Subtitle heroes speak complexity in many languages

They speak Bulgarian, Italian, Arabic, Mandarin, Spanish, and more. Together, they’ve put thousands of hours into making complexity research accessible to people around the world. “Subtitle heroes,” as they’re known in the SFI education office, are a community of people worldwide who have dedicated their time to making SFI’s online courses available in 63 languages to date.

Since its inception, SFI’s online education platform, Complexity Explorer, has been dedicated to making complexity science accessible. While this mission initially involved keeping all core content free, it has expanded to offer language accessibility as well, with subtitles in multiple languages, including English. What most viewers don’t realize is that these subtitles are provided by volunteers, many of whom are former students in the courses themselves who want to stay involved and give back to the community.

“If you can’t donate, you can participate,” says Teufel. “One of the things SFI is really good at is bringing people together around shared and so the platform. And they give us so much.”

Worldwide accessibility — facilitated by a global, cooperative network — also has added resonance in today’s political climate. “In this moment, the international reach of Complexity Explorer feels more important to us than ever,” says Dave Feldman, SFI’s interim Vice President for Education. “That reach includes those living in countries whose governments are at odds with ours.”

As of this year, the top non-English languages offered as subtitle options are Arabic, Spanish, and Mandarin. However, offering captions in English is also a core piece of the project, as it makes courses accessible to those who are non-hearing as well as those for whom English is a second language. A good English transcription can also speed up the process of subtitling in other languages, since subtitles have a textual foundation from which to work.

In 2014, when the subtitling project was launched by then-Interim VP for Education, Melanie Mitchell, much of the organization of subtitling was painstakingly in-house with a small team of volunteers. Now, the Education team works with the subtitling platform Amara, a branch of the Participatory Culture Foundation, to help recruit volunteers, coordinate assignments, and monitor the accessibility of individual courses. All subtitling is done on a volunteer basis, though individuals who subtitle 120 minutes or more receive a free Complexity Explorer T-shirt as a gesture of thanks.

“Subtitle heroes,” as they’re known in the SFI education office, are a community of people worldwide who have dedicated their time to making SFI’s online courses available in 63 languages to date. (Photo: Nicholas Rojas)

Looking for entrenchment in all the right places

Over the last few years, molecular biologist Ashley Teufel has begun to notice an emerging trend in high-profile papers on protein evolution. In particular, researchers are reporting on entrenchment, a phenomenon in which a single event can have a widespread effect on an entire system. For a protein, a genetic mutation that occurs at one point in time may help determine the way the molecule evolves later. Teufel, an SFI Complexity Postdoctoral Fellow, realized that entrenched systems occur elsewhere.

“Entrenchment speaks broadly to the idea that the history of a system determines its current behavior. That idea is similar to hysteresis, a phenomenon in which a change in one part of the system can change its behavior later in time (often observed in magnetic systems). Entrenchment is also similar to the concept of evolutionary contingency, which suggests that random accidents shape the future course of a living system. The first plant seeds to land on a new volcanic island, for example, may determine its future vegetation. Evidence for entrenchment can be found in biology, ecology, computer science, and elsewhere. People’s ideas and feelings can even become entrenched over time.”

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Wanted: Algorithms for quantum computing

The first theoretical framework for a quantum computer was proposed in 1982 by Richard P. Feynman, and in less than 40 years science and tech have rushed to build quantum machines. Today’s quantum computers sustain temperatures approaching absolute zero and are designed to solve problems that would require millions of years for even the world’s best supercomputers. However, the rate of hardware development is seemingly outpacing the growth of algorithms that can leverage the phenomena of quantum mechanics.

To put it another way: “Everyone is trying to build these quantum machines, but we don’t know how to use them in many application domains,” says Helmut Katzgraber, a Principal Research Manager at Microsoft and an External Professor at SFI. “The number of quantum algorithms we have is limited, and most of them don’t really have any practical value,” he adds.

Quantum computers today excel at solving small ray problems for a select subset of disciplines, such as chemistry and physics, but the lack of practical algorithms limits their widespread application. And without useful algorithms, many fields will continue to rely on classical, silicon-based computers and potentially miss out on the revolutionary potential of quantum machines.

