Lab-on-a-chip

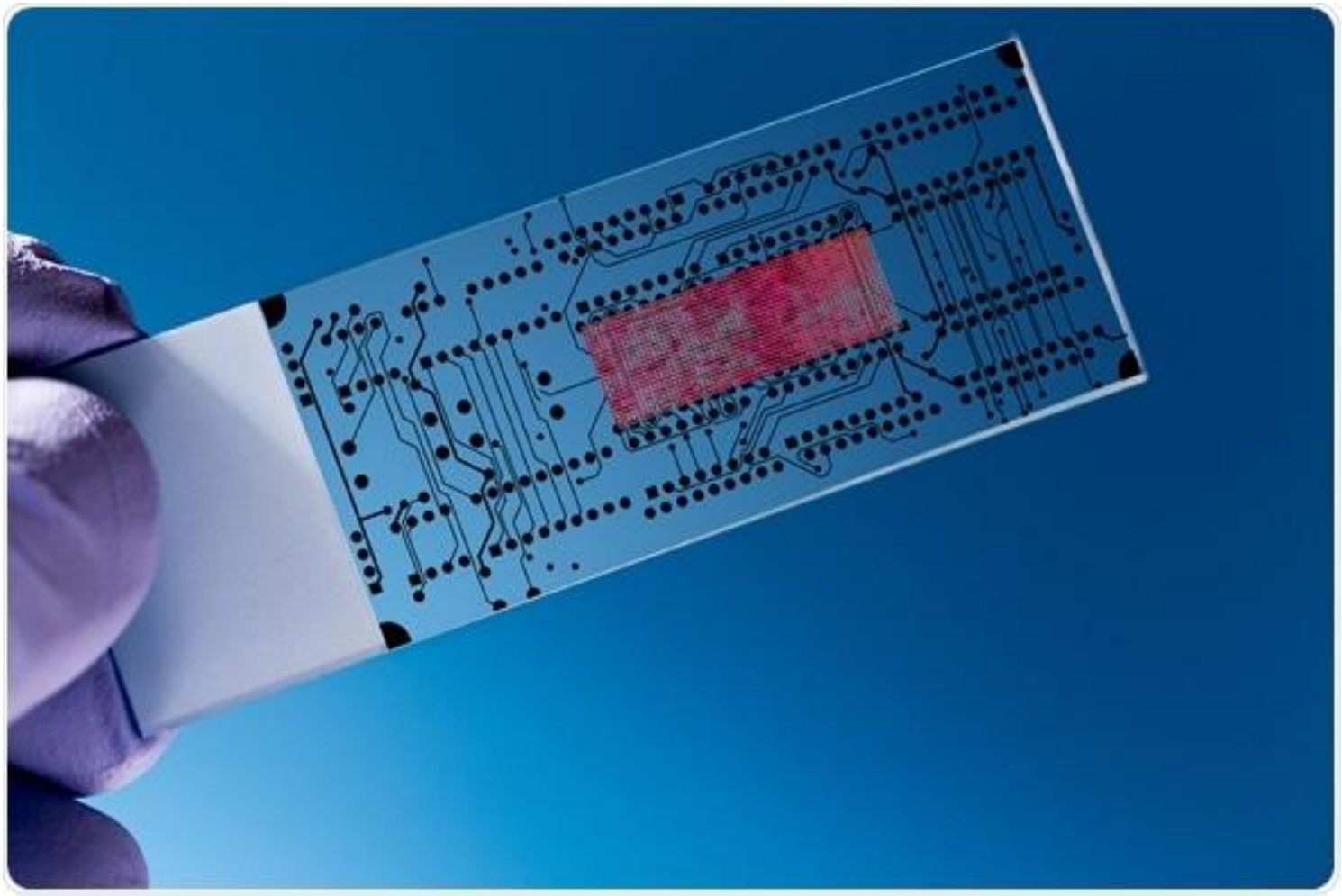
Lecture 23

Lab-on-a-chip

- A lab-on-a-chip is a miniaturized device that integrates onto a single chip one or several analyses, which are usually done in a laboratory
- Analyses such as DNA sequencing or biochemical detection.

Lab-on-a-chip

- LOC technology is concerned with laboratory experiments carried out on a very small scale.
- It can integrate several laboratory functions on a chip of size ranging from a few millimeters to a few square centimeters.
- This helps achieve high-throughput screening and automation.



