

Bioluminescence from insects

What is bioluminescence?

Light produced by a living organism: bacteria, fungi, crustaceans, fish, insects, molluscs, millipedes and centipedes.

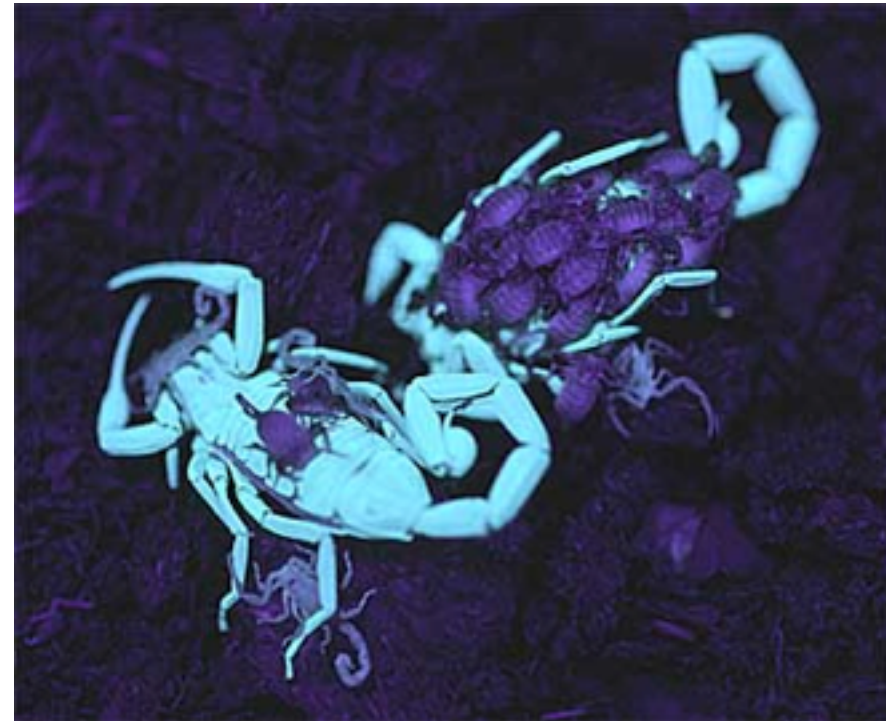
What is bioluminescence?

Light produced by a living organism: bacteria, fungi, crustaceans, fish, insects, molluscs, millipedes and centipedes.

What is not bioluminescence?

Fluorescence, release of light at one wavelength due to exposure to a different wavelength, e.g. scorpions

*Fluorescent lights
UV- \rightarrow visible*



millipedes and centipedes.



What insects are capable of bioluminescence?

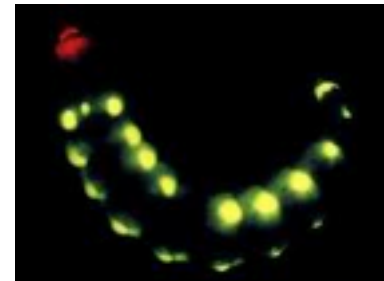
Members of Coleoptera and Diptera only.

Coleoptera

Fireflies: Lampyridae (fireflies and glow-worms),

Phengodidae (railroad worms)

Click Beetles Elateridae (click beetles)



Diptera: Keroplatidae

1. *Genus Arachnocampa*: “glowworms” Aus/NZ
2. *Genus Orfelia*: “dismalites” from North America

Fireflies: Lampyridae (fireflies and glow-worms)



Fireflies: Lampyridae



Click Beetles Elateridae (click beetles)



What insects are capable of bioluminescence?

Phengodidae (railroad worms) larviform females and larvae bioluminesce



BIOLUMINESCENT OR NOT?

2012: *Light-mimicking cockroaches indicate Tertiary origin of recent terrestrial luminescence*, in *Naturwissenschaften*.

Cited first report of bioluminescence in the genus: 1977 a collector of cockroaches in Brazil notes that a single cockroach is bioluminescent, published in *Amazonia*.

Assumption that all members of genus are bioluminescent

Captive specimens not bioluminescent

These photographs of dead specimens show **fluorescence** of cuticle, **not bioluminescence**

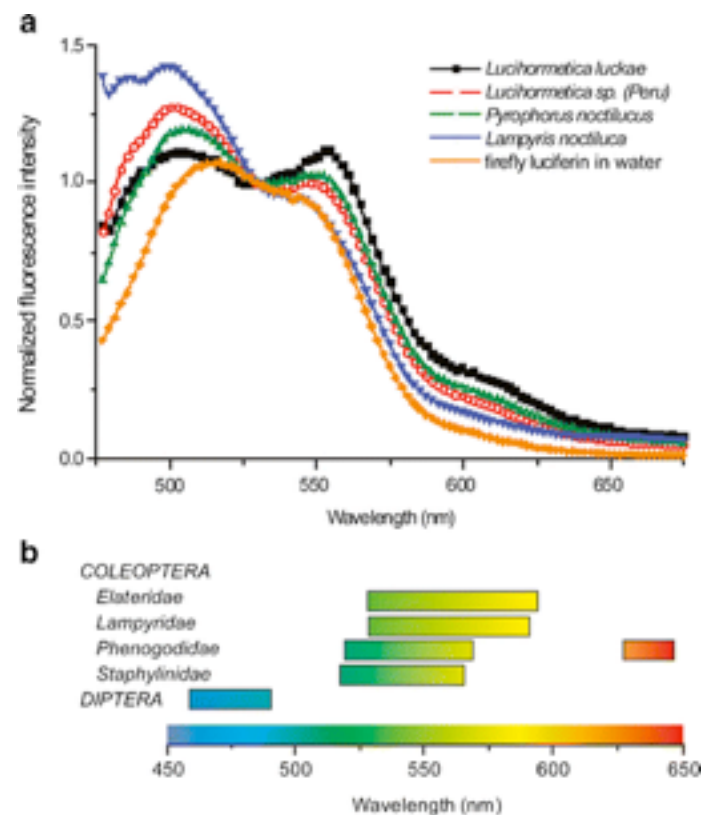


BIOLUMINESCENCE BREEDS BAD BIOLOGY

Compared autofluorescence characteristics of cuticle on twin eye spots with the cuticle of known light organs in beetles.

