Health Benefits of Detecting Bioluminescence

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Abstract

Bioluminescence refers to the fascinating phenomenon of light emission from living organisms. By contrast, biophotons are internally generated photons that are continually released as surface emissions. Some disorders (such as diabetes, hemiparesis, protoporphyria, or a common cold), and even cerebral intention/relaxation (brain activity/meditation), appear to affect ultra-weak photon emission (UPE), as reported in medical literature. The popularity of bioluminescence imaging (BLI) has skyrocketed over the past decade, which has been incredibly helpful to the advancement of the field of biomedicine including neurology, oncology, virology, and immunology, with the use of instruments made possible by BLI technology. The need for easy-to-use, low-cost, broadly accessible, and transportable nucleic acid diagnostic tools was brought into sharp focus by the SARS-CoV-2 (COVID-19 virus) pandemic. One low-cost and efficient method for detecting viruses in saliva is a bioluminescence test. Ultra-weak photon emission (UPE) spectroscopy is a non-invasive, organic technology that can aid in the diagnosis of a variety of diseases or stress/mood issues related to reactive oxygen species (ROS) or free radicals. Long-term meditators have been shown to experience a variety of physiological and biochemical changes, and it is hypothesized that these changes may have an effect on free radical activity. This paper presents an overview of recent developments in bioluminescence imaging (BLI) and its potential uses in a wide range of sectors, with a special emphasis on human health and the diagnostic use of bioluminescence in a variety of applications. Future research into UPE and alternative therapies is recommended, particularly in the context of Rosicrucian techniques that involve the mind-body connection.

Keywords: Bioluminescence, biophoton, ultra-weak photon emission (UPE), bioluminescent imaging (BLI), SARS-CoV-2 (COVID-19 virus), reactive oxygen species (ROS), meditation, theranostics, affibody

Avantages pour la santé de la détection de la bioluminescence

Résumé

La bioluminescence désigne le phénomène fascinant de l'émission de lumière par les organismes vivants. Par opposition, les biophotons sont des photons générés en interne, continuellement libérés sous forme d'émissions de surface. Certains troubles (tels que le diabète, l'hémiparésie, la protoporphyrie ou même un simple rhume), tout comme l'intention/la relaxation cérébrale (activité/méditation du cerveau), semblent affecter, ainsi que l'indique la littérature médicale, l'émission de photons ultra-faibles (EPU). La popularité de l'imagerie par bioluminescence (IBL) est montée en flèche au cours de la dernière décennie, ce qui a été incroyablement utile pour faire progresser le domaine de la biomédecine - notamment la neurologie, l'oncologie, la virologie et l'immunologie, grâce à l'utilisation d'instruments rends possibles par la technologie IBL. La

pandémie de SRAS-CoV-2 (virus COVID-19) a mis en évidence la nécessité de disposer d'outils de diagnostic des acides nucléiques faciles à utiliser, peu coûteux, largement accessibles et transportables : le test de bioluminescence est une méthode peu coûteuse et efficace pour détecter les virus dans la salive.
La spectroscopie d'émission photons ultra-faible (EPU) est une technologie organique non-invasive qui peut aider à diagnostiquer une variété de maladies ou de problèmes de stress et d'humeur liés aux espèces réactives de l'oxygène (ERO) ou aux radicaux libres. Il a été démontré que les personnes qui s'adonnent à la méditation depuis de nombreuses années subissent divers changements physiologiques et biochimiques, et l'on présume que ces changements peuvent avoir un effet sur l'activité des radicaux libres.
Cet article présente une vue d'ensemble les développements récents en matière d'imagerie par bioluminescence (IBL) et de ses utilisations potentielles dans un large éventail de secteurs, avec un accent particulier sur la santé humaine et l'utilisation diagnostique de la bioluminescence dans une variété d'applications. Des recherches futures sur l'EPU et les thérapies alternatives sont vivement conseillées, en particulier dans le contexte des techniques rosicruciennes qui exploitent le lien entre le corps et l'esprit.

Mots-clés : Bioluminescence, biophoton, émission de photons ultra-faibles (EPU), imagerie par bioluminescence (IBL), SARS-CoV-2 (virus COVID-19), espèces réactives de l'oxygène (ERO), méditation, théranostique.

Beneficios de la Salud Detectando Bioluminiscencia

Abstracto

La bioluminiscencia se refiere al fascinante fenómeno de la emisión de luz de los organismos vivos. Por el contrario, los biofotones son fotones generados internamente que se liberan continuamente como emisiones superficiales. Algunos trastornos (como diabetes, hemiparesia, protoporfiria o un resfriado común), e incluso la intención/relajación cerebral (actividad cerebral/meditación) parecen afectar la emisión de fotones ultra débiles (UPE sus siglas en inglés) como se informa en la literatura médica. La popularidad de las imágenes por bioluminiscencia (BLI por sus siglas en inglés) se ha disparado durante la última década, lo que ha sido increíblemente útil para el avance del campo de la biomedicina, incluyendo neurología, oncología, virología y la inmunología, con el uso de instrumentos gracias a la tecnología BLI (sus siglas en ingles). La pandemia del SARS-CoV-2 (virus COVID-19) hizo que se enfocara la atención en la necesidad de contar con herramientas de diagnóstico de ácidos nucleicos fáciles de usar, de bajo costo, ampliamente accesibles y transportables. Un método eficiente y de bajo costo para detectar virus en la saliva es una prueba de bioluminiscencia. La espectroscopia de fotoemisión ultra débil (UPE sus siglas en inglés) es una tecnología orgánica no invasiva que puede ayudar en el diagnóstico de una variedad de enfermedades o problemas de estrés/estado de ánimo relacionados con especies reactivas de oxígeno (ROS sus siglas en inglés) o radicales libres. Los meditadores a largo plazo han demostrado experimentar una variedad de cambios fisiológicos y bioquímicos y se plantea la hipótesis de que estos cambios pueden tener un efecto sobre la actividad de los radicales libres. Este artículo presenta una descripción general de los desarrollos recientes en imágenes por bioluminiscencia (BLI sus siglas en ingles) y sus usos potenciales en una amplia gama de sectores, con un énfasis especial en la salud humana y el uso

del diagnóstico de la bioluminiscencia en una variedad de aplicaciones. Se recomiendan futuras investigaciones sobre la UPE y las terapias alternativas, particularmente en el contexto de las técnicas rosacruces que involucran la conexión mente-cuerpo.

