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McMaster iGEM x Shad at Mac Design Case Competition 2026: Expanding Blood Donor Eligibility with Synthetic Biology

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Abstract
Approximately 7.1 million people are deterred from donating blood due to certain exclusion criteria placed by the Canadian Blood Services to allow for safe transfusion. Participants were required to devise synthetic biology solutions to widen the blood inclusion criteria set by the Canadian Blood Services to allow more individuals to donate. The following are abstracts from the case competition hosted by Shad@Mac and iGEM McMaster.

Keywords: blood; blood transfusion; Canadian blood services; synthetic biology; research; iGEM, Shad@Mac

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Conference Abstracts
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Three-chamber Self-Calibrating SHERLOCK-Cas13 Cartridge: A Research Study

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Blood transfusions save millions of lives each year, yet systems designed to ensure their safety struggle to meet the growing demand, contributing to a persistent global blood shortage. Strict deferral policies exclude individuals with a history of Human Immunodeficiency Virus (HIV) infection due to epidemiological risk. Although SHERLOCK Cas13-based assays offer high sensitivity, they lack standardized controls that account for variability between individuals and their samples, which can lead to false positives. These false positives contribute to unnecessary donor exclusion and further strain the global blood supply. A self-calibrating diagnostic that accounts for individual sample variability and background noise could reduce unnecessary exclusions and restore eligibility for valid donors. Our solution involves a re-engineered three-channel SHERLOCK-Cas13

cartridge that includes a donor specific internal noise control. The cartridge uses a symmetric trident manifold that equally splits the processed donor blood into three identical chambers, ensuring uniform fluid resistance and equal blood distribution. The first chamber is a target detection chamber containing Cas13 with HIV-specific guide RNAs that target highly conserved HIV RNA regions. Fluorescent reporter molecules in the solution release fluorescent signals when they recognize the viral RNA, causing Cas13 to perform collateral cleavage. The second chamber, designed for noise-control, contains a decoy system with reporter fluorescent molecules and Cas13 combined with a negative control guide RNA that does not match any known viral or human sequence. The third chamber acts as an internal recovery chamber, containing synthetic HIV RNA spike, which is lab-made HIV-like RNA at known concentrations, along with HIV-specific guide RNAs and fluorescent reporter molecules. This chamber serves as a positive internal control to confirm successful extraction, amplification, and Cas13 activation to be freeze-dried. By measuring the fluorescent signals in the three chambers, the device can distinguish true viral detection from assay background noise, which may reduce false-positive results. Ethically, this approach ensures that the decision to exclude a donor is based on the actual presence of a virus rather than on noise that might cause a false positive, such as the body's response to HIV antibodies. This approach respects the donor's contribution and increases the blood supply by identifying healthy individuals who were unfairly rejected in the past. The feasibility of this solution lies in its use of fixed physical structures that replace complex laboratory machinery. The cartridge internal geometry splits blood and generates turbulence for mixing, eliminating the need for centrifuges, manual pipetting, or technician intervention. Since this automation is built into the plastic itself, it removes the need for the expensive pre-processing equipment and manual pipetting steps that usually occur in a lab. Mass-produced, injection-molded plastic and freeze-dried reagents makes the system shelf-stable and cost-effective and reduces startup costs. Low costs allow the technology to be easily integrated into existing laboratory networks without needing new hardware that requires high maintenance or specialized staff training. This approach provides a scalable method for blood centers to increase their yield and lower costs.

Aptamer-SPION Magnetic Filtration System for the Removal of Malaria-Infected Erythrocytes to Expand Blood Donor Eligibility in Canada: A Synthetic Biology Approach

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Introduction: Stringent blood donor eligibility criteria heavily strain healthcare systems due to the blood shortages they produce. Canadians returning from malaria-endemic regions are required to wait three months before donating, as they are at risk of low-level parasitemia that may be undetectable to standard screening methods. Many otherwise healthy donors are excluded as existing strategies rely on travel-based deferrals rather than direct pathogen removal. These limitations highlight the need for targeted removal strategies that maintain transfusion safety while expanding donor eligibility.

Proposed Synthetic Biology Solution: To reduce the three-month deferrals for Canadians returning from malaria-endemic regions, an aptamer-SPION magnetic filtration system is proposed. The approach focuses on selectively removing malaria-infected red blood cells (iRBCs) by targeting the PfEMP1 surface marker, which appears on the surface of Plasmodium falciparum-infected erythrocytes. Highly specific 5'-azide-modified DNA aptamers will be generated through whole-cell SELEX. This process iteratively selects DNA sequences that bind to the remodelled iRBC membrane while selecting against uninfected RBCs to ensure extreme specificity. The solution uses superparamagnetic iron oxide nanoparticles (SPIONs) clustered into 50 nm cores with a PEG-dextran shell, promoting hemocompatibility. EDC/NHS coupling chemistry is used to bind the 5'-amine-modified DNA aptamers to a carboxyl-terminated PEG chain on the SPION surface. The SPIONs will be incubated in the blood unit, where the aptamers bind to the iRBCs' surface antigens. The proposed filtration mechanism with an inline high-gradient magnetic separation (HGMS) column will trap the SPION-labelled iRBCs. A second magnetic guard is used downstream to capture residual particles and ensure all parasites are removed. The system is designed to achieve ≥ 6log10 reduction, the threshold required to clear a unit containing ~1 parasite/μ/mL. The presented solution seeks to remove blood donation deferrals while promoting high recipient safety.