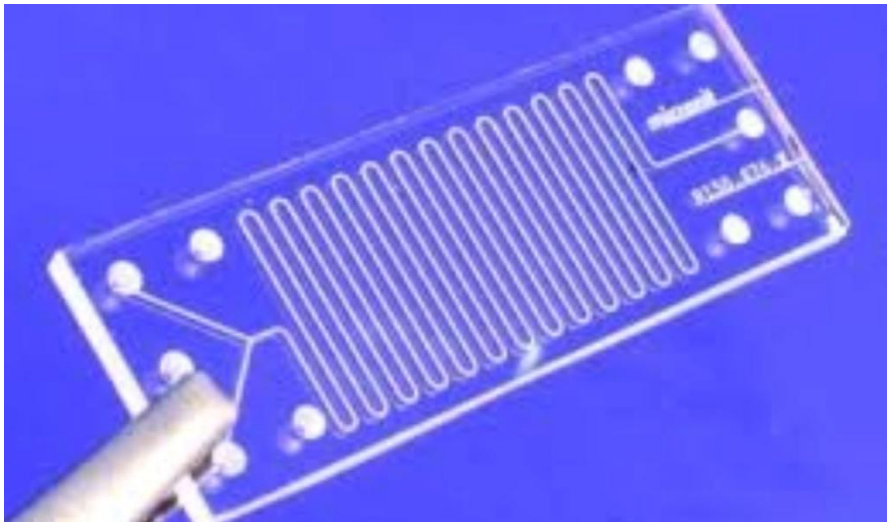
Lab on chip (LOC) is device that integrates laboratory functions on nano chip

Advantages

- Miniaturization of biochemical operations normally handled in a laboratory has numerous advantages, such as
  - cost efficiency, parallelization, ergonomy, diagnostic speed and sensitivity.
- The emergence of the lab-on-a-chip field mainly relies on two core technologies:
  - microfluidics and molecular biology.

Microfluidics

- **Microfluidics** is the study of systems that can process small quantities of fluids by using tiny channels having dimensions at the microscale – typically in micrometres.



Microfluidic technologies

- Microfluidic technologies used in lab-on-a-chip device allow to manufacture millions of microchannels, each measuring mere micrometers, on a single chip.
- The microchannels enable the handling of fluids in quantities as low as a **few picoliters** as well as the manipulation of biochemical reactions at **very small volumes**

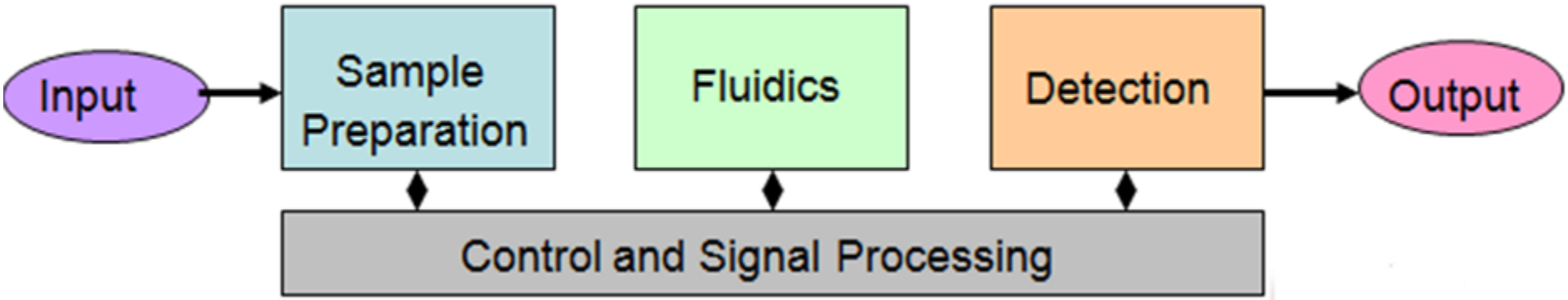
MEMS

- MEMS = **Micro Electro Mechanical System**
- Any engineering system that performs electrical and mechanical functions
- with components in micrometers.

