Argonne NATIONAL LABORATORY

ARGONNE ACT-SO HIGH SCHOOL RESEARCH PROGRAM (ARP)

NOVEMBER 7, 2020

ARGONNE: A NEXUS FOR SCIENCE AND ENGINEERING

PEOPLE

Workforce

>1590 scientists and engineers, including 274 joint faculty and 273 post-docs

569 students:160 grad and 409 undergrad

>1100 visiting scientists

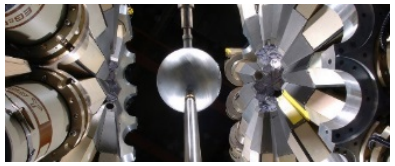
> 8300 users of our major facilities

MAJOR USER FACILITIES

Advanced Photon Source

Argonne Leadership Computing Facility

Center for Nanoscale Materials



Argonne Tandem Linear Accelerator System

Atmospheric Radiation Measurement Southern Great Plains Site

ARGONNE'S SCIENCE AND TECHNOLOGY STRATEGY

Hard x-ray sciences

An upgraded APS to revolutionize knowledge of materials' structures and propel progress in science, medicine and technology

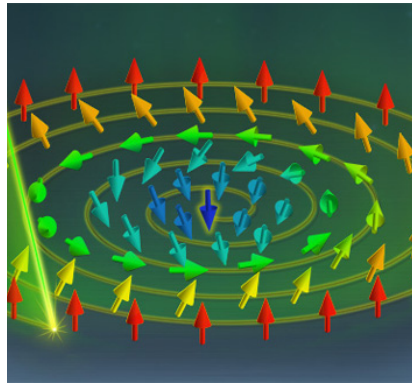
Advanced computing

The most powerful supercomputers, to overcome the biggest challenges in energy, materials, climate, cancer and more

Universe as our laboratory

Pioneering techniques to simulate the universe and detect elementary particles, to unlock mysteries of the cosmos

Materials and chemistry



Unprecedented ability to manipulate matter to optimize advanced batteries, catalysts, quantum materials and clean water systems

Manufacturing science and engineering

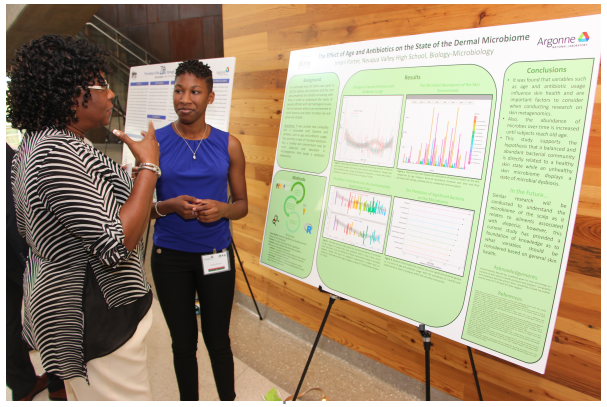
Breakthroughs to boost American industrial success in producing innovative materials for energy technologies of the future

ARGONNE ACT-SO MISSION

Mission To provide one-on-one research opportunities for minority high school students across the Chicagoland area

Tools We leverage the educational labs, user facilities and external collaborators to instruct students in an array of disciplines

People Through volunteer efforts from postdoctoral and staff scientists, we focus on theoretical, experimental, and computational science



Argonne NATIONAL LABORATORY

ARGONNE ACTSO BY THE NUMBERS (FY20)

7

PROGRAM DURATION

200+

NUMBER OF STUDENTS

150+

NUMBER OF MENTORS

100+

LOCAL MEDALIST

30+

NATIONAL MEDALIST

90%

STUDENTS AT 4-YEAR INSTITUTIONS

WHAT IS ARGONNE ACT-SO

An enrichment program (run and staffed by volunteers) designed to recruit, stimulate, improve and encourage high academic achievement within STEM in collaboration with DuPage County ACT-SO

- Biology/Microbiology
- Medicine & Health
- Computer Science
- Earth & Space Science
- Physics
- Engineering
- Mathematics
- Architecture*