Impact, Ethics, and Unmet Needs: The proposed aptamer-SPION magnetic filtration system removes the three-month temporary deferral period applied to over three million Canadians who travel to malaria-endemic regions annually. Ethical considerations include ensuring that both the nanoparticles and the pathogen are completely removed before transfusion. A thorough validation of the mechanism and a risk assessment would be necessary before clinical use. There remains a clear need for scalable methods that can safely remove iRBCs from donated blood without damaging healthy erythrocytes. Hence, developing an affordable pathogen reduction method for donated bloodremains an important global challenge.

Implementation and Feasibility: A malaria nucleic acid test (NAT) has recently been approved by Health Canada and is expected to be implemented by blood services in 2027. In this workflow, the aptamer-SPION magnetic filtration system would function as a post-screening processing step. Any donation identified as malaria-positive or inconclusive through NAT would undergo the filtration process to magnetically separate and remove iRBCs, after which it would continue through standard component processing and storage. A preliminary cost analysis based on commercially available products suggests economic feasibility and strong compatibility with existing blood processing workflows. Ultimately, this system offers a cost-effective, feasible, and scalable solution to reclaim millions of previously deferred units with minimal operational disruption.

DENV-Detect: A Pan-Dengue Nucleic Acid Testing Strategy for Safe Blood Donor Screening

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Every year, over 2 million Canadians return from trips to dengue virus (DENV) affected regions like Mexico, just to be turned away from blood clinics for weeks. This reliance on geographic deferral policies accompanies a crisis where only 2% of Canadians donate blood, despite a 10% rise in demand. While intended to mitigate risk and block transmission of a deadly disease, a large portion of potentially unaffected individuals are unable to donate blood. Transitioning to DENV-Detect, a molecular pan-dengue nucleic acid test (NAT), enables a "test-and-release" model. By detecting viral RNA, the proposed mechanism can safely identify unaffected donors, mitigating the national blood crisis. Currently, the cobas Malaria Test screens donated blood for malaria by detecting parasitic genetic material. The test involves extracting nucleic acid from the donor plasma. It then amplifies specific target sequences using real-time PCR with fluorescent probes that signal when the pathogen's DNA is present. Using a similar molecular framework, this test can be modified to target and detect dengue viral RNA. Any viral RNA present in the donor plasma will be extracted using lysis buffers and silica-based columns, which separate the nucleic acid from proteins and other components. Viral RNA is first converted into complementary DNA (cDNA) using reverse transcription. During this process, primers bind to the conserved C-prM (capsid-pre-membranes) region of the dengue genome, providing a starting point for the cDNA synthesis. A dengue-specific hydrolysis probe containing the fluorescent reporter dye FAM, and the quencher BHQ-1, will be used to help detect the virus. During PCR amplification, the probe will bind to the target DNA sequence. As the polymerase copies the DNA, it will cause the probe to cleave. This separates FAM from BHQ-1, creating a fluorescent signal, indicating the presence of dengue genetic material. The system will include a nucleic acid sequence incorporated as a checkpoint for the assay. The internal control target will include its own primers and probe to confirm successful RNA extraction and amplification, while ensuring no inhibitors affect the results. This approach addresses a major need by replacing broad travel-based deferrals with precise molecular screening. Instead of turning away donors based on travel, those units can be flagged and sent to centralized facilities such as Canadian Blood Services or Héma-Québec laboratories which already have NAT screening protocols in place for other viral infections. Real-time PCR platforms and liquid handling systems would mean samples could be processed efficiently in parallel, with units that test negative for all DENV serotypes released into the national blood supply. At a system level, it can lower costs linked to donor loss, discarded units, and preventable infections. It also offers important ethical and social benefits by creating a more equitable screening process for international travelers and globally connected communities. Overall, DENV-Detect has the potential to strengthen safety, equity and public trust in the blood supply, while alleviating the stress on blood banks worldwide.

Conflicts of Interest
The author(s) declare that they have no conflict of interests.

Authors' Contributions
AB and AZ: Served as a planning committee for the conference, reviewed the abstract submissions and ensured that they adhered to correct formatting standards, and gave final approval of the version to be published JR and MP: Presidents of the iGEM team, served as the planning committee for the conference, and gave final approval of the version to be published.
KT: Served as a planning committee for the conference, assisted authors with their abstract submissions, and gave final approval of the version to be published.

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