

Infinite Possibilities: Profiles of Summer Research from
The Gatton Academy of Mathematics and Science in Kentucky

Volume Five – Summer 2015



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THE GATTON
ACADEMY 
of Mathematics and Science

Infinite Possibilities:
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The Gatton Academy of Mathematics and Science in Kentucky

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Andrew Brown



Dimitri Leggas



Erin Burba



Ben Guthrie



Vir Patel

About the Gatton Research Internship Grant Program

The Gatton Academy of Mathematics and Science in Kentucky created the Gatton Research Internship Grant program in 2010. Made possible by a gift from Mr. Carol Martin “Bill” Gatton, the program offers grants to Gatton Academy students between their junior and senior years to support summer research internships across the Commonwealth, the USA, and the world. By providing funding, the program directly creates research internships that otherwise would not have existed for Gatton Academy students. In its first six years, the program has created 95 research internships for Gatton Academy students to study STEM problems in their areas of interest in a devoted, full-time research setting.

As evidence of the program’s effectiveness, consider the accomplishments by summer 2014 recipients of the Gatton Research Internship Grant. Four of the students (Andrew Brown, Ben Guthrie, Dimitri Leggas, and Vir Patel) were recognized by the Siemens Competition—the nation’s premier research program for high school students—as national semi-finalists. Three of the summer 2014 recipients were recognized by the Goldwater Scholarship as a result of research conducted during the summer—two as scholars (Andrew Brown and Dimitri Leggas) and one as an honorable mention (Ben Guthrie). Erin Burba’s research from last summer advanced all the way to the Intel International Science and Engineering Fair. Meanwhile, last summer’s Gatton Research Internship Grants resulted in 25 student-delivered presentations at conferences across the state and nation in the 2014-15 academic year.

In the summer of 2015, the Gatton Research Internship Grant program funded 20 rising high school seniors. The following pages feature these students.



Dear Mr. Gatton,

When I ask students what they love about The Gatton Academy, they always say the community followed by the range of experiences offered to them. This is a place where they can fully be themselves in a community that not only accepts them, but greatly values their passionate pursuit of knowledge and excellence. Within this supportive community, they relish research and study abroad opportunities which are beyond any they could access elsewhere.

It is incredibly rewarding to watch students light up as they describe the complex, engaging research they are doing. Their understanding of the problems and their enthusiasm for pursuing solutions are infectious. The opportunity to do real work with great minds makes a significant impact on our students as they consider future careers and their next educational endeavors.

Thanks to your generosity, some of Kentucky's brightest students are tackling topics such as knot theory, agricultural biochemistry, antibiotic resistance, artificial intelligence, oncogenic proteins, and much more. They have started intellectual endeavors that many will continue through their Gatton experience and beyond. These students are well on their way to contributing in meaningful ways to the Commonwealth, as well as our nation. You have our sincerest gratitude for supporting these bright minds and through them, the future of Kentucky.

Sincerely,
Lynette Breedlove, Ph.D.
Director





Hayden Brooks
Sturgis, Kentucky (Union County)

Dear Mr. Gatton,

For starters, I would like to thank you for supporting The Gatton Academy. Without you none of the opportunities that I have been blessed to receive would be possible. I would also like to thank you for making it possible for me to be able to participate in a summer Gatton Research Internship Grant. I saw this as a great opportunity that most high school students will go without, and I didn't want to be one of them that missed out when I had the opportunity to apply. So far in my research this summer, I have learned a lot and enjoyed each day and its new experiences which have all been made possible because of you.

The Gatton Academy is a life-changing experience that students are lucky to experience. Having the option to apply for and participate in a Gatton Research Internship Grant is just one of the memorable experiences that students can be involved in. I can't thank you enough for what you have done in supporting The Gatton Academy. I can honestly say that you have changed my life and the lives of many other students for the better. We are all appreciative of what you did for Kentucky and its education programs. I feel honored to be able to be a part of it.

Thank you,
Hayden Brooks

Hayden Brooks

Home High School:

Crittenden County High School

Research Area:

Knot Theory

Career Goal:

Business or Math Major

Research Mentor:

Dr. Claus Ernst

WKU Department of Mathematics

Extracurricular Activities:

Chess, Film Club, Football, Frisbee,
and Volleyball

"The part of my summer experience that I have most anticipated has been having an office and more freedom to really be able to experience a work environment. The biggest challenge that I have had to overcome while involved in my research is working on my budgeting skills. Having the amount of freedom this summer is a double-edged sword."

"The thing that I'm most looking forward to next year at the Academy would be spending another year with my friends. The community and environment at the Academy is amazing, and I'm excited to be returning for my senior year."

"Summer research is very different than what a normal high school student will ever participate in during their summer. Most high school students have summer jobs where they are given tasks and are expected to do exactly that with little freedom to expand on their ideas. My research project is different. It allows me to expand on ideas and discover new things. Plus, I get to know my research professor better and learn new things that he is passionate to talk with me about."





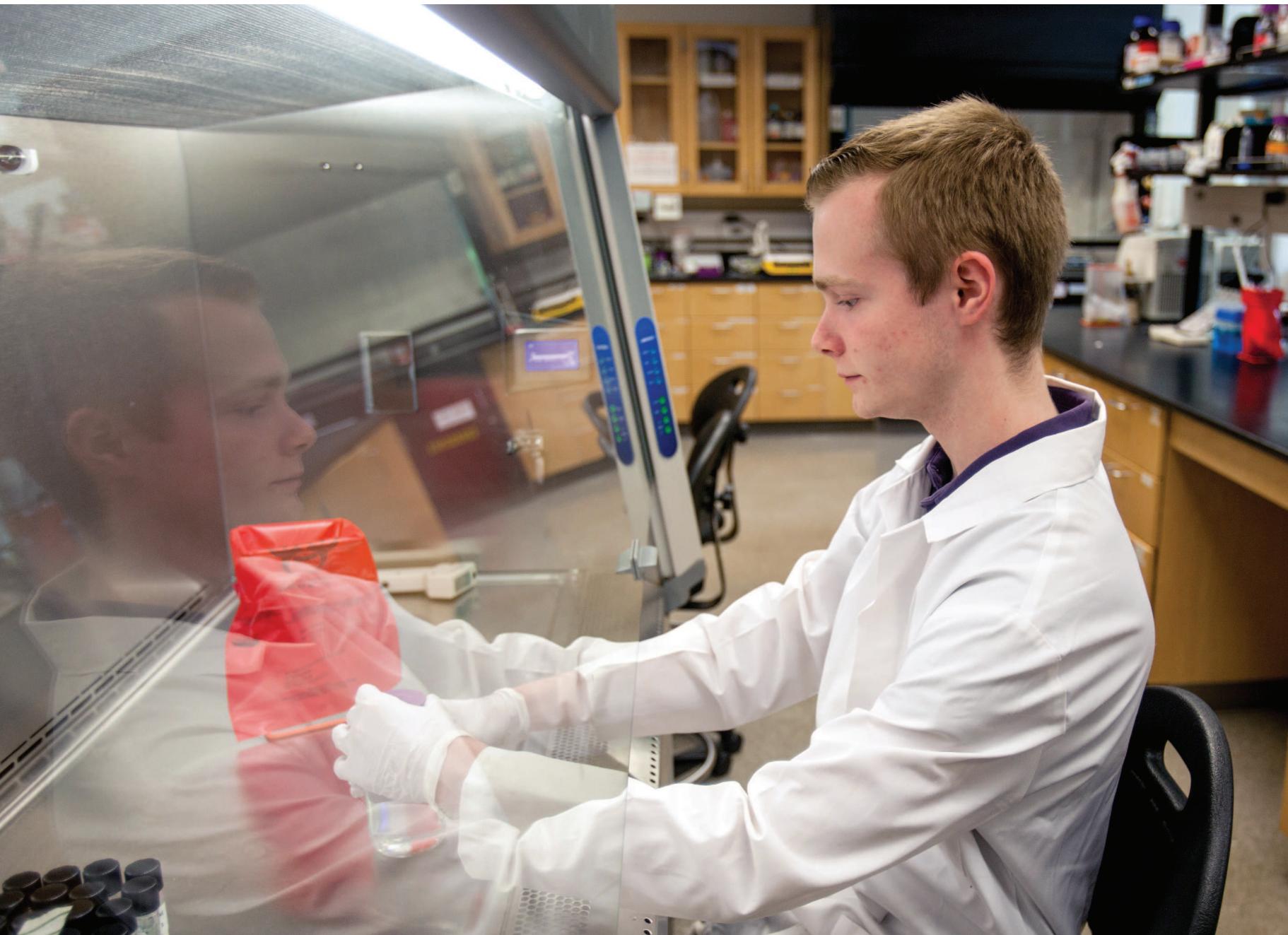
Nolan Calhoun
Corinth, Kentucky (Owen County)

Dear Mr. Gatton,

I first heard about The Gatton Academy from the Commissioner of Education in an education advisory board. Had he not asked me about the school, I would not be where I am today. I knew going from a normal high school to the nation's number-one high school would be a big jump. There were many things I had to adjust. Being from northern Kentucky, location was probably the hardest adjustment. However, I am glad I decided to further my education at The Gatton Academy.

This summer, I am researching signaling pathways in cancer at the Wood Hudson Cancer Research Laboratory in Newport, Ky. This is not my first research experience. I have participated in the Genome Discovery and Exploration and Bioinformatics programs at Western Kentucky University. In addition, I have researched dung beetles as indicators of overall ecological diversity in the rainforest of Costa Rica. As you can tell, I am interested in the biological sciences. Biology just has so much to offer: ecology, evolution, cellular, molecular, medicine, anatomy, physiology, and so on. I hope to use my experiences at Gatton to evaluate whether I want to pursue a career in STEM. So far, I have been leaning to either medical school or graduate school for Biology. I would eventually like my Ph.D. in Biology. Also, I am quite interested in politics, so hopefully I will be in Congress one day. Thank you for your generous gift that has allowed me and others many opportunities.

