from polar to tropical seas. All live on the bottom, where they prefer rocky habitats, but some may be found on sand.

The sea urchin has a rigid internal shell, or test, that is formed by joined skeletal plates. The regular echinoid test is radically symmetrical and marked by regularly arranged tubercules on which the spines are set. The test wall is formed by an alternation of five interambulacral plates, which are imperforate, and five ambulacral plates, which pierced by pores that hold slender tube feet. A cycle of genital plates at the aboral end surrounds a membranous periproct, the area containing the anus. One of the genital plates contains the madreporite, a porous plate that allows fluids to pass in and out of the water-vascular system.

The mouth of the sea urchin lies in the center of a membranous peristome and is equipped with a remarkably complex jaw apparatus. The ambulacral system centers in a water ring surrounding the mouth and a stone canal extending to the madreporite. Radial canals run on the on the inner surface of the test to connect the ring canals and tube feet. In many sea urchin, muscles associated with Aristotle's lantern pump coelomic fluid in and out of a whorl of peristomal gills.

Sea urchins move about with their oral surface downward, using either spines or tube feet or both. Species using spines for locomotion are the fastest, some reaching speeds of 7 feet (2 meters) per minute. Sea urchins feed on algae, dead matter, and sessile or sedentary animals. Feeding is slow. Two or three weeks may be required to consume a clump of seaweed.

COMMOM NAME	Rock Barnacle
SCIENTIFIC NAME	*Balanus balanoides*
FAMILY	Balanidae
ORDER	Cirripedia
CLASS	Crustacia
PHYLUM	Athropoda

The Rock Barnacle is a tenacious animal that adheres its rough-shelled adult stage to whales, piers, rocks and other solid seaborne objects. It was once classified as mollusks with shelled creatures as oyster and clams, but now is included with lobsters, crayfish and others of the class Crustacea that pass through free-swimming larval stages in early life. Barnacles can be found in seas around the world, thriving mainly in brackish waters.

Their size varies from one eighth to one quarter of an inch high to 3 to 4 inches in diameter and five to six inches in height.

There are two types of barnacle, the sessile and the stalked. In the sessile, (also called acorn), the barnacle is totally encased in a cone shaped shell of overlapping plates. The stalked barnacle rests on a fleshy stem and the main portion of the body is enclosed in paired calcified plates.

Barnacles are generally hermaphroditic and capable of fertilizing their own eggs, but are usually crossed fertilized. The barnacle hatches as a free swimming larva, called the nauplius, which has three pairs of appendages to help it swim and feed. This simple form molts several times into the cypris larva, which is also free-swimming but more complex than the nauplius and partly enclosed in a bivalved shell. The cypris then attaches itself to a solid object and then proceeds to a pupal stage to its adult form. The adult then secretes about itself a calcareous substance that turns into a heavy shell (to which the barnacle is attached at the back of the "neck"). In common barnacles, such as the *Balanus balanoides*, the shell is white, gray, or brown. To feed, the barnacle extends short featherlike *cirri* or feet, that pass through the operculum, a movable opening at the top of the shell, and comb the water for particles of food.

COMMON NAME	Sand Hopper
SCIENTIFIC NAME	Gammarus
FAMILY	Gammcricae
ORDER	Amphipoda
CLASS	Crustacea
PHYLUM	Arthropoda

Sandhoppers are anyone of a number of amphipods which, like the sand bug, are sometimes called sandfleas. In contrast to the sand bug, the sandhopper seldom exceeds 1 inch long and is laterally compressed, more nearly resembling a shrimp. Some species of sandhoppers live in dry sand and decaying seaweed, and still others are free swimming in both fresh and saltwater. The freshwater amphipods are called scuds. When masses of seaweed are disturbed, the sandhoppers hop flea-like, thus providing their common name. Due to their small size they have little value as bait and though edible, they are seldom used by man.

Coloration in living amphipods is frequently brilliant, (preserved specimens' bleach out). Light brown or greenish are common, but bluish, purple, brown, or reddish populations are often found.

Sandhoppers are voracious, omnivorous, general scavengers, which feed on all kinds of animal and plant matter. Only rarely do they attack and feed on living animals, but freshly killed animals are consumed readily.

Fishes are the chief predators, although birds, predaceous aquatic insects, and amphibians probably take an appreciable toll. They serve as intermediate hosts to a wide variety of parasites, including tapeworms of waterfowl and fishes.

Breeding occurs sometime between February and October, depending largely on water temperature. Males carry females on their backs, and they feed and swim about for about 7 days, but actual copulation and transfer of sperm are completed in less than one minute. The female averages from 15 to 50 eggs per brood and the average lifespan is a year or less.

COMMON NAME	Mole Crab
SCIENTIFIC NAME:	*Emerita talpoida*
FAMILY	Hippidae
ORDER	Decapoda
CLASS	Crustacea
PHYLUM	Arthropoda

The animal commonly known as the Sand Bug differs greatly in appearance from crab. When the appendages are folded under the carapace it somewhat resembles an egg, the body being ovate, about half as broad as long, and the sides forming nearly a regular curve. The carapace is about one a half inch long, cones, yellowish white and nearly smooth. The abdomen is long and pressed under the body, reaching nearly to the front. The eyes are minute and at the end of long, slender stalks. The antennae are plume-like and about as long as the carapace. The sand bug lives on sandy beaches at or near low water mark, exposed to the action of the waves. It burrows with great rapidity into the loose and shifting sands, using short and stout second, third and fourth thoracic legs and the appendages of the sixth abdominal segment for pushing and digging. Crabs of this species are gregarious and may be seen in great numbers, though but few will be captured together by digging as they rapidly disappear in the sand. Sometimes they are found swimming together in tide pools. They seem to live upon the organic particles contained in the sand, which they swallow, the mouth not being adapted for mastication. The species ranges from Cape Cod to Florida.

COMMON NAME	Hermit Crab
SCIENTIFIC NAME	*Pagarus pollicaris*
FAMILY	Paguridae
ORDER	Decopoda
CLASS	Crustacea
PHYLUM	Arthropoda

Hermit crabs belong to the class Crustacea and closely related to lobster. These crabs live in spirals shells. Moreover, they use empty shells of sea snail or other mollusks as a shelter for protection and containment of the body. Hermit crab fights viciously when attacked and scavenges for its foods.

Hermit crabs have two pairs of antennae and four pairs of legs. With two pairs of walking legs the crabs drag their shells about with them: however, the right one usually larger. That are shaped so as to cover the shell entrance when the animal is inside. Moreover, the crab walks on its second and third pairs of legs and uses its last pair on the end of the abdomen, to grip the central callum of the inside shell.

Pagurus pollicaris, the so called large Hermit crab, live of the Atlantic costal water of north America, is reddish brown and about 10 to 12cm (4 to S) long. Abdominal appendages in the female carry the eggs which are held there until the hatch; then the young immediately pass into the water and search for their own shells. As the crab grows, it periodically leaves its shell and move into a larger one.

Hermit crabs, worldwide in distribution, occur in sandy or muddy-bottomed waters and occasionally on land and in trees. Some lives in the tubes of plants stems. Semi terrestrial, tropical species of Coenobita inhabit sections of bamboo stems, broken coconut shells, and other articles, in addition to seashells. Pylocheles, a deep water crab of the Indian Ocean, lives in bamboo sections; Xyloparqus, found In West Indian waters at depths of 180 to 360m (600 to 1,200 feet), lives in hollow cylinders of wood. Other species make homes in coral or sponge.

COMMON NAME	Blue Crab
SCIENTIFIC NAME	*Callinectes sapidus*
FAMILY	Portunidae
ORDER	Decapoda
CLASS	Crustacea
PHYLUM	Arthropoda

Callinectes sapidus - Common blue crab, hard shell or soft shell crab. This is the common edible crab of the eastern United States. They are prized as delicacies for crab meat and soft crabs are sold just after the shell has been shed and before the new shell has hardened.

The shell is a variation of dark green shades on top and dingy white bellow. It is about three inches long and fifteen to eighteen centimeters wide. The legs are blue, and the c1aws are tipped with red. The blue crab is a good swimmer and fights well with its strong claws.

A distinctive large, spine projects from each side of the crab. It is unusually strong. Eight short spines occur on each side between the large spine and the eyes the fifth pair of legs is flattened for swimming. Between the eye-sockets there are six frontal teeth.The chelae, or pincers are large and somewhat unequal in size.

This species occurs from Cape Cod southward to Florida and around the Gulf of Mexico to the Mississippi River (and rarely from as far north as Nova Scotia). Their usual habitat is muddy shores, bays, and estuaries.

The crabs are scavengers, feeding on the bodies of dead animals. At spawning time, the female's abdomen swells 5 with eggs. Larvae hatch after fertilization and remain attached to the female for a short time.

Although the supply of blue crabs in the Chesapeake Bay region was once thought to be inexhaustible, the very extensive fishing in the past depleted the supply to the point where conservation measures became necessary.

COMMON NAME	Lady Crab
SCIENTIFIC NAME	*Ovalyses ocelatus*
FAMILY	Portunidae (Swimming Crab)
ORDER	Decapoda
CLASS	Crustacea
PHYLUM	Arthropoda

The lady crab is sometimes called the "swimming crab" because its last pair of legs are equipped with swimming paddles. This helps the crab get away from danger. It is an exceptional swimmer.

The lady crab grows to be two inches long and two and one-quarter inches wide. This is a very normal size for a crab, so their size has no bearing on their self-defense capabilities.

When they are fully grown, the lady crab is a bluish white with red or purple spots on its hard-shell. The red and purple colors blended on its back helps the crab to be camouflaged.

The lady crab can be found anywhere from Cape Cod to the Gulf of Mexico. The lady crab likes the warm water. It also likes to live on the sandy bottoms of beaches and coral reefs, so it has natural protection.

COMMON NAME Rock Crab

SCIENTIFIC NAME *Cancer borealis*

Family Cancroidae

Order Decapoda

Class Crustacea

Phylum Arthropoda

The Rock Crab is transversely oval, granulated but smooth, yellowish with bronzy-purplish spots, sometimes with light spots in a circular design and light borders to front spine.

The carapace is fused dorsally to all the thoracic segments and overhangs on each side to enclose gills in a bronchial chamber through which water is caused to flow by the movements of a flap attached to a maxilla. This flap, the gill boiler (scaphognathite), produces a current which flows from the rear forwards, outflowing water usually passes on either side of the mouth and past the bases of the antennae or antennules.

The shell is actually an outgrowth of one segment of the head region. The first pair of legs, the chelipeds, is generally modified into claws by the extension of part of the next-to-last joint to form a pincer.

The Rock Crab's reproductive organs are situated near and just below the heart and open to the outside at the base of the last pair of walking legs in the male and at the base of the middle pair of walking legs in the female.

The female carries the eggs cemented to her undersides in a large mass, called a sponge and protected by the flexed tail. The eggs hatch in about two weeks in a larval form called a zoea. Each zoea is a tiny free swimming animal. After molting, or shedding its 'shell a few times, the zoea passes through an intermediate stage, molts again, and becomes an adult.

The crab is found among rocks between the tide markers to a depth of several hundred feet, from Labrador to Florida and in deeper water south of Cape Cod.

COMMON NAME	Fiddler Crab
SCIENTIFIC NAME	*Uca minax*
FAMILY	Oeypodidae
ORDER	Decapoda
CLASS	Crustacea
PHYLUM	Arthropoda

The Fiddler Crab is the name of a group of small crabs that live along temperate and tropical seacoasts. These crabs burrow into sand and mud on beaches, salt marshes, and mangrove swamps. Like all crabs, a Fiddler Crab has two claws called chelae. In the male, one chela is much larger than the other. The male waves the large chela to threaten other males or to attract women crabs. These movements somewhat resemble the movements of a person playing the violin, and give Fiddler Crabs their name.

Fiddler Crabs eat water organisms called algae. The crabs feed by picking up small balls of sand and mud with their claws. They scrape algae from the sand grains and discard the clean sand. Males cannot use the large chela for feeding because it is too long to maneuver to their mouth.

Some Fiddler Crabs change in color from light to dark during the day. This change occurs because of the movement of pigment within special cells in the skin.

In the fall, the crabs in cold regions close their burrows and hibernate.

The Fiddler Crab is an animal that is covered in a hard shell, and has jointed legs

COMMON NAME	Spider Crab
SCIENTIFIC NAME	*Libini emarginota*
FAMILY	Malidae
ORDER	Decopda
CLASS	Crustacea
PHYLUM	Arthropoda

The spider crab can be found around most of the world in marine waters. The coast of Australia boasts almost 100 different species of spider crabs.

The spider crabs are crustaceans that have ten jointed legs. Their feet are pointed to help dig under the sand. They have long walking legs. Unlike other crabs, the spider crab can walk diagonally as well as sideways.

Their physical forms vary according to specific species, but the basic structure is a small body and long legs. The spiny spider crab has spiny pricks all over its body. The Japanese spider crab is the largest living spider crab and measures about 4 feet long and 1 foot wide. They use their pincers to catch and hold their prey.

Despite the spider crabs' long legs, they are easy prey because they are slow moving creatures. Even though they are fearsome looking, they are often caught for food. In japan, the Japanese spider crab can provide food for an entire large family.

The spider crab's reproductive organs are located just below the heart and open to the outside at the base of the last pair of walking legs in the male and at the base of the middle pair of walking legs in the female. The female carries the eggs cemented to her undersides and are protected by the flexed tail.

COMMON NAME	Horseshoe Crab
SCIENTIFIC NAME	*Limulis polyphemus*
FAMILY	Limmulaidae
ORDER	Xiphosura
CLASS	Meristomeato
PHYLUM	Arthropoda

The Horseshoe Crab is what scientists call a living fossil. Their present body form is similar to those found in rocks over 500,000,000 years old. Its present form, ranging in size from 20 to 24 inches, has not changed at all for almost 200,000,000 years.

The entire body is covered in a thick shell that resembles the shape a horse's hoof and the tail, which serves as a digging lever, is long, pointed, and barbed. As you can see, the Horseshoe Crab is well protected and will eat anything from small clams, worms and fish eggs to seaweed and decaying matter; so, it’s no wonder this species has survived for so long. It has six pairs of legs, and the mouth is hidden by the front pair which are used for grinding and tearing the food and pushing it into the crab's mouth.

The Horseshoe Crab is related to both crabs and spiders. The scientific name describes the creatures’ eyes. Limulus means "glancing sideways" and the crabs’ eyes are both on the side of the head as well as in the front. Polyphemus refers to the eyes in the front.

A Horseshoe Crab breathes through "gill books" that are found on the abdomen. Each gill book has around 150 thin leaves which take oxygen from the water and allows the animal to breathe.

Mating season for the Horseshoe Crab is between May and July. The female carries the male on her back to shore, where she will lay hundreds of eggs ranging in color from greenish blue, yellow or black and the male will then fertilize the eggs.

Home to the Horseshoe Crab is from Nova scotia to the Gulf of Mexico and along the coasts of Southeast Asia.

COMMON NAME	Greenhead Flier
SCIENTIFIC NAME	*Tabanus nigrovitatus*
FAMILY	Tobanidae
ORDER	Diptera
CLASS	Insecta
PHYLUM	Arthopoda

The Greenhead Fliers are called true flies, they are in the same order as mosquitoes. All diptera have one pair of wings. Their antennae are long or short. Their habits are extremely varied; many are very annoying but most are beneficial.

The mouth parts are essentially suited to liquid feeding, but have proved highly adaptable for piercing, sucking and lapping. They can extract fluid from almost any living thing or decaying source with the aid of two muscular pumps within the head.

The flight machinery consists of two quite short wings. The sense organs in their bases tell them how fast they are flying or turning and whether it is being blown off course,

All these habits are aided by sensory information from the haltress, which acts like a tiny gyroscope. Fly larvae are legless they can survive in a vast range of moisture providing microhabitats. They require heat to operate their wings, so they are rarely seen around dawn or dusk, when it is too chilled for effective flight.

They are most commonly found around beaches, irrigated land and ponds. Their eggs are laid in masses on vegetation over or near water. They mature in damp, wet soil or litter.

COMMON NAME	Blue Mussel
SCIENTIFIC NAME	*Myritilus edulis*
FAMILY	Mytilldae
ORDER	Prionodesmacea
CLASS	Pelycypoda
PHYLUM	Mollusca

The Blue Mussel is a freshwater mussel, worldwide in distribution they are most common in cool seas. There are about 1,000 known species and inhabit steams lakes and ponds over most of the world. Blue mussel belongs to the marine family, marine mussels are usually wedge-shaped or pear-shaped and range in size about 5 to 11 centimeters (about 2 to 4 inches) they may be smooth or ribbed and often have a hairy covering, the periostracum. The shells of many species are dark blue or purple on the outside; on the inside they are often pearly. They attach themselves to solid objects or to one another by strands called byssus threads and often occur in dense clusters. Some burrow into soft mud or wood.

Principal enemies of the blue mussel are vertebrates such as walruses, birds (herring, gulls, oystercatchers, ducks) and flounders and the invertebrate sea stars.

The blue mussel is an important seafood in Europe and are raised commercially there. It is now widely being cultivated in Europe and has been since the 13th century. Mussels are collected from deep water by means of dridges or rakes. They spoil quickly after removal from the water and are therefore seldom shipped.

In mussels the gonads (ovary, testis or ovatestis) open through the nephridial (kidney) and the gametes pass through a nephridial pore. In mussels the sexes are usually separate and there is one gonad with an associated pore a structure combining the functional gonads of both sexes which is located in the visceral hump and connected to the outside by a reriL'1ant of the right kidney. The gonadal ducts of females often secrete a protective capsule around the fertilized eggs.

Mussels on occasions can be poisonous when during red-tide in which swarms organism known as dinoflagellates (usually Gonyaulax) are taken in with the normal planktonic food (which are microscopic plants and animals).

COMMON NAME	Ribbed Mussel
SCIENTIFIC NAME	*Geukensia demissus*
FAMILY	Mytilidae
ORDER	Prionodesmacea
CLASS	Pelycypoa
PHYLUM	Mollusca

The Atlantic Ribbed Mussels are found from the Gulf of St. Lawrence to South Carolina. They have a1so been introduced to California. They are the only ribbed modiolus found in American waters.

Atlantic Ribbed Mussels are 2 to 4 inches in length, black-brown in color. They are often shiny and have strong, rough, radial, bifurcating ribs. Their interior is a bluish-white color with the posterior end flushed with purple or purplish red. The meat inside their shells is used for food. The beautiful pigments contained in their shell (a calcium material) is used for aesthetic purposes, such as jewelry making.

These mussels use their gliding foot to grasp their food and trap it in their calcified shell. Once the food is trapped inside their shell, they either suck out their prey's body fluids or swallow their prey.

The Atlantic Ribbed Mussel is often confused with *Brachidontis recurvus*, which has a strongly curved back, tiny teeth at the umbo, and is a solid rosy-brown on the inside. There is a very similar subspecies to the Atlantic Ribbed Mussel, it has two times as many ribs which are finely and neatly beaded.

COMMON NAME	Scallop
SCIENTIFIC NAME	*Aequipecten irradians*
FAMILY	Pectinidae
ORDER	Priondesmacea
CLASS	Pelecypoda
PHYLUM	Mollusca

This scallop measure 1.25 - 4 [3.8 to 10.2 cm.] long. It is circular, with valves convex; ears equal; byssal notch small, triangular with few or no teeth on lower edge. Exterior white to dark gray or brown, often with color bands or radial rays, its rib is dark. It has 17 or 18 radial ribs.

Their interior is whitish, gray or pinkish with dark margin, ears often spotted with brown, radial slot present between broad, flattened ridges, which are strongly angled at margin. It has two muscles, a smaller and a large muscle. It is the scallop part that we eat.

It swims only when is disturbed or wants scape of predator, such as Sea star and octopus. It swims open and close the valves and expelling water through mantle flap. When the scallop opens the valves and take water it drives backward and when it closes the valves it drives forward. It is a little powerful swimmer, it looks like a plate thrown into water. Also, with its convex valve is able to jump itself when is out of water.

It has hundred or more blue eyes like a beautiful pearl. If it lese all its eyes it can replace them by other in two months. It perceives the presence of enemies by its chemical sense or see them through its eyes.

They live in semi closed bay in 1 to 60 ft. of water and sand bottom near to algae.

COMMON NAME	Atlantic Jingle Shell
SCIENTIFIC NAME	*Anomia simplex*
FAMILY	Anomiidoe
ORDER	Anomolodesmacea
CLASS	Pelecypoda
PHYLUM	Mollusca

Atlantic Jingle Shells are known as the Family Anomiidae. Its Scientific Name is *Anomia simplex.* The Jingle Shell is found within the range between Novia Scotia and the West Indies. The shells habitat is located in shallow water.

Jingle Shells are thin, translucent clams which usually appear pearly. These shells are autochthonous to the warm and temperate seas. It is only about 1 to 2 inches long in width. Its color also varies. It can be a sulfur-yellow to coppery red, or silvery gray/black. The surface is scaly and has a waxy luster. The Jingle Shell is a bivalve. A bivalve is an animal such as a clam which ~has a 2-valved shell.

The Jingle Shell gets ashore because it attaches itself to an object anchor "known as a stalk like byssus" which passes through an opening in the lower valve; the byssus then becomes calcified and then is permanently attached. Since the jingle shell has this "threadlike anchor" it is known as a pelecypoda. When the animal dies, the top of the 2-valved shell can be found ashore. As for the lower valve, it is very hard to find.

The Jingle Shell is the most abundant and familiar shells on many beaches. Children are fascinated and admire them. One popular custom was to string the shells on a cord and hang them in an open window on a shore cottage to hear them tingle by a passing breeze.

COMMON NAME	Eastern Oyster
SCIENTIFIC NAME	*Crossotrea virginica*
FAMILY	Ostreidoe
ORDER	Prionodesmacea
CLASS	Pelecypoda
PHYLUM	Mollusca

The Eastern oyster is usually colored a deep purple, the rest of the shell, interior and exterior is dirty-gray. Beaks are normally long and strongly curved.

Their size ranges from two to six inches in length. This oyster's value margins are only slightly undulating or are straight.

There are different types of Eastern oysters. " Blue paints ", a. form originally harvested at Blue Point, Long Island, New York. They are rounded in shape and with a deep inside. It has a lower value. ":Lynnhavens" are broad, elongated forms originally harvested at Lynnhaven bay, in Virginia. These variations are due to environmental difference.

Oysters, like clams, scallops, and some other shellfish, are called mollusks. Mollusks make up a major division of the animal kingdom.

An oyster's shell is the animal's skeleton. It consists of two parts called valves. Oysters are often called bivalves, which means two valves. The valves are held together at one end by a hinge. One valve is deeper, larger, and thicker than the other, and the oysters body rests in **it.** The second valve acts as a lid.

COMMON NAME	Northern Quahog
F A M I L Y	Veneridoe
ORDER	Teleoclesmacea
CLASS	Pelecypoda
PHYLUM	Mollusca

3 to 5 inches in length, ovate-trigonal, 5/6 as high, heavy, and quite thick. Moderately inflated. Sculpture of numerous, concentric lines of growth or small riblets. Near the beaks these lines are prominent and distantly spaced. The exterior center of the valves has a characteristic smoothish or glossy area. Exterior dirty-gray to whitish interior white, commonly with purple staining. The entire lunule is 3/4 as wide as long. The form *Notata say* from the same region is externally marked with brown, zigzag mottling's.

This species is very common and is used commercially (or chowders and as clams-on-the-half-shell or "cherrystones". Also known as the hard-shelled clam.

The American Quahog (*Mercenaria mercenaria) is* another member of the Venus clams. It was introduced to north western France from the eastern coast of North America. The Algonquin tribes, which formerly inhabited what is now the eastern U.S.A., used to make beads out of the shells, which they pierced in the middle and strung together into necklaces. These strings of shell beads also served as money which was known by the Indian name of wampumpeag. The Indians also strung these shell beads into very intricately designed belts known as wampums, which were used as tokens to bind treaties.

It is found in Gulf of St. Lawrence to Florida and the Gulf of Mexico. Introduced to Humboldt Bay, California, and to England.

COMMOM NAME	Soft Shell Clam
SCIENTIFIC NAME	*Mya arenaria*
FAMILY	Myacidae
ORDER	Teleodesmacea
CLASS	Pelecypoda
PHYLUM	Mollusca

The *Mya arenaria* also known **as** the sand gaper or soft-shell clam, are frequently found in New England, the North Atlantic, the North Sea and the Baltic Sea.

The soft shell clam is found burrowed into sandy flats of moderate depth. Only the fused inhalant and exhalent siphons are in contact with the upper surface. These siphons can be extended to several times the length of the shell. Consequently, this bivalve can be buried in the sand at a depth of more than 30 centimeters and thereby be safely hidden without suffering from food or oxygen shortage.

E1lipical, gaping at both ends chalky. Periostracum thin grayish flaky. A long spoon shape structure called the chondrophore is present in the left valve to receive the resilium. The *Mya arenaria* has no true hinge teeth.

If one was to walk to the territory of the sand clam at low tide, little vertical spurts of water will be seen where the siphons have been drawn down as a measure of safety. These clams feed only on sand. Deep burrows can reach large size.

Eggs are usually shed by the female into water and fertilized there by sperm released form the male. The eggs develop into larvae that swim permanently at the bottom.

The clam is an important food mollusk. It was the original basis of the famous Rhode Is1and clam chowder.

COMMON NAME	Jacknife Clam
SCIENTIFIC NAME	*Enaia directus*
FAMILY	Solnidale
ORDER	Teleodesmacea
CLASS	Pelecypoda
PHYLUM	Mollusea

There are two Jacknife Clams, the common sand clam (*Tagelua plebeius*) and the divided sand clam (*Tagelua divisua).*

The two common representatives of the solenidae family have rectangular valves and they resemble the razor clams in the solenidae family. Both clams are intertidal filter feeders that construct deep burrow in tine sediments. They inhabit permanent burrows in mud or muddy sand. They extend the two siphons to the sands surface. There they make & characteristic pair of openings 1-3 inches apart. The siphons must be long enough to over extend the distance of the length of the clam in order to reach the sediment surface. The valves have large pallial sinus to accommodate the retracted siphons.

The most common of the two clams is the *Tagelua plebiua*. This clam is very large it reaches three inches in length. You can find a lot of them on muddy intertidal flats where the burrows of large individuals extend aa much as twenty inches into the sand. The valves are wider than those of a razor clam. In adults there is a dark periostracum to reveal the chalky white shell beneath it. The younger clams have a yellowish shell beneath them. This color is the same as the adult clam of the *Tagelus plebeius.*

Tagelua plebeius is often called the “spit clam”. They are called this because of its habit of squirting water into the air when the tide is out. Young commensal crab (*Pinnixa chaetopterana*) often occupy the burrow of this clam. The ribbon worm (*Cerebratulus lacteus*) is a major predator of the *Tagelua plebeius*.

The other clam *Tagelus divisus* is smaller it is 1.5 inches at the most, with rounded less rectangular valves. They are glossy yellow in color throughout its life. The central region of each valve bears a faint purple wedge-shaped band. This runs from the umbo to the edge. Inside each valve is a radial ridge which the *Tagelua plebeius* does not have. This clam is common on intertidal flats and builds a burrow similar to that of a *Tagelus plebius*. Except in this clam it is often J-shaped with a deep end curved upward. The burrow of this is small and do not exceed more than eight inches in depth.

COMMON NAME	Surf Clam
SCIENTIFIC NAME	*Spisulla solidissima*
FAMILY	Mactridae
ORDER	Teleodesmacea
CLASS	Pelecypoda
PHYLUM	Mollusca

Surf Clams live in the sandy bottom of the Atlantic Ocean in the eastern half of the United States. It is the major source of canned clams.

The shell is characterized by a grayish-yellow valve with light stripes which radiate out from the umbo. It is a thin shelled species reaching 5 cm in length, with a smooth shiny surface.

They are endowed with lamellar like lateral teeth in the hinge. The clam has a large organ called the foot which is used to burrow and move from place to place. The shell is made up of two parts called valves. The growth lines on the valves show how the shell has enlarged from time to time. The mantle, a fleshy part of the body just inside the shell, secretes the shell material. The space between the main body of the clam and the mantle with its shell is call the mantle cavity.

