1. **Smart hydrogels for phage delivery (TA in charge: Alice Pellegrino)**

Antibiotic-resistant infections pose a major threat to global health, necessitating alternative antibacterial strategies. Bacteriophages (phages) are highly specific viruses that target and kill bacteria, but their effectiveness is limited by rapid clearance, environmental instability, and inefficient delivery. Smart hydrogels could offer a promising controlled-release system for phages, ensuring targeted bacterial eradication while maintaining phage viability. This project aims to develop and evaluate stimuli-responsive hydrogels that release phages upon chronic *Pseudomonas aeruginosa* infections that are antibiotic resistant. You must design a biomaterial that delivers phage upon detection of a bacterial infection while stably maintain phage activity. You will propose methods to evaluate controlled phage release in response to bacterial infection.

1- Pengxiao Zuo, Jordin Metz, Pingfeng Yu, Pedro J.J. Alvarez, Biofilm-responsive encapsulated-phage coating for autonomous biofouling mitigation in water storage systems, Water Research, Volume 224, 2022, 119070, ISSN 0043-1354, https://doi.org/10.1016/j.watres.2022.119070.

2- Brouns, Joyce E. P., Dankers, Patricia Y. W. Introduction of Enzyme-Responsivity in Biomaterials to Achieve Dynamic Reciprocity in Cell–Material Interactions Biomacromolecules American Chemical Society 1525-7797 doi: 10.1021/acs.biomac.0c00930

2. **Phage-Loaded Nanoparticles (TA in charge: Alice Pellegrino)**

The rise of antibiotic-resistant bacteria has created an urgent need for alternative therapeutic strategies. Bacteriophages (phages)—viruses that selectively infect bacteria—offer a promising solution. However, their stability, short half-life, and potential immune clearance in the body limit their effectiveness. Nanoparticle-based delivery systems can protect phages from degradation, enhance their bioavailability, and enable targeted release at infection sites. This project aims to design and evaluate phage-loaded nanoparticles as a controlled-release system against bacteremia (presence of bacteria in the blood). The project should include the choice of the biomaterial, the method of fabrication of phage-loaded nanoparticles along with the release strategy.

1- Elsayed, M.M., Elkenany, R.M., EL-Khateeb, A.Y. et al. Isolation and encapsulation of bacteriophage with chitosan nanoparticles for biocontrol of multidrug-resistant methicillin-resistant Staphylococcus aureus isolated from broiler poultry farms. Nature Sci Rep 14, 4702 (2024). https://doi.org/10.1038/s41598-024-55114-5

2- Yajing Xu, Tao Yang, Yao Miao, Qinglei Zhang, Mingying Yang, Chuanbin Mao Injectable Phage-Loaded Microparticles Effectively Release Phages to Kill Methicillin-Resistant Staphylococcus aureus, ACS Applied Materials & Interfaces
Injectable Phage-Loaded Microparticles Effectively Release Phages to Kill Methicillin-Resistant Staphylococcus aureus | ACS Applied Materials & Interfaces

3. **3D-printed biomaterial scaffolds for liver organoid growth (TA in charge: Alice Pellegrino)**

Most drugs orally-administered must ultimately be cleared out by our liver. Traditional methods for assessing drug toxicity rely heavily on animal models or 2D cell cultures that sometimes do not mimic human liver function. 3D liver organoids could emulate human liver architecture and function. However,

traditional organoid cultures often lack the structure of actual organs, leading to poor organization and limited functional maturation. Biomaterial-based 3D-printed scaffolds can mimic the extracellular matrix (ECM), providing mechanical support, biochemical signals, and enhanced nutrient exchange for improved organoid growth and differentiation. This project aims to design and evaluate 3D-printed biomaterial scaffolds to enhance liver organoid development in terms of architecture and functionality such as drug metabolism and detoxification. Throughout the project you will have to optimize biomaterial composition and scaffold architecture, as well as measure organoid growth, differentiation, and functionality on printed scaffolds in comparison with traditional organoid cultures.

