# Travail personnel

# Cnidaria

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## Why did I choose this topic?

I've been interested in biology for as long as I can remember. I never really wanted to do anything else, and doing my internship, working on the project Aqualyse in LEM Science and working with all the different animals in our school, just made me even more certain of my choice. I know now for sure that I want to study and work with animals in the future, so it was clear to me that my travail personnel this year was going to be about an animal. The question now was which one? The thing that fascinates me about biology, is that nothing is certain, there are exceptions for every rule, it's the study of life, but we can't even really define life. We have a broad definition, but even for that there are exceptions, for example "every living organism is made up of one or more cells", no, viruses don't have any, they're acellular[1].

So, I wanted to write about something strange, something that wouldn't normally seem possible and most importantly, something that I've never studied before. I had no idea what this topic could be; until one day, I was on a flight listening to a podcast out of boredom, it was an episode about Medusology (the study of jellyfish) with Dr. Rebecca Helm form a podcast called Ologies made by Alie Ward. It intrigued me, because it occurred to me that I knew nothing about these simple creatures; sure, I knew that they were mainly made up of water and that they could sting pretty badly, but other than that I was completely clueless. So, I turned it on and I was completely blown away. It was not only entertaining, but also incredibly interesting, it spoke about all the weird qualities of a jellyfish, their life cycle, their manner of reproducing and so on.

It was exactly the odd topic I was looking for.

[1] Definition of acellular: an organism without any cells.

# Introduction

The phylum cnidaria is comprised of more than ten thousand soft-bodied manly aquatic animals. They vary vastly in habitat and variety, from giant to microscopic sea jellies, from sea anemones, that can live in both the freezing arctic such as in the warm tropical waters by the equator, to corals colonies that span kilometers. Some live in the shallows and some in the deepest parts of the ocean. A few certain species don't even live in the ocean but in freshwater lakes.

# What are Cnidarians?

Cnidaria is a phylum, comprised of soft-bodied aquatic animals, such as jellyfish (in marine biology usually referred to as sea jellies, seeing as they're not fish), corals, sea anemones and hydrae. The name Cnidaria originates from the ancient Greek word "cnid", which translates to nettle, as in the stinging plant.

They are characterized by a couple of distinctive features. Every species in this phylum possesses very specific kinds of stinging cells called **cnidocytes**, that enable them to capture prey and defend themselves against predators, thanks to an organelle called nematocysts which releases toxin.

They exhibit either **radial or biradial symmetry**; the former meaning they are completely symmetric on all sides from a central point, like a bicycle wheel. It enables them to sting and capture food coming from any direction. The latter meaning, the body of the organism cannot be divided equally along multiple planes but instead only along two planes.

Cnidarians have two main body plans, the **polyp and medusa** form. Some species alternate between the two life stages, whereas others only possess one. Such as sea anemones and corals, which exclusively exist as polyps, or some species in the Class Cubozoa, which solely exist as medusa, lacking completely the polyp stage.

The last defining characteristic is that they only possess **two germ layers** instead of three, making them diploblastic.

# Taxonomy

Cnidaria is a phylum composed of four classes: Anthozoa, Cubozoa, Hydrozoa and Scyphozoa. All organisms of this phylum have cells with nuclei making them part of the domain Eukaria and lack cell walls and photosynthetic organelles thus making them all part of the kingdom Animalia (they are all animals).

This classification covers solely living cnidarians and is based on the system created by D.G. Fautin in S.P. Parker (ed.), *Synopsis and Classification of Living Organisms*, vol. 1 (1982), and L.H. Hyman, *The Invertebrates*, vol. 1, *Protozoa Through Ctenophora* (1940).

**Domain** Eukaria

**Kingdom** Animalia

**Phylum** Cnidaria

Composed of about 9000 species

- **Class** Anthozoa
    - *Subclass* Alcyonaria
        - Order Stolonifera
        - Order Telestacea
        - Order Gorgonacea
        - Order Alcyonacea
        - Order Helioporacea
        - Order Pennatulacea
    - *Subclass* Ceriantipatharia
        - Order Antipatharia
        - Order Ceriantharia
    - *Subclass* Zoantharia
        - Order Actiniaria
        - Order Corallimorpharia
        - Order Ptychodactiaria
        - Order Scleractinia
        - Order Zoanthinaria
- **Class** Cubazoa
        - Order Carybdeida
        - Order Chirodropida
- **Class** Hydrozoa
        - Order Actinulida

        - Order Chondrophora
        - Order Hydroida
            - Suborder Anthomedusae
            - Suborder Leptomedusae
            - Suborder Limnomedusae
        - Order Milleporina
        - Order Siphonophora
        - Order Stylasterina
        - Order Trachylina
            - Suborder Laingiomedusae
            - Suborder Narcomedusae
            - Suborder Trachymedusae

- Class Scyphozoa
        - Order Coronatae
        - Order Rhizostomae
        - Order Semaeostomeae
        - Order Stauromedusae

# Morphology

## General body plan

Adult Cnidarians have two possible body plans; they can either appear as free swimming medusae or sessile non-motile polyps. Polyps and medusae possess more or less the same body plan, the main difference being that medusae are motile and umbrella shaped with their opening (mouth) and tentacles facing down, and polyps are non-motile and tubed shaped with their tentacles and mouth facing up, they are the upside down from of the other. For example, a sea anemone is a polyp cnidarian and a jellyfish is a cnidarian in the medusa form.

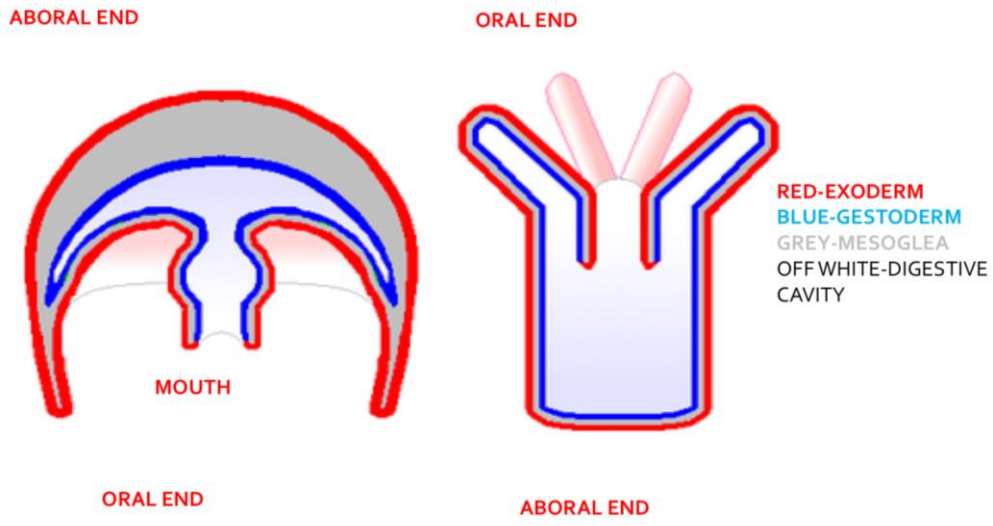
They do not possess a head, so scientists describe their ends as; the oral end, which is nearest to the mouth, and the aboral end which is furthest from the mouth.

