SigmaCamp Lectures

August 13-19, 2023

Lecture dates are subject to change

Contents

Sun, Aug 13: Opening Lecture

The Ocean: A Voyage Through Complexity
by ***Elena Yakubovskaya***

The ocean is a mysterious puzzle, an exciting frontier for exploration and conservation. Countless interconnected elements, including diverse marine life as well as dynamic physical and chemical processes, shape its waters. Most of us underestimate how vital the ocean is to the planet, not as a mass of water, but as a living body. In this lecture, I'll attempt to give you a sense of the ocean's remarkable intricacy and the ongoing research that brings us one step closer to unraveling its mysteries.

About the lecturer: *Elena received her PhD in biochemistry and spent several years working as a molecular and structural biologist, exploring the architecture of DNA protein complexes. Her career took an unexpected turn five years ago when she joined the Department of Marine and Atmospheric Sciences at Stony Brook University to investigate algal viruses and extracellular vesicles. Elena's passion and excitement for marine science have increased progressively over the years, but she can only consider herself a true field marine scientist after her first 6-week ocean expedition to research oxygen minimum zones in the spring of 2023. Elena loves the ocean, its complexities, and mysteries, and plans to deepen her studies in marine biology.*

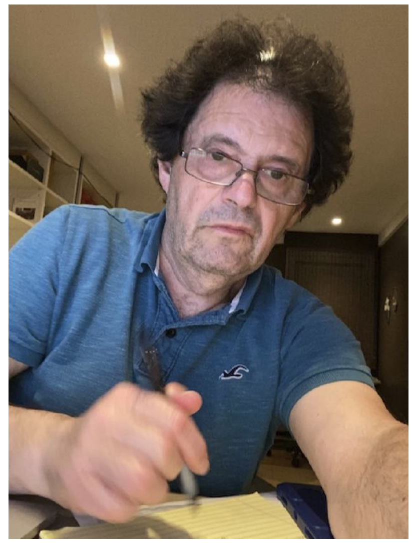
Monday, Aug 14

Entropy? How to Model Complex Systems
by ***Boris Barron***

There tends to be a belief that human systems are too complex to predict, but our intuition contradicts this. Many of us have mastered the art of avoiding rush hour traffic and those among us who are particularly clever understand why restrooms tend to be cleaner on upper floors. But how can we model such human systems and, more importantly, how can we justify our choice of parameters? In this lecture, our working example will be residential segregation – the apparent separation by race of where people live – and we will claim that the model we construct for this system is the 'best' possible. Our mathematical tools will come from information theory, and we will cover the axioms of entropy and the ideas behind entropy maximization (MaxEnt). Come learn why I believe entropy is the best thing since sliced bread.

About the lecturer: *Boris is working on his PhD in Physics (with a minor in Policy Analysis) at Cornell University. He has a BSc in Biophysics from York University (2017) and MSc in Mathematical and Theoretical Physics from the University of Oxford (2018). He has broad research interests and is presently working on building data-driven models of residential segregation, basketball, and high-entropy alloys. He is also a fan of good bread.*

100 Years of Relativity
by *Michael Bershadsky*



The special relativity was an ingenious breakthrough at the beginning of 20th century that united the space and time. The general relativity was a natural generalization of special relativity that allowed to include gravity. It turned out that the natural language to describe gravity was not a Newtonian potential but the geometry. We will show how the geometric description of gravity naturally leads to the prediction of black holes and gravitational waves. Today, we know that there are many black holes in the universe around us and recently, a 100 years later, the gravitational waves were finally observed.

About the lecturer: *Michael Bershadsky got his PhD in physics from Princeton University in 1990. Immediately after this he came to Harvard University, where he was on the faculty until 2000. In 2000 he resigned from Harvard University and joined a financial company. In late 2022 he retired from financial company and join Princeton genomics project as a volunteer. At Princeton he is involved with various data analysis of genomics data.*

Around Longest Increasing Sequences
by *Alexander Borodin*

Write all numbers between 1 and 1000 in random order (there are 1000! possibilities), and look for the longest left-to-right increasing sequence. How long is it going to be? This innocently looking question has many equivalent formulations that include a game of solitaire, airplane boarding, and crystal growth. The goal of the lecture is to explain those and to discuss how the answer to the original question brings all of them together.

About the lecturer: *Alexei Borodin received his Ph.D. in mathematics from the University of Pennsylvania in 2001. He was a professor at Caltech in 2003-2010, and since 2010 he is a professor of mathematics at MIT. Alexei enjoys working on problems on the interface of algebra and probability.*

AI and Precision Medicine: Can ChatGPT and Deep Learning Help Decode Our Genomes?
by *Olga Troyanskaya*

A key challenge in medicine and biology is to develop a complete understanding of the genomic architecture of disease. How does a specific letter of our DNA relate to whether we have curly or straight hair, or are at higher risk of cancer? How is it that all cells have the same "genes", yet highly specialized cells in our kidney are so different from those in our skin? I will focus on the 98% of the genome that is outside of genes (noncoding genome) and is most challenging to "decode". We will talk about how AI approaches and deep learning have become critical in understanding the regulatory language of DNA and how those methods can help us identify variants that are functional and may lead to disease. Both deep learning models and their applications to medicine will be discussed, focusing on deep convolutional networks, autism, and cancer.

