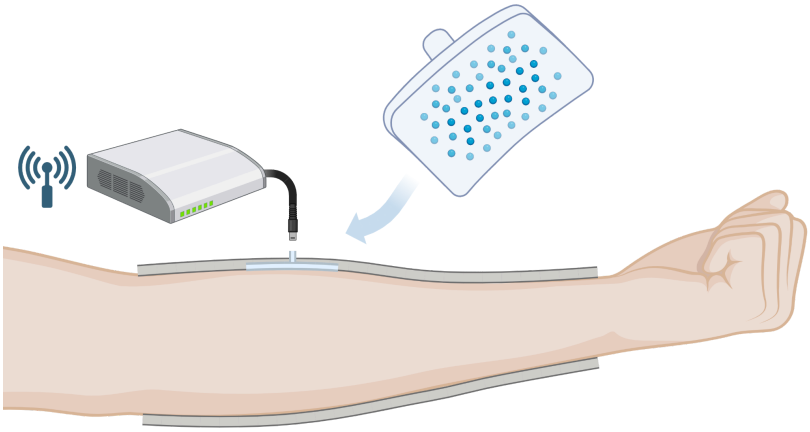

“Cast Sense”

A01 Group 2

Christopher Amaya

Emily Holpuch

Kiana Kalman

Joshua Lopez

Gunica Sharma

Julie Nguyen

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Executive Summary

Product Name: Cast Sense

Company Name: BioTens

Mission Statement: At Biotens, we strive to strengthen patient care by prioritizing efficiency, accessibility, and safety in innovative biotechnology.

Team Members:

- **Chris**: A fourth-year Biotechnology major at the University of California, Davis with an emphasis in Bioinformatics, minoring in Chicana/o Studies and actively involved in Clinica Tepati, a student run clinic, and works in research at a Dermatology Lab.
- **Emily**: A transfer undergraduate at University of California Davis pursuing a bachelor's degree in Biotechnology with a focus on Microbiology, and member of the B-Hours Engineering club and The Davis Alt Protein Project.
- **Kiana**: A third-year transfer student majoring in Biotechnology with a focus on Plant Biotechnology at the University of California Davis, and has participated in the BIG-RT BioInnovation Group as well as the Biotechnology club at UC Davis.
- **Joshua**: A third-year Biotechnology major with an emphasis in Microbiology at the University of California Davis and passionate about microbial research.
- **Gunica**: A third year undergraduate transfer student pursuing her bachelors in Biotechnology with a focus on bioinformatics and a minor in Statistics, with previous genetics research particularly in the rice and agricultural fields.
- **Julie**: A third-year Biotechnology Major at the University of California Davis, previously a co-leader of a project examining the distribution of *Orthorhyncus cristatus* in the Caribbean islands.

Problem:

Infections in orthopedic casts are a significant health issue which can lead to potential complications, increasing medical visits and costs. The traditional approach to monitoring these infections most often happens after they have escalated.

Solution:

Our product, Cast Sense, unites orthopedic casts with modern biosensor technology to continuously monitor for bacterial infections. Our system detects bacteria that is most associated with cast-related infections (*Staphlycoccus* epidermidis and *Acinetobacter* baumannii) and sends real-time data to an app via Bluetooth. This new solution reduces the need for frequent doctor visits and ensures patients get timely medical interventions, ultimately reducing healthcare costs and improving patient outcomes.

Description of the Problem

Problem Description:

Orthopedic casts are widely used to treat bone fractures, but they present a risk when it comes to infections. Our biosensor-enabled cast can address a critical issue in healthcare when it comes to the treatment of bone fractures and associated infections. This affects a substantial number of individuals and has significant implications for patient outcomes, treatment efficiency, and healthcare costs.

Magnitude of the Problem:

Annually, approximately 7 million people in the United States and 178 million people globally suffer from bone fractures, needing fixed casts for treatment[1,12]. Despite the modernness in medical technology, the risk of infection with casts remains a major concern. 90% of pediatric fiberglass casts analyzed contained bacterial contamination, with 83.6% of samples including bacteria responsible for severe infections like sepsis, drug-resistant strains, or surgical site infections[42]. The problem affects a wide range of individuals which include: adults and elderly as people over 50 years old are at an increased risk of sustaining fractures due to osteoporosis and a weakened immune system[9] and people of all ages who sustain bone fractures requiring cast treatment are susceptible to infection risks associated with standard care.

