General Biology of Jellyfish, Including the Genus *Aequorea*

Abstract: Jellyfish are simple multi-celled animals that have populated the oceans millions of years before the dinosaurs. The bell shaped body that opens and closes like a water balloon being squeezed is the form that is observed at the ocean's surface, is called the medusa. At the bottom of the ocean the asexual form of these jellyfish is represented by their fixed polyp stage. Jellyfish are represented in two classes: Hydrozoa, with well-developed polyps, and Scyphozoa, in which *medusae* predominate, of the phylum Coelenterata (or Cnidaria). Some jellyfish glow bright colors under certain conditions. This ability of a living organism to transfer energy from a chemical reaction into visible light is called bioluminescence. One type of bioluminescent jellyfish found along the coast of the Pacific Ocean, *Aequorea*, glows bright green around the outer edges of it's bell shaped medusa under UV light.

Introduction:

Many people know jellyfish and other gelatinous animals only as unidentifiable jelly-like blobs on the beach. Jellyfish are also often treated as a scourge, deadly creatures that should be avoided due to their venomous sting. In reality, jellyfish and other gelatinous animals are among the most beautiful and stunning animals of the sea. Although a few types may present some danger to people, most are harmless. And, you won't need to worry about dying after a jellyfish encounter on the Pacific coast – there is nothing like the deadly sea wasp (box jelly) of Australia.

Jellyfish are simple animals that were swimming in the oceans over 500 millions of years ago. They have changed little since then because they are so well adapted to their surroundings. Jellyfish have colonized almost all of the water on Earth, with many species living right in the Pacific coast. The jellyfish family name, Coelenterata, comes from a Greek work meaning, "hollow gut." The Coelenterate family, also referred to as Cnidaria, contains two other marine animals, the sea anemones and corals. True to their name, jellyfish, sea anemones, and corals have hollow, baglike bodies with a single opening through which they eat and dispose their waste.

Figure 1. Scyphozoans are extremely rare as fossils; their soft bodies, which are composed mostly of water, can only be preserved under very unusual conditions. Shown here, from the collections of the Senckenberg Museum in Frankfurt, Germany, is a specimen of *Rhizostomites* from the Late Jurassic Solnhofen Limestone of Bavaria, Germany, a body of rock which has yielded many fossils of exceptional preservation.
http://www.ucmp.berkeley.edu/cnidaria/scyphozoafr.html

Structure of Jellyfish:

Their bodies have two skin-like layers with a space filled with gel, called mesoglea. The outer skin layer contains stings for defense called nematocysts, and sensory cells that can detect light and gravity. The latter also gives the jellyfish its sense of direction. The inner skin is responsible for absorbing food. Between the two layers runs a network of nerves and muscles that work in conjunction to open and close the jellyfish's body like an umbrella, propelling it gently and rhythmically through the water.

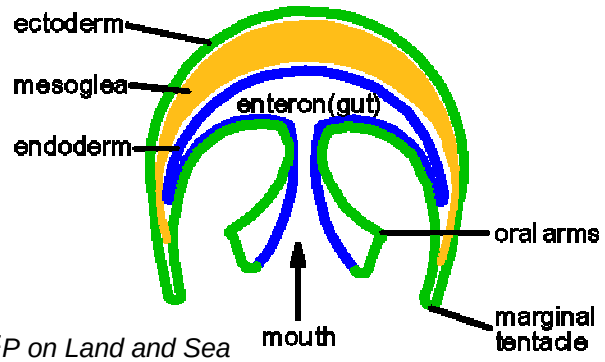


Figure 2: Simplified drawing of the jellyfish body.
http://www.ucmp.berkeley.edu/cnidaria/scyphozoamm.html

The jellyfish has a single opening, or mouth, that food enters, and waste cells and sex cells (sperm or eggs) exit. Cilia in this cavity help to circulate water and dissolved substances throughout their body.

Food web:

The sting cells, or nematocysts, are used to capture prey and defend themselves against predators. The actual stinger is shaped like a harpoon and is tightly wrapped up inside the nematocyst (Figure 3). As soon as the jellyfish brushes up, against something, the nematocysts fire off their harpoons (Figure 4). Toxin (poison) starts to flow down the harpoon, causing extreme pain in its victim. Their prey includes a wide range of small animals that drift in the currents, from plankton to small fish. They do not chase their prey; instead, they swim through the currents hoping to drift into an area rich in microscopic marine life.

