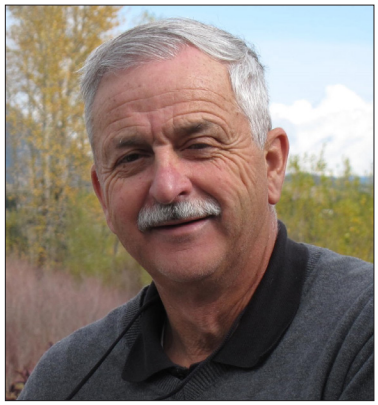
Mathematical Sciences

UNIVERSITY OF MONTANA FALL 2016

Darrel Choate Receives Distinguished Alum Award

By Kelly McKinnie and Nikolaus Vonessen



Darrel Choate

Each Homecoming, the University of Montana Alumni Association honors outstanding alumni with Distinguished Alumni Awards. The recipients of the award are individuals who have distinguished themselves in a particular field and who have brought honor to the University, the state or the nation. One of the awardees this year was **Darrel Choate**, who earned two degrees in mathematics from UM: a B.A. in 1965 and an M.A. in 1967. (Please see the accompanying box on page 4 for a description of his quite exceptional career.)

During Homecoming Week this fall, Darrel participated in a Question and Answer session hosted by the math department. He first gave a delightful presentation about his career to an audience of faculty and students, recalling some of his memories of the early computers on campus, and providing many interesting details. Afterwards, the audience asked a series of questions, focusing on the pros and cons of working in industry and how he overcame adversity.

One of the interesting details Darrel mentioned was about the job he took at the Aerospace Corporation in San Bernardino, CA, after graduating from UM. There, his first assignment was to translate computer programs written in IBM's PL1 language (programming language #1) from a system which used 36 bit words to the new IBM 360 computer which used 32 bit words.

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Challenges in Disease Modeling: An Introduction

By Cody Palmer

After finishing his Ph.D. in Mathematics last May under the direction of Professor Emily Stone, Cody spent the fall semester as an instructor at the University of Louisiana at Lafayette. He just accepted a position as postdoctoral fellow at the Institute for Disease Modeling in Seattle. In this article, he gives us an introduction to his area of research.

Cody Palmer

Introduction. The goal of modeling disease mathematically is to gain insight in reducing disease burden, or optimally, eradicating the disease entirely from a population. Creating a model for the spread of a disease has two difficult issues. First, we are trying to model behavior that involves complicated interactions among social creatures. Modeling exposure through interaction is thus difficult, but modeling whether or not people are infected upon exposure is an even harder problem due to the complexity of our immune systems. These processes have a stochastic component, which we overcome with an "averaging" approach: while stochastic on the individual level, on the population level these interactions have an essentially deterministic effect. The justifications for the assumptions are essentially intuitive, and so often these models can be considered as caricatures of reality.

Another challenge is determining the correct scale on which to make conclusions. While there are many methods for determining behavior in the long term in differ-

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Inside

Notes from the Chair

By Emily Stone

As I write this note for the newsletter, we are in the midst of an upper administration upheaval that promises to leave no corner in Main Hall undusted. As many of you know, President Engstrom stepped down at the end of Fall semester, and we have an interim Provost, due to be replaced this year as well. With new leadership comes a new cabinet, so we are mirroring the government in Washington during its "transition period". However, I promise not to start a twitter feed, such as: "Musings from Math at UM".

We weathered the initial storm of budget cuts last year quite well, but apparently the administration were not going to stop until they drew blood, so after the semester ended we received a directive that our operating budget for 2016-2017 would be cut by 50%, and our adjunct budget by 30%. Thankfully I have a hard-working and creative staff, and we were able to pare away expenses to address the cut in operating budget, but don't ask for any freebies in our main office these days! Our service course enrollment numbers were down, which took care of the cut in the adjunct budget, because we needed fewer adjunct class hours over all. In the past year we have been transferring our reliance on adjuncts to graduate students, but have maintained a core of highly trained people we can count on to deliver quality courses and run programs such as our Math Learning Center. A shout out here to these folks: Rick Darnell, Dick Lane, Dara Laobeul, and Joyce Schlieter.

