

# Lab-on-a-chip

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Nanoanalytics and Biophysics Seminar

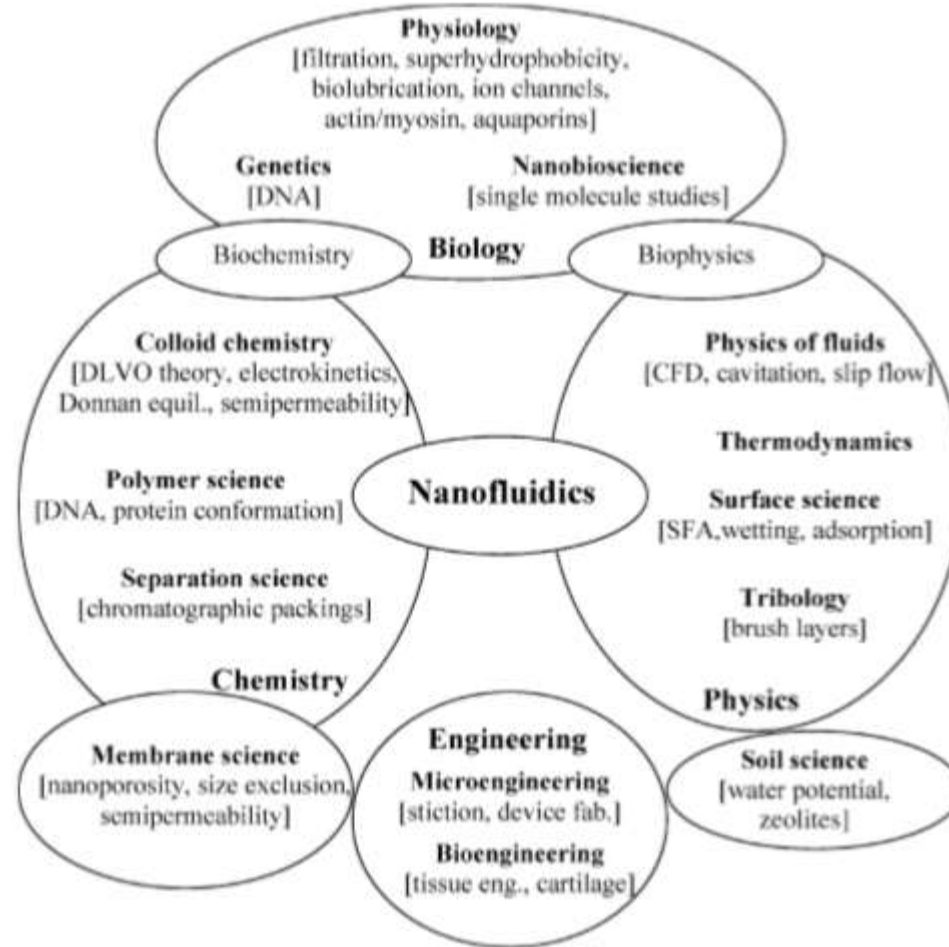
25.06.2019

# *Content*

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  - Advantages
  - Materials
  - Applications
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# Nanofluidics

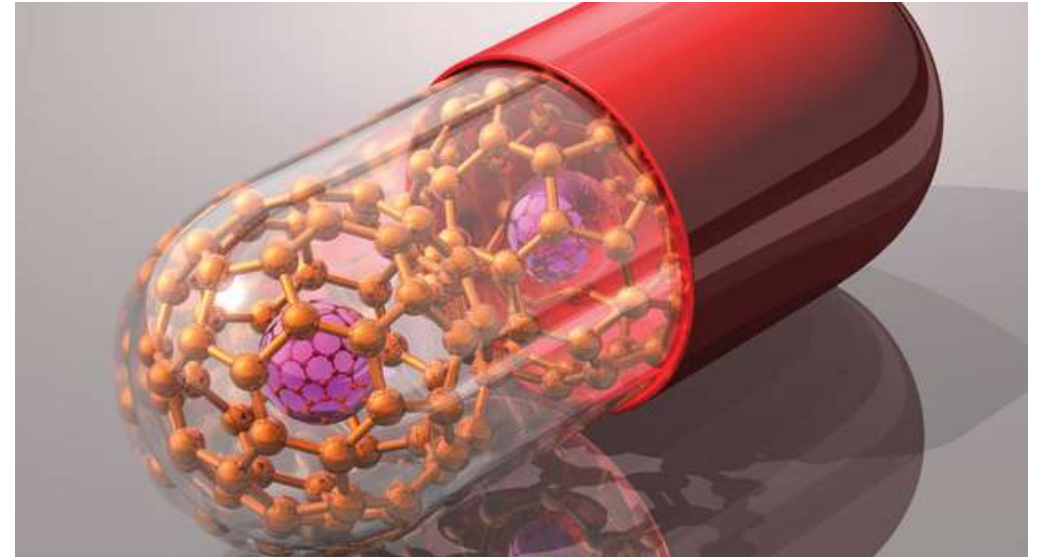
The study and application of fluid flow in and around nanosized objects.



*Eijkel et al. Microfluid (2004)*

# Nanomedicine

- Application of nanotechnology to medicine for therapy and diagnosis of diseases
- Nanoparticles can be chemically modified for targetting specific disease tissues
- Drugs can encapsulated inside nanoparticles and released in a controlled manner



