



Cnidaria

(Animal Phylum)

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Chapter- 1

Cnidaria

Cnidaria
Temporal range: 580–0 Ma
Ediacaran–Recent



Pacific sea nettles, *Chrysaora fuscescens*

Scientific classification

Domain: Eukaryota
Kingdom: Animalia
Phylum: **Cnidaria**
Hatschek, 1888

Subphylum/Classes

Anthozoa—corals and sea anemones
Medusozoa—jellyfish:
Cubozoa—box jellyfish, sea wasps
Hydrozoa—hydroids, hydra-like animals
Scyphozoa—true jellyfish
Staurozoa—stalked jellyfish
Unranked, may not be scyphozoans
Myxozoa—parasites

Polypodiozoa—parasites

Cnidaria is a phylum containing over 9,000 species of animals found exclusively in aquatic and mostly marine environments. Their distinguishing feature is cnidocytes, specialized cells that they use mainly for capturing prey. Their bodies consist of mesoglea, a non-living jelly-like substance, sandwiched between two layers of epithelium that are mostly one cell thick. They have two basic body forms: swimming medusae and sessile polyps, both of which are radially symmetrical with mouths surrounded by tentacles that bear cnidocytes. Both forms have a single orifice and body cavity that are used for digestion and respiration. Many cnidarian species produce colonies that are single organisms composed of medusa-like or polyp-like zooids, or both. Cnidarians' activities are coordinated by a decentralized nerve net and simple receptors. Several free-swimming Cubozoa and Scyphozoa possess balance-sensing statocysts, and some have simple eyes. Not all cnidarians reproduce sexually. Many have complex lifecycles with asexual polyp stages and sexual medusae, but some omit either the polyp or the medusa stage.

Cnidarians were for a long time grouped with Ctenophores in the phylum Coelenterata, but increasing awareness of their differences caused them to be placed in separate phyla. Cnidarians are classified into four main groups: sessile Anthozoa (sea anemones, corals, and sea pens (sea anemones are not sessile but only move 3-4 inches an hour)); swimming Scyphozoa (jellyfish); Cubozoa (box jellies); and Hydrozoa, a diverse group that includes all the freshwater cnidarians as well as many marine forms, and has both sessile members such as *Hydra* and colonial swimmers such as the Portuguese Man o' War. Staurozoa have recently been recognised as a class in their own right rather than a sub-group of Scyphozoa, and there is debate about whether Myxozoa and Polypodiozoa are cnidarians or closer to bilaterians (more complex animals).

Most cnidarians prey on organisms ranging in size from plankton to animals several times larger than themselves, but many obtain much of their nutrition from endosymbiotic algae, and a few are parasites. Many are preyed upon by other animals including starfish, sea slugs, fish and turtles. Coral reefs, whose polyps are rich in endosymbiotic algae, support some of the world's most productive ecosystems, and protect vegetation in tidal zones and on shorelines from strong currents and tides. While corals are almost entirely restricted to warm, shallow marine waters, other cnidarians live in the depths, in polar seas and in freshwater.

Fossil cnidarians have been found in rocks formed about 580 million years ago, and other fossils show that corals may have been present shortly before 490 million years ago and diversified a few million years later. Fossils of cnidarians that do not build mineralized structures are very rare. Scientists currently think that cnidarians, ctenophores and bilaterians are more closely related to calcareous sponges than these are to other sponges, and that anthozoans are the evolutionary "aunts" or "sisters" of other cnidarians, and the most closely related to bilaterians. Recent analyses have concluded that cnidarians, although considered more "primitive" than bilaterians, have a wider range of genes.

Jellyfish stings killed several hundred people in the 20th century, and cubozoans are particularly dangerous. On the other hand, some large jellyfish are considered a delicacy in eastern and southern Asia. Coral reefs have long been economically important as providers of fishing grounds, protectors of shore buildings against currents and tides, and more recently as centers of tourism. However, they are vulnerable to over-fishing, mining for construction materials, pollution, and damage caused by tourism.

Classification

Cnidarians were for a long time grouped with Ctenophores in the phylum Coelenterata, but increasing awareness of their differences caused them to be placed in separate phyla. Cnidarians are classified into four main groups: sessile Anthozoa (sea anemones, corals, sea pens); swimming Scyphozoa (jellyfish); Cubozoa (box jellies); and Hydrozoa, a diverse group that includes all the freshwater cnidarians as well as many marine forms, and has both sessile members such as *Hydra* and colonial swimmers such as the Portuguese Man o' War. Staurozoa have recently been recognised as a class in their own right rather than a sub-group of Scyphozoa, and there is debate about whether Myxozoa and Polypodiozoa are cnidarians or closer to bilaterians.

Modern cnidarians are generally classified into four classes:

	Hydrozoa	Scyphozoa	Cubozoa	Anthozoa
Number of species	2,700	200	20	6,000
Examples	<i>Hydra</i> , siphonophores	Jellyfish	Box jellies	Sea anemones, corals, sea pens
Cells found in mesoglea	No	Yes	Yes	Yes
Nematocysts in exodermis	No	Yes	Yes	Yes
Medusa phase in life cycle	In some species	Yes, except for Stauromedusae if they are scyphozoans	Yes	No
Number of medusae produced per polyp	Many	Many	One	(not applicable)

Stauromedusae, small sessile cnidarians with stalks and no medusa stage, have traditionally been classified as members of the Scyphozoa, but recent research suggests they should be regarded as a separate class, Staurozoa.

The Myxozoa, microscopic parasites, were first classified as protozoans, but recently as heavily modified cnidarians, and more closely related to Hydrozoa and Scyphozoa than to Anthozoa. However other recent research suggests that *Polypodium hydriforme*, a parasite *within* the egg cells of sturgeon, is closely related to the Myxozoa and that both

Polypodium and the Myxozoa are intermediate between cnidarians and bilaterian animals.

Some researchers classify the extinct conulariids as cnidarians, while others propose that they form a completely separate phylum.

Ecology



Coral reefs support rich ecosystems

Many cnidarians are limited to shallow waters because they depend on endosymbiotic algae for much of their nutrients. The life cycles of most have polyp stages, which are limited to locations that offer stable substrates. Nevertheless major cnidarian groups contain species that have escaped these limitations. Hydrozoans have a worldwide range: some, such as *Hydra*, live in freshwater; *Obelia* appears in the coastal waters of all the oceans; and *Liriope* can form large shoals near the surface in mid-ocean. Among anthozoans, a few scleractinian corals, sea pens and sea fans live in deep, cold waters, and some sea anemones inhabit polar seabeds while others live near hydrothermal vents over 10 kilometres (6.2 mi) below sea-level. Reef-building corals are limited to tropical seas between 30°N and 30°S with a maximum depth of 46 metres (151 ft), temperatures between 20°C and 28°C, high salinity and low carbon dioxide levels. Stauromedusae, although usually classified as jellyfish, are stalked, sessile animals that live in cool to Arctic waters. Cnidarians range in size from *Hydra*, 5–20 millimetres (0.20–0.79 in)

long, to the Lion's mane jellyfish, which may exceed 2 metres (6.6 ft) in diameter and 75 metres (246 ft) in length.

Prey of cnidarians ranges from plankton to animals several times larger than themselves. Some cnidarians are parasites, mainly on jellyfish but a few are major pests of fish. Others obtain most of their nourishment from endosymbiotic algae or dissolved nutrients. Predators of cnidarians include: sea slugs, which can incorporate nematocysts into their own bodies for self-defense; starfish, notably the crown of thorns starfish, which can devastate corals; butterfly fish and parrot fish, which eat corals; and marine turtles, which eat jellyfish. Some sea anemones and jellyfish have a symbiotic relationship with some fish; for example clown fish live among the tentacles of sea anemones, and each partner protects the other against predators.

Coral reefs form some of the world's most productive ecosystems. Common coral reef cnidarians include both Anthozoans (hard corals, octocorals, anemones) and Hydrozoans (fire corals, lace corals) The endosymbiotic algae of many cnidarian species are very effective primary producers, in other words converters of inorganic chemicals into organic ones that other organisms can use, and their coral hosts use these organic chemicals very efficiently. In addition reefs provide complex and varied habitats that support a wide range of other organisms. "Fringing" reefs just below low-tide level also have a mutually beneficial relationship with mangrove forests at high-tide level and sea grass meadows in between: the reefs protect the mangroves and seagrass from strong currents and waves that would damage them or erode the sediments in which they are rooted, while the mangroves and seagrass protect the coral from large influxes of silt, fresh water and pollutants. This additional level of variety in the environment is beneficial to many types of coral reef animals, which for example may feed in the sea grass and use the reefs for protection or breeding.

History

Fossil cnidarians have been found in rocks formed about 580 million years ago, and other fossils show that corals may have been present shortly before 490 million years ago and diversified a few million years later. Fossils of cnidarians that do not build mineralized structures are very rare. Scientists currently think that cnidarians, ctenophores and bilaterians are more closely related to calcareous sponges than these are to other sponges, and that anthozoans are the evolutionary "aunts" or "sisters" of other cnidarians, and the most closely related to bilaterians. Recent analyses have concluded that cnidarians, although considered more "primitive" than bilaterians, have a wider range of genes.

Distinguishing features

Cnidarians form an animal phylum that is more complex than sponges, about as complex as ctenophores (comb jellies), and less complex than bilaterians, which include almost all other animals. However, both cnidarians and ctenophores are more complex than sponges as they have: cells bound by inter-cell connections and carpet-like basement membranes; muscles; nervous systems; and **some** have sensory organs. Cnidarians are distinguished

from all other animals by having cnidocytes that fire like harpoons and are used mainly to capture prey but also as anchors in some species.

Like sponges and ctenophores, cnidarians have two main layers of cells that sandwich a middle layer of jelly-like material, which is called the mesoglea in cnidarians; more complex animals have three main cell layers and no intermediate jelly-like layer. Hence, cnidarians and ctenophores have traditionally been labelled diploblastic, along with sponges. However, both cnidarians and ctenophores have a type of muscle that, in more complex animals, arises from the middle cell layer. As a result some recent text books classify ctenophores as triploblastic, and it has been suggested that cnidarians evolved from triploblastic ancestors.

	Sponges	Cnidarians	Ctenophores	Bilateria
Cnidocytes	No	Yes		No
Colloblasts		No	Yes	No
Digestive and circulatory organs		No		Yes
Number of main cell layers	Two, with jelly-like layer between them		Two or Three	Three
Cells in each layer bound together	No, except that Homoscleromorpha have basement membranes.		Yes: inter-cell connections; basement membranes	
Sensory organs	No		Yes	
Number of cells in middle "jelly" layer	Many		Few	(Not applicable)
Cells in outer layers can move inwards and change functions	Yes		No	(Not applicable)
Nervous system	No	Yes, simple		Simple to complex
Muscles	None	Mostly epitheliomuscular	Mostly myoepithelial	Mostly myocytes

Description

Main cell layers

Cnidaria are diploblastic animals, in other words they have two main cell layers, while more complex animals are triploblasts having three main layers. The two main cell layers

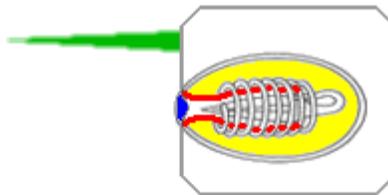
of cnidarians form epithelia that are mostly one cell thick, and are attached to a fibrous basement membrane, which they secrete. They also secrete the jelly-like mesoglea that separates the layers. The layer that faces outwards, known as the ectoderm ("outside skin"), generally contains the following types of cells:

- Epitheliomuscular cells whose bodies form part of the epithelium but whose bases extend to form muscle fibers in parallel rows. The fibers of the outward-facing cell layer generally run at right angles to the fibers of the inward-facing one. In Anthozoa (anemones, corals, etc.) and Scyphozoa (jellyfish), the mesoglea also contains some muscle cells.
- Cnidocytes, the harpoon-like "nettle cells" that give the phylum Cnidaria its name. These appear between or sometimes on top of the muscle cells.
- Nerve cells. Sensory cells appear between or sometimes on top of the muscle cells, and communicate via synapses (gaps across which chemical signals flow) with motor nerve cells, which lie mostly between the bases of the muscle cells.
- Interstitial cells, which are unspecialized and can replace lost or damaged cells by transforming into the appropriate types. These are found between the bases of muscle cells.

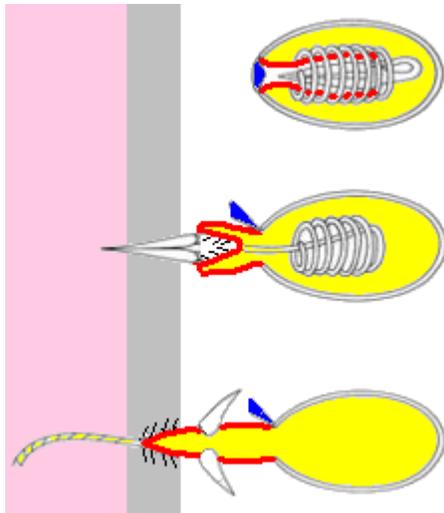
In addition to epitheliomuscular, nerve and interstitial cells, the inward-facing gastroderm ("stomach skin") contains gland cells that secrete digestive enzymes. In some species it also contains low concentrations of cnidocytes, which are used to subdue prey that is still struggling.

The mesoglea contains small numbers of amoeba-like cells, and muscle cells in some species. However the number of middle-layer cells and types are much lower than in sponges.

Cnidocytes



A hydra's nematocyst, before firing.
■ "trigger" cilium



Firing sequence of the cnida in a hydra's nematocyst

- Operculum (lid)
- "Finger" that turns inside out
- /// Barbs
- Venom
- Victim's skin
- Victim's tissues

These "nettle cells" function as harpoons, since their payloads remain connected to the bodies of the cells by threads. Three types of cnidocytes are known:

- Nematocysts inject venom into prey, and usually have barbs to keep them embedded in the victims. Most species have nematocysts.
- Spirocysts do not penetrate the victim or inject venom, but entangle it by means of small sticky hairs on the thread. Only members of the class Anthozoa (sea anemones and corals) have spirocysts.
- Ptychocysts are not used for prey capture — instead the threads of discharged ptychocysts are used for building protective tubes in which their owners live. Ptychocysts are found only in the order Cerianthria, tube anemones.

The main components of a cnidocyte are:

- A cilium (fine hair) which projects above the surface and acts as a trigger. Spirocysts do not have cilia.
- A tough capsule, the cnida, which houses the thread, its payload and a mixture of chemicals which may include venom or adhesives or both. ("cnida" is derived from the Greek word κνίδη, which means "nettle")
- A tube-like extension of the wall of the cnida that points into the cnida, like the finger of a rubber glove pushed inwards. When a cnidocyte fires, the finger pops out. If the cell is a venomous nematocyte, the "finger"'s tip reveals a set of barbs that anchor it in the prey.

- The thread, which is an extension of the "finger" and coils round it until the cnidocyte fires. The thread is usually hollow and delivers chemicals from the cnida to the target.
- An operculum (lid) over the end of the cnida. The lid may be a single hinged flap or three flaps arranged like slices of pie.
- The cell body which produces all the other parts.

It is difficult to study the firing mechanisms of cnidocytes as these structures are small but very complex. At least four hypotheses have been proposed:

- Rapid contraction of fibers round the cnida may increase its internal pressure.
- The thread may be like a coiled spring that extends rapidly when released.
- In the case of *Chironex* (the "sea wasp"), chemical changes in the cnida's contents may cause them to expand rapidly by polymerization.
- Chemical changes in the liquid in the cnida make it a much more concentrated solution, so that osmotic pressure forces water in very rapidly to dilute it. This mechanism has been observed in nematocysts of the class Hydrozoa, sometimes producing pressures as high as 140 atmospheres, similar to that of scuba air tanks, and fully extending the thread in as little as 2 milliseconds (0.002 second).

Cnidocytes can only fire once, and about 25% of a hydra's nematocysts are lost from its tentacles when capturing a brine shrimp. Used cnidocytes have to be replaced, which takes about 48 hours. To minimise wasteful firing, two types of stimulus are generally required to trigger cnidocytes: their cilia detect contact, and nearby sensory cells "smell" chemicals in the water. This combination prevents them from firing at distant or non-living objects. Groups of cnidocytes are usually connected by nerves and, if one fires, the rest of the group requires a weaker minimum stimulus than the cells that fire first.

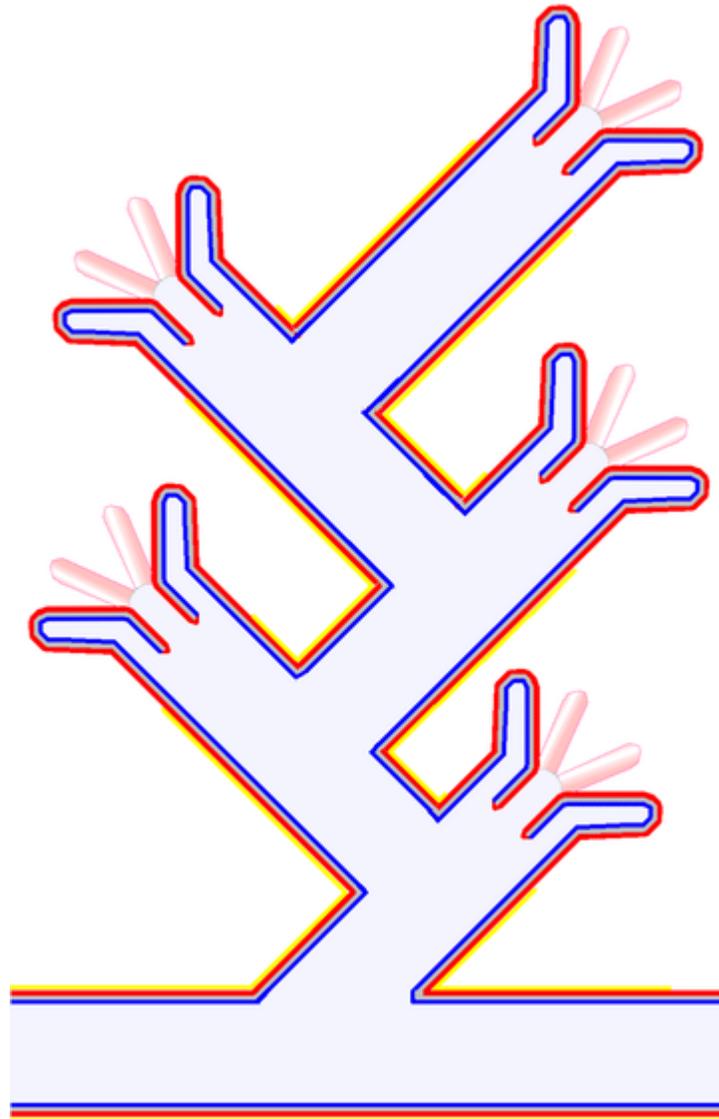
Basic body forms



Oral end of actinodiscus polyp, with close-up of the mouth

Adult cnidarians appear as either swimming medusae or sessile polyps. Both are radially symmetrical, like a wheel and a tube respectively. Since these animals have no heads, their ends are described as "oral" (nearest the mouth) and "aboral" (furthest from the mouth). Most have fringes of tentacles equipped with cnidocytes around their edges, and medusae generally have an inner ring of tentacles around the mouth. The mesoglea of polyps is usually thin and often soft, but that of medusae is usually thick and springy, so that it returns to its original shape after muscles around the edge have contracted to squeeze water out, enabling medusae to swim by a sort of jet propulsion.

Colonial forms



Tree-like polyp colony

Cnidaria produce a variety of colonial forms, each of which is one organism but consists of polyp-like zooids. The simplest is a connecting tunnel that runs over the substrate (rock or seabed) and from which single zooids sprout. In some cases the tunnels form visible webs, and in others they are enclosed in a fleshy mat. More complex forms are also based on connecting tunnels but produce "tree-like" groups of zooids. The "trees" may be formed either by a central zooid that functions as a "trunk" with later zooids growing to the sides as "branches", or in a zig-zag shape as a succession of zooids, each of which grows to full size and then produces a single bud at an angle to itself. In many cases the connecting tunnels and the "stems" are covered in periderm, a protective layer

of chitin. Some colonial forms have other specialized types of zooid, for example, to pump water through their tunnels.

Siphonophores form complex colonies that consist of: an upside-down polyp that forms a central stem with a gas-filled float at the top; one or more sets of medusa-like zooids that provide propulsion; leaf-like bracts that give some protection to other parts; sets of tentacles that bear nematocytes that capture prey; other tentacles that act as sensors; near the base of each set of tentacles, a polyp-like zooid that acts as a stomach for the colony; medusa-like zooids that serve as gonads. Although some of these zooids resemble polyps or medusae in shape, they lack features that are not relevant to their specific functions, for example the swimming "medusae" have no digestive, sensory or reproductive cells. The best-known siphonophore is the Portuguese Man o' War (*Physalia physalis*).

Skeletons

In medusae the only supporting structure is the mesoglea. *Hydra* and most sea anemones close their mouths when they are not feeding, and the water in the digestive cavity then acts as a hydrostatic skeleton, rather like a water-filled balloon. Other polyps such as *Tubularia* use columns of water-filled cells for support. Sea pens stiffen the mesoglea with calcium carbonate spicules and tough fibrous proteins, rather like sponges.

In some colonial polyps a chitinous periderm gives support and some protection to the connecting sections and to the lower parts of individual polyps. Stony corals secrete massive calcium carbonate exoskeletons. A few polyps collect materials such as sand grains and shell fragments, which they attach to their outsides. Some colonial sea anemones stiffen the mesoglea with sediment particles.

