SASTA OLIPHANT SCIENCE AWARDS

SOUTH AUSTRALIAN SCIENCE TEACHERS ASSOCIATION

Prize Winner

Science Writing

Year 7-8

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Adelaide Botanic High School

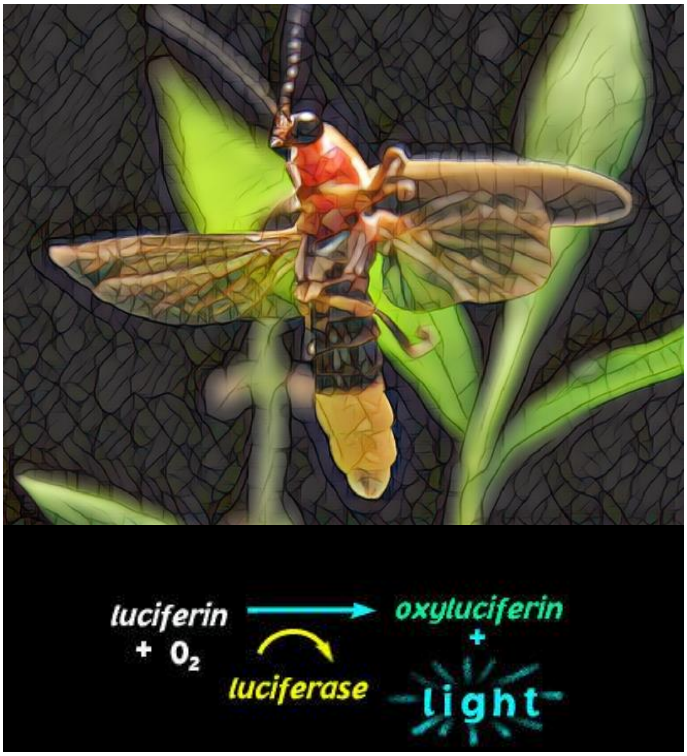

Photo-firefly-adapted from (Zielinski 2012); Photo-bioluminescence equation (Bio n.d.)

BIOLUMINESCENCE

A superior tool in COVID 19 vaccine and drug developer's toolkit

ABSTRACT

Bioluminescence is observed in nature in both land and marine animals. Animals use bioluminescence for a variety of purposes. Fireflies use an enzyme called luciferase to produce bioluminescence. Now, this same enzyme is being used by scientists to diagnose and combat COVID 19 in a far faster and efficient way than other traditional methods allow. Time is of essence in a pandemic and bioluminescence is providing the superior tool needed to help mankind in this pandemic.

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(Word count – 1265)

30th June 2022

Bioluminescence – A superior tool in COVID 19 vaccine and drug developer's toolkit

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Introduction

Bioluminescence is the making and discharging of light by living organisms (Tim Kahlke 2016). As a chemical reaction is responsible for creating this light in the living organisms, bioluminescence is a form of chemiluminescence. Creation of light by a chemical reaction is called chemiluminescence (K.V Ragavan 2019). Light produced by bioluminescence is a non-heat emitting cold light. Bioluminescence can be observed in micro-organisms including in bacteria that lights up waves with a blue glow, in large invertebrates such as the giant squid and in many other organisms such as mushrooms and other fungi (Kricka 2005). Living organisms that use bioluminescence can be found in almost all land and marine habitats. Not all bioluminescent creatures produce the same colour glow though. Bioluminescence in land dwelling creatures mostly glow with a green, yellow or even red colour but in the marine environment, bioluminescent creatures most commonly glow blue or green. For example, the ghost mushroom glows greenish yellow while the giant squid glows blue. Some creatures even glow two colours. The larva or the larvaiform of the adult female beetle belonging to the family *Phengodidae*, popularly known as the railroad worm is a large beetle larva that glows red at its head and green at its body (Branham, Glow worms, Railroad worms (insecta Coleoptera: Phengodidae) 2019).