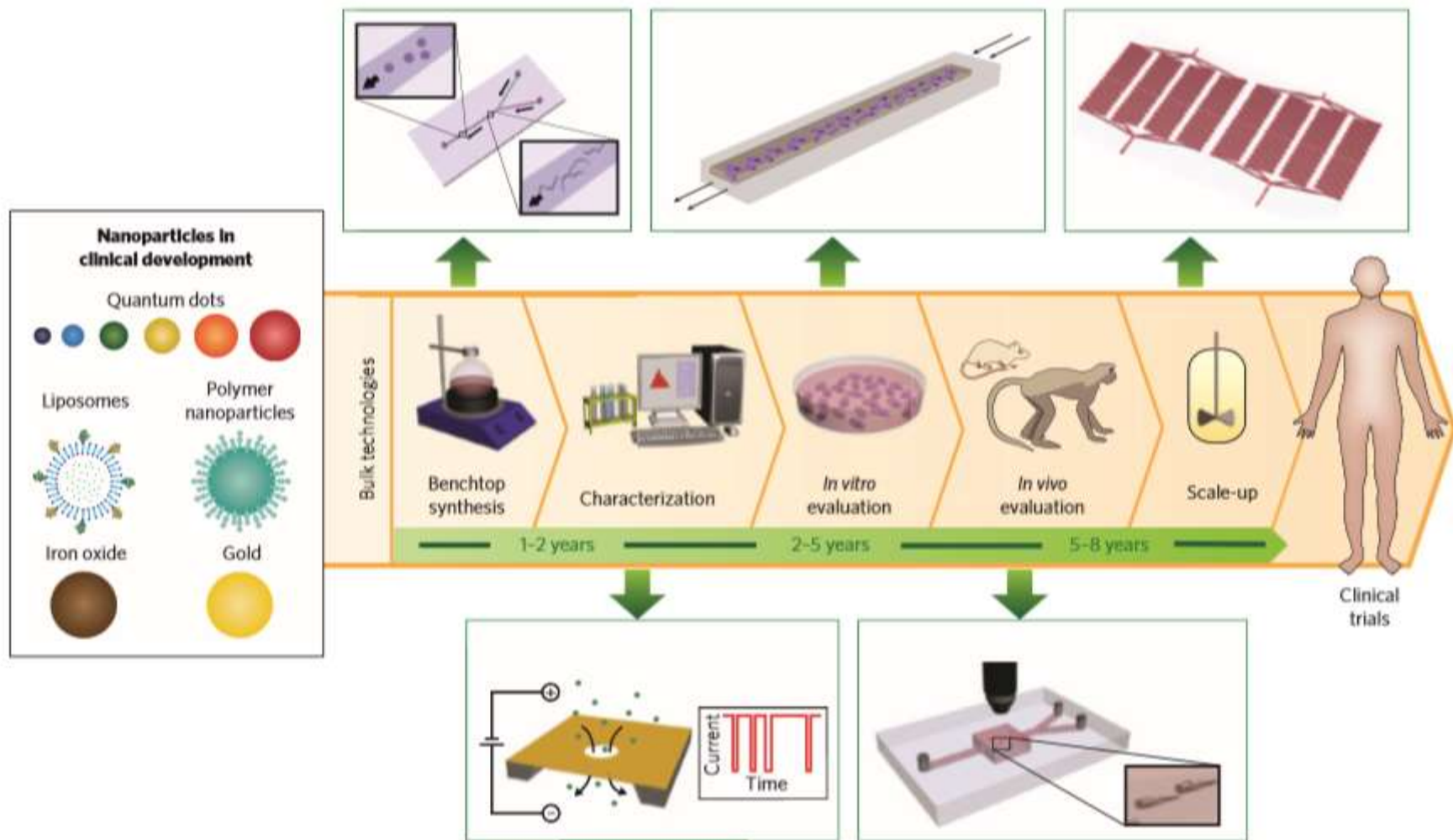
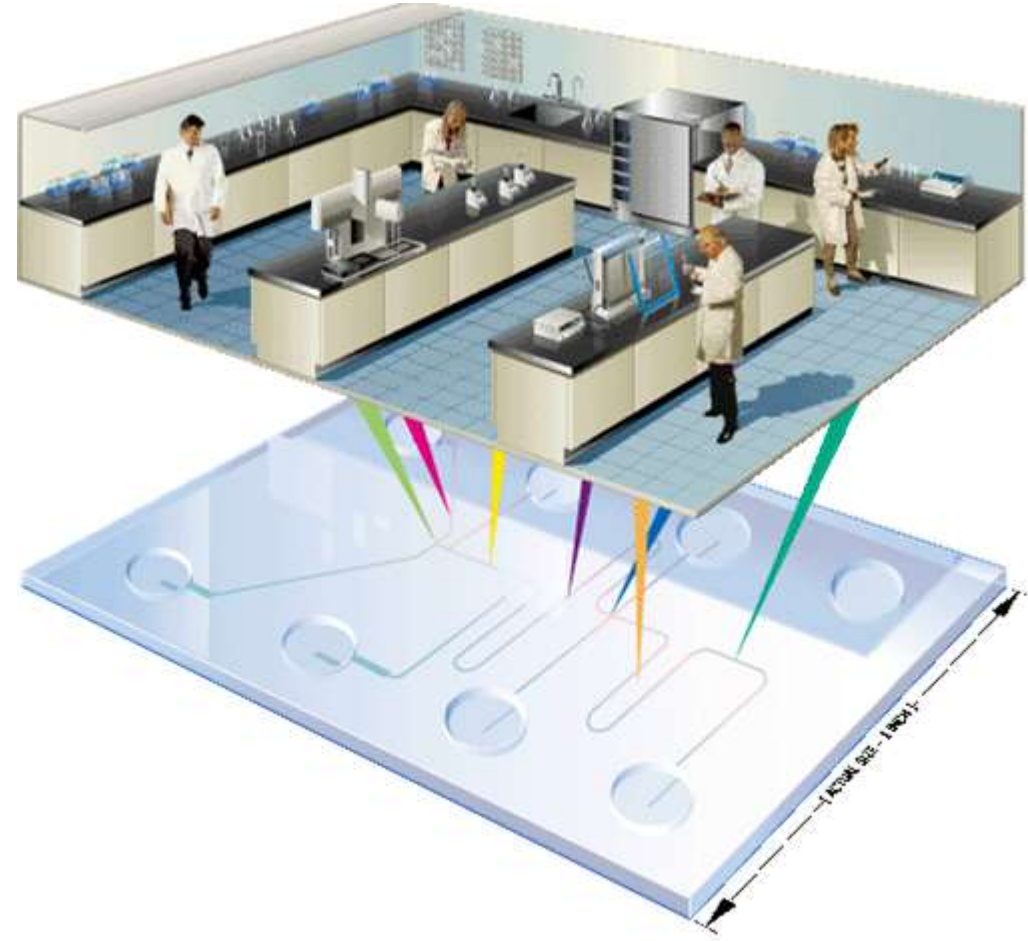


Fig. Nanoparticles in clinical development.