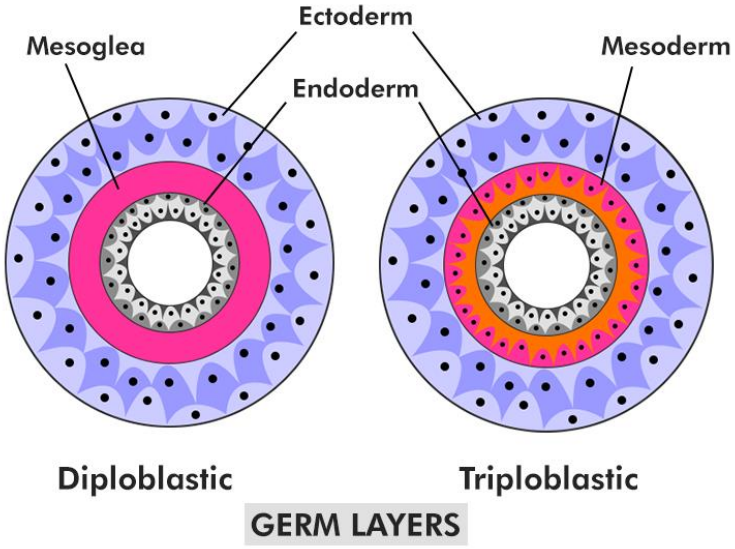
## Germ layers

Germ layers, also known as embryonic cell layers, are the primary layers of cells that are developed during the animal's embryonic development. In most animal phyla there are three germ layers, the inner layer known as the endoderm, the middle layer called the mesoderm and lastly the outer layer known as the ectoderm. These layers later form all different kinds of tissues and organs.

The interesting fact about Cnidarian germ layers is that they only possess two, the inner and outer layer, which makes them diploblastic instead of triploblastic (for example humans).

The ectoderm is responsible for forming the outer most layer known as the epidermis; on the other hand, as the endoderm develops, it forms all the internal tissues and structures, such as the gastrodermis and the gastrovascular cavity, who are responsible for the animal's digestive system. `

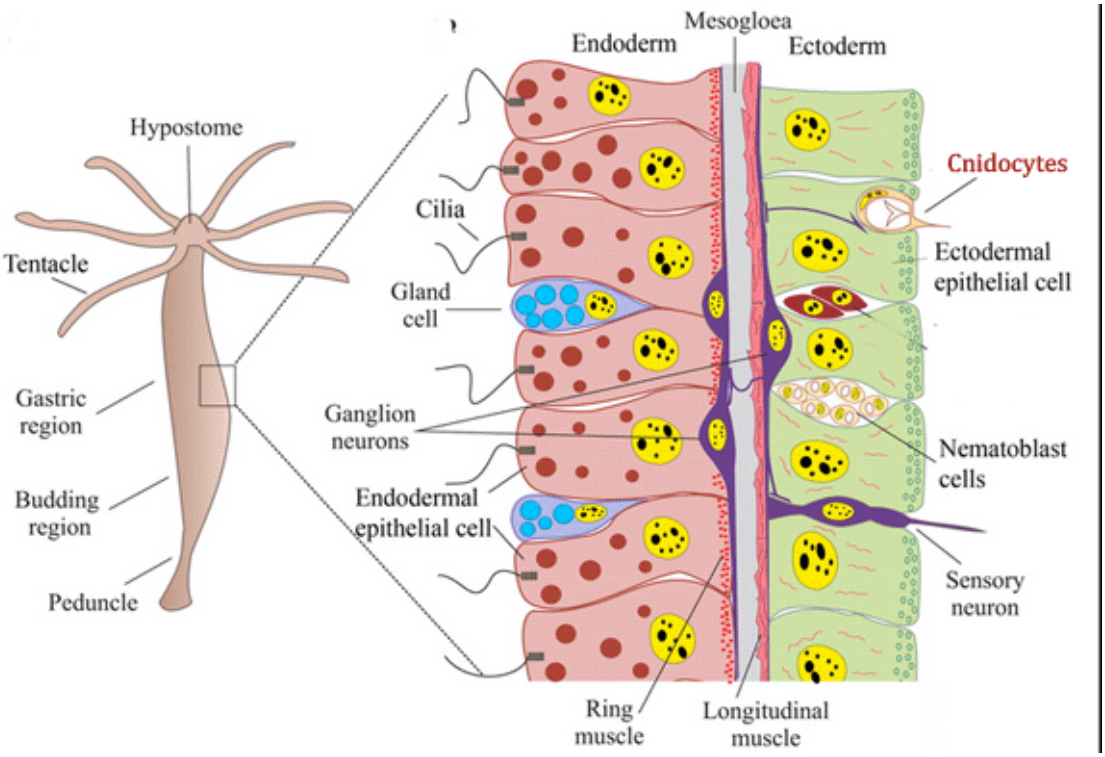





## Epithelium

An epithelium is the tissue that forms the outer layer of an organism's body and lines the hollow structures.

By cnidarians it's comprised of an epidermis (ectoderm) the outermost layer of the organism which in addition contains the cnidocytes (the stinging cells), an inner layer known as the gastrodermis (endoderm) and in between there  is a gelatinous layer called the mesoglea.




General epithelium of a cnidarian polyp

## Gastrovascular cavity

The gastrovascular cavity, also known as the Coelenteron[2], is the central cavity. It opens out through the mouth, which is surrounded by tentacles, since it's the animal's only hole it's responsible for both ingestion and egestion.

The two main functions of the gastrovascular system are circulation and digestion. Gastro refers to where digestion takes place and vascular stand for vessels. These animals, however, do not possess blood vessels nor blood, they use their gastrovascular cavities as their circulatory system. The function of the cardiovascular system in humans is to provide oxygen and nutrients to every cell of the organism and to get rid of the waste and carbon dioxide. In cnidarians the cavity has the same function. When food comes in through the mouth so does sea water and along with it Oxygen; the cells lining the central cavity (the Gastrodermis) take in nutrients and the Oxygen from the water and give out Carbon dioxide and waste products. The waste and the Carbon dioxide are then expelled back into the sea trough the mouth.

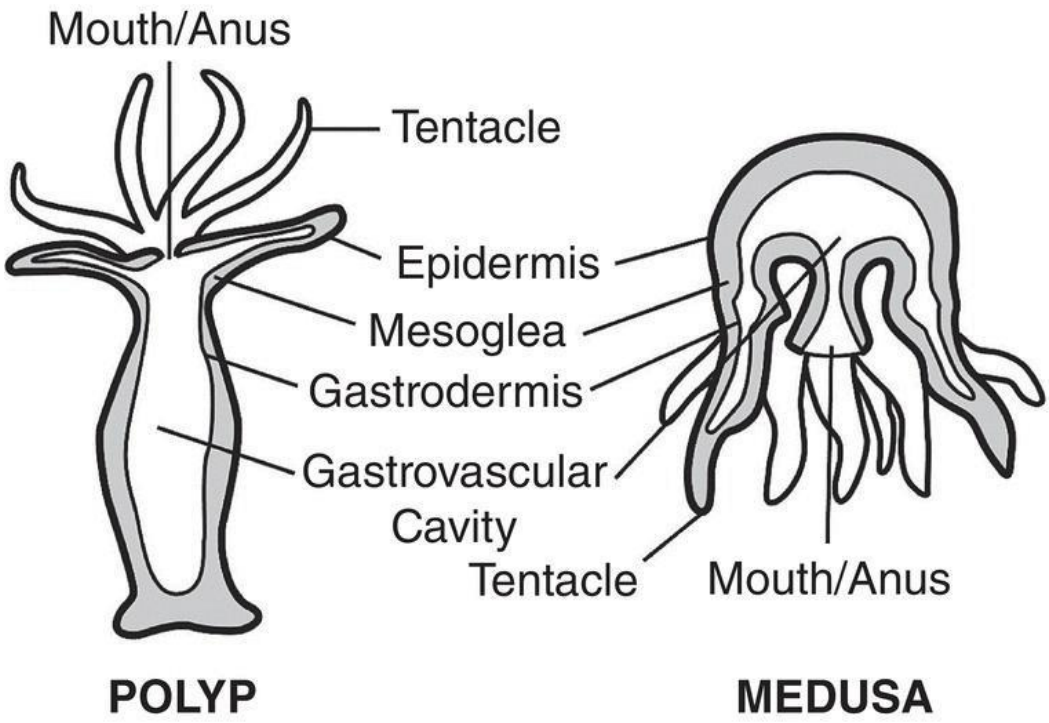
By medusa the gastrovascular cavity is specialized into stomach, radial canal and ring canal. It equally extends into the tentacles, so that it can reach every part of the organism.

