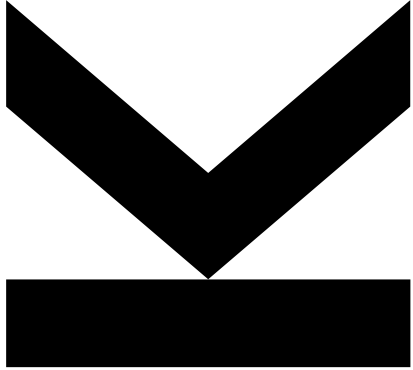


Internet of Bio-Nano Things

Extending Connectivity to Unconventional Domains



Werner Haselmayr
Institute for Communications Engineering and RF-Systems



Life Sciences at the JKU

- **Center for Medical Research (ZMF), Univ.-Prof. Dr. David Bernhard**
 - **1500m² laboratory spaces, 7 Core Facilities**
 - **Biobank**: acquisition and storage of high-quality, project-specific samples
 - **Biomedical research**: conduction of animal experiments with highest ethic and quality standards
 - **Cytometry**: examination and characterization of cell populations, immunophenotyping, cell cycle analysis, and cell function
 - **Histology**: rapid analysis in brightfield and fluorescence, identification of over 100 biological markers in a single tissue section
 - **Imaging**: acquisition and analysis of microscopic data in 2D, 3D, and 4D
 - Mass spectrometry
 - **NGS and molecular biology**: genome and transcriptome sequencing at DNA and RNA levels
 - **19 research groups** (12 clinical and 7 pre-clinical research)
 - The Department of Physiology is the world's leading center for measuring serum calcification tendency; **Univ.-Prof. Dr. Jakob Völkl**

<https://www.jku.at/en/faculty-of-medicine/research/center-for-medical-research/>

