LABORATORY FOR
Computational
Sensing + Robotics
THE JOHNS HOPKINS UNIVERSITY

JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

Automation of Mosquito Dissection for Malaria Vaccine Production

<u>Literature Review:</u>

An Efficient Production Process for Extracting Salivary Glands from Mosquitoes

Mariah Schrum, Amanda Canezin, Sumana Chakravarty, Michelle Laskowski, Suat Coemert, Yunuscan Sevimli, Greg Chirikjian, Stephen L. Hoffman, and Russell H. Taylor. *arXiv:1903.02532.* 2019

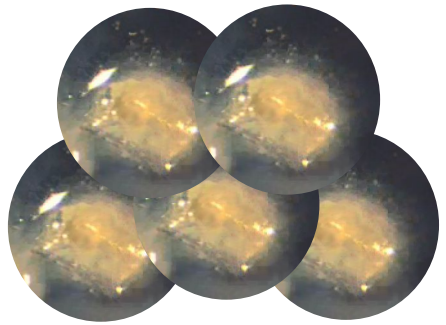
Group 1: Alexander Cohen, Michael Pozin, Henry Phalen
Mentors: Drs. Russell Taylor, Iulian Iordachita

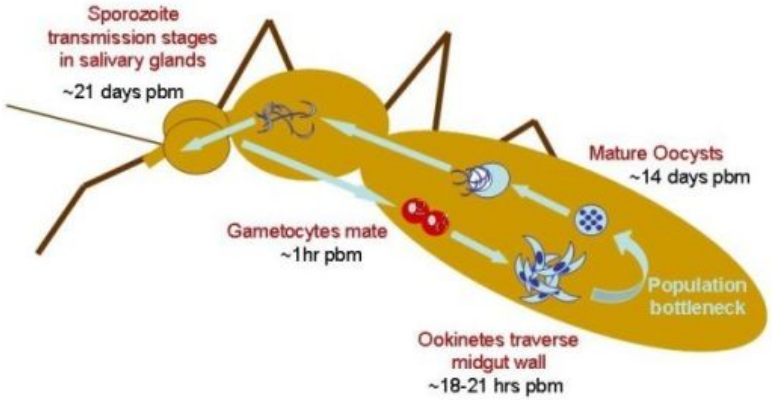
Project Summary

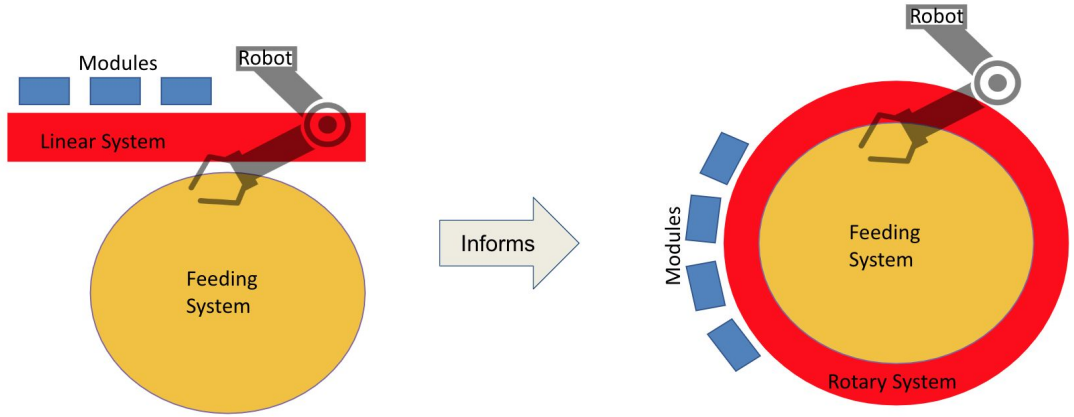
- **Problem**: Sanaria needs to increase their production rate of *Plasmodium falciparum* sporozoites (PfSPZ) from infected mosquito glands to help produce a promising malaria vaccine

- **Overall Goal**: Automate the gland dissection process via robotic systems

- **Personal Goal**: Take the current linear stage processing method and develop a continuous rotary stage to further streamline automation







