Hunting ExoEarths | Denisovan DNA in Full | Secrets of Semen

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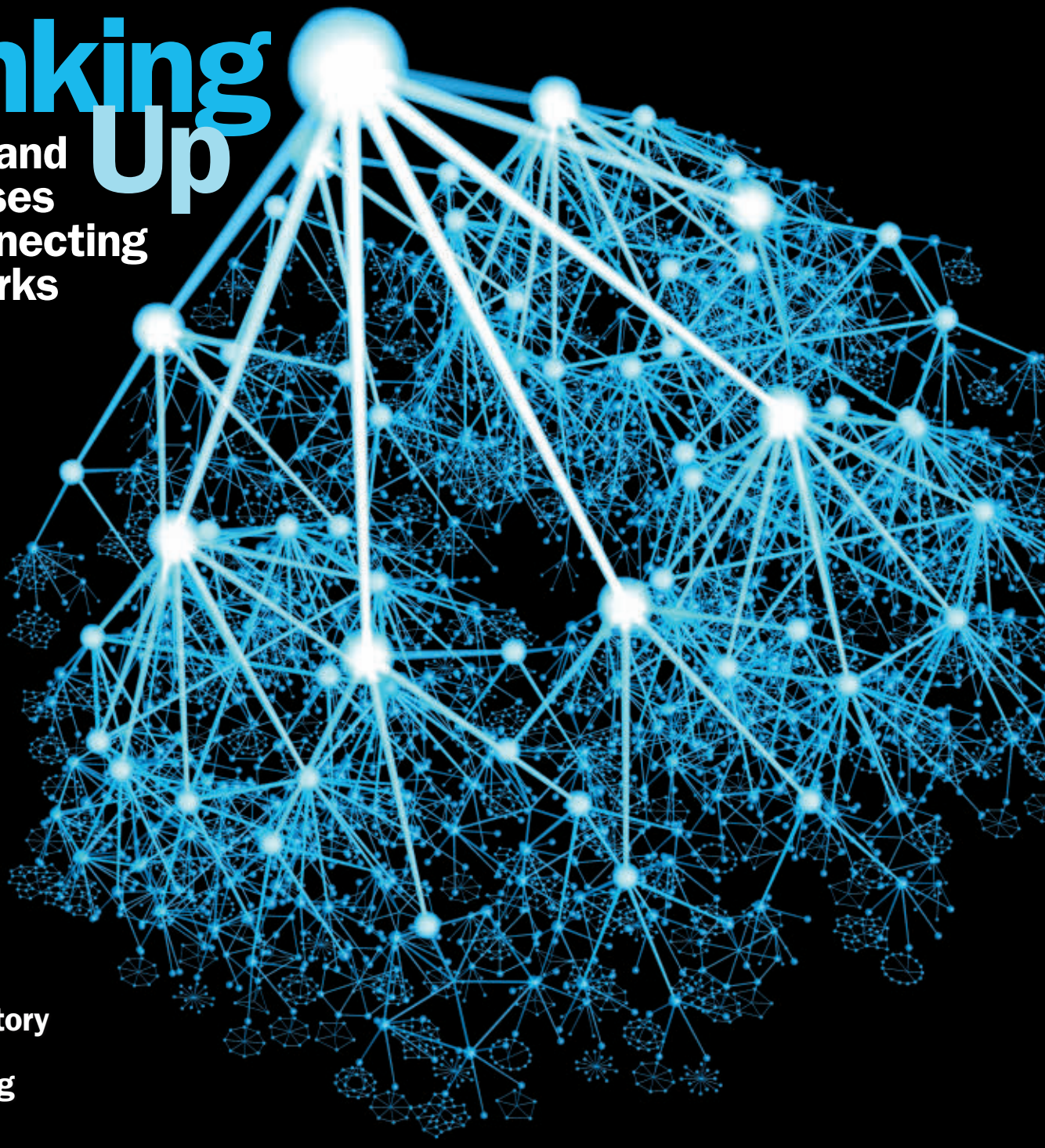
ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ SEPTEMBER 22, 2012

Linking Up

Perils and promises of connecting networks



Star Factory

Sickening Tattoos

Crime-Solving Camera

We live in an area which is known for very cold winters. Our facility is nearly 7000 square feet in area. When we began to utilize the first unit we were amazed to see how even the heat was for the entire living room area. We ordered a second and a third unit which now warms the entire home. Much to our surprise we are saving over $250 a month and had the lowest expense for heating we have ever experienced here. I would heartily recommend your products to anybody who is interested in really nice, even heat in their home and also interested in saving on their utility expenses.

Dennis Crystal, Troy, MT (Retired Airline Pilot)

Enclosed you will find printouts of our electric bill and gas/heating/cooking bills for 2007 - 2008. Our gas company, AmeriGas, stated that more money was saved than would show up because of the cost going up. We would turn the gas on early in the morning and turn it down to 60 degrees; We would use the EdenPURE® heaters from then on and they provided such warmth and cozy heat. We, also, had fewer colds last winter than in previous years, before we purchased the EdenPURE® heaters. Many of our friends have informed me recently that they are going to purchase these heaters for their homes this winter.

Gloria D. Smith, Boydton, VA (Retired Elementary Principal)

EdenPURE® ranked #1

Save $192 – biggest savings ever

Richard Karn,
North Canton, Ohio

Never be cold again

As Al Borland on Home Improvement I was the man with all the answers. However, as Richard Karn I still look for money saving and efficient heating in my home. I have an EdenPURE® Infrared Portable Heater in my California home and like millions of others found it to be a super-safe, reliable source of portable heat all year long.

