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Features

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INNOVATION.

The Bleaching of Coral Reefs: Why We Should Be Concerned

Hannah Wood

As witnessed throughout the last few decades, coral reefs are shifting from their known colorful image to a white, bleached organism dying in the ocean. Thousands of marine species are undergoing a severe shift to different resources due to the tragic killings of the reefs they rely on for food or shelter (Williams, 1990). Along with the disturbance of ecosystems, comes the negative economic effect that the bleaching of coral reefs has globally. The killing of reefs means the killing of the tourist industry that thrives off of the colorful ecosystem (Cho, 2019). As the reefs die it causes the dismantling of the protective barrier provided by coral reefs for coastlines. Without this barrier, the possibility of coastline flooding increases (Martin, 2019). The disruption of ecosystems, the threat to tourist industries, and destruction of the protective barrier for coastlines are all consequences of the prevailing coral reef bleaching.

Coral reefs are marine ecosystems made up of coral polyps that hold an abundance of species. These reefs primarily lie in the tropics, where they host more than one quarter of all marine species (IUCN, 2021). Well known reefs that attract tourists include the Great Barrier Reef and the Papahanaumokuakea National monument, harbors more than 7000 species of fishes, invertebrates, plants, sea turtles, birds, and marine animals (NOAA, 2019). These reefs also hold a special mutualistic symbiotic relationship with an algae known as zooxanthellae. The coral provides both the protected environment and waste product the algae needs for photosynthesis. In return, the algae provides the carbohydrates the coral will use as both food and pigmentation (NOAA, 2019). However, this relationship is only accomplished in near perfect conditions. In order for the algae to fully manage photosynthesis, water conditions must be clear and shallow to allow the light used in photosynthesis to fully

penetrate. These water temperatures must be between 23 and 29° C (77-84°F), (Cho, 2019). Whenever temperatures rise above this average, the coral expels the zooxanthellae algae, which additionally takes its color and food source with it (IUNC, 2021). This is referred to as coral reef bleaching: where corals are stripped of their colors, and threatened with death. This is all reflected in the current downfall of the coral reef species today due to increased global temperatures. Temperatures have continuously risen over the last few decades, where the mean global surface air temperature ranges from 1.5-2.0°F higher than pre-industrial temperatures (Taylor, 2018). In 1998 it was recorded that the rising temperatures had caused approximately 42% of coral reefs to be bleached to some extent; rising to 54% by 2002 (Berklemans, 2004). These devastating rates of bleaching are also being escalated by the event of a current that runs along the equator known as El Nino. During the 1997-1998 El Nino, a widespread coral bleaching occurred, killing off 16% of the world's coral reefs (Cho, 2019). This is primarily due to the increased water temperature of the current negatively affecting the coral reefs' relationship with the algae. The destruction of coral reefs can be prevented through a number of climate oriented activism, such as sustainable fishing, scientifically designed to allow the coral reefs to survive the threatening bleaching within 10 to 15 years. However, the current trend of increasing global temperatures creates the scary reality that they may never be saved (Cho, 2019). With this unfortunate chain of events in mind, a number of outside factors are impacted by the destruction of coral reefs.

As global temperatures rise, killing much of the ocean's coral reefs, a disruption in ecosystems takes place. Coral reefs hold much of the ocean's diversity. Even if they only occupy less than 1% of the ocean as a whole, these reefs are home to more than a quarter of all marine species: crustaceans, reptiles, bacteria, and more (Cho, 2019). These packed marine ecosystems are under severe threat from the rising rates of coral reef bleaching. Consequences of bleaching include both temporary loss of energy for

reef hosts and total destruction of the community (Williams, 1990). The results of a study completed in 1990 by Williams depicts the ramification of the reef bleaching with the unfortunate decline of two of the most important reefs in the Atlantic Ocean (Williams, 1990). With this destruction, comes the simplification of these ecosystems causing a decrease in habitat availability for the species that depend on the reefs as homes and food sources (Cho, 2019). As seen in a 1983 bleaching event in the eastern Pacific, whole reefs died causing the densely populated ecosystems to either adapt to a different home or just diminish completely (Williams, 1990). While some countries have made progress in taking action in order to protect the threatened communities, such as creating marine protected areas (MPAs), these actions are not fully solving the issue. Many MPAs can only withstand so much stress from the ecosystems, such as overfishing and pollution. Whereas climate change is a much larger and more complex situation to mitigate, the coral bleaching that is primarily caused by climate change cannot be helped by these programs. Therefore, the ecosystems protected by MPAs are unfortunately still feeling the wrath of coral reef bleaching, causing an overall decline in species like corallivores, and planktivores (Graham, 2007). All this to say that the general consequences of coral reef bleaching are costing the lives of many marine species.

As coral reefs continue their decline, the tourism industry is seeing a decline as well. The unique diversity and natural beauty of the reefs attracts many tourists to come and explore it for themselves. The tourism industry fuels the economy of these coastal cities through the cost of fuel to travel, booking of hotels, buying food, and countless other sources of profit. It is predicted that these coastal cities can sometimes account for 80% of a country's total income (Cho, 2019). These coastal cities that benefit from the coral reefs are negatively impacted by the destruction of the coral reefs. With no colorful coral reefs, or fun fish to see, no profit is seen either (Cho, 2019). This is seen on a global scale as well, for “some 30% of the world's reefs

are of value in the tourism sector" (Spalding, 2019). Small countries such as Fiji, or the Philippines, known for their stunning waters and coral reefs, rely on these reefs to provide the tourist induced profit needed to fuel their economy (Cho, 2019). The bleaching of coral reefs produces a chain of events that impacts millions of people's lives economically.