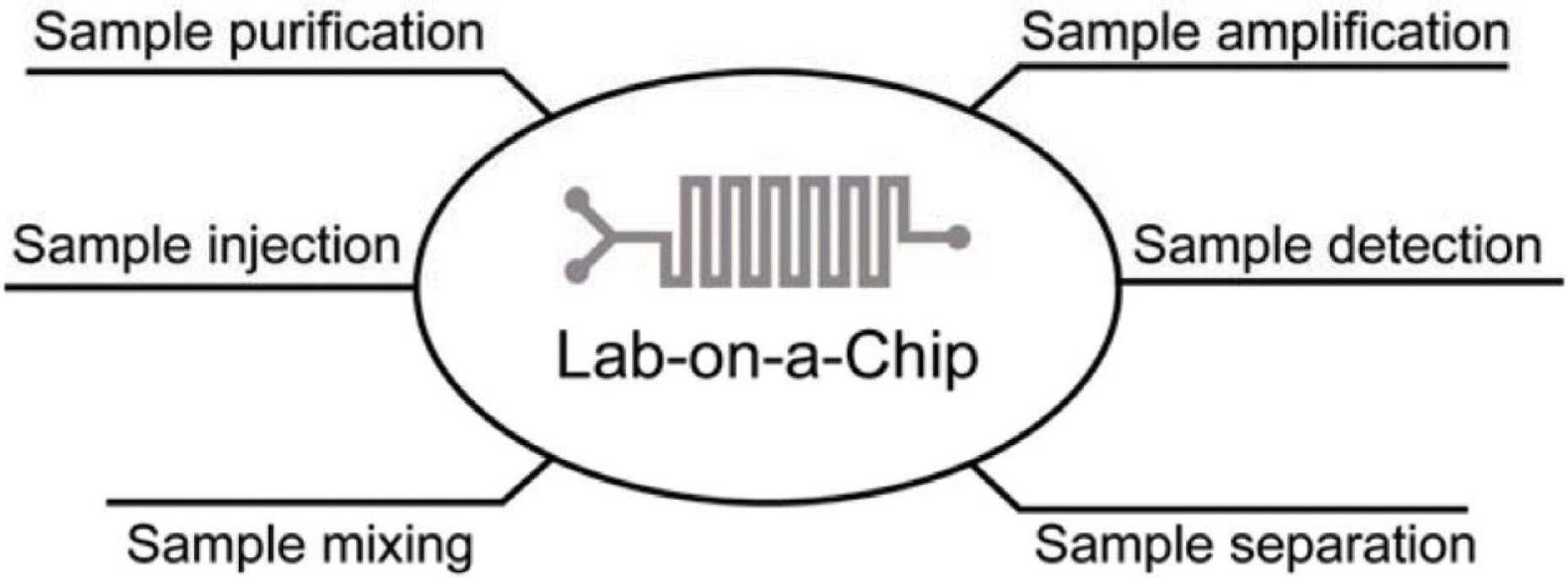
BIO MEMS

- BioMEMS are biomedical or biological applications of MEMS (micro electro mechanical systems).

Components


Input
Sample Preparation
Fluidics
Detection
Output
Control and Signal Processing

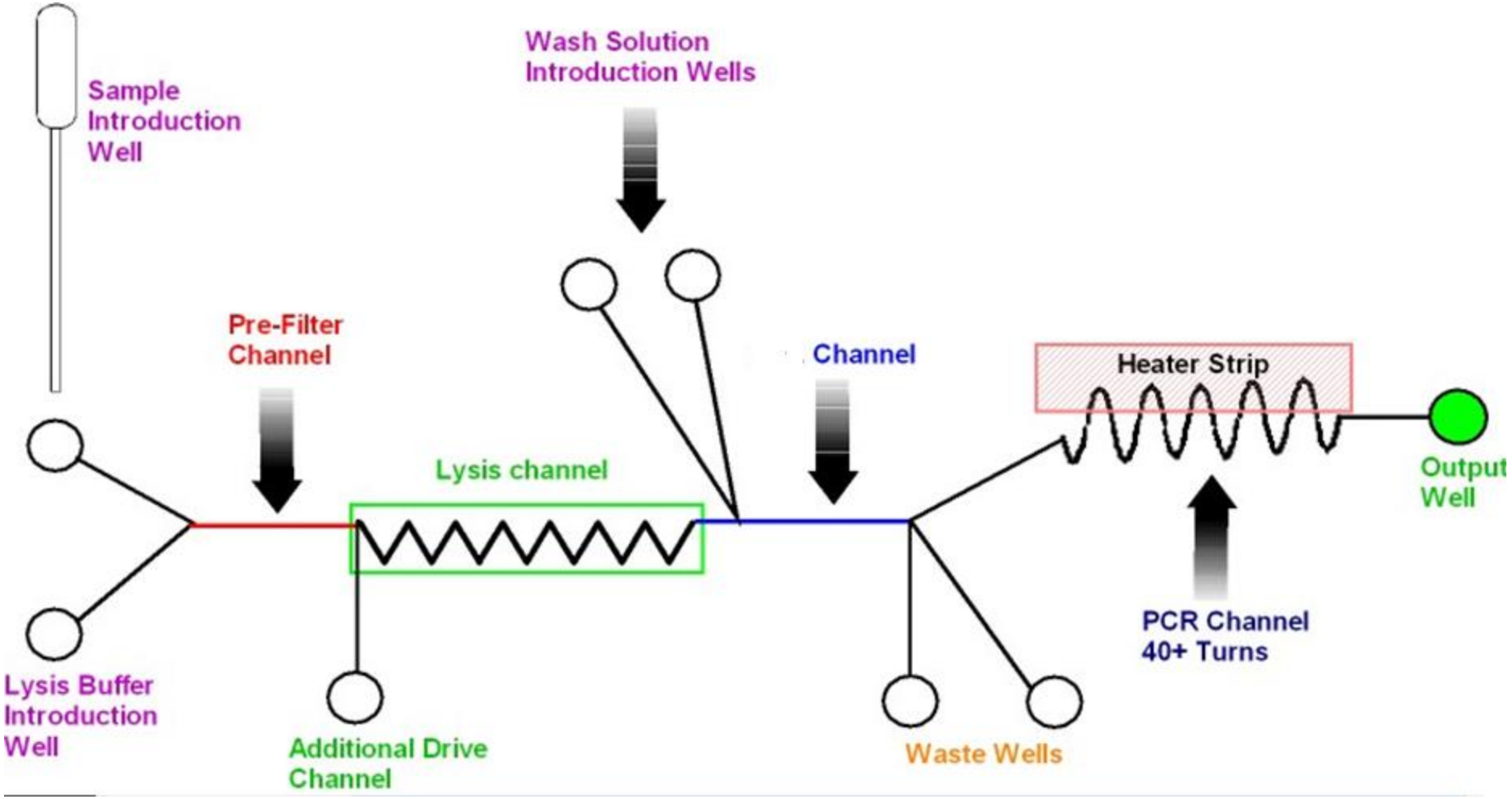
Unit components making up the lab-on-a-chip (LOC) system



