Cone Snails

Education Outreach
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Graphics

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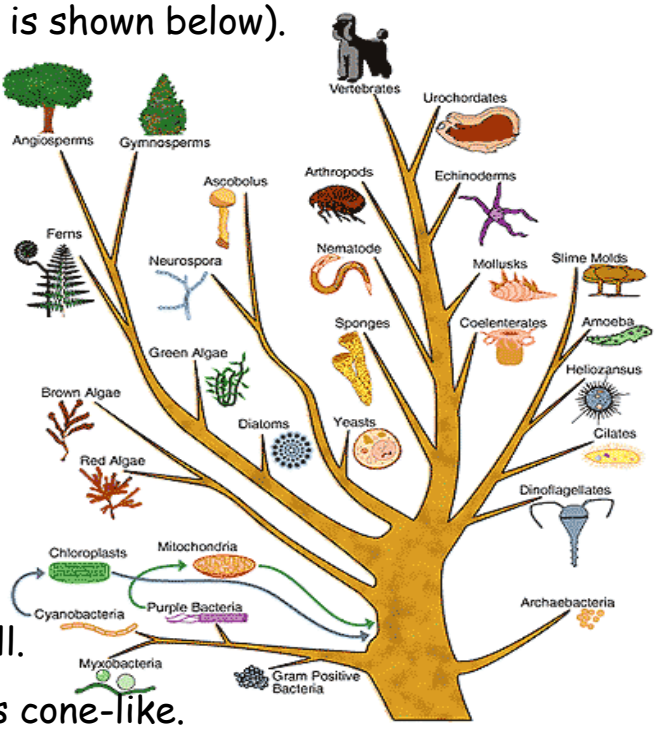
Introduction to Cone Snails

Though most of us are familiar with garden snails, few of us have heard about cone snails. These are a type of marine snail belonging to the genus *Conus*. In Linnean classification, they fall into the phylum of Mollusca and the class Gastropoda. This is where they belong on the "tree of life" (a simplified version is shown below).



Like garden snails, they have a shell.
Its shape, as the name indicates, is cone-like.
Like all gastropods, the snail propels itself on the floor of the ocean with its muscular foot, seen in the picture above.

These snails are of particular interest to researchers because of the variety of venom they contain. They also have a novel system of venom delivery.

In this book we will discuss cone snail anatomy and the production of venom, as well as the special evolutionary adaptations cone snails have that allow them to survive.

Habitat

Cone snails are found in many oceans of the world, primarily in the Western Atlantic, Indian and Pacific oceans.

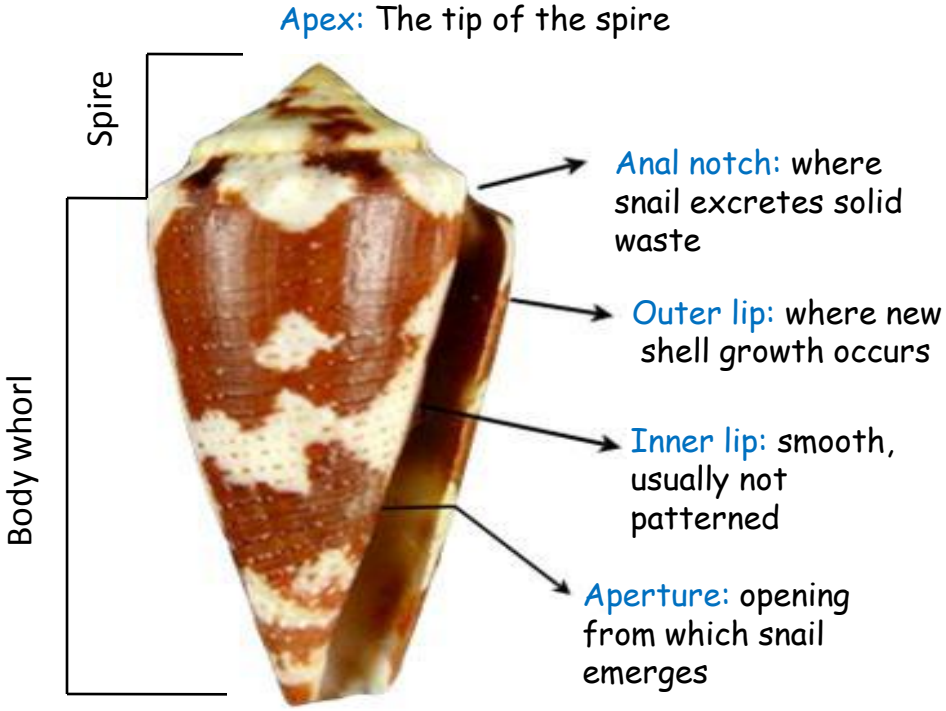
Cone snails can live in many different environments in the ocean, but cannot survive in fresh water. They can live in the coral reefs (shown below) or in shallow sandy waters, where they will often bury themselves under the sand. They may also live in deep sea waters. Each species of cone snails has a preferred environment depending on its diet and other survival factors, and will stay in the same location for most of its life.