Sincerely,
Nolan Calhoun





"This internship in cancer biology will serve several purposes. While investigating transforming growth factor beta receptor one, I hope to learn whether or not I want to go to graduate school for biology, medical school, or something else. In addition, my research experience will help in my future career searches and job interviews."

"The biggest challenge in my research is the fact that cancer biology can be really complicated. To compensate for this, I have read through many articles and am reading a cancer biology textbook. This way, the signaling pathways, receptors, caspase cascades, and so forth will be ingrained."

"With my second year at The Gatton Academy, I am most looking forward to the accomplishments I will have by graduation. I will graduate with almost eighty hours of credit and a minor in biology, so I will be able to go on and make the most of my next steps. In the next ten years, I aspire to have a Bachelor's degree, possibly a Master's and a Ph.D. in Biology. If I decide to go to medical school, I would like to be in my residency ten years from now (or out of it). Some political experience would also be nice."

Nolan Calhoun

Home High School:
Grant County High School

Research Area:
Cancer Biology

Career Goal:
Biologist in Congress

Research Mentor:
Dr. Julia Carter
Wood Hudson Cancer Research
Laboratory

Extracurricular Activities:
Politics, Track & Field, Television,
and Reading



Rohan Deshpande
LaGrange, Kentucky (Oldham County)

Dear Mr. Gatton,

I grew up in a tiny town in rural Wisconsin. Because of the small population, my academic opportunities there were very limited. When I moved to Kentucky in the 8th grade, I was astonished. The number of courses offered was far greater than in Wisconsin. Although I was taking the highest-level classes available at my new school, I still didn't feel appropriately challenged. The subjects I enjoyed only had two years of material, so I felt limited by a low academic ceiling.

In my freshman year of high school, my older brother was accepted to The Gatton Academy's class of 2014. Every closed weekend he came back gushing about how amazing the school was. I was entranced by the idea of living on a college campus and taking college-level classes. During my sophomore year of high school I applied and was accepted into the program as a member of the class of 2016.

Now that I have finished my first year, I can say Gatton was everything I wanted and more. I finally feel motivated; school is no longer a drab place to spend seven hours bored out of my mind. It is refreshing to be challenged academically. This summer, I am doing research in biomathematics—modeling the effects of topical oxygen therapy on chronic wounds, and I love it. I cannot thank you enough for the amazing opportunity presented by The Gatton Academy. This past year has been an incredible experience—the best in my academic career—and for that, I am truly grateful. In the future, when I look back at the two years I spent at The Gatton Academy, I will remember them fondly. Thank you.

Sincerely,
Rohan Deshpande

$$\frac{b}{t} = k_b b(1-b) - b \frac{\lambda_{rb} b + 1}{\lambda_{rb} b + 1} * \frac{w + k_w}{w + k_w} - \lambda_b b$$

$$\frac{n}{t} = k_p e^{-\lambda_p t}(1-n) + \frac{k_{ni} b n (1-n) g_{nw}}{\lambda_{ni} n + 1} - \frac{\lambda_n n}{1 + \epsilon b}$$

$$\frac{w}{t} = \beta + \gamma * u(t) - \lambda_w w - \lambda_{bw} b w - \lambda_{nw} n w$$

$$(0) = 0, b(0) = b_{init}, w(0) = w_{init}$$

$$\lambda_1' = -\frac{\partial H}{\partial b} = -[1 + \lambda_1 \left(\frac{(k_{nr}n + \delta)b\lambda_{rb} - (\lambda_{rb} * b + \lambda_b)}{(\lambda_{rb}b + 1)^2} \right) + \lambda_2 (-\lambda_{bw}w)]$$

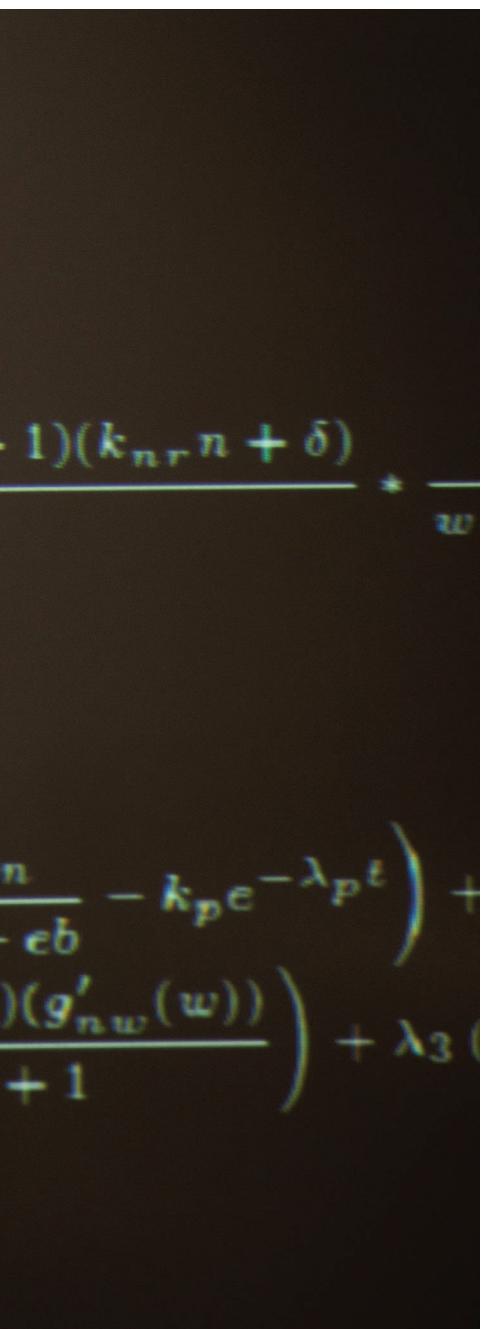
$$\lambda_2 \left(\frac{k_{ni} n (1-n) (g_{nw})}{\lambda_{ni} * n + 1} + \frac{\lambda_{nw} * n e}{(1 + \epsilon b)^2} \right) + \lambda_3 (-\lambda_{bw} w)]$$

$$\lambda_2 \left(\frac{g_{nw}(w)[(\lambda_{ni} * n) - \lambda_{nw} w]}{(\lambda_{ni} b n + k_w)} \right)$$

$$\lambda_2 \left(\frac{g_{nw}(w)[(\lambda_{ni} * n) - \lambda_{nw} w] - k_{ni} b n (1-n) \lambda_{ni}}{(\lambda_{ni} b n + k_w)} - \frac{\lambda_{nw} w}{1 + \epsilon b} \right) + \lambda_3 \left(\frac{k_{ni} b n (1-n)}{(\lambda_{ni} n + 1)^2} \right)$$

$$\lambda_3' = -\frac{\partial H}{\partial w} = -[\lambda_1 \left(\frac{k_w}{(w + k_w)^2} \right) + \lambda_2 \left(\frac{k_{ni} b n (1-n)}{\lambda_{ni} n + 1} \right) + \lambda_3 \left(\frac{k_w}{(w + k_w)^2} \right)]$$

$$\lambda_1(T) = 0, \lambda_2(T)$$



"My first year at The Gatton Academy was an incredible experience. The unique atmosphere and people ensured there was never a dull moment. I hope this upcoming year is as amazing as the last."

Rohan Deshpande

Home High School:
Oldham County High School

Research Area:
Biomathematics

Career Goal:
Biomedical Engineer

Research Mentor:
Dr. Richard Schugart
WKU Department of Mathematics

Extracurricular Activities:
Science Bowl, Chess Club, Beta Club,
Tae Kwon Do, Forensics, and Soccer

"The Gatton Academy is advertised as an atypical high school. It attracts individuals from all over the diverse state of Kentucky whose only common trait is age and a love for academics. By aggregating these students in one building, Gatton creates an atmosphere unlike any other school, and that's what I love about it."

"I have always been interested in STEM fields, especially biology and math. I am currently involved in a research project at WKU that involves modeling chronic wound healing. This project has been a great opportunity for me to apply my knowledge and skills in a real-world setting. I am grateful for the support and guidance of my mentor, Dr. Richard Schugart, who has helped me develop my research skills and gain a deeper understanding of the subject matter. I am excited about the potential applications of this research and how it can contribute to medical advancements in the future."



Jenna Ellis
Warsaw, Kentucky (Gallatin County)

Dear Mr. Gatton,

Before coming to the Academy, I had never really been exposed to any sort of computer science. I really had no idea what computer science was, yet I knew that it was on my schedule for my fall semester at my new school. A few weeks into classes, I started to think that CS was actually pretty fun. I liked the idea of controlling what a person could do with the computer in front of them, and coding started to come easy to me after a fairly large amount of studying and paying attention in my class.

Now, I've made the decision to continue my education in computer science. Without the Academy and your generous gifts to our program, I don't think I would have ever been able to learn how to code and find out what my passion really is. For that, I cannot thank you enough.

This summer, I am partnered with my close friend and research partner Eura Shin to do computer science research with one of our favorite professors under the aid of the Gatton Research Internship Grant program. Not only have we learned a lot about our specific area of study, but also what it's really like to work in the computer science field rather than just be a student. It has been a fun, informational, and great experience.

Thank you again for making all of my time at the Academy possible! I couldn't imagine being anywhere else!

