

# BIOLUMINESCENCE IN WATASENIA SCINTILLANS (FIREFLY SQUID)

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Biol 428 Winter 2015

*“Some things which are not  
fire nor forms of fire seem to  
produce light by nature” –*

Aristotle (~2,500 years ago)



# OUTLINE

1. Introduction
2. Light generating mechanism
3. Adaptation
4. The origin of bioluminescence
5. Conclusion and future of bioluminescence



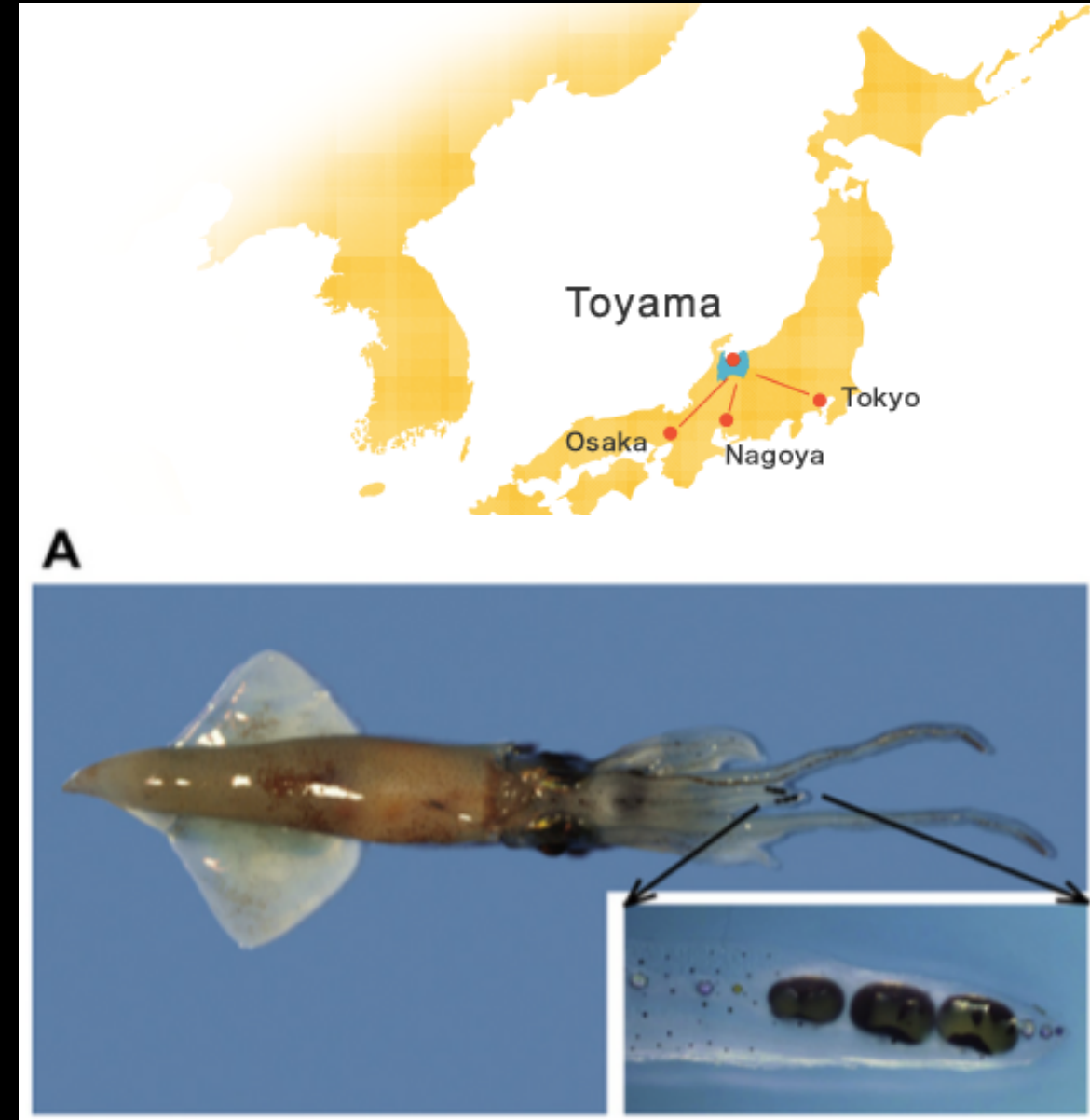
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# INTRODUCTION

- Commonly known as “**hotaru-ika**” or the **firefly squid**
- Found only in Japan – **Toyoma Bay**
- 1-year life cycle
- Large array of **photophores** throughout the body
- Emits blue light