Locomotion



Chrysaora quinquecirrha ("sea nettle") swimming

Medusae swim by a form of jet propulsion: muscles, especially inside the rim of the bell, squeeze water out of the cavity inside the bell, and the springiness of the mesoglea powers the recovery stroke. Since the tissue layers are very thin, they provide too little power to swim against currents and just enough to control movement within currents.

Hydras and some sea anemones can move slowly over rocks and sea or stream beds by various means: creeping like snails, crawling like inchworms, or by somersaulting. A few can swim clumsily by wagging their bases.

Nervous system and senses

Cnidaria have no brains or even central nervous systems. Instead they have decentralized nerve nets consisting of: sensory neurons that generate signals in response to various types of stimulus, such as odors; motor neurons that tell muscles to contract; all connected by "cobwebs" of intermediate neurons. As well as forming the "signal cables", intermediate neurons also form ganglia that act as local coordination centers. The cilia of the cnidocytes detect physical contact. Nerves inform cnidocytes when odors from prey or attackers are detected and when neighbouring cnidocytes fire. Most of the

communications between nerve cells are via chemical synapses, small gaps across which chemicals flow. As this process is too slow to ensure that the muscles round the rim of a medusa's bell contract simultaneously in swimming the neurons which control this communicate by much faster electrical signals across gap junctions.

Medusae and complex swimming colonies such as siphonophores and chondrophores sense tilt and acceleration by means of statocysts, chambers lined with hairs which detect the movements of internal mineral grains called statoliths. If the body tilts in the wrong direction, the animal rights itself by increasing the strength of the swimming movements on the side that is too low. They also have ocelli ("little eyes"), which can detect the direction from which light is coming. Box jellies have camera eyes, although these probably do not form images, and their lenses simply produce a clearer indication of the direction from which light is coming.

Feeding and excretion

Cnidarians feed in several ways: predation, absorbing dissolved organic chemicals, filtering food particles out of the water, and obtaining nutrients from symbiotic algae within their cells. Most obtain the majority of their food from predation but some, including the corals *Hetroxenia* and *Leptogorgia*, depend almost completely on their endosymbionts and on absorbing dissolved nutrients. Cnidaria give their symbiotic algae carbon dioxide, some nutrients and a place in the sun.

Predatory species use their cnidocytes to poison or entangle prey, and those with venomous nematocysts may start digestion by injecting digestive enzymes. The "smell" of fluids from wounded prey makes the tentacles fold inwards and wipe the prey off into the mouth. In medusae the tentacles round the edge of the bell are often short and most of the prey capture is done by "oral arms", which are extensions of the edge of the mouth and are often frilled and sometimes branched to increase their surface area. Medusae often trap prey or suspended food particles by swimming upwards, spreading their tentacles and oral arms and then sinking. In species for which suspended food particles are important, the tentacles and oral arms often have rows of cilia whose beating creates currents that flow towards the mouth, and some produce nets of mucus to trap particles.

Once the food is in the digestive cavity, gland cells in the gastroderm release enzymes that reduce the prey to slurry, usually within a few hours. This circulates through the digestive cavity and, in colonial cnidarians, through the connecting tunnels, so that gastroderm cells can absorb the nutrients. Absorption may take a few hours, and digestion within the cells may take a few days. The circulation of nutrients is driven by water currents produced by cilia in the gastroderm or by muscular movements or both, so that nutrients reach all parts of the digestive cavity. Nutrients reach the outer cell layer by diffusion or, for animals or zooids such as medusae which have thick mesogleas, are transported by mobile cells in the mesoglea.

Indigestible remains of prey are expelled through the mouth. The main waste product of cells' internal processes is ammonia, which is removed by the external and internal water currents.

Respiration

There are no respiratory organs, and both cell layers absorb oxygen from and expel carbon dioxide into the surrounding water. When the water in the digestive cavity becomes stale it must be replaced, and nutrients that have not been absorbed will be expelled with it. Some Anthozoa have ciliated grooves on their tentacles, allowing them to pump water out of and into the digestive cavity without opening the mouth. This improves respiration after feeding and allows these animals, which use the cavity as a hydrostatic skeleton, to control the water pressure in the cavity without expelling undigested food.

Cnidaria that carry photosynthetic symbionts may have the opposite problem, an excess of oxygen, which may prove toxic. The animals produce large quantities of antioxidants to neutralize the excess oxygen.

Regeneration

All cnidarians can regenerate, allowing them to recover from injury and to reproduce asexually. Medusae have limited ability to regenerate, but polyps can do so from small pieces or even collections of separated cells. This enables corals to recover even after apparently being destroyed by predators.

Reproduction

Sexual

In the Cnidaria sexual reproduction often involves a complex life cycle with both polyp and medusa stages. For example in Scyphozoa (jellyfish) and Cubozoa (box jellies) a larva swims until it finds a good site, and then becomes a polyp. This grows normally but then absorbs its tentacles and splits horizontally into a series of disks that become juvenile medusae, a process called strobilation. The juveniles swim off and slowly grow to maturity, while the polyp re-grows and may continue strobilating periodically. The adults have gonads in the gastroderm, and these release ova and sperm into the water in the breeding season.

Shortened forms of this life cycle are common, for example some oceanic scyphozoans omit the polyp stage completely, and cubozoan polyps produce only one medusa. Hydrozoa have a variety of life cycles. Some have no polyp stages and some (e.g. *hydra*) have no medusae. In some species the medusae remain attached to the polyp and are responsible for sexual reproduction; in extreme cases these reproductive zooids may not look much like medusae. Anthozoa have no medusa stage at all and the polyps are responsible for sexual reproduction.

Spawning is generally driven by environmental factors such as changes in the water temperature, and their release is triggered by lighting conditions such as sunrise, sunset or the phase of the moon. Many species of Cnidaria may spawn simultaneously in the same location, so that there are too many ova and sperm for predators to eat more than a tiny percentage — one famous example is the Great Barrier Reef, where at least 110 corals and a few non-cnidarian invertebrates produce enough to turn the water cloudy. These mass spawnings may produce hybrids, some of which can settle and form polyps, but it is not known how long these can survive. In some species the ova release chemicals that attract sperm of the same species.

The fertilized eggs develop into larvae by dividing until there are enough cells to form a hollow sphere (blastula) and then a depression forms at one end (gastrulation) and eventually become the digestive cavity. However in cnidarians the depression forms at the end further from the yolk (at the animal pole), while in bilaterians it forms at the other end (vegetal pole). The larvae, called planulae, swim or crawl by means of cilia. They are cigar-shaped but slightly broader at the "front" end, which is the aboral, vegetal-pole end and eventually attaches to a substrate if the species has a polyp stage.

Anthozoan larvae either have large yolks or are capable of feeding on plankton, and some already have endosymbiotic algae that help to feed them. Since the parents are immobile, these feeding capabilities extend the larvae's range and avoid overcrowding of sites. Scyphozoan and hydrozoan larvae have little yolk and most lack endosymbiotic algae, and therefore have to settle quickly and metamorphose into polyps. Instead these species rely on their medusae to extend their ranges.

Asexual

All known cnidaria can reproduce asexually by various means, in addition to regenerating after being fragmented. Hydrozoan polyps only bud, while the medusae of some hydrozoans can divide down the middle. Scyphozoan polyps can both bud and split down the middle. In addition to both of these methods, Anthozoa can split horizontally just above the base.

Evolutionary history

Fossil record



The fossil coral *Cladocora* from Pliocene rocks in Cyprus

The earliest widely accepted animal fossils are rather modern-looking cnidarians, possibly from around 580 million years ago, although fossils from the Doushantuo Formation can only be dated approximately. The identification of some of these as embryos of animals has been contested, but other fossils from these rocks strongly resemble tubes and other mineralized structures made by corals. Their presence implies that the cnidarian and bilaterian lineages had already diverged. Although the Ediacaran fossil *Charnia* used to be classified as a jellyfish or sea pen, more recent study of growth patterns in *Charnia* and modern cnidarians has cast doubt on this hypothesis, and there are now no bona-fide cnidarian body fossils in the Ediacaran. Few fossils of cnidarians without mineralized skeletons are known from more recent rocks, except in lagerstätten that preserved soft-bodied animals.

A few mineralized fossils that resemble corals have been found in rocks from the Cambrian period, and corals diversified in the Early Ordovician. These corals, which were wiped out in the Permian-Triassic extinction about 251 million years ago, did not dominate reef construction since sponges and algae also played a major part. During the Mesozoic era rudist bivalves were the main reef-builders, but they were wiped out in the

Cretaceous-Tertiary extinction 65 million years ago, and since then the main reef-builders have been scleractinian corals.

Family tree

It is difficult to reconstruct the early stages in the evolutionary "family tree" of animals using only morphology (their shapes and structures), because the large differences between Porifera (sponges), Cnidaria plus Ctenophora (comb jellies), Placozoa and Bilateria (all the more complex animals) make comparisons difficult. Hence reconstructions now rely largely or entirely on molecular phylogenetics, which groups organisms according to similarities and differences in their biochemistry, usually in their DNA or RNA.

It is now generally thought that the Calcarea (sponges with calcium carbonate spicules) are more closely related to Cnidaria, Ctenophora (comb jellies) and Bilateria (all the more complex animals) than they are to the other groups of sponges. In 1866 it was proposed that Cnidaria and Ctenophora were more closely related to each other than to Bilateria and formed a group called Coelenterata ("hollow guts"), because Cnidaria and Ctenophora both rely on the flow of water in and out of a single cavity for feeding, excretion and respiration. In 1881 it was proposed that Ctenophora and Bilateria were more closely related to each other, since they shared features that Cnidaria lack, for example muscles in the middle layer (mesoglea in Ctenophora, mesoderm in Bilateria). However more recent analyses indicate that these similarities are rather vague, and the current view, based on molecular phylogenetics, is that Cnidaria and Bilateria are more closely related to each other than either is to Ctenophora. This grouping of Cnidaria and Bilateria has been labelled "Planulozoa" because it suggests that the earliest Bilateria were similar to the planula larvae of Cnidaria.

Within the Cnidaria, the Anthozoa (sea anemones and corals) are regarded as the sister-group of the rest, which suggests that the earliest cnidarians were sessile polyps with no medusa stage. However it is unclear how the other groups acquired the medusa stage, since Hydrozoa form medusae by budding from the side of the polyp while the other Medusozoa do so by splitting them off from the tip of the polyp. The traditional grouping of Scyphozoa included the Staurozoa, but morphology and molecular phylogenetics indicate that Staurozoa are more closely related to Cubozoa (box jellies) than to other "Scyphozoa". Similarities in the double body walls of Staurozoa and the extinct Conulariida suggest that they are closely related. The position of Anthozoa nearest the beginning of the cnidarian family tree also implies that Anthozoa are the cnidarians most closely related to Bilateria, and this is supported by the fact that Anthozoa and Bilateria share some genes that determine the main axes of the body.

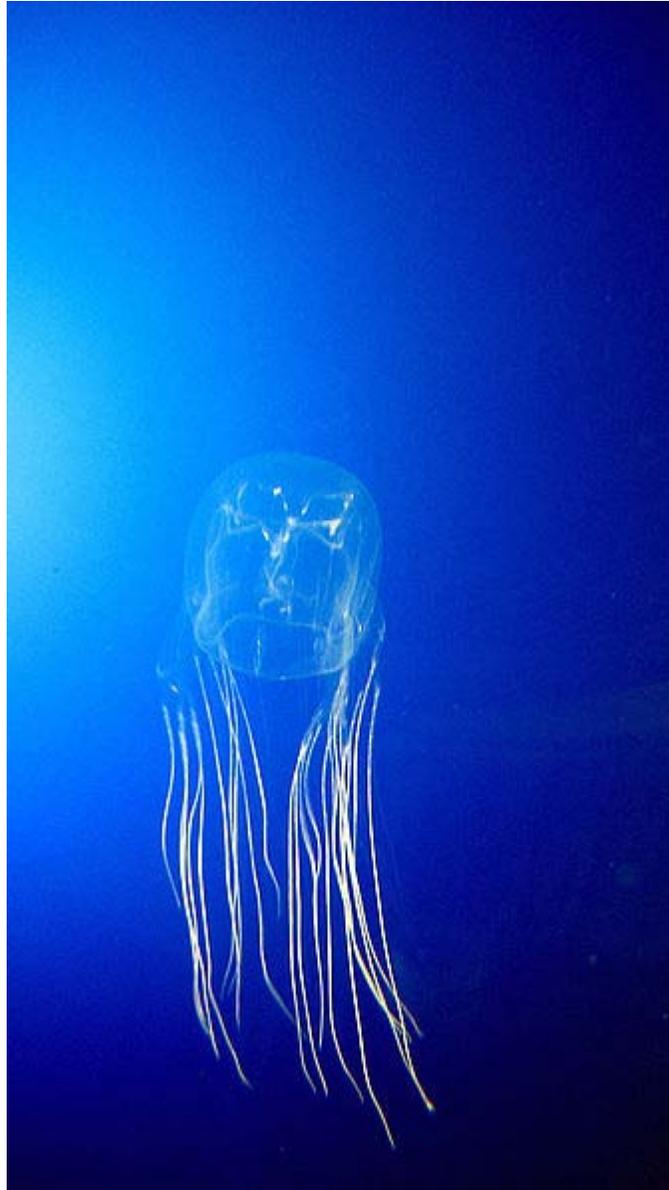
However in 2005 Katja Seipel and Volker Schmid suggested that cnidarians and ctenophores are simplified descendants of triploblastic animals, since ctenophores and the medusa stage of some cnidarians have striated muscle, which in bilaterians arises from the mesoderm. They did not commit themselves on whether bilaterians evolved from early cnidarians or from the hypothesized triploblastic ancestors of cnidarians.

In molecular phylogenetics analyses from 2005 onwards, important groups of developmental genes show the same variety in cnidarians as in chordates. In fact cnidarians, and especially anthozoans (sea anemones and corals), retain some genes that are present in bacteria, protists, plants and fungi but not in bilaterians.

Interaction with humans

Jellyfish stings killed about 1,500 people in the 20th century, and cubozoans are particularly dangerous. On the other hand, some large jellyfish are considered a delicacy in eastern and southern Asia. Coral reefs have long been economically important as providers of fishing grounds, protectors of shore buildings against currents and tides, and more recently as centers of tourism. However, they are vulnerable to over-fishing, mining for construction materials, pollution, and damage caused by tourism.

Beaches protected from tides and storms by coral reefs are often the best places for housing in tropical countries. Reefs are an important food source for low-technology fishing, both on the reefs themselves and in the adjacent seas. However despite their great productivity reefs are vulnerable to over-fishing, because much of the organic carbon they produce is exhaled as carbon dioxide by organisms at the middle levels of the food chain and never reaches the larger species that are of interest to fishermen. Tourism centered on reefs provides much of the income of some tropical islands, attracting photographers, divers and sports fishermen. However human activities damage reefs in several ways: mining for construction materials; pollution, including large influxes of fresh water from storm drains; commercial fishing, including the use of dynamite to stun fish and the capture of young fish for aquariums; and tourist damage caused by boat anchors and the cumulative effect of walking on the reefs. Coral, mainly from the Pacific Ocean has long been used in jewellery, and demand rose sharply in the 1980s.



The dangerous "sea wasp" *Chironex fleckeri*

Some large jellyfish species have been used in Chinese cuisine at least since 200 AD, and are now fished in the seas around most of South East Asia. Japan is the largest single consumer of edible jellyfish, importing at first only from China but now from all of South East Asia as prices rose in the 1970s. This fishing industry is restricted to daylight hours and calm conditions in two short seasons, from March to May and August to November. The commercial value of jellyfish food products depends on the skill with which they are prepared, and "Jellyfish Masters" guard their trade secrets carefully. Jellyfish is very low in cholesterol and sugars, but cheap preparation can introduce undesirable amounts of heavy metals.

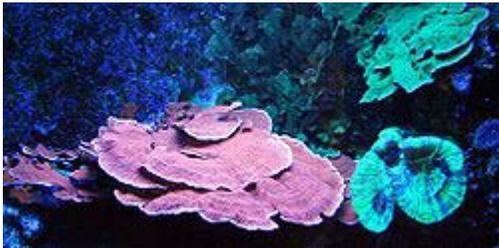
The "sea wasp" *Chironex fleckeri* has been described as the world's most venomous animal and is held responsible for 67 deaths, although it is difficult to identify the animal as it is almost transparent. Most stings by *C. fleckeri* cause only mild symptoms. Seven other box jellies can cause a set of symptoms called Irukandji syndrome, which takes about 30 minutes to develop, and from a few hours to two weeks to disappear. Hospital treatment is usually required, and there have been a few deaths.

Chapter- 2

Anthozoa

Anthozoa

Temporal range: 570–0 Ma
Late Ediacaran to Recent



Stony corals

Scientific classification

Kingdom:	Animalia
Phylum:	Cnidaria
Class:	Anthozoa Ehrenberg, 1831

Anthozoa is a class within the phylum Cnidaria that contains the sea anemones and corals. Unlike other cnidarians, anthozoans do not have a medusa stage in their development. Instead, they release sperm and eggs that form a planula, which attaches to some substrate on which the cnidarian grows. Some anthozoans can also reproduce asexually through budding.

Biology and anatomy

Like those of other cnidarians, the individual polyps have a cylindrical body crowned by a ring of tentacles surrounding the mouth. The mouth leads into a tubular pharynx which descends for some distance into the body before opening into the gastrovascular cavity that fills the interior of the body and tentacles. Unlike other cnidarians, however, the cavity is subdivided by a number of radiating partitions, or mesenteries. The gonads are also located within the cavity walls.

All cnidarian species can feed by catching prey with nematocysts; sea anemones are capable of catching fish and corals of catching plankton. Some of the species also harbour a type of algae, dinoflagellates called zooxanthellae, in a symbiotic relationship; the reef building corals known as hermatypic corals rely on this symbiotic relationship particularly. The zooxanthellae benefit by using nitrogenous waste and carbon dioxide produced by the host or, and the cnidarian gains photosynthetic capability and increased calcium carbonate production in hermatypic corals.

Anemones and certain species of coral live in isolation, however most corals form colonies of genetically identical polyps; these polyps closely resemble anemones in structure, although are generally considerably smaller. Most kinds of stony coral live in all parts of the underwater world.

Phylogeny

Anthozoa is subdivided into two subclasses Octocorallia and Hexacorallia which form monophyletic groups and generally show 8-way and 6-way symmetry in polyp structure respectively. Historically Ceriantipatharia was thought to be a separate subclass but the two orders it comprised, Ceriantharia and Antipatharia, are now considered part of Hexacorallia. The extant orders are shown to the right.

Hexacorallia includes important coral reef builders the stony corals (Scleractinia), sea anemones (Actiniaria) and related tube-dwelling anemones (Ceriantharia), and zoanthids (Zoantharia). Genetic studies of ribosomal DNA has shown Ceriantharia to be a monophyletic group and the oldest, or basal, order among them.

Octocorallia comprises the sea pens (Pennatulacea), soft corals (Alcyonacea), and blue coral (Helioporacea). Sea whips and sea fans, known as gorgonians, are part of Alcyonacea and historically were divided into separate orders.

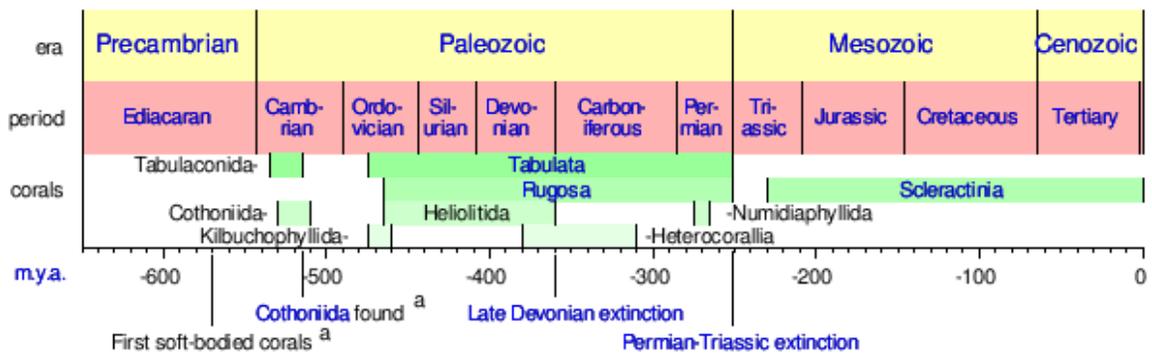


Giant green anemone, likely *Anthopleura xanthogrammica*, Southern California

A number of extinct orders of corals have been classified as their calcium skeleton forms a prolific fossil record. These are generally thought to be close to the ancestors of modern Scleractinians and existed during the Paleozoic Era 570-245 million years ago:

- Numidiaphyllida †
- Kilbuchophyllida †
- Heterocorallia †
- Rugosa †
- Heliolitida †
- Tabulata †
- Cothoniida †
- Tabuloconida †

These are all corals and correspond to the fossil record time line shown below; they comprise the majority of the fossils of Anthozoa due to their calcareous skeleton being preserved.

