



Focus Specialization in Engineering for Health

(formerly the Biomedical Engineering focus)

Prof. Brad Nelson
Multi-Scale Robotics Lab

Engineering for Health



- **Engineering for Health** bridges engineering and biological systems in order to improve our health and our healthcare systems. The focus covers **biomedical engineering** and **global health engineering**.
- **Biomedical engineering** creates new medical technologies to improve patient care and quality of life.
- **Global health engineering** creates new technical innovations to improve living conditions for everyone.



A Day in the Life of a Biomedical Engineer

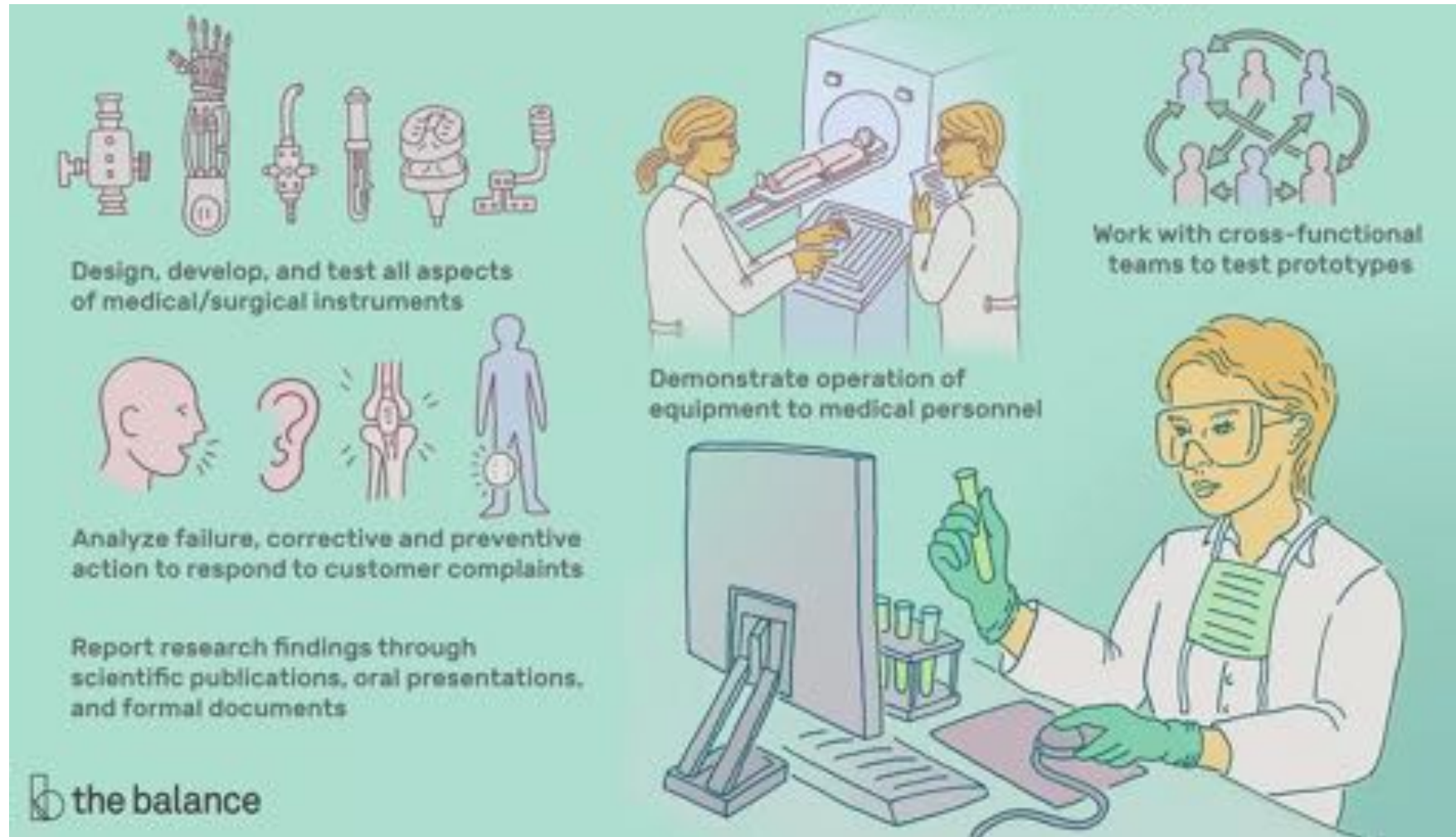
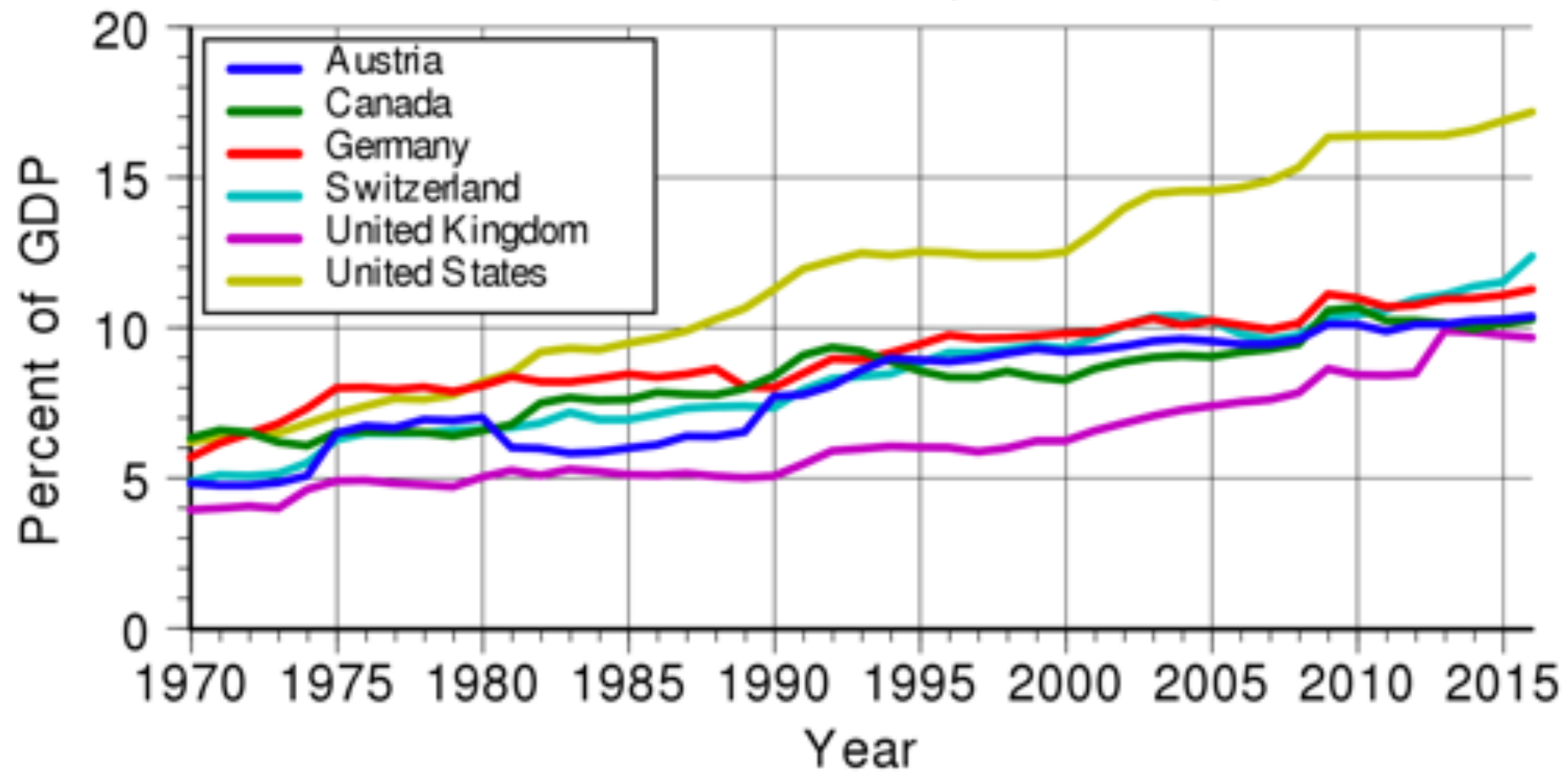