The clam has two openings at the back end called the siphons, which allow water filled with food and oxygen to pass into the mantle cavity through the ventral, or lower syphon, and out again through the dorsal, or upper syphon. Oxygen passes from the water in the mantle cavity into the gills. Tiny hairs fan the food particles through a small opening, or mouth, into the stomach. The food is digested *in* the stomach and passes into the intestine, where most of it is absorbed.

The clam has a heart and blood vessels. Other spaces of the clam's body in which the blood circulates are called sinuses. Blood circulates through the gills, takes oxygen from the water and gives off carbon dioxide.

COMMON NAME	NORTHERN MOON SNAIL
SCIENTIFIC NAME	*Luntia heros*
FAMILY	Naticidae
ORDER	Mesogastropoda
CLASS	Gastropoda
PHYLUM	Mollusca

The moon snails are among the most active of the gastropod carnivores. They feed on bivalves. some consuming three or four small clams a day. Moon snails dig through the sand, uprooting the clam, which is then held by the strong foot and is pierced by a neat round hole made by a combination of rasping by the radula teeth and corrosion v a gland producing acid.

Radulae are teeth found in all mollusks except bivalves, are attached to a ribbon, or odontophore, in the mouth. They are used a rasp. The teeth are made of hard chitinous material. There may be from 20 to 300 rows of teeth in the ribbon.

When the sail is active, the exposed soft parts are much larger than the shell. and the fleshy foot can be accommodated only by large quantities of water. The moon snails move rapidly through waterlogged sand in its hunt for prey, guided by a strong sense of smell. The eyes are much reduced.

The egg mass is gelatinous and is surrounded by a protective “sand collar” formed while the eggs are being deposited. This sand collar tends to have a characteristic shape for each species, and its form is determined by the shape and size of the female’s shell. When dried the “sand collar" becomes very fragile.

It is found in shallow water from Canada to North Carolina. It is very common along the Long Island shore, where it may be found on the open beach in pools with a sandy bottom left by a receding tide. It is usually partially or fully buried in the sand.

COMMON NAME	Atlantic Moon Shell
SCIENTIFIC NAME	*Polinices duolicatres*
FAMILY	Naticidae
ORDER	Prosobranchiata
CLASS	Gastropoda
PHYLUM	Mol1usca

Moon shells, and the closely related Nalica, include about a dozen widely distributed species. They are carnivorous snails, found in all seas specially on all Atlantic and Pacific beaches. The shell is usually globular, sometimes depressed smooth, and polished.

This shell is from one to two inches in height, and pale bluish white in color, with spiral chestnutbars, stripes. and zigzag markings along with various mottlings of dark brown and purple. The shape is globular, somewhat flattened at the top. with a smooth and shining surface.

The body whorl is large and expanded, the apex small and the spire depressed. The umbilicus is deep and part.ly fil1ed with a shiny white callus. The operculum is calcareous, white thick and it has several deeply cut grooves following its outside curvature.

The colorful spotted moon shell prefers sandy bottoms where it may be found burrowing just beneath the surface of the sand at the low-tide mark.

These carnivores feed on other shellfish, which they hold down with their unusually large foot and then drill a hole through the shell with their toothy tongue, or radula. Moon shells build a circular sand collar cementing the sand grains with a glue they produce. Eggs are deposited inside the protective ring.

COMMON NAME	Atlantic Slipper Shell
SCIENTIFIC NAME	*Crepidula fornicata*
FAMILY	Calyptraeidae
ORDER	Prosobrachiata
CLASS	Gastropoda
PHYLUM	Mollusca

The Slipper Shell location ranges from Nova Scotia to the Gulf of Mexico. Its habitat is in shallow water.

The Shell is 1.5 inches in length. It is obliquely oval, apex prominent and turned to one side but not separate from the body of the shell. The Shell is moderately convex, according to the object on which it is seated on. The cavity is divided by a horizontal white plate. Its color is pale gray flecked with purplish chestnut.

They are generally found flattened against the inside of the aperture of dead shells, prticularly large examples of Busycon and Pilinices.

The shell is also called Boatshell and Quaterdeck. These shells are among the first objects collected by children at the seashore, since they make excellent miniature boats to sail in tide pools and also serve as tiny scoops for digging in the sand.

The empty shell has a commercial value; under the name Quaterdeck many tons are annually scattered over the ocean floor for embryo oysters to settle upon.

COMMOM NAME	Periwinkle
SCIENTIFIC NAME	*Littorina littorea*
FAMILY	Littorinidae
ORDER	Prosobranchiata
CLASS	Gastropoda
PHYLUM	Mollusca

Littorina is probably the most characteristic gems of Northern littoral regions. Together with some of its allied genera it is also, probably, equally characteristic of various tropical littoral faunas all over the world. The family comprises strictly between-the-tides genera and species. Indeed, it is suspected that some species of *Littorina* are making very fair progress toward a terrestrial condition, for they actually live above high- tide mark, even in the branches of overhanging trees, and must certainly pass days at a time out of their natural element. That such a transformation is possible need not for a moment be doubted, for there are many land mollusks today that give abundant evidence of having been at some past time aquatic or marine species. These changes in nature are constantly going on, and the gradual substitution of a lung for a gill is no very startling metamorphosis.

The littorinas fairly swarm in favorable localities upon all shore stations. In Maine and Massachusetts the bold, rocky coast furnishes a home for several species. Often the rocks at low tide are black with them; the algae that cling' in wet masses to the exposed rocks are alive with them. One cannot walk about in such localities without crushing hundreds of specimens. Sometimes they will be found clinging in clusters upon the piling of old wharves or crawling about the bottom at or about the low-tide mark. The best specimens of *Littorina* are found in stations where they are bathed twice a day by pure, uncontaminated seawater; those living near the mouths of streams, or where the water is brackish or impure are usually small and degenerate. They are vegetable feeders and have received the common name of "periwinkles." In Great Britain they are used among the poorer classes for food. The animal has a short, broad muzzle, and eyes at the outer bases of the tentacles. The foot is longitudinally grooved, and there is a rudimentary siphonal fold in the mantle. The shells are turbinated, usually heavy, few-whorled, and with a round aperture.

COMMOM NAME:	Oyster Drill
SCIENTIFIC NAME	*Urosalpinx cinera*
FAMILY	Urosalpinidae
ORDER	Prosobranchiata
CLASS	Gastropoda
PHYLUM	Mollusca

U. cinerea. This well-known species is regarded by Chesapeake and Long Island Sound oystermen much in the light of a p1ague. These active predaceous mollusks live upon bivalves, and preferably upon oysters. They bore a small round hole through the shell of their helpless victims, and then proceed to extract the succulent, fleshy animal from within. The oystermen call them by the suggestive name of "drill," and wage incessant warfare upon them. In some years these mollusks appear ‘o go into partnership with the large sea star *Asterias,* and the combination of the two can soon destroy any oyster-bed, The original borne of this destructive little creature is presumed to be in Chesapeake Bay, but the transplanting of oyster-spat thence to Long Island Sound has introduced the enemy at the same time. The species has a wide range from Florida to Cape Cod, and 1ocally north of that point in fact, it may be counted upon to appear wherever there are oyster: beds. The shell is dingy gray in color, and its whorls are crossed by a dozen or more rib-like undulations, and numerous revolving' striae. The anterior canal is produced and is yellowish-brown within. Length under an inch.

COMMON NAME	Knobbed Whelk
SCIENTIFIC NAME	*Busycon carica*
FAMILY	Melon Genidae
ORDER	Prosobranchiata
CLASS	Gastropoda
PHYLUM	Mollusca

The knobbed whelk is a marine snail. Its knobs developed as protection against predation. The animal feeds on other mollusks through its long proboscis (it's long flexible snout) much like an elephant uses its trunk to feed. Whelks occur worldwide most are cold-water species.

It has a thick, spiral shell usually from about 3 to 6 inches in length, with a wide aperture (opening hole) and ridged whorls. It is active and carnivorous, feeding on living or dead animals, which it grasps with its foot. The mouth is located at the end of a large probiscis, and the radula or tongue is toothed and capable of boring holes in the shells of other mollusks on which whelk prey.

Common along the northern coasts of the North Atlantic Ocean, the whelk occurs from the low-water mark to a depth of 600 ft. Several hundred eggs are laid in individual capsules; the latter are attached to each other, forming spongelike masses. In many European countries the Whelk is used for food.

The snails body consists of four main parts: visceral hump, mantle, head, and foot. The body is attached to the shell either by one columellar muscle or by a series of muscles.

The visceral hump is contained within the shell it holds the bulk of the digestive, reproductive, excretory, and respiratory system. The mantle is the fleshy ling of the outer wa1l of the shell.

The head is bilaterally symmetrical having one or two pairs of tentacles often with accessory palps, and the mouth in the middle of the ventral margin. Eyespots are rarely eyes capable of image formation are present near or on that larger pair of tentacles at its base.

The foot is flat broadly tapered muscular organ which is highly granularized and dilated used for in swimming.

COMMON NAME	Three Line Mud Snail
SCIENTIFIC NAME	*Nassarius trivittatus*
Family	Nassaridae
Order	Prosobranchiata
Class	Gastropoda
Phylum	Mollusca

Two common species, *N. trivittatus* and *N. obsolete* are the two nassas of the New England and New Jersey coasts. The first has a more northerly range, extending to the Gulf of St. Lawrence; the other id not usually found north of Cape Cod, but below that point as far as Hatteras it is probably the commonest shell of the coast. If fairly swarms in sheltered muddy reaches about low tide. Little pools left by the tide on the Jersey flats are sometimes so crowded with *N. obsolete* that for lack of room the animals crawl over one another. *N. trivittatus* is more commonly taken at small depths in the harbors, where it seems to live well upon all kinds of sea-bottoms. Probably they exist in great numbers along the southern shore of Long Island, for the beaches are often lined with their dead and worn shells. Over half the specimens thus found will have a litt1e round perforation upon some whorl, showing that they were victims of some cannibalistic brother. The shells of the *Nassida* have a short, ovate aperture, with a short anterior canal. The inner lip is smooth, and usually coated over with a more or less heavy deposit of enamel. *N. trivittatus* is about one half to seven tenths of an inch long, and is yellowish-white. A series of revolving grooves cutting across a series of longitudinal lines gives the shell a decussated or granulated appearance. The whorls are somewhat shouldered at the sutures, and are white inside.

N. obsulcta cannot be called a handsome shell by the most enthusiastic collector. Its spire is usually eroded or completely dissolved away. The color is blackish to olive, with the aperture purplish-black. The columellar lip is arched, with a twist or fold in its lower portion. It is decussated by crossing lines and grooves, though not so conspicuously as *N. trivittatus;* sutures simple; length one half of an inch to one inch. Old specimens not only become eroded, but are usually covered with vegetable matter, and are not over-inspiring to the collector. They often live in brackish water and frequent all the inlets and marine flats between Cape Cod and Hatteras. Below Hatteras both this and the last-named species occur, though not plentifully.

COMMON NAME	Mud Dog Whelk
SCIENTIFIC NAME	*Ilynassa obsoleta*
FAMILY	Nassariidoe
ORDER	Prosobranchiata
CLASS	Gastropoda
PHYLUM	Mollusca

Mud Nassas are known as the Family Nassariidae. Its Scientific Name is *Ilynassa obsoleta*. The Family Nassariidae is known as Dog Whelks. The reason why Dog Whelks are part of the gastropoda class is because a dog whelk is a type of snail. Dog Whelks are little snails which subsist or feed on animal tissues. This type of feeding is known as a carnivore feeder.

The Family Nassariidoes' shells are compact, sturdy, and have a relatively thick build. The shells also have pointed spines. The aperture is strongly notched at both of its ends, and most commonly found there is a calcareous deposit. This shells habitat would be located in shallow waters.

A Mud Dog Welk is an example of the Family Nassariidaes. The Mud Dog Whelk is found within the range between the Gulf of St. Lawrence to Florida. The Mud Dog Whelks habitat would be mudflats. Its color is dark reddish purple to almost black. It is 1 inch high, has 6 whores and a moderately elevated spine. The Whelks aperture is oval, its outer part (around the lip area) is thin and very sharp. The inner part of the lip area is arched.

The Mud Dog Whelk is abundantly found along the Atlantic coast. It is a scavenger which feeds on dead fish or crushed clams; Hundreds of these individuals can be found in area with th1se conditions.

NAME	Tunicate - Sea Squirt
SCIENTIFIC NAME	*Ciona sp.*
FAMILY	Cionidae
ORDER	Ascidian
CLASS	Ascidiacea
SUBPHYLUM	Tunicata
PHYLUM	Chordata

This phylum takes its, name from notochord, a stiffened rod consisting of fibrous sheath around translucent cells whose turgid condition provides firmness and flexibility. No member of any other phylum has a notochord. Procession of a notochord prevents a chordates body from telescoping when its longitudinal muscles contract. Instead, it bends from side to side.

Sea Squirts live in the sea, always permanently fixed and when touched they contract suddenly. squirting out two long jets of water. Some Sea Squirts are solitary, others live in clusters and there is a third group that lives in colonies. In all, the body is enclosed in a firm jelly like coat or tunic from which they also derive the name tunicates. The two jets of water we see when we touch a sea squirt are ejected through two openings, the inhalant opening and the exhalent opening; which is on its side. Water is drawn in by the beating cilia through the inhalant opening bringing in food and oxygen. And it is driven out through the exhalent opening carrying away waste products.

These creatures are nourished by plankton screened from the sea water that passes through a good sized sponge at the rate of two quarts every minute.

Sexual reproduction by budding produces numerous individuals in the compound tunicates. Nearly all tunicates are hermaphroditic with both ovaries and testes. Some species spawn eggs and sperm and fertilization and development occur in the sea. Others produce yolky eggs that remain in the atrium, where development to the tadpole stage occurs.

COMMON NAME	Skate Egg Case
Scientific name	*Raja batis*
FAMILY	Batoidae
ODER	Selachii
CLASS	Chondrichthyes
SUBPHYLUM	Vertebrata
PHYLUM	Chordata

SKATE

Skate, in zoology, any of numerous flat bodied cartilaginous fishes (skates, rays, and others). Skates are found in most parts of the world, from tropical to near-Artic waters and from the shallows to depths of more than 8,900 feet. Skates are round to diamond shaped in form. They have large pectoral fin extending from the snout to the base of the slender tail. The mouth and gill openings are on the under side of the body. They are innocuous bottom dwellers often found partly buried, and they swim with a graceful undulating movement of their pectoral fins.

SKATE EGG CASE

The eggs, the "Mermaids Purse", are often found on the beaches and are oblong and protected by a leathery case. Sometime after mating the female lays her eggs, each enclosed in a capsule with a horn like process at each corner, which in some species is drawn out into a tendril. These help to anchor the egg case to objects on the sea floor. In places the surface of the capsule is covered with a felt of loose fibers. In the common skate the fibers near the corners, and at the base of the processes, are long filaments. The capsules differ in size with the species, those of the thornback being 3-4 inches long, while those of the common skate are more than double this. The baby skate when it hatches is almost as broad across the pectoral fins as the capsule it carne from is long.

The capsules are amber colored at first but turn black after the young have hatched. As the capsules are rolled about on the sea bed the fibers are rubbed off.

COMMON NAME	Northern Lobster
SCIENTIFIC NAME	*Homarus americanus*
FAMILY	Homaridae
ORDER	Decapoda
CLASS	Crustacea
PHYLUM	Arthropoda

The American lobster is found from Labrador to North Carolina. It goes to deep water in the fall and returns to shallower regions in summer, although some of these lobsters may remain in the shallower water throughout the entire season. Like most crustaceans, lobsters are much more active at night than during the day. They often build burrows 2 or 3 ft. long, which they enter backward. The American lobster is a scavenger, living on whatever it can pick up, and it also eats algae and eelgrass to some extent. Lobsters are also cannibalistic, preying on smaller members of their own species. On the whole, they are not sufficiently active to capture a great deal of food alive, but such food is acceptable whenever procured.

The greatest size recorded by Herrick for the East Coast lobster is 35 lb. The large claws make up from one fourth to one-half the weight of the entire animal. Herrick records a giant whose large claws weighed more than two-thirds that of the entire body.

The enemies of the lobster take the greatest toll during the time that the lobsters are small. Predaceous fishes are probably the main enemy other than man, and the cod is perhaps the most destructive to small lobsters.

REPRODUCTION: The sperm from the male is deposited in pockets on the underside of the female, and she uses this sperm to fertilize her eggs as she lays them. The sperm may remain functional for several months after it is deposited on the female, but it is usually used before the lapse of several months. The American lobster lays eggs chiefly during July and August, though lobsters in berry. i.e., lobsters carrying eggs, may be found earlier than this, and some individuals may lay eggs later than August. The number of eggs laid per lobster varies with the size of the lobster.

MOLTING: Shedding of the skeleton occurs during the summer months. There is some question as to whether the female molts only every 2 years or every year. The indications are that males molt more frequently than females of egg bearing size. Although the new shell becomes fairly rigid in a day after molting, it takes from 6 to 8 weeks before the shell becomes as completely hardened as the one cast off. Young lobsters molt from 14 to 17 times during the first year. A 10-in. lobster has molted about 25 times and is about 5 years old. From this time onward it is doubtful if molting occurs more than once a year.

COMMON NAME	Channeled Whelk
SCIENTIFIC NAME	*Busycon canaliculatum*
FAMILY	Melongenidae
ORDER	Prosodbranchiata
CLASS	Gastrapoda
PHYLUM	Mollusca

DESCRIPTION: 7" (18cm) long, 3.5" (89mm) wide. Pear-shaped. Pale buffy-gray. Periostracum yellowish-brown, intact in young specimens, mostly eroded away in older ones. Spire short. 5-6 whorls with square shoulder bearing small, low knobs; fine spiral lines, deeply channeled suture. Aperture and siphonal canal two-thirds body length, yellowish inside. Outer lip flared. Head and foot whitish. Operculum horny, brown.

HABITAT: On sand and sandy-mud bottoms; from low-tide line to water 60 ft. (18m) deep.

RANGE: Cape Cod to north Florida; introduced into San Francisco Bay.

COMMENTS: The Channeled Whelk feeds mostly on bivalves, which it digs out of the bottom. The Knobbed Whelk (*B. carica'*) shares the Channeled Whelk's range and habitat. It grows to 9” (23 cm) in length and 4" (114mm) in width, has a series of large knobs on the shoulder, and a black head and foot. Its shell is yellowish gray with a reddish-orange interior.

COMMON NAME	False Angel Wing
SCIENTIFIC NAME	*Petricola pholadiformis*
ORDER	Eulamellibranchia
CLASS	Pelecypoda
PHYLUM	Mollusca

DESCRIPTION: 2" (51mm) long, three-fourths in. (19mm) high. Long, fragile, convex; front end rounded, rear end long. Chalky-white. Valves equal; umbones low, forward; slight gape for siphons at rear end. Surface with about 10 heavy, scaly, radial ribs at front end ending as saw-toothed margin; many smaller ribs toward rear, crossed by strong growth lines. Siphons separate, large, tubular, gray.

HABITAT: Boring into clay, peat, or soft rock in protected areas; near low-tide line and below in shallow water.

RANGE: Gulf of St. Lawrence to Florida, Texas and Mexico; introduced into San Francisco Bay and c. Washington.

COMMENTS: This clam bores into a hard substrate by anchoring its foot in the end of the burrow, drawing the valves down, and rasping with their saw-toothed margins.

COMMON NAME	Atlantic Rock Crab
SCIENTIFIC NAME	*Cancer irroratus*
FAMILY	Canceridae
ORDER	Decapodae
CLASS	Crustacea
PHYLUM	Arthropoda

DESCRIPTION: 5.25" (133 mm) wide, 3.5” (89 mm) long. Fan-shaped. Upper side yellow, closely dotted with reddish or purplish spots, whitish to creamy yellow underneath. Carapace oval, fairly smooth, frontborder rounded. 3 teeth between eye sockets, middle one longest; 9 simple teeth to side of eye socket. Pincer’s stout, short, fingers bent downward, black at tips. Walking legs short, hairy at edges.

HABITAT: On rock, sand, or gravel bottoms, in estuaries and on open shores; from low tide line to water 2600' (780m) deep.

RANGE: Labrador to South Carolina.

COMMON NAME	Jonah Crab
SCIENTIFIC NAME	*Cancer borealis*
FAMILY	Canceridae
ORDER	Decapodae
CLASS	Crustacea
PHYLUM	Arthropoda

DESCRIPTION: 61" (16cm) wide, 4" (102mm) long. Fan-shaped. Upper side dull rosy to brick-red, yellowish beneath, legs yellow mottled with reddish-purple. Carapace oval, granular, length two thirds width, front border rounded.3 teeth between eye sockets, middle one largest; 9 teeth to side of eye socket, each with several smaller points. Pincer's stout, short, fingers bent downward, black at tips, joint next to hand with sharp spine on inside upper border. Walking legs short, hairy. black-tipped.

HABITAT: On rocky shores and bottoms; from low tide line to water 2620' (799m) deep.

RANGE: Nova Scotia to Florida; Bermuda.

COMMON NAME Hooded Merganser

SCIENTIFIC NAME *Lophodytes cucullatus*

FAMILY Anatidae

ORDER Anseriformes

CLASS Aves

PHYLUM- Chordata

SUBPHYLUM Vertebrata

DESCRIPTION: 16-19" (40-48 cm). A small duck with a slender, pointed bill. Male has white, fan-shaped, black-bordered crest; dark blackish body; dull rusty flanks; white breast with two black stripes down the side. Female is dull gray-brown with head and crest warmer brown. Both sexes show a white wing patch in flight.

VOICE: Hoarse grunts and chatters.

HABITAT: Wooded ponds, lakes, and rivers; sometimes in tidal channels in winter.

RANGE: Alaska, Manitoba and Nova Scotia south to Tennessee, Nebraska, and Oregon; occasionally in southeastern states. Winters from British Columbia, Nebraska, and New England south to Mexico and the Gulf Coast.

NESTING: 8-12 white eggs in a down-lined cup ina natural tree cavity, or sometimes in a fallen hollow log.

COMMENTS: The smallest of our mergansers, they are most often seen along rivers and in estuaries during the fall and winter. They are usually found in flocks of up to a dozen, and when startled are among the fastest flying of our ducks. They feed chiefly on small fish, which they pursue in long, rapid, underwater dives, but also take frogs and aquatic insects.

COMMON NAME	Wood Duck
SCIENTIFIC NAME	*Aix sponsa*
FAMILY	Anatidae
ORDER	Anseriformes
CLASS	Aves
SUBPHYLUM	Vertebrata
PHYLUM	Chordata

DESCRIPTION: 17-20" (43-51 cm). A beautiful, crested, multicolored small duck. Male patterned in iridescent greens, purples, and blues with a distinctive white chin patch; red, rather long bill; long tail. Female grayish with broad white eye ring.

VOICE: Loud wooo-eeek. Also softer peet and cheep notes.

HABITAT*:* Wooded rivers and ponds; wooded swamps. Visits freshwater marshes in late summer and fall.

RANGE*:* British Columbia, Nova Scotia, and Minnesota south to Florida and Texas. Winters north to British Columbia in the West and the Carolinas in the East, rarely farther north. Also breeds in Cuba.

NESTING: Up to 15 whitish eggs in a nest made of down in a natural tree cavity or nest box sometimes 50 feet or more from the ground.

COMMENTS: The Wood Duck's habit of nesting in cavities enables it to breed in areas lacking suitable ground cover. The young leave the nest soon after hatching, jumping from the nesting cavity to the ground. Once in the water, they travel through wooded ponds with their mother. Snapping turtles take a heavy toll of them.

COMMON NAME	Pintail
SCIENTIFIC NAME	*Anas acuta*
FAMILY	Anatidae
ORDER	Anseriformes
CLASS	Aves
SUBPHYLUM	Vertebrata
PHYLUM	Chordata

DESCRIPTION: Males 25-30" (63-76 cm), females 21-23" (53-58 cm). Slim, graceful duck with slender neck. Male has brown head and white neck with white line extending up the side of the head. Central tail feathers long, black, and pointed. Female streaked brown, similar to female Mallard but paler, grayer, and slenderer, with brown speculum that is bordered with white at the rear edge only; tail is more pointed than in female Mallard.

VOICE: Distinctive two-toned whistle. Females quack.

HABITAT: Marshes, prairie ponds, and tundra; sometimes salt marshes in winter. Breeds from Alaska and Greenland south to western Pennsylvania, Nebraska, and California. Locally and occasionally farther east. Winters south to Central America and the West Indies. Also breeds in Eurasia.

NESTING: 7-10 pale greenish-buff eggs in a shallow grass bowl lined with down and hidden in grass, often some distance from water.

COMMENTS: The Pintail, a widely distributed and common duck, is a strong flier and long-distance migrant like the mallard. Seeds of aquatic plants are its main food, but in winter small aquatic animals are also taken; when freshwater habitats freeze over, it resorts to tidal flats, where it feeds on snails and small crabs. A popular gamebird because of its tasty flesh and fast flight, it is one of our wariest ducks.

COMMON NAME Bufflehead

SCIENTIFIC NAME *Bucephala albeola*

FAMILY Anatidae

ORDER Anseriformes

CLASS Aves

PHYLUM- Chordata

SUBPHYLUM Vertebrata

DESCRIPTION: 13-15" (33-38 cm). Small, chubby duck. Male largely white, with black back, black head with greenish- and purplish gloss, and a large white patch from eye to top and back of head. Female all dark with a single whitish patch on cheek. It is a fast flier and has a rapid wingbeat.

VOICE: A squeaky whistle (male); a soft, hoarse quack (female).

HABITAT: Northern lakes and ponds; in winter, mainly on salt bays and estuaries.

RANGE: Alaska, Mackenzie, and Ontario south to Manitoba and the mountains of California. Winters on both coasts south to Mexico, the Gulf Coast, and Florida.

NESTING: 8-12 pale buff eggs in a mass of down placed in 2 woodpecker hole up to 20 feet aboveground.

COMMENTS: The Bufflehead, or "Butterball" as it is known to hunters, is e smaller relative of the goldeneyes and like them breeds in tree cavities. Its courtship is similar to that of the Common Goldeneye. It is one of the most familiar ducks along the coast in winter. Usually in small parties, it does not form great rafts as do scaups, Redheads, and Canvasbacks.

COMMON NAME	American Wigeon
SCIENTIFIC NAME	*Anas americana*
FAMILY	Anatidae
ORDER	Anseriformes
CLASS	Aves
PHYLUM	Chordata
SUBPHYLUM	Vertebrata

DESCRIPTION: 18-23" (46-58 ern). Male is brownish with white crown, green ear patch, and bold white shoulder patches easily visible in flight. Female is mottled brown with grayish head and whitish shoulder patch. Pale blue bill and feet in both sexes.

VOICE: Distinctive whistled whew-whew-whew. Also quacks.

HABITAT: Marshes, ponds, and shallow lakes.

RANGE: Alaska, Mackenzie, and Minnesota south to Nebraska and northern California. Rarely farther east. Winters south to Central America and the West Indies.

NESTING: 8-10 whitish or cream-colored eggs in a down-lined hollow in grass. often several hundred yards from water.

COMMENTS: The American Wigeon, or "Baldpate," is a wary species, often seen on marshy ponds in the company of diving birds such as coots, Redheads, and Canvasbacks. They wait at the surface while the other birds dive, then snatch the food away when the birds reappear. They also visit grain fields and meadows to graze, like geese, on tender shoots. The birds found in winter along the Atlantic coast seem to come mainly from the Far North, while birds in the interior of the continent move south to the Gulf Coast and West Indies.

COMMON NAME	Bull Shark
SCIENTIFIC NAME	*Carvharhinus leucas*
FAMILY	Carcharhinidae
ORDER	Squali
CLASS	Chindroichthys (cartilage fish)
PHYLUM	Chordata
SUBPHYLUM	Vertebrata

REQUIEM SHARKS

(Family Carcharhinidae)

Because they resemble each other so closely, many requiem sharks are difficult to identify. They have 2 dorsal fins, the first large than the second, neither with spines. The upper lobe of the caudal fin is elongate and pointed upward. The teeth are bladelike cups, and the cutting edges may be smooth or serrate. It is unusual for more than a single row of teeth to be functional at once. This is the largest family of sharks, containing 26 species that occur in North America. Most species are pelagic, although some occur close to shore. While some of the large species are dangerous, many others are harmless to people.

