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Bioluminescence

Did you know that over **76%** of marine organisms are bioluminescent, according to research conducted by scientists? Bioluminescence can be defined as the production and emission of light in a living organism through chemical reactions in their bodies. While copious amounts of bioluminescent organisms live in the unexplored depths of the oceans, some bioluminescent organisms also live on land, most notably fireflies and mushrooms. At first glance, it may seem as though bioluminescence is just another way in which mother nature beautifies itself yet in reality, it allows many species of plants and animals to survive and thrive every day. It is quite astonishing to think that small chemical reactions that produce light not only allow organisms to perform vital functions everyday, they have also allowed humans to make major advancements in medicine as well as science.

The chemical reaction

To begin with, the most common form of bioluminescence occurs when luciferin, which is a chemical compound that can produce light, undergoes a chemical reaction with oxygen. However, in order to unlock the full potential to interact with oxygen, **luciferin** is required to be in the presence of a substance known as luciferase. In this scenario, luciferase acts as a catalyst **enzyme**, with an enzyme being a biological protein that causes or speeds up a chemical reaction. In other words, luciferase allows luciferin to create bonds with oxygen (National Geographic, n.d.). This creates many byproducts such as oxyluciferin, water as well light or bioluminescence.

However it has been recently identified that some organisms produce light without the presence of the catalyst, luciferase. This chemical reaction involves **photoprotein,** any of several proteins that give off light when combined with oxygen (Britannica, n.d.). A form of photoprotein known as Green fluorescent protein (GFP) was first discovered in the 1960's in an organism known as the crystal jellyfish (*Aequorea victoria*), in the West Coast of North America. Soon afterwards, it was also discovered that this special protein had the ability to emit bioluminescent light in the presence of special agents such as calcium.

Figure 1: crystal jelly
Source: (https://www.ncbi.nlm.nih.gov, 2009)

As the understanding of bioluminescence increases day by day, scientists have begun to question how organisms obtain luciferin. They have been able to conclude that organisms either **synthesise** their own luciferin or obtain luciferin from other organisms. Many organisms such dinoflagellates (single celled organisms that live in the ocean) and sea plankton synthesise their own luciferin. On the contrary, many other organisms obtain luciferin from the food they consume or even through **symbiotic relationships** with other organisms. As an example, a glowing form of bacteria thrives on the undersides of some forms of squid. The squid provides

the bacteria with nutrients required to survive while the bacteria provides luciferin that allows the squid to become bioluminescent.

Why are animals bioluminescent?

Figure 2: Glow worm (*Lampyris noctiluca)*
Source: (The Guardian, 2017)

Through the use of bioluminescence, many organisms are able to protect themselves from predators. Some creatures, such as glow worms (*Lampyris noctiluca)*, use bioluminescence to warn predators that they are toxic or poisonous, resulting in their survival. Another fascinating creature is known as the vampire squid - a creature that does not produce ink sacs (as most species of squid do) but uses bioluminescent mucus to startle predators instead. Some species of sea cucumber, brittle stars and deep sea squid are well-known for detaching bioluminescent segments of their bodies in order to confuse and mislead predators. Cunningly, they occasionally detach these bioluminescent body parts onto other fish, misleading the predators into chasing another fish and ensuring their survival (oceans.si.edu, 2018).

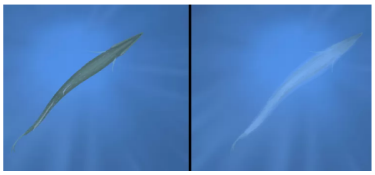

Figure 3: *An image of a fish using Counterillumination In order to blend into its surroundings*
Source (ocean.si.edu, n.d.)

Furthermore, many sea creatures use **counter-illumination**, a form of camouflage, in order to survive. Counter illumination is when fish create light from their undersides in order to blend into the light patterns and wavelengths above in order to hide from predators below them. A great example of this is the hatchet fish, which is a fish that uses counter-illumination to escape from predators and survive.

Figure 4: *an anglerfish uses its bioluminescent filament to attract its prey*
Source: (Britannica, n.d.)

Not only does bioluminescence allow animals to protect themselves, it also allows them to search for food. Many deep sea creatures use bioluminescence to illuminate their surroundings and even lure their prey towards them. For instance, the anglerfish has a filament, which is a long thin fleshy growth, at the head. At the end of its filament, there is a bioluminescent spherical structure that the anglerfish uses to light up its surroundings. When the area is lit up, smaller fish and sea creatures will be attracted towards and to their subsequent deaths.