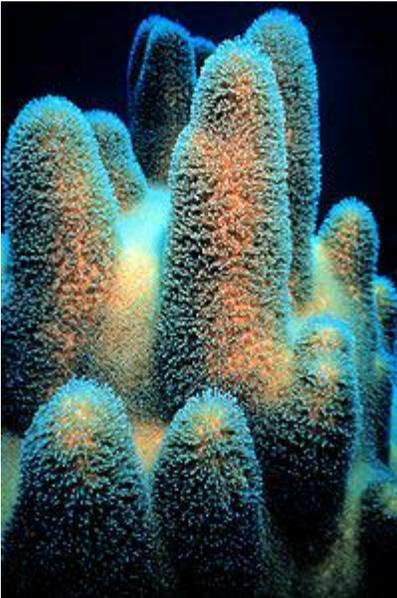


Timeline of the major coral fossil record and developments from 650 m.y.a. to present.

Chapter- 3

Coral

Coral



Pillar coral, *Dendrogyra cylindricus*

Scientific classification

Kingdom: Animalia
Phylum: Cnidaria
Class: Anthozoa
Ehrenberg, 1831

Extant Subclasses and Orders

Alcyonaria
Alcyonacea
Helioporacea
Zoantharia
Antipatharia
Corallimorpharia
Scleractinia
Zoanthidea

Corals are marine organisms in class Anthozoa of phylum Cnidaria typically living in compact colonies of many identical individual "polyps." The group includes the important reef builders that inhabit tropical oceans, which secrete calcium carbonate to form a hard skeleton.

A coral "head," which appears to be a single organism, is a colony of myriad genetically identical polyps. Each polyp is typically only a few millimeters in diameter. Over many generations the colony secretes a skeleton that is characteristic of the species. Individual heads grow by asexual reproduction of individual polyps. Corals also breed sexually by spawning. Polyps of the same species release gametes simultaneously over a period of one to several nights around a full moon.

Although corals can catch small fish and animals such as plankton using stinging cells on their tentacles, most corals obtain the majority of their energy and nutrients from photosynthetic unicellular algae called zooxanthellae. Such corals require sunlight and grow in clear, shallow water, typically at depths shallower than 60 metres (200 ft). Corals can be major contributors to the physical structure of the coral reefs that develop in tropical and subtropical waters, such as the enormous Great Barrier Reef off the coast of Queensland, Australia. Other corals do not have associated algae and can live in much deeper water, with the cold-water genus *Lophelia* surviving as deep as 3,000 metres (9,800 ft). Examples live on the Darwin Mounds located north-west of Cape Wrath, Scotland. Corals have also been found off the coast of the U.S. in Washington state and the Aleutian Islands in Alaska.

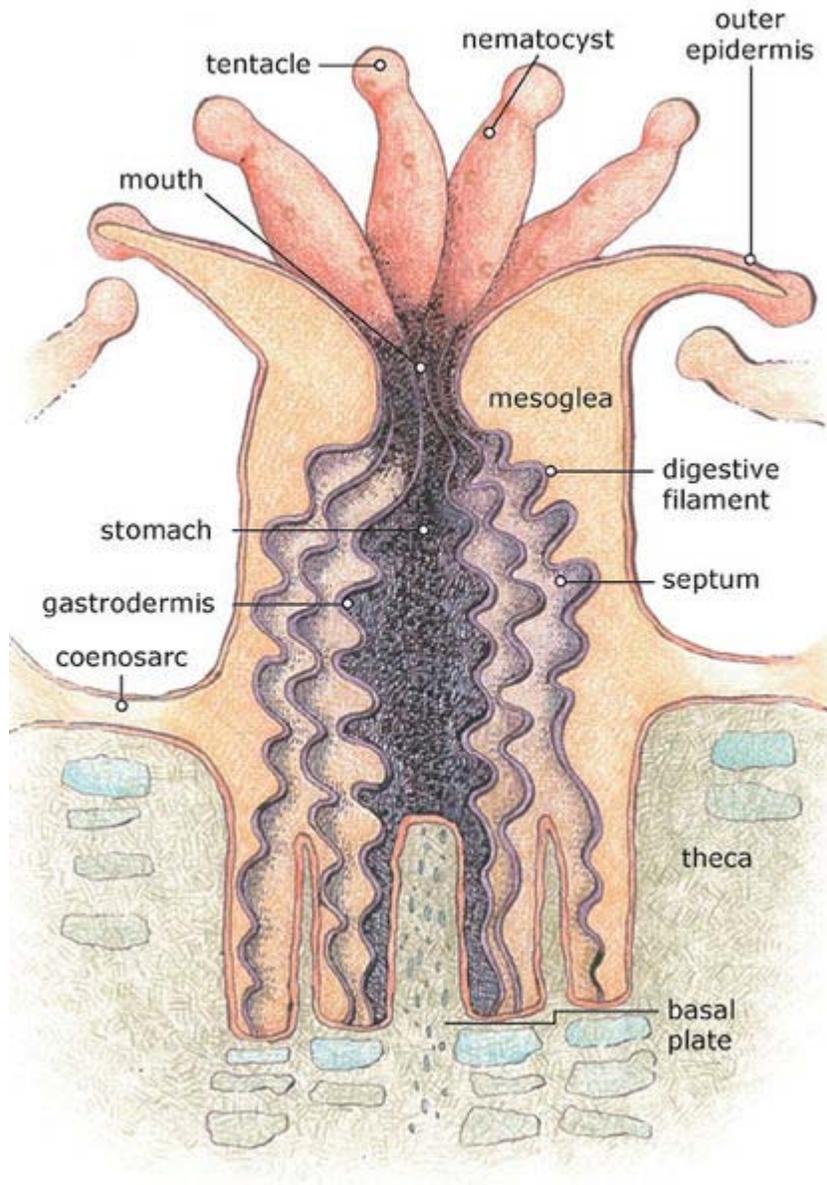
Taxonomy



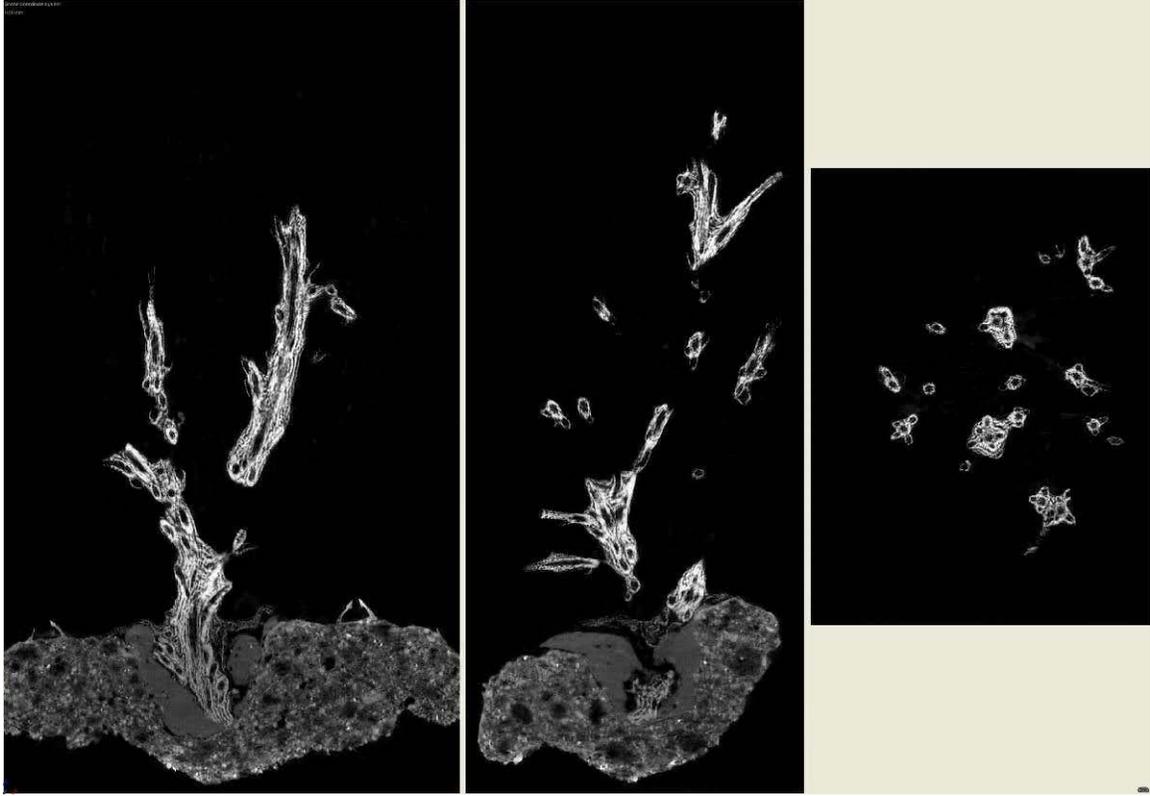
A Short Tentacle Plate coral in Papua New Guinea

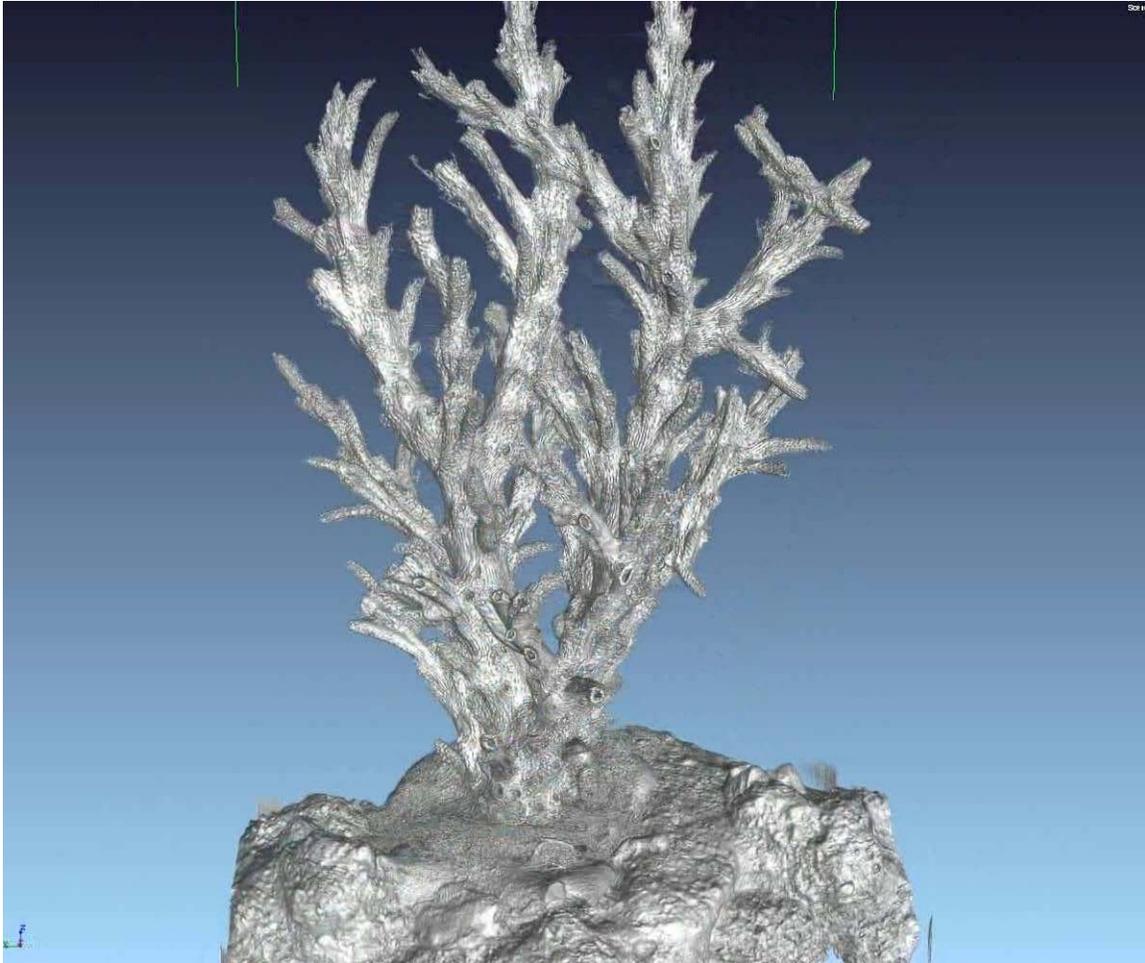
Corals divide into two subclasses, depending on the number of tentacles or lines of symmetry, and a series of orders corresponding to their exoskeleton, nematocyst type and mitochondrial genetic analysis. Those with eight tentacles are called octocorallia or Alcyonaria and comprise soft corals, sea fans and sea pens. Those with more than eight in a multiple of six are called hexacorallia or Zoantharia. This group includes reef-building corals (Scleractinians), sea anemones and zoanthids.

Anatomy



Anatomy of a coral polyp





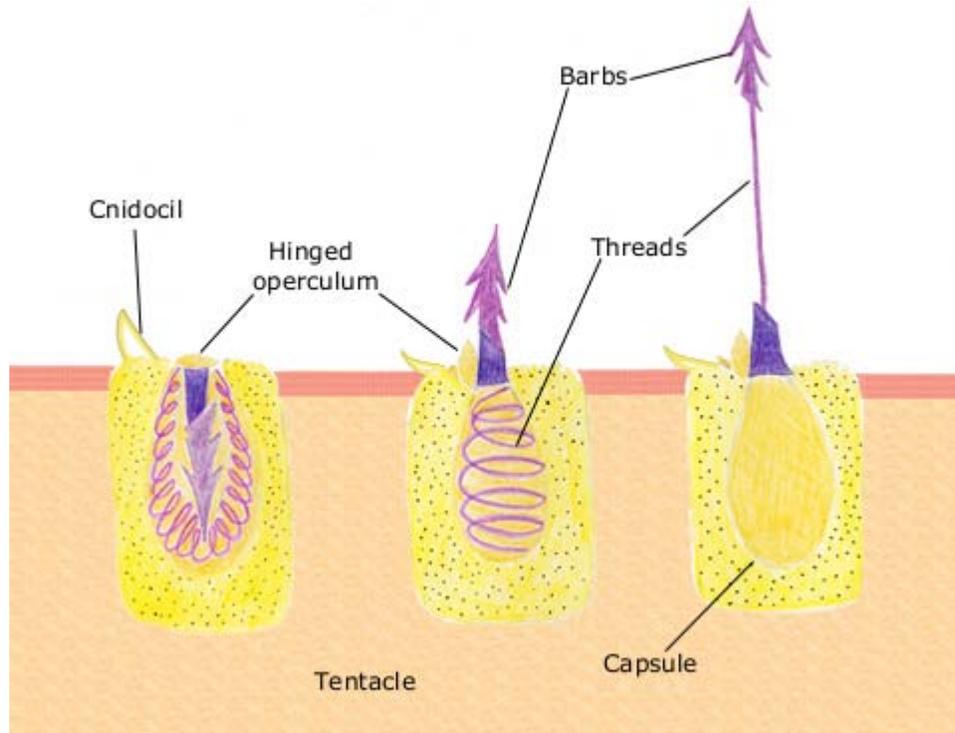
Initially believed to be a plant, William Herschel used a microscope to establish in the 18th Century that Coral had the characteristic thin cell membranes of an animal.

While a coral head appears to be a single organism, it is actually a group of many individual, yet genetically identical, polyps. The polyps are multicellular organisms. Polyps are usually a few millimeters in diameter, and are formed by a layer of outer epithelium and inner jellylike tissue known as the mesoglea. They are radially symmetrical with tentacles surrounding a central mouth, the only opening to the stomach or coelenteron, through which food is ingested and waste expelled.

The stomach closes at the base of the polyp, where the epithelium produces an exoskeleton called the basal plate or calicle (L. small cup). The calicle is formed by a thickened calcareous ring (annular thickening) with six supporting radial ridges (as shown below). These structures grow vertically and project into the base of the polyp. When a polyp is physically stressed, its tentacles contract into the calyx so that virtually no part is exposed above the skeletal platform. This protects the organism from predators and the elements.

The polyp grows by extension of vertical calices which occasionally septate to form a new, higher, basal plate. Over many generations this extension forms the large calcareous structures of corals and ultimately coral reefs.

Formation of the calcareous exoskeleton involves deposition of the mineral aragonite by the polyps from calcium and carbonate ions they acquire from seawater. The rate of deposition, while varying greatly across species and environmental conditions, can be as much as 10 g / m² of polyp / day (0.3 ounce / sq yd / day). This is light dependent, with night-time production 90% lower than that during the middle of the day.



Nematocyst discharge: A dormant nematocyst discharges response to nearby prey touching the cnidocil, the operculum flap opens and its stinging apparatus fires the barb into the prey leaving a hollow filament through which poisons are injected to immobilise the prey, then the tentacles manoeuvre the prey to the mouth.

Nematocysts are stinging cells at the tips of the calices that carry poison which they rapidly release in response to contact with another organism. The tentacles also bear a contractile band of epithelium called the pharynx. Jellyfish and sea anemones also carry nematocysts.

The polyps interconnect by a complex and well developed system of gastrovascular canals allowing significant sharing of nutrients and symbiotes. In soft corals these range in size from 50–500 micrometres (0.0020–0.020 in) in diameter and allow transport of both metabolites and cellular components.



Close-up of *Montastrea cavernosa* polyps. Tentacles are clearly visible.

Many corals as well as other cnidarian groups such as sea anemones (e.g. Aiptasia), form a symbiotic relationship with a class of algae, zooxanthellae, of the genus *Symbiodinium*. Aiptasia, while considered a pest among coral reef aquarium hobbyists, serves as a valuable model organism in the study of cnidarian-algal symbiosis. Typically a polyp harbors one species of algae. Via photosynthesis, these provide energy for the coral, and aid in calcification. The algae benefit from a safe environment, and consume the carbon dioxide and nitrogenous waste produced by the polyp. Due to the strain the algae can put on the polyp, stress on the coral often drives the coral to eject the algae. Mass ejections are known as coral bleaching, because the algae contribute to coral's brown coloration; other colors, however, are due to host coral pigments, such as GFPs (green fluorescent protein). Ejection increases the polyp's chances of surviving short-term stress—they can regain algae at a later time. If the stressful conditions persist, the polyp eventually dies.

Feeding

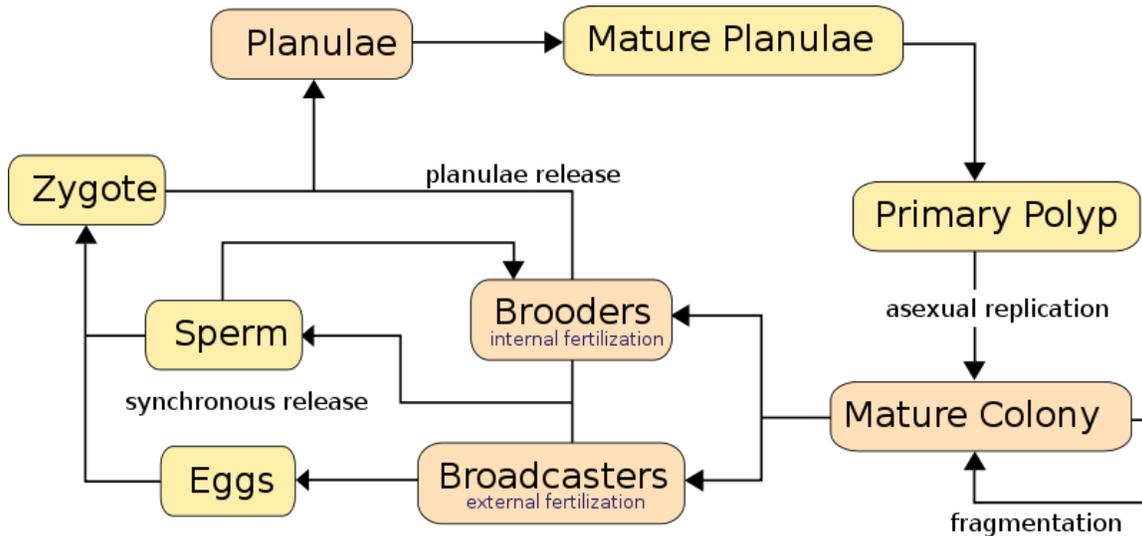
Polyps feed on a variety of small organisms, from microscopic plankton to small fish. The polyp's tentacles immobilize or kill prey using their nematocysts. The tentacles then contract to bring the prey into the stomach. Once digested, the stomach reopens, allowing the elimination of waste products and the beginning of the next hunting cycle.

These poisons are usually too weak to harm humans. An exception is fire coral.

Reproduction

Corals can be both gonochoristic (unisexual) and hermaphroditic, each of which can reproduce sexually and asexually. Reproduction also allows coral to settle new areas.

Sexual



Life cycles of broadcasters and brooders

Corals predominantly reproduce sexually. 25% of hermatypic corals (stony corals) form single sex (gonochoristic) colonies, while the rest are hermaphroditic. About 75% of all hermatypic corals "broadcast spawn" by releasing gametes—eggs and sperm—into the water to spread offspring. The gametes fuse during fertilization to form a microscopic larva called a planula, typically pink and elliptical in shape. A typical coral colony form several thousand larvae per year to overcome the odds against formation of a new colony.

Planulae exhibits positive *phototaxis*, swimming towards light to reach surface waters where they drift and grow before descending to seek a hard surface to which it can attach and establish a new colony. They also exhibit positive *sonotaxis*, moving towards sounds that emanate from the reef and away from open water. High failure rates afflict many stages of this process, and even though millions of gametes are released by each colony very few new colonies form. The time from spawning to settling is usually 2–3 days, but can be up to 2 months. The larva grows into a polyp and eventually becomes a coral head by asexual budding and growth.