I know why millions of Americans are saving on their heating bills with the EdenPURE® Portable Infrared Heaters.

And now you can save up to $192 on new EdenPURE® models, our biggest savings ever, on heaters I personally rank #1 in North America.

I was fortunate enough to attend the grand opening of the new EdenPURE® factory in North Canton, Ohio. The new plant brought hundreds of new jobs back to Ohio and reversed the common practice of sending Midwest manufacturing jobs to China.

American Labor, American Quality

With over 3 million portable heaters sold EdenPURE® is the best selling portable infrared heating system in North America. However, like any classic, EdenPURE® has dozens of would-be competitors who create Asian copies at low prices using cheap, foreign labor. Don't be fooled by these imitations. Look for the EdenPURE® logo and the Made in North Canton, Ohio stamp. Save like millions of others on your heating bills and say "NO" to cheap foreign imitators.

Save up to 49% on 2013 EdenPURE®s

Now readers can save up to 49% ($192 the largest savings ever on new EdenPURE®s). EdenPURE® is not just the best-selling portable heating system in North America. As an EdenPURE® owner I rank EdenPURE® #1 for quality, safety and efficiency. And now is the perfect time to save like never before on our expanded 2013 EdenPURE® line made in our brand new North Canton, Ohio facility.

Stay Comfortable 365 Days a Year

"Never be cold again" is the EdenPURE® promise. EdenPURE® provides you insurance against the cold all year long. Stay comfortable on those unseasonably chilly evenings no matter the season. I live in California but believe me it gets cold at night. Keep your expensive furnace turned down until it's absolutely necessary. And if we are fortunate enough to experience a mild winter as many of us did in the Midwest last year, you keep your furnace off all season and save even bigger.

New, More Efficient Models

The engineers at EdenPURE® listened to their millions of customers and somehow managed to improve the #1 portable heater in North America. Through old fashioned American ingenuity the new EdenPURE® line is more efficient to save you even more money.

The EdenPURE® Personal Heater now heats a larger area, an increase from 350 square feet to 500 square feet. That's a 30% increase in efficiency! That's American engineering at its best!

We all know heating costs are expected to remain at record levels. The cost of heating our homes and apartments will continue to be a significant burden on the family budget. The EdenPURE® can cut your heating bills and pay for itself in a matter of weeks, and then start putting a great deal of extra money in your pocket after that.

Super Safe Infrared Heat

Now remember, a major cause of residential fires in the United States is carelessness and faulty portable heaters. The choice of fire and safety professional, Captain Mike Hornby, the EdenPURE® has no exposed heating elements that can cause a fire. And a redundant home protection system that simply shuts the EdenPURE® down if it senses danger. That's why grandparents and parents love the EdenPURE®.

The outside of the EdenPURE® only gets warm to the touch so that it will not burn children or pets. And your pet may be just like my dog who has reserved a favorite spot near the EdenPURE®. You see the EdenPURE® uses infrared heat. And just as pets enjoy basking in a beam of sunlight they try to stay close to EdenPURE®'s "bone-warming" infrared heat.

The Health Secret is in the Copper

EdenPURE®'s engineers have taken the original concept through revolutionary changes. EdenFLOW™ technology uses copper heating chambers to take the energy provided by our special SYLVANIA infrared bulbs and distribute our famous soft heat evenly throughout the room.

Now our copper isn't ordinary. It's 99.9% pure antimicrobial copper from an over 150 year old American owned company in Pennsylvania. Researchers have discovered copper as an antimicrobial is far more effective than stainless steel or even silver. That's why our special antimicrobial copper is marked Cu+ and used in hospitals on touch surfaces. So your EdenPURE® heater is continuously pushing soft, healthy, infrared heat throughout your room.

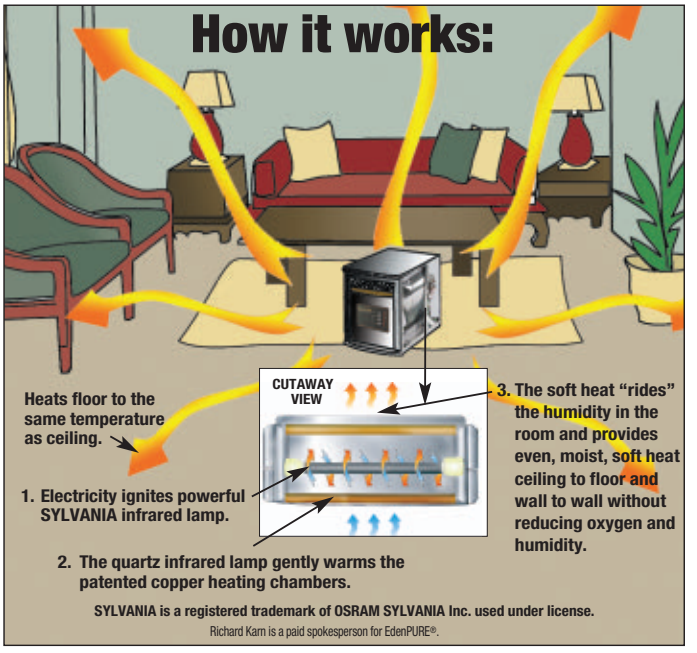
How to Order

During our 2013 introduction you are eligible for a $175 DISCOUNT PLUS FREE SHIPPING AND HANDLING FOR A TOTAL SAVINGS OF $192 ON THE EDENPURE® PERSONAL HEATER.