About the lecturer: *Olga Troyanskaya is the director of Princeton Precision Health and professor of Computer Science and Genomics at Princeton University. She is also the Deputy Director for Genomics at the Center for Computational Biology at the Flatiron Institute of the Simons Foundation. Her lab employs AI and modeling techniques to decode genomes and understand what makes cells different, how our genomes encode who we are, and the complex networks at all levels of biology. Through developing integrative analyses and modeling of complex molecular-level changes captured via diverse multi-omics techniques, including in experimental and clinical context, the approaches enable systems-level molecular views of human health and complex diseases. She holds a Ph.D. in Biomedical Informatics from Stanford University, is a ACM fellow and is a recipient of the Sloan Research Fellowship, the National Science Foundation CAREER award, the Overton award from the International Society for Computational Biology, and the Ira Herskowitz award from the Genetic Society of America.*

Automata Theory: The Foundations of Computer Science
by *Anatoly Zavyalov*

Automata theory is a foundational pillar of theoretical computer science, allowing us to abstractly represent computers and other computational models. By studying automata theory, we can answer questions about what computers are capable of, and how efficient they are at certain tasks. Automata are used everywhere, from theoretical problems like P vs NP, to real-world applications like the design of programming languages, compilers, and interpreters. Automata theory can even help to solve problems in various areas of math such as number theory, creating another fascinating intersection between computer science and mathematics. In this lecture, we will introduce different kinds of automata like finite automata and Turing machines, and showcase many intriguing applications of automata theory.

About the lecturer: *Anatoly Zavyalov is an undergraduate student at the University of Toronto studying mathematics, computer science, and physics. His recent research is on how automata theory can be used to solve problems in number theory and other areas of math, and on finding algebraic methods for concurrent program verification. In 2021-2022, Anatoly created software for tracking the layout and deployment of large radio interferometers, which will be used in the upcoming Hydrogen Intensity and Real-time Analysis eXperiment (HIRAX) and the Simons Observatory.*

Tuesday, Aug 15

JWST and the "Crisis" of Early Galaxy Formation
by *Betsy Barton*

Most of the time, when newspapers talk about a "crisis" in science, the crisis part is overblown. The James Webb Space Telescope, launched on Christmas Day in 2021, is not really any different. One of its flagship science capabilities is to search in the very distant universe for the first galaxies to form significant amounts of stars. Happily, the telescope has revealed bright, big galaxies much earlier than most models expected. Is it really a crisis or just a wonderful new set of information about how galaxies formed?

About the lecturer: *Betsy began her career as an academic astrophysicist, studying the evolution of galaxies, as a professor in the Department of Physics & Astronomy at the University of California, Irvine. There, she studied galaxy interactions and galaxy formation in both the nearby and distant Universes. She was also instrumental in the early development of large, ground-based telescopes such as the Thirty Meter Telescope. In 2011, she moved to Renaissance Technologies, where she modeled equity and futures markets using new techniques. Later she joined Walmart In-Home Delivery as a senior director, where she formed and led the data science team. She founded a tech company, Infiniscape, in 2020 and launched its flagship app, Kyndr, in 2022, to spark a revolution of kindness and authenticity in social media. Believing that "astrophysics, quantitative finance and data science are just three forms of the same skill set," Betsy continues to focus on the big picture, serving as a board member of The Association of Universities for Research in Astronomy (AURA).*

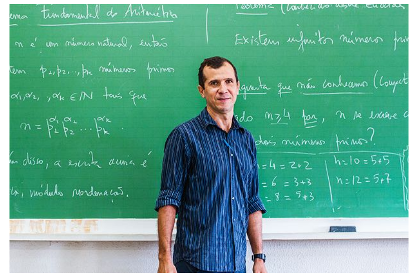
Beyond Good and Evil: Oxygen in the Living Cell
by ***Alexander Galkin***

This captivating exploration delves into the intricate transformation of oxygen in the living cell, unveiling the paradoxical duality of oxygen effects. Oxygen, a vital component of our life, serves as both a key molecule in energy production and a destroying force capable of damaging of cellular structures. We will examine the fascinating interplay between oxygen's constructive function as a key participant in intracellular energy production, and its detrimental role as an oxidant of vital molecules, including DNA, cellular membranes and proteins. By digging into the delicate balance between oxygen's utility and damage, we gain insights into the fundamental dynamics that shape processes in aerobic cells and the implications for maintaining cellular function in health and disease.

About the lecturer: *Alexander received his PhD in Biochemistry in 2001 at Moscow State University and completed postdoctoral studies at Frankfurt University and University College London. Dr. Galkin's research lab at the Brain and Mind Research Institute, Weill Cornell Medicine, focuses on studying the role of mitochondria-associated metabolic changes in tissue injury during cardiovascular diseases such as stroke and neonatal ischemia, as well as neurodegeneration.*

Can Machines Think? Exploring the World of Intelligent Chatbots and Their Impact

by *Krerley Oliviera*



The age-old question, "Can a machine think?" has sparked continuous debates and criteria, such as the Alan Turing's "imitation game", to define what "thinking" truly is.