Spectrum similar -> concluded bioluminescent when alive.

Didn't compare to any other cuticle from non-bioluminescent region or non-bioluminescent cockroach



Concluded:
Use light to mimic toxic bioluminescent click beetles
“a new type of defensive, Batesian and interordinal mimicry”

SCIENCE

SCIENTISTS FIGURE OUT HOW – AND WHY – THIS COCKROACH GLOWS IN THE DARK

Posted on August 24, 2012 at 11:20pm by [Liz Klimas](#)

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This cockroach is not your everyday insect to scurry out from under the refrigerator or one that elicits startled shrieks when you turn on the bathroom light. In fact, you wouldn't have to even turn on your light to see this one coming.



Lucihormetica luckae glows in the dark due to bacterium crevices in its back. (Image: Vršanský et al., Naturwissenschaften via Discover Magazine)

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Glowing insects evolved surprisingly recently

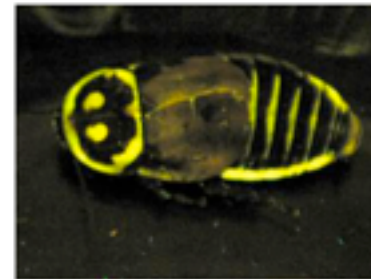
14:40 21 August 2012 by [Karl Gruber](#)
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Fireflies, one of the most conspicuous of nocturnal insects, are a relatively recent addition to the twilight world. A new analysis of all bioluminescent species suggests that those living on land might be mere tens of millions of years old – a fraction of the age of bioluminescing marine groups.

Bioluminescence serves many purposes, from communication to finding mates, scaring off predators to attracting prey. Yet while many marine species bioluminesce, very few terrestrial animals have evolved the ability. Besides fireflies and a few other insects, only one snail, a few earthworms and a handful of millipedes can produce light.

To better understand this striking difference between land and sea [Peter Vršanský](#), a palaeobiologist at the Slovak Academy of Sciences in Bratislava, and his colleagues, studied the evolutionary history of all known marine and terrestrial groups of bioluminescent species.

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Bioluminescent cockroach (*Lucihormetica luckae*)

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Glowing Cockroach Mimics Toxic Beetle

Roach's bioluminescence tricks predators into thinking it's distasteful.



80beats

• Mayan Tree Chopping May Have Worsened Droughts, and Contributed to The Civilization's Demise
Older Dads Pass on More Mutations to Their Kids •

Look at This: Glowing South American Roaches Mimic Toxic Beetles



Under normal light, this roach looks normal enough. But under a fluorescent light, its three spots—two large ones and one very tiny one just visible under the right spot—light up like a Christmas tree.

This remarkable species of South American cockroach, *Lucibormeticus luckae*, owes its fluorescence to bacteria. The spots on the dark brown area of its carapace are pits inhabited by microbes that glow under fluorescent light.

“The spots on the dark brown area of its carapace are pits inhabited by microbes that glow under fluorescent light.”

What do insects use it for?

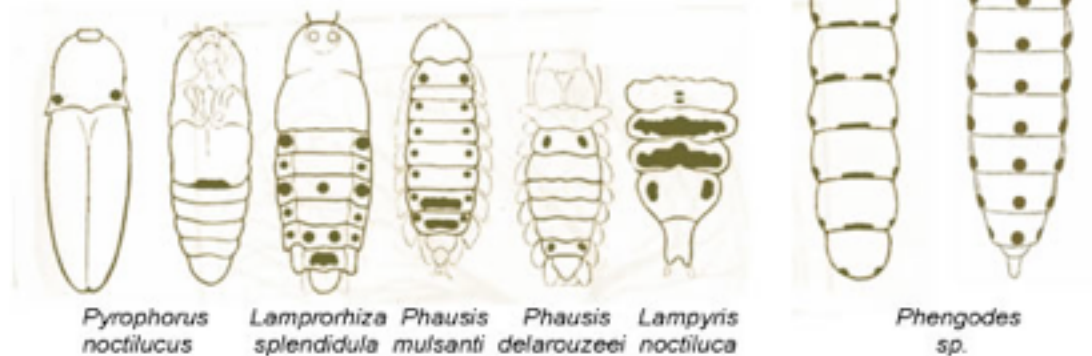
Larval beetles: aposematic, associated with distaste

Adults: sexual signalling, female commonly apterous and larviform

Larval and adult light organs are unrelated

Co-option of the light emission pathway into different specialised organ system by adults

