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Preface

Biomaterials, Drug Delivery and Bionanotechnology—The Research that Paved the Way: Professor Nicholas Peppas' Research Over the Years

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Professor Nicholas A. Peppas.

Professor Nicholas A. Peppas was born in Athens, Greece in 1948. He graduated from the National Technical University Athens with a degree (Dipl. Eng.) in Chemical Engineering. He then moved to the Massachusetts Institute of Technology where he completed a doctoral degree (Sc.D.) in Chemical Engineering in 2 years. His graduate work was performed in the laboratory of Professor E.W. Merrill. He continued as a Postdoctoral Associate working with Professors C.K. Colton, K.A. Smith and R. Lees in the Arteriosclerosis Center of MIT, before he was appointed as an Assistant Professor of Chemical Engineering at Purdue University in 1976. He was promoted to Associate Professor in 1978 and Professor in 1982. From 1993 to 2002 he was the Showalter Distinguished Professor of Chemical and Biomedical Engineering at Purdue University. As of 2003, he is the Fletcher Stuckey Pratt Chair in Engineering with appointments in the Departments of Chemical Engineering, Biomedical Engineering and the College of Pharmacy at the University of Texas at Austin. Professor Peppas has received honorary doctorates from the Universities of Ghent, Parma and Athens. He is the author of 1100 publications, 38 patents, and 33 books, and is one of the most cited pharmaceutical scientists. He is a HighlyCited ® scientist in the Pharmacology and Engineering fields. He is a member of the Institute of Medicine (IOM) of the National Academy of Sciences, the National Academy of Engineering (NAE), the National Academy of France (Pharmacy) and the Academy of Medicine, Engineering and Science of Texas (TAMEST).

The Peppas laboratory has made groundbreaking contributions to the advancement of polymer science. Specifically, polymerization reactions were a topic of research in the early years. Polymer network formation was investigated and kinetic analyses of polymerization and crosslinking reactions were performed. Polymer physics and transport phenomena in glassy polymers were studied, and the findings were applied to, among other fields, drug delivery applications. This was one of the first significant contributions to develop quantitative models that could be applied to the pharmaceutical sciences. Towards that goal, fundamental polymer research examined the laws that govern solute and penetrant diffusion through a polymer medium. Models were developed to express experimentally observed phenomena in polymer swelling, penetrant sorption and solute release. Prediction of the matrix dissolution based on physical and mathematical models was one step further towards controlled drug release. Furthermore, the interactions of polymers and biological tissues were studied and gave valuable new information on the bioadhesive properties of materials.

Hydrogels are a class of crosslinked polymers that the Peppas laboratory contributed greatly to, both on the fundamental aspects of their preparation and characterization as well as their application as biomaterials. Due to their hydrophilic and biocompatible nature, hydrogels are now widely used by biomedical and pharmaceutical scientists. Dr. Peppas' studies on the synthesis and characterization of poly(vinyl alcohol) hydrogels resulted among others in the highly cited Peppas–Merrill equation (1974), which can be used to calculate the number average molecular weight between crosslinks. Having identified the potential of hydrogels as drug delivery vehicles, parameters that optimize the release process were systematically determined, as for example the hydrogel mesh size. Hydrogels that swell in response to changes in the environment, such as pH or glucose concentration, have been another exciting topic of research in the Peppas laboratory. These intelligent hydrogels can be used as drug carriers which will release their load in a controlled manner upon even small changes in the

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environmental stimulus. Peppas and his associates developed also the widely used exponential expression of drug release (known as the Korsmeyer–Peppas equation (1981)) that has been used to analyze the release behavior of matrix systems. Moreover, the Peppas laboratory evaluated hydrogels as biomaterials for cartilage regeneration and vocal cord replacements. Other aspects of hydrogels investigated include their use as membranes and for blood contact applications.

The characterization of polymers, and hydrogels in particular, as drug release systems led to addressing the problem of the development of systems for protein delivery. The Peppas laboratory has been investigating the oral delivery of therapeutic proteins, which are used for the treatment of conditions such as diabetes, multiple sclerosis and cancer and are most commonly delivered by injection. However, injectable delivery increases discomfort for patients, and a simpler and less costly administration method has been sought for, especially one that mimics the physiological delivery of proteins. The sensitive nature of protein molecules requires protection from the environment until the target location is reached. Dr. Peppas and his associates developed complexation hydrogels that could shield the proteins from the acidic environmental conditions of the upper gastrointestinal system, and allow them to be released at the desired site, where an increase in the pH resulted in breaking the associated hydrogen bonds (complexes) allowing hydrogel swelling. Studies with insulin have shown significant bioavailability of the protein. The study of the interactions between proteins and polymeric carriers has brought this endeavor one step further, establishing the most efficacious delivery vehicles for proteins.

The Peppas laboratory provided outstanding contributions that also examine the interactions between delivery systems, proteins and the physiological environment in order to optimize the targeted delivery and increase the bioavailability of the protein. pH-sensitive hydrogels were functionalized with proteins that could bind to the intestinal mucosa, prolonging the residence time of the vehicle at the location the protein is to be released and enhancing its absorption. Moreover, hydrogels were modified in that they also promoted mucoadhesive behavior. Principles of bionanotechnology were employed towards molecular recognition of biologically significant molecules. Intelligent drug delivery systems based on molecular recognition could be automatically activated once these molecules are detected. This way, the drug would be delivered according to need. Another aspect of bionanotechnology with the potential of truly revolutionizing drug delivery are injectable nanoparticles, which can provide spatially and temporally controlled release. The Peppas laboratory is currently investigating their use also as for imaging, biosensing, biomolecular recognition or multimodal purposes.

Professor Peppas has always emphasized education. He has been the mentor to 81 doctoral students as of November 2008, and has advised numerous postdoctoral fellows and undergraduate students. Thirty-five of his former advisees are currently holding academic positions in universities in the USA and overseas. Professor Peppas' unique perspective on the use of chemical engineering principles towards the solution of medical problems has made pioneering advancements in the fields of polymer and biomaterial science as well as drug delivery. The establishment of quantitative models for various biological, chemical and physical phenomena gave a new direction to the pharmaceutical sciences. His research was based and focused on societal needs, and its impact was apparent not only in drug delivery but in other fields as well. Professor Peppas has had a long interaction with industry and his research ideas have been translated into commercial successes with the aim of improving people's medical conditions.

We would like to congratulate Dr. Peppas on the occasion of his 60th birthday and wish him and his laboratory every success in their endeavors. We are all excited to hear about their future contributions.