While opinions differ, it is undeniable that we are increasingly utilizing technologies that emerged after 2013, including intelligent chatbots. If you thing that you are not using, be sure that someone is using to trick you. Like me, asking them to write this summary :) This lecture aims to enhance our understanding of these systems (a.k.a.: language models and large language models) , with a special emphasis on their applications in critical areas such as health, justice, and corruption prevention, particularly in Brazil. We will delve into their origins and the underlying, often overlooked, some mathematical principles. However, brace yourselves for a thought-provoking discussion that might lead to more questions than answers, as we delve into the intricate world of artificial intelligence and its societal impact.

About the lecturer: *Krerley Oliveira is mathematician working on Ergodic Theory (google it!) and math applications on real problems on Natural Language Processing and Computer Vision at Federal University of Alagoas, at Maceió-Brazil (google it also! :). He expanded his professional and cultural experiences by undertaking academic roles at renowned institutions like Penn State and Université de Paris XI for one year each, some time ago. In addition to his research, Oliveira exhibits a strong dedication towards fostering mathematical proficiency in young learners. Outside academia, he has a keen interest in endurance sports. As an amateur trying-athlete, Krerley particularly enjoys participating in triathlon events and has developed a preference for long-distance races.*

Artificial Intelligence and the Society
by *Michael Schwarts*

This talk offers a short overview of the evolution of AI technology. L.J. Henderson famously said that "Science owes more to the steam engine than the steam engine owes to science". Is AI the 21st century steam engine? Will science owe more to AI than AI to science? I will discuss connection between AI and information theory. You will learn about the connection between Shannon's Game that was invented over 70 years ago and today's large language models. Last but not the least we will discuss the impact of AI on the economy and the society.

About the lecturer: *Michael Schwarz is Microsoft's chief economist and Corporate Vice President. Before joining Microsoft, Michael worked at Google for six years in various roles. Most recently he was the Chief Economist for Google Cloud. Prior to that he was the Chief Scientist for Waze. Before his tenure at Google, Michael was the head of the economics research unit at Yahoo! His most externally visible project at Yahoo! was developing algorithms for setting optimal reserve prices for search advertising auctions, which had a noticeable impact on overall company earnings. Michael started his professional life as a faculty member at Harvard University's Economics Department. Michael holds a PhD from Stanford Graduate School of Business and an MS in Physics from the University of California at Davis.*

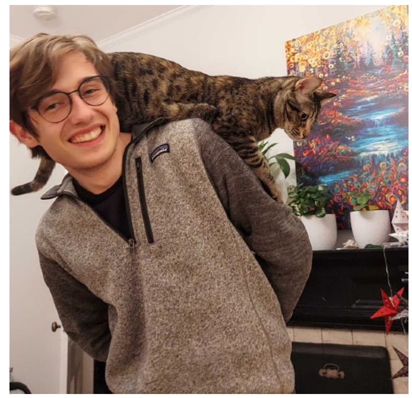
The Final Frontier: Brains and How to Harness Them
by *Alexander Suponya*

What is neural engineering? Where is it going? And when will AI cyborgs seize the means of production? Two ongoing booms - in neuroscience and computer engineering - are driving many mind-blowing advances in the current landscape of medical technology. At the same time, high level reasoning machines - whether artificial or biological - pose many unknowns that are yet to be explored. Today, we will test our knowledge of our brains and discuss how innovations like brain-computer interfaces, smart prosthetics, and other aspects of brain-adjacent robotics can benefit the fields of medicine, cognition and so much more.

About the lecturer: *Alexander Suponya is a fifth-year Sigma counselor and a rising senior studying biomedical engineering and computer science at Rutgers University. His prior research explored the effects of epigenetics on neural plasticity in the auditory cortex as well as retinal autophagy in animal models. Alexander worked at a co-op program for Ring Therapeutics on qPCR primer design and tissue processing and at Bristol Myers Squibb developing Python scripts for small molecule drug discovery. This fall, Alexander will enter a soft robotics project under Dr. Joseph Freeman and is working on computational polymer chemistry pipeline for Dr. Adam Gormley. Alexander is the founder and president of the Rutgers Linguistics Club and lacks any identifying cyborg features in any way, shape or form.*

Wednesday, Aug 16

Keeping Time Through Time: A History of Timekeeping Devices and (Brief) Overview of Quantum Sensing
by *Alec Douglas*



Recent studies have been able to make time pieces so accurate as to measure the difference in gravitational potential across millimeter scales. The progress in precise measurements in time has steadily allowed us to measure smaller and smaller regimes ultimately reaching deterministic control of atoms, as well as synchronize larger and larger systems, from train systems, then GPS and now GHz speed telecommunications. I will talk about the evolution of timekeeping from mechanical devices, to electromechanical, and ultimately atomic methods. I will then give a brief overview of the future of time keeping: entangling atoms.