To address this shortage of algorithms, Katzgraber and his colleagues Malühé Aramon (iQBit) and Jon Mocha (the University of Massachusetts and SFI) are convening a working group this summer at SFI from July 30 to Aug. 2. During the workshop, an interdisciplinary team of attendees will consider several themes posed as questions. The considered topics will touch on which domains classical and quantum algorithms are likely to thrive, problems facing quantum computing, and recent developments in hardware, to name a few. The group will also discuss and develop algorithms for optimization, sampling, and machine learning.

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The main reason for the meeting is to think about how entrenchment works, says Teufel. “One of the strengths is having so many people from different fields collaborate on this to build some larger framework,” she says.
MURRAY GELL-MANN: THE METAPHYSICAL DETECTIVE

A few years ago, at a conference I was involved in, we had a panel on a book on the topic of borders. I was asked to discuss the idea of borders, and I said, ‘I love that book title. It’s so interesting and complex.’ So we had a lively discussion. I mentioned that I had a friend, a German philosopher, who wrote a book on borders. I think it was called ‘Borders: Theological, Philosophical, and Political.’

In my research, I have explored the idea of borders in various fields, including physics and philosophy. I have always been fascinated by the concept of borders, and how they can be used to define different spaces and concepts.

One of the most interesting aspects of borders is that they are always changing and evolving. In science, for example, the boundaries between different disciplines are constantly shifting. In philosophy, the concept of borders is often used to explore the nature of reality and the universe.

In my own work, I have been interested in the idea of borders as a way to understand the complexity of the world. I have explored this idea in my research on complexity theory, which I believe is a powerful tool for understanding the interconnectedness of different systems.

In conclusion, I believe that the concept of borders is a crucial one for understanding the world, and I encourage others to explore this idea further. Thank you for this stimulating discussion.”

Nobel prize-winning physicist and SFI co-founder Murray Gell-Mann passed away on May 13, 2019, at age 86. Best known for his contributions to particle physics, Gell-Mann also wanted to understand the relation of “chaos” to turbulence. He connected the universal laws of physics to complex systems like economies and human cultures. He died in celebration in more than two dozen publications following his death, including the New York Times, Nature, the BBC, Scientific American, The Guardian, and The Washington Post.

Nobel — Gardens in the air” (Illustration: Anat Zeligowski)

Working group seeks ‘Mendelian moment’ for cultural evolution

Until Greg Mendel came along, students of Darwin explored biological evolution without a mechanism to explain heredity. With his experiments, Mendel began to illuminate the generic processes that underlie evolution — and eventually gave evolutionary theory a causal substrate.

According to former Complexity Postdoctoral Fellow Vanessa Ferdinand, now a cognitive scientist at the University of Melbourne, the field of cultural evolution is ripe for a Mendel-inspired moment. Ferdinand hopes that in the next several years, theorists of cultural evolution will deepen their account of the mechanisms that underlie cultural replication — and give themselves the kind of causal clarity that Mendel gave to Darwin’s beginnings.

“Cognitive science,” Ferdinand says, “is the Mendel of cultural evolution.”

This summer, from Aug. 5-7, the Santa Fe Institute will host its second working group on cumulative cultural evolution. Along with Ferdinand, the event is led by longtime SFI External Professor Rob Boyd, who is also Origins Professor at Arizona State University’s School of Human Evolution and Social Change, and Bill Thompson, a cognitive scientist at Princeton University and Berkeley’s Computational Cognitive Science Lab.

Last year, Boyd and Ferdinand brought together a group to explore the meaning of cultural cumulative more broadly. The working group gathered scientific and social scientists studying cultural evolution from a broad range of fields including anthropology, cognitive science, and philosophy of biology.

Their task was to synthesize the ways that different fields understand cumulative culture.

By all accounts, workshop participants found the group exciting and fruitful — and their institute will host its second working group on cumulative cultural evolution. Along with Ferdinand, the event is led by longtime SFI External Professor Rob Boyd, who is also Origins Professor at Arizona State University’s School of Human Evolution and Social Change, and Bill Thompson, a cognitive scientist at Princeton University and Berkeley’s Computational Cognitive Science Lab.

The experience was transformative.

“arly on, I met with a participant who was interested in the idea of cultural evolution. We had a long conversation and he shared some of his ideas. I was impressed by his insights, and we continued to discuss our work for the rest of the week.”

