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Mini Review

Light producing organs of fishes

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Abstract Light produced by living organisms is known as Bioluminescence. The light produced by luminescent organs in fishes, depends on luminescent bacteria living on the fish in a symbiotic relationship in special cells. However some fishes do produce a chemical that reacts with water to produce light. The bacterial light usually produced as a result of an enzyme luciferase mediated oxidation reaction in which a molecule luciferin changes its shape and emits a single photon of light in the process. The luciferin molecule is a complex molecule and can later be returned to its original shape through a reduction reaction during which it gains an amount of energy equivalent to the single photon of light and fish can control the amount of light emitted by controlling the blood flow, and hence the oxygen supply, to the cells containing the bacteria. In symbiosis ,the bacteria are nourished with readily available food sources for growth, and at the same time the host utilizes the adapted illumination for communication, preying for food, and attracting mates, to masquerade itself from predators.

Keywords: Bioluminescence, Luminescent bacteria, Symbiotic relationship, Luciferase, Luciferin, Communication, Attraction, Predators.

INTRODUCTION:

Bioluminescence is the production and emission of light by a living organism. It is a form of chemiluminescence. Bioluminescence occurs widely in marine vertebrates and invertebrates, as well as in some fungi, microorganisms including some bioluminescent bacteria and terrestrial invertebrates such as fireflies. In some animals, the light is produced by symbiotic organisms such as Vibrio bacteria (Randall and Anthony 1997).

The uses of bioluminescence by animals include counter illumination camouflage, mimicry of other animals, for example to lure prey, and signaling to other individuals of the same species, such as to attract mates. In the laboratory, luciferase-based systems are used in genetic engineering and for biomedical research. Other researchers are investigating the possibility of using bioluminescent systems for street and decorative lighting,

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and a bioluminescent plant has been created (Randall and Anthony, 1997).

Deep in the ocean, where sunlight can no longer penetrate, lies an incredible world of darkness. The creatures here have evolved their own ways of dealing with the darkness. Through a process known as bioluminescence; they have developed the ability to use chemicals within their bodies to produce light. Bioluminescence is mainly a marine phenomenon, it is not found in fresh water. On land it, is only seen in few species of insects and fungi. It is the ocean where this unique ability achieves its highest form.
Bioluminescence occurs when certain chemicals are mixed together. Most of the light created by marine organisms is blue green in colour. This is because blue light travels best in water, and because most marine organisms are sensitive to blue light. A notable exception is the Malacosteid family of fishes, also known as Loosejaws. These fishes can produce red light and can see it when others can not. This gives them an advantage by allowing them to see their prey while without making their presence known. Marine creatures produce light with special organs called photophores. At least two chemicals are required to produce bioluminescence. The first is known as luciferin. This is the chemical that actually creates the light. The second chemical is called luciferase and is the substance that actually canalizes the chemical reaction. When these chemicals are mixed together in the presence of oxygen, light is produced. A by-product of this process is an inert substance called oxyluciferen.
Deep-sea organisms generally inhabit bathypelagic (1000-4000m deep) and abyssopelagic (4000m-6000m deep) zones. However characteristics of deep sea organisms, such as bioluminescence can be seen in the mesopelagic (200m-1000m deep) zones as well (Randall and Anthony 1997).

Characteristics

Many deep-sea fishes are blind relying on their other senses;those that aren't blind have large and sensitive eyes that can use bioluminescent light. These eyes can be as much as 100 times more sensitive to light than human eyes. Also, to avoid predation, many species are dark to blend in with their environment (Trujillo and Harold, 2011)
Many deep-sea fish are bioluminescent, with extremely large eyes adapted to the dark. Bioluminescent organisms are capable of producing light biologically through the agitation of molecules of luciferin, which then produce light. This process must be done in the presence of oxygen. These organisms are common in the mesopelagic region and below (200m and below). More than 50% of deep-sea fish as well as some species of shrimp and squid are capable of bioluminescence. About 80% of these organisms have photophores – light producing glandular cells that contain luminous bacteria bordered by dark colourings. Some of these photophores contain lenses, much like those in the eyes of humans, which can intensify or lessen the emanation of light. The ability to produce light only requires 1% of the organism's energy and has many purposes: It is used to search for food and attract prey, like the anglerfish; claim territory through patrol; communicate and find a mate; and distract or temporarily blind predators to escape. Also, in the mesopelagic where some light still penetrates, some organisms camouflage themselves from predators below them by illuminating their bellies to match the color and intensity of light from above so that no shadow is cast. This tactic is known as counter illumination (Ryan 2007).