Anatomy of Cone Shell

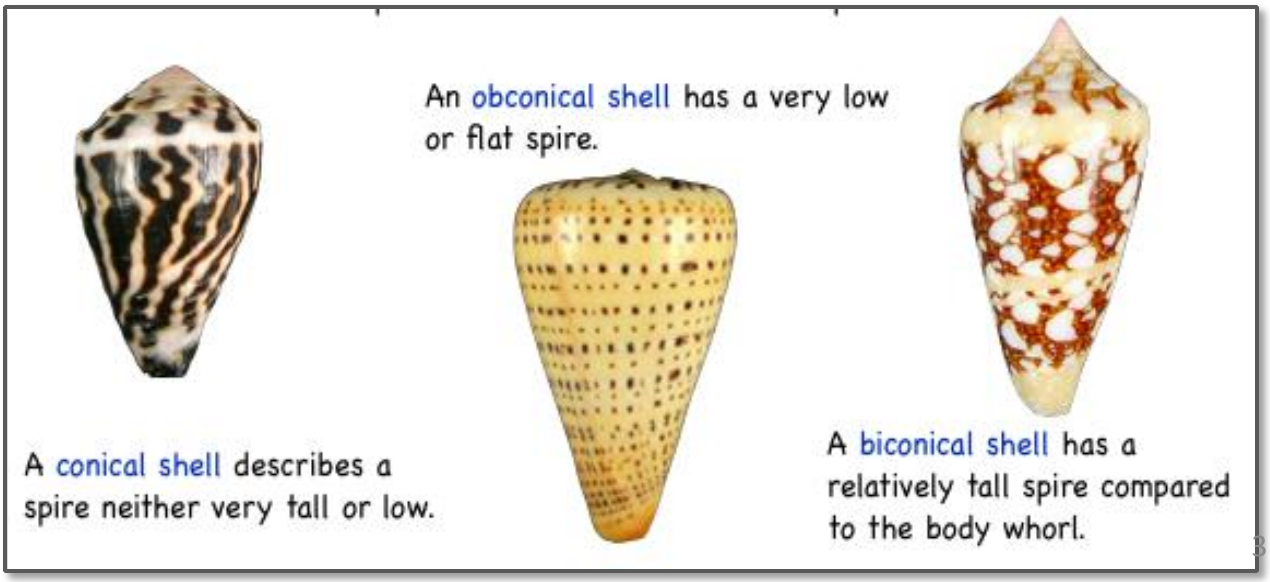
Snail shell anatomy can be divided into two main groups: The spire and the body whorl.

The spire represents the pointed top of the shell and be varied in shape and pattern between different species and also within the same species.

The body whorl is the lower part of the shell, which contains the soft body of the snail.