Microfluidic channels

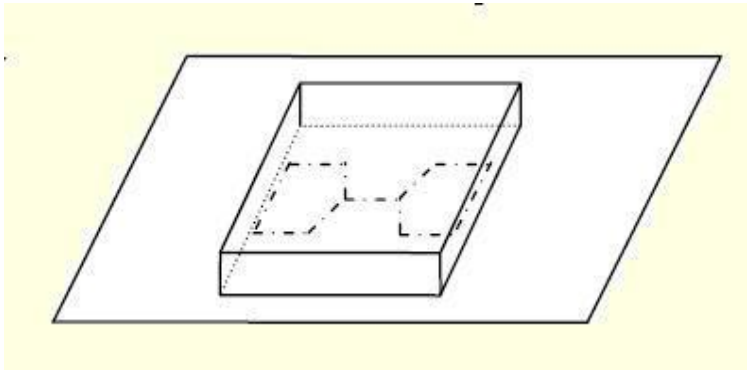
- Networks of micron scale channels that are integrated together to perform functions.

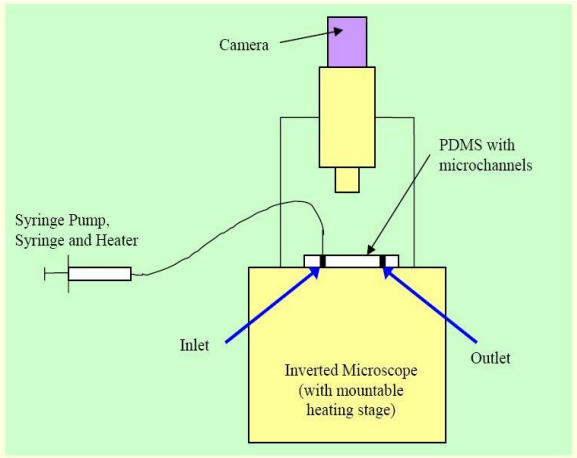
System Schematic



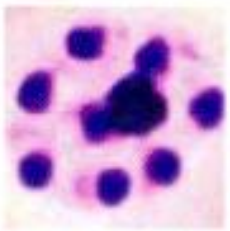
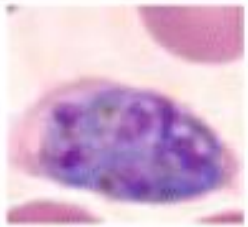
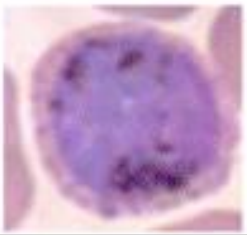
Microfluidic Device in Malaria Diagnosis

- Pressure (range from 80mmHg to 120mmHg) is applied
- Malaria affected RBC is injected through inlet
- Behavior is recorded under high speed camera