Mesopelagic fish

Mesopelagic fish usually lack defensive spines, and use colour to camouflage themselves from other

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fish. Ambush predators are dark, black or red. Since the longer, red, wavelengths of light do not reach the deep sea, red effectively functions the same as black. Migratory forms use counter shaded silvery colours. On their bellies, they often display photophores producing low grade light. For a predator from below, looking upwards, this bioluminescence camouflages the silhouette of the fish. However, some of these predators have yellow lenses that filter the (red deficient) ambient light, leaving the bioluminescence visible (Munz, 1976; Kenaley, 2007) The stoplight loosejaw is also one of the few fishes that produce red bioluminescence. As most of their prey cannot perceive red light, this allows it to hunt with an essentially invisible beam of light (Ryan, 2007).

Bathypelagic fish

Bathypelagic fish are sedentary, adapted to outputting minimum energy in a habitat with very little food or available energy, not even sunlight, only bioluminescence. The humpback anglerfish is a bathypelagic ambush predator, which attracts prey with a bioluminescent lure (Moyle and Cech, 2004). The pelican eel uses its mouth like a net by opening its large mouth and swimming at its prey. It has a luminescent organ at the tip of its tail to attract prey (Iqbal, 2008).

Types of bioluminescence

Luminescence of fishes is of two types:

1. Luminescence that results from the presence of luminous bacteria living on the fish in a symbiotic relationship. For example: Leognathidae, Acropomatidae, Monocentridae and Gadidae.

2. Luminescence that arises from self-luminous cells on the fish. It may be of two types:

  i. **Intracellular luminescence:** In this type light is generated by the animals within its own tissue. Luminescence of many fishes belongs to this class.
  ii. **Extracellular luminescence:** In this type light is produced by discharge of luminous secretion. E.g.: Ceratias.

Structure of light organ

The possession of light producing organs is quite common in fish particularly, but not only, in those species that live in deeper waters. Forty-five percent of fish that live at depths below 300 meters and 75% of all bathypelagic fish have some light emitting organs. The light glands of different fish species show quite a wide variety in complexity. The simplest are just a few cells embedded in the skin. The complex systems involve a light producing gland, a reflecting layer behind the light source (black or silver), a color filter and a lens. The positioning of the light organs is also highly variable between species. Important structural parts of light organs are as follows:

Light glands

Photocytes (light glands) are the light producing cells. They are glandular in nature as they secrete luciferin and luciferase, the two essential components of light production. Mainly two types of photocytes are observed. They are photocyte A and photocyte B. Photocyte A occupies the inner and deeper region of photophore. While photocyte B occurs in the outer region of photophore. Both have secretory characteristics.

Lens

Lenses of light organs are structures containing a mass or plate of clear tissue and are so called because of their resemblance to ocular lenses. The tissue is epithelial and the cells have a homogeneous cytoplasm devoid of inclusions. Presumably these lenses

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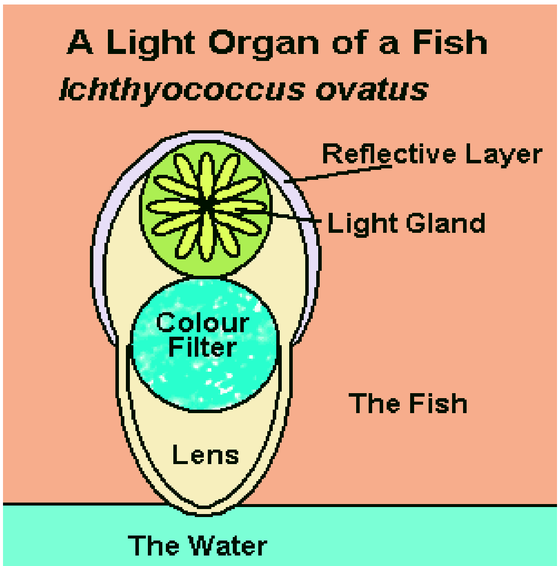
function is in concentrating the light beam. This however, requires that the refractive index of the lens be greater than that of the surrounding.