This special offer expires in 10 days. If you order after that we reserve the right to accept or reject order requests at the discounted price. See my attached savings Coupon to take advantage of this opportunity.

The made in North Canton, Ohio EdenPURE® carries a 60-day, unconditional no-risk guarantee. If you are not totally satisfied, return it at our expense and your purchase price will be refunded. No questions asked. There is also a 3 year warranty on all parts and labor.

How it works:



SYLVANIA is a registered trademark of OSRAM SYLVANIA Inc. used under license.

Richard Karn is a paid spokesperson for EdenPURE®.

RICHARD KARN'S SAVINGS COUPON

The price of the EdenPURE® Personal Heater is $372 plus $17 shipping, but, with this savings coupon you will receive a $175 discount on the Personal Heater with free shipping and be able to get the Personal Heater delivered for only $197.

The Personal Heater has an optional remote control for only $12. Check below the number you want (limit 3 per customer)

☐ Personal Heater, number _____
☐ Optional Personal Heater Remote $12, number _____

- To order by phone, call TOLL FREE **1-800-856-8998 Offer Code EHS6001**. Place your order by using your credit card. Operators are on duty Monday - Friday 6am - 3am, Saturday 7am - 12 Midnight and Sunday 7am - 11pm, EST.
- To order online, visit **www.edenpure.com** enter **Offer Code EHS6001**
- To order by mail, by check or credit card, fill out and mail in this coupon.

This product carries a 60-day satisfaction guarantee. If you are not totally satisfied return at our expense, and your purchase price will be refunded – no questions asked. There is also a three year warranty.

NAME _____

ADDRESS _____

CITY _____ STATE _____ ZIP CODE _____

Check below to get discount:

☐ I am ordering within 10 days, therefore I get a $175 discount plus Free shipping and my price is only $197 for the Personal Heater.
☐ I am ordering past 10 days, therefore I pay full price for the Personal Heater plus shipping and handling.

Enclosed is $_____ in: ☐ Check ☐ Money Order

(Make check payable to EdenPURE®) or charge my:

☐ VISA ☐ MasterCard ☐ Am. Exp./Optima ☐ Discover/Novus

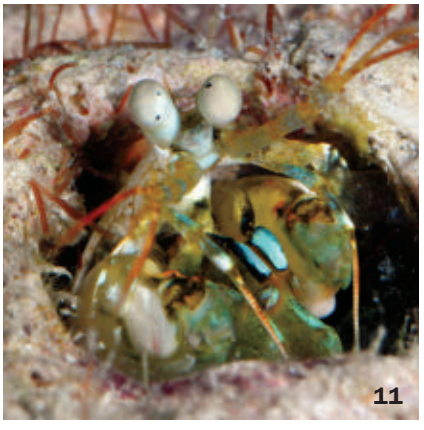
Account No. _____

Exp. Date _____/_____

MAIL TO: EdenPURE®
Offer Code EHS6001
7800 Whipple Ave. N.W.
Canton, OH 44767

All of the testimonials are by actual EdenPURE® customers who volunteered their stories, and were given another EdenPURE® heater as thanks for their participation. Average homeowners save 10% to 25%.

SEPTEMBER 22, 2012 • VOL. 182 • NO. 6

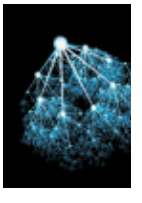


ScienceNews

In The News

Features

Departments



COVER New views of interacting systems show that networks linked to other networks can exhibit surprising strengths and unexpected vulnerabilities. *Artwork by Bryan Christie Design*

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FROM THE EDITOR

Frontiers of knowledge at the edges of ignorance

Once there were only nine. Now, scientists find themselves awash in planets: Even after counting out Pluto, there are upwards of 840 known planets. And NASA's Kepler spacecraft, busily spying on thousands of candidate exoplanets in just one tiny section of the sky, threatens to send on a tidal wave of new discoveries. Already, as Nadia Drake reports on Page 26, Kepler scientists have confirmed the existence of 77 worlds orbiting distant stars — and expect to soon confirm roughly 800 more. Some, the scientists think, may even resemble Earth.

But — and this is where science gets fun — they might not. Either way, it will require some serious rethinking, just as those of us who grew up thinking there were nine planets have had to recognize our previous ignorance.

Understanding how ignorance inspires discovery is, in fact, the subject of a new book, actually entitled *Ignorance: How it Drives Science*. Speaking on the *Diane Rehm Show*, the book's author, neuroscientist Stuart Firestein, said: "I use that term purposely to be a little provocative. But I don't mean stupidity.... I don't mean a callow indifference to facts or data or any of that." What he means is all that is yet to be known.

His book came out of his course at Columbia University in which he invites other scientists to guest lecture, relating the depths of the current ignorance in any of a number of fields. The students have been thrilled — the talks capture the excitement many scientists feel about their work but that rarely makes it into lectures and textbooks. To me, that sounds like what *Science News* aims to do in every issue.