Sincerely,
Jenna Ellis

Jenna Ellis

Home High School:

Gallatin County High School

Research Area:

Computer Science

Career Goal:

Software Engineer

Research Mentor:

Dr. Uta Ziegler

WKU Department of Computer Science

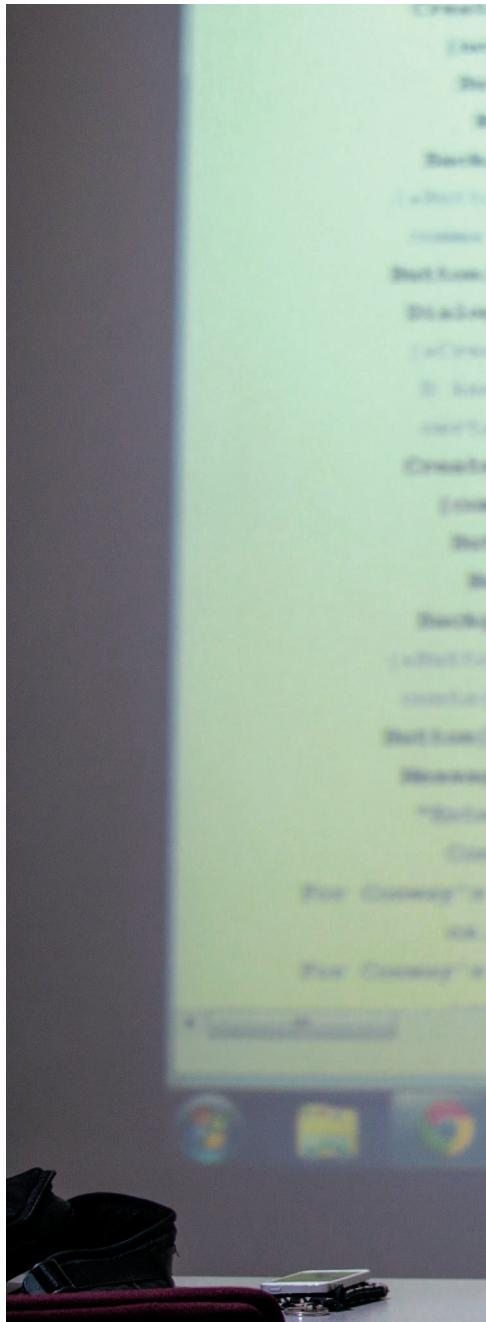
Extracurricular Activities:

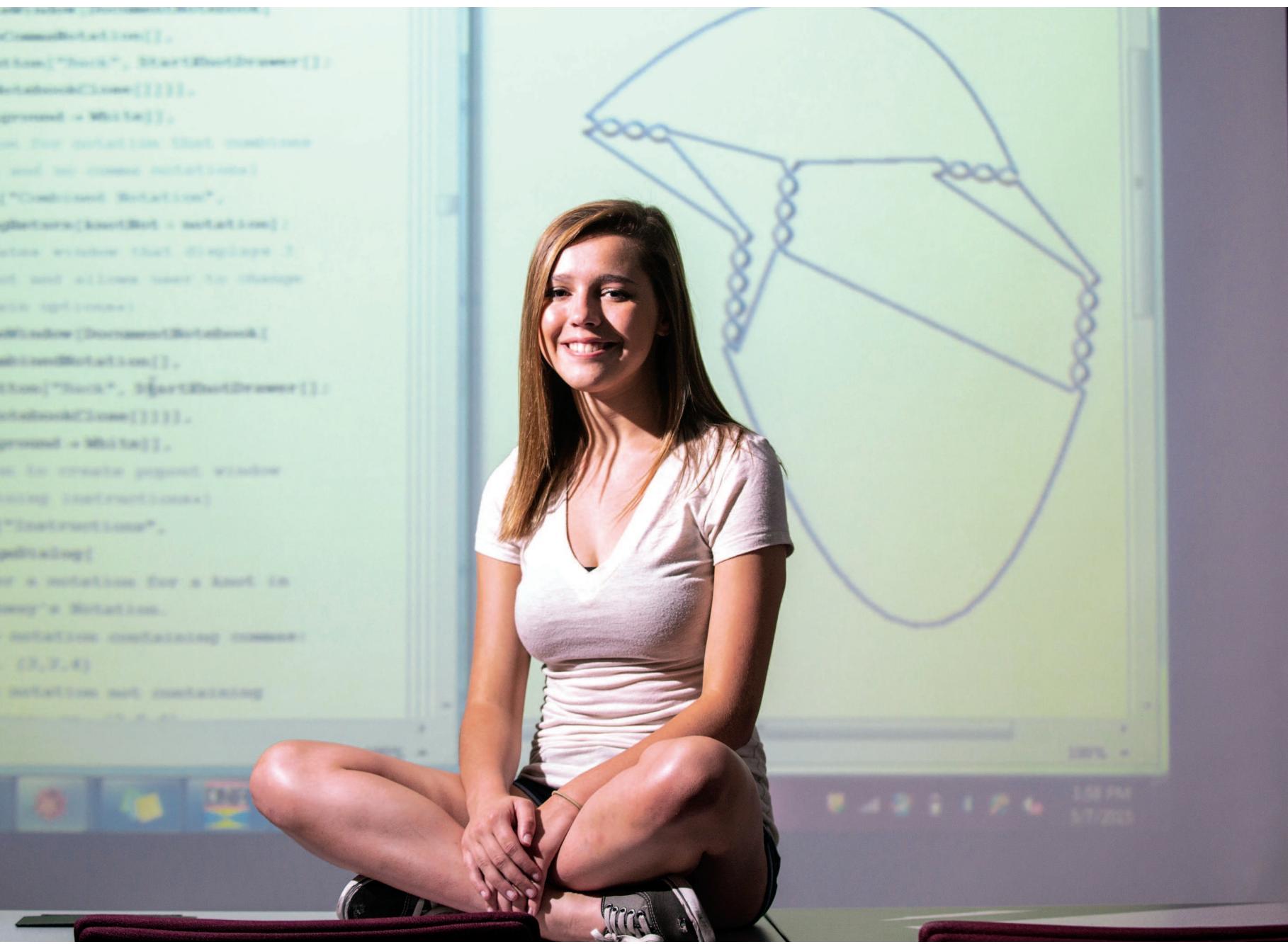
Beta Club, KEEs Club, Gatton Academy Avatar, and Academic Team

"The coolest thing about my summer research is being able to bring my own ideas about a contemporary topic in abstract mathematics and computer science into validation when no one else has before. Some of my ideas could become a trial for future work. It is really cool and empowering to be involved in documenting and designing relatively untouched information and algorithms."

"I will be using my research experience as a launching point for applying to the Siemens Competition and as a basis for future presentations at research conferences and mathematics and science symposiums. I hope to use my research as a way of narrowing down my interests in the field of computer science, which will be helpful in my college search and application process."

"I think most typical high school students spend their summers working at a part-time job, spending time with friends and family by the pool, on a boat, or just relaxing in whatever way they can. Instead, I'm living on my own, working as a student and researcher, and sacrificing a lot of social and relaxation time before school starts again. Although my summer is going to be filled with finding abstract patterns and coding, I wouldn't want to spend it any other way."







Linyue "Joy" Fan
Bowling Green, Kentucky (Warren County)

Dear Mr. Gatton,

It would be impossible for me express the extent to which The Gatton Academy has changed my life. I come from a family that holds extremely high expectations for me as a student. For my entire life, my parents have pushed me to learn more, read more, and work more. I have shelves full of supplementary math materials and science textbooks that I was instructed to read over the summer. I sought out as many challenging courses as I could in high school, but none of this compared to the experience I've had at Gatton.

What I experienced here was challenging to a whole new level, and I loved it. The first class I attended as a Gatton student just so happened to be computer science. I had no prior knowledge as to what computer science was, and I was inclined to think that I wouldn't like it. I was beyond confused when the teacher showed up and began writing code on the board. As the semester progressed, however, I realized that computer science was something that I loved and would even consider pursuing as a career. This is something that I never would have realized had I not come to Gatton.

My research this summer is another thing that I would not have gotten to take part in at my home high school. I am working with the Department of Biology in learning about gene expression in fruit flies. Not only is this extremely relevant to my aspirations of becoming a medical researcher, it is also extremely interesting. As the summer progresses, I look forward to learning more and more, and giving back to the community in knowledge for what has been given to me in experiences. Thank you so much for making all of this possible.

Sincerely,
Joy Fan





"I find the concept of research fascinating. As a young person interested in STEM, I feel incredibly honored to be a part of research. The fact that the discoveries I make will help further science alongside the discoveries made by the geniuses of the past and present world is infinitely exciting for me."

"The biggest change that I experienced in my first year at Gatton has to do with my personality. As a child, I was extremely shy and nervous about speaking in front of people. In my late middle and early high school years, that shyness lightened to introversion. It wasn't until Gatton, however, that I truly grasped a new level of gregariousness and confidence. I now love talking to and meeting people, as well as giving presentations."

"One of my favorite Gatton Academy memories is the day before our final projects in Computational Problem Solving (CPS) were due. Though this may sound a little crazy, I enjoy thinking back to the desperation with which my partner and I worked; it's almost comical. Never before have I solved so many problems in such a short amount of time. Having come through the whole ordeal in one piece, looking back makes me feel a welcome sense of having accomplished something noteworthy."

