Course Scope

- Applying Electrical/Computer/Mechanical Engineering and Computer Science Methods and Tools to Neural Systems
- For treatment of neurological disorders and restoration of function
- Potentially for enhancement of human capabilities
Functional Electrical Stimulation

- The use of electrical stimulation to restore function to individuals with paralysis or other neurological disorders

- *Neural Prostheses (neuroprotheses): devices to replace the damaged function of the nervous system [or sensory systems]*
Types of Patients

- Stroke
- Spinal Cord Injury
- Head Injury
- MS, ALS
- Amputees
- Parkinson’s Disease
- Essential Tremor
- Tourette’s Syndrome
- Obsessive Compulsive Disorder
- Depression (not responsive to drugs)
Applications/devices (partial list)

- Bladder Control
- Standing
- Walking
- Grasp and Hand Manipulation
- Respiratory Pacing
- Cochlear Implants
- Retinal Implants
- Neural control/sensory feedback in prosthetics
Applications/Devices (partial list)

- Pacemakers
- Implanted Defibrillators
- Deep Brain Stimulators (and recording)
- Cortical Recording, eCoG electrodes
  - Brain Computer Interfaces (with or without sensory feedback)
- EEG electrodes (recording)
  - Brain Computer Interfaces
Applications/Devices (partial list)

- Transcutaneous systems for stimulation (pain, motion)
- Transcranial Magnetic Stimulation
- Optogenetic Stimulation
- Memory Implants (Hippocampus)
- Not-yet-existing high resolution Brain Computer Interfaces
  - DARPA projects
  - Elon Musk *Neurolink*
  - Facebook *mystery projects*
Systems View

- Inputs
- Outputs
- Subsystems
Organic Components

- Muscles and their innervation
- Mechanical Structure (skeletal, tissue)
- Sensors (skin, muscles, joints)
- CNS—spinal cord (communication and computation)
- CNS—motor signal generation
- CNS—sensory signal processing
- CNS—decision making
Engineered Components—Stimulation and/or Signal Acquisition

- Muscle Electrodes (e.g., surface, epimysial, intramuscular)
- Nerve Electrodes (e.g., nerve cuff)
- Spinal Electrodes
- Cortical Electrodes (ECoG)
- Deep Brain Stimulating Electrodes
- Organ Stimulation (e.g., cardiac, diaphragm, bladder)
- Sensory organ stimulation (e.g., cochlear, retinal)
- Optogenetic stimulation
Other Engineered Components

- Muscle/nerve transplant options
- Sensors (external and implanted)
- Bracing and Exoskeletons (passive, active)
- Power Supplies and Batteries
- Recharging and energy harvesting
- Computation hardware (implanted or external) and software/firmware
- Communication (wired, wireless)
- Algorithms (control, machine learning, feature recognition, signal processing)
Not new—photos from ~1996 [Peckham et al]
Not new—~1998 [Peckham et al]