The bleaching of coral reefs also destroys the protective barrier that coral reefs provide for coastlines. As coral reefs lie in shallow waters closer to coastlines, they serve as barriers between potential flooding and storms coming in from the deep ocean towards coastlines. The reefs effectively break down the waves' energy, creating a smaller wave (Ap van Dongeran, 2017). A study from 2017 based in the Republic of the Marshall Islands compared portions of the island that had surrounding coral reefs with portions of the island that had no surrounding coral reefs. The study observed both "In Storm Conditions", observing the impact coastal storms, or flood-induced conditions, had on the island near reef-lined and non-reef-lined shores; and "Blue Sky Conditions", observing the shores in what would be considered normal functioning day-to-day conditions. After careful observation, it was seen that the side of the island with no coral reefs increased from 12 mph to 30 mph storm maximum wind speeds. This escalates the size of the waves, creating a greater risk for coastal flooding (Ap van Dongeran, 2017). The study concluded with the fact that coral reef-lined islands are less-susceptible to wave-induced flooding (Ap van Dongeren, 2017). This supports the claim that coral reefs are a buffer between coastlines and the ocean, while also supporting the claim that coral reefs impact the coastlines that depend on them.

The continued bleaching of coral reefs is a prevalent issue in society because of the disruption of ecosystems, the financial threat to tourism industries, as well as the destruction of the protective barrier for coastlines. With the consistent rising temperatures due to climate change, comes the continued bleaching of coral reefs

within the oceans (Berklemans, 2004). Without the stop of climate change, global temperatures are predicted to continue to rise 3.5°F by the end of the century (Taylor, 2018). This, in turn, will only escalate coral reef bleaching, continuing to worsen the lasting negative impacts experienced across many sectors globally.

Neuralink: An Overview

Suyash Jain and Shruti Patel

For as long as long as machines have been around, humans have always had an obsession with augmenting their own capabilities. The earliest forms of this ingenuity include the use of ramps to help move heavy objects and axes to concentrate forces on specific points during prehistoric eras. More modern examples include the device you are reading this article on in which the petabytes of information are available at a moment's notice. Yet, one of the most elusive forms of mechanical augmentation has been that of direct integration with biology – bionics.

The field of bionics is vast and has had significant development in the past few decades. In fact, technology has advanced so much that whole limbs can be replaced using targeted muscular reinnervation, which transfers the signal of nerves from available muscles to a machine that augments the signals and controls the function of mechanical limbs [1]. However, the holy grail of bionics – the brain-computer interface – has only just been scratched, with majority of the successes attributed to one company – Neuralink.

Neuralink has boiled down the issues of interfacing with the brain to three main categories – development of probes, an insertion system, and custom electronic components [2].

Previous research has already established the ability to control speech synthesizers, computer cursors, and robotic limbs by using no more than 256 electrodes to read the electrical activity of the brain neural networks. However, while this demonstrates the possibility of an interface between human brains and computers, no advancements have been made in interfacing with a large number of neurons. Noninvasive measurements of many neurons have proved to have too much noise with very nonspecific interpretations such that specific intents cannot be deciphered. To address the issues of high-bandwidth requirements when interfacing

with many neurons, while maintaining high levels of biocompatibility, Neuralink developed fine flexible polymer probes that can be inserted across many regions. The flexible nature of the probes prevents the bio rejection that more rigid materials cause by disrupting the blood brain barrier. Moreover, the wafer-level manufacturing of these devices allows each array of probes to have either 48 or 96 threads (area with contacts and traces) each with 32 independent electrodes, thereby allowing for high bandwidth transfer of neurological data.

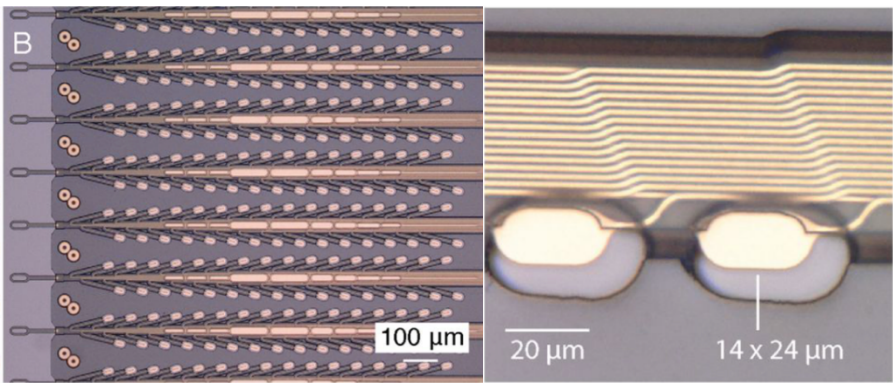

Figure 1. Left: One probe example with 32 electrodes spaced 75 micrometers apart. Right: Increased magnification of singular electrodes.

While the use of polymer probes has many advantages, it also has one significant drawback. The flexible nature of the polymer is such that it cannot directly be inserted into the brain as the insertion process is significantly complicated. To address this concern, Neuralink developed a robotic solution for rapid, reliable insertion of probes. This robotic solution uses a "needle-pincher". The needle is used to hook onto insertion loops and pierce the surface of the brain. The pincher is used to guide the threads and ensure correct placement of electrodes along a specified path.

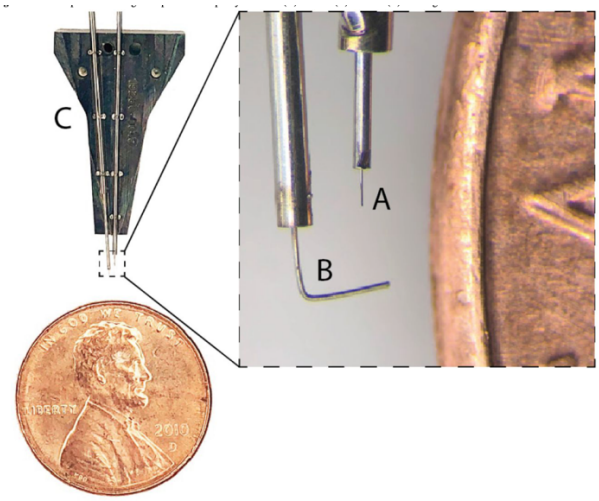

Figure 2. Robotic assembly. (A) Needle (B) Pincher (C) Cartridge

The final part of the puzzle includes a custom electronics board that not only interfaces with the electrodes, but also amplifies signals and wirelessly streams information to a separate device. As there were no commercially available circuits of this design, Neuralink developed an application-specific integrated circuit (ASIC). This circuit contains 256 individually programmable amplifiers that allow the extreme fine tuning of amplification of small neural signals and the rejection of out-of-band noise. A number of these ASIC's can be placed on a standard PCB allowing modularity with the number of channels needed in various applications. In addition to these custom neural processing units, a base station was created to connect up to 3 implants simultaneously via 10GB ethernet protocols. The base station was further supported by custom software that allows for plug-and-play solutions for streaming neural data.