Figure 3: The stinger is triggered when it touches or senses an organism.

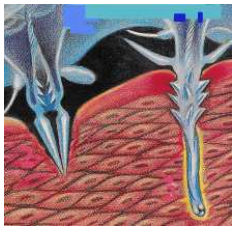
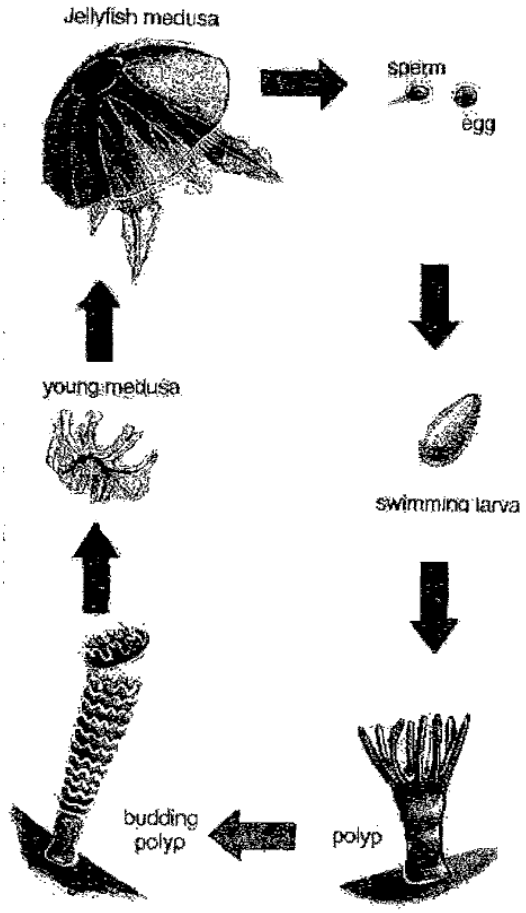


Figure 4: The cell burst open launching a stinger into the skin and anchored by a barb. A long tube is injected by the stinger delivering the poinson.

Although equipped with a strong defense system, jellyfish are eaten by animals that are unaffected by their stings. Their predators include a variety of fish, crabs, and sea snails. They are the favorite food for the giant leatherback turtles. The sea slugs eat the jellyfish and instead of digesting the jellyfish's stings, they steal the nematocysts for it's own defense against predators, placing them on their own backsides.

Life cycle:



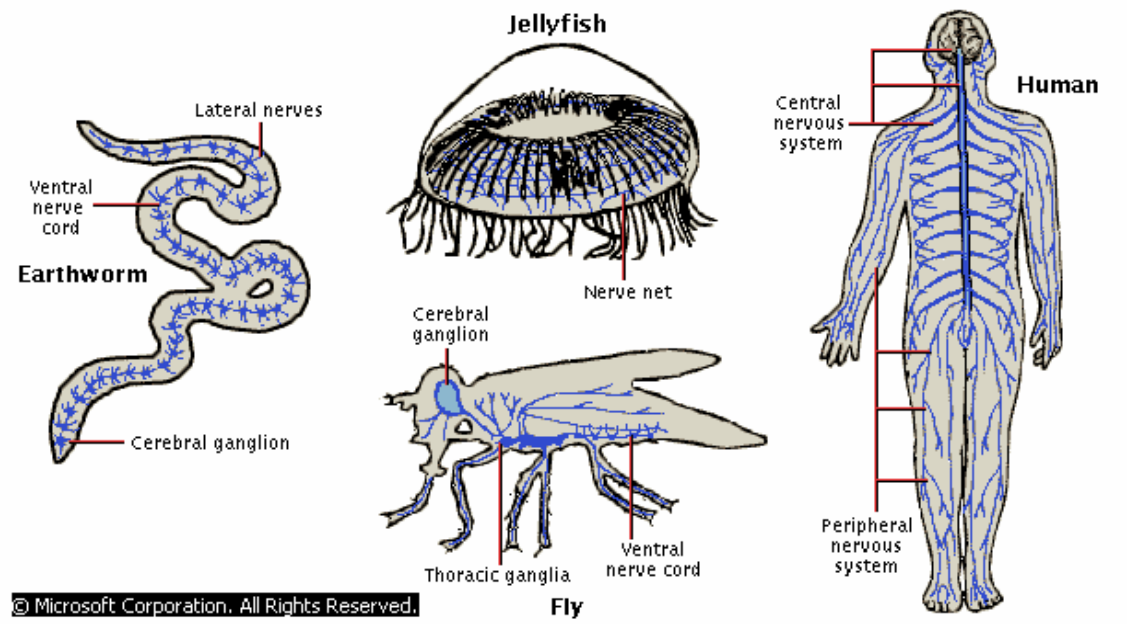
Jellyfish have a very interesting life cycle. Their bell shaped medusa form, often referred to as their feeding or sexual stage, is the stage that is observed on the surface of the ocean and along the beaches when they come in with the tides. The medusas shed sperm and eggs into the sea. Once a sperm fertilizes an egg, it develops into a swimming larva, which settles on the bottom of the sea and grows into a little polyp. The polyp stage stays fixed upon the ocean floor and grows stacks of miniature medusas. At a specific time, the polyps bud off these tiny medusas, which glide toward the light to the surface of the ocean to dine on plankton and small marine life. As they grow, their bodies fill out. It may be months or even years before they are old enough to lay eggs on their own.

