To: Dr. Susan Freeman

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Date: October 21, 2018

Subject: Hybrid Biomembrane–Functionalized Nanorobots for Removal of Pathogenic Bacteria and Toxins

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**Introduction**

The topic of this research is one of the most advanced modern nanobots. It was created in the department of nanoengineering, university of California San Diego. The original paper’s title is “Hybrid Biomembrane–Functionalized Nanorobots for Removal of Pathogenic Bacteria and Toxins”. It was published in Science Robotics journal (1). The team created nanobots with one purpose- to resist the arraised bacterial thread. Antibiotic resistance became one of the biggest public health challenges of our time. Researches choose one of the growing threads to defeat - Methicillin-resistant Staphylococcus aureus . Developed bots are supersmall, kill bacteria, and capture the toxins in your bloodstream. The team used properties of both platelets and red blood cell membranes to accomplish the task. Platelets membrane proteins are binding to bacterias bodies, capturing them, while red blood cell membrane proteins are bonded to toxins produced by the bacteria. Best of all nanobots are not a concept idea. First experiments with newly developed machines were already conducted and showed promising results.

**Development of Cell Membrane Onto the NanoRobot**

Each cell membrane has a function and can be disease targeting. This nanorobot is special because it fuses two membranes to create a variety of proteins and biological functions. They extract the membranes from platelets(PL), which bind pathogens bacteria and red blood cells (RBC), which neutralize the toxins produced by these bacteria.

The nanorobot is made with the basis of gold nanowire. It is because red blood cells measure about 7 micrometers and the wire is small, it can pierce a biological cell to stimulate the cell membrane and investigate its interior. Developing the cell membrane onto the gold nanowire first requires developing a template synthesis through a process called Electrochemical deposition protocol. This process involves two electrodes, and anode and cathode -one containing the polycarbonate membrane- inside a solution of gold ions and when electricity is produced in the solution the gold ions are plated it onto a polycarbonate membrane. This is the basis the membranes are going to be fused onto. Then the cell membranes from RBC and PL are extracted through a process called cell lysis and are fused to the template through a 5 minute ultrasonication and high surface tension energy through a process called “Dual cell membrane cloaking technique”(1). The resulting size has a diameter of 400 nanometers and a length of 1 to 2.5 micrometers.

**Movement**

This device moves through ultrasound rather than mechanical forces. Compared to mechanical forces, these devices moved by ultrasound “produce a 2.4-fold lower rupture of red blood cells and a 3.5-fold increase in bacteria binding”(1). Doctors move these nanorobots through ultrasound in the body by beaming ultrasonic signals into the body. The signals pass through the body and reflect back to the source of the signals. Using ultrasonic sensors, doctors keep track of the nanorobots location and maneuver it to the right part of the body.

Experiments were performed comparing the movements of a bare robot without the membranes through blood and a nanorobot with cell membranes movement through blood. Results display that bare robots were 10 nanometers per second creating protein fouling and biofouling -the damage of red blood cells-. Robots containing the RBC and PL membranes mimicked the movement of natural motile cells to the point that there was no biofouling whatsoever.

**Conclusion**

Nanobots function by latching onto bacteria and killing. These bots can be used widely in medicine, but their main purpose will most likely be combating bacteria without causing antibiotic resistance. Once they can be widely produced, these will be much more cost effective and less time consuming than other treatments

**Citations**

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**Roshinie Persaud - Reflection**

This research project was a fun, creative, and innovative experience. The hardest part I would have to say is deciding what type of robot we wanted to pursue in researching because we wanted to find a robot we would all be interested in. Because the topic of biomedical nanorobots was found to be intriguing by all three of us, this made the research process much more smoother and fun. Diving the work amongst each other was not a problem for we all chose a field in within the nanorobot that we found personally interesting and because this robot consisted of so much research content no one was left out when it came to working. Oleks was in charge of research of the background as to the necessities of creating this robot by providing information on disease that are growing stronger than vaccines and was also in charge of the introduction. This worked out perfectly because he is a bioengineer/premed student so this suited his interests. I myself was in charge of researching the development of the cell membrane onto the nanorobot and the creation and movement of the nanorobot which I found intriguing myself being a bioeningeering major as well. Gemma was in charge of researching how these nanorobots work in terms of constraints and how they can be improved as well as the conclusion.