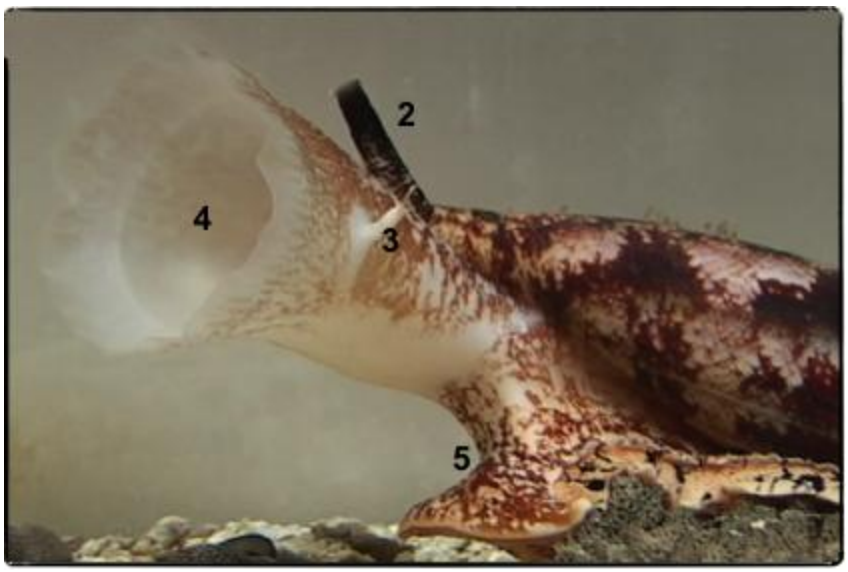


The spire can have different shapes. Some have a tall spire, while some are flat.



Internal Anatomy

The body whorl contains the parts of the snail essential for movement and capture of prey. All parts are shown in the two pictures below. On the right, the snail has opened his large mouth and his foot can clearly be seen. On the left is a clearer view of the siphon and proboscis.



1. The proboscis, a long extendable tube, is used for hunting purposes. Harpoons are loaded into the tube and propelled into their prey, injecting it with venom.
2. The siphon, seen in both pictures, is similar to a nose. The snail uses it to detect its prey in the surrounding waters. It is also a tool for respiration, directing water to the gills.
3. The eye stalks are located on either side of the mouth.
4. The mouth of the snail can be much extended to engulf its prey. A muscle is contracted to bring the mouth back into the shell.
5. A long muscular foot extends to allow the snail to move along surfaces. The columellar, or foot, muscle contracts to pull the foot in and close the aperture (the opening) of the shell.

Life Cycle and Reproduction

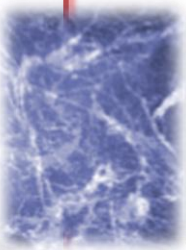
What is the life cycle of a cone snail?

It is difficult to track the entire natural life cycle of a cone snail because very few researchers are able to breed them in captivity.

The female deposits egg capsules under the sand, from which the young eventually emerge as swimming larvae or miniature adults. There are 500-700 eggs in each capsule, but of that number, very few survive to hatch and even fewer survive all the way to adulthood. A diagram of the snail´s life cycle is shown on the next page.

The egg capsules are flask-shaped and translucent

The snail secretes chemicals that become its shell. The shell is mostly made of calcium carbonate, the same material found in egg shells and marble. The snail secretes these chemicals as it grows so the shell continues to fit the body size of the snail at all stages of its life.



Life Cycle of *Conus*

adult

Adults mate

reproduction

Egg-laying female

intracapulsar

Egg-capsule cluster

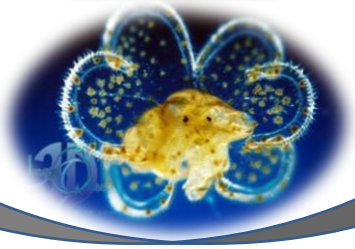
Postmetamorphic growth

Sub-adult

1 mm

Crawling stage

veliger



metamorphosis

Planktonic development

Feeding and Hunting

What does a cone snail eat?
Cone snails are carnivores: they attack and eat other animals. Different species of cone snail have a preference for a certain type of prey. Piscivores eat fish, molluscivores eat other snails, and vermivores eat worms.

Some snails can be very selective in their prey, eating only certain types of worms or fish, and as such can be difficult to breed in captivity, if the correct food is not available. In these cases the snails will only eat when absolutely necessary.