Purpose of Bioluminescence:

Many types of jellyfish are bioluminescent and produce beautiful patterns of light. No one knows why jellyfish glow, some think it may be for attracting prey. Some plankton are attracted to bright light and swim up toward the surface where it is brighter. At night, these same plankton may mistake the bright lights of a group of jellyfish (know as a shoal of jellyfish) for the sunlight hitting the surface and swim right into the tentacles of their predators.

Figure 5: Comparison of the nervous systems of invertebrates and vertebrates

Nervous systems range in complexity from the jellyfish's network of nerve cells to the central and peripheral systems of humans. Common to many animals is the nervous structure of the earthworm, which consists of a cerebral ganglion, a main nerve cord, and branching pairs of lateral nerves. In some cases, as in insects, the cerebral ganglion acts as a primitive brain, controlling and coordinating various basic functions.



Interesting Facts on the Jellyfish *Aequorea:*

Aequorea is from the phylum Cnidaria or Coelenterata, Class Hydrozoa, Order Leptomedusae, and Family Aequoreidae. Several species of *Aequorea* inhabit the West Coast of North America, including the Monterey Bay. Although individuals in some populations are capable of reaching a bell diameter of 25 cm (observed off the coast of Alaska), those in Monterey Bay grow between 5-10cm.

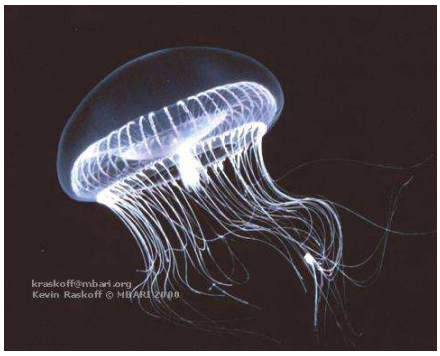


Figure 6. An image that shows bright light reflected off various morphological features of the jellyfish by using an overhead flash in an aquarium. NOT luminescence.
http://www.mbari.org/~kraskoff/aequorea.htm

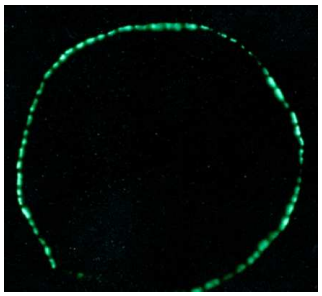


Figure 7. Green luminescent pattern in *Aequorea*.
http://aesop.rutgers.edu/~crebb/ring.html

A green bioluminescent pattern is produced around the margin of the bell due to the presence of green fluorescent protein (GFP), which is coupled to another photoprotein known as aequorin.

For many years, *Aequorea* was collected commercially to obtain minute quantities of these proteins for use in biomedical research. After the successful cloning of GFP in 1995, there was no need to harvest large quantities of *Aequorea*. These jellyfish used to be abundant during the summer in Friday Harbor, Washington, from 1960 through the 1980s. Hundreds of thousands of medusa were harvested by scientists interested in their luminescent properties. But recently, *Aequorea* medusas have become relatively scarce and it is not believed to be due to over fishing for these jellyfish.

Aequorea feed primarily on soft-bodied prey, which includes other jellyfish and plankton. It is believed that they live for 6 months as free-floating medusa in the ocean. The entire population of medusa disappears by mid autumn each year. The polyp colonies persist on the bottom of the ocean floor and produce a new generation of medusa each spring. Little is known about the polyp stage of the life cycle and what triggers the release of medusa in the early spring.