Image by Evan Polenghi © The Balance 2019

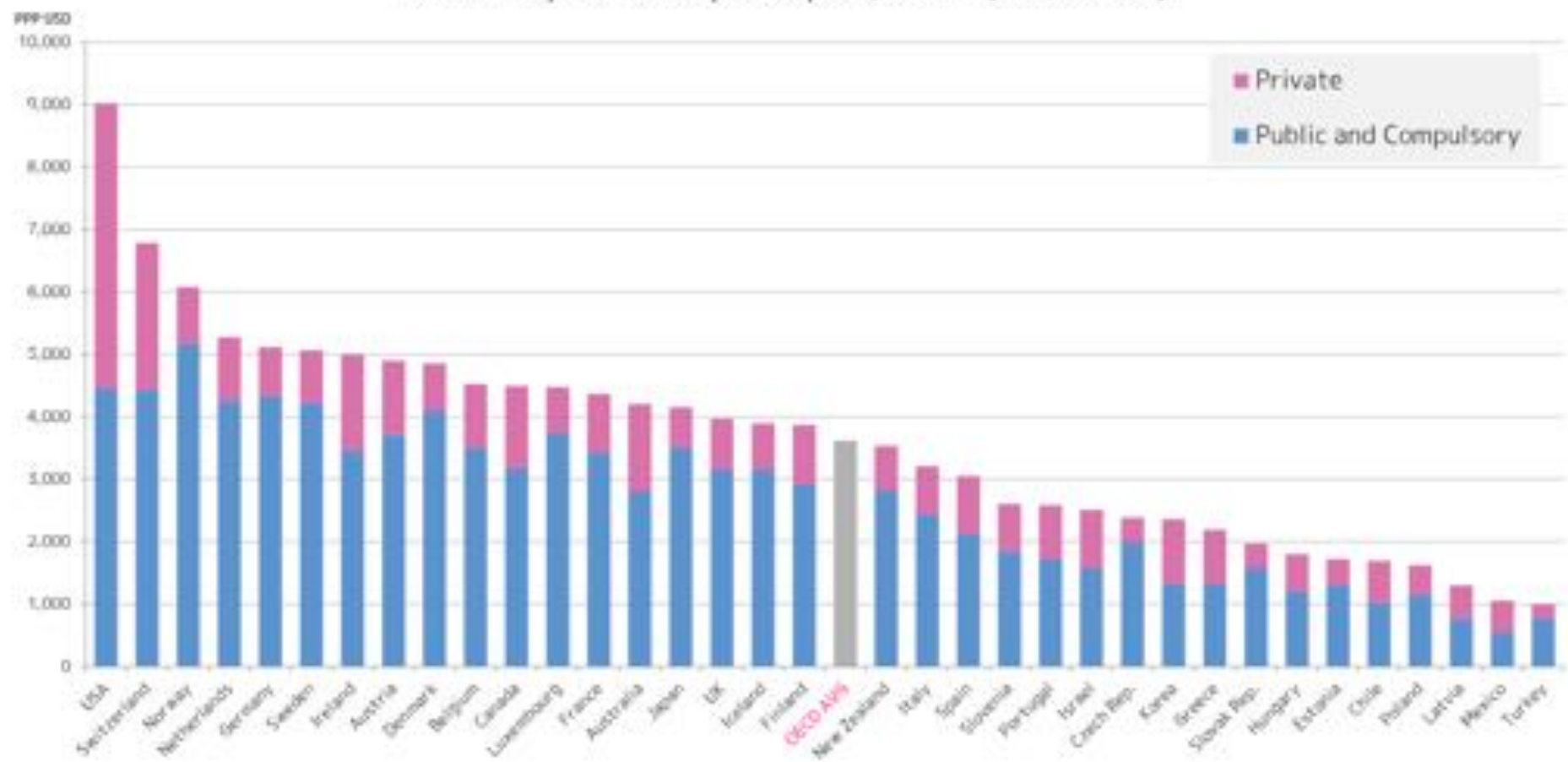
Biomedical Engineering



Health Care Cost (1970-2016)



Health expenditure per capita, 2014 (OECD stat)

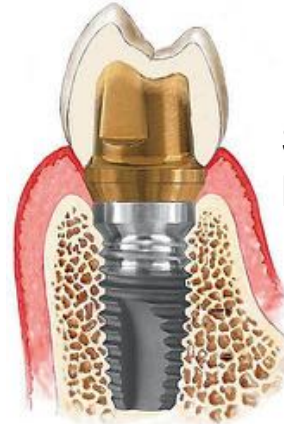


Medtech Industry in Switzerland

Hocoma



Phonak/Sonova



Straumann,
Nobel Biocare

Scanco Medical



Ypsomed



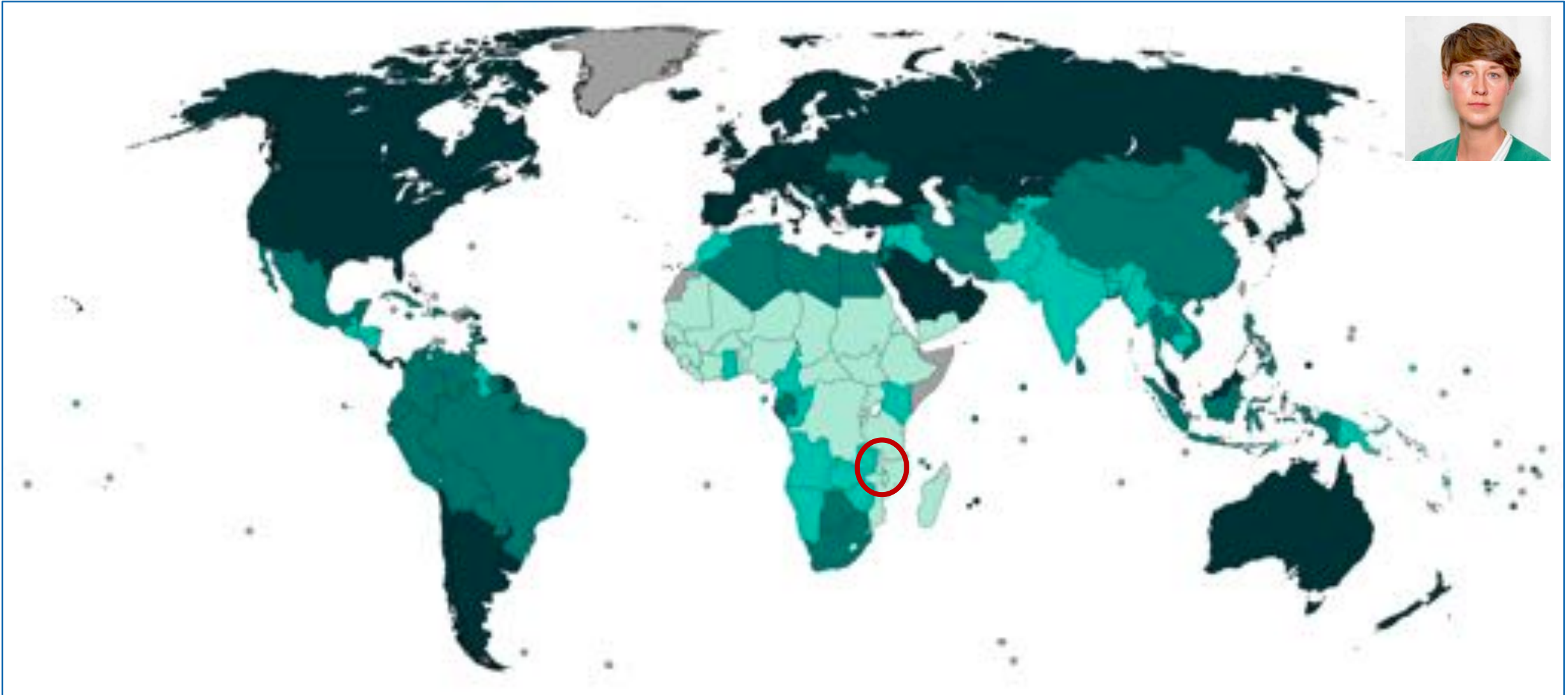
Johnson&Johnson,
Mathys, Smith&Nethew,
Stryker, Synthes, Zimmer, etc.

Global Health Engineering

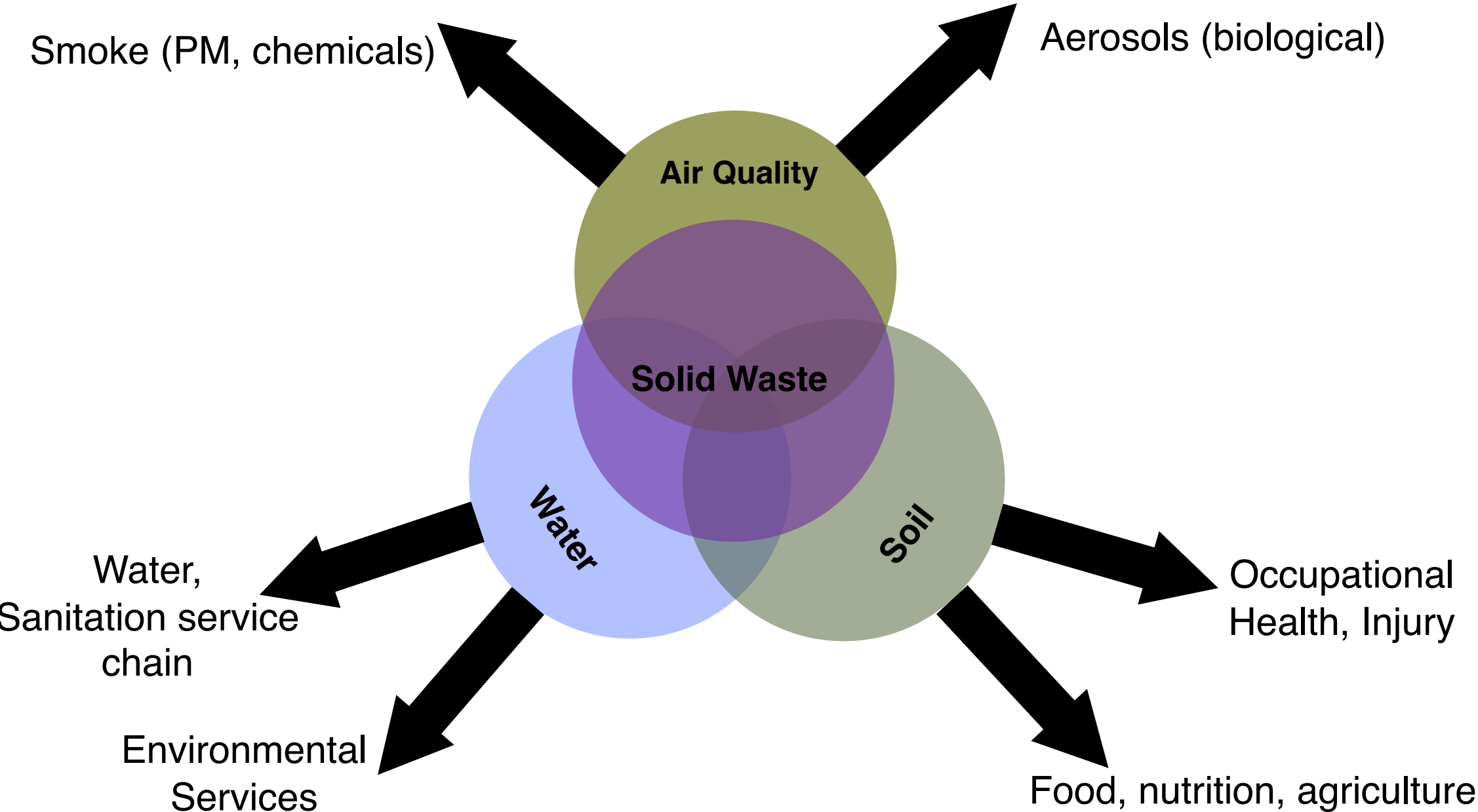


- Global Health Engineering considers how
 - engineered tools and technologies;
 - the natural environment;
 - organizational systems;
 - and human health are interconnected
- The field looks at ways of reducing the negative impacts of modern life while addressing equity and social justice, particularly in urban areas of over-exploited countries.
- Methodologically, applied research is conducted by working with interdisciplinary partners and relevant stakeholders, at the interface of engineering and economics.