In polyps it equally acts as a hydrostatic skeleton. Hydrostatic skeletons are fluid filled cavities, in this case the coelenteron, surrounded by muscles and tissues, that provide structural support and enable movement through the pressure provided by the fluid against the muscles.

### *Digestive system and gastrodermis*

Their digestive track does not only take place in the cavity, but also in the **Gastrodermis.** This is the innermost cell layer of the body plan; it lines the gastrovascular cavity and assists in the circulatory and digestive system. It secretes digestive enzymes into the Coelenteron which break down food. The food is first digested in the cavity, which is known as extracellular digestion since it takes place outside of cells, then intracellular (inside the cells) in the nutritive muscular cells of the gastrodermis and lastly defecated through the mouth.

[2] Coelenteron derives from the name Coelenterata, which is a no longer existing phylum that covered the animals in the phyla Cnidaria and Ctenophora (comb jellies).




## Mesoglea

The mesoglea is a gelatinous layer found in between the gastrodermis and the epidermis. It's a noncellular structure composed of networks made of complex elastic fibers, it can either be quite thick or microscopically thin. In medusae the mesoglea makes up most of the body's mass and acts as a sort of flexible skeleton enabling the organism to hold its structure. In polyps the cell layer is rather thin, and along with the gastrovascular cavity allows the animal to keep its shape.

## Muscles

Cnidarians don't possess separate muscles structures such as mammals. Instead, their muscles are extensions of cells deriving from the ectoderm and the endoderm. The muscles cells can either appear as dense bands with long and grouped together cells, especially in sea jellies and sea anemones, or as thin sheets at the base of the ectoderm and endoderm which is the case for most cnidarians.

In the polyp form, there are two main muscle groups, the muscles of the ectoderm (outer layer) span lengthwise along the cylindrical body and tentacles, and the muscles of the endoderm (inner layer) are usually circular and line the gastrovascular cavity.

When the circular muscles (deriving from the endoderm) contract, they push against the fluid found in the coelenteron stretching the polyp in the process. When the lengthwise

muscles contract, they shorten back the body. Similar muscles are found in the tentacles enabling them to move and sting the prey.

To move sideways or to bend, they contract their lengthwise muscles more on one side than the other.

In the medusa form, all muscles derive from the ectoderm and are located in the subumbrellar surface, known as the concave surface. They are organized into circular and radial tracts. When the circular muscles contract, they compress the gastrovascular cavity forcing out the water, thus propelling themselves forward through jet propulsion. They recover their original shape thanks to the mesoglea, which equally re-extends the muscles.

When the radial muscles contract, they alternate the shape of the bell enabling them to move in different directions.

## Skeletons

Cnidarian species are considered soft-bodied, even though most possess a sort of skeleton, not including the hydrostatic skeleton found in polyps. These skeletons only appear in the polyp form and can either be internal or external.

Cold Water Images, Photography by Kawika Chetron - Encrusting hydrocoral, Stylantheca porphyra

Most hydroid polyps (polyps from the class Hydrozoa) secrete a hard external skeleton made of chitin (the same material found in the exoskeleton of insects). It practically acts as a protective tube surrounding the polyp and their network of surrounding stolens[3], it's tough while still allowing motion. Something worth mentioning are hydrocorals, even though they are part of the class Hydrozoa, they closely resemble the true stony corals from the class Anthozoa, due to their internal skeleton composed of calcium carbonate and their manner of encrusting and branching it out.

Pink Branching Hydrocoral- by Connie Bishop

Anthozoan coral polyps, which resemble sea anemones, have a hard exoskeleton made of calcium carbonate that is secreted by the lower portion of the polyp and takes the shape of a cup, also called a calyx, in which the coral polyp sits in. Surrounding this external skeleton are walls of tissue called the theca. Their skeletons come in three main forms, massive, encrusting and arborescent.

The last major type of cnidarian skeleton is found in the anthozoan subclass Alcyonaria and the order Antipatharia. It's internal, and in sea fans[4] and sea whips[5] it's composed of a horny protein called gorgonin fused with calcareous spicules. These two substances together form a solid or sometimes jointed central rod that supports the colony.

Sea anemones do not possess any hard skeletons, although their close relatives, species in the order Zoanthidea of the class Anthozoa, are known to incorporate foreign objects, such as grains of sand or sponge spicules, into their body walls, to act as a sort of support and protection. We additionally discovered that small sea anemones that inhabit rough

[3] Stolens are tube shaped structures that connect polyps that live in colonies, allowing them to distribute nutrients, reproduce asexually and so on.
[4] sea fan, any member of a genus under the suborder Holaxonia (class Anthozoa, phylum Cnidaria)
[5] sea whip, all species of several genera of corals of the order Gorgonacea (phylum Cnidaria)

and intense areas with lots of current use abandoned barnacle shells, referred to as barnacle tests, as protection and for the benefits one gets with a skeleton.

## Nervous system

Cnidarians do not have a brain or in other words a central nervous system, this phenomenon is known as a rudimentary nervous system. However, even though they drift along “mindlessly” with the currents or stay immobile on the sea floor, they still possess a nervous system and are aware of their surroundings. It’s simple and is composes of interconnected neurones scattered across the body which resemble a sort of net, which is why it’s referred to as a nerve net.

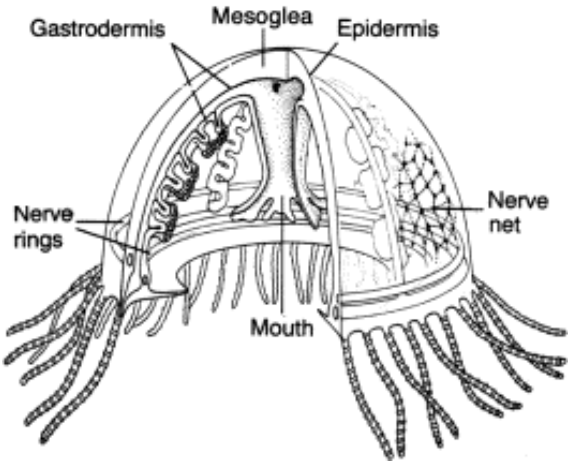
It allows them to feel the temperature and salinity of the surrounding water, oxygen concentration, ocean currents, capture prey, avoid predators and more.

Such as other structures, the nervous system of a polyp isn’t identical to the one of medusae. Polyps possess two main interconnected nerve nets, one found all throughout the epidermis (the outer layer), and one found all throughout the gastrodermis (inner layer). Typically, the neurones of the nerve net tend to be more condensed at the oral and aboral ends of the organism. In addition, some polyps have smooth gastrodermises, also known as a plain epithelial sheet, such as in medusae. Other species have a gastrodermis that carry folds, which are known as mesenteries, they divide the gastrovascular cavity, which is the case in many Anthozoans (more on mesenteries in the chapters Anthozoans). In some species of polyps with mesenteries, there are signs of early organisation of the nerve nets. They possess bundles of neurites, in other words bundles of any sort of projection from the cell body of a neurone such as an axon or a dendrite, that run along the base of these mesenteries.

Medusae are capable of locomotion and orientation, so it is only natural that they have more organised and complex nervous system compared to polyps. Just like polyps they have a nervous system comprised of nerve nets; a large nerve net responsible for swimming and locomotion, and a small nerve net that is responsible for all other behaviour. When a medusa detects a stimulus, be it finding prey or being attacked by a predator, through the nerve net, the neurones proceed to transmit this information to the circular nerve rings, the rhopalia and all other nerve cells to conduct an appropriate response.  Where the nervous system of medusae becomes interesting is that in comparison to polyps they do in fact possess organised structures that one could simply put have the same role as a central nervous system.