A male star coral, *Montastraea cavernosa*, releases sperm into the water

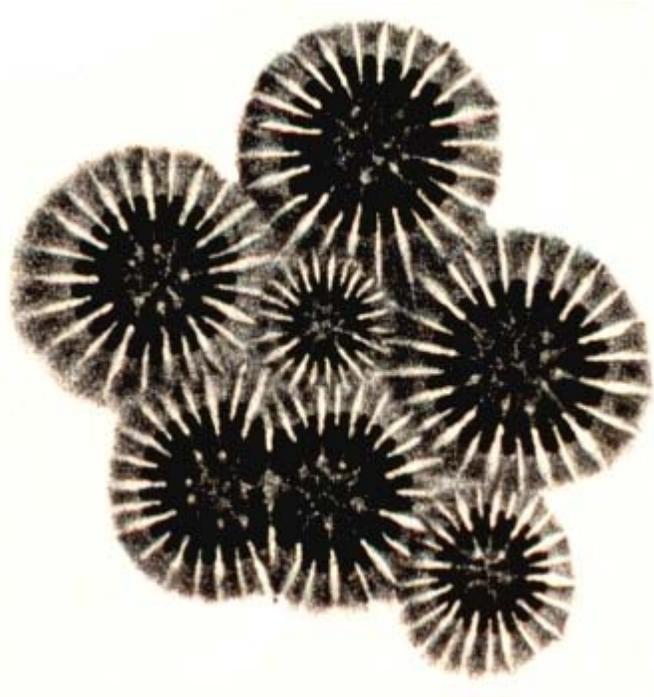
Synchronous spawning is very typical on the coral reef and often, even when multiple species are present, all corals spawn on the same night. This synchrony is essential so that male and female gametes can meet. Corals must rely on environmental cues, varying from species to species, to determine the proper time to release gametes into the water. The cues involve lunar changes, sunset time, and possibly chemical signalling. Synchronous spawning may form hybrids and is perhaps involved in coral speciation. In some places the spawn can be visually dramatic, clouding the usually clear water with gametes, typically at night.

Corals use two methods for sexual reproduction, which differ in whether the female gametes are released:

- **Broadcasters**, the majority of which mass spawn, rely heavily on environmental cues, because they release both sperm and eggs into the water. The corals use long-term cues such as day length, water temperature, and/or rate of temperature change. The short-term cue is most often the lunar cycle, with sunset cuing the release. About 75% of coral species are broadcasters, the majority of which are hermatypic, or reef-building corals. The positively buoyant gametes float towards the surface where fertilization produces planula larvae. The larvae swim towards the surface light to enter into currents, where they remain usually for two days, but can be up to three weeks, and in one known case two months, after which they settle and metamorphose into polyps and form colonies.

- **Brooders** are most often ahermatypic (non-reef building) in areas of high current or wave action. Brooders release only sperm, which is negatively buoyant, and can harbor unfertilized eggs for weeks, lowering the need for mass synchronous spawning events, which do sometimes occur. After fertilization the corals release planula larvae which are ready to settle.

Asexual



Calices (basal plates) of *Orbicella annularis* showing multiplication by gemmation (small central calice) and division (large double calice)



The tabulate coral *Aulopora* (Devonian) showing initial budding from protocorallite

Within a coral head the genetically identical polyps reproduce asexually, either via gemmation (budding) or division, both shown in the photo of *Orbicella annularis*. Budding involves a new polyp growing from an adult, whereas division forms two polyps each as large as the original.

- **Budding** expands colony size. It occurs when a new corallite grows out from an adult polyp. As the new polyp grows it produces its body parts. The distance between the new and adult polyps grows, and with it the coenosarc (the common body of the colony). Budding can be:
 - **Intra-tentacular**—from its oral discs, producing same-sized polyps within the ring of tentacles.
 - **Extra-tentacular**—from its base, producing a smaller polyp.

- **Longitudinal division** begins when a polyp broadens and then divides its coelenteron. The mouth also divides and new tentacles form. The two "new" polyps then generate their missing body parts and exoskeleton.
- **Transversal division** occurs when polyps and the exoskeleton divide transversally into two parts. This means that one has the basal disc (bottom) and the other has the oral disc (top). The two new polyps must again generate the missing pieces.

Colony division

- **Fission** occurs in some corals, especially among the family Fungiidae, where the colony splits into two or more colonies during early developmental stages.

Whole colonies can reproduce asexually through fragmentation or bailout, forming another individual colony with the same genotype.

- **Bailout** occurs when a single polyp abandons the colony and settles on a different substrate to create a new colony.
- **Fragmentation**, involves individuals broken from the colony during storms or other situations. The separated individuals can start new colonies.

Reefs



Locations of coral reefs

The hermatypic, stony corals are often found in coral reefs, large calcium carbonate structures generally found in shallow, tropical water. Reefs are built up from coral skeletons and held together by layers of calcium carbonate produced by coralline algae. Reefs are extremely diverse marine ecosystems hosting over 4,000 species of fish, massive numbers of cnidarians, mollusks, crustaceans, and many other animals.

Types

Perforate corals

Corals can be perforate or imperforate. Perforate corals have porous skeletons, which allows their polyps to connect with each other through the skeleton. Imperforate corals have hard solid skeletons.

Hermatypic corals

Hermatypic or stony corals build reefs. With the help of zooxanthellae, they convert surplus food to calcium carbonate forming a hard skeleton. Hermatypic species include Scleractinia, Millepora, Tubipora and Heliopora.

In the Caribbean alone 50 species of uniquely structured hard coral exist. Well known types include:

- Brain coral grow to 1.8 meters (6 ft) in width.
- Acropora and Staghorn coral grow fast and large and are important reef-builders. Staghorn coral displays large antler-like branches and grows in areas with strong surf.
- Galaxea fascicularis or star coral is another important reef-builder.
- Pillar coral forms pillars which can grow to 3 meters (10 ft) in height.
- Leptopsommia or rock coral, appears almost everywhere in the Caribbean.

Ahermatypic corals

Ahermatypic corals have no zooxanthellae and do not build reefs. They include Alcyonaceas, as well as some Anthipatharia-species (Black coral, Cirripathes, Antipathes). Ahermatypic corals such as sea whips, sea feathers, and sea pens are also known as soft corals. Unlike stony corals, they are flexible, undulating back and forth in the current, and often are perforated, with a lacy appearance. Their skeletons are proteinaceous, rather than calcareous. Soft corals are somewhat less plentiful (in the Caribbean, twenty species appear) than stony corals.

Evolutionary history



Solitary rugose coral (*Grewingkia*) in three views; Ordovician, southeastern Indiana

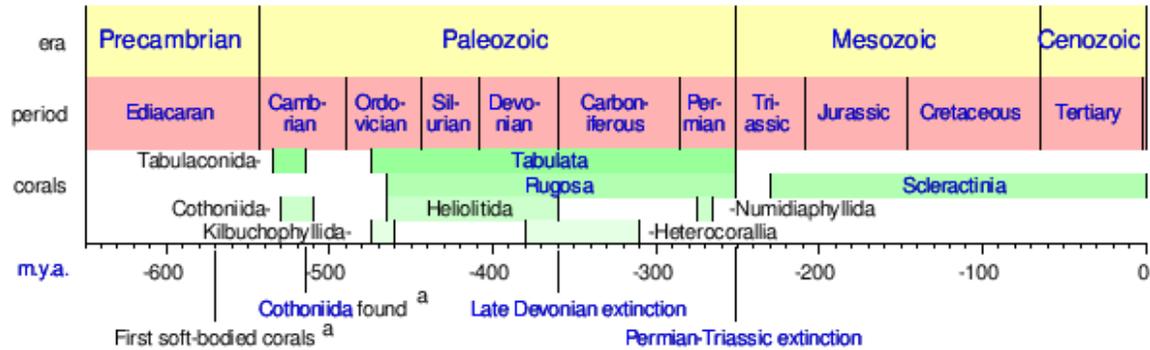
Although corals first appeared in the Cambrian period, some 542 million years ago, fossils are extremely rare until the Ordovician period, 100 million years later, when Rugose and Tabulate corals became widespread.

Tabulate corals occur in the limestones and calcareous shales of the Ordovician and Silurian periods, and often form low cushions or branching masses alongside Rugose corals. Their numbers began to decline during the middle of the Silurian period and they finally became extinct at the end of the Permian period, 250 million years ago. The skeletons of Tabulate corals are composed of a form of calcium carbonate known as calcite.

Rugose corals became dominant by the middle of the Silurian period, and became extinct early in the Triassic period. The Rugose corals existed in solitary and colonial forms, and are also composed of calcite.

The Scleractinian corals filled the niche vacated by the extinct Rugose and Tabulate species. Their fossils may be found in small numbers in rocks from the Triassic period,

and become common in the Jurassic and later periods. Scleractinian skeletons are composed of a form of calcium carbonate known as aragonite. Although they are geologically younger than the Tabulate and Rugose corals, their aragonitic skeleton is less readily preserved, and their fossil record is less complete.



Timeline of the major coral fossil record and developments from 650 m.y.a. to present.

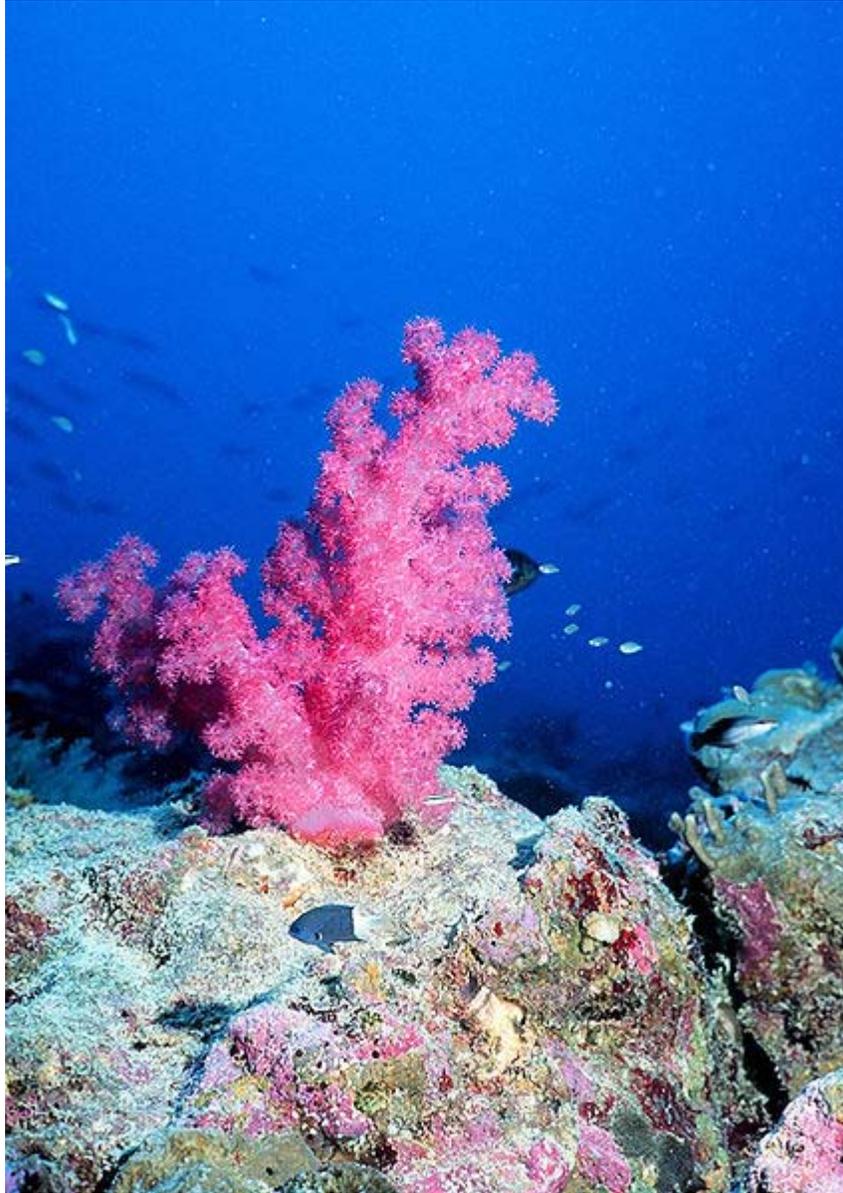
At certain times in the geological past corals were very abundant. Like modern corals, these ancestors built reefs, some of which now lie as great structures in sedimentary rocks.

Fossils of fellow reef-dwellers algae, sponges, and the remains of many echinoids, brachiopods, bivalves, gastropods, and trilobites appear along with coral fossils. This makes some corals useful index fossils, enabling geologists to date the age the rocks in which they are found.

Coral fossils are not restricted to reef remnants, and many solitary corals may be found elsewhere, such as *Cyclocyathus*, which occurs in England's Gault clay formation.

A Petoskey stone is a rock and a fossil, often pebble-shaped, that is composed of a fossilized coral, *Hexagonaria percarinata*. They are found predominantly in Michigan's Upper Peninsula, and the northwestern portion of Michigan's lower peninsula.

Threats



A healthy coral reef has a striking level of biodiversity in many forms of marine life

Corals are highly sensitive to environmental changes. Scientists have predicted that over 50% of the world's coral reefs may be destroyed by 2030; as a result most nations protect them through environmental laws.

Seaweed/Algae can destroy a coral reef. In the Caribbean and tropical Pacific, direct contact between ~40 to 70% of common seaweeds and coral cause bleaching and death to the coral via transfer of lipid-soluble metabolites. Seaweed and algae proliferate given adequate nutrients and limited grazing by herbivores. Coral die if surrounding water temperature changes by more than a degree or two beyond their normal range or if water

salinity drops. In an early symptom of environmental stress, corals expel their zooxanthellae; without their symbiotic algae, coral tissues become colorless as they reveal the white of their calcium carbonate skeletons, an event known as coral bleaching.

Many governments now prohibit removal of coral from reefs and use education to inform their populations about reef protection and ecology. However, many other human activities damage reefs, including runoff, mooring, fishing, diving, mining and construction.

Coral's narrow niche and the stony corals' reliance on calcium carbonate deposition makes them susceptible to changes in water pH. The increase in atmospheric carbon dioxide has caused enough dissolution of carbon dioxide to lower the ocean's pH, in a process known as ocean acidification. Lowered pH reduces corals' ability to produce calcium carbonate, and at the extreme, can dissolve their skeletons. Without deep and immediate cuts in anthropogenic CO₂, many scientists fear that acidification will severely degrade or destroy coral ecosystems.



A section through a coral, dyed to determine growth rate

Importance to humans

Local economies near major coral reefs benefit from an abundance of fish and other marine creatures as a food source. Reefs also provide recreational scuba diving and snorkeling tourism. Unfortunately these activities can have deleterious effects, such as accidental destruction of coral. Coral is also useful as a protection against hurricanes and other extreme weather.

Coral reefs provide medical benefits for humans. Chemical compounds taken from corals are used in medicine for cancer, AIDS, pain, and other uses. Corals are also commonly used for bone grafting in humans.

Live coral is highly sought after for aquaria. Given the proper ecosystem, live coral makes a stunning addition to any salt water aquarium. Soft corals are easier to maintain in captivity than hard corals.

Isididae may be usable as living bone implants and in aquatic cultivation, because of their potential to mimic valuable biological properties.

In jewelry

Coral's many colors give it appeal for necklaces and other jewelry. Intensely red coral is prized as a gemstone. It is sometimes called fire coral, but is not the same as fire coral. Red coral is very rare because of overharvesting due to the great demand for perfect specimens.

In construction



Tabulate coral (a syringoporid); Boone Limestone (Lower Carboniferous) near Hiwasse, Arkansas. Scale bar is 2.0 cm.

Ancient coral reefs on land provide lime or use as building blocks ("coral rag"). Coral rag is an important local building material in places such as the East African coast.

In climate research

The annual growth bands in bamboo corals and others allow geologists to construct year-by-year chronologies, a form of incremental dating, which underlie high-resolution records of past climatic and environmental changes using geochemical techniques.

Certain species form communities called microatolls, which are colonies whose top is dead and mostly above the water line, but whose perimeter is mostly submerged and alive. Average tide level limits their height. By analyzing the various growth morphologies, microatolls offer a low resolution record of sea level change. Fossilized microatolls can also be dated using radioactive carbon dating. Such methods can help to reconstruct Holocene sea levels.

Deep sea bamboo corals (*Isididae*) may be among the first organisms to display the effects of ocean acidification. They produce growth rings similar to those of tree and can provide a view of changes in the condition in the deep sea over time.



Brain coral, *Diploria labyrinthiformis*



Staghorn coral, *Acropora*



Orange cup coral, *Balanophyllia elegans*



Brain coral spawning



Brain coral releasing eggs



Fringing coral reef off the coast of Eilat, Israel

Chapter- 4

Sea Anemone

Sea anemone



Various examples of sea anemones

Scientific classification

Kingdom:	Animalia
Phylum:	Cnidaria
Class:	Anthozoa
Subclass:	Hexacorallia
Order:	Actiniaria

Suborders

- Endocoelanthaeae
- Nyantheae
- Protantheae
- Ptychodactaeae

Diversity

46 families



The 49th plate from Ernst Haeckel's *Kunstformen der Natur*, 1904, showing various sea anemones classified as Actiniae

Sea anemones are a group of water-dwelling, predatory animals of the order **Actiniaria**; they are named after the anemone, a terrestrial flower. Sea anemones are classified in the phylum Cnidaria, class Anthozoa, subclass Zoantharia. Anthozoa often have large polyps that allow for digestion of larger prey and also lack a medusa stage. As cnidarians, sea anemones are closely related to corals, jellyfish, tube-dwelling anemones, and *Hydra*.

Anatomy

A sea anemone is a polyp attached at the bottom to the surface beneath it by an adhesive foot, called a basal disc, with a column shaped body ending in an oral disc. Most are from

1.8 to 3 centimetres (0.71 to 1.2 in) in diameter, but anemones as small as 4 millimetres (0.16 in) or as large as nearly 2 metres (6.6 ft) are known. They can have anything from a few tens of tentacles to a few hundred tentacles.

A few species are pelagic, and are not attached to the bottom; instead they have a gas chamber within the pedal disc, allowing them to float upside down in the water.

The mouth is in the middle of the oral disc surrounded by tentacles armed with many cnidocytes, which are cells that function as a defense and as a means to capture prey. Cnidocytes contain nematocyst, capsule-like organelles capable of everting, giving phylum Cnidaria its name. The cnidae that sting are called *nematocysts*. Each nematocyst contains a small vesicle filled with toxins (actinoporins), an inner filament, and an external sensory hair. When the hair is touched it mechanically triggers the cell explosion, a harpoon-like structure which attaches to organisms that trigger it, and injects a dose of poison in the flesh of the aggressor or prey. This gives the anemone its characteristic sticky feeling. The sea anemone eats small fish and shrimp.

The poison is a mix of toxins, including neurotoxins, which paralyzes the prey and allows it to be moved to the mouth for digestion inside the gastrovascular cavity. Actinoporins have been reported as highly toxic to fish and crustaceans, which are the natural prey of sea anemones. In addition to their role in predation, it has been suggested that actinoporins could act, when released in water, as repellents against potential predators. Anemonefish (clownfish), small banded fish in various colors, are not affected by their host anemone's sting and shelter from predators within its tentacles.

The internal anatomy of anemones is quite complex.

Digestive system

There is a gastrovascular cavity (which functions as a stomach) with a single opening to the outside which functions as both a mouth and an anus; waste and undigested matter is excreted through the mouth/anus, which can be described as an incomplete gut. The mouth is typically slit-like in shape, and bears a groove at one or both ends. The groove, termed a *siphonophore*, is ciliated, and helps to circulate water through the gastrovascular cavity. Some anemones feed on small particles, which are caught with the aid of a mucus secretion and moving currents that are set up by the tentacles. Most sea anemones are predacious, immobilizing their prey with the aid of their nematocysts.

The mouth opens into a flattened pharynx. This consists of an in-folding of the body wall, and is therefore lined by the animal's epidermis. The pharynx typically runs for about two-thirds the length of the body before opening into the gastrovascular cavity that fills the remainder of the body.

The gastrovascular cavity itself is divided into a number of chambers by mesenteries radiating inwards from the body wall. Some of the mesenteries form complete partitions with a free edge at the base of the pharynx, to which they connect, but others reach only

partway across. The mesenteries are usually found in multiples of twelve, and are symmetrically arranged around the central pharynx. They have stomach lining on both sides, separated by a thin layer of mesoglea, and includes filaments of tissue specialised for secreting digestive enzymes. In some species these filaments extend below the lower margin of the mesentery, hanging free in the gastrovascular cavity as *acontial filaments*.

Nervous system

A primitive nervous system, without centralization, coordinates the processes involved in maintaining homeostasis as well as biochemical and physical responses to various stimuli. There are no specialized sense organs.

The muscles and nerves are much simpler than those of most other animals, although more specialised than in other cnidarians, such as corals. Cells in the outer layer (epidermis) and the inner layer (gastrodermis) have microfilaments that group into contractile fibers. These fibers are not true muscles because they are not freely suspended in the body cavity as they are in more developed animals. Longitudinal fibres are found in the tentacles and oral disc, and also within the mesenteries, where they can contract the whole length of the body. Circular fibres are found in the body wall and, in some species, around the oral disc, allowing the animal to retract its tentacles into a protective sphincter.