Current Means of Addressing the Problem:

Currently, fiberglass casts or plaster are the standard means of immobilizing and treating bone fractures[6]. However, these casts present challenges in regards to infection risk, evidenced by their high rates of bacterial contamination[42]. Healthcare providers currently rely on periodic check-ups and patient compliance for cast care based on our team's personal experience with a broken wrist, but these are not foolproof methods and may result in undetected infections or complications. The main shortcomings of current methods are that traditional casts harbor bacteria which increases the risk of severe infections[42], healthcare providers rely on periodic visits and patient self-care which may not detect early signs of infection, and patients face challenges such as restricted mobility, discomfort, and the need for frequent medical visits which increases costs and inconvenience experienced by the patient.

Description of the Product

The Castsense biosensor will be equipped with two nodes, to detect the presence of the two bacteria that we determined to be the most harmful for patients requiring a cast as treatment; Staphylococcus epidermidis and Acinetobacter baumannii[34].

The node responsible for detecting the presence of the *S. epidermidis* will be compiled of a layer of a MgZnO nanostructure that functions with the integration of a protein tag. If the bacteria is present, it will produce a biofilm containing the enzyme lysostaphin, that will bind to the protein tag connected to the MgZnO in the nanostructure [25, 23,22]. The binding will allow for a chemical reaction to take place consisting of electron transfer, therefore creating an electrical signal[21]. Due

to the presence of metal magnesium nanoparticles in the nanostructure, it allows for conductivity of the signal to the transducer.

For the node detecting the presence of *A. baumannii*, our device utilizes the chemical reaction between the bacteria's biofilm and a polymeric film on the gold tipped node. In the biofilm of *A. baumannii*, there is the small molecule specific to the organism, 1,3-diaminopropane (1,3-DAP)[3]. The chemical compound has a specific Ph of 8-9 that is unique compared to the human skin microbiome that is typically a Ph of 4.5-5.5, making contamination highly identifiable[3]. The polymeric film we are affixing to the tip of our device reacts to the change in protonation based on the amount of H_3O^+ present, and if the substrate is more basic, surpassing Ph 8, there will be a swell[26]. The polymeric film covers the gold at the end of the electrode, so when a swell occurs forming an electrical impulse, the gold conducts the electrical signal to the transducer[27].

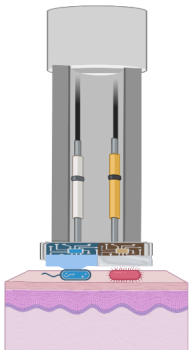


Figure 1. *BioRender illustrating the independent nodes for S. epidermidis and A. baumannii.*

Once a signal is received by the transducer it is sent through an operational amplifier, to establish a significant detectable voltage. When the signal is received by the processor information can be correlated to the voltage. There is a wire connecting each node separately to the processor, affixed with a transducer and operational amplifier. If the voltage coming from a node is above 2V, then the processor will register that as a 1 in the code indicating a positive result that the node specific bacteria is present [21]. If the voltage is below 2V, it will register as a 0 in code indicating a negative result and that the bacteria is not present [21]. The data will be sent through bluetooth from the processor to the app, designed by a hired software engineer to create a friendly and informational user interface[2]. If either bacteria is present, it will inform the patient that there is a high probability of its presence and instruct them to make an appointment with their primary care provider.

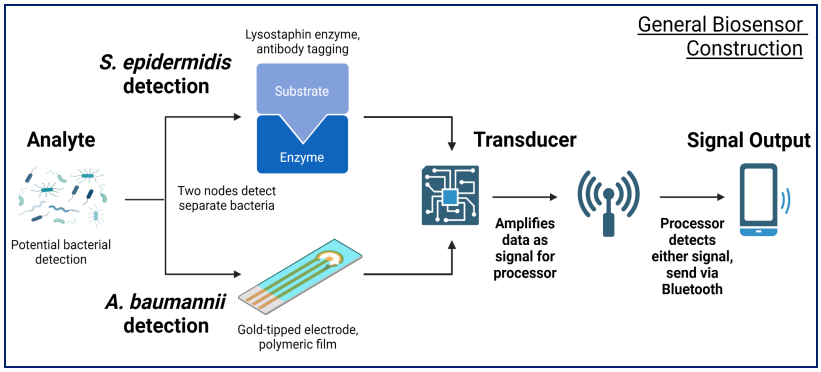


Figure 3. *BioRender illustration of electrical signal from sensor to user.*

Insertion will be the same for the two most common types of casts, synthetic and plaster. The pad of the biosensor will be placed on alcohol wiped skin. Both of the aforementioned types of casts will allow for the biosensor input port to be situated into a cut in the fabric while wrapping the stockinette fabric [31,10]. While plaster or casting tape are being wrapped, a small cut through each layer can be made and the sensor port can be pulled into place, while the pad maintains flat contact with skin [31,10]. The doctor can add an additional tape layer around the port to assure it is secured in place [31,10]. The transducer, wires, and port will be secured in a silicone covering for protection. There will be an attached silicone port cover to seal the opening, to protect from water or dust. The patient will be able to uncap the port to plug the processor device into, in order for a reading to be done. The port should not extend past the outer edge of the cast, in order to allow for ease of wear by the user.