One of these structures are the two inner and outer nerve rings found in the margin of the medusa’s bell. The inner nerve ring is thought to be a fused giant axon, which acts as a type

Diagram of basic morphology of a medusae




of communication centre, it has specialised morphological features that enable rapid signalling between cells. The outer nerve ring processes all sensory information and enables the organism to appropriately respond to stimuli.

They equally have specialized sensory structures, called rhopalia (singular: rhopalium). They are part of the larger nerve net, and they are found in some scyphozoan species and all organisms part of the Cubozoan class. Rhopalia are placed on the edge of the medusa's bell rim. They resemble small domes and they are interconnected by stalk-like structures that run through the ectoderm creating a scalloped edge. These structures vary in size, number and form depending on the species and can be very divers; nonetheless, they always have two specific features: ocelli and statoliths. Ocelli are light sensors they work similarly to eyes, also known as eyespots, in most species can hardly perceive more than a few pigmented patches; but in some Cubozoans, ocelli are so far developed and complex, that they can form blurry images. Statoliths are structures that perceive gravity, allowing medusae, such as jellyfish, to remain upright and have a sense of orientation in the water.

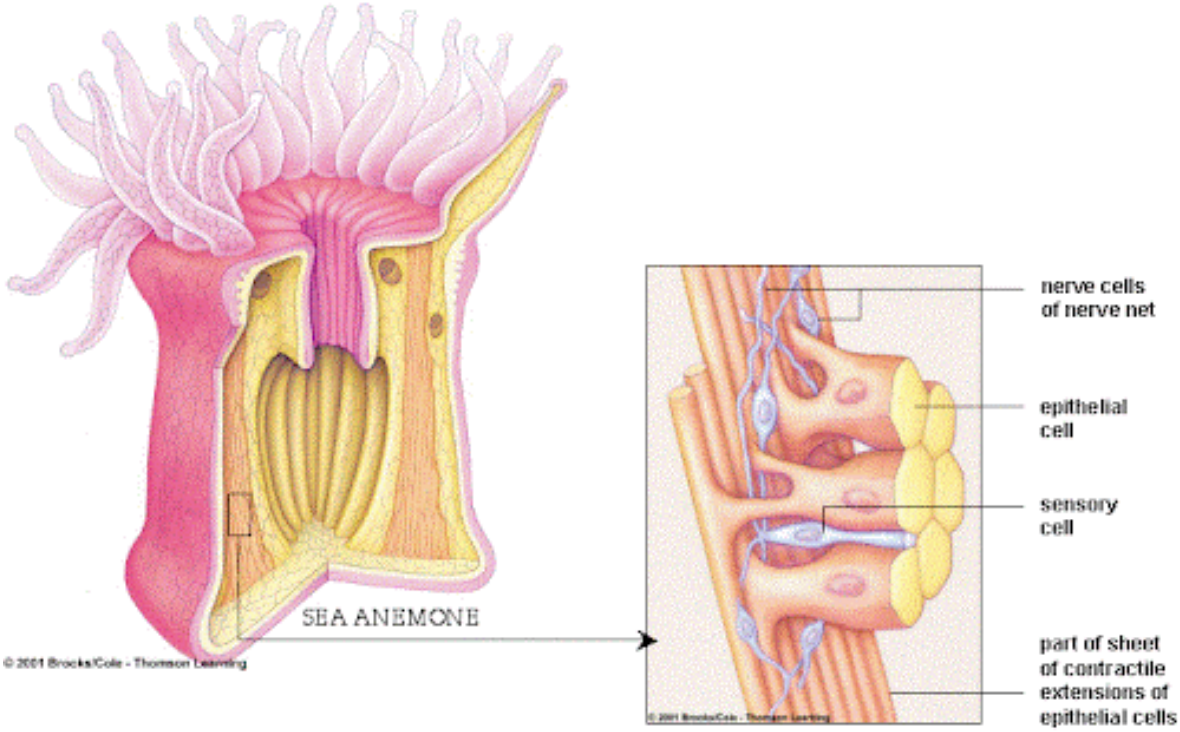
The cells that compose a cnidarian's nervous system are divided into three main groups of nerve cells: sensory or sensory-motor neuron, ganglion neuron and mechano-sensory cells known as cnidocytes.

Sensory neurons are positioned up right in the epithelium (the layers of cells that line a cavity, in this case the gastrodermis, mesoglea and epidermis) and are characterized by the presence of a special organelle called an apical cilium. This organelle is located on the surface of the medusa's body, enabling it to sense things in its surroundings, for example something or someone touching it.

Ganglion neurones function exactly like interneurons; they interconnect neurone, and in a few species, they also synapse ("connect") on muscle and stinging cells. Their soma (cell body) is found in the base/bottom of the epithelium.

Meaning, sensory neurons detect stimuli at the top of the epithelium, they send signals to the ganglion neurons which proceed to process them and send out appropriate responses through the nerve net.

# Nerve Net


SEA ANEMONE
© 2001 Brooks/Cole - Thomson Learning
nerve cells of nerve net
epithelial cell
sensory cell
part of sheet of contractile extensions of epithelial cells

## Cnidocytes

Cnidocytes are the most important characteristics of cnidarians. They are a reason why organisms of this phylum, such as jellyfish, can sting. Located around the mouth and tentacles, they allow the animal to immobilize prey and ward of predators, thanks to the (sometimes very potent) toxin contained within the cells.

These cells (cnidocytes) are capable of ejecting toxins, due to a specialized organelle called a nematocyst. It is a hollow capsule that contains a coiled hollow thread which sometimes bears a barb, resembling closely to a harpoon. The cell wall is lined with hairlike projections known as cnidocils, which have the same function as triggers. Since nematocysts lie under high osmotic pressure; when an external stimulus (such as a human arm) comes into contact with the cnidocils and the lid of the cell pops open, sea water fills the capsule consequently firing the coiled thread which releases toxins in the prey or predator.

The firing of nematocysts can happen in less than a millionth of a second, making it one of the fastest natural biomechanical processes.

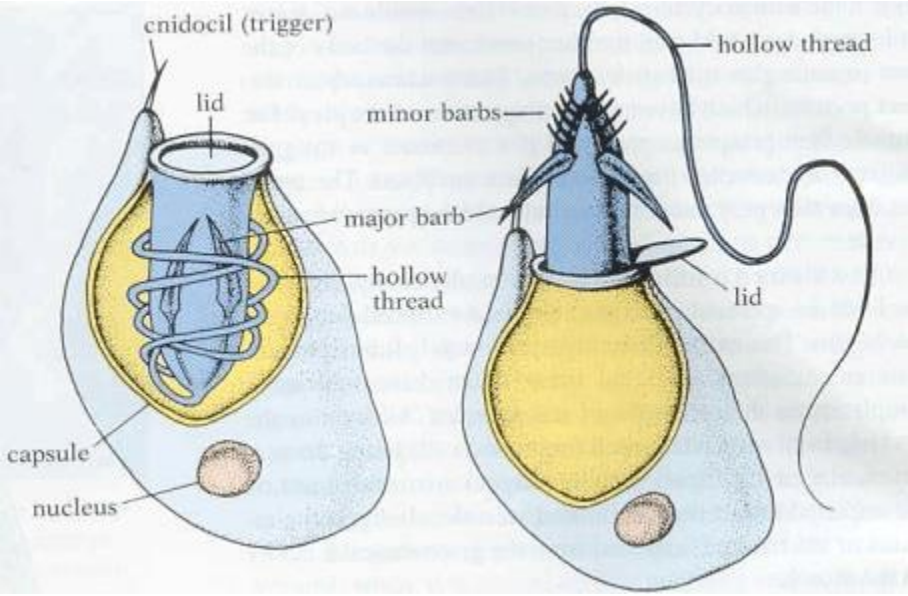



Diagram of a cnidarian cnidocytes (stinging cell)

# Reproduction

Cnidarians can either be unisexual or bisexual. In biology, bisexuality refers to the condition of an organism possessing both female and male gonads (reproductive organs), also known as monoecious or hermaphroditic and unisexual organism only posses a single type of sexual organ, thus being capable of producing solely male or female gametes (sexual cells). Typically, bisexual species in cnidaria are incapable of self-fertilizing so with sexual reproduction two individuals are required.