Since the anemone lacks a skeleton, the contractile cells pull against the gastrovascular cavity, which acts as a hydrostatic skeleton. The anemone stabilizes itself by shutting its mouth, which keeps the gastrovascular cavity at a constant volume, making it more rigid. Although generally sessile, sea anemones are capable of slow movements using their pedal disc, or of swimming, using either their tentacles or by flexing their body.

Life cycle



Asexual reproduction of sea anemone via budding

Unlike other cnidarians, anemones (and other anthozoans) entirely lack the free-swimming medusa stage of the life cycle; the polyp produces eggs and sperm, and the fertilized egg develops into a planula that develops directly into another polyp.

Anemones tend to stay in the same spot until conditions become unsuitable (prolonged dryness, for example), or a predator attacks them. In that case anemones can release themselves from the substrate and use flexing motions to swim to a new location. Most sea anemones attach temporarily to submerged objects; a few thrust themselves into the sand or live in furrows; a few are parasitic on other marine organisms.

The sexes in sea anemones are separate in some species, while others are protandric hermaphrodites. The gonads are strips of tissue within the mesenteries. Both sexual and asexual reproduction can occur. In sexual reproduction males release sperm to stimulate females to release eggs, and fertilization occurs. Anemones eject eggs and sperm through the mouth. The fertilized egg develops into a planula, which settles and grows into a single polyp.

Anemones can also reproduce asexually, by budding, binary fission (the polyp separates into two halves), and pedal laceration, in which small pieces of the pedal disc break off and regenerate into small anemones.

Ecology



Venus' fly-trap anemone (*Actinoscyphia*) in the Gulf of Mexico

The sea anemone has a pedal disc, which the organism uses to attach itself to rocks or which it anchors in the sand. Others also burrow into a stronger object. Some species attach to kelp and others are free-swimming. Although not plants and therefore incapable of photosynthesis themselves, many sea anemones form an important facultative symbiotic relationship with certain single-celled green algae species which reside in the

animals' gastrodermal cells. These algae may be either zooxanthellae, zoochlorellae or both. The sea anemone benefits from the products of the algae's photosynthesis, namely oxygen and food in the form of glycerol, glucose and alanine; the algae in turn are assured a reliable exposure to sunlight and protection from micro-feeders, which the sea anemones actively maintain. The algae also benefit by being protected due to the presence of stinging cells called nematocysts, reducing the likelihood of being eaten by herbivores. Most species inhabit tropical reefs, although there are species adapted to relatively cold waters, intertidal reefs, and sand/kelp environments.

Exploitation

The global trade of marine ornamentals has been a rapidly expanding industry involving numerous countries worldwide. In the early 1980s the estimated value of imported marine fish and invertebrates was US\$24–40 million annually. Current estimates place that value at US\$200–330 million, with the United States accounting for 80% of the industry imports. Despite advances and the expansion of aquaculture, post-larval capture and rearing, the majority of marine ornamentals are collected in the wild as adults or juveniles. Anemones are susceptible to overexploitation due to their long life spans, slower relative growth rates, and lower reproductive rates than their resident fish, which are also affected due to the fact that they settle exclusively and are restricted to specific host sea anemones. The demand for these organisms is reflected in fishermen's catch records, which document the value they are paid per catch, and on average sea anemones were valued at five times the average value of anemonefish, and ten times the value of the most abundant anemonefish, and in fact only made up 4.1% of the total value of the catch. Research has shown that aquarium fishing activities significantly impact the populations of anemones and anemonefish by drastically reducing the densities of each in exploited areas, and could also negatively impact anemone shrimp, and any organisms obligately associated with sea anemones. It should be noted that anemonefish can survive alone in captivity, as has been shown by multiple research efforts.

Fossil record

Most Actiniaria do not form hard parts that can be recognized as fossils but a few fossils do exist; *Mackenzia*, from the Middle Cambrian Burgess Shale of Canada, is the oldest fossil identified as a sea anemone.

Chapter- 5

Jellyfish

Jellyfish



Pacific sea nettle jellyfish
Chrysaora fuscescens.

Scientific classification

Kingdom: Animalia
Phylum: Cnidaria
Subphylum: **Medusozoa**
Petersen, 1979

Classes

Cubozoa
Hydrozoa
Polypodiozoa
Scyphozoa
Staurozoa

Jellyfish (also known as **jellies** or **sea jellies** or **Medusozoa**) are free-swimming members of the phylum Cnidaria. Jellyfish have several different morphologies that represent several different cnidarian classes including the Scyphozoa (over 200 species), Staurozoa (about 50 species), Cubozoa (about 20 species), and Hydrozoa (about 1000–1500 species that make jellyfish and many more that do not). *Medusa* is another word for *jellyfish*, and refers to any free-swimming jellyfish stages in the phylum Cnidaria.

Jellyfish are found in every ocean, from the surface to the deep sea. Some hydrozoan jellyfish, or hydromedusae, are also found in fresh water; freshwater species are less than an inch (25 mm) in diameter, are colorless and do not sting. Many of the best-known jellyfish, such as Aurelia, are scyphomedusae. These are the large, often colorful, jellyfish that are common in coastal zones worldwide.

In its broadest sense, the term jellyfish also generally refers to members of the phylum Ctenophora. Although not closely related to cnidarian jellyfish, ctenophores are also free-swimming planktonic carnivores, are generally transparent or translucent, and exist in shallow to deep portions of all the world's oceans.

Alternative names for groups of jellyfish are scyphomedusae, stauromedusae, cubomedusae, and hydromedusae. These may relate to an entire order or class.

Terminology

The word *jellyfish* (which has been in common usage for more than a century) is used to denote several different kinds of cnidarians, all of which have a basic body structure that resembles an umbrella, including scyphozoans, staurozoans (stalked jellyfish), hydrozoans, and cubozoans (box jellyfish). Some textbooks and websites refer to scyphozoans as "true jellyfish".

Since jellyfish are not even vertebrates, let alone true fish, the usual word *jellyfish* is considered by some to be a misnomer, and American public aquariums have popularized use of the terms *jellies* or *sea jellies* instead.

In its broadest usage, some scientists occasionally include members of the phylum Ctenophora (comb jellies) when they are referring to jellyfish. Other scientists prefer to use the more all-encompassing term "gelatinous zooplankton", when referring to these, together with other soft-bodied animals in the water column.

A group of jellyfish is sometimes called a bloom or a swarm. "Bloom" is usually used for a large group of jellyfish that gather in a small area, but may also have a time component, referring to seasonal increases, or numbers beyond what was expected. Another collective name for a group of jellyfish is a *smack*.

Jellyfish are "bloomy" by nature of their life cycles, being produced by their benthic polyps usually in the spring when sunshine and plankton increase, so they appear rather suddenly and often in large numbers, even when an ecosystem is in balance. Using

"swarm" usually implies some kind of active ability to stay together, which a few species like *Aurelia*, the moon jelly, demonstrate.

Most jellyfish have a second part of their life cycle, which is called the polyp phase. When single polyps, arising from a single fertilized egg, develop into a multiple-polyp cluster, connected to each other by strands of tissue called stolons, they are said to be "colonial." A few polyps never proliferate and are referred to as "solitary" species.

Anatomy

Jellyfish do not have specialized digestive, osmoregulatory, central nervous, respiratory, or circulatory systems. They digest using the gastrodermal lining of the gastrovascular cavity, where nutrients are absorbed. They do not need a respiratory system since their skin is thin enough that the body is oxygenated by diffusion. They have limited control over movement, but can use their hydrostatic skeleton to accomplish movement through contraction-pulsations of the bell-like body; some species actively swim most of the time, while others are passive much of the time. Jellyfish are composed of more than 90% water; most of their umbrella mass is a gelatinous material — the jelly — called mesoglea which is surrounded by two layers of epithelial cells which form the umbrella (top surface) and subumbrella (bottom surface) of the bell, or body.

A jellyfish does not have a brain or central nervous system, but rather has a loose network of nerves, located in the epidermis, which is called a "nerve net". A jellyfish detects various stimuli including the touch of other animals via this nerve net, which then transmits impulses both throughout the nerve net and around a circular nerve ring, through the rhopalial lappet, located at the rim of the jellyfish body, to other nerve cells. Some jellyfish also have ocelli: light-sensitive organs that do not form images but which can detect light, and are used to determine up from down, responding to sunlight shining on the water's surface. These are generally pigment spot ocelli, which have some cells (not all) pigmented.

Jellyfish blooms



Aurelia sp., occurs in large quantities in most of the world's coastal waters. Members of this genus are nearly identical to each other.

The presence of ocean blooms is usually seasonal, responding to prey availability and increasing with temperature and sunshine. Ocean currents tend to congregate jellyfish into large swarms or "blooms", consisting of hundreds or thousands of individuals. In addition to sometimes being concentrated by ocean currents, blooms can result from unusually high populations in some years. Bloom formation is a complex process that depends on ocean currents, nutrients, temperature, predation, and oxygen concentrations. Jellyfish are better able to survive in oxygen-poor water than competitors, and thus can thrive on plankton without competition. Jellyfish may also benefit from saltier waters, as saltier waters contain more iodine, which is necessary for polyps to turn into jellyfish. Rising sea temperatures caused by climate change may also contribute to jellyfish blooms, because many species of jellyfish are better able to survive in warmer waters. Jellyfish are likely to stay in blooms that are quite large and can reach up to 100,000 in each.

There is very little data about changes in global jellyfish populations over time, besides "impressions" in the public memory. Scientists have little quantitative data of historic or current jellyfish populations. Recent speculation about increases in jellyfish populations are based on no "before" data.

The global increase in jellyfish bloom frequency may stem from human impact. In some locations jellyfish may be filling ecological niches formerly occupied by now overfished creatures, but this hypothesis lacks supporting data. Jellyfish researcher Marsh Youngbluth further clarifies that "jellyfish feed on the same kinds of prey as adult and young fish, so if fish are removed from the equation, jellyfish are likely to move in."

Some jellyfish populations that have shown clear increases in the past few decades are "invasive" species, newly arrived from other habitats: examples include the Black Sea and the Caspian Sea, the Baltic Sea, the eastern Mediterranean coasts of Egypt and Israel, and the American coast of the Gulf of Mexico. Populations of invasive species can expand rapidly because there are often no natural predators in the new habitat to check their growth. Such blooms would not necessarily reflect overfishing or other environmental problems.

Increased nutrients, ascribed to agricultural runoff, have also been cited as an antecedent to the proliferation of jellyfish. Monty Graham, of the Dauphin Island Sea Lab in Alabama, says that "ecosystems in which there are high levels of nutrients ... provide nourishment for the small organisms on which jellyfish feed. In waters where there is eutrophication, low oxygen levels often result, favoring jellyfish as they thrive in less oxygen-rich water than fish can tolerate. The fact that jellyfish are increasing is a symptom of something happening in the ecosystem."

By sampling sea life in a heavily fished region off the Namibian coast, total jellyfish biomass has overtaken that of fish, following intense fishing in the area in the last few decades.

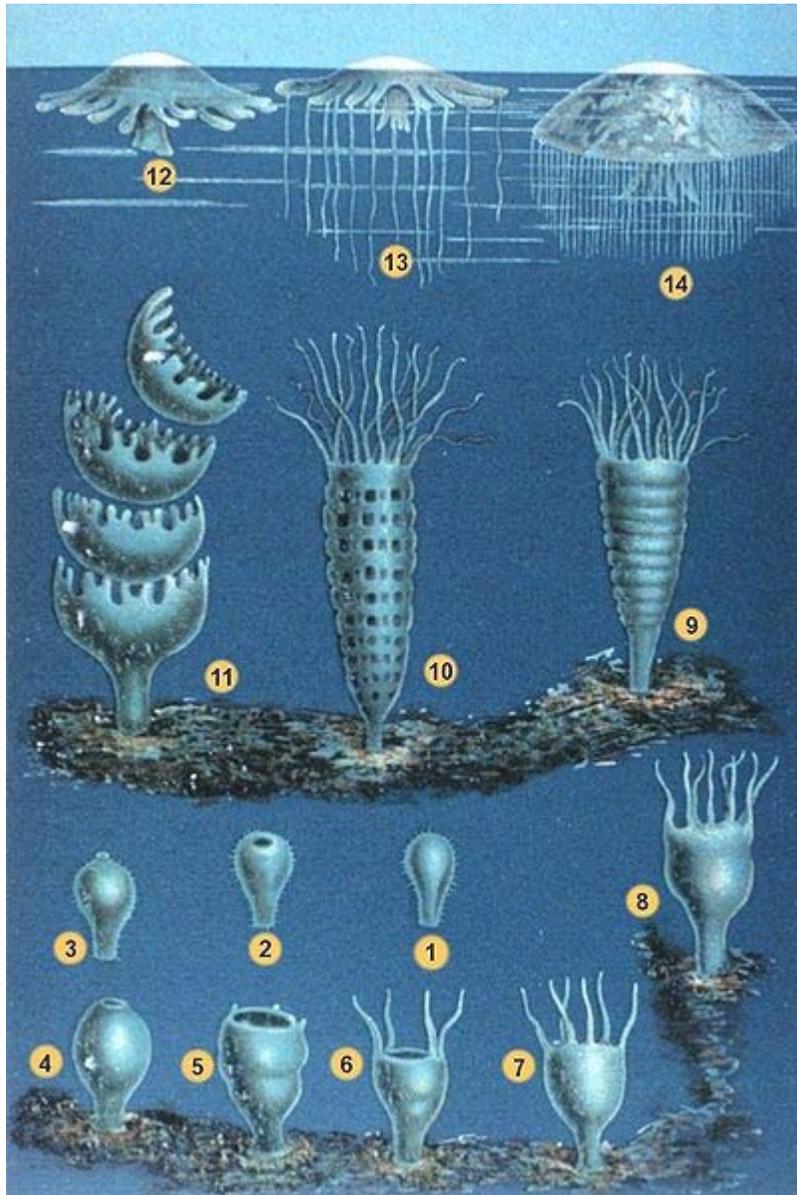
Areas which have been seriously affected by jellyfish blooms include the northern Gulf of Mexico, about which, Graham states, "Moon jellies have formed a kind of gelatinous net that stretches from end to end across the gulf."

Detrimental effects

Jellyfish blooms cause problems for mankind. The most obvious are stings to humans (sometimes deadly), and causing coastal tourism to decline. Other problems are destroying fish nets, poisoning or crushing captured fish, and consuming fish eggs and young fish.

Clogging also causes many problems including stoppage of nuclear power plants and desalination plants, as well as clogging engines of ships and even overturning of boats by one of the largest species, the Nomura's jellyfish.

Life cycle



The developmental stages of scyphozoan jellyfish's life cycle

Most jellyfish undergo two distinct life history stages (body forms) during their life cycle. The first is the *polypoid* stage, when the animal takes the form of a small stalk with feeding tentacles; this polyp may be sessile, living on the bottom or on similar substrata such as floats or boat-bottoms, or it may be free-floating or attached to tiny bits of free-living plankton or rarely, fish or other invertebrates. Polyps generally have a mouth surrounded by upward-facing tentacles like miniatures of the closely related anthozoan polyps (sea anemones and corals), also of the phylum Cnidaria. Polyps may be solitary or colonial, and some bud asexually by various means, making more polyps. Most are very small, measured in millimeters.

In the second stage, the tiny polyps asexually produce jellyfish, each of which is also known as a *medusa*. Tiny jellyfish (usually only a millimeter or two across) swim away from the polyp and then grow and feed in the plankton. Medusae have a radially symmetric, umbrella-shaped body called a *bell*, which is usually supplied with marginal tentacles - fringe-like protrusions from the bell's border that capture prey. A few species of jellyfish do not have the polyp portion of the life cycle, but go from jellyfish to the next generation of jellyfish through direct development of fertilized eggs.

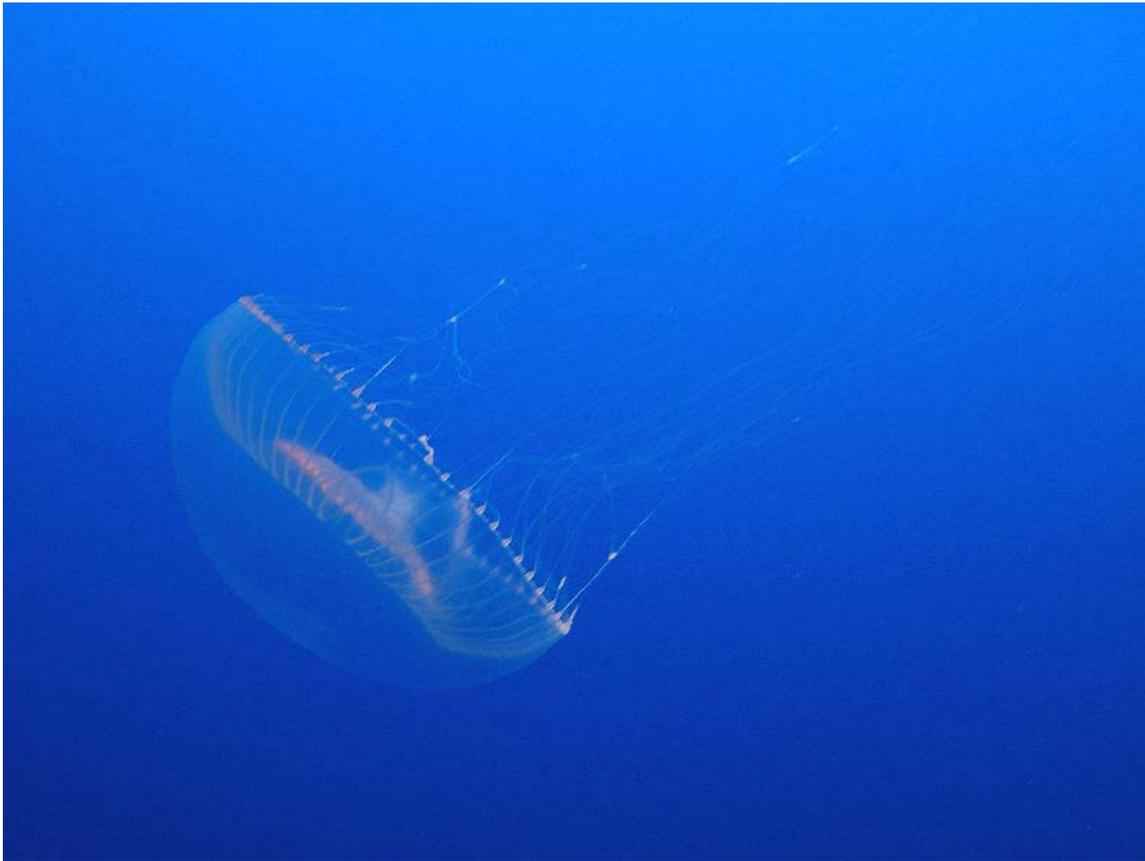
Jellyfish are dioecious; that is, they are usually either male or female (occasionally hermaphroditic specimens are found). In most cases, both release sperm and eggs into the surrounding water, where the (unprotected) eggs are fertilized and mature into new organisms. In a few species, the sperm swim into the female's mouth fertilizing the eggs within the female's body where they remain for the early stages of development. In moon jellies, the eggs lodge in pits on the oral arms, which form a temporary brood chamber for the developing planula larvae.

After fertilization and initial growth, a larval form, called the *planula*, develops. The planula is a small larva covered with cilia. It settles onto a firm surface and develops into a polyp. The polyp is cup-shaped with tentacles surrounding a single orifice, resembling a tiny sea anemone. After a growth interval, the polyp begins reproducing asexually by budding and, in the Scyphozoa, is called a *segmenting polyp*, or a scyphistoma. New scyphistomae may be produced by budding or new, immature jellies called *ephyrae* may be formed. A few jellyfish species can produce new medusae by budding directly from the medusan stage. Budding sites vary by species; from the tentacle bulbs, the manubrium (above the mouth), or the gonads of hydromedusae. A few of species of hydromedusae reproduce by *fission* (splitting in half).

Other species of jellyfish are among the most common and important jellyfish predators, some of which specialize in jellies. Other predators include tuna, shark, swordfish, sea turtles and at least one species of Pacific salmon. Sea birds sometimes pick symbiotic crustaceans from the jellyfish bells near the sea's surface, inevitably feeding also on the jellyfish hosts of these amphipods or young crabs and shrimp.

Jellyfish lifespans typically range from a few hours (in the case of some very small hydromedusae) to several months. Life span and maximum size varies by species. One unusual species is reported to live as long as 30 years. Another species, *Turritopsis dohrnii* as *T. nutricula*, may be effectively immortal because of its ability to transform between medusa and polyp, thereby escaping death. Most large coastal jellyfish live 2 to 6 months, during which they grow from a millimeter or two to many centimeters in diameter. They feed continuously and grow to adult size fairly rapidly. After reaching adult size, jellyfish spawn daily if there is enough food. In most species, spawning is controlled by light, so the entire population spawns at about the same time of day, often at either dusk or dawn.

In biotechnology



The hydromedusa *Aequorea victoria*

In 1961, Osamu Shimomura of Princeton University extracted green fluorescent protein (GFP) and another bioluminescent protein, called aequorin, from the large and abundant hydromedusa *Aequorea victoria*, while studying photoproteins that cause bioluminescence by this species of jellyfish. Three decades later, Douglas Prasher, a post-doctoral scientist at Woods Hole Oceanographic Institution, sequenced and cloned the gene for GFP. Martin Chalfie of Columbia University soon figured out how to use GFP as a fluorescent marker of genes inserted into other cells or organisms. Roger Tsien of University of California, San Diego, later chemically manipulated GFP in order to get other colors of fluorescence to use as markers. In 2008, Shimomura, Chalfie, and Tsien won the Nobel Prize in Chemistry for their work with GFP.