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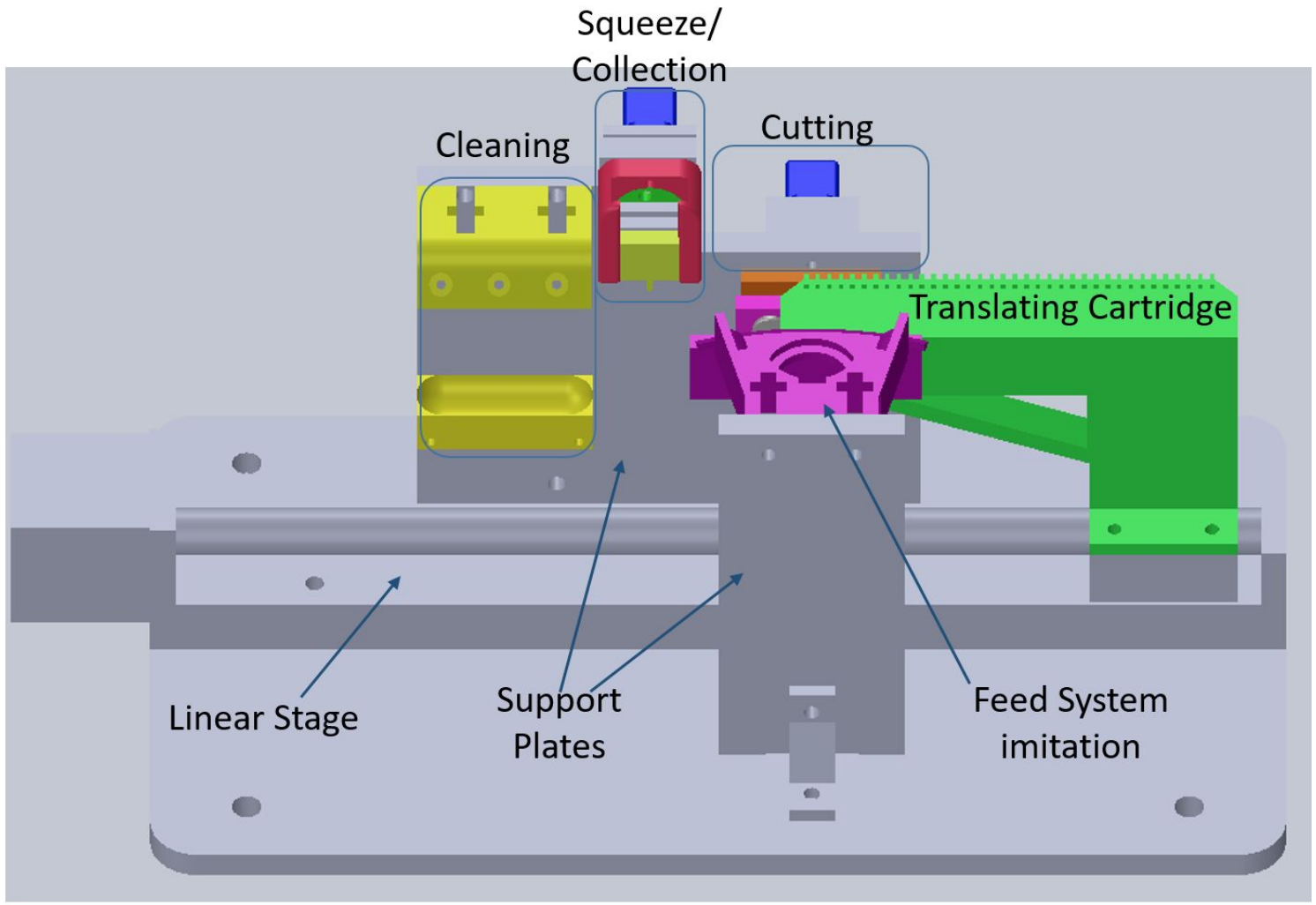
Current System

Linear stage Design

- Linear stage with slotted Cartridge
- Decapitation unit
- Gland pressing/collection unit
- Cleaning unit



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Paper Selection Motivation

Mariah Schrum, Amanda Canezin, Sumana Chakravarty, Michelle Laskowski, Suat Coemert, Yunuscan Sevimli, Greg Chirikjian, Stephen L. Hoffman, and Russell H. Taylor, "An Efficient Production Process for Extracting Salivary Glands from Mosquitoes" *arXiv:1903.02532.* 2019

- Discussed the design of a semi-automated mosquito microdissection system (SAMMS)
- Extremely relevant to the work since many design decisions discovered in paper inform the current design
- There are only a few papers in this area of research / there is an issue of confidentiality
- Useful as an introduction on the motivation of this project from early in its conception

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Summary & Background

- Sanaria has made significant progress in developing PfSPZ vaccines from the salivary glands of infected mosquitoes
  - Limited in their ability to manufacture this vaccine at scale
  - Automation of this process has significant challenges
    - **SAMMS** was developed since it was done on a short timeline