Palabras clave: Bioluminiscencia, biofotón, emisión de fotones ultra débiles (UPE), imágenes bioluminiscentes (BLI), SARS-CoV-2 (virus COVID-19), especies reactivas de oxígeno (ROS), meditación, teranóstica.

Benefícios da deteção por bioluminescência para a saúde

Resumo

A bioluminescência refere-se ao fascinante fenómeno de emissão de luz por organismos vivos. Já os biofotões, por sua vez, são fotões gerados internamente e continuamente libertados como emissões de superfície. Algumas doenças (como a diabetes, a hemiparesia, a protoporfiria ou uma simples constipação), e até a intenção/relaxamento cerebral (atividade cerebral/meditação), parecem afetar a emissão ultrafraca de fotões (UPE), de acordo com a literatura médica. A popularidade da imagiologia por bioluminescência (IBL) disparou na última década, o que tem sido extraordinariamente útil para o avanço da área da biomedicina, incluindo a neurologia, a oncologia, a virologia e a imunologia, graças ao uso de instrumentos que a tecnologia de IBL tornou possível. A necessidade de ferramentas de diagnóstico de ácidos nucleicos fáceis de utilizar, de baixo custo, largamente acessíveis e transportáveis foi posta em evidência pela pandemia do SARS-CoV-2 (vírus da COVID-19). O teste de bioluminescência é um método eficiente e de baixo custo para detetar vírus na saliva. A espectroscopia de emissão ultrafraca de fotões (UPE) é uma tecnologia orgânica e não invasiva que pode ajudar ao diagnóstico de um grande número de doenças ou problemas de stresse/humor relacionados com espécies reativas de oxigénio (ROS) ou radicais livres. Está provado que os meditadores de longa data passam por uma série de alterações fisiológicas e bioquímicas, admitindo-se a hipótese de estas alterações influenciarem a atividade dos radicais livres. Este estudo apresenta uma panorâmica dos desenvolvimentos mais recentes da imagiologia por bioluminescência (IBL) e das suas potenciais aplicações aos mais variados setores, com especial destaque para a saúde humana e a utilização da bioluminescência para fins de diagnóstico, com diversas aplicações. Recomenda-se investigação futura da UPE e de terapias alternativas, particularmente no contexto das técnicas rosacrucianas que envolvem a ligação mente-corpo.

Palavras-chave: bioluminescência, biofotão, emissão ultrafraca de fotões (UPE), imagiologia por bioluminescência (IBL), SARS-CoV-2 (vírus da COVID-19), espécies reativas de oxigénio (ROS), meditação, teranóstica, affibody

Positive Wirkungen für die Gesundheit mit dem Biolumineszenz Verfahren

Zusammenfassung

Als Biolumineszenz wird das spannende Phänomen bezeichnet, wobei Lebewesen fähig sind, Licht zu erzeugen und auszustrahlen. Biophotonen hingegen sind intern generierte Photonen, die oberflächliche Strahlung fortwährend freisetzen. In der medizinischen Literatur wird berichtet,

dass manche Krankheiten (wie Diabetes, Hemiparese, Protoporphyrie oder eine einfache Erkältung) aber auch willentlich gesteuerte Vorgänge/Entspannung des Gehirns (Gehirnaktivitäten/Meditation) eine sehr schwache Photonenemission (UPE) anregen. Während der letzten Dekade ist die Popularität der bildlichen Biolumineszenz Darstellungsverfahren (BLI) sprunghaft angestiegen. BLI konnte in neuen Instrumenten eingebettet werden und folglich zu einem unglaublich starken Fortschritt in der Biomedizin einschließlich Neurologie, Onkologie, Virologie und Immunologie mitwirken. Die Pandemie mit dem SARS-CoV-2 (COVID-19 Virus) verursachte eine sehr große Nachfrage für leicht anzuwendenden, kostengünstigen, generell lieferbaren und transportfähigen Nukleinsäure Diagnose Werkzeuge. Der Biolumineszenz Test ist eine kostengünstige und effiziente Methode um Viren im Speichel festzustellen.
Die ultraschwache Photonenemission (UPE) Spektroskopie ist eine nicht-invasive organische Technologie. Sie hilft bei der Diagnose von verschiedenen Krankheiten oder durch Stress/Gemütszustände generierte Probleme in Zusammenhang mit (ROS) reaktiven Sauerstoffgattungen oder freien Radikalen. Es wurde festgestellt, dass Langzeit-Meditierenden eine Vielfalt von physiologischen und biologischen Änderungen nachweisen wobei eine Hypothese aufgestellt wurde, dass diese Änderungen einen Einfluss auf die Aktivitäten der freien Radikalen ausüben. Dieser Aufsatz bietet eine Übersicht der neuesten Entwicklungen im Bereich der bildlichen Darstellung von Biolumineszenz (BLI) und ihr potentielles Nutzen für einen breiten Sektor insbesondere für die humane Gesundheit und den diagnostischen Einsatz der bildlichen Darstellung von Biolumineszenz (BLI) für viele verschiedene Anwendungen. Es wird empfohlen, UPE und alternative Heilverfahren, insbesondere im Rahmen der rosenkreuzerischen Techniken, die Geist und Körper miteinbeziehen, weiter zu untersuchen.

Schlüsselworte: Biolumineszenz, Biophoton, ultraschwache Photonenemission bei Chemolumineszenz (UPE), Bildliche Darstellung von Biolumineszenz (BLI), SARS-CoV-2 (COVID-19 Virus), Reaktive Sauerstoffspezies (ROS), Meditation, Theranostik

Introduction

Bioluminescence is the emission of light by living organisms, mainly some species of jellyfish, insects like fireflies, and some algae, bacteria, and fungi. Biochemicals unique to these species are responsible for the luminescence. Brilliant colors serve six functions for bioluminescent creatures: detecting prey, luring prey, attracting a partner, communicating, warding off predators, and navigating (Syed and Anderson 2021). Unfortunately, many animals (including humans) lack the genetic machinery necessary to synthesize these biochemicals. Therefore, only a small number of species actually produce bioluminescence.

In contrast, biophotons are continually radiated from the surface of the body and are created inside the human body (Van Wijk et al. 2008, 272-309; Srinivasan 2017, 57). All living organisms emit spontaneous ultraweak photon emission (UPE) as a result of cellular metabolic processes. It is essential to realize that UPE in humans increases in intensity due to internal disease states, ultra-violet light exposure that results in skin damage, exposure to tobacco smoke, and other environmental stressors: "human ultra-weak photon emission (UPE) is mainly due to the metabolic oxidative stress processes that the skin cells undergo in the presence of reactive oxygen species (ROS), external stressors (like UV radiation), but also internal stressors (like diseases or brain activity) [that] might strongly influence the UPE" (Zapata et al. 2021).

