# Preface

Substances that absorb significant quantities of water are called gels or hydrogels. Naturally occurring materials with these properties play a very important role in all forms of life. In this Handbook, the biomedical applications of hydrogels are addressed by experts in the field from around the world. The phenomenal properties of hydrogels continue to stimulate scientists to seek new insights into the development of novel biomaterials and bioapplications.

Composed of three-dimensional polymer networks, hydrogels can absorb large quantities of water. Consequently, they are soft, pliable, wet materials with a wide range of potential biomedical applications. Hydrogels are currently widely used in bioapplications and play a crucial role in modern strategies to remedy malfunctions in and injuries to living systems.

The high water content of hydrogels renders them compatible with most living tissue and their viscoelastic nature minimizes damage to the surrounding tissue when implanted in the host. In addition, their mechanical properties parallel those of soft tissue, which makes them particularly appealing to tissue engineers. These novel, bioactive materials are capable of interacting with the host tissues, assisting and improving the healing process, and mimicking functional and morphological characteristics of organ tissue.

Biomaterials play a crucial role in modern strategies of tissue replacement and restoration because they provide the biophysical and biochemical surroundings that are able to direct cellular behavior and functions. The concept of designing hydrogels as temporary or permanent devices for regeneration and restoration of tissues is being vigorously pursued in many laboratories, that often involve international cooperative endeavors. Both natural and synthetic hydrogels are used for repairing and regenerating a wide variety of tissues and organs. The ability to engineer composite hydrogels has generated new opportunities in addressing challenges in tissue engineering as well as in tissue function restoration.

Most hydrogels have biological traits, such as high tissue-like water content and permeability for influx of nutrients and excretion of metabolites. Cells encapsulated in a 3-D hydrogels environment are surrounded by a gels matrix that does not promote attachment or potential phenotype differentiation, thus making hydrogels especially suitable for engineered scaffolds. These hydrophilic composite structures are being designed to mimic the transport and mechanical properties of natural soft tissue. Hydrogels can homogeneously incorporate and suspend cells as well as growth factors and other bioactive reagents while allowing rapid diffusion of hydrophilic nutrients and metabolites to the incorporated cells or surrounding tissue.

One of the essentials for an effective tissue scaffold is that it degrades in a controlled manner so that when the bioreplacement is complete and functional in vivo none of the scaffolding materials remain. Biodegradable hydrogels are derived from fibrin, hyaluronic acid, collagen, chitosan, and poly(lactic acid) components to create hybrid hydrogels that are biocompatible and can provide appropriate signals to regulate cell behavior. Degradation of hydrogels leads to a loss in mechanical strength and finally disintegration. Therefore, the degradation rate of the gels needs to be carefully controlled to match the rate of new tissue formation.

There are a number of hydrogels that behave as smart materials and offer natural adaptations, such as sensing devices, actuating and regulating functions, and feedback control systems. These stimuli-responsive polymer gels react to changes in their surroundings, such as surrounding composition, temperature, and pH. They are of interest as intelligent, or smart, biomimetic materials that can function as biosensors, processors, and activators of an electrical response. The applications of electroconductive hydrogels as biorecognition membranes for implantable biosensors, as electro-stimulated drug-eluting devices and as a low interfacial impedance layer on neuronal prostheses present new horizons for biodetection devices. Both biomolecular recognition and responsive functions that perceive a biomolecule target and induce structural changes can be introduced into the hydrogels network.

Hydrogels-based drug delivery systems with integrated smart systems and biomolecular imaging capability open many opportunities for effective therapeutic delivery and monitoring as well as molecular imaging probes in noninvasive procedures for early detection and treatment of disease. This multifunctionality makes it possible to self-regulate and control hydrogels-based devices to maintain physiological variables for applications such as drug delivery and cell cultures.

Hydrogels implants for drug delivery can be preformed or injected. The preformed hydrogels are processed with the active reagent in vitro prior to in vivo implantation. Injectable hydrogels are implanted as a liquid that gels in situ with the reagent incorporated and suspended in the gels precursor prior to gelation, enabling homogenous and facile implantation. In situ gelling of stimuli-sensitive block copolymer hydrogels has many advantages, such as simple drug formulation, site-specificity, sustained drug release behavior, less systemic toxicity, and the ability to deliver both hydrophilic and hydrophobic drugs. For example, PEG-based amphiphilic copolymers are extensively used for biomedical applications due to their unique self-assembly and biocompatibility properties. The PEG-based amphiphilic copolymers exhibit unique changes in micellar architecture and aggregation number in response to changes near physiological temperature and/or pH. Therefore, in situ gelling systems made with PEG-based amphiphilic copolymers are being investigated worldwide.

These topics as well as several other biomedical applications of hydrogels are covered in the ensuing chapters by the most highly qualified experts in the field. I wish to thank them and the many others who have contributed to this publication.

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