- **Main Focus**: was on improving the harvesting method of PfSPZ from the salivary glands of Anopheles sp. Mosquitoes through the development of a mechanical system
  - deskill the task
  - Increase the rate of production

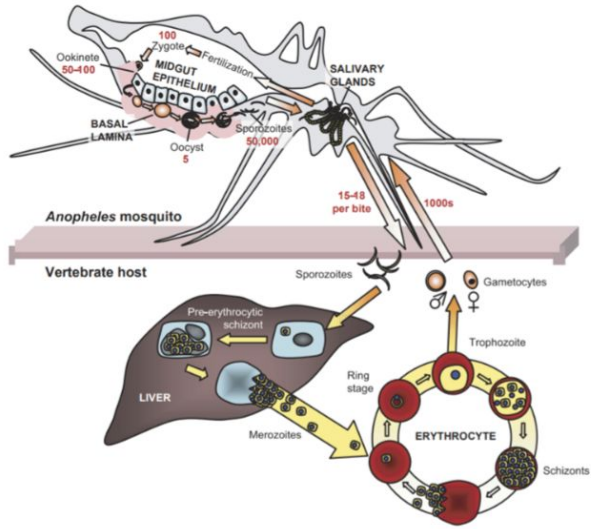

Fig 1. Life cycle of *plasmodium falciparum.* Note the location of the salivary glands in the mosquito. [1]

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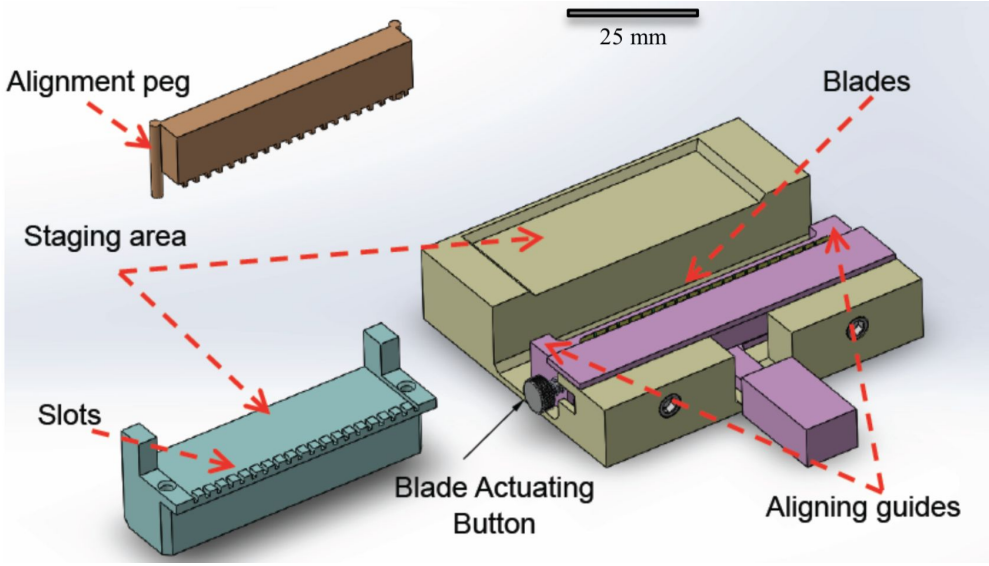
The Device and its Significance



- Device consists of several modular components:
  - a sorting stage in which mosquitoes are placed into slots,
  - a decapitation stage,
  - a squeezing and gland collecting stage

- Allows for **several** downstream steps to be done **concurrently**
  - by a single technician in a shorter time

- This system provides valuable design lessons
  - Inform engineers developing the automated system
  - Also provided short term improvements on the existing method of collection

- The results of this paper have directly informed current design concepts that are currently being utilized
- Serves as a strong educational guide as to why certain design avenues where pursed