1- Ren Y, Yang X, Ma Z, Sun X, Zhang Y, Li W, Yang H, Qiang L, Yang Z, Liu Y, Deng C, Zhou L, Wang T, Lin J, Li T, Wu T, Wang J. Developments and Opportunities for 3D Bioprinted Organoids. Int J Bioprint. 2021 Jun 28;7(3):364. doi: 10.18063/ijb.v7i3.364. PMID: 34286150; PMCID: PMC8287496.

2- Y. Hu, T. Zhu, H. Cui, H. Cui, Integrating 3D Bioprinting and Organoids to Better Recapitulate the Complexity of Cellular Microenvironments for Tissue Engineering. Adv. Healthcare Mater. 2025, 14, 2403762. https://doi.org/10.1002/adhm.202403762

4. Vascularized organoids using biomaterials (TA in charge: Alice Pellegrino)

Organoids have emerged as powerful models for disease research, drug testing, and regenerative medicine. However, a major limitation of current organoid technology is the lack of vascularization, which restricts their function when considering tissue interfaces. Without a “blood” supply, cells deep within organoids suffer from hypoxia and nutrient deprivation, leading to limited development. For example, the lungs are among the most vascularised organs for functional purposes (gas exchange). However, to date, there are no realistic lung organoids recapitulating functional vascularization.
This project aims to design and fabricate biomaterial scaffolds that include vascularization to lung organoids, improving their survival, organization, and function.

1- Zhao X, Xu Z, Xiao L, Shi T, Xiao H, Wang Y, Li Y, Xue F, Zeng W. Review on the Vascularization of Organoids and Organoids-on-a-Chip. Front Bioeng Biotechnol. 2021 Apr 12;9:637048. doi: 10.3389/fbioe.2021.637048. PMID: 33912545; PMCID: PMC8072266.

2- Peter N. Nwokoye, Oscar J. Abilez, Bioengineering methods for vascularizing organoids, Cell Reports Methods, Volume 4, Issue 6, 2024, 100779, ISSN 2667-2375, https://doi.org/10.1016/j.crmeth.2024.100779.

5. Biomaterial-based sensors for organoid health monitoring (TA in charge: Alice Pellegrino)

Organoids have revolutionized disease modeling, drug screening, and regenerative medicine. However, traditional methods for evaluating organoid health—such as endpoint immunofluorescence —are labor-intensive and invasive, limiting continuous observation of organoid dynamics. Biomaterial-based sensors can provide real-time, non-invasive monitoring of organoid health by detecting key physiological parameters. In this project, you will develop biosensors that interface with organoids for continuous live monitoring. You will particularly focus on biosensors that track markers of infection in lung organoids. These organoids will be used to model chronic infections by bacterial pathogens. You must develop

biomaterial-integrated sensors that continuously track lung organoid health without disrupting their growth or function.

1- I. L. Moldero, A. Chandra, M. Cavo, C. Mota, D. Kapsokalyvas, G. Gigli, L. Moroni, L. L. del Mercato, Probing the pH Microenvironment of Mesenchymal Stromal Cell Cultures on Additive-Manufactured Scaffolds. Small 2020, 16, 2002258. https://doi.org/10.1002/smll.202002258

2- Kim, Y., Chica-Carrillo, E.C. & Lee, H.J. Microfabricated sensors for non-invasive, real-time monitoring of organoids. Micro and Nano Syst Lett 12, 26 (2024). https://doi.org/10.1186/s40486-024-00216-y

6. Implantable Aptasensors for In Vivo Cancer Biomarker Detection (TA in charge: Xinyi Huang)

Early cancer detection is crucial for improving patient outcomes, yet current diagnostic methods often lack the sensitivity and real-time monitoring capability needed to identify malignancies at their earliest stages. Aptasensors—biosensors utilizing aptamers as highly specific molecular recognition elements—offer a promising approach for in vivo cancer biomarker detection. Aptamers are synthetic oligonucleotides that selectively bind to target molecules, providing advantages over antibodies, such as enhanced stability, lower immunogenicity, and ease of chemical modification for integration into biomaterials.