PROGRAM STRUCTURE

Argonne Meeting

- Monthly meetings
- Career speakers from minority leaders in STEM
- Student workshops for research skill development
- Facilitate student-mentor engagement

DuPage Meeting

- College-readiness development
- Professional skill development
- Career speakers
- Student fellowship and outreach

Mentor Meeting

- Meeting at mentor's discretion (weekly/biweekly)
- Instruction and assignment based (formal/informal)
- Point-of-contact for research project

ACT-SO TIMELINE

November 2020 – April 2021 (Nationals in July)

November 7th – Student/Mentor Pairing

December 5th – Coding Workshop (CEPA)

January 9th – Project Planning

February 6th – Data Collection & Analysis

March 6th – First Draft

April 3rd – Finalized Paper and Poster

- **Note**: If virtual, poster will be a power point presentation

STUDENT EXPECTATION

Communication is essential!

1. All meetings are mandatory
2. You are expected to lead your research project

   Note: Your mentor is your personal guide/resource

3. **<u>Check emails daily (and respond within the same day)</u>**
4. Expect to spend 2-4hr/wk
5. If you are unsure, ask questions.

   Note: There is nothing wrong with not knowing.

PROGRAM COMMUNICATION

ACTSO@anl.gov

- All email communications between mentor and student must have a parent and Argonne co-chairs (actso@anl.gov) on it.

- Slack will be utilized for daily communications and updates
  - Channels have been set up for mentors, parents, and students
  - [Slack link]

- Materials for Saturday meetings will be made publicly available on Indico
  - Link will be provided by DuPage

MENTOR BREAKOUT

Argonne NATIONAL LABORATORY

MENTOR EXPECTATIONS

ACTSO@anl.gov

- Students come with an array of experience
  - From never doing research to building their own plasma beams
  - Traditionally students need help with literature search, scientific writing, and this year coding
- Students will not be allowed on site in any capacity
  - Field sites and virtual experiments are possible (we have to be creative)
- Expectation is a project comparable to SULI
- Mentor resource guide will be distributed to give frame of reference

Investigation of Pneumococcal Induced Hemolysis of Artificially Sickled Red Blood Cells

Allyson Amegashie Neuqua Valley High School, DuPage ACT-SO County 3012 Mentor: Nicole Inniss, Medicine and Health

BACKGROUND

Sickle Cell Anemia and Pneumonia

Streptococcus pneumoniae (Pneumococcus) is a bacterium that asymptomatically colonizes humans by binding to the upper respiratory tract because of its highly nutritious mucosal layer. It is the leading cause of bacterial meningitis and pneumonia.[1] An important group at risk for infection are sickle cell anemia (SCA) patients. The disease is most commonly found in individuals of African, Indian, and Middle Eastern descent.[2] It is the splenic sequestration many patients face which weakens their immune system.[3] The results from this study showed that when differing amounts of $Na_2S_2O_5$ were added to test tubes containing red blood cells (RBCs), the cell's stability decreased. Test tubes in which 0.02% and 0.002% $Na_2S_2O_5$ were present had the fastest and slowest decrease in absorbance respectively. The test tube with 0.01% had the steadiest decrease in absorbance with a slope of -0.03 over the incubation period. Because this concentration showed graphical and visual results symbolic of sickle cell, this concentration was chosen as an influence for this experiment to test the effects $Na_2S_2O_5$ has on pneumococcal growth. When infecting RBCs, the pneumococcus produces hydrogen peroxide to damage RBCs in a type of lysis called alpha-hemolysis. In this study we are looking to identify this form of hemolysis by the greenish halo that surround the nuclei of the pneumo colonies.

PURPOSE

Like previously stated, SCA patients suffer from decreased splenic function which in term weakens their immune systems. The purpose of conducting this study is to be able to identify whether alpha-hemolysis induced by the pneumococcus has the ability to successfully infect blood agar "SCA models" that would represent the population SCA patients.

