FACTA ANATOMICA

ROBOTICS AND TECHNOLOGY IN ANATOMY

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Latest Research Trends in Anatomy

World Anatomy day: 15th October

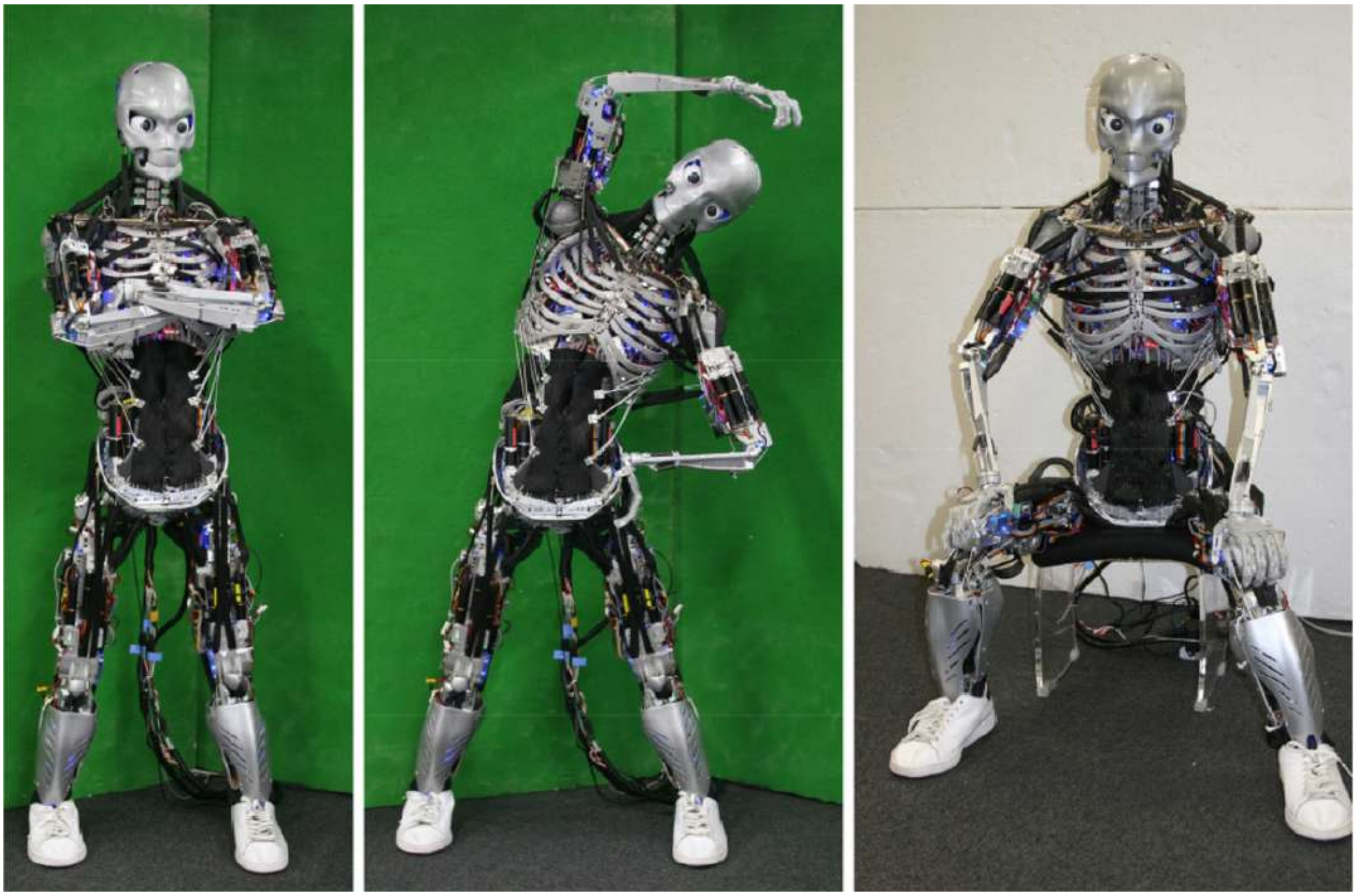
October 15th is World Anatomy Day, declared by the International Federation of Associations of Anatomists (IFAA) to honour Andreas Vaselius, a Belgium physician and author who lived in the 16th century. He is considered the founder of modern human anatomy as he published the most famous anatomy book ever written, De Humani Corporis Fabrica Libri Septem (Seven Books on the Fabric of the Human Body), known as the Fabrica. Which is considered the first western book on human anatomy to be quite accurate!