This project aims to develop an implantable aptamer-functionalized biosensor for real-time, in vivo detection of cancer biomarkers. The sensor will consist of a biocompatible hydrogel matrix or nanomaterial-coated implant, functionalized with aptamers targeting early-stage cancer markers such as circulating tumor DNA (ctDNA), exosomal proteins, or small molecule metabolites. Upon biomarker binding, the aptasensor will generate a detectable optical or electrochemical signal, which can be wirelessly transmitted for continuous monitoring. By creating a continuous, implantable sensing platform, this project seeks to revolutionize early cancer detection and monitoring, potentially enabling personalized diagnostics and real-time assessment of treatment response[1] Downs, A. M., & Plaxco, K. W. (2022). Real-time, in vivo molecular monitoring using electrochemical aptamer based sensors: opportunities and challenges. ACS sensors, 7(10), 2823-2832.

[2] Ram, T. B., Krishnan, S., Jeevanandam, J., Danquah, M. K., & Thomas, S. (2024). Emerging Biohybrids of Aptamer-Based Nano-Biosensing Technologies for Effective Early Cancer Detection. Molecular Diagnosis & Therapy, 28(4), 425-453.

[3] Zahra, Q. U. A., Khan, Q. A., & Luo, Z. (2021). Advances in optical aptasensors for early detection and diagnosis of various cancer types. Frontiers in Oncology, 11, 632165.

[4] Hassan, E. M., & DeRosa, M. C. (2020). Recent advances in cancer early detection and diagnosis: Role of nucleic acid based aptasensors. TrAC Trends in Analytical Chemistry, 124, 115806.

7. Blood-Brain Barrier-on-a-Chip for Modeling Parkinson's Disease and Drug Screening (TA in charge: Xinyi Huang)

The blood-brain barrier (BBB) is a highly selective interface that regulates the passage of substances between the bloodstream and the central nervous system, posing a significant challenge for delivering therapeutic agents to the brain. Traditional in vitro models often fail to accurately replicate the complex architecture and functionality of the BBB, leading to discrepancies in drug permeability assessments. To address this, the development of a blood-brain barrier-on-a-chip (BBB-on-a-chip) offers a promising solution. This microfluidic platform emulates the dynamic microenvironment of the human BBB. Additionally, Disruption of the blood-brain barrier (BBB) is a hallmark of several neurological disorders, including Alzheimer's disease (AD), Parkinson's disease (PD), Huntington's disease (HD), and amyotrophic lateral sclerosis (ALS). In PD, progressive degeneration of dopaminergic neurons is accompanied by cerebrovascular dysfunction, neuroinflammation, and compromised BBB integrity, which can impair drug delivery to affected brain regions. The limited permeability of the BBB to therapeutic compounds remains a major obstacle in developing effective treatments for PD.

This project aims to engineer a physiologically relevant BBB-on-a-chip model tailored for studying PD pathogenesis and evaluating BBB-permeable drugs. By introducing inflammatory cues and PD-related stressors, this model will replicate key aspects of BBB dysfunction associated with the disease. Furthermore, this approach could facilitate the development of personalized medicine strategies by testing patient-specific drug responses in vitro.

[1] Wang, X., Hou, Y., Ai, X., Sun, J., Xu, B., Meng, X., ... & Zhang, S. (2020). Potential applications of microfluidics based blood brain barrier (BBB)-on-chips for in vitro drug development. Biomedicine & Pharmacotherapy, 132, 110822.

[2] Vatine, G. D., Barrile, R., Workman, M. J., Sances, S., Barriga, B. K., Rahnama, M., ... & Svendsen, C. N. (2019). Human iPSC-derived blood-brain barrier chips enable disease modeling and personalized medicine applications. Cell stem cell, 24(6), 995-1005.

[3] Wang, Y. I., Abaci, H. E., & Shuler, M. L. (2017). Microfluidic blood–brain barrier model provides in vivo-like barrier properties for drug permeability screening. Biotechnology and bioengineering, 114(1), 184-194.

