we're all affecting each other's evolution.

The early Wittgenstein was all about solving problems,” Miller said. “He wanted to ground language in logic, so he wrote the Tractatus.” Following a meeting with critic Frank Ramsey, Wittgenstein “completely changed his way of thinking, and spent the rest of his career on philosophical investigations which were just forays, snippets into this or that.” Why we should bother with snippets of isolated insights is a recurring question for Miller, and for SFI. A legendary investor, Miller is often asked how he chooses his investments, and whether his time at SFI has had any practical applications to his work. In response, he gives examples:

- Citing External Professor Brian Arthur’s work on lock-in technologies and path-dependence, Miller says he was inspired to research and buy technology stocks such as Dell, AOL, Nokia, and Apple in 1995 when they were widely perceived as too unpredictable.
- Based on an insight from an early SFI topical meeting on innovation and evolution, Miller says he bought Google shares on their Initial Public Offering (IPO), when each share went for $85. The current share price hovers near $1,500.
- He discussed Geoffrey West’s work on scaling laws and company mortality during a recent long-term planning meeting with Jeff Bezos and the Amazon.com leadership. (Miller is one of Amazon’s early investors.)
- Finally, Miller credits a 2015 SFI symposium on Decarbonizing the energy supply Shifting from carbon-emitting energy sources to renewable ones will be an essential part of addressing climate change, but the path to a renewable power grid is uncharted. A few states have already set specific renewable energy goals; last March, New Mexico passed legislation mandating that, by 2045, the state’s public electric utilities will be 100 percent carbon-free. This February 26–28, an SFI working group will explore how New Mexico might best approach the transition to renewable energy sources, and what lessons could be useful for other regions. The working group will include SFI faculty and other researchers, as well as experts who work in advocacy, government, and New Mexico’s public utilities.

"SFI has held lots of workshops on the theory of power grids, but to really work toward decarbonization, we need to dive into the details — hence the mix of local and global expertise," says SFI Professor Cira Transch (HIT), Seth Blumsack (Penn State), and Paul Hines (University of Vermont). Moore expects the meeting will result in ‘strategies specific enough to New Mexico to be useful, but at the same time provide insights that we can export to the rest of the world.’ Planning for a low-carbon energy future is inherently uncertain. We don’t know how demand, prices, or regulations will shift, and renewable energy sources themselves are variable over different timescales. Planning for daily fluctuations in wind speed or sunlight will require different technological and financial strategies than for rare, severe events that might, say, envelop an entire region in cloud cover for a week. A primary question in planning a net-zero energy system is how to avoid highly suboptimal lock-ins, says Trancik. “Once infrastructure and technology develop, it can be hard to put on the brakes. If we move toward a renewables-heavy system, for example, we’ll need ways to address extended shortages even if they pop up only once or twice every twenty years,” she says. It’s important to plan now for future challenges,
Beyond Borders

Cantor's Invisible Chemistry

The mysteries of the universe that complexity science seeks to explain are widespread and ubiquitous. Whatever the rules that govern power production, fees, or transmission. Most people, including academics and lawmakers, know little about the Regional Transmission Organizations, or RTOs, that develop these rules. But last September, committees from both the U.S. House and Senate invited SFI External Professor Seth Blumsack, with colleagues from Boise State University and Duke University, to fill them in on what the researches have learned about how it's similar and different across the tree of life.

For something as ubiquitous in modern life as electrical power, few of us know much about the rules that govern power production, fees, or transmission. Most people, including academics and lawmakers, know little about the Regional Transmission Organizations, or RTOs, that develop these rules. But last September, committees from both the U.S. House and Senate invited SFI External Professor Seth Blumsack, with colleagues from Boise State University and Duke University, to fill them in on what the researches have learned about how it's similar and different across the tree of life.

