PREFACE

Nature has evolved over millions of years to create matter with amazing complexity. Nowhere this complexity is more apparent than in plants and animals: non-sticking self-cleaning lotus leaves, the lizard's ability to walk on walls without falling down, walking ability of water strider on the water surface, self-healing of earthworm, or water collecting ability of desert beetles, to name a few. Biomimetics goes back to the time of Leonardo da Vinci who made sketches of bird-mimetic flying machines (Leonardo da Vinci, Wikipedia). The Wright brothers were inspired by the flight of birds to design, build, and fly the first aircraft in 1903 (Wright Brothers, Wikipedia). Thirty-four years later in 1937, Otto H. Schmitt noticed partial or variable conduction along the giant squid axons by non-linear responses from a nerve much too depressed to conduct (Otto H. Schmitt, Wikipedia). Based on that observation, he invented a biomimetic thermionic trigger (Schmitt trigger) to remove noise from electrical signals in circuit boards. As a biophysicist, he focused on device technologies that mimic natural or biological systems and eventually coined the term biomimetics in 1957 as an approach to problems in biological science utilizing the technology of physical science. Later in 1941, George de Mestral during a hunting trip became curious when the burdock burrs kept sticking to his cloth and his dog's fur (George de Mestral, Wikipedia). He observed an array of hook-like structures on the burrs' surface when he examined them under the microscope. Based on that observation, he invented the biomimetic Velcro fasteners in 1948 and formed a successful company around that idea. Subsequently in 1958, Jack E. Steele who investigated stress effects of motion, sound, and wind on human body at Wright-Patterson Air Force Base introduced the term bionics as the science of systems, which have some function copied from nature (Jack E. Steel, Wikipedia). Today the term biomimetics and bioinspiration is the science of nature and living systems for the development of sustainable technologies, leading to highly efficient, reliable, environmentally responsive materials, devices, and systems. Biomimetics and bioinspiration is one of the most revolutionary scientific fields of the 21st century with seven-fold increase in scientific activity in the last 10 years. A keyword search of biomimetic shows about 6000 or more articles, compared to 1500 in the year 2010 and 300 in 2000. Biomimetics and bioinspiration are poised to impact all segments of the economy from engineering materials and electronic products to healthcare and waste management, transportation, energy, and food production. It is expected that biomimetic market share to grow to a trillion dollar in 15 years (http://bioinspiration.sandiegozoo.org/content/economic-impact).

The concept of biomimetic is providing a transformative approach, using nature and living systems as a guide, to solving global problems such as global warming, pollution, cyberspace security, land erosion, healthcare, food and water shortage, and over-population. Our understanding of complex biological systems at different length scales has increased dramatically as our ability to observe nature has expanded from macro to molecular scale, leading to rational nature-driven solution to technological problems. Although biomimetics and bioinspiration is applicable to a wide range of everyday problems, the focus of this multi-volume handbook is on medicine and engineering to create miniaturized, multi-functional, hierarchical materials, devices, systems, living tissue models and organs to perform complex tasks. This handbook is divided into three volumes: Bioinspired Materials, Electromechanical Systems, and Tissue Models.

Chapters in the first volume focus on rational design of nano- and microstructured hierarchical materials using living systems. These include materials inspired by self-cleaning of lotus leaves and cicada wings, superior walking ability of water strider, antifogging functionality of mosquito eyes, water collecting ability of Namib Desert Beetle and spider silk, high adhesivity of gecko feet and rose pedal, high adhesivity of mussels in wet aquatic environments, anisotropic wetting of butterfly wings, antireflecting cicada wings, underwater self-cleaning fish scale, shape anisotropy of intracellular particles, dielectric properties of muscles, spectral characteristics of plant leaves, regenerating and self-healing ability of earthworm, self-repairing ability of lotus leaves, broadband reflectivity of moth eyes, multivalent binding, self-assembly and responsiveness of cellular systems, biomineral formation in bacteria, plants, invertebrates, and vertebrates, multi-layer structure of skin, organization of tissue fibers, DNA structures with metal-mediated artificial base pairs, and anisotropic microstructure of jellyfish mesogloea. Sensor and microfluidic technologies combined with surface patterning are explored for diagnosis and monitoring of diseases and high throughput combinatorial testing of biomaterials in regenerative medicine.

Chapters in the second volume cover electromechanical devices and systems. These include actuators and robots based on movement of muscles, algal antenna and photoreception, non-imaging light sensing system of sea stars, optical system of insect ocellus, smart nanochannels and pumps in cell membranes, neuromuscular and sensory devices that mimic the architecture of peripheral nervous system, olfaction based odor sensing, cilia-mimetic microfluidic systems, infrared sensory system of pyrophilous insects, ecologically inspired multizone temperature control system, cochlea and surface acoustic wave resonators, cricket cercal system and flow sensing, locust wings and flapping micro air vehicles, visual motion sensing of flying insects, hearing aid devices based on human cochlea, geometric perception of tortoise and pigeon, organic matter sensing of cats and dogs, and the silent flight of rats.

The chapters in the third volume cover engineered models of biological tissues. These include engineered matrices to mimic cancer stem cell niche, *in vitro* models for bone regeneration, models of muscle tissue to study cardiac infarction and myopathy, 3D models for differentiation of embryonic stem cells, bioreactors for *in vitro* cultivation of mammalian cells, human lung, liver and heart tissue models, topographically-defined cell culture models, ECM mimetic tissue printing, biomimetic constructs for regeneration of soft tissues, engineered constructs for regeneration of musculoskeletal tissues and corneal tissue. This multi-volume set is valuable to anyone who is interested in understanding the complexity of living systems and how to exploit that complexity to find transformative solutions to the most pressing technological challenges of the 21st century.

Finally, we would like to extend our deepest appreciation to all contributing authors whose expert contributions made the publication of this handbook possible. We would also like to express our deepest appreciation to Dr. Zvi G. Ruder and colleagues at World Scientific for encouragement and technical guidance. In addition, we would like to thank Amanda Yun and Dipasri Sardar for editorial assistance and final stages of editing and publishing.

Esmaiel Jabbari
University of South Carolina

Deok-Ho Kim
University of Washington

Luke P. Lee
University of California at Berkeley

Amir Ghaemmaghami
University of Nottingham

Ali Khademhosseini
Harvard Medical School