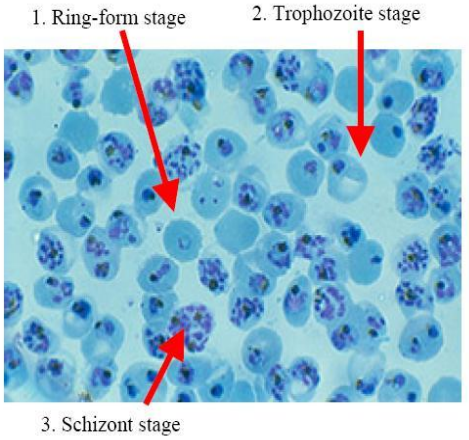


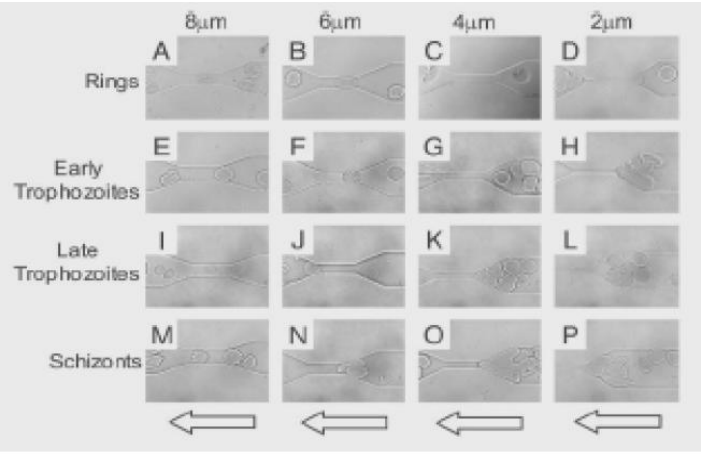
Blood smear

Species / Stage	Falciparum	Vivax	Malariae	Oval
Ring Stage				
Trophozoite				
Schizont				
Gametocyte				

