Bioluminescence
An introduction

Leonardo Andrés Espinosa Leal\textsuperscript{1,2}

\textsuperscript{1}Nano-bio Spectroscopy Group. European Theoretical Spectroscopy Facility (ETSF) nanoquanta. Network of Excellence.

\textsuperscript{2}Departamento de Física de Materiales, Facultad de Ciencias Químicas, Universidad del País Vasco, Centro Mixto UPV-CSIC.

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beamertheme Bogota copyright Leonardo Andrés Espinosa Leal
e-mail: laespinosa001@ikasle.ehu.es
Abstract

In this talk, I will show you a fast overview on bioluminescence phenomena, main characteristics and a very basic theoretical description using first principles tools.
Outline

1. **Introduction: Theory of Luminescence**
   - Characteristics of Luminescence

2. **Luminescence of Living organisms**
   - Main aspects
   - Mechanisms of CL and BL
   - Chemiluminescence
   - Bioluminiscence

3. **The primary Bioluminescents Systems**
   - Structures of Luciferins-Luciferase
   - BL system of the Firefly
   - BL in others systems

4. **Conclusion**

What is Luminescence?

“weak glow”

Luminescence as a weak cold glow

- Rotting wood
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- Certain insects
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Emission of energy in the form of visible light during chemical or biochemical processes is called Chemiluminescence (CL) or Bioluminescence (BL).
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1. The energy released should be higher than that of the electronically excited product or intermediate molecules.
2. The product must be a fluorescent molecule so that the transformation of the excited molecule to the ground state is accompanied by visible light emission, or the reaction mixture has to include energy acceptor molecules with fluorescent properties.
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Main aspects
Mechanisms of CL and BL
Chemiluminescence
Bioluminiscence

Mechanisms of chemiluminescence and Bioluminescence
Formation of a product whose subsequent transformation are sufficiently exothermic to emit visible light (400nm - 700 nm).
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2. Transition of a some reaction intermediate to the electronically excited state.
3. Light emission from the excited state that has been formed.
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Chemiluminescence Reactions

The most effective CL reactions can be divided into three groups according to mechanism of *chemiexitation*. 

1. **CL of Electron Transfer.**
2. **CL of Singlet Oxygen.**
3. **CL Reactions of Peroxide Decomposition.**

- **CL Reactions with Electron Transfer.**
  - CL of Oxalates.
  - CL of Acridium Compounds.
  - CL of Dioxetanes.

- **Cellular CL.**
  - Recombination of free ion radicals.
  - Oxidation of anion radicals of aromatic hydrocarbons.

- **Emision of red ligth is observed during oxidation of hydrogen peroxide by chloride in alkali media.**

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Main Aspects

My fancies are fireflies,
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twinkling in the dark.

by Rabindranath Tagore,
Fireflies.
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Bioluminescence: An introduction
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- The basis of BL is a CL reaction catalyzed by a specific enzyme.
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- The Quantum yields of BL reactions usually lie between 0.1-0.9.
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- The basis of BL is a CL reaction catalyzed by a specific enzyme.
- The Quantum yields of BL reactions usually lie between 0.1-0.9.
- All proteins catalysts of BL reactions isolated are oxygenases (luciferin-luciferase or Photoproteins).

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Luciferins-Luciferase

Peer to peer, illuminating

**Figure**: Reaction scheme for bioluminescence generation via luciferase-catalyzed conversion of luciferin (L2911, L2912, L2916) to oxyluciferin.
Luciferins-Luciferase

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Luciferins are a class of small-molecule substrate each for their corresponding protein enzyme luciferase.

Luciferin and luciferase are not specific molecules. They are generic terms for a substrate and its associated enzyme (or protein) that catalyze a light-producing reaction.

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BL system of the Firefly

- This reaction have a higher Quantum yield (~ 0.9).

\[ \text{ATP} + \text{O}_2 + \text{Mg}^{2+} \rightarrow \text{Luciferyl adenylicate} + \text{pyrophosphate} + \text{Cyclic peroxide dioxetanone} + \text{AMP} \]

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\( ^b \) J. Am. Chem. Soc. 2007, 129, 8756-8765
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\[ \text{Oxyluciferin} \]

\[ + \text{hv} \]

\[ \text{CO}_2 + \text{AMP} + \text{H}^+ \]

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Other sets of Luciferin-Luciferase systems
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- **BL Systems of Bacteria.**
  
  Common in seawater and in the guts of organisms. Also used in the lure of Anglerfish and in the ventral counterillumination of the bobtail squid (Euprymna scolopes)

- **Reduced riboflavin phosphate (FMNH₂).**

- **Yellow Fluorescent Protein (YFP).**
Other sets of Luciferin-Luciferase systems
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- Coelenterazine BL Systems.
  Different species employ photoproteins or a variety of luciferases to trigger luminescence from coelenterazine. The luminous groups include Scyphozoa ("true" jellyfish), Hydrozoa (hydroids, siphonophores, and hydromedusae), and Anthozoa (sea pens and sea pansies).

- Imidazopyrazine.

- Bioluminescence is widespread in all major Cnidarian groups except for the Cubozoa.
Other sets of Luciferin-Luciferase systems

Cypridina BL.
Common in seawater and in the guts of organisms. Also used in the lure of Anglerfish and in the ventral counterillumination of the bobtail squid (Euprymna scolopes). Most pelagic crustacean groups (with the exception of isopods) have luminous members. These include copepods, ostracods, amphipods, decapod shrimp and euphausiids (krill). Amazingly, three of the major marine luciferins are used in various crustaceans (ostracod-type luciferin, dinoflagellate-type luciferin, coelenterazine). Crustaceans are also the most likely source for coelenterazine in the sea, as there is evidence that they can produce it.

Imidazopyrazine derivative.
Pycnogonids (sea spiders).
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If you see luminous sparkles in the wake of a boat, or in splashing waves on the beach, it is probably coming from dinoflagellates. These single-celled protists can be photosynthetic, or they may be heterotrophic (eat other organisms), or some combination of the two. They may become very abundant during red tides, and are thought to use their light as a burglar alarm to attract predators to animals that are grazing on them.
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- **Dinoflagellate BL System.**

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- **Tetrapyrrole.**

- **Pyrocystis fusiformis.**
Bioluminescence is a very important physical phenomena until now not well understand but very common in undersea organisms, some kind of mushrooms and insects. The physical knowledge of Bioluminescence can be important for ecological generation of light and like source of energy.
Bibliography

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