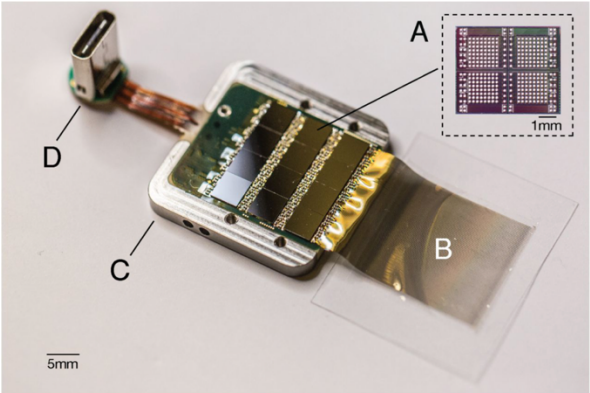

Figure 3. Electronic implant. (A) ASIC (B) Polymer threads (C) Titanium enclosure with lid removed (D) USB-C Connector

The application of this technology is limitless. Some proposed uses include bypassing spinal cord injuries by virtually recreating neural connections between the brain and appendages, thereby allowing for regained limb function. Another use consists of amputees controlling a computer via interfacing cursors and keyboard programmatically.

Applications of Lasers in Medicine

Dreshta Boghra, Mark Gao, Michel Coffey, Barrett Meeks, Jamie Travis

Introduction

What is Biophotonics

Biophotonics is a combination of biology and photonics in which the generation, manipulation and detection of photons are applied for use in the field of biology. Photons are particles of light that have mass of zero and travel at the speed of C, which is the speed of light from the moment they are formed. Combining the two disciplines of biology and photonics has allowed for many advancements in the medical field such as better diagnostics and treatments. Biophotonics are often used to identify, discover, change or understand molecular structures in biology. This article will be discussing different applications of photons, particularly lasers in medicine.

How lasers work

Light is defined as electromagnetic radiation. Importantly, manipulation of light and photons via lasers opens up a world of potential applications especially in the medical field, manufacturing industry and technological industry. Laser is actually an acronym for Light Amplification by Stimulated Emission of Radiation, and there are multiple types of lasers that are used in the medical field.

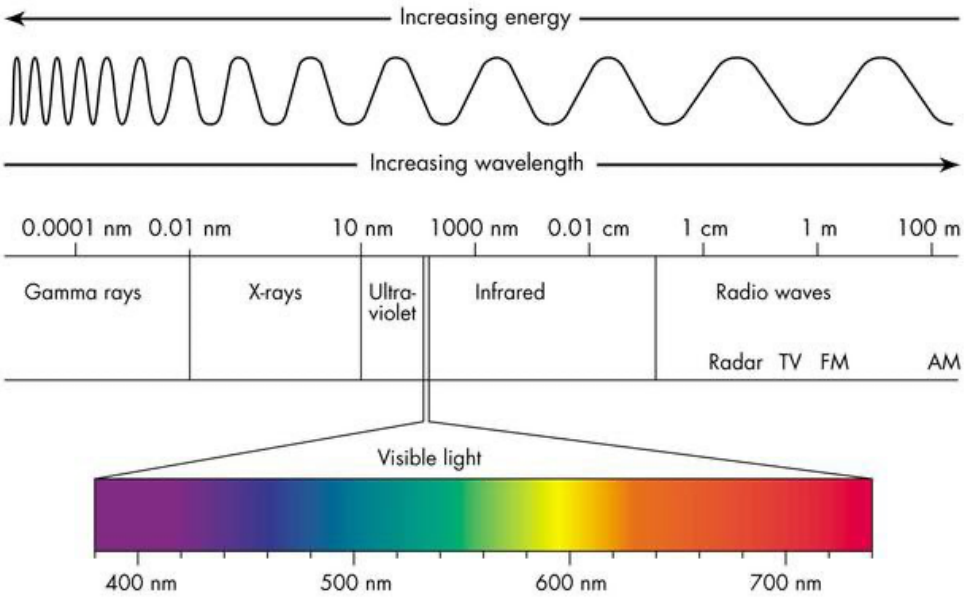

Figure 1. Electromagnetic spectrum demonstrating wavelength and visible light spectrum. https://sites.google.com/a/coe.edu/principles-of-structural-chemistry/relationship-between-light-and-matter/electromagnetic-spectrum

For a laser light to function, a substance known as a media is added. The media is energized by an external voltage and moves electrons to a higher energy state. When the electron goes from that higher state back to a lower state, it thus emits photons creating the laser of a monochromatic wavelength. Some lasers are formed through electrons of an atom bouncing off reflections. The result of these electrons moving is a focused beam. There will be one surface that is completely reflective where no light can pass through while the other will be partially reflective and miniscule abouts of light will pass through. As electricity flows through, the electrons will be excited and bounce faster and more frequently thus allowing more light to be exerted from the partially reflective surface. The light that comes out of the partially reflective side is the laser that can be seen and the wavelength of the photons should be the same and

the crests and troughs are meant to travel coincidently, thus giving the beam more potency.