RTOs are charged with helping ensure a reliable electrical grid. (Photo: Matthew Henry)

Why Congress cares about Regional Transmission Organizations (and you should too)

What does it mean to grow old? Many fields of study have offered answers, but none of them provides a universal theory. According to former SFI Postdoctoral Fellow Ric Griffo (International Center for Theoretical Physics), we understand the when but not the how of aging: when the components of an organism fail, not the causes of these failures or if the process serves an evolutionary purpose. This February, a diverse international working group met at SFI to find a fresh take on the problem. Grilli and fellow researchers, including SFI Professor Chris Kompe, External Professor Swindriy Iyer-Biswas (Purdue), and Matteo Osella (University of Turin) will focus the discussion on single-celled organisms as bacteria and yeast in hopes of finding general features in simpler settings. Part of the challenge, Grilli says, has been that aging happens across many scales, from DNA and proteins to organs and entire organisms. By narrowing the inquiry, the group intends to prune the complications and see aging in its essence. A single yeast cell may provide analogies for human beings, and colonies are in some ways like organs. “Looking at things in this way,” says Grilli, “allows us to see multiple levels at the same time.”

One goal is to identify fruitful questions for a laboratory setting. Grilli notes the project has recruited members “with the experimental expertise to actually test theories in the real world!” Sriy Iyer-Biswas and Lin Chao (UC San Diego) are two such researchers whose innovative labs can track individual bacteria through out their life cycles.

“A key challenge in aging studies has been to identify clean experimental systems in which extrinsic (e.g., environmental) and intrinsic (e.g., genetic) factors contributing towards the aging of an organism can be precisely controlled,” says Iyer-Biswas. “Consequently, even basic questions such as how aging should be defined remain open.” In her SFI Community Lecture, Iyer-Biswas noted that new methods in cell biology reveal a cellular unit of time. “One can now ask questions that we’ve had a hard time getting a handle on previously,” she observed. “The scaling laws for growth and division of cells as they age remain the same, except the cellular unit of time itself gradually slows down.”

The implications are far-reaching. This workshop, Grilli hopes, “can unify views on aging, how it’s similar and different across the tree of life.” As biology itself approaches its 400th year, perhaps the discipline is ripe for more questions.

Working group to study aging in single-celled organisms

Since its release in September, External Professor Allison Stanger’s new book, Whistleblowers: Honesty in America from Washington to Trump, has been featured in nearly two dozen outlets, including The New Yorker, The Atlantic, NPR’s “Morning Edition,” the Washington Post, and The New York Times. The CBC featured External Professor Jessika Tranvik in a November 9 story about second-life solutions for aging batteries from electric vehicles.

SFI External Professor Dan Rockmore published an essay on November 7 in The New Yorker about where new ideas come from, and how to keep the brain moving and “get unstuck.” A November 8 BBC article explores Parkinson’s Law—the concept that any given task will take up much time as it is allotted, originally intended to point out inefficiencies in bureaucracies—citing External Professor Stephen Thau’s mathematical models testing Parkinson’s Law.


A November 8, 2021 feature on his work unearthing financial risks that regulators miss. It may provide analogies for human beings, and colonies remain the same, except the cellular unit of life itself gradually slows down.”

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Leading scientists and legal scholars are weighing in on their letter, the SFI and UNM experts demand transparency in the validation process. Their full response is posted on the Federal Register, along with over 3,500 other public comments. The co-signatories are members of The Interdisciplinary Working Group for Algorithmic Justice and are available to provide thoughts and expertise to policymakers around the proposed regulation.

The letter lays out four arguments against the proposed regulation:

1. To ensure that an algorithm does not have disparate impact, it is not enough to show that individual input factors are not “substitutes or close proxies” for protected characteristics.
2. It is impossible to audit an algorithm for bias without an adequate level of transparency or access to the algorithm.
3. Allowing defendants to deflect responsibility to proprietary third-party algorithms effectively destroys disparate-impact liability.
4. The proposed regulation fails to take into account the cumulative impact of multiple users of algorithms that result in disparate impact on protected classes where no individual user has liability under the proposed regulation.

For more information, visit: santafe.edu/research/projects/algorithmic-justice/

New books by SFI authors

The Ethical Algorithm (Oxford University Press, 2019) by SFI External Professor Michael Kearns and a colleague at the University of Pennsylvania, Aaron Roth, offers a set of principled solutions based on the emerging science of socially aware algorithm design. The algorithms that dominate much of our modern life, from advertising and consumer lending to college admissions and hiring, have also routinely violated basic rights of individual citizens. Most fixes thus far have focused on legal and regulatory solutions, but Kearns and Roth propose fixing technology from the inside with algorithms embedded with precise definitions of fairness, accuracy, transparency, and ethics.