Image 1: Andreas Vaselius

Source: ElMaghawry M, Zanatta A, Zampieri F. The discovery of pulmonary circulation: From Imhotep to William Harvey, Global Cardiology Science and Practice 2014:31 http://dx.doi.org/10.5339/gcsp.2014.31

RESEARCH TRENDS

***Tendon Tissue Engineering**: Clinically Useful Tendons Can be Constructed With Advanced Robotics.*



Tendon injury is one of the common injuries compelling patients to seek active medical intervention and affecting their socio-economical status. In grievous conditions, it may lead to temporary or permanent disability also.

Tissue Engineering and advanced robotics are rays of hope to manage such musculoskeletal disabilities. **Tendon Tissue Engineering (TTE)** is a technology which can generate tissues in-vitro using a bioreactor system, scaffolds, and human cells in appropriate growth conditions (Image 2). Tendons constructed in-vitro should have fibril number alignment and biomechanical properties matching the target site of replacement.

Traditional bioreactors work only on uniaxial or biaxial tensile strength mechanisms and fail to replicate the in-vivo physiological biomechanical properties of the tendon. **A major translational gap in the development of functional engineered tissue grafts is the lack of a bioreactor system which can recapitulate in vivo tendon loading.**

Musculoskeletal humanoid robots have been proposed as a bioreactor platform to assist in growing tissue grafts for clinical application.