Both asexual[6] and sexual reproduction are present in this phylum. In general, polyps reproduce asexually; however, there are some species that produce gametes and thus reproduce sexually. For the most part medusae procreate sexually. Therefore, a single cnidarian organism may use both asexual and sexual reproduction in their life cycle.

Cnidarian species that procreate asexually, do so through either budding, fission or fragmentation. Budding is when a new individual splits off from the parent, fission is when the parent splits into two or more individual organisms and lastly fragmentation is when a piece of the parent breaks off, which then divides into further pieces and lastly regenerate. Polyps tend to reproduce asexually, seeing as they are sessile and can't go find a partner to mate with.

Cnidarians that procreate sexually, usually medusae, can either reproduce internally or externally.

The species that reproduce externally gather in huge numbers for a process called spawning, they release ova and sperm into the water in hopes an egg might get fertilized and become a zygote. By cnidarians that procreate internally, the female must ingest the male's sperm to reach the females egg cells for fertilization.

Spawning may be triggered by external factors such as water temperature or tidal range and release of gametes is triggered by lighting conditions, such as the sunset or sunrise and the phase of the moon.

The zygote, the fertilized egg cell, then developpes into a ciliated larva known as a planula.

[6] Asexual reproduction is when an organism procreates without sex, resulting in the offspring being completely genetically identical to the parent.

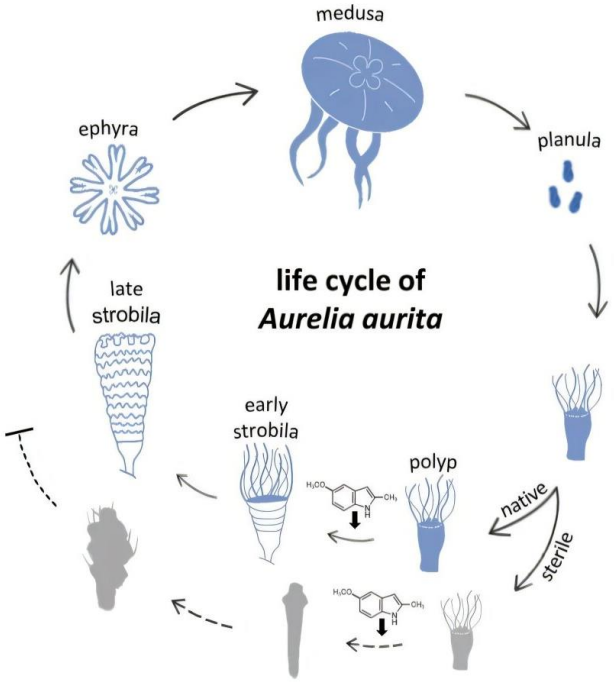
# Life cycle

As we previously saw, Cnidarians can either be in the form medusa or polyp, some species only go through a single life stage in their life cycle, and some go through both. Either way, if they reproduce sexually, then generally an organism will start off as a planula. There are naturally a few exceptions, such as the Aplanulata and the parasitic Myxozoa, where the planula stage has been lost entirely.

With species that exhibit both life stages, the fertilized egg of a medusa, a result of a spawning event, developpes into a planula, a free-swimming and ciliated larva. The planula then finds a spot where to grow into a polyp. Polyps can stay dormant for many years, eventually when they decide to develop onto medusae, they do so in the form of asexual reproduction. The polyp forms a stack of medusoid structures, structures that resemble the shape of a medusa, that then bud off as immature tiny jellies, known as ephyra, which then develop into independent medusae. This process is known as strobilation. The medusae will then eventually reproduce sexually, forming a planula and continuing the cycle.

In species that exhibit a single life stage, be it polyp or medusa, the planula is formed by either a fertilized medusa or polyp ova depending on the species. If it's an offspring of a species which exhibits solely the medusa stage, it metamorphoses directly into a free-swimming miniature version of a medusa.

If it derives from a polyp with only a polyp stage, it will navigate through the water until it finds a hard surface to grow on, such is the case for a lot of Anthozoan species.




Most common cnidarian life cycle

# Class Anthozoa

The class Anthozoa, meaning “flower animals”, is composed primarily of sea anemones, sea pens and corals, summing up to approximately 6000 species.

Organisms in this class are found exclusively in the polyp stage and mostly show biradial symmetry. Their oral end is shaped like a disk with a mouth/anus located in its center, the mouth connects to the gastrovascular cavity through the stomodaeum, which acts as their throat in a way. In the stomodaeum are grooves lined with microscopical hairs called cilia, these grooves are referred to as siphonoglyphs, their function is to transport water in and out of the cavity. Their gastrovascular cavity is divided into sections by radial wall-like structures called mesenteries that line the gastrodermis. If they reach the stomodaeum, they’re known as complete mesenteries, if they don’t, they’re known as incomplete mesenteries. They can either be found living and working together as a colony, such as coral or solidary staying separate from other organisms, such as sea anemones.

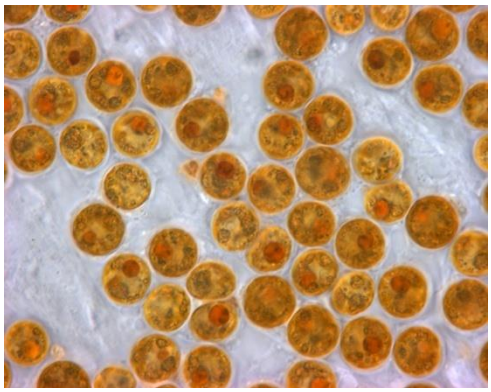
## Corals

Coral polyps

When we think of corals, we imagine these huge coral reefs spanning for miles, with a variety of beautiful different colors, but those are not the corals themselves, those are huge colonies composed of thousands of small polyps. Coral is the individual polyp animal, while a coral reef is the colony in which these polyps are found in. Coral reefs are some of the most diverse ecosystems, even though they make up solely 1% of the ocean, they house about 25% of all marine species. There are two main types of coral, stoney/hard corals and soft corals, both of which form colonies. The corals that build these huge reefs are the stoney corals, these polyps are capable of doing this thanks to the hard skeleton composed of calcium carbonate ($CaCO3$) they secrete and attach themselves to. Soft corals on the other hand do not secrete skeletons, instead they possess a sort of flexible support structure made out of a protein known as gorgi, which contains tiny calcium carbonate structures called sclerites. This allows them to move with ocean currents, while still being able to grow in their characteristic vertical manner, often visually resembling plants or trees. When though they are incapable of forming reefs, they are found in coral reef ecosystems.

Majority of reef-building corals contain zooxanthellae in their tissues; these are photosynthetic unicellular algae that have a mutualistic relationship with the corals.

Mutualism is when two organisms benefit from a relationship between each other. For example, ticks and cats have a parasitic relationship since there's one party is benefiting and the other is being harmed, whales and barnacles have what is called a commensalism relationship one party is benefiting, the barnacle has an easier time finding food, while the other is unaffected both positively and negatively (the whale), lastly as said before a mutualistic relationship is when both parties benefit positively such as bees and plants, one gets pollinated and the other gets what is needed to produce nectar. In this case corals provide the zooxanthellae with shelter in addition to the carbon dioxide and water that the polyp's cells produce which are vital for the zooxanthellae to photosynthesize. The zooxanthellae then, in return provide the coral with the biproduct of their photosynthesis, sugar and protein, which the coral needs to survive and replicate. Zooxanthellae do not only provide majority of nutrients for corals, but they're also the reason why coral reefs come in so many different colors. Which is why corals turn white during coral bleaching, when the polyps become stressed due to external stimuli, such as a sudden rise in temperatures or a drastic change in water salinity (often biproducts of climate change), they expel the algae out of their bodies causing them to lose all their color and to only survive for maximum a few more days before eventually dying of starvation.



