Biological and physical time meet in sleep

Sleep is a confounding phenomenon. Everybody does it, but no one has a precise understanding of why we sleep or what sleep does to our brains. And to researchers in a broad variety of fields, from biologists who study sleeping flies to clinicians treating sleep disorders, the pull of sleep is irresistible. “It’s obviously essential to life, it’s persisted across millions of years of evolution, and it’s altered in a large range of brain disorders,” says cognitive neuroscientist and psychiatrist Alex Savage. “But we know so little about it.”

Sleep is deeply tied to learning, bodily health, brain development, and aging, but its function in the processes largely remains a mystery. It’s also intricately tied to time, says SFI External Professor Van Savage, a mathematical biologist at UCLA. For example: “How long do you sleep? How long is REM (rapid-eye movement) sleep?” he asks.

Sleep patterns change from birth to adulthood, and, in general, people sleep less as they get older. Researchers have also observed patterns associated with organism size: Mice sleep for 16 hours per day, while blue whales, the largest animals on the planet, sleep for only 1.5 hours.

Savage and Herman have organized a working group with invitees from a wide range of fields, all united by their interest in sleep. The working group, to be held at SFI over three days in November, will begin to unpack the causes, timescales, and consequences of sleep. In particular, participants will focus on how sleep time changes across species, and how it changes with age and during adulthood.

The working group is part of SFI’s Complex Time: Adaptation, Aging, and the Arrow of Time research theme, which looks at how adaptation and entropy play out in complex systems. The study of sleep suggests new ways to think about how biological time, represented by aging or changing sleep patterns, for example, are encangled with physical time, determined by the regular movement of Earth around the sun.

“Understanding how these multiple clocks are coupled together is very much what we mean when we talk about complex time,” says Amy P. Chen, who manages the program at SFI. But understanding these connections requires a multidisciplinary effort, she says. “We want to get the people who don’t usually talk to each other in the same room.”

The researchers’ goals for the working group include novel collaborations and, ultimately, a book in the SFI Press to collect new insights in the field. The Complex Time research theme is funded by a grant from the James S. McDonnell Foundation.

Can evolution reveal how life emerged from chemistry?

All life that we see on Earth originated from a population of organisms that biologists call the Last Universal Common Ancestor — a single-celled life form that likely lived off the energy in deep-sea hydrothermal vents. Though all organisms carry traces of this billions-year old ancestor in our DNA, we know very little about how life’s progenitor emerged in the first place. How did the originator . . . originate?

A group of biologists think that a new synthesis of evolutionary theory might help answer this question. The working group, to be held November 19-11, is part of SFI’s ongoing Research Coordination Network for Exploration of Life’s Origins, sponsored by NASA and the National Science Foundation. In the spirit of the larger research program, the November meeting will bring together evolutionary theorists and experimentalists to explore which evolutionary models might best explain how chemical systems become biological systems. The group will ask not only about the import of existing models, it will also ask what is missing from current theories that could account for selection-like processes in prebiotic systems that are the precursors to adaptive evolution.

Generating a theory that bridges chemistry and biology entails “thinking about chemical evolution in a new way,” says SFI Professor Chris Kempe, who is co-organizing the group with geneticist David Baum of the University of Madison and computational biologist Dana Carage of Carnegie Mellon University. Since Kempe is a theoretical physical biologist who often works on astrophysics, he’s ultimately interested in arriving at “general principles for life anywhere in the Universe.”

For Carage, the workshop will be a forum to explore whether, and how far, her research on the spatial and temporal constraints on evolution can apply in a prebiotic context. “Can we use existing evolutionary theory to understand the precursors to life?” Carage asks. “Do conditions are so different that we need entirely new frameworks?”
Continuous process of idea generation, refutation, and transitions between epochs of approximate stasis — of ideas Kuhn describes discontinuous, revolutionary figure views of scientific change. In some suitable space Revolutionary (top figure) and evolutionary (bottom figure) views of scientific change. In some suitable space.
When it changes states, as from solid to liquid, or liquid to gas. But Elena, who studies virus evolution at the Institute of Integrative Systems Biology in Valencia, Spain, says emerging evidence suggests biological systems, such as our hub of new virus particles. As the population-level level, Elena says, the point where an outbreak becomes an epidemic can also be seen as a phase transition. This idea emerged at the end of last year’s meeting. “There were people saying yes, saying no,” she tells us. “The one thing that was clear was that they needed to keep talking about it. But there wasn’t enough discussion.” Elena suspects phase transitions may be a critical step in understanding connections between levels of virus evolution, and hopes this year’s working group can dive into questions about their role.

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Summer in the rearview

2019 SFI summer schools

SFI’s “social reactor” kicked into overdrive this summer, welcoming 163 undergraduates, graduate students, and professionals. Intensive summer programs form the core of the Institute’s educational programming, bringing future complexity scholars to Santa Fe to train with leading scientists.

This year, the Graduate Workshop in Computational Social Science and Complexity (GWCSS) celebrated its 25th anniversary with programming for alumni as well as a new cohort of advanced graduate students.

The flagship Complex Systems Summer School (CSSS), now in its 31st year, returned to the campus at the Institute for American Indian Arts to tour complex behavior in mathematical, physical, living, and social systems.

In partnership with the University of Chicago’s Mansueto Institute for Urban Innovation, SFI hosted a two-week Global Sustainability Summer School (GSSS) to explore how the battle for sustainable development can be won in cities by kick starting “virtuous cycles” of improvement.

And the NSF-funded Research Experience for Undergraduates (REU) program paired a dozen undergrads with SFI mentors to develop research projects of their own choosing. At the end of their 10 weeks, they presented their work on topics as varied as the origins of agriculture, vaccine hesitancy, paleolithic climate, and associative memory.

Read more about our annual summer programs at santafe.edu/schools.