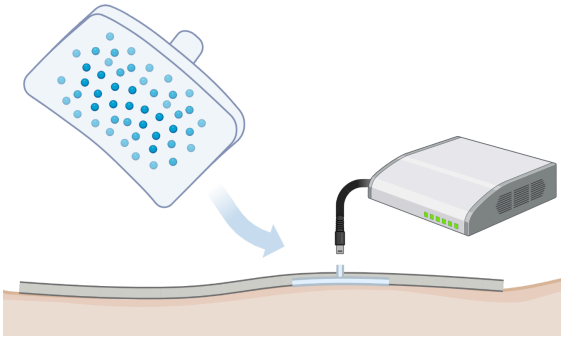


Figure 2. *BioRender depicting product in use and how the permeated pad will appear on skin.*

To construct the components of our biosensor we will have to work with a research institute such as University of California, Davis, to fine tune the construction of the MgZnO nanostructure affixed with protein tags and the polymeric film that will swell uniquely to the Ph of 8-9 [22,21,23]. Both of the aforementioned components are in the research phase by other groups and have not made it to market yet, so there is no patent conflict. For the more mechanical aspects, such as the transducer, processor, and circuits we will utilize open source hardware such as the Arduino UNO R4 WiFi that allows for data to be sent through bluetooth. The transducers we will be utilizing are the amperometric transducer for the *S. epidermidis* node to convert enzyme based input, as well as, a combination potentiometric/conductometric for the *A. baumannii* node as it is

for redox and ion selective electrodes with a conductive tip such as gold [25]. We will also hire mechanical and software engineers to fine tune the aforementioned non biological based components. Our device is designed to identify and alert patients if the pathogenic bacterias S. epidermidis and *A. baumannii* are present in their cast, to prevent significant complications associated with castings.

Intellectual Property Landscape

BioTens is insistent on developing and marketing *CastSense* within the United States, and therefore plans to submit a patent application to the USPTO. To ensure that we do not infringe on other patents currently active in the US, we carefully examined all active patents related to biosensors. Although there are currently 49,980 active patents[32] related to biosensors, the number of relevant patents is small:

Patent WO 2018/026931 A1[28], entitled "Biosensor Disease and Infection Screening" describes a wearable biosensing device that claims to screen for disease or infection presence through the detection of biomolecules in biofluid like sweat that the microbes would produce, such as proteins, nucleotides, antigens, antibodies, and more. This device is described to include presymptomatic detection as well as determination of the type of pathogen as being viral, bacterial, or fungal.

Patent US 11490852 B1[5], entitled "Wearable device for detecting microorganisms, sterilizing pathogens, and environmental monitoring" describes another wearable biosensing device consisting of a smart band and display unit; the smart band consists of three types of biosensors for microbes, particles, and the environment, as well as a computer and a power supply unit. This device claims to differentiate between beneficial microbes and pathogens and sterilize only the pathogens, as well as continuously send data to be accessible to the user via a mobile application.

Resolving Potential Infringement

Patent WO 2018/026931 A1[28] is currently pending approval and so is not active yet. Because of its inactive state, we are free to file a patent without concern about infringement.

Patent US 11490852 B1[5] describes a device that sounds similar to *CastSense* on a surface level, but differs heavily in different areas. The method of detection is not well described in this patent but can be inferred to make use of particulate matter sensors. Besides this, there are environmental sensors that measure air quality, pollen levels, ambient light, UV index, sound, etc. that are not central to the design of *CastSense*. Because of the narrow description of our device compared to this patent, we can avoid infringement.

In general, with most patents that we looked at that were related to our device, we found that there was no infringement based on the fact that they all differed in at least one of three areas: 1) the components used, 2) the method of detection, and 3) the sensor target. Because the claims of our device are quite narrow, we do not foresee infringement with many patents now or in the future, giving us confidence in our intellectual property.

Prospective Market Analysis

The potential customers for Cast Sense are those who require a fixed cast in order to treat an injury, specifically in the forearm region. This customer range alone will include around 7 million people annually in the United States[20], though globally the potential customers for our product would be approximately 178 million people via fractured bones[20].

Due to the increased risk for infection and bacteria presence in standard casts[33], our product applies to a large audience. Another specific area for potential customers would be people over the age of 50, as generally those who are older will be more likely to have weaker immune systems to fight off potential infection. Our product may also apply to children with weakened immune systems.