The most surprising result of the working group was a deepening of understanding and collaboration among different fields. The participants were able to communicate and build on each other’s work, which created a vibrant and collaborative atmosphere.

“My favorite part of the conference was the final plenary session, where we all had the opportunity to present our work and receive feedback. It was a great way to share ideas and learn from each other.”

The working group was successful in bringing together scientists from different disciplines to explore the concept of cultural evolution. The organizers plan to continue hosting these working groups to foster further collaboration and innovation in this field.

> MORE ON PAGE 4

From academia to industry and back: A case study in applied complexity

As a Texas Instruments researcher working on artificial neural networks and speech recognition in the early 1990s, SFI Science Board member and TI fellow Kunle Olumua began applying science to real-world problems every day. But he wanted to dig deeper.

“It seemed to me that the work that I was doing on pattern recognition and speech recognition might be related to how our immune systems recognize different strains of pathogens.”

Smith explains, “So I started thinking around to see where I might do such work.”

An invitation from SFI External Professors Stephanie Forrest (Arizona State University) and Alan Persson (LANE) to join Forrest’s Ph.D. program at the University of New Mexico came with a suggestion. First, attend the Complex Systems Summer School at SFI.

One month later, Smith took a leave of absence from industry and began the summer program. The experience was transformative.

“arly on, Mike Simmons, VP for Academic Affairs, talked about how at SFI there were no barriers between disciplines. I was completely overwhelmed.”

Smith says. “I knew this was the place for me to explore my ideas.”

After his studies at SFI, Smith went on to work in industry at Popular Power to develop these ideas, worked closely with US public health colleagues at the US Centers for Disease Control, and eventually ended up as a full-time researcher at the University of Tennessee.

> MORE ON PAGE 4

Postdocs get reckless in sixth group conference

Reckless Ideas will feature high on the agenda of the sixth Postdocs in Complexity Conference, the latest in a two-yearly series held at SFI and generously funded by the James S. McDonnell Foundation (JSMF). The conference, to take place Aug. 27-30, brings together early career complexity postdoc fellows in a wide range of disciplines from institutions around the world.

The Reckless Ideas format encourages the participants to bring up unstated propositions they would otherwise be reluctant to share. Originally started in 2010 by SFI President David Krakauer (then the SFI Faculty Chair), past Reckless Ideas have included a session of “selfish” neurons, presented by SFI External Professor Daniel Dennett, and apparently “telepathic” phenomena in sand dunes, presented by former Omidyar Fellow Jeremy Van Clee.

To encourage recklessness in presenters, audience members give feedback in the form of “yes, and ...” statements, rather than the more critical “no, but ...” Presenters do their part by limiting themselves to no more than one slide, no matter how complex the topic.

All postdocs at the August conference will present Reckless Ideas. They will then divide into smaller groups and choose four ideas for brainstorming and serious discussion.

“In the past, participants have consistently rated the group brainstorming session as the best parts of the conference,” said Hilary Skolnik, Program Manager of SFI Post-doctoral Fellows Program. “So this is a novel way of incorporating group discussions so that participants can share ideas and collaborate with each other.”

In addition to off-the-wall collaborative sessions, the participants will receive professional training, practice science communications through an improv session, and engage in social activities that include a mushroom hunt in the Santa Fe National Forest and a yoga session on the SFI beach.

> MORE ON PAGE 4
Workshop: Do living things compute?

Biologists agree on many things that living organisms can do: They eat, they respire, organisms can do: They eat, they respire, they reproduce, they die. Many would also agree, implicitly or explicitly, that living things compute. But a trio of SFI researchers want to know: What does it mean for biological systems to carry out computations? The answer isn’t clear.

“Biologists have a vague sense of what they mean by computation,” says biologist Albert Kauffman, SFI’s Complexity Postdoctoral Fellow. “At a certain point, if your definition is too loose, then anything can be computed. But if you make it too tight, then maybe nothing is computational in biology.”

For three days this fall, biologists, physicists, neuroscientists, and computer scientists will come together for an SFI workshop to investigate the links between computational theory and biological systems. The workshop is the brainchild of SFI Professor David Wolpert, who leads the Thermodynamics of Computation project at SFI. It was co-organized by Kauffman and SFI Professor Jessica Flack, who runs the Institute’s Collective Computation Group. Flack says the workshop’s goal is “to first establish a rigorous conceptual framework for studying the computational foundations of biology so that the foundations of computation in adaptive systems can be identified and compared to those in synthetic computing systems.”