BULL SHARK (*Carcharhinus leucas*)

Description: To 11 inches (3.5m). Fusiform, relatively robust; back grayish, belly white, tips in fins dusky in young. Snout short, rounded, length less than width of mouth; teeth strongly serrate, those in upper jaw broadly triangular, in lower jaw slender. No spiracle; no ridge between dorsal fins or keel on caudal peduncle. Pectoral fins large, broad, with pointed tips; first dorsal fin much larger than second, first dorsal fin origin in front of axil of pectoral fins.

Habitat: Inshore, never far from land. Ascends rivers for considerable distances.

Range: In Atlantic from New York to Rio de Janeiro, Brazil, including Bermuda, Gulf of Mexico, and Antilles; in Pacific from South Baja California to Peru.

Comments: Bull Sharks are often caught on hook and line but do not rise to the surface and leap as do some of the other members of the family. Several attacks on humans.

COMMON NAME	Bluefish
SCIENTIFIC NAME	*Pomatomus saltatrix*
FAMILY	Pomatomidae
ORDER	Percomorphi
CLASS	Osteichthyes or Pisces
PHYLUM	Chordata
SUBPHYLUM	Vertebrata

BLUEFISH

Size: Recorded to 45 inches in length, commonly about half of that.

Color: Blue to blue-green or blue-gray above, sides lighter, belly silvery to white; snappers are rich blue on the top with a metallic sheen on the sides and a silver-white belly.

Range: Commonly from Cape Cod south; may round the Cape and stray as far north as Nova Scotia.

Comments: Few fish are as popular as the bluefish both as food fish and as a sport fish. They are sought after from shore and from boasts and support a substantial commercial fishery as well.

Bluefish are voracious feeders, often killing more fish than they can eat. They may travel in schools or wait under tidal rips, snapping up small fish caught in the current. It is not uncommon to find them in company with the bonito (*S. sarda*). Their small first dorsal fin and deeply forked caudal fin resemble those of some of the jacks (Carangidae), but the bluefish is clearly distinguished by its large, rounded head; long, sharp teeth; lack of bony plates (scutes); and smooth caudal peduncle.

Bluefish exhibit a migratory instinct, traveling north along our coast in the spring and returning south in the late fall. Schools of bluefish are made up of nearly the same size, probably because large blues readily attack the young of their own species.

The spawning habits of the bluefish are not well known, but the abundance of young (snappers) in channels, bays, and estuaries suggests that these waters are not far from their usual ranges. The snapper, as well as the adult bluefish, is an excellent table fish.

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COMMON NAME	Albacore tuna
SCIENTIFIC NAME	*Thunnus alalunga*
FAMILY	Scombridae
ORDER	Percomorphi
CLASS	Osteichthyes or Pisces
PHYLUM	Chordata
SUBPHYLUM	Vertebrata

ALBACORE

Size: To 4 feet long.

Color: Steel blue above, silver-white beneath.

Range: New Jersey and south, but not common north of Florida.

Comments: The long pectoral fin clearly distinguishes the albacore from other tunas, as does the narrow white margin on the caudal fin.

Not very common in northern waters, this, is the "White-meated" tuna that is so popular. It is caught with hook and line as opposed to yellowfin and bluefin tuna, which are caught by purse seining, which causes the deaths of many, many thousands of porpoises each year.

Albacores feed on fishes, squids, shrimps, and crabs. They support significant fisheries in warm seas throughout the world.

COMMON NAME	Ocean Sunfish
SCIENTIFIC NAME	*Mola mola*
FAMILY	Molidae
ORDER	Tetraodontiformes
CLASS	Osteichthyes or Pisces
PHYLUM	Chordata
SUBPHYLUM	Vertebrata

OCEAN SUNFISH

Size: Grows to a length of 8 or more feet and a weight of nearly 1 ton.

Color: Gray to gray-brown above; silver-gray sides; gray-white beneath.

Range: A tropical species wandering as far north as the coast of New England.

The Protozoa

The Protozoa are single-celled organisms, only a few species of which can be seen without the aid of a microscope. Protozoans are divided into four classes on the basis of the method of locomotion, though there are other distinctive characteristics of each class.

These classes are **Flagellata**, those protozoans having thread like swimming organs; **Ciliata**, those having cilia or hairlike structures for swimming or crawling; **Rhizopoda**, those using extensions or protrusions of the body to enable them to move about; and **Sporozoa**, those without means of locomotion. The sporozoan are all parasitic. All four classes have their parasitic representatives, but in the first three the great majority are free living.

As we become acquainted with the protozoans, we find them showing many of the traits manifested by organisms having many cells. This is not surprising, for all animals have much in common, whether single celled or multicellular, they all must obtain food, reproduce, and carry on other activities important to survival.

Even within a single-celled body, protozoans have many interesting structures (organelles). The organelles for locomotion are cilia, flagella and outpouchings or extensions of the cell body itself. The latter are exemplified by the pseudopodia (false foot) of an amoeba.

All species of animals have a tendency to be selective in their choice of a 1ocality to carry on their activities. Likewise, some species of Protozoans show a decided preference for a certain type of habitat, whereas others occur everywhere. Some protozoans are commensal, being found only in connection with some particular host. For example, various species of Boveria are found only in the circulatory water passing through the gills of certain clams. A giant amoeba (large enough to been seen with the naked eye) *Trichamoeba schaefferi*, is found on the base of the sea anemone *Anthopleura (Cribrina) xanthogrammica.* A stalked ciliate, *Stentor sp.* lives attached to holdfasts of the kelp, Nereocystis. A greenish species of stentor, large enough to be seen without the aid of a microscope, lives attached to hydroid colonies under floats in Newport Bay. The parasitic type of habitat is the most specialized of all. For instance, the malarial parasite (a sporozoan) of Humans lives in the red blood corpuscles; and several species of ciliates live in the intestine of certain sea urchins. Other protozoans, e. g., the ciliates belonging to the group known as the tintinnids, are found widely distributed in the ocean.

Certain groups of protozoans are so important in economy of the sea that they deserve special attention. Some species of protozoans are specific in their food habits, eating only a particular type of food; others feed on many things. As a group they make use of any organic material which can be ingested. Some feed on bacteria; some feed on plants (Diatoms mainly); some eat other protozoans; and, as has been said, some are parasitic.

Some protozoans are scavengers and although they may use bacteria, they also ingest cells from decaying bodies .Two protozoans, *Uronychia trancfugia* and *Styloplotes appendicularis*, have eaten dead or decaying anemone cells, and because the commensal alga Zooxanthella in the anemone cells is not digestible, the protozoans throw off parts of their bodies in order to get rid of the algal cells that collect in their bodies as platelets or boluses (litt1 flattened spheres or

ellipsoids). In some instances, this process of getting rid of the indigestible material takes away so much of the protozoans body that It becomes deformed within a short time the organism is usually able to regenerate the lost body part and become normal again.

Foraminifera

Foraminifera Ameboid protozoans that possess chitinous calcareous or siliceous shells that are usually. Multichambered. Calcareous foraminifera are the main constituent in chalk. Foraminiferan tests, are usually constructed as a series of chambers of increasing size, with a main aperture in the largest chamber. Much of the rest of the shell typically bears numerous tiny perforations through which the cytoplasm extends as a thin sheet around the outside of the test. Certain planktonic foraminiferan occur in such high numbers that the tests of dead individuals provide a major contribution to the sediments of the ocean basins. In some parts of the world, these sediments called, foraminiferan oozes, are many meters thick. Such sediments are restricted to the depths shallower than about 3000 to 4000 meters because the $CaCO_3$ dissolves under high pressure. Foraminiferan tests not only are very abundant in recent and fossil deposits, but also are extremely durable. On the island of Bali, the tests of one species are minded and used as gravel in walks und roads. Much of the world's chalk, limestone, and marble is composed largely of foraminiferan tests or the residual calculous material derived from the tests. Most of the stones used to build pyramids of Egypt are foraminiferan in origin.

Radiolaria

Radiolaria. The radiolaria are another abundant group of marine protozoans, their skeletons forming areas on the ocean floor called, radiolarian ooze. Their framework, or skeleton, is internal and is built of silica. This skeleton varies for each species but is always a beautiful geometric figure. One group of radiolarians (Acantharia) makes its skeleton of strontium sulfate. The element strontium occurs in ocean water In such small quantities that chemists are able to find only minute traces of it, yet here is an animal making a skeleton of strontium sulfate, illustrating how efficient the selective powers of an organisms tissue may be.

Tintinnoidea

Tintinnoidea. One group of the ciliates, the tintinnids (suborder Tintinnoinea), 1 seldom mentioned in books on zoology, but these ciliates are very abundant in ocean water. They are mostly planktonic, and we seldom look at a sample of plankton without seeing from one to several species. No doubt there are thousands of species.

Dinoflagellata

Dinoflagellata. It is often difficult to distinguish some of the protozoans from single-celled plants. One group of s ingle celled organisms claimed by both the botanists and the zoologists is the Dinoflagellata, and as the name implies, they are usually classified with one of the four major

divisions of protozoans, the Flagellata. (flagellum have a threadlike appendage; dino means two). The dinoflagellata have a general body plan that, though varying for each species of the group, separates them from all other protozoans. One of the chief distinguishing characteristics is the possession of two whiplike flagella, one of which is said to be directed backward, while another is wrapped around the bodu on a groove. The one described as being directed backward supplies a means of locomotion. (However, in those dinoflagellate with which we are familiar, the free flagellum is directed forward and pulls the organism along by means of a wiggling, snakelike motion).

Certain members of the dinoflagellates, besides furnishing much food particularly in southern waters , for plankton feeders, are themselves of more than passing interest. Noctiluca (meaning night light), which together with *Pyrocysitis noctiluca* is the source of the most striking luminescence in the sea water. That luminescence may be caused by microscopic organisms emphasizes the fact that they must occur in great numbers. Other species *Gonyaulax polyedra* and *Prorocentrum micans,* often occur along the coast of California in numbers, great enough to cause coloring of the water. Fishermen speak of it as " brown water ".

Another member of this group, *Gonyaulax catenella*, is toxic and gives rise to what is known as mussel Poisoning, which is often fatal. When this dinoflagellate is sufficient in number, the plankton feeders or strainers, such as the mussels and clams, ingest it in quantities sufficient to cause people who eat shellfish to become ill. Cooking does not destroy this poison. This dinoflagellate, though often abundant in Summer is never so abundant in the winter as to cause sickness; therefore, if they are otherwise clean, mussels and clams are safe to eat during this time.

One reason why botanists claim that dinoflagellates are more similar to plants than animals is that many of them live like plants, i.e., they have pigments or coloring matter within their bodies that make it possible for them to manufacture their own food just as plants do. However, other members of the group capture and ingest prey as do animals, and still others live on products of decomposition.

Phylum Porifera: The Sponges

From the point of natural history, sponges are perhaps the least interesting of all animal groups, for they are sessile and show practically no movement. However, it would be a strange group of animals indeed that did not have some interesting features.

In the first place, sponges show very little relationship to any other group of animals, unless it be a subgroup of the flagellate protozoans called the Choanoflagellata. The latter are considered by many to be the ancestors of the sponges. In sponges the motion that is most evident to the observer is the flow of water outward from the large opening on the sponge body. A sponge may have from one to many of these opening. The cells that account for this movement of water are microscopic cells equipped with whiplike flagella that are known as collar cells. This current filters through tiny pores from the outside to the inside of the body of the sponge – hence the name Porifera ("pore bearer"). The aggregate of this water that enters through the thousands or hundreds of pores over the surface of the body finds its way out through the central opening called the osculum. The outpouring of the water through the osculum of the sponge, or in colonial forms the osclua, is the visible indication of life. Sponges are the only animals whose opening is strictly 1imited to an outward current (excurrent) of water.

Commensal Relationships and Enemies. There are many instances of commensal relationships between sponges and other animals, especial1y crustaceans. Annelid worms and brittle stars are common in the water passages of sponges; and other animals, such as bryozoans and barnacles, often attached to the outer surface of the sponges.

At Tortugas one biologist found over 16,000 small shrimp of the genus Synalpheus (two species) in the large loggerhead sponge (*Speciospongia vespera).* This species is disk shaped, and a large specimen will find a tub. From a smaller specimen of this sponge 13,500 animals) over 12,000 of which were Synalpheus) where taken. These animals represent 19 species and included annelid worms, copepods, amphipods, and a fish.

Shrimps of the genus Spongicola live in pairs in certain siliceous sponges. They enter the sponge with the water currents, and as they grow larger, they are unable to leave because the osculum of the sponge is covered with a sieve - like plate

Some sponges live in or anchor themselves in shells of barnacles or snails or clams. An example of' this on our western shores is the *Cliona celata* var. California, which is often found in barnacle shells, abalone shells, and certain clam shells. One sponge grows on Snail shells inhabited by hermit crabs. As the sponge increases in size it completely envelops the shell, except for the opening. Finally, the shell is dissolved away by the sponge and the grab continues its life within the cavity of sponge.

Some crabs use pieces of the sponge, among other things, to place on their backs and legs. These pieces often continue growing until the entire back of the crab is covered with the sponge. Crabs of the genus Dromia break off pieces of the sponge and hold them over their backs with their last pair of legs. In this relationship between crustaceans and sponges the former

receive the benefit of protection, because few animals molest sponges. When the crustaceans are motile the sponge benefits by transportation, but in those instances in which the crustaceans remain imprisoned within the cavity of the sponge, it is difficult to see, wherein the sponge the crustaceans derive any advantage from the relationship.

Sponges have few enemies, but they are eaten by certain gastropods (snails), principally nudibranchs (snails without shells). Along the coast of California, a yellow species of Lamellaria feeds upon a yellow sponge and at Corona Del Mar we often find a small brick red Lamellaria that feeds upon a sponge of the same color. These snails are so nearly the color of the sponge upon which they feed that they are difficult to see, but the streak they leave behind them as they feed aids in locating them.

Reproduction. Practically sponges are hermaphroditic, but the eggs and the sperm may develop at different times. Probably all marine sponges reproduce by means of eggs, which are fertilized within the body of the sponge and develop into tiny swimming larvae that go out with the excurrent water. After n period of swimming about in the ocean they become fixed and metamorphose and grow into parents' type.

One of the methods of reproduction of the freshwater sponges consists of the formation of tiny bits of sponge cells into structures called gemmules. These may be frozen or dried, yet upon immersion in water of the right temperature they begin to develop. Certain marine sponges of the same tropics also reproduce by means of gemmules as a means of escaping desiccation.

Some sponges reproduce by budding off portions of their body that become separated from the parent body. Any piece of sponge is capable of developing into a complete sponge under favorable conditions, but the process is extremely slow. In the majority of sponges the bud does not separate for the parent body and budding serves only to enlarge the colony.

Class: Demospongiae

Class Demospongiae. The vast majority of living sponges, more than 95% are members of this class. The skeletal composition varies with various combinations of silica spicules, spongin, and/or collagen-like fibers. The spicules, ,when present are divisible into the large megascleres or the smaller microscleres. The axonal variety of the spicules is also quite diverse.

The demosponges are often used for commercial purposes and hold the greatest potential for further exploitation in these regards. The ceractinomorph order Dictyoceratida includes the bath sponges. These sponges produce skeletons that are characterized by a fine mesh of slender-fibers with few inclusions of foreign matter. In addition, several orders, again especially among ceractinomorphs, are noted to produce biochemically interesting compounds, such as

cyclopropenes, sterols, and terpenes, that may prove useful in biomedical and other commercial uses.

Demosponges occur in marine habitats extending from intertidal to abyssal depths of 5000 or more. One family, the myxillid ceractinomorphs, extends through this entire range. Most families, however, have a more restricted distribution. Demosponges especially the spongillids, also occur ln freshwater rivers, streams, and lakes.

Class: Sclerospongiae

Class Sclerospongiae. The coralline sponges build a skeleton that contains spicules of both silica and aragonitic calcite as well as spongin. This very ancient group, which includes extinct members of the order Stromatoporoida, bears so many resemblances to various demosponges that some authorities treat sclerosponges as merely a subclass of the Demospongiae.
The rarely encountered sclerosponges generally exhibit rather cryptic habits, and prefer caves, tunnels, crevices and deep-water overhangs on coral reefs.

Class: Hexactinellida

Class Hexactinellida. Until recently these sponges were thought to be restricted to habitats that extended from moderately deep to abyssal depths. Because most were brought up from great depth by dredge collections and, if they survived , where difficult or impossible to maintain in the laboratory, little had been known of their fine anatomy or biology. The identification of *Rhabdocalyptus dawsoni* in shallow waters has ready resulted in new insights concerning the glass sponges.

Phylum Cnidaria or Coelenterata

The coelenterates form one of the major groups of the animal kingdom. There are three classes in this phylum: The Hydrozoa, or hydroids and siphonophores: the Scyphozoa, or jellyfishes; and the Anthozoa, or sea anemones, sea pens, sea pansies, and most corals

The coelenterates get their name from the fact that (with the exception of one order) all members of the group have within the body only a single hollow cavity, called the coelenteron, which functions as a digestive sac. There is no secondary body cavity, such as that found in the higher animals, between the walls of the sac and the body wall. The single opening into the coelenteron serves as both an inlet for food and an outlet for undigested matter and also as an outlet for sperm.

Many corlenterates, particularly corals and even many anemones and hydroids, are vividly colored. Green is a common color among the anemones, but brilliant red and orange are not uncommon. The column may be striped or splotched. Hydroids are usually white or cream, but there are deep purple ones. Jellyfishes may be translucent, blue, brown or- purple. Nearly all the coelenterates are marine.

The body form of the coelenterates assumes two typical shapes. One is the polyp, or cylindrical form, which is the only form found among the anemones and is the predominant body plan of all hydroids. The mouth, which is situated at the top of a column or stalk, is surrounded by one or more rings or tentacles. The base of the column, called the pedal disk, is usually f1at and adheres to the object to which the polyp is fixed.

The other body form is bell-shaped and is called a medusa. It is typical of jellyfishes and occurs as a part of the life cycle of the hydroids. Around the outer edge of the bell there is usually a rather conspicuous circle or fringe of tentacles. The mouth is located on a stalk on the under surface of the bell. In some species there are tentacles around the mouth, and in others the mouth is surrounded by oral lobes. In some species the oral lobes may be long and elaborately frilled.

Many of the coelenterates, particularly the hydroids and corals, are colonial. In colonial forms each individual unites with other individuals, and all individuals of a colony are connected, as it were, by a system of tuber – the common digestive tube. Many of the hydroid colonies are branched so that they appear featherlike or treelike in miniature form, the tip of each branchlet being a head or polyp. All the branches unite until they form a main trunk that is fastened to a rock or other object. They are often mistaken for seaweeds. Many hydroids are protected by a chitinous sheath that surrounds the stems and at the ends of the branches enlarge into a cuplike expansion into which the

heads may be withdrawn when they are contracted. Other hydroids have no such protecting sheath.

The siphonophores, a subgroup of the class to which the hydroids belong, are interesting in that they are a free swimming colony of individuals in which some members perform one function and some another. One set of individuals pulsates rhythmically and furnishes a means of locomotion although such l=motion is relatively slow; another set obtains and ingests food: still another set has the function of reproduction: and others are the sensory members of the colony. In some instances. E. g. the Portuguese man-of-war, one or more individuals may develop into a float filled with gas that is the siphonophore at the surface of the water.

Luminescence is common among the coelenterates. The light comes from granules that in some cases may be rubbed off or come off in slime. Among the hydroids, luminescence has been observed in the genera Obelia, Plumularia, and Campanularia. Certain hydroid medusae emit luminescence upon stimulation. Upon stimulation, the sea pens, which are the most the most luminous of the coelenterates, exude a slime that contains luminescent granules. Some sea pens are luminous throughout the entire body: in others only, certain parts are luminous. Some will luminesce at any time, others only at night, and others only after being in the dark for a while.

All coelenterates are equipped stinging cells called nematocysts, which are used for paralyzing prey. They also probably serve a defense purpose. Nematocysts more or less cover the surface of the body but are more concentrated in certain region than in others. In. many members of the group they are also found in portions of the gastrovascular cavity.

Undoubtedly all nematocysts discharge poison from the bulbar part of the structure as the thread is injected into the tissue of the prey. Also, almost any moving contact with the body of the coelenterate will cause discharge of these stinging cells. They are not always sufficiently large to penetrate through the skin of one's hands when such animals are handled. We have often demonstrated their stinging to ourselves and to students by touching the tongue to an anemone. But many coelenterates, particularly some of the jellyfishes and siphonophores, have cells sufficiently large enough to cause much irritation and smarting. The jellyfishes Chiropsalmus (Japan and Philippines) and Dactulometra (East Coast and tropics) are the most dangerous. The Portuguese man-of-war siphonophore Physalia inflicts the most powerful sting of all, and swimmers who have become entangled in their tentacles have sometimes had to be treated in hospitals.

Locomotion. The freshwater Hydra mover by turning somersaults, alternately attaching and releasing the pedal disk and tentacles. Locomotion in the marine hydroids is limited to the larval planulae and to the jellyfish stages of those hydroids that have free-swimming medusae.

In siphonophores certain individuals have the function of pulsating for propelling the colony through the water. The by-the-wind-sailor siphonophore Velella has a small sail that is set at an angle with the long axis of the oval colonial body so that the animal is more efficiently propelled through the water by the wind. The Portuguese man-of-war siphonophores have a float for keeping them at the surface. Most siphonophores can sink downward by altering the gas content of the floats, but Velella and Physalia cannot do this.

Digestion and Feeding**.** The lack of a circulatory system is apparently of no disadvantage to the coelenterates, for the larger ones particularly the anemones, are constructed in such a way that food material has to travel only a short distance from the digestive region to reach any part of the body. Many coelenterates have thin membranes, or sheets, called mesenteries, which radiate inward from the outer wall toward the middle of the cavity, thus greatly increasing the surface of the cavity. The inner edges of these mesenteries are thrown into folds that are capable of great extension and that move so as to completely enfold food, which is digested by juices and enzymes secreted from their surfaces.

The functioning of these thin sheets can be demonstrated easily by cutting am anemone in two and lying beside it a piece of clam meat or fish. The filaments will move out and surround the food. Some of the cells in the inner surface of the coelenteron engulf food and digest it within the cells. This is called intracellular digestion in contrast with digestion in the open cavity, which is caller intercellular digestion.

In jellyfishes there is a system of canals that facilitate the movement of food throughout the body. In some of the large jellyfish's food has to be transported for some distance through the jellylike substance called. Mesoglea. The latter is often rich in stored food contained within the bodies of amoebocyte cells. These cells migrate wherever food is needed and give up food to the tissues.

All coelenterates are carnivorous. In fact, most, if not all, are unable to digest starches.

In addition to stinging cells, most coelenterates also have adhesive or sticky cells which help to hold prey while it is being stung or carried to the mouth.

The tentacles or fingerlike processes arranged around the mouth of a hydroid or anemone and around the edge of the bell of a medusa or jellyfish are well supplied with stinging cells. When come in contact with the tentacles, these stinging cells discharge their poison into its body and paralyze it. It is then moved to the mouth by contraction if the body and tentacles and swallowed.

Colonial hydroids obtain their food means of their tentacles. Their polyp bodies or heads, are, on the whole, very small, and their prey consists of small animals such as small and larval crustaceans and the larvae of mollusks. Since every head of a colony of hydroids is connected with every other head by the digestive tube, every particle of food

ingested by one head may serve as nutriment for less fortunate individuals at a far distant region of the colony.

Most anemones are capable of swallowing objects very large in proportion to themselves. They often swallow objects that are too large for a single meal and a portion of it will, after several hours, be regurgitated. We have seen strings of squid eggs and even other sea anemones swallowed and retained for from one to a few hours and then expelled, apparently little the worse for the experience. This does not mean that digestion does not take place readily within the body of an anemone, but simply that squid eggs and other anemones are difficult to digest.

Longevity. Judging from what evidence we have been able to obtain, jellyfishes have a relatively short life lifespan. Sometimes Scyphistoma, the stage in the life of the jellyfish Aurelia that vids off tiny young jellyfishes, occurs in considerable numbers on the undersides of floats in Newport Bay. In the first week if February 1942, great numbers of tiny Aurelia were seen floating in the bay. These were from 1/2 to 1 inch in diameter. They continued to float and grow within the bay until the end of April, and a few scattered specimens were still present during the first week in May. The oldest of them therefore reached an age of three months and averaged between 6 and 8 inches in diameter. If these jellyfish had been carried to the open ocean away from shore, it is probable that they would have attained a diameter of 12 inches or more.

In contrast with the hydroids and jellyfishes, most sea anemone grow very slowly. An anemone brought into the laboratory will grow rather rapidly when fed or will decrease its size if of starved, so it is possible to increase or decrease its size by controlling it intake of food. It is safe to say that any species of anemone has a definite size beyond which it will never grow. No doubt it is also safe to say that all individuals of a particular species have a definite life span. As we pointed out in the chapter on "growth rates," we do not mean that the individuals of a certain species of anemone will grow only to an exact size or that any individual of a species will live to be an exact age. The size for any particular individual of a species is limited by its inheritance, i.e. the size to which its ancestors grew, and be said of its age. It is quite possible and even probable that certain anemone may live to be one, two or even three hundred years old.

Symbionts and Commensals**.** The common green sea anemones, many corals, and certain medusae have living within their tissues a single celled algal plant called Zoochlorella. Here there is contained in the body of one organism an example of what we often called the
carbon dioxide cycle. The plant uses the waste products of the life processes of the anemone i.e. the byproducts of metabolism. The anemone in turn is furnished oxygen for respiration. The oxygen being the by-product of photosynthesis, or food making, on the part of the plant. By means of oxygen derived from plants, the anemone "burns" its food

within its tissues, and the carbon dioxide and other waste products, given off as a result of this process are used by the plants. Hence both members of the relationship benefit by the presence of the other. However, since the anemone is able to take oxygen from the water, it is not entirely dependent upon the oxygen given off by the plants, so the plants probably benefit from the relationship that the anemone does.

Coelenterates also harbor within their tissues brown and yellow cells called Zooxanthellae, which are mostly flagellate protozoans. The same relationship exists between them and their hosts as holds between the Zoochlorellae and their hosts, Zoochlorellae and zooxanthellae are often present in the same animal. Both are ejected from the host when the latter becomes starved.

The hydroid *Endocrvpta huntsmanni* lives, with several other commensals, in the branchial cavity of the large solitary tunicate *Ascidiopsis paratropa,* which occurs in deep water in Puget Sound and farther north.

One of the most interesting commensal relationships is that of the small fish *Nomeus gronovii* (common in the Gulf of Mexico), which lives among the tentacles of *Physalis*. The sting of Physalis is dangerous to man, but Nomeus is uninjured, probably because it has an immunity to the poison of the stinging cells of Physalis or does not irritate its host. As the small fish swims about, a larger fish may dash in with the intention of dinning on Nomeus only to find itself in the meshes of the trailing tentacles of the Physalis. The latter and its commensal partner may then make a meal of the captured fish. This relationship may be nearer a symbiotic one, but it is further complicated by the fact that Nomeus sometimes nibbles on the tentacles and other parts of its host, thus verging on parasitism.

Another commensal relationship among the coelenterates is that of the small anemone *Bucidium aequorea* and the hydroid medusa *Aequorea aequorea,* found in Puget Sound waters. The anemone fastens its disk to the undersurface of the medusa and is thus provided with transportation. The anemone also no doubt helps itself to some of the food captured by the tentacles of its host.

Many crustaceans, especially young forms, seek refuge in the bells of jellyfishes and siphonophores and thus gain transportation and probably bits of food.

Another curious commensal or, more probably, parasitic, relationship is the existence in all the Aleyonaria (a subclass of the Anthozoa) of the copepod genus Lamippe. The aleyonarians include most of the corals. the sea fans, sea feathers, sea pens, and sea pansies, and throughout the entire world Lamippe can be found in every genus.