Furthermore, as explored in recent studies, consistent meditators have lower UPE, that is, a calmer mind affects not only psychological health but also the biological health of human beings. This paper explores some of the research related to bioluminescence and biophotons over the last several decades with implications for further research, particularly to mind-body studies. Practices such as meditation, vowel intonations, visualization, and healing treatments (as taught in the AMORC monographs) could form the subject of future studies in biophoton imaging as an adjunct to testing the psychological and biological efficacy of such practices.

Bioluminescence in Living Organisms

The intriguing phenomenon of bioluminescence is the production of light by living creatures. Bioluminescence imaging (BLI) has emerged as a powerful tool in the past several decades for molecular imaging of tiny laboratory animals, making it possible to observe biological processes as they unfold in real time during *in vivo* research. This inexpensive, non-invasive imaging method allows scientists to see disease processes in real time in living animals and in humans.

According to Syed and Anderson (2021), light is generated in bioluminescence when the chemical luciferin is oxidized by the enzyme luciferase. Over 30 bioluminescent systems have been discovered thus far, although research has been conducted on only 11 luciferin-luciferase pairs as of 2021, and research is on-going. "The different luciferin–luciferase pairs have different light emission wavelengths and hence are suitable for various applications…. The bioluminescence reaction is now routinely used for gene assays, the detection of protein–protein interactions, high-throughput screening (HTS) in drug discovery, hygiene control, analysis of pollution in ecosystems [(Figure 1)] and *in vivo* imaging in small mammals" (Syed and Anderson 2021).

Figure 1. Bioluminescence in ocean water has been described by the biologist Maria Sinetova (2016) regarding the algae *dinoflagellates*. This type of algae glows during stress, and it glows more brilliantly

during disturbance when healthy. Monitoring the algae reveals the overall health of ocean habitats and also allows scientists to determine the safety of such waters for humans and other sea life due to the toxicity of *dinoflagellates*. Image is from *Serious Science* 2016.

In 2011, many popular media outlets revealed that scientists at the Mayo Clinic College of Medicine had introduced the bioluminescent gene called the green fluorescent protein (eGFP) from a type of jellyfish into domestic cats making them glow under ultra-violet light. This genetic manipulation was used in conjunction with a protective gene from a rhesus monkey as a means of studying and preventing FIV or feline AIDS (acquired immunodeficiency syndrome in cats), research that has implications for the study of HIV-AIDS in humans. See Figure 2.

Figure 2. To learn whether the rhesus gene that blocks FIV (feline AIDS) was successfully introduced, scientists also inserted the gene associated with green bioluminescence. Such research has implications for endangered wild feline populations, including larger cat species like the Iberian lynx (Meli et al. 2009) and others that are also susceptible to FIV and species extinction due to disease. Moreover, this research has broader implications since the immunodeficiency illness that makes cats vulnerable is similar in humans. Image is from the original paper published online September 11, 2011 in *Nature Methods.*

Ultra-weak Biophoton Emission Contrasted with Bioluminescent Light

It is important to note that ultra-weak photon emission (UPE) means just that. In humans and in non-bioluminescent creatures, "[t]he existence of such light emission was labeled 'low-level' chemiluminescence or 'dark' chemiluminescence to differentiate it from the more effective photoemission of the luciferin/luciferase systems [in bioluminescent creatures] which is 10^3 – 10^6 times brighter" (R. Van Wijk et al. 2008).

Since the human eye is unable to detect such low-level photon emission, special measuring devices began using CCD imaging (sensitive charge-coupled devices) a decade and a half ago. Today, the use of "enhanced sensitive imaging systems based on a complementary metal-oxide-semiconductor (CMOS) camera with multiple electronic sensors" (Owais Ali 2022) can capture ultra-weak photon emissions, a method that includes computer "stacking" of the images to enhance image quality rather than using single exposures.

Health Benefits of Understanding Biophoton Emission in Humans

A nation's physical capital and productivity rise in direct proportion to the health of its inhabitants. Economic growth is accelerated and its advantages are shared more widely when people's health and nutrition improve. It has always been true that a nation can only develop if its citizens do well. When the economy improves, families are able to spend more on things like nutritious food and preventative healthcare. It is possible that people may adopt preventative measures in the face of health problems rather than on the defensive (Lange and Vollmer 2017, 48, 49). Imaging of biophotons or bioluminescence (the effect of biophotons) has the potential to enhance preventative medicine and clinical practice. Allopathy, homeopathy, acupuncture (H. Jung 2003), and ayurvedic medicine are only some of the alternative approaches that might be incorporated into future health evaluations using biophoton research.

Bioluminescence in Oxidative Stress Evaluation

It has been proposed that oxidative stress, a major contributor to chronic illnesses, can be evaluated by monitoring patterns of ultra-weak photon emission. Diseases caused by ROS or free radicals have led some writers to conclude that ultraweak photon emission imaging has potential biological uses. According to Roeland Van Wijk and colleagues (2008), low-level photon emission is a "state-of-the art" technology that can examine free radical damage and antioxidant metabolism at the cellular level, where ROS is related to diseases like diabetes, Alzheimer's, and age-related degeneration. Healthy subjects generally have lower ultra-weak photon emission compared to those experiencing disease (R. Van Wijk et al. 2008).

For example, in a study of spontaneous ultraweak photon emission described by Rastogi and Pospíšil (2011), the involvement of ROS, or free radicals, formed as the byproduct of oxidative metabolic processes in human hand skin. Rastogi and Pospíšil (2011) made use of a charge-coupled (CCD) camera and photomultiplier tubes. They observed that topical ascorbic acid (Vitamin C) and antioxidant therapy mitigate the detrimental effects of UV radiation and cigarette smoke on the skin, hence decreasing biophoton emission. This research demonstrates spontaneous ultraweak photon emission (UPE) as a method for measuring oxidative and aging processes in human skin.