HYPOTHESIS

Previous research indicates that SCA patients are more likely to suffer from invasive pneumococcal diseases. We hypothesized that if blood agar plates were treated with $Na_2S_2O_5$ then RBCs would be more susceptible to lysis by pneumococci, leading to increased hemolysis (possibly β-hemolysis).

Normal and Sickled Red Blood Cell Morphology

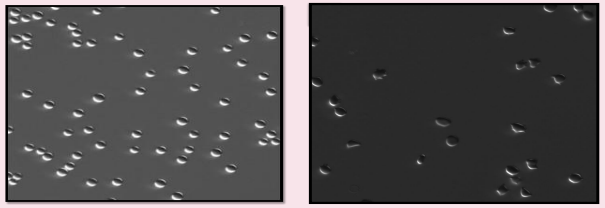


Figure 1. Microscope images of RBCs. Left Wild type RBCs are imaged under a light microscope. **Right** Sickled RBCs treated with $Na_2S_2O_5$ are pictured under a microscope.

Blood Agar Plates With Hemolysis

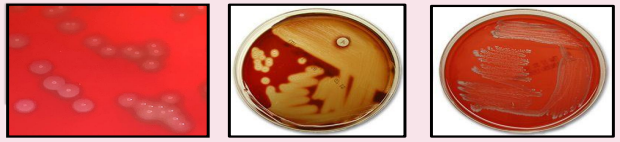


Figure 2. Examples of the types of hemolysis that can be expressed. When infecting humans, the pneumonia utilizes peroxide production as a defense mechanism to combat attack by human immune cells, which results in alpha-hemolysis. The production of peroxide poses a threat to RBCs because of how peroxide kills the cells in comes in contacts with. **Left. Alpha-hemolysis. R**esults in development of a green halo. **Middle. Beta-Hemolysis.** Results in complete lysing of cells. **Right. Gamma-Hemolysis.** Results in minor discoloration of blood agar plate.

$Na_2S_2O_5$ Alters Red Blood Cell Morphology and Survival

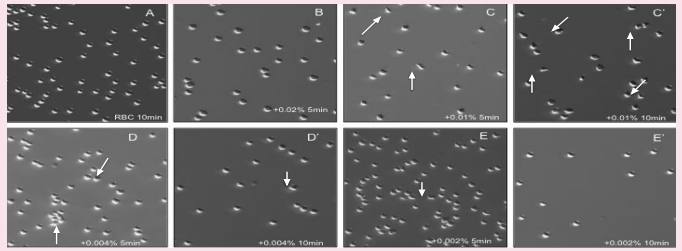


Figure 3. Red blood cell morphology after $Na_2S_2O_5$ treatment. Phase contrast images of red blood cells treated with varying amounts of $Na_2S_2O_5$. Images were taken at 5 and 10 minutes for most samples. Arrows point to cells with altered morphology.

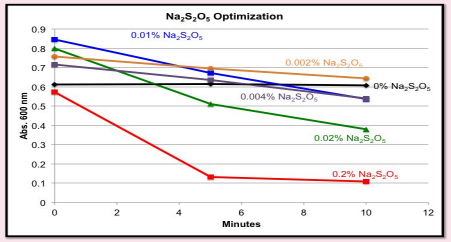


Figure 4 . From Previous study: absorbance after $Na_2S_2O_5$ treatment. Left Observed decreases in absorbance, over of 10 min, of cells treated with varying amounts of $Na_2S_2O_5$. **Right** Slopes of each curve, as estimated by excel, are listed in the table.