Proposed that adults originally diurnal -> nocturnal

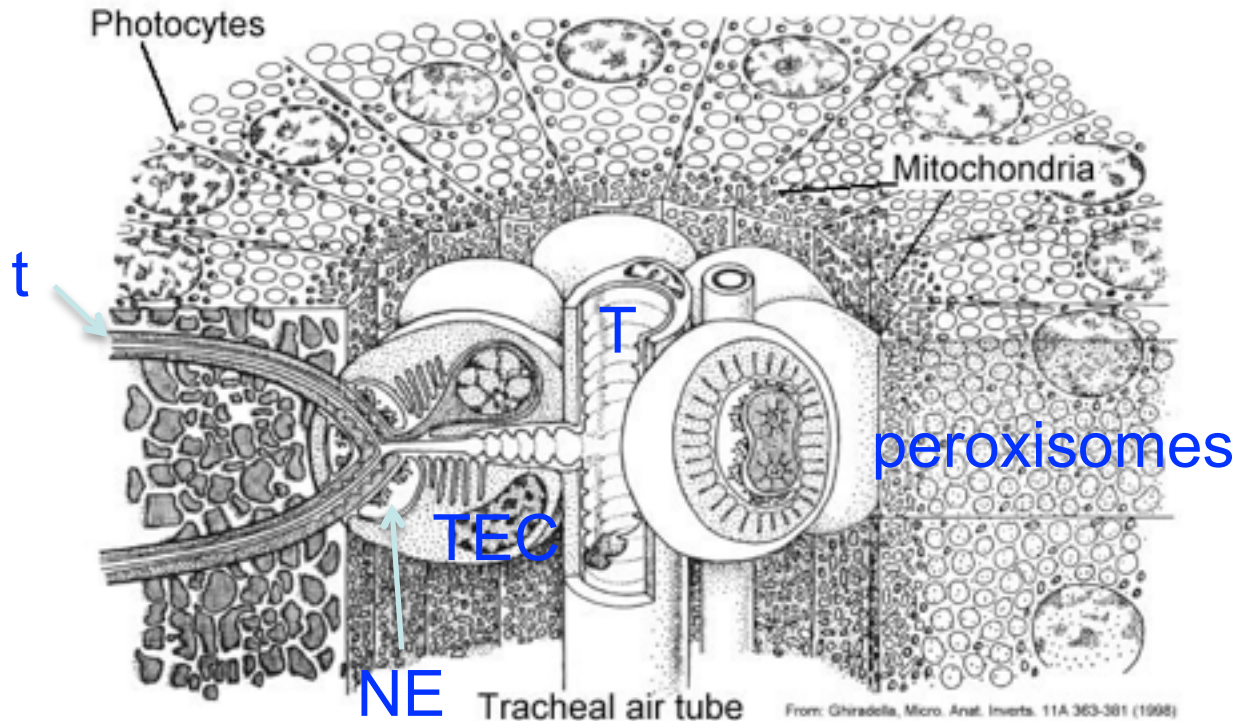
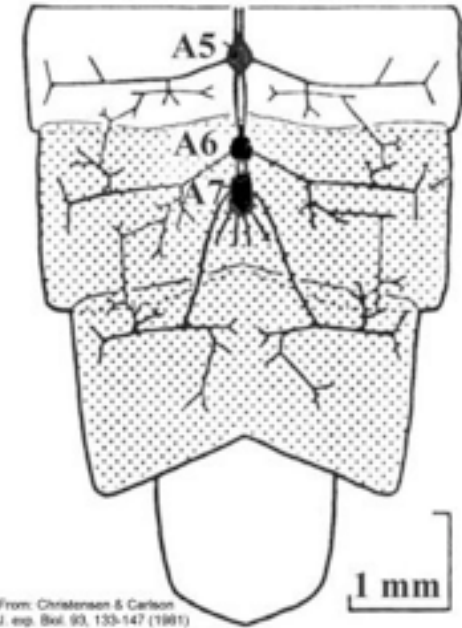


Diversity of lantern morphology in bioluminescent beetles. Lanterns are shown as dark areas. Modified from Buck 1948.



Firefly flashing: neural and chemical basis

- Adult light organs appear to be evolutionarily derived from fat body
- Possess a large tracheal reflector
- Nerve supply: neurons contain octopamine: 40-60 milliseconds between action potential and flash
- Peroxisomes within photocytes produce light



NE, nerve ending;
t, tracheole;
T, trachea;
TEC, tracheal end cell

Firefly flashing: neural and chemical basis

Nitric oxide (NO) control of the firefly lantern flash

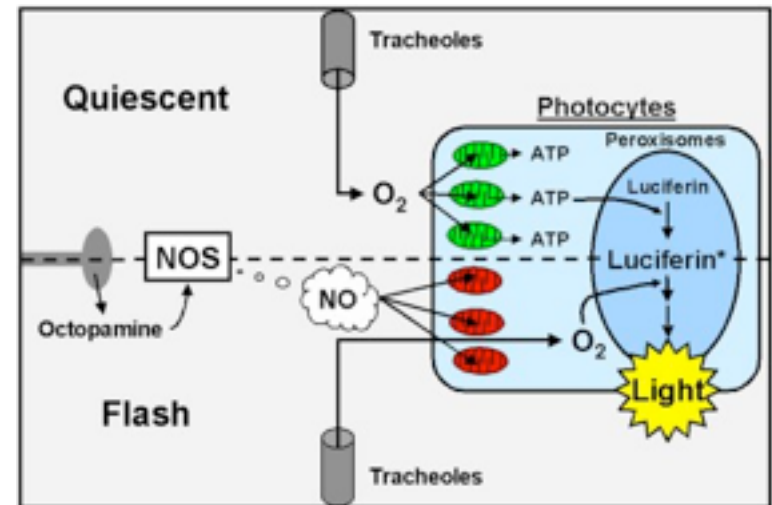
O₂ from trachea consumed by respiration in photocyte mitochondria (green) -> little O₂ reaches peroxisomes
ATP produced by oxidative phosphorylation -> formation and accumulation of activated luciferin* by luciferase.

Flash mode (bottom)

Nerve -> octopamine release -> transiently activates lantern NOS.

NO diffuses -> inhibits oxygen use by photocyte mitochondria (red).