Our product is meant to serve as a comfortable and easily-accessible way to monitor one's health as well as decrease the amount of money spent on hospital visits. Because of this, we may also need to include doctors as potential customers in order to directly sell our product via doctor prescription and utilization.

Partners & Collaborators

The main collaborators for our product are doctors, hospitals, and insurance companies. Despite there being multiple cast types being produced, there are no current casts containing a biosensor component on the market. The Boston Children's hospital describes most common casts being made from plaster or fiberglass and occasional waterproof capabilities[33], but all lack any biosensor component that may be used for bacterial analysis. Because of this niche, doctors would be a large focus for BioTen's potential partners.

Considering the cost of hospital fees including x-rays, labs, and ER care[4], we will partner with insurance companies in order to reduce costs for patients and increase the accessibility of Cast Sense. We will also need to collaborate with manufacturing departments in order to produce the parts necessary for our biosensor and bacterial development. This includes the method of our product itself and its interactions with both *S. epidermidis* and *A. baumannii*, specifically the biochemical interactions and the use of multiple bacterial detection via multiple biosensor nodes.

Competitors

One main competitor of Cast Sense is the CastMinder system which was produced by Alex Wuff. It uses Bluetooth sensors to predict any potential problems in casts, specifically changes in pressure, moisture levels, and temperature[8]. Despite this, there is no existing patent for this product and at this point has not been developed into the market. Our biosensor within Cast Sense is made to specifically focus on bacterial analysis, which competitors in our market industry lack.

Two indirect competitors for our product are the cast brace currently being developed by Cast21, as well as 3D-Printed PLA Splints by Adam Tibor Schlegl. Cast21 focuses on breathability and water resistance through the use of a resin lattice, while Schlegl's product focuses on strengthening previous traditional casts via CaCO3. Cast21's product could potentially negate the need for Cast Sense if there were a decrease in the likelihood of general microbial growth and damage, but Schlegl's development does not directly affect our methods of bacterial measurement and determination via portable biosensors.

Market Share - estimated market analysis

The total addressable market for our biosensor technology in the U.S. annually is approximately 1.9 billion dollars per year, with a CARR of 7.5% from 2023 to 2030[7]. Globally, the wearable biosensor industry is expected to grow with a CAGR of 8.2% from 2023 to 2033[13].

Our product is expected to reach a majority of the market for when arm casts are needed, making our SAM value somewhat high. Distribution will depend on the jurisdiction of hospitals and insurance capabilities per patient, which could potentially lower or serviceable available markets. Our location being specifically in the United States may also cause challenges for distribution. Because of this, an expected max SAM value would be around 80%.

Realistically, the max SOM percentage we may obtain will be around 70-75%. There is no lack of resources in regards to bacteria recognition, biosensor components or its coding aspects. Our indirect competitor Cast21 may cause a decrease in our SOM if the product is able to circumvent bacterial growth due to breathability. However, we do not have any direct competitors and because of this our product should be able to capture a majority of the market. Assuming Cast21 does not become a direct competitor, our product should be able to capture most of the wearable biosensor cast market.

If adoption of our product is successful, the growth of Cast Sense should be significant. We will have no problems branching from the U.S. and Canadian markets, but research into existing patents will be required in order to branch out further. Previously-existing patents may potentially limit our growth rate, and regulatory approval will be necessary when considering expansion of our product. Other considerations include the amount of time and how often our casts will be needed, though this should not be a problem due to the amount of bone fractures globally[20]. Our use of wearable biosensors and comfortable bacterial detection could offer products in the future that detect bacteria and infections on differing parts of the body with more diverse analysis methods.

Regulatory Compliance Strategy

Our target jurisdiction is the United States for our initial release. Since our product is classified under medical devices we would have to go through the Food and Drug Administration[36] as the main regulatory compliance body. Additionally we would also have to consider the Environmental Protection Agency (EPA) and potentially the Federal Trade Commission (FTC) .

The FDA is responsible for ensuring the safety and efficacy of our product and it will do so via The Center for Devices and Radiological Health (CDRH) within the FDA[38]. The approval pathway that our device will take will be the 510(k) premarket notification processes which is necessary for all Class I, II, III medical devices for human use and helps to demonstrate that the device is going to be marketed as safe and effective. Under the Center for Devices and Radiological Health our product will also be under the Patient Monitoring and Control Program to ensure its safety in regards to the patients that will be using our device[40].