Piscivores eat fish | Molluscivores eat snails | Vermivores eat worms

Mulluscivores will eat other types of cone snail, but sometimes also cowries, olive shells and conch snails.

How does the molluscivore manage to extract the prey from its shell?

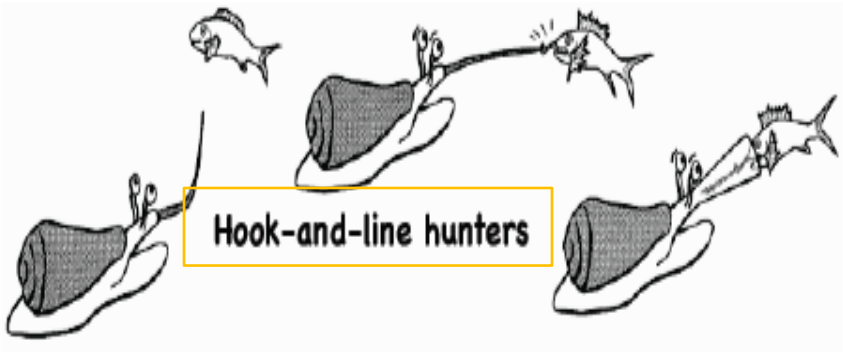
It is supposed that the columellar muscle, the one that the snail uses to retract back into its shell, is paralysed when the snail is stung. If the snail cannot retract back into its shell, and cannot tighten the columellar muscle, its predator will be able to pull it out of its shell and eat it.

Feeding and Hunting Strategies

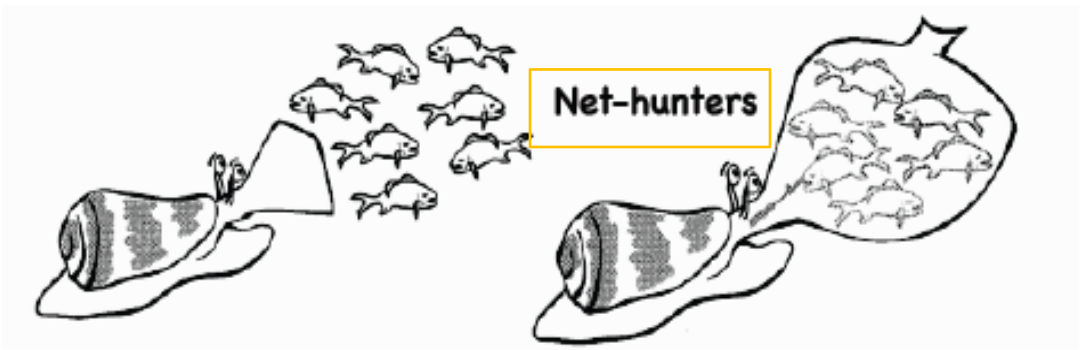
Of the piscivores, there are two types of hunters:
hook-and-line hunters and net-hunters.

Hook-and-line hunters catch their prey using a method similar to using a fishing line. The hook-and-line hunters extend their proboscis toward their prey, eject a venom-filled harpoon, and reel the fish into their open mouth using the harpoon.

