President Vest, Chairman Holliday, Fellow Members of the Academy, Distinguished Guests, Ladies and Gentlemen:

It is a great honor for me to receive the Founders Award of the National Academy of Engineering today. The Founders Award is not only recognition of an individual’s achievements but also an acknowledgement of the hard work and contributions of all the collaborators who contributed to this work. I am touched by the generosity of the Academy and its Awards Committee and I am humbled to be included among the giants of engineering who have received this award before.

My contributions over the past forty-two years have been in the fields of biomaterials science, polymer science, drug delivery and biomedical engineering. But when I arrived in the United States, in Boston, on a hot and humid late afternoon of July 1971, I could not imagine what a turn my life would take. Indeed, my aspirations in the early years were quite different. I was born in Athens, Greece, in August 1948. My father, Athanassios Peppas, was an economist and playwright, my mother Alice Rousopoulos a teacher of French literature. I was brought up in a loving home in the suburbs of Athens and in the early days I was taught to read and admire the classics. Classics in our household did not mean only a love for Greek and Latin history and literature, but also an appreciation for European traditions and the work of German, French, British, Italian, and Russian authors. A loving circle of relatives had a major influence on me and I was sure I wanted to study archaeology like my great grand father Athanassios Rousopoulos who was a Professor of Archaeology at the University of Athens. But I also loved chemistry and I had inherited all the books of my grand father Peter Rousopoulos, a chemistry professor at the Commercial Academy of Athens, who did his doctorate at the University of Göttingen under the supervision of Otto Wallach, a 1910 Nobel laureate in chemistry. History, archaeology and Italian opera kept me busy as I was growing up in the sixties. But the educational environment was fertile and eventually chemistry prevailed. Upon taking national examinations, as was the norm at that time, I entered the Chemical Engineering Department of the National Technical University of Athens, at that time the most prestigious department in Greece. As students at NTU in the middle and late sixties in Athens, we were all fascinated by novel mathematical techniques, advanced transport phenomena and chemical reaction engineering, courses taught by a group of young faculty members who had arrived from the USA.

When the time came for me to continue my studies towards a PhD degree, I had the fortitude, audacity would be a more appropriate word, to deviate from the mathematical norm and study biomedicine, something that was unheard of in European engineering circles at that time. So, I arrived in Cambridge, MA, in August 1971 and I was enrolled in chemical engineering at MIT. At MIT, we all had the great fortune to be students of this great pioneer of biomedical engineering, one of the fathers of the field, Edward Wilson Merrill. Ed instilled upon all of us the idea that the principles of engineering and physiology could be applied to the solution of important medical problems. Those were the days when medical scientists from the Harvard Medical School and the main hospitals of Boston would cross the Charles river to collaborate with MIT professors on medical problems requiring modeling, rheology, new materials, and innovative technical solutions. I was fortunate to be in the same class and laboratories with other ambitious young men, notably Bob Langer of MIT, who became a giant in the biomedical field and preceded me as a NAE Founders Award recipient in 2010, Michael Sefton, now of the University of Toronto and member of the Royal Society, and even a young undergraduate chemist, David Tirrell, who was helping us in the lab and who is now a distinguished member of all three Academies.
Those were truly wonderful days for biomedical education. Along with many friends, we embarked upon the study of biomedical engineering, biomaterials science and allied fields, with the enthusiasm and dedication that only the young innocent generation of the early seventies could exhibit. We worked on the development of new non-thrombogenic biomaterials for artificial organs, on valves for artificial hearts, on new membranes for artificial kidneys, on contact lenses, prostheses, but also on a fundamental understanding of the causes of diseases from thrombosis to arteriosclerosis. These were the wonderful days when NIH funding was plentiful. I will always be grateful to this country for allowing a young engineer like me to delve into important medical problems and make an impact in the field.

At MIT I had the opportunity to meet many giants of the field. Several made an impact on me such as the late Robert Reid and Elias Gyftopoulos, both NAE members, who taught us to be responsible scientists and engineers. The legendary Warren K “Doc” Lewis at the age of 91 taught us a short IAP course on anemometry in January 1973, the same year he received the NAE Founders Award. Paul Flory (Nobel 1974) had been invited by Ed Merrill to MIT and was a Visiting Professor in ChE at a time we were all doing our PhDs. You can imagine the impact he had to our thinking about biopolymers and crosslinked structures. A year later I had the opportunity to work as a postdoctoral fellow at the Arteriosclerosis Center of MIT under the direction of Clark Colton and Ken Smith, another NAE member. They both taught me to appreciate engineering and science but also to strive for advanced modeling and biological understanding.

Soon thereafter, I joined the faculty of chemical engineering at Purdue University. As I was starting my independent career there in July 1976 I realized how “open” the biomedical engineering field was to new ideas. I recall a summer meeting in Boston when Bob Langer and I met at a delicatessen in Boylston Street and over a long dinner we decided that we could “save the world” with novel biomaterials and drug delivery systems. We decided to work on the solution of important biomedical and pharmaceutical problems. So, in my laboratories at Purdue University, I started working on hydrogels as biomaterials, first for artificial vocal cords, then for articular cartilage replacement, followed by work on contact and intraocular lenses, non-thrombogenic biomaterials, and new artificial kidney membranes. These were also the early days of drug delivery, a subject we started pursuing in 1977. In the beginning there were some obstacles but funding came early, first with Research Corporation and NSF grants in 1977, and a PETC grant on three dimensional crosslinked structures in 1978. NIH funding was not easy for engineers, but by 1981 I had secured my first R01 grant, one that I must admit with pride I continue having. Acceptance of biomedicine into the chemical engineering field was equally questionable with other researchers making statements such as “this is not chemical engineering.”