One slender species of sea pen that is dredged off the coast of California has an anemone living commensally on it. This anemone attaches itself to the stalk among the polyps of the sea pen, and as ot groes ot sends an extension out from either side of its basal disk. These two extensions finally meet and fuse together on the opposite side of the sea pen. Thus, the anemone remains attached, resembling a solitaire ring on a finger.

The anemone *Adamsia pal1iata* wraps its pedal disk around the snail shell occupied by the hermit crab *Eupagurus prideauxi*. The normal food of this anemone is crustaceans, and its stinging cells cause tetany in the prey, but *Eupagurus prideauxi* is entirely immune to the poison, although other species of Eupagurus are not.

The relationship between hermit crabs and certain anemones is so close that when such a hermit crab changes to a larger shell it removes the anemones and places the latte on the new shell. If the hermit crab loses its anemone, it will seek another and hold it against its shell until the anemone attaches. Different species of crabs are associated with specific anemones, and these crabs recognize and select the right species of anemone.

Certain crabs live in pits or galls formed in corals. Female Harpalocarinus live among corals that branch dichotomously. The young female crabs settle in the new forks of the branching corals. The respiratory currents of the crabs cause the branches to broaden and curve until a chamber is formed around the crab and the latter is imprisoned. The males, which are

much smaller than the females, remain free and are able to crawl into the pits occupied by the females. In Cryptochirus both male and female live in chambers in certain types of corals.

Enemies. Because coelenterates are well equipped with stinging cells, there are few animals that use them for food. However, the giant sunfish *Mola mola* liver almost entirely upon a diet of jellyfishes and similar coelenterates. In several instances *Mola mola* had apparently wandered far beyond its usual northern range in order to feed on the siphonophore Velella.

A small fish, Pseudoscarus, which lives in the Red Sea, feeds on corals. It is equipped with a parrot-like beak for biting off chunks of the coral. To ingest so much indigestible material in order to obtain the comparatively small amount of animal tissue seems a hard way of obtaining food. But an animal that has become adjusted to this sort of diet can browse in the coral fields with no competition except from members of its own species.

Some nudibranchs (snails without shells) feed on hydroid, and one, Acolis, feeds on anemones. Along the coast of southern California the nudibranch *Antiopella aurcotincta* feeds on the solitary hydroid Corymorpha and nibbles off its head. The hydroid can regenerate a new head.

Since coelenterates have so few enemies, what holds them in check? Except for the limits which have already been mentioned, it may be that not much of anything holds corals in check when conditions are favorable. The softer bodied anemones and hydroids are limited in range by needing not just a place for attachment but one where they are

well sheltered. Unusual disturbances, such as storms or fresh water, at times kill great numbers of hydroids and even anemones.

Corals and Coral Reefs. Some of the hydroids and some of the members of the class to which the anemones and sea pens belong secrete calcareous exoskeletons upon which and among the lamellations of which the living part of the animal rests. This skeleton gives solidity to what would otherwise be without support. Coelenterates that secrete such skeletons are all included under the general term of corals. Some corals are solitary individuals, but most are colonial. Each species gives its own particular shape to this skeletal structure, thus accounting for the great variety of skeletal forms.

Coral skeletons are on display in all museums, so no attempt will be made here to describe them. These “corals" on display are simply skeletons. As colonial corals grow, the feeding heads on the outer edges of the colony do most of the feeding, and as the lowest members are gradually smothered out, the animals themselves die, leaving only the bare skeletons. Thus, corals grow upon their own old skeletons, constantly increasing the amount of calcareous material that is withdrawn from the water.

The fact that corals grow on the skeletons of dead corals accounts for the reef-and island-building activities of some of the corals. There are three types of coral formations, known as fringing reefs, barrier reefs, and atolls. Fringing reefs are coral formations that develop fairly close to land and have only a shallow channel between them and the land itself. Barrier reefs are several miles from land and have between them and the land a channel which often affords passage for relatively large boats. Atolls, of which there are great number in the mid-Pacific, are ring or horseshoe-shaped islands. These have in their centers lagoons or small bays that are never very deep, usually no more than 30 ft. In small atolls these lagoons may be only a few hundred yards in extent, but in larger ones they may be many miles in diameter.

Most of the corals that form these reefs or atolls are relatives of the sea anemones; others are relatives of the hydroids. In addition, certain plants that secrete a calcareous covering also furnish a great deal of calcareous material. In some formations it has been estimated that plants make up as much as half or more of the entire coral deposit.

Corals in sufficient abundance to form coral reefs or atolls are found only in warm seas, mainly between Lat. 30^{o} N. and 30^{o} S. Corals of the type that form reefs and atolls cannot grow below a depth of 200 ft. While living, corals have few destructive enemies of an animal nature, but they rather easily smothered out by accumulating sediments. As we learned in our discussion on the carrying of sediments by fresh as salt water, finely divided material is much more easily carried than are larger particles. If a wave rushing toward shore with a certain velocity could carry with it a piece of coral whose volume

was 1 cubic inch, doubling the velocity of this current would enable it to carry a piece with a volume of 64 cubic inch.

Applying these facts to a fringing reef we see that the coral growth is limited to the sloping sides of an island or continent to a depth of less than 200 ft. Year after year corals grow upon each other until the mass reaches the surface and waves break off pieces of it and grind it up. Also, we find that because corals are limited to a shadow depth, the outer edge of a coral formation becomes rather steep as the formation extends outward from land. As chunks of coral break off the growing front, some are carried onto the beaches of the island and are gradually ground up. Others sink and form a talus, the slope of which is quite abrupt because large chunks will form a much steeper bank than smaller pieces that are more easily spread out by the action of currents. The outer surface of this talus is full of large interstices, i.e., it has many openings and crevices between the chunks that afford excellent refuge for many animals. These interstices gradually fill up with finer material from the grinding going on above in the surf zone. But, since the process is a continuous one, the general aspect of the face of the talus remains practically the same. Those masses of coral that are thrown toward the land are carried only so far as the power of the surf is able to carry each particular piece. Smaller pieces are carried proportionately farther, and large pieces remain farther out or roll down the face. Hence a coral beach is always building outward. The portion of the reef between the outer edge and the land, where the less turbulent water collects, is gradually dissolved, and carried away~ forming shallow channel areas between the outer portion of the coral formation and the land, thus forming a fringing reef. Dissolution, or the dissolving of the lime between the reef and the land, is no doubt also helped or accelerated by the fact that organic matter of plants~ being lighter, would be carried nearer shore, where the decay of this material gives rise to carbonic acid. This acid then reacts with calcium carbonate, of which the dead portions of corals are composed. The activities of animals of one sort and another in this narrow channel, the currents themselves, and the somewhat spent effect of the waves washing over in times of severe storm tend to divide the materials in this region more finely and therefore offer more surface for dissolution and also make them more easily carried away by currents.

The same principles apply to atolls, but it is not so easy to explain the formation of barrier reefs. The barrier reef of Australia, which is the largest barrier reef, is an enormous structure, 1,350 miles in length, and in places is from 25 to 90 miles from the mainland of Australia.

Cnidae

Cnidae, which are often referred to collectively as nematocysts are the most unique and characteristic structures in cnidarians. They serve a variety of functions, including prey capture, defense, locomotion, and attachment. They are produced by cells called **cnidoblasts**, which develop from interstitial cells in the epidermis. Once fully formed, the cell is properly called a cnidocyte, in which resides the cnida. Cnidae are

among the largest and the most complex intracellular structures known. About three dozen kinds of cnidae have been described. **True** nematocysts have double walled capsules containing a toxic mixture of phenols and proteins. The tube is usually armed with spines or barbs that aid in penetration of and anchorage in the victim's flesh. The toxin is injected into the victim, often through a terminal pore in the thread. Cnidae have usually been viewed as independent effectors, and, indeed, they often discharge upon direct stimulation.

The ejection of the tube from a cnida is called exocytosis, and an individual cnida can be fired only once. Three hypotheses have been proposed to explain the mechanism of firing: (1) the discharge is the result of increased hydrostatic pressure caused by a rapid influx of water (**osmotic hypothesis**); (2) intrinsic tension forces generated during cnidogenesis are released at discharge (**tension hypothesis**); and (3) contractile units enveloping the cnida cause the discharge by "squeezing" the capsule (**contractile hypothesis**).

The coiled capsular tube is forcibly everted and thrown out of the bursting cell to penetrate or wrap around a portion of the unwary victim. It takes only a few milliseconds for the cnida to fire, and the everting tube may reach a velocity of 2 m/sec., an acceleration of about 40,000 , making it one of the fastest cellular processes in nature.

Although nematocyst toxins vary in strength, as a class of chemicals they are potent biological poisons capable of subduing large active prey, including fishes. Most appear to be neurotoxins.

Stony, or Scleractinian, Corals

Closely related to sea anemones are the stony, or scleractinian, corals (also called madreporarian corals), which constitute the largest order of anthozoans. In contrast to sea anemones, stony corals produce a calcium carbonate skeleton.

The skeleton is composed of calcium carbonate crystals and is secreted by the epidermis of the lower half of the column as well as by the basal disc. Their secreting process produces a skeletal cup, within which the polyp is fixed. The cup is termed the calyx, the surrounding walls of the cup, the theca, and the floor of the cup, the basal plate. The floor contains thin, radiating, calcareous septa. Each scleroseptum projects upward into the base of the polyp, folding the basal layers and inserting them between a pair of mesenteries. As long as a colony is alive, calcium carbonate is deposited beneath the living tissues.

The polyps of colonial corals are all interconnected, but the attachment is lateral rather than aboral, as in hydroids. The column wall folds outward above the skeletal cup and connects with similar folds of adjacent polyps. Thus, all the members of the colony are connected by a horizontal sheet of tissue. Since this sheet represents a fold of the body wall, it contains an extension of the gastrovascular cavity as well as an upper and lower layer of gastrodermis and epidermis. The lower epidermal layer secretes the part of the skeleton that is located between the cups in which the polyps lie. The living coral colony, therefore, lies entirely above the skeleton and completely covers it.

The coral colony expands by the budding of new polyps, from the bases of the old polyps or from the oral discs of old polyps. In the latter case, the oral disc of the parent lengthens in one direction. Gradually, the oral disc constricts, and the separation extends down the length of the column to form two new polyps. The budding process is accompanied by simultaneous changes in the deposition of the underlying sclerosepta. As might be expected, brain corals arise by intratentacular budding, in which the oral discs and columns never constrict after a few mouths are formed. Thus, the polyps in a row of brain coral share a common oral disc bearing many mouths.

Calcium carbonate is continually deposited by the basal epidermis of the living colony that rests upon it. In many corals the polyps periodically lift their bases and secrete a new floor to their cup. This closes off a minute chamber in the skeleton. The growth rate varies greatly, depending upon the species and water temperature. Many dome and plate corals grow only 0.3 to 2 cm a year through vertical or linear deposition of calcium carbonate. Some branched corals, on the other hand, grow rapidly, increasing in the linear direction as much as 10 cm per year.

The density of the secreted $CaCO_3$, is not the same throughout the year, the change being governed by seasonal. shifts of temperature and light. Thus, many coral skeletons exhibit seasonal growth bands like tree rings. They can be revealed with x-radiographs to determine the age and growth rate of the coral.

Corals feed like sea anemones, and the prey ranges from small fish down to small zooplankton, depending on the size of the polyps. When the expanded, the outstretched tentacles of adjacent polyps present a broad, continuous mesh that prey might touch. In addition to capturing zooplankton, many corals also collect fine particles in mucous films or strands, which are then driven by cilia to the mouth.

Although there are many exceptions, most corals feed at night and are contracted during the day. Over 60 genera of corals contain symbiotic zooxanthellae within the gastrodermal cells. The algal symbionts give most of their coral host a yellow-brown to dark brown color. Our knowledge of the physiological relationship between hermatypic corals and their symbiotic algae has grown considerably in recent years.

The nutritive needs of the coral are supplied in part by the planktonic animals upon which it feeds and in part by the planktonic animals upon which it feeds and in part by its algal symbionts. A large portion of the carbon fixed by the algae in photosynthesis is passed to the coral, largely in the form of glycerol but including glucose and alanine. The food caught by the coral probably supplies both coral and algae with nitrogen, which is then cycled back and forth between the two. Thus, the coral requires zooplankton prey even though the photosynthate supplies a major part of its energy needs.

Sexual reproduction is similar to that in the sea anemones. The planula, which is produced by sexual reproduction, attaches and the subsequent first polyp (which develops by asexual budding) Becomes the parent of all other members of the colony.

Corals are subject to injury or death from storms, extremely low tides, predation, and disease. The living colony can regenerate about 1 cm of destroyed tissue but not much more.

Octocorals

Sea anemones and corals, because of their structural similarities, are grouped in the subclass Zoantharia. The remaining anthozoans, including such common marine forms as sea pens, sea fans, whip corals, form the subclass Octocorallia. The Octocorallia possess a number of distinctive features. Octocorallians always have eight tentacles, and these are pinnate--that is, they possess side branches, as does a feather.

The amebocytes of the mesoglea secrete calcareous skeletal material that supports the colony. Thus, the skeleton of the Octocorallia is internal and is an integral part of the tissue. This arrangement is in sharp contrast to that of the stony corals, whose skeletons are entirely external.

Among the most familiar of the octocorallians are the gorgonian, or horny, corals of the order Gorgonacea which include the whip corals, sea feathers, sea fans, and precious red coral (Corallium). The body of most gorgonian corals contains a central axial rod composed of an organic substance called gorgonin (proteins plus mucopolysaccharides). The axial rod is commonly impregnated with calcium carbonate.

Around the axis is a cylinder of coenchyme and polyps. The coenchyme contains embedded calcareous ossicles or spicules of different shapes and colors. It is the color of the calcareous skeletal components that accounts for the yellow, orange, or lavender color of some species. The yellow-brown color of many reef species results from the presence

of symbiotic zooxanthellae. The colonies of most gorgonian corals are erect branching rods and are thus rather plant-like.

Gorgonians are more commonly expanded during the day than during the night. They have been assumed to feed on zooplankton like most scleractinian corals, but recent studies on a number of gorgonians and other octocorallians indicate that they have small numbers of cnidocysts and feed on smaller particles than zooplankton. Gorgonians harbor many symbiotic animals that either are attached to or crawl over the gorgonian surface--colonial tunicates, barnacles, bivalves, snails, and gobies. Some take on the colors of their gorgonian host.

Summary of the Characteristics

of the

Phylum Cnidaria or Coelenterata

1. Members of the class Anthozoa are polypoid cnidarians; the medusoid stage is entirely lacking.

2. The anthozoan polyp is more specialized than that of hydrozoans, and its cellular mesoglea, septate gastrovascular cavity, cnidocysts in gastric filaments, and gastrodermal gonads indicate a closer phylogenetic relationship with the Scyphozoa than with the Hydrozoa.

3. The difference in the body form of the Scyphozoa and the Anthozoa (medusa versus polyp) may be reconciled if the anthozoans are derived through the polypoid larva of scyphozoans.

4. The two subclasses, the Zoantharia and the Octocorallia, reflect different levels of structural evolution within the Anthozoa. The Octocorallia have retained an arrangement of eight complete mesenteries and eight tentacles, which may be the primitive anthozoan condition. Colonial organization is characteristic of almost all octocorallians, and the polyps are interconnected through a complex mass of mesoglea and gastrodermal tubes. The zoantharia display a more complex system of mesenteries, which always exceed eight in number. There are many solitary forms, and colonial species are connected by more or less simple outfoldings of the body wall.

5. Sea anemones are the principal group of solitary anthozoans, and perhaps because of their solitary condition, many species have evolved a larger size than most other anthozoan polyps. The number and complexity of their mesenteries, providing a large surface area of gastric filaments, may be related to the utilization of larger prey.

6. The majority of anthozoans are colonial, and this type of organization has evolved independently a number of times within the class. Although colonies may reach a large size, the individual polyps are generally small. There are some groups with polymorphic colonies, but this condition is not as widespread as in the hydrozoans.

7. Scleractinian corals, although similar to sea anemones, are largely colonial and are unique in their secretion of an external calcareous skeleton. The skeleton provides the colony with a uniform substrate on which the living colony rests. The sclerosepta may contribute to the adherence of the polyps within the thecal cups and provide some protection against grazing predators when the polyps are withdrawn.

8. The majority of scleractinian corals are tropical reef inhabitants (hermatypic) and harbor zooxanthellae. Zooxanthellae are found in many other anthozoans as well as some scyphomedusae and some hydrozoans.

9. The colonial alcyonaceans, or soft corals, which are most abundant on Indo-Pacific reefs, in many ways parallel the scleractinian corals, for the massive coenechymal mass forms the substrate from which the individual polyps arise.

10. The branching, rod-like colonies or gorgonian corals are adapted for exploiting the vertical water column while using only a small area of the substrate for attachment. Flexible support is provided by a central, organic skeletal rod and separate calcareous spicules embedded in the coenenchyme.

11. The pennatulaceans, which include sea pens, sea feathers, and sea pansies, are adapted for life on soft bottoms. A large, primary polyp, which determines the form of the colony, not only provides anchorage in the sand but also acts as the substrate from which the small, secondary

polyps arise.

12. A planula larva is characteristic of most anthozoans and develops into the polyp. Colonial forms derived by budding from the first polyp.

Phylum Ctenophore: The Comb Jellies

The ctenophores are a group of strictly marine animals that are structurally slightly more advanced than the coelenterates. This is evident by a digestive track in which digestion is more localized and by the presence of an elaborate sense organ on the aboral pole (end opposite the mouth). The digestive tube ends at. the aboral pole in two pores, one on either side of the sense organ. Blind, tube-like branches that extend throughout the body are given off from, the alimentary tract. There is no cavity between the digestive tube and the body wall, for this space is filled with a solid, jelly-like substance that gives the animals their shape. There is no skeleton. Ctenophores do not possess stinging cells.

A typical ctenophore is spheroidal and transparent, but some are compressed and elongated. Some are colored pink, others are orange, and some olive. In one order (Cestida), which comprises two genera (Cestum and Valamen), the body id flattened, and a broad band extends laterally on either side of the mouth, this shape has given the name of *Venus girdle* (*Cestum veneris)* to one species, which is often over 3 ft. long (or wide). This species has a pale violet hue.

The chief distinguishing characteristic of the" ctenophores is the eight rows or plates of cilia that radiate from the aboral pole and extend toward the oral or mouth of the animal. These ciliated plates are responsible for the name of the ~phylum which comes from two words meaning “comb” and "to bear". This is because the cilia are arranged in rows, like the teeth in a comb, across the eight plates. Because of this and the gelatinous nature of their, bodies, the: ctenophores are often popularly called comb jellies. The comb rows are often highly iridescent.

All ctenophores are luminescent. The ability to luminesce begins shortly after the fertilizes egg starts dividing. The ability of the ctenophores to luminesce is lifelong, but only after being placed in the dark for some time.

Locomotion. The majority of ctenophores are pelagic, and many species occur in schools. They are largely carried about by water currents, for they are not powerful swimmers. The ciliated plates are the organs of locomotion. Each comb in the eight rows beats in succession the combs nearest the aboral end beating first, the beating continuing in succession from comb to comb down the row like a wave. The working stroke of the cilia is toward the aboral end, so the animal is propelled oral end first. Some ctenophores can reverse the direction of the working stroke and thus progress in the direction of the aboral end.

In one genus the flapping if the large lover around the mouth furnishes the means of propulsion. Cestum and Velamen swim not only by means of their combs but also undulations of the body.

Several ectoparasitic genera merely creep about on their hosts. Some ctenophores can swim and can creep about on extended oral lobes and everted pharynx.

Feeding: All ctenophores are carnivorous. Their prey is captured and held by means of adhesive cells and lasso cells. These holding organs are sometimes located on a pair of tentacles, as in Pleurobeachia, or they mat ne located over the surface of the body, as in Leucothea. As far as we have been able to determine, these holding structures are stimulated to function only by movement of the prey. The tentacles of Pleurobranchia are very extensive, for an animal only ½ in. in diameter has tentacles that can trail out in the water at least 6 in. The tentacles are provided with numerous short branches, which increases the surface area and thus increase the chances of prey coming in contact with them.

The surface of the Leucothea is covered with papillae, the apex of each one of which ends in a sticky sucker. These suckers fasten ti any animal that comes near or in contact with the body of the animal. The papilla are capable of quickly elongating and extending out from the surface of the body ½ inch or more, so that an animal that is swimming by within this distance is captured by the quick extension of papillae nearest it. The prey is then transferred from papillae to papillae and then to the mouth where it is swallowed. A glass rod moved along the side of a Leucothea in an aquarium will cause a eave of extended papillae to rise under it as it moves along. The fact that movement is necessary to the function of the holding structures is in keeping with the carnivorous habit of the ctenophores.

Some ctenophores are equipped with ciliated lobes about the mouth, and these are used in combination with or instead of the structures mentioned above for capturing pret. Beroe, a vase-shaped ctenophore has no tentacles. It sometimes swallows prey larger than itself.

Habit: The ctenophore most commonly seen on out western coast from Vineyard sound to the Carolinas, *Pnemiopsis leidyi*, a larger ctenophore famous for its luminescence is exceedingly abundant and is often seen in immense swarms. Among other things this animal is known to eat mollusk larvae and copepods. One investigator found a specimen that had eaten 126 oyster larvae. A sea anemone, *Edwardsia leidyi*, is often attached to this ctenophore.

Size and Age: The smallest ctenophores are about the size of a garden pea (Pleurobrachia), and the largest (Leucothea) the size of a small watermelon. The size of the elongated *Venus girdle*, has already been given.

A swarm of Leucothea (now species) in Monterey Bay was so thick that one looking sown from a skiff could see from 20-30 at a time. Though they are not round like a watermelon they grow to 13 inches in length.

Nothing is known about the age of ctenophores, but none of them probably live more than a year or two at most. Pleurobrachia perhaps does not love more than a few months.

Reproduction and Regeneration: All ctenophores are hermaphroditic. In the majority of species the sperm and eggs are discharged through the mouth into the sea water, where they are fertilized. In two genera the testes are provided with ducts that open through pores on the aboral surface. In Coeloplana (Red Sea and Japan) the eggs are attached to the oral surface until the larvae become free-swimming. Tjalfiella (Greenland) has broad pouches on its aboral surface where the eggs develop into swimming larvae. In sine species a complex metamorphosis occurs

but no alteration of generations. Some of the creeping forms are known to reproduce in a manner similar to that described for the anemone *Sagartria sp.*

Ctenophores possess remarkable powers of regeneration. Combs or whole plates of combs may be regenerated, and an entire animal can be regenerated from any half. Experimental zoologists have found that pieces from one animal may be grafted into another. Rows of combs may be grafted in reverse position and the cilia continue beating in their usual direction, it is possible to cause an animal to swim round and round.

Phylum: Platyhelminthes

Phylum Platyhelminthes. The phylum Platyhelminthes (Greek platy, "flat"; helminth, "worm") includes about 20,000 extant species of free-living and parasitic worms. These animals are a grade of complexity that. May be call the triploblastic acoelomate Bilateria. Platyhelminthes display a variety of body forms and are successful inhabitants of a wide range of environments. The majority of flatworms are parasitic members of the Classes (Trematoda and Monogenean (the flukes) and Cestoda (the tapeworms). The class Tubellaria includes primarily free- living forms in the marine and freshwater benthic habitats: a few are terrestrial, and some are symbiotic in or on other invertebrates. As their name suggests, most of these animals are strikingly flattened dorsoventrally although the body shape varies from broadly oval to elongated and ribbon-like; a few bear tentacles at the anterior end or have other elaborations of the body surface. The free-living forms range in size from less than 1mm to about 30cm long. The largest of all the flatworms are certainly tapeworms that attain lengths of several meters.

The combined features of the platyhelminths may represent a set of derived traits making major advancements in the evolution of metazoan. Some recent work suggests that these animals might have had a coelomate ancestry. Flatworms have a character in common with the coelenterates, i.e., they have only one opening into their bodies. This opening serves both for the ingestion of food and the egestion of indigestible material. Radial symmetry is found in the coelenterates, but the flatworms exhibit bilateral symmetry, i.e., they may be divided longitudinally into right and left. halves that are alike. Coupled with a third germ layer (mesoderm), bilateral symmetry, and cephalization are some sophisticated organs and organ systems. There is a trend toward cephalization of the nervous system. The solid (acoelomate) usually includes a relatively (dense mesenchyme between the gut and the body wall. Within this mesenchyme we find discrete excretory/osmoregulatory structures. These structures Protonrphridia, are found in a number of invertebrate taxa, especially among protostomes and pseudocoelomates. Most flatworms possess complex reproductive systems and an incomplete, yet complex gut with a single opening serving for both ingestion and egestion. The mouth leads to a pharynx of varying complexity and thence to a blind intestine. In the turbellarian order Acoela, the digestive area contains not permanent cavity and the gut is entirely lacking in tapeworms.

Classes: Turbellina

Order Acoela.

In this order the free-flatworms have characteristics in common with the green anemones, in that these worms have within their tissues single-celled microscopic algal plants. They differ from the anemone in that they make use of this garden within their flesh for food. In fact, the alimentary tract of this worm is vestigak, being filled with a cellular, flesh-1ikc material. It is

said that they will actually swim near the surface of the water in the daytime so their internal plants may get the sun light necessary for manufacturing of food. The plants can then reproduce and replace those that are digested by the host. *Convoluta roscoffensis,* a tiny acoelan that Inhabits the flat sandy beaches of France, appears at the surface of the sand during the low tide in such numbers that the beach becomes greenish. When the tide comes in the worm's burrow into the sand and escape the surf.

Order Rhabdocoeles.

This order has a single finger-shaped, or sometimes slightly branched, alimentary tract, with the mouth near the anterior end of the animal. Marine Phabdocoelcs may be found crawling about in the upper layers of the mud in estuaries or the ocean bottom and among almost any mass of plant or animal material that one may examine. In spite of the fact that they are exceedingly common, relatively few of the Marine forms have been named. *Microstomum davenporti* is found on seaweeds Ulva and Fucus in the waters of Long Island Sound.

Order Polycladida.

Members of this fourth order have a digestive *tract* that is much ramified or branched. Portions of it are thus brought in close contact with all portions of the body of the animal. Polyclads have no circulatory system, but the ramifications of the alimentary tract mean the animal can take food material to all parts of the body. The mouth is located near the middle of the underside of the animal.

This order contains members at least 6 inches in length. Their bodies are very flat and thin from the back to the underside, and few of them have bodies more than twice as long as they are broad. Therefore, a Polyclad that is 2 inches long usually has a body that is about 1 inch wide and perhaps only 1/32 inch thick.

Polyclad flatworms are limited almost to the rocky regions of the seashore, where by means of their cilia they are able to craw; about the rocks and seaweeds with a gliding sinuous motion, inconspicuous in color, bring grayish or brownish, but others are consider among the most beautiful animals in the ocean almost rivaling sone of the brilliant butterflies of the land. Some are fairly good swimmers, using the margins if th eir bodies in an undulating motion to propel themselves through the water. To see one of these beautiful creatures swimming is a sight ling to be remembered.

Large polyclads are unusually abundant beneath rocks at the rocky point of Puerto Penasco in the Gulf of California. A Brown flatworm, over 2 inches in length that swims with graceful undulating motions of the margins is common.

Size and Habitats. The largest polyclad flatworm with which we are acquainted (*Cryptophallus magnus*), lives in regions where there are rock-boring clams (*Barnca pacifica, Zirfaea gabbi,* etc.) or mussel beds and it uses these mollusks for food. One of these flatworms that we found was practically 6 inches long and 3 inches wide, but the average size if this species is perhaps between 3 and 4 inches in length. One individual about 3.5 inches long ate a clam that weighed 32 grams without the shell. At Monterey Bay a boat that was brought into dry dock was covered with mussels and crawling among the mussels were dozens of Cryptophallus from 2 inches to 4 inches long. Unfortunately, many of our flatworms are still unnamed.

Class: Trematoda

The majority of trematodes are parasitic forms with the mouth toward the anterior end with a sucker or suckers surrounding the mouth, and usually with a sucker in the ventral surface, often at or toward the posterior end. They are without cilia in the outer surface, but in general their shape resembles the turbellarians.