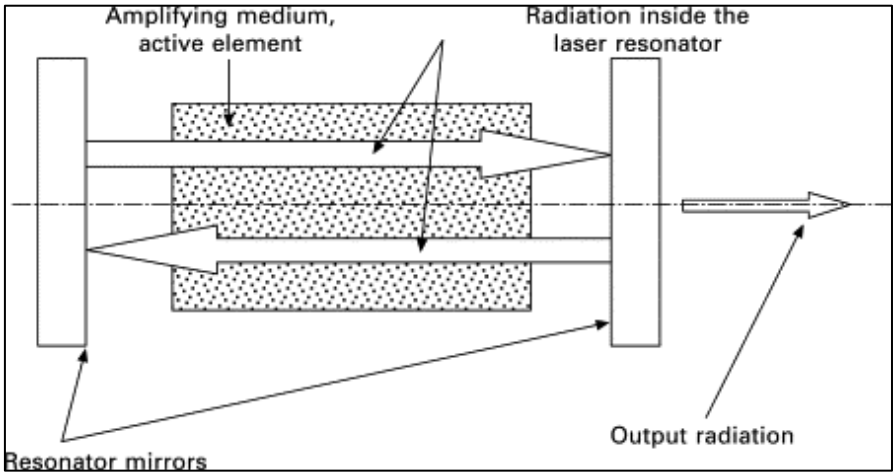

Figure 2. Demonstration of a laser, right side is semi reflective allowing little light to go through while the left side is completely reflective allowing the photons to bounce back and forth. https://ars.els-cdn.com/content/image/3-s2.0-B9780857092724500075-f07-03-9780857092724.gif

Types of Lasers

Pulsed-Dye Laser

An application of laser technology in the medical field is the use of lasers in lithotripsy. When a patient has stones in their kidney or gallbladder, etc., to remove it, a shock laser called pumped-dye laser is the most popular option. This shock laser uses a coumarin dye to help patients with calculi in their body. The pulsed-dye laser uses a monochromatic light, with a wavelength of 504nm to target the calculi stones

by exciting the coumarin dye. This will grind the calculi into smaller pieces, so it is easier to get the stones out. Pumped-dye lasers only affect the structure that can absorb its wavelength color.

For example, this laser is useful when stones in the urinary tract are present. The Pumped-dye laser emits a green color and this is absorbed by the yellow color of the urinary stone and oftentimes, it will be only the stone that absorbs the laser. The other surrounding tissues don't get damaged because of the dye used in the laser.

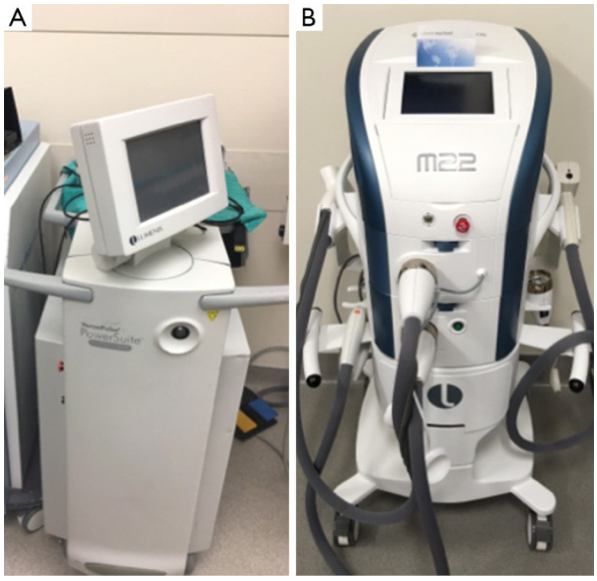

Figure 3. A picture of the Ho:YAG lithotripsy laser (A) and an neodymium:yttrium-aluminum-garnet (Nd:YAG) dermatologic laser (B).
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5220034/

Holmium: YAG Laser

Another laser used in lithotripsy is called a long-pulsed Holmium:YAG laser with a wavelength of 2100 nm, which uses an active medium of Holmium and yttrium-aluminium-garnet or yttrium-scandium-gallium-garnet. This laser can go deeper than

other light lasers and are used more often to go into deeper parts of the body. The yttrium-aluminium-garnet or yttrium-scandium-gallium-garnet are garnets with different ions, giving different wavelengths. This laser is absorbed very easily by water so when the laser is needed in an area concentrated with fluids, the long-pulsed Holmium:YAG laser will absorb the energy and a cloud of vapor is produced. The remaining energy will go to attacking the surface of the calculi and drilling a hole to fragment it.

Argon laser

The argon laser is a gas laser that uses the noble gas, argon, as its active medium. It produces a visible blue-green light with a wavelength between 350nm - 515nm. This laser will usually go for short distances into the tissue. The heat from this laser will destroy the cells in the tissue. Argon lasers are used to burn off and seal damaged blood vessels. For example, glaucoma is an eye condition in which pressure builds up due to the inability to release natural fluids. The fluids must be released in order to maintain the proper pressure in your eye. Without proper treatment, the optic nerves can permanently be damaged resulting in vision loss until one is blind. The extreme pressure or intraocular pressure will damage the optic nerves in the eye. The increased pressure is primarily due to the effect of a damaged pupil which inhibits the flow of aqueous fluid out of the eye. The argon laser is capable of puncturing tiny openings into the iris to permit the flow of fluid. The free flow of fluid releases pressures thus preventing vision loss and possible blindness.

Figure 4. A picture of an Argon laser being utilized in glaucoma treatment. https://www.medicinenet.com/what_is_an_argon_laser_used_for_in_ophthalmology/article.htm

CO_2 lasers

The CO_2 laser uses CO_2 and its active medium with a wavelength of 10,600 nm which is primarily absorbed by water. The heat from CO_2 lasers destroys cells thus vaporizing tissue. Due to its high heat, the laser significantly reduces bleeding by sealing blood vessels.

CO_2 lasers are utilized by reconstructive surgeons as a treatment method to tighten and relive the skin of patients through the process known as laser resurfacing. In laser resurfacing, the CO_2 laser punctures columns of ablations into the skin. Skin is comprised of collagen and elastic tissue. However, as humans age, the collagen and elastic tissue becomes weaker and is seen as "saggy skin." The CO_2 laser is able to puncture tiny columns of ablations into the skin with healthy skin around the columns. The skin will refill it with new fresh and tight collagen and elastic tissue. Once the collagen heals, the skin will appear tighter and feel healthier.