Experimental Design

Detailed Protocol

1. Sterilize each spreader with ethanol and fire before each use.
2. Bring blood agar plates to room temperature
3. Check the optical density of the three pneumo cultures
4. Use a serial dilution for the optical density of each culture using the medium CAT to get it to 0.08 in 10mL
5. Add 50 microliters of each respective culture to sets 1, 2, and 3 of blood agar plates
6. Incubate blood agar plates at 37℃ with 5% CO_2 for 24 hours
7. Remove plates from incubator and examine

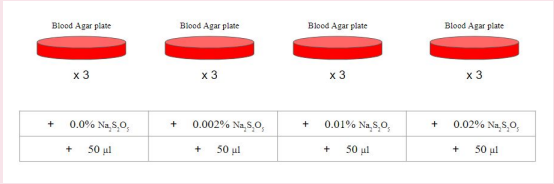


Figure 5. Experimental procedure. Blood agar plates were incubated with 0%, 0.002%, 0.01%, or 0.02% $Na_2S_2O_5$ for 30 minutes at room temperature. 50µl of pneumococcal cells at OD_{550} 0.05 were then spread on each plate, in triplicate, and incubated overnight at 37°C with 5% CO_2. The number of colonies on each plate was counted, and plates were analyzed for hemolysis type. Experiments were performed for three separate pneumococcal cultures. Refer to supporting documents for full methods explanation.

RESULTS

Microscope Images of Pneumococcal Growth on Plates

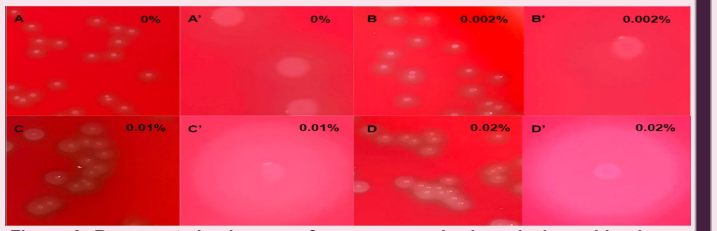


Figure 6. Representative images of pneumococcal α-hemolysis on blood agar plates. Blood agar plates with pneumococcal cells at varied concentrations of $Na_2S_2O_5$ are shown. The primer images are zoomed-in images of single colonies.

Change in OD of Pneumococcal Cultures

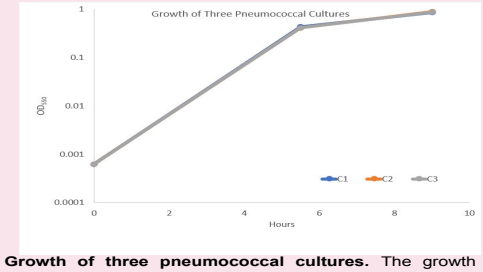


Figure 7. Growth of three pneumococcal cultures. The growth of the three independent pneumococcal cultures are shown in the above graph at a 0, 5.5, and 9 hours. The ODs of the three cultures show the same rate of growth.

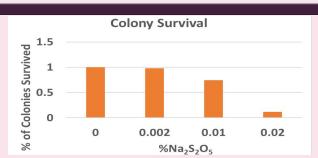


Figure 8. Colony Survival. The above bar graph shows the percentage of pneumococcal colony survival on the plates with and without $Na_2S_2O_5$ present.

- All three cultures reached an OD 550 of 0.410 in five and a half hours, and an OD 550 of 0.855 in nine hours. Therefore, all three cultures grew at the same rate (Figure 4).
- As expected, cells plated on blood agar that lacked $Na_2S_2O_5$, grew well resulting in a 100% survival and showed α-hemolysis, with dark green halos surrounding each colony.
- The plates with 0.002% and 0.01% $Na_2S_2O_5$, which had survivals of 98% and 74%, respectively, had more colonies present in the center of the plates than plate with 0.02% $Na_2S_2O_5$ which had a 12% survival rate (Figure 6).
- As the concentration of $Na_2S_2O_5$ increased, there were no obvious changes in the level of hemolysis observed, and all colonies on all plates showed α-hemolysis (Figure 5).