The pathway for the FDA will be as follows:

- 510(k) Process - a premarket notification to demonstrate the device is equivalent to legally marketed devices
- De Novo Classification - if no previous device exists we would have to submit a De Novo request to classify the device under a new pathway[39]
- Premarket Approval - we will likely need to submit a PMA application with clinical data to ensure safety and effectiveness of our device[41]

Another regulatory body that may be involved will be the EPA. For our purposes the EPA regulates the environmental effects of our biosensor and if the components we are using are safe for the environment. The oversight of this will fall under the jurisdiction of the Computer and Electronic Product Manufacturing Sector along with the biological substances being regulated under the TSCA to ensure that our product's components do not cause harm to the patient in any way.[34]

Expected Restrictions

The FDA regulates wearable sensors differently depending on if they are for wellness or medical uses. In particular since our device will be used for medical information we will have to conduct human trials to ensure safety and efficacy of our product[29]. We will also be expected to highlight the risks of using our product and any of the warnings a user would be faced with*. The EPA also addresses the different kinds of biosensors, however, there is no mention of any chemicals associated unless they pose a risk to human health which would be regulated under the TSCA[35]. Regulation and restrictions would need to be overseen by both the FDA and EPA, with broad coverage of biosensors as a general method.

Management Team

Name: Christopher Amaya Bautista

Email: csab@ucdavis.edu

Team Name: BioTens

Product Name: Cast Sense

Department: College of Agriculture and Environmental Science

Major: Biotechnology, Bioinformatics

LinkedIn: **https://www.linkedin.com/in/christopher-amaya-bautista-48389b252/**

Christopher Amaya Bautista is a fourth-year Biotechnology major at the University of California, Davis with an emphasis in Bioinformatics. They also minored in Chicana/o Studies. They are actively involved in Clinica Tepati, a student run clinic on campus, which provides free healthcare to primarily the Latine community in Sacramento but the clinic is open to everybody. They work in a dermatology lab as a lab assistant in Sacramento where they perform a variety of experiments. As a part of the BioTens team, Chris strives to use his background of competent and cultural patient care as well as their background in marketing for the product to succeed.

Skills:

Clinical Research and Testing:

-Leverage clinical experience to design and conduct research and testing protocols on patients, ensuring thorough evaluation of BioTens' efficacy, usability, and safety.

-Utilize market design strategies to identify target patient demographics and their specific needs, integrating patient feedback into product development to optimize user experience.

Market Design:

-Utilize data-driven approaches to assess market demand and pricing strategies, ensuring BioTens meets the needs of the healthcare industry while maintaining a competitive edge.

Name: Joshua Lopez

Email: jkmlopez@ucdavis.edu

Team Name: BioTens

Product Name: Cast Sense

Department: College of Agricultural and Environmental Sciences

Major: Biotechnology, Microbiology

LinkedIn: https://www.linkedin.com/in/joshua-kanoe-lopez-8182332b8/

Bio:

Joshua Lopez is a third-year Biotechnology major with an emphasis in Microbiology at the University of California Davis. He is passionate about microbial research and is interested in working as a clinical lab scientist after graduation. As a part of the Biotens team, Joshua strives to dedicate his passion for medical biotechnology and invest time to ensure the product for the project is successful.

Skills:

Market Research:

-Conduct research to find target consumers and cater to their needs in the cast as well as be up to date with trends of the market. Will analyze our competitors and any future barriers that might inhibit our product from being successful.

Regulatory Knowledge:

-Will familiarize the regulatory aspects and how it would affect the marketing of our cast as a medical device. Ensure that the claims with our marketing for the cast will comply with regulatory guidelines and not violate them.

Name: Emily Holpuch

Email: epholpuch@ucdavis.edu

Team Name: BioTens

Product Name: Cast Sense

Department: College of Agricultural and Environmental Sciences

Major: Biotechnology, Microbiology

Linkedin: www.linkedin.com/in/emily-holpuch-0a2371258

Emily Holpuch is a student at University of California Davis pursuing a bachelor's degree in Biotechnology with a focus on microbiology. She is an active member of the B-Hours Engineering club and The Davis Alt Protein Project on campus. After graduation she will be attending a Clinical Laboratory Scientist program to become licensed. In the team, Emily will utilize her interdisciplinary skills and passion for innovative medicine to help the BioTens project succeed.

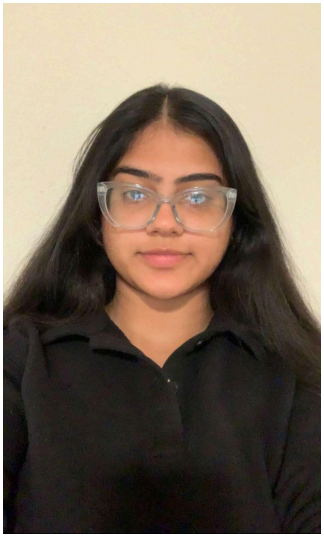
Skills:

Product Design

- Utilized my understanding of chemistry and biology to identify bacterial components adaptable for sensor identification and how the small molecule reactions will interact with the mechanical components of the sensor. Prior experience with engineering supported the design of signal conversion and processing.