This issue features many a story probing the edge of what's known. Elizabeth Quill's in-depth look at the emerging understanding of interacting networks, on Page 18, reveals all that remains unknown about how connecting up may make networks more or less vulnerable to failure. Laura Sanders, on Page 14, describes how a protein best known for its role in Alzheimer's disease appears to quell inflammation in a mouse model of multiple sclerosis. How it works remains an open question. On Page 16, it's the many unknowns of semen on display. As Meghan Rosen reports, a protein that in humans plays an important role in nerve growth shows up in the semen of llamas. Scientists have found that in llamas the protein helps trigger ovulation and the early stages of pregnancy. It may do something similar in humans. But we don't know. Yet. — *Eva Emerson, Acting Editor in Chief*

PHILIP CHANNING

Limited to the first 2500 respondents

Spectacular Treasure from Mount St. Helens

The Beauty in the Beast

For almost a hundred years it lay dormant. Silently building strength. At 10,000 feet high, it was truly a sleeping giant, a vision of peaceful power. Until everything changed in one cataclysmic moment. On May 18, 1980, the once-slumbering beast awoke with violent force and revealed its greatest secret.

It was one of nature's most impressive displays of power. Mount St. Helens erupted, sending a column of ash and smoke 80,000 feet into the atmosphere. From that chaos, something beautiful emerged… our spectacular ***Helenite Necklace***. Produced from the heated volcanic rock dust of Mount St. Helens, this brilliant green creation has captured the attention of jewelry designers worldwide. Today you can wear this 6½-carat stunner for the exclusive price of only $129!

Your satisfaction is guaranteed. Our ***Helenite Necklace*** puts the gorgeous green stone center stage, with a faceted pear-cut set in gold-layered .925 sterling silver. The explosive origins of the stone are echoed in the flashes of light that radiate as the piece swings gracefully from its 18" gold-plated sterling silver chain. Today the volcano sits quiet, but this unique piece of natural history continues to erupt with gorgeous green fire.

Add the 3-carat earrings!

Your satisfaction is guaranteed. Bring home the Helenite Necklace and see for yourself. If you are not completely blown away by the rare beauty of this exceptional stone, simply return the necklace within 30 days for a full refund of your purchase price.

Helenite Necklace (6 ½ ctw)—~~$249~~ **$129**

Helenite Earrings (3 ctw)—~~$249~~ **$129**

Helenite Set (necklace & earrings)—~~$498~~ **$199** *Save $299*

Call now to take advantage of this extremely limited offer.

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– James Fent
Certified Gem Guru

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JEWELRY SPECS:
- 6 ½ ctw Helenite in gold over sterling silver setting
- 18" gold-fused chain

Smart Luxuries—Surprising Prices

Say What?

Frass ***FRAS***\ ***n.*** Insect excrement. Frass has various functions, and not just as a fun expletive. Some caterpillars, for example, grow up inside bumps on leaf stems and leave an entire childhood's worth of frass behind after moving out. This might help explain why the leaves decompose slowly, a team of researchers at Pennsylvania State University suggests in the June *Functional Ecology*. Other insects turn excrement into architecture, such as beetles (shown) that are born in a nugget of their mother's frass and then carry around a protective suit made of the stuff. In contrast, some grasshoppers kick frass, with females booting their poop an average of 487 millimeters upon defecation, a team at Kyushu University in Japan reported in 2011. —*Susan Milius*

Science Past | FROM THE ISSUE OF SEPTEMBER 22, 1962

PIGMENT MAY HELP VISION — The same chemical that gives you that golden tan from the summer sun may also help you to see. The brown pigment, melanin, may take part in controlling the messages sent from the eye to the brain, Lieut. Raymond J. Sever, U.S. Navy, told the American Chemical Society in Atlantic City. Melanin is found in the retina, the light sensitive part of the eye. Here, the energy of light is picked up and changed into nerve impulses. It is not known how this is done, he said. When melanin, extracted from cows' eyes, was exposed to light, there was a rapid appearance of free radicals — high energy particles capable of creating an electric charge.... These free radicals could produce an electrical voltage across the retina, thus controlling the nerve impulses from the eye to the brain, he suggested.

Science Future

September 29
The "Make it Science Day" at the Columbus, Ohio, Center of Science and Industry explores the science of manufacturing. You can even try your hand at basic soldering. See bit.ly/SFmakeit

October 17
For National Fossil Day, a part of Earth Science Week, paleontologists and U.S. National Park rangers will explain fossil discoveries at events nationwide. See bit.ly/SFfosday for more information.

SN Online

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ON THE SCENE BLOG
Spinning neutron stars called pulsars keep turning up in new and exotic flavors. Read "Weird pulsars debut at Beijing astronomy meeting."

SCIENCE & SOCIETY
The world's first moonwalker left a legacy of exploration. See "Neil Armstrong, first man on moon, dies at 82."

NUMBERS
The busiest air-traffic hubs aren't always tops for epidemics. See "Top airports for spreading germs ID'd."

GENES & CELLS
Teens with one form of a gene may have a harder time just saying no. Read "Gene may boost effects of peer pressure."

