1. OPIS PROJEKTU DOKTOSKIEGO (4000 znaków max., łącznie z celami i planem pracy, do umieszczenia na stronie internetowej Szkoły)

Tytuł projektu:

Tailored polysaccharide- and protein-based crosslinkers for materials in biomedical applications

1.1. Cele projektu

The project aims to design and synthesise new macromolecular cross-linking agents based on polysaccharides and proteins for use in materials with biomedical applications. The obtained and characterised cross-linkers will then be used to produce final biomaterials.

1.2. Ogólna charakterystyka projektu

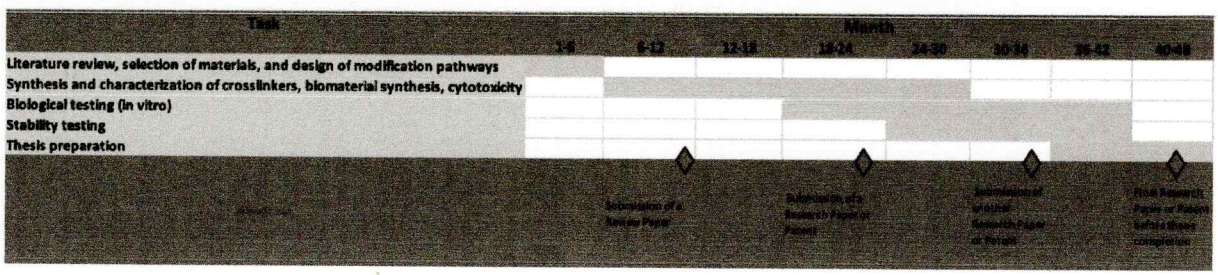
The degradation processes of biopolymer materials make them incompatible for long-term biomedical applications due to their rapid degradation, especially in electrolyte solutions, which affects the achievement of targeted therapeutic effects. Damage to biomaterial networks can lead to a loss of the material's structural integrity, potentially shortening its functional life. This has led to efforts to develop materials with improved elasticity and strength, while remaining non-toxic. Formulating such biomaterials that are both chemically and morphologically stable and mechanically robust requires the use of a cross-linking agent. Most synthetic cross-linkers, such as glutaraldehyde and glyoxal, are cytotoxic, in contrast to natural cross-linkers.

The project aims to develop and synthesise new cross-linking agents for biomaterials. Polysaccharides and proteins will be used as matrices for modification to introduce reactive groups suitable for crosslinking. Once fully characterised, the resulting cross-linkers will be used to obtain biomaterials based on polysaccharides and proteins. This will lead to a range of polysaccharide-polysaccharide, polysaccharide-protein and protein-protein materials.

The materials obtained will be characterised by their composition, structure, morphology, mechanical properties and ability to interact with proteins, including in the acute phase. The best of these will be submitted for biological studies. The project will also investigate the behaviour of the materials after a standard ageing process for medical devices.

The research will develop new biocompatible cross-linking agents based on biopolymers and the biomaterials cross-linked with them. The work results will be published in JCR-listed journals, and those promising for implementation will be patented.

1.3. Plan pracy (w tym okres projektu min. 36 m max. 48 m)



1.4. Literatura *(max. 7 pozycji/sugestia lektury dla kandydatów)*

- Mahamudul Hasan Rumon et al., Progress in hydrogel toughening: addressing structural and crosslinking challenges for biomedical applications, *Discover Materials*, **2025**, 5, DOI: 10.1007/s43939-025-00178-x
- Hien A. Tran et al., Emerging silk fibroin materials and their applications: New functionality arising from innovations in silk crosslinking, *Materials Today*, **2023**, 65, DOI: 10.1016/j.mattod.2023.03.027
- Lee, Y.B.; Lim, S.; Lee, Y.; Park, C.H.; Lee, H.J. Green Chemistry for Crosslinking Biopolymers: Recent Advances in Riboflavin-Mediated, Photochemistry, *Materials* **2023**, 16, DOI: 10.3390/ma16031218
- Song-Yi Wu et al., From Bench to Clinic: Crosslinking Approaches for Next-Generation Collagen Fillers, *Advances in Polymer Technology*, **2025**, DOI: 10.1155/adv/3899983

1.5. Wymagana wstępna wiedza i umiejętności kandydata/tki na doktoranta/kę

The PhD candidate is required to know biopolymers and methods for their characterisation and modification, organic synthesis, and medicinal chemistry. Knowledge of basic general pharmacology will be an added advantage.

1.6. Oczekiwany rozwój wiedzy i umiejętności kandydata/tki na doktoranta/kę

Scientific and Technical Skills

Advanced Biomaterials Knowledge: Familiarity with natural vs synthetic cross-linking agents, including their chemical properties and biocompatibility. Understanding of biopolymer degradation mechanisms, particularly in biomedical environments. Knowledge of chemical and morphological stabilisation techniques for polymers.

Cross-linker Design and Synthesis: Design of novel cross-linking agents tailored for biocompatibility. Synthesis techniques for modifying polysaccharides and proteins to introduce reactive groups. Development of protein–protein, polysaccharide–polysaccharide, and hybrid biomaterials.

Material Characterisation: Structural and compositional analysis, morphological imaging (e.g., SEM, TEM), mechanical testing (e.g., tensile strength, elasticity). Surface interaction studies with biological molecules (e.g., protein adsorption assays). Evaluating the mechanical, biological and structural stability of biomaterials over time.

Biological and Biomedical Competence: Understanding cytotoxicity, protein interaction, and acute-phase response testing. Planning and interpretation of *in vitro* biological assessments. Knowledge of criteria for selecting safe, non-toxic, and durable biomaterials for medical applications.

Research and Analytical Skills: Designing multi-phase experiments, from synthesis to biological validation. Troubleshooting and optimising chemical and biological workflows. Data analysis and conclusions. Writing scientific papers and patent applications.

Professional and Soft Skills: Planning and executing a long-term interdisciplinary research project. Coordinating multiple research phases, including synthesis, characterisation, and biological testing. Ability to work in a multidisciplinary team.