But by 1978 we had started addressing important new areas of drug targeting, drug delivery, parenteral and oral delivery, mucosal targeting, cell transport, and so on. My students and I became passionate on providing solutions to significant medical problems. We believed that the treatment of diabetes, osteoporosis, asthma, cardiac problems, and cancer should not be based only on conventional pharmaceutical formulations. Indeed, I believe that a key problem of biology and medicine this century has been to reduce the problems of disease to problems of molecular science. Many of the associated methodological advances in biomedical sciences are the result of earlier investments in the basic sciences. I believe that breakthroughs in molecular science have led new opportunities for curing disease. In the last few years, Phil Sharp of MIT has been promoting the idea of “convergence in biomedical sciences”. Of course, this is a paramount idea in bioengineering and has been a standard in my laboratory in the last 30 years and especially at the University of Texas at Austin. These interactions have led to collaboration with biologists, pharmacists, and practicing physicians.

I was fortunate to have had some great doctoral students in all my years at Purdue and the University of Texas at Austin, close to 100 PhDs, 42 of them professors in academia. Two of them were particularly instrumental in biomedical research in those days and they are both here today, as they were inducted to the National Academy of Engineering as new members about an hour ago. Dr. Richard Korsmeyer, a Senior
Fellow of Pfizer and internationally known leader in development of new pharmaceutical formulations, was a PhD student in my laboratory with whom we applied transport theory to understand drug transport in controlled release systems and in tissues. Those pioneering studies of 1979–1982 have led to an equation and a theory (Korsmeyer–Peppas theory) that is now the basis for the design of new drug delivery system. The other newly inducted NAE member is Antonios Mikos of Rice University, with whom we studied targeting to specific sites and developed advanced theories of bioadhesion in tissues. Dr. Mikos went on to become one of the brilliant engineers and scientists in tissue engineering and regenerative medicine.

My career in the 1980s, and 1990s, and especially this past decade at the University of Texas at Austin has allowed me to design, study and utilize advanced biomaterials and advanced drug delivery formulations. These formulations do not simply release the drug, peptide or protein at some characteristic rate, but do so in a way that we design them to do. Consequently, pulsatile swelling/deswelling of a polymer carriers and the associated drug delivery are consequences of significant changes of the physiological environment. For example, in collaboration with my former PhD student Anthony Lowman, now Vice Provost at Temple University, we have developed new systems with which insulin may be delivered to diabetic patients only when the glucose concentration in the blood is above the normal level. Calcitonin may be directed to bypass the stomach and be delivered only in the upper small intestine of women suffering from osteoporosis, from where it will be finally absorbed and pass in the blood. Finally, large molecular weight, genetically engineered molecules can be delivered across tissues at acceptable rates. For example, we have exciting new results on oral delivery of interferon-beta–1a for treatment of multiple sclerosis.

These biomedical developments and inventions use intelligent, hydrophilic, biomedical polymers, often hydrogels or networks, as carriers. The structure of these materials plays a key role in their diffusional behavior and the molecular stability of the incorporated bioactive agents. In my scientific career we have also advanced fundamental aspects of materials science and polymer gel theory. Some of the major developments in the field of rapid photopolymerizations came from the PhD work of my former students Alec Scranton, now Dean of Engineering at the University of Iowa, and Christopher Bowman, Head of Chemical Engineering at the University of Colorado. Dr Bowman and I had the fortune to meet and work together with a brilliant young student at different stages of her career. Kristi Anseth, a member of both NAE and IOM, has become a major contributor to the field of biomaterials and tissue engineering. She was the nominator for the NAE Founders award that I am receiving today and I want to thank her for her support and collaboration over the years. Among other hydrogel-based formulations, we have also studied new polymers that can respond to changes of the physiological environment, especially changes of the pH, temperature, ionic strength and analyte concentration. The pioneer in this work was Lisa Brannon-Peppas with whom we developed not only some of the early pH-sensitive but also the associated theories for swelling behavior and diffusion through ionic networks. I thank her for being a wonderful and highly innovative scientist but also for having been a great partner in life.

As I close I want to say that for me this NAE Founders Award is not the end of a career. I was fortunate enough to have wonderful colleagues, great collaborators and brilliant, innovative graduate students and postdoctoral fellows who shared my vision to do research based on the principles of my field but also with an immediate application and a concern for patients. I am glad the medical and pharmaceutical industry used these ideas for important medical products. I share the feelings of my friend and 2010 NAE Founders Award recipient, Bob Langer that “by the end of the next century disease as we know it today will no longer pose a major threat to human life and that highly effective methods to diagnose disease, prolong life, and relieve suffering will have been created.” I believe that the convergence in biomedical sciences, chemistry, biology and engineering will allow us to understand how diseases and genetic defects occur, develop new chemicals, biomaterials and drugs to treat these diseases, engineer delivery systems that will target drugs and genes to the correct tissues, cells or cell components, noninvasively diagnose diseases, and create new replacement tissues and organs.
I thank you for this great honor you are bestowing to me today and I am grateful to all those who helped me pursue and achieve a dream.