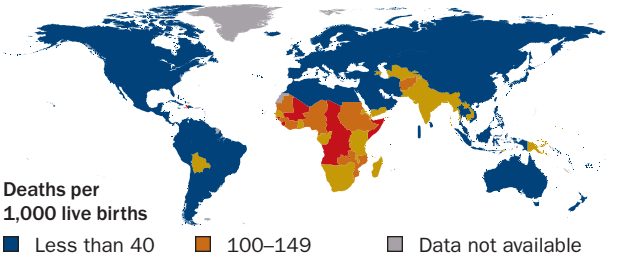
The –est | BIGGEST WALLOP

An impact crater in Greenland may be the largest and oldest ever found. The meteorite that created the crater 3 billion years ago was about 30 kilometers across — the length of 11 Golden Gate Bridges laid end to end — and punched a hole about 500 kilometers wide, Adam Garde of the Geological Survey of Denmark and Greenland and colleagues report in the July 1 *Earth and Planetary Science Letters*. If a chunk of rock that size hit Earth today, "all higher life would be extinguished," Garde says. Erosion has erased the crater's features (left), but the team was able to gauge the meteorite's original size and impact by inspecting pulverized granite in the ruins. —*Meghan Rosen*

Science Stats | DYING YOUNG

Despite a drop in child mortality globally over the last two decades, children born in parts of Africa and South Asia still face a substantial risk of death before age 5, an analysis of 2010 data shows.

Mortality rate under age 5



SOURCE: U.N. INTER-AGENCY GROUP FOR CHILD MORTALITY ESTIMATION, K. HILL *ET AL/PLOS MEDICINE* 2012

CLOCKWISE FROM TOP LEFT: CHRISTOPHER R. BROWN; NASA; A.A. GARDE *ET AL/EARTH AND PLAN. SCI. LETTERS* 2012

“Our kids need hands-on experiences to develop their science, technology, engineering and math skills.”
—PAULA GOLDEN, PAGE 12

In the News

STORY ONE

Denisovan DNA reveals history of enigmatic group

Extinct Neandertal relative lived about 75,000 years ago

By Bruce Bower

A replica of part of an ancient finger bone, resting on a modern human hand, underscores just how little fossil material scientists had to work with when they extracted a full DNA sequence of the Denisovans.

COURTESY OF MAX PLANCK INSTITUTE FOR EVOLUTIONARY ANTHROPOLOGY

Genetic data of unprecedented completeness have been pulled from the fossil remains of a young Stone Age woman who lived roughly 75,000 years ago. The information encoded in her DNA helps illuminate the relationships among her group — ancient Siberians known as Denisovans — Neandertals, and humans.

The Denisovan’s genetic library suggests that she came from a small population that expanded rapidly as it moved south through Asia, says a team led by Matthias Meyer and Svante Pääbo of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. Denisovans passed genes to Papua New Guineans but not to Asians, Europeans or South Americans, the researchers report online August 30 in *Science*. That’s in line with previous evidence that Denisovans contributed to the ancestry of present-day Australian aborigines and Melanesians.

The new investigation also finds that Asians and South Americans possess more Neandertal genes than Europeans do. Although Neandertals inhabited Europe and West Asia, they may have interbred most frequently with *Homo sapiens* in East Asia, or, possibly, had their genetic contributions to Europeans diluted as increasing numbers of Stone Age humans reached that continent.

“We can now start to catalog essential genetic changes that occurred after we separated from our closest extinct relatives,” Pääbo says. Preliminary DNA comparisons between people today and the young female Denisovan have identified eight human-specific genes involved in brain functions, including one linked to language and speech development.

Despite the advance in retrieving ancient DNA, Denisovans’ evolutionary history is far from settled. Denisovan fossils, which date to at least 50,000 years ago, consist of only a finger bone and two teeth from Siberia’s Denisova Cave.

Previous work partly reconstructed DNA from the finger fossil and unveiled a close genetic link between Neandertals and Denisovans (*SN: 1/15/11, p. 10*).

For the new study, Meyer and Pääbo’s group devised a method that gets around the problems of missing data, an inevitable consequence of DNA degrading over time. The new method stitches together the remaining pieces of genetic material, allowing the researchers to assemble a version of Denisovan DNA that’s about as complete and accurate as what can be obtained from a living person.

“Producing a full genome of such high quality from such an old specimen illustrates how far we have come in just a few years in the field of ancient DNA sequencing,” says evolutionary geneticist Rasmus Nielsen of the University of California, Berkeley.

Comparisons of premium-grade Denisovan DNA with large samples of DNA from people today should begin to clarify where and when ancient

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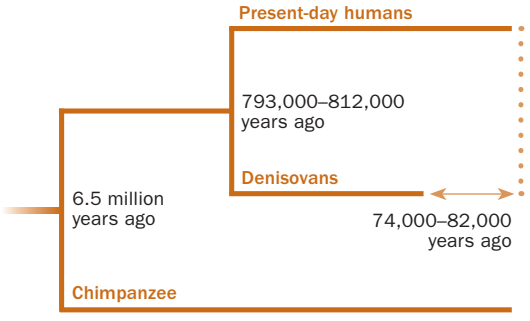


Family split Comparing Denisovan DNA with 11 modern people suggests that Denisovans and present-day humans split from a common ancestor about 800,000 years ago. Comparisons with chimp DNA helped researchers date the fossil to about 75,000 years ago.
SOURCE: M. MEYER *ET AL*/*SCIENCE* 2012

interbreeding took place, Nielsen says.

Meyer and Pääbo's team compared its new-and-improved Denisovan material with genetic samples from 11 living people, including five Africans from different tribes or ethnic groups; two Europeans, one from France and one from Sardinia; two Chinese, one from a northern ethnic group and one from a southern ethnic group; a Papua New Guinean; and a villager from Brazil's Amazon forest.

Relative to chimpanzee DNA, Denisovan DNA displayed fewer alterations than the genetic code of people today did. That disparity reflects the fact that Denisovans died out in the Stone Age and thus had less time than surviving humans to generate as many genetic changes. The scientists used that difference to calculate a provisional age of between 74,000 and 82,000 years for the Denisovan finger bone, tens of thousands of years older than previous data had suggested.

