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BIOLUMINESCENCE IN INSECTS AND ITS SIGNIFICANCE

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Abstract: -

Bioluminescence-the emission of light by living organisms through biochemical reactions is a significant evolutionary trait seen in many insect species such as fireflies (Lampyridae), click beetles (Elateridae), and railroad worms (Phengodidae). This light is generated by the oxidation of luciferin, catalyzed by luciferase, producing visible light with minimal energy loss as heat. Bioluminescence serves various ecological functions such as sexual communication, where fireflies use species-specific flashing patterns to attract mates. Other functions include predator deterrence, where constant glow in larvae signals unpalatability. The luciferin-luciferase system has been widely adopted in molecular biology, including in medical diagnostics, cancer research, and environmental monitoring due to its high sensitivity and ease of visualization. Fireflies in particular have contributed to the development of bioassays and imaging technologies.

Introduction:

The word Bioluminescence derived from Greek word bios = "living" and the Latin word lumen = “light” (Longkumer and Kumar, 2018). It is defined as “the production and emission of light by a living organism as the result of a chemical reaction energy.” (Longkumer and Kumar, 2018). during which chemical energy is converted to light Bioluminescence is the phenomenon of light emission by living organisms. Bioluminescence phenomenon is mostly due to the substrate-enzyme complex of luciferin

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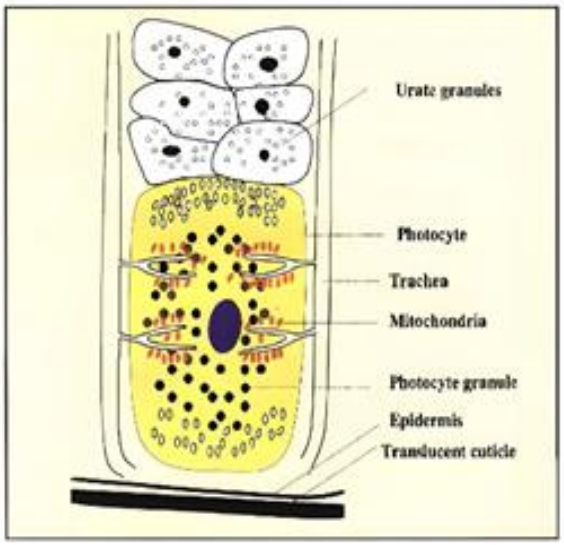
luciferase occurring within the cellular cytoplasm. Luciferin is a heat-resistant substrate and the source of light; luciferase, an enzyme, is the trigger, and oxygen is the fuel. The light production is the result of chemical reactions and hence it is also called 'chemiluminescence'.

Scientists have discovered that the brightest insect is the very large *Pyrophorus noctilucus* (Elateridae), with a brightness of 45 millilamberts. This insect is also known as the Jamaican click beetle and the 'cucujo' beetle of the West Indies. The immature forms of Phengodidae are called railroad worms.

Organs of Light Production in Insects

The light organs in insects are situated very close to the body surface behind a window of translucent cuticle. These organs are mostly on the ventral side of the thorax or abdomen. In *Photuris* (Lampyridae), males have two pairs of the light organ while females possess only one pair. Larvae and adult females of railroad worm have 11 pairs of light organs on the lateral sides of the thorax and abdomen and another pair on the head. In *Fulgora* (Homoptera) the light organ is situated only on the head. The light organs generally originate from fat bodies, except in *Arachnocampa* (Diptera) where these stem from the enlarged distal ends of malpighian tubules. Photogenic organs consist of a large number of specialized cells called photocytes, arranged cylindrically at right angles to the translucent cuticle, which permits light to pass through it. Behind the photocytes there is a reflecting surface chiefly consisting of urate granules. The photocytes receive oxygen through air tubes or tracheoles. They also contain a heavy aggregation of mitochondria that supplies (ATP) required for the chemical reaction.



Biochemistry of Light Production

ATP first activates luciferin in the presence of magnesium (Mg^{2+}) and luciferase to produce adenylluciferin, which is then oxidized to form excited oxyluciferin, which then releases a photon of light as it decays to the ground state.

Bioluminescent insects

Photinus pyralis:

About 2000 species are discovered in which most of them produce unique, species-specific, short, and flashes of visible light (Babu and Kannan, 2002). They use

bioluminescence to attract mating partners, for communication, to attract prey, and as a warning to protect themselves (Baldwin, 2016).