O₂ diffuses through photocytes -> peroxisomes -> triggers the light-producing reaction



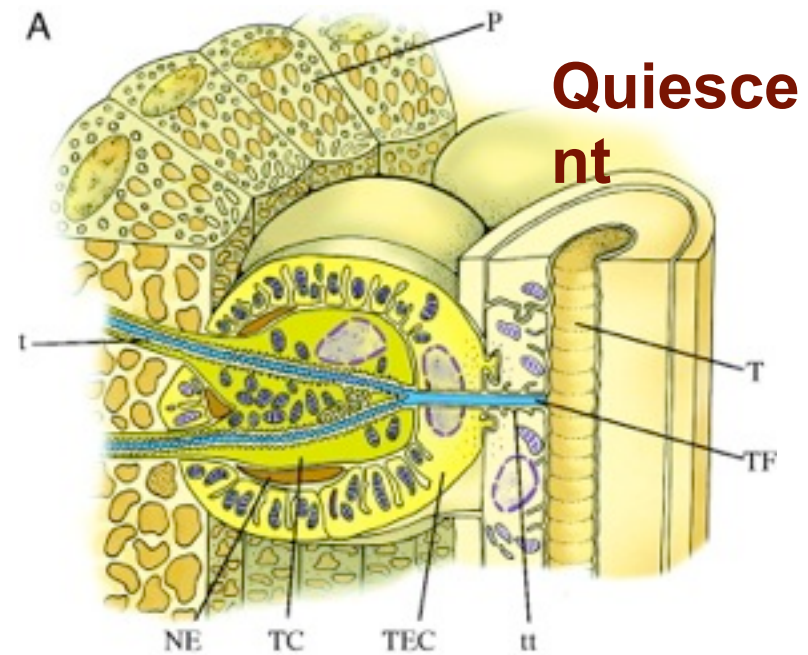
Alternative mechanism

Increased fluid length during no light emission

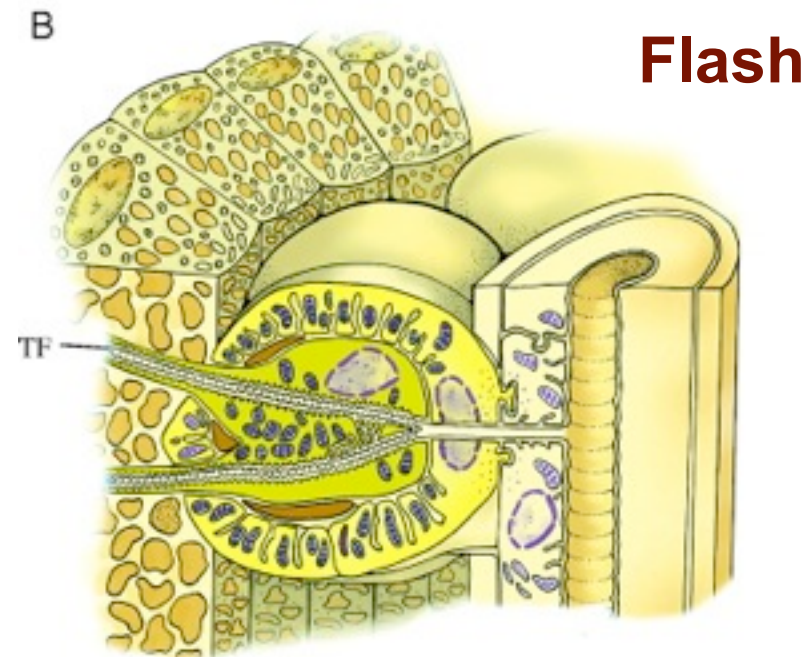
Neural stimulation -> transient increase in the osmotic potential of the tracheolar cell -> decreased tracheolar fluid levels.
Decreased diffusional barrier allows greater oxygen supply to the photocytes, relieving intracellular anoxia and enabling light emission (molecular oxygen is required).

Decreased fluid length during light emission

As tracheolar cell osmotic potential returns to the resting state, tracheolar fluid levels increase, oxygen diffusion to the photocytes is decreased, intracellular anoxia occurs in the photocytes and light emission is inhibited.



TIMMINS G S et al. J Exp Biol 2001; 204:2795-2801



What do insects use it for?

Diptera

Arachnocampa (Aus/NZ) and *Orfelia* (Nth America)

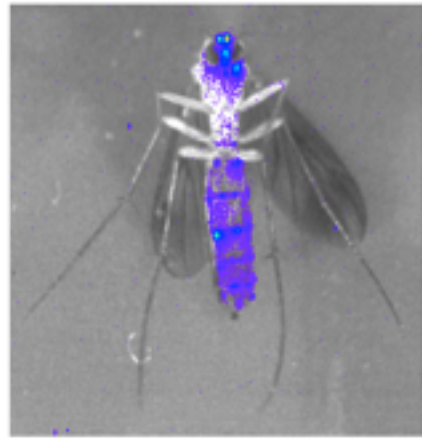
Prey attraction: unusual in terrestrial habitats

Orfelia (Nth America)