8. Developing Patient-Derived 3D-Bioprinting models of pancreatic cancer for novel drug discovery (TA in charge: Xinyi Huang)

Pancreatic ductal adenocarcinoma (PDAC) is a highly lethal malignancy with limited effective treatment options. Traditional two-dimensional (2D) cell cultures and animal models often fail to accurately replicate the complex tumor microenvironment of PDAC, leading to a pressing need for more representative preclinical models. Recent advancements in three-dimensional (3D) bioprinting technology have enabled the creation of patient-derived tumor models that closely mimic the architecture and cellular heterogeneity of native pancreatic tumors. These 3D-bioprinted models incorporate various cell types, including cancer-associated fibroblasts and immune cells, within a biomimetic scaffold, providing a more physiologically relevant platform for studying tumor biology and drug responses.

The primary objectives of this project are to develop patient-specific 3D-bioprinted PDAC models that retain the histological and genomic features of the original tumors. These models will be utilized to evaluate the efficacy of existing chemotherapeutic agents and to screen for novel

therapeutic compounds, with the ultimate goal of personalizing treatment strategies and improving patient outcomes. By integrating genomic analyses with drug sensitivity data, this approach aims to identify biomarkers predictive of treatment response, thereby facilitating the development of targeted therapies for PDAC.

[1] Melzer, M. K., Resheq, Y., Navaee, F., & Kleger, A. (2023). The application of pancreatic cancer organoids for novel drug discovery. Expert Opinion on Drug Discovery, 18(4), 429-444.

[2] Sun, H., Wang, Y., Sun, M., Ke, X., Li, C., Jin, B., ... & Mao, Y. (2024). Developing Patient-Derived 3D-Bioprinting models of pancreatic cancer. Journal of Advanced Research.

9. Wearable Electrochemical Biosensors for Noninvasive Blood Glucose Monitoring (TA in charge: Xinyi Huang)

Diabetes management relies on frequent monitoring of blood glucose levels to prevent complications, yet conventional methods involve invasive finger-prick tests, causing discomfort and reducing patient compliance. Sweat-based electrochemical glucose sensors offer a promising, noninvasive alternative for continuous blood sugar monitoring. Since sweat contains glucose in correlation with blood glucose levels, advanced biomaterials can be engineered to enhance sensor sensitivity, stability, and biocompatibility for real-time monitoring.

This project focuses on designing a wearable electrochemical sensor integrated into a biomaterial-based platform for continuous glucose detection from sweat. The sensor will incorporate: development of an optimized biomaterial for efficient sweat absorption and stable enzyme immobilization; integration of a nanostructured electrochemical transducer to improve signal amplification and selectivity; optimization of a user-friendly wearable design that enables wireless monitoring and real-time data sharing. By achieving these goals, this project aims to revolutionize noninvasive glucose monitoring, enhancing diabetes care through personalized and real-time tracking of blood sugar levels.

[1] Bandodkar, A. J., Jeang, W. J., Ghaffari, R., & Rogers, J. A. (2019). Wearable sensors for biochemical sweat analysis. *Annual Review of Analytical Chemistry, 12*, 1-22.

[2] Kim, J., Campbell, A. S., de Ávila, B. E. F., & Wang, J. (2019). Wearable biosensors for healthcare monitoring. *Nature Biotechnology, 37*(4), 389-406.

[3] Teymourian, H., Parrilla, M., Sempionatto, J. R., Montiel, N. F., Barfidokht, A., Van Echelpoel, R., ... & Wang, J. (2020). Wearable electrochemical sensors for the monitoring and screening of drugs. ACS sensors, 5(9), 2679-2700.

[4] Bandodkar, A. J., & Wang, J. (2014). Non-invasive wearable electrochemical sensors: a review. Trends in biotechnology, 32(7), 363-371.

10. Smart Contact Lens Biosensors for Early Detection of Heart Disease (TA in charge: Xinyi Huang)

Cardiovascular diseases (CVDs) remain the leading cause of mortality worldwide, with early detection being critical for prevention and management. Conventional diagnostic methods rely on blood tests and electrocardiograms (ECGs), which are often invasive and require clinical visits. Tear fluid, however, contains key biomarkers related to heart disease, such as C-reactive protein

(CRP), lactate, and cholesterol-related metabolites. Recent advancements in smart contact lens biosensors offer a noninvasive, real-time monitoring solution to detect these biomarkers directly from tears, providing continuous cardiac health assessment.