Zooxanthellae found in corals

Giant sea fan- soft coral

Cup coral- stony coral

# Class Cubazoa

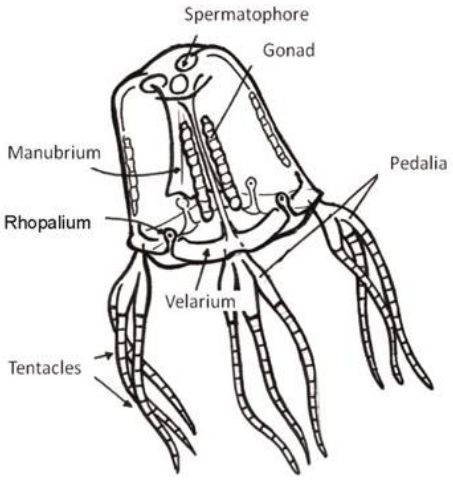


Diagram of the morphology of a box jellyfish

The class Cubozoa includes about 50 species of box jellyfish.

They inhabit tropical waters, such as the warm coastal regions of northern Australia (where the most venomous box jelly is found) or in the mangroves forest of Florida.

As the name entails, they are box shaped with a dominant medusoid form, the polyp stage of most species is unknown, but for the ones we do know polyps may bud off to create a colony, and each individual polyp becomes a single medusa. Cubozoans are similar to Scyphozoans in Anatomy and Morphology; however, they are smaller in size, ranging from 15 to 25 cm. A key difference between the two is the position of tentacles, cubozoans possess muscular pads known as pedalia in the corners of their square bell with single or grouped tentacles attached to each pedalium. In some species the gastrovascular cavity extends to these pedalia.

Box jellyfish are known for being extremely dangerous, they possess potent toxins capable of killing a human in under 5 minutes. This class does not solely possess the most venomous cnidarians, but some of the most venomous species in the world. Even cnidocytes, in some species, are arranged spirally along the tentacles, to make hunting prey and stinging more effective, making them even more dangerous.

The organisms of this class possess the most acute ocelli (eye spots), capable of forming images, their ocelli are located in clusters of four in sensory structures known as rhopalia between each pair of pedalia. No one really knows how they're able to form images; because they do have highly developed light sensing structures, but the manner in which these images are processed remains a mystery, for cubozoans possess nerve nets and not a central nervous system.

Box jellies are divided into separate sexes, sexual reproduction occurs internally and planula larvae sometimes equally develop inside the female.

## Australian box jellyfish

The Australian box jellyfish (*Chironex fleckeri*) is regarded as the most venomous animal in the entire world. It preys on fish and crustaceans; however, its venom is lethal to humans. Their bell grows up to 38 cm in diameter with each of its corners usually possessing 15 tenacles, that can grow to up to 3 meters, making them not only the most dangerous but also the largest of all box jellyfish. Unlike other medusae, they do not flow with the ocean currents but can actually swim and reach speeds up to 4 knots, making it very rare for them to get washed up like other jellyfish. They inhabit the warm coastal waters of northern Australia, anywhere north of Gladstone in Queensland to Exmouth in western Australia.

When stung by one of these dangerous animals, specialized stinging cells that run along their tentacles, known as cnidocytes, inject a potent venom. Not much is known about its biochemical structure, since it is really hard to get a pure venom sample without getting contaminated or destroying the proteins found in the toxin (they are really fragile and easily degraded by simple changes in temperatures or pH levels). What some studies have recently found out is that their venom is composed of a variety of different porins (transmembrane proteins), neurotoxic peptides and bioactive lipids. The consequences of a sting are, immediate and excruciating pain, followed by skin cell death, and if really bad and not immediately treated, one can experience Cardiac arrhythmias (abnormal or irregular heartbeats) and Cardiac arrest (which is usually what kills you). All this can happen as quickly as only five minutes.

The box jellyfish (*Chironex fleckeri*), also known as the sea wasp

# Class Hydrozoa

Hydrozoa is composed of more or less 3000 different species, most of which are marine animals and inhabit salt water; however most freshwater cnidarians are Hydrozoan.

There are species that exhibit both the polyp and medusa from and there are some where one of the life stages is completely absent or dominated. The organisms that live in colonies are usually polymorphic and composed of zooids. Unlike Anthozoans, Hydrozoans do not possess a divided gastrovascular cavity. Their most important characteristic, that divides them from all the other classes, is that their gonads (reproductive organs) derive from the epidermis layer (outer cell layer) whereas in all the other classes, gonads derive from the gastrodermis (inner cell layer). The medusa form of Hydrozoans possesses a muscular veil known as a velum below the border of the bell.

## Portuguese man o' war

The man o' war gets its name from its resemblance to an 18th-century Portuguese armed sailing ship (man-of-war) at full sail. They inhabit warm tropical and sub-tropical water along the Atlantic Ocean, the Pacific Ocean, the Indian Ocean, the Caribbean and the Sargasso Sea.

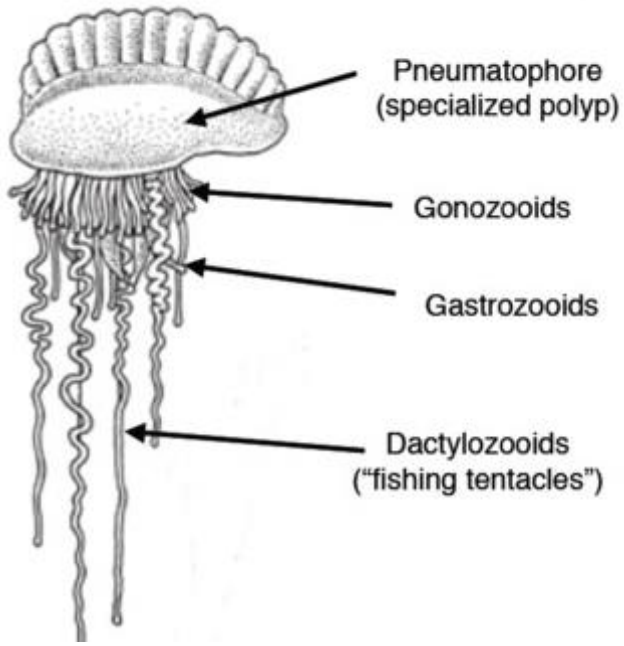
Often believed to be a jellyfish, the Portuguese man o' war is actually a species of siphonophore. It's a colony of multiple polyps, each genetically identical and with a specific task and function, these kinds of organisms are known as zooids, think of them as many floating polyps stuck and working together. There are four main kinds of zooids that compose the man o' war: the uppermost polyp (pneumatophore), the tentacles (dactylozooids), the digestive polyp (gastrozooids), and the reproductive polyp (gonozooids); all completely dependent of the other unable to survive on their own (unlike coral zooids).

Being polyps, they are incapable of locomotion, so they move with the ocean currents and float thanks to specialized zooid known as the pneumatophore. The pneumatophore possesses a gas-filled bladder that sits on top of the water, along with buoyancy it's also used as a sail, catching the wind and drifting along the colony. The gases filling the sail are a mix of carbon monoxide (CO), oxygen (O), nitrogen (N2), and argon (Ar). It's the first to form during development, with all the other zooids growing of it.