MATERIALS

Hardware
- Incubator
- Light Spectrophotometer
- Micropipettes
- Microscope
- Pipette tips
- Spreaders
- Test tubes

Solutions/Cells:
- Medium CAT
- $Na_2S_2O_5$
- Pneumo
- Sheep blood agar plates

Measurements Tools
- ImageJ

CONCLUSION

The data from this experiment demonstrates that $Na_2S_2O_5$ can be toxic to pneumococci. This is supported by the gradual decrease in colony survival as the percentage of $Na_2S_2O_5$ was increased. Additionally, inducing sickling on the blood agar plates increases their susceptibility to α-hemolysis by pneumo peroxide production, but it does not allow for β-hemolysis by pneumo. This would mean that despite plates with 0.02% $Na_2S_2O_5$ having a low average colony survival of 12%, this would not allow the pneumococcus to be able to express a stronger form of hemolysis (i.e. β-hemolysis). Knowing that the pneumococcus desires a nutrient host for infection, it is plausible that this is also why successful colonization decreased as $Na_2S_2O_5$ amounts were increased. Furthermore, because cells experience lysing from the addition of $Na_2S_2O_5$, the findings from this experiment may support the idea that those with more severe cases of SCA may face larger consequences from invasive pneumococcal diseases and other bacterial infections such as sepsis, bacteremia, sinusitis, meningitis, and sinus. The data supports the future study of how infection should be treated in different SCA patients.

REFERENCES

1. Centers for Disease Control and Prevention (Ed.). (2013, May 8). Pneumococcal Disease (Streptococcus pneumoniae). Retrieved March 3, 2019, from CDC website: https://wwwnc.cdc.gov/travel/diseases/pneumococcal-disease-streptococcus-pneumoniae
2. American Anthropology Association. (2016). Sickle Cell Disease. Retrieved March 3, 2018, from Understanding Race website: http://www.understandingrace.org/humvar/sickle_01.html
3. Indiana Hemophilia & Thrombosis Center (Ed.). (n.d.). Sickle Cell Disease Spleen Complications. Retrieved March 3, 2019, from Indiana Hemophilia & Thrombosis Center, Inc. website: https://www.ihtc.org/sickle-cell-splenic-sequestration/

ACKNOWLEDGEMENTS

Thanks to Argonne National Laboratory for allowing us to use their various facilities. Thanks to the College of DuPage for hosting Enrichment Sessions. Thanks to the ACT-SO staff and families. Thanks to my mentor, Nicole Inniss, for her guidance in the development, execution of my project, and experimental training. Without everyone's help, I would not have been able to successfully complete my last year in ACT-SO.

Investigations and Mathematical Demonstrations In The Topological Dynamics Of Fluid Vortices

Erik Imathiu-Jones, Providence St. Mel, DuPage County ACT-SO #3012, Mathematics

ABSTRACT

Background
Vortex Dynamics is the study of the crucial role of vorticity in governing the dynamics of fluids. It is a sub-field which has proven to provide **useful and novel insights** into the mathematical foundations of fluid dynamics.

One of the main benefits of vortex dynamics is that it links the dynamics of a fluid to the topology of the fluid. Specifically, the link between **topology and fluid dynamics** provides a natural entrance for **knot theory** and its applications to fluid dynamics

PURPOSE AND HYPOTHESIS

Purpose
The goal of this project is to use key developments in vortex dynamics to computationally **model** the time evolution of vortex knots.

Hypothesis
Using known vortex dynamic and fluid dynamic models, the time evolution of a vortex knot can be **numerically approximated** and modelled in Mathematica.

MATERIALS AND METHODS

Tools
WOLFRAM MATHEMATICA 11

Research Material
Previous work on vortex dynamics by Renzo Ricca, Keith Moffatt, Francesca Maggioni, and William Irvine was used to gather equations and knowledge necessary for this project.

Areas of Mathematics
Partial Differential Equations, Topology, Analysis, and Differential Geometry

Methods
The tools used to solve the specific problem of **vortex knot** evolution under localized induction approximation are discussed. These tools include Green's functions to solve the vector Poisson Equation which leads to solutions in the form of the Biot-Savart integral. The Biot-Savart integral is then expanded in first order to derive the **localized induction approximation (LIA)**. After LIA is derived, the induced velocity flow equation is solved numerically in **Wolfram Mathematica** in order to model the time evolution of a vortex knot in an **Euler fluid** under LIA.