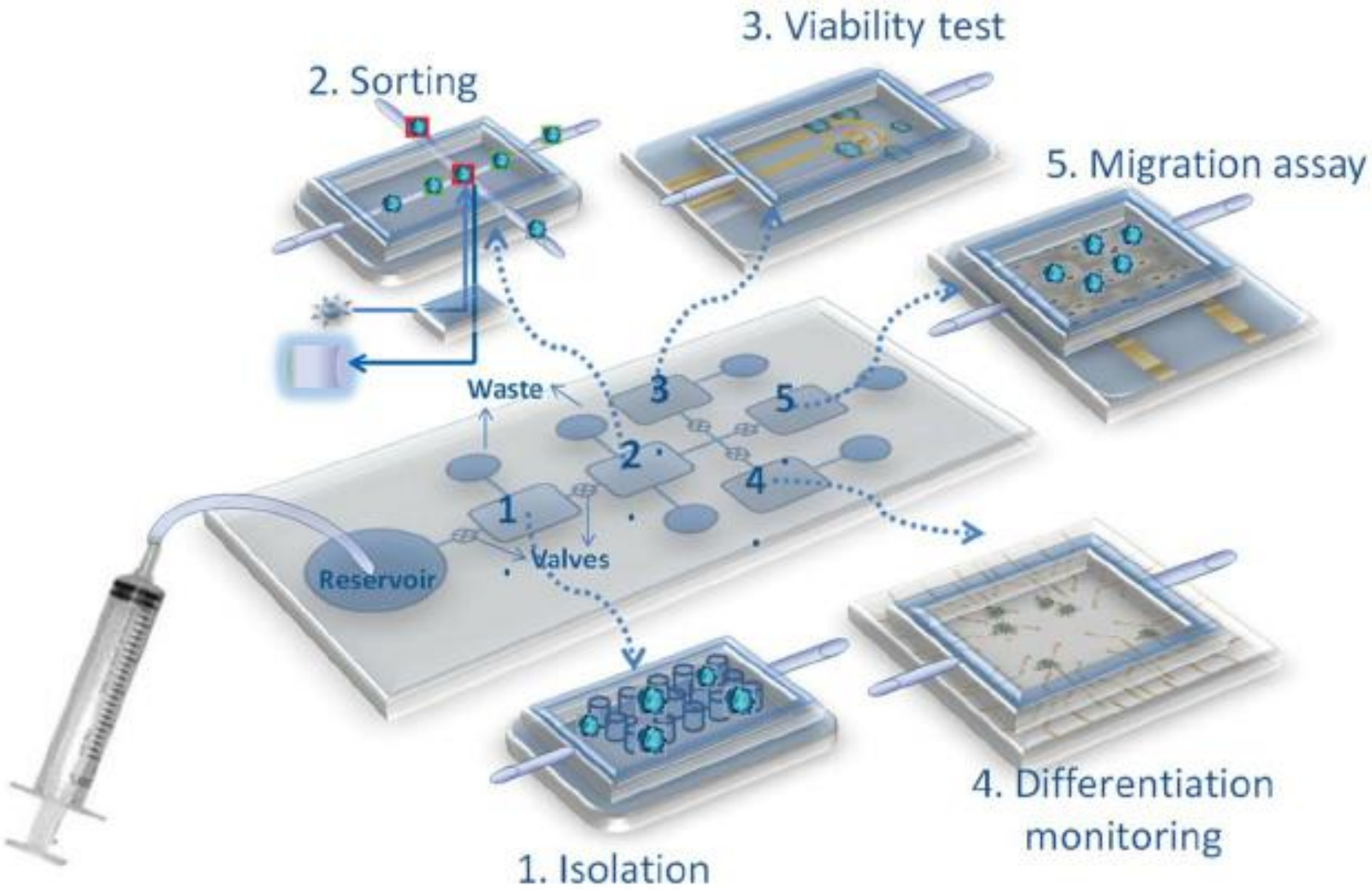
Microfluidics Technology

- Results
  - 3 phases
    - **Ring-form Stage**
    - **Trophozoite Stage**
    - **Schizont Stage**
  - Different behaviors
  - Quantitative measurements
    - Recovering time
    - Instrusion length
  - Viscoelastic behavoir of RBC





Shelby *et al*, PNAS, Vol. 100 No. 25 14618-14622 (2003)



Example of a modular lab on a chip for stem cell studies. Several microfluidic components and sensing modules are integrated together for cell isolation, detection and counting, viability or migration assays and differentiation studies.

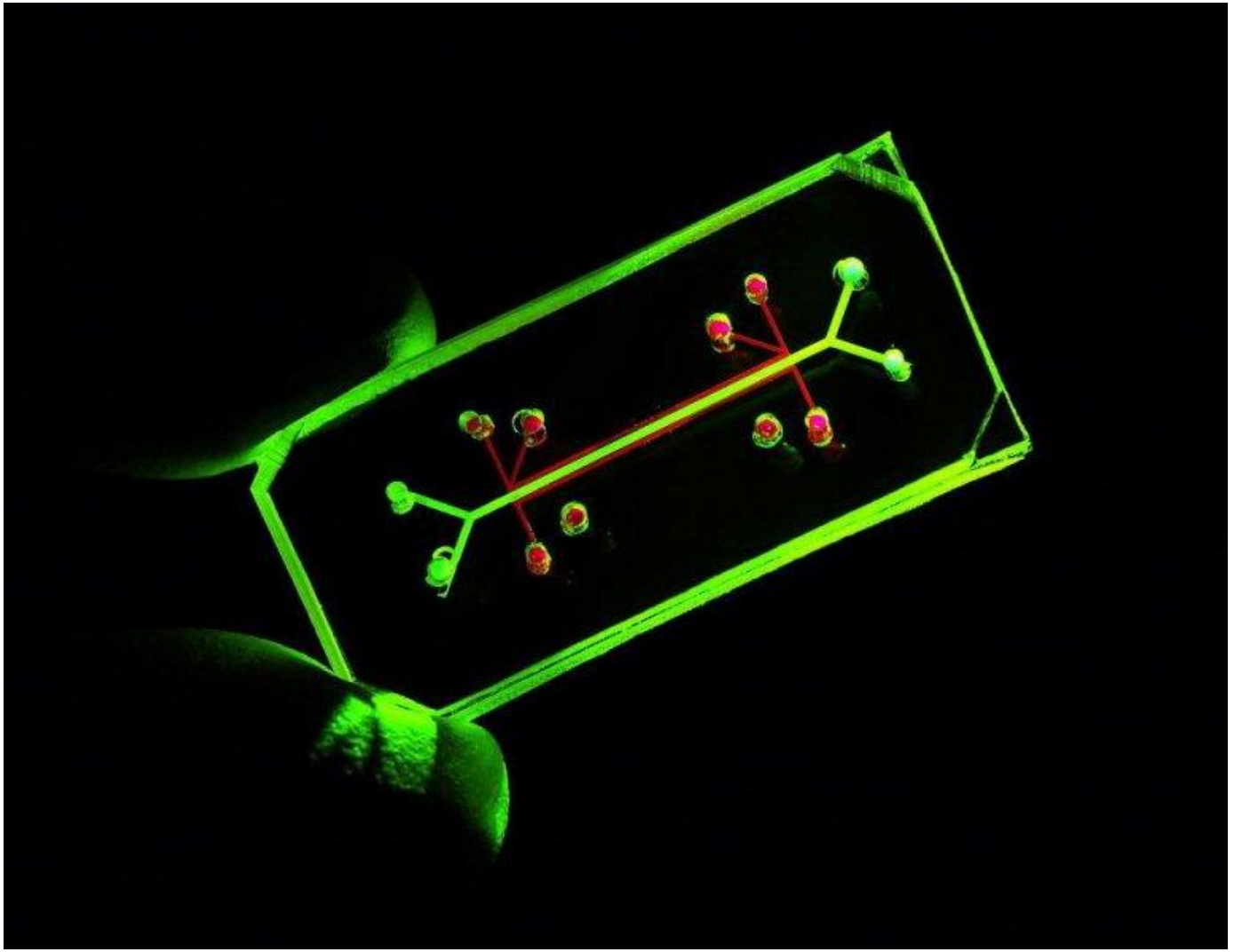
Organs-on-chip

- Physical context of real living cells, tissues and organs.
- Replace animal studies
- Detection of pathogens