There are two types of luminescence production found in living organisms in nature. The first is bacteriogenic light and the other is autogenic light. Bacteriogenic light is produced by bioluminescent bacterium (such as bacteria from the genera *Vibrio*) that occupy a part of another living organism (such as the ink sac of certain squids) and enjoys a symbiotic relationship with this other organism (M. K. Nishiguchi 2004). The second type is autogenic light in which light is produced by the living organism itself, like the bioluminescence observed in fireflies.

Bioluminescence is used by living organisms for several different purposes, including to communicate with each other, for self-defense, during mating rituals, to hunt for preys and for mimicry or camouflaging purposes (Lloyd 1983).

This paper will examine how bioluminescence is created in fireflies and discuss how medical researchers are using bioluminescence to respond quickly to create vaccines and drugs in pandemic situations.

Bioluminescence in Fireflies

Chemiluminescence reaction responsible for bioluminescence in the firefly, takes place in an organ called the lantern found in its lower abdomen. The lantern is lined with photocyte cells which contains an organic compound called *luciferin* and an enzyme called *luciferase*. Oxygen taken in by the firefly is normally directed to the mitochondria of its cells to produce energy. However, when the firefly intends to use bioluminescence, a chemical process allows most of this oxygen to be redirected to the photocyte cells present in the lantern. When the *luciferin* and *luciferase* come in contact with the oxygen and binds to each other they create *oxyluciferin*. When agitated, *oxyluciferin* lights up, creating bioluminescence. When oxygen is directed back to the mitochondria of the cells by the firefly, this *oxyluciferin* returns to a stable state, and the bioluminescence stops (Branham, How and Why do fireflies light up 2005). The figure below (fig.1) shows a simplified representation of how bioluminescence is created when *luciferin* combines with *luciferase* in an oxygen rich environment to create *oxyluciferin*. When *oxyluciferin* molecules are disturbed, it creates bioluminescence.

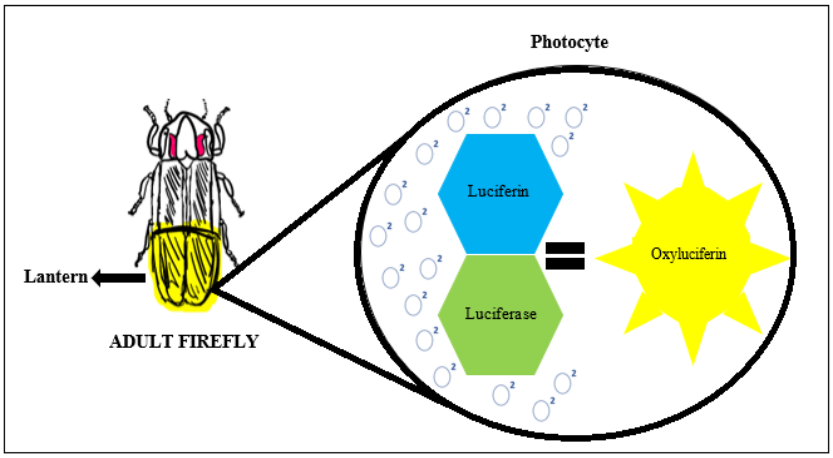

Fig. 1 (Ismail 2022)

Using Firefly Bioluminescence to Respond to the COVID 19 Pandemic

Fast and efficient diagnostic tests are crucial to stop the spread of coronavirus disease 2019 (or COVID-19) during peak pandemic periods. Currently used diagnostic test for COVID 19; the Polymerase Chain Reaction (PCR) test is a complex and time-consuming procedure. This test identifies SARS-CoV-2 (i.e., the virus that causes COVID 19) from the mucus and saliva samples. This is done by amplifying the DNA that is present in the sample and looking for any genetic material from SARS-CoV-2 in that sample (NIH 2020). Although this is a highly effective method, an individual must wait for 24 to 48 hours *after* a potential exposure to COVID 19 before the test can be taken (Becker 2020). This is because PCR tests need to wait for enough SARS-CoV-2 genetic material to be generated before it is able to detect its presence in the samples.