The Leipzig scientists' method of analyzing the DNA also allowed them to spot a relatively small number of differences between Denisovan genes inherited from the mother and the father. That observation suggests the ancient Siberians had an extremely low genetic diversity, the researchers say. A small population of Denisovans probably expanded into new territories where interbreeding with *H. sapiens* occurred, with not enough time elapsing for many survival-enhancing genetic modifications to accumulate, the team proposes.

The same gene variants carried by the Denisovan individual are commonly found today in living people with dark skin, brown hair and brown eyes.

Papuans inherited 6 percent of their genes from Denisovans, the team estimates. Papuans share more genes with Denisovans on chromosomes other than the sex-linked X chromosome. Females inherit two X chromosomes, whereas males inherit one X and one Y chromosome.

That makes it possible that Denisovan males primarily mated with female humans, thus leaving a small genetic mark on present-day Papuan X chromosomes. Or, genetic incompatibility between Denisovans who interbred with modern humans may have resulted in the loss of Denisovan genes in later generations of Papuan ancestors, primarily on the X chromosome, the researchers suggest.

DNA found in living Chinese displays contributions from Neandertals but not Denisovans, although a tiny fraction of a percent of Chinese ancestry may have come from the ancient Siberian crowd, Pääbo says.

In contrast to the new findings, evolutionary geneticists Pontus Skoglund and Mattias Jakobsson, both of Uppsala University in Sweden, recently reported that southern Chinese possess roughly 1 percent Denisovan ancestry (*SN: 8/25/12, p. 22*). Skoglund and Jakobsson compared Neandertal and a less complete record of Denisovan DNA to genetic instruction books from more than 1,500 people living in different parts of the world.

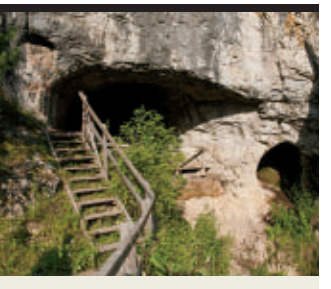
Meyer and Pääbo's team analyzed DNA from only two Chinese individuals, limiting the ability to statistically distinguish between Neandertal and Denisovan genetic contributions, Jakobsson says. "Until we have population data from East Asians and a high-quality Neandertal genome," he says, "I think the jury is still out." ■

Back Story | CAVE TREASURES

Before it became the namesake of a mysterious genetic ancestor of at least some present-day people, Siberia's Denisova Cave was known as the home of numerous Stone Age archaeological finds excavated since 1977. Digs in the multichambered cave have revealed tens of thousands of years of inhabitants.

Stone tools dating to more than 100,000 years ago presumably were made by Neandertals. Researchers attribute stone and bone tools and personal decorations unearthed in 50,000- to 30,000-year-old soil layers inside the cave to modern humans. These finds include ornaments made of mammoth tusks, animal teeth, ostrich eggshells, seashells and semiprecious stones. Bone needles with drilled eyes and cylinder-shaped bone beads were found as well. Other artifacts found in the cave date to as recently as several hundred years ago.

Scientists can't say whether Denisovans made any stone tools or ornaments that have been found in the cave. Fragmentary fossil remains make it impossible even to say what Denisovans looked like. —*Bruce Bower*



The Denisova Cave in Russia has yielded at least 100,000 years' worth of artifacts.

FROM TOP: E. FELICIANO; COURTESY OF MAX PLANCK INSTITUTE FOR EVOLUTIONARY ANTHROPOLOGY; GEOATLAS/GRAPHI-OGRE, ADAPTED BY E. FELICIANO

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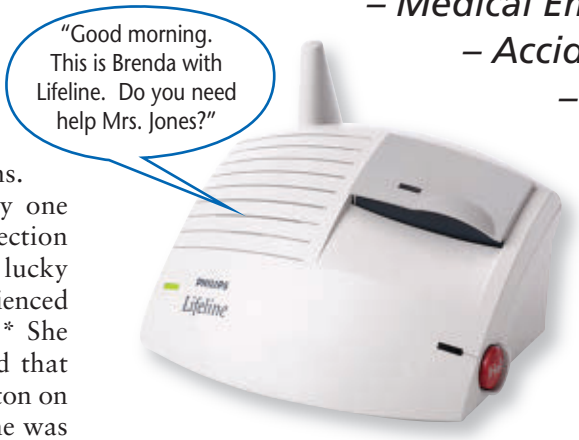
This medical alarm may save your life when others can't

Lifeline with AutoAlert is the only Medical Alarm pendant that can automatically call for help if a fall is detected.

Have you thought about what you would do in case of an emergency in or around your home? You're not alone. Many people have tried to protect themselves by purchasing PERS, or Personal Emergency Response Systems. That's a smart move, but only one system offers the extra protection of AutoAlert. That's what a lucky subscriber named Arlene experienced when she fell in her driveway.* She hit her head and was so dazed that she didn't think to press the button on her PERS pendant. Suddenly she was amazed to see an ambulance coming up the street. She wondered, "How did they know I fell?"

Lifeline with AutoAlert... for an added layer of protection.** Luckily for Arlene, her doctor had recommended Lifeline with AutoAlert. This revolutionary system features the only Medical Alarm pendant that can automatically call Lifeline's state-of-the-art response center, if it detects your fall. Then if you need help or can't respond, expert emergency response operators quickly call friends, family or local ambulance, police or firefighters to summon help… quickly and reliably.

