My path toward applying physics to biological topics in graduate research began in the winter of my freshman college year. Eager to begin hands-on experiments and looking to explore physics research possibilities, I enrolled in a one-month exploratory program for undergraduates which I extended into an eight-month research project. Working with Prof. Min-Chang Lee of the Plasma Science and Fusion Center of MIT, I studied plasma physics and related fields, including waveguide theory, transmission line theory and circuit analysis. Along with Prof. Lee's other students, I participated in weekly group discussions and conducted several lab experiments pertaining to antenna radiation theory and diode circuit construction. A few months later, we prepared for field experiments at a two-week summer program, the Polar Aeronomy and Radio Science summer school at the University of Alaska. My work with this group solidified my decision to pursue a bachelor's degree in physics and motivated me to continue with experimental physics research.

From my junior spring until my college graduation I worked with Prof. Bernd Surrow of the Department of Physics at MIT. In his lab, I assembled and characterized several triple-GEM (Gas-Electron Multiplier) prototype detectors. Triple-GEM detectors are micro-pattern, gaseous, particle detectors first developed by Dr. Fabio Sauli at CERN in 1996 [1]. GEM foils are thin sheets of polymer material, metal-clad on both sides and chemically perforated with a high-density foil pattern. When voltages are applied to the upper and lower metal layers of a foil, the resulting electric fields within the holes draw in electrons from above the foil, causing charge multiplication within the holes. The transferred ionization pattern below the foil is a close mirror of the pattern which existed above the foil; multiple foils may be stacked to repeatedly amplify the charge distribution. A 2D readout board below the foils collects the charge distribution. After assembling the detectors, I recorded the detector gain distribution of two prototypes containing different sets of GEM foils using a Fe-55 radioactive test source. Since my graduation, the group has presented the detector at a conference [P1], and a publication is currently in review [P2]. Working with Prof. Surrow taught me important laboratory electronics techniques, and I also learned how to prepare and organize an 80-page bachelor's thesis.

During my senior year of college, I attended several lectures by biophysicists and became interested in applying my skills in experimental physics to biological research topics. These lectures strongly influenced my decision to pursue doctoral research in the Applied Physics department at Stanford University, where students frequently engage in interdisciplinary biophysics research typically involving cutting edge optical technologies. As I entered Stanford, I decided to first focus on the field of fiber optics in an effort to develop a base for future work integrating optics and photonics into biophysics research.

During my first quarter of graduate school at Stanford, I worked with Prof. Shanhui Fan and Dr. Michel Digonnet to study the effect of magnetic fields on fiber-optic gyroscopes, which are currently under development for use in aircraft navigation. I set up and began measurements to determine the Verdet constant of air-core fiber by looking at the Faraday effect. The Faraday effect is described as follows: for a given length L of fiber exposed to a constant magnetic field B parallel to the direction of travel of the light in the fiber, the angle of linearly polarized light will shift by an amount $F=VBL$, where F is the angular shift and V is the Verdet constant for the fiber.

For my experimental setup, linearly polarized IR light was coupled into a fiber that passed through the center of a 10 cm long solenoid. The magnetic field within the solenoid was modulated at 10 Hz. After exiting the solenoid, the light was incident upon a polarizing beam splitter cube; the two resulting beam powers A and B were transmitted to a lock-in amplifier, along with the 10 Hz reference signal, to obtain (A-B). The quantity T = (A-B)/(A+B) is related to F, the

polarization angle shift caused by the Faraday effect. We studied this quantity to understand how stray magnetic fields experienced by air-core fiber-optic gyros in aircraft navigation systems will affect the reliability of the device. The strong foundation in fiber optics that I gained from this research rotation has proved invaluable to my current research efforts to apply fiber-optic techniques to *in vivo* fluorescence imaging.

My graduate thesis research in the laboratory of Prof. Mark Schnitzer, who has joint appointments in Applied Physics and Biological Sciences, spans the exciting intersection of optics and neuroscience. A longstanding goal in the field of brain imaging has been to develop imaging techniques for observing brain activity at the cellular scale in behaving mammalian subjects. Physicists interested in biology are well-suited for combining quantitative analysis with optics theory to do innovative biophysics research. With the goal of correlating mammalian behavior and learning with underlying cellular mechanisms, the lab has developed a miniature fiber-optic epifluorescence microendoscope for brain imaging in freely moving mice [2]. Light is delivered via a flexible fiber-optic bundle to the microendoscope, which is mounted directly to the mouse's head. Micro-lenses within the microendoscope guide the light from the fiber bundle to the imaging plane within the brain. The optical design utilizes a 1 mm diameter gradient refractive index (GRIN) objective lens for minimally invasive imaging of deep brain structures, such as the hippocampus. Fluorescence generated in the imaging plane is collected by the microendoscope, passed through the fiber bundle, and imaged onto a high speed CCD camera. The fiber bundle is mounted in a commutator to eliminate torsional forces due to head rotation during awake behavior.

I am currently using the microendoscope to investigate blood flow dynamics in microvasculature of the CA1 hippocampal area. Before imaging, I inject a small amount of dextran-conjugated fluorescein into the mouse's tail vein. Fluorescein is excited by blue light and emits green fluorescence, so red blood cells, which do not absorb the fluorescein, show up as moving dark patches within the microvasculature. Last September, I gave a research talk at a Stanford symposium about the lab's research using this microendoscope [T1]. My next project will involve imaging cellular activity using neuronal calcium-sensitive fluorescent probes, such as Oregon Green Bapta-1 488. I plan to study neuronal activity in the hippocampus and cerebellar cortex. In my proposed plan of research essay, I present the novel approach to develop a new microendoscope for *in vivo* chronic imaging studies of the expression of Arc, a protein associated with learning and memory.

Drawing upon my undergraduate and graduate training in physics, my laboratory experience, and my first year's work in fiber optics, I am well prepared for my current work in optics and neuroscience. I am excited to work in this stimulating field combining physics and biology and believe that my graduate years will be excellent preparation for my career as an innovative biophysicist.

Publications & **Talks.** [P1] F Simon *et al*. *Development of Tracking Detectors with industrially produced GEM Foils.* Nuclear Science Symposium Conference Record, IEEE. **2**:660, 2006. [P2] F Simon *et al*. *Development of Tracking Detectors with industrially produced GEM Foils.* Submitted Sept 2007, IEEE TNS. [T1] LD Burns. *Imaging cellular level brain activity in freely moving mice using fiber-optic microscopy.* Stanford Photonics Research Symposium, 2007.
Citations. [1] F Sauli. *GEM: A new concept for electron amplification in gas detectors.* Nuclear Instrum Meth. **A386**:531, 1997. [2] BA Flusberg *et al*. *High-speed cellular level brain imaging in freely moving mice using fluorescence microendoscopy.* Manuscript in preparation.