While the overall enrollment numbers at the University are down by several thousand, the number of math majors has remained steady, which I take to mean an overall increase in math majors. I believe we can continue this trend through proper "marketing", if you will. We need to reach out to high school students in the region to let them know that Missoula=Math, if you want to study in-state. We have collected mailing lists and other data, and are preparing a brochure to be sent to as many students as we can find who have shown either an interest or aptitude in Math. I was inspired by the beautiful brochures our enrollment services sent out last spring, see https://admissions.umt.edu/admissions/publications.php for an example. We hired a student photographer to take photos (one of which appears on this page) for our brochure. We will make sure to send one to everyone on our newsletter list as well, so you can pass it along to any high school student you may know personally.

The Math Building

This Fall brought a new tenure track faculty member, Katia Smirnova, to the department. See the article about her later in this newsletter. We are also hosting visiting professors Dan Johnston (C&O) and James Tipton (Analysis), who are covering our current faculty vacancies and contributing to graduate education and research in the Dept.

Briefly, I would like to note some of our other accomplishments this Fall. Our proposal for a Masters in Data Science was approved by the administration and will be considered at a Board of Regents meeting in January. We are also working with Salesforce VP Peter Coffee to develop course offerings for their cloud computing clients, and received a generous anonymous donation to support the data science program. Our faculty has been very active in writing grant proposals, we have had 11 go out this fall, for a total of almost 3 million dollars. Even if only a fraction of these are awarded, I can say that on the department level we are doing very well indeed.

Finally, I would like to thank you for continuing to support liberal arts education in Montana through your kind donations. It is our shared responsibility to ensure that in future generations all citizens are able to read critically, write effectively, think logically, and act compassionately.

Best Wishes for a Happy Holiday Season and New Year from all of us at the Math Dept.

Emily F. Stone

New Tenure-Track Faculty: Fred Peck and Katia Smirnova

Teaching as Pre-Destination

By Bharath Sriraman

Frederick Peck joined the mathematics education group as an assistant professor in August 2015. Fred, a native of Colorado has an unusual story that led to his PhD in mathematics education. Teaching was the last thing in mind as a career choice for him partly because of witnessing first-hand the busy life of his mother, who was an elementary school teacher. The initial career choice for Fred was to be on Wall Street, as a business banker. This led him to pursue his first degree at Carnegie Mellon in Business Administration with an emphasis in computing and information technology.

During his undergraduate experience, Fred met Dr. Suresh Bhavnani who was working on a post-doc in human-computer interaction which involved teaching expert strategies to users. In other words users were made familiar with dependency taxonomies in strategic use of computers to help them build up expertise. This foray into teaching and software development for a year was followed by graduate work at the University of Michigan, where human computer interaction was being implemented on a larger scale by his mentor Suresh. One of Fred's projects at Michigan was designing and teaching an experimental course on *Strategic use of computer applications* to undergraduate students, and an exposure to more teaching as a consequence.

At this point in his career, Fred also started taking math courses at University of Michigan and volunteering in high schools. As a result, mathematics teaching became a vocation for Fred and led to a graduate degree in Curriculum and Instruction and 6 years as a math teacher at Centaurus High School in Lafayette, CO. During this time, a branch of the Freudenthal Institute (from Utrecht University in the Netherlands) which is a major proponent of "Realistic Mathematics Education" was established at the University of Colorado, Boulder under Dr. David Webb. Coincidentally Fred's school district became involved in a design research project with the Freudenthal Institute at UC-Boulder. The seeds of pursuing a PhD were sowed at this point, culminating in a dissertation in 2015 on *"The intertwinement of activity and artifacts: A cultural perspective on Realistic Mathematics Education"* under the supervision of Dr. Webb.

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From Russia to Montana

By Jon Graham

The newest member of the statistics group is Ekaterina Smirnova, who joined the department this fall as an assistant professor. Katia is originally from Kazan, Russia. She later attended North Central College in Naperville, Illinois where she received a BA in German with a minor in mathematics. From there, she accepted a teaching assistantship at Michigan State to teach German but kept taking math classes in preparation for applying to graduate programs in statistics. Katia began her master's work in 2008 at Texas Tech University where she worked on a high energy physics project involving the modeling of particle jets using the Compact Muon Solenoid (CMS) calorimeter at the Large Hadron Collider in Switzerland. This work resulted in her master's thesis "Covariance Matrix for Jet Reconstruction". She then moved on to the PhD program in statistics at the University of Texas Dallas where she worked on shrinkage methods for signal processing using orthogonal series decomposition, with applications to functional magnetic resonance imaging (MRI), under the direction of Sam Eromovich. Dr. Eromovich received his PhD under the direction of a student of Andrey Kolmogorov, so I suppose you could say *Katia is the academic great-granddaughter of Kolmogorov!*