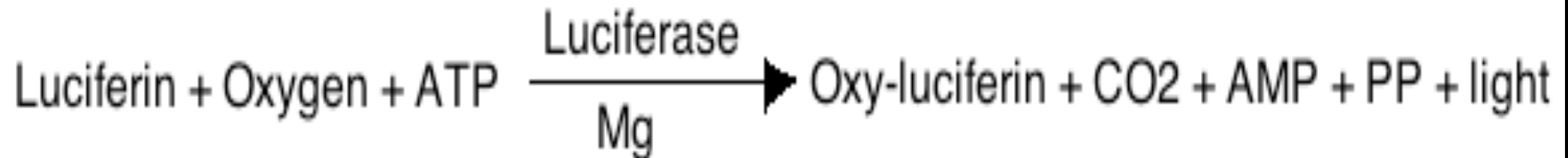
# CHALLENGES

- They cannot be kept alive for more than 3-5 days in captivity
- The animal dies in about 10-20 min when taken out of water causing irreversible damage to the photophores
- The luminescence system is highly unstable even when the photophores are kept in an ice bath

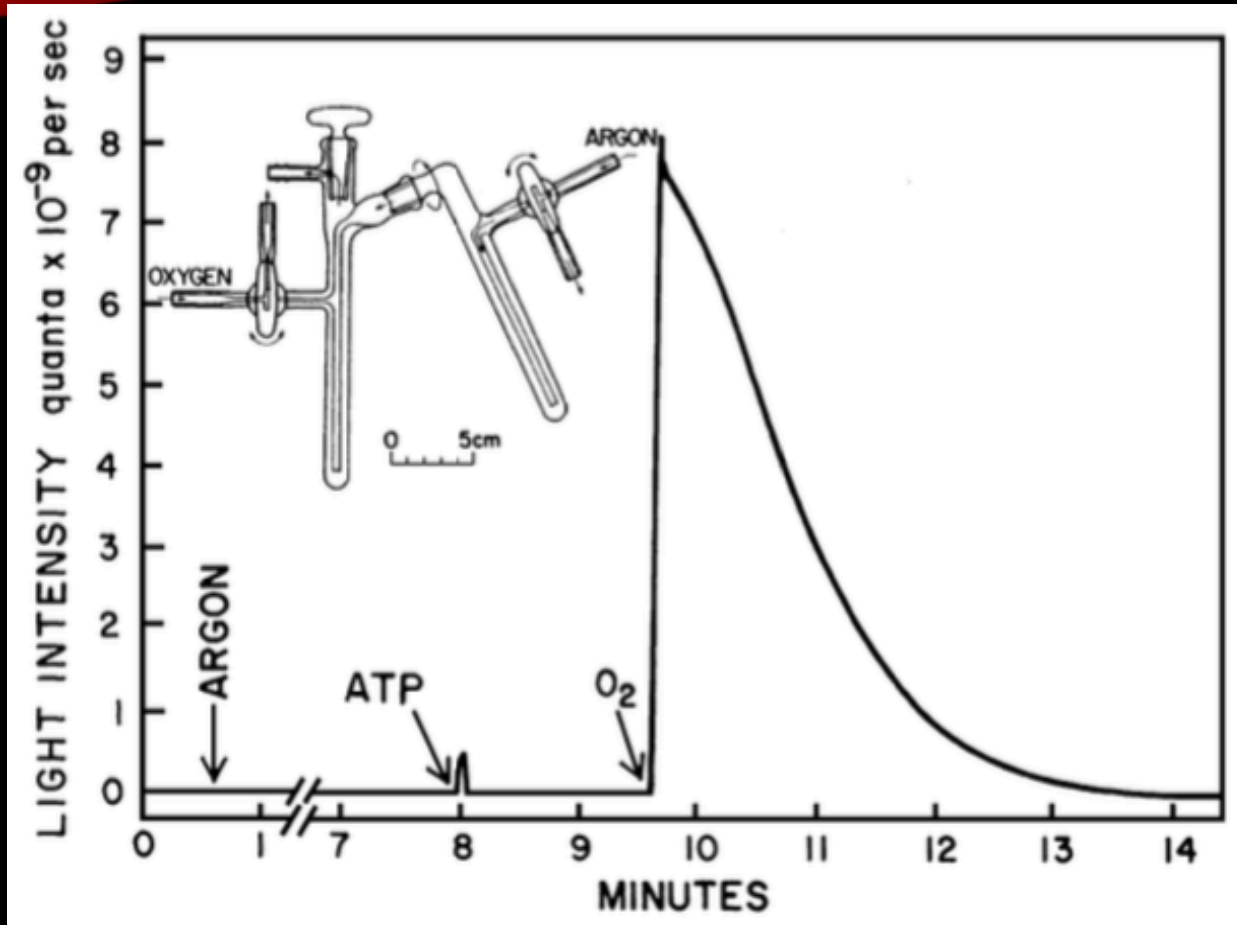


# 1. LIGHT GENERATING MECHANISM

- 2 ways to generate light:
  - (a) internal biochemical reaction → my species!
  - (b) symbiotic luminous bacteria
- Luciferin-luciferase reaction:



Light generating mechanism → adaptation → origin of bioluminescence → conclusion and future



- ✓ ATP
- ✓ Oxygen
- ✓ pH 8.8

CONCLUSION:  
ATP or Oxygen alone is not sufficient. Both are necessary. (Tsuji, 2002)

Light generating mechanism → adaptation → origin of bioluminescence → conclusion and future



## 2. ADAPTATION

- Most cephalopods are color blind because they only have one visual pigment in their retina (Brown & Brown, 1958)
- Instead of perceiving color, most cephalopods are found to utilize contrast
  - Cephalopods contrast difference → 15%
  - Humans contrast difference → 2%

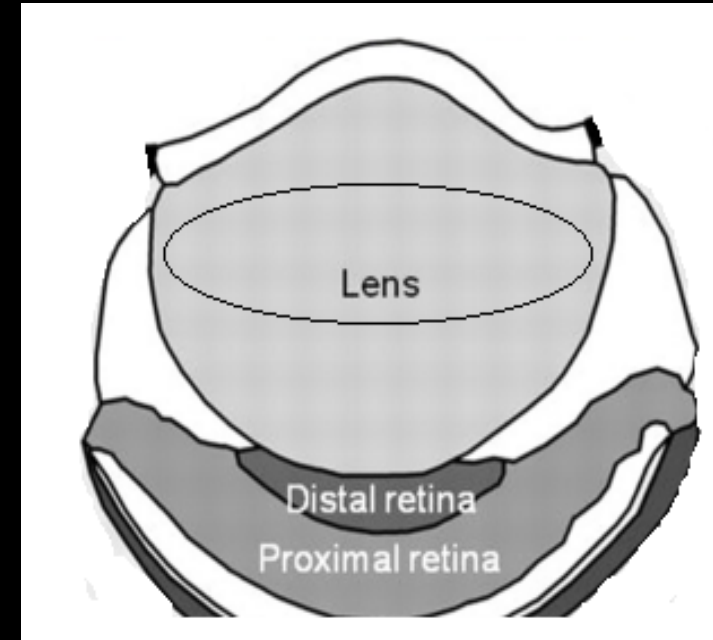
**WHY BOTHER BIOLUMINESCENCE WHEN THEY CANNOT EVEN SEE COLOR ???!!**



Light generating mechanism → adaptation → origin of bioluminescence → conclusion and future

# WATASENIA IS AN EXCEPTION

- They have 3 visual pigments in their retina (Michinomae *et al.*, 1994)
- 2 of the photopigments (470nm & 500 nm) are present in the **proximal part** of the retina
- The other photopigment (484nm) is present in the **both distal and proximal part of the retina**.