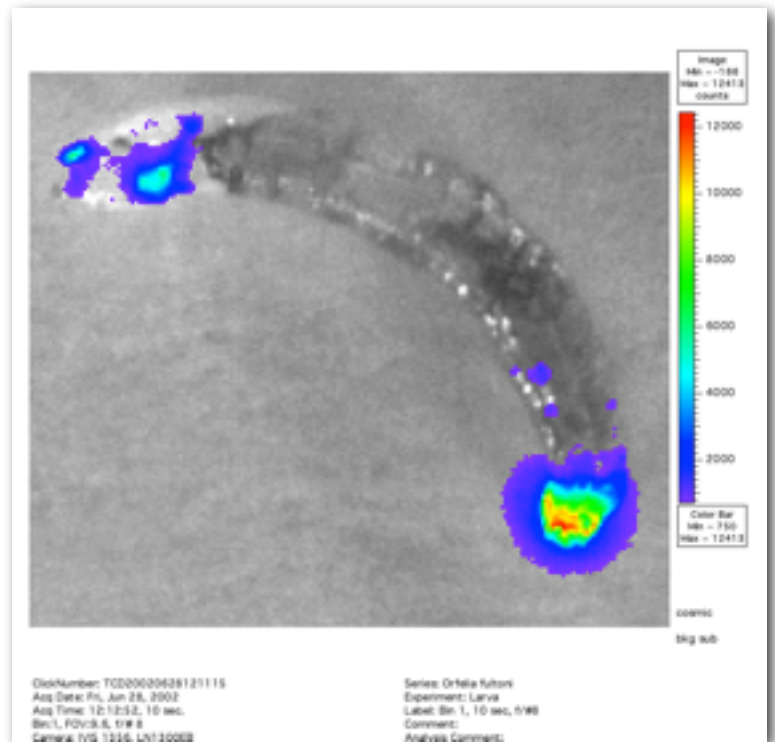
Adults also bioluminescent



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Comment: See Fig 1
Experiment: Larva



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What do insects use it for?

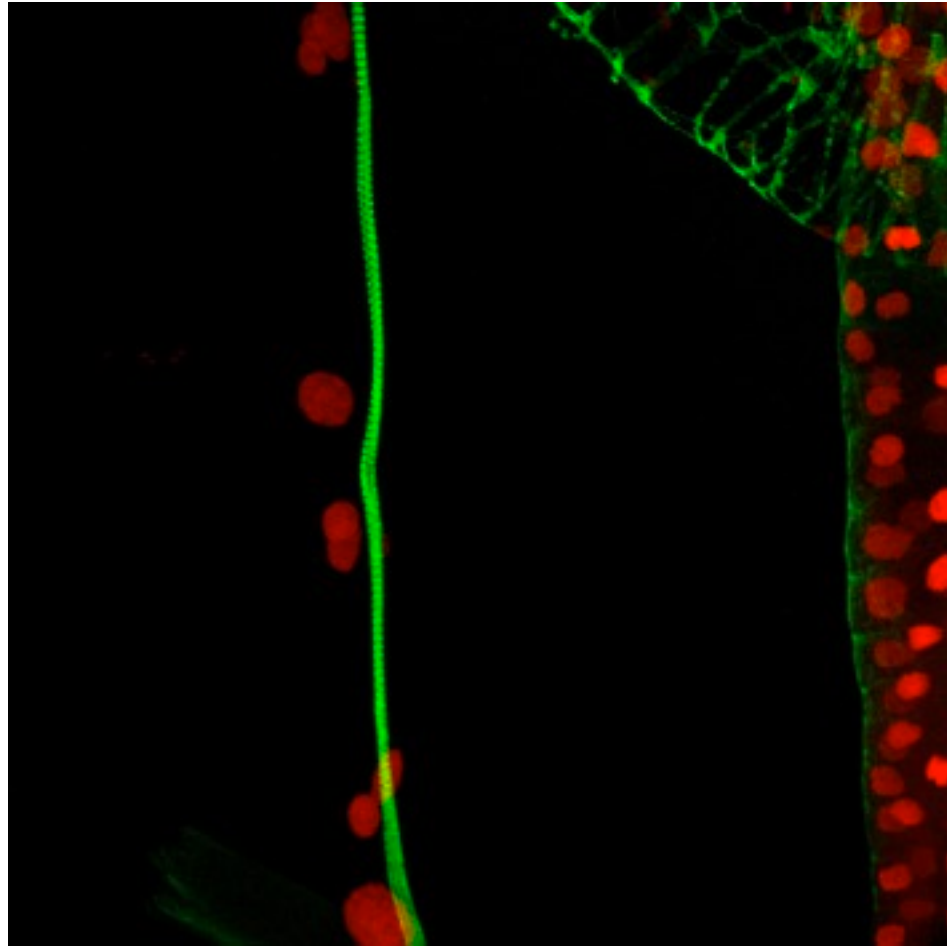


What do insects use it for?

