Sample Responses to Select Questions on the Goldwater Scholarship Application—Student #1

Question D: What are your professional aspirations? Indicate in which area(s) of mathematics, science, or engineering you are considering making your career and specify how your current academic program and your overall educational plans will assist you in achieving this goal.

Few generations have had the amazing power to impact our environment on a worldwide scale. Even fewer generations have realized humankind could have such a large impact on the Earth. The past century has seen many advancements in technology and quality of life. These great achievements have also given humankind the power to permanently alter our Earth and its fragile ecosystems. It is important to improve our quality of life, but it is also important not to compromise that of future generations by sacrificing our natural environment. My professional aspirations are to lead a team conducting research on new methods to reduce and control pollution output from industrial chemical processes. My research will be performed either in an industrial setting or in combination with teaching as a college professor.

My current academic program in chemical engineering provides knowledge of industrial chemical processes along with a solid background in mathematics and chemistry. My current research project provides a jumpstart on the type of research I can expect to perform as a graduate student and as a professional investigator. Graduate school in chemical engineering provides the in-depth knowledge required to understand and improve pollution control in industrial chemical processes. A Ph.D. degree will provide me with the essential skills needed to develop my own research projects and lead a team of researchers.

Question E: Describe an activity or experience that has been important in clarifying or strengthening your motivation for a career in science, mathematics, or engineering.

My research experience this past summer has greatly solidified my interest in pursuing a career in scientific and engineering research. I have always had an interest in how the world operates and how humankind has obtained its vast wealth of knowledge, but I was not certain how I would pursue these interests in my career. In my first month of laboratory research, I encountered several unique challenges. Bacteria would not grow properly and the ionic strength of sample solutions and ratios of particles to bacteria had to be constantly altered and adjusted. I soon realized the tremendous degree of work, number of failed attempts, and good amount of luck that can go into even the smallest of advances. It gave me a newfound respect and admiration for the great minds of the past to which we owe our knowledge of the world. When I was ultimately able to perform a successful bacterial adhesion experiment, I had a great feeling of satisfaction. It reminded me that the most rewarding achievements are often those that require many failures before success is achieved.

Working with the graduate students in lab, each of whom had his or her own specialized research topic, was inspiring. I realized that there are plenty of opportunities available and there is plenty of room to make an impact. Most of all I realized that I would genuinely enjoy working to solve new problems and learning more about our world as a scientific researcher.

Question F: Goldwater Scholars will be representative of the diverse economic, ethnic, and occupational backgrounds of families in the United States. Describe any characteristics or other personal information about yourself or your family that you wish to share with the review committee.

I grew up in a highly rural area. My father works as a Union Ironworker traveling between jobsites throughout the seasons while my mother works as a bookkeeper. I will be the first member of my family to pursue a technical degree and a career in science. I was fortunate enough to be raised by a family that worked very hard to provide the opportunities available to me and instilled in me the importance of respecting people of diverse backgrounds and differing views on life.

To gain a more global perspective, I will study abroad in New Zealand next semester. I am excited about the opportunity to be immersed in a new culture. I hope that I can continue to expand my horizons by experiencing new cultures throughout my life.

Sample Nominee's Essay for the Goldwater Scholarship Application—Student #1

Title: "Investigating the Role of Orientation in Bacterial Adhesion"

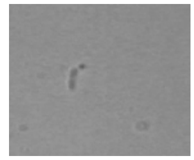
Bacterial adhesion can cause industrial equipment biofouling (1), medical implant failure (2), and is a problem for in situ bioremediation of polluted soils (3). Despite extensive studies, mechanisms of bacterial adhesion remain inadequately understood. This makes it difficult to treat or control biofilm formation (a result of bacterial adhesion), which is the long-term goal of this research.