Linyue "Joy" Fan

Home High School:
South Warren High School

Research Area:
Biology

Career Goal:
Undetermined

Research Mentor:
Dr. Ajay Srivastava
WKU Department of Biology

Extracurricular Activities:
Music (Orchestral Violin and Music Theory), Tutoring as part of the Gatton Academy Leadership in Education Club, and Academic Team



Esther Huggins
Elizabethtown, Kentucky (Hardin County)

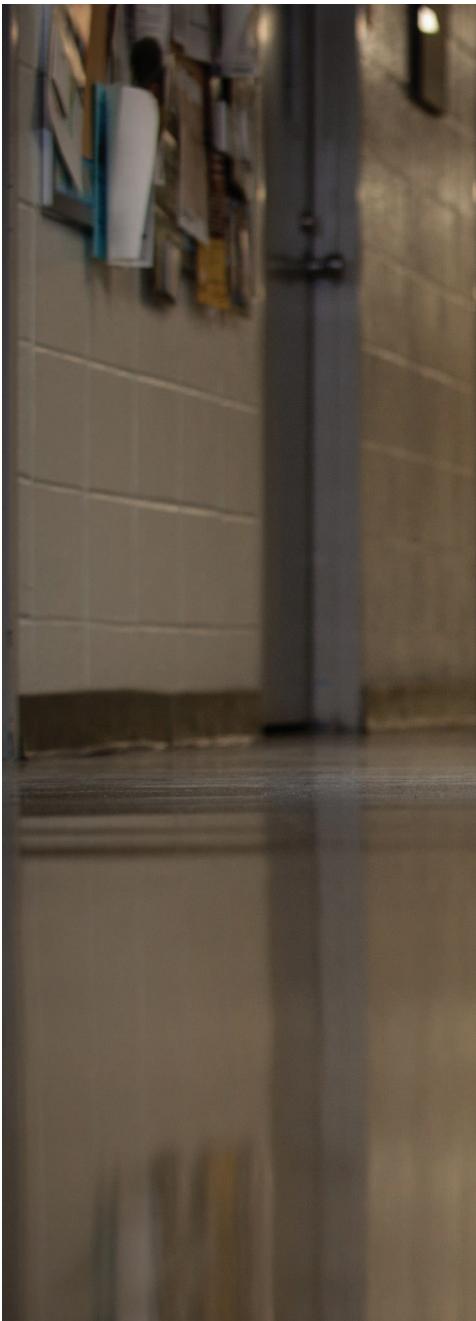
Dear Mr. Gatton,

I would like to thank you for allowing me to conduct independent research this summer. The internship was not only rewarding in its results but also in its career knowledge. I am striving to be a biomedical engineer in a government facility. Research of that caliber is somewhat daunting, but the six weeks that I have dedicated to my project has given valuable insight into what intensive study entails. It has brought me convincing confidence and marketable experience in what I want to pursue. Few students my age are able to say that they spent 40 hours a week attacking a computational chemistry problem for fun.

The Gatton Academy has not just been the next level of academic challenge for me; it has become a place where I can develop in unfamiliar environments. These are environments I could have never been introduced to at my home high school. Research has been one of the cornerstones of that development as I learned how to work efficiently and to think creatively. These skills were fostered by my summer internship.

Four years ago, my family and I moved from a coastal city in Virginia to a much smaller suburban town in Kentucky--Elizabethtown. In that time, my world shrank considerably, as well as my perception of my potential. The Gatton Academy has enabled my ambitions and my world to expand again. I owe that to you.

Sincerely,
Esther Huggins



Esther Huggins

Home High School:

Elizabethtown High School

Research Area:

Computational Chemistry

Career Goal:

Biomedical Engineer

Research Mentor:

Dr. Matthew Nee

WKU Department of Chemistry

Extracurricular Activities:

BETA, Gay Straight Alliance, Cultural Club, Volunteer Art Teacher, and Flute

"What I love most about The Gatton Academy is the community's network. There is a staff that provides support and knowledge, and all of them are willing to help each student through their time at the Academy. I consider that priceless."

"As a STEM-focused student, research is the next level. It is not only learning about principles but possibly discovering something to redefine those principles. It is extremely exciting to be the one advancing a field by choosing to delve further than others before. Being able to dedicate days this summer to focus on one sole problem allows creative solutions."

"From this research experience, I hope to use the final report and the potential advances for the Siemens Competition and for the American Chemical Society Conference—the world's largest gathering of professional chemists. I also plan to apply for the SMART Scholarship (a Department of Defense scholarship) that will enable me to work in a DoD facility. With this internship, I already have experience in what that future work entails."





Hayden Justice
Danville, Kentucky (Boyle County)

Dear Mr. Gatton,

I am from Danville, Ky., a small town about forty-five minutes from Lexington. While there is nothing like the comfort of home, The Gatton Academy has shown me that there is more to Kentucky than just horse racing and tobacco farming. I cannot thank you enough for the opportunity to broaden my horizons.

During my first semester at the Academy, I discovered my passion of computer science. My artificial intelligence research at the University of Kentucky concerns modeling how humans make decisions. I first represent an individual's preferences in a directed graph and then determine what would be the optimal outcome given all possible choices. This will have myriad applications for marketing and other automated services.

Your generous gifts to The Gatton Academy give students like me the opportunity to reach their full potential while making scientific advancements that give back to society. As I thank you for this experience, I cannot help but refer back to your speech at the Academy's expansion celebration where you gave a reading of "The Bridge Builder" by Will Allen Dromgoole. Thank you for building a bridge for me and my fellow students. In the future, I hope to also facilitate the climb to success for others who would not have the chance to do so otherwise.

Thank you,
Hayden Justice





"The biggest challenge I have had to overcome this summer is learning how to be wrong. The path to success is not linear: research is all about making mistakes and then trying again."

"I think the best part about senior year will be the freedom to design my own class schedule. Since I took most of my general, required classes my junior year, I have a lot of room for more specific electives like Digital Circuits and Linguistics."

"My favorite aspect of the Academy is the sense of community. It is something much deeper than just a networking opportunity. I actually worked this summer in Lexington with a couple of Gatton alumni on my research, and we immediately bonded over talking about our adventures at the Academy."

Hayden Justice

Home High School:
Boyle County High School

Research Area:
Computer Science

Career Goal:
Computational Linguistics

Research Mentor:
Dr. Judy Goldsmith
University of Kentucky Department
of Computer Science

Extracurricular Activities:
Beta Club, Dance, Playing Ukulele,
Running, Speech and Debate,
Theatre, and Creative Writing



Emily Keeter
Frankfort, Kentucky (Franklin County)

Dear Mr. Gatton,

As a recipient of a Gatton Research Internship Grant, I want to thank you for the opportunities you and the Academy have presented me. I've wanted to go to the Academy since I was in fifth grade. My older brother received a brochure for the Academy, but wasn't interested. However, when I read it, I was hooked. I decided that I wanted to go to the Academy. I've always loved learning, and the idea that I would be able to start taking college classes early excited me. Then, as I learned more and more about the Academy, I began to desire not only the knowledge I could gain, but also the great community and the amazing opportunities that the Academy offers its students. I'm so grateful that I was able to get in.

I've been able to do things at the Academy that I never would have been able to do otherwise. This summer alone, I'm doing research with a government office and going to England to study abroad. The Academy has also encouraged me to pursue things I would not have had the confidence to do in the past.

I never would have been able to do any of these things if it weren't for your generous gifts to the Academy. Once again, I would like to thank you for all of your support for The Gatton Academy and its students.

Sincerely,
Emily Keeter

Emily Keeter

Home High School:

Western Hills High School

Research Area:

Data Mining and Sociology

Career Goal:

Computer Programming

Research Mentor:

Dr. Kate Akers

Kentucky Department of Education
and Workforce Development Cabinet

Extracurricular Activities:

Cultural Club, Genome Discovery
and Exploration Program Research,
and Yearbook

"I'm really enjoying working with people who are experienced at what they do. It is cool seeing the way statistically based research works outside of a college setting."

"I believe that research is the most important part of learning in the STEM fields. It allows you to apply what you've learned in the classroom as well as allowing you to do work in your field, even before graduating."

"The Academy is great all around. The chance to study abroad, the challenging courses, and the many other opportunities it presents are all great. However, the best part of the Academy is its community. From classmates to teachers and staff, the Academy has a great community. There is always someone there to help. Students are never far from a friend or a safety net. Everyone at the Academy does their best to help each other succeed."







Noah Latham
Franklin, Kentucky (Simpson County)

Dear Mr. Gatton,

I first became interested in the Academy around nine years ago. I was participating in a summer program at Western Kentucky University, and meanwhile my mom went to a seminar to hear Dr. Julia Roberts speak. This was before even the first class had entered into the Academy and the concept of a Kentucky high school on a college campus was being discussed and established. Ever since my family and I heard about the Academy, it has been my goal to be a part of the Gatton community.

Mr. Gatton, without you, what I am doing this summer would be nigh-on impossible. I am researching the clothes drying process with one of the engineering professors at WKU and how we can make the process more efficient. Without your efforts to catalyze the Academy's growth, not only would I not be able to participate in my research this summer, my entire Academy experience would be less full. The Academy for me is the culmination of nine years of waiting and preparation, and while it has been incredibly challenging to be here, I guarantee you that I would have it no other way. There is no other way to say it but "thank you."

Sincerely,
Noah Latham





"I believe that my summer is unusual because of how academic it is. For most high school students, I think the amount of free time they probably have this summer is polar opposite to mine."

Noah Latham

Home High School:
Franklin Simpson High School

Research Area:
Electrical Engineering

"I have every intention of continuing to do research wherever I go to college. By learning the basics of working with a professor, I hope to accelerate my educational goals."

Career Goal:
Aerospace Engineering

Research Mentor:
Dr. Farhad Ashrafzadeh
WKU Department of Engineering

"On my very first day at The Gatton Academy, I felt very wary. Practically everything was new to me, people and classes alike. Now I just feel at home. I absolutely love the community that I have forged at The Gatton Academy. No matter who you are here, you can always say that you have friends."

Extracurricular Activities:
Chess and Gatton Academy
Miscellaneous Musicians Association



Seth Marksberry
Owensboro, Kentucky (Daviess County)

Dear Mr. Gatton,

There was a point when I did not think there was anything good about being a student in Kentucky. I felt that educational efforts in our state had stagnated, especially in the STEM areas. This was before I knew about The Gatton Academy and all that it had to offer. Not only has the Academy given me the opportunity to advance in my education, but also to explore different areas of research. Goals that I would not have imagined to be achievable as a high school student have been brought within my reach. For giving me and so many others these opportunities, I thank you.