## HERE COMES ANOTHER PROBLEM!

**Chromatic defocus** → different wavelength of light focusing on different parts of the retina creating a blurry image

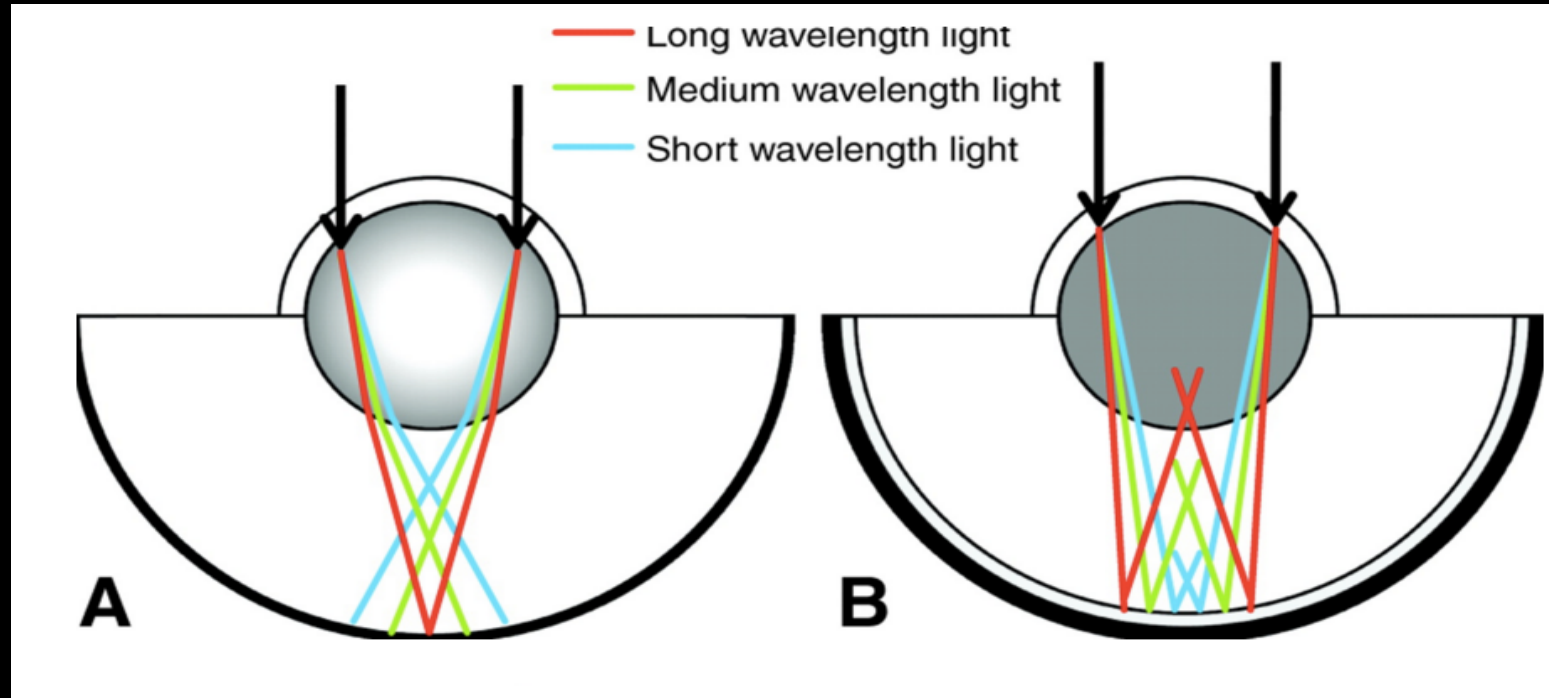
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## Problem solved:

- A bank of photoreceptors sensitive to short and long wavelength. (Kröger & Gislén, 2004)

This allows visualization of well focused images



A: Chromatic defocus

B: Chromatic defocus solved

**Bank of photoreceptors + layered organization → maximizes sensitivity and sharpness**

Light generating mechanism → adaptation → origin of bioluminescence → conclusion and future

### 3. ORIGIN OF BIOLUMINESCENCE

- Complex diversity of mechanism use to generate light suggests that perhaps **multiple independent origins** of bioluminescence arose over the course of evolution. (Buck, 1978)
- Current hypothesis:
  - (a) luciferin → shape the evolution of bioluminescence
  - (b) luciferase → serves to express the chemiluminescent properties of luciferin



Light generating mechanism → adaptation → origin of bioluminescence → conclusion and future

- Research has shown that photogenic substrate (luciferin) has a strong antioxidative property → highly reactive with ROS (Suzuki, 1993)

- Proposed that luciferin (Rees *et al.*, 1998):

Original function → detoxify the deleterious effect of ROS



Animals started colonizing deeper layers of the ocean



- 1) Low penetration by sunlight.  
**lower ROS**
- 2) Decrease in metabolic activity,  
**decrease ROS**

Evolved function: functional shift from detoxification to light-emitting

Light generating mechanism → adaptation → origin of bioluminescence → conclusion and future

# 4. FUTURE

## Agriculture



## Medicine



Light generating mechanism → adaptation → origin of bioluminescence → conclusion and future



# SUMMARY

1. Light is generated via the luciferin-luciferase complex for *Watasenia scintillans*.
2. BOTH oxygen and ATP are necessary for the generation of light in *Watasenia scintillans*.
3. Most cephalopods are color blind BUT *Watasenia scintillans* evolve retina that contains 3 types of photopigments.
4. Bank of photoreceptors + layered organization → maximizes sensitivity and sharpness
5. It is suggested that bioluminescence might have arose multiple times independently across various phyla
6. Photogenic substrate (luciferin) might have undergone a functional shift from detoxification of ROS to the production of light.

Light generating mechanism → adaptation → origin of bioluminescence → conclusion and future

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