About the lecturer: *Alec is a Harvard Physics Graduate student. His PhD work is related to simulating exotic materials, such as high temperature superconductors by trapping and observing the collective behavior of many atoms tapped by light. In particular we can simulate the behavior of insulating materials by mapping the behavior of electrons hopping around in a crystal of atoms to atoms hopping around in crystals made of light. When he is not in the lab, Alec enjoys biking, rock climbing, video and board games.*

How Brains Think ... and How ChatGPT Thinks.
by ***Richard Granger***

Up through 2022, expert naysayers were patiently explaining to us why "deep learning" neural networks could never conquer natural language, without fundamental changes to their architecture. They were right, and the large language models (such as chatGPT) do indeed represent a fundamental swap-out of standard artificial neural nets, for the newer architecture of transformers. So, then, what are transformers doing so differently? In short, quite unlike standard deep learning networks, transformers build the mathematical structure of grammars. Substantial research programs indicate that the circuitry of your brain also builds grammars. Perhaps, then, it makes very good sense that transformers have abruptly succeeded where previous methods fell short.

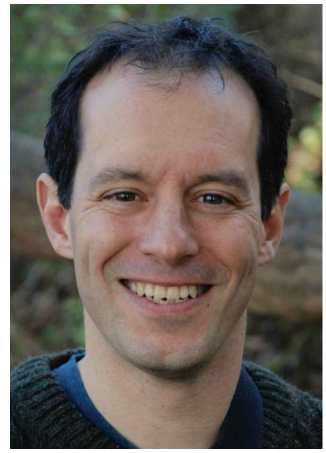
About the lecturer: *Richard Granger received his Bachelor's and Ph.D. from MIT and Yale. He is a Professor at Dartmouth with joint appointments in the Department of Psychological and Brain Sciences, the Thayer School of Engineering, and the Cognitive Science Program; he directs Dartmouth's interdisciplinary Brain Engineering Laboratory (brainengineering.org), with publications and patents ranging from computation to cognition to basic neuroscience. He advises multiple technology corporations and government research agencies, is co-inventor of FDA-approved devices and drugs in clinical trials, and has been the principal architect of a series of advanced computational systems for military, commercial, and medical applications.*

What Color is Sigma Spirit? Short Stories about Chemistry and Light
by ***Eugene Pinkhassik***

Chemistry is awesome. We will use spectacular demonstrations to illustrate several topics in one of the most fascinating areas of chemistry, the interactions between molecules and light. We will talk about why chemical substances have incredibly diverse colors, how light can influence chemical reactions, and what we can learn from observing the interplay between light and molecules.

About the lecturer: *Eugene Pinkhassik graduated from Kazan State University in Russia and obtained his PhD in Chemistry in the Institute of Chemical Technology in Prague, Czech Republic. After a visiting scientist stay in Parma, Italy and a postdoctoral fellowship at the University of Colorado, Boulder, he began an independent faculty career. He is currently an Associate Professor at the University of Connecticut. His research interests focus on making nanomaterials and nanodevices with new and superior properties to address current problems in energy-related technologies, medical imaging and treatment, and environmental sensing.*

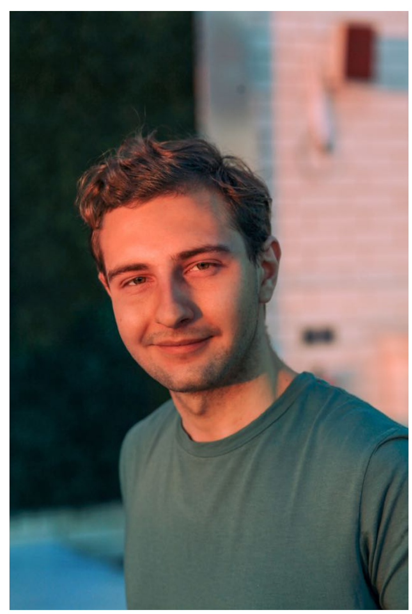
How to Agree With Your Friends When You Don't Know Who Your Friends Really Are
by *Adam Smith*



How can a group of people or computers who don't trust each other agree on something when all they can do is talk to each other one-on-one? We will see why this problem, variants of which are called "consensus" or the "Byzantine generals problem", can be very hard to solve. We'll also talk about how systems like Bitcoin get around the fundamental difficulties. Along the way, we'll touch on issues from the nature of time—can a network really be synchronized?—to how computers elect their own leaders.

About the lecturer: *Adam is a professor of computer science at Boston University and, for the 2023-2024 academic year, a research scientist at Google. His areas of research include cryptography and information privacy. He is known as one of the co-inventors of differential privacy, for which he won the 2017 Gödel Prize and the 2022 Kanellakis Prize.*

How Game Theory Plays Out In Our Lives
by *Nestor Tkachenko*



From the logic behind war and religion to the success of Google, game theory shows up everywhere in our world. In this lecture we will discuss the basics of game theory, a branch of mathematics, and how it materializes in the world around us in many forms such as bidding strategies and military tactics. Throughout the lecture we will also discuss how to use game theory to make optimal decisions, and allow you to participate first-hand in the prisoner's dilemma to apply game theory to win a cash prize.