As a bacterium nears a surface, a balance between several forces will determine its course of action. Such forces include van der Waals, electrostatics, hydrophobic, solvation, depletion, and biospecific interactions. The importance of these forces can depend on a number of factors including the structure of the bacterial surface, solution ionic strength, and properties of the inert surface. The large variety in bacterial surfaces and the conditions under which adhesion can occur prove to complicate the bacterial adhesion process (4).

There have been only a few studies examining the orientation of a bacterium as it adheres to a surface (5,6). One such study performed by Jones et al. has observed that when the bacterium *Escherichia coli* adheres to colloidal particles, over 90% of the particles adhere to nanoscale regions at the ends of the rod-shaped bacterium (7). These findings suggest that the ends of the bacterium may play a key role in the adhesion process. It is possible that the ends of the bacterium contain surface nonuniformities that facilitate the adhesion process. Surface nonuniformities may include lipopolysaccharide (LPS) chains and surface proteins in addition to the often-seen flagella (5). If these surface nonuniformities can be isolated and identified, it may be possible to control the adhesion process through molecular biology.

In my undergraduate research project, the work of Jones et al. has been extended to two strains of the bacterium *Bulkholderia cepacia*. *B. cepacia* has been shown to degrade both trichloroethylene (TCE) and tetrachloroethylene, molecules representative of many halogenated pollutants (7,8). Injection of this bacterium into polluted soils is a promising method of bioremediation, but bacterial adhesion to soil prevents movement through porous media (9,10). As the particles adhere to the bacteria, the bacteria are less likely to be transported through small micro-pores in the soil. It would be advantageous to decrease adhesion in order to enable the bacteria to better disperse through polluted soils during in situ bioremediation.

In order to examine bacterial adhesion, we used video microscopy to observe and record the orientation of various sized particles as they adhered to bacteria. Images of rod-shaped bacteria adhering to various-sized spheroid particles are shown below.

B.cepacia G4 1.54 µm silica particle *B. cepacia G4* 0.9 µm silica particle

The rate of end-on adhesion for the *B. cepacia* was observed to be near 75% with the same-sized particles used by Jones et al. in studying *E. coli* bacteria. This indicates that there may be different surface nonuniformities on *B. cepacia* or perhaps a different mechanism of adhesion. It was also observed that the size of the particles plays an important role in determining where the particle will adhere to the bacterium. Larger particles tend to adhere on cell ends more often than smaller particles of the same silica or polystyrene material. The preference for bacteria to adhere to larger particles end-on can be partially explained by geometric coincidence. As a particle approaches a bacterium rotating under Brownian motion, depending on the particle size it may rarely be able to meet the middle of the bacterium without first encountering the ends.

Future work will include additional oriented adhesion experiments substituting spheroidal colloidal particles for bacteria. These experiments will provide a basis of comparison for the previous sets of data. We will examine whether the high end-on adhesion rates are observed when there are no biological factors in play. In addition, oriented bacterial adhesion experiments with varying particle sizes will be performed to see if a quantifiable relationship between particle size and rate of end-on adhesion can be obtained. This research will help identify molecular mechanisms of bacterial adhesion, which will enable strains of bacteria to be altered in order to improve bioremediation processes. This study will be submitted to a scientific journal for publication in the near future and will be included in my senior honors thesis in chemical engineering.

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Sample Responses to Select Questions on the Goldwater Scholarship Application—Student #2

Question D: What are your professional aspirations? Indicate in which area(s) of mathematics, science, or engineering you are considering making your career and specify how your current academic program and your overall educational plans will assist you in achieving this goal.

Currently, I am pursuing a combined B.S./M.S. through the Integrated Undergraduate Graduate program because it allows me to take upper-level classes in my major earlier than one would experience in the normal B.S. program. This accelerated coursework is preparing me for a technical internship this summer. My participation in the Women in Science and Engineering Research Program has given me the unusual opportunity to work in a research group of graduate students as an undergraduate sophomore. The research I have been doing on nanoindentation of glass and glass melting has provided a hands-on experience to complement my accelerated coursework. It is also a way to prepare for my honors thesis.