A hook-and-line hunter with its proboscis extended, ready to harpoon its prey

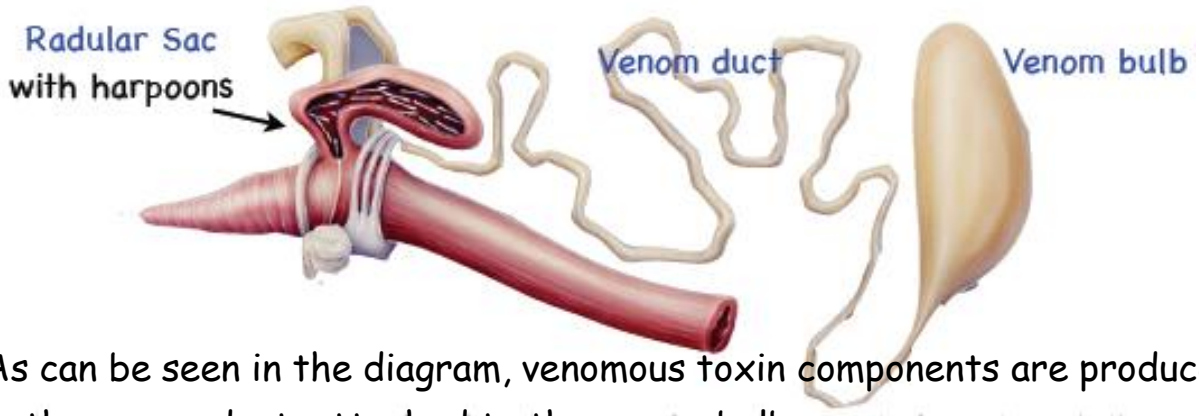


Net hunters also harpoon and paralyse their fish before eating, but their first strategy is to lie in wait for the fish, mouth open, hoping that the fish will crawl in. Once the fish is inside, it will be harpooned, and paralysed. As shown, they are able to reel in whole schools of fish.



Venom System

The snail uses the its venom system to produce and store the venom and to prepare it for delivery.



As can be seen in the diagram, venomous toxin components are produced in the venom duct, attached to the venom bulb.

Snails catch their prey by loading their proboscis with a harpoon full of venom, and using the proboscis to fire the harpoon at the prey.

The harpoons are modified teeth that are stored in the radular sac. Each harpoon is filled with venom before being propelled from the snail´s proboscis into its prey.

The venom bulb, a modified salivary gland, contracts to push venom into the harpoons. The harpoon is like a disposable, hypodermic needle. Once a harpoon has been used, it is discarded. The snail reloads another harpoon for its next attack. As can be seen in the diagram above, many harpoons are stored, ready for such an event.

The tip of a harpoon under a microscope

This is a microscopic view of a harpoon at the end of the proboscis

Human Nervous System

The human nervous system can be split into two parts:

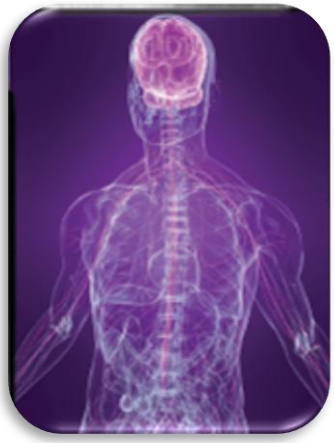
the central nervous system (CNS)

and the peripheral nervous system (PNS).

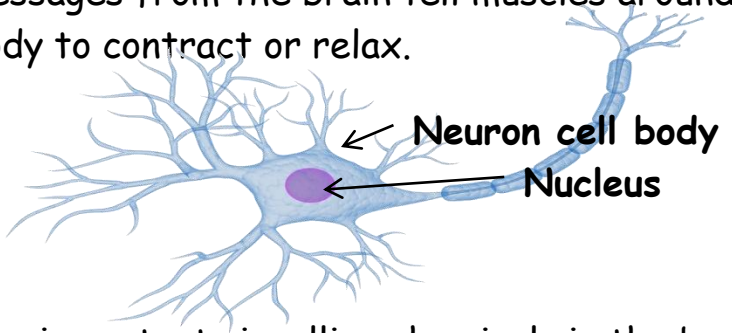
The CNS is composed of the nerve cells (neurons) in the brain and the spinal cord.

The PNS consists of nerve fibres around the body which send and receive sensory information to and from the CNS.

How do neurons carry messages?



Neurons (see image below) send messages electrochemically to one another; **chemicals cause electrical signals**. Messages are sent from different parts of the body to the brain, and messages from the brain tell muscles around the body to contract or relax.



The important signalling chemicals in the body are electrically charged: they are called ions. Some examples of the ions used for signalling between neurons are Sodium (Na^+) and Calcium (Ca^{2+}).

Nerve cells are surrounded by a membrane that allows some ions to pass through ion channels, but blocks the passage of others (a semi-permeable membrane).

The channels open and close like gates.