I am an aspiring engineer, inventor, and entrepreneur. From a young age I was captivated by science from the time I learned about space exploration and robotics. I worked to advance my knowledge outside of the classroom and decided I wanted a career in aerospace engineering. Expanding on the dream of solving the problems of the world we face today and in the future, inventing has captured my attention as a means of making the world better. The research I am participating in this summer works towards that goal, as I am researching an advanced form of agriculture called hydroponics. Hopefully, through advancement of this technology, society will one day be able to subdue the issue of world hunger and help facilitate our expansion out into the cosmos.

Thank you for giving me the opportunity to work on these problems and have these great experiences.

Sincerely,
Seth Marksberry





“What I love the most about The Gatton Academy is the opportunity to be in such a nurturing environment with so many students dedicated to advancement. I feel that the whole idea of advancement is not fully expressed in other schools around the country, and that’s a shame. It really feels like we are here to change the world.”

“The best piece of advice my mentor has given me is that there are no questions that don’t deserve to be asked. Further, he has always emphasized how important it is to question what you see around you and see how you can make it better. Even something as unassuming as an herb used in cooking could hold the cure to cancer.”

“The most interesting thing about my research is the range of potential applications it could have with regards to solving problems in the real world. Hydroponics and related agricultural technologies can potentially solve the problems of hunger and even help to cure diseases. We’re talking about taking a shot at world hunger AND curing diseases like cancer all with one set of technologies. That’s the business I want to be in.”

Seth Marksberry

Home High School:
Daviess County High School

Research Area:
Biotechnology

Career Goal:
Aerospace Engineering or
Entrepreneurship

Research Mentor:
Dr. Chandra Emani
WKU-Owensboro
Department of Biology

Extracurricular Activities:
Science Bowl



Harsh Moolani
Owensboro, Kentucky (Daviess County)

Dear Mr. Gatton,

Thank you for providing me profound opportunities. Being able to live in the Academy community, perform groundbreaking research, and excel in rigorous courses truly means a lot to me. I come from a family where we are constantly trying to push ourselves to be the best we can be. I have always taken the most challenging courses available to me, and The Gatton Academy provided the next great challenge!

When I first came to Gatton, I believed that I would not have any problems managing my time because I played varsity tennis, varsity soccer, and travel soccer at Daviess County High School. However, I quickly realized that time management was tough at Gatton. Managing all of my classes with research and my social life was difficult! Many times I questioned if I even belonged at Gatton. Then I realized that I chose to come here and that I wanted the next challenge. I realized that I have developed more in one semester at Gatton than I did in the two years before. By being with a group of individuals who are trying to grow and better themselves just as much as I am, I have been able to expand my horizons even further. Collaborating with Kentucky's finest has taught me important skills like proactive thinking, efficient work distribution, and productive teamwork. So once again, I would like to thank you for providing Gatton alumni, my colleagues, and me with these special opportunities.

Sincerely,
Harsh Moolani



"An unusual quirk that most people do not know about me is that I am willing to get up at 3 o'clock in the morning to watch a cricket match."

Harsh Moolani

Home High School:

Daviess County High School

Research Area:

Biochemistry

Career Goal:

Physician

Research Mentor:

Dr. Rajalingam Dakshinamurthy
WKU Department of Chemistry

Extracurricular Activities:

Soccer, Tennis, Gatton Academy
Tutoring at Dishman McGinnis
Elementary, Research, and Beta Club

"The biggest challenge I have had to overcome in my research is learning how to accept the results the experiment yields. I have always been able to predict the answer or results to a particular situation by simply knowing the conditions. In my research, however, I don't know what will work and what won't, and learning how to accept this fact was difficult."

"Next year, I am looking forward to leading and assisting my juniors in their journeys in reaching their goals. My favorite quality about Gatton is the environment. The students and staff are always willing to help each other no matter the time or place. The feeling of belonging simply allows everyone to put his or her best foot forward. My seniors instilled various qualities and taught numerous lessons, and I would love to have the same impact on my juniors."





Kristen Pedersen
Barbourville, Kentucky (Knox County)

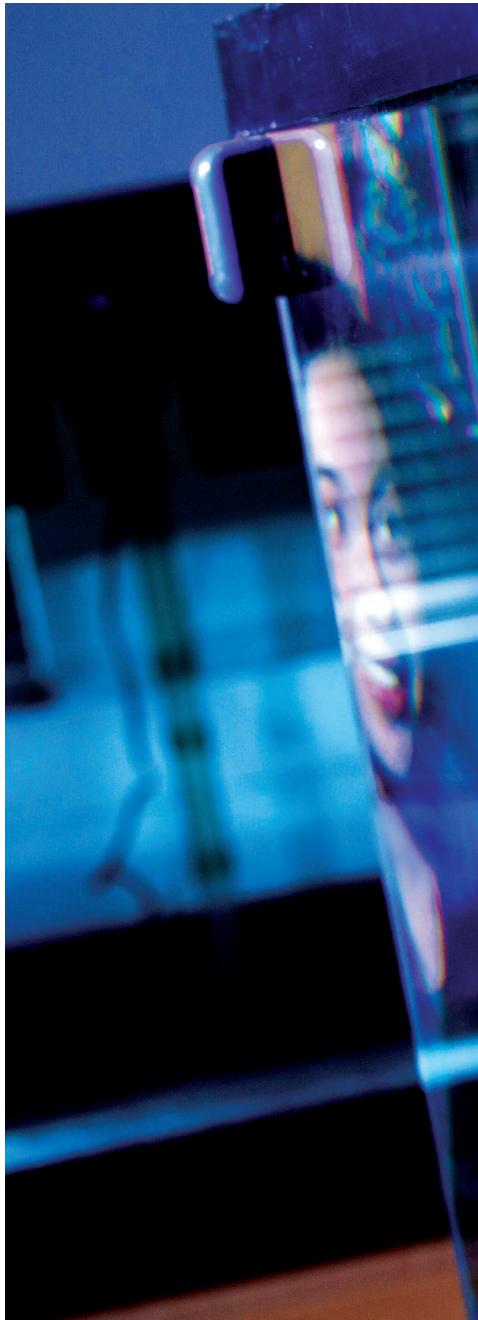
Dear Mr. Gatton,

One year ago, if someone had told me that I was going to move away from home two years early, enroll completely in college courses, venture to Costa Rica, stroll through England, and participate in undergraduate-level biology research for the summer, I would have thought they were completely out of their mind. Yet, here I am, a year later, a rising senior at The Gatton Academy with more experiences and opportunities than I could have previously imagined in my rural hometown in Knox County.

After my study abroad trip to Costa Rica in the winter, I knew that I wanted to do more biology research, but maybe closer to home this time. It was such an amazing experience, and I did not want it to end when I unpacked my bags back in Kentucky. This is what led me to start my current summer research project on the kinematics of stingray envenomation. None of this would have been possible without your unwavering support.

I would like to thank you for providing opportunities for students at The Gatton Academy to achieve greatness. Thank you for giving students the means to explore topics that they are passionate about in the form of scientific research. The valuable friendships I have made and the information that I have learned will stay with me forever as results of your gift.

Sincerely,
Kristen Pedersen



Kristen Pedersen

Home High School:
Barbourville High School

Research Area:
Biology

Career Goal:
Biological Engineering

Research Mentor:
Dr. Steve Huskey
WKU Department of Biology

Extracurricular Activities:
Odyssey of the Mind, Beta Club,
Tennis, Private Pilot Training, Key
Club, SCUBA Diving, Cultural Club,
and Petting Dogs

"I am spending my summer studying and working with live stingrays. They are fascinating animals, and I am extremely excited to learn more about them. I am planning on using my research to enter the Siemens Competition and the Intel Science Talent Search. I am really grateful that my summer research experience has opened opportunities to me that I would not have readily thought about before."

"The biggest change that I have experienced in my first year attending The Gatton Academy is the extreme level of dedication and discipline it takes to thrive in such a demanding environment. Students must have the time-management skills and responsibility to learn and complete coursework without the structure that is provided in a normal high school setting."

"The Gatton Academy provides Kentucky with a place for gifted youth to challenge themselves in a unique and welcoming environment. Our school offers opportunities and experiences that many of us would never have dreamed of participating in during our high school careers."





Lauren Pedersen
Barbourville, Kentucky (Knox County)

Dear Mr. Gatton,

I have always had an unquenchable curiosity. This mindset is what led me to The Gatton Academy. Since then, my life has been a roller coaster of unforgettable moments and adventures. After moving from a small, Appalachian county to the Academy, my life has made an unexpected turn that has allowed me to study abroad in Costa Rica and England, participate in undergraduate-level research, and integrate myself in a community of passionate individuals who share my love for knowledge.

Throughout my research experience, I have learned and matured so much. Being a researcher is more than mixing chemicals, performing experiments, and sitting in a laboratory. It is about using one's curiosity to question the world around them. Researchers do not disregard the unusual; they explore it to its end.

I would like to take this opportunity to thank you for your generosity in funding my exploration. I am currently performing research in the Department of Psychological Sciences at Western Kentucky University and studying how aging affects one's abilities to visually perceive the world. I hope to use the results of this study to make a difference in others' lives like you have made a difference in mine.

Sincerely,
Lauren Pedersen





“Although I will not be spending my summer by the pool, I will be spending it investigating whether the neurotransmitter GABA effects aging and spatial perception, which I think is equally as cool.”

“One of the biggest challenges I’ve had to face in my research is letting my voice be heard. My lab consists of many qualified graduate students. From where I am still in high school, I often felt like they did not take me seriously. Throughout the six weeks, I learned to be more confident in my ideas and communicate with my fellow researchers.”

“During my senior year, I am looking forward to representing the Academy as an Avatar (our student ambassador group). I would like to share my experiences and encourage prospective students to take advantage of the opportunities that Gatton offers.”