Man-made GFP is now commonly used as a fluorescent tag to show which cells or tissues express specific genes. The genetic engineering technique fuses the gene of interest to the GFP gene. The fused DNA is then put into a cell, to generate either a cell line or (via IVF techniques) an entire animal bearing the gene. In the cell or animal, the artificial gene turns on in the same tissues and the same time as the normal gene. But instead of making the normal protein, the gene makes GFP. One can then find out what tissues express that protein—or at what stage of development—by shining light on the

animal or cell and observing fluorescence. The fluorescence shows where the gene is expressed.

Jellyfish are also harvested for their collagen, which can be used for a variety of applications including the treatment of rheumatoid arthritis.

In captivity



A group of Pacific sea nettle jellyfish, *Chrysaora fuscescens*, in an aquarium exhibit

Jellyfish are displayed in aquariums in many countries. Often the tank's background is blue and the animals are illuminated by side light, increasing the contrast between the animal and the background. In natural conditions, many jellies are so transparent that they are nearly invisible.

Jellyfish are not adapted to closed spaces. They depend on currents to transport them from place to place. Professional exhibits feature precise water flows, typically in circular tanks to prevent specimens from becoming trapped in corners. The Monterey Bay Aquarium uses a modified version of the *kreisel* (German for "spinning top") for this purpose. Jellyfish are becoming a popular trend in home aquariums. It is now possible to buy jellyfish aquariums and live jellyfish online. It is also possible to assemble a jellyfish aquarium for personal use.

Toxicity to humans

All jellyfish sting their prey using nematocysts, also called cnidocytes, stinging structures located in specialized cells called cnidocytes, which are characteristic of all Cnidaria. Contact with a jellyfish tentacle can trigger millions of nematocysts to pierce the skin and inject venom, yet the sting of only some jellyfish species causes an adverse reaction in humans. When a nematocyst is triggered by contact by predator or prey, pressure builds up rapidly inside it up to 2,000 lbs/sq. inch until it bursts open. A lance inside the nematocyst pierces the victim's skin, and poison flows through into the victim. Touching or being touched by a jellyfish can be very uncomfortable, sometimes requiring medical assistance; sting effects range from no effect to extreme pain to death. Because of the wide variation in response to jellyfish stings, it is wisest not to contact any jellyfish with bare skin. Even beached and dying jellyfish can still sting when touched.

Scyphozoan jellyfish stings range from a twinge to tingling to savage agony. Most jellyfish stings are not deadly, but stings of some species of the class *Cubozoa* and the Box jellyfish, such as the famous and especially toxic Irukandji jellyfish, can be deadly. Stings may cause anaphylaxis, which can be fatal. Medical care may include administration of an antivenom.

In 2010 at a New Hampshire beach, pieces of a single dead lion's mane jellyfish stung between 125 and 150 people. Jellyfish kill 20 to 40 people a year in the Philippines alone. In 2006 the Spanish Red Cross treated 19,000 stung swimmers along the Costa Brava.

Treatment

The three goals of first aid for uncomplicated jellyfish stings are to prevent injury to rescuers, deactivate the nematocysts, and remove tentacles attached to the patient. Rescuers need to wear barrier clothing, such as pantyhose, wet suits or full-body sting-proof suits. Deactivating the nematocysts (stinging cells) prevents further injection of venom.



Like many species of jellyfish, the sting of some species of *Mastigias* have no discernible effect on humans.

Vinegar (3 to 10% aqueous acetic acid) is a common remedy to help with box jellyfish stings, but not the stings of the Portuguese Man o' War (which is not a true jellyfish, but a colony). For stings on or around the eyes, a towel dampened with vinegar is used to dab around the eyes, with care taken to avoid the eyeballs. Salt water is also used if vinegar is unavailable. Fresh water is not used if the sting occurs in salt water, as changes in tonicity can release additional venom. Rubbing wounds, or using alcohol, spirits, ammonia, or urine may have strongly negative effects as these can also encourage the release of venom.

Clearing the area of jelly, tentacles, and wetness further reduces nematocyst firing. Scraping the affected skin with a knife edge, safety razor, or credit card can remove remaining nematocysts.

Beyond initial first aid, antihistamines such as diphenhydramine (Benadryl) can control skin irritation (pruritus). For removal of venom in the skin, a paste of baking soda and water can be applied with a cloth covering on the sting. In some cases it is necessary to reapply paste every 15–20 minutes. Ice or fresh water is not be applied to the sting, as this may help the nematocysts to continue releasing their toxin.

Overpopulation and impact

Evidence in recent years suggest that the population of jellyfish has swelled as a result of overfishing which reduces the number of predatory organisms that feed on them. This has allowed jellyfish to proliferate to the extent that they adversely effect humanity by interfering with public systems and harming swimmers.

By clogging cooling equipment in mass, jellyfish have disabled power plants in several countries, including a cascading blackout in the Philippines in 1999 as well as in the Diablo Canyon Power Plant in California in 2010.

Taxonomic classification systematics

Taxonomic classification systematics within the Cnidaria, as with all organisms, are always in flux. Many scientists who work on relationships between these groups are reluctant to assign ranks, although there is general agreement on the different groups, regardless of their absolute rank. Presented here is one scheme, which includes all groups that produce medusae (jellyfish), derived from several expert sources:

Phylum Cnidaria

Subphylum Medusozoa

Class Hydrozoa

Subclass Hydroidolina

Order Anthomedusae (= Anthoathecata or Athecata)

Order Leptomedusae (= Leptothecata or Thecata)

Order Siphonophorae

Suborder Physonectae

Families: Agalmatidae, Apolemiidae, Erennidae, Forskaliidae, Physophoridae,

Pyrostephidae, Rhodaliidae

Suborder Calycophorae

Families: Abylidae, Clausophyidae, Diphyidae, Hippopodiidae, Prayidae,

Sphaeronectidae

Suborder Cystonectae

Families: Physaliidae, Rhizophysidae

Subclass Trachylina

Order Limnomedusae

Families: Olindiidae, Monobrachiidae, Microhydrulidae, Armorhydridae

Order Trachymedusae

Families: Geryoniidae, Halicreatidae, Petasidae, Ptychogastriidae,

Rhopalonematidae

Order Narcomedusae

Families: Cuninidae, Solmarisidae, Aeginidae, Tetraplatiidae

Order Actinulidae

Families: Halammohydridae, Otohydridae

Class Staurozoa (= Stauromedusae)

Order Eleutherocarpida

Families: Lucernariidae, Kishinouyeidae, Lipkeidae, Kyopodiidae

Order Cleistocarpida

Families: Depastridae, Thaumatoscyphidae, Craterolophinae

Class Cubozoa

Families: Carybdeidae, Alatinidae, Tamoyidae, Chirodropidae, Chiropsalmidae

Class Scyphozoa

Order Coronatae

Families: Atollidae, Atorellidae, Linuchidae, Nausithoidae, Paraphyllinidae, Periphyllidae

Order Semaestomeae

Families: Cyaneidae, Pelagiidae, Ulmaridae

Order Rhizostomeae

Families: Cassiopeidae, Catostylidae, Cepheidae, Lychnorhizidae, Lobonematidae, Mastigiidae, Rhizostomatidae, Stomolophidae

Largest Jellyfish

Lion's Mane jellyfish, *Cyanea capillata*, have long been cited as the largest known jellyfish, and arguably the longest animals in the world, with fine, thread-like tentacles up to 36.5 m (120 feet) long, but most Lion's Mane jellyfish are nowhere near that large. The increasingly common giant Nomura's jellyfish, *Nemopilema nomurai*, found some, but not all years in the waters of Japan, Korea and China in summer and autumn is probably a much better candidate for "largest jellyfish", since the largest Nomura's jellyfish in late autumn can reach 200 cm (79 inches) in bell (body) diameter and about 200 kg (440 lbs) in weight, with average specimens frequently reaching 90 cm (35 inches) in bell diameter and about 150 kg (330 lbs) in weight. The large bell mass of the giant Nomura's jellyfish can dwarf a diver and is nearly always much greater than the occasionally-up-to-100 cm bell diameter Lion's Mane. The rarely-encountered deep-sea jellyfish *Stygiomedusa gigantea* is another solid candidate for "largest jellyfish", with its 100 cm wide, and thick, massive bell and four thick, "paddle-like" oral arms extending up to 600 cm in length, very different than the typical fine, threadlike tentacles that rim the umbrella of more-typical-looking jellyfish, including the Lion's Mane.



Upside-down jellyfish harbor algae in their tentacles which they turn up to the sun to promote photosynthesis.



The Lion's mane jellyfish



Chrysaora colorata, the purple-striped jellyfish, lives off the coast of Southern California



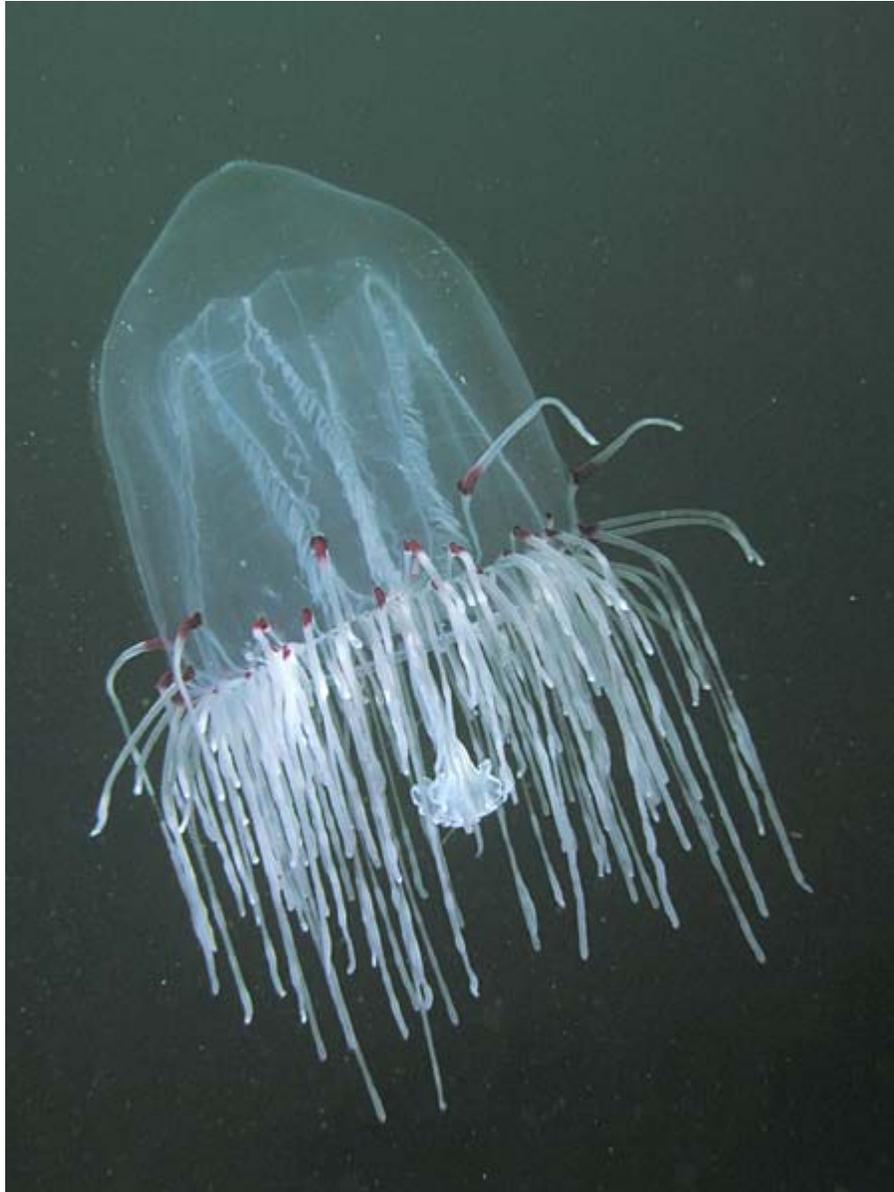
Olindias sp.



Lion's mane jellyfish, *Cyanea capillata*, the largest jellyfish, are known for its painful, but rarely fatal, sting.



A species of Mediterranean jellyfish, *Cotylorhiza tuberculata*, on display at the Monterey Bay Aquarium.



Scrippsia pacifica, a cup-sized jellyfish from the coast of California



Aurelia sp.

Chapter- 6

Box Jellyfish

Box Jellyfish



Chironex sp.

Scientific classification

Kingdom: Animalia
Phylum: Cnidaria
Class: **Cubozoa**
Werner, 1975

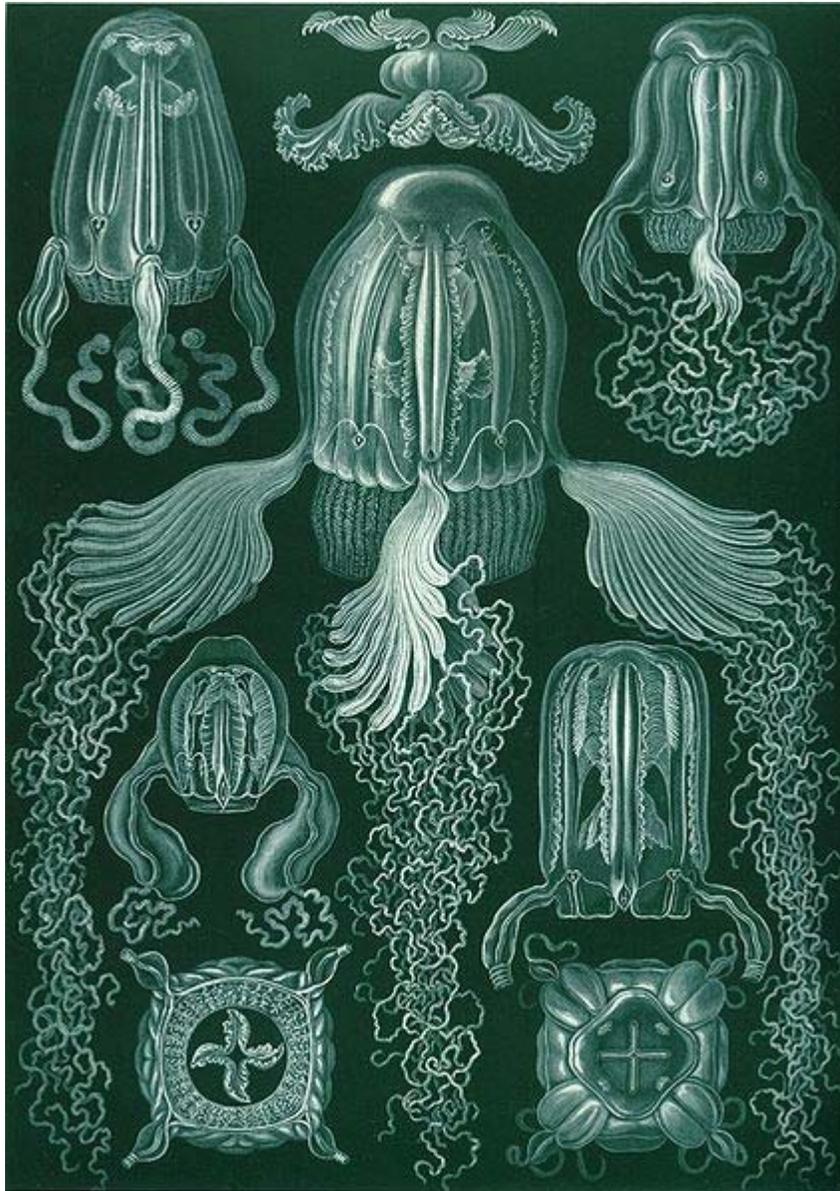
Orders

- Carybdeida

- Chirodropida

Box jellyfish or "sea wasp" is also a common name for the notoriously dangerous *Chironex fleckeri*. The ambiguous but commonly used terms "sea wasp" and "marine stinger" are sometimes used to refer to the more venomous species of box jellyfish.

Anatomy



"Cubomedusae", from Ernst Haeckel's *Kunstformen der Natur*, 1904

Box jellyfish most visibly differ from the "true" or Scyphozoan jellyfish in that their umbrellas are cubic, rather than domed or crown-shaped. The underside of the umbrella includes a flap, or *velarium*, concentrating and increasing the flow of water expelled from the umbrella. As a result, box jellyfish can move more rapidly than other jellyfish. In fact, speeds of up to six metres per minute have been recorded.

The box jellyfish's nervous system is also more developed than that of many other jellyfish. Notably, they possess a nerve ring around the base of the umbrella that coordinates their pulsing movements; a feature found elsewhere only in the crown jellyfish. Whereas some other jellyfish do have simple pigment-cup ocelli, box jellyfish are unique in the possession of true eyes, complete with retinas, corneas and lenses. Their eyes are located on each of the four sides of their bell in clusters. These enable them to see specific points of light, as opposed to simply distinguishing between light and the dark. Box jellies also retain the lesser type of eye, because the strong eyes are only one of four subsets.

Distribution

Although the notoriously dangerous species of box jellies are largely, or entirely, restricted to the tropical Indo-Pacific, various species of box jellies can be found widely in tropical and subtropical oceans, including the Atlantic and east Pacific, with species as far north as California, the Mediterranean (e.g., *Carybdea marsupialis*) and Japan (e.g., *Chironex yamaguchii*), and as far south as South Africa (e.g., *Carybdea branchi*) and New Zealand (e.g., *Carybdea sivickisi*).

Defense and feeding mechanisms



Box jellyfish warning signpost at a Cape Tribulation beach in Queensland, Australia



Jellyfish/stinger net enclosure at Ellis Beach, Queensland

The box jellyfish has been called "the world's most venomous creature," though only a few species in the class have been confirmed to be involved in human deaths and some species pose no serious threat. For example, the sting of *Chiropsella bart* only results in short-lived itching and mild pain.

Each tentacle has about 500,000 cnidocytes, harpoon-shaped needles that inject venom into the victim. In Australia, the fatal envenomations are most often perpetrated by the largest species of box jelly, *Chironex fleckeri*, owing to its high concentration of nematocysts. The recently discovered and very similar *Chironex yamaguchii* may be equally dangerous, as it has been implicated in several deaths in Japan. It is unclear which of these species usually is involved in fatalities in the Malay Archipelago. In 1990 a 4-year-old child died after being stung by *Chiropsalmus quadrumanus* at Galveston Island in the Mexican Gulf, and either this species or *Chiropsoides buitendijki* are considered the likely perpetrators of two deaths in West Malaysia. At least two deaths in Australia have been attributed to the thumbnail-sized *Carukia barnesi*. Those who fall victim to *C. barnesi* may suffer severe physical and psychological symptoms known as Irukandji syndrome. Nevertheless, most victims do survive, and out of 62 people treated for Irukandji envenomation in Australia in 1996, almost half could be discharged home with few or no symptoms after 6 hours, and only two remained hospitalized approximately a day after they were stung.

In Australia, *C. fleckeri* has caused at least 64 deaths since the first report in 1883, but even in this species most encounters appear to only result in mild envenoming. Most recent deaths in Australia have been in children, which is linked to their smaller body mass. In April 2010, a 10 year old Australian girl survived multiple stings from box jellyfish and her survival is considered a medical miracle. In parts of the Malay Archipelago, the number of lethal cases is far higher (in the Philippines alone, an estimated 20-40 die annually from Chirodropid stings), likely due to limited access to medical facilities and antivenom, and the fact that many Australian beaches are enclosed in nets and have vinegar placed in prominent positions allowing for rapid first aid. Vinegar is also used as treatment by locals in the Philippines.

The box jellyfish actively hunts its prey (zooplankton and small fish), rather than drifting as do true jellyfish. It is capable of achieving speeds of up to 4 knots (1.8 m/s).

Box jellyfish are known as the "suckerpunch" of the sea not only because their sting is rarely detected until the venom is injected, but also because they are almost transparent.

The venom of cubozoans is distinct from that of scyphozoans, and is used to catch prey (fish and small invertebrates, including shrimp and bait fish) and for defense from predators, which include the butterfish, batfish, rabbitfish, crabs (Blue Swimmer Crab) and various species of turtles (Hawksbill turtle, Flatback turtle). Sea turtles, however, are apparently unaffected by the sting and eat box jellies.

In northern Australia, the highest risk period for the box jellyfish is between October and May, but stings and specimens have been reported all months of the year. Similarly, the highest risk conditions are those with calm water and a light, onshore breeze; however, stings and specimens have been reported in all conditions.

In Hawaii, box jellyfish numbers peak approximately 7 to 10 days after a full moon, when they come near the shore to spawn. Sometimes the influx is so severe that lifeguards have closed infested beaches, such as Hanauma Bay, until the numbers subside.

Taxonomy

As of 2007, at least 36 species of box jellyfish were known, grouped into two orders and six families. A few new species have been described since then, and it is likely undescribed species remain.

Class Cubozoa

- Order Carybdeida
 - Family Alatinidae
 - Family Carybdeidae
 - Family Tamoyidae
 - Family Tripedaliidae

- Order Chirodropida
 - Family Chirodropidae
 - Family Chiropsalmidae

Treatment of stings

Once a tentacle of the box jellyfish adheres to skin, it pumps nematocysts with venom into the skin, causing the sting and agonizing pain. Successful use of Chironex antivenom by members of the Queensland Ambulance Transport Brigade showed that Acetic acid, found in vinegar, disables the box jelly's nematocysts that have not yet discharged into the bloodstream (though it will not alleviate the pain). Common practice is to apply generous amounts of vinegar prior to and after the stinging tentacle is removed. Removal of additional tentacles is usually done with a towel or gloved hand, to prevent secondary stinging. Tentacles will still sting if separated from the bell, or if the creature is dead. Removal of tentacles without prior application of vinegar may cause unfired nematocysts to come into contact with the skin and fire, resulting in a greater degree of envenomation.