This project aims to revolutionize cardiac disease monitoring by providing a painless, real-time, and wearable diagnostic tool. Smart contact lenses can serve as early-warning systems for heart disease progression, thereby reducing the need for invasive tests and enhancing preventative healthcare strategies. We propose developing a biocompatible smart contact lens embedded with nanomaterial-based electrochemical sensors to detect biomarkers associated with cardiovascular diseases, such as CVD-related biomarkers including CRP, lactate, and lipid metabolites in tear fluid. Furthermore, wireless data transmission will be integrated to connect with mobile health platforms, enabling continuous cardiovascular health tracking and timely intervention.

[1] Chen, X., Manshaii, F., Tioran, K., Wang, S., Zhou, Y., Zhao, J., ... & Wang, K. (2024). Wearable biosensors for cardiovascular monitoring leveraging nanomaterials. Advanced Composites and Hybrid Materials, 7(3), 97.

[2] Shrivastav, A., Singh, G., Mishra, A., Kumar, P., Kaushik, A., & Mathur, A. (2024). Advanced biosensing technologies for cardiac troponin I Detection: Challenges and future directions in personalized heart health management. Microchemical Journal, 112462.

11. Developing Internal Wound Dressings with Bacteriophage and Antibiotic Integration (TA in charge: Dea Müller)

Antibiotic-resistant bacterial infections in wounds can lead to chronic, difficult-to-treat conditions. Recent advances in hydrogel-based dressings have demonstrated efficacy in both wound protection and the controlled release of therapeutic agents, such as antibiotics or bacteriophages. By employing dynamic covalent crosslinking, phages can be sustainably released over time, effectively managing topical wound infections.

However, treating internal wounds, such as those in knee prostheses, the colon, or the urinary tract, presents additional challenges. This project aims to develop an internal wound dressing that integrates bacteriophages and antibiotics while being biodegradable upon experiencing an end-of-infection signal. Such a system would enable localized, sustained antimicrobial activity without requiring surgical removal, providing an innovative solution for internal wound management.

1. Lin YH, Dharmaraj T, Chen Q, et al. Optimized Dosing and Delivery of Bacteriophage Therapy for Wound Infections. Published online May 10, 2024. doi:10.1101/2024.05.07.593005
2. Bai H, Borjihan Q, Li Z, et al. Phage-Based antibacterial hydrogels for bacterial targeting and Ablation: Progress and perspective. *European Journal of Pharmaceutics and Biopharmaceutics*. 2024;198:114258. doi:10.1016/j.ejpb.2024.114258

12. Developing Large-Scale Bone Substitutes for Enhanced Self-Healing and Integration (TA in charge: Dea Müller)

Significant advancements have been made in the development of personalized bone substitutes,

with 3D printing enabling precise replication of bone structures. Nanoarchitecture and microporosity in promoting osteoconduction and facilitating bone integration, contributing to the successful regeneration of small bone defects.

However, replacing large bone segments remains a major challenge due to structural complexity. This project aims to develop a novel method for reconstructing large bone defects, ensuring both mechanical integrity and biological integration. By optimizing scaffold design and bioactive properties, the goal is to create a functional bone substitute that supports natural regeneration and long-term healing.

1. Ghayor C, Chen TH, Bhattacharya I, Özcan M, Weber FE. Microporosities in 3D-Printed Tricalcium-Phosphate-Based Bone Substitutes Enhance Osteoconduction and Affect Osteoclastic Resorption. *IJMS*. 2020;21(23):9270. doi:10.3390/ijms21239270
2. T. A, C. J. Osteoinduction, osteoconduction and osseointegration. *European Spine Journal*. 2001;10(0):S96-S101. doi:10.1007/s005860100282

13. Development of Immune-Compatible, Ready-to-Use Tissue-Engineered Heart Valve Grafts (TA in charge: Dea Müller)

Heart valve replacement is often an urgent necessity, particularly in cases of an accident or stroke. However, current options—such as transplants or xenograft-derived materials—are often rejected due to immune incompatibility.