After obtaining my Ph.D., I plan to work in research and development for a national lab such as Sandia or a government institution such as NASA. I would like to have my own lab with a research team and eventually take a project into space as a mission specialist. To prepare for a future career in research, I am applying to Sandia National Labs for a summer internship.

I plan to continue to participate in the activity of glass blowing throughout my professional career. By occasionally working as a glass blower at a seasonal Renaissance Faire I would be able to raise the awareness of materials science through one of its more artistic forms.

Question E: Describe an activity or experience that has been important in clarifying or strengthening your motivation for a career in science, mathematics, or engineering.

I became aware of the field of Materials Science and Engineering (MatSE) during my junior year of high school when I attended the Society of Women Engineers High School Day at Carnegie Mellon University. Up until that point I had been considering Aerospace Engineering because of my acute interest in space. That day every student was sent to three workshops; one was for their preemptively chosen major and the other two were random. One of the workshops I attended was on Materials Engineering. I was instantly fascinated. The demonstration that I remember most vividly was the brittle fracture of metals after immersion in liquid nitrogen. I immediately decided to major in MatSE.

My next college visit was to Mythic University for an Engineering Open House. The glass blowing demonstration impacted me the most. The Materials Science and Engineering Department at Mythic University has a facility for off-hand glass blowing. I pursued that interest last semester by stopping by the glass lab for 3 or 4 hours every week to watch the graduate students blowing glass. My interest paid off because starting this semester I will be taking glass blowing lessons from the same graduate students I watched at the open house two years ago. I will also have the opportunity to help out with the glass blowing demonstration at this year's open house.

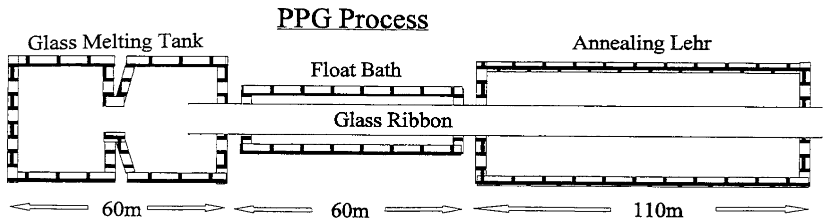
Question F: Goldwater Scholars will be representative of the diverse economic, ethnic, and occupational backgrounds of families in the United States. Describe any characteristics or other personal information about yourself or your family that you wish to share with the review committee.

My family lives in a very rural area, and as such there was sparse opportunity for distinction in high school. I did my best, graduated as valedictorian, and completed my graduation project my junior year. My graduation project was inspired by my long-standing interest in space and a search through a NASA website. With the help of my father, a senior bank auditor but country man at heart, I built a drop box with a special candle holder to successfully demonstrate the effect of microgravity on candle flames.

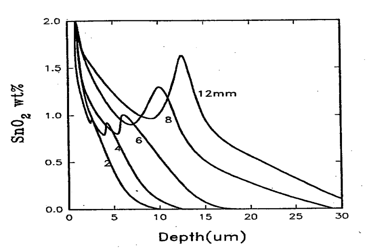
When I go home over breaks from school, I make a point to visit my former high school teachers and present MatSE information to their new students. Living in a rural area, while refreshing and without frills, often does not provide information about the wealth of opportunities available, including career opportunities such as engineering for women. I always look forward to these visits home to share my experiences with other upcoming students.