Although commonly recommended in folklore and even some papers on sting treatment, there is no scientific evidence that urine, ammonia, meat tenderizer, sodium bicarbonate, boric acid, lemon juice, fresh water, steroid cream, alcohol, cold packs, papaya, or hydrogen peroxide will disable further stinging, and these substances may even hasten the release of venom. Pressure immobilization bandages, methylated spirits, or vodka should never be used for jelly stings. Often in severe *Chironex fleckeri* stings, cardiac arrest occurs quickly, so cardiopulmonary resuscitation (CPR) can be life saving and takes priority over all other treatment options.

Chapter- 7

Hydrozoa

Hydrozoa

Scientific classification

Kingdom:	Animalia
Phylum:	Cnidaria
Subphylum:	Medusozoa
Class:	Hydrozoa Owen, 1843

Subclasses

Leptolinae
Anthomedusae
Leptomedusae
Siphonophorae
Trachylinae
Actinulidae
Limnomedusae
Narcomedusae
Trachymedusae

Hydrozoa (hydrozoans) are a taxonomic class of very small, predatory animals which can be solitary or colonial and which mostly live in saltwater. A few genera within this class live in freshwater. Hydrozoans are related to jellyfish and corals and belong to the phylum Cnidaria.

Some examples of hydrozoans are the Freshwater Jelly (*Craspedacusta sowerbyi*), the freshwater polyps (*Hydra*), *Obelia*, the Portuguese Man o' War (*Physalia physalis*), the chondrophores (Porpitidae), "air fern" (*Sertularia argenta*) and the pink-hearted hydroids (*Tubularia*).

Anatomy

Most hydrozoan species include both a hydroid and a medusoid stage in their life cycle, although there are a number that have only one or the other. For example, *Hydra* has no medusoid stage, while *Liriope* lacks the hydroid stage.

Polyps

The hydroid form is usually colonial, with multiple polyps connected together by tubelike *hydrocauli*. The hollow cavity in the middle of the polyp extends into the associated hydrocaulus, so that all the individuals of the colony are intimately connected. Where the hydrocaulus runs along the substrate it forms a horizontal root-like stolon that anchors the colony to the ground.

The colonies are generally small, no more than a few centimeters across, and may have a tree-like or fan-like appearance, depending on species. The polyps themselves are usually tiny, although some non-colonial species are much larger, reaching 6 to 9 centimetres (2.4 to 3.5 in), or, in the case of the deep sea *Branchiocerianthus*, a remarkable 2 metres (6.6 ft).

The hydrocaulus is usually surrounded by a sheath of chitin and other proteins called the *perisarc*. In some species, this extends upwards to also enclose part of the polyps, in some cases including a closable lid through which the polyp may extend its tentacles.

In any given colony, the majority of polyps are specialized for feeding. These have a more or less cylindrical body with a terminal mouth on a raised protuberance called the hypostome, surrounded by a number of tentacles. The polyp contains a central cavity, in which initial digestion takes place. Partially digested food may then be passed into the hydrocaulus for distribution around the colony and completion of the digestion process. Unlike some other cnidarian groups, the lining of the central cavity lacks stinging nematocysts, which are found only on the tentacles and outer surface.

All colonial hydrozoans also include some polyps specialized for reproduction. These lack tentacles and contain numerous buds from which the medusoid stage of the life-cycle is produced. The arrangement and type of these reproductive polyps varies considerably between different groups.

In addition to these two basic types of polyp, a few colonial species have other specialized forms. In some, defensive polyps are found, armed with large numbers of stinging cells. In others, one polyp may develop as a large float, from which the other polyps hang down, allowing the colony to drift in open water instead of being anchored to a solid surface.

Medusae

The medusae of hydrozoans are smaller than those of typical jellyfish, ranging from 0.5 to 6 centimetres (0.20 to 2.4 in) in diameter. Although most hydrozoans have a medusoid stage, this is not always free-living, and in many species, exists solely as a sexually reproducing bud on the surface of the hydroid colony. Sometimes these medusoid buds may be so degenerate as to entirely lack tentacles or mouths, essentially consisting of an isolated gonad.

The body consists of a dome-like umbrella ringed by tentacles. A tube-like structure hangs down from the centre of the umbrella, and includes the mouth at its tip. Most hydrozoan medusae have just four tentacles, although a number of exceptions exist. Stinging cells are found on the tentacles and around the mouth.

The mouth leads into a central stomach cavity. Four radial canals connect the stomach to an, additional, circular canal running around the base of the bell, just above the tentacles. Striated muscle fibres also line the rim of the bell, allowing the animal to move along by alternately contracting and relaxing its body. An additional shelf of tissue lies just inside the rim, narrowing the aperture at the base of the umbrella, and thereby increasing the force of the expelled jet of water.

The nervous system is unusually advanced for cnidarians, or even than in the polyps of the same species. Two nerve rings lie close to the margin of the bell, and send fibres into the muscles and tentacles. The genus *Sarsia* has even been reported to possess organised ganglia. Numerous sense organs are closely associated with the nerve rings. Mostly these are simple sensory nerve endings, but they also include statocysts and primitive light-sensitive ocelli.

Life cycle

Hydroid colonies are usually dioecious, which means that they have separate sexes - all the polyps in each colony are either male or female, but not usually both sexes in the same colony. In some species, the reproductive polyps, known as gonozooids (or "gonotheca" in thecate hydrozoans) bud off asexually-produced medusae. These tiny, new medusae (which are either male or female) mature and spawn, releasing gametes freely into the sea in most cases. Zygotes become free-swimming planula larvae or actinula larvae that either settle on a suitable substrate (in the case of planulae), or swim and develop into another medusae or polyp directly (actinulae). Colonial hydrozoans include siphonophore colonies, *Hydractinia*, *Obelia*, and many others.

The medusa stage, if present, is the sexually-reproductive life cycle phase (that is, in hydrozoan species that have both polyp and medusa generations). Medusae of these species of Hydrozoa are known as "hydromedusae". Most hydromedusae have shorter life spans than the larger scyphozoan jellyfish. Some species of hydromedusae release gametes shortly after they are themselves released from the hydroids (as in the case of fire corals), living only a few hours, while other species of hydromedusae grow and feed

in the plankton for months, spawning daily for many days before their supply of food or other water conditions deteriorate and cause their demise.

Systematics



The highly apomorphic Siphonophorae - like this Portuguese Man o' War (*Physalia physalis*) - have long misled hydrozoan researchers.

Hydrozoan systematics is highly complex. Several approaches for expressing their interrelationships were proposed and heavily contested since the late 19th century, but in more recent times a consensus seems to be emerging.

For long, the hydrozoans were divided into a number of orders, according to their mode of growth and reproduction. Most famous among these was probably the assemblage called "Hydroida", but this group is apparently paraphyletic, united by plesiomorphic (ancestral) traits. Other such orders were the Anthoathecatae, Actinulidae, Laingiomedusae, Polypodiozoa, Siphonophora and Trachylina.

As far as can be told from the molecular and morphological data at hand, the Siphonophora for example were just highly specialized "hydroids," whereas the Limnomedusae - presumed to be a "hydroid" suborder - were simply very primitive hydrozoans and not closely related to the other "hydroids." Therefore, today the hydrozoans are at least tentatively divided into two subclasses, the Leptolinae (containing the bulk of the former "Hydroida" and the Siphonophora) and the Trachylinae, containing the others (including the Limnomedusae). The monophyly of several of the presumed orders in each subclass is still in need of verification.

In any case, according to this classification, the hydrozoans can be subdivided as follows, with taxon names emended to end in "-ae":

Class Hydrozoa

- Subclass Leptolinae
 - Order Anthomedusae (= Anthoathecata(e), Athecata(e), Stylasterina(e)) - includes Laingiomedusae but monophyly requires verification
 - Order Leptomedusae (= Leptoathecata(e), Thecaphora(e), Thecata(e))
 - Order Siphonophorae
- Subclass Trachylinae
 - Order Actinulidae
 - Order Limnomedusae - monophyly requires verification; tentatively placed here
 - Order Narcomedusae
 - Order Trachymedusae - monophyly requires verification

ITIS uses the same system but unlike here does not use the oldest available names for many groups.

In addition, there exists a weird cnidarian parasite, *Polypodium hydriforme*, which lives inside its host's cells. It is sometimes placed in the Hydrozoa, but actually its relationships are better treated as unresolved for the time being - a somewhat controversial 18S rRNA sequence analysis found it to be closer to Myxozoa. It was traditionally placed in its own class Polypodiozoa and this view is presently often seen to reflect the uncertainties surrounding this highly distinct animal.

Other classifications



Limnomedusae like the Flower Hat Jelly (*Olindias formosa*) were long allied with Anthomedusae and Leptomedusae in the "Hydroida"

Some of the more widespread calen blasdell classification systems for the Hydrozoa are listed below. Though they are often found in seemingly authoritative Internet sources and databases, they do not agree with the currently available data. Especially the presumed phylogenetic distinctness of the Siphonophora is a major flaw that was corrected only recently.

The obsolete classification mentioned above was as follows:

- Order Actinulidae
- Order Anthoathecatae
- Order Hydroida
 - Suborder Anthomedusae
 - Suborder Leptomedusae
 - Suborder Limnomedusae
- Order Laingiomedusae
- Order Polypodiozoa
- Order Siphonophora



Fire corals were initially considered a separate order. They are actually a family of the Anthomedusae.

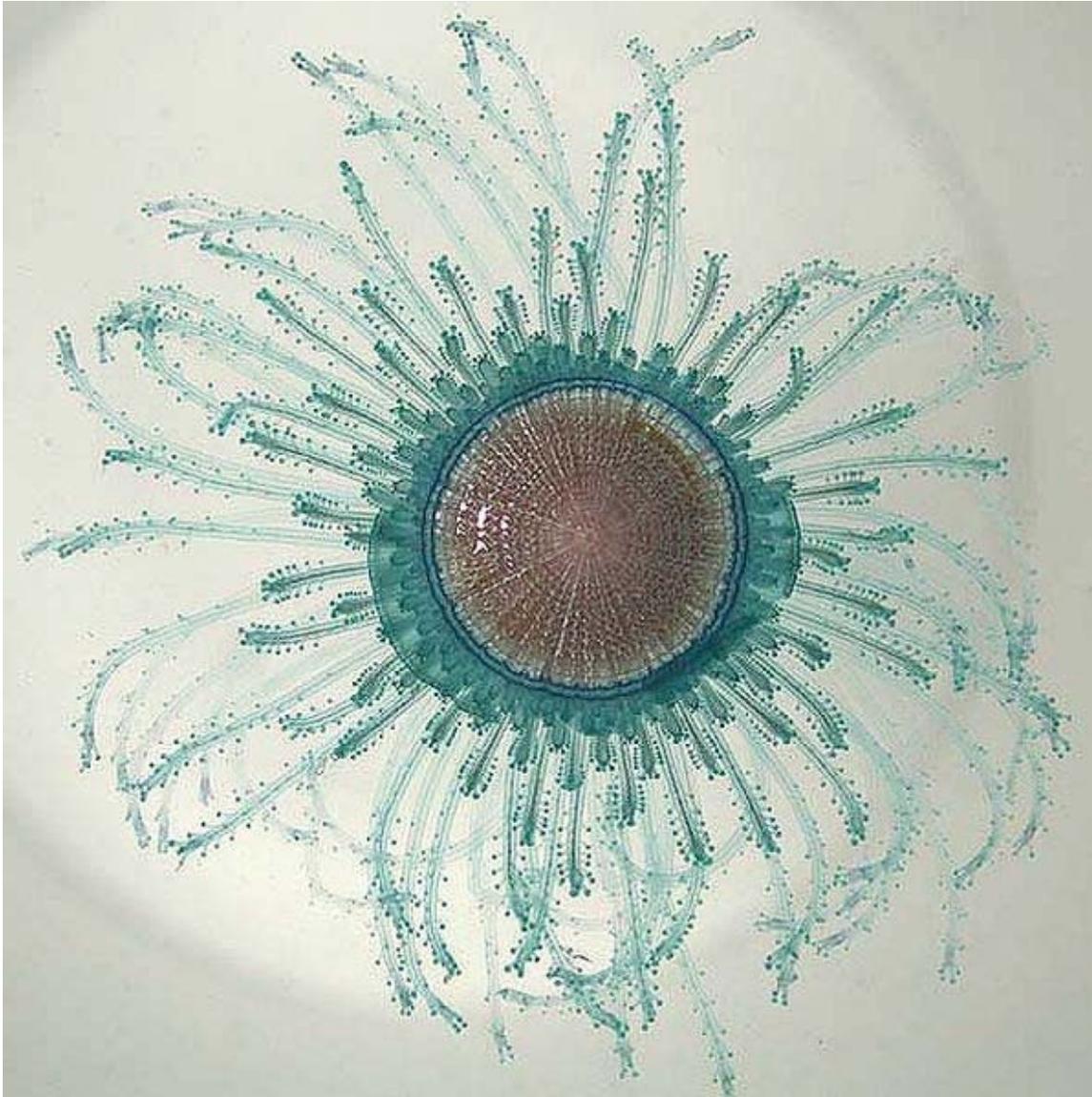
- Order Trachylina
 - Suborder Narcomedusae
 - Suborder Trachymedusae

A very old classification that is sometimes still seen is:

- Order Hydroida
- Order Milleporina
- Order Siphonophorida
- Order Stylasterina (= Anthomedusae)
- Order Trachylinida

Catalogue of Life uses the following:

- Order Actinulida
- Order Anthoathecata (= Anthomedusae)
- Order Hydroida



Some place the anthomedusan family Porpitidae in a separate order "Chondrophora"

- Order Laingiomedusae
- Order Leptothecata (= Leptomedusae)
- Order Limnomedusae
- Order Narcomedusae
- Order Siphonophora
- Order Trachymedusae

Animal Diversity Web uses the following:

- Order Actinulida
- Order Capitata
- Order Chondrophora

- Order Filifera
- Order Hydroida
- Order Siphonophora

Hydra, a *freshwater genus*

The most widely-known and researched freshwater hydrozoan is Hydra, which is found in slow-moving waters.

Hydra has a pedal disc composed of gland cells that helps it attach to substrates, and like all cnidarians uses nematocysts, or "stinging cells," to disable its prey. Hydra eat small crustaceans (such as brine shrimp), insect larvae, and annelid worms. Hydra may reproduce sexually, through the spawning of sperm (and thus insemination of eggs on the female body column), or through asexual reproduction (budding).

Chapter- 8

Scyphozoa and Stauromedusae

Scyphozoa

Scyphozoa



Chrysaora colorata

Scientific classification

Kingdom:	Animalia
Phylum:	Cnidaria
Subphylum:	Medusozoa
Class:	Scyphozoa Götte, 1887

Orders

Byroniida
†Conulariida
Semaestomeae

Scyphozoa is a class within the phylum Cnidaria, sometimes referred to as the "true jellyfish".

The class name *Scyphozoa* comes from the Greek word *skyphos* (σκύφος), denoting a kind of drinking cup and alluding to the cup shape of the organism.

Scyphozoans range in geological time from the Ediacaran period through the Recent.

Biology

Most species of Scyphozoa have two life history phases, including the planktonic medusa or jellyfish form, which is most evident in the warm summer months, and an inconspicuous, but longer-lived bottom-dwelling polyp, which seasonally gives rise to new medusae. Most of the large, often colorful, and conspicuous jellyfish found in coastal waters throughout the world are Scyphozoa. They typically range from 2 to 40 centimetres (0.79 to 16 in) in diameter, but the largest species, *Cyanea capillata* can reach 2 metres (6.6 ft) across. Scyphomedusae are found throughout the world's oceans, from the surface to great depths; no Scyphozoa occur in freshwater (or on land).

As medusae, they eat a variety of crustaceans and fish, which they capture using stinging cells called nematocysts. The nematocysts are located throughout the tentacles that radiate downward from the edge of the umbrella dome, and also cover the four or eight oral arms that hang down from the central mouth. Some species, however, are instead filter feeders, using the tentacles to strain plankton from the water.

Anatomy

Scyphozoans usually display a four-part symmetry and have an internal gelatinous material called mesoglea, which provides the same structural integrity as a skeleton. The mesoglea includes mobile amoeboid cells originating from the epidermis.

Scyphozoans have no durable hard parts, including no head, no skeleton and no specialized organs for respiration or excretion. Marine jellyfish can consist of as much as 99% water and therefore are rarely found in fossil form.

Unlike the hydrozoan jellyfish, hydromedusae, scyphomedusae lack a velum, which is a circular membrane beneath the umbrella that helps propel the (usually smaller) hydromedusae through the water. However, a ring of muscle fibres is present within the mesoglea around the rim of the dome, and the jellyfish swims by alternately contracting and relaxing these muscles. The periodic contracting and relaxing propels the jellyfish through the water, allowing it to escape predation or catch its prey.

The mouth opens into a central stomach, from which four interconnected diverticula radiate outwards. In many species, this is further elaborated by a system of radial canals, with or without an additional ring canal towards the edge of the dome. Some genera, such as *Cassiopea*, even have additional, smaller mouths in the oral arms. The lining of the digestive system includes further stinging nematocysts, along with cells that secrete digestive enzymes.

The nervous system usually consists of a distributed net of cells, although some species possess more organised nerve rings. In species lacking nerve rings, the nerve cells are instead concentrated into small structures called *rhopallia*. There are between four and sixteen of these small lobes arranged around the rim of the umbrella, where they

coordinate the muscular action allowing the animal to move. Each rhopallium is typically associated with a pair of sensory pits, a statocyst, and sometimes a pigment-cup ocellus.

Reproduction

Most species appear to be gonochorists, with separate male and female individuals. The gonads are located in the stomach lining, and the mature gametes are expelled through the mouth. After fertilization, some species brood their young in pouches on the oral arms, but they are more commonly planktonic.

The fertilized egg produces a planula larva which, in most species, quickly attaches itself to the sea bottom. The larva develops into the hydroid stage of the life-cycle, a tiny sessile polyp called a *scyphistoma*. The scyphistoma reproduces asexually, producing similar polyps by budding, and then either transforming into a medusa, or budding several medusae off from its upper surface. The medusae are initially microscopic, and may take years to reach sexual maturity.

Commercial importance

Scyphozoa includes the moon jelly *Aurelia aurita*, in the order Semaestomeae, and the enormous *Nemopilema nomurai*, in the Order Rhizostomeae, found between Japan and China and which in some years causes major fisheries disruptions.

Most of the jellyfish that are fished commercially for food are scyphomedusae in the order Rhizostomeae. Most rhizostome jellyfish live in warm water.

Taxonomy

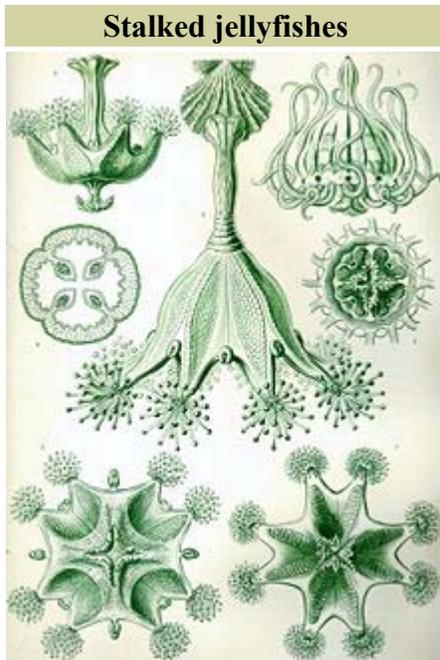
Although the Scyphozoa was formerly thought to include the animals now referred to the classes Cubozoa and Staurozoa, it is now thought to include just three orders:

Class Scyphozoa

- Order Coronatae
 - Family Atollidae
 - Family Atorellidae
 - Family Nausithoidae
 - Family Paraphyllinidae
 - Family Periphyllidae
- Order Semaestomeae
 - Family Cyaneidae
 - Family Pelagiidae
 - Family Ulmaridae
- Order Rhizostomeae
 - Family Archirhizidae
 - Family Cassiopeidae

- Family Catostylidae
- Family Cepheidae
- Family Lobonematidae
- Family Lychnorhizidae
- Family Mastigiidae
- Family Rhizostomatidae
- Family Stomolophidae
- Subclass Discomedusae

Stauromedusae



Stauromeduse from Ernst Haeckel's
1904 *Kunstformen der Natur*

Scientific classification

Kingdom: Animalia
 Phylum: Cnidaria
 Class: Staurozoa
 Order: **Stauromedusae**
 Haeckel, 1879

Families

Cleistocarpidae
 Eleutherocarpidae
 Kyopodidae

Tesseranthidae

Stauromedusae are the **stalked jellyfishes**, of the class Staurozoa within the phylum Cnidaria. They are unique in that they do not have an alternation of polyp and medusa life cycle phases, but are interpreted as an attached medusa stage, with a life style more resembling that of polypoid forms. They have a generally trumpet-shaped body, positioned upside-down in comparison with other jellyfish, with the tentacles projecting upwards, and the stalk located in the centre of the umbrella.