The parasitic forms live attached to the surface of their hosts, either externally or internally according to the species. Familiar landforms are liver flukes in the bile ducts of sheep, ling flukes in frogs, cats, etc., and flukes found in the urinary bladders of frogs.

A common habitat of externally parasitic marine forms is the gills of fishes. The gills provide protection and a soft place for attaching and obtaining food.

At Elkhorn Slough we found the common sting ray *Aetobatus californicus* parasitized by three species of trematodes. One, *Probolitrema californiense*, a translucent worm about 2 inch long and ½ inch wide, inhabits the body cavity of its host. These were sufficiently transparent that one could watch the working of some of the internal organs of the worm under the microscope. Another, *Epibdella pacifica* a small white trematode with suckers at both ends, liver in the mouth cavity. Still a third species, *Calinella myliobati,* is parasitic upon a copepod, *Trebius ray*, chiefly in the folds at the vase of tail and around the mouth. The copepod is about 1/5 of an inch long and the trematode is about 1/25 of an inch long.

Feeding. Trematodes have a digestive tract and obtain food by sucking juices from their host. Reproductively trematodes are hermaphroditic. The internally parasitic forms have a complicated life history, requiring two or three hosts for their complete development. For example, *Stichocotyle nephropsis* (3/4 to 4 inches long) lives as an adult in the liver of the skate *Raja*, on the Atlantic Coast. Fertilized eggs are passed from the intestine if the Raja and the developing larvae swim about for a while and enter some animal that is later water by lobsters or crabs. Here, the larvae become encysted in the walls if the intestine. When infected lobsters or crabs are eaten by skates, the encysted larvae are released. Find their way to the liver and become adult trematodes.

Similarly, *Hemiurus appendiculatus* lives as an adult in the digestive tract of the herring. The larvae occur in the copepods that are eaten by the herring.

Since the sting ray *Aetobatus* mentioned above also feeds on clams, it is probable that larval form of the trematode inhabiting its body cavity is encysted in the clams also.

Class: Cestoda

The cestodes or tapeworms are parasitic flatworms with a body consisting of two parts, a head and a strobila. The head is equipped with two or four suckers, and sometimes hooks, for attachment to the intestine of its host. No sense organs are present. The strobila consists of a "neck" followed by one to several thousand segments. These segments, or proglottids, form along the free portion if the worm in back of the head and in those with many segments, they became more and more distinct as the worm grows longer. When the worm reaches a certain length depending on the species, the ripe segments begin to drop off, sometimes singly and sometimes several at one time.

A tapeworm has no mouth and no digestive system but absorbs nourishment through its body wall from the digested food in the intestine of its host. It is amazing that an animal has developed a body wall capable of absorbing food and at the same time capable of resisting the action if the digestive juices of its host. In the case of the larvae, the cysts surrounding them are digested away, vit the larvae remain unharmed to thrive and grow into adults.

Reproduction. Each segment of the tapeworm contains both male and female organs, and fertilization occurs between different segments. In sone species the fertilized eggs are expelled into the intestine of the host and later pass out of the body with the feces of the host. On others the eggs develop into embryos while still within the segments, and as the hindermost segments become mature they are cat odd and are excreted with the feces of the host. In these embryos, which are provided with hooks and suckers are taken into the digestive tract of some other animal they will bore through the intestine wall and migrate to certain tissues. Here the larvae grow and undergo further development, then from a cyst around themselves and remain inactive until their host is eaten by another animal, usually a vertebrate animal. When this happens, the encysted larvae are freed by the digestive juices of the host and attach themselves to the walls of the intestine if the host, where they develop onto adult tapeworms. Thus two hosts are required for tapeworms one kind of animal for the larvae and another for the adults.

Life Histories. The largest tapeworm known, *Diphullovathraum latum*, grows to a length of nearly 30 feet. The larvae occur in perch and other freshwater fishes of Europe and Japan. The adult lives in the intestines of cats, dogs, and humans, who become infected through eating fish that are not thoroughly cooked. The eggs of the tapeworms get into the water from fecal material

from infected cats, dogs or humans. They develop into swimming larvae that finally enter copepods. When these copepods are eaten by fish, the larvae bore their way into the muscles of the fish and encyst themselves.

Fish may be infected with either the larval stages or the adults of the tape worms, and ot is possible for one fish to harbor the adult of one species and the larvae of another.

At Elkhorn Slough we found that the foot muscles of the gaper clam *Schizothaerus nuttalliii*, contained the encysted larvae of a species of Anthibithrium. We took 140 cysts from the clan, and each cyst contained from one to five larvae. Occasionally a specimen pf the *Macina nasuta* and *Paphia staminea* was likewise infected but only lightly. Schizothaerus at Humboldt Bay and Newport Bay are also infected with larvae, but not as heavily as those at Elkhorn Slough. It is interesting to note that another species of clam, *Saxidomus nuttallii* of similar size and often occurring in the same bed with *Schizothaerus nuttallii*, is never infected with these larval cestodes. These two clams feed in the same manner, straining material from the current of the water that they pump through their gills and Saxidomus must ingest the larvae as well as Schizithaerus.

Later we discovered that the host of the adult form of this cestode in the sting ray *Aetobatus californicus.* The adults which are only 1/5 of an inch long and have only four to six segments, live in the spiral valve (intestine) of the sting ray. Sea gulls also eat these clams and we thought they might be the host of the tapeworm, but investigation proved otherwise. Sea gulls can eat only those clams that are left exposed by other hunters, such as humans and sting rays. Sting rays cam dig for their own clams. IF the tapeworm depended for its existence upon the chance infection of the seagull it might perish.

At Newport Bay three specimens if the jumbo squid *Dosidicus gigas* were heavily infested with the juvenile species of the tetraphyllid tapeworm. They were in the gizzard, liver and intestine. The species were about 6 inches long.

Phylum: Nematoda

The Nematodes, or round worms (from nema, meaning "thread"), are beat known through their parasitic members such as hook worms, trichina, and pinworms, which infest humans and their domestic animals. As the name implies, they are round, usually tapered at both ends, and are covered with a tough shiny cuticle. Very few of the marine forms have been described and named. Classification of the nematodes is rendered difficult because there are few distinctive external characteristics and is further complicated by the parasitic habits of many of them.

The nematode worms are truly the most ubiquitous phylum of animals. Their abundance is shown by the statement made by a man who spent his life studying this particular group. He said that "if the earth and all that is in it were to disappear and leave nothing but the nematode worm, the earth would still be outlined by them. The oceans, the rivers, the lakes, the trees would be shadowed by nematode worms; even a bird sitting in the limb of a tree would be outlined by nematode worms in its alimentary tract".

The ocean has its quota of nematodes, both free living and parasitic, but the majority of them are microscopic or near- microscopic in size. Consequently, their numbers and their importance are easily underestimated.

One often finds nematodes in the lumen of the intestine of fish, in the intestinal wall, I the body cavity, or coiled up in the muscles. We have often found a large reddish nematode (4 to 6 inches long) lying within the tissues along the base of the fin rays of the flounder. One large nematode, *Lethyonema grayi*, lives within the test of a sea urchin, *Tripneustes esculentus*, where it often almost fills the body cavity of the species from the West Indies or South Atlantic Coast. All fishes have their nematode parasites, but some species seem to have more than their share. Even seaweeds have "nematode trouble", for a tiny thread-like species of the nematode id the cause of galls in the seaweed Ascophyllum (Atlantic Coast).

These parasitic nematodes range in size from those that are microscopic to some that are 5 or 6 ft. long. Nematodes possess a complete digestive system, and their muscular and nervous systems so not show much, if any degeneration. Never the less they are well adapted to a parasitic life as evidence by their enormous production of eggs and the high resistance of both eggs and the adults to desiccate (for periods of many months or even years); and their slender, smooth, tapering bodies offer so little resistance that they often fill their hosts without interfering seriously with the passage of food.

Trichinellids are also parasites of the alimentary canal of vertebrates, especially birds and mammals. The whipworm, Trichuris, which infects human beings, dogs, cats, cattle and other mammals, are relatively small (the human whipworm, *Trichuris trichiura*, is about 4cm) and have a life cycle similar to that of the pinworm. Certainly, the most familiar of the trichinelloids is the Trichinella spiralis of the mammals, the cause of the disease, trichinosis. The minute worms. Which lives in the intestinal wall, is viviparous, and its juveniles are carried in the blood to the striated muscles. There, the juveniles form calcifies cysts and if infection is high, they can

produce pain and stiffness. Transmission to another host can occur only if flesh containing encysted juveniles are ingests. Thus, in some animals, such as the rat, this can be one-host parasite; in others, such as humans and the pig, it would normally require two hosts.

Phylum Annelida:

The Segmented Worms

The annelid body plan represents the classic example of the metameric, triploblastic, coelomate bilateria, and provides a good model for comparison with other protostomes. The elongate body is usually cylindrical, but it has be come markedly flattened in some groups, notably the leeches. The head is composed of a prostomium and a peristomium, the latter bearing the mouth. The gut is separated from the body wall by the coelom, except in those species in which the
body cavity is lost. The trunk segmentation is visible externally as rings, or annuli, and is reflected internally by the serial arrangement of coelomic compartments separated from one another by intersegmental septa. This basic arrangement has been modified to various degrees among the annelids, particularly by reduction in the size of the coelom or by loss of septa; the latter modification has led to fewer but larger internal compartments.

Segmentation is further reflected internally by the metameric arrangement of organs and system components. In the primitive condition, each segment contains a portion of the circulatory, nervous, and excretory systems, in addition to the coelomic compartments. This arrangement in the annelids reflects the principle of system compatibility, which has been stressed in various ways as being critical to the success of any Bauplan. That is to say, given the relative isolation of the body segments from one another by the septa, it is necessary to provide each individual segment with system components to adequately serve their structural and physiological needs. Thus, the origin of the segmented coelomic condition must have involved the co-evolution of this serially homologous arrangement of other parts.

The combination of characteristics listed, especially the coelom, segmentation, closed circulatory system, region ally specialized gut, and nature of the excretory structures, act in concert to alleviate many of the constraints imposed by some other body plans. The annelids are not bound to the small size of the extremely flattened shapes dictated by the necessity for small diffusion distances. Actions of the body wall musculature do not interfere directly with the internal organs as they do in "solid" body constructions, and more active lifestyles are served by the metabolic functions.

Class Chaetopoda

Order Polycheata

Polychaeta comes from two words- poly. "many"; and chaeta, which refers to the bristle like structures of the appendages along the sides of the body of a polychaetae worm. These

appendages are called parapodia, meaning "feet along the sides of the body." The majority of polychaetes have a blood system, with either colorless or red blood.

The red coloring is due to hemoglobin, which is in the plasma rather than in the cells as in mammalian blood. A definite head, usually with eyes, is present. The digestive tract runs the entire length if the animal.

Habitat. The polychaetes are a highly successful and abundant group of marine animals. Some species of polychaete may be found in practically every type of habitat in the ocean. Polychaetes are extremely numerous in the rocky regions along shore, quite common on the sandy beaches, and especially abundant in the mud flats and the ocean bottom. Some specimens are found in the great depths of the ocean, and a few are found swimming freely in the water. Many species build strong, compact tubes of calcium carbonate in which to live. Others build leathery tubes of mucus, some species incorporating sand grains, shell, and debris with the mucus to make the tube more protective. The exposed ends of some of these tubes are branched or sometimes frayed-looking. This affords further protection to the worms, for the extended cirri are difficult to see, or to snatch, among the branches or stringlike ends of the tube. *Diopatra tridentata* (an onuphid worm dredged off southern California) lives in an annulated mud tube so reinforced with tough mucous fibers that it is difficult to tear the tube apart.

Sabellaria cementarium construct tubes of sand concreted together with mucus. These tubes overlap each other so as to form large, thick, incrusted areas over rocks at the low-water line, only the open ends of the tubes being exposed. Some polychaetes just burrow in the mud or sand, much as an earthworm does on land. Others are free-living, roaming about in search of food but practically always con fining their activities to the undersides of rocks, among seaweed, or in places where they are protected from predators, for a polychaete worm is just as desirable a morsel of food to a marine fish as an earthworm is to a trout or bass.

Many of the polychaetes have taken up unique habitats. *Polydora ciliata* burrows into oyster shells. *Platynereis agassizi* builds itself a nest in sea grass (Phyllospadix) by matting

strands of it together with strings of mucus. It can easily be located by these tangled bunches among the grass.

Capitella ovincola lives among the eggs of squids and has never been found elsewhere. This is the only animal that has ever been found that can readily digest the jelly in which the squid eggs are embedded. It infests the masses of squid eggs about the time that they are laid and becomes sexually" mature and reproduces about the time the squids hatch. Several of the worms, which are about 6 in. long, may be crawling about in the jelly of a single string of eggs, but they apparently do not harm the developing squids in any way.

Habits. A large majority of the marine annelids feed on plankton or detritus. The remainder may be called predators, as they eat small crustaceans, other worms, larvae of other marine animals, etc. As will be seen later, there are a few worms with exceptional diets. Most of the annelids that live on plankton are equipped with feather gills at the head end that are mucus-covered when feeding, to entrap planktonic organisms, as has already been described for bryozoans, phoronids, sipunculids, etc. A few have methods of pumping water through mucous traps and later swallowing the mucus with its contained plankton.

1. Plankton Feeders. Some of the gill structures of the polychaete plankton feeders are beautiful. The commonly called feather-duster worms are usually equipped with handsome headgear. They extend their heads with their feathery gills just outside the opening of the tube in which they live. The cilia covering the surface of these gills drive currents of water against them, and the microscopic organisms are entrap-. ped in mucus, which is carried down channels to the mouth where it is continuously swallowed as the annelid feeds. When any plankton-feeding worm has its head and gills extended from the burrow, any disturbance will cause it to jerk back very quickly into the tube.

2. Detritus Feeders. Most of the detritus feeders among the polychaetes obtain their food by one of four methods. Perhaps the most common method is that used by the terebellid (meaning "borer") worms. The head end of these worms is equip ped with fine threadlike structures, called tentacles or cirri, which are capable of great extension. These cirri -are covered with cilia and are well supplied with mucus glands. They usually have a groove running down one side of each cirrus.As the cirri creep out over the surface of the mud, the organic particles, bacteria, etc., of the detritus adhere to the mucus and are carried down the grooves to the mouth of the worm. After being extended to its fullest length, anyone of these cirri may be drawn completely back.

   Most of the worms that use this method of feeding make permanent burrows in the mud of the mud flats or ocean bottom and build about them a firm leathery tube, into which is usually incorporated grains of sand or bits of shell. Only the tip of the head with its bundle of cirri and gills is ever exposed at the opening of the tube. The gills of these detritus feeders are different from those of the feather duster worms in that they are branching, treelike structures serving only the function of respiration.

A second method of feeding on detritus is illustrated by the lungworm Arenicola (meaning "sand-dweller," though.

Arenicola is provided with an reversible proboscis for burrowing through the mud or sand. The outside of this everted organ is well supplied with glands that secrete mucus when the worm is feeding, causing organic matter and sand to stick to it. Upon inversion, the proboscis carries the entrapped material inward to be swallowed. There is a certain amount of selection, since only the finer material and grains of sand adhere to the proboscis, and coarser material is shoved to one side. Probably two-thirds of the material ahead of the worm, where the future burrow will be, is swallow ed, the rest being shoved to the side. Arenicola passes a great quantity of indigestible material through its alimentary tract, the food material being digested out as it passes through the worm.

Like the presence of earthworms on land, the presence of Arenicola is made known by the castings of indigestible material that are evacuated at the surface of the mud or sand. The passing of the indigestible material through the alimentary tract of Arenicola is not a continuous process; the material is stored up in the posterior portion of the body and evacuated at intervals. When the worm is actively feeding, castings are evacuated at intervals closely approximating 30 min. Sometimes castings are forced out beside the old castings, at other times the worm has moved forward sufficiently for the castings to be expelled in a new place. The burrowing activities are carried on from 2 to 4 or 6 in. under the surface, though deeper burrows are often found. When the casting is evacuated, the last bit of it is left plugging the burrow where it was extruded.

When Arenicola is actively feeding, the process of everting and inverting the proboscis and then swallowing occurs about every 5 sec. Also, after a certain number of swallows, ranging from 8 to 15, the worm takes a rest period of a few minutes, then begins feeding again. Lungworms feed on an average of from 5 to 7 or 8 hr. a day. When exposed by the tide, they normally cease feeding until its return, though if the sand or mud is sufficiently moist, they will continue to force out castings for an hour or so after the tide is out.

Another method of feeding on detritus is by means of feather-duster gills as was described for the more common plankton- feeding feather-duster worms. One such detritus feeder, a sabellid, *Myxicola infundibulum*, builds a thick jellylike transparent mucous tube in which it lives, with the small end of the tube in the mud and the larger end projecting above. When the worm is withdrawn, this exposed part looks like nothing more than a blob of mucus. This annelid was well named, for Myxicola means "slime dweller," and infundibulum refers to the funnellike shape of the worm, the body of the worm corresponding to the stem of the funnel and the black feathery gills being arranged in the form of the funnel itself. When Myxicola feeds, it projects this funnel of gills above the surface of the mud, where it is surrounded and protected by the portion of the mucous tube projecting above the surface.

3. Predaceous Feeders. Nereid worms have a short reversible proboscis, which when fully everted shows two hooklike teeth on the end, one on either side. These hooks open

and close upon the prey, holding it firmly. As the proboscis is inverted, the prey is drawn inward and swallowed, a process that may require several minutes if the prey is long or fairly large.

Another group of rather voracious predators, which live not only in the mud flats and ocean bottom but also in the sandy beaches, is the glycerid worms. At the outer end of the everted proboscis of Glycera are four, instead of two, teeth. The proboscis is also a very efficient burrowing organ, and when a glycerid is handled, the proboscis is often quickly everted and forced between the fingers as the worm attempts to conceal itself below the surface.

The carnivorous annelids feed on many kinds of small animals, including small crustaceans and mollusks, and often on other annelids smaller than themselves. The prey is usually swallowed whole, for, except for the hooklike jaws, which are used for holding the prey, they have no means of tearing prey to pieces. The proboscis can be everted with such speed and force that it creates a snapping sound audible through the walls of an aquarium. Some of the scale worms are very belligerent and drive away or kill other members of the group that may invade their burrows. It is probable that many of them, especially the free-living forms, are carnivorous, but it's known that many of the commensal forms eat small particles that enter the burrows of their hosts or feed on small particles that can be snatched from the feeding host.

4. Seaweed Feeders. Although it is not probable that many polychaete worms eat seaweed, one of the largest annelids on the Pacific Coast of North America feeds on seaweed, mainly on Ulva (sea lettuce) or on Enteromorpha (green sea moss). *Neanthes brandti* sometimes reaches a length of 6 ft. when relaxed and a width of about three-fourths in., its body being somewhat flattened from the dorsal to the ventral side.

Commensalism. So far as we know, none of the polychaetes that live in hard tubes of calcium carbonate harbor commensals; but the majority of those that live in leathery or sandy tubes harbor either a commensal worm or a crab or both.

The predaceous *Glycera robusta*, common in regions of Zostera, often plays host to a species of the stalked, colonial protozoan of the genus Zoothamnium, which grows attached between the parapodia.

The sea mouse Aphrodite (and its allies) commonly has one or more small clams, *Pseudophythina rugifera*, attached to its broad annulated "foot." In annelids of this type, the ventral side of the body is flattened to form a creeping sole. The thick, long setae of the parapodia form a mat along the sides and over the back of the animal, which is oval in outline, and the general appearance is responsible for the popular name sea mouse. These annelids are dredged from muddy ocean bottom When first dredged, they are muddy and drab colored.

However, if they are allowed to crawl through clean sand for a day, they become beautifully iridescent. Some species are over 3 in. in length.

Among the polynoid worms, there are probably more commensal species than in any other group of polychaetes. These worms are often called scale worms because of the two rows of scales, or elytra, along their backs. Many species of polynoids live in burrows or tubes with other worms, but others are free-living. As with other forms of commensal animals, the commensal worms vary in their degree of specificity of hosts. Some remain with only one host, other species may live with anyone of several hosts, and still others have both free-living and commensal individuals.

Some scale worms live attached to the body of sea cucumbers, and some of the setae of their parapodia may be modified so that they are hooklike for clinging to the cucumber.

When we dredge the large hermit crab *Paguristes bakeri*, which lives in the shells of *Polinices lewisi*, we nearly always find a *Halosydna brevisetosa* living in the umbilicus of the shell. From this vantage point, it can easily obtain its meals from the prey of the hermit crab.

In southern waters, one hesionid worm crawls about on the underside of the sea star *Patiria miniata*. If the Patiria is removed from water, the annelids immediately crawl into the grooves, where they are inaccessible. Sometimes as many as 20 of these 2-in. worms may be found on a single sea star.

Another fragile worm, *Flabelligera commensalis*, lives among the spines of the purple sea urchin *Strongylocentrotus purpuratus* and is the same color as its host. We have never found this worm anywhere but on the sea urchin, and then only the half-grown or adult worms.

Reproduction. All polychaetes, including those just mentioned, reproduce by means of sperms and eggs, and a few polychaetes can also reproduce by budding or breaking in two. In most cases the sperms and eggs are discharged into the ocean water and their union takes place by chance meeting. But because spawning is done in unison by the individuals of a species within a certain locality, fertilization of all eggs is practically assured.

Ctenodrilus serratus, a polychaete, just visible to the naked eye, that is found in debris, reproduces by dividing into either six or seven new worms by constricting across the body. This type of reproduction may go on for many generations and is then varied by a generation of sexual individuals, the exact nature of which is not known. The young worms develop within the body cavity of the parent worm, and after escaping and growing to adult individuals, they begin reproducing by dividing. Ctenodrilus is hermaphroditic, functioning first as a male and then as a female.

The time of spawning in different species of polychaetes is dependent upon a combination of various factors. The lunar cycle, tides, temperature, season of the year, time of day, light, and calmness of the water are some of the factors that influence spawning.

In some species spawning may recur several nights in succession and may be repeated during certain phases of the moon over a period of several months. The males usually appear first and are soon joined by the females. Both males and females swim madly about in the water, the females some what more slowly than the males, leaving a trail of eggs or sperm. They remind one of an airplane and pilot skywriting. Small fishes often gather to feed on the spawning worms, and larger fishes gather to feed on the small fishes. When one *sees* the way in which spawning polychaete worms attract fishes and crustaceans, and sometimes even squid. one realizes how necessary it is for the worms to remain in seclusion except during these short spawning periods.

One of the classic examples of spawning being correlated with the tide and moon changes is that of the Palolo worm *Eunice viridis* of the Samoan and Fiji Islands. This worm. appears in vast swarms during the last quarter of the moon at the lowest tides during the months of October and
November. The date of spawning is so definite that the natives know it ahead of time and are on hand to gather the worms for a feast.

Some of the syllid worms become luminescent during spawning. Two zoologists have observed a Bermudan species that spawns about sunset at certain times of the month during late summer. It is luminescent during the time that it swims about at the surface. Even the discharged

Eggs are luminous for a while. Odontosyllis phosphorea. which occurs all along our western coast. has similar habits, which have been described by other zoologists.

On our West Coast. *Nereis virens* swarms about midnight in the dark of the moon during the summer months. Ripe males are white with sperm showing through the body wall. and the hinder segments of the females are red with eggs. An embryologist has described the spawning habits of *Platynereis megalops*, an East Coast species that swarms for about 2 hr. every night during the dark of the moon in the summer months. During swarming, the female Megalops bites off from a male the posterior segments containing the sperms. Upon being swallowed, the sperms go through the wall of the pharynx into the body cavity to fertilize the eggs. The fertilized eggs then issue from ruptures in the body wall of the posterior segments of the female. Female Megalops never discharge the eggs until they are fertilized, and the eggs of this species cannot be artificially fertilized in sea water.

In many annelids the sex products escape through ruptures in the body wall. At Humboldt Bay during the month of January. we have found female *Neanthes brandti* so distended and heavy with eggs that they broke in two when we tried to pick them up. In some species, these ruptures occur in certain segments, usually the posterior ones, and the ruptures soon heal, but in other species the entire body becomes filled with eggs and ruptures occur throughout the length of the worm. In such cases the spawned females are nothing but tubes of thin tissues, and they probably die after spawning.

Tubicolous worms in general do not leave their burrows to spawn but simply expel their products into the water. Pectinaria expels eggs or sperms in a continuous stream from a pore in the tip of the hindermost segment" of its body.This segment elongates during the process of spawning.

A few worms, e.g., the tiny sabellid Spirorbis, brood their young, either within the tube or within a cavity of the operculum that has become modified into a brood pouch. Spirorbis is hermaphroditic; the posterior segments of the abdomen contain sperm, and the anterior ones contain eggs.

Some polychaetes discharge their eggs by throwing off the posterior portion of their body at spawning time. They then return to the bottom to hide among the rocks and regenerate a new posterior region.

Class Hirudinea

Leeches are parasitic annelids, usually somewhat oval and flattened and usually with a sucker at each end. By far the vast majority of leeches are land or fresh- water forms, but there are several genera of marine leeches. These are widely distributed but seem to be rare. They are parasitic mainly on rays and sharks.

The genus Branchellion is characterized by having a row of arborescent gills along each side. At Elkhorn Slough nearly every specimen of the sting ray *Aetobatus californicus* has from one to four *Branchellion torpedinis* on it.

Phylum: Echinodermata

The phylum Echinodermata is divided into five subgroups, or classes: The Asteroidea, or sea stars; the Echinoidea, or sea urchins and sand dollars; the Ophiuroidea, or serpent stars and brittle stars; the Holothuroidea, or sea cucumbers; and the Crinoidea, or feather stars or sea lilies. There is not a single terrestrial or fresh-water representative. There are no parasitic echinoderms. The echinoderms are all more or less radially symmetrical, i.e., the parts of the body are radially arranged around a central region in which the mouth is located, and in nearly all cases the body is five-rayed. An other characteristic of the echinoderms is the presence of a calcareous skeleton, made up either of definitely shaped plates more or less rigidly joined together or of scattered spicules or plates. The name of the phylum is derived from word meaning "hedgehog" and "skin" and refers to the spiny skin of many members of the group. In all except the sea cucumbers the outer skin is ciliated.

Class: Asteroidea

The body of a sea star consists of a central portion with, typically, five radiating processes or arms, although the number is by no means uniform throughout the group. At least one species (*Culcita tetraoona*, from Europe) normally has only four arms, while others may have six~ seven, eight, ten, and even as many as forty. Often a typically five-rayed sea stars may be found with as few as four or as many as eight. The arms are not definitely separated from the central. portion of the animal, i.e., there is no line showing where the central portion ends, and the arms begin. The proportion of the central part in relation 'to the arms varies markedly in the different genera. Some sea stars have long slender arms with a very small central portion, and in others the central portion and arms are so merged that the arms are only tips of a pentagon. The centrally located stomach extends out into the rays, as do the ovary and testis. The mouth is located in the center of the undersurface of the body, and the anus on the opposite or upper surface.

Locomotion. Most free-living animals have an anterior-posterior region, i.e., head and tail, with the head end containing most of the sensory organs. Such animals move forward, and the most highly sensitized portion of the body first meets the changing environment. Since each arm of a sea star is practically a duplicate of the others, with rather highly sensitive ends, a sea star can move in the direction of motion without turning around.

The echinoderms have a unique system of organs, which in some members of the phylum is given over largely to 1ocomotion. Without going into details, we may say that, the main working portion of this system consists of a great number of so-called "tube feet," which, as part of a water vascular system, are forced out by relaxing this bulb and contracting the muscles in the walls of the tube feet. These muscles are of two kinds: the circular muscles that go around the tube feet and the longitudinal ones that lie lengthwise in the walls of the tube feet. In most of the sea stars these tube feet end in a sucking disk that enables them to adhere very firmly to any

object against which they are pressed. Thus, a sea stars is able to cling firmly to a rock and resist the action of the surf. In fact, these sucking disks are so efficient that often when one pulls a sea star from a rock many of the disks break loose from the tube feet and remain clinging to the rock. If a sea star is placed on its back it can slowly right itself again by extending the tube feet near the tip of one or two arms until they can adhere to some surface. Then the body is pulled over so that more and more tube feet can attach, until the animal is finally right side up. An average sized *Pisaster ochraceus* can sustain a pull of more than 100 lb. for a short time.