Global Health Engineering



Global Health Engineering





EfH: HS Lectures

Lerneinheit	Lerneinheitstitel	Dozierende	Kreditpunkte
376-0021-00L	Materials and Mechanics in Medicine	M. Zenobi-Wong, J. G. Snedeker	4
376-0203-00L	Bewegungs- und Sportbiomechanik	Taylor, W. R. (H), List, R., Lorenzetti, S.	4
376-1504-00L	Physical Human Robot Interaction (pHRI)	Gassert, R. (H), Lambercy, O.	4
376-1714-00L	Biocompatible Materials	Maniura, K. (H), Möller, J., Zenobi-Wong, M.	4
227-0385-10L	Biomedical Imaging	Kozerke, S. (H), Prüssmann, K. P.	6
227-0393-10L	Bioelectronics and Biosensors	Vörös, J. (H), Yanik, M. F., Zambelli, T.	6
151-0255-00L	Energy Conversion and Transport in Biosystems	Ferrari, A. (H)	4
151-0509-00L	Microscale Acoustofluidics	Dual, J. (H)	4
151-0524-00L	Continuum Mechanics I	Mazza, E. (H)	4
151-0604-00L	Microrobotics	Nelson, B. (H)	4
151-0619-00L	Introduction to Nanoscale Engineering	Pratsinis, S. E. (H), Wegner, K., Mavrantzas, V., Eggersdorfer, M.	5
151-0621-00L	Microsystems I: Process Technology and Integration	Haluska, M. (H), Hierold, C.	6

EfH: FS Lectures

Lerneinheit	Lerneinheitstitel	Dozierende	Kreditpunkte
376-0022-00L	Imaging and Computing in Medicine	R. Müller, P. Christen	4
376-0210-00L	Biomechatronics	Riener, R. (H), Gassert, R.	4
151-0515-00L	Continuum Mechanics 2	Mazza, E. (H), Röhrnbauer, B.	4
151-0540-00L	Experimentelle Mechanik	Dual, J. (H)	4
151-0630-00L	Nanorobotics	Pané Vidal, S. (H)	4
151-0641-00L	Introduction to Robotics and Mechatronics	Nelson, B. (H), Shamsudhin, N.	4
151-0980-00L	Biofluidynamics	Obrist, D. (H), Jenny, P.	4

We are also introducing “Studies on Engineering for Health”, a 4 KP self-study literature review that can be combined with your Bachelor’s Thesis to allow you to dive more deeply into a particular focus topic.

151-8101-00L International Engineering: from Hubris to Hope offered by Prof. Liz Tilley

- Capacity of 40, Thursday at 15-18 in HS21
- For engineers who are interested in pursuing an ethical and relevant career internationally, and who are willing to examine the complex role that well-meaning foreigners have played and continue to play in the disappointing health outcomes that characterize much of the African continent.
- After completing the course, participants will be able to
 - critique the jargon and terms used by the international community, i.e. “development”, “aid”, “cooperation”, “assistance” “third world” “developing” “global south” “low and middle-income”
 - understand the political, financial, and cultural reasons why technology and infrastructure have historically failed
 - Propose improved SDG indicators that address current shortcomings
 - Explain the inherent biases of academic publishing and its impact on engineering failure
 - Analyse linkages between the rise of philanthropy and strategic priority areas
 - Recommend equitable, just funding models to achieve more sustainable outcomes
 - Formulate a vision for the international engineer of the future

Engineering for Health at D-MAVT

Orthopedic Biomechanics



Cell Manipulation,
DNA Analysis

Computational
Biomechanics



Robotics for Health

Rehabilitation
Engineering



Wireless
Strain Sensor

Biothermofluidics
and Control



Soft Tissue Biomechanics

Tissue Engineering



Mechanobiology

Global Health Engineering

Lung Flow Control

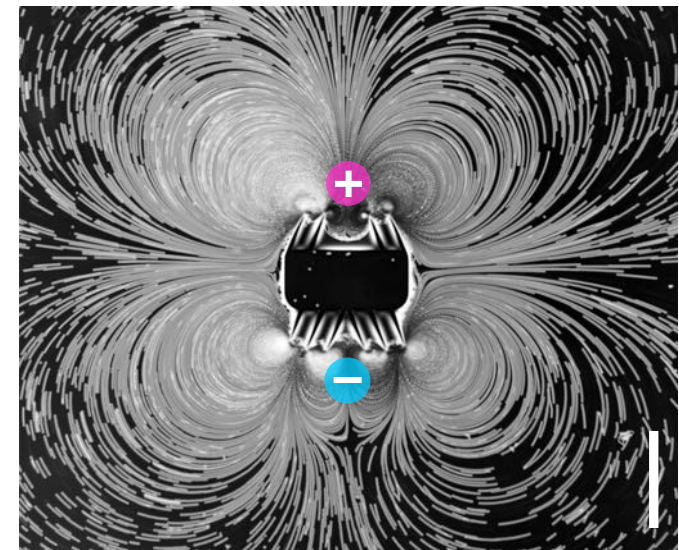
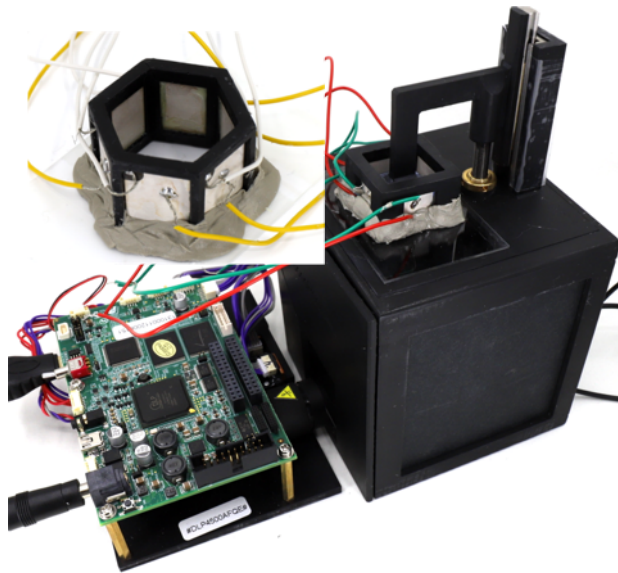
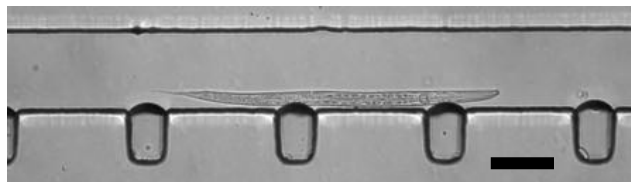
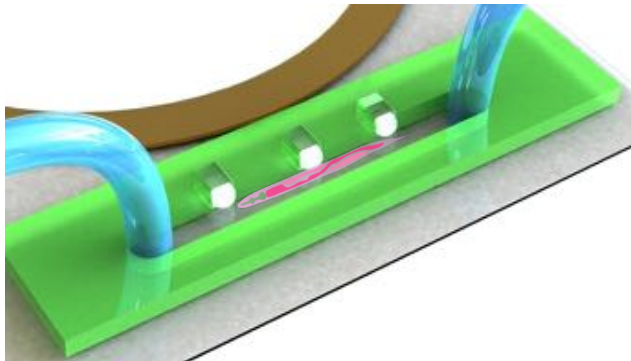
Prof. Daniel Ahmed

Acoustic Robotics for Life Sciences and Healthcare



Main Research Interests:

- Microfluidics and acoustofluidics devices to investigate disease models
- Acoustic 3D printing
- Acoustic-powered micro/nanorobots



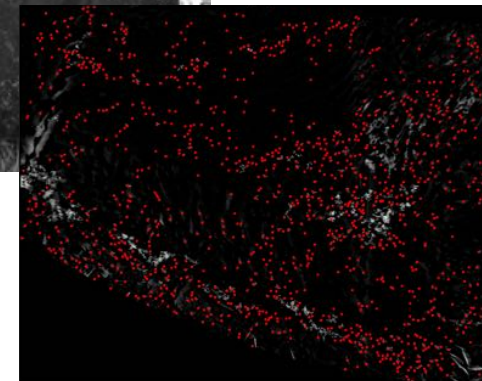
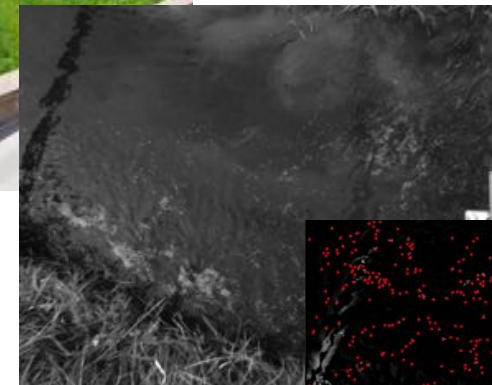
www.arsl.ethz.ch