Bioluminescent Enzymes as Bioanalytical Tools

In order to take advantage of the rapidity and sensitivity of bioluminescence and chemiluminescence spectroscopy, several biotechnological methods have been developed as a direct result of developments in molecular biology that examine important minerals like the deployment and utilization of iron in the body. Ferritin is a protein that stores iron and releases it for use within human cells. A recent study based on a bioluminescent enzyme immunoassay was helpful in detecting ferritin: "[f]erritin, widely present in liver and spleen tissue, is considered as a serological biomarker for liver diseases and cancers. The detection of ferritin may be an important tool in health diagnosis" (Qiyi He et al. 2022).

Bioluminescence in the Detection of Fungal Infections

Fungal infections pose a significant hazard to the survival of immunocompromised hosts. Due to a lack of reliable diagnostic methods and effective treatment options, many invasive fungal infections have fatal consequences particularly post-surgery as in transplant medicine (Brock 2012). A better understanding of infection routes is crucial for lowering death rates. To accomplish these aims, bioluminescence imaging (BLI) has proven to be an invaluable tool due to its ability to track the development of an infection in real time. BLI has been widely used for tracking bacterial infections as well as fungal infections due to *Candida albicans* and *Aspergillus fumigatus*. In his paper on bioluminescent imaging for bacterial and fungal infections, Matthias Brock (2012) states, "Although BLI was, in principle, suitable to study the infection process, some limitations remained," and he notes several means to overcome problems associated with future bioluminescent studies in this realm of research.

Bioluminescence in the Detection of Copper-related Diseases

Copper is a trace micronutrient that is essential for the proper functioning of all living organisms. Cu (II) and Cu (I) oxidation states are used by nature for vital enzyme catalysis, mitochondrial respiration, and cell proliferation activities. Obesity-related metabolic diseases, dementia, and several types of cancer have all been linked to defective copper biology. Unwanted protein aggregation and aberrant redox activity that can cause oxidative stress have been associated with diseases affected by copper dysregulation. As a result, life has evolved very complex mechanisms for regulating and transporting copper. A recent study suggests that a bioluminescence-based imaging probe (pic-DTZ) has been developed as a diagnostic tool for detecting oxidation states where serum and plasma from human donors can help diagnose diseases associated with copper (O'Sullivan et al. 2022).

Bioluminescence as a Low-cost Diagnostic Tool for COVID-19

RNA or ribonucleic acid diagnostic technologies have become more important in the wake of the SARS-CoV-2 (COVID-19) virus pandemic. The research and development of a technology for point-of-care detection of viral infections in saliva using bioluminescent detection is described by J. Porter Hunt and colleagues in a 2022 paper in the *New Biotechnology* journal:

> The biosensor generates a visible signal in as few as seven minutes following administration of 15 μL [microliters] saliva enriched with high concentrations of SARS-CoV-2 RNA sequences. The estimated cost of this test is less than 0.50 USD, which could make this platform readily accessible to both the developed and developing world. While additional research is needed to decrease the limit of detection, this work represents important progress toward developing a diagnostic technology that is rapid, low-cost, distributable and deployable at the point-of-care by a layperson.

Bioluminescence in Cancer Detection and Vitamin B3

Vitamin B3 or niacin in the form of nicotinamide riboside (NR), found in cow's milk, red meats, nuts, seeds, and many other foods (Harvard 2023), is presently one of the most studied NAD+ precursors (nicotinamide adenine dinucleotide coenzyme) necessary for cellular metabolism and "healthy ageing" (Maric et al. 2023). Whereas the human body requires Vitamin B3 to regulate its cellular metabolism, NAD+ declines with increasing age. Supplementation is vital in diseases like "cognitive decline, cancer, metabolic disease, sarcopenia and frailty. Many of these ageing-associated diseases can be slowed down and even reversed by restoring NAD+ levels" (Maric et al. 2023). Niacin deficiency can occur in persons with certain forms of cancer like carcinoid syndrome (the effect of slow-growing cancer cells in the digestive system) (Harvard 2023). "The syndrome causes tryptophan in the diet to be converted into serotonin rather than niacin, which increases the risk of decreased niacin" (Harvard 2023).

However, NR supplements may not be safe in all cases. The role of nicotinamide uptake in cancer development is still largely unknown despite the need of NAD+ for cellular metabolism. By using a bioluminescent nicotinamide riboside (NR) uptake probe (BiNR) for non-invasive longitudinal imaging of nicotinamide riboside (NR) uptake, researchers have investigated the role of NR uptake in cancer prevalence and metastases formation. Tamara Maric and colleagues (2023) suggest that some aggressive breast cancers and brain metastases increase dramatically when NR is consumed by supplementation. Further research will enhance our knowledge of whether or not we can "effectively restore NAD+ levels during ageing, whether doing so is safe and whether NAD+ repletion will have beneficial effects in ageing humans" (Maric et al. 2023).

Bioluminescence in Tumor Evaluation

Healthy tissue is quite different in terms of how cells function in contrast to cancerous cells. Using new low light bioluminescent technology in order to investigate tumor cell metabolites, scientists were able to consider several important research questions:

> Tumor heterogeneity at the genetic level has been illustrated by a multitude of studies on the genomics of cancer, but whether tumors can be heterogeneous at the metabolic level is an issue that has been less systematically investigated so far. A burning-related question is whether the metabolic features of tumors can change either following natural tumor progression (i.e., in primary tumors versus metastasis) or therapeutic interventions. (Indraccolo and Mueller-Klieser 2016, 15)

In a study published in *Frontiers in Oncology*, researchers Stefano Indraccolo and Wolfgang Mueller-Klieser (2016) confronted these questions using bioluminescent technology to

investigate metabolic changes. They reveal that induced metabolic bioluminescence imaging (imBI) can detect glycolysis-related metabolites in tumor sections, aiding in metabolic classification and therapy-induced changes. This technology can also reveal molecular changes triggered by metabolic stress, potentially improving cancer treatment through metabolic strategies.

Further, recent research into pancreatic cancer has used affibodies as defined by Science Direct (2023) as small engineered proteins first described in 1999 and bioluminescent imaging to identify pancreatic ductal adenocarcinoma (PDAC), which is "the most common type of pancreatic cancer and has an extremely low survival rate" (Hersh et al. 2023). Researchers were able to discern "tumor shape, identify multiple masses, and locate metastases" (Hersh et al. 2023). This research suggests "bioluminescent proteins as a way to improve *in vivo* bioluminescent imaging" (Hersh et al. 2023).