After receiving her PhD, she took a position as a postdoctoral research associate in the Department of Statistics at the University of Wyoming in 2014. In her two years as a post-doc, Katia developed an extensive research agenda, working on the Vaginal Microbiome Project with VCU, nonnegative matrix factorization and constrained regression methods for microbiome data analysis, and several other methods involving microbiome data analysis, resulting in five research papers submitted or in preparation. She also participated in writing a Mountain West Clinical and Translational Research Infrastructure Network (CTR-IN) small pilot grant to support her postdoc mentor and two students during the summer of 2015.

Katia arrived at UM this fall as an assistant professor of statistics. Her general research interests are centered around working on real problems with real data, with particular interest in statistical modeling issues and the mathematical justification of existing algorithms and data

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Darrek Choate, continued from page 1

Darrel also talked about his graduate studies at UM. For his Master's thesis, he worked with Professor **Robert Banaugh**, a mathematician and computer scientist who, as the director of UM's Computer Center, was in charge of UM's first computer. This was an enormous machine which was housed in a huge room in the basement of the Liberal Arts building. It enabled them to invert large matrices in order to compute numerical approximations to Green's functions. Around the time Darrel graduated, Professor Banaugh became the chair of the newly-created Department of Computer Science. While we are very proud to number Darrel Choate as one of our students, it is probably appropriate to also consider him as one of UM's very first Computer Science alumni.

Congratulations, Darrel, form all of us at the Math Department!

More About Darrel Choate - From the Citation of the Alumni Association

As a member of the Boeing Company's Technical Fellowship program, Darrel Choate of Bozeman was recognized among the top one percent of Boeing engineers who demonstrate technical leadership across the industry and who make a significant difference in U.S. and global engineering excellence.

During Ronald Reagan's administration, Darrel was instrumental in coordinating Boeing's efforts in the Strategic Defense Initiative, also known as Star Wars, for which he performed sensitive trade studies and analyses that influenced the current U.S. ballistic missile defense architecture. He also served as the systems engineering manager for the development of Sea Launch, a program in cooperation with Russian, Ukrainian and Norwegian companies to launch commercial satellites from one of the world's largest self-propelled, semi-submersible platforms. The system is in full operation and has launched more than 30 satellites, including some that provide XM Radio. The successful management of a multi-hundred million dollar undertaking involving several countries required Darrel to coordinate a diverse set of people with national and political differences as well as differing technical capabilities.

Darrel began his career in the aerospace industry with the Aerospace Corporation and continued with the Kaman Science Corporation, eventually retiring from Boeing. While employed at Boeing, he earned a master's degree in computer science/electrical engineering from the University of Washington. He authored many papers and talks, though most of his work was highly classified. In addition to his technical excellence, Darrel was known for his coaching, mentoring and leadership abilities. A firm proponent of the "learn-by-doing" model, he helped young engineers learn new capabilities by helping them solve some of the world's biggest aerospace challenges. Upon retirement, he adapted his technical and personal skills to assist the development of infrastructure in Mexico, Honduras and Haiti, and made significant contributions to the Japan International Project, a tsunami rebuilding effort.

Teaching as Pre-destination, continued from page 3

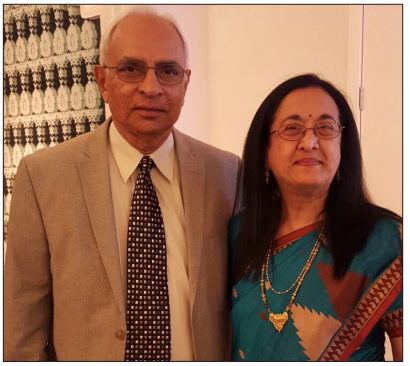
We are very pleased to welcome Dr. Frederick Peck to our faculty and the mathematics education group. Fred has been very active as a scholar with papers in esteemed journals such as *Educational Studies in Mathematics*, M*ind, Culture and Activity,* and *Journal of the Association for Information Science and Technology*, among others. He loves the outdoors and exploring as many trails as possible skiing and snowshoeing.

