

 **Debkalpa Goswami**

Soft Robots for Hard Problems in Disease Modeling and Therapy

Imagine: catheters that steer themselves through arteries with reduced risk, wearable rehabilitation devices that assist muscle movement post-stroke, artificial organs or muscles that expand and contract like natural tissue, or smart bandages that control compression and drug delivery. Soon, “soft” robotic technology may bring all of these to a clinic near you!

Soft robotics is a subfield of robotics that focuses on designing and building robots using compliant, flexible, and deformable materials – like silicone, rubber, or hydrogels – rather than traditional rigid materials like metal or hard plastics. These robots often mimic biological systems in form and function, making them more adaptable and safer for interaction with humans and living tissues. The growing field of soft robotics provides an ideal opportunity for the development of implantable devices and biomimetic simulation testbeds due to the constituent materials possessing mechanical properties comparable to that of biological tissue. Furthermore, soft robotic actuators are excellent candidates to replicate the mechanics of dynamic organ systems in our body, such as the heart, lungs, diaphragm and peristaltic motion in the esophagus, to name just a few. Soft robotic devices are pushing the boundaries of robotics in accomplishing tasks that are out of the reach of traditional rigid-body systems.

The vision of our new, interdisciplinary research group at TU Graz is the development of novel soft robotic medical devices and implants, which can one day make their way into the clinic. We realize this vision by combining principles from traditional robotics, such as continuous sensing and closed-loop feedback mechanisms, with the bioinspired approaches of soft robotics to eventually reach towards mimicking physiologically accurate biological function. We incorporate in vitro, in vivo, and in silico research, by

complementing our experience in soft robotics with expertise in 3D printing, bio-sensing, small and large animal models, computational biomechanics, and drug delivery. Being situated within the Institute of Healthcare Engineering, which houses the accredited European Testing Center for Medical Devices, provides an ideal setting for our translational research.

Representative projects:

SOFT ROBOTIC BENCHTOP AND IN VIVO MODELS OF CARDIOVASCULAR DISEASE

Since no two human hearts are exactly the same, it is often important to tailor

treatments for patients with heart disease. We combined soft material 3D printing with patient-specific soft robotic sleeves to recreate the patients' hemodynamics in a benchtop, synthetic beating heart model. These models can act as personalized platforms for surgeons, device designers, and researchers to test treatment strategies before actual procedures. They are especially useful for complex or atypical geometries where off-the-shelf devices may not fit optimally. We also demonstrated the use of soft robotic actuators to recreate, in animals, certain heart disease conditions that take decades to develop in the human body.

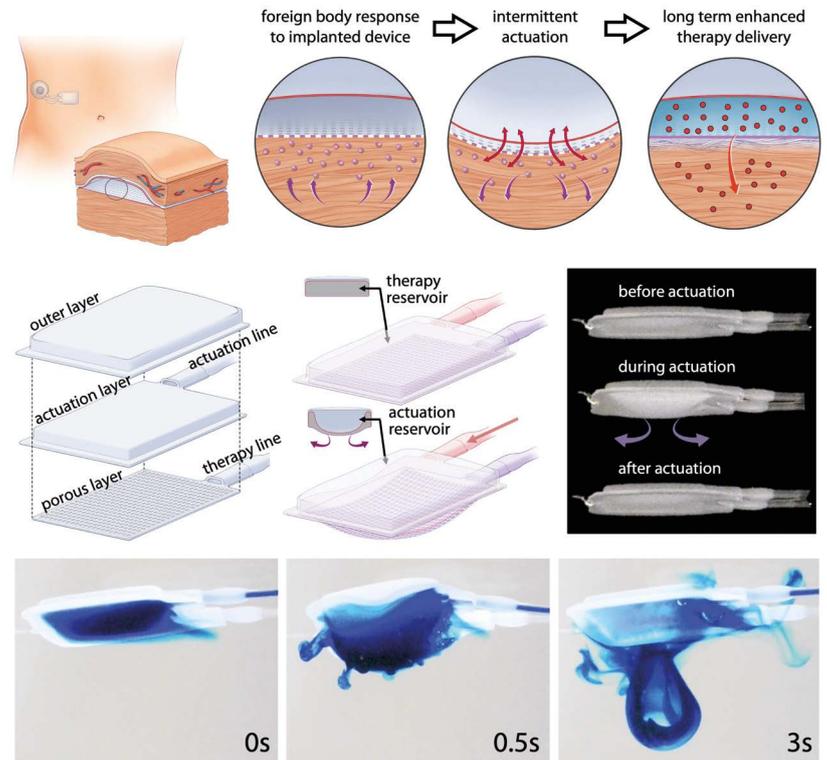


Patient-specific, soft robotic aortic and left ventricular sleeves.