Venom and its Effects

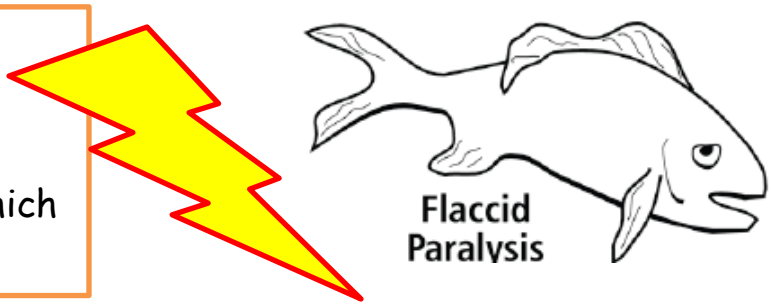
Neurotoxins are found in a variety of organisms in nature, including spiders, snakes, pufferfish, bees and cone snails.

Neurotoxins have an effect on the nervous system. They usually act by blocking or activating ion channels, interfering with communication between neurons and muscles.

Cone snails make neurotoxins (called conotoxins) that can affect many ion channels. Snail venom contains hundreds of different conotoxins to ensure paralysis of prey.

Once injected, the venom acts in different stages.

The first is called the "lightning strike". It immediately immobilises the prey, which starts to jerk violently.



Another is known as the "motor cabal". The venom components interfere with neuromuscular transmission.

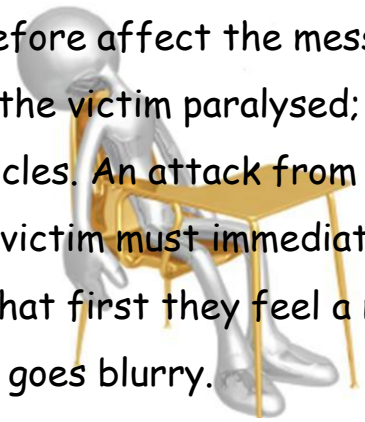
As can be seen above, there are two types of paralysis that can occur: flaccid paralysis, which leaves the prey limp and unable to move, and excitotoxic shock, which contracts all the muscles of the prey at once, making it completely rigid.

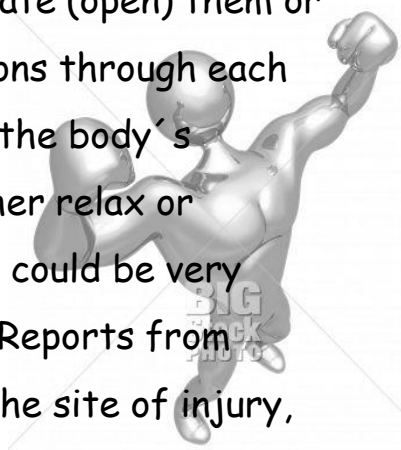
What about us?
Cone snail venom and the human nervous system

Conotoxins have evolved to effectively target the nervous system of fish, worms and other snails. However, the human nervous system can also be affected by these venomous cocktails. Watch out!

Remember that neurons transfer messages to each other using signalling ions like sodium and calcium, and that the membrane has "gates" that allow certain ions through, but block others.

Conotoxins affect these ion channels and can activate (open) them or block them. By doing this they change the flow of ions through each neuron and therefore affect the messages sent to the body´s muscles, leaving the victim paralysed; unable to either relax or contract his muscles. An attack from any cone snail could be very serious, and the victim must immediately get help. Reports from survivors claim that first they feel a numbness at the site of injury, then their vision goes blurry.





There have been human deaths as a result of a sting from *Conus geographus*. Divers who pick up the shell as a souvenir get stung while underwater and cannot get help quickly enough. However, it is possible to survive the venomous sting if they can get to the hospital on time.

Snail Adaptations

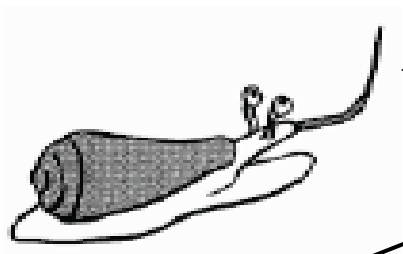
50 million years of evolution have made cone snails very successful marine animals. With time, the snails have adapted to their environment, acquiring different modifications that allow them to successfully evade their predators and effectively capture their prey.