From Russia to Montana, continued from page 3

analysis techniques. More specifically, she plans on pursuing research in the areas of signal analysis, dimension reduction problems, and analysis of longitudinal data as with microbiome data. She is hoping to move from descriptive to more inferential analysis in microbiome applications and to become involved in the analysis of signals from wearable devices. Along this path, she brought in Dr. Ciprian Crainiceanu from the Department of Biostatistics at Johns Hopkins University, who gave an excellent colloquium this fall on wearable computing and structural brain imaging. As a result of this colloquium, one of our graduate students in statistics will be working with Dr. Crainiceanu this coming summer.

Katia enjoys being active and staying fit through exercise and dance and does a little bit of sewing. But I knew she would fit in well here in Missoula when she asked me if my daughter could work with her on some basic soccer skills so Katia could begin playing soccer in Missoula! Congratulations on your many successes and we are pleased to have you as a member of our department!

Alumni News



Champak and Meena Panchal

We recently heard from Purvi and Nirmita Panchal about their father, **Champak Dayaram Panchal**, who completed his PhD in 1977 under the direction of Professor Emeritus **Bill Derrick**: "Born in Gujarat, India, Champak Dayaram Panchal, '77, journeyed to Montana to pursue a Ph.D. in Mathematics before moving on to his greatest passion, teaching. He taught for 30 years at the University of North Florida. During that time, he was acknowledged for Excellence in Teaching and served as Graduate Director. He became an amazing mentor and educator to many. Eager to continue helping students, he came out of retirement and not only began teaching at Edward Waters College, but began donating a portion of his salary as scholarships for the school's students and to strengthen the department.

"Dr. Panchal's dedication to helping others extends well beyond his professional career. He and his wife of over 40 years, Meena, enjoy giving back to their local community in Jacksonville, by helping students, volunteering, and providing warm meals to anyone in need. When they have the opportunity to travel back to his hometown in India, Dr. Panchal is often found encouraging local village students to pursue their education or contributing to the needs of the local schools.

"In his spare time, he enjoys traveling, playing Sudoku, watching cricket, and, most importantly, spending time with his family, including his children and grandchildren. Dr. Panchal truly exemplifies what it means to be an educator, mentor, and contributor to society."

Calculus Dreams in Dubai, continued from page 8

and tourist-obligated experiences.

I visited one of my best friends who lives in London. Between trips to museums and old churches, she took me to Camden Market, which she should not have done – I officially have a new favorite spot on the globe.

My trip to Bahrain was a bit of a whirlwind. We left on Saturday before dawn and returned Sunday evening with more than enough time for dinner. Sounds like a quick trip, but two days gave us a great first impression of the island country. Bahrain boasts the Tree of Life (a 400 year old tree in the middle of the desert) and a wonderful Islamic calligraphy museum. My friends had to drag me out of the gallery, and subsequently, out of the main souk in Manama (probably the best souk I saw while abroad).

I spent spring break in Sri Lanka a few weeks later. I cannot rave enough about travelling from Dubai. On a few hundred dollars, I flew there and back, stayed in nice hotels with great views, climbed mountains, ate well, and did things which scare me. Afraid of heights, I climbed stairs on the side of a cliff to get to Sigiriya (an ancient palace). On top of the world, I scaled 5,000 steps to reach Adam's Peak by sunrise. I wouldn't give up that experience.

While in Oman, I swam in the Gulf of Oman. It is a big country to just go swimming in, but that's it, that's all I did. Even so, I enjoyed it greatly. Everyone needs a study break and mine came at the perfect time: between two weeks of performances of *Little Shop of Horrors*.

I was given the great opportunity to perform as Crystal in the AUS spring 2016 musical. Between that, three choirs, and a voice lesson, I spent most of my free time practicing. Honestly, I have never felt so good about singing before. The people around me supported and encouraged me in a way no one previously had. Overall, the general work ethic and atmosphere felt all the better for my studies.

Katerina Hall

Academically, this semester abroad was very nearly my most successful in college. I may have earned my lowest GPA to date (still well above a 3.0), but I finally let go of some of my grade-based anxiety. For once, I was learning without the stress of requiring a perfect score from myself.

Pertinent to this newsletter, it was during my travels that I rediscovered my love of calculus. In particular, I love multivariable more than ever. Admittedly, I thought I would fail the course after my first quiz came back. It was an eye-opener. Before that quiz, I had never gotten such a low score. I haven't since. With a renewed sense of purpose, I attacked my homework. By the end of the semester, I had one of the top scores in the class.