Help when you need it ***most***:
– Medical Emergency
– Accident
– Burglary
– Fire



Remarkably sophisticated… easy to use. Now, they've introduced AutoAlert. All you do is plug the base unit into a power outlet and a phone land line. Then, you wear the AutoAlert pendant. If you experience any kind of emergency, from fires to falls, a break-in or even just shortness of breath, press the button and it calls the Lifeline Emergency Response Center. If you fall and can't press the button for any reason, AutoAlert with advanced fall detection technology can automatically call for you, even if you can't. Lifeline Response Center Associates are trained to assess the situation and will summon help quickly.

• Free shipping
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and the setup takes only seconds. Call now and find out how you or a loved one can get this added layer of protection to help you stay living independently in your home.

Call now and receive Free equipment, Free activation, Free shipping and a Free gift – valued at $35.

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	Lifeline	Competition
Long-Term Contract	✓ NONE	Some
Activation/Equipment	✓ FREE	up to $300
35 Years of Experience	✓ YES	No
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Atom & Cosmos

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Galaxy cluster extremely fertile

Stars turned out fast thanks to a lazy central black hole

By Nadia Drake

The Phoenix Cluster, shown here in a composite image, hosts roughly 1,000 galaxies. Orange reveals the hot gas found throughout the galaxy cluster, while visible and ultraviolet imaging reveal the galaxies within.

Nearly 6 billion light-years away, one of the most massive galaxy clusters ever seen is birthing stars at an incredible rate, with its central galaxy producing more than 700 suns per year in its cold, cold heart.

"It should be producing less than one, and it's producing 740," says Michael McDonald of MIT, coauthor of a study describing the cluster in the Aug. 16 *Nature*.

Called "Phoenix" by the team for its location in the constellation Phoenix — its official name is SPT-CLJ2344-4243 — the cluster comprises roughly 1,000 galaxies, is more than 4 million light-years across, and contains more mass than 2,000 Milky Ways.

In other words, it's big.

It's bright, too: The galactic conglomerate is the most luminous cluster ever observed in the X-ray spectrum. The star-birthing galaxy center is 50 times larger than the Milky Way. "It's kind of the boss galaxy," McDonald says.

The cluster's cold core and excessive fertility suggest the presence of a slacker black hole at the galaxy's center. Normally, radiation from a supermassive black hole — in this case, something around 10 billion times the mass of the sun — warms the surrounding environment, making it hard for gas to coalesce into stars. Whether this black hole is simply overworked, permanently off duty or just taking a break is unclear, but scientists think they've captured the cluster at an exceptionally frisky moment.

"Stars are forming at a much higher rate than we've seen before in any of these galaxies," says astrophysicist Martin Rees of the University of Cambridge in England. "It's a fascinating step toward putting this picture together of the tussle between the black holes and the star formation."

But the rate of star formation in the cluster may be somewhat overestimated, says astronomer Andrew Fabian, also at Cambridge. "There's no doubt that they've found a really exciting and fascinating object," he says. "Just how extreme it is, we don't know yet."

Astronomers discovered the riot of starbirth using the South Pole Telescope, a radio antenna that searches for the shadows cast by galaxy clusters on the cosmic microwave background, the thermal radiation left over from the Big Bang.

In the central galaxy, scientists are observing stars forming much faster than expected for a galaxy of this type. Calculating the stellar birth-rate involves measuring the amount of X-rays emitted by gas as it cools off and falls toward the central galaxy. Though the swirling gas starts off at temperatures exceeding 10 million degrees Celsius, stars can't begin coalescing until it cools to temperatures nearer the ambient temperature of space — a few hundred degrees below zero.

Fabian and his colleagues suggested decades ago that star formation can proceed through such "cooling flows," but that process hadn't been observed in this type of central galaxy until now.

McDonald and his colleagues calculated that approximately 740 stars are bursting out of this central galaxy each year. But the sprinter's pace is unlikely to be a permanent feature of the cluster, because over a marathon distance it would produce a monster galaxy 1,000 times larger than anything ever observed.

It's more likely that scientists have captured the cluster in a fit of fertility, though it's unknown just how long that fit will last. "I think something around 100 million years is reasonable," McDonald says. Determining exactly how much gas — fuel for the fertile fire — is present will help resolve the timescale question. Scientists hope to make that measurement using the ALMA telescopes in northern Chile. ■

UV: NASA, JPL-CALTECH, M. MCDONALD; OPTICAL: AURA, NOAO, CTIO, MIT, M. MCDONALD; MICROWAVE: SPT/NSF

Technology

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Camera hack can find crime scene

Simple infrared technology detects painted-over bloodstains

By Rachel Ehrenberg

Spattered blood intentionally hidden under layers of paint can be detected with a standard digital camera that's been tweaked to record infrared light. The approach could become an important tool for cold-case investigators sizing up an old crime scene.

"We hope it gives law enforcement the ability to go on hunches," says Glenn Porter, an expert in forensic photography at the University of Western Sydney in Australia. Blood is potentially powerful evidence, as it may harbor DNA that could help identify a killer or victim.

Porter, formerly a forensic photographer with the Australian Federal Police, had heard of cases where investigators suspected that a crime had taken place in a later-remodeled house. So he and his colleagues decided to see if infrared photography might reveal blood hidden under paint. The researchers took a digital camera and swapped its light filters so the camera's sensor would record only infrared light. With slightly longer wavelengths than visible light, infrared is better at penetrating layers of paint.