*Valencia et al. Nature (2012)*

# Lab-on-a-chip

integrates one or several laboratory functions on a single integrated circuit to achieve automation and high-throughput screening



# *Advantages of Lab-on-a-chip*

- Low cost
- High parallelization
- Faster response time
- Easy to use and compact
- Reduction of human error
- Low volume samples

# Materials for Lab-on-a-chip



- **PDMS**

- + easy to fabricate
- + cheap
- hard to integrate electrodes



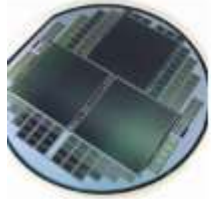
- **Thermopolymers**

- + transparent
- + chemically inert
- more expensive



- **Glass**

- + transparent
- + chemically inert
- + compatible with micrometer sized machining
- fabrication requires clean rooms



- **Silicon**

- + ability to integrate any kind of microelectrodes and even electronics
- expensive
- not optically transparent
- requires a clean room and a strong knowledge of microfabrication



- **Paper**

- + ultra low cost
- not good mechanical properties

# *Applications*

- Point-of-care diagnostics
- Cell analysis
- Drug metabolism
- Organ-on-a-chip
  - Kidney on a chip
  - Gut on a chip
  - Lung on a chip
  - Heart on a chip etc.

# *Drug development*

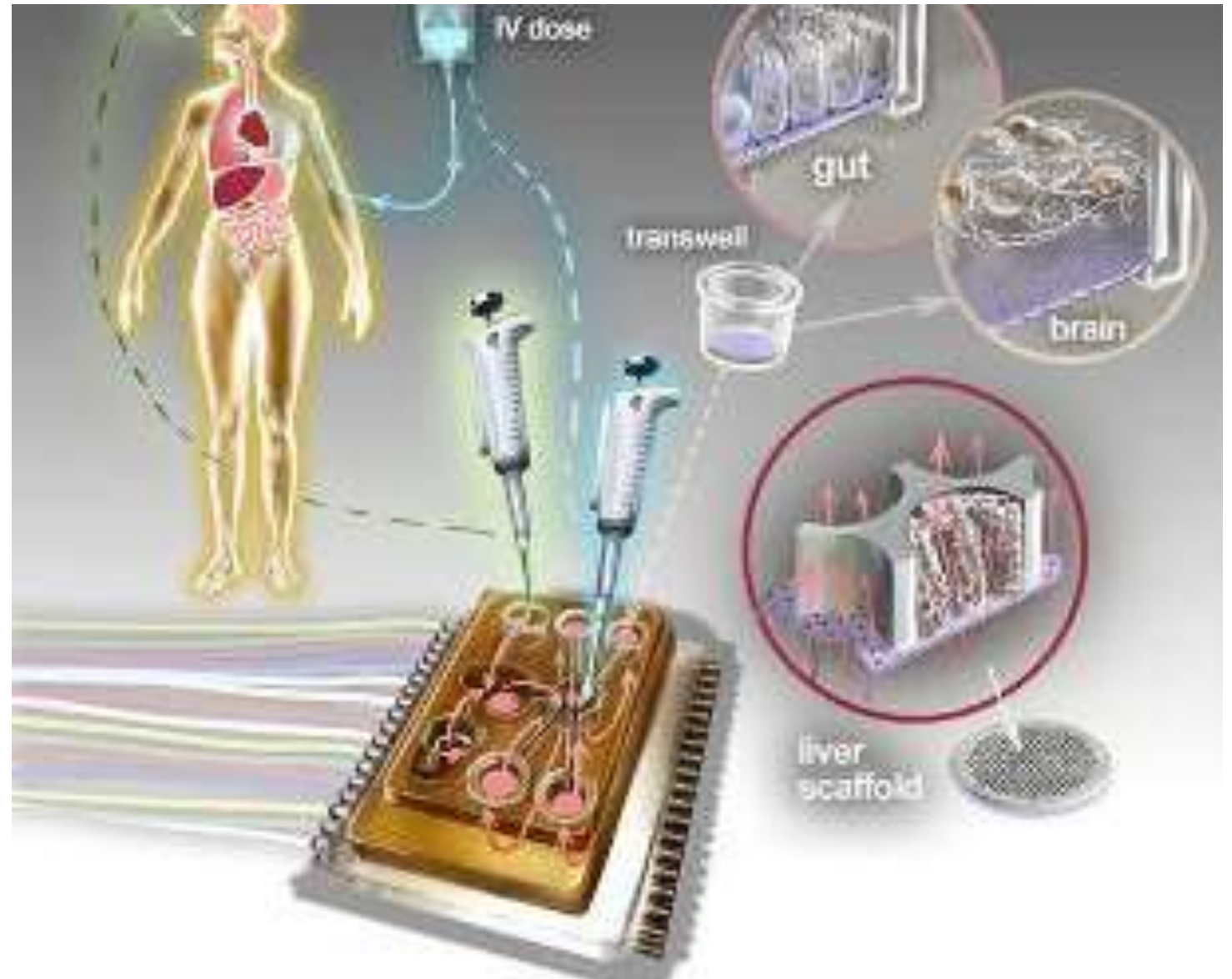
- 2D cell cultures
  - No information about complex interactions
  - Lack organ level structures and fluid flows
- Animal models
  - No native tissue specific microenvironment
  - Cannot predict therapeutic responses in humans