About the lecturer: *Nestor is the CEO of Rito Foods, a company that runs robotic restaurant kiosks and is working towards disrupting the food service industry. Nestor previously dropped out of Harvard to pursue the startup, where he studied physics and computer science. Before starting the company, Nestor had worked on a wide variety of business and research projects, including doing research on commercially viable levitating vehicles and electronically stimulated paraplegic walking devices. He also implemented the launch of a scooter sharing service on Harvard's campus and commercialized the phosphorescent drawing board for the online market.*

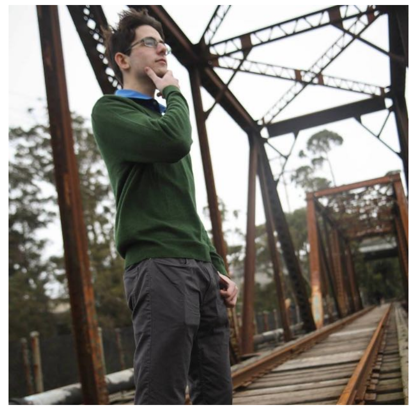
It's All Modeling: What do Cells, Social Networks, and Weather Prediction Have In Common?
by *Olga Troyanskaya*

Biology is complicated business - each cell is made up of complex networks of interacting biomolecules, and dysregulation in these processes can lead to devastating consequences such as cancer. I will discuss how we can study these networks using advanced computational methods to 'dig' through millions of noisy and often irrelevant data points to map out key cellular relationships. I will introduce how we use Bayesian networks, a machine learning and statistical approach often used in other domains, including weather forecasting, to make confident predictions from many noisy measurements. Finally, we will explore how all these methods are applied to cutting-edge biological data to understand (and hopefully help treat) complex diseases.

About the lecturer: *Olga Troyanskaya is the director of Princeton Precision Health and professor of Computer Science and Genomics at Princeton University. She is also the Deputy Director for Genomics at the Center for Computational Biology at the Flatiron Institute of the Simons Foundation. Her lab employs AI and modeling techniques to decode genomes and understand what makes cells different, how our genomes encode who we are, and the complex networks at all levels of biology. Through developing integrative analyses and modeling of complex molecular-level changes captured via diverse multi-omics techniques, including in experimental and clinical context, the approaches enable systems-level molecular views of human health and complex diseases. She holds a Ph.D. in Biomedical Informatics from Stanford University, is a ACM fellow and is a recipient of the Sloan Research Fellowship, the National Science Foundation CAREER award, the Overton award from the International Society for Computational Biology, and the Ira Herskowitz award from the Genetic Society of America*

Thursday, Aug 17

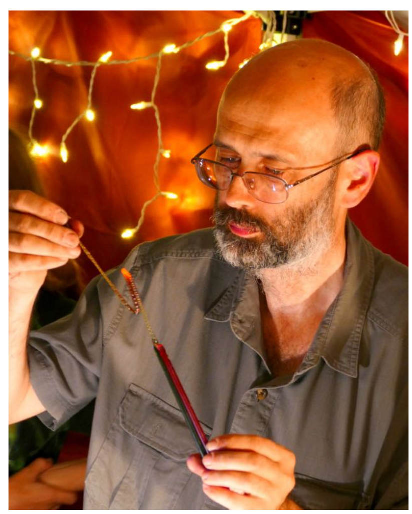
Quantum Mechanics and Baby Universes
by *Alex Frenkel*



It turns out that combining quantum mechanics and general relativity forces upon us the idea of the multiverse. In fact, this idea appears in so many different flavors that the definition of a multiverse depends on which physicist you're talking to. In this talk, I will go over a few different ideas in modern quantum gravity that could be called a multiverse (the string landscape, baby universes, and the Everett Many Worlds interpretation) and why they seem to be inescapable.

About the lecturer: *Alex is a fourth year Ph.D. Student and NSF GRFP fellow at Stanford University, after graduating from UC Berkeley in 2019. His primary research interest is in studying how to cut open spacetime in string theory - an idea that's crucial to a our modern understanding of event horizons and quantum gravity at large.*

Did Darwin's Theory "Justify" Racism?
by *Mark Lukin*



According to many modern authors, Darwin, along with Abraham Lincoln and other great contemporaries, definitely was a racist, and "ideology of evolution" was used to "justify" racism. Is this view correct, and can 19th century European science be considered racist? What does modern Darwinism actually say about race and racism? What is the future of humankind from the point of view of evolutionary theory? What is a danger of the term "racism"?

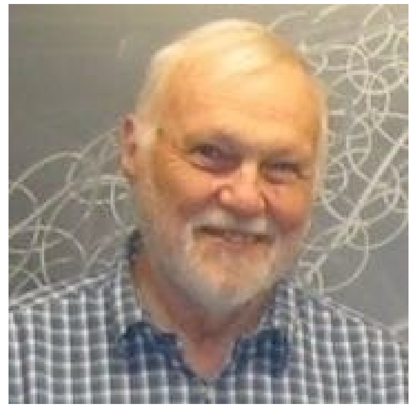
About the lecturer: *Mark Lukin is a Research Assistant Professor in Pharmacology Department of Stony Brook University, NY. The focus of Mark Lukin's scientific interest are nucleic acids (DNA and RNA) — the molecules responsible for storage and transfer of hereditary information in living organisms. How does DNA get copied? What happens when DNA molecules break? To answer these, as well as many other questions, Mark needs to prepare artificial (modified) nucleic acids and their building blocks, the crazy compounds that normally do not exist in nature. The only way to obtain them is to do a chemical synthesis, the thing Mark likes the most. Besides that, Mark loves music, history, Greek philosophy, and science fiction. When he was young, he loved to do simple but spectacular chemical experiments. Recently, he realized he still loves to do that.*

Lies, Damned Lies, and Statistics
by ***Lilianne R. Mujica-Parodi***

Statistical inference is normally considered to be the bedrock of the biomedical sciences, yet in many ways, it also has the potential to mislead. In this talk, we'll review where standard statistics adds value, where its underlying assumptions and misuse become problematic, and motivate the integration of other approaches.