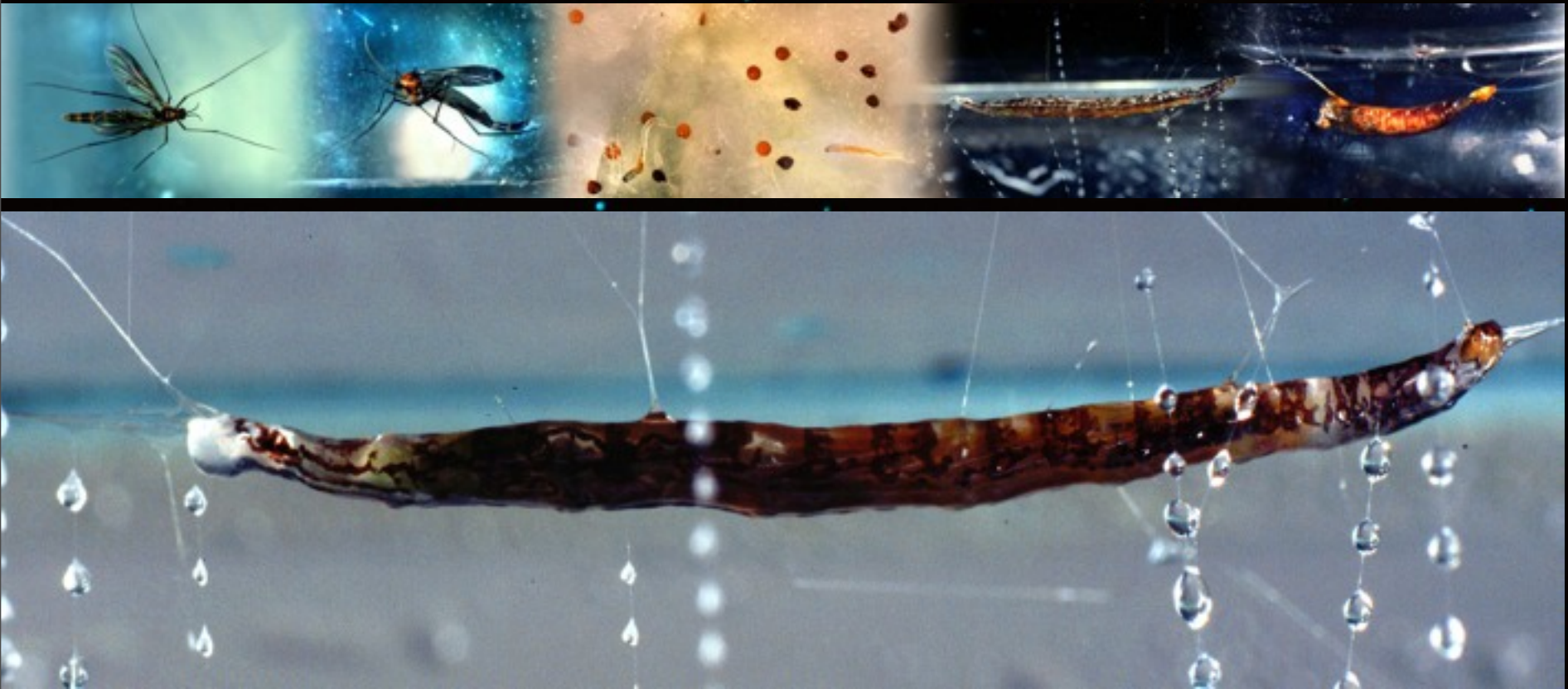
Orfelia



Very large pigmented cells called black bodies sit on a muscle fibre.
Appears that cells release bioluminescent substance into hemolymph.
Maybe by flexing muscle?
Nothing known about neural regulation.



Immature stage of keroplastid fly



Immature stage of keroplatid fly



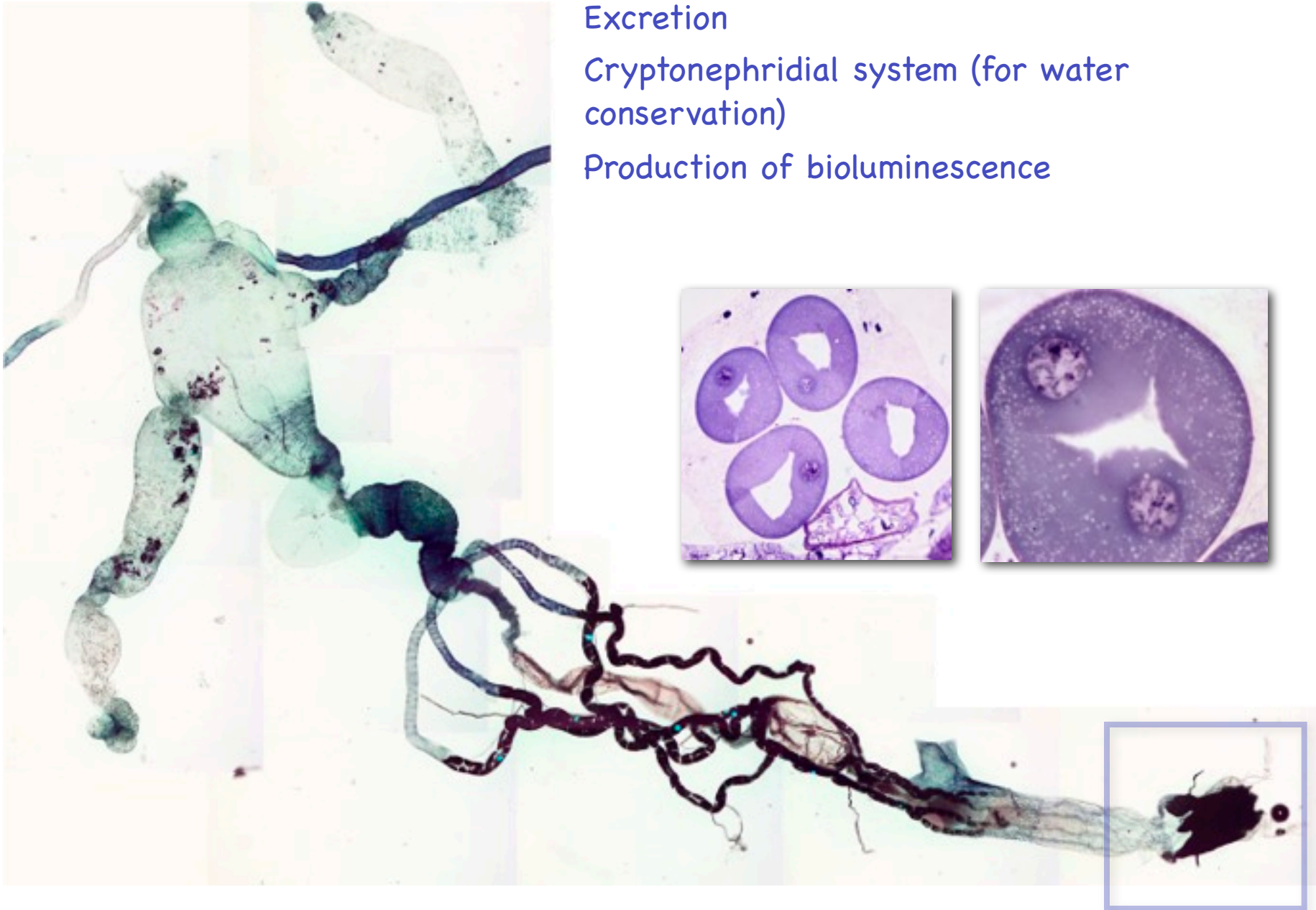
Arachnocampa flava: south-east Queensland
Arachnocampa tasmaniensis: Tasmania

