**Background**

**Slide 1 - Introduction (Oleks)**

Today we going to talk about one of the most advanced modern nanobots. It was created in the department of nanoengineering, university of California San Diego. The original paper was published in Science Robotics journal. You can see the names of the researchers and a full title of their work in the slide. Nanobots were created with one purpose in mind - to resist the arraised bacterial thread. It is supersmall, kills bacteria, and captures the toxins right in your bloodstream. Best of all is not just a concept. First experiments with newly developed machines were already conducted and showed promising results. Let me give you some background in the bacterial problem to understand the importance of the innovation.

**Slide 2 - “Superbug” (Oleks)**

Antibiotics were first used to treat serious infections in the 1940s. Since then, antibiotics have saved millions of lives and transformed modern medicine. During the last 70 years, however, bacteria have shown the ability to become resistant to every antibiotic that has been developed. And the more antibiotics are used, the more quickly bacteria develop resistance.

In addition to this the number of new antibiotics developed and approved has steadily decreased over the past three decades, leaving fewer options to treat resistant bacteria. As a result researchers are trying to find new ways to kill bacteria.

//Antibiotics are a limited resource. The more that antibiotics are used today, the less likely they will still be effective in the future.

//The total economic cost of antibiotic resistance to the U.S. economy has been difficult to calculate. Estimates vary but have ranged as high as $20 billion in excess direct health care costs, with additional costs to society for lost productivity as high as $35 billion a year (2008 dollars).

**Citations:**

<https://www.cdc.gov/drugresistance/threat-report-2013/pdf/ar-threats-2013-508.pdf>

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4378521/>

**Slide 3 - “Superbug” Examples (Oleks)**

Antibiotic resistance became one of the biggest public health challenges of our time. In 2013, CDC published a comprehensive analysis outlining the top 18 antibiotic-resistant threats in the U.S.

Methicillin-resistant Staphylococcus aureus (MRSA) causes a range of illnesses, from the skin and wound infections to pneumonia and bloodstream infections that can cause sepsis and death. Staph bacteria, including MRSA, are one of the most common causes of healthcare-associated infections. Staph bacteria was targeted by the creators of nanobots.

Citations:

<https://www.cdc.gov/drugresistance/biggest_threats.html>

<https://www.cdc.gov/drugresistance/threat-report-2013/pdf/ar-threats-2013-508.pdf>

**Slide 4 - Bacteria and Platelet (Oleks)**

Growing evidence suggests that platelets, in addition to slowing bleeding, contribute to protection against infection. In addition to expressing many receptors important to combating pathogens, platelets have been shown to aggregate with and kill bacteria in vitro.

//Scientists found that in the livers of mice, platelets collaborated with specialized white blood cells to capture and engulf blood-borne bacteria, and this interaction helped protect the animals from bacterial infection.

Platelet Toll-like receptor (TLR) expression enables activated platelets to bind and capture bacteria. Subsequently, the platelets may directly kill the bacteria by producing thrombocytes or by aggregating around the bacteria and “trapping” them for elimination by professional phagocytes. The same strategy you will see was used in nanobots to capture bacteria.

Citations:

<http://www.bloodjournal.org/content/127/24/2947?sso-checked=true>

<https://weareblood.org/blog/platelets/>

<https://www.nature.com/articles/nm0407-403/figures/1>

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4341565/>

**Slide 5 - Toxins (Oleks)**

Let’s talk about toxins, the main thread created by bacteria are not their bodies, but deadly proteins they release into the environment, that kill cells and decreases human body activity. One of the first targets for toxins released by the bacterias are red blood cells. Their membrane protein is targeted by the toxic molecules and create “holes” in them. Such process results in high damaged cells, that are not able to properly transfer oxygen, as a result, human start feeling thickness, and in severe cases causes death. This targetness of the red cell membrane was used by researchers to capture toxins using the nanobots. Now let’s see how bots were created.

Citations:

<https://www.ncbi.nlm.nih.gov/pubmed/3281562>

**Technology Behind**

**Slide 6 - Approach-Replicating Cell Membrane (Roshinie)**

The approach for creating this technology involves using single cell membranes to coat the nanodevices and mimic the functions and properties of the source sells and bear unique functions. Each cell membrane depending on the cell has a function and can be disease targeting.

* For instance, lipid membranes separate and filter the inner contents of the cell from outside forces and is a protection barrier
* These functions can also be disease-relevant targeting ability.
* New Experiment and development of fusing two membranes to create a variety of functional proteins and multifaceted biological functions.
  + Platelets, which bind pathogens bacteria and red blood cells, which absorb and neutralize the toxins produced by these bacteria.