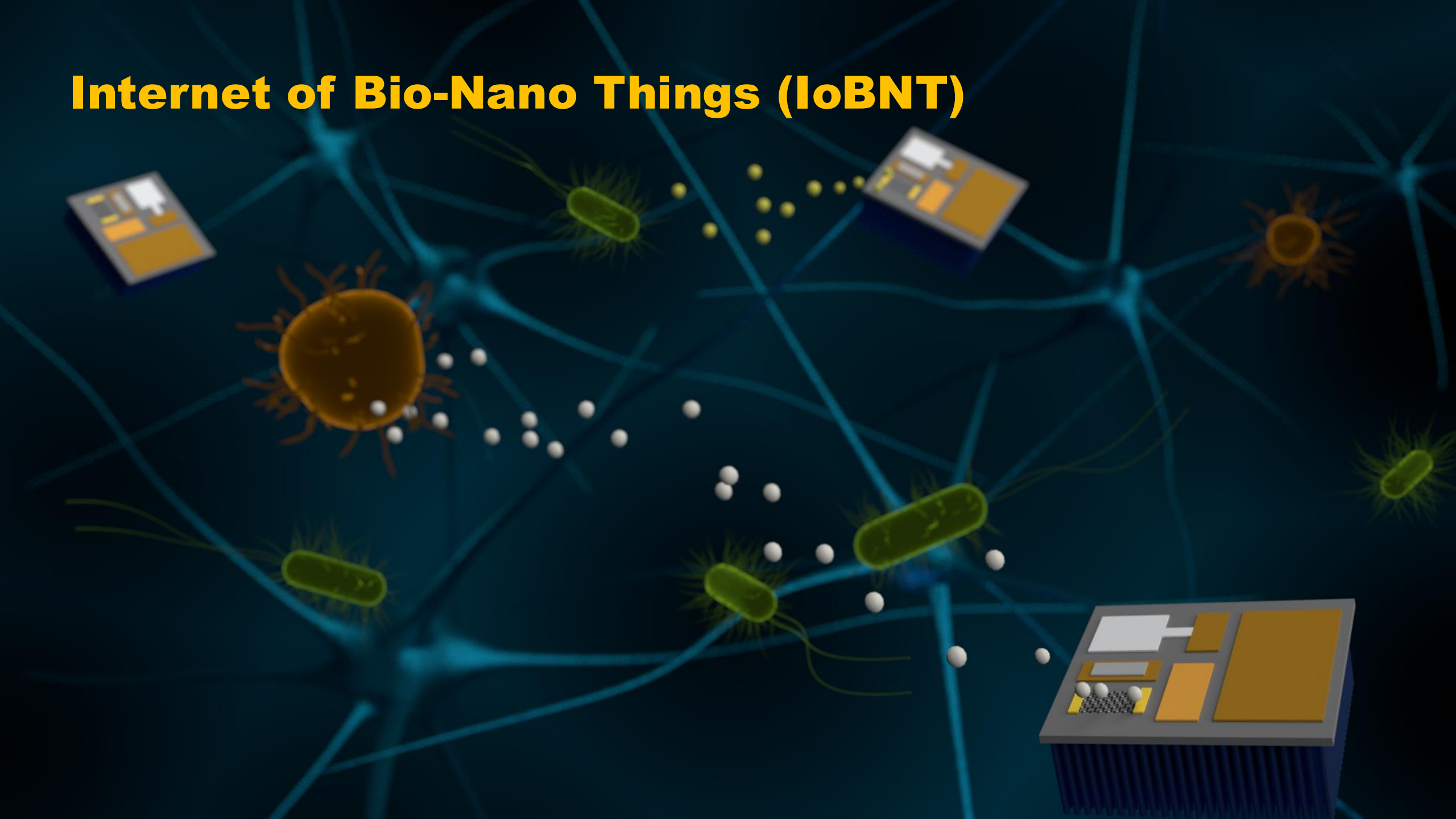
Life Sciences Research Topics



- **Experimental Orthopaedics**, **Dr. Eleni Priglinger**
 - Development and application of novel treatment methods using tissue engineering and regenerative medicine for personalized medicine; 3D- bioprinting of bone and cartilage for osteoarthritis
 - Together with Assoc.-Prof. Ian Teasdale, Institute of Polymer Chemistry, and
 - Resorbink, 3D biodegradable printable polymers for medical technology
- **Cellular and Molecular Ophthalmology**, **Ass.-Prof. Dr. Ahmad Salti**
 - Establishment of a new retinal organoid model to explore therapeutic approaches while avoiding animal testing and the development of novel organic retinal prostheses
 - Together with Univ.-Prof. Dr. Serdar N. Sariciftci, Institute of Physical Chemistry – LIOS, and
 - Univ.-Prof. Dr. Martin Kaltenbrunner, Soft Matter Physics
- **Experimental Dermatology**, **Univ.-Prof. Dr. Wolfram Hötzenecker, Dr. Susanne Kimeswenger**
 - Investigation of the underlying mechanisms of inflammatory skin diseases and pressure ulcer risk prevention with AI (wound healing and prevention)