However, the use of lasers in medicine has not been perfected. For example, many eye problems such as glares, halos, eye infections, and vision loss, etc., may be results of laser resurfacing. Since lasers are fairly new in the scientific field, there are bound to be risks involved with such applications. However, researchers and scientists are working through these problems and hopefully in the near future, lasers will be perfected.

Conclusion

Laser applications do not end there. There is still so much to discover with biophotonics. Hypothetically, Lasers may be used to clear infections in the future. Currently, antibiotics are prescribed to combat infections. However, many microorganisms are becoming resistant to the antibiotics thus the efficiency is decreasing. Lasers can potentially replace or decrease the need for antibiotics by utilizing them in the infected area.

Lasers such as the Pulsed-Dye laser, Holmium:YAG laser, Argon laser CO_2 lasers are all evidence of how far lasers have come since the first laser was built in 1960 which was simply a high-power flash lamp shinned on a ruby rod with silver-coated surfaces. The use of lasers has already revolutionized medicine and will continue to do so allowing for once risky procedures to be practiced safely. Lasers can be more precise than a surgeon's hands allowing surgeries to be performed safely. This is just a scratch on the surface of what lasers can do for medicine.


EDUCATION.

The Wonders of Alice in Wonderland Syndrome

Sophia German, Jamie Travis, Mark Gao, Michael Coffey, Barrett Meeks

Recall the scenes in Alice's Adventures in Wonderland, where Alice falls down a rabbit hole and begins to experience strange occurrences such as repeatedly changing sizes from big and tall to short and small? These attention-drawing scenes are daily difficulties for individuals with Alice in Wonderland Syndrome (AIWS). With merely 166 diagnosed patients discussed in the scientific literature (Blom, 2016), this disorder is seemingly rare amongst the general public, resulting in reduced public pressure for experimental studies. However, this infirmity holds many questions yet to be fully answered. Alice in Wonderland Syndrome is a neurological disorder, introduced in 1955 by the British psychiatrist John Todd, characterized by visual and somesthetic distortions (Todd, 1955). The most consistent clinical features are micropsia and macropsia, visual distortions that cause objects to appear too big or too small. Other symptoms include but are not limited to telopsia (perceiving objects further than actuality), achromatopsia (inability to visualize colors), dysmorphopsia (lines appearing wavy), pelopsia (perceiving objects closer than actuality), derealization, depersonalization, and the incapability of time perceiving (Palacios-Sánchez et al., 2018). In addition, illusions and hallucinations may also be present. For instance, patients can hear voices that are ultimately non-existent. These clinical features distort the reality of an individual just as the Cheshire Cat distorts his

surroundings in the infamous Alice's Adventures in Wonderland storyline. In fact, it is proposed that the author of this book, Lewis Carrol, was experiencing episodes of AIWS himself (Lansley, 2015). Symptoms are usually resolved within a couple of weeks or months after onset. Episodes can last anywhere from 10 seconds to 10 minutes, according to AIWS clinical patients. Although, some cases lean towards chronicity. These visual distortion episodes usually disappear throughout the course of a patient's life. Diagnosis of this syndrome includes various testing techniques, including psychiatric consultations, MRI neurological scans, EEG (electroencephalography) testing, constant blood profiling, and numerous other assessments perceived as practical by the patient's doctor (Mastria, Mancini, Vigano, & Di Piero, 2016). Specifically determined brain area involvement is undetermined and understudied. Electroencephalography usually leads toward the diagnosis of seizures or epilepsy that are precursors or consequences of AIWS. Nonetheless, the occurring symptoms and prognostics of AIWS are highly individual.

Numerous hypotheses have evolved around triggering events causing the initiation and establishment of these neurological symptoms (Montastruc, Schwarz, Schmitt, & Bui, 2012). Literature reports indicate viral/antimicrobial etiology, including exposure to Epstein Barr virus (EBV), pharmacological etiology, where the use of psychoactive agents or topiramate intake can cause the precipitation of symptoms. Finally, selected central nervous system (CNS) conditions, such as brain

tumors, migraines, and epilepsy, can be accompanied by AIWS and referred to as neurological etiologies (Weissenstein, Luchter, & Bittmann, 2014).

In support of viral etiologies, one can find an overlap between the spread of EBV and AIWS. For example, it is known that EBV is a prevalent herpes virus that primarily spreads through saliva and is commonly found in young children (Stock, 2013). Similarly, a study conducted in 2014 by Alessandra Liu, Grant Liu, and others has found that Alice in Wonderland Syndrome frequently occurs in younger children (Liu, Liu, Liu, & Liu, 2014). The authors conclude that the Epstein Barr virus is a leading instigation of Alice in Wonderland Syndrome. In another case, a 7-year girl was experiencing short lapses of unusual visual perceptions as seeing her mother's head as a green color and much smaller than her body (Cinbis & Aysun, 1992). The girl was admitted to a children's hospital, tested, and showed no signs of brain abnormalities in her neurological scans. Furtherly, it was found she had a prominent EBV infection. In addition to viral origins, a single report of Lyme disease accompanied by AIWS was reported, suggesting that bacterial infection can modulate neurological responses (Binalsheikh, Griesemer, Wang, & Alvarez-Altalef, 2012).