Source Trujillo Alan et.al.[2]

Reflector

The wall of light organ (photophore) often contains a reflector together with a backing of dark pigment. The reflectors consist of elongated connective tissue cells. The cells contain platelets of guanine, arranged in regular piles above one another, parallel to the surface of the reflector. The shape of the reflector and the orientation of its component platelets play a very important role in controlling the direction and spread of the light beam.

Pigment mentle

Pigment mentle often lying underneath the light organ contains black melanophores. Dark pigmented mentle probably ensures that no light diffuses inward into the tissue of the fish. They occur even when there is a well-organized reflector presumably mopping up light transmitted through the latter. Besides, pigment hulls also play important role in controlling the emission of light in preferred direction. The Color filters are used to adjust the overall color composition of an image (Haygood, 2008).

Light organ in various species of fishes and their role

Many species of fish have lights on the lower parts of their bodies. Scientists believe they use these lights to prevent their bodies becoming silhouetted against the surface. By having lights on their underside fish can break up the pattern of their body and effectively hide in the haze. Lights along the sides of the body are more likely to be for communicating with other members of their own species, either whilst shoaling, or to attract potential mates. In other fish, such as the well-known angler fish the light organs seem designed to attract prey. Nearly all angler fish possess luminous baits. The same applies to other types of fish with lights near their jaws or at the ends of fins or barbels. Malacocephalus laevis has light producing bacteria in a gland near its anus, when it is disturbed it can eject some of these bacteria into the water through its anus, the sudden appearance of this luminescent mass would easily disorientate a predator. It is possible that fish with lights distant from the center of their body, such as on or near their tail, may use these lights to disorientate predators. Some fish can actually produce a beam of light, and such a beam would obviously help them find prey. Many bathypelagic fish with light producing organs also have addition light organs that shine into their own eyes; scientists believe that this may work to accustom their eyes to a certain level of light so that when they turn on their main lights they do not blind themselves. Most luminous fish are teleost but there are some luminous sharks as well such as Euprotomicrus bispinatus, which is also the smallest shark in the world. Some examples of bioluminescent fish are: Isistius brasiliensis which has thousands of small luminescent organs on its belly; Anamalops koptroton and Photoblepheron

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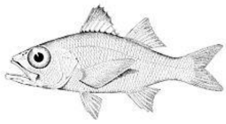
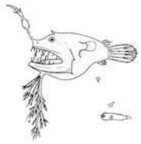
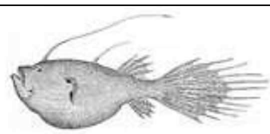
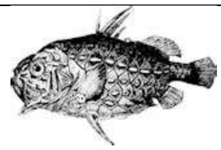
palpebratus which are coastal; Giganticus vanhoffeni and Dolopichthys niger which are both deep-sea angler fish (Haygood, 2008; Sparks et al., 2014; http://en.wikipedia.org/w/index.php)

Location of light organs on fish body

S. No.	Location of light organ	Genus name	Picture
1	Ventral musculature	Acropoma	
2	Within abdomen	Apogon	
3	Entire body surface	Idiacanthus	
4	Lower surface of the body	Etmopterus	
5	Beneath the eyes	Astronesthes	
6	On the tongue	Neoscopelus	
7	On the tail	Saccopharynx	
8	On the tentacle	Linophryne	
9	On the dorsal fin rays	Ceratias	
10	On the lower jaw	Monocentris	

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CONCLUSION:

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The uses of bioluminescence by animals included camouflage, mimicry of other animals, and signaling to other individuals of the same species, such as to attract mates. In the laboratory, luciferase-based systems are used in genetic engineering and for biomedical research. Other researchers are investigating the possibility of using bioluminescent systems for street and decorative lighting, and a bioluminescent plant has been created.

Bioluminescent organisms are a target for many areas of research. Luciferase systems are widely used in genetic engineering as reporter genes, each producing a different color by fluorescence, and for biomedical research using bioluminescence imaging. For example, the firefly luciferase gene was used as early as 1986 for research using transgenic tobacco plants. Vibrio bacteria symbiose with marine invertebrates such as the Hawaiian bobtail squid (Euprymna scolopes), are key experimental models for bioluminescence. Bioluminescent activated destruction is an experimental cancer treatment. See also optogenetics which involves the use of light to control cells in living tissue, typically neurons, that have been genetically modified to express light-sensitive ion channels, and also see biophoton, a photon of non-thermal origin in the visible and ultraviolet spectrum emitted from a biological system.

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