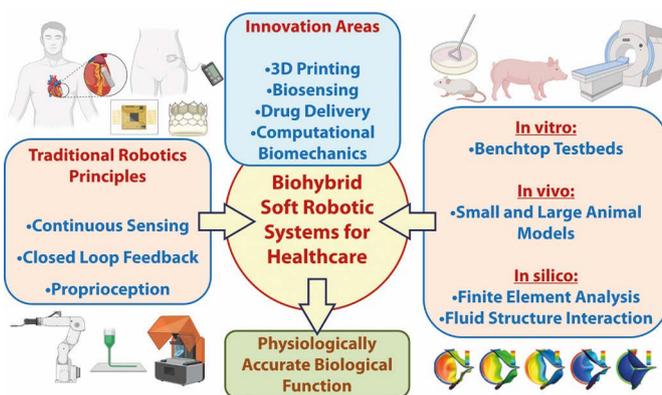
Source: BioHues Digital, Toronto, Canada

IMPLANTABLE SOFT ROBOTIC DRUG DELIVERY DEVICES WITH POTENTIAL APPLICATIONS IN THE TREATMENT OF TYPE 1 DIABETES

Our immune system has an inherent foreign body response that minimizes exposure to potential toxins and is often advantageous; for example, soldiers with bullet wounds rarely develop clinical symptoms of lead poisoning. This protective response, however, is detrimental to the long-term durability of implantable biomedical devices such as heart valves, pacemakers, breast implants, and insulin pumps. We showed, in a mouse model, that intermittent soft robotic actuation of an implanted device, for only 10 minutes every day, can overcome this host immune response, preserving long-term, rapid delivery of a model drug (insulin) over 8 weeks of implantation.

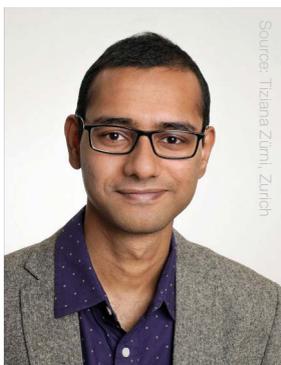


↑ **Implanted soft robotic drug delivery platform can overcome foreign body response by intermittent actuation.** Source: Adapted from Nat Commun 13, 4496 (2022), under the terms of Creative Commons Attribution 4.0 International License. [this paper <https://doi.org/10.1038/s41467-022-32147-w>]



Source: Debkalpa Goswami, created with BioRender.com

Our soft robotic approach leverages both engineered materials and biological cues, bridging the gap between mechanical devices and living tissue. It represents a convergence of robotics, biomedical engineering, and computational modeling, aiming to redefine the interface between machines and the human body for next-generation medical therapies. The aforementioned platforms can be harnessed to simulate disease progression, enabling more accurate and personalized treatment strategies.



Source: Tiziana Zurni, Zurich

Debkalpa Goswami became a tenure-track professor at the Institute of Health Care Engineering, in the Faculty of Computer Science and Biomedical Engineering on in July 2025. Originally from Kolkata, India, Debkalpa spent the last 10 years in the USA, where he received his PhD from Purdue University and completed postdoctoral training at the Massachusetts Institute of Technology (MIT). Before joining TU Graz, Debkalpa was an assistant professor of medicine and biomedical engineering at the Cleveland Clinic Lerner College of Medicine, Case Western Reserve University, and also served as director of biomechanics at the Cleveland Clinic's Cardiovascular Innovation Research Center. Outside work, Debkalpa enjoys hiking and visiting art galleries with his wife, playing table tennis, and following Liverpool FC.