However, I could not have done it alone. I constantly asked questions of the professor and read the textbook incessantly. Actually, he quite reminded me of the professors here. He cared more about whether the students learned something rather than pushing for higher grades.

The experience was fantastic. Friends, experiences and food, all wonderful. What more can I say?

Except, I still hate dates.

ential equations, we may be more interested in the short-term behavior of the disease. This transient behavior can be difficult to analyze in many cases, but can be important in determining effective control strategies, for instance.

In what follows we will consider two examples that illustrate these challenges, and how they can be addressed.

Interactions. We can, perhaps, simplify the social problem of interaction by considering only interactions between less social creatures. For example, we can only consider the interaction between the vector of a disease with its host. To motivate this we will consider the spread of malaria by mosquitoes, in particular the model developed by Sir Ronald Ross in 1911. The following development of the model can be found in *A Short History of Mathematical Population Dynamics* by Nicolas Bacaër.

Consider a population N of people, a number of which $I(t)$ is infected with malaria at time t. In the area we will assume that there is a population of mosquitoes n, of which $i(t)$ of them are carrying malaria. Consider a small time interval Δt. If b is the average biting rate of the mosquitoes, then $b\Delta t$ humans will be bitten by mosquitoes in that time interval. Among the humans bitten, only a proportion, $(N\text{-}I)/N$ are susceptible to infection. Assume that the probability of infection when bitten by an infected mosquito is p' so that each of the $i(t)$ infected mosquitoes is generating on average

$$b\,p'\frac{N-I}{N}\Delta t$$

infections. Let a be the average recovery rate of infection, which means that $a\,I\,\Delta t$ infected individuals recover. So then, we have

$$\Delta I = b\,p'i\frac{N-I}{N}\Delta t - a\,I\,\Delta t.$$

Dividing through by Δt and letting $\Delta t \to 0$ gives

$$\frac{dI}{dt} = b\,p'i\frac{N-I}{N} - a\,I.$$

A similar calculation can yield a similar ODE for infected mosquitoes:

$$\frac{di}{dt} = b\,p\left(n-i\right)\frac{I}{N} - m\,i$$

where p is the probability of disease transmission from an infected human to a mosquito, and m is the mortality rate of mosquitoes.

This derivation may give the perception of formality, but this is not the case. You will notice the liberal usage of the term "average" in the previous derivation. We did not really do any true averaging in the probabilistic sense.

A feeding mosquito (Pratheep P S at English Wikipedia)

We modeled the interactions by assuming that somehow the interactions are "on average" uniform throughout the population and have not offered any meaningful justification for this beyond intuition. We have not, as is done in other physical modeling problems, started with a physical law. So while we have modeled interactions between humans and mosquitoes, we are left with the question: Have we modeled it correctly? Answering this question is beyond the scope of this article, but there are ways to evaluate how effective the model is, e.g. comparison with data.

Long-Term vs. Transient Behavior. We continue with the previous example to highlight the next challenge. Since malaria is endemic in many of the countries that interested Ross, what can be done to eliminate it in this endemic state? One way to study this is to consider equilibrium solutions, where populations of people and mosquitoes remain constant, and the number of infected individuals in each population remain constant. We can solve the ODEs for zero time rate of change and find the constant solutions:

$$\bar{i} = n\frac{1-\dfrac{amN}{b^2pp'n}}{1+\dfrac{m}{bp}} \qquad \bar{I} = N\frac{1-\dfrac{amN}{b^2pp'n}}{1+\dfrac{aN}{bp'n}}$$

These are only physically feasible when they are non-negative, and in an endemic state, these constant solutions should be positive. A brief calculation yields the following threshold for n: Equilibria are only positive if

$$n > \frac{amN}{b^2pp'}\,.$$

When n is less than or equal to this value the disease cannot be endemic. This inequality can then be used to justify the assertion that malaria can be removed from a population by merely decreasing the population of mosquitoes

