

Biolumenecence: Biology of a Firefly

Introduction



Figure 1: Boy cathing a firefly.

For hundreds of years children have been fascinated by fireflies. They ask how and why the fireflies light as they run to catch one.(See Figure 1)

Scientists have also been interested in the way that fireflies create such energy efficient light, most light bulbs give off at least half of the energy they generate

as heat, whereas fireflies give off very little heat, they have a 96% efficiency, giving off less than 10% of the energy that they create inside their bodies as heat, leaving almost all of the energy to be used as light to attract mates and prey. What scientists have discovered is that fireflies use chemical reactions to create the enchanting glow. This light will be explained by taking a look at the simple chemical reaction between oxygen and luciferin in a firefly's abdomen and by examining the reasons for the glow.

What are fireflies?

These insects are not actually flies; they are a type of beetle. The difference is that flies have one pair of wings, two wings to be exact, while bugs with –flies in their name that aren't really flies such as, Fireflies, dragonflies and scorpionflies have two pairs of wings, or four wings. The beetles we call fireflies or lightning bugs are mostly found in rotting wood, but some species live underwater. Fireflies

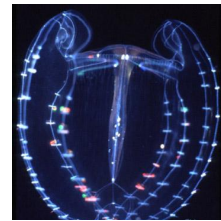


Figure 2: a bioluminescent fish.

typically have brown bodies with colorful vertical stripes. There are about 136 different species of fireflies in the world. They come out at night, so that their flashing signal can be seen by other fireflies with which they wish to mate. These creatures are bioluminescent, which means they use a “process wherein light is produced by a chemical reaction which originates in the organism” (Branham). In other words creatures that are bioluminescent give off light that they created within their bodies. Most bioluminescent creatures live at the bottom of the ocean, such as bioluminescent fish. (See Figure 2) Firefly larvae are bioluminescent but not all adult fireflies can create light.

Why Fireflies Light

Fireflies, like almost all other animals, need to mate to produce offspring. In order to mate, they need to find a firefly of the opposite sex. While most other animals use mating calls or “dances,” fireflies

use light to attract a mate. Male fireflies fly around at night flashing this light to attract a female firefly, who is sitting in the foliage waiting and flashing its approval and encouragement. Most fireflies tend to fly upward when they are emitting light and tend to fly downward when they stop giving off light. Females will wait, on average, about two seconds after they see a male flash before flashing their encouragement and then the male flies closer to the encouraging female. Different species, or types, of fireflies have different light flashing patterns, or signals. The patterns are determined by the flash length and flash speed of the fireflies mating signal. Every species has a distinct flash, but the difference is so miniscule that humans can't tell that there is a difference, but fireflies seem to be able to. Some female fireflies might prefer longer, slower flashes, while others might prefer short, fast flashes. This means that a male firefly will only attract a female that is the same type of firefly as it is.

There is another reason why a firefly might light. Some female fireflies light to attract prey. As mentioned before, each species of firefly has a specific flash length and speed. Some female fireflies will imitate the mating flash of another species of firefly to attract the male of that species as prey. The male of the imitated species will react as if it is a female of its own species that is flashing its approval and encouragement and wants to mate with the male. When this male goes to mate with the imposter female, she eats him. This is also true of the males of the species *Photuris lucicrescens*, these males also mimic the signal of another species to lure their prey.

Adult fireflies are not the only fireflies that glow. Firefly larvae are said to glow. Scientists believe that they glow as a self-defense mechanism. They use the glow as a warning to predators that they taste bad and should not be eaten. The glow is supposed to warn that they contain harmful chemicals. This protects their undeveloped defenseless bodies.

The Process in Which Fireflies Light

The light-producing organ in fireflies is located in the sixth or sixth and seventh abdominal regions. (Branham). Fireflies have a chemical called luciferin in their abdomens. (See Figure 3) Also in their abdomen is an enzyme

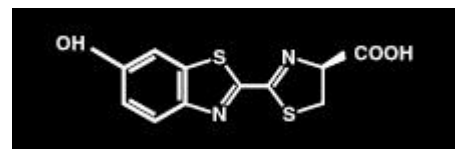


Figure 3: A firefly luciferin.

called luciferase, enzymes are proteins that come from living cells and are capable of chemical changes in organic (is or came from living tissue) substances, such as digestion. Luciferase is used to speed up the

process in which the light is made. The chemical luciferin combines with oxygen from the tracheoles (small tubes that transport and obtain oxygen), where fireflies obtain their oxygen from, as it passes through the light organ to create its flashing light.