Bioluminescence in Detection of Cathepsin B (CTSB)

Lysosomes contain a cysteine protease called cathepsin B (CTSB), which results in protein destruction and recycling. It is required for the development, growth, and formation of new blood vessels, but also is responsible for the invasion and spread of cancer. Cancers of the esophagus, stomach, prostate, pancreas, colon, and breast are only a few of the many in which CTSB functions in humans. Therefore, CTSB is a biomarker for the early detection of cancer. Several different optical methods such as fluorescence, colorimetry, and chemiluminescence have been developed for CTSB detection and its inhibitors that "have also been considered as anticancer drug candidates" (Chan-Jin Kim et al. 2014). Fluorescence has been widely used in this field because of its convenience and speedy results. Regardless, Michal E. Roth-Konforti and colleagues (2017) developed a chemiluminescence probe that "showed unprecedented sensitivity compared to that of a classic fluorescent probe for cathepsin B and provided the first chemiluminescence microscopy cell images of a natively expressed enzyme, thereby enabling differentiation between cancerous cells and normal tissue."

Multiple types of human cancer have been associated with CTSB lysosomal protease expression, and Yanhan Ni and colleagues (2019) have developed a CTSB-specific bioluminescence (BL) probe for CTSB detection in living cells and tumors, a vital advance in diagnostic imaging. According to Islam Mohamed Mostafa and colleagues (2023), "Imaging technologies based on chemiluminescence (CL) and bioluminescence (BL) have seen a tremendous growth in the past decade due to their extensive contributions to biochemical analysis and biomedical science" particularly in the area of cancer research.

Using Bioluminescence in Theranostics

Theranostics is an emerging medical field that combines diagnosis and therapy with particular relevance to cancer. Conventional treatments take time to deliver post-diagnosis and are not always effective. Nanomedicine is a newer treatment option that targets specific cells while avoiding others, and "the possibility for integrating imaging into nanomedicine will assist with the diagnostic arm of theranostics. The advantages of employing such a strategy are vast, and would enable us to make great strides in the management of oncogenic conditions with theranostics" (Damien Jonas Wilson 2023).

Glioblastoma multiforme (GBM) is a fatal brain tumor, and recent advancements in imaging and navigation, such as MR-guided and optical coherence tomography-guided laser ablation, have expanded its use in GBM resections and treatment efficacy assessment (Fan et al. 2018). Yingwei Fan and colleagues (2018) have combined photoacoustic imaging (PAI) with BLI to provide guided surgery with a multipurpose nanoprobe. BLI is a non-invasive technology method for monitoring tumor development and progression and for assessing and improving therapy efficacy. Near-infrared fluorescence-guided surgery and combinatorial phototherapy are two examples of uses for the nanomedicine platform for tumor-activatable theranostics.

Bioluminescence Helps in Reducing Surgical Site Infections

Surgical site infections (SSIs) are the second most common kind of healthcare-associated infection (HAI) in Europe and the United States, accounting for 20 percent of all HAIs, according to the UK's National Institute for Health and Care Excellence (2020). The increased morbidity and death among surgical patients caused by surgical site infections significantly increases healthcare costs (World Health Organization 2023). The operating room is a high-risk environment and must therefore be cleaned often. Bacteria that cause illness can live for some time on unclean surfaces before being dispersed in the air or via direct contact with healthcare workers (through, for example, their hands) (Allen 2014).

The organic substance adenosine triphosphate (ATP) generates energy for and supports a variety of functions in living cells, including muscular contraction, nerve impulse transmission, condensate dissolving, and chemical synthesis. Adenosine Triphosphate (ATP) Bioluminescence Assay, a test that was originally designed for the food industry, has been examined as an objective tool for monitoring hospital cleanliness in high-risk locations (Boyce et al. 2009) because of its ease of use and speedy findings. Some authors have expressed skepticism about the usefulness of bioluminescence for hygiene monitoring in hospital settings, despite the fact that other studies have found a correlation between ATP levels and total viable count (TVC values) of heterotrophic organisms within a sample (Whiteley et al. 2015).

Bioluminescence Helps in Making Hygienic Food

It takes a systematic approach comprising regular hygiene monitoring to see if high standards are fulfilled during food preparation. There are several metrics that may be used to gauge the efficacy of cleaning and disinfection programs. Nursing home patients' already-compromised-health makes it all the more crucial to keep an eye on how they are being fed. The food processing sector often makes use of quick hygiene monitoring systems based on ATP bioluminescence, which are offered by a number of companies. BLI's mobility and constant-light output chemistry make it a great choice for on-site testing (Seeger and Griffiths 1994), and the process may be completed in less than 5 minutes. Many individuals become ill every year due to eating tainted food, making it a key priority for public health officials to find ways to reduce the incidence of food-borne illnesses. Common sources of alarm include physical and chemical contaminants as well as infectious microbes (Newell et al. 2010).

There are many potential routes of microbial contamination in food, including natural raw material contamination and cross-contamination events (typically caused by microorganisms

from air, water, human or animal feces, mucous, hair, open wounds, dirt, dust, etc.) (Petruzzelli et al. 2014; Osimani et al. 2013). Food safety relies on the absence of microorganisms; hence it is imperative that the working environment (surfaces, equipment, and utensils) be kept clean (Martinon et al. 2012).

Bioluminescence and Meditation

Several studies using BLI conducted over that last twenty years have attempted to show a relationship between meditative states and a reduction in oxidative stress as evidenced by lower bioluminescent emissions. Some of these preliminary studies show promise for future research using a larger number of subjects, mind-body techniques, and also electromagnetic fields produced by both technology and human beings themselves.

A study conducted in India by Praerna Bhargav and team (2016) measured electro-photonic emissions from the fingertips using Gas Discharge Visualization (GDV) equipment (similar to what is used in Kirlian photography) to compare the effects of cell phone EMF (electro-magnetic frequency) exposure with and without a yogic alternate-nostril breathing practice in teenagers. The researchers found that such a breathing practice enhanced the subtle energy produced by the finger-tips when cell phones were in the off-position, but did not create a protective effect while cell phones were on. This study suggested that future research be conducted using meditative techniques to explore their effects on those who are exposed to cell phone EMF radiation. Other researchers in a later study theorized that yogic practices have a beneficial effect through decreasing electron emission, which, like decreased biophoton emission, is taken to be an indication of decreased oxidative stress (Deo and Srinivasan 2018).