Research and Testing

- Evaluation of cast application and current research for microprocessing sensors, ideal for noninvasive wearable biosensors that have high accuracy. Leading to the development of our devices structure and format for insertion.



Name: Gunica Sharma

Email: gsksharma@ucdavis.edu

Team Name: BioTens

Product Name: Cast Sense

Department: College of Agricultural and Environmental Sciences

Major: Biotechnology, Bioinformatics

LinkedIn: https://www.linkedin.com/in/gunicasharma/

Gunica Sharma is a third year undergraduate transfer student pursuing her bachelors in Biotechnology with a focus on bioinformatics and a minor in Statistics. She has done previous genetics research particularly in the rice and agricultural fields. She is also a part of the bioinnovation group and the biotechnology club. After graduation she plans to pursue her PhD in computational biology. As part of the BioTens group she can contribute her diverse knowledge and prior experience to develop a new and innovative product.

Skills:

Product design

- Experienced in product design and development with experience to excel in combining concepts with tangible designs that merge to create a viable product. Knowledgeable in the process of designing a biosensor and the different components

Regulatory Compliance

- knowledged in the different rules and regulations our product will have to adhere to when it comes time to release. Can navigate through FDA approvals and regulations such as the 501(k) pathway. These skills are critical in order to have a safe and marketable product.

Name: Kiana Kalman

Email: kmkalman@ucdavis.edu

Team Name: BioTens

Product Name: Cast Sense

Department: College of Agricultural and Environmental Sciences

Major: Biotechnology, Plant

LinkedIn: https://www.linkedin.com/in/kiana-kalman-b7053b297/

Kiana Kalman is a third-year transfer student majoring in Biotechnology with a focus on Plant Biotechnology at the University of California Davis. She has previously participated in multiple biotechnology fields, including the BIG-RT BioInnovation Group as well as the Biotechnology club at UC Davis. She is interested in the agricultural and medical applications of biotech and hopes to use this interest to further strengthen the BioTens group project.

Skills:

Market Prediction

- Understanding of components and competitors present in products' markets. Can make educated predictions via provided market information regarding product, competitors, and market growth. Able to understand and express data analysis for optimized outcome of cast product.

Lab Testing

- Through previous lab work and experiment building, experienced in physical testing of products. Able to design tests for products accurately and efficiently. Ability to gather data from experiments for data analysis and development, using data to express results in an easy to understand way.

Name: Julie Nguyen

Email: junguy@ucdavis.edu

Team Name: BioTens

Product Name: Cast Sense

Department: College of Agricultural and Environmental Sciences

Biotechnology

Major: Biotechnology, Microbiology/Fermentation

LinkedIn: https://www.linkedin.com/in/julie-nguyen-998b53257/

Julie is a third-year Biotechnology Major at the University of California Davis. She previously studied at Evergreen Valley College where she demonstrated flexibility as a co-leader of a project examining the distribution of *Orthorhyncus cristatus* in the Caribbean islands. As a team member of BioTens, Julie has dedicated her technical skills in creating an innovative and serviceable product as both an intellectual property analyst and graphic designer.

Skills:

Intellectual Property Analysis

- Extracted and examined patents related to *Cast Sense*, achieving a better understanding of competitor devices currently on the market. Employed critical thinking to evaluate risks or weaknesses in an IP.

Graphic Design

- Contributed to visual concepts used to market and advertise *Cast Sense.* Designed the overall theme and layout for the presentation pitch and created an illustration of the product in vivo.