**SOLUTION?**

more complex model is needed

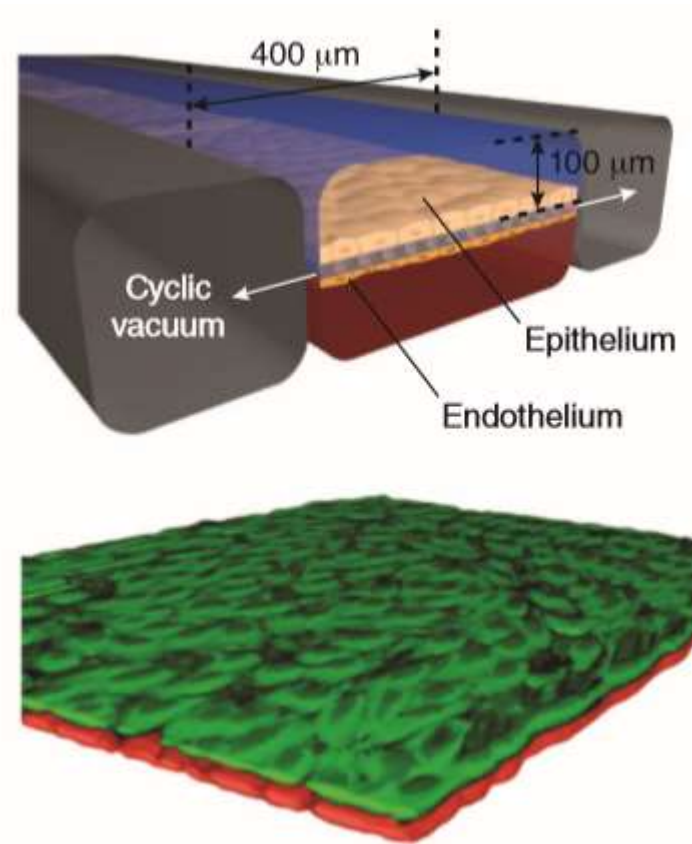
# Organ-on-a-chip

microfluidic system with controlled, dynamic environment in which cultured cells exhibit functions that simulate organ level physiology

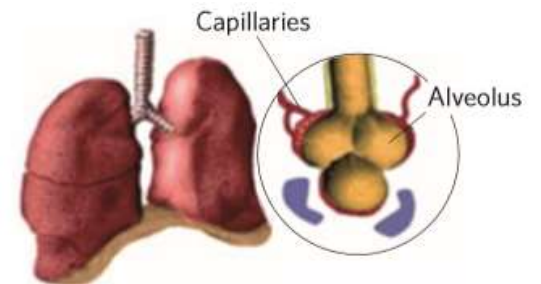
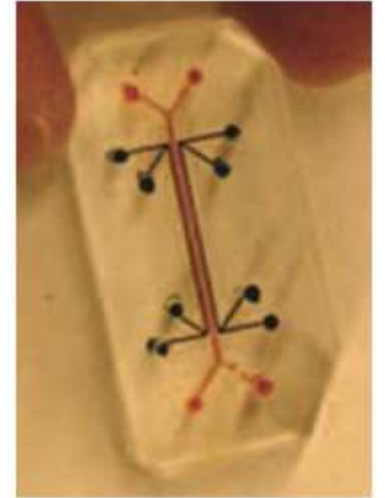


# Lung-on-a-chip

- Human alveolar epithelial cells are cultured on top of flexible, porous, ECM-coated membrane and human capillary endothelial cells on the bottom
- Air is passed through the upper channel to create air-liquid interface
- Breathing motion is mimicked by applying cyclic suction



*Bhatia et al. Nature (2014)*



- Cardiovascular diseases is a leading cause of death
- High demand to create a realistic heart model

SOLUTION?

## Heart-on-a-chip

- challenging
  - mimic the heart's main properties:
    - mechanical contractions
    - molecular transport
    - electrical activity
  - contraction movement is extremely important



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***ENGINEERED TISSUES DERIVED FROM INDUCED-PLURIPOTENT STEM CELLS (IPSCs) FOR DISEASE MODELING, DRUG DISCOVERY, AND REPLACEMENT THERAPIES\****

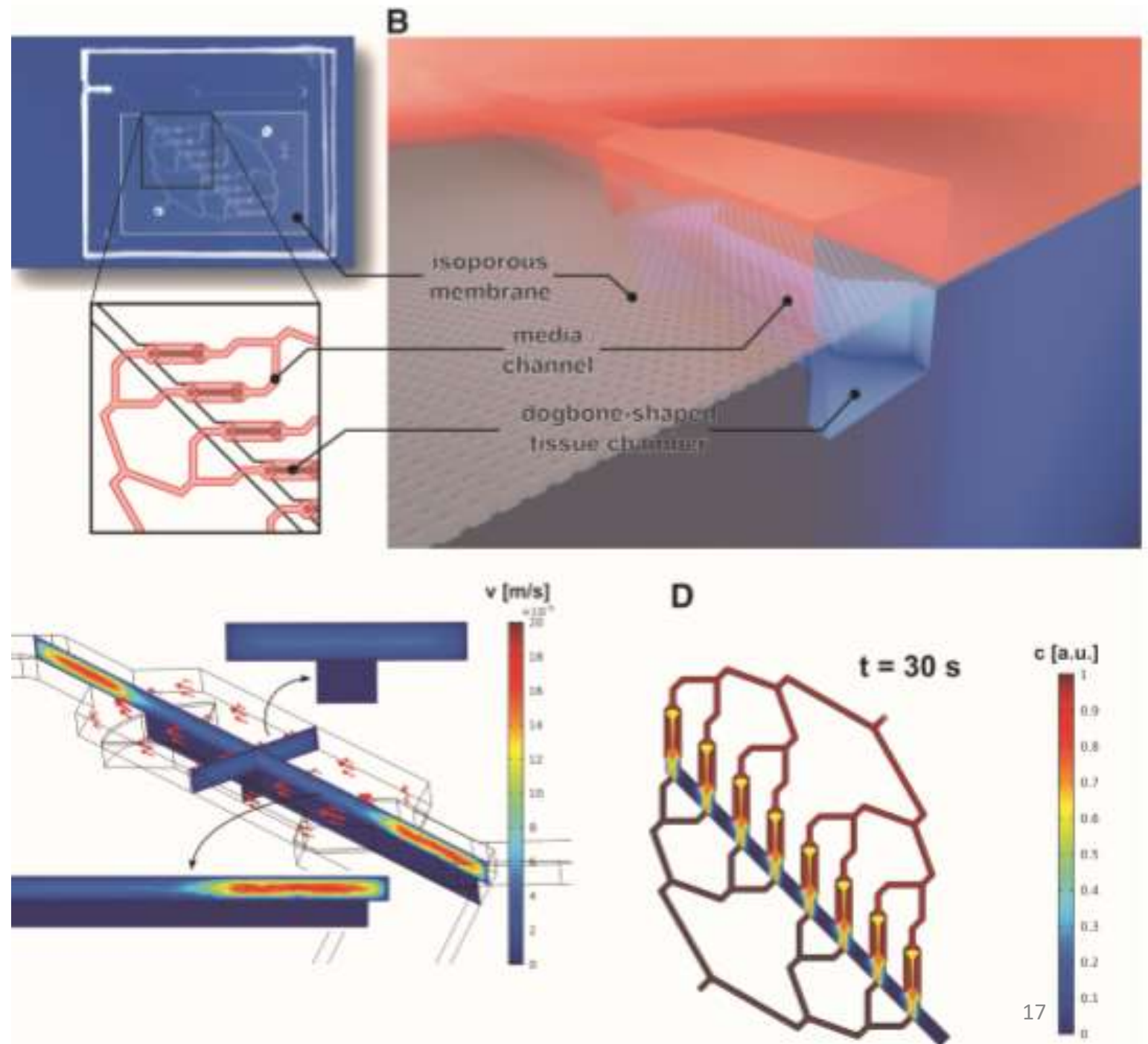
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## User-Friendly and Parallelized Generation of Human Induced Pluripotent Stem Cell-Derived Microtissues in a Centrifugal Heart-on-a-Chip