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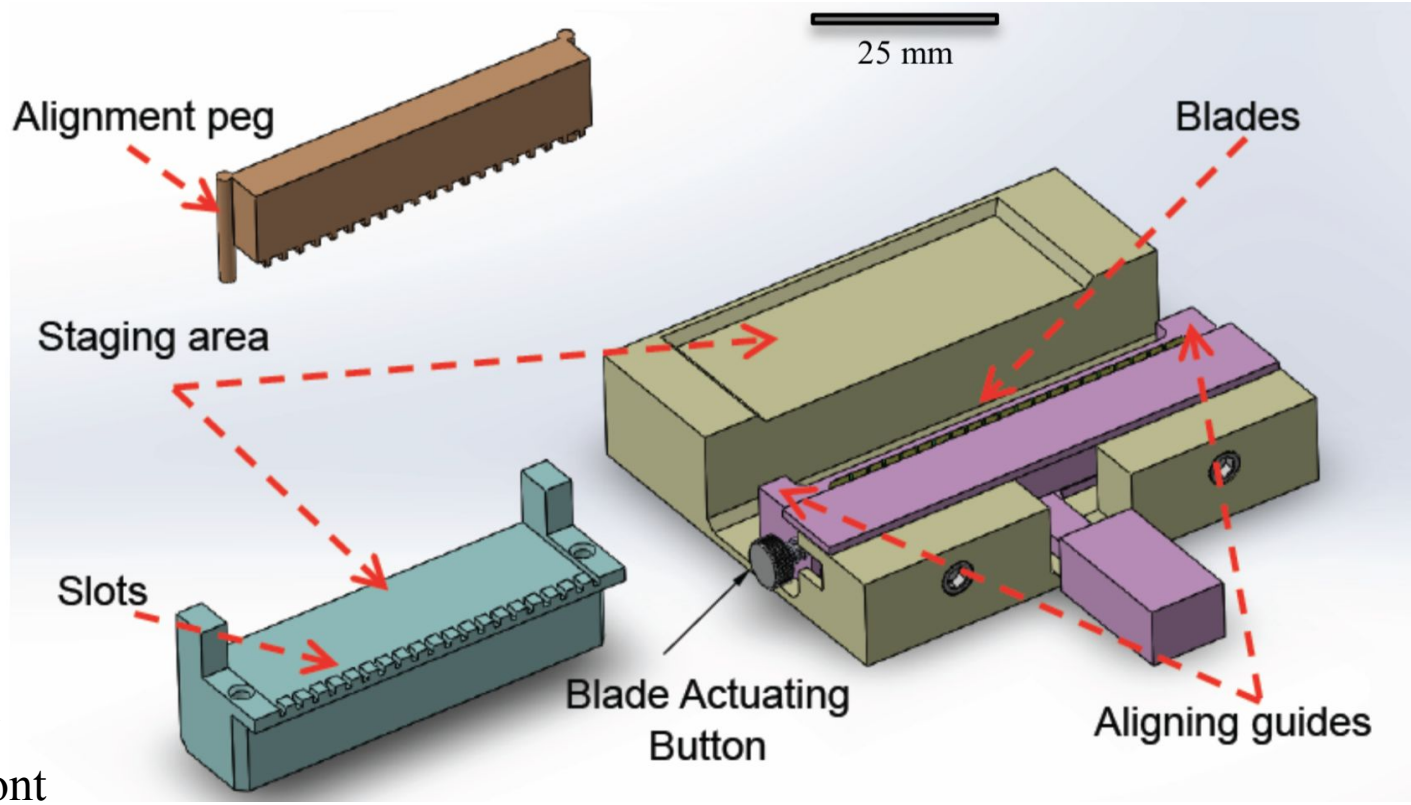
Design Specifics

- Sorting Cartridge
  - Holds 20 mosquitoes in slots
  - Large enough to just fit the body to keep them aligned during squeezing
  - Removeable
- Blade Assembly
  - Balde is clipper like design
  - Notches for each slot each 0.6mm wide
  - Made of 50µm thick stainless steel
  - Blades are removable
- Squeezer
  - Designed to fit into slots with negative geometry
  - Tight fit ensured that all glands are forced out front
  - Alignment pegs for increased user constraint and repeated placement
- Staging Area
  - Smooth Surface (so dragging of mosquitoes does not damage them
  - Large enough for 30-40 mosquitoes to be piled on
  - Efficient filling time