Lauren Pedersen

Home High School:
Barbourville High School

Research Area:
Psychological Sciences

Career Goal:
Medicine

Research Mentor:
Dr. Farley Norman
WKU Department of
Psychological Sciences

Extracurricular Activities:
Private Pilot Training, SCUBA diving,
Odyssey of the Mind, Beta Club,
Tennis, Key Club, and Cultural Club



D.J. Price
Perryville, Kentucky (Marion County)

Dear Mr. Gatton,

I'd like to start by telling you that I am only the second person in my family who will attend college. My mother was the only one before me, and my father had the unfortunate luck to have to drop out of school during his 8th grade year. The Academy is definitely something that will launch me on the right track in life. I am taking advantage of all the Academy offers to the best of my ability. I want to pursue a career in STEM, and with the Academy's help, I have a great start.

I became interested in the Academy when I was told that it focused heavily on mathematics and engineering. I have since learned that I really don't like engineering as much as I once thought—an awesome discovery! I'm extremely excited to have confirmed my passion for mathematics. The Academy has helped me narrow my interests and really figure out what I want to do. Nothing makes me happier than challenging myself and learning things that I can share with others. If I'm happy with my life, there's nothing more I can ask for.

This summer, I am researching with one of my favorite professors, Dr. Claus Ernst, in an advanced area of mathematics. I am currently researching the area of knot theory which delves into many high-level math courses. It's so exciting! I get to do what I love every single day and also work with some of the smartest and nicest people I have ever met. So in conclusion, I would like to thank you. Thank you for allowing me to have one of the most memorable experiences of my entire life.

Thanks so much!
D.J. Price

D.J. Price

Home High School:
Marion County High School

Research Area:
Theoretical Mathematics

Career Goal:
To Be Happy

Research Mentor:
Dr. Claus Ernst
WKU Department of Mathematics

Extracurricular Activities:
Film Club, Film Team, Eco Club,
Knitting, and Composing and Playing
Music

"My summer researching differs greatly from the summer of most high school students. Most students are spending their summer at a job or sleeping at home. Working alongside a mentor and researching something I love is much more rewarding than sleeping in my opinion. So far, the coolest thing about summer research is getting to know my mentor."

"This research experience will help me greatly in my educational and professional life. I am learning a massive amount of mathematics, and I am getting used to working with coworkers on a common project. This will help me greatly in my life after Gatton while researching with people I don't know and on topics that I still have to learn about."

"The best piece of advice that my mentor has given me is that mathematics research happens very slowly. Many times my best ideas will not amount to anything, and the patterns I find end up not working in general. It's good experience to realize that you will not always achieve something right away, but, if you keep trying, you will meet your goal."





Elizabeth Pulsifer
Union, Kentucky (Boone County)

Dear Mr. Gatton,

The Academy has been a huge milestone in my life and one that I never expected. I only learned about the Academy a few months before the application was due, but after a few conversations with my parents, I knew it was where I needed to be. Sure, I could have gotten along fine at my old high school, but the challenge and excitement that taking college classes and living in a small community on a college campus brings was an experience that I knew would change me for the better.

Entering the Academy, I thought I knew what I wanted to do with my life: chemistry or microbiology. However, now that I've come to the Academy and taken two computer science courses, my career goals have changed dramatically. I did not realize how much I would enjoy programming, but for some odd reason, I absolutely love it. It has become something that I want to pursue as a career. While I no longer see biology as my final career path, I do still have plans to delve into it in the future, which is one of the reasons I chose to do research over the summer. I am continuing my junior year's research with both the Genome Discovery and Exploration Program and the field of bioinformatics. My project is to annotate the entire genome of a virus I isolated last fall, and then I will publish my findings to the scientific community. It seems a fitting conclusion to my two semesters of research last year, and it will serve as a platform for my future research in other fields.

My research this summer would not be possible without your help, and for that I must thank you. You have made a positive impact in my life. Thank you.

Sincerely,
Elizabeth Pulsifer





"This summer, I'm most looking forward to having freedom...not just in being independent, but freedom in research. I chose to do bioinformatics research here because I have the freedom to decide how to go about my research. My first step is the only one set in stone, but after that I can look into anything I want to include in my research."

"I knew coming into the Academy that it would require a level of maturity that I had not had to display in the past. I didn't realize, however, how much I would grow up here. I have matured and evolved on a huge scale, both intellectually and emotionally. It's been a journey for sure, with its ups and downs, but I wouldn't change a thing. The great thing about the Academy is the challenges it presents and the safe environment it creates to face the challenges."

"The Academy offers many different amazing opportunities to experience, but there's just one thing that I can say I love most about the Academy: the study abroad trips. These trips are something that you just can't find at a normal high school, and it's certainly not something I thought I'd get to do before college. I ended up going to Costa Rica with the Biodiversity study abroad trip, and it was an amazing experience. I would love to go again, but with limited spots I'll let someone else have the fun."

Elizabeth Pulsifer

Home High School:
Larry A. Ryle High School

Research Area:
Bioinformatics

Career Goal:
Computer Science/Cyber Security

Research Mentor:
Dr. Claire Rinehart
WKU Department of Biology

Extracurricular Activities:
Alto Saxophone, Gay-Straight
Alliance, National Honors Society,
French Honors Society, and Beta Club

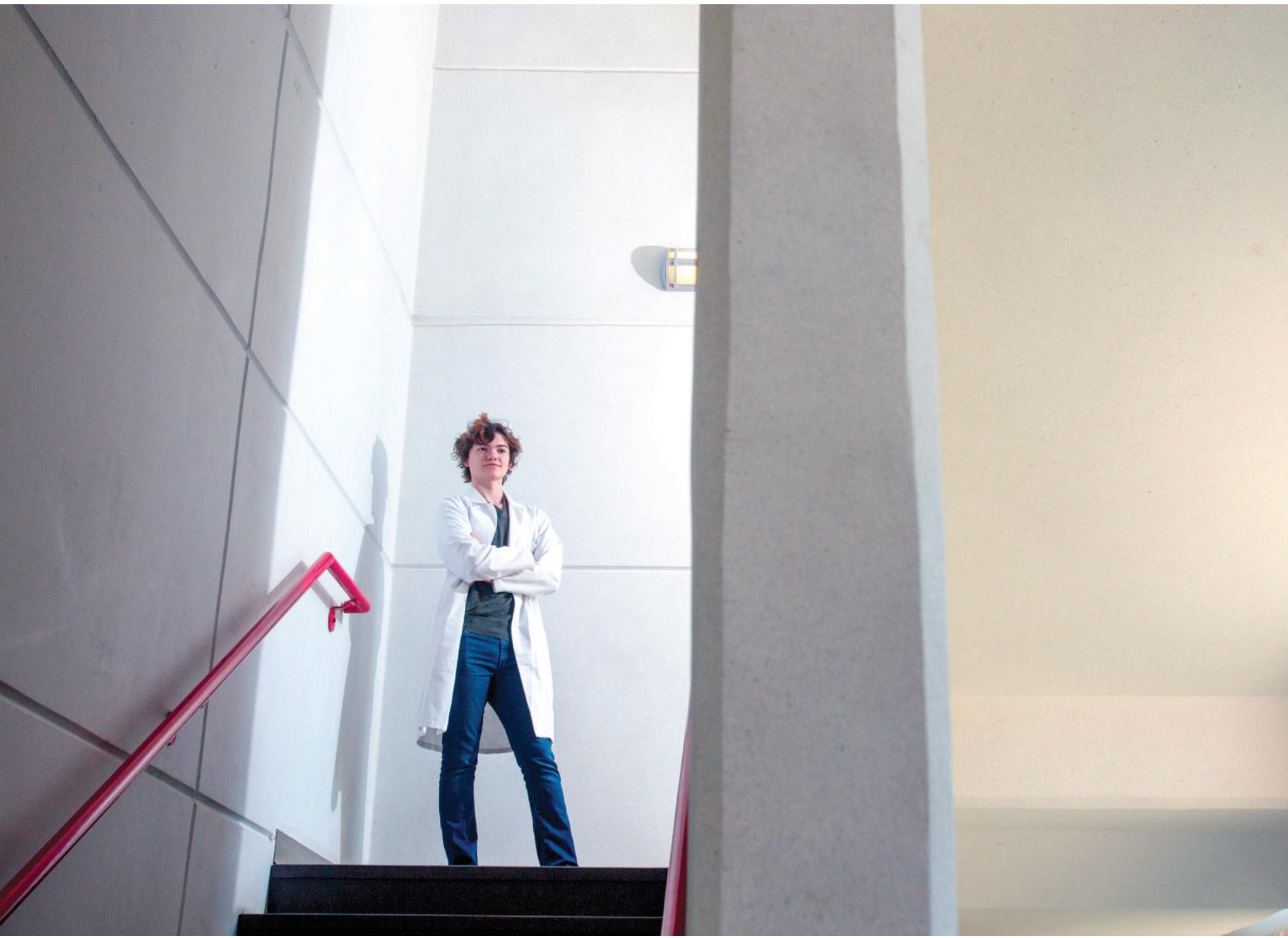


Graham Reynolds
Owensboro, Kentucky (Daviess County)

Dear Mr. Gatton,

I really cannot express how amazing an opportunity The Gatton Academy is. For young kids like me who are interested in STEM areas, our school is absolutely invaluable. Whenever I think about Gatton and how it came to be, I'm always so happy that people still have faith in younger generations. After hearing so many times that our generation is lazy, that our generation doesn't know what it's like to work hard, it means so much to me that you're personally investing in our future. It means so much to me that there are individuals like you who hold a lot of people's respect who make such a difference in this world, that realize the potential we have. Your investment is not only in individual students, but in Kentucky's future. It makes me so proud to know that I live in a state where young people are valued.