Overall research and development was executed smoothly however we can improve on meeting times in terms of increasing the amount of times we meet and sticking to our planned schedule in the contract, however I understand because sometimes we all have different evens, work schedules, and homework loads. I think our strength throughout this process has been our work ethic and communication skills for when it comes to decision making we are all very open minded and accepting of others thoughts and we hardly ever disagree. In terms of presentation I believe we can improve on how much time we spent practicing and maybe not procrastinate as much however I think our delivery content wise and execution wise in terms of visuals, appearance, and vocal execution of the content was great because we were all confident in one anothers information and supportive of each other when we presented. I think the audience responded well and understood what we were saying because we had a good flow and execution of ideas. Especially when it came to biomedical information it is very complex and hard to explain these concepts. I think we did a great job of summarizing these ideas but executing our points in simplistic terms very well. During the presentation I think we could have possibly improved on using less filler words such as “like, um, uh etc.”.

This research process has taught me a lot in terms of teamwork, collaboration, and patience. I realized the importance of being open minded and time management especially with everyone's busy schedule. Overall I think we are a dream team because we collaborate so well and the best part is we had fun with this project with lots of laughter and smiles. This project with my team was overall perfect because we are a dream team.

**Oleksandr Litus - Reflection**

The research project in general turned out to be a great success. I learned a lot about the modern technologies from the research and about the workflow from other members of my group. Each of us contributed something special towards the end goal. Teamwork turned out to be easier than I expected, because of the interest every person found in the project. I was fascinated by the technological and biological background for the bots. I answered questions like: Why do we need them? What problem do they solve? What other solutions are out there? And it went well, because I was interested in the topic of “superbugs” before the assignment. As a result, I did not simply completed the task, I learned more in my future field of work. Same goes for Roshinie and Gemma. They took parts of great interest to them and did a great job of discussing and showing it to the people. I would not be able to finish the presentation and analysis of the research in such a small scope of the time without their contribution. Our workflow was agile and as some issues were found on the way (for example we did not describe the experiment conducted by the researchers) we dealt with them fast and efficiently by dividing the work and helping each other out.

I believe our presentation went phenomenal for the amount of time we were actually practicing the performance. The response from our peers was great and lots of question were addressed to me after the class about the research. Given more time we definitely could have improved the visual content of the slides. Additionally, we could have met couple times on the weekend instead of preset time to practice more.

As for the general improvements, I think we can create a faster communication flow, as sometimes, when we are not on the meeting, it takes up to 4-5 hours for everyone to get the message and agree on the actions. Otherwise, our experience of working in a team was great and productive. I would love to work more with my teammates.

**Gemma Bruce - Reflection**

The research process was a new concept for me, because I never did research that was this intense in high school. Using the resources we learned about in the library research session was very helpful in finding reliable articles. When we compiled the research into a presentation, it was a little unorganized at first. I think it would have been easier to organize our research, then put it into a powerpoint, but we created the powerpoint before we had a solid idea of exactly how we were going to present it. Once we had clear responsibilities on what topics each of us had to cover, the presentation preparation went much more smoothly. The topics I was responsible for were the actual mechanisms of the nanobots and its medical applications. When it came to presentation day, I felt that we were very prepared. We had all rehearsed our parts together and individually. I think it went very well and I felt that each group member held their own weight. One thing we could improve on would be smoother transitions. While I don’t think there was any awkward silence or flustered moments, we could have saved some time by switching from one group member to another a little more quickly.