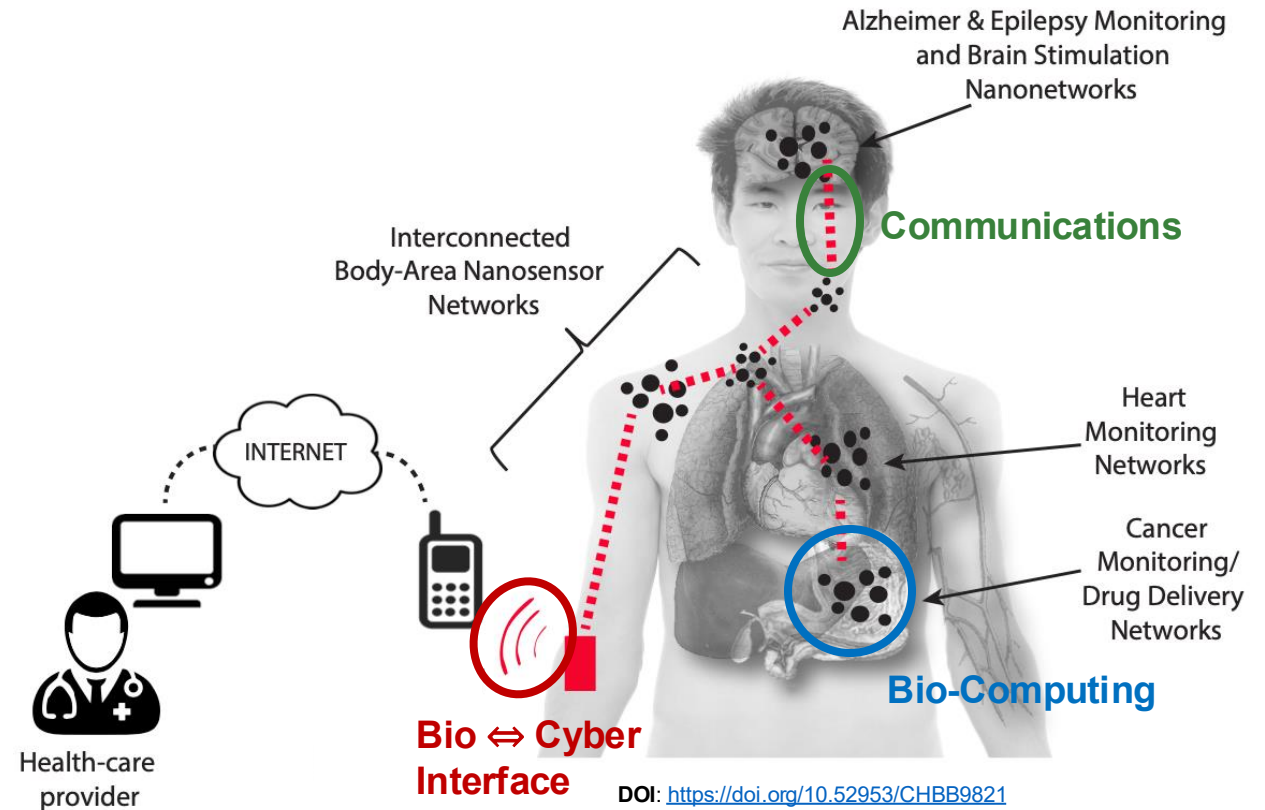


Internet of Bio-Nano Things (IoBNT)



Internet of Bio-Nano Things (IoBNT)

- Connection of natural and artificial (biological) units, **Bio-Nano Things (BNT)**, to the internet
- Unique challenges
 - Novel communication methods
 - Bio-cyber interface
 - Bio-computing
 - Security
- Tight energy-efficiency, size, low-complexity, and bio-compatibility constraints



Bio-Nano Things

Passive Molecular/Nano Agents

- Primitive, single/few-molecule agents
- Fluorescent proteins, quantum dots, nanoparticles
- Communication through FRET, coagulation cascade
- May require external stimuli or biochemical trigger
- Minimum control over network topology
- Optimization of information flow in passive networks through initial conditions and external stimuli

Abiotic Devices

- Potentially host more complex functionalities
- Requires energy harvesting
- Molecular, electromagnetic (THz), acoustic, optical comm.
 - THz and optical comm. problematic inside human body
- Nano-macro interfacing through EM communication
- Bio-cyber interfacing and biocompatibility issues

Biosynthetic Devices

- Inherently biocompatible
- Synthetic biology tools to modify/add new functionalities
- Nano-macro interfacing is a challenge
 - Optogenetics, fluorescent proteins, biosensors
- Many fundamental open questions on biophysics
- Functionality limited by energy and molecule constraints

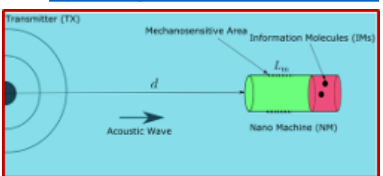
Recent IoBNT Projects

- Brain-Machine-Body Connectivity
 - B-CRATOS (2021-2025)
 - Battery-free high-speed wireless in-body communication platform
 - Website: <https://www.b-cratos.eu/>
- Health Monitoring
 - ERMES (2025-2028)
 - Information transfer between medical doctors and active implanted medical devices (AIMD)
 - Website: <https://www.b-cratos.eu/>

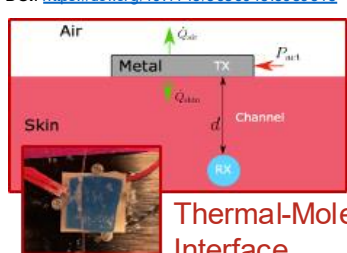
IoBNT Research at the JKU



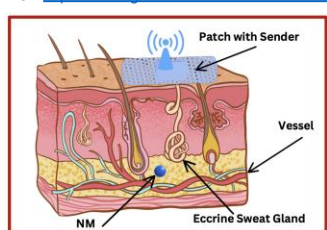
Chemical-Electrical Interface
DOI: <https://doi.org/10.1109/TBMC.2023.3277391>