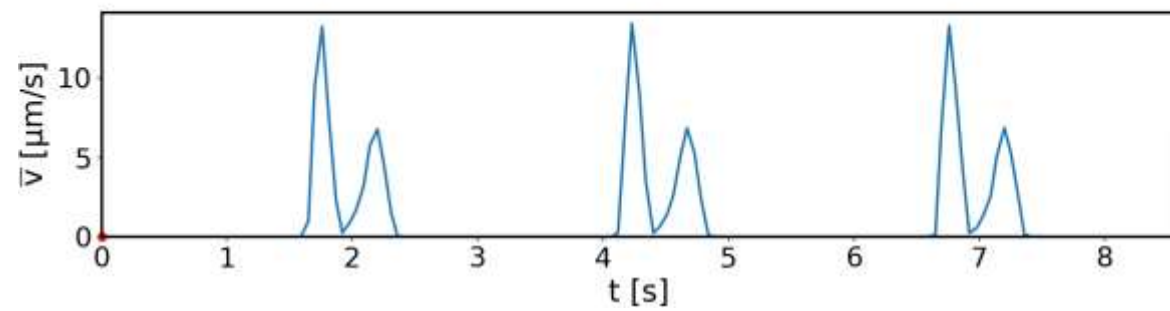
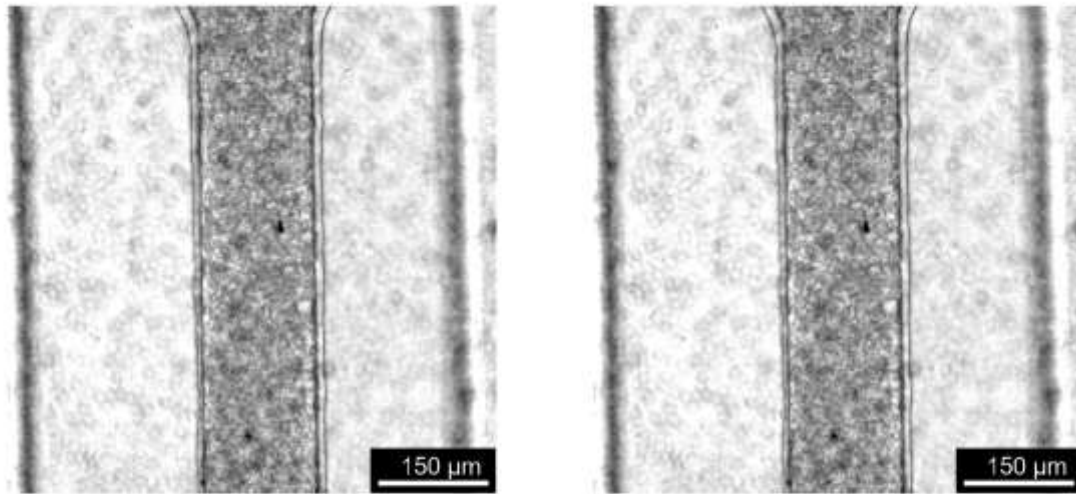
Oliver Schneider, MS,<sup>1</sup> Lisa Zeifang, MS,<sup>1</sup> Stefanie Fuchs, MS,<sup>1</sup> Carla Sailer, BS,<sup>1</sup> and Peter Loskill, PhD<sup>1,2</sup>

- Human induced pluripotent stem cells, cardiomyocytes and rat cardiac myocytes were used
- Two microfluidic modules (PDMS) with a PET membrane
- Tissue chamber allows large adhesion