Malpighian tubules

Excretion

Cryptonephridial system (for water conservation)

Production of bioluminescence



Cells at tip of Malpighian tubules produce bioluminescence
Cells next to a reflector made of trachea



Bioluminescence

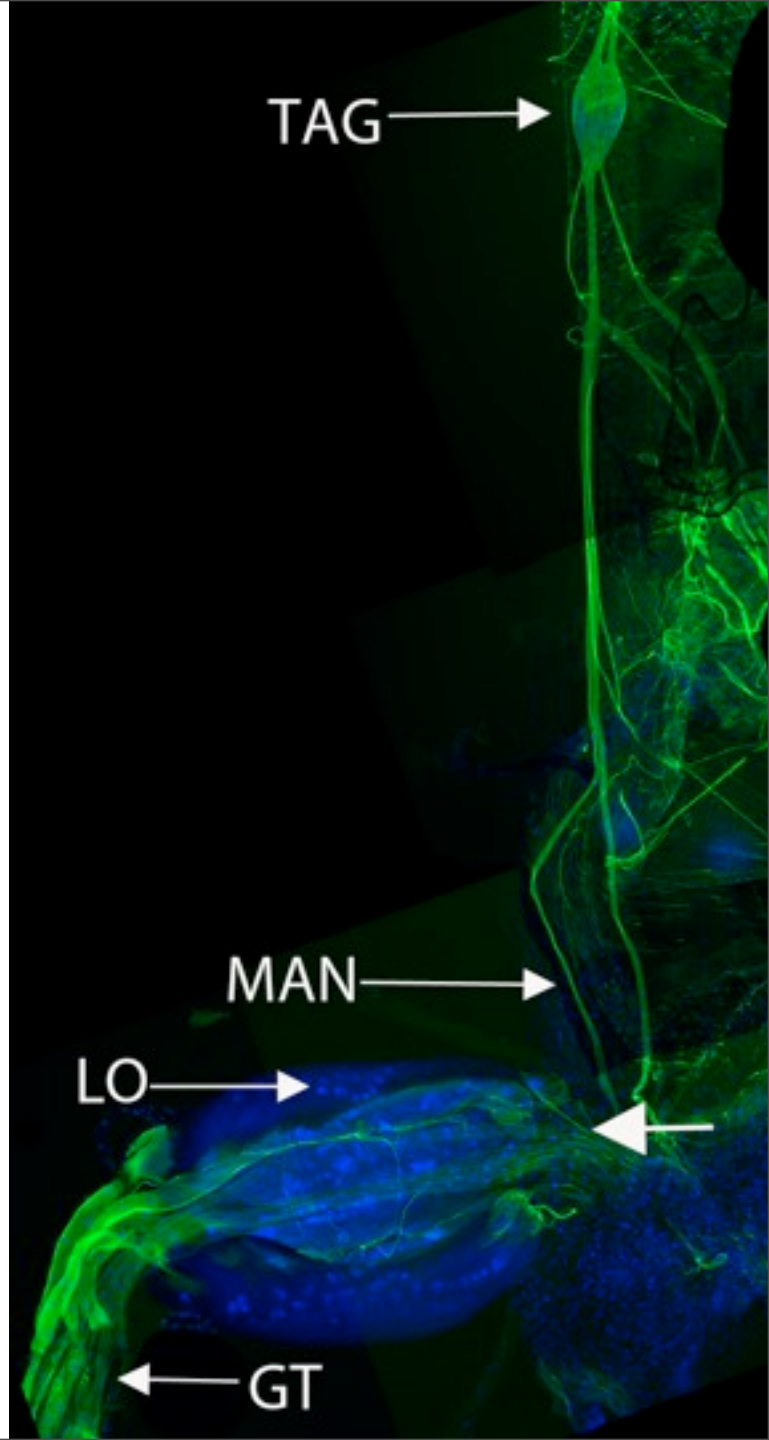
- Blue-green (peak at 485 nm)
- ATP dependant
- Enzyme/substrate reaction (luciferin/luciferase):
not identical to fireflies

Behaviour

- Glow persistently through night
- Intensity varies (brightest in early evening)
- Intensify when stimulated by vibration
- Intensify during aggressive interactions