Thank you for seeing in me what others would put down,
Graham Reynolds





"My summer of research is different than most high school students' summers because my days are highly planned out. I don't have as much time as I did in past years to goof around, but that's a good thing! Having structure in my time is a lot more fulfilling than doing nothing all day."

Graham Reynolds

Home High School:
Daviess County High School

Research Area:
Biology

Career Goal:
Plastic Surgeon

Research Mentor:
Dr. Nobuyuki Matoba
Owensboro Cancer Research
Program

Extracurricular Activities:
Gay-Straight Alliance and Yearbook

"I really love the introspection The Gatton Academy induces. Coming here, I realized that I'm not the smartest person, I'm not the most active. I really had to think about the reasons I was here, why I was chosen, why I should stay, etc., despite not being the best, and the answer was that I was still doing the best I could for me. And that's what it made me realize: I shouldn't compare myself to others. That realization improved so many facets of my life, and I have the Academy to thank for it."



Eura Shin
Morehead, Kentucky (Rowan County)

Dear Mr. Gatton,

My name is Eura. I'm from the comparatively small town of Morehead, Ky. Coming to Gatton, I went from being a big sister of a sassy twelve-year-old, playing guitar with my best friend Grace in our local coffee shop, and attending speech and debate tournaments every weekend to being part of a 120-member family, playing guitar with a circle of friends in the WKU Colonnade, and curling up on the couch to code computer programs on the weekends. I am confident that the experiences that I have had here are unparalleled.

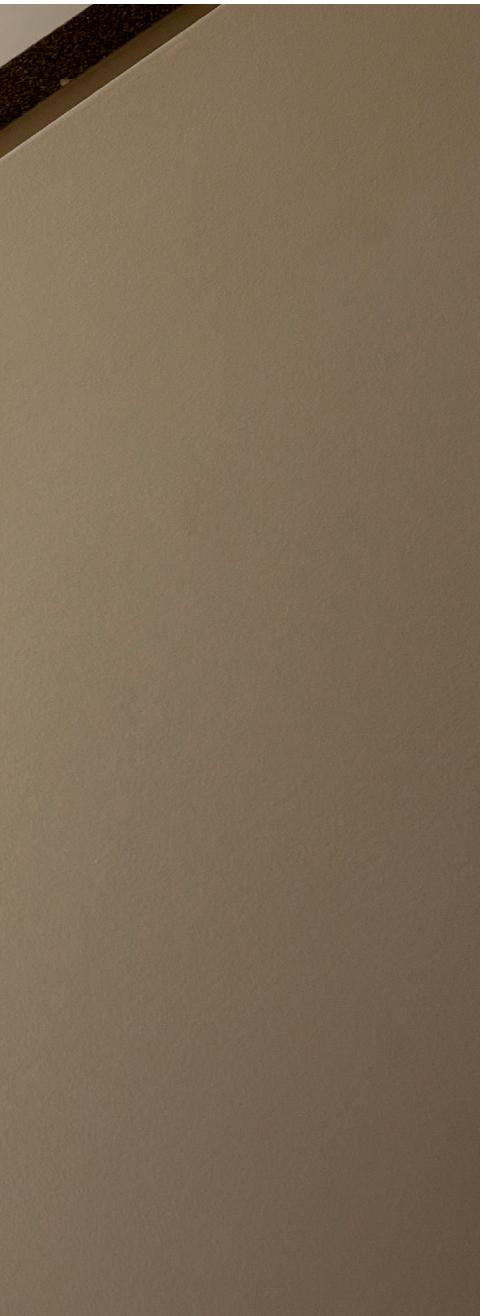
At Gatton, I have learned more than I knew was possible within a year. I've learned how to code in two different programming languages. I've learned not to be afraid to ask questions during class. I've learned how to understand the meaning behind the Gs, Cs, Ts, and As of a bacteriophage's DNA sequence. I've learned the value of letting yourself be wrong. I've learned how to be a friend.

The amazing part is, all of these lessons have prompted other lessons – some that I'm still in the process of learning. Participating in WKU's Genome Discovery and Exploration Program has motivated me to take on a summer research project in knot theory. Having the opportunity to experience the STEM fields first hand has inspired me to aim toward a M.D.-Ph.D., so I can continue to conduct research while practicing medicine.

I would have had none of these opportunities if it weren't for your support. Thank you so much. Here's to a lifetime of unparalleled experiences.

Sincerely,
Eura Shin





“Although learning about hyperbolic knots and Reidemeister moves is by no means easy, surprisingly, I found that the hardest aspect of my research internship was the act of being an intern. Researching means knowing how to speak up and be an engaged student. Grasping the professional dynamic of working with a mentor and communicating confidently was the hardest, and most helpful, challenge I’ve overcome.”

Eura Shin

Home High School:
Rowan County Senior High School

Research Area:
Computer Science

Career Goal:
Undecided, but something that incorporates Biology and Computer Science.

Research Mentor:
Dr. Uta Ziegler
WKU Department of Computer Science

Extracurricular Activities:
Speech & Drama and Co-ed-Y

“As someone from Appalachian Kentucky, I have experienced the startling educational transition from my home school to the rigor of the Academy. Academically, I believe that Gatton not only provides a foundation for motivated students, it is also an embodiment of what happens when you nurture the potential of Kentucky’s youth. The Academy is a successful model to school systems within the Commonwealth.”



Jeremiah Wayne
Henderson, Kentucky (Henderson County)

Dear Mr. Gatton,

I would like to personally thank you for the incredible blessing you have bestowed upon me and my family. At my home high school, I was being decently challenged, but I always felt like I could be pushed a little bit harder. The Gatton Academy has challenged me well beyond what I ever thought was possible.

By the end of my two years here, I will have around 80 college credit hours! As for research, I chose to participate in the Genome Discovery and Exploration Program during my first year. By already having two semesters of research under my belt, I was able to transition easily into an actual laboratory studying cancer at the Owensboro Cancer Research Program (OCRP) this summer. This internship has been one of the most challenging and interesting projects that I have ever encountered. I am studying the binding capacity of an antibody, Averen-Fc (that OCRP already fused), on liver cancer cells. I am determining first if it is able to bind to the cells, second if it induces cell death once it binds, and third where the binding occurs on/in the cell. I find this research to be incredibly interesting and extremely applicable to the medical field that I hope to enter.

By participating in this summer research internship, I have learned numerous laboratory techniques and gained crucial experience that will expand my future opportunities. You willingly donated to furthering the education of me and 19 other students this summer. And for that reason, Mr. Gatton, you have earned a great deal of my respect and gratitude.

Sincerely,
Jeremiah Wayne

Jeremiah Wayne

Home High School:

Henderson County High School

Research Area:

Biochemistry

Career Goal:

Medical Field

Research Mentor:

Dr. Nobuyuki Matoba

Owensboro Cancer Research Program

Extracurricular Activities:

Swimming, Ultimate Frisbee, Y-Club,
Bible Study, Academic Team, Soccer
Referee, and YMCA Camp Counselor

"Most high school students will end up working at summer jobs that do not relate to their future careers. I was blessed with the privilege of working and studying in a field that I am sincerely interested in. The Owensboro Cancer Research Program has taught me so much more than I ever thought I would learn about cancer in the small amount of time I was given, and I fully realize most other students my age will not have an opportunity like this one."

"It has been a long-term goal of mine to present at a national science fair. With the wonderful experience I had at the Owensboro Cancer Research Program, I am proud to say I will be entering the Siemens Competition and hope to excel in my endeavor. I have plans to use the knowledge I have gained by continuing research in the biochemistry field in the summers to come and throughout the school year as well."

"As I return to the Academy for my second year, I am most looking forward to having the opportunity to take classes related to my interests. My first year at the Academy consisted mostly of core courses, but in my second year, I am signed up to take courses such as Neurobiology and Anatomy. I don't know if I have ever been more excited about taking a school course."







Anne Barrett Wetzel
Princeton, Kentucky (Caldwell County)

Dear Mr. Gatton,

This summer I am conducting research in the Department of Animal Science at the University of Kentucky. I am studying the genomic expression of cattle. There are two components of my research, including an experimental trial (with actual animals) and laboratory analysis. This experience will help me in preparation for a future in STEM. I hope to use the skills I develop this summer in my college and graduate education and my career.

Coming from a small town in western Kentucky, I was not given many opportunities to challenge myself inside or outside the classroom. I have been offered a multitude of opportunities since enrolling at The Gatton Academy. I have been able to explore various STEM fields, take courses in a critical language (Arabic), conduct research, and travel abroad. The Gatton Academy is an inspiring community of students and staff whose support is unwavering. I am so blessed to be able to spend my final two years of high school at the Academy. Thank you for supporting The Gatton Academy and the many of endeavors of the students.