During a pandemic, time is of essence. On average an individual may have 16 personal contacts daily (S.Y. Del Valle 2007). The 'R naught' (R_0) for COVID 19, that is the number which represents the average number of people who can be infected with COVID 19 by one COVID 19 positive person is between 2 and 2.5. (Morgan McFall-Johnsen 2020). There is no legal requirement to isolate at home, if the individual does not have COVID 19 symptoms and has not undertaken the PCR test yet (Government 2022). Which means in pandemic situations, COVID 19 would have spread at a rapid pace by the time the test results are back. Fig.2 shows how COVID 19 spreads exponentially as the R_0 for COVID 19 is as high as 2 to 2.5 (Morgan McFall-Johnsen 2020).

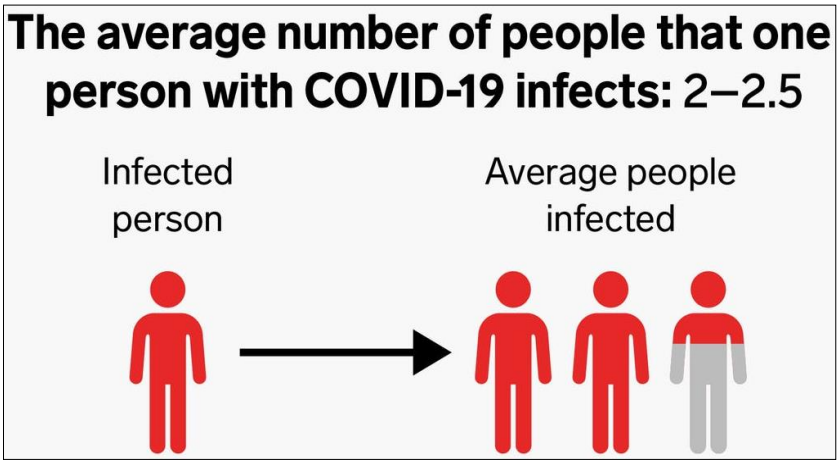

Fig. 2 (Morgan McFall-Johnsen 2020)

Since time is of essence during pandemics, medical researchers have been examining use of *Firefly Luciferase* (FLuc) to develop faster diagnostic tests and more efficient vaccines. Bioluminescence from animals such as fireflies have been used in biomedical research for

many decades. FLuc was first cloned for scientific research from the North American firefly *Photinus Pyralis* (Taha Azad 2021). Research scientists are now investigating how they can use FLuc to speed up the development of new vaccines and drugs to diagnose and combat COVID 19 (Becker 2020). Characteristics that are unique to FLuc make it an excellent biosensor, making vaccine and drug development much faster than when compared with traditional methods of antibody response testing (Becker 2020).

Studies from the University of Texas Medical Branch at Galveston shows that while existing COVID 19 diagnostic tests can be used to detect the virus only 24 to 48 hours *after* a potential exposure to infection, using FLuc based diagnostic tests can reduce this time period to as little as 4 hours (Becker 2020). In addition to diagnosing COVID 19 in individuals exposed to the virus faster, FLuc is being used by researchers to measure the antibody response in people who have recovered from COVID 19. Fig 3. shows how scientists insert FLuc into their experiments to make presence of Anti SARS-CoV-2 antibody visible in a way that is more sensitive and more time efficient than other traditional methods to study antibody response to COVID 19 (Taha Azad 2021).