Prof. Filippo Coletti

Institute of Fluid Dynamics

Main research interests

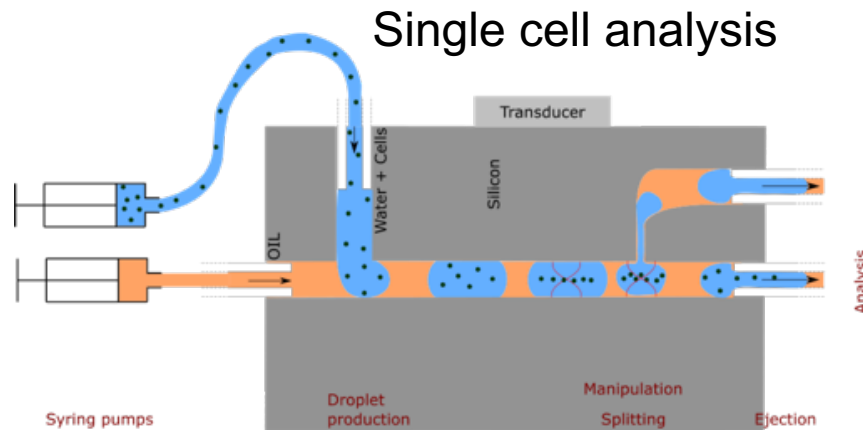
- Particle-laden flows in environmental and biomedical settings
- Transport of particles in atmosphere, rivers, human airways, and blood vessels
- Optical and medical imaging techniques: laser diagnostics, magnetic resonance imaging



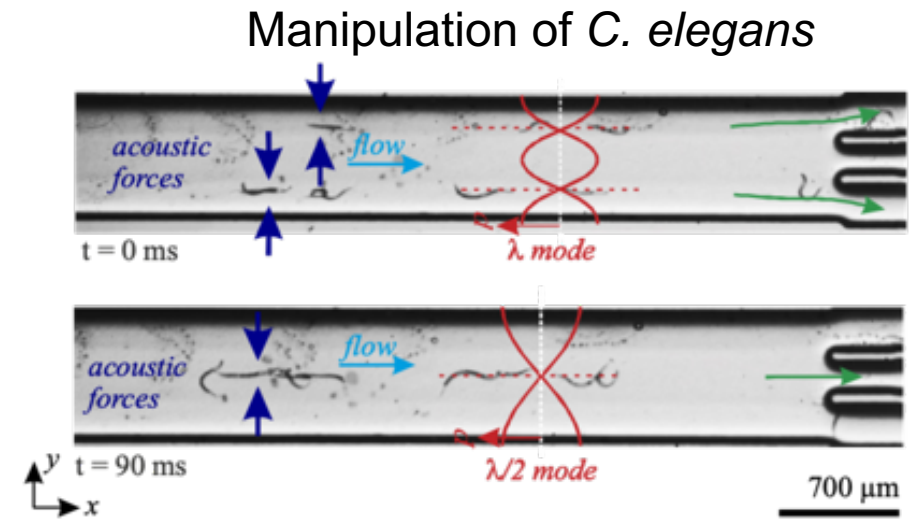


Main Research Interests:

- Ultrasonic particle/cell manipulation
- Tissue engineering via acoustics
- Microfluidics



Gerlt, Michael S., et al. (2020). *Biomicrofluidics* 14(6), 064112.

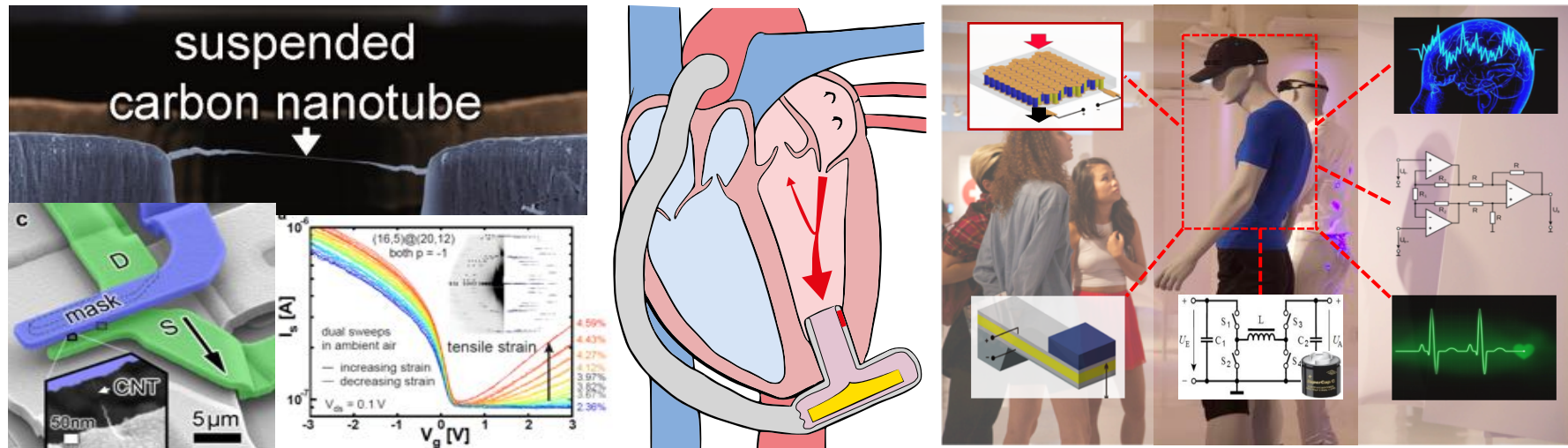


Baasch, T., et al. (2018). *Biophysical journal*, 115(9), 1817-1825.



Main Research Interests:

- **Microsystems for medical applications:**
e.g. thermoelectric generators, acoustic sensors, and pressure sensors
- **Nanotransducers and nanosensors:**
e.g. ultra low power carbon based sensors



Prof. Inge K. Herrmann

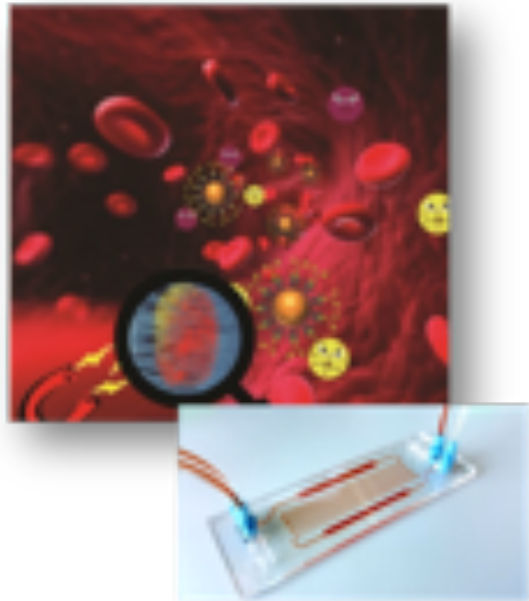
Nanoparticle Systems Engineering Laboratory (NSEL)



ingeh@ethz.ch

Main Research Interests

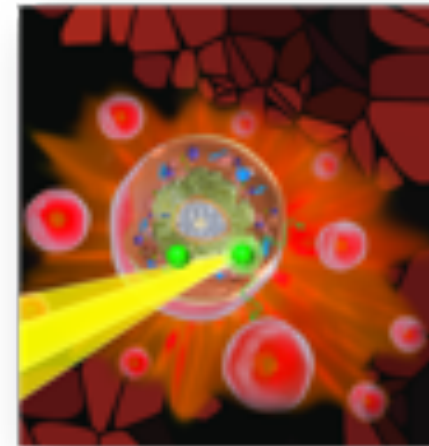
- Materials innovation for healthcare (from concept to clinics)
- Engineering nanoscale interventions based on multiscale multimodal analytics (microscopy - spectroscopy - data integration - simulations - machine learning)



Theranostic Blood Purification
(bacteria & tumor cell removal)

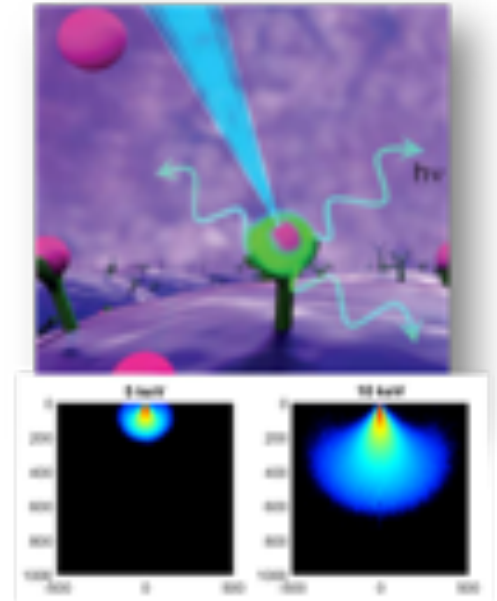


Smart Surgical Adhesives
(Nanogluue & AnastoSeal)



$$DEF_{NP} = \frac{\int_{E=0}^{E_{max}} \Psi'(E) \left(\frac{\partial \sigma_{\text{eff}}(E)}{\rho} \right)_{M_{\text{TD}}+NP} dE}{\int_{E=0}^{E_{max}} \Psi'(E) \left(\frac{\partial \sigma_{\text{eff}}(E)}{\rho} \right)_{M_{\text{TD}}} dE}$$

Nanoparticle-augmented
Radiotherapy (preXision)