The neurological origins explain the connection between intense migraines as the most common preceding occurrence of Alice in Wonderland Syndrome. In fact, the first etiology described for AIWS was a report of conditions in two children with a

pronounced family history of migraines (Golden, 1979). Their recurrent episodes include distorted body images and an altered sense of time. In the other case, a patient has reported the sense of aura, a known symptom of migraines, while developing AIWS episodes (Kew, Wright, & Halligan, 1998). However, some studies show that Topamax (topiramate) is the underlying factor of this disorder (Evans, 2006). Topamax, nerve pain and anticonvulsant medication, is commonly used by individuals experiencing heavy migraines. A 17 yr old girl was put on a heavy schedule of Topamax due to her ongoing migraines, later leading to the establishment of many pathophysiological misperceptions (Jurgens, Ihle, Stork, & May, 2011). Another case shows two patients taking Topamax due to migraines, consequently leading to palinopsia (continued viewing of an object even after removing the object from visionary lengths). As soon as topiramate intakes were avoided, these visual misperceptions disappeared (Evans, 2006). Finally, a recent report by Naarden et al., has shown a connection between the AIWS and Creutzfeldt-Jacob Disease. This fatal prion disease that is characterized by abnormally misfolded prion proteins (Naarden, Ter Meulen, van der Weele, & Blom, 2019). Hallucinogenic or psychoactive drugs that trigger a modulation of various CNS pathways are also known to stimulate sensory distortions. These causative agents are grouped into pharmacological etiology. In one case, a 15-year-old boy who presented with AIWS

symptoms was reported to be a vivid cannabis user, warranting further studies as these types of chemicals have become more available to the public (Montastruc et al., 2012). In another case, prolonged abusive inhalation of toluene-based solvents resulted in AIWS episodes in a 22-years-old woman (Takaoka, Ikawa, & Niwa, 2001). However, the lack of diagnostic procedures specific to AIWS limits the identification of agents that strongly correlate with the development of the syndrome.

Unfortunately, treatment of the actual syndrome is currently unavailable. The various symptoms can be alleviated using available medicinal agents, minimizing the copious side effects. Some new cases have shown success rates from the use of the anxiolytic agent alprazolam (Tunç & Başbuğ, 2017).

In summary, reported studies point to many causative factors of AIWS, including infection with the EBV and topiramate-based therapy. However, not all pathways underlying the establishment and progression of this neurological disorder are understood. The heterogenicity of symptoms may be because AIWS is a collection of symptoms associated with a variety of disease states, not a stand-alone type of disorder. If this is true, then treatment strategies should include therapies for the underlying causes as well as therapeutic agents to alleviate AIWS symptoms. Further, it is important to understand any links between establishing AIWS during early childhood and developing of psychological disorders, such as schizophrenia, bipolar disorder, and PTSD, during adulthood. Further studies must be funded and carried

out to draw prominent conclusions about Alice in Wonderland Syndrome and its effect on the general population's mental health.


CATAPULT
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STEM & LEAF CORPS
GROWING EDUCATORS
Who We Are
MAGIC MILK
• An education-oriented outreach initiative associated with TTU Honors College
• Help support and provide high-quality academic enrichment for local K-12 students
Where We Are
What We Do
SPAGHETTI ENGINEERING
We meet in the OL Slaton Cafeteria from 4-5pm on Tuesdays and Thursdays
Project-based learning to help instill a passion for the STEM fields

SERVICE.

Malaria and Urbanization – an Investigation into the Contribution Human Urbanization has on Disease Prevention and Decline

Chinaza Aham-Neze, Barrett Meeks, Jamie Travis, and Mark Gao

Africa, also known as the "heartland", is famous for its biodiversity and vast, unique ethnic groups. Although Africa is teeming with life and beauty, it is the most poverty-stricken continent in the world. Malaria, one of the deadliest infections known to man, poses an extreme public health crisis around world, especially in Africa, as it is a leading cause of death and disease in many developing countries. Africa accounts for approximately 94% of recorded malarial incidences and deaths.[1] Infants and children, pregnant women, patients with HIV/AIDS, and non-immune migrants have considerably higher risks of contracting malaria and developing severe disease compared to other immunocompetent patients.[1] Children with severe malaria can develop respiratory distress and severe anemia while adults can develop complications such as multi-organ failure[1]. The cause for the infection most commonly stems from the parasite *Plasmodium falciparum* that is transmitted through the bites of female *Anopheles* mosquitoes.[1] The transmission of malaria is more frequent in places with favorable climate factors like high rainfall and flooding which is why this disease is more widespread in countries of sub-Saharan Africa[1]. While Africa as an entire continent has made progress in controlling the transmission of malaria and lowering the death toll, there are many possible factors contributing to its decrease in morbidity and mortality.

The countries of Nigeria, Democratic Republic of Congo (DRC), Ethiopia, and Uganda combined account for approximately 50% of global malarial deaths in total.[2] According to the World Health Organization (WHO)'s World Data Bank, these countries indicate a gradual decrease in infection rates since 2000.[3] However, Uganda and Ethiopia's malaria data reports a net decrease with a fluctuating wave about every

5 years (Figure 1).[3] The WHO World Malaria Report 2020 includes an up-to-date assessment of the burden of malaria globally, regionally, and within specific countries. This report stated that in 2019, $3 billion USD was received for malaria programs, however, these funds were short of the needed goal of $5.6 billion USD.[4] This money was needed for researching advancements in new treatment and prevention tools and better targeting of interventions. Additionally, since 2000, these four countries have increased their Gross Domestic Product (GDP) (Figure 2) and grown economically over the past 20 years.[4] However, the percent of their GDP on current health expenditure has either decreased or remained practically constant.[5] The most noticeable decrease in health spending is in Uganda where they peaked in 2006 with 11.8% of their GDP being spent on healthcare but dropped to 6.5% in 2018 (Figure 3).[6] Nigeria also experienced an exponential increase in their GDP since 2000, but the amount of money spent on health has barely shifted as it is hovering at about 4% of their GDP.[6]

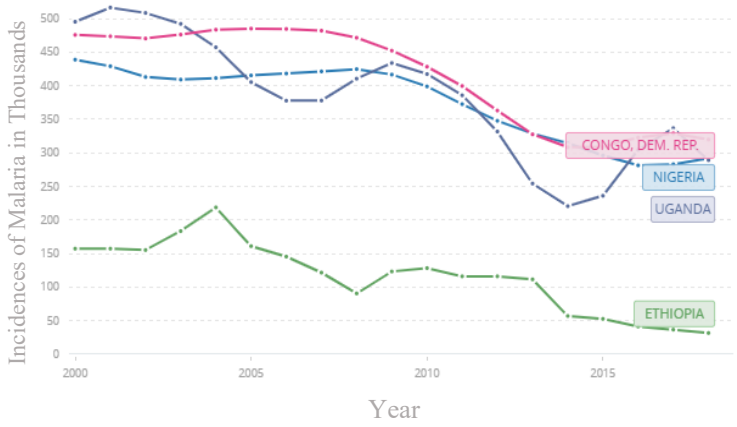

Figure 1. Incidences of malaria (per 1000) in Nigeria, Ethiopia, Uganda, and Democratic Republic of Congo reported by the World Health Organization as a function of time[3]