Other than for survival, many creatures also use bioluminescence in order to perform vital functions everyday. Research shows that a species of crustaceans known as the caribbean ostracod uses bioluminescent “vomit” and signals to attract mates and to reproduce (oceans.si.edu, 2017). Many other species of lanternfish also use bioluminescence for communication and to send signals to others of its kind. Amazingly, scientists have also found evidence that many species of mushrooms may be using bioluminescence in order to make other organisms consume them and indirectly spread their spores.

Henceforth, it is undeniable that bioluminesce is vital to the survival of many organisms and is not just a means of beautifying the environment.

Advancements in science and medicine

Not only has bioluminescence allowed many animals to survive, it has also allowed humans to make many scientific and medicinal discoveries over the last few decades. As a matter of fact, in 2008, three scientists, involving Osuma Shimomura from Japan, Martin Chaflie from the USA and Roger Tsien from the USA, won the nobel prize in chemistry for their work regarding bioluminescence. They were able to discover, genetically modify and use GFP (Green fluorescent protein), which is a type of photoprotein, for medicinal research.

To elaborate, GFP allows organisms that can not naturally glow to produce light through a chemical reaction. Knowing this, scientists have been able to use GFP as a tagging tool by attaching GFP to previously invisible **proteins** so they can produce light. This innovative use of GFP has become crucial for detecting cell damage due to diseases, the spread of HIV, and even detecting and fighting cancer cells (Smithsonian Magazine, 2019; The Conversation, 2018).

As mentioned above, bioluminescence has been useful to find innovative ways to treat cancer. "*When we see species that create light and do it chemically, it's amazing. The only thing we can do up to now is borrow these systems from nature, translate them into our systems, our research and our needs*," stated Theodossis Theodossiou, who is a cancer research scientist at the university of Oslo. He explained how bioluminescence has been useful to treat cancer. Most of the time, cancer is treated through Photodynamic Therapy by using laser light to attack cancer cells. Yet sometimes, the laser beams can not reach cancer hidden deeper within the body. To resolve this dilemma, a new treatment method known as BLADe (bioluminescence activated destruction of cancer) has been adopted recently.

In the BLADe technique, a photosynthesising agent is first used to make the cancer more vulnerable to light. Then a combination of luciferin and luciferase are used to generate bioluminescent light from within the body. In short, The BLADe technique allows cancer to self-destruct from within, no matter how deep-rooted the cancer is. Therefore, it should be appreciated that the concept of bioluminescence can be very useful for treating illnesses.

In addition to being used for treating illnesses, bioluminescence can also be used to test the effectiveness of medicinal drugs. According to News-medical.net (2019), Canadian researchers have developed thirteen slightly different bioluminescent drug sensors in order to test the effectiveness of new medical drugs. The biosensors they created are based on G-protein coupled receptors (GPCR). GPCRs are pathways through which cells communicate to each other. Amazingly, scientists are able to use the concept of

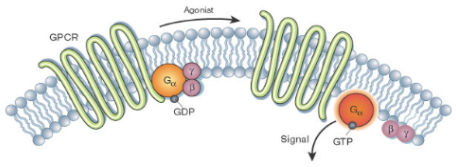

Figure 5: The structure of a GPCR
Source: (nature.com, n.d.)

bioluminescence to track the light levels and other changes of the signals cells send to each other in order to determine whether the used pharmaceuticals are effective or not.

To conclude, it is undeniable that bioluminescence is not just a way of beautifying the environment. One chemical reaction between luciferin and luciferase could be the difference between life and death for many organisms and even prevent a species from going extinct through reproduction. The concept of bioluminescence could also be the only path to curing deep-rooted variants of cancer. It is quite astonishing to think that such a beautiful, complex yet simple natural phenomenon could help human beings make revolutionary medicinal discoveries and make advancements scientifically.

Word count - 1406

Glossary

- **Enzyme** - a biological protein that speeds up and causes chemical reactions.
- **Luciferin** - an organic substance or chemical compound found in organisms that generate bioluminescence.
- **Luciferase** - an enzyme that helps to speed up the chemical reaction between luciferin and oxygen.
- **Substrate** - the substance on which an enzyme acts on (eg - luciferin)
- **Synthesise** - create on their own
- **Symbiotic relationship** - various interactions and relationships between dissimilar organisms
- **Protein** - naturally occurring large chains of amino acids joined together to form macromolecules

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