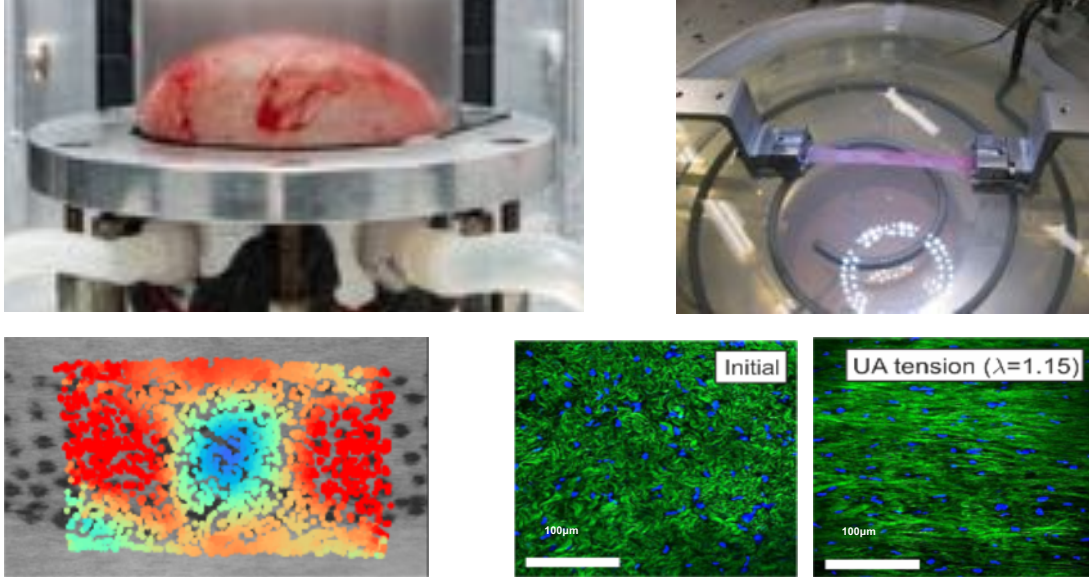
Electron microscopy-based
Visual Proteomics (CCLEM)

Prof. Edoardo Mazza

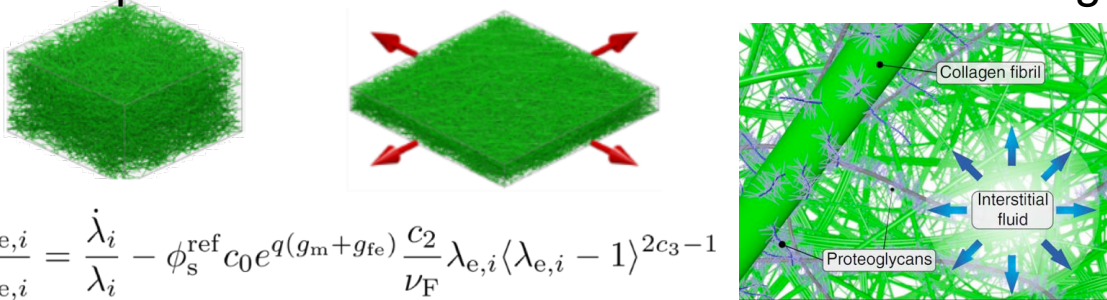
Soft Tissue Biomechanics



- Multiscale mechanical characterization



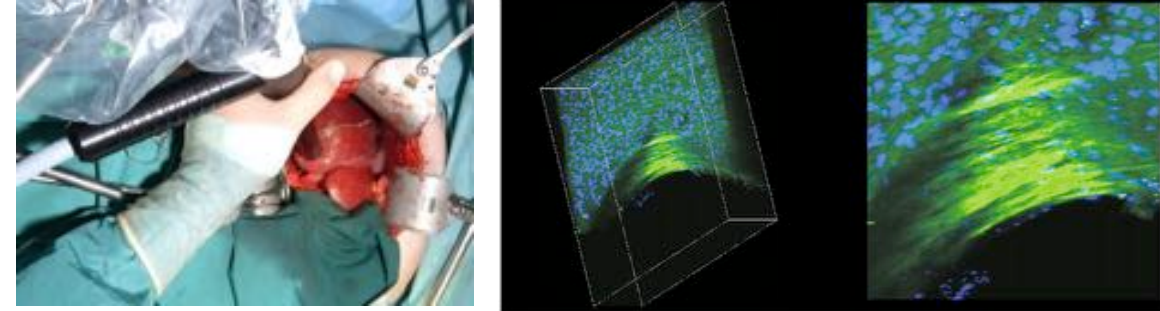
- Multiphase continuum and discrete tissue modeling



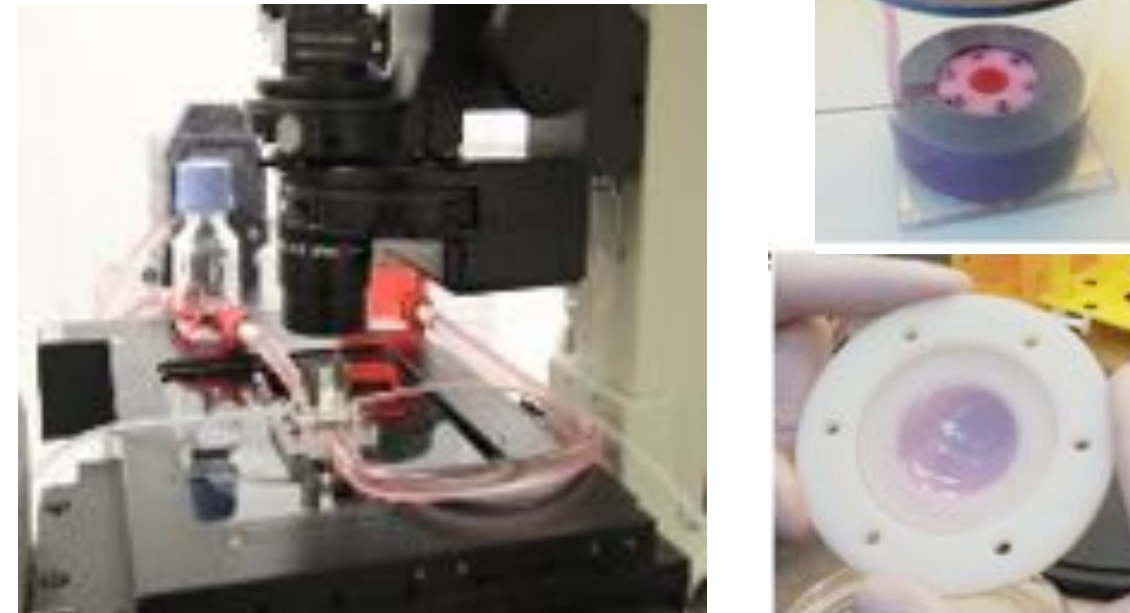
$$\frac{\dot{\lambda}_{e,i}}{\lambda_{e,i}} = \frac{\dot{\lambda}_i}{\lambda_i} - \phi_s^{\text{ref}} c_0 e^{q(g_m + g_{fe})} \frac{c_2}{\nu_F} \lambda_{e,i} \langle \lambda_{e,i} - 1 \rangle^{2c_3 - 1}$$

$$\hat{\Psi}(\mathbf{F}, \{\alpha\}, \mu) = \hat{\Psi}_s(\mathbf{F}, \{\alpha\}) + \hat{\Psi}_x(J, \mu) - \frac{\mu}{V_m} (J - \phi_s^{\text{ref}})$$

- Diagnosis (in-vivo measurements)