Citations:

<http://robotics.sciencemag.org/content/3/18/eaat0485>

**Slide 7 - Developing Cell Membrane (Roshinie)**

The NanoRobot is made with the basis of gold nanowire

* It is a model of a fuel-free robot with potential biomedical applications”
* Why AuNW? Well, I'll tell you! red blood cells measure about 7 micrometers. Because the wire is so small, it can pierce a biological cell to stimulate the cell membrane and investigate its interior

Electrochemical deposition protocol

* This approach ‘template synthesis’ because the pores within these nanoporous membranes act as templates for the synthesis of nanostructures of the desired material. It’s like setting up the tree before putting the ornaments on
* Electrochemical deposition works because Two electrodes, an anode, and a cathode, are dipped into an electrolytic solution. When electricity is run through the electrodes and the electrolyte, oxidation, and reduction occur. The flow of ions through the electrolyte onto one of the electrodes causes the electrochemical deposition to occur.
* Gold deposition within the nanopores of a polycarbonate membrane, followed by the membrane dissolution and release of the resulting AuNWs. The surface of the AuNWs modified with 3-mercaptopropionic acid before membrane coating
* Dual–cell membrane–cloaking technique fusion of the RBC and PL membranes -during a 5-min ultrasonication. The resulting RBC-PL-vesicles, having diverse biological capabilities, were mixed with the MPA-modified AuNWs under ultrasonication for 5 min and due to high surface tension energy were prone to bind with it

Citations:

<http://robotics.sciencemag.org/content/3/18/eaat0485>

**Slide 8 - Resulting Size (Roshinie)**

Don’t read off the slide but display pictures and what you mean

Citations:

<http://robotics.sciencemag.org/content/3/18/eaat0485>

**Slide 9 - Movement (Roshinie)**

Ultrasound

* Not only is it a device with multiple functions due to the hybrid membrane that detoxifies RBC and moves around with targets but it does not need any other external mechanical forces
* Produced a synergistic effect of enhancing mass transport
* “Samples treated with acoustically-propelled robots produce a 2.4-fold lower rupture of red blood cells and a 3.5-fold increase in bacteria binding, compared with static nanorobots.”
* “A 4.5 times lower hemolysis was found when using US-propelled RBC-PL-robots compared with the use of the RBC-PL-robots under static conditions”

Blood vs. bare robot

* The bare robots displayed notable hindered propulsion, with a greatly diminished speed of ~10 μm s−1, nearly independent of the incubation time “(right after mixing and after 1-hour incubation in the blood)” This hindered movement reflects severe protein fouling of the robots
* Define what biofouling is “ “

Blood vs Robot with RBC-PL membranes

* No biofouling, and mimicked
* The protein profile of the coated robots closely matched that of the hybrid membranes, indicating that the RBC-PL membranes can be translocated onto the nanorobot surface without altering their protein profile.

Citations:

<http://robotics.sciencemag.org/content/3/18/eaat0485>

**Discussion**

**Slide 10 - How do they work? (Gemma)**

Nanobots are able to attach to bad things in the bloodstream. By disguising themselves simultaneously as red blood cells and platelets, these bots can attack both individual bacteria and the toxins released by that bacteria. This image shows a nanobot attacking an MRSA bacteria, which is something a red blood cell would do. It can also attack the toxins associated with MRSA like a platelet.

Citations:

<http://robotics.sciencemag.org/content/3/18/eaat0485>

**Slide 11 - Potential Problems (Gemma)**

Nanobots can become victim to something called protein adherence, sometimes referred to as biofouling. This is when proteins attach to the surface of the nanobot, which can hinder its performance and slow it down.

As with most medical advancements, there are ethical questions about the use of nanorobots in the human body. Many people are uncomfortable with the idea of robots in their body long term, though over time these bots may become as commonly used as antibiotics.

Citations:

<http://robotics.sciencemag.org/content/3/18/eaat0485>

<https://www.nature.com/articles/nm0407-403/figures/1>

**Slide 12 - Nanobots in Medicine (Gemma)**

Medical nanobots can be used in a variety of ways, including delivering drugs and taking tissue samples, or “biopsies.”

As nanobots become smaller and more easily integrated into the human body they become better at these tasks. This is best accomplished by their membrane coating.

Citations:

<https://spectrum.ieee.org/the-human-os/biomedical/devices/squishy-clockwork-biobot-could-dose-you-with-drugs-from-the-inside>

<https://spectrum.ieee.org/the-human-os/biomedical/devices/magnetic-field-controls-drug-delivery>

<https://onlinelibrary.wiley.com/doi/full/10.1002/adbi.201700160>

**Slide 13 - Future Applications (Gemma)**

Medical robots used in human bodies is nothing new, but before nanobots, most were intrusive and served one purpose. Whether it was to deliver medicine, take a sample, or capture an image, these robots did their job and were done, soon to be rejected by the body.

Nanobots are different because they can camouflage themselves. By mimicking a cell and a platelet, they integrate themselves into the bloodstream and can stay long term, without interrupting the body’s natural functioning.

As was mentioned earlier, antibiotic-resistant bacteria are becoming a problem and nanobots could be a solution by killing bacteria without the use of antibiotics.

Most experiments using nanobots so far has been done on MRSA, but these results could be expanded to a number of bacterial infections, such as strep infections.