This project aims to develop a ready-to-use tissue-engineered heart valve graft that is universally immune-compatible or rapidly adaptable to the recipient's cells. A key focus will be on designing a method that enables quick seeding with patient-specific cells, ensuring both biocompatibility and reducing rejection risks. Additionally, for this approach to be clinically viable, the graft must be efficiently stored and preserved prior to transplantation. Developing a stable, storable scaffold that maintains structural integrity and cell-seeding capacity will be essential to ensuring availability and rapid deployment in emergency situations.

This project aims to provide an immediate yet personalized solution for life-saving valve replacements, combining advances in biomaterials, regenerative medicine, and tissue engineering.

1. Lintas V, Fioretta ES, Motta SE, et al. Development of a Novel Human Cell-Derived Tissue-Engineered Heart Valve for Transcatheter Aortic Valve Replacement: an In Vitro and In Vivo Feasibility Study. *J of Cardiovasc Trans Res*. 2018;11(6):470-482. doi:10.1007/s12265-018-9821-1
2. Mendelson K, Schoen FJ. Heart valve tissue engineering: concepts, approaches, progress, and challenges. *Ann Biomed Eng*. 2006;34(12):1799-1819. doi:10.1007/s10439-006-9163-z

14. Development of an Anti-Infective Catheter to Prevent *Acinetobacter baumannii* Colonization (TA in charge: Dea Müller)

Catheterization is a routine medical procedure but significantly increases the risk of bacterial infections, particularly from antibiotic-resistant pathogens such as Acinetobacter baumannii. Bacterial colonization on catheter surfaces can lead to persistent infections, complicating patient outcomes and increasing healthcare burdens.

This project aims to develop a catheter designed to prevent A. baumannii adhesion and colonization, thereby reducing infection risk following catheter insertion. By integrating advanced antimicrobial surface modifications or coatings, this approach seeks to provide a passive, long-term infection prevention strategy, lowering the incidence of catheter-associated infections.

1. Hazen JE, Di Venanzio G, Hultgren SJ, Feldman MF. Catheterization of mice triggers resurgent urinary tract infection seeded by a bladder reservoir of *Acinetobacter baumannii*. *Sci Transl Med*. 2023;15(678):eabn8134. doi:10.1126/scitranslmed.abn8134
2. Shuman EK, Chenoweth CE. Urinary Catheter-Associated Infections. *Infectious Disease Clinics of North America*. 2018;32(4):885-897. doi:10.1016/j.idc.2018.07.002

15. **Development of a Soft, Self-Healing Non-Hormonal Intrauterine Device (IUD) to Minimize Side Effects (TA in charge: Dea Müller)**

With over 200 million users worldwide, copper intrauterine devices (Cu-IUDs) are the most widely used form of non-hormonal, long-acting contraception. Despite their effectiveness, they are often associated with side effects such as increased menstrual bleeding and cramping, likely due to copper-induced irritation and inflammation. These issues frequently lead to early removal, limiting their long-term usability. With the rise in concerns about potential physical and psychological side effects from hormonal contraceptives, there is an increasing demand for improved non-hormonal alternatives.

This project aims to develop a next-generation non-hormonal IUD that minimizes irritation and inflammation by utilizing soft, flexible, and biocompatible materials. The device will be designed to remain sterile and effective while reducing discomfort. Additionally, incorporating self-healing properties could enhance tissue recovery and further improve user experience, offering a novel approach to non-hormonal contraception.