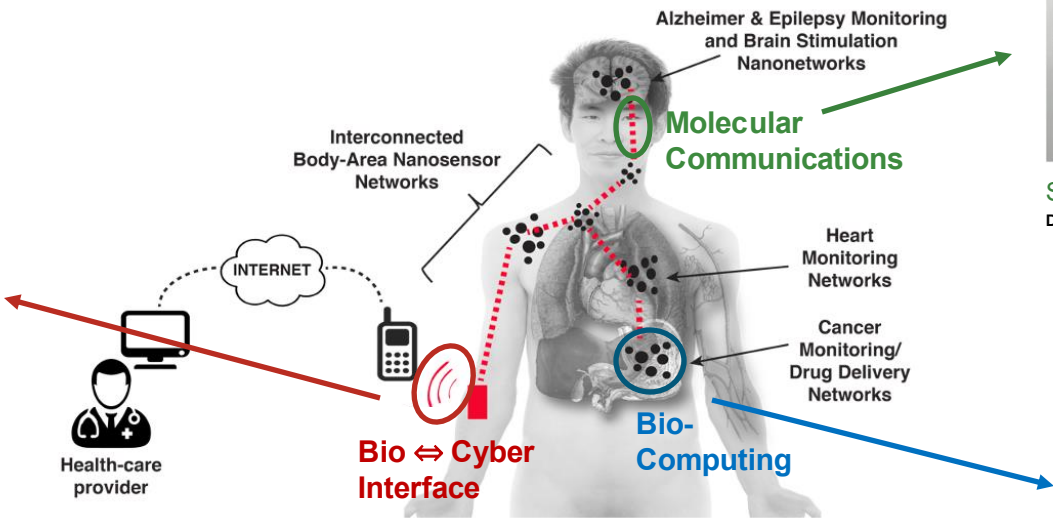
Acoustic-Molecular Interface
DOI: <https://doi.org/10.1145/3686015.3689348>



Thermal-Molecular Interface
DOI: <https://doi.org/10.1109/TBMC.2025.3556883>

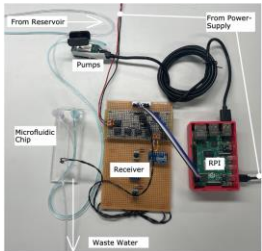


Exploiting pre-existing infrastructure (sweat glands)
DOI: <https://doi.org/10.1109/ICC52391.2025.1160832/CHBB9821>

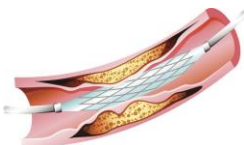


DOI: <https://doi.org/10.52953/CHBB9821>

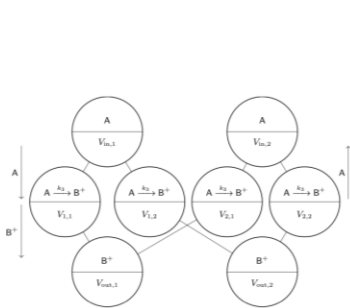
- Mathematical modeling
- *In-silico* models
- *In-vitro* (microfluidic) prototyping
- Multidisciplinary cooperations



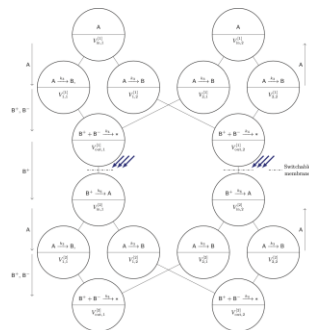
Salinity-based Comm.
DOI: <https://doi.org/10.1109/TBMC.2023.3277391>



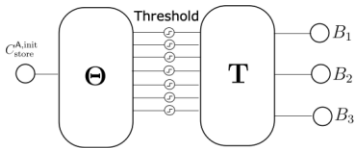
Drug-eluting Stents
DOI: <https://doi.org/10.36227/techrxiv.174702260.0529731v1>



Molecular Matrix Multiplication
DOI: <https://doi.org/10.1109/TBMC.2024.3397050>



Molecular Nano Neural Network
DOI: <https://doi.org/10.1109/ICC51166.2024.10622358>



Molecular Analog-to-Digital Converter
DOI: <https://doi.org/10.1109/GLOBECOM52923.2024.10901464>