Pyrearinus termitilluminans:

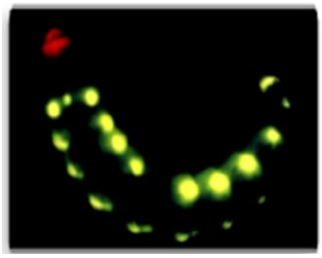
They emit the greenest light from their prothoracic lanterns that can be observed during the rainy season. The larvae found in the illuminated termite mounds and extend the head and shinning prothorax out of the tunnel mouth to attract flying adult termites and other insects (Bechara and Stevani, 2018).

***Arachnocampa luminosa*:-**

These are carnivorous and also show cannibalism and produce luminescence to attract the prey (Viviani *et al.,* 2018). Larva constructs a horizontal web surrounding a ribbon like gallery in caves and on banks in the bush where the humidity is high and where they are protected from wind (Meyer-Rochow, 2007). It suspends up to 30 small, sticky, vertical fishing lines and continuously produces Blue-Green light to attract the flying insects on which they prey (Viviani *et al.,* 2001).

***Phrixothrix sps.*:-**

Females appear to be larviform (adult female resembles the larvae) and able to show luminescence by paired photic organs which are located on each segment of the body (Babu and Kannan, 2002). The head shows red luminescence while the second thoracic through 9 abdominal segments shows yellowish-green (Bechara and Stevani, 2016).



***Keroplatus sps.*:-**

Larvae emit blue light from their body (Falaschi *et al.,* 2019). The larvae feed only on fungal spores (Falaschi *et al.,* 2019).

Luminescence can act as a warning signal and repel negatively phototropic enemies (Osawa *et al.*, 2014).

Significance of Bioluminescence in Insects

i) Mating signal:

Light is known to act as a mating signal in fireflies. Flash patterns in bioluminescent insects vary between species and between sexes. On a relatively cool night, some species wait 5.5 seconds then emit a single short flash. Male and female fireflies of *Photuris pyralis* emerge at dusk, emitting a single short flash at regular intervals. The flashes are usually from male fireflies seeking mates. Males ratios to the females fifty to one. Females climb a blade of grass, flashing when males flash within 10-12 feet of the females. This Exchange of signals is repeated 5 to 10 times until they start mating and then the mating procedure continues.

ii) Predation:

The female fly deposits eggs on the ceiling of dark caves. Upon hatching, the larvae hang down by a sticky thread and produce light. During night, the entire cave may glow with this light, attracting other insect species. These attracted insects get entangled in the sticky threads and are preyed upon by the larvae. The caves inhabited by flies are popularly known as 'luminous caves' and are tourist attraction spots in New Zealand.

iii) Defence:

Sudden flashes can repel potential predators. The railroad worm larvae live at high densities, confined to small areas, and may use simultaneous emission to frighten potential enemies.

iv) Illumination and Navigation:

In dark environments, such as caves, bioluminescent insects like the larvae of the fungus gnat (*Arachnocampa luminosa*) use light to attract and catch prey, using silk threads illuminated by their glow.

Applications of Bioluminescence

i) Medical research:

Injection of luciferin and luciferase exhibit different reactions in a normal and cancerous cell, and can aid in detecting energy problems in human cells. This technique is now used to study heart ailments, muscular dystrophy, urological problems, etc. Bioluminescent organisms are used to illustrate progression of infection and to assist in AIDS research. ATP bioluminescence was also used as a measure of cell proliferation and cytotoxicity.

ii) Fluorescent marker gene:

Fluorescent marker genes make the trans formed cells glow under light.

iii) Space Research:

Luciferin are system can be used in spacecrafts and can be sent to other planets to explore the existence of lifeforms dwelling on the outer space.

Interesting fact about firefly

- Firefly species *Pyrophorus noctilucus*, which has been documented as having a surface brightness of 45 millilamberts.
- Firefly is the state insect of Indiana.
- World Firefly Day, an annual celebration focused on raising awareness about fireflies and their celebration and conservation, was launched in 2018 by the Fireflyers International Network (FIN). The date of celebration is typically July 4-5.
- Firefly day 2025 theme :- "Help us keep the sparkles glowing!“
- Firefly festival Bhandardara, Ahmedanagar in Maharashtra from 15th May to 10th June.
- Firefly parks in world are Firefly Valley Leisure Park in Malaysia and Roman-no Mori Kyowakoku in Japan.

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