About the lecturer: *Lilianne R. Mujica-Parodi is Director of the Laboratory for Computational Neurodiagnostics, Baszucki Endowed Chair of Metabolic Neuroscience, and Professor in Stony Brook University's Department of Biomedical Engineering. She also holds academic appointments in the Laufer Center for Physical and Quantitative Biology, Program in Neuroscience, and Departments of Neurology, Psychiatry, and Physics. In addition, she is Research Staff Scientist and Lecturer in the Department of Radiology at Massachusetts General Hospital and Harvard Medical School (Athinoula A. Martinos Center for Biomedical Imaging). Dr. Mujica-Parodi received her undergraduate and graduate degrees from Georgetown University and Columbia University, respectively, studying mathematical logic and foundations of physics. After her Ph.D. (Niles G. Whiting Fellow), she completed an NIH Training Fellowship in Clinical Neuroscience at Columbia University's College of Physicians and Surgeons. She was subsequently promoted to Assistant Professor there, where she performed research until being recruited by Stony Brook University. She is the recipient of the the National Science Foundation's Career Award, the White House's Presidential Early Career Award in Science and Engineering, and the Fulbright Distinguished Scholar Award. Dr. Mujica-Parodi's research interests focus on the extension of control theory to allostatic regulation of neural circuits and their interactions with other physiological systems, in health and disease.*

SAT Labyrinths: The Math Hidden In a 5000-Year-Old Cultural Archetype
by ***Tony Phillips***



Labyrinth here will mean a special kind of maze with no forks and only one path. (Before the 16th century, all mazes were of this type). SAT labyrinths are a special type that has been around for some 5000 years. One of them, connected with a drawing game still played by children in India, is the well known "Cretan Maze." These labyrinths have a simple mathematical structure that we will work out and use to generate new examples.

About the lecturer: *Tony Phillips is a topologist, Professor Emeritus of Mathematics at Stony Brook. He works in differential topology -the interplay of calculus with shapes- and in its applications to problems in physics. He has always been interested in the relations between mathematics and the other sciences, and between mathematics and human culture in general.*

Algorithms for Streams
by ***Sofya Raskhodnikova***

Suppose at the Sigma tournament, you are shown a sequence of cards with an integer on each card, one card at a time. You are told that all numbers from 1 to 100, except for one number, will appear in an arbitrary order. Your goal is to figure out what number is missing as quickly as you can after the last card is shown. The caveat is that you are not allowed to write anything down. Can you come up with a strategy that will allow you to do a computation in your head and remember one 2-digit number after each card is shown? This is an example of an algorithmic problem, where data arrives as a stream, and we have to perform some computation while using as little memory as possible. In this lecture, we will discuss a solution to this puzzle and to several other streaming problems. In some cases, our algorithms will use randomness.

About the lecturer: *Sofya Raskhodnikova is a professor of Computer Science at Boston University. She received her undergraduate and graduate degrees in mathematics and computer science from MIT. Sofya works in the areas of randomized and approximation algorithms and also data privacy. These areas are part of theoretical computer science. Before joining Sigma faculty, Sofya has taught at Epsilon Camp and C.A.M.P. (Camp for Algorithmic and Mathematical Play). Her best memories of her childhood are from a math camp she attended in Belarus. As far as her hobbies go, recall that she works on privacy.*

Scientific Machine Learning: Can We Replace Scientists?
by *Helmut Strey*

In this lecture, I will introduce the field of scientific machine learning. In the last decade, Machine learning has made tremendous advances in image recognition, language modeling (ChatGPT), and has now many practical applications. Unfortunately, most of machine learning is not interpretable. Scientific machine learning is trying to extract rules from data that are interpretable. I will introduce several approaches to turn data into equations.

About the lecturer: *Helmut Strey is a Biophysicist who is interested in developing micro- and nanotechnologies for applications in basic and applied research. Specifically, his lab is working on 1) micropatterning techniques for single-cell studies, 2) study of gene circuit dynamics using probabilistic modeling, 3) developing software to simulate the human brain (Neuroblox.org). Helmut received the Dillon medal for research in Polymer Physics from the American Physical Society in 2003. He recently converted to Bayesianism and is passionate about making things, Soccer, Chess and Table Tennis.*

Friday, Aug 18

What Makes It Great: Famous Examples of Data Visualization
by ***Alexander Brook***

Graphs, charts, and plots are everywhere, from news articles to your homework to scientific papers. We will look at some landmark examples of data visualization, talk about their context, try to guess their purpose, and answer the question: what makes them great?

About the lecturer: *Alexander Brook is a biostatistician at Beth Israel Deaconess Medical Center. He has a PhD in Applied Mathematics, and used to work in computer vision. Currently, his job is to work with clinical researchers to help them design their research, collect and analyze their data, and report the results.*

The Science of Tradeoffs: Doing Economics with Everything
by ***Ori Heffetz***

I'm an economist. Economists study the tradeoffs that people make. Because when resources are limited, we always have to give up something to be able to get something else. So how much are you willing to give up one thing—like time, or money, or health—to get another thing that you'd like to have—like going on a crazy adventure? We will talk about how economists estimate the tradeoffs that people are willing to make, which are called the "marginal rates of substitution" (MRS). We will use examples from everyday life, and discuss how economists use these estimates to put a price, or at least value, on everything, including on being happy and on being outside.