Sample Nominee's Essay for the Goldwater Scholarship Application—Student #2

Title: "Nanoindentation Interrogation of Float Glass for Elastic Modulus and Hardness"



Contemporary window glass is made by the float bath process to ensure that both sides are perfectly parallel and smooth. The molten glass batch is poured from the melting tank onto a bath of molten tin. As the glass floats across the tin it cools. It then flows off the bath onto rollers that take it through an annealing lehr to remove thermal stress. As the glass rolls out of the lehr it is cut into pieces for further processing. Tin is chosen for the float because of its low reactivity with soda lime silica glass. However, it is not perfectly unreactive because contaminants enter the tin bath and change its chemistry. Some of the tin diffuses into the float side of the glass as Sn2+ and Sn4+. The diffusion of tin is governed by many factors including the composition of the glass and the time spent on the float bath. The thicker the glass is, the longer it spends on the bath. Consequently the tin has more time to diffuse. This difussion process typically produces a hump in tin content as shown.



EPMA profiles for the bottom surfaces of 2, 4, 6, 8 and 12mm clear float glasses

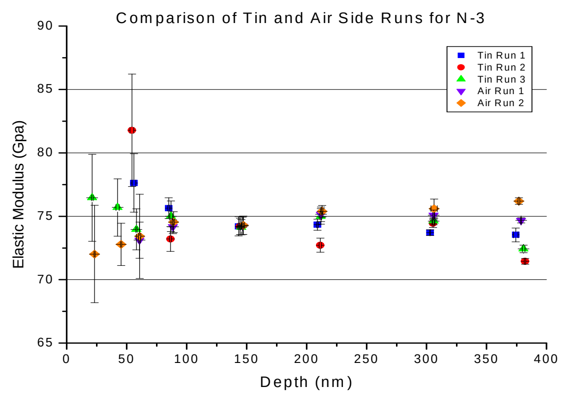
Traditionally, the bottom side of float glass is used as the external side of the glass when it is used in applications such as automobile windshields and commercial windows. This side was found to perform better during normal use. A better understanding of this phenomenon is desired in order to improve the mechanical and chemical durability of these glasses for future applications.

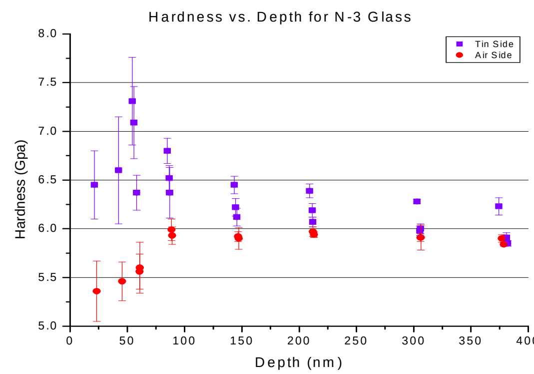
A hypothesis was formed by Dr. John Teacher that there should be a significant difference in the elastic modulus and hardness of the air and tin sides of float glass. This would be expected to alter the resilience of the float side of the glass relative to the unaltered surface. A nanoindentation technique was chosen to interrogate whether or not this is the case. Three different 4-mm-thick soda lime silica float glasses varying in iron content were chosen for examination. A Hysitron nanoindenter outfitted with a Berkocitch indenting tip was chosen for the analysis because it would be able to analyze the upper 400 nanometers of the chosen samples for hardness and elastic modulus. The loads used were 100, 300, 500, 1000, 2500, 5000, 10000, and 15000 micronewtons, yielding data points for depths of 20, 40, 60, 90, 150, 200, 300, and 380 nanometers, respectively. Nine indents were performed at each load per run and at least 3 runs were performed to ensure reproducibility.

The results obtained did not show the expected differences in elastic modulus or hardness. Instead they were almost identical at about 75 GPa for the elastic modulus. The elastic modulus of the fused silica with which the nanoindenter was calibrated was 72 Gpa.

These results suggest that the observed enhanced durability of the tin-side of float glass is due to more complex issures, possibly related to chemical interactivity between the glass and the atmosphere in service. The research group I work in is currently investigating these issues, through controlled atmospheric exposure and nanoindentation techniques. This research is expected to provide a fundamental insight into how to compositionally tailor float glass for improved chemical and mechanical durability in structural applications.

(A statement identifying research team members appears in the original here.)





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