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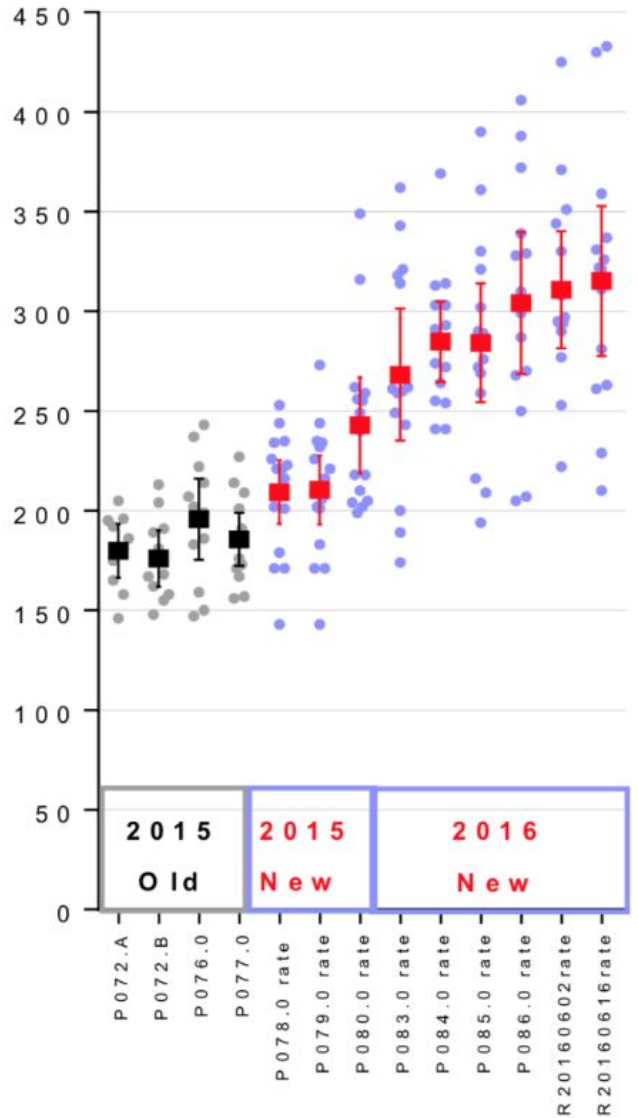
Results

- **Overall Quality** of the Salivary Gland SPZ
  - SAMMS the overall quality of the glands was found to be nearly identical those to that of the manual method

- The Impact on **Training Time**
  - Overall reduction in training time
  - Limiting factor was the time it took to load mosquitoes into the slots
  - Operators were quickly able to use SAMMS effectively

- **Increased Throughput** as Compared to Manual Method
  - 470 mosquitoes per hour on average
  - There were improvements made to the manual method but there was quite a large deviation and much less than the targeted 600 mosquitoes per hour



	1	2	3	4	5	6	7	8	Avg.
(A)	2.4	2.5	2.3	2.5	1.5	1.3	1.1	1.2	**1.9**
(B)	0.7	0.8	0.8	1.1	1.2	0.7	1.1	0.7	**0.8**
Total	3.1	3.3	2.8	3.6	2.7	2.0	2.2	1.9	**2.7**
Rate	393	364	429	338	444	600	545	649	**470**

Table 1: Operation times and production rates for 8 operators using a proposed apparatus. **(A)** Minutes to align 20 mosquitoes; **(B)** Minutes for gland extrusion and collection. Total time for 20 mosquitoes is in minutes, and rate is mosquito throughput per hour. [1]

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Discussion

- The system developed in the paper demonstrated the effectiveness of a high level prototype for semi-automating the current task of gland extraction.
  - Capable of batch-processing serval mosquitoes at a time,
    - Researchers suggesting a maximum of 40 do to specimen drying issues
  - Gland extraction can be done at scales from tens to hundreds of mosquitoes at once

- As a result the team expects SAMMS to allow for single operator throughput to be increased **two** to even **three** fold as compared to the manual method
  - SAMMS greatest advantage is its radical reduction in training time, **15 - 20 fold**
  - Reduced operator fatigue
  - glands extracted are comparable, if not better then, that extracted by the manual method

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Assessment & Critique

- Insight into why the current automated design exists the way it does
- **HEAVILY** informed current automated design
- Important lessons on key designs
- Educational tool for engineers joining the project
- Overall the work was very well done however maybe more **advanced manufacturing** techniques could have been implemented in the development of the prototype that was handed off to Sanaria
  - It should be noted that the design was given to Keytech to make a manufactured version of the system after the team finalized the design of the prototype.

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Key Lessons

The following are all key design lessons that have informed our current automated design and have proven to be essential to the success of the system:

- Method for placing the mosquito into the cartridge
  - The method of dragging the mosquito by the proboscis into the slots is a task we have been able to automate with a pick and place robot and vision system.

- Squeezer geometry
  - In our automated version we have taken the same

- Decapitation Blade Geometry and Mechanism
  - The same method of cutter is used and has been shown to still be effective once properly aligned within the automated system.

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References

1. “An Efficient Production Process for Extracting Salivary Glands from Mosquitoes” Mariah Schrum, Amanda Canezin, Sumana Chakravarty, Michelle Laskowski, Suat Coemert, Yunuscan Sevimli, Greg Chirikjian, Stephen L. Hoffman, and Russell H. Taylor. *arXiv:1903.02532. 2019*


Questions?