Artificial Intelligence: A Guide for Thinking Humans (Macmillan Publishers, 2019) by SFI Science Board co-chair and David Travis Professor of Complexity Melanie Mitchell lays bare the inner workings of the potential tools of AI, exposing their limitations and patiently detailing our deployment errors. It presents a plain-speak, human-readable primer on the new technologies that have transformed human computing and makes use of that foundation to caution the reader against placing too much trust in automated systems that they don’t fully understand. It is going to be a while before machines can think, and until then we need more people who can think for our machines, and for ourselves. [1]

Asking questions that matter

If you could answer any question you put your mind to, what would you ask?

For Ramanan Laxminarayan this is not a hypothetical, three-wishes kind of question— it’s a real dilemma that early career researchers need to confront head-on. At the seventh Postdocs in Complexity conference, he’ll be coming to Harvard to hash out some answers with the Santa Fe Institute and James S. McDonnell Foundation’s postdoctoral fellows in a presentation titled “Asking questions that matter— the choice of where to dig.”

“Generally I find there are a lot of bright people out there who can answer any question they want,” Laxminarayan says, commenting on his eight years of experience on the fellowship committee for the James S. McDonnell Foundation. After interviewing scores of talented researchers for the competitive early-career fellowship, he’s noticed that raw talent and skill are rarely the limiting factors for applicants. Often times, he says, “they’re pursuing a topic where it’s not obvious why they’re pursuing it.”

The founder and director of the Center for Disease Dynamics and Economic Policy in Washington, D.C., Laxminarayan has dedicated his own career to understanding how to counter the global onslaught of antibiotic-resistant bacteria. Though he himself chose to research antibiotic resistance for its potential to save tens of millions of lives, says good questions don’t always have to be utilitarian in nature.

Theoretical work, such as Turing’s theories on the general relativity, unveiled secrets of the universe even though they have very little immediate application to people’s everyday lives.

Whether fellowships seek universal principles, real-world applications, or both, Laxminarayan advises them “not to pursue research based on a skill set or set of methods, which is often emphasized in graduate education programs. Rather, like SFI and the James S. McDonnell Foundation, he advocates for problem-driven approaches that bring together scientists with different disciplinary back-grounds and skillsets.

As an added bonus, he says once a researcher has found their question, they’ll have a much easier time communicating their research to outsiders.

For more information on the seventh SFI-JSMF Postdocs in Complexity Conference, and an agenda, visit https://www.santafe.edu/events/jsmf-sfi-postdocs-complexity-conference-vii.

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RAMANAN LAXMINARAYAN

Beyond borders (cont. from page 2)

There was a time not too many years ago when the idea of general theories of complexity seemed absurd. Early efforts that tended to overgeneralize from toy models without strong empirical support engaged a skeptical scientific community at large as well as among complexity scientists. The recent turn to strong empiricism has led to discoveries of startling regularity not dissimilar to those discoveries in the physical sciences made over the last few centuries. This is a very exciting time in complexity science that promises not only to discover emergent laws of nature, but to explain why a diversity of approaches to understanding is required, why a grand unified theory is wrong-headed, and possibly to discover principled means of establishing connections across the full landscape of complexity theories.

— David Krakauer
President, Santa Fe Institute

Elizabeth Bradley
G. Matthew Fricke
Mirta Galesic
Joshua Garland
Alfred Mathewson
Christopher Moore
Melanie Moses
Kathy Powers
Sonia M. Ciporen Rankin
Gabriel R. Sanchez

NM experts fight for transparency and fairness in housing algorithms

and that includes keeping available several paths to deep decarbonization that also ensure reliable energy supply.

While many people are already thinking about specific technologies and solutions to production, storage, and transmission, Blameck says this working group will be more focused on the transition process, using New Mexico as a test case. “We want to think through the transition process for New Mexico — where the state is going to have to make critical decisions and what those critical points might be — and then offer those lessons to apply in other states.”


money and currency, which he co-organized with SFI President David Krakauer, for prompting him to buy Bitcoin when it was trading for $200. In December of 2018, it hit a high of $20,000. Its value currently hovers between $17,000 and $18,000.

The example of Bitcoin was especially timely, because in 2018 Miller donated $5 million from this SFI-inspired investment to fund the Institute’s expansion to the campus.