Sincerely,
Anne Barrett Wetzel

Anne Barrett Wetzel

Home High School:
Caldwell County High School

Research Area:
Animal Science

Career Goal:
Physician

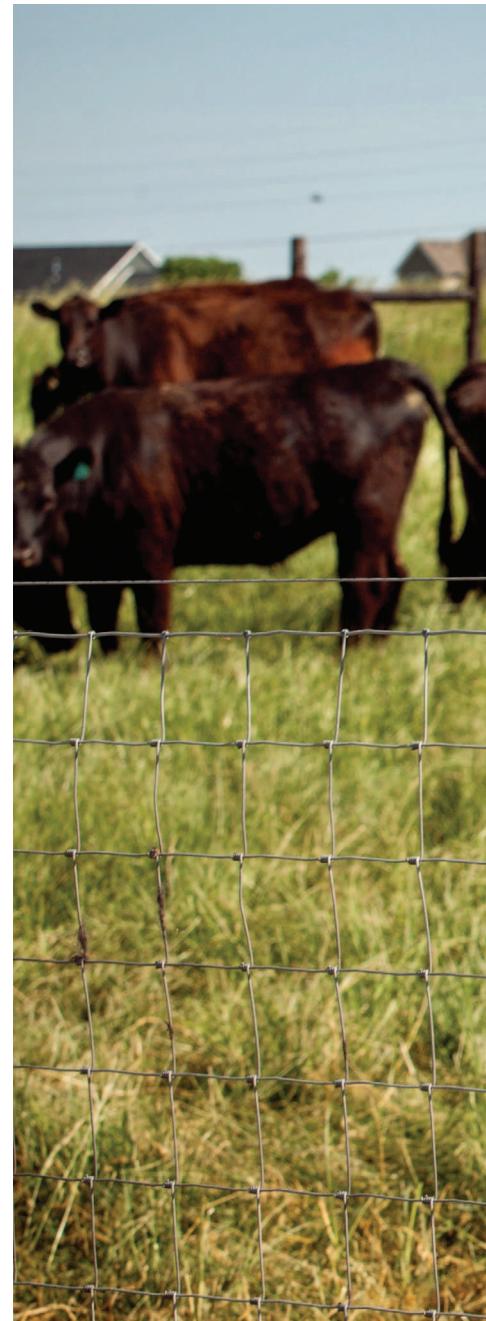
Research Mentor:
Dr. Roy Burris
University of Kentucky Research and
Education Center
Department of Agriculture

Extracurricular Activities:
Key Club President, Varsity Tennis,
Future Business Leaders of America,
STEM + Arabic, and Beta Club

"I am most looking forward to gaining a better understanding of meaningful biological research through this summer experience. I am excited about gaining insight into the regulation of gene expression while working with live animals."

"In the future, I would like to conduct research at the undergraduate and graduate levels. This summer experience is giving me an introduction to the research process and will serve as a stepping-stone for future endeavors."

"My biggest Gatton Academy accomplishment is finding the balance between schoolwork and social time. Having success in school while enjoying the atypical high school experience has been rewarding in so many ways. I am looking forward to spending time with the students and staff of the Academy during my second year. Their companionship has been meaningful and life changing."







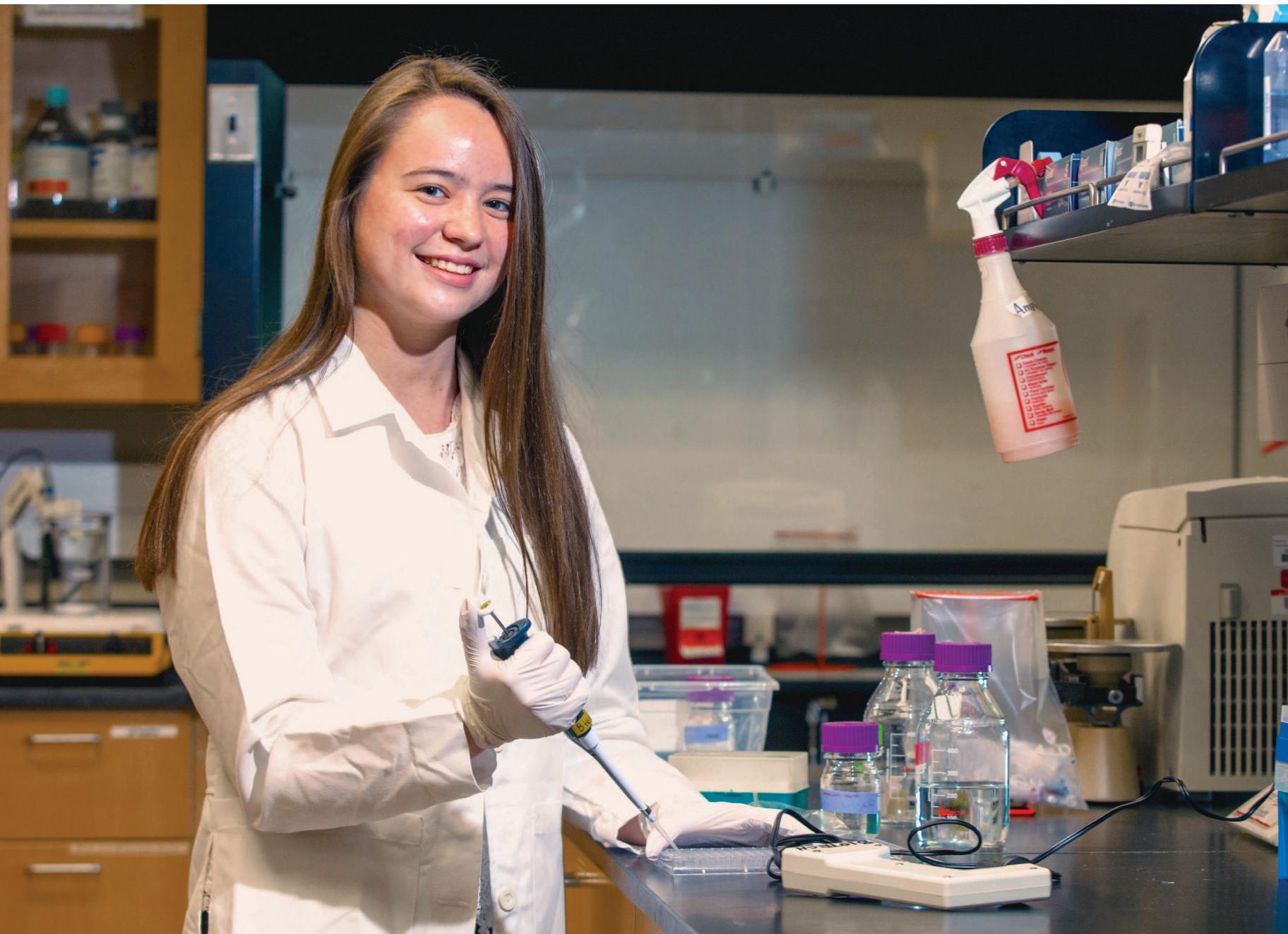
Alexandra Wright
Union, Kentucky (Boone County)

Dear Mr. Gatton,

The day I found out that I would be working at the Wood Hudson Cancer Research Laboratory was one of the most anticipated days of my life. Working as a student research assistant in a cancer lab represents my very first job in the field of my interest. And considering that I was selling popcorn at a movie theatre in northern Kentucky just last summer, it's safe to say that my summer experience has changed drastically. Thanks to your generosity through the Gatton Research Internship Grant, I will be spending my summer enriching my knowledge about cancer and learning new lab techniques, both of which will be highly relevant as I pursue a career in biochemical engineering.

I had high expectations for my internship at the Wood Hudson Cancer Research Center. So far, their program has proven to be much more than I had even anticipated. Already, I have been trained in complex experimentation protocols with names like "Western Blotting" and "Trypan Blue Exclusion." I am honored to interact with a group of staff members who are professionals in their field. Each week, these staff members prepare presentations and discuss journal articles to facilitate our understanding of cancer biology. Between the seminars, article analyses, and the hands-on approach we take in the lab, this summer internship is absolutely invaluable to me. Of course, all of this is made possible through your support and dedication to gifted education. Thank you for allowing me to spend this summer doing what I love: learning.

Sincerely,
Alexandra Wright





"The coolest part of my summer research is the opportunity to work in the field of my interest. This summer, I am gaining independence in performing new lab protocols. To me, there's nothing more exciting than throwing on a lab coat and a new pair of gloves and running my own experiment."

"I love the lab work I am doing this summer, and I can see myself working as a researcher in the future. I plan to pursue a career in biomedical engineering. Experience in a molecular biology lab like this one will lay the foundation for my future coursework, research, and employment. I may even be inspired to specialize in cancer!"

"During my second year at the Academy, I am most looking forward to reuniting with my classmates and meeting new people. It's nice to be part of a community of people who share the same academic dedication and interests as me."

Alexandra Wright

Home High School:
Larry A. Ryle High School

Research Area:
Biochemistry

Career Goal:
Biomedical Engineer

Research Mentor:
Dr. Alexandra Fajardo
Wood Hudson
Cancer Research Laboratory

Extracurricular Activities:
Tennis and Volunteering



THE GATTON ACADEMY



of Mathematics and Science



“The path to success is not linear: research is all about making mistakes and then trying again.”

— Hayden Justice

“Researchers don’t disregard the unusual; they explore it to its end.”

— Lauren Pedersen



$$n) + \frac{k_{ni}bn(1-n)g_{nw}}{\lambda_{ni}n+1} - \frac{\lambda_n n}{1+\epsilon b}$$

$$= \beta + \gamma * u(t) - \lambda_w w - \lambda_{bw} bw - \lambda_{nw} nw$$

$$= 0, b(0) = b_{\text{init}}, w(0) = w_{\text{init}}$$

$$-\frac{\partial H}{\partial b} = -[1 + \lambda_1 \left(\dots \right) - \lambda_b + \frac{(k_{nr}n + \delta)b\lambda_{rb} - (\lambda_{rb} + \dots)}{(\lambda_{rb}b + \dots)}]$$

$$\left(\frac{k_{ni} n(1-n)(g_{ni} - ne)}{\lambda_{ni} * n + \frac{1}{\epsilon b})^2} \right) + \lambda_3 (-\lambda_{bw} w)]$$

$$\Rightarrow -\frac{\partial H}{\partial n} = -[\lambda_1 * \left(\frac{w}{\lambda_1 + k_w}\right)]$$

$$\left(\frac{g_{nw}(w)[(\lambda_{ni} * n) - k_{ni}bn] - k_{ni}bn(1-n)\lambda_{ni}}{2} \right)$$

$$-\frac{\partial H}{\partial w} = -[\lambda_1 \frac{k_w}{w + k_w})^2] + \lambda_2 \left(\frac{k_n i b n(1 - \lambda)}{\lambda} \right)$$