The net hunter has finger-like projections on the end of its mouth, resembling those of a sea anenome. The unsuspecting fish could crawl in, thinking the mouth is a hiding place within the coral.

A net-hunter chasing its prey

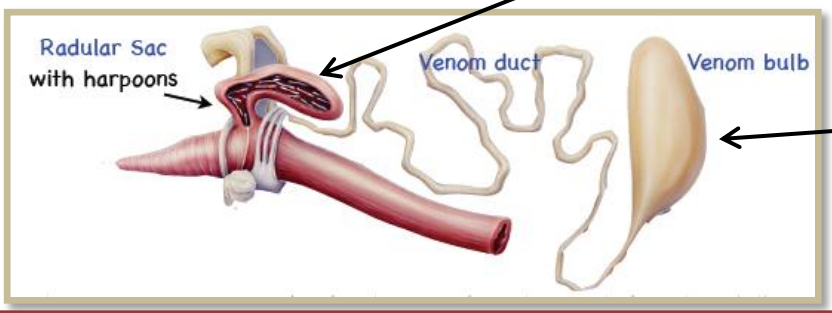
Sea-anenome

The harpoons are evolutionarily modified "teeth". All gastropods, including garden snails have these radula, but cone snails have evolved to make them into venom-filled harpoons.



Long proboscis so that it can stretch out to get the prey

Many disposable harpoons



The venom bulb is a modified salivary gland

Shell Adaptations

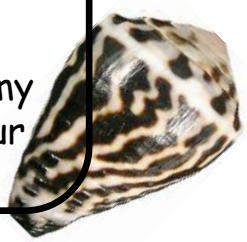
Cone snails are predators but to some marine organisms they are prey! Adaptations of the shell help the snail to survive.

Can you think of a predator that would be a danger to cone snails?

The cone-shape of the shell allows the snail to bury itself into the sand. In this picture we see nothing bu the snail´s siphon sticking out of the ground (can you spot it?). This keeps it hidden, which means it is able to hunt without being seen. It is also able to hide while it digests its food, which could take it a few days!

We already know that some cone snail species hunt other cone snails. Crabs also pose a threat to the snails. They have the ability to reach into the shell with their claws. However, the shape of the shell makes it hard for the crab claws to grasp.

Finally, you might think that the pattern on the cone snail shell has some useful purpose. However, scientists still aren´t sure why these intricate and diverse patterns appear on each shell. Even in nature, the patterns are hidden by a slimy yellow coat. Do you have a theory of your own about the patterns?



Medicinal Uses

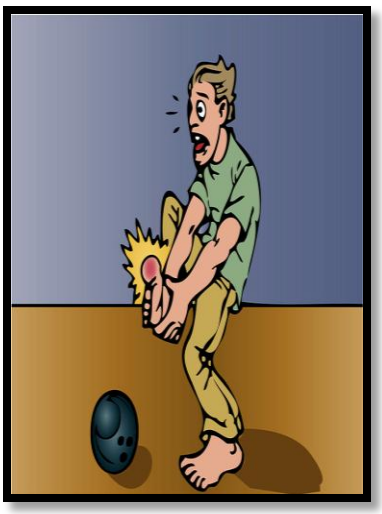
Some of the ion channels that the conotoxins affect are part of our body´s system for perceiving pain.

Scientists have been able to modify the venom, using only the parts that affect the pain channels to develop treatments. These new drugs can block pain that is untreatable with traditional medicine.

Current research is focused on finding more ways to use cone snail venom to help people.

Pain is an unpleasant sensory and emotional experience associated with damage (or potential damage) to tissue. Pain is a message that our body sends to us to warn us that a body part has been damaged, to make sure that we do not keep using that part. That way we avoid further damage or injury to that body part.

Prialt is a drug currently available that was made using a peptide from *Conus magus* and acts by blocking calcium (Ca^{2+}) channels. It is mainly used to treat the extreme pain experienced by cancer patients.