In Sea stars the tube feet lie in grooves on the underside, one groove radiating out each arm from the mouth. They are all coordinated so that they work together to move the animal efficiently, even though the rate of progression is somewhat snail-like. Movement is affected by extending the tube feet ahead, attaching the suckers to an object, and then shortening the tube feet to exert a forward pull. The tube feet are then relaxed and again extended ahead for a new attachment.

Pedicellariae**.** Sea stars are always clean and seldom have other animals growing on their backs or, as a zoologist would express it, on the aboral surface. Microscopic examination of this upper surface of a sea star reveals over the backs and particularly abundant around the bases of the spines a great number of tiny pinching organs which grasp and crush any larvae or small animals that may land upon the surface of the sea star. Thus, no animal is able to make attachment to a sea star. These little grasping or pinching organs, called pedicellariae are not confined to the upper surface alone but are found over nearly all the surface of the body of the sea star. To test the action of these forceps-like or scissors-like organs without being able to see them, one need only place a sea star upside down on the back of one's hand where hair is abundant, or even on the head. The tiny pincers will grasp the hair but usually are not sufficiently strong to pullout the hair when the sea star is removed. A few species of sea stars do not have pedicellariae.

Feeding. It is possible that all tube feet are more or less sensory, but at the outer tips of the arms the tube feet are modified and are entirely sensory in function. These enable the sea star to avoid danger and to detect food. This latter function can easily be demonstrated by putting some food material like clam meat or a piece of fish into an aquarium with a sea star. The sensory tube feet at the ends of the arms begin to wave about in the water, and the sea star proceeds in the direction from which the stimulus of the food material comes. Certain investigators have maintained that sea stars come upon their food only by chance, but anyone who has the time and patience to experiment with sea stars will soon become thoroughly convinced that this is not true.

Most sea stars are carnivorous, and the majority of them feed principally upon shellfish such as clams, mussels, scallops, oysters, etc. When a sea star is in a mussel bed or an oyster bed, it finds its prey by searching, for a living mussel or oyster gives off practically no odor detectable by a sea star. this is no series drawback, for oysters and mussels are so abundant in a bed that the sea star has no trouble finding its food. However, if an oyster or mussel is broken up or smashed, a sea star will sense the broken animal and go more or less directly to it. When a sea star eats a clam, oyster, or mussel, it attaches its tube feet to the valves of its prey, and, by raising its central portion in a tent-like manner, it is able to bring its arms into a position to exert a considerable

pull from opposite sides. In practically all cases the sea star has more endurance than the animal it is trying to open, and the shell of the clam, oyster, or mussel soon begins to gape slowly. Then the stomach of the sea star, a thin, sac-like affair, is extruded from the body of the prey secrete digestive juices that soon dissolve the flesh, and, as this process goes on, the fluid is taken in and absorbed by the body of the sea star. After feeding, the stomach is with drawn into the body.

Reproduction**.** With few exceptions, the sexes are separate in the sea stars. Young *Asterina gibbosa* are all males, but as they grow larger, they become females and produce eggs only. In most sea stars the eggs or sperm are spawned into the water and the fertilized eggs develop into ciliated larvae that are free-swimming for from 2 weeks-to 2 months. The larvae go through various changes before attaching them selves to rocks, seaweeds, etc., where they metamorphose into the adult form. *Patiria miniata*, which ranges from Sitka to La Paz, will shed its eggs or sperm at almost any time of the year if it is laid out of water--unless it has already spawned not more than 2 months previously. *Posaster ochraccus* discharges its eggs or sperm into the water during the summer when the temperature of the water reaches a certain point.

Growth**.** The rate of growth of sea stars depends upon the abundance of food. A well-fed specimen may be many times the size of a poorly fed one at the same age. Sea star may go without food for months, but during this time growth ceases, and, like the anemone, if starvation is continued long enough they may actually decrease in size, although this is not so noticeable as in the anemone.

At least in certain species, sexual maturity depends upon size rather than age. If the food supply is ample, many species of sea stars grow fast enough to be sexually mature by the end of the first year.

Each species of sea star has its own average age limit. Some, like Astropecten, live only about five years, while others, like Pisaster, may live for twenty years.

Class: Echinodea

The echinoids include the regular, or round, sea urchins, the heart urchins, and the flattened cake urchins or sand dollars.

All echinoids have pedicellariae, and as many as four kinds are found in some species. The function and action of these organs have been described by various workers. There are three-jawed pedicellariae that crush larvae that might settle on the animal. There are others that assist in removing foreign particles or prevent the settling of such particles. Others with powerful jaws seize and help hold very small animals until they can be conveyed to the mouth. Other with powerful jaws seize and help hold very small animals until they can be conveyed to the mouth. Other three-jawed pedicellariae with almost globular heads have poison glands and are protective in function.

Sand dollars, heart urchins, and regular urchins grow by the deposition of shell on the outside by the external body membrane, or epithelium, and by the resorption of the shell on the inside.

Regular Urchins and Heart Urchins

Although sea urchins and sea stars are little alike superficially, they are found to be very much alike when carefully examined. If one could remove the upper surface of a sea star, except for a little round disk in the center, bring the arms upward together so that their tips touch and surround the little disk, and then fuse all together, one would roughly have the body of a sea urchin. However, many technical adjustments would have to be made, such as moving the openings of the reproductive organs up to this little round disk in the center, supplying the mouth regions with a very efficient set of five teeth and jaws, elongating the spines, etc. As om the sea stars, the mouth of the sea urchin is located on the underside and the anus in the upper side. They have very ling, slender, tube feet that are able to reach out beyond the ends of the spines and attach to the surface upon which the sea urchin rests. Sea urchins also use their spines making practically no use of the spines in locomotion while in others they are the chief means of movement. The spines can be mover in any direction, for they are hinged to the test by a ball-and-socket joint. One Hawaiian species of sea urchin, *Heterocentrotus mammailatus* has somewhat flattened spines about ½ in. wide and 5 in. long. Others have long slender spines, and still others have short thick, blunt spines.

Habitat and Habits. Some sea urchins along rocky shores remain practically fixed in one place, and it is said that by means of constant abrasion by their spines they are able to dig pockets in solid rock into which they fit and are thus protected from wave shock. However, since all echinoderms except the sea cucumbers have over the surface of their bodies a skin of ciliated epithelium, which covers even the spines themselves, we do not see how these spines can work through such a delicate covering to scrape away rock. We are more inclined to think that it is done by keeping the surface of the rock very clean, thus allowing the sea water gradually to dissolve the surrounding rock. This may be helped by the mechanical action of the sea urchin, particularly by the tube feet continually pulling off tinny vits of the rock as the solvent action of the ocean water takes effect. Such a cavity as we are discussing is not made in a day or a month or a year but om several years.

In many sea urchins the spine serves as a trap for gathering bits of seaweed to be passed around to the mouth, bitten into small pieces by the five teeth, and swallowed. Most sea urchins will also eat flesh, but in nature the capture of such material is infrequent, for so many other more active animals are on the alert for it. With the aid of the pedicellariae very small animals may be caught and carried to the mouth. Small dead animals or portions of larger ones are easily transferred to the mouth.

Respiration**.** Breathing is done mainly by the tube feet and by five groups of tube feet around the mouth that are modified into gills or branchiae. As the body of the sea urchin is a large rounded globe, and the cavity inside is large in proportion to the surface area, sea urchins

have developed special ciliated blood cells that swim constantly, thus keeping all of the body fluid in circulation so that all of it may become oxygenated.

Sand Dollars

The sand dollars, sea biscuits, or cake urchins, as they are called in different localities, resemble very much flattened sea urchins with both upper and lower surfaces covered with short spines. When an object is round like a globe it has much more strength than does an object that is flattened or wafer-like. Because of the manner in which sand dollars live, it is advantageous for them to be wafer-like. To strengthen their shells, they have built little supporting pillars on the inside between the upper and lower surfaces. These little pillars are absent in the central region where most of the viscera of the animal lie. Some sand dollars have even gone so far as to leave holes around the edge of the disk. These holes no doubt help to strengthen the surrounding regions of the body.

In sand dollars the mouth with its five jaws is located in the center of the undersurface, but the anus has also moved to the lower surface near one edge or, in some cases, to the edge. This gives sand dollars a secondary bilateral symmetry, perhaps not so pronounced as that of the heart urchins but sufficiently that they move in a forward direction, i.e., away from the side on which the anus is located. The mouth remains in the center, which is advantageous in view of their method of feeding.

Feeding**.** The spines on the upper side of the sand dollar are club-shaped and are covered with cilia. These cilia create currents that flow from the direction in which the animal is moving toward what could be called the posterior edge, or that edge on which the anus is located. As the currents flow through these spines, little eddies are created at the posterior sides of the spines. These eddies allow tiny particles and organisms to become entrapped in mucus that is secreted on the surface of the spines. This mucus goes downward and is led into tiny tracts to unite with others. These in turn unite again, passing around the edge to the underside, until near the mouth five tracts or strings of mucus feed directly into the mouth of the sand dollar.

Enemies**.** The principal enemies of the echinoids are sea star and man. Certain sea star feed on sea urchins and others on sand dollars. The sea urchins can take certain protective measures against the sea stars, but unless the Sea star is small in proportion to the sea urchin, the latter usually loses out. When a hungry sea star approaches a sea urchin, the protective pedicellariae grasp the tube feet of the starfish and exude a poison. As the starfish retreats the pedicellariae are pulled off. In the succeeding attacks more pedicellariae are pulled off until all are gone, and the starfish is free to make a meal of the sea urchin. In the event that the starfish is bested, the sea urchin can regenerate new pedicellariae.

In many countries the egg masses of sea urchins are sold in markets of coastal towns. In Italy they are sold as Frutta di mare and in the West Indies as sea eggs. At low tide at Pacific Grove we have seen groups of Italians gather sea urchins~ break them open, remove the egg

masses and wash them in sea water, then fill 2-qt. jars to take home. Large specimens became increasingly difficult to find.

Reproduction**.** With few exceptions' sea urchins and sand dollars simply extrude their eggs and sperm into the water, and the developing larvae are left entirely to their own devices.

Like most other marine animals that simply extrude their sexual products into the surrounding water, colonies of sea urchins~ heart urchins, and sand dollars spawn simultaneously. The first individual to start spawning causes all of the surrounding individuals to spawn, and this spreads throughout the bed until all have shed their sexual products. In nature this first individual to spawn perhaps does so because it has become so gravid that it can no longer retain the sexual products and because of a rise in temperature, which usually produces spawning when the gonads are ripe. However, when the sexual products are ripe, even though the gravid condition has not been reached, a bed of any of these animals can be made to spawn by breaking open an individual and dropping the sex products into the colony. For this reason, whenever we break open a sea urchin or a sand dollar to see if the sex products are ripe~ we are always very careful not to throw the broken specimen back into the water, for it might induce spawning, a month or two before they would spawn voluntarily, in animals that otherwise might be used for experimental embryology. The eating of a sea urchin by a sheep fish or the breaking of an urchin by some floating object or rolling rock could very well account for some of the great variation that we find in the time of spawning of a sea urchin bed. We have found that the time of spawning of sea urchins varies from year to year by as much as 3 months.

Class: Ophiuroidea

The name of this class is derived from words meaning "serpent-tail forms" and was applied to serpent stars and brittle stars because of their long slender arms with snake like movements. The common name of the brittle star came from the fact that these arms break very easily if the animals are handled or disturbed.

The opiuroids have a relatively small round or pentagonal disk from which five arms radiate. In contrast to the disk is definitely set off from the sea stars arms. The digestive and reproductive organs are located in the central disk and do not extend into the arms as in the sea stars. The mouth is situated in the center of the lower surface, and, since there is no anal opening, indigestible material must be extruded through the mouth. The disk is covered with short spines or flat plates, and the arms contain articulated ossicles that permit varying degrees of movement, depending on the type of joint. The arms are covered with plates, between which spines may project.

Locomotion. In the serpent stars the tube feet are small and are used more for sensory organs and for organs of respiration than for locomotion. The tube feet may aid in movement to some extent, but the flexible, jointed arms are the main organs of locomotion. In a small, six-rayed species, *Ophiactis arenosa*, common near our laboratory, the tube feet, equipped with suckers, are the major organs of locomotion. *Amphiodia psara* is able to move fairly rapidly by

extending one arm ahead, trailing two behind, and using the remaining two as sort of wing-like structures to pull itself over the sand. It swims with the arms as wings or fins. Anyone of the arms may be used as the forward arm. Fully grown specimens with longer arms lose the ability to swim. Other species, e.g. *Ophiacantha eurvthra*, swim by trailing just one arm behind and using the other four as propelling organs. With one arm trailing behind and the other four curved forward and sideways, Ophiacantha travels along the bottom in sort of hopping movements. Still other species progress by using two of the arms for grasping objects and the remainder for pushing themselves forward. The spines along the arms assist in clinging to objects.

Habitat and Food. Perhaps because of their fragility, serpent stars are retiring by nature and nocturnal in habit, so that, although they are abundant, one must hunt for them among the seaweeds, under rocks, or on the ocean bottom.

Those living in rocky regions subsist mainly on detritus that gathers on the rocks or on the sand and mud, or on small dead animals or particles of larger ones. The tube feet aid in the selection of food particles of larger ones. The tube feet aid in the selection of food particles and in passing them along the arms to the mouth.

Reproduction. On the wall of each bursa are two glands that produce either eggs or sperms, depending upon the sex of the serpent star. In practically all serpent stars the sexes are separate, and the eggs and sperm are simply discharged through the genital slits into the sea water. At breeding times ophiurouds od the same species congregate in large numbers under rocks, etc.

Class: Holothuroidea

At first glance sea cucumbers seem to have little in common with a sea star or sea urchin, bit one were to take a sea urchin by the mouth and anus and stretch it out inro a tube, remove the spines and soften the body wall somewhat, this “made” animal would be a fair sea cucumber, although other technical changes would have to be accounted for as was the case with the sea urchin “made” from a sea star.

A cucumber has five regions running lengthwise of its body that are the same as, or homologous with, the five arms of a starfish or the five regions of a sea urchin where the tube feet are located. In fact, most cucumbers have tube feet along these areas, although in most cases they are functional in only three of the areas, the other two being devoid of tube feet. Sea cucumbers have no pedicellariae.

The skeleton of sea cucumbers is usually limited to scattered ossicles embedded in the skin. These are of various shapes and sizes, depending upon the species, and many vary in different regions of the body of the same species. There are platelike ossicles with smooth or serrated margins and with holes of varying number and size, wheel-like ossicles complete with hub, and anchor-like ossicles.

Respiration. Cucumbers have a peculiar method of breathing. They have a large, branching, tree-like set of tubes inside the body, the trunk of which opens into a large cavity, called the cloaca, just inside the anus of the animal. By gulping in water through the anus and filling this tree-like structure with fresh water, they are able to bring the oxygenated water to almost all portions of their inner regions and thus supply the body fluid with its required oxygen. After the oxygen has been partially used, the water is squirted out and a new supply taken in.

Some cucumbers live in the mud and stick their tentacles out on the surface, and as the detritus washes back and forth past them the material is trapped and fed into the mouth in mucous strings. They lie with their anal opening at the surface, their bodies forming the shape of a widely broadened U. Several small cucumbers that live thus often present in dredge hauls from off Newport Bay. In a few cases we have dredged pieces of rock in which some cucumbers, *Cucumaria pseudopopuliferal* occupied the old burrows of rock-boring clams. They appeared to be imprisoned. This species always grows with the two ends of the body at right angles to each other, forming a 90^{o} bend in the middle.

Commensals. The space, or cloaca, at the end of the alimentary tract of the sea cucumber makes a good place for an animal to live, for it is protected and well supplied with fresh water. In one of the larger cucumbers in the West Indies, a little fish lives in the cloaca~ often putting its head out of the anal opening. At Newport Bay, the pea crab *Pinnixa barnharti* is almost invariably found in the cloaca of *Caudina arenicola,* and the ubiquitous Ophisthopus transversus is often found in Stichopus. The latter cucumber often has a scale worm clinging to its body. Under "Annelida" and "Protozoa" other commensals are mentioned.

Enemies**.** On the whole, sea cucumbers have few enemies. We have seen a few animals eating them, such as hungry sea gulls eating those left exposed by the tide. Humans probably take the heaviest toll, for in some localities sea cucumbers are dried and sold in the markets. Under the name trepano and beche-de-mer they are eaten by the Chinese and some of the South Sea Islanders.

Reproduction**.** The sexes are usually separate in sea cucumbers. Many discharge their sexual products into the sea water through an opening within or near the ring of oral tentacles. *Stichopus californicus* spawns in summer in northern waters, and specimens at Newport Bay have spawned in August.

The brooding of eggs and young is common among sea cucumbers. *Thyonepsolus nutrien* (coast of central California) broods its young in little pouches in its back, somewhat after the habit of the Surinam toad of the Amazon regions. At Pacific Grove we have found it with brood in June and August. *Cucumaria curata,* a small black cucumber about an inch long, broods its young under the ventral surface of its body, i.e., between itself and the rock to which it is attached. At Pacific Grove it may be found with brood in December. Members of the genus Psolus, including our northern *Psolus chitonoides,* carry their eggs among the calcareous plates on the back.

Class: Crinoidea

Although sea feathers, or sea lilies, or feather stars are abundant, most of them are deep-sea animals and are seen only by investigators on dredging boats or by visitors in museums. Over 2,000 fossil species have been described, and there are almost 800 living species, but practically nothing is known of their natural history. They have mot pedicellariae and no spines.

Some of the sea lilies are permanently anchored to *the* ocean bottom by a stalk that projects from the aboral side. Thus anchored, mouth upward and with their branched and pinnated arms outspread, they feed on detritus or small organisms that are carried down the grooves by cilia.

Phylum: Mollusca

The phylum Mollusca is very large. It includes five classes: the Pelecypoda, or clams, mussels, and oysters; the Gastropoda, or snails; the Scaphopoda, or tooth shell; the Amphineura, or chitons; and the Cephalopoda, or octopuses and squids. Mollusca, which means "soft", refers to the soft body possessed by members of this group. It is only the shell on the outside of the body that is hard.

Because of the interest shown by a great number of people in shells and mollusks, many fine and beautiful collections have been made. Notwithstanding the fact that due to intensive collecting, mollusks have been fairly well classified, relatively little is known of the natural history of marine species. Much more is known of the fresh-water mussels and snails and of the land snails. The subgroups to which the freshwater mussels and snails and land snails belong have become well distributed in fresh water and on land. We have found freshwater mussels as high as 9,000 feet in the Sierra Mountains and have seen snails in Death Valley that secrete membranes across the openings of their shells, thus preventing the loss of moisture and making it possible for them to live in this region, although they are perhaps active only a few weeks at most during a year, or possibly not at all, depending upon the rains.

Marine mollusks are found in all depths of the ocean and floating on its surface. Certain mollusks live on the sand or mud, and still others live on rocks, within rocks, and beneath them.

Nearly all mollusks hatch as veliger larvae (modified trochophores) having two ciliated lobes with which they swim. The length of time that a mollusk is a free-swimming larva depends largely on the species, varying from a few hours to many days. In most cases settling is due to the larvae having reached a certain stage of development. However, there are certain stimuli which cause the larvae of some mollusks to settle in suitable places.

In general, mollusk shells are composed of three layers, an outer horny layer, a middle lusterless thick limey layer, and an inner pearly lustrous layer of nacre. There is considerable variation in the amount of each layer, e.g, some snails (cowries) have the pearly layer on the outside as well as on the inside. The pearly layer varies in luster and color. The inside of an abalone shell shows great iridescence and vies for color supremacy with a film of oil on water. The luster and iridescence of the pearly, or nacreous, layer of shells is due to the pearly substance being laid down in thin layers one over the other.

When a grain of sand or other foreign substance gets under the mantle where this pearly layer is being deposited the object is covered by layer after layer of nacre until a pearl is formed. Cultured pearls are raised by inserting some object under the mantle. Pearls are formed by many oysters, mussels, and abalones, and also by freshwater species of clams and mussels.

When a mollusk grows the animal enlarges its shell by adding material to the edge of the shell so as to extend it in the particular direction the shell needs to be enlarged. Usually this is accompanied by a thickening of the shell as the animal lays down more material in the inside.

There are certain factors that inhibit or initiate the laying down of new material by the mantle and its edge to enlarge the shell. Three of the factors concerned are available food, temperature, and time of spawning. In the tropics the abundance of food is greatly increased during the longer days of summer. Temperatures are higher in summer, and it is also during this season that most mollusks spawn. If one had only to consider food and temperature, one could expect that mollusks would grow rapidly during simmer and that the rate of growth would be considerably slowed down during winter. This would give rings of growth on the shell's pf mollusks that, like rings on a tree, would indicate their ages. But this picture is somewhat complicated by the reproductive activities of the mollusks, because while eggs and sperm are being manufactured at a high rate the animal may not be growing. In such cases it is only between spawning times that the shell is enlarged.

There are two ways of determining the age of mollusks by examining shells. One is to gather great numbers of shells of one species, take careful measurements, and plot the data; then it is often evident that the shells can be separated into district sixes which can be correlated with the actual rings in the shell so as to hive year groupings or ages. Another way is to have the animals in an aquarium or place where they can be watched, note their spawning periods, and correlate this for a season with the growth of the shell.

The former method has been used to a limited extent, and it has been found that it is possible to tell the ages of a few of our commercial species of edible mollusks. What meager information we have read or have found concerning the ages of mollusks is given later.

Mollusks have considerable powers of regeneration, but much less than those of some of the lower animals. A snail can regenerate eyes and tentacles, and a pelecypod can regenerate portions of a foot or a torn mantle, and at least some of them can regenerate siphons. Probably the octopuses have the highest powers of regeneration among the mollusks, for they can regenerate an arm.

Class: Pelecypoda

The word pelecypod means "hatchet foot." This group includes the clans, scallops, mussels, oysters, etc. The members of this group are characterized by having a double shell that is composed of right and left valves, the central side of the animal being toward the open side pf the shell and the dorsal side being toward the hinge. There are exceptions to this, as we shall see later. Many of the members of this group have a digging organ called the foot which. By some stretch of the imagination, may be said to resemble a hatchet, hence the name. This foot has been modified in a great variety of ways, and there are actually no two species of pelecypods with feet

exactly alike. The foot of a pelecypod is not always used for digging, and in species that so not dig it is usually not so well developed.

The Shell. There are no two species of pelecypods with shells exactly alike, and in most cases the animals can be classified from shell characters alone. The shell is usually modified in some way that makes it more advantageous for the animal under the conditions in which it lives. Some pelecypod shells are so atypical that one would scarcely recognize them as pelecypod shells. On the hoof shells, or Chamas, one of the valves forms a cup, and the forms a lid to this cup, the cup being firmly cemented to a rock.

Structure. There is a general misconception regarding the orientation of a clam in its shell, brought about by the popular application of the term neck to the siphons of a clam. Actually, the head end of a clam is the end opposite the siphons, so that of a clam is on end in the mid it is "standing" on its head. The hinge side of a clam is the dorsal side, and the open side of the shell is the ventral side. If the siphons of the clam point toward the observer, the right calve of the shell is to the right of the observer.

If the clam is entirely retracted within the shell, the anterior end can usually be distinguished by the fact that the beaks usually point forward. The ligament is nearly always behind the beaks so the end toward the ligament would be the posterior end. A mussel is always attached near the head or anterior end, and the shell is more oriented toward that end. In clams with siphons the empty shells may be orientated by the muscle scars where the muscles foe retracting the siphons were attached. These scars are U-shaped markings at the posterior end, and the larger the siphon, or neck, the deeper the U.

The body of a clam is enclosed within the two valves of the shell. An analogy might be drawn from an overcoat surrounding the human body if one would imagine a sleeveless overcoat hinged at the back and surrounding arms and head. The mantle might be compared with the lining of the overcoat. The mantle *is* a fold of tissue that comes out from the side of the body near the back or the dorsal side and continues around on the insides of the valves to the ventral, or open, edges of the valves. The free edges of the mantle are thickened, and it is the outside of the mantle next to the shell and this thickened edge at the open edges of the shell that secrete the valves and enlarge them as the clam grows.

Respiration. Pelecypods breathe by pumping water in through the incurrent siphon, or opening, through the gills, and out the excurrent siphon, or opening. The siphon toward the open, or ventral, side of the pelecypod is the incurrent siphon, and the one on the hinge *side* is the excurrent opening. Cilia pump a current of water in along the ventral side of the clam toward the head, filling the mantle cavity, or cavity between the shell and the body of the clam. The cilia responsible for the current of water are located on the borders of tiny holes in the gills. The gills

are double and have water canals on the inside between the two layers. From the mantle cavity the water is pumped through these little holes into the canals and then flows upward into a larger canal at the top of the gills. These larger canals from each side of the body of the clam unite and discharge into a cavity at the posterior end of the body of the clam. From this cavity the water goes out the excurrent siphon. In brief, the water comes in the incurrent siphon to the ventral cavity, through the gills into the dorsal cavity, and then out the excurrent siphon.

Locomotion. Many clams can move over the mud or sand by extending the foot and then contracting the muscles violently so that the foot acts as a spring. Some clams, such as the jackknife clams Solen and Tagelus can jump a foot or two in this manner.

Even the heavier, thicker bodied Cardium can make considerable progress by this method. Those clams which usually lie with the posterior end level with the surface often creep through the mud by extending the foot ahead and then drawing the body after it. Such clams (also some freshwater mussels) leave a V-shaped track behind him.

Many clams can dig rapidly. As the foot is extended the pointed tip is worked into the mud. Then the foot is contracted in such a manner that the end becomes bulbous and serves as an anchor while the body *is* being drawn into mud or sand. This process is repeated so rapidly that the clam *is* soon buried. Many clams, such as Macoma, move the body back and forth sideways as they are digging so that the shell aids by cutting into the mud or sand.

There are a few pelecypods that can swim, and most of them are pectens, or scallops.

Feeding. When pelecypods feed they secrete a sheet of mucus over the gills so that the respiratory water propelled by cilia has to flow through the mucus as it enters the tiny holes in the gills. The mucus strains every particle from the water as it flows through the gills. Other cilia transport this mucus to the mouth where it is swallowed as foodladen strings. The paths that this mucus follows from the gills to the mouth vary different pelecypods, but in most clams it goes to the hanging free edges of the gills, then along them to the mouth. Just above and below the mouth there are two paired, fleshy appendages, pointed at the free ends, that hang down on each side of the mouth. These four structures are called labial palps, which means "lip feelers." To some extent they sort out indigestible material from the strings of mucus that pass by them to the mouth. This undesirable material is allowed to accumulate in the ventral water cavity and at intervals is forcibly ejected through the incurrent siphon. This accounts for at least part of the squirting that a clam does when the tide is out.

The majority of pelecypods feed in the manner just described, but several species have highly specialized and sometimes unique methods of feeding. As shipworms burrow and the wood is scraped away, the "sawdust" is swallowed and digested. Physiologists have shown that about 80 per cent of the cellulose disappears from wood (Douglas fir) during its passage through the alimentary tract *Teredo navalis*. This unique diet of shipworms furnishes one with

evolutionary information that is difficult to explain. Clams are considered to be among the most efficient feeders of the marine animals, and other closely related boring members of the class, such as Pholadidea and Lithophaga, which make protective burrows in rocks still retain the typical pelecypod manner of feeding. Since plankton and detritus and abundant food materials, one can only guess why shipworms have taken on a diet of wood, which is much more difficult to digest than plankton or detritus.