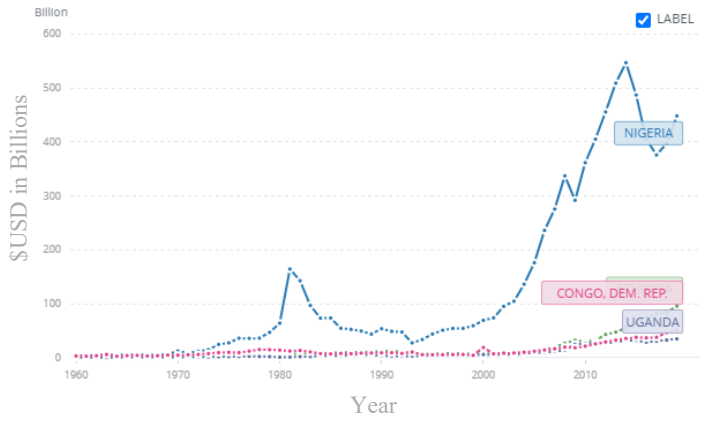

Figure 2. Change in GDP (in $USD) since 1960 in Nigeria, Ethiopia, Uganda, and Democratic Republic of Congo as reported by the World Health Organization[5]

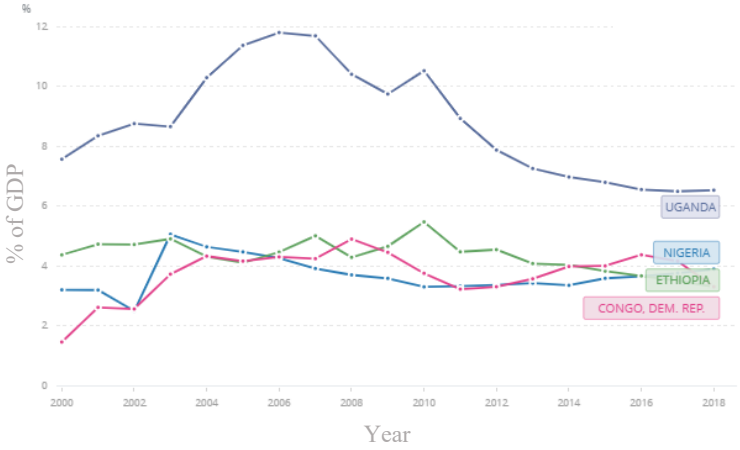

Figure 3. Healthcare expenditure (% GDP) in Nigeria, Ethiopia, Uganda, and Democratic Republic of Congo since 2000[6]

The fact that these countries have experienced a growth in their economy but a drop in healthcare expenditure over time, although they are facing an ongoing malaria health crisis, poses a new question: where is all the money going, and why?

Since 2000, the electric power consumptions of Nigeria, DRC, and Ethiopia have increased (Figure 4)[7]. Uganda, whose energy primarily comes from hydropower, has one of the lowest electrification rates in the world.[8] The USAID and Power Africa released in their 2018 report, *Power Africa Transmission Roadmap to 2030*, their plans to practically approach bringing additional energy to these countries and more.[8] This report poses the argument that Nigeria, DRC, Uganda, and Ethiopia are experiencing rapid urban growth with consequential increases in energy needs. A significant percentage of their GDP may be being shifted from healthcare spending to electricity and infrastructure. Nigeria, DRC, Ethiopia, and Uganda have experienced an exponential increase in their urban population size for the past 20 years, but the migration from rural to urban populations does not ensure proper living conditions (Figure 5).[9] Infrastructure spending, especially construction, indicates that the government is designating more money into amenities that allow for greater sanitation to improve living conditions. Nigeria, DRC, Ethiopia, and Uganda all have experienced a net increase in this field over the past 20 years, with Nigeria experiencing the greatest increase in industry value, skyrocketing from approximately $23 billion to $122 billion.[10] The other countries, although having a net increase, have not shared the same rate of national industrial value growth as Nigeria.[10] No matter how small the increase in construction may be, when paired with the rates of people moving to urban populations, it can play a great factor in malarial rates.

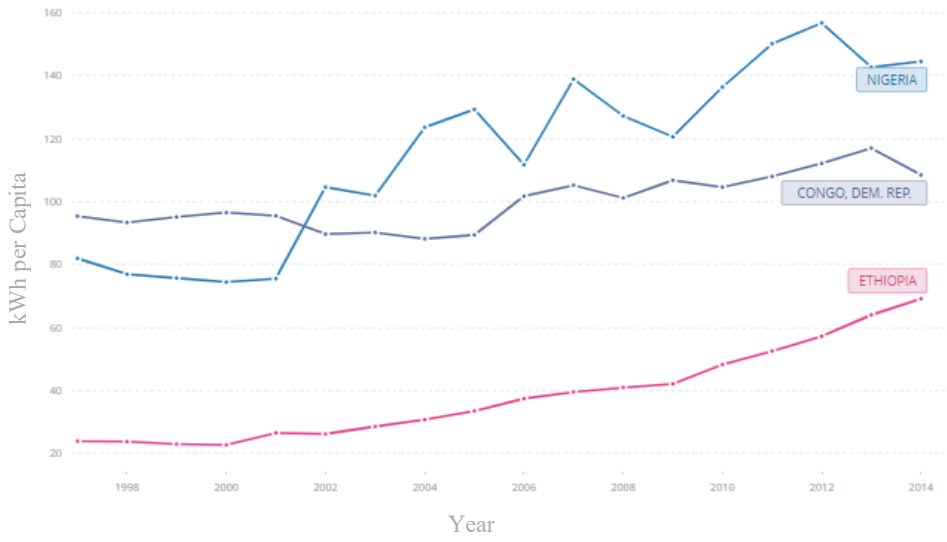

Figure 4. Electric power consumption (kWh per capita) of Nigeria, Ethiopia, and Democratic Republic of Congo since 1997[7]