An instantaneous decrease in biophoton emission has been documented during Transcendental Meditation (TM) in several studies conducted in the early 2000s by Wijk et al. “They found that the UPE intensity from volunteers who practiced transcendental meditation was lower than that of volunteers who neither practiced meditation nor any other relaxation technique” (Zapata et al. 2021). Long-term meditators have been shown to experience a variety of physiological and biochemical changes, and it is hypothesized that these changes may have an effect on free radical activity (Van Wijk et al. 2006, 31-38). Further, Roeland Van Wijk (2008) reviewed several studies that compare non-meditators with those who practice consistent meditation and concludes that the data indicate that meditators seem to experience less free-radical oxidation biologically as measured by lower UPE (ultra-weak photon emissions). Such studies suggest that reducing one’s psychological stress levels particularly through a consistent meditative practice has “prophylactic and therapeutic health benefits” (Van Wijk et al. 2008). Meditators’ reduced stress levels explain why their biophoton emission values are lower. Furthermore, “Stress is connected to increased production of reactive oxygen species and related chemical reactions that result in cell and tissue damage” (Zapata 2021). Theta and delta waves, as produced by the brain’s neuronal activity as measured by EEG (electroencephalography) equipment indicative of deep relaxation and an altered state of consciousness, are induced during sleep but also during relaxation practices like meditation, according to evidence (Pagliaro 2017). Thus, one of the benefits of meditation is reduced biophoton emission indicating less oxidative stress.

Furthermore, various emotional states and UPE were studied using a highly sensitive CCD detector by Felix Zapata and colleagues (2021). Anger as an emotional state was shown to

increase UPE in nine subjects compared to when feeling relaxed. Zapata and colleagues suggest through their paper that more studies that increase the number of subjects need to be done to confirm their preliminary research.

That biophoton emissions can be controlled on purpose is strongly suggested by a study conducted by Gioacchino Pagliaro and colleagues who used a CCD FUTURA camera and FAST video camera to detect luminescence not visible to the human eye. These observations show a luminescence effect during intentional energy transfer in their experiment using a Tibetan meditative practice, suggesting that it is possible to experience energy exchange between a meditator (performer of the technique) and a recipient (Pagliaro et al. 2017). Pagliaro and colleagues speculated that relaxation methods like meditation, which increases theta and delta wave generation signifying a deep state of relaxation and changed state of consciousness, corresponded to a bioluminescent effect detected by their imaging. Further, these researchers suggest "the observation that bio-fields seem [to] be intentionally modified and not only those belonging to the performer but also those of other individuals external to the performer of the practice, is a significant conclusion for innovative trends in quantum entanglement" (Pagliaro 2017).

Conclusion

Many creatures produce a bioluminescent effect. However, this phenomenon should not be confused with ultra-weak biophoton emission (UPE). Bioluminescent imaging (BLI) of UPE has important implications for human health. Gene assays, protein-protein interaction detection, medication research, hygiene management, pollution monitoring, and *in vivo* imaging are just a few of the many uses for bioluminescent detection that can better examine human disease states, particularly cancer and other metabolic processes affecting organs like the liver and pancreas. Bioluminescence has been utilized for monitoring bacterial infections and diagnosing disorders linked to iron and copper dysregulation in human blood and plasma. ATP-bioluminescence has been used to evaluate hygiene standards in high-risk environments like hospitals. Metabolites involved in glycolysis can be detected in tumor samples with the use of imBI (induced metabolic bioluminescence imaging). The COVID-19 pandemic highlights the urgent need for broadly accessible, low-cost, and rapid nucleic acid diagnostic tools. Significant progress has been made in this area thanks to the creation of a paper-based COVID-19 biosensor that uses saliva as an activator and then offers a visual readout. Furthermore, spectroscopic analysis of ultra weak photon emission (UPE) can be viewed as "a non-invasive, organic method to assist in the diagnosis of a number of illnesses or stress/mood disorders caused by free radicals (ROS)" (Zapata, et al. 2021).

Long-term meditation practice has been shown to cause a variety of physiological and biochemical changes, and it is assumed, particularly through UPE research, that meditation may have an effect on free radical activity. This paper explored some of the research related to bioluminescence and biophotons over the last several decades with implications for further research aimed particularly at mind-body studies. Practices such as meditation, vowel intonations, visualization, and healing treatments (as taught in the AMORC monographs) could form the subject of future studies in biophoton imaging as an adjunct to testing the psychological and biological efficacy of such practices.

Conflict of Interest Statement

The author declares no conflict of interest.

Bibliography

Affibody Definition. 2023. *Science Direct.* Elsevier. https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/affibody#:~:text=Affibodies%2C%20first%20described%20in%201999,selectively%20bind%20to%20a%20target.&text=Being%20made%20of%20only%2058,expression%20in%20simple%20cell%20lines.

Allen, George. 2014. "Implementing AORN Recommended Practices for Environmental Cleaning." *Journal of the Association of peri-Operative Registered Nurses* 99, no. 5 (2014): 570-582.

Ali, Owais. 2022. "Study Uses Digital Image Techniques for Bioluminescence Imaging." AZoOptics October 17, 2022. https://www.azooptics.com/News.aspx?newsID=28035.

Bhargav, Praerna, Vandana Suresh, Alex Hankey, and Hemant Bhargv. 2016. "Application of Gas Discharge Visualization Technique for Assessing Effects of Mobile Phone-induced Electromagnetic Field on Subtle Energy Levels of Teenagers and Protective Value of Yoga Intervention." *International Journal of Yoga: Philosophy, Psychology and Parapsychology* 4, no. 2: 36-41. https://www.ijoyppp.org/article.asp?issn=2347-5633;year=2016;volume=4;issue=2;spage=36;epage=41;aulast=Bhargav.

Boyce, John M., Nancy L. Havill, Diane G. Dumigan, Michael Golebiewski, Ola Balogun, and Ramo Rizvani. 2009. "Monitoring the Effectiveness of Hospital Cleaning Practices by Use of an Adenosine Triphosphate Bioluminescence Assay." *Infection Control and Hospital Epidemiology* 30, no. 7: 678-684.

Brock, Matthias. 2012. "Application of Bioluminescence Imaging for *In Vivo* Monitoring of Fungal Infections." *International Journal of Microbiology* October 27, 2012. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3205719/.

Calcerrada, Matias, and Carmen Garcia-Ruiz. 2018. "Human Ultraweak Photon Emission: Key Analytical Aspects, Results and Future Trends: A Review." *Critical Reviews in Analytical Chemistry* 49, no. 4: 1–14.