1. Bunting JJM, Leung ZCL, Boboc B, et al. Revolutionizing Women's health: the quest for materials for next-generation, non-hormonal intrauterine devices. *npj Womens Health*. 2024;2(1):24. doi:10.1038/s44294-024-00026-y
2. Wildemeersch D, Hasskamp T, Nolte K, et al. A multicenter study assessing uterine cavity width in over 400 nulliparous women seeking IUD insertion using 2D and 3D sonography. *European Journal of Obstetrics & Gynecology and Reproductive Biology*. 2016;206:232-238. doi:10.1016/j.ejogrb.2016.09.023

16. **Printing a heart: constructing a biocompatible 3D printed heart for surgical transplantation (TA in charge: Jose Vasquez Porto)**

Novel biomaterials and scaffolds have been developed to take advantage of 3D printing techniques to print a new heart, or at least its basic components. Numerous preliminary trials have been conducted for 3D printed heart scaffolds in vitro to test its capacity to pump blood and to maintain hydrostatic pressure. The goal of this project is to assess the potential of developing an artificial 3D printed heart for future heart transplantations. What is required? Is there a way to print the heart? The cells that make the heart? Can we print the scaffold and then grow the cells? Please, present a concise plan to develop a 3D printed heart for patient transplantations.

[1] Gómez-Ciriza, G., Gómez-Cía, T., Rivas-González, J. A., Velasco Forte, M. N., & Valverde, I. (2021). Affordable Three-Dimensional Printed Heart Models. Frontiers in Cardiovascular Medicine, 8. https://doi.org/10.3389/fcvm.2021.642011

[2] Yadid, M., Oved, H., Silberman, E., & Dvir, T. (2022). Bioengineering approaches to treat the failing heart: from cell biology to 3D printing. In Nature Reviews Cardiology (Vol. 19, Issue 2, pp. 83–99). Nature Research. https://doi.org/10.1038/s41569-021-00603-7

17. **Exploration of novel knee replacement technologies for performance sports (TA in charge: Jose Vasquez Porto)**

Knee replacement is a surgical procedure to restore function on patients whose limb has been severely damaged. The removed cartilage and bone are replaced with metallic or plastic prosthetics that can endure the forces experienced by the original knee. Revascularization and calcification are also targets of the procedure. The artificial knee can be made of different biomaterials and architectures depending on their usage. This project aims to assess state-of-the-art biomaterials and methods for knee replacement with a focus on restoring functionality in performance sports. Please, design a novel knee prosthetic using innovative biomaterials and supporting chemicals. The knee prosthetic needs to withstand intense performance sport activity.

[1]Kluyskens, L., Debieux, P., Wong, K. L., Krych, A. J., & Saris, D. B. F. (2022). Biomaterials for meniscus and cartilage in knee surgery: state of the art. In Journal of ISAKOS (Vol. 7, Issue 2, pp. 67–77). International Society of Arthroscopy Knee Surgery and Orthopaedic Sports Medicine. https://doi.org/10.1136/jisakos-2020-000600

[2] Sass, J. O., Kebbach, M., Lork, C., Johannsen, J., Weinmann, M., Stenzel, M., & Bader, R. (2024). Computational biomechanical study on hybrid implant materials for the femoral component of total knee replacements. Journal of the Mechanical Behavior of Biomedical Materials, 158. https://doi.org/10.1016/j.jmbbm.2024.106681

18. **Applications of silk as a novel biomaterial for nerve regeneration (TA in charge: Jose Vasquez Porto)**

Silk, a material originally produced by worms and spiders, has outstanding mechanical and biological properties. Silk fibers were originally used to suture medical procedures, but current applications go beyond. Silk fibers serve as tissue scaffolds, drug delivery systems, and even nerve regeneration agents. The goal of this project is to explore the full potential of silk as a biologically inspired material that promotes nerve regeneration.

[1] Vepari, C., & Kaplan, D. L. (2007). Silk as a biomaterial. In Progress in Polymer Science (Oxford) (Vol. 32, Issues 8–9, pp. 991–1007). https://doi.org/10.1016/j.progpolymsci.2007.05.013

[2] Peter, K., Stadlmayr, S., Naghilou, A., Ploszczanski, L., Hofmann, M., Riekel, C., Liu, J., Burghammer, M., Gusenbauer, C., Konnerth, J., Schniepp, H. C., Rennhofer, H., Sinn, G., Radtke, C., & Lichtenegger, H. C. (2025). Exploring the Unique Properties and Superior Schwann Cell Guiding Abilities of Spider Egg Sac Silk. ACS Applied Bio Materials. https://doi.org/10.1021/acsabm.4c01587