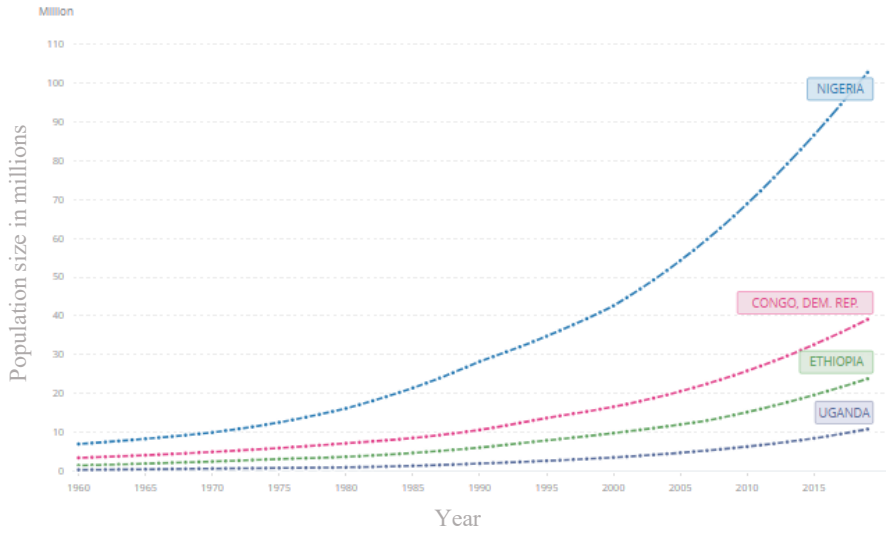

Figure 5. Urban Population size (millions) of Nigeria, Ethiopia, and Democratic Republic of Congo since 1960 in millions[9]

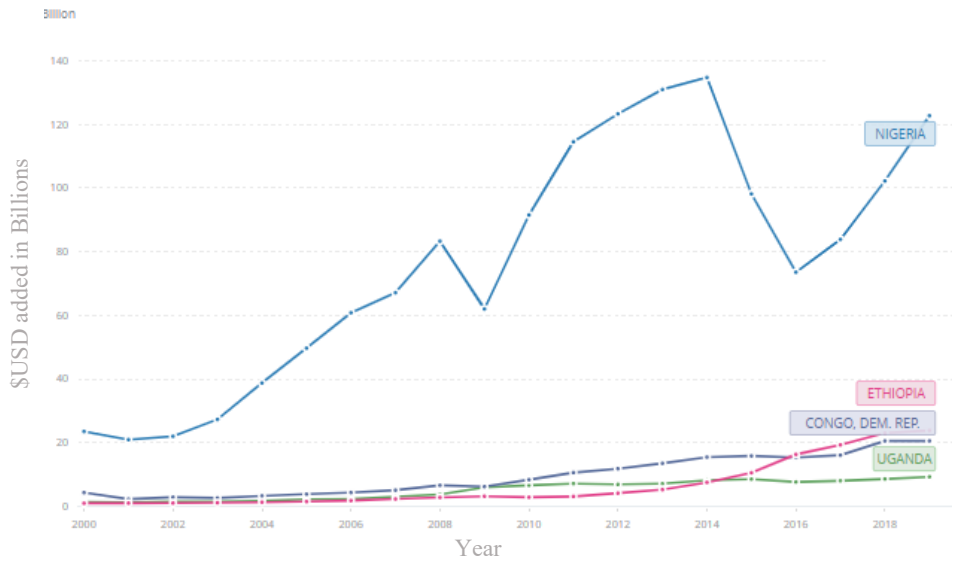

Figure 6: Industry including construction value added (in $USD) in Nigeria, Uganda, Ethiopia, and DRC[10]

Population growth equates to an increase in energy needs. Implications of urbanization include new job opportunities, a need for improved transportation and communication, growth in industry, and improved standards of living. Access to electricity and energy services are important to improving the health and well-being in sub-Saharan African countries. Funding the needed changes to support economic and urban growth is costly and complicated, and there are significant challenges to fund increased energy demands and maintain the fight against malaria.

The urban populations in Nigeria, Uganda, Ethiopia, and DRC have increased dramatically since 2000. The entomological inoculation rate (EIR), which finds the quantitative relationship between the proportion of people infected with malaria and the rate at which they are bitten, is rarely recorded in Africa due to lack of research funding. This limits the mathematical proof that urbanization decrease malaria rates. However, seeing as to how the reproductive lifecycle of the female *Anopheles* Mosquito carrying the *Plasmodium falciparum* rely on excessive water sources, this could be an implication in the net decrease of malaria infections in the countries observed.

Urban spaces rely increased clean water supplies and typically have a sanitation system. Cleaning water supplies in the vicinity of the urban space decreases human exposure and proximity to contaminated water. Because humans are living next to fewer contaminated water resources and are instead granted more access to relatively cleaner water (as would be found in cities), there is less opportunity for pathogen-vector growth and maturation. It can be assumed that the increased expenditure on energy and costs associated with maintenance and erection of urban environments contributes to the decrease in funding for public health measures associated with malaria infection. However, the data above suggests that urbanization plays a greater role in infection attenuation than the decreased spending on public healthcare measures.

There are many potential reasons other than urbanization for why malaria rates are decreasing in these areas, despite the decline in healthcare expenditure in these regions. While not all could be considered in this writing, factors like the spreading of awareness for bite prevention. Increased use of repellent and mosquito nets, and the improvement and distribution of antimalarial tablets are all contributing factors. Nevertheless, given the increase of urban population rates as well as infrastructure which leads to cleaner access to water in Nigeria, DRC, Uganda, and Ethiopia, it can be argued that urbanization that has occurred over the past 20 years plays a key role in the decrease spread of malaria. It is still important for these countries to remain vigilant for infection and vector control as the fight against malaria still requires consistent research and funding into changes in rural malaria to urban malaria and more.

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