"Engineering Approaches for Functional Nerve Regeneration"

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Damage to spinal cord and peripheral nerve tissue can have a devastating impact on the quality of life for individuals suffering from nerve injuries. Our research is focused on analyzing and designing biomaterials that can interface with neurons and specifically stimulate and guide nerves to regenerate. We also study the mechanisms of axon extension so that we can more rationally design devices to promote nerve repair. Ultimately, biomaterials formed into nerve guides could be used to aid the repair of damaged peripheral nerves, such as might be required for facial and hand reconstruction or in trauma cases, and potentially could be used to aid the regeneration of damaged spinal cord.

New technologies to aid nerve regeneration will ultimately require that biomaterials be designed both to physically support tissue growth as well as to elicit desired receptor-specific responses from particular cell types. One way of achieving such interactive biomaterials is with the incorporation of biological molecules into synthetic matrices or the use of natural-based biomaterials that interact favorable with the body. Further specificity may be gained by choosing a material with inherent properties that enhance desired cellular responses – for example, an electroactive material that can stimulate electrically responsive cell types such as nerve. Along these lines, we have created new biomimetic electronic materials by processing electrically conducting polymer composites (e.g., polypyrrole) with biological moieties and using novel peptides that directly bind to conducting polymers (uniquely selected using phage display). In a parallel approach to foster nerve regeneration, we have developed natural tissue scaffolds created by chemical processing of intact tissue (acellular tissue grafts).

Finally, we have been interested in understanding how neurons make decisions between different types of environmental stimuli, so that we can better design therapies for nerve repair. In particular, we have created microfabricated cell analysis devices for testing how neurons respond to signals (physical signals in the form of microgrooves, chemical cues in the form of immobilized growth factors, and electrical signals in the form of conducting polymers) both in combination and in competition. We have found distinct differences in how cells respond to physical versus chemical guidance cues presented simultaneously, and found that these responses depend on the growth/differentiation stage of the neuron (axon formation versus steady-state axon elongation).