EQUATIONS

Euler Equations

$$\frac{\partial u}{\partial t} + (u \cdot \nabla)u = \frac{\nabla P}{\rho}$$

$$\nabla \cdot \vec{u} = 0 \qquad \nabla \times \vec{u} = \vec{\omega}$$

Biot-Savart Equation

$$u(x,t) = \frac{\Gamma}{4\pi} \oint_{\gamma_t} \frac{\hat{t} \times (x - X(s))}{|x - X(s)|^3} ds$$

$$\vec{t} = \frac{\partial X}{\partial s} \qquad \Gamma = \oint u \cdot dl$$

Localized Induction Approximation

$$u_{LIA} = \dot{X}(s,t) \propto \frac{\Gamma}{4\pi}\left(\frac{\partial X}{\partial s} \times \frac{\partial^2 X}{\partial s^2}\right)$$

$$\left(\frac{\partial X}{\partial s} \times \frac{\partial^2 X}{\partial s^2}\right) = \kappa \hat{b}$$

RESULTS

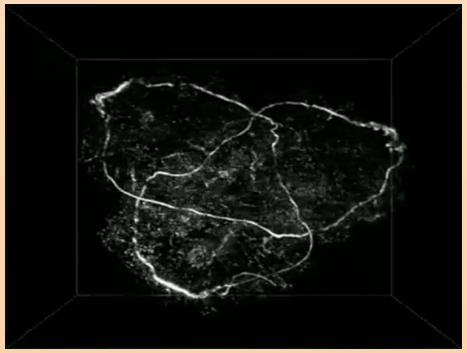


Figure 1. Trefoil vortex knot created by Irvine Laboratory at the University of Chicago.

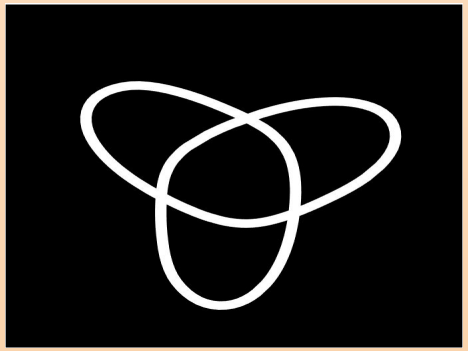


Figure 2. Trefoil vortex knot created in Mathematica under LIA approximation.

Figure 3. 4-Frame time evolution of trefoil vortex knop from top view (left) and side view (right).

DISCUSSION AND CONCLUSION

Discussion
The results computed in Mathematica are not only elegant but consistent with reality. This code is quick and can be used to approximate the time evolution of any closed vortex line.

Conclusion
In the future, this project will thoroughly investigate **invariant** quantities in fluids and the topological interpretation of these invariants. Special emphasis will be placed on the role of **differential forms** as links between the physical/geometric and topological interpretations of fluid invariants.

ACKNOWLEDGEMENTS

Thanks to Argonne National Laboratory and Du Page County ACT-SO for sponsoring such a wonderful research opportunity.

Thanks to Dr. Carl Spight for providing patient and enthusiastic guidance through this project.

STUDENT BREAKOUT

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STUDENT EXPECTATIONS

ACTSO@anl.gov

- Ask questions! Ask questions! Ask questions!
  - For many this is new, we and your mentor are here to help you every step along the way
- Manage your time to include ACT-SO
  - Do not wait to the last minute, and do not underestimate the time it will take to complete an assignment
- Identify the problem you want to solve not what you are interested in
- **Respect your mentor's time**

PARENT BREAKOUT

Argonne NATIONAL LABORATORY

PARENT EXPECTATIONS

ACTSO@anl.gov

- You are the liaison between your child and his/her mentor
  - You know your child better than mentor and most mentors will be tentative to push students beyond their comfort level
- Your participation will often reflect your child's success in the program
  - Ensure your child understands the next steps/takeaways from each meeting
  - Your child's research should make sense to you as well
- Coding will likely be a mandatory component
  - It is becoming the Microsoft office in a person's resume


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