Beneath the sail is a cluster of polyps composed of digestive and reproductive polyps, off them grow the dactylozooids, tenacles bearing polyps whose tentacles lined with cnidocytes can reach lengths over 30 meters. When these zooids successfully capture prey, they pass it along to the gastrozooids. Gastrozooids are known as the feeding zooids,

they’re the only polyps capable of digestion, which can be both extracellular and intracellular. They start by secreting enzymes that break down the proteins, carbohydrates and fats of their prey, consequently liquefying it, which makes it possible to start the intracellular digestion, which simply breaks down the prey even further. Lastly, the nutrients get absorbed into the body and eventually will circulate to the other zooids of the colony. Another important note is that gastrozooids do not possess any tentacles.

The last kind of zooid are the gonozooids responsible for reproduction. Even though a man o’ war is a colony, each colony is either completely female or completely male, so during reproduction they act similar to a single organism. The sexual reproduction process is very similar to the one of medusae, they gather in large groups and their gonozooids release gametes (sexual cells) into open water hoping they get fertilized. When an ovum gets fertilized and develops into a larva, the first zooid it will form is the pneumatophore (the “sail”) and then through asexual reproduction the rest of the colony will grow.




Morphology diagram of Physalia physalis (the Portuguese man o’ war)

the Portuguese man o’ war

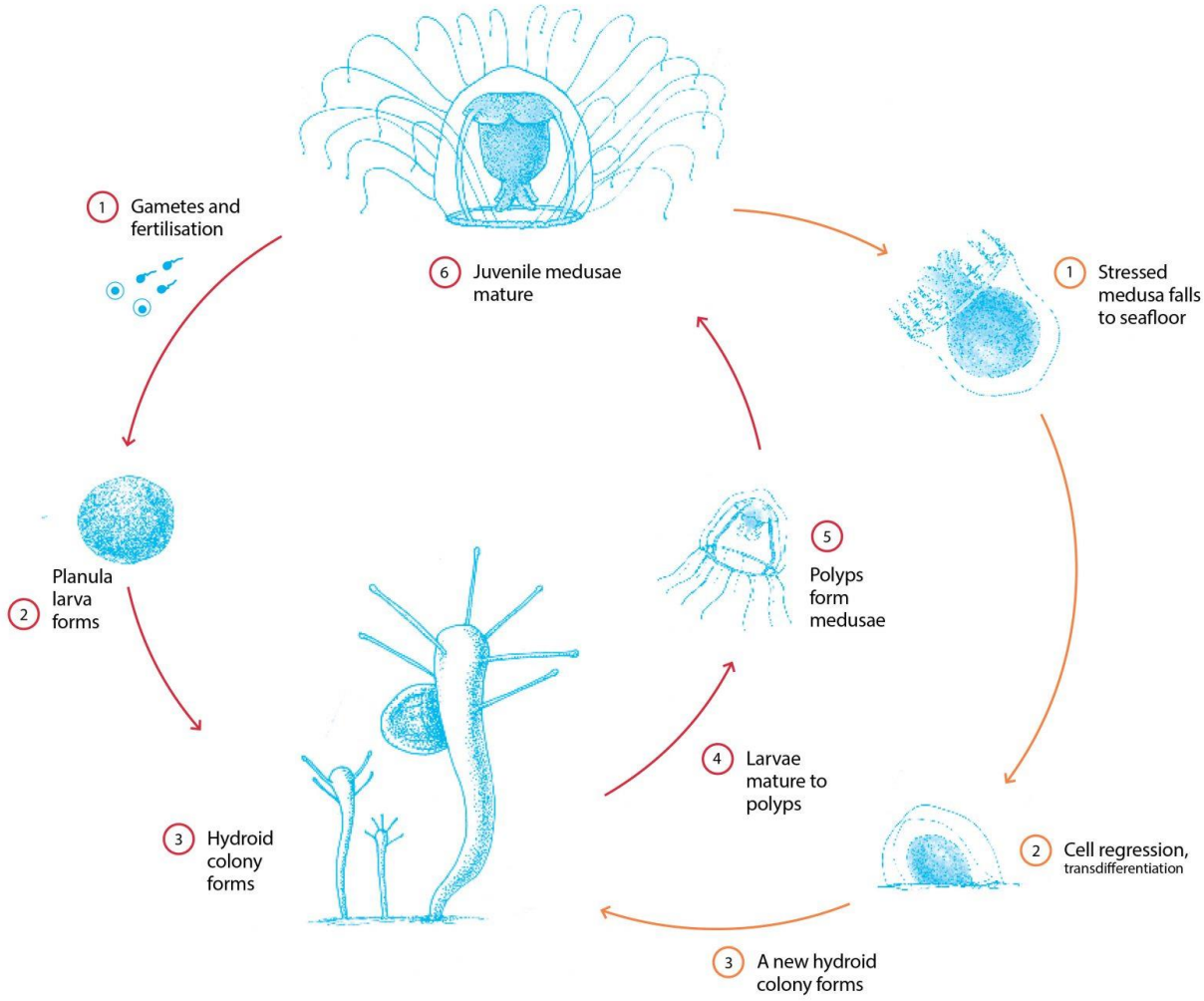
## The immortal jellyfish

The immortal jellyfish, *Turritopsis dohrnii,* was discovered completely by accident. In the late 1980s two laboratory students, Christian Sommer and Giorgio Bavestrello, were collecting samples of what they thought were *Turritopsis nutricula*, a species of hydrozoan which resembles almost identically to its immortal relative. These organisms are less than a centimeter long and the ones the young scientists collected were in their immature medusoid form (ephyra). They then brought them back to their laboratory for observation, they placed the specimens in a tank and neglected them for a little while. When they came back, expecting sexually mature medusae, they found fewer medusae than before and a surprising number of polyps on the bottom of the tank. It was a rather short time span; so even if improbable it was possible that the animals had reproduced, even so it didn't explain the fate of the missing adult medusae.

The scientists, therefore, started to keep a closer eye on these specimens, eager to find an answer. What they discovered was revolutionary. The sea jellies were not spawning and reproducing new polyps, they were themselves reversing and metamorphosing back to their juvenile state, a polyp, completely reversing their life cycle to be able to start again. They are, as far as we know, capable of doing this over and over again; achieving what was thought to be absolutely impossible, biological immortality.

The immortal jellyfish's regular life cycle is the same as most two life staged cnidarians. They start as a fertilized egg after a swarming, which develops into a planula (a floating larva), the planula eventually attaches itself onto a hard surface to grow on, such as a rock. It then forms into a polyp, which grows and eventually starts to develop a stack of medusoid structures to bud off, the ephyra (immature medusae) are thus released and mature over time into full-grown medusae. Typically, that is as far as a cnidarian (with two life stages) will grow; they'll procreate, eat, swim and eventually die as medusae.

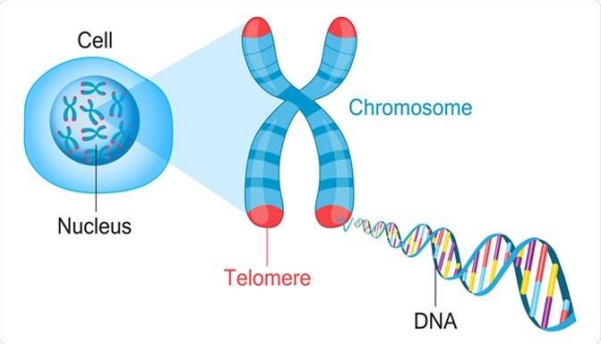
Dying as medusae is, however, not the case with the immortal jellyfish, they found a way to keep on living after this "final" stage, to elude death by natural causes. When they experience high levels of stress, such as starvation or serious injury, they are capable of changing all their cells back to their juvenile state. The medusa shrinks itself down, during a process known as regression or reserve metamorphosis, into a blob-like structure which then settles on a hard surface, maybe a rock (exactly like a planula) and becomes what is known as a cyst, a special intermediate stage. Within more or less three days the cyst developpes into a polyp and the specimens life cycle restarts again. This entire process takes about as little as a week to complete.