Members of the family Tridacnidae, which includes *Tridacna derasa* (gigas), the largest of clams, have a method of feeding that is unique indeed. In an exceedingly interesting paper, Dr. C.M. Yonge, of England, has described the habits and feeding methods of members of this family, which live in the coral reefs of the Philippines, South Sea Islands, Great Barrier Reef, etc. In a clam of this group the shell lies hinge down, and the body of the clam has turned 180 degrees in its shell, so that the dorsal side of the clam is toward the gaping portion of the valves and the ventral side is toward the hinge. Its main source of food is a commensal alga that lives in its tissues and which the clam digests for food. Tridacna also feeds to a certain extent as other bivalved mollusks feed, but its digestive tract is somewhat degenerate. The single-celled plants are concentrated in the area next to the opening of the valves. When a clam is covered by the tides it lies with its valves open and with its algae-filled tissues spread out and beyond the shell in large folds making it possible for the algae to get a maximum of sunshine, which enables them to grow and reproduce rapidly. The penetration of light is further facilitated by tiny crystalline, globular-flask-shaped bodies in the surface of the flesh that diffuse light beneath the surface, thus making it possible for the algae to live at a much greater depth in the tissues.

Oysters live attached to some object, rocks, or debris, or more often the dead shells of their ancestors. They thus build up beds of shell many feet thick. Oysters cannot exist in places where they become covered with sediment or mud in amounts sufficient to interfere greatly with feeding or with the currents of water flowing in and out. We have seen specimens of *Ostrea gifantea* (or *pacifica*), the Japanese oyster that was imported for culture on this coast, make valiant efforts to escape sedimentation.

Other Pelecyods find an excellent refuge for themselves by burrowing into solid rock. One can trace a series of clams and their habitats from the clam that lives in the mud flat to the clam that is able to burrow into solid rock. For example, the first type might be represented by the gaper clam, which lives in sandy mud; the next by a clam like Platyodon, which lives in heavy clay the next by a clam like Zirfaea, which burrows into heavy clay or soft sandstone; and the next by a clam like Pholadidae or the date mussel, which burrow into solid rock.

In the case of mussels and certain clams, the foot is used as an organ for attaching byssus threads from the animal to rocks or other hard surfaces. The foot of a mussel is very extensible, but when not in use it is little more than a knob. Situated in the base of the foot is the byssus gland, which secretes a substance that is sticky when fresh but hardens and becomes remarkably strong after being exposed to sea water for a few minutes. Down the posterior side of the foot is a groove and as the foot is extended for an inch or more the secretion from the byssus gland runs down this groove to the top of the foot. The tip of the foot is them flattened and pressed firmly against the rock and held there until the thread, or byssus material, adheres and hardens. The

mussel puts out many of these threads, which form such a firm attachment that it is almost impossible to pull a mussel loose from a rick without using a pry.

Shipworms, which are clams and not worms, yearly do a tremendous amount of damage to wooden pilings, wharfs, ship bottoms, etc. When a shipworm larva comes into contact with suitable wood it fastens on and begins to bore into the wood. As soon as the animal is beneath the surface or is well protected, and from there on the burrow is enlarged both in diameter and in length as the animal grows, so that the original opening serves throughout the life pf the animal as its only contact with the outside water. The siphons of shipworms are exceedingly long.

The shells, or valves, of a shipworm, which serve as the boring organ, remain small and cover only the anterior tip of the animal. Boring is accomplished by downward and inward movements of the valves while the body of the animal is held solidly in the burrow by the sucker like foot. The anterior portion of the body is also wedged tightly against the walls by the animal forcing body fluids into the region to expand it.

Shipworms vary in size from certain species of Teredo that make burrows only about 6 inches ling to others, *Bankia setacea*, that make burrows nearly ½ inch in diameter at the inner end and about 3 feet in length. A shipworm, very seldomly extends its burrow and that of its neighbor, even though such partitions may be paper thin. We have seen pieces of four-by-four timbers so honeycombed with shipworm burrows that they were easily crushed by stepping on them. Teledo and Bankia have been known to bore ¾ inch per day and to honeycomb lumber within 6 months, although a year or more may be required in some instances.

Reproduction. In practically all pelecypods the sexes are separate, although in some such as *Ostrea lurida*, the animal may be male one season and female the next. In almost all marine pelecypods the eggs and sperm are simply discharged into the water through the excurrent siphon. The fertilized egg develops into a veliger larva that swims until it metamorphoses and is ready to settle. Many pelecypod reproduce in enormous numbers. A large eastern oyster, *Ostrea virginica*, may lay nearly a half-billion eggs in one season.

Class: Gastropoda

The gastropods (from words meaning “stomach foot”) include the snails, limpets, slugs, nudibranchs, etc. Unlike the pelecypods, the gastropods have a distinct head, usually with eyes and tentacles. Typically, gastropods are enclosed within a spiraled shell, and the visceral mass is twisted to accommodate itself within the shell. There is usually only one kidney, and sometimes only one gill. This reduction in organs is an adjustment to the shell.

Snails are fairly abundant on the ocean floor and have been dredged at depths of up to and exceeding 3 miles. A few gastropods are pelagic. Many species live on rocks, others crawl about over the sand or just beneath its surface.

Certain species live on seaweed, corals, and other animals.

Some species are confined to a narrow range of depth; others such as *Natica groenlandica*, which is found from 18 to 1,675 fathoms, either have a greater tolerance for depth or else find food and living conditions suitable over a wider range of depth. Likewise, some snails are more tolerant of changes in temperature than others. Some of the limpets can stand great variation in temperature compared with other marine animals.

The Shell. The majority of gastropods have a spiral shell. As one looks at a snail shell from the upper, or pointed end, the spiral goes clockwise, or to the right. There are some rare exceptions to this e.g., *Antiplanes perversa.* This rather common shell in the dredging's from the West Coast of North America is always left-handed. Some snails have shells so flattened, i.e., so nearly a helix in form (like a clock spring) that it is difficult to tell whether they are right – or left- handed, but an examination of the animals themselves shows that they are right-handed.

Limpets characteristically have spiral shells during the larval stage, but the spirals disappear shortly after the larvae settle down. In some of the gastropods, e.g., Sinum, the shell is so small in proportion to the body of the animal that the snail cannot retract itself entirely within the shell.

Every species of snail has a shell that differs from that of every other species. Many of the differences between the shells of different species of snails may be accounted for by the demands of the particular locality in which they live. A long cone-shaped structure is not nearly so strong as a cone that is spiraled and cemented together. The long, slender, spiraled shells of such snails as Terebra and its allies offer much less resistance to the surface as they are being dragged along the mud or sand than so shorter, rounded shells. Also, slender shells make burrowing easier, though perhaps the best shaped shell for burrowing is the torpedo-shaped Olivella type.

Locomotion. Practically all gastropods have a foot, which usually takes the form of a broad sole upon which the animal crawls or glides along. In a few gastropods the front part of the foot is marked off by a groove on the underside. Animals with this type of foot, such as Melampus and Pedipes, travel by advancing this forward portion of the foot and then pulling the rest after it in a sort of looping movement. Other snails, such as *Lacuna porrecta*, which lives on Zostera on our West Coast, have a groove down the length of the foot. These snails go forward

by advancing first in one side of the foot and then the other, thus producing a swaying or waddling motion.

The creeping sole of many snails adheres firmly to the surface over which it is crawling. We feel certain that this adhesion is due to fine elongated depressions in the sole of the foot acting as suckers. A portion of an abalone foot in which the ridges between the depressions are colored dark, thus making it possible to see these sucker-like depressions very clearly. The shell of this abalone measures 5.5 inches in length, end together then bending in the opposite direction. It swims upside down so that the cerata stream downward, thus offering little resistance. In addition, the foot is creased in the middle and the edges brought close so that the animal is more flattened than ever while swimming.

Respiration. Most snails respire by means of the gills. Instead of being flat, curtain-like structures like those in most of the clams, the gills of snails are usually plume-like. Seldom do they serve the purpose of getting food as do those of the clam. Within the mouth of the snail shell, above the head of the animal, a cavity is provided to contain the gills-or gill., since there is sometimes but one, an adaption to the spiraled shape of the body. Water is pumped in and out over these gills by means of cilia. Since in most snails the cavity is blind at the upper end, the water passes in, makes a turn, and passes out again, both entrance and exit being near the head. Most of the carnivorous snails have a more or less closed tube called the branchial siphon that conducts water to the gills. Many shells have a tube-like prolongation of the shell, called the canal, for protecting the siphon. In others there is simply a notch in the mouth of the shell or a short, grooved prolongation.

Certain gastropods, called keyhole limpets, have a hole at the top of the shell so that the water can come in near the head and go out through this hole at the top, making an almost straight passage across the gills.

A few marine snails are air breathers. They have a cavity with walls well supplied with blood vessels where oxygen is taken from the air. The white limpet-like button shell *Gadinia reticulata*, found from San Francisco to Cape Lucas, is an example of an air breather.

Feeding. Snails have a rasping organ, called a radula, with which they obtain their food. The radula is a long ribbon attached at each end by muscles and is pulled over a cartilage that acts as a bearing, or pulley, for the ribbon. Roughly, one might illustrate the action of this radula, or rasping organ, by taking a piece of tape by the ends, one in each hand, and pulling it back and forth over some rounded object like a chair round. Then suppose that the tape has teeth on the outer side like a file or wood rasp, and as the tape is pulled toward the body by the left hand the place where it passes around the chair round is pushed against some object. The teeth on the tape will scrape off a certain amount of the object against which it is pressed. As the tape is

pulled back by the right hand, the chair round is also moved back a little form the object so that the tape does not touch the object to be rasped, and thus the rasping takes place only as the tape is pulled toward one by the left hand, or in one direction only. This is the way that most snails use their radula, although the process is somewhat more complicated. The number, size, shape, and arrangement of the teeth on the radula differ in every species. The cartilage over which the radula passes is near the opening of the mouth, so what as the rasping stroke is made the cartilage is forced forward and presses the radula against the material that the snail is eating thus filling or rasping off portions to be swallowed.

In some animals the radula is used for grasping food rather than for rasping it.

The radula, or rasping apparatus, of the snail is one of two instances in the animal kingdom in which a near approach to the pulley has been used. The other case is one of the muscles of the mammalian eye, which passes over a cartilage so that the direction of pull for turning the eyeball is correct.

The majority of snails that live in rocky regions feed by rasping the film of plant growth that covers the rocks. In the sides of aquariums in which snails like Norrisia and Astraea are kept marked will be left showing where the snails have rasped the scum from the glass in their "grazing".

Crepodula onyx, the brown slipper shell, or shelf limpet, lives on detritus, which it strains from the water by means of mucous coverings of the gills. The gills are paired, one gill extending backward along each side of the foot. The animal feeds from first one side and then the other, twisting its mouth at intervals from one side to the other to gather up the mucus with its collected food. It may feed for about 4 minutes on one side, sucking in the threads of mucus, and then turn its mouth to the other side and feed foe approximately the same length of time.

A great many snails are scavengers or predators, the former living in what they can find if dead or decaying flesh and the latter living at the expense of some of their relatives. *Nassarius fossatus* is a good example of a scavenger. The shell of this snail is about 1 inch long. Nassarius is fairly active, moving along at a good rate for a snail. The foot, or sole. Upon which it glides is fairly extensive. The top of this sole is speckled to imitate the sand, but whatever measure of inconspicuousness is gained by the foot is lost by the shell, which is a rich reddish brown. One morning at Morro Bay, Calif., when the tide was running out, we saw a dead fish lying in a narrow channel. For a distance of at least a hundred feet below the fish, numbers of Nassarius, having scented the food, were plowing upstream, while many others were already busy at the feast. The mouth of *Nassarius fossatus* is on the end of a long eversible proboscis that reminds one somewhat of an elephant's trunk. An average sized Nassarius can extend this proboscis fully 1.5 inches. The radula, or rasping organ is at the end of the proboscis when it is everted, and, I addition, the mouth of the snail, or the end of the proboscis, has a sucking action that makes it possible for it to cling quite tightly to food once the latter is found.

The Naticas (Polinices), or moon shells, often burrow down into the sand or mud after clams, wrap the foot about the clam, drill the shell, and then rasp and suck the prey through the hole they drilled.

On the outer lip of the shell of certain snails there is a tooth, or spine, that has a very definite use. Snails possessing such a tooth live on barnacles, small mussels, etc., as exemplified by *Acanthina spirata.* This snail crawls over a barnacle, inserts its tooth between the two parts of the operculum and, while the two-piece door is thus wedges apart, inserts its proboscis into the barnacle and eats it.

Reproduction. In contrast with the pelecypods, about half the gastropods are hermaphroditic, at least as adults. As far as is known, all the opisthobranchs (tectibranchs and nudibranchs) and pulminates are functionally hermaphroditic, and each individual has a complete set of male and female organs. I these animals copulation and cross-fertilization are the rule, and in most of the opisthobranchs that we have observed, copulation and egg laying alternate. A few hermaphroditic species of other groups discharge their sex products into the water after the manner of most pelecypods. Of the remaining gastropods certain families or genera may ne hermaphroditic, but there is often great variations within a group, for one species of a genus may be hermaphroditic and another unisexual. Various investigators have found that in the slipper shells or shelf limpets, the cup-and-saucer limpets, and other species, the young or smaller animals are all males. As they grow larger, they become females, and makes are furnished by the new crop of young ones. In Crucibulum and Crepidula one or two young males may usually be found attached to the upper surface of the shell of a female. As males these snails have fully developed phallus for copulation, but during the transition stage this organ atrophies, so that in the females only a rudiment remains. In a few hermaphroditic species of snails the sperm develop first and are discharged then the eggs develop and are discharged, and then the cycle is repeated.

In many snails the sexes are separated, and the eggs are fertilized internally. In some cases, one copulation may supply sperm that is used to fertilize eggs that are laid over a period of weeks or even months. In other snails in which the sexes are separated the sperms and eggs are discharged into the water. Most of the true limpets, keyhole limpets, and abalones reproduce in this way.

The moon shells (Natica and Polinices) lay their eggs in a coiled or collar-shaped sheet of mucus impregnated with sand, which is shaped over the shell as the eggs are laid. The sand "collar" is formed beneath the sand and is pushed up as the eggs are laid. We have found egg collars of the West Coast moon shell *Polinices lewisii* that were 3.5 inches wide and 6 inches across the coil. They are deposited on the bottoms of shallow bays and estuaries, where they are often exposed at low tide. When the larvae hatch, the sand collar collapses.

Class: Amphineura

The Amphineura includes the chitons, or sea cradles, all of which are marine. Chitons are slugging animals that creep on a broad foot. Across the upper surface, which is convex, are eight calcareous plates or valves that articulate and overlap. They are partly covered by a fold of the integument called the girdle. The broad foot enables the animal to adhere firmly to rocks, pilings, or other solid objects. When a chiton is detached, it curls up, thus forming a "sea cradle". In some localities chitons are referred to as butterfly fish, a name suggested by the shape of the dorsal valves or shells.

The mouth of a chiton is located at the anterior end just ahead of the foot. Gills are located in grooves extending backward from the mouth on either side of the body. By means of a radula, most chitons feed on minute algae and diatoms that form a surface film on rocks. However, some species use seaweed debris.

The radulas of those chitons that we have watched eating are much shorter than those of most of the gastropods, and the scraping movements are somewhat different. In *Mopalia mucosa*e.g., the first movement of the mouth parts is from the sides toward the midline with jaw-like motions followed by an upward or forward movement of the whole apparatus. Just below the jaw-like parts of the radula is a single smooth-edged, bone-like scraper that finishes cleaning the center mark left by the approximation of the two "jaws", thus making a clean sweep of the spot to which the radula, or scraping apparatus is applied.

So far as we know, most chitons are nocturnal, and many of them have a "homing spot" where they may be found except when they are grazing.

Class: Scaphopoda

Scaphopods are commonly called tooth shells or elephant tusk shells. The shells are tubular, tapering, slightly curved, and are open at both ends, the head end having the larger opening. The animals are not distorted like the gastropods but are bilaterally symmetrical like the pelecypods. There are no eyes, not destiny heart, and no gills. Respiration takes place through the mantle. The food id exerted through the larger opening of the shell for digging into the sand. The animal liver in an oblique position in the sand with the head down and the smaller or posterior opening at the surface. They apparently live in the small plants and animals and organic materials in the sand.

Scaphopods live in the sand beyond the low-tide mark, some of them at great depths. Indians of the West Coast used *Dentalium pretiosum* for wampum and for ornaments. The shells

were strung on deer sinews. Except for empty shells that were washed ashore, the Indians had to dredge the tooth shells from canoes by means of long rakes.

The sexes are separate in the scaphopods, and the eggs are laid singly.

Tooth shells are eaten by certain animals, and they are affected by parasites. Specimens of *Dentalium neohexagonum* that we have dredged off Corona Del Mar often have their ovaries nearly filled with trematode larvae of an unknown species.

Class: Cephalopoda

The name if this class of mollusks comes from two words meaning "head" and "foot" and was applied to the group because the head and foot are so closely associated. This class includes cuttlefish and argonauts (with eight arms), and the Nautilus. All cephalopods are strictly marine.

The anterior part of the foot surrounds the well-developed head and is divided into eight or ten parts called arms. The arms are united at their bases by a web, the extent of which varies in the different species, being greatest in the octopuses. The arms are equipped with suckers. In the squids and cuttlefishes these suckers are stalked and have horny rims that may be serrated. In the octopuses and argonauts the suckers are sessile and are without horny rims. In squids and cuttlefishes, the arms of the fourth pair are elongated for prehensile organs. In some species the suckers in the palms of the pair of prehensile arms are replaced by very sharp hooks like extended cat claws.

The trunk, or main portion of the body, is either bulbous (octopuses) or elongated (most squids) and is surrounded by the mantle. The mantle encloses a large mantle cavity that surrounds the two gills and the visceral mass. In all except Nautilus there is an ink gland that secrets a dark fluid that is stored in an ink sac. The posterior part of the foot is modified into a funnel. The mouth of which forms a valve that fits against the free edge of the mantle and the "stem" of which is a tube that projects beyond the mantle cavity.

In the cephalopods the mollusk shell is not much in evidence. In Nautilus, which comprises only three species, there is a shell into which the entire animal may withdraw. In the female argonaut there is an external shell that, instead of being secreted by the mantle, is secretes by a pair of arms modifies for the purpose. In the octopuses the shell is only a pair of vestigial internal structures to which muscles are attached. In cuttlefishes there is a calcareous internal shell (the source of the cuttlebone that is hung in bird cages), but in the squids this internal shell is reduced to a long horny structure running the length of the trunk.

In the "skin" of cephalopods are located many chromatophores, or cells containing pigment some black, some brown, some reddish yellow, etc. Normally these pigment cells are more or less contracted, but when the animal is alarmed, different sets, according to color, are pulled out into flat plates by tiny muscles attached to their edges. Thus, it is possible foe an octopus to change color in a flash. These pigment organelles are functional as soon as a little octopus hatches, and under the microscope it is easy to see the way in which they are manipulated by the tiny muscles at their edges.

Squids and octopuses possess a horny beak that is very much like that of a parrot except that the lower mandible closes over the upper. The mandibles are used for cutting up their food, and in at least sone forms, perhaps all, it is used for defense. Although we have handled several thousand octopuses, we have never been bitten by one, in spite of having tried to provoke them to vita; but we have seen them use their beaks in fighting each other. Squids, however, have been

known to bite when handles, and one must be particularly careful when handling the large squid *Dosidicus gigas.*

Locomotion. Octopuses and some squids can creep around in their arms. Octopuses normally swim with the bulbous part of the body forward and the arms trailing out behind. Water is taken into the mantle cavity and forcibly ejected through the siphon, or funnel. This creates a jet that forces the animal through the water much on the same principle that a skyrocket is propelled through the air. Squids normally swim forward leisurely by means of fins located in either side of the body. A squid also swims in the same manner as an octopus buy it may dart either forward or backward by pointing the siphon backward or forward and forcing water out of its siphon in a direction opposite to that from which it wants to go. Because it has a more streamlined body and because its mantle is much more muscular than that of the octopus, squid can actually dart through the water. An octopus swims slowly, though jerkily because of the intermittent jets. An octopus can also help to propel itself by alternately spreading and closing the skirt, or web between the arms.

Habitat and Habits. Some if the smaller forms of squids, at least the genus Loligo, swim in large schools. *Loligo pealei* and *Loligo opalescens*, the first about 10 inches long and the latter with a body averaging about 6 inches long, are very abundant on the East and West Coasts, respectively. Members of the genus Rossia, small squids with bulbous bodies like that of an octopus creep about over the bottom in search of food but bury themselves in the mud while at rest. *Rossia pacifica*, which is found on the ocean bottom along the West Coast, has a body less than 2 inches long. It buries itself quickly in the bottom by shooting jets of water into the sand or mud and snuggle into the hole thus made, allowing the sand or mud to resettle around its body. It leaves its siphon just level with the surface so that breathing is not interfered with.

The larger squids are seldom seen, probably because they so not come so near the surface as do the smaller forms and are more difficult to net. However, the hitherto rare jumbo squid *Dosidicus gigas* appeared abundantly off the coast of California during the summer of 1934. It continued to be abundant until 1937, inclusive, after which it seemed to disappear. Net, troll, and setline fishermen from Monterey to San Diego considered this squid a pest, for the animals stole bait and fouled lines. Those that were captured showered the fishermen with ink, and occasionally one would bite a fisherman severely. During 1935 and 1936 several of these squid were taken at the entrance to Newport Harbor when the jetty was being built, and others were speared from the ramp of the Kerckhoff Marine Laboratory within the bay.

Octopuses are nocturnal or crepuscular and are exceedingly timid and retiring in nature. We doubt if any of the stories about their attacking people are true.

The common octopus along the coast of southern California is *Paroctopus bimaculatus*, a comparatively small species that lives along rocky shores, in estuaries under the edges of rocks, or in old shell beds. It makes a hole for its body, moving pieces of shell or small pebbles with its arms, or tentacles, and mud or sand by means of jets from the siphon. After crawling backward into its burrow, the animal reaches its tentacles out to pull shells or debris in front of the opening. *Paroctopus bimaculatus* was so abundant in some regions that 140 were taken by one individual from an area not more than an acre in extent, while collecting other animals during three consecutive low tides. Farther north the larger *Octopus Apollyon* id found. It lives in crevices among the rocks and is seen only infrequently while collecting. It seems to be much less abundant than the southern form, but this scarcity is probably only apparent because of its inaccessibility.

Feeding. So far as we knowm all octopuses and squids are carnivorous and predaceous. They live on fish, crustaceans, other mollusksm and worms. Some are quite specific in their food habits. *Octopus apollyon,* of the north coast of western North American feeds mostly on crabs, supplemented by what fish it may be able to capture. The southern *Paroctopus bimaculatus* lives mainly on mollusks such as scallops, mussels, and clams. However, it will occasionally capture a crab or fish.

On low tide at just about dusk we have often watched the hunting activities of the octopuses in the southern mud flats. The animals go sliding about over the mud flat, exploring with the top of a tentacle every hole that they encounter. More than once, they have slid across our feet as we watched them on their forays for food. When they capture a clam or scallop, they simply pull the shells apart by main strength and eat the mollusk. In aquariums at the laboratory they often make attempts to capture fish, and in rare occasions they are successful, though fish are usually to fast for octopuses to catch. The rapidity with which an octopus can extend a tentacle in an attempt to capture a fish is surprising.

Size and Age. Squids range in size from 1.5 inches (Rossia) to the giant of all invertebrate animals, the great squid Architeuthis. A specimen of the latter obtained off the Grand Banks of Newfoundland had an over-all length of 55 feet. Its body was 20 feet long and 3.67 feet in diameter, or 12 feet in circumference. This squid would have weighed 29.25 tons, or 30 tons including the tentacles, truly a noble animal, being a little more than one-fifth the weight of the largest whale and larger than the whale sharks and basking sharks, the largest of all fishes. So, few of these giants have been seen that we so nor know what the greatest size may be. Two arms of Architeuthis that were 42 feet long were found, and of one reconstructed a body for this squid by using measurements proportional to those of above, the squid to which these arms belonged was 4.6 feet in diameter and 24 feet long, with an over-all measurement of 66 feet. It would have weighed about 42.5 tons.

The lower limit of size of octopuses is quite small, some species not exceeding 1 inch in length when mature. A newly hatched octopus Apollyon will barely span one's little fingernail, while a full-grown one brought into Monterey weighed 110 lbs. and could easily have touched the sides of a circle with a radius of 10 feet. Octopuses much larger than this are known to exist, but we have no records such as those given for squids.

Reproduction. In all of the cephalopods the sexes are separate. One of the arms of the male is modified for the purpose of transferring sperm to the female. The sperms are massed together into bundles called spermatophores. During copulation the male, using the modified tentacle, takes spermatophores from the genital opening and inserts them into the mantle cavity of the female. In the argonauts (octopuses with a special type of shell) the modified arm of the male is actually detached and left in the mantle cavity of the female with the spermatophores. In some cephalopods only the tip of the arm is detached. Female cephalopods lay eggs that vary in size and in the manner of deposition with different species.

Phylum: Arthropoda

This is the group to which the insects, spiders, and mites, centipedes and millipeds, and crustaceans belong. Arthropoda means “jointed legs”. With the exception of a few insects, the spider-like pycnogonids, and a few others, no members of these classes besides the crustaceans are marine. Most crustaceans are found in the sea, but there are also some land and fresh- water forms, such as sow bugs, pill bugs, crayfishes, and the tiny copepods and phyllopod found in ponds.

Class: Crustacea

Crustaceans range in size from the almost microscopic forms to those weighing several pounds. Specimens of the eastern lobster 3 feet long and weighing 35 pounds have been taken. Specimens of the much lighter giant spider crab of Japan have been taken with legs approximately 5 feet long. Average specimens of the eastern lobster and Japanese spider crab are much smaller than the records given. These crustaceans represent the extremes. Most of the common forms range between 0.5 inches to 10 inches in length.

External Skeleton. Most of the skeleton of crustaceans is external; it is shed at intervals to aloe for growth. Before a crustacean shed its skeleton a new one is formed just beneath the old one and is ready to take the place of the old one as soon as it is shed. Otherwise, a crustacean would be unprotected while a new skeleton was forming, and the advantages of having an outside skeleton would be lost. As it is, a crustacean has a soft skeleton for only a few hours or less, and during this time it seeks some secluded spot. In most crabs and shrimps the skeleton breaks at the junction of the carapace and abdomen and the animal simply pulls back out of its shell. Molting is a laborious process. Every protuberance and every hair must be pulled out of the old coating of chitin.

Since the stomach of crustaceans is lined with chitin that is continuous with the outside skeleton, though much thinner, the movements of the stomach are not brought about as in mammals. In crustaceans, strands of muscles are attached from the outside skeleton to the walls of the stomach at different places. And by their contraction and relaxation the proper stomach movements are performed. In many of the higher crustaceans the internal walls of the stomach are equipped with horny teeth that serve to macerate the food that has been chopped up by the mandibles or horny mouth parts and then swallowed.

Order: Branchiopoda

Only relatively few animals have become adapted to making appreciable adjustments to changes in the salt concentration of water. The few that have made such adjustments have become adapted to water with almost any concentration of salt. If one visits the evaporating ponds of salt works, one will find ponds, in which the salt is actually precipitating out. Swarming with a crustacean of a primitive type, viz., Artemia. Artemias, or brine shrimp are able to accustom themselves to practically any concentration from freshwater to saturated brine, but there is an optimum concentration, which is above that of ocean water, that is necessary for their reproduction. After going through a certain amount of development, the eggs of Artemia wash up on the beaches of salt ponds in great quantities. Normally, these eggs hatch the following year when the salinity is lowered by rainwater. They are distributed from pond to pond on the feet of birds. The membranes of these eggs are quite impervious to outside influences and they remain fry and dormant for several years, but when they are again submerged in water of the proper concentration they will hatch. The eggs are often so plentiful along the shores of salt ponds that they form layers 2 or 3 inches deep. They are gathered and sold in pet stores all over the United States. The buyer immerses the eggs in saltwater of the proper concentration, and when the young Artemias hatch, they are fed to fish.

Order: Copepoda

This order of the crustaceans was called Copepoda because the animals swim by means of oar-shaped appendages. Copepoda play a very important role in the economy of the sea because they are the main link in the food chain between the diatoms and the larger animals.

The copepod the is most abundant and the greatest source of food is *Calanus finmarchicus* but a great many other species of copepods are associated with it in the plankton of the oceans of the world. Some of them are extremely bizarre.