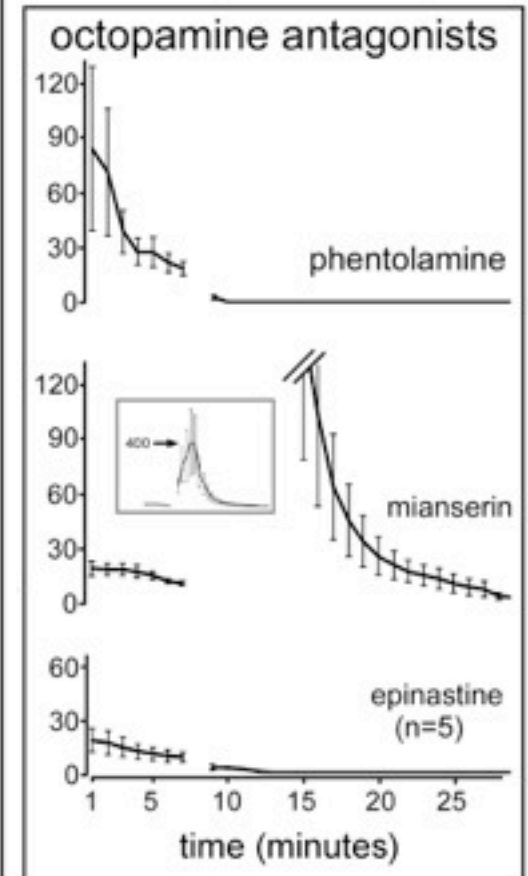
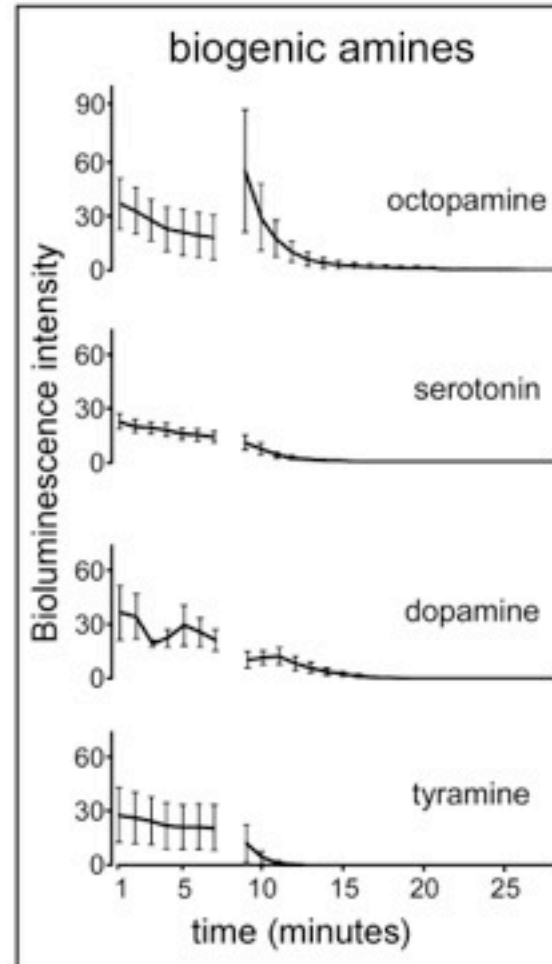
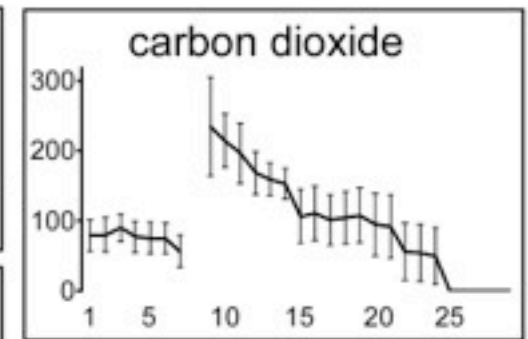
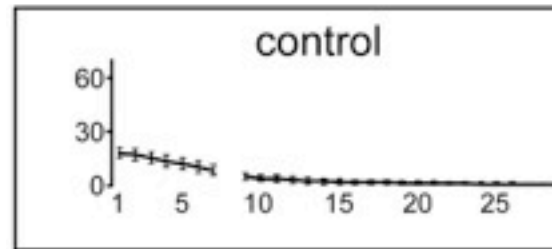
Light organ is innervated from TAG

- Nervous system represses bioluminescence when exposed to light
- Anaesthetic (CO₂) causes release of light
- Ingesting biogenic amine (octopamine) causes release of light
- Ingestion, bathing light organ, injection whole larva



Isolated light organ

- Control: releases small amount of light after removal
- Anaesthetic (CO_2) causes release of light
- Bathing in octopamine causes release of light
- Bathing in serotonin, dopamine, tyramine has minimal effect



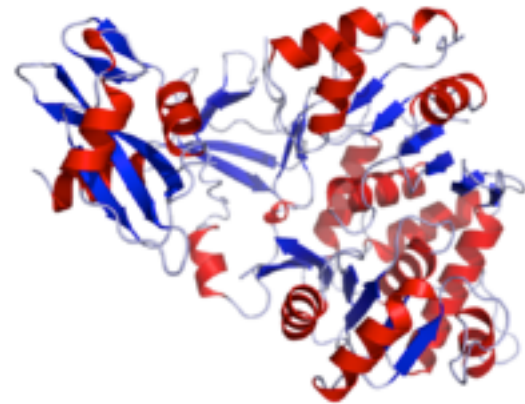
How do they make light?

In all biological systems: an enzyme-mediated reaction between molecular oxygen and an organic substrate.

Terms **luciferin** for substrate and **luciferase** for enzyme
luciferase-bound peroxy-luciferin intermediate that breaks down to provide energy for excitation.

Light is generated in a bioluminescent reaction very rapidly and efficiently as a part of a multi-step chemical reaction

Different systems, e.g.
Diptera cf Coleoptera
not necessarily
homologous



How have we made use of insect bioluminescence?

Patent covers all beetle bioluminescence

Scientific

Transgenic animals to track gene expression

Luc gene under control of promoter

Commercial

Measurement of ATP levels: luminometer

Cancer research equipment: image and track cells in living organisms

How have we made use of insect bioluminescence?

For in vivo bioluminescence imaging, tumor cells, or genes are tagged with a reporter gene that encodes beetle luciferases.

Firefly luciferase (*luc*) gene from *Photinus pyralis* encodes a 550 amino acid protein, Luc.

In its native configuration, the enzyme produces light with broad spectral emission that peaks at 560