Workshop participants will identify components of living systems that might look like elements of computation. They may have possible inputs and outputs, for example, or processes that look like algorithms. Researchers have also observed that the modular, hierarchical organization of biological systems resembles that of digital computers. A body is organized into separate organs, each containing cells that are organized into many separate organelles.

Finding links between computers and biological systems has been a longstanding goal of complexity science, developed along with the adjacent possible to understand better the potent intuitions of the initial wave of research in more rigorous terms. Kauffman’s impact can be felt around the world, both among scientists and in the broader public that was inspired by his many books on complexity.

“It’s hard to imagine the early years of SFI without Stu’s presence,” explains workshop co-organizer John Miller, who became the Institute’s first postdoc in 1998. The workshop, co-organized by Miller and Shannan Distinguished Professor and Past President Jeffrey West, brings in dozens of researchers, many of whom have co-authored with Kauffman. Their talks will span the broad panorama of Kauffman’s research interests and contributions.

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SFI celebrates Thirty Years of Complex Systems Thinking

This August 21–22, SFI will celebrate Stuart Kauffman’s contributions to complex systems science in a workshop: “Thirty Years of Complex Systems Thinking.” The two-day workshop will cover new research linked to Kauffman’s adventurous career.

Already a prestigious scholar by the 1980s, Kauffman moved to Santa Fe in 1986 after the Institute’s first full-scale workshop on Complex Adaptive Systems. A MacArthur Fellow and one of SFI’s first resident researchers, he helped define the early science of complexity, developed new theories of the origins of order in biological and technical systems, and added various other tools and ideas like NK fitness landscapes and the “adjacent possible” to the complexity lexicon. Kauffman’s scientific curiosity and desire to follow ambitious questions that disregarded the traditional boundaries between domains fit well within the nascent institute and formed a key part of its lasting culture.

Kauffman remembers those years of intense collaboration and recombinant ideas. “Probably the most thrilling ten-year period of my life. We thought we were onto something, but we didn’t know what. It was like a Rorschach test... and it led to this sprawling, innovative learning from one another. I’ve never experienced it anywhere else.”

Since his early years at the Institute, much has changed — “most of the rail has been laid down since then” for complex systems science, as he puts it.

New books by SFI authors

The SFI Press publishes affordable, enlightening books on some of the most ground-breaking areas of complexity science, distilling scientific meetings and public-facing panels, as well as fresh takes on historical tests. In recent months, the SFI Press has released four new titles.

Worlds Hidden in Plain Sight, (SFI Press, Compass Series, 2019) edited by SFI President David Krakauer, is a collection of popular essays from the past thirty years of research by SFI scientists, offering a clear and accessible overview of the deepest challenges and insights of complexity science.

InterPlanetary Transmisions: Genesis, (SFI Press, Compass Series, 2019) edited by SFI External Professor David Krakauer and Caitlin McShea, is a record of the proceedings of SFI’s first InterPlanetary Festival held in June 2018.

Law as Data, (SFI Press, Seminar Series, 2019) edited by External Professor Daniel Rockmore (Dartmouth College) and Michael Lewmore, (University of Virginia Law School), explores the new field of computational legal analysis, which uses legal texts as data. This book introduces the legal world to a broad range of computational tools already proving themselves relevant to law scholarship and practice.

The Energics of Computing in Life and Machines, (SFI Press, Seminar Series, 2019) edited by SFI’s David Wolpert, Chris Kremes, Peter Stadler, and Joshua Grochow, explores the fundamental physical laws governing the relationship between the precise computation run by a system, natural or artificial, and the amount of energy such computations require.
The task is not to see what no one else has seen, but to think beyond borders.

REMEMBRANCES OF MURRAY GELL-MANN

I have lost more than a mentor and collaborator: we were like brothers, and he was “one of the great ones in science.”

Beyond Borders (cont. from page 2)
Melanie Mitchell

Computer scientist Melanie Mitchell, creator of SFI’s online education platform, was named co-chair of SFI’s Science Board at its 2019 spring meeting.

