Microdevices for Point-of-Care Diagnostics

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POC Diagnostics
Microdevices for Medicine
Advantage of Microfluidic Systems

- Small sample volume
- Small reagent volume
- Low production cost
- Portable, potential for integration and automation
- High surface to volume ratio
- Laminar flow, predictable transport property
Global Health

The area of study, research and practice that places a priority on improving health and achieving equity in health for all people worldwide

Leading causes of death, high-income countries

Top 10 causes of deaths in high-income countries in 2016

- Ischaemic heart disease
- Stroke
- Alzheimer disease and other dementias
- Trachea, bronchus, lung cancers
- Chronic obstructive pulmonary disease
- Lower respiratory infections
- Colon and rectum cancers
- Diabetes mellitus
- Kidney diseases
- Breast cancer


Leading causes of death, low-income countries

Top 10 causes of deaths in low-income countries in 2016

- Lower respiratory infections
- Diarrhoeal diseases
- Ischaemic heart disease
- HIV/AIDS
- Stroke
- Malaria
- Tuberculosis
- Preterm birth complications
- Birth asphyxia and birth trauma
- Road injury


36.9 million adults living with HIV/AIDS, 2017
HIV Diagnostics
Cell

Bacteria (TB, Typhoid)

Virus (HIV, hepatitis, SARS, influenza)

HIV emerging from a cell
Impact of Treatment

Begin ART

CD4

Weeks

Years

--- time ---
Impact of Treatment

Before
Impact of Treatment

After 9 months
Impact of Treatment - Society

Source: Centers for Disease Control, 2001
HIV Diagnostic and Molecular Testing

State of the Art Technologies

Viral load count: determining resistance
Lab Diagnostics in Resource Poor Settings
What is Needed

• Low cost
• Easy to use
• Rapid and Robust
• Portable
• Sensitive and specific
Nanoporous Membrane for Viral Processing and Sensing

- Controllable pore size
- High porosity
- Bio-functionality
- Tight pore size distribution
- Thin membranes
Virus Sensing in Porous Membrane

Standardized Peak Current

\[
\frac{iP}{iP_c} \text{ vs. Simulated Virus Concentration (beads/mL)}
\]

\[R^2 = 0.93229\]
Virus Sensing in Porous Membrane

Peak Current Values of Control and Threshold Viral Loads

![Graph showing peak current values for control and threshold viral loads.](image-url)
Device Assembly

Roof substrates

Outlet

Inlet

electrode

Finalized devices

Separation membrane

Syringe tubing

electrodes
Sickle Cell Screening
Sickle Cell Anemia

- Inherited disease where red blood cells become sticky and sickle shaped
- Causes episodes of pain, fatigue, and breathlessness; makes individual more prone to infections
- Sickle cell crisis occurs when the sickle cells clump together, blocking capillaries in the brain, lungs, and other vital organs
- Without treatment, SCD can be fetal due to resulting stroke or organ damage
5/100 children under the age of 5 die from sickle cell anemia each year.
Sickle Cell Anemia Trait Prevalence

Someone with the HbS allele either carries or is affected by sickle cell disease

Standard Diagnostic

- Electrophoresis

- HPLC

http://erasmeinfo.ulb.ac.be/globule/English/sickle_diag.htm
Paper-based lateral flow test where a liquid sample flows, by capillary action, up a paper strip (A.)

- As the liquid flows, the analyte (targeted biomarker) will either be detected or not via a color indicator on the strip
- Advantages: Low-cost, rapid, simple, and portable
Lateral flow devices typically utilize direct binding, sandwich mechanisms as they maximize specificity.

Problem: hemoglobin concentration in blood is very high, which can result in the hook effect.

- Hook effect: high concentrations of analyte (hemoglobin) cause the beads and test line to be oversaturated, preventing the bead from “sticking” to the test line and the result showing a false negative.

Solution: E-junction design incorporates a wash step, preventing the beads and analyte from premixing.

**Hook Effect and Solution**
FUSION 5 can be used as a blood separator because red cells are attracted to the surface of the glass fiber and become trapped within the depth of the matrix.

Using Whole Blood and On-device Lysing
Casing, Accessories and other Innovations
John Fraser (BS, 2015)

TE teams led by Fraser since 2016 on HIV diagnostics

GSIF team in Sierra Leone to study sickle cell diagnostics

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Student Participants

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Thomas Reidy, graduate student

BDSI summer students (2012)
Sickle Cell Diagnostics TE team (2018, 2019)
CINQ397 Team (2018, 2019)