About the lecturer: *Ori Heffetz is a professor in the Bogen Family Department of Economics and the Federmann Center for the Study of Rationality at the Hebrew University of Jerusalem, an associate professor in the Johnson Graduate School of Management at Cornell University, and a research associate at the National Bureau of Economic Research. He is a data-based economist, using lab and field surveys and experiments to study the psychological, social, and cultural aspects of economic behavior, well-being, and policy. He holds a BA in physics and philosophy from Tel Aviv University and a PhD in economics from Princeton University.*

The World of Cryptocurrencies
by ***Julia Kempe***

In this lecture we will delve into some of the history and the underlying principles of cryptocurrencies and aim to understand how decentralized payment schemes could work. We will illustrate what terms like "proof of work", "distributed ledger" and "blockchain" mean and how they are used.

About the lecturer: *Julia Kempe is a Professor of Computer Science and Mathematics at the NYU Courant Institute since 2018 working in Machine Learning. Before that she worked for 7 years in the finance sector. She was a Professor at Tel Aviv University and a Senior Researcher at the CNRS in France and holds PhDs in Mathematics and Computer Science, working in Quantum Computing.*

Mind-Altering Substances
by ***Tim Pinkhassik***

Mind-altering substances permeate our society and culture. Some are demonized, while some have campaigns for their legalization. What makes these substances different from each other, and why are some particularly dangerous? I will discuss the broad classes of common psychotropic substances (both legal and illegal), the pharmacological mechanisms behind a few specific cases, and the neurobiological foundations of addiction.

About the lecturer: *Tim Pinkhassik is an undergraduate chemistry student at the University of California, Berkeley and a researcher in the Hartwig group. His research focus is discovering new ways to use palladium and copper to form carbon-nitrogen and carbon-carbon bonds. At Sigma Camp, Tim is a TA for the Nobel Chemistry and Forensics semilabs.*

Astrocytes: Guardians of Brain Communication
by ***Nathan A. Smith***

Astrocytes are a type of cell in the brain that play a role in regulating communication between nerve cells. They influence different types of communication, including long-lasting and temporary changes, but understanding their role in these temporary changes remains a mystery. Some believe that chemicals released by astrocytes, such as ATP, may be involved, yet other pathways could also be at play. Using various methods to manipulate astrocytes in mice, we have discovered the vital role astrocytes play in these temporary changes. In this talk, we explore how a specific type of receptor and a molecule called endocannabinoid, produced by astrocytes, are involved in suppressing neurotransmitter release during these temporary changes. This study uncovers exciting new insights into how astrocytes regulate brain function.

About the lecturer: *Dr. Nathan A. Smith is the new Associate Dean for Equity and Inclusion in Research and Research Education and an Associate Professor of Neuroscience in the School of Medicine and Dentistry at the University of Rochester. Previously, he served as the Director of Basic Neuroscience Research, Principal Investigator at the Center for Neuroscience Research at Children's National Research Institute, and Assistant Professor of Pediatrics and Pharmacology & Physiology at George Washington University School of Medicine and Health Sciences. Dr. Smith earned his B.S. in Biology from Xavier University of Louisiana and his M.S. and Ph.D. in Neuroscience from the University of Rochester School of Medicine and Dentistry. In 2013, he became the first Black American to receive a Ph.D. from the neuroscience program at the University of Rochester School of Medicine. Following graduation, Dr. Smith conducted postdoctoral research at the University of Utah, Boston University, and Children's National Research Institute. Dr. Smith has received numerous honors and awards throughout his career, including the Vanderbilt University Juneteenth Award in 2022. He was elected as a 2021 Fellow of the American Association for the Advancement of Science (AAAS) and was recognized by Cell Press as one of the 1000 most inspiring Black Scientists in America in 2020. Additionally, he received the 2019 Neuroscience Alumni Award from the University of Rochester and the 2018 Children's National President's Award for Innovation in Research. Dr. Smith's research focuses on investigating the understudied and novel mechanisms by which neuromodulators mediate interactions between neurons, astrocytes, and microglia in normal and disease states. He utilizes a combination of transgenic animals, electrophysiology, pharmacology, behavioral assays, and 2-Photon Ca2+ imaging in acute slices and awake-behaving animals.*

Saturday, Aug 19

The Art and Science of Seeing Through Things
by *Olga R. Brook*

Diagnosis in modern medicine is now nearly exclusively based on imaging, which includes X-Ray, CT, MRI, and ultrasound. In this lecture, we will explore how different imaging techniques use the principles of anatomy, physiology, and physics to construct detailed visual representations of the human body as well as to guide minimally invasive surgery. Through several real-life cases from the daily practice of a radiologist you will gain firsthand experience in diagnosing illnesses with imaging.