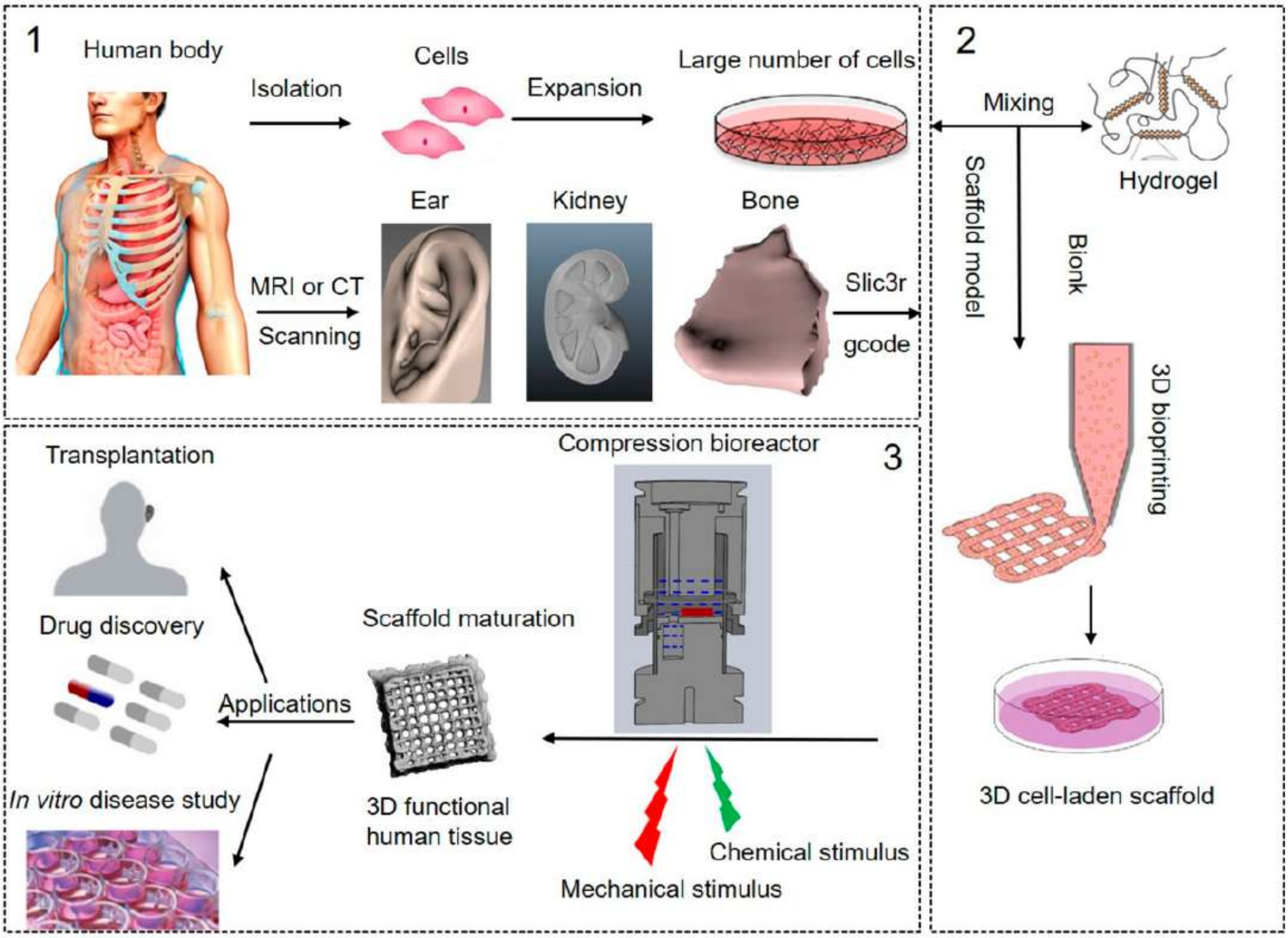


Image 2: Process of 3D bioprinting of human tissues
Image Resource: Zhang J, Wehrle E, Rubert M, Müller R. 3D Bioprinting of Human Tissues: Biofabrication, Bioinks, and Bioreactors. International Journal of Molecular Sciences. 2021; 22(8):3971. https://doi.org/10.3390/ijms22083971

Functionality and Musculoskeletal anatomy required to imitate by the robots are body proportion, skeletal structure, muscle arrangement and joint performance. The robots comprise of strategically positioned myoneural units based on human anatomy with cables replicating human muscle attachments. Design of numbers of degrees of freedom, microfilaments, a load of the movement, analogues anatomical position, strength and tension in humanoid robots have made it possible to mimic the natural biomechanical action of the muscle; which will help to create a replica of the target muscle and tendon.

Biohybrid Soft Robotics: *Biohybrid Soft Robotics*, are biomimetic and compliant and are in the developmental stage. Various clinical trials to create smooth muscle using biohybrid soft robotics are in progress. Robotic implant for in-vivo tissue regeneration via mechanical stimulation in the porcine model is also being explored by some scientists (Damian D et al, 2018).

Cost Comparison:

Conventional commercial TTE bioreactor systems: 25000 to 50000 USD.

Humanoid robots: around 15000-25000 USD.