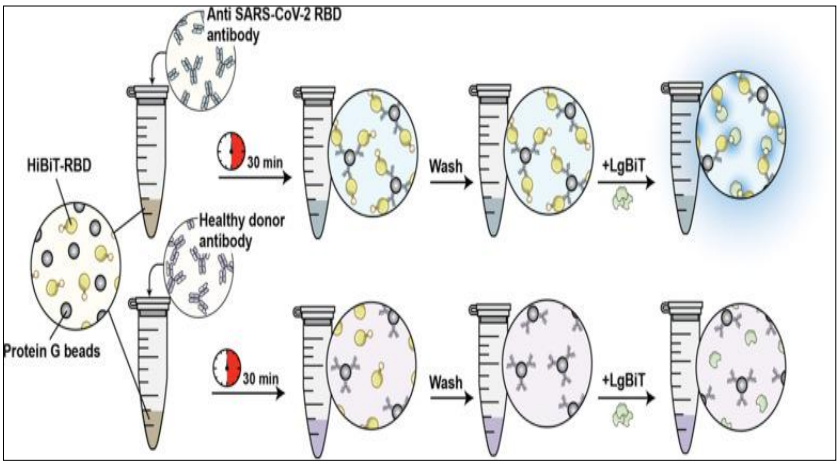

Fig. 3 (Taha Azad 2021)

Conclusion

This paper introduced bioluminescence, describing its non-heating emitting nature and habitats where you can find bioluminescence. It distinguished between bacteriogenic light and autogenic light producing bioluminescence. It also identified what bioluminescence is used for by the living organisms and how bioluminescence is created in the firefly. We then discussed how important time is in a pandemic to respond with appropriate diagnostic tests and vaccines quickly. This paper demonstrated how research scientists are using FLuc to develop diagnostic and vaccine solutions to address the pandemic. FLuc has advantages over other traditional

methods because it makes experiments using FLuc more sensitive, more time efficient, and easier to test on large samples. Fireflies are a valuable source for COVID 19 vaccine testing and diagnostic test development because, it is the *luciferase* enzyme that fireflies produce which has been cloned for science that gives this advantage to scientists.

It seems we have found salvation in the very insects buzzing around us in our backyards!

Bibliography

Becker, Alexandra. 2020. "Fireflies help kindle new tests." *TMC.* 21 July. Accessed 2022. https://www.tmc.edu/news/2020/07/fireflies-help-kindle-new-tests-and-treatments-for-covid-19/.

Bio, Marine. n.d. "THE OVERALL PROCESS." Accessed 2022. https://bioluminescenceintromarinebio.weebly.com/reactions-and-systems.html.

Biologicals, Novus. n.d. *Luciferase Antibody.* Accessed 2022. https://www.novusbio.com/products/luciferase-antibody_nb100-1677#:~:text=Luciferase%20Antibody%20Summary&text=This%20Luciferase%20antibody%20is%20purified,against%20the%20buffer%20stated%20above.

Branham, Marc. 2019. "Glow worms, Railroad worms (insecta Coleoptera: Phengodidae)." *University of Florida George A Smathers Libraries.* Accessed 2022. doi:doi:10.32473/edis-in609-2005. .

Branham, Marc. 2005. "How and Why do fireflies light up." *Scientific American.* Accessed 2022.

Colleen Mcclain, Lee Raine. 2020. *The Challenges of Contact Tracing as U.S. Battles COVID-19.* 30 October.

Conversation, The. 2022. *15 things not to do when using a rapid antigen test, from storing in the freezer to sampling snot.* Melbourne, 10 February. Accessed 2022. https://theconversation.com/15-things-not-to-do-when-using-a-rapid-antigen-test-from-storing-in-the-freezer-to-sampling-snot-176364.

Data, Our World in. 4. *Coronavirus (COVID-19) Vaccinations.* 2020 Dec. Accessed 2022. https://ourworldindata.org/covid-vaccinations?country=OWID_WRL.

DeFranco, Elyse. 2022. *Railroad Worms Glow in Multiple Colors.* 6 January. Accessed 2022. https://asknature.org/strategy/railroad-worms-glow-in-multiple-colors/.

EarthSky. 2020. *Fireflies: How and why they light up.* 8 June. Accessed 2022. https://earthsky.org/earth/fireflies-light-up-why-how/.

Government, NSW. 2022. *What COVID-19 test should I do?* 28 June. Accessed 2022. https://www.nsw.gov.au/covid-19/stay-safe/testing/get-tested-for-covid-19.

Hausheer, Justine e. 2021. *When Mammals Glow in the Dark.* 5 April. Accessed 2022. https://blog.nature.org/science/2021/04/05/when-mammals-glow-in-the-dark/.