The principal role of the Science Board is to advise the President and the Board of Trustees on matters of scientific strategy for the Institute. Mitchell joins co-chair Daniel Schrag (Harvard University), who has co-chaired the board since 2017, and co-chair Emerita Paula Sabloff (University of Chicago), an External Professor.

“We are delighted to have Melanie play an important advisory role for SFI — especially given the significant multidisciplinary involvement since the early days of the Institute,” says VP for Science Jennifer Dunne. “With her long view of SFI science activities and education programs, and her expertise in artificial intelligence, she is a valuable addition to the Science Board.”

Since 1993, Mitchell has served SFI as a faculty member, advisor, and interim Vice President for Education. In addition to being a Science Board co-chair, she is also currently an SFI External Professor, and is based at Portland State University, where she researches artificial intelligence, machine learning and evolutionary computation, in cognitive science and complex systems.

Mitchell earned her PhD in computer science from the University of Michigan in 1990, then in 1992, she “jumped at the chance” to work at SFI on the new Advanced Computation Program. She became the director of the program, which, over the course of six years made significant contributions to the rapidly developing field.

She also originated the Santa Fe Institute’s Complexity Explorer platform, which offers online courses and other educational resources in the field of complex systems. Her widely popular “Introduction to Complexity” has introduced more than 360,000 students from around the world to complexity science, and is Complexity Explorer’s flagship course.

Mitchell is the author or co-author of scholarly papers in the fields of artificial intelligence, cognitive science, and complex systems, and is the author or editor of six books including Complexity: An Introduction (with Guido T. D’Ovidio, 2007), which won the 2010 Phi Beta Kappa Science Book Award. Her newest book is Artificial Intelligence: A Guide for Thinking Humans, which will be published by Farrar, Straus and Giroux in October 2019.

During her tenure as Science Board co-chair, Mitchell will also return to SFI for an extended residency, from Jan. 1 to Dec. in 2020.

**Acknowledging royal women’s political power**

The narratives we tell about the past often feature a cast of familiar main characters: kings and their royal husbands. “Political agency wasn’t just for men,” says Jenna Bednar. “Women used.”

In a recent paper published in the Journal of Archaeological Research, SFI External Professor Emerita Paula Sabloff analyzes two different time periods — people who may be biologically identical from two different time periods — people who may be biologically identical from two different time periods — people who may be biologically identical from two different time periods — people who may be biologically identical from two different time periods — people who may be biologically identical from two different time periods — people who may be biologically identical from two different time periods — people who may be biologically identical from two different time periods — people who may be biologically identical from two different time periods — people who may be biologically identical from two different time periods.

As Sabloff described in another recent paper, women were used as bargaining chips, used to form political alliances, and used to secure power for their families.

“Women rulers held nearly the same political power as kings,” she explains. “Main wives were active players in determining succession, governing the polity, building and defending the polity, and expanding or defending territory.”

These women also exerted influence by obligating couriers and agents for their polity. Sabloff’s research on political relations, intersected on behalf of their relatives, and sometimes passed on or conspired against their royal husbands. “Political agency wasn’t just about ways of making a living,” says Sabloff. “It was about being able to influence policy, to influence who is on the throne. There were levels of agency, but they were right behind his right."

**Language**

(cont. from page 1)

The next generation of algorithms, says Katzgraber: “We will not just focus on quantum hardware, but any type of hardware. We do not expect that a quantum device will be able to solve all problems; the key is to determine what problems will work really well, and what will not work at all.”

Katzgraber hopes the meeting will spur new algorithms, collaborations, and perhaps a new collection of white papers or a special issue of a journal.

**Mendelian**

(cont. from page 2)

response reflects current enthusiasm in the field more generally. At the moment, the field is lumping together new questions and diverse approaches. There are both micro (cognitive) and macro (social) approaches to cultural evolution, and a wide variety of methods for studying it that range from large-scale network experiments to social decision-making models to computational textual analysis.

According to Thompson, both the plethora of new ideas and the debate about the implement- ment of computational methods have fueled current research. He explains that if we take two people who are biologically identical from different time periods — people who may have had very different technological experiences — we find that their cognitive capabil- ities are often very different. “Yet we cannot explain this difference biologically or in terms of individual learning, and this suggests some other kind of explanation.”

