Chronic wounds, such as pressure ulcers, diabetic foot ulcers, venous leg ulcers, and arterial ulcers, present a significant healthcare challenge. Unlike common cuts that heal on their own, chronic wounds linger for an extended period, often exceeding 12 weeks, and carry an increased risk of complications. The traditional approaches to wound care often fall short in addressing these prolonged healing times. At the heart of this challenge lies a deficiency in cytokines, specifically growth factors (GFs), crucial proteins that orchestrate the body's healing process. GFs play a vital role in regulating inflammation, encouraging tissue growth, and stimulating the formation of new blood vessels. When chronic wounds experience a shortage of these essential proteins, the healing process becomes protracted and often stalls. To tackle this issue, researchers are exploring innovative ways to deliver GFs effectively. The goal is to create biomaterials that provide controlled and sustained release of these growth factors, fostering optimal conditions for wound healing while minimizing risks and side effects.

Our project aims to design a system comprising a porous drug-releasing polymeric scaffold coated with diverse polyelectrolyte nanofilms, creating GF gradients for guided cellular activity. To address challenges in drug release and distribution, we plan to synthesize a drug-polymer conjugate based on biocompatible polyesters, which will serve as material for scaffold preparation. The Layer-by-Layer (LbL) deposition technique is crucial for the proposed project. It enables creating ultrathin GF-loaded films on diverse surfaces and within tissue engineering scaffold pores. Its versatility stems from the broad range of available polyanions and polycations, enabling the design of complex coatings. In the inflammatory environment of chronic wounds, excess metalloproteinases hinder the initiation of wound healing by rapidly degrading GFs and cytokines. Incorporating GFs into the LbL matrix serves as a protective strategy, ensuring a sustained and controlled release of GFs over time.

By employing various gradients into the scaffold, such as porosity, stiffness, or chemical gradients, cellular responses in specific wound regions may be induced. This strategy proves advantageous for initiating healing in chronic ulcers, where the repopulation of the wound edge through cellular migration is one of the healing stages impaired. In our pursuit of a comprehensive wound healing solution, we are focusing on regulating cell migration and inducing spatially and temporally controlled cell proliferation. Our goal is to investigate three possible variants of the LbL deposition method for chemical gradient generation: (1) deposition in separation chambers, (2) under centrifugal force, and (3) under an electric field. These modifications are tailored for surface altering within a few-millimeter-thick scaffold, optimizing their suitability as wound dressings.

Further leveraging the tunable platform provided by LbL films, we plan to implement barrier films composed of polyelectrolytes modified through click chemistry. In this process, nanofilm components embedded with reactive moieties will undergo in-situ reactions during LbL assembly, forming crosslinked diffusional barriers that segregate GF-loaded segments of the multilayers. Our objective is to investigate whether we can precisely tailor the quantity and timing of GF release by controlling the thickness of specific film components. This strategic approach holds the potential to mimic the necessary stages of GF presence for chronic wound healing, offering a promising avenue for advanced wound care.

In summary, our research explores advanced biomaterials and innovative deposition techniques to develop a smarter wound dressing. By integrating drug release modulation and cell guidance, our proposed system aspires to offer a multifunctional platform for enhanced wound healing. This venture represents a convergence of technologies and biological insights, offering a step forward in the treatment of chronic wounds.