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“Now that someone is a part of the larger community who’s interested in the black sphere,” Beatty said. “We’re looking to the future and thinking about where we want to go as a community.”

Researchers, Applied Complexity Network, members, and friends of SFI celebrate the dedication of the newly renovated Matt Miller Campus. (Photo: Gabrielle Marks)
In November of 2019, 14 SFI postdocs withdrew to an isolated research location to accomplish, in just 72 hours, a monumental task — decoding the first complex communication from an alien civilization.

For the benefit of humanity, the aliens managed to divert their spacecraft for enough time to transmit a scientific treatise in a fundamental difference between their complex biology and ours. They were responding to images on the Golden Record, which launched aboard the Voyager spacecraft, engendered with a cosmic introduction to Earth and its inhabitants. Among the record’s 115 encoded images were multiple depictions of the two parent system of reproductive biology. “The aliens were totally shocked by these images, because in their world children are conceived and raised by three parents instead of two,” says Albert Kao, an Omidyar Fellow and Baird Scholar. “For scientists who study complex, living systems, it brings up all kinds of interesting questions about why three-parent systems would arise and what that might imply for the evolution of everything from molecular mechanisms to social institutions.”

With combined expertise in biology, evolution, information theory, mathematics, physics, philosophy, archaeology, cognitive science, and economics, the postdocs were uniquely qualified to receive and interpret the wide-ranging alien treatise. In three days and with little sleep, they documented biological consequences of tri-parental reproduction, spread four games of the brad-like combining of the aliens’ chromosones, the size differentiation between their gametes, the coordination of ‘muting events’ among three sexes, and the cultural implications of their family structures.

According to the postdocs, the aliens’ three-parent system confers a distinct evolution advantage to a wide range of life forms. Not just as sexual reproduction protects organisms from the harmful mutations that proliferate in asexual species, like dandelions, the three-parrent reproductive system additionally adds another layer of protection and genetic diversity, especially on planets bombarded with high radiation, which can cause a high mutation rate. Exactly why the aliens’ three-parent system came to dominate, as opposed to a four-, five-, or six-parent system, might be explained by the coordination costs and social ramifications of searching for multiple mates at once. In their treatise, the authors describe the exponential difficulty of finding a “soul triplet” — a perfect romantic combination in a sea of possibilities.

Other social consequences of the three-parent system include a heightened risk of disease transmission and a societal trend towards a uniform culture. According to Omidyar Fellow David Kinney, such a uniform culture is needed to avoid the cognitive overload caused by trying to juggle the cultures and languages of three parents, nine grandparents, and potentially dozens of partial siblings. There are so many social angles to explore in this system,” says sociologist Tamara van Wagner for the Santa Fe Institute.

The average skin cell lives for 28 days. A white blood cell, four months. Yet a human being might live 90 years or more, unaware of the millions of lifetimes unfolding at their own paces inside.

“We tend to think of time in terms of a constant rate, but in a complex system there are multiple clocks that are all ticking at different rates,” says David Krakauer, SFI President and William H. McElwain Professor of Complexity.

It’s this cacophony of clocks that has produced one of the most persistent of urban legends: that all the cells in our bodies get ‘replaced’ every seven years. That’s not true — not even close! — but it points the way towards profound questions about the way time operates in the body and beyond.

“The big picture is: what is time?” says Krakauer. “In each of the application areas, we want to know how time organizes phenomena, but “the deeper set of issues has to do with how things unroll in time . . . and that’s the common theme in all of these. The time to make something, and the time to break something.”

Also integral to the meeting will be new participants, including Simon Grondin (Université Laval, Québec), who can offer insight from areas not currently in the Complex Time portfolio, such as psychology and philosophy. These are subjects well-equipped to tackle what may be complex time’s most mind-bending hurdle: the fact that, as Krakauer notes, “we build the clock.” Does absolute time exist, and if so, how could we theorize it?

Only time will tell.
Workshop to explore diversity, inequality through "science of science"

In his 2008 Einstein Lecture to the American Mathematical Society, Freeman Dyson noted, "When I look at the history of mathematics, I see a succession of illogical jumps, improbable coincidences, jokes of nature." As an example, Dyson cited Erwin Schrödinger's discovery that his wave optics equation happens to describe the behavior of hydrogen atoms. The revelation that nature functions with complex numbers and not real numbers shocked both Schrödinger and the greater scientific community.