Health, Australian Department of. 2022. *How COVID-19 vaccines work.* 4 May. Accessed 2022. https://www.health.gov.au/initiatives-and-programs/covid-19-vaccines/approved-vaccines/how-they-work#:~:text=The%20vaccines%20train%20your%20immune,restore%20and%20extend%20this%20protection.

Ismail, Shaya. 2022. *How Fireflies Light Up.*

K.V Ragavan, Suresh Neethirajan. 2019. "ScienceDirect." *Nanoparticlea as Biosensors for Food Qualty and Safety Assessment.* https://www.sciencedirect.com/topics/materials-science/chemiluminescence#:~:text=Chemiluminescence%20is%20the%20emission%20of,shorter%20wavelength%20(425%20nm).

Kricka, L.J. 2005. "Bioluminescence." *Encyclopedia of Analytical Science (Second Edition).* Edited by Alan Townshend, Colin Poole Paul Worsfold. Elsevier. 277-284. Accessed 2022. doi:https://doi.org/10.1016/B0-12-369397-7/00045-5.

Lloyd, James E. 1983. "Bioluminescence and Communication in Insects." *Annual Review of Entomology* 28 (1): 131-160.

M. K. Nishiguchi, J. E. Lopez,S, V. Boletzky. 2004. "Enlightenment of old ideas from new investigations: more questions regarding the evolution of bacteriogenic light organs in squids." *Evolution and Development* 6 (1): 41-49.

Morgan McFall-Johnsen, Aria Bendix. 2020. *An average coronavirus patient infects at least 2 others. To end the pandemic, that crucial metric needs to drop below 1 — here's how we get there.* 19 April. Accessed 2022. https://www.businessinsider.com/coronavirus-contagious-r-naught-average-patient-spread-2020-3.

NIH. 2020. *Polymerase Chain Reaction (PCR) Fact Sheet.* 17 August. Accessed 2022. https://www.genome.gov/about-genomics/fact-sheets/Polymerase-Chain-Reaction-Fact-Sheet.

Pfizer. n.d. *How the Immune System Protects You From Infection.* Accessed 2022. https://www.pfizer.com/news/articles/how_the_immune_system_protects_you_from_infection#:~:text=There%20are%20two%20types%20of,cells)%20to%20kill%20the%20pathogens

S.Y. Del Valle, J.M. Hyman, H.W. Hethcote, S.G. Eubank. 2007. "Mixing patterns between age groups in social networks." *Social Networks* 29 (4): 539-554. Accessed 2022.

Solis-Moreira, Jocelyn. 2021. *How did we develop a COVID-19 vaccine so quickly?* Edited by Ph.D. Anna Guildford. 13 November. Accessed 2022. https://www.medicalnewstoday.com/articles/how-did-we-develop-a-covid-19-vaccine-so-quickly.

Staff, NWC. 2022. *The Science: How Did Bioluminescence Evolve?* 6 March. Accessed 2022. https://nationalwildlifecouncil.com/bioluminescence-science/.

Taha Azad, Helena J. Janse van Rensburg, Jessica Morgan, Reza Rezaei, Mathieu J. F. Crupi, Rui Chen, Mina Ghahremani, Monire Jamalkhah, Nicole Forbes, Carolina Ilkow, John C. Bell. 2021. "Luciferase-Based Biosensors in the Era of the COVID-19 Pandemic." *ACS Nanoscience Au.* doi:acsnanoscienceau.1c00009.

TGA. 2022. *COVID-19 rapid antigen self-tests that are approved in Australia.* 6 May. Accessed 2022. https://www.tga.gov.au/covid-19-rapid-antigen-self-tests-are-approved-australia#:~:text=This%20includes%20a%20clinical%20sensitivity,specificity%20of%20at%20least%2098%25.

Tim Kahlke, Kate D.L. Umbers. 2016. *Bioluminescence.* 25 April. Accessed 2022. https://www.cell.com/current-biology/pdf/S0960-9822(16)00046-4.pdf.

Zielinski, Sarah. 2012. “14 Fun facts about fireflies.” *Smithsonian Magazine.*