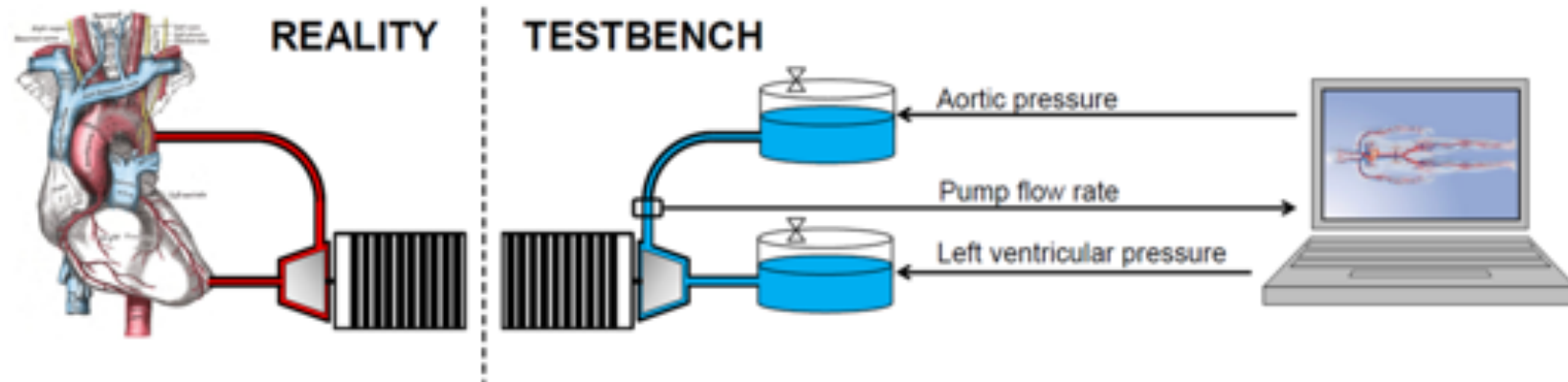


- Bioreactors for tissue engineering and cell mechanobiology



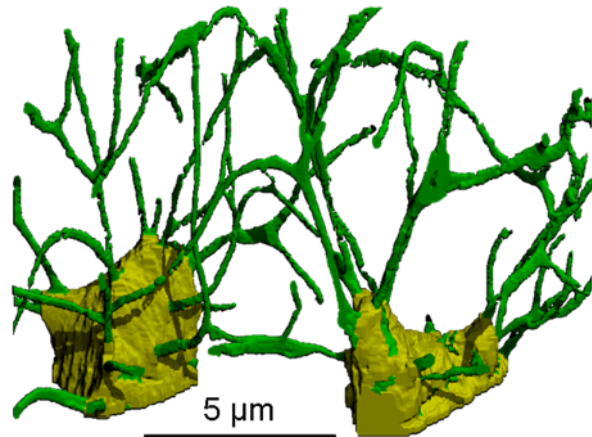
Prof. M. Meboldt

Test bench for ventricular assist devices

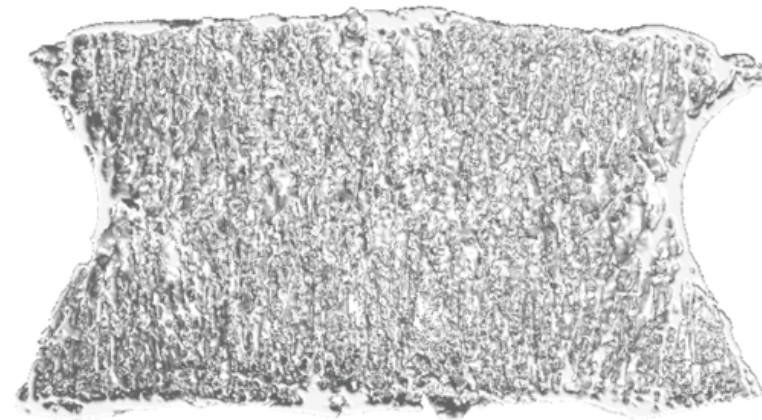


Prof. Ralph Müller

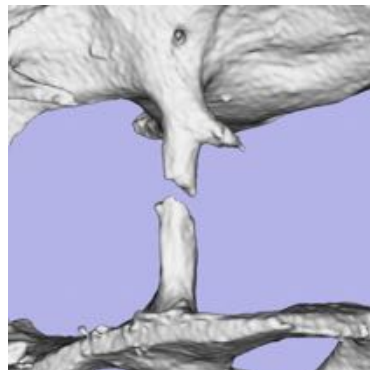
In silico medicine for the prediction of bone fractures



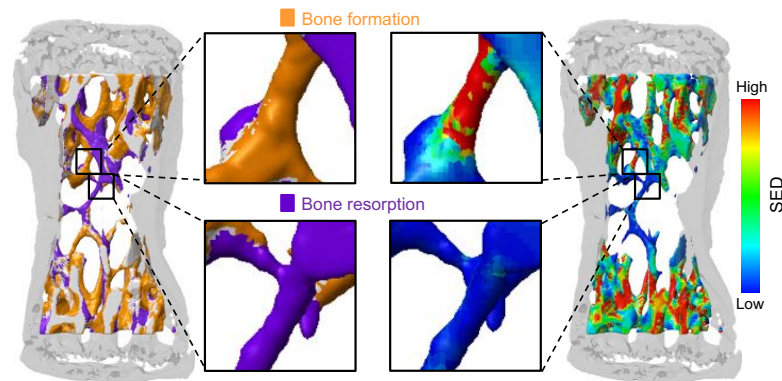
nanoscale cell imaging



in silico simulation of bone aging



micromechanics

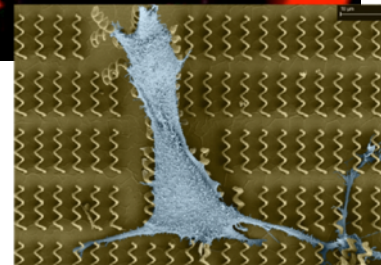
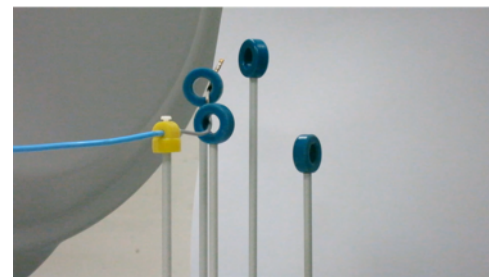
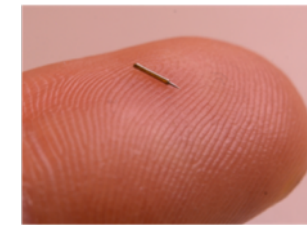
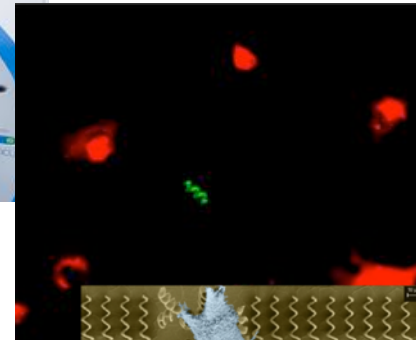
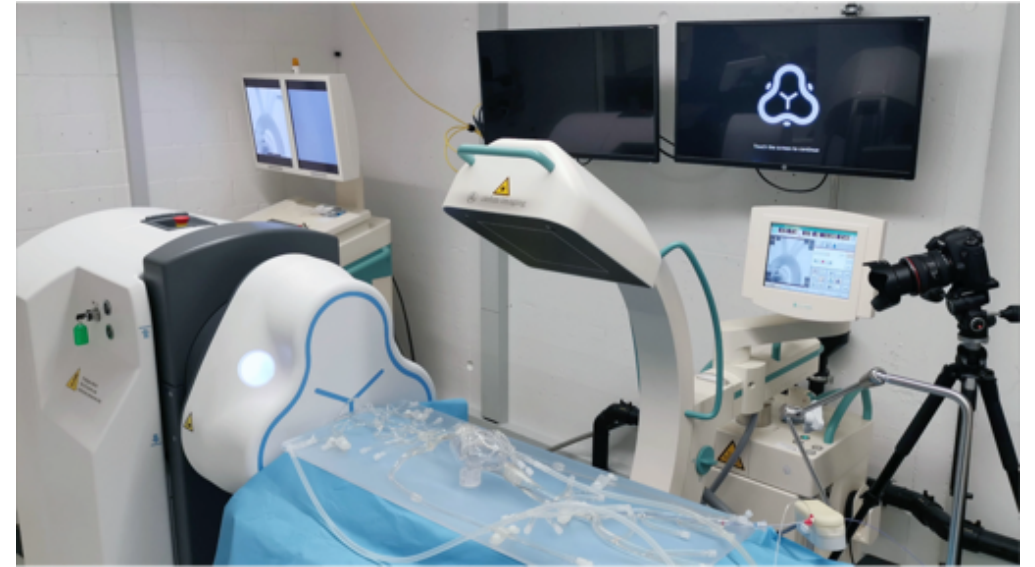


in vivo finite element analysis

Prof. Brad Nelson

Medical Robotics
Multi-Scale Robotics Lab

www.msrl.ethz.ch



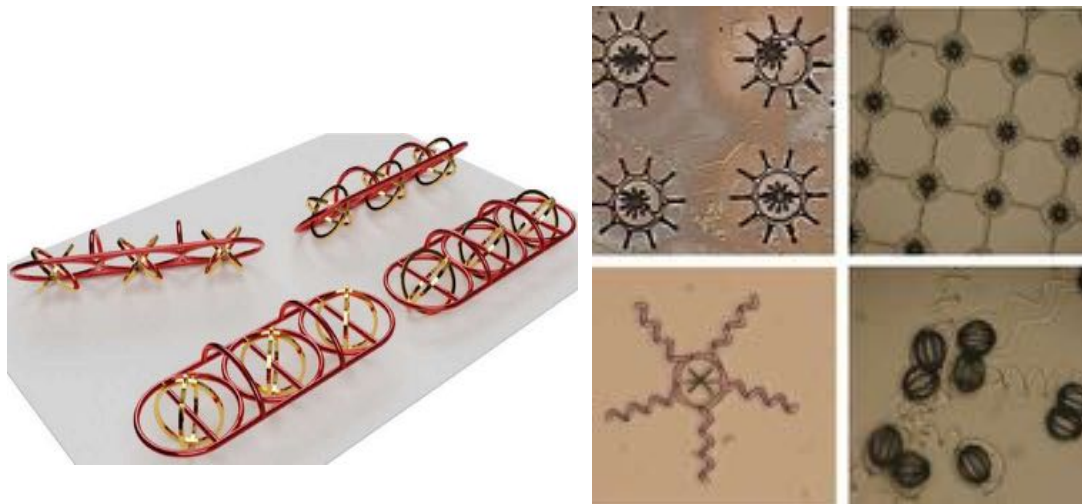
Remote Magnetic Navigation of
catheters, endoscopes, and
microrobots



Main Research Interests:

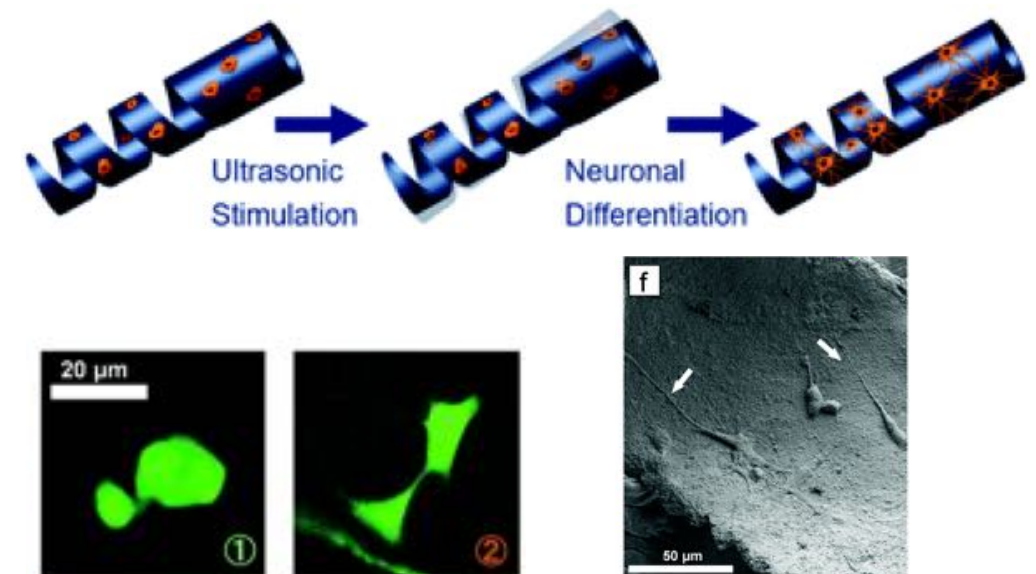
- Development and processing of material for robotics
- Small-scale Robotics for Water Cleaning
- Micro- and nanorobotics for therapeutic delivery and cell stimulation