Many species pf copepods may be found free-living in tide pools. Commensal woth other animals. Living semiparasitically on the gills of divers marine invertebrates, or actually parasitic upon other animals.

Habitat and Habits. Copepods are found in practically every marine habitat. Many species prefer a definite habitat: in practically every association there are certain copepods that are not found elsewhere. Hydroid colonies, such as Obelia and Tubularia, will be found harboring copepods in great abundance.

Just as they are taken from the water, many marine fishes have little spots, from the size of the head of a thumbtack to almost invisible specks, darting about over their surfaces. These se called “fish lice” are copepods; they are ectoparasitic, or outside parasites. Others are to be found

firmly attached to the surface of the gills or walls of the mouth cavity, living on the blood or lymph which they suck from the tissues of the fish.

Some parasitic copepods are so degenerate in body form that they can scarcely be recognized as copepods. One characteristic that they have in common with other copepods is that they carry their eggs in brood pouches, usually two, as do the free-living forms.

Order: Cirripedia

To those unacquainted with this zoological classification, it is usually a surprise to find that barnacles are classified with crustaceans. In their embryological developmet they fo through the same stages in development that many other crustaceans follow.

As in copepods, a barnacle hatches as a naupliusm and after several molts it becomes a cypris larva, which fixes itself to some rock or other object by its antennules. It then goes through a pupal stage and metamorphoses into the adult form whereupon it secretes around itself a shell of calcium carbonate and from then on is a typical sessile barnacle.

The cypris stage of barnacles corresponds very closely to that of the more primitive Cypris of fishponds. Adult Cypris, for which cypris larvae are named, belong to a subgroup of the crustaceans called the ostracods. Though this is a large group in the ocean, they are mostly planktonic forms they are partially enclosed by a bivalved shell that gives them a superficial resemblance to miniature transparent or semitransparent clams.

The shells of barnacles have a very definite shape. Those commonly seen along the shore may be divided inro two different types, the gooseneck barnacles and the acorn barnacles. The gooseneck barnacles are fastened by a leathery stalk of varying length, depending upon the species or how badly crowded the animals are. The sides and back of the animal itself are protected by five calcareous plates. In most of the acorn barnacles there is also an operculum, or movable covering, that is divided into two parts. When these two parts are separated, the feet of the animal can be extended from the opening to perform their feeding movements.

Both the gooseneck barnacles and the acorn barnacles are able to close the operculum as a protection from enemies, from fresh water, and from the unfavorable conditions of tidal exposure. The shell or outer covering of a barnacle is a covering secreted to protect the animal itself.

Feeding. After the cypris larva settles and adheres to some object and metamorphoses into the adult form, the young barnacle feeds by extending through the opening of the shell feather-loke cirri (homologous to the jointed legs of the other crustaceans), which sweep through the water and entrap food particles. As the cirri, or feet, are folded back after making a sweep or several sweeps through the water, combs of the mouth parts scrap the entrapped food material from the inside of the feet and feed it into the mouth, where it is swallowed. A barnacle is

fastened to the inside of its shell by what could be termed the cack of its neck, the rest of the body being free within the shell One zoologist described a barnacle as an animal that lies in its back and kicks its food into its mouth with its feet. (The food of barnacles consists of plankton for the shore forms and of detritus for those which are found within estuaries or bays. Barnacles living near the entrance of bays and estuaries may feed on both plankton and detritus).

Reproduction. Barnacles are hermaphroditic At the end of the abdomen of most barnacles there is a long slender extensible penis, or cirrus, that can be protruded a considerable distance through the opening in the shell.

Sacculina parasitize several species of crabs. The crab mist often parasitized by Sacculina on our Southwest Coast is *Loxorhynvhus gradis.* Farther north it is the kelp crab *Pugettia porducta,* and in the Puget Sound region it is the rocky tide-pool crab *Lophopanopeus bellus.* On the East Coast Sacculina parasitizes *Carcinides marnas.*

The eggs of Sacculina hatch as nauplii, which swim about for some time and molt several times until they change to the cypris form. The nauplius and cypris larvae of Sacculina are very much like those of any other barnacle except that they do not feed. The cypris larva of Sacculina swims about in the ocean until it either dies or finds a suitable crab to parasitize. The larval Sacculina in the cy0ris stage attaches itself to a "hair" on the body of the crab. The antennules pierce the covering of the hair, which is hollow, and a group of cells from the body of the cypris migrates down the antennules, through the hair, and thence into the body of the crab. These cells float about in the blood stream of the crab until they come to rest at the junction of the body and abdomen, or where the tail is folded under. This is also the point where the stomach of the crab ends and the intestine begins. This group of attached cells takes nourishment from the body of the crab and begins to grow, sending out root-like processes to all parts of the body of its host. These processes not only take nourishment from the body of the crab but actually absorb the reproductive organs as well. The crab thus becomes a feeding organism for the parasite.

When the crab molts, the Sacculina dissolves or absorbs a portion of the new skeleton at the junction of the abdomen with the body or carapace, forming a hole through which it protrudes a portion of its body this external part of Sacculina then grows into a large bulbous structure which becomes a brood pouch.

If the parasitized crab is a female, its wide abdomen server as a protection for this bag - like portion of the Sacculina. If the parasitized crab is a male, after its sex organs have been devoured by the internal root-like processes of Sacculina it takes on female characteristics when it molts. The new skeleton will have a wide abdomen like that of a female crab. Thus, what was a male crab now looks like a female, with a broad abdomen that gives protection to the tumor-like body of the parasite.

If Sacculina is removed from a female crab, the crab will regenerate its reproductive organs and become a normal female again. If Sacculina is removed from a male crab, the crab may regenerate both male and female reproductive organs and become hermaphroditic.

In going from the barnacles to the isopods we skip several groups of crustaceans that are transitory stages between the primitive crustaceans and the more highly specialized groups from the isopods on. Many of these are very interesting, but some of them are only rarely encountered even by specialists who study crustaceans.

Isopods are flattened dorsoventrally, i.e. from top to bottom, and their usual seven pairs of legs are of about equal size it is from this characteristic that they received their name, for iso means "equal" and pod means "leg" or "foot". The common sow bug of the garden is a typical isopod.

Isopods are quite abundant in practically all littoral marine habitats. Most of them range in size from 1/8 to 2 inches in length, though there are greater extremes. The giant of the isopods is *Bathynous giganteus*, a deep-sea form found in the Gulf of Mexico and the Indian Ocean, which is sometimes 12 inches long and 4 inches wide.

For the most part isopods are scavengers, picking up whatever they can find. One West Coast species, *Cirolana harfordi*, occurs in great abundance, especially in mussel beds. Some ichthyologists obtain fish skeletons by placing the whole fish in a jar in a tide pool and covering the opening of the jar with a screen having a mesh that will admit nothing larger than *Cirolana.* The isopods then enter the container and remove all the flesh, leaving only the skeleton.

Another Cirolana (*C. linguiforns*) that is very common along the sand beaches of southern California often starts biting on one's toes of one stands in the water too long in one place. It begins its meal on the tender skin between the toes. The bite causes a stinging sensation the is rather uncomfortable.

Order: Amphipoda

Amphipods are flattened sideways, i.e., their bodies are compressed from side to side. With few exceptions, they can be distinguished from the isopods by this characteristic. The feet of amphipods are used both for swimming and for walking, and it is from this characteristic that they derive their name – amphi, "both" and poda, "feet", i.e., both kinds of feet.

Over 1,000 species of amphipods have been described, but knowledge of the species of the West Coast of America is still meager, and we are constantly finding species that have not yet been described. For example, the genus Hyalella is said to be confined to fresh waters, but we

have taken an undescribed species of Hyalella from saltwater on the beach at Ensenada, Lower California.

Amphipods range in size from near microscopic forms to some an inch or more in length.

Locomotion. Anyone who has visited the sandy beaches of the ocean has no doubt seen what are called sand hoppers, amphipods that burrow into the sand just above the high-water mark. They are able to jump a considerable distance by using their abdomens, or tails, and the last three pairs of legs as a "spring".

Cyamus ceti, the whale louse, is a parasitic caprellid with a body that is dorsoventrally depressed like that of an isopod. It lives in great numbers in the skin of whales. It is about ½ inch or more in length and about the same in width, for the legs spread out sideways to hook into the skin of the whale.

Order: Decapoda

As the name indicates, members of this group have five pairs of legs (deca, "ten"). To ft belong all the shrimps. Lobsters, crayfishes, hermit crabs, and crabs. With the exception of the smaller shrimps. Practically all in this subgroup strengthen their chitinous skeletons by the deposition of calcium carbonate.

The decapods are further divided into three divisions: The Macrura, or large-tailed decapods, such as the shrimps, lobsters, and crayfishes; the Anomura, or those with peculiarly shaped tails, such as the hermit crabs, mole crabs, etc.: and the Brachyura, or short-tailed true crabs. What is here referred to as the tail of a crab is actually the abdomen, or the portion of the body back of the stomach. These three groups have well-developed sense organs. With the exception of practically no anomurans or brachyurans are pelagic, members of each of the different groups are found in any environment in the ocean.

The body of decapods is divided into two regions, a head-thorax region, and an abdomen. The former is unjointed, but its segmentation is indicated by pairs of appendages. The head portion of the head-thorax has five pairs of appendages: the antennules, the antennae, the mandibles, and the first and second maxillae. The mandibles are the jaws, and the maxillary are accessory mouth organs. The antennae are "feelers". The antennules, which are usually shorter than the antennae, have special chemical detectors, or organs of "smell", on them. The thorax portion has eight pairs of appendages: the first, second, and third maxillae. Which are mouth parts that are placed over the maxillae; a pair of legs with claws called chelae or chelipeds; and four pairs of walking legs. A firm plate of exoskeleton, called the carapace, covers the head-thorax. Along the back the carapace is fastened to the body, but at the sides it hangs free as a flap that covers the gills, which are contained in the space between the sides of the carapace and the body.

The abdomen is composed of six movable segments and a tailpiece called the telson or tailfan. From the lower side of the abdomen several pairs of appendages arise. There may be three or four pairs of these appendages, called swimmerets, that are fitted for fanning water. Others may function as egg-bearing organs in the females. The makes usually have a single pair of appendages that function as copulatory organs.

The gills consist of several pairs of plume-like organs. A thin leaf-like or paddle-like appendage in each second maxilla is located just in front of the fills on each side between the body and gill flaps. The up-and-down beating or flapping of these two organs keep a current of water flowing in where the legs join the body and out past the head. This respiratory current flows over the gills in a posterior-anterior direction.

Suborder: Macrura

Pelagic and Tide-pool Shrimps

Some of the macrurans are pelagic; for some of the shrimps travel in great shoals like schools of fishes. The edible shrimps, pr at least those marketed, come mainly from the Atlantic Coast and the Gulf of Mexico. On the West Coast of the United States only one species, *Crago franciscorum* is caught commercially to any extent. *Pandalus danac*, the coonstriped shrimp, is fished to some extent in the Puget Sound area. The young individuals of this shrimp are all males, but when they are about two years old, they become females. The second pair of legs if this genus are very long and slender, are divided into many segments or joints, and have small ponders, or chelae, at their tips. The shrimps use these legs for cleaning the surface of their bodies. It is an amusing sight to see ine of the shrimps put its legs beneath its body, around over its back, and then clean the base of the antenna that is on the same side to which the leg is attached.

Crago franciscorum makes up the greatest part of the shrimp catch of the West Coast of North America. It is fairly abundant from southern Alaska to Sam n Diego, but the main fisheries are in Puget Sound and San Francisco Bay. The females of this species average about 3 inches in length, and the males are smaller, seldom if ever exceeding 2.5 inches. *Crago nigricauda* is the next in commercial importance, and usually there are a few *Crago nigromaculata* in the markets with the two species just mentioned. These shrimps go to deeper water of the same salinity as that of the outside ocean to allow their eggs to hatch. As soon as the larvae have reached the adult form they are found at a considerable distance from the ocean in brackish or sometimes nearly fresh water.

Practically all of the commercial shrimp from the East Coast belong to the species *Penacus setiferus*, though there are six species that are found in commercial catcher. Shrimp fishing is carried on from North Carolina to the Mexican border, including the Gulf States. Louisiana furnishes nearly 40 percent of the total amount marketed. Florida, Texas, Georgia,

Mississippi, Alabama, North Carolina and South Carolina follow each other in the order given in the amount of commercial shrimps supplied to the markets. The total catch averages about 100,000 tons annually.

Pistol Shrimp

Pistol shrimps are the gunmen of the tide pools. The bodies of adults range between 1 and 2 inches in length. They possess a large chela, or pistol hand, equipped with a snapping device that is truly wonderful in its efficiency as a weapon of offense and defense. This hand, which may be either right or left, is at least half the size of the body.

Suborder Anomura

The anomurans are midway between the macrurans and the brachyurans in that the abdomen is larger than the abdomen of the brachyurans but, on the other hand, is often partially flexed like that of the brachyurans. The fifth legs are often reduced in size, and they differ in position from those of the other legs.

Hermit Crabs

Hermit crabs are anomurans that live within old snail shells. Since practically all snail shells are right-handed, that is, whorls in the shell turn to the right, a hermit crab is shaped to fit these shells. The abdomen of the body is always flexed to the right (of the hermit crab) so ghat it fits the turning cavity in the snail shell. The tail appendages are modified into hood-like structures that cling to the shell so firmly that a hermit crab will nearly always allow itself to be pulled in two before it can be pulled out of the shell. The appendages on the right side of the abdomen are usually entirely lost or, if present, are vestiges of the original structures. The female carries eggs in the remaining appendages of the left side only. The abdomen is soft for the cuticle is not impregnated with calcium carbonate.

The chalae, or claws, of the hermit crabs are usually of such size and shape that they efficiently block the opening of the shell when the hermit withdraws its body into the safety of the shell. The hermit is also equipped with a set of muscles that enable it to jerk back very quickly.

As a hermit crab grows, it is necessary for it to find successively larger snail shells. Hermit crabs do not kill snails to obtain new homes, as they use only empty shells. The same shell may be used time after time by different hermit crabs when they reach the appropriate size. Hermits in a tide pool may be observed hunting for a new shell and moving to the new quarters

then a hermit finds a new shell that seems to be of appropriate size, it first turns the shell over and over and investigates it very thoroughly, it reaches down inside to find out whether the cavity within is clear of other crabs or other animals or whether the space is filled with debris. If everything appears to be satisfactory the hermit hastily emerges from the old shell and settles into the new one. If, after moving to the new one, the shell is found to be unsuitable for occupancy, the hermit very quickly changes back to its old shell and proceeds in its search for a more suitable one.

Feeding. Probably the majority of hermit crabs are scavengers, living in whatever they are able to pick up as they scurry about the rocky tide pools. Some are able to pick feed by fanning detritus or plankton out of the water with modified mouth parts. This is particularly true of these that live in the estuarine regions or on the muddy ocean floor a common method of feeding among pagurids of the ocean bottom is to stir up the surface of the mud with their big claws and strain the detritus from the material thus stirred up.

Coconut Crabs

Birqus, the coconut crab of the South Sea Islands, is one of our most interesting anomurans, for it has left the ocean and lives entirely on land as an adult. Its gill chambers are modified for air breathing. It builds burrows at the bases of coconut trees and lines them with the husks of coconuts. Its food consists of coconut meat, which is obtained by hammering a hole in the "eye" end of the coconut with its large chela and extracting the meat from the inside through this hole by means of the smaller claw. When fallen coconuts are nit to be found, Birqus climbs a tree to cut coconuts loose for food.

Birqus is not so far removed from its hermit crab ancestry as sone of the other lithode crabs, and it still retains the desire to hide its abdomen within some protective device. It is often seen with its abdomen within a coconut shell that is broken in such a way that there is an opening large enough for its abdomen.

Specimens of Birqus weighing several pounds and with a carapace 6 inches wide have been taken.

Suborder: Brachyura

The brachyurans, or true crabs, are the most highly specialized of the crustaceans. The body is composed mainly of the carapace, the abdomen being reduced to a small flap. Int outline brachyurans are usually rounded or squarish, but a few members of the group have very highly specialized structures that give them a strange appearance. The name *Brachyura* meaning "shott-

tailed", is quite appropriate for this group, for the abdomen is a shortened flap that is folded under the body. All brachyurans possess five pairs of legs, and the first pair is always chelate, or equipped with pincers. The true crabs range in size from sone that are not larger than a grain of wheat to others at least 15 inches across the back or carapace.

In the true crabs the third maxillipeds are plate-like and when at reat are folded over the other mouth parts and the mouth.

In the subtribe called *Oxystomata* ("sharp-mouth") the third maxillipeds are triangular and come to a sharp point at the forward end. These crabs are generally compact, short-legged creatures and many of them, perhaps most of them, burrow in the sand. One member of this group *Calappa* possesses legs so shaped that when they are tightly folded the crab is as well protected as a land tortoise wot hots head, legs, and tail drawn in and its box shell closed. Two small tubes are extensions of the first maxillipeds, open to the surface just below the beak of the carapace so that the outgoing current from the gills may readily escape. Because of the tight box-like structure that *Calappai* makes by folding its legs, it is necessary that these two opening be left for the exhalant current of water to pass outward.

Most crabs are scavengers, though a few have means of capturing live prey. A few, particularly among the pea crabs, fan plankton or detritus for food; and some are both plankton and detritus fanners and scavengers. Certain crabs have extremely specialized diets.

Spider Crabs

In the superfamily Oxyhrhyncha, or "Sharp-nosed" crabs, also commonly known as spider crabs because their legs are ling and slender in proportion to their bodies, we find the phenomenon of masking highly developed. Crabs that show the masking instinct are also commonly known as decorator crabs. They cover their bodies and legs with bits of seaweed or debris, with sponges, hydroids, bryozoans, or tunicates, either singly or together to form a covering that masks them from their enemies or makes them mimic their surroundings. Bits of seaweed, sponges, etc., fastened to the backs of the crabs continue to grow after being put in place and thus more efficiently conceal their owner.

Swimming Crabs

The main edible crab od the East Coast of North America is *Callinectus sapidus* (Cape Cod to Louisiana), commonly known as the blue swimming crab. The lady crab *Ovalipes ocrllatue* (also a swimming crab) inhabits sandy beaches from Cape Cod to the Gulf of Mexico and is used for food in the South.

Fiddler Crabs

Fairly closely related to the shore crabs, and always of interest to the visitor at the seashore, are the fiddler crabs, so called because the males each have one huge claw that is carried crosswise in front of their bodies. Sometimes they at by their burrows and move their large claws back and forth much as a fiddler moves his arm when playing.

From Cape Cod to Florida there are at least three species of Uca or fiddler crabs. They are attractive crabs ranging in size from 0.75 inches to more than 1 inch across the body, which is wider than long. Some are beautifully mottled and the carapace is so shiny that t looks like china. No two seem to be colored or patterned exactly the alike.

The East Coast Ucas often go in "herds". At Cold Spring Harbor, Long Island, we saw them in "herds" of a thousand or more.

Other Stomatopoda

The stomatoods, or "mouth-footed" shrimps are so called because they have eight pairs of appendages modifies for moth parts. The largest and most exterior of these mouth parts are very efficient weapons of offense and defense. These crustaceans are sometimes called Mantis shrimps, a very appropriate name because they resemble a praying mantis not only in shape but also in their methods of eating. Because the carapace dies not coalesce with the last segments of the thorax, the head-thorax region of mantis shrimps appears unduly shortened and the abdomen appears to be unusually long.

Mantis shrimps have what is called a jackknife claw because the outer portion or end segment fits into a groove in the inner portion just as a jackknife blade fits into its groove. When closed this blade is smooth and sharp, in other species it is divided into sharp spines like short teeth on a comb. If one will fold one's arm tightly at the elbow with the first alongside the jaw and the elbow tight against the body, then suddenly make an outward uppercut movement, finishing by bringing the arm to the original position, one will get a good idea of how the mantis shrimp uses its jackknife claw. We have seen one of our local mantis shrimps, *Pseudosquilla bigelowi*, which has a smooth sharp edge in its blade, cut a shrimp (Callianassa) in two so quickly and with such precision that the two portions of the shrimp dropped to the bottom of the aquarium in the same relative position they were in before it was cut. Mantis shrimps make slashing motions with their jackknife claws so quickly that one can scarcely see the movement.

Reproduction and Recapitulation. In practically all of the crustaceans the sexes are separate, and the sperm cells are nonmotile. This means that some type of mating activity is necessary for reproduction. In the majority of cases the sperm are transferred to the seminal receptacle of the female and is used by her to fertilize the eggs as they are laid. In some cases, the sperm are plastered on the outside of the ventral surface of the female, but the exact manner in which she makes use of them to fertilize her eggs as they are laid is not known. In nearly all of the crustaceans some means is provided for carrying the eggs until they hatch. Sometimes egg sacs are formed at the time the females lay the eggs (see Copepods), sometimes the eggs are carried in brood pouches (see Isopods), but in the higher crustaceans the eggs are usually fastened in festoons to hair- like structures on the abdominal appendages that are modifies for the purpose of carrying eggs. In most of the marine decapods the eggs are small and are laid in great quantities.

During development, particularly of the higher crustaceans, the embryo goes through a definite set of stages varying in number and character for the different groups. in some cases, particularly in higher decapods, the early stages are gone through in the egg. In those crustaceans in which the embryos hatch and go through some of their stages as free-swimming larvae, the stages are nearly always accompanied by a number of molts, which allow for the growth of the embryos.

It was early recognized that the stages through which the embryos of the higher crustaceans pass in their development closely resemble the adult forms of more primitive crustaceans. This les to the formulation of a theory called the recapitulation theory, which means that in their larval development animals go through stages that are comparable to the evolutionary or ancestral history of such animals.

The crustaceans and vertebrates show these recapitulation stages very well, though there are a great many indications of it in other groups. It must be remembered that modifications have been taking place in the larval forms during geologic time, for marine larvae in particular are subject to environmental selection or modification, though perhaps not to the extent that the adults are.

Class: Arachnida

The East Coast is fortunate in having an arthropod (*Limulus Polyphemus*) that is undoubtedly a holdover from ages past and that may be considered somewhat of a “living fossil”. Although Limulus is an arthropod, it is not a crab, nor does it even belong to the crustaceans, but instead it is a relative of the arachnids, or spiders. It is commonly called the king crab or horseshoe crab. The latter name was suggested by the horse-hoof-shaped carapace. The king crab lives in shallow water alongshore, where it burrows in the sand and mud and wats worms and other small animals. It comes to sandy beaches in the early summer to breed and lay its eggs in a

depression it makes in the sand. As it emerges from the egg the embryo bears a resemblance to a trilobite (a fossil arthropod common in Cambian times) and lacks the spine-like telson and abdominal appendages of the adult Limulus. Although horseshoe crabs are large (up to 1 foot in length) they have little economic importance. They are sometimes fed to chickens and pigs. *Limulus polyphemus* occurs from Nova Scotia to Florida.

The flatworm *Bdelloura candida* is commonly found crawling over the surface of Limulus, and the shelf limpet *Crepidula fornicate* often lives attached to its exoskeleton.

Phylum: Chordata

Chordates. Animals with 5 primary characteristics that as larval or adulthood stages distinguishes them from all other taxa. These include the presence of a notochord (from which chordates get their name. The notochord is important for chordate structure and movement), a dorsal hollow nerve cord, endostyle or thyroid gland, pharyngeal slits, and a post-anal tail. They possess bilateral symmetry, have a coelom, a circulatory system and exhibit metameric segmentation.

Class: Osteichthyes

(Pisces of many authors) Bony fishes. Skeleton more or less bony; skin usually with embedded dermal (bony) scales of cycloid or etenoid form, some with ganoid scales; both paired lateral and median fins usually present, and some supported by fin rays; no pelvic girdle; mouth usually terminal; gills present throughout life, not in separate clefts; air bladder usually present; heaty 2-chambered; nor cloaca; ova small, segmentation meroblastic; Devonian to Recent, in salt, brackish and fresh waters; about 25,000 species.

Class: Amphibia

(Batrachia) Amphibians. Living forms with moist glandular skin and no external scales; typically with 2 pairs of limbs (no paired fins); 2 nostrils connecting to a mouth cavity; skull with 2 occipital condyles; heart 3-chambered; respiration by gills, lungs, or skin; eggs with gelatinous coverings, usually laid in water; larvae usually aquatic; adults aquatic or in moist places on land. Devonian to Recent; nearly 2,500 living species.

Class: Reptilia

Reptiles. (characteristics of living forms). Skin dry, cornified, usually with scales or scutes; linbs typically 4, each with 5 clawed toes, but reduced or absent in some; skeleton bony; 1 occipital condyle; Permian to Recent; terrestrial, fresh water, marine, in tropics and warm temperate regions; about 6,000 species.

Class: Aves

Birds. Body covered with feathers; fore limbs modified as wings, usually adapted for flight; hind limbs for walking, perching or swimming, usually 4 toes, never more; mouth extended as a beak, no teeth (in living birds); skull with one occipital condyle; pelvis fused to numerous vertebrae, forming a synsacrum, open ventrally; heart 34- chambered; lungs compact, with air sacs: voice box at base of trachea; no bladder; body temperature regulated; oviparous; Upper Jurassic to Recent 8,000 species.

Class: Mammalia

Mammals. Body usually covered with hair; skin with various glands; skull with 2 occipital condyles; jaws usually with differentiated teeth, in sockets; limbs adapted for walking, climbing, burrowing, swimming, or flying; toes with claws, nails, or hoofs; heart 4-chambered with aortic arch only; lings large, elastic; a diaphragm between thoracic and abdominal cavities; male with a penis; fertilization internal; eggs small or minute, usually retained in uterus for development; female with mammary glands that secrete milk to nourish the young; body temperature regulated (homoiothermous): Triassic to Recent: 4,400 living species (many subspecies) and numerous fossil forms.

Order: Cetacea

Class: Mammalia

Subphylum: Vertebra

Whales, dolphins and porpoises: Size: medium to very large: body usually spindle-shaped; head elongated, often pointed, joined directly to body (no neck region); some with a fleshy dorsal "fin"; fore limbs (flippers) broad and paddle-like, digits embedded, no claws; no hind limbs; tail long, ending in two broad transverse fleshy flukes, and notched I mid-line; teeth when present alike, lacking enamel; nostrils 1 or 2 on top of head; ear openings minute; body surface smooth, no hairs save for a few on muzzle; no skin glands except mammary and conjunctival glands; a thick layer of fat (blubber) under skin, affording insulation; stomach complex; Eocene to Recent; oceanic, over the world, always in water, dies from crushing of internal organs if stranded on shore; whales may dive to 3,600 feet when wounded and can remain sub-merged many minutes without breathing; upon reaching surface, warm moist air is blown from lungs, forming a "spout" as condensed by cooler air over ocean; mate and bear young large at birth and suckled like those of other mammals

Suborder 1. **Archaeoceti**. Zeuglodonts. Eocene to Oligocene.

Suborder 2. **Osontoceti**. Toothed whales. Teeth 2 to 40 in various species. *Physeter catodon*, sperm whale or cachalot, to 60 feet long, head squarish, about one-third total length; food of large squids and some fishes; a large "reservoir" in head' yields sperm oil, a fine lubricant; ambergris, formed in the stomach, is used for perfume. *Deliphinus delphis*, common dolphin, to 7 feet long and *Phocaena phocaena*, harbor porpoise, both feed on fishes; 4 species of dolphins native to rivers in China, India, and most of South America. *Orcinus orca*, killer whale, most aggressive cetacean, attacks larger fishes, seals, porpoises, and even big whales; *Monodon monoceros*, Narwhal, of Arctic, with but 2 teeth, of which one in male is a slender twisted tusk 8-9 feet long. The "unicorn" of European fables.

Suborder 3. **Mysticeti**. No teeth; mouth with numerous parallel horny plates of "whalebone" on sides of upper jaw, used to strain small animals from water; food chiefly of krill (Euphasia, a

schizopod crustacean about 2 inches long often enormously abundant). *Balaena mysticetus*, "Right" whale, no dorsal fin; *Balaenoptera musculus*, the Blue whale, with fin in back and lengthwise grooves on throat; the largest living animal to about 105 feet long, young 23 feet long at birth; *Eschricius robustus*, California grey whale, Pacific, now scarce.