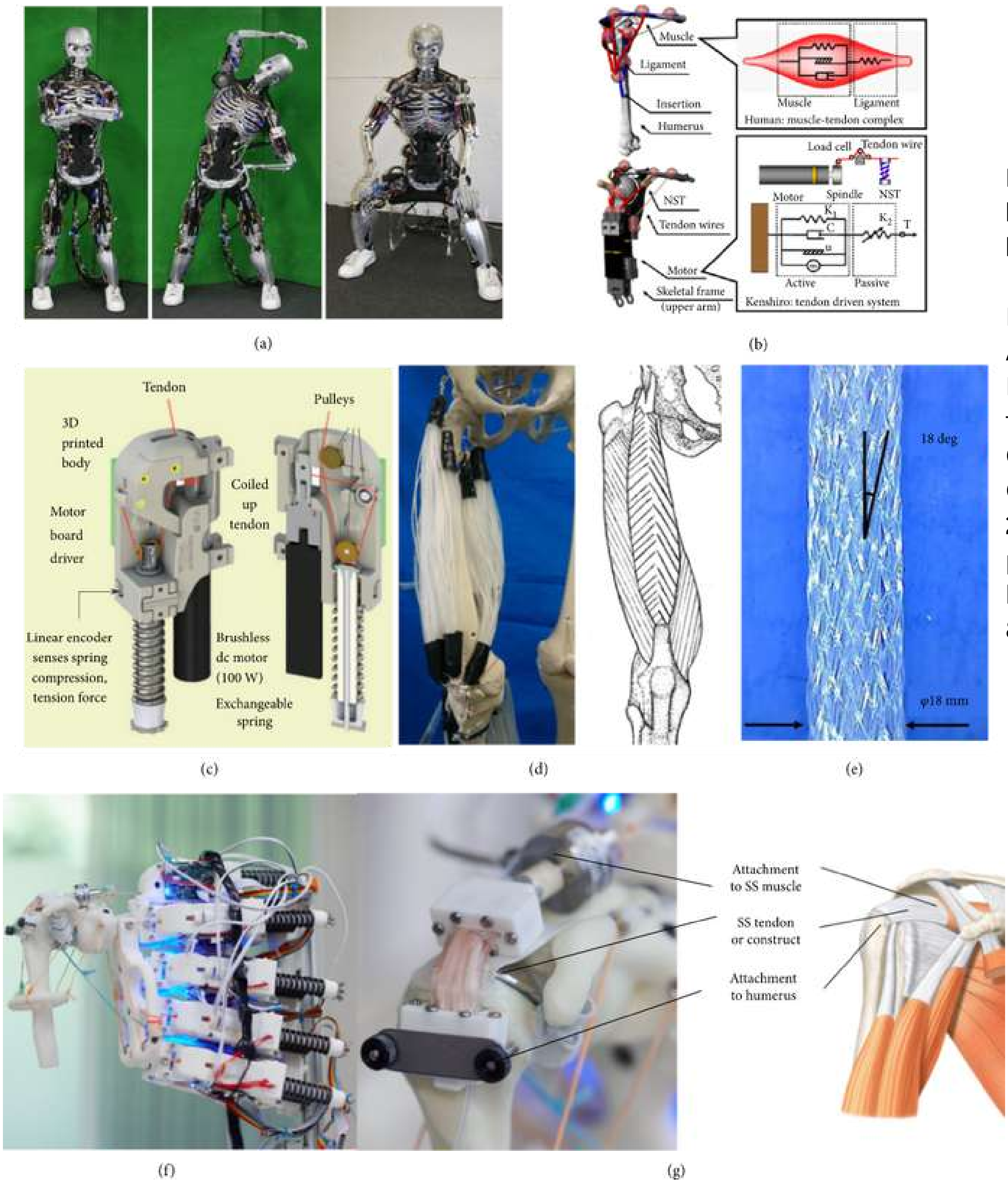


Image 3: Musculoskeletal humanoid robot proposed as a bioreactor system

Image Resource: Iain L. Sander, Nicole Dvorak, Julie A. Stebbins, Andrew J. Carr, Pierre-Alexis Mouthuy, "Advanced Robotics to Address the Translational Gap in Tendon Engineering", Cyborg and Bionic Systems, vol. 2022, Article ID 9842169, 18 pages, 2022. https://doi.org/10.34133/2022/9842169

Humanoid Robotics in Medical Education.

Preparing qualified medical professionals is a complex academic program; which requires passionate teaching with the highest level of accuracy and patience. Medical students are supposed to acquire psychomotor skills, presence of mind, and decision-making capacity. Psychomotor skills should be assessed objectively to minimize errors.

Humanoid robots can be prepared as teaching aid, assessment tool, and simulation tool. Many repetitive tasks can also be replaced by humanoid robotics. With advancements in technology, ***Virtual Reality* and interactive graphics obtaining teaching instruments are considerably economical while offering a higher fidelity to the representation of the human anatomy.** This provides the trainee a rapid learning experience without any risk to the patient.

Robotic surgical simulation is an optimal training instrument and can be used by both young surgeons in training, for learning basic surgical techniques, and the veteran surgeon for practising complex surgical manoeuvres. **Robot simulators** can simulate delicate operations to allow the surgeon to correct any eventual technical errors. Robotic simulation can be used to gain the dissection skill in Anatomy.
The use of robotics in different formations for example Chatbots is capable of serving as clinical simulations and teaching medical students how to interact with patients. The government is promoting telemedicine to reach remote areas which require strict protocols for medical management and to protect patient privacy.
Nowadays robots are configured to provide nursing care.

A disadvantage of robotics and artificial intelligence in medical education: Although robots can stimulate students' learning motivation and classroom participation, they may also hinder students from participating in group activities. Robots can not simulate emotional factors and natural human variations.
The use of robotics and advanced technology in medical education is always debatable and controversial, but careful and appropriate use of technology will help in training medical professionals.

Is Human Splenic Circulation Entirely Open?

> "*For more than 170 years there have been debates, on whether splenic red pulp capillaries join sinuses, i.e., whether the microcirculation is closed or open—or even simultaneously closed and open.* We have now solved this question by three-dimensional reconstruction of a limited number of immunostained serial sections of red and white pulp areas, which were visualized in virtual reality."

With the mentioned quote, recently a research work published by Steingeir et al (2022, Lancet) concludes that splenic circulation is entirely an open circulation. The spleen consists of white pulp and red pulp. White pulp comprises Peripheral arterial lymphatic sheath (PALS) and follicles surrounding the central arterioles. While the red pulp surrounding the white pulp contains splenic cords and sinuses.