The "science of science" is a growing interdisciplinary field with a broad goal of understanding the structure and dynamics of science itself. The discipline evaluates the relationship between scientists and their scholarly products to try to determine the drivers of scientific discovery. In March, SFI will host a workshop, "A New Synthesis for the Science of Science." The workshop is being organized by SFI External Professor Aaron Clauset (University of Colorado Boulder), SFI Professor and Cowan Chair in Complex Systems, and former Omidyar Fellow Daniel B. Larremore (University of Colorado Boulder). The meeting will bring together a diverse collection of researchers to formulate a synthesis of concepts, models, methods, and data to craft a new vision for the science of science.

The workshop will also focus on the individual and structural inequalities within science that slow the pace and limit the diversity of discovery. Specifically, participants will explore the mechanisms that produce epistemic and social inequality. For example, why do a handful of graduate programs produce 50 percent of all tenure-track faculty across different fields? Why do women produce fewer papers through their careers than their male peers? "Scientific investigations of complex problems benefit from diverse perspectives," says Clauset. "This research can help us to see how some deeper changes in the system can alleviate structural barriers and inequalities."

By using the scientific method to study the scientific ecosystem, the organizers hope to set an agenda for the future growth of the science of science. "The past 20 years have been really exciting because now we have the data and computational tools to understand the creation of new knowledge," says Clauset. "This workshop aims to articulate the organizing questions that should guide the next five to ten years of work and help us address the underlying causes of pervasive inequalities in science."

Wealth inequality and social network structure

The historic wealth of Istanbul and Singapore owed much to their positions on the Bosporus and the Malacca Strait, respectively. Situated on an essential link in the flow of wealth, the elites of these cities profited from their hold-up power. An ongoing project of the Behavioral Sciences Program at SFI is exploring this basic idea, but applied to wealth differences within societies. Social networks with bottlenecks like the Bosporus or the Malacca Strait may support high levels of wealth disparity. Similarly, the company store stands between the miner and the suppliers of the necessities of life within societies around the world and for two centuries around the world and for two centuries. Social networks with bottlenecks like the company store or the Malacca Strait may support high levels of wealth disparity. Similarly, the company store stands between the miner and the suppliers of the necessities of life within communities of the world and for two centuries. Social networks with bottlenecks like the company store or the Malacca Strait may support high levels of wealth disparity.

A regular map of the United States showing results of the 2016 presidential election by county, with red, blue, and purple to indicate voting percentages (right). A cartogram (left) illustrates the same data, but skewed to represent population. (Image: Omidyar Professor Mark Newman)

RESEARCH NEWS BRIEFS

Media in the U.S. have already been covering the lead-up to the 2020 U.S. presidential election for months, and in the years since the 2016 election, researchers at SFI have been taking a complex systems approach to understanding the political landscapes in the U.S. and around the world. As we enter this election season in earnest, here are some of the highlights of our election-related science, from new ways to illustrate political maps to different polling questions for better predictions.

WHAT MATTERS IN AN ELECTION?

In 2017, SFI External Professor Mark Newman (University of Michigan) developed a variety of election cartograms that play with scale, representing counties and states proportionally based on their populations or representation in the electoral college. These graphical representations offer a fresh perspective on the political landscape in the U.S. by combating the "apparent paradox" of the traditional, geographically proportional red and blue map. This paradox, Newman notes on his website, "fails to allow for the fact that the population of the red states is on average significantly lower than that of the blue ones. The blue may be small in area, but they represent a large number of voters, which is what matters in an election."

IT'S WHO YOU KNOW, NOT WHAT YOU KNOW

We usually rely on pre-election outcomes, but those polls are not always reliable. In the 2016 U.S. presidential election, Hillary Clinton lost in five states where polls had anticipated her victory. In a February 2018 paper published in Nature Human Behaviour, SFI Professor Mirta Galesic and co-authors examined an alternative approach. Whereas most election polls ask people about their own voting habits, Galesic and her colleagues found that questions about the views of a voter's social circle actually provide more insight, improving the accuracy of voting predictions. The researchers studied the usefulness of social-circle questions in both the 2016 U.S. presidential election and the 2017 French presidential election by means of national pre-election surveys and aggregate polls. The results indicate the efficacy of social-circle questions in tapping into "local" wisdom rather than asking potential voters to make assumptions about the behavior of the general population.