Chen, Xiaoxia, Xingxing Ren, Yuhan Zhu, Ziyan Fan, Lele Zhang, Zhengjie Liu, Ling Dong, and Zijuan Hai. 2021. "Cathespin B-Activated Fluorescent and Photoacoustic Imaging of Tumor." *Analytical Chemistry* 2021 93 (27), 9304-9308. https://pubs.acs.org/doi/full/10.1021/acs.analchem.1c02145.

Deo, Guru, and Thaiyar M. Srinivasan. 2018. "Effect of Anapanasati Meditation Technique through Electrophonic Imaging Parameters." *International Journal of Yoga: Philosophy, Psychology and Parapsychology* 6, no. 2: 94.

Fan, Yingwei, Yu Sun, Wei Chang, Xinran Zhang, Jie Tang, Liwei Zhang, and Hongen Liao. 2018. "Bioluminescence Imaging and Two-photon Microscopy Guided Laser Ablation of GBM Decreases Tumor Burden." *Theranostics* 8, no. 15: 4072.

Harvard T.H. Chan School of Public Health. 2023. "The Nutrition Source: Niacin – Vitamin B3." https://www.hsph.harvard.edu/nutritionsource/niacin-vitamin-b3/.

He, Qiyi, Li Yang, Mingxia Lin, Huiyi Yang, Xiping Cui, Mark R. McCoy, Bruce D. Hammock, Yanxiong Fang, and Suqing Zhao. 2022. "Generation of Bioluminescent Enzyme Immunoassay for Ferritin by Single-chain Variable Fragment and its NanoLuc Luciferase Fusion." *Analytical and Bioanalytical Chemistry* 414, no. 23: 6939-6946.

Hersh, Jessica, Yu-Ping Lan, Evan Roberts, Daniel Bilbao, Wensi Tao, Alan Pollack, Sylvia Daunert, and Sapna K. Deo. 2023. "Targeted Bioluminescent Imaging of Pancreatic Ductal Adenocarcinoma Using Nanocarrier-Complexed EGFR-Binding Affibody–Gaussia Luciferase Fusion Protein." *Pharmaceutics* 15, 7 (19 July, 2023). https://www.mdpi.com/1999-4923/15/7/1976.

Hunt, J. Porter, Emily Long Zhao, Tyler J. Free, Mehran Soltani, Chandler A. Warr, Alex B. Benedict, Melissa K. Takahashi, Joel S. Griffitts, William G. Pitt, and Bradley C. Bundy. 2022. "Towards Detection of SARS-CoV-2 RNA in Human Saliva: A Paper-based Cell-free Toehold Switch Biosensor with a Visual Bioluminescent Output." *New Biotechnology* 66 (January 25, 2022): 53-60. https://www.sciencedirect.com/science/article/pii/S1871678421000893?via%3Dihub.

Indraccolo, Stefano, and Wolfgang Mueller-Klieser. 2016. "Potential of Induced Metabolic Bioluminescence Imaging to Uncover Metabolic Effects of Antiangiogenic Therapy in Tumors." *Frontiers in Oncology* 6: 15. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4733917/.

Jung, Hyun-Hee, W.M. Woo, J.M. Yang, C. Choi, J. Lee, G. Yoon, J.S. Yang, S. Lee, and K.S. Soh. 2003. "Left-right Asymmetry of Biophoton Emission from Hemiparesis Patients." *Indian Journal of Experimental Biology* 41 (2003), 452-456. https://imsear.searo.who.int/items/0ebfe4e2-ce82-4d75-9466-34e79cdfef9a.

Kim, Chan-Jin, Dong-Ik Lee, Cheonghee Kim, Kangtaek Lee, Chang-Ha Lee, and Ik-Sung Ahn. 2014. "Gold Nanoparticles-based Colorimetric Assay for Cathepsin B Activity and the Efficiency of Its Inhibitors." *Analytical Chemistry* 86, 8: 3825-3833. https://pubmed.ncbi.nlm.nih.gov/24673125/.

Lange, Simon, and Sebastian Vollmer. 2017. "The Effect of Economic Development on Population Health: A Review of the Empirical Evidence." *British Medical Bulletin* 121, no. 1: 47-60.

Martinon, Alice, Ultan P. Cronin, J. Quealy, A. Stapleton, and Martin G. Wilkinson. 2012. "Swab Sample Preparation and Viable Real-time PCR Methodologies for the Recovery of *Escherichia coli*, *Staphylococcus aureus* or *Listeria monocytogenes* from Artificially Contaminated Food Processing Surfaces." *Food Control* 24, no. 1-2: 86-94.

Maric, Tamara, Arkadiy Bazhin, Pavlo Khodakivskyi, Georgy Mikhaylov, Ekaterina Solodnikova, Aleksey Yevtodiyenko, Greta Maria Paola Giordano Attianese et al. 2023. "A Bioluminescent-based Probe for *in vivo* Non-invasive Monitoring of Nicotinamide Riboside Uptake Reveals a Link between Metastasis and NAD+ Metabolism." *Biosensors and Bioelectronics* 220 (2023): 114826. https://www.sciencedirect.com/science/article/abs/pii/S0956566322008661.

Meli, Marina L., Valentino Cattori, Fernando Martínez, Guillermo López, Astrid Vargas, Miguel A Simón, Irene Zorrilla, Alvaro Muñoz, Francisco Palomares, Jose V López-Bao, Josep Pastor, Ravi Tandon, Barbara Willi, Regina Hofmann-Lehmann, and Hans Lutz. 2009. "Feline Leukemia Virus and other Pathogens as Important Threats to the Survival of the Critically Endangered Iberian Lynx (*Lynx pardinus*)." *Public Library of Science ONE* 4. https://pubmed.ncbi.nlm.nih.gov/19270739/.

Mostafa, Islam Mohamed, Abubakar Abdussalam, Yuriy Tymofiiovych Zholudov, Dmytro Viktorovych Snizhko, Wei Zhang, Morteza Hosseini, Yiran Guan, and Guobao Xu. 2023. "Recent Applications and Future Perspectives of Chemiluminescent and Bioluminescent Imaging Technologies." *Chemical and Biomedical Imaging* 1 no. 4, 297-314. https://pubs.acs.org/action/showCitFormats?doi=10.1021%2Fcbmi.2c00002&href=/doi/10.1021%2Fcbmi.2c00002.

National Institute for Health and Care Excellence. 2020. "Surgical Site Infections: Prevention and Treatment." https://www.nice.org.uk/guidance/ng125.