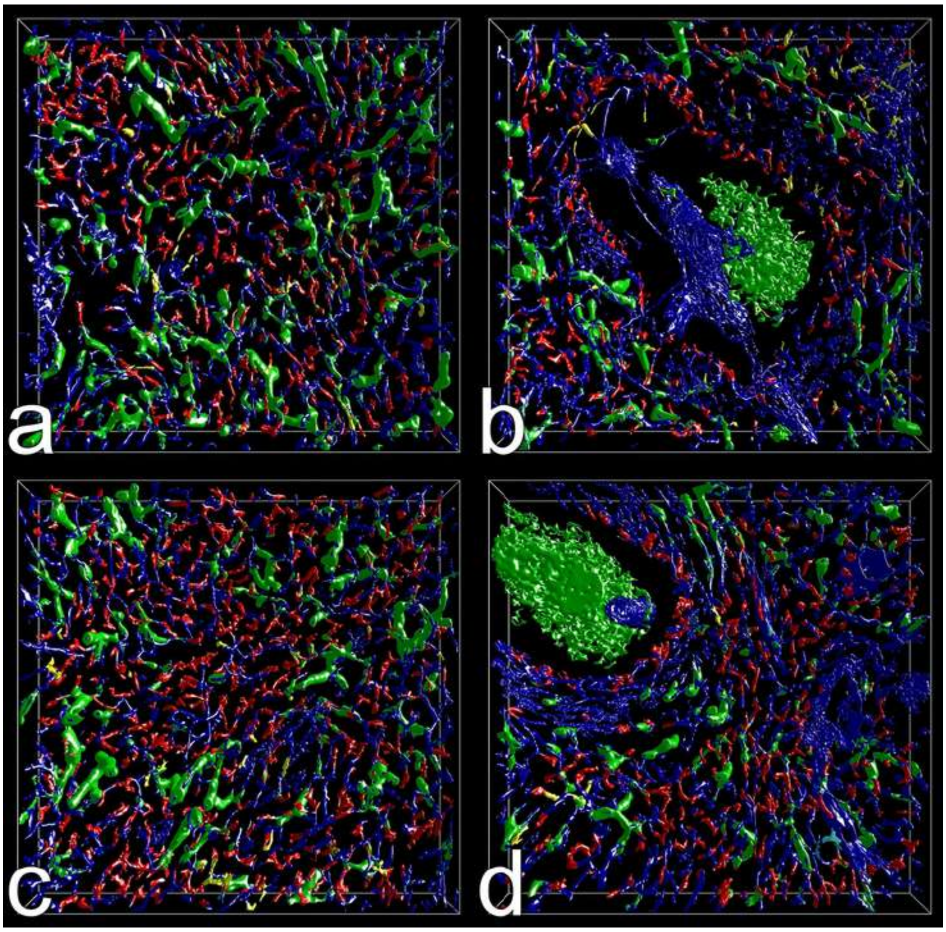


Image 3: Image showing the VR model of the splenic circulation. Open capillary ends unconnected to sinuses manually highlighted in red. The ends were individually inspected for typical capillary end processes by fusing the model with the sequence of registered sections Artificial interruptions of capillaries and ambiguous findings are marked in yellow.

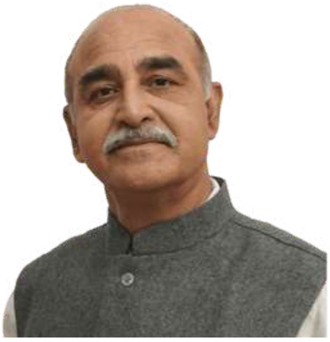
Image resource: *Steiniger, B.S., Pfeffer, H., Gaffling, S. et al. The human splenic microcirculation is entirely open as shown by 3D models in virtual reality. Sci Rep 12, 16487 (2022). https://doi.org/10.1038/s41598-022-19885-z*

The workers checked the presence of a closed circulation by 3D reconstruction of serial paraffin sections triple-immunostained for CD141 (sinus endothelial, large vessel endothelial and superficial white pulp fibroblasts), CD34 (primary endothelial with exception of most sinus endothelial) and CD271 (stromal capillary sheath cells, FDCs, weak expression in ubiquitous red pulp fibroblasts) using a subtractive technique for transmitted light microscopy. A Digital 3D model was reconstructed using a special technique and the model was analyzed in virtual reality. Capillary end processes were found at a certain distance from the CD141+ sinus endothelia in the splenic cords. No end-to-end anastomosis was found in any sections. The workers demonstrated that a true arterio-venous "gap" exists in the entire human splenic microcirculation.

Virtual Reality and 3D reconstruction technology have opened new ways to find facts in microanatomy. It will be interesting to know whether future studies support this development or not.

MESSAGE FROM EXECUTIVE DIRECTOR

PROF.DR. (COL.) CDS KATOCH, AIIMS RAJKOT



I heartily congratulate the Department of Anatomy for bringing this informative newsletter on the unified anatomical explanation of Robotics and Technology in Anatomy. My best wishes to the entire team.

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