References:

Sites on jellyfish -

http://www.ucmp.berkeley.edu/cnidaria/scyphozoa.html
Jellyfish site from UCBerkely. Also has references to other jellyfish web sites.

http://www.ucmp.berkeley.edu/cnidaria/scyphozoafr.html
Fossil of jellyfish.

http://www.ucmp.berkeley.edu/cnidaria/scyphozoamm.html
Jellyfish anatomy.

http://jellieszone.com/gelatinousid.htm
The Jellies Zone, a fantastic site on jellyfish. Awesome photos and will answer questions.

http://seattletimes.nwsource.com/news/health-science/html98/jell_071498.html
Easy to read newspaper article titled “Shedding light on how jellyfish glow”.

http://www.mbayaq.org/
The web site for the Monterey Bay Aquarium. They have a great aqua cam. Their jellyfish exhibit “Drifters” is incredible. A must see.

http://www.discovery.com/area/nature/jellyfish/jellyfish2.html
Discovery Channel web site on jellyfish has a lot of slides and a few films. Also has links to other web sites.

Sites on Aequorea -

http://faculty.washington.edu/cemills/Aequorea.html
Wow! Excellent site from one of the *Aequorea* researchers in Puget Sound. Very interesting information about problems with colleagues and the press. A must read!

www.mbari.org/~kraskoff/aequorea.htm
This is a picture of *Aequorea* when exposed to bright light, NOT UV LIGHT.

http://aesop.rutgers.edu/~crebb/ring.html
Aequorea marginal ring bioluminescent photo! A must see!

Glossary for General Biology of Jellyfish

aequorin
A protein found in the jellyfish *Aequorea* that is activated by calcium and emits blue light through a bioluminescent reaction. This blue light is then absorbed by GFP, stimulates a chemical reaction which results in the emission of a visible green light. Both aequorin and GFP are found in high concentrations in the light producing cells on the periphery of the medusa of this jellyfish.

green fluorescent protein (GFP)
A protein found in jellyfish that fluoresces, or emits a green visible light when excited by UV light with a wavelength of 395 nanometers. It can function as a biological marker when attached to other proteins. The structure of the protein is cylindrical with the glowing component, an amino acid complex called a *fluorophore*, in the middle of it.

light
Consists of electromagnetic waves of specific frequencies and wavelengths. Light is often drawn as a ray. The ray shows the path taken by the light waves, the direction in which the energy is being carried.

bioluminescence
A complex chemical reaction that occurs within a living organism, in which the end product of energy is released in the form of light instead of heat. Some organisms which have this ability are glowworms, fireflies, jellyfish, fungi, and some deep-sea fish.

chemiluminescence
A general term for the production of light when the excitation energy has come from a chemical reaction. Bioluminescence is a type of chemiluminescence that occurs in a living organism.

electromagnetic waves or radiation are made up of oscillating electric and magnetic fields that can travel through many substances. Particles that make up the waves are called photons. They consist of many frequencies. At the high frequencies are the gamma rays and X rays, followed by ultraviolet, then the visible light. At the lower frequencies are the infrared radiation waves and microwaves. Within the lower frequencies are the radio waves.

fluorescence
A phenomenon shown by certain substances when they are hit by ultraviolet radiation. The substance absorbs high frequency wavelengths and emits it at a lower frequency light. This emission stops as soon as the high frequency radiation is removed. For example, GFP absorbs the higher frequency blue light emitted by aequorin, undergoes a chemical reaction, and emits the lower wavelength green light.

phosphorescence
Occurs when certain substances are hit by high frequency (short wavelength) electromagnetic waves, and waves of longer wavelength are emitted and released for a longer period of time, continuing long after the original hit by the high frequency wavelengths. It is similar to fluorescence, except that the excited product is more stable so that the time until the energy is released is much longer. This results in a glow after the light has been removed. This is the basis behind glow-in-the-dark stickers.

ultraviolet radiation (UV)
Electromagnetic radiation produced by the sun and or produced when an electrical current passes through ionized gas between two electrodes. It consists of wavelengths between 200 and 400 nanometers. Exposure to excessive amounts of UV radiation damages DNA and can cause health problems such as skin cancer and cataracts in the eyes.

visible light
Electromagnetic waves or radiation that is produced by the sun detectable by our eyes. It consists of wavelengths between 400 and 750 nanometers. Colors depend on the wavelength lengths; a short wavelength (the 400 nm side) looks blue and a long wavelength (the 750 nm side) looks red.