This year, the working group will focus specifically on mechanisms of cultural inheritance. By homing in on the mechanisms that drive cultural change, they hope to gain more clarity about the cognitive processes that generate the fabric of cumulative culture — and open the way for a new causal framework.

**Industry**

(cont. from page 2)

professor at Cambridge University.

As a direct result of Smith’s work at SFI, he and colleagues Ron Bednar and Alan Lapedes developed a method to understand the evolution of viruses they called antigenic topology, and their work was published in Science (2014).

“We looked at the evolution of a virus in a new way, in particular, how it escapes our immune response,” Smith explains. “Diseases like HIV, malaria, and influenza persist and are very difficult to control. We had to be able to understand what makes them more difficult to understand.”

Soon after the paper was published, Smith and team were invited to apply their work to the approximately 20,000 influenza strains analyzed each year by public health laboratories for the World Health Organization. Their objective? Learn how the virus was evolving to identify which strains of flu should go in the vaccine — a process he has integrated into since that first invitation.

“We felt it was our responsibility to do this work because people’s lives are on the line,” Smith says. “But we also recognized that by applying our work, there was a real oppor- tunity. The possibility to see the complete global evolution of the virus, in real time, is an evolutionary biologist’s dream.”

Empowered by this global data and $24 mil- lion in funding from NIH and BARDA, Smith and his colleagues are now working to understand this evolution well enough to predict it and apply it to the flu vaccine.

“Derek’s success with his flu vaccine work is a perfect example of the insights that can be found in the lateral space between the tradi- tional domains of academia, industry, and public health,” says Wil Tracy, SFI’s VP for Applied Complexity.
Thousands of Earth and space enthusiasts attended SFI’s second InterPlanetary Festival in the Santa Fe Railyard Park. Fueled and inspired by the research at the Santa Fe Institute, the mid-June festival offered an exploration of complexity science and human ingenuity in the setting of a summer festival full of music, film, art, food, drinks, and more.

“Stardust” was the code name for the second annual festival, which expanded upon the inaugural “Genesis” theme of 2018 with a more playful investigation of the InterPlanetary Project’s central question — What would it take to become an InterPlanetary civilization?

In addition to live music, podcasts, immersive art, games, and an innovation expo, festival-goers enjoyed panel discussions with leading thinkers on topics central to the future of our species—space exploration, extremophile cities, game design, world building, diverse intelligences, creative black futures, and the origins of life.

Video recordings of all panel discussions are available through the Santa Fe Institute’s YouTube channel: youtube.com/user/santafeinst. Additional information about the annual festival, including information about the upcoming 2020 festival (code name: Voyager), can be found on the InterPlanetary Festival website: www.interplanetaryfest.org

‘Stardust’ in the rearview

InterPlanetary Festival 2019

That instead some form of selection governs word choice. In particular, our choice of dominant words is guided by positive frequency-dependent selection, a bias that makes us disproportionately likely to use the words that most others use.

DISCRETE POWER-LAWS AND SELF-SIMILARITY

Continuous power-law distributions are commonly used in studying complex systems, and are associated with scale-free behavior and self-similarity. However, many self-similar processes occur only at discrete steps that do not follow a continuous scale-free distribution. In a publication in Physical Review Letters on April 19, External Professor Van Savage (UCLA) and collaborator Mitchell Newberry introduce a discrete power-law distribution, and derive the maximum-likelihood estimate for its exponent. They then apply this empirical data to show that modeling discrete self-similar processes with a continuous power-law distribution can lead to errors, and that a discrete distribution is essential for properly describing many biological and physical systems.

A NEW NORMAL: STUDY EXPLAINS UNIVERSAL PATTERN IN FOSSIL RECORD

The fossil record of marine invertebrates since the Cambrian period reveals that extreme events of diversification and extinction have happened more often than a typical, Gaussian, distribution would predict. Previously, in 2009, SFI External Professor Miguel Fuentes used superstatistics to describe a similar fat-tailed distribution in the stock market. In a June 26 paper published in Science Advances, Fuentes, Omidyar Fellow Andy Rominger, and External Professor Pablo Marquet show that using Fuentes’ approach — in this case, looking at fluctuations within groups of animals that share a common lineage rather than fluctuations across all types of organisms — could also accurately describe the unusual patterns in the fossil record.