This process takes place in two steps. In the first step luciferin combines with ATP (adenosine triphosphate, found in all cells) to form luciferyl adenylate and PP (pyrophosphate, a salt that comes from pyrophosphoric acid) on the surface of the luciferase enzyme. The luciferyl adenylate then sticks to the surface of the luciferase enzyme the PP is released. Then the luciferyl adenylate combines with oxygen to form oxyluciferin and AMP (adenosine monophosphate, a nucleotide, a group of molecules that make up parts of DNA and RNA that is found in muscles, it helps with metabolism and can be converted to ATP). When the oxygen and the luciferyl adenylate combine, light is given off and the oxyluciferin and the AMP are released from the surface of the luciferase enzyme.

Oxygen theory

While there is more than one explanation as to how fireflies control the release of light, this is the most widely accepted theory. When there is oxygen available, the fireflies will light; when the oxygen supply is hampered, the light goes off. Fireflies don't have lungs; instead they obtain oxygen

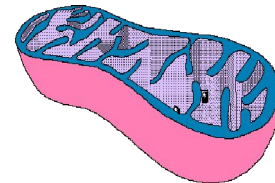


Figure 4: mitochondria

through tracheoles, small tubes. Fireflies produce nitric acid for the lighting process. When there is not nitric acid being produced, the oxygen that travels through the tracheoles attaches to the mitochondria (See Figure 4), the energy producing organelle (specialized organ-like part of a cell) in all cells, before it can reach the light producing part of the body, called the photic organ. Photic means of or pertaining to light, so the photic organ is the light organ, thus preventing the production of light. It is believed that the desire to find a mate triggers the production and release of nitric acid. When the firefly desires a mate, it produces nitric acid which, when it passes, bonds to the mitochondria. While the mitochondria are occupied by the nitric acid and cannot bond to the oxygen, it can pass by and into the light organ. You can think of the nitric acid as a wall between the mitochondria and the path of the oxygen preventing the oxygen from being able to attach to the mitochondria. When the wall is there the light can be created but if the wall comes down the oxygen can not get through. Since nitric acid breaks down rapidly, the flashing effect of the light is created between the time when the acid is available and the time when it has broken down.

Neural Activation Theory

This alternate theory states that fireflies have neural control over the parts of the body that control the light creation, the light organ. “Neural” means relating to or located in a nerve or the nervous system, so neural control is using nerves to control parts of the body. This is like the nerves in the hands being connected to the brain allowing the brain to control the hand and make it close.

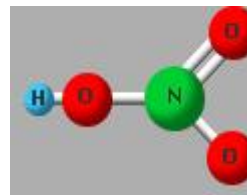


Figure 5: nitric acid molecule.

The part that fireflies control is the tracheal end cells (which are exactly what they sound like, cells at the end of the tracheoles). It is said that the end cells, when stimulated by the need for a mate or for prey, send a “messenger” signal to the light organ, causing the light producing process to start.(See Figure 5)

Practical Application of the Light Producing Process

The process in which bioluminescent organisms create light depends on the presence of ATP. This means that ATP is a good indicator of life. Scientists are already using the glow made from the chemical reaction to test for life. (See Figure 6) They are using the bioluminescent process to fight Tuberculosis. Since the light is a

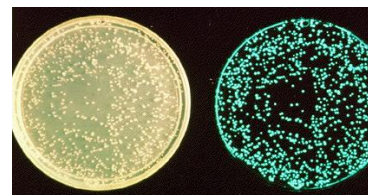


Figure 6: bacteria glowing with the glowing process

sign of life, scientists administer an antibiotic to a germ culture. If the germ culture continues to glow after a few days the scientist can conclude that the antibiotic that had been administered to the germ culture was not strong enough. This allows doctors to find the strongest and most affective cure, allowing them to cut treatment time, which was originally three months, to just three days. NASA has considered using the glowing process to test for ATP on other planets thus testing for life, since ATP is a sign of life. Scientists are also beginning to use the glow in gene activation therapy. Scientists add luciferase to the cells that they are experimenting on, and then they use ultraviolet rays to seek out cells that have been treated with the luciferase enzyme. This allows them to determine if the attempted gene activation therapy was successful or if it failed.

Conclusion

For centuries, people have been interested in fireflies. It really is no mystery how they create light. Fireflies create a chemical reaction inside their abdomens to create their signature glow. Though scientists have discovered a lot about the firefly, there is still much to be learned, such as how the firefly can control this

process, making the light flash. Scientists have already begun to apply this technology in practical applications such as making medicine. Fireflies continue to provide us with technological ideas and a fascinating living lights show.

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