Mechanically Interlocked 3D Multimaterial Magnetic Microrobots



Nature Communications (2020). DOI: [10.1038/s41467-020-19725-6](https://doi.org/10.1038/s41467-020-19725-6)

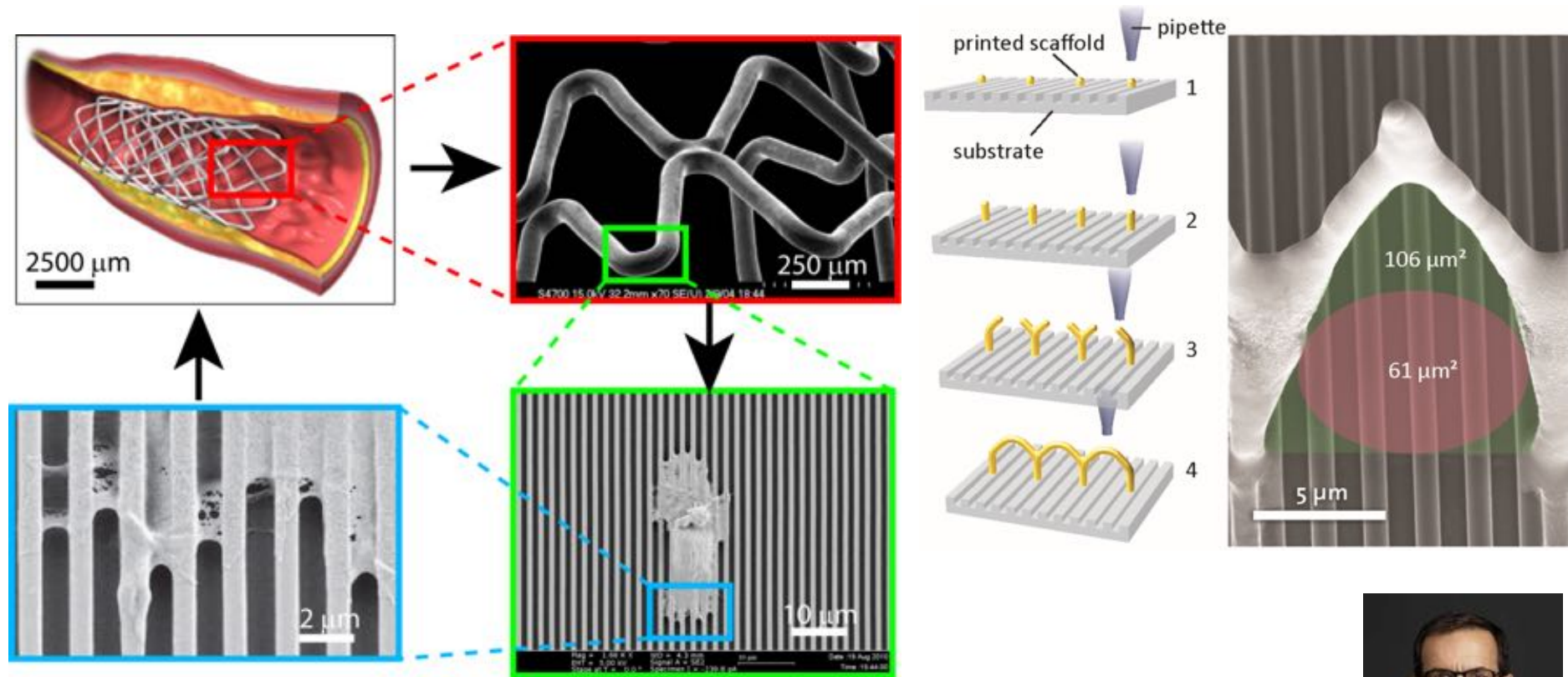
Soft microrobots for neuron delivery & neuronal differentiation



Materials Horizons (2020). DOI: [10.1039/C9MH00279K](https://doi.org/10.1039/C9MH00279K)

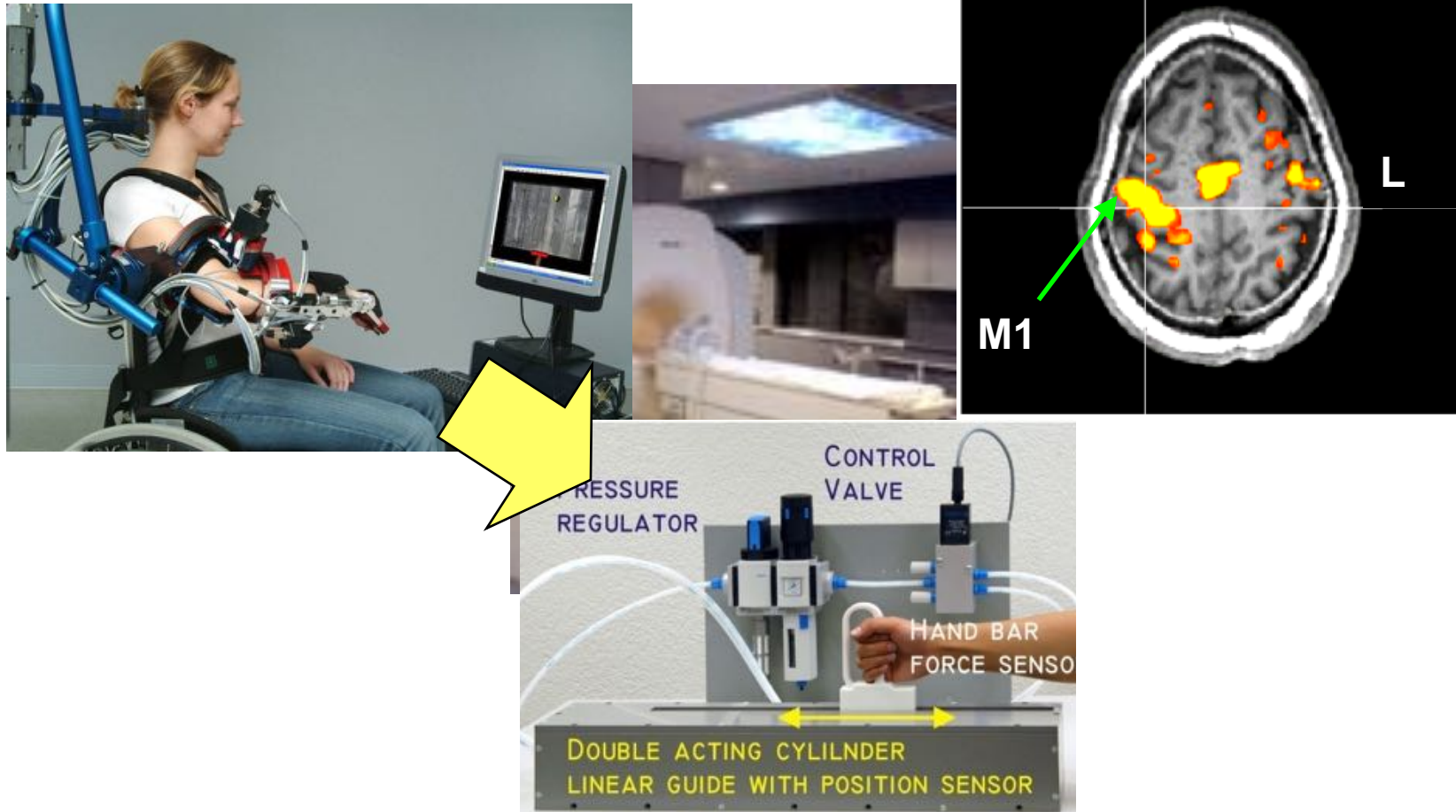
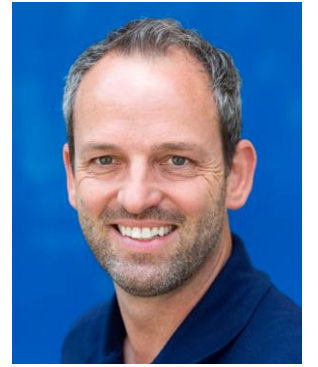
Prof. Dimos Poulikakos