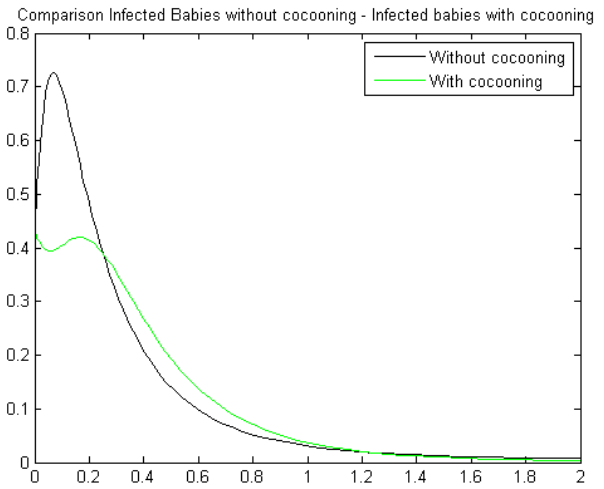


Figure 1 - Simulations of a Pertussis Model with and without cocooning

below a certain level. However, this was based on many assumptions that we hope are at least approximately true, e.g. constant populations. But even if we assume that the model describes all of these things perfectly, we still have many unanswered questions that are relevant, e.g. how long will it take for the disease to be eliminated from the population?

In the midst of an epidemic, we are not in the endemic state: the number of individuals being infected by the disease is climbing. It is generally not an acceptable public health policy to allow the disease to run its course until it reaches some long term steady state. We want to reduce disease burden immediately, and so when we develop control strategies from our models, we need to be mindful of what we want to accomplish. In a malaria epidemic, while we may, in the long term, reduce disease burden to 0 over a long enough period of time, we still need to consider how we can reduce disease burden in the short term.

To illustrate why this is important, consider an example from my recent research. When a child is first born, the current vaccination schedule has them wait at least two months before they receive their first dose of a Pertussis vaccine. In the interim, doctors will often recommend that the parents "cocoon" the child: Have everyone in the household receive a pertussis vaccine, and limit interactions with non-vaccinated individuals. In recent years the effectiveness of this strategy has been called into question with statistical studies being divided on the issue, particularly in light of recent outbreaks of the disease in regions with high vaccine coverage.

To address the issue from a modeling perspective, we construct models with and without a cocooning strategy implemented. We can then compare the two models with a stability analysis. My findings suggest that there are cases in which the long term behavior of the system is unchanged whether cocooning is implemented or not. With only this analysis, we may conclude that the cocooning strategy is ineffective. However, when we consider again our goals of reducing disease burden and disease eradication, we need to also consider the transient behaviors of the disease spread on its way to equilibrium. In Figure 1 we see that though the long term behavior is the same, the cocooning strategy has the potential to reduce disease burden in the short term, and hence it would be hasty to write off cocooning as ineffective just because long term behavior remains unchanged.

Conclusions. In these two examples we have seen some of the challenges in developing models for the spread of a disease. Disease spread is governed by not only biological factors, but by social and cultural factors as well. So then, modeling these details is not always a question of making a more complicated model since we may not even know how to include these factors. We have also seen that while long-term analyses can tell us much about the extended future of a disease, in order to assess the effectiveness of a control strategy we must be willing to take into account the transient behavior of the disease. The goal, as a disease modeler, is to develop novel methods to overcome these difficulties as well as applying known methods into new contexts with the goal of improving quality of life for individuals as well as whole populations.

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Calculus Dreams in Dubai

By Katerina Hall

I came to UM initially with three thoughts in mind. Well, more like three subjects. I wanted to sing, speak Arabic, and do as much math as I possibly could. Today, I am a math major with minors in vocal performance and Arabic studies, so I guess you could say I have found what I was looking for. A sort of culmination of this search happened last spring semester.

From February to May, I flew across oceans and continents to study in the United Arab Emirates. As the first student from UM to study abroad at the American University of Sharjah (AUS), I was understandably nervous. However, my desire to visit the Arab World extends back to the day I first learned to speak Arabic.

As a student at AUS, time not spent studying or sleeping becomes time spent roaming Dubai with friends. Oddly enough, in Dubai, you hardly hear Arabic spoken between people on the street. It is an extremely international city, nearly everyone speaks English. In fact, very few residents of Dubai are actually Arab, let alone Emirati. Due to this, I fit in quite well.

Yet, I am a Montana girl, more accustomed to surrounding mountains than to craning my neck to see the top of the world's tallest building from its base. While I occasionally felt out of place, Dubai and Sharjah slowly grew to be another home. There, as here, my friends thought I was crazy to take so many credits and do so much outside of school.

Katerina overlooks the foothills of Al Ain in the Emirate of Abu Dhabi during a study break from the AUS.

As a central point of global interaction, it is incredibly easy – and common – to use Dubai as a jumping off point for travel. In under five months, I saw Oman, Bahrain, Sri Lanka, and London. Each place had its own personality

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