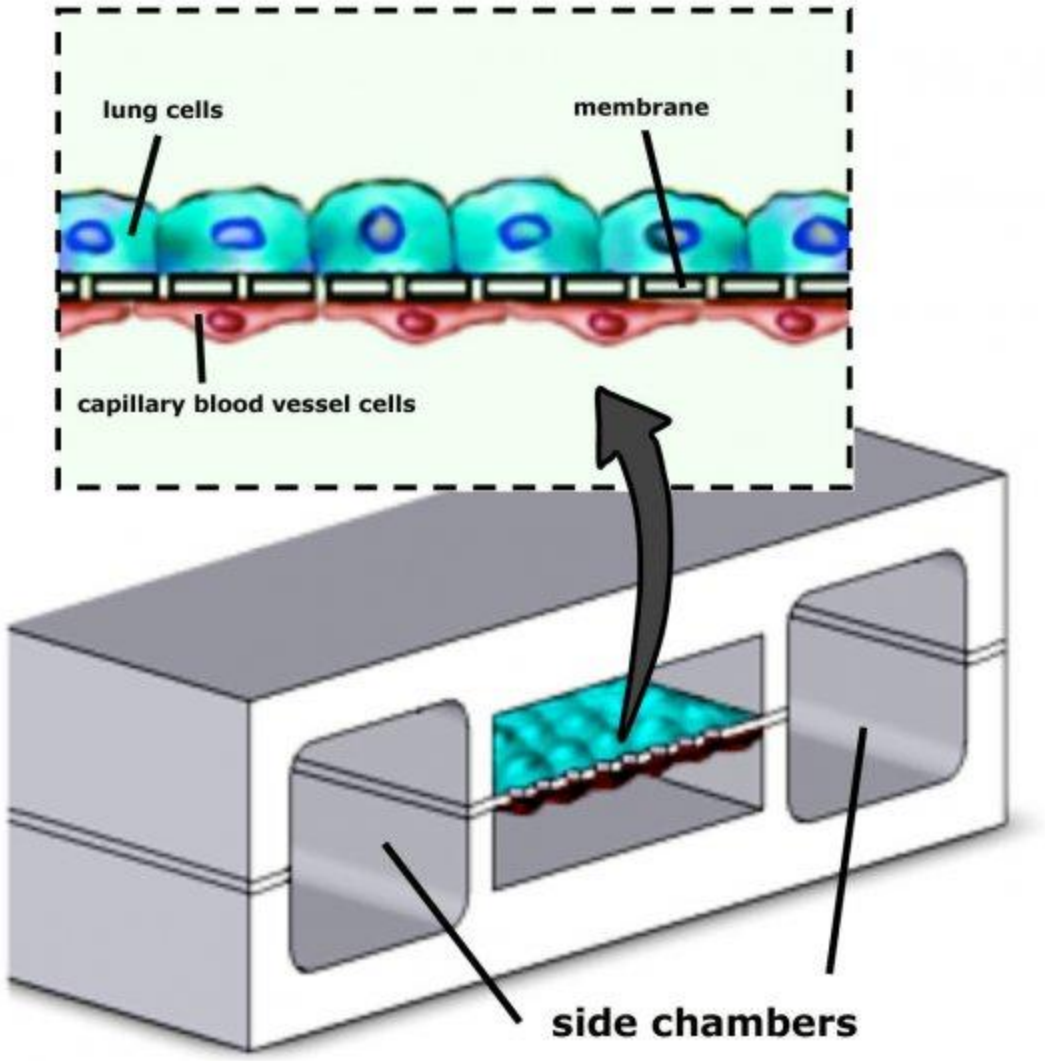
Lung-on-a-chip

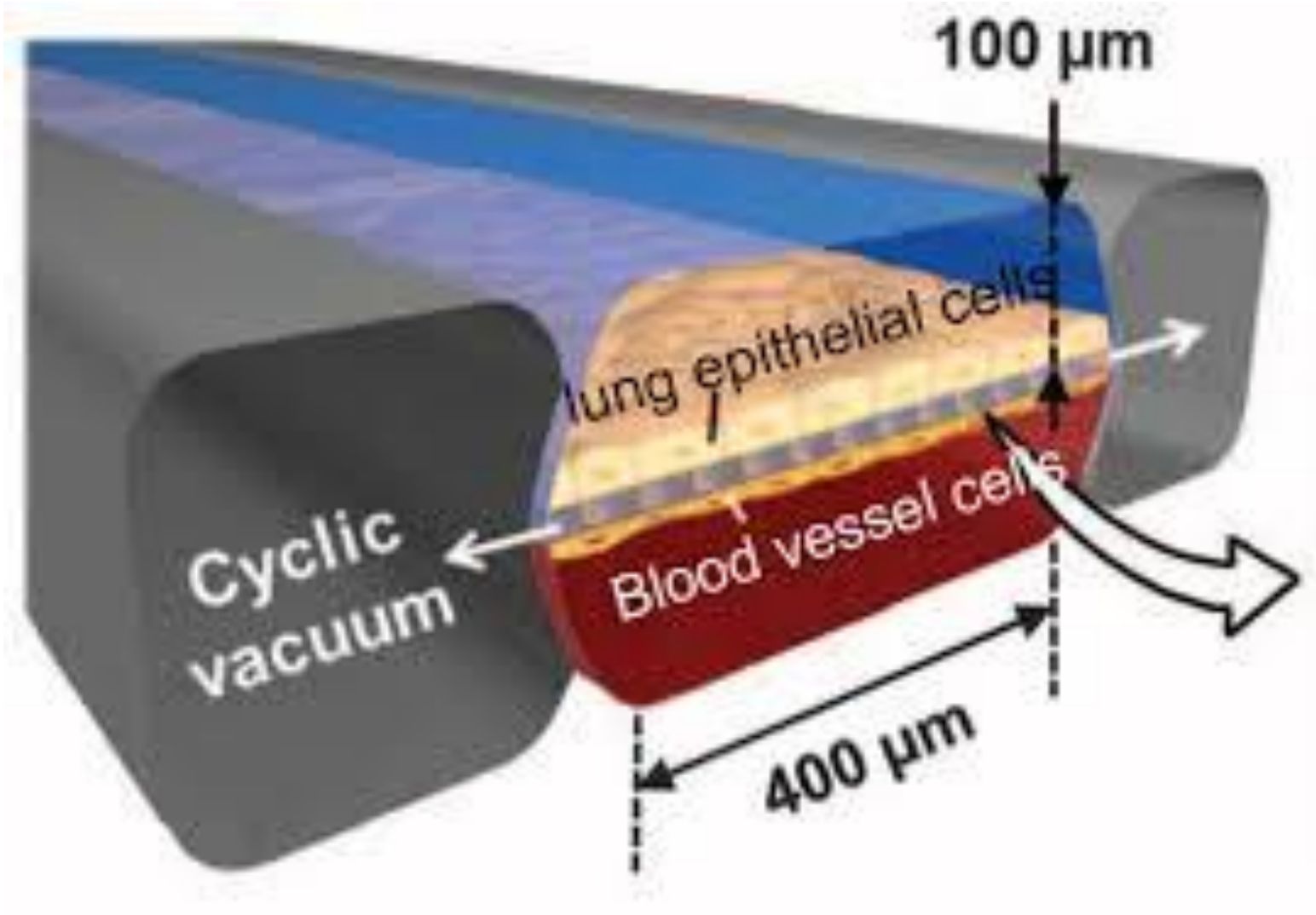
- Device that mimics a human lung
- Scientists at Harward Medical School and the Children's Hospital in Boston
- Lung and blood vessels incorporated into a microchip

Lung-on-a chip



Lung-on-a chip




100 µm
lung epithelial cells
Blood vessel cells
Cyclic
vacuum
400 µm

Significant biological, chemical, medical, environmental and energy applications

- Nucleic acid biotechnology and analysis (DNA and RNA sequencing, genotyping, gene manipulation)
- Protein analysis (proteomics and metabolomics for targeted and global analysis)
- Medical diagnostics (for example point of care and molecular)
- Medical devices and treatments (including implantable and wireless)
- Drug development (screening and delivery)

Significant biological, chemical, medical, environmental and energy applications

- Cells, tissues, organs on chip and integrated tissue engineering
- 3D cell culture
- Single cell analysis
- Cell and organism motility and interactions
- Systems and synthetic biology and medicine
- Energy, biofuels, fuel extraction
- Environmental and food monitoring for health and security

Advantages

- LOC technology enables the use of small fluid volumes which helps cut costs and the analysis of reagents and response time.
- It also allows greater control over sample concentrations as well as interactions to reduce the quantity of chemical waste.
- This technology can aid the development of highly compact systems through mass production.

Disadvantages

- The physical and chemical effects such as surface roughness, capillary forces, and chemical interactions between materials are more significant at the microscale level.
- This can often result in complications during LOC experiments which would not be expected with traditional lab equipment.
- The principles of detection might not always be in agreement with microscale dynamics and this can result in a low signal-to-noise ratio.