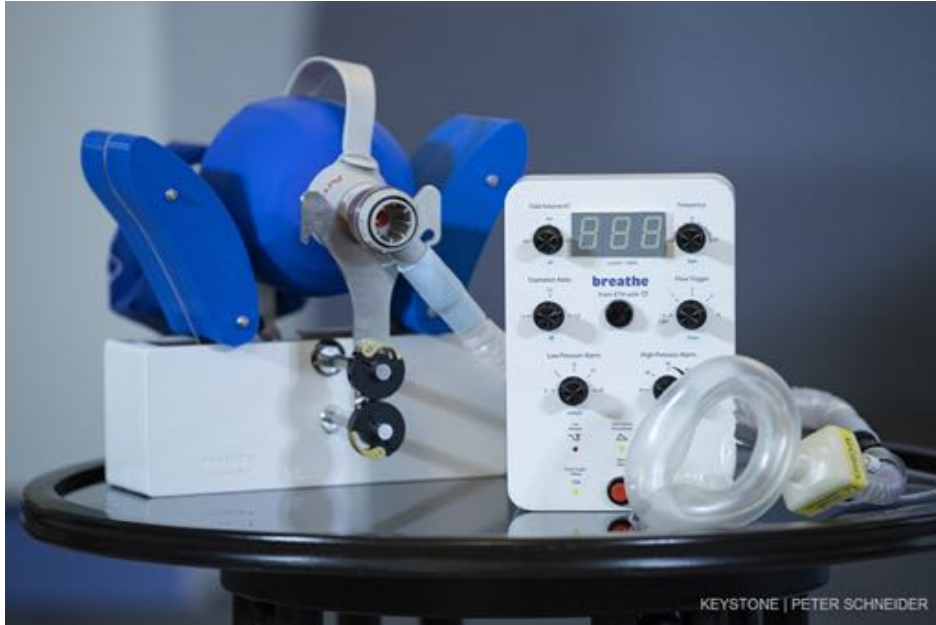
Microfluidics and thermodynamics of biological interactions with engineered surfaces



Prof. Robert Riener

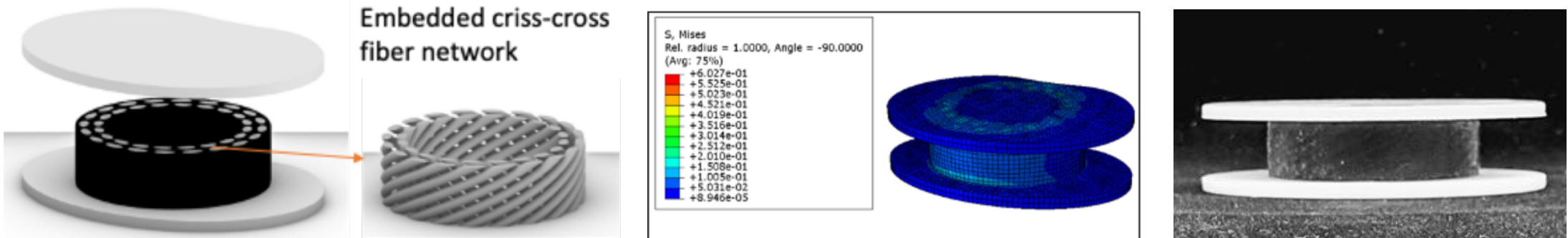
From robots to fMRI compatible devices





- Research Interests
 - Development of low-cost, high-tech medical devices for Low and Middle Income Countries (LMICs), e.g. a mechanical ventilator
 - Computational design, personalization, simulation and optimization of implants, e.g. a spinal disc
 - 3D printing of implant prototypes
 - Further topics coming...

3D Printed Personalized Spinal Disc Concept: CAD (left), Simulation (middle) and Prototype (right)



Prof. Jess Snedeker

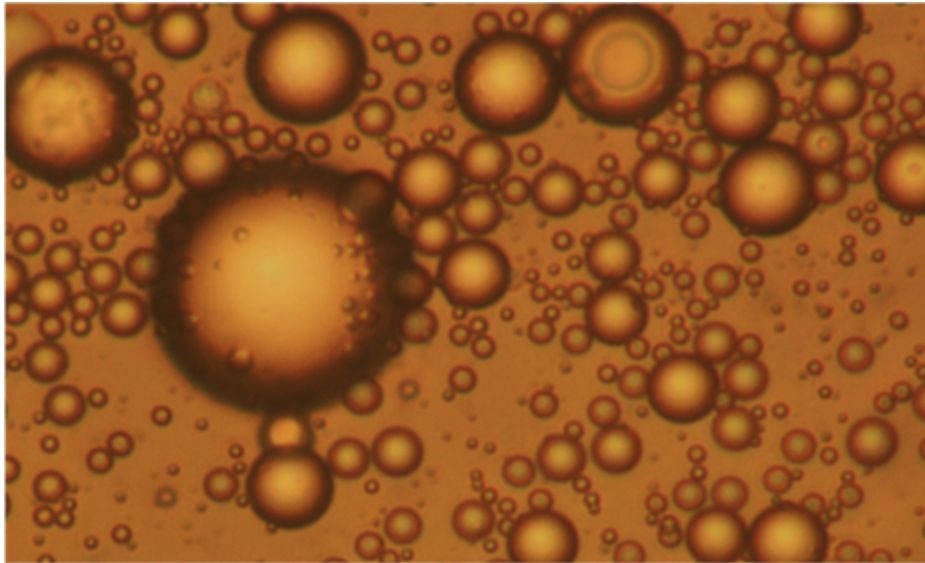
ORTHOPEDIC BIOMECHANICS



- medical technologies & regenerative surgery
- mechanobiology
 - tissue engineering
 - microengineering
 - data science & bioinformatics

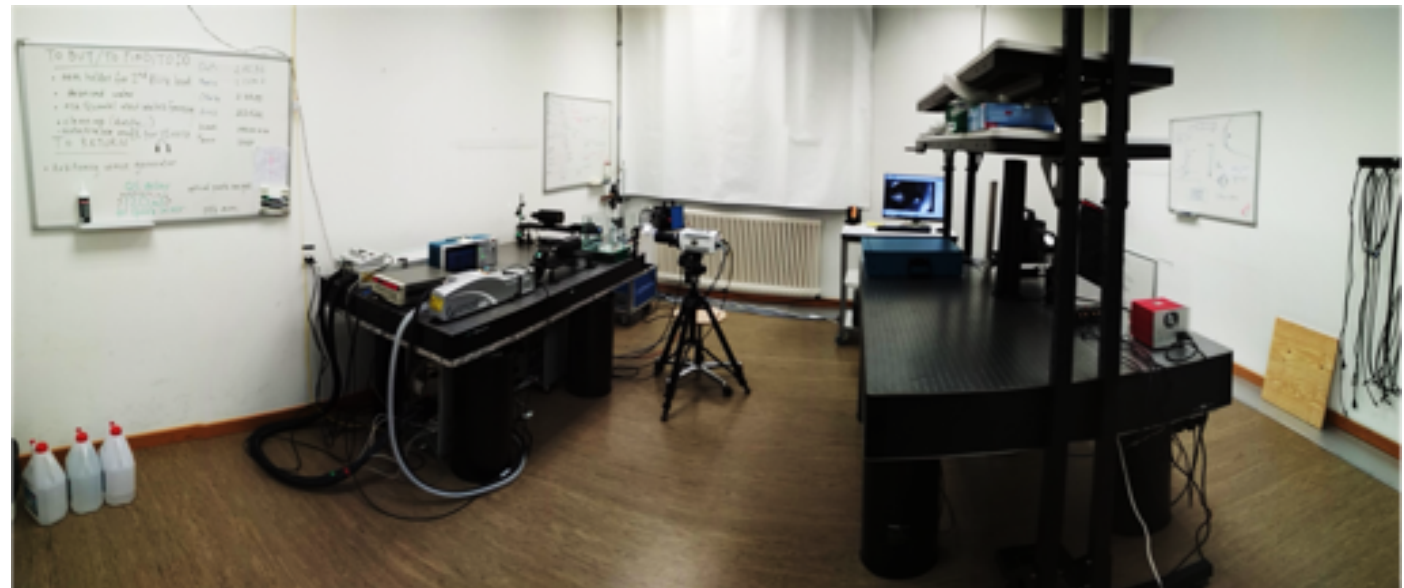
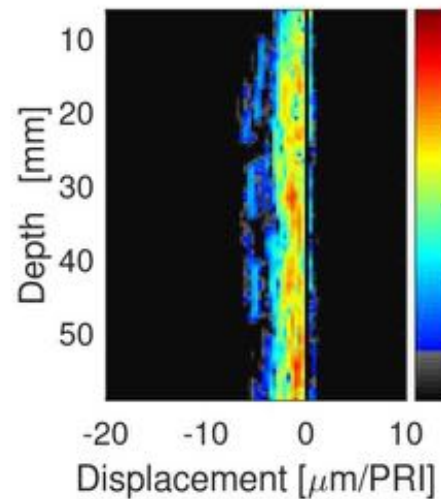
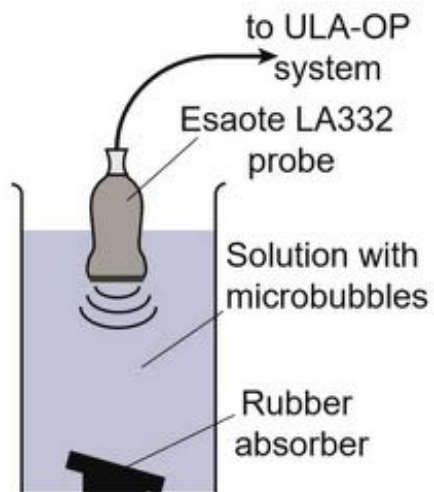
Balgrist
University Hospital





Multiphase fluid dynamics group

- Ultrasound contrast agent microbubbles
- Phase-change agents for drug delivery
- Medical ultrasound for imaging and therapy, high-intensity focused ultrasound, shock wave lithotripsy
- Photoacoustics, microfluidics





Example Areas of Study/ Research Topics

- Design:
 - Robust, low-cost, locally-produced push carts for informal waste collectors
 - High-powered, agile pit-emptying device to evacuate pit latrines without clogging due to trash
- Logistics/Optimization
 - City-wide collection and routing for parallel collection of trash (dumping), and organic waste (composting)
- Behaviour change/economics
 - Benefit/cost analysis of fertilizer replacement with compost considering nutrient yield and labour
 - Willingness to use/pay for improved sanitation technologies/services in tourist hot-spots



D-MAVT Student Administration



Lorena Luzi



Maggie Sallauka



Silvia Häfliger



Maddalena Velonà

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