Cone snails and culture

The shells of cone snails are so beautiful and intriguing that humans have long wanted to collect them and use them as items of value.

One cone shell, the glory-of-the-seas cone (*C. gloriamaris),* has in the past been bought for two thousand dollars. There is also a tale of a cone shell that sold at an auction for more than a very famous painting!

Shells as money:

Cowrie shell

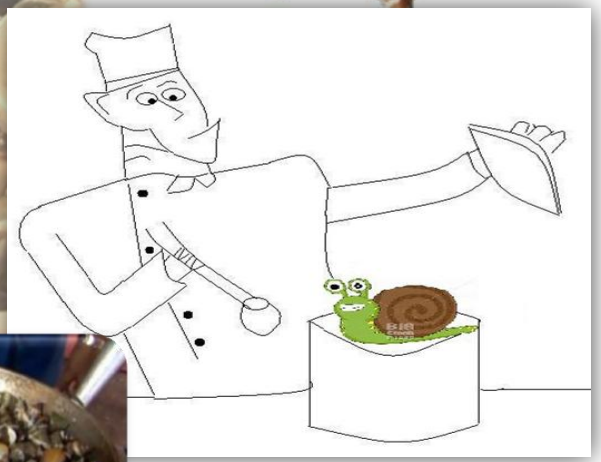
Cowrie shells and cone shells have both been used for trade in certain regions, by tribes in New Guinea and in Mauritania.

Etched cone shells used as currency in Mauritania from the 14th to 17th centuries.

The beauty of the shells has also inspired people to make necklaces and other jewellery out of them. Here is a necklace found in Mesopotamia (what is now called Iraq)

Does anyone eat them?

In the Philippines, *Conus magus, Conus radiatus and Conus furvus* can be bought at markets selling snails and other marine products. The snails can be cooked in coconut milk with garlic, onions, peppers and ginger making a tasty, creamy soup.



Vocabulary

Adaptation: changes in an organism that allows it to survive in its environment better than before

Carnivore: an organism that eats meat

Central nervous system (CNS):

Conotoxin: the toxins made by cone snails. They use them to capture their prey, and to defend themselves against predators.

Harpoon: part of the snail´s venom delivery system. The harpoons are filled with venom and are fired into the prey.

Hook and line hunter: a snail that harpoons its prey and then reels it into its mouth. This strategy reminds us of the way a fisherman catches fish.

Ion: an atom or small molecule that carries a positive or negative charge

Ion channel: a channel which allows ions to pass through. It opens and closes like a gate, and will allow some ions to pass, but will block others.

Lightning strike cabal: the venom components that work together to instantly paralyse the prey. This has the effect of an electric shock.

Modification (modified): changes in an organism caused by environment (see adaptation).

Molluscivore: a cone snail that eats other molluscs (mostly other cone snails)

Motor cabal: the venom components that come together to inhibit neuromuscular function.

Net hunter: a cone snail that hunts by extending its huge mouth and enveloping the fish before harpooning them

Vocabulary

Neuron: a nerve cell

Pain: an unpleasant sensory or emotional experience associated with damage to tissue

Paralysis: the inability to move

Prey: an animal that is hunted by a predator

Peptide: a small protein.

Peripheral nervous system (PNS)

Piscivore: A cone snail that hunts for and eats fish.

Prialt: A drug used for severe pain. It is made from a peptide from *Conus magus* which blocks specific calcium channels.

Proboscis: an elongated organ. On cone snails it is used in hunting. Harpoons are fired at prey through the proboscis.

Radula Sac: Where the venomous harpoons are made and stored.

Semi-permeable membrane: A selective membrane that only certain molecules can pass through.

Siphon: a tube-shaped organ in animals that is used to draw in fluids. Cone snails also use it to smell and sense prey in the water.

Spire: The pointed top of the cone shell.

Venom bulb: A bulb at the end of the venom duct in cone snails, where the venom is stored.

Venom Duct: A long, coiled tube where venom is made in cone snails.

Vermivore: A cone snail that hunts for and eats worms.