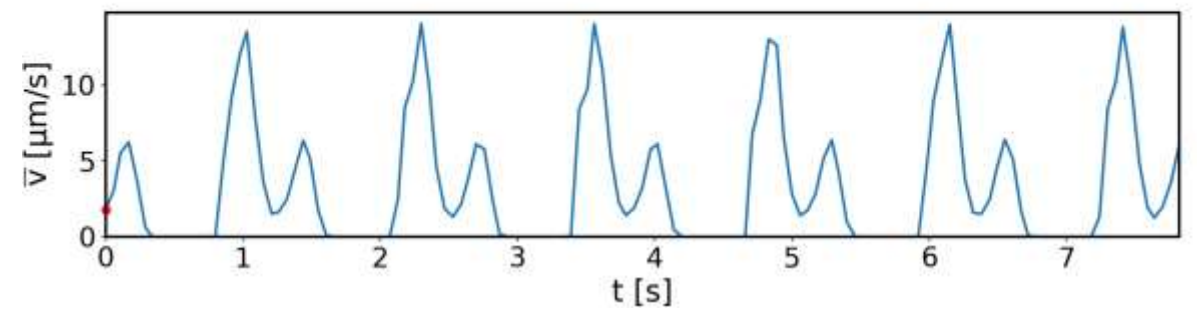
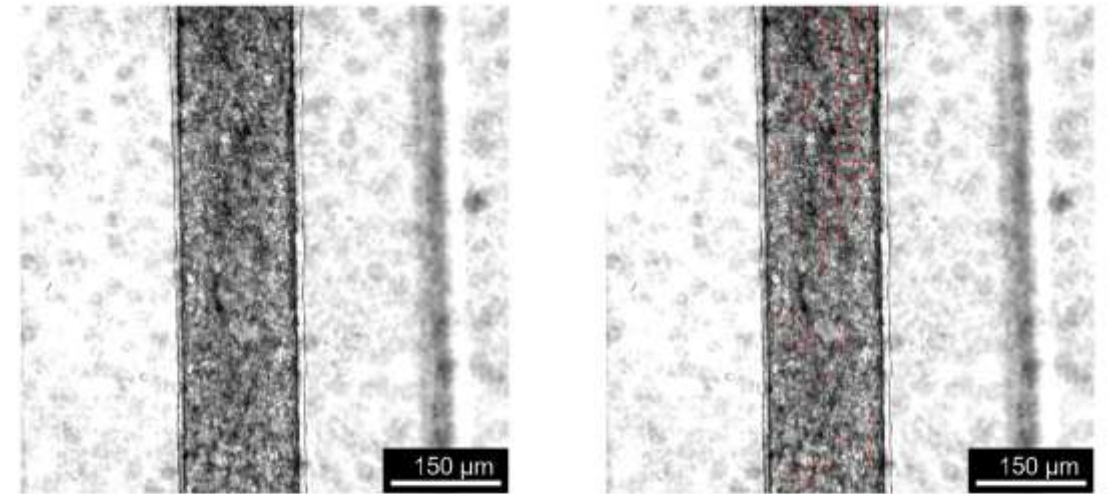
# Concept of Heart on Chip



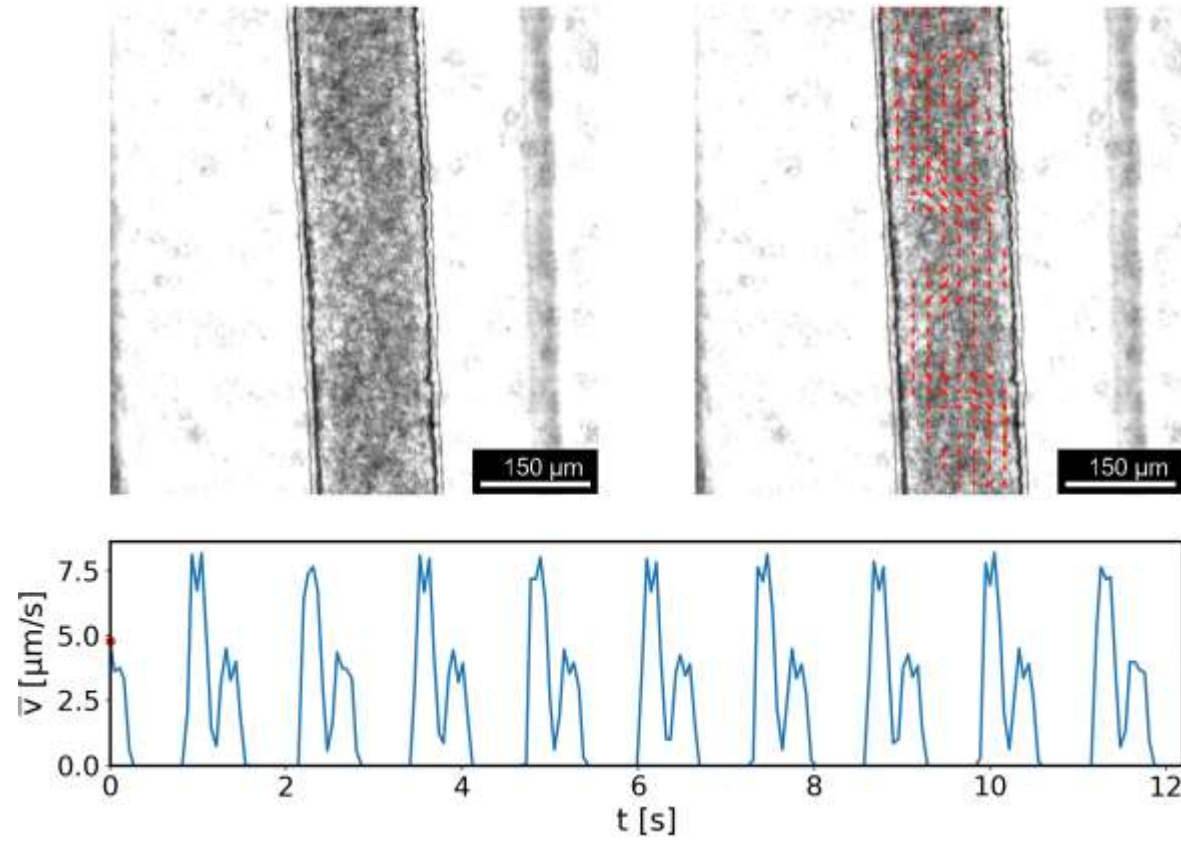
hiPSC-derived cardiac  $\mu$ -tissue, d2