References

1. Amin, S., Achenbach, S.J., Atkinson, E.J., Khosla, S., Melton, L.J., 2014. Trends in fracture incidence: a population-based study over 20 years. J Bone Miner Res 29, 581–589. https://doi.org/10.1002/jbmr.2072
2. Arduino® UNO R4 WiFi [WWW Document], n.d. . Arduino Online Shop. URL https://store-usa.arduino.cc/products/uno-r4-wifi (accessed 6.13.24).
3. Armalytė, J., Čepauskas, A., Šakalytė, G., Martinkus, J., Skerniškytė, J., Martens, C., Sužiedėlienė, E., Garcia-Pino, A., Jurėnas, D., 2023. A polyamine acetyltransferase regulates the motility and biofilm formation of Acinetobacter baumannii. Nat Commun 14, 3531. https://doi.org/10.1038/s41467-023-39316-5
4. Average Cost of a Broken Bone | Chicago Personal Injury Attorneys [WWW Document], n.d. URL https://www.curcio-law.com/blog/average-cost-of-a-broken-bone/ (accessed 6.13.24).
5. B, Kurani Hemal, and Kurani Hetal B. Wearable Device For Detecting Microorganisms, Sterilizing Pathogens, And Environmental Monitoring. US 11490852 B1, 8 Nov. 2022, https://lens.org/072-571-177-559-602.
6. Banerjee, Rahul. "Cast Types and Care Instructions." University of Rochester, 2024. URL www.urmc.rochester.edu/encyclopedia/content.aspx?contenttypeid=90&contentid=P02750.
7. Biosensors Market Size, Share, Trends, Analysis and - Industry Growth | 2031 [WWW Document], n.d. URL https://www.skyquestt.com/report/biosensors-market (accessed 6.13.24).
8. CastMinder - Smart Cast Monitoring [WWW Document], n.d. URL https://www.alexwulff.com/CastMinder/ (accessed 6.13.24).
9. Coughlan, T., Dockery, F., 2014. Osteoporosis and fracture risk in older people. Clin Med (Lond) 14, 187–191. https://doi.org/10.7861/clinmedicine.14-2-187
10. Delta-Cast. Plaster of Paris Long Arm/Elbow Circular Cast Application. 2014. YouTube, https://www.youtube.com/watch?v=4w76zbUHH-g.
11. Development, O. of R.&, n.d. BIOSENSORS RESEARCH FOR DEVELOPMENT OF INNOVATIVE MONITORING TECHNIQUES THAT SUPPORT EXPOSURE ASSESSMENT RELATED TO THE SUPERFUND PROGRAM [WWW Document]. URL

https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=56147&Lab=NERL (accessed 6.13.24).

12. GBD 2019 Fracture Collaborators. “Global, regional, and national burden of bone fractures in 204 countries and territories, 1990-2019: a systematic analysis from the Global Burden of Disease Study 2019.” *The lancet. Healthy longevity* vol. 2,9 (2021): e580-e592. doi:10.1016/S2666-7568(21)00172-0
13. Global Market Study on Wearable Biosensors: Application in Healthcare and Environment Monitoring to Remain Prominent [WWW Document], n.d. . Persistence Market Research. URL https://www.persistencemarketresearch.com/market-research/wearable-biosensors-market.asp (accessed 6.13.24).
14. Health, C. for D. and R., 2024. Center for Devices and Radiological Health [WWW Document]. FDA. URL https://www.fda.gov/about-fda/fda-organization/center-devices-and-radiological-health (accessed 6.13.24).
15. Health, C. for D. and R., 2023a. De Novo Classification Request. FDA.
16. Health, C. for D. and R., 2023b. How to Determine if Your Product is a Medical Device. FDA.
17. Health, C. for D. and R., 2023c. Premarket Approval (PMA) [WWW Document]. FDA. URL https://www.fda.gov/medical-devices/premarket-submissions-selecting-and-preparing-correct-submission/premarket-approval-pma (accessed 6.13.24).
18. Health, C. for D. and R., 2023d. Premarket Notification 510(k) [WWW Document]. FDA. URL https://www.fda.gov/medical-devices/premarket-submissions-selecting-and-preparing-correct-submission/premarket-notification-510k (accessed 6.13.24).
19. Health, C. for D. and R., 2021. Patient Monitoring and Control Program: Research on Patient Monitoring and Control Devices. FDA.
20. Justia. (2024). Patents Assigned to QTL Biosystems, LLC. Patents Assigned to QTL Biosystems, LLC - Justia Patents Search.
21. Lakard, B., Herlem, G., de Labachelerie, M., Daniau, W., Martin, G., Jeannot, J.-C., Robert, L., Fahys, B., 2004. Miniaturized pH biosensors based on electrochemically modified electrodes with biocompatible polymers. Biosensors and Bioelectronics 19, 595–606. https://doi.org/10.1016/S0956-5663(03)00270-7