REALISTIC IF NOT (YET) REAL

In the 2017 Computer Science and Physics, SFI Professor Sidney Redner offered a mini-review of the voter model that has played a central role in both probability theory and statistical physics. The classic voter model, which randomly selects a voter who then adopts the state of one of their neighbors, has been used to model a variety of systems including the spread of diseases, rumors, and even political opinions. The model assumes that each voter's opinion is independent of the opinions of their neighbors, which is unrealistic for many real-world systems. Redner and his collaborators have developed extensions of this model that incorporate social influences, such as the influence of friends and family, to better understand the evolution of opinions in large-scale networks.

FORENSIC ANALYSIS FOR VOTER FRAUD

The U.S. isn't the only country concerned with voter fraud. The results of Turkey's 2017 constitutional referendum indicated majority support for the country's shift to autocracy, but allegations of electoral irregularities and misconduct suggest otherwise. In a 2018 PLOS One paper, SFI External Professor Stefan Thurner (Complexity Hub Vienna) and his collaborators applied statistical forensic methods to identify and verify cases of malfeasance. They utilized
WHY DO SO MANY ELECTIONS VERGE ON STALEMATE?

History offers up numerous examples of near 50-50 election results. In the past decade alone, we’ve witnessed the 2014 Swiss referendum on mass immigration, the 2016 U.S. presidential election, and the British Brexit vote (also in 2016). All three were characterized by controversial issues and hostile attacks on both sides, and all three ended in a near stalemate, with a narrow margin of defeat or victory for the losing and winning parties.

In a 2019 paper in Physical Review E, SFI collaborator Stefan Bornholdt (Institute Rudjer Boskovic) and his colleagues present a voter model that explains what drives public opinion toward stalemate. In a word, it is repulsion. As voters are either convinced or repelled by statements, they can change sides or switch to an undecided state if they come to doubt their former opinion. In a contentious debate, when a voter is repelled by at least one out of four statements, a phase transition occurs where neither party can win in the long run and no clear winner emerges. To shift these dynamics from stalemate to majority, the study offers several recommendations for moving away from hostile statements and toward rational discourse. Their most radical proposal? “To declare results as invalid where the difference between yes and no is less than ten percent.”

SFI COMMUNITY LECTURE SERIES: SPRING 2020 LINEUP

The Santa Fe Institute Community Lectures bring leading thinkers to Santa Fe to explore the most alluring questions in science, and to address the complex issues that face our species and our planet.

Tuesday, February 25
RAJIV SETHI
“Stereotypes, Crime, and the Pursuit of Justice”
7:30 p.m., The Lensic Performing Arts Center

Tuesday, March 24
SARA WALKER
“The Information Origins of Life”
7:30 p.m., The Lensic Performing Arts Center

SFI’s 2020 InterPlanetary Festival is expanding this summer, launching from the success of three-day events in 2018 and 2019 to eight weeks of lectures, working groups, musical performances, interviews, and immersive art, each focusing on one of eight topics crucial to the future of our interplanetary civilization.

EIGHT COMPLEX TOPICS SPANNING EIGHT WEEKS
July 2–4 Emergent Engineering
July 9–11 Astrobiology & Life Detection
July 16–18 Motion & Energy Technology
July 23–25 Architecture, Cities, & Scale
July 30–Aug 1 Autonomous Ecosystems
Aug 6–8 Time Design
Aug 13–15 Intelligent Systems
Aug 20–22 Planetary Policy, Law, & Regulation

EXPLORE THE DEPTHS EACH WEEKEND
THURSDAYS
• Curated film screenings, introduced by luminaries from science, media, technology, and beyond
FRIDAYS
• InterPlanetary panel discussions • Live outdoor concerts • Cosmic ales & cocktails
SATURDAYS
• Live podcast recordings • Keynote presentations • Multimedia art performances

WWW.INTERPLANETARYFEST.ORG
GET THE LATEST DEVELOPMENTS, PRE-REGISTER, AND MARK YOUR CALENDARS FOR SUMMER 2020!