Newell, Diane G., Marion Koopmans, Linda Verhoef, Erwin Duizer, Awa Aidara-Kane, Hein Sprong, Marieke Opsteegh et al. 2010. "Food-borne Diseases—the Challenges of 20 Years Ago Still Persist while New Ones Continue to Emerge." *International Journal of Food Microbiology* 139: S3-S15.

Ni, Yanhan, Zijuan Hai, Tong Zhang, Yanfang Wang, Yanyun Yang, Shusheng Zhang, and Gaolin Liang. 2019. "Cathepsin B Turning Bioluminescence 'On' for Tumor Imaging." *Analytical Chemistry* 91, no. 23: 14834-14837. https://pubs.acs.org/doi/full/10.1021/acs.analchem.9b04254.

Osimani, Andrea, Lucia Aquilanti, Stefano Tavoletti, and Francesca Clementi. 2013. "Evaluation of the HACCP System in a University Canteen: Microbiological Monitoring and Internal Auditing as Verification Tools." *International Journal of Environmental Research and Public Health* 10, no. 4: 1572-1585.

O'Sullivan, Justin J., Valentina Medici, and Marie C. Heffern. 2022. "A Caged Imidazopyrazinone for Selective Bioluminescence Detection of Labile Extracellular Copper (II)." *Chemical Science* 13, no. 15: 4352-4363. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9006956/.

Pagliaro, Gioacchino, N. Mandolesi, G. Parenti, L. Marconi, M. Galli, F. Sireci, and E. Agostini. 2017. "Human Bio-Photons Emission: an Observational Case Study of Emission of Energy Using a Tibetan Meditative Practice on an Individual." *BioAccent Journal of Pharmaceutical Sciences* 2, no. 4: 1-9. https://emmind.net/openpapers_repos/Endogenous_Fields-Mind/Endo._Biophotons/Biophotons_Various/2017_Human_Bio-Photons_Emission_an_observational_Case_Study_of_Emission_of_Energy_Using_a_Tibetan_Meditative_Practice_on_an_Individual.pdf.

Petruzzelli, A., M. Foglini, V. Vetrano, F. Paolini, N. Orazietti, B. Ambrosini, A. Osimani, F. Clementi, S. Tavoletti, and F. Tonucci. 2014. "The Occurrence of Thermotolerant Campylobacter spp. in Raw Meat Intended for Public Catering." *Public Health* 128, no. 4: 388-390.

Rastogi, Anshu, and Pavel Pospíšil. 2011. "Spontaneous Ultraweak Photon Emission Imaging of Oxidative Metabolic Processes in Human Skin: Effect of Molecular Oxygen and Antioxidant Defense System." *Journal of Biomedical Optics* 16: 096005-096005.

Roth-Konforti, Michal E., Christoph R. Bauer, and Doron Shabat. 2017. "Unprecedented Sensitivity in a Probe for Monitoring Cathepsin B: Chemiluminescence Microscopy Cell-Imaging of a Natively Expressed Enzyme." *Angewandte Chemie International Edition* 56, no. 49: 15633-15638.

Seeger, Klaus, and Mansel W. Griffiths. 1994. "Adenosine Triphosphate Bioluminescence for Hygiene Monitoring in Health Care Institutions." *Journal of Food Protection* 57, no. 6: 509-512.

Sinetova, Maria. 2016. “Bioluminescent Algae.” *Serious Science.* (September 2, 2016). https://serious-science.org/bioluminescent-algae-6827.
Srinivasan, T. M. “Biophotons as Subtle Energy Carriers.” *International Journal of Yoga* 10, no. 2 (2017): 57.
Syed, Aisha J., and James C. Anderson. 2021. “Applications of Bioluminescence in Biotechnology and Beyond.” *Chemical Society Reviews* 50, no. 9: 5668-5705.
Whiteley, Greg S., Chris Derry, Trevor Glasbey, and Paul Fahey. 2015. “The Perennial Problem of Variability in Adenosine Triphosphate (ATP) Tests for Hygiene Monitoring within Healthcare Settings.” *Infection Control and Hospital Epidemiology* 36, no. 6: 658-663.
Wijk, Eduard P.A. Van, Heike Koch, Saskia Bosman, and Roeland Van Wijk. 2006. “Anatomic Characterization of Human Ultra-Weak Photon Emission in Practitioners of Transcendental Meditation™ and Control Subjects.” *Journal of Alternative and Complementary Medicine* 12, no. 1: 31-38.
Wijk, Roeland Van, Eduard P. A. Van Wijk, Fred A. C. Wiegant, and John Ives. 2008. “Free Radicals and Low-level Photon Emission in Human Pathogenesis: State of the Art.” *Indian Journal of Experimental Biology* 46, no.5: 273-309. https://pubmed.ncbi.nlm.nih.gov/18697612/.
Wilson, Damien Jonas. 2023. “What is Theranostics?” *News Medical: Life Sciences.* https://www.news-medical.net/health/What-is-Theranostics.aspx.
Wongsrikeao, Pimprapar, Dyana Saenz, Tommy Rinkoski, Takeshige Otoi, and Eric Poeschla. 2011. “Antiviral Restriction Factor Transgenesis in the Domestic Cat.” *Nature Methods* 8: 853-859. https://www.nature.com/articles/nmeth.1703#ref-CR3.
World Health Organization. 2023. “Infection Prevention and Control.” https://www.who.int/teams/integrated-health-services/infection-prevention-control/surgical-site-infection.
Yang, Meina, Jiangxiang Pang, Junyan Liu, Yanli Liu, Hua Fan, and Jinxiang Han. 2015. “Spectral Discrimination between Healthy People and Cold Patients using Spontaneous Photon Emission.” *Biomedical Optics Express* 6, no. 4: 1331-1339.
Zapata, Felix, Victoria Pastor-Ruiz, Fernando Ortega-Ojeda, Gemma Montalvo, and Carmen Garcia-Ruiz. 2021. “Increment of Spontaneous Human Biophoton Emission Caused by Anger Emotional States.” *Microchemical Journal* 169: 106558. https://www.sciencedirect.com/science/article/pii/S0026265X21006445#b0080.
Zapata, Felix, Victoria Pastor-Ruiz, Fernando Ortega-Ojeda, Gemma Montalvo, Ana Victoria Ruiz-Zolle, and Carmen Garcia-Ruiz. 2021. “Ultra-weak Photon Emission as a Non-invasive Spectroscopic Tool for Diagnosis of Internal States.” *Journal of Photochemical Biology* 216: 112141. https://pubmed.ncbi.nlm.nih.gov/33540236/.