[3] Sahoo, J. K., Hasturk, O., Falcucci, T., & Kaplan, D. L. (2023). Silk chemistry and biomedical material designs. In Nature Reviews Chemistry (Vol. 7, Issue 5, pp. 302–318). Nature Research. https://doi.org/10.1038/s41570-023-00486-x

19. **Artificial extracellular matrix for wound healing (TA in charge: Jose Vasquez Porto)**

The extracellular matrix (ECM) is composed of a rich assortment of proteins that are essential to maintain the integrity of tissue and to modulate cellular responses to traumatic events such as wound formation and healing. Novel biomaterials that either mimic the properties of the ECM or are composed of the basic components of the ECM have been developed to address this problem. This project looks at finding novel ECM or ECM-like biomaterials applied to the complex process of wound healing for clinical purposes. In this project specifically we will look at how we can develop a ECM scaffold to promote wound healing after severe burns.

[1] Hosty, L., Heatherington, T., Quondamatteo, F., & Browne, S. (2024). Extracellular matrix-inspired biomaterials for wound healing. In Molecular Biology Reports (Vol. 51, Issue 1). Springer Science and Business Media B.V. https://doi.org/10.1007/s11033-024-09750-9

[2] Solarte David, V. A., Güiza-Argüello, V. R., Arango-Rodríguez, M. L., Sossa, C. L., & Becerra-Bayona, S. M. (2022). Decellularized Tissues for Wound Healing: Towards Closing the Gap Between Scaffold Design and Effective Extracellular Matrix Remodeling. In Frontiers in Bioengineering and Biotechnology (Vol. 10). Frontiers Media S.A. https://doi.org/10.3389/fbioe.2022.821852

20. **Novel endoscopic biomaterials (TA in charge: Jose Vasquez Porto)**

Endoscopes are used to access, visualize, and sample internal body structures for therapeutic purposes, such as the gastrointestinal tract, mucosal membranes, and arteries. Biomaterials are essential for the construction, functionality and sampling capacity of the endoscopes. This project focuses on analyzing optimal biomaterials for the construction and functionality of endoscopes and their target procedures. The students will search for two biomaterial solutions that can enhance endoscopic function. The first biomaterial must improve gastrointestinal tract endoscopy to treat polyps. The second must improve plaque treatment during artery exploration.

[1] Qin, G., Wu, R., Wang, Q., Sun, M., Li, Y., Duan, S., & Xu, F. J. (2024). Injectable Hyaluronic Acid-Based Hydrogels for Rapid Endoscopic Submucosal Dissection. ACS Biomaterials Science and Engineering. https://doi.org/10.1021/acsbiomaterials.4c01703

[2] Ni, P., Ye, S., Xiong, S., Zhong, M., Shan, J., Yuan, T., Liang, J., Fan, Y., & Zhang, X. (2023). A chitosan-optimized polyethyleneimine/polyacrylic acid multifunctional hydrogel for reducing the risk of ulcerative arterial bleeding. Journal of Materials Chemistry B, 11(23), 5207–5222. https://doi.org/10.1039/d3tb00239j

21. **Stable and robust bacterial-derived wound dressing (Dea)**

Wound dressings commonly suffer from a limited lifetime due to normal wear and tear of passive

biomaterials. This can lead to poor wound healing and chronic bacterial infections. Novel approaches to synthesis include the ability of a material to heal itself, that is to autonomously recover its mechanical properties upon damage, or to heal itself upon specific stimulus (e.g. light, temperature). In this project, we are asking you to come up with a healing biomaterial that takes advantage of the ability of bacteria to produce robust hydrogel matrices. The biomaterial can either contain bacteria or remain abiotic, depending on the approach taken. In this project, care must be taken to safety aspects, as bacteria cannot penetrate the wound.

references

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Caprioli, M., Roppolo, I., Chiappone, A. *et al.* 3D-printed self-healing hydrogels via Digital Light Processing. *Nat Commun* **12**, 2462 (2021). https://doi.org/10.1038/s41467-021-22802-z