About the lecturer: *Dr. Olga R Brook is a diagnostic and interventional radiologist. She serves as section chief of Abdominal Radiology and vice chair of Research at the Department of Radiology, Beth Israel Deaconess Medical Center in Boston. She is an Associate Professor at Harvard Medical School and has authored over 150 publications. Her research focuses on minimally invasive procedures, advanced CT techniques, and improvement in women's health interventions.*

So How EXACTLY do Quantum Computers Factor Semiprimes?
by ***Andrey Khesin***

Many of us have heard it said that quantum computers can factor large integers into their prime factors much faster than classical computers. But how exactly do they do that? We sometimes hear of quantum computation being able to ”do many operations in parallel” but what is really happening under the hood? Unlike what first comes to mind, quantum computers are not dividing our semiprime by every possible prime factor and seeing if it divides evenly. Instead, they use some clever number theory to find a periodic pattern that repeats predictably with a frequency determined by the prime factor we seek. In this lecture, I'll go over the details of how this works and demonstrate some of these steps with examples. See you there! Basic familiarity with remainders or modular arithmetic recommended.

About the lecturer: *Andrey has been at SigmaCamp since the very beginning. He is working on his PhD in Math at MIT. He is always open to chat about math, physics, or computer science! At SigmaCamp, he runs the Game Theory semilab. His favourite hobby is playing board games, some of his favourites are Terraforming Mars and Spirit Island. Additionally, he greatly enjoys square dancing and contra. He tries to find time to play guitar, so if you want to jam together, let him know! His research is in quantum computing and quantum information theory. He is investigating quantum compilers and ZX calculus, studying applications of linearizing quantum non-local games.*

Epidemic Modeling
by ***Katrina Ligett***

During the COVID pandemic, scientists needed to make predictions about how quickly the pandemic would spread, how many hospital beds would be needed, and what the impact of vaccines would be. It turns out that even a pretty simple mathematical model of epidemics can offer a lot of insights on these issues. In this lecture, we'll learn the basics of the SIR epidemic model (for Susceptible-Infectious-Removed—the three conditions that the model assumes people can be in) and use it to make some key observations about the factors that affect the spread of epidemics. We'll also discuss some of the simplifications that the model makes, and why those might matter.

About the lecturer: *Katrina Ligett is a professor of computer science at the Hebrew University of Jerusalem. Her research interests often involve mathematical modeling of things that relate to people and data, including data privacy and algorithmic fairness (what's that? ask me!). During the first year and a half of the COVID pandemic, she (like many others) did some work on epidemic modeling to try to understand the potential impact of various policy interventions on the epidemic's spread. When she has a bit of spare time, Katrina enjoys cooking, baking, gardening, singing, and playing the violin.*

Killing the Schroedinger Cat
by ***Alexei Tkachenko***

Almost everyone these days has some idea what quantum mechanics is about. Have you heard of a Schroedinger cat that can be both dead and alive? Or how Einstein was allegedly wrong saying that God does not play dice? Or how our world is an uncertain place because of Quantum Uncertainty? What if I tell you none of these claims are true?

About the lecturer: *Alexei Tkachenko is a theoretical physicist at Brookhaven National Laboratory working on nanoscience and in the field called soft condensed matter. He studies problems that range from from living matter (DNA, proteins, membranes) to nanoparticles, plastics, and even sand. He also teaches physics at School Nova. At past SigmaCamps, Alexei was responsible for the tastiest of all the semilabs, called "Thermal Physics in the Kitchen"*

Chernobyl Accident: What Went Wrong and How It Happened
by *Igor Zaliznyak*

Several years ago, I visited the site of the Chernobyl nuclear power plant accident and explored the situation there with a dosimeter from the Radioactivity Semilab that I was teaching at Sigma Camp. In first days of May of 1986, at the time of the disaster, I was in Kiev and saw some of the response that was happening and the overall confusion as the scale, the cause, and the implications of the accident were totally unclear. Things have been mostly clarified since then, and now the causes, how the disaster unfolded, and much of its outcomes are known. In 2019, the HBO made a mini-series about the 1986 accident at the Chernobyl nuclear power plant, while following my visit I have prepared a presentation of my own covering the science, the causes, the timeline, and the consequences of the disaster. In this lecture, I will discuss the 1986 Chernobyl events and the science behind them, how my findings compare with the HBO TV series, and how accurate the series is in depicting the accident.

About the lecturer: *Dr. I. Zaliznyak is a physicist at Brookhaven National Laboratory, where he studies microscopic quantum properties of matter using neutron particles. Among others, these properties include exotic quantum states of electrons in metals, such as superconductivity, magnetism, and superfluidity in quantum liquids, and also various structural responses of materials relevant for emergent technologies, such as negative thermal expansion. Using neutrons as probe particles similar to electrons in an electron microscope, allows to study microscopic structure and atomic motions in bulk materials with atomic resolution. These studies are conducted at large national facilities where neutrons are produced either in a specially built research nuclear reactor, or in an accelerator complex by protons smashing the nuclei of a heavy element target, such as tungsten or mercury. Dr. Zaliznyak performed his doctoral research jointly at P. Kapitza Institute for Physical Problems in Moscow and the CEA-Grenoble and obtained the Ph. D. degree in 1993. He joined Brookhaven Lab in 1999, following a postdoctoral appointment at the Johns Hopkins University. Dr. Zaliznyak also teaches math at SchoolNova.*