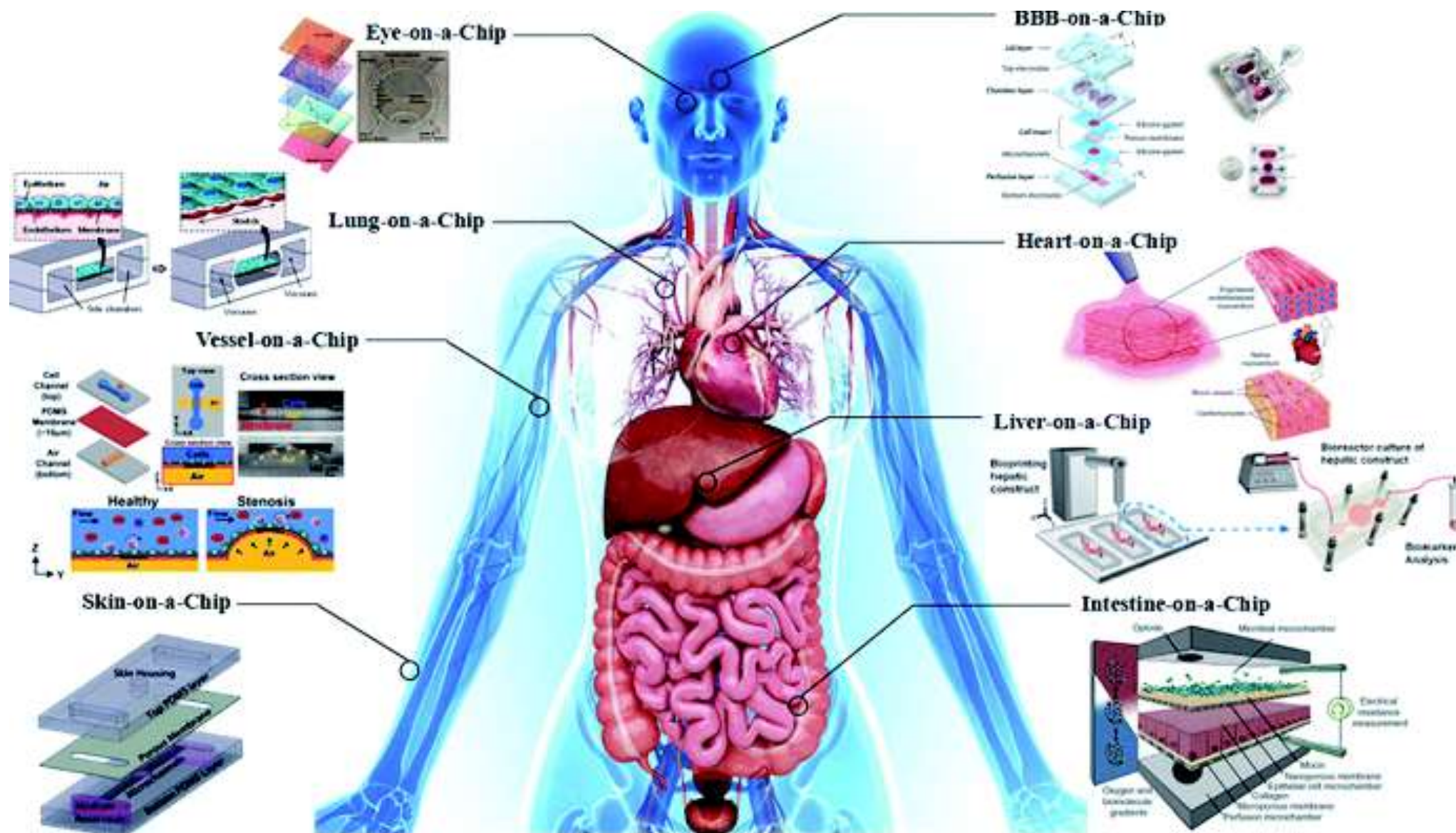
hiPSC-derived cardiac  $\mu$ -tissue, d28



hiPSC-derived cardiac  $\mu$ -tissue, d7 post-Isoprot.



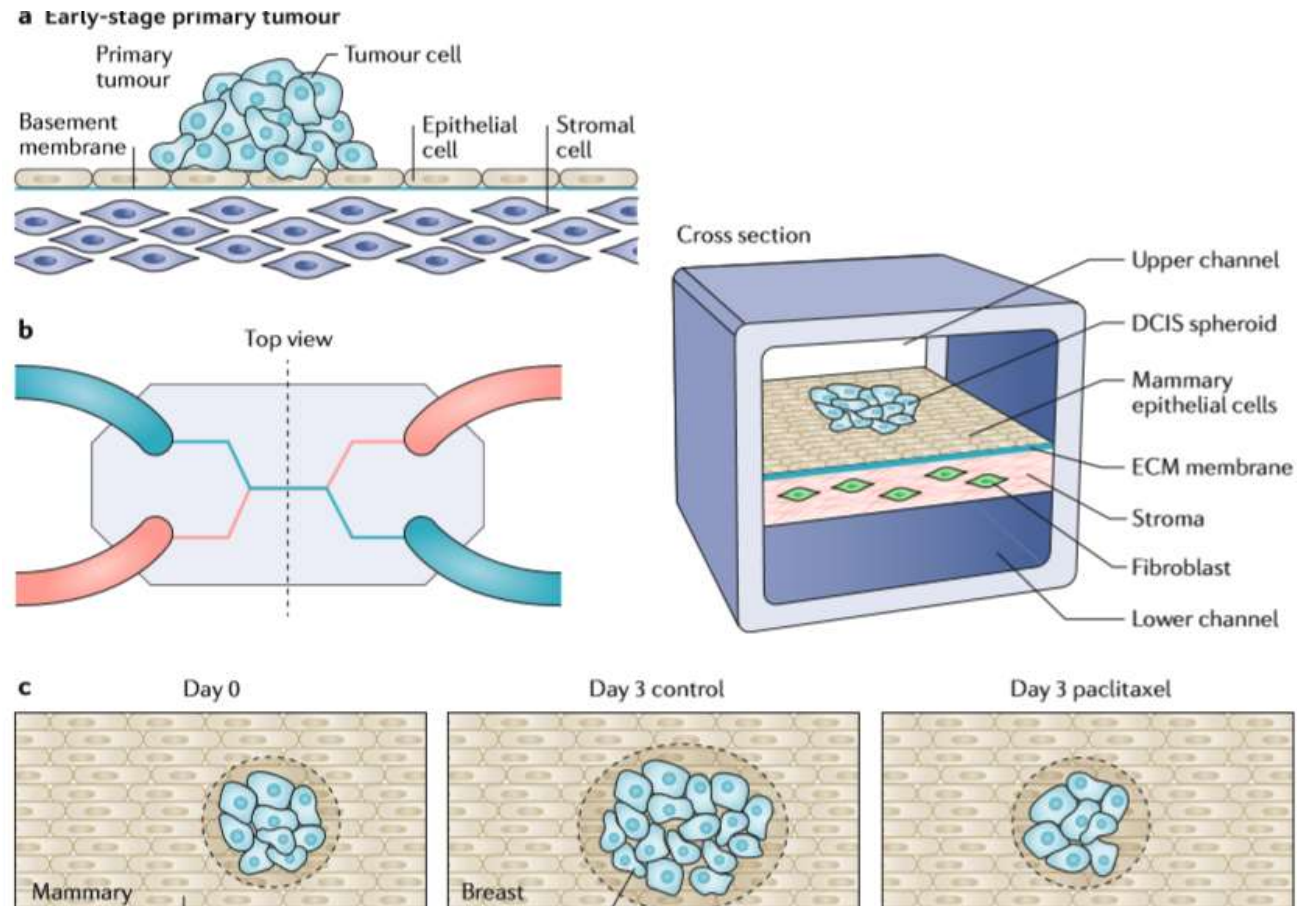
- A physiologically relevant heart on chip system was developed
- Enables robust loading, culturing, optical analysis of individual morphologically and functionally complex miniaturized cardiac tissues each consisting of around 12500 cells
- Perfect platform for various biomedical applications:
  - drug testing
  - personalised medicine



