To Glow or Not to Glow….

Abstract: Bioluminescence is a chemical process in which a living organism gives off light. Certain bacteria, fungi, worms, jellyfish, insects, and marine fish are bioluminescent. These animals may use their bioluminescence for obtaining food, warning their enemies, or for attracting mates. One jellyfish, *Aequorea*, needs two proteins; aequorin and Green Fluorescent Protein (GFP), to work together resulting in a bright green glow at the bottom of its bell shaped medusa.

Introduction:

The light that emits from the lantern in the firefly is due to a process called bioluminescence. It involves a chemical reaction that occurs in living organisms, which results in the production of light. Most chemical reactions that result in a loss of energy give off this energy as heat. But in bioluminescent organisms, that transition from a high level energy state to a lower level energy state results in the emission of visible light.

What exactly is going on? Electrons circle atoms in patterns called orbitals, with each orbital having a specific energy level. Electrons closest to the nucleus have less energy than atoms traveling in orbitals farther from the nucleus. When an electron in a lower energy level gains some energy, as in a chemical reaction, it jumps to the next level and the atom is said to in the excited state (Figure 1). As this electron moves, it looses energy and falls back to the lower energy, releasing energy equal to the difference between the higher and lower energy levels. This quantum of energy may be released as heat, or in the case of bioluminescence, in the form of a photon of visible light.

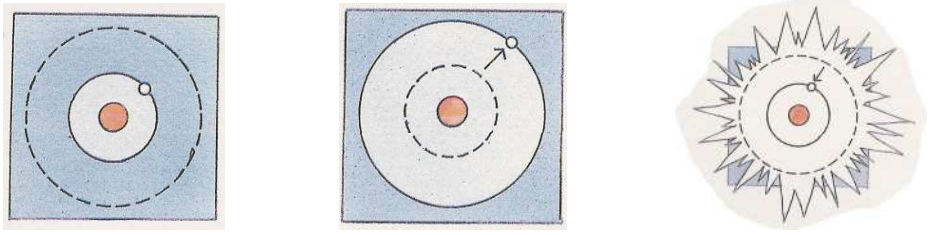
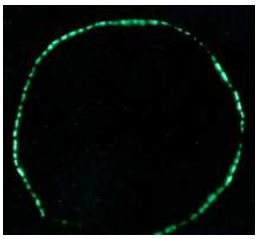


Figure 1:

Electron in normal orbit | Electron boosted to a higher orbit | Electron falling back to a lower orbit, releasing energy as light

Bioluminescent jellyfish

Many jellyfish are bioluminescent. The jellyfish *Aequorea* has a two-step process for generating the visible green light seen around their medusa ring.



http://aesop.rutgers.edu/~crebb/ring.html
This is a great photo of *Aequorea* when exposed to UV light. Notice the fluorescent green is only in the outer rim of the medusa.

The energy transfer starts with a chemical reaction involving the protein aequorin and calcium. This first reaction results in the release of blue light. This blue light is quickly absorbed by GFP, another reaction occurs, and a visible green light is the final product. This all occurs in the photocells that are located on the edges of the bell of the jellyfish. This reaction does not occur continually. Jellyfish, in fact, rarely luminesce when observed in aquariums. It is still unknown what causes these jellyfish to start this chemical reaction and glow green.

Did you know that almost all marine bioluminescence occurs in the blue or green wavelength of visible light? This is because blue green light (wavelength around 470nm) travels furthest in water. This is the reason that underwater photos usually look blue. Red light is quickly absorbed as you descend into the depths of the ocean. Also, most marine organisms can only observe blue-green light because they lack

the visual pigments that allow them to absorb longer (yellow and red) or shorter (indigo and ultraviolet) wavelengths.

Purpose of bioluminescence:

Why would various animals acquire or retain bioluminescence during the course of evolutionary time? Bioluminescence is observed naturally in many different organisms, such as bacteria, mushrooms, worms, shrimp, insects, and some fish. There appears to be three different functions for bioluminescence: (1) to help deter predators; (2) to aid in obtaining food and; (3) as communication signals in mating and courtship. It is thought that the jellyfish *Aequorea* may become bioluminescent to scare off possible predators.

References:

http://lifesci.ucsb.edu/~biolum/
UC Santa Barbara's web site on bioluminescence. It has nice photos of many types of organisms that are bioluminescent. Be cautious-most of the photos do not show these organisms in conditions that result in their display of bioluminescence. They are photos taken with artificial light settings.

http://fp.redshift.com/pelagia/index.htm
The JelliesZone established by Dave Wrobel (a.k.a. JellyMan) to showcase the incredible diversity of gelatinous zooplankton that visit waters of the U.S. West Coast.

http://aesop.rutgers.edu/~crebb/ring.html
Web site of Aequorea photo showing bioluminescence.

http://faculty.washington.edu/cemills/Aequorea.html
Mills, C.E. 1999-2001. Bioluminescence of *Aequorea*, a hydromedusa. Published by the author, web page established June 1999, last updated May 21, 2001.

The Way Life Works: The Science Lover's Illustrated Guide to How Life Grows, Develops, Reproduces, and Gets Along by Mahlon Hoagland and Bert Dodson. Three Rivers Press, New York.1998. pp. 72-73.

Glossary for Understanding Bioluminescence

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.

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

chemical reaction
Any change that alters the chemical properties of a substance, or forms a new substance. During a chemical reaction, reactants are changed into products.

chemiluminescence
A general term for the production of light when the excitation energy comes 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 encounter 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.

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 co-expressed with 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.

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 are produced by the sun and detectable by our eyes. It consists of wavelengths between 400 and 750 nanometers. Colors depend on the specific wavelength; a short wavelength (the 400 nm side) looks blue and a long wavelength (the 750 nm side) looks red.