Lifecycle of the immortal jellyfish

They are able to accomplish such a feat, thanks to a process known as cellular transdifferentiation. Cellular transdifferentiation is when a cell has the ability to become a completely different type of cell, directly, without having to be a stem cell first; for example, they can turn a muscle cell into a neuron. Scientists have further proven this fact by discovering that this species does not possess any stem cells (cells that have the ability to become any other type of cell) so immortal jellyfish must repurpose other cells. It is, however, unknown how they are capable of cellular transdifferentiation specifically.

During their cyst form, the stage before becoming a polyp and after being a medusae, most of their energy is consumed protecting their DNA (genetic material). Biologists have observed that these organisms are able to protect and regenerate their telomeres (protective parts found on the tips of chromosomes). Telomeres protect the DNA stored in the chromosomes especially during mitosis (cell division), however, every time a cell regenerates a bit of the telomere is damaged and lost in the process. Since they are quite




long it takes a while before any damage is inflicted on the DNA, but when it does, damaged genetic material leads to cell death and eventually death of the entire organism. This is what happens to humans, fish, dogs etc., immortal jellyfish on the other hand can prevent this. As cysts, they possess a high number of special genes that produce an enzyme capable of repairing telomeres, these are known as telomerase. Scientists believe these enzymes prevent the cells from naturally aging by simply elongating the telomeres, thus keeping the DNA safe.

Originally from the Mediterranean the tiny *Turritopsis dohrnii* are found in almost every ocean today, probably due to sea voyages and human exploration, inhabiting shallow waters for who knows how long.

*Turritopsis dohrnii*- commonly known as the immortal jellyfish

# Class Scyphozoa

Scyphozoans, meaning “cup animals”, includes solely marine sea jellies also known as “true jellyfish”. This class is made up of about 200 species, with the medusa form being the most prominent one in the life cycle, even so the polyp stage is present in the life cycle of most species. The gastrovascular cavity of both the medusa and polyp can be sectioned by four interconnected sacs, called diverticuli. Their nervous system is slightly more complex than a simple nerve net, some species possess rhopalia, which are sensory organs found around the margin of the bell, with statocysts and/or ocelli. They’re most abundant in coastal waters; however, there are some species that inhabit ocean waters.

## Indo-Pacific Upside-Down Jellyfish

The upside-down jellyfish, *Cassiopea andromeda*, inhabits tropical and sub-tropical waters, found in shallow bays and lagoons, often near mangroves. As their name entails, they lie on their bell on the sea floor with their oral arms facing the surface. They feed on plankton, but what makes them interesting is that even in their medusa stage (their most dominant stage) they receive most of their nutrients from a mutualistic relationship with zooxanthellae (a type of dinoflagellates), just like many coral species. Which is why they live in shallow waters, usually around a meter deep, to receive enough sunlight for the algae (zooxanthellae) to conduct photosynthesis. Another interesting characteristic of the upside-down jellyfish, and equally in all species of the *Cassiopea* genus (“the upside-down jellyfish genus”), is that scientists recently discovered they sleep, or at least they do something similar. Earlier studies have shown that that cnidarian soft corals and box jellyfish become inactive during a period of time, this is important because being inactive is a fundamental feature in sleep. Scientists chose the upside-down jellyfish as their test subject, since it has a regular pulsing movement (similar to a heartbeat in humans), which enables long-term behavioral tracking. They started by monitoring these jellyfish day and night and found out that at night the specimens became almost completely inactive and were reacting slower to stimuli, this state was, moreover, quickly reversible which resembled waking up from sleep. To find out if this stage could be considered a sleeping stage, the researchers deprived the jellyfish of their nighttime rest, the next day the specimens exhibited a decrease in activity and slower responses to stimuli. Their reaction shows homeostasis; their bodies were acting “sleep deprived". These results prove that the upside-down jellyfish, even though lacking a brain, does in fact have a sleep-like stage.

*Cassiopea andromeda* – common name upside-down jellyfish

# Phylum Coelenterata

The phylum Coelenterate is a now rejected phylum that encompasses the phyla Cnidaria and Ctenophora (comb jellies). The name derives from the two Ancient Greek words, “koilos” meaning hollow and “enteron” meaning intestine, this refers to the hollow body cavity that both phyla possess called Coelenteron or gastrovascular cavity.

Other similarities of these two phyla are that their species are both radially symmetric and both lack a central nervous system.

However recent studies show that both phyla are too different to be placed in the same phylum.

Cnidarians are comprised of two cell layers with a mesoglea in between, their gut has a single opening known as the mouth and they possess stinging cells called cnidocytes.

Ctenophores on the other hand are comprised of eight “comb rows” which are plates made up of fused cilia, their gut not only has a mouth but also anal pores and instead of stinging cells to capture their prey they have sticky cells called colloblasts.

Other than their morphological differences, their common ancestry was put into question, for one of the biggest arguments to put these two phyla together was that they shared a common ancestor that no other phyla had. This is still in debate; since scientists are still arguing whether Ctenophora or Porifera (sponges) is the earliest branch of the Animal Kingdom. None the less, no one has proven yet that Cnidaria and Ctenophora have a unique common ancestor. Hence every ancestor that they have in common, that we know of, is also a common ancestor of the Placozoa or the Bilateria.

So, in conclusion, there is no justification to group them into the same phylum.

## Predators

Leatherback sea turtle (Dermochelys coriacea)

Even though cnidarians possess toxic stinging cells that protect them from a lot of predators, they are not completely without them. Some hydroids are preyed on by nudibranchs, that eat their way through the hydroid's chitin composed skeleton or in some cases penetrate their prey by crawling inside it through its opening and devouring it from within. In addition, nudibranchs also steal the stinging cells they consume from their pray and use them to line their bodies as a defense against their predators, this stealing process is known as kleptocnidae.

Esophagus of a leatherback sea turtle lined with papillae (the backwards facing spines).

Crown of thrones starfish feast on coral colonies by extruding their stomachs out of their body onto their prey, releasing digestive enzymes which break down the coral tissue into liquid, allowing the starfish to absorb the liquified coral. Along with starfish, there are many fish that feed on corals, such as parrotfish and butterflyfish which are immune to the effects of cnidocytes. This is also true for sunfish and sea turtles, such as the leatherback sea turtle. They have specialized adaptations that enable them to pray on jellyfish, such as backward facing spines in sea turtles that line their mouth and esophagus or recurved teeth behind the sunfish's checks prevent a slippery jellyfish from escaping.

# Nutrition

All cnidarians are carnivores; however, none of them really pursue their prey the way other predators do.

Polyps, being sessile, wait patiently for a potential prey to come into contact with their tentacles, when one does, they sting and paralyses it, to then reel it into their mouth/hole to digest.

Medusae even if motile don't hunt, they swim upwards and then let themselves sink with their tentacles spread out to "fish" for their prey, when they finally come into contact with it, they use their cnidocytes to inject it with their venom and their oral arms place it into their mouth.

The prey they consume varies depending on their own size, from microscopic zooplankton (animal larvae) and phytoplankton (plant larvae) to small fish and crustacean.

Box jellyfish preying on a fish

# Conclusion

I really enjoyed writing this trape, I learned something new and interesting in every chapter. I learned how cnidarians function, how they reproduce, how even though they're some of the simplest animals on the planet, they developed such amazing and complex features. For me the study of cnidaria is so captivating, because they are such simple organisms. They do not possess a brain, a heart, not even blood, and even so they are capable of things like bioluminescence, producing highly potent toxins, and even immortality. Every species has something incredible about it. I would love to keep discovering this branch of biology.

Photography by Serge Vanneste at Pairi Daiza aquarium

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