Members of this class are commonly found in relatively cold waters, close to the shoreline.

Sexually mature stauromedusae free-spawn eggs or sperm, which fertilize in the sea and form a creeping, unciliated planula larva. The larvae crawl across the sea floor and find a suitable place, attaching themselves typically to rock or algae, where they eventually develop into a new, attached stauromedusa. Unlike most scyphozoan jellyfish that practice strobilation, or the process of dividing themselves into body segments, which become new individuals, nearly all stauromedusae develop directly into the adult form.

Although conventionally considered to be an order in the class Scyphozoa, recent genetic studies suggest that Stauromedusae should be elevated to a taxon equivalent of Scyphozoa and Cubozoa, and should therefore be known as the class **Staurozoa**.



Haliclystus antarcticus

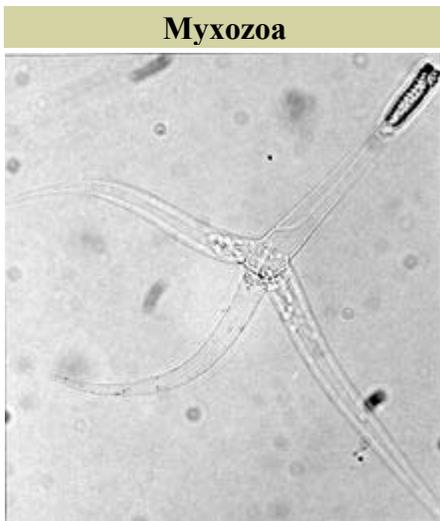


Haliclystus stejnegeri

Chapter- 9

Myxozoa, Polypodium Hydriforme and Hydra (Genus)

Myxozoa



Triactinomyxon stage of *Myxobolus cerebralis*.

Scientific classification

Kingdom:	Animalia
Phylum:	Cnidaria
(unranked):	Myxozoa Grassé, 1970

Classes

Malacosporea
Myxosporea

The **Myxozoa** (etymology: Greek: *myx*- "slime" or "mucus" + *zoa* "animals") are a group of parasitic animals of aquatic environments. Over 1300 species have been described and

many have a two-host lifecycle, involving a fish and an annelid worm or bryozoan. The average size of a Myxosporea spore usually ranges from 10 µm to 20 µm and Malacosporea up to 2 mm. Infection occurs through valved spores. These contain one or two sporoblast cells and one or more polar capsules that contain filaments which anchor the spore to its host. The sporoblasts are then released as a motile form, called an amoebula, which penetrates the host tissues and develops into one or more multinucleate plasmodia. Certain nuclei later pair up, one engulfing another, to form new spores.

Phylogenetics

The Myxozoa were originally considered protozoan, and were included among other non-motile forms in the group Sporozoa. As their distinct nature became clear through 18S ribosomal DNA (rDNA) sequencing, they were relocated in the metazoa. Further classification was hindered by conflicting evidence: although 18S rDNA suggested an affinity with Cnidaria, other rDNA sampled, and the HOX genes of two species, were more similar to those of the Bilateria.

The discovery that *Buddenbrockia plumatellae*, a worm-like parasite up to 2 mm in length, is a myxozoan appeared to strengthen the case for a bilaterian origin, as the body plan is superficially similar. Nevertheless, closer examination reveals that *Buddenbrockia* is not longitudinally symmetrical by two ways, but four, casting doubt on this hypothesis.

Further testing has sourced the first three HOX genes found in previous research (*Myx1-3*) to the bryozoan *Cristatella mucedo*, and the fourth (*Myx4*) to Northern pike. This explained the confusion; original experiments had used contaminated tissue from host organisms, leading to false positives for a position among the Bilateria. More careful cloning of 50 coding genes from *Buddenbrockia* established the clade as severely modified members of the phylum Cnidaria, with medusozoans as their closest relatives. Similarities between myxozoan polar capsules and cnidarian nematocysts (stinging cells) had been drawn for a long time, but were generally assumed to be the result of convergent evolution (Still these are insufficient information).

Taxonomists now recognize the outdated subgroup Actinosporea as a life-cycle phase of Myxosporea.

Species

Some species of myxozoa include:

- Class Malacosporea
 - *Buddenbrockia plumatellae*
 - *Tetracapsuloides bryosalmonae* - an important salmon parasite.
- Class Myxosporea
 - *Myxobolus cerebralis* - an important parasite of salmon and trout.

Pathology

Relationships between myxosporeans and their hosts are often highly evolved and do not usually result in severe diseases. Infection in fish hosts can be extremely long-lasting, potentially persisting for the lifetime of the host, however, an increasing number of myxosporeans have been recognised as commercially important pathogens of fish, largely as a result of the recent increase in aquaculture. The economic impact of such parasites can be severe, especially where prevalence rates are high; they may also have a severe impact on wild fish stocks

The most significant diseases worldwide caused by myxosporeans in cultured fishes are PKD-Proliferative Kidney Disease, caused by a Malacosporea member, *Tetracapsuloides bryosalmonae*, and whirling disease, caused by a Myxosporea member *Myxobolus cerebralis*; both diseases affect salmonids. Furthermore, Enteromyxosis is caused by *Enteromyxum leei* in cultured marine sparids, while "Hamburger disease" or Proliferative Gill Disease is caused by *Henneguya ictaluri* in catfish and *Sphaerosphora renicola* infections occur in common carp.

Polypodium hydriforme

Polypodium hydriforme



Two specimens of free-living
Polypodium

Scientific classification

Kingdom:	Animalia
Phylum:	Cnidaria
Subphylum:	Medusozoa
Class:	Polypodiozoa Raikova, 1994
Family:	Polypodiidae
Genus:	<i>Polypodium</i> Ussov, 1885
Species:	<i>P. hydriforme</i>

Binomial name

Polypodium hydriforme
(Ussov, 1885)

Polypodium hydriforme is a species of a parasite attacking the eggs of sturgeon and similar fishes (Acipenseridae and Polyodontidae). It is one of few metazoans living inside the cells of other animals. It is also the only known intracellular cnidarian parasite.

Polypodium hydriforme is the only species in the genus *Polypodium* (monotypic genus). It is also the only species and genus within the whole family **Polypodiidae**.

Taxonomy

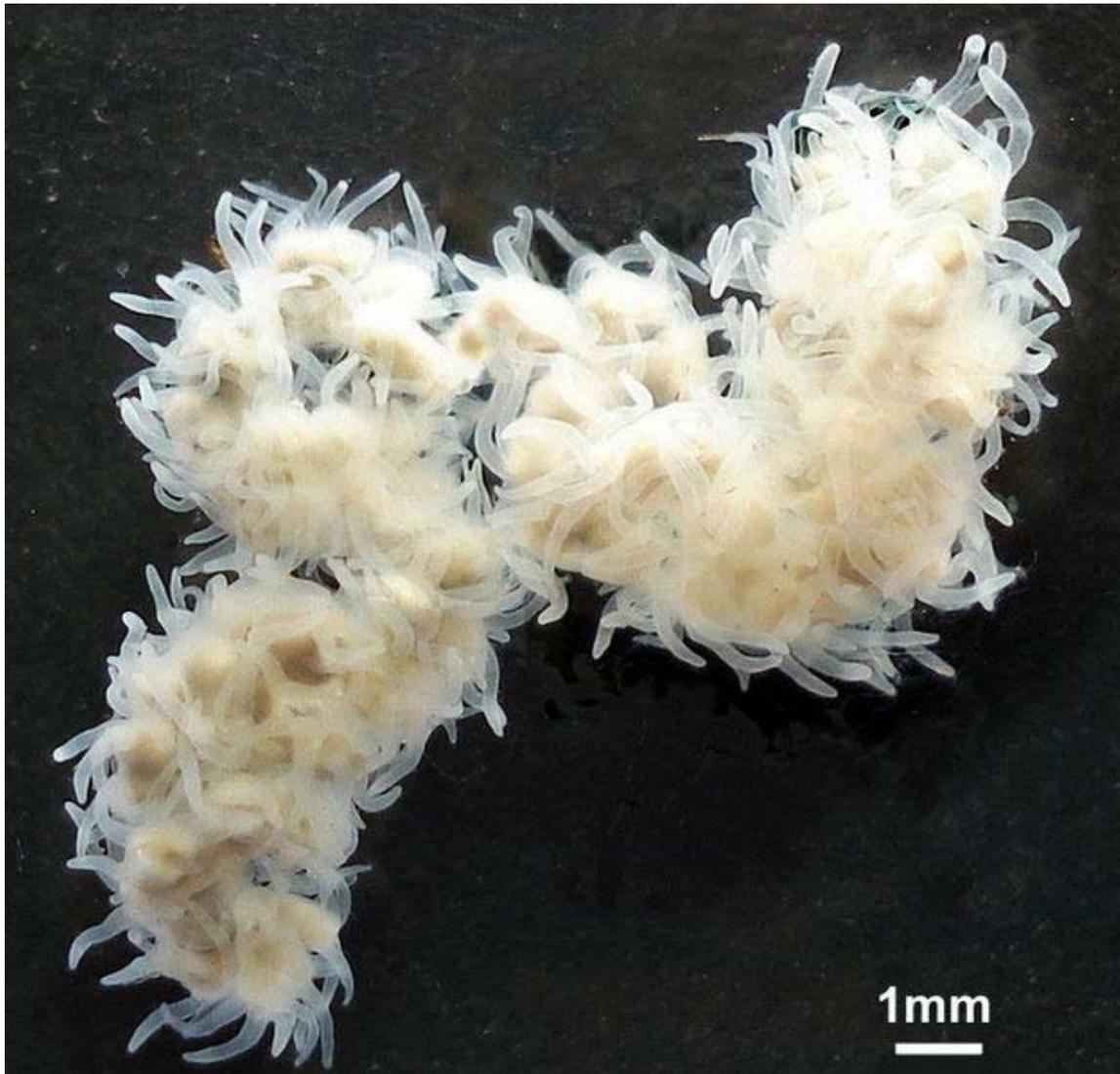
Unusual characteristics have led to much controversy regarding its phylogenetic position within metazoans.

Polypodium has traditionally been considered a cnidarian because it possesses nematocysts, the stinging structures characteristic of this phylum.

However, molecular phylogenetic studies using 18S rDNA sequence data have challenged this interpretation, and have shown that *Polypodium* is a close relative to myxozoans and together they share a closer affinity to bilaterians than cnidarians (Zrzavý & Hypša 2003). Due to the variable rates of 18S rDNA sequences, these results have been suggested to be an artifact of long branch attraction.

Evans et al. (2008) have performed phylogenetic analyses of metazoans with 18S and partial 28S rDNA sequences in a large dataset that includes *Polypodium* and a comprehensive sampling of cnidarian taxa. This support the placement of *Polypodium* within Cnidaria. This accords with the fact that *Polypodium* possesses nematocysts and a cnidarian-like body plan. The ML combined analysis places *Polypodium* as its own class **Polypodiozoa**. By contrast, the combined parsimony analysis and the ML analyses of 28S alone place *Polypodium* within the hydrozoan clade Leptothecata.

Description and life cycle



Free living stolon

Polypodium hydriforme is an endocellular parasite with unusual life cycle, peculiar morphology, and high rates of DNA evolution. *Polypodium* spends most of its life inside the oocytes of acipenseriform fishes (sturgeons and paddlefish). Among its hosts include for example *Acipenser ruthenus*, *Polyodon spathula* and *Scaphirhynchus platorynchus*. During this time, *Polypodium* develops from a binucleate cell into an inside-out planuliform larva and then into an elongate inside-out stolon; the epidermal cell layer is located internal to the body and the gastrodermis is located externally. The embryo, larva and stolon are surrounded by a protective polyploid cell, which also functions in digestion. Just prior to host spawning, *Polypodium* everts to the normal position of cell layers, revealing tentacles scattered along the stolon. During eversion, the yolk of the host oocyte fills the gastral cavities of the parasite, supplying the future free-living stage with nutrients. Finally, upon emerging from the host egg in fresh water, the free-living stolon

fragments into individual medusoid-like forms that go on to multiply by means of longitudinal fission, form sexual organs, and ultimately infect host fish with their gametophores.

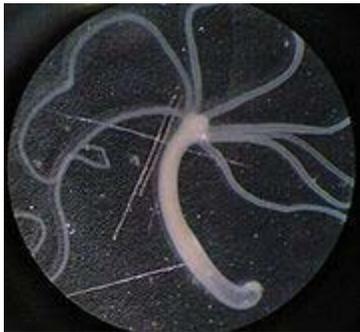
Habitat

Habitat of *Polypodium hydriforme* is freshwater.

Although the fresh water habitat of *Polypodium* is unusual for cnidarians, it is not unheard of, especially within hydrozoans. For instance, the model organism *Hydra* and the jellyfish *Craspedacusta* are both exclusively fresh-water hydrozoans. *Hydra* and *Craspedacusta* are distantly related and they are not closely related to *Polypodium*. Thus, it appears that in the evolution of cnidarians, invasion to fresh-water habitats has happened at least three separate times.

Hydra

Hydra



Hydra species

Scientific classification

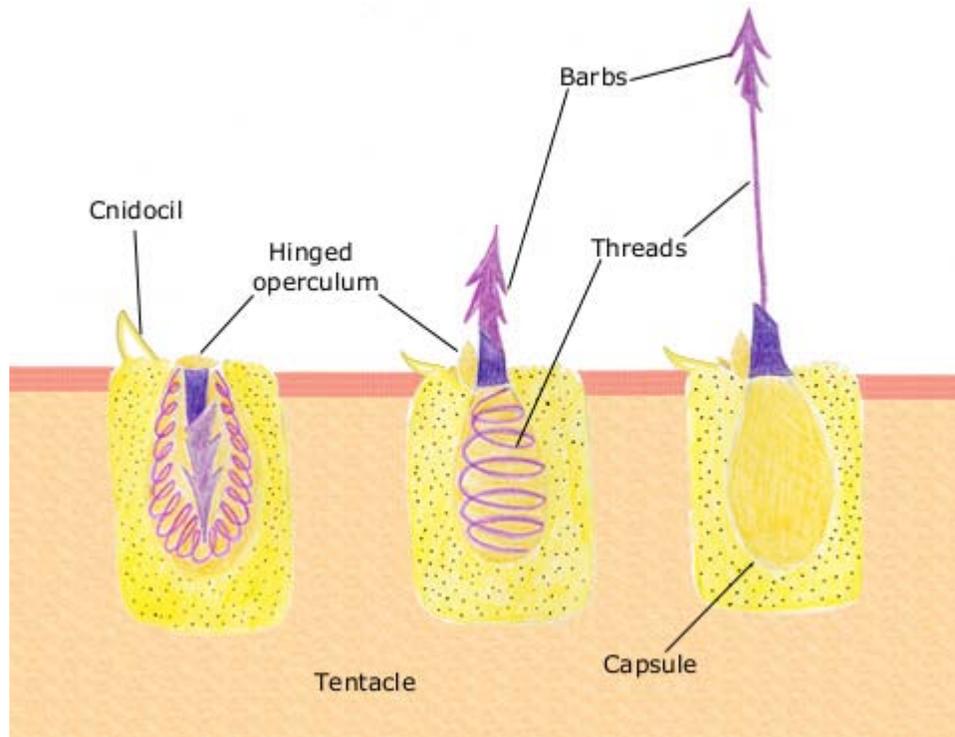
Kingdom: Animalia
Subkingdom: Eumetazoa
Phylum: Cnidaria
Subphylum: Medusozoa
Class: Hydrozoa
Subclass: Leptolinae
Order: Anthomedusae
Suborder: Capitata
Family: Hydridae
Genus: ***Hydra***
Linnaeus, 1758

Species

Hydra americana
Hydra attenuata (or *Hydra vulgaris*)
Hydra canadensis
Hydra carnea
Hydra cauliculata
Hydra circumcincta
Hydra hymanae
Hydra littoralis
Hydra magnipapillata
Hydra minima
Hydra oligactis
Hydra oregona
Hydra pseudoligactis
Hydra rutgerensis
Hydra utahensis
Hydra viridis
Hydra viridissima
Hydra vulgaris

Hydra is a genus of simple fresh-water animal possessing radial symmetry. Hydras are predatory animals belonging to the phylum Cnidaria and the class Hydrozoa. They can be found in most unpolluted fresh-water ponds, lakes, and streams in the temperate and tropical regions and can be found by gently sweeping a collecting net through weedy areas. They are usually a few millimetres long and are best studied with a microscope. Biologists are especially interested in hydras due to their regenerative ability; and that they appear not to age or die of old age. However, there is not scientific unanimity yet on whether Hydra undergo senescence, as discussed below.

Morphology



Schematic drawing of a discharging nematocyst

Hydra has a tubular body secured by a simple adhesive foot called the basal disc. Gland cells in the basal disc secrete a sticky fluid that allows for its adhesive properties.

At the free end of the body is a mouth opening surrounded by one to twelve thin, mobile tentacles. Each tentacle, or cnida (plural: cnidae), is clothed with highly specialised stinging cells called cnidocytes. Cnidocytes contain specialized structures called nematocysts, which look like miniature light bulbs with a coiled thread inside. At the narrow outer edge of the cnidocyte is a short trigger hair called a cnidocil. Upon contact with prey, the contents of the nematocyst are explosively discharged, firing a dart-like thread containing neurotoxins into whatever triggered the release which can paralyse the prey, especially if many hundreds of nematocysts are fired.

Hydra has two main body layers separated by mesoglea, a gel-like substance. The outer layer is the epidermis, and the inner layer is called the gastrodermis. The cells making up these two body layers are relatively simple. Hydracin is a bactericide recently discovered in *Hydra*; it protects the outer layer against infection.

The nervous system of *Hydra* is a nerve net, which is structurally simple compared to mammalian nervous systems. *Hydra* does not have a recognizable brain or true muscles. Nerve nets connect sensory photoreceptors and touch-sensitive nerve cells located in the body wall and tentacles.

Respiration and excretion occurs by diffusion through the epidermis.

Motion and locomotion

If a *Hydra* is alarmed or attacked, the tentacles can be retracted to small buds, and the body column itself can be retracted to a small gelatinous sphere. Hydras generally react in the same way regardless of the direction of the stimulus, and this may be due to the simplicity of the nerve net.



Hydra showing sessile behaviour

Hydras are generally sedentary or sessile, but do occasionally move quite readily, especially when hunting. They do this by bending over and attaching themselves to the substrate with the mouth and tentacles and then release the foot, which provides the usual attachment. The body then bends over and makes a new place of attachment with the foot. By this process of "inch-worming" or "somersaulting", a hydra can move several

inches (c. 100 mm) in a day. Hydras may also move by amoeboid motion of their bases or by simply detaching from the substrate and floating away in the current.

Reproduction and life cycle

When food is plentiful, many hydras reproduce asexually by producing buds in the body wall, which grow to be miniature adults and simply break away when they are mature. When conditions are harsh, often before winter or in poor feeding conditions, sexual reproduction occurs in some hydras. Swellings in the body wall develop into either a simple ovary or testes. The testes release free-swimming gametes into the water, and these can fertilize the egg in the ovary of another individual. The fertilized eggs secrete a tough outer coating, and, as the adult dies, these resting eggs fall to the bottom of the lake or pond to await better conditions, whereupon they hatch into miniature adults. Hydras are hermaphrodites and may produce both testes and an ovary at the same time.

Many members of the Hydrozoa go through a body change from a polyp to an adult form called a medusa. However, all hydras, despite being hydrozoans, remain as polyps throughout their lives.

Feeding

Hydras mainly feed on small aquatic invertebrates such as *Daphnia* and *Cyclops*.

When feeding, hydras extend their body to maximum length and then slowly extend their tentacles. Despite their simple construction, the tentacles of hydras are extraordinarily extensible and can be four to five times the length of the body. Once fully extended, the tentacles are slowly manoeuvred around waiting for contact with a suitable prey animal. Upon contact, nematocysts on the tentacle fire into the prey, and the tentacle itself coils around the prey. Within 30 seconds, most of the remaining tentacles will have already joined in the attack to subdue the struggling prey. Within two minutes, the tentacles will have surrounded the prey and moved it into the opened mouth aperture. Within ten minutes, the prey will have been enclosed within the body cavity, and digestion will have started. The hydra is able to stretch its body wall considerably in order to digest prey more than twice its size. After two or three days, the indigestible remains of the prey will be discharged by contractions through the mouth aperture.

The feeding behaviour of the hydra demonstrates the sophistication of what appears to be a simple nervous system.

Some species of *Hydra* exist in a mutual relationship with various types of unicellular algae. The algae are protected from predators by the *Hydra* and, in return, photosynthetic products from the algae are beneficial as a food source to the *Hydra*.

Morphallaxis

Nineteenth-century biologists reported that the *Hydra* was such a simple animal that it was possible to force one through gauze to separate it into individual cells; if the cells were then left to themselves, they would regroup to form a hydra again.

The hydra undergoes morphallaxis (tissue regeneration) when injured or severed.

Senescence

It has often been assumed that hydras are one of the few animals that do not undergo senescence (aging), and so are biologically immortal. Daniel Martinez appeared to provide evidence for this assumption in a 1998 article in *Experimental Gerontology*. This publication has been widely cited as evidence that hydra do not senesce and that they are proof of the existence of non-senescent organisms generally. However, in 2010 Preston Estep published (also in *Experimental Gerontology*) a letter to the editor claiming that the Martinez data support rather than refute the hypothesis that hydra senesce.

Genomics

A draft of the genome of *Hydra magnipapillata* was reported in 2010.