22. Li, G., 2021. Magnesium zinc oxide dual gate thin film transistor-based biosensor for monitoring the biofilm formation. Rutgers University - School of Graduate Studies. https://doi.org/10.7282/t3-t5t8-4e40
23. Li, J., Wang, J.-L., Zhang, W.-L., Tu, Z., Cai, X.-F., Wang, Y.-W., Gan, C.-Y., Deng, H.-J., Cui, J., Shu, Z.-C., Long, Q.-X., Chen, J., Tang, N., Hu, X., Huang, A.-L., Hu, J.-L., 2022. Protein sensors combining both on-and-off model for antibody homogeneous assay. Biosensors and Bioelectronics 209, 114226. https://doi.org/10.1016/j.bios.2022.114226
24. McGuffie, M.J., Hong, J., Bahng, J.H., Glynos, E., Green, P.F., Kotov, N.A., Younger, J.G., VanEpps, J.S., 2016. Zinc Oxide Nanoparticle Suspensions and Layer-By-Layer Coatings Inhibit Staphylococcal Growth. Nanomedicine 12, 33–42. https://doi.org/10.1016/j.nano.2015.10.002
25. Murugaiyan, S., Ramasamy, R., Gopal, N., Velu, K., 2014. Biosensors in clinical chemistry: An overview. Advanced biomedical research 3, 67. https://doi.org/10.4103/2277-9175.125848
26. Namvar, A.E., Bastarahang, S., Abbasi, N., Ghehi, G.S., Farhadbakhtiarian, S., Arezi, P., Hosseini, M., Baravati, S.Z., Jokar, Z., Chermahin, S.G., 2014. Clinical characteristics of Staphylococcus epidermidis: a systematic review. GMS Hyg Infect Control 9, Doc23. https://doi.org/10.3205/dgkh000243
27. Parameswaranpillai, J., Ganguly, S., 2023. 1 - Introduction to polymer composite-based sensors, in: Parameswaranpillai, J., Ganguly, S. (Eds.), Polymeric Nanocomposite Materials for Sensor Applications, Woodhead Publishing Series in Composites Science and Engineering. Woodhead Publishing, pp. 1–21. https://doi.org/10.1016/B978-0-323-98830-8.00006-0
28. Robert, Beech, et al. Biosensor Disease And Infection Screening. WO 2018/026931 A1, 8 Feb. 2018, https://lens.org/096-632-345-802-059.
29. Scheid, J.L., Reed, J.L., West, S.L., 2023. Commentary: Is Wearable Fitness Technology a Medically Approved Device? Yes and No. International Journal of Environmental Research and Public Health 20, 6230. https://doi.org/10.3390/ijerph20136230
30. Sharma, A. AND K. Rogers. BIOSENSORS. U.S. Environmental Protection Agency, Washington, D.C., EPA/600/J-95/318.
31. Synthetic Casting Short Leg application_EN_by BSN Medical.Mov. 2012. YouTube, https://www.youtube.com/watch?v=VYB6FBSN8gw.

32. The Lens - Free & Open Patent and Scholarly Search [WWW Document], n.d. . The Lens - Free & Open Patent and Scholarly Search. URL https://www.lens.org/lens (accessed 6.13.24).
33. Types of Casts | Boston Children's Hospital [WWW Document], n.d. URL https://www.childrenshospital.org/treatments/types-casts (accessed 6.13.24).
34. U.S. Environmental Protection Agency. (2002). Biomarkers: Clarification of use, measurement, and application. National Exposure Research Laboratory. Retrieved from https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=56147&Lab=NERL
35. U.S. Environmental Protection Agency. (2004). Biosensors (EPA/600/R-04/039). Office of Research and Development. Retrieved from https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=ORD&dirEntryID=49230
36. U.S. Food and Drug Administration. (2021). How to determine if your product is a medical device. Retrieved from https://www.fda.gov/medical-devices/classify-your-medical-device/how-determine-if-your-product-medical-device
37. U.S. Food and Drug Administration. (2022). Premarket notification 510(k). Retrieved from https://www.fda.gov/medical-devices/premarket-submissions-selecting-and-preparing-correct-submission/premarket-notification-510k
38. U.S. Food and Drug Administration. (2023). Center for Devices and Radiological Health. Retrieved from https://www.fda.gov/about-fda/fda-organization/center-devices-and-radiological-health
39. U.S. Food and Drug Administration. (2023). De novo classification request. Retrieved from https://www.fda.gov/medical-devices/premarket-submissions-selecting-and-preparing-correct-submission/de-novo-classification-request
40. U.S. Food and Drug Administration. (2023). Patient monitoring and control program: Research on patient monitoring and control devices. Retrieved from https://www.fda.gov/medical-devices/medical-device-regulatory-science-research-programs-conducted-osel/patient-monitoring-and-control-program-research-patient-monitoring-and-control-devices
41. U.S. Food and Drug Administration. (2023). Premarket approval (PMA). Retrieved from https://www.fda.gov/medical-devices/premarket-submissions-selecting-and-preparing-correct-submission/premarket-approval-pma

42. Walker, B., Amato, C., Palyvoda, O., Vangipuram, S., Weaver, M., Sayeed, Z., Talha Padela, M., Yassir, W.K., 2020. Prevalence of Bacterial Contamination of Casting Material in a Pediatric Population. International Journal of Pediatrics 2020, 4717385. https://doi.org/10.1155/2020/4717385