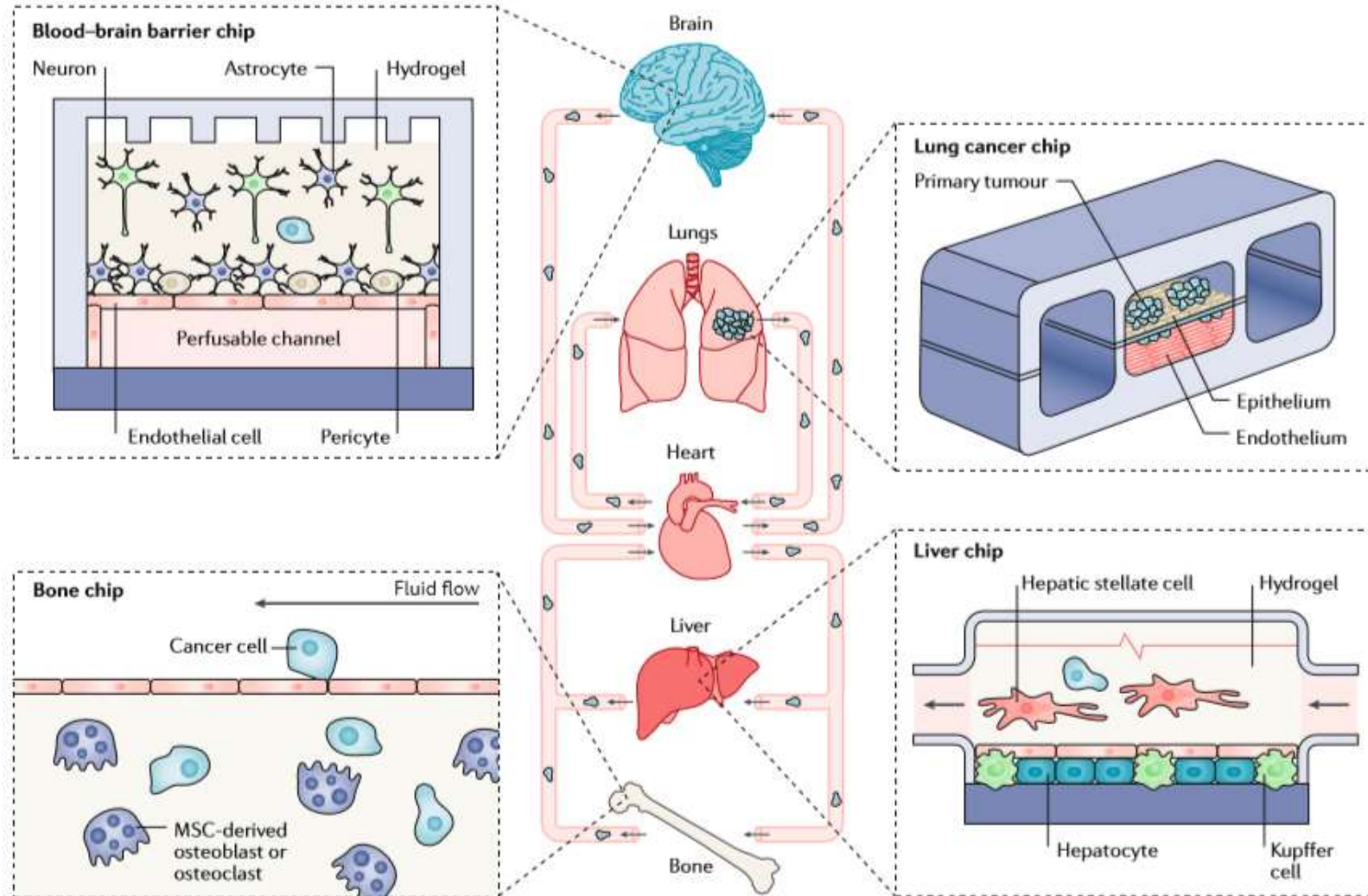
# *Cancer on a chip*

- reproduce specific key aspects of the tumor microenvironment
- possible to personalise chips for each patient to choose the most effective and least toxic therapy
- Drugs can be tested in a high throughput manner directly on the chip to better predict response to many therapies at once

# Breast cancer on chip



# Mechanisms of metastasis



# Summary

- Level of tissue and organs functionality
- Provide information about complex interactions between cells
  - High-resolution, real time imaging
- Personalised treatment and prevention strategies
- More effective healthcare, time and cost reduction of drug development

Thank you for your attention!

# Lab on a chip turns smartphones into mobile disease clinics

- Cheap, easy to use smart phone attachment can test patient for multiple infectious diseases in 15 minutes from one drop of blood from a finger
- Pressing the big black button creates a vacuum that sucks blood into a maze of tiny channels within its disposable credit card sized cartridge
- Several detection zones snag any antibodies in the blood that reveal the presence of particular disease