The researchers diluted horse blood to one-tenth its original strength and put 200-microliter drops onto plasterboard that had been painted over with primer. After allowing the blood to dry for 48 hours, they painted over the bloodstained plasterboard, testing several colors of acrylic paint and three different types of white paint.

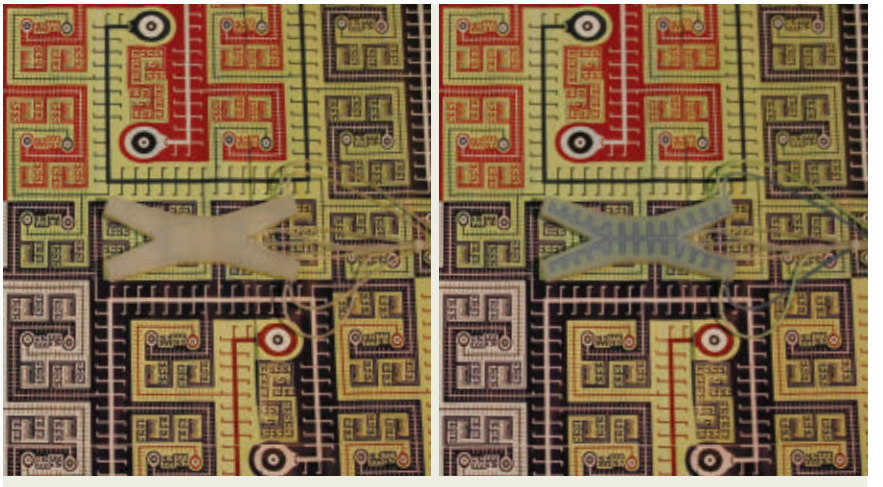
Under two layers of black paint, the blood was completely invisible to a standard digital camera. But in photos taken with the infrared camera, the blood could be seen even under six black layers, Porter and colleagues report online July 30 in the *Journal of Forensic Sciences*. The camera also exposed blood under layers of purple, orange, blue, yellow and green.

The approach revealed blood under three layers of both white oil-based paint and white spray paint. Red paint, perhaps an obvious choice for a would-be killer, didn't conceal the blood from the naked eye — even after six layers.

The infrared technique could allow investigators to test a hunch about a crime scene with little effort and disturbance, says Porter. "You can have your suspicions and then get a hit behind the paint," he says. "Then you decide if you want to start scraping paint off or take out a wall."

The camera couldn't see through more than three layers of white acrylic paint, probably because the particles used in the pigment — often lead or titanium — are good at scattering light, says Dan Kushel, a specialist in art conservation and imaging at Buffalo State in New York.

The art world has used infrared imaging since the 1930s to reveal drawings hidden under paintings, a technique that often works because the underdrawings were done using black pigments made of carbon, such as charcoal. These "carbon-blacks" are very good at absorbing infrared light. The black paint in the current study must have contained a noncarbon-based dye or it would have absorbed the infrared light in the same way as blood, creating no contrast, says Kushel. The size and concentration of pigments in the paint also play a role. "It's a very complex mix of variables that determines whether you are going to see what's below," he says. ■



S. MORIN/HARVARD UNIV.

A robot made for disguise

A soft-bodied robot with silicone skin and colorful veins can blend into its surroundings (right) — or stick out (left). Dyes injected into tiny canals in the silicone camouflaged the robot on different surfaces or made it easy to find, researchers report in the Aug. 17 *Science*. Heating or cooling the dyes made the robot visible in the infrared spectrum — bright white for hot fluids, purply-blue for cool. The color-changing skin could be glued to robots for search and rescue missions, where tracking and locating machines is key. The technology could also help prosthetic devices look more natural by matching a limb's coloring to a new summer tan, says study coauthor Stephen Morin of Harvard University. But the robot isn't quite ready for its first mission: It's tethered to a pumping station and power supply by long, skinny tubes. — *Meghan Rosen*

Humans

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New roots for a big language family

Indo-European tongues are traced back to ancient Turkey

By Bruce Bower

Indo-European languages are spoken throughout Europe and South Asia, yet the roots of this widespread family of tongues have long been controversial. A new study adds support to the proposal that the language family expanded out of Anatolia — what's now Turkey — between 8,000 and 9,500 years ago, as early farmers sought new land to cultivate.

Quentin Atkinson of the University of Auckland in New Zealand and his colleagues used a mathematical method to calculate the most likely starting point and pattern of geographic spread for a large set of Indo-European languages. Their investigation, published in the Aug. 24 *Science*, rejects a decades-old idea that Kurgan warriors riding horses and driving chariots out of West Asia's steppes 5,000 to 6,000 years ago triggered the rise of Indo-European tongues.

"Our analysis finds decisive support for an Anatolian origin over a steppe origin of Indo-European languages," Atkinson says.

He and his colleagues generated likely family trees for Indo-European languages, much as geneticists use DNA from different individuals to reconstruct humankind's genetic evolution. The group analyzed 207 commonly used cognates — words with similar meanings and shared sounds, such as *five* in English and *fem* in Swedish — in 103 ancient and modern Indo-European languages. The researchers produced possible language trees based on estimated rates at which languages gained and lost cognates.

The researchers combined their language trees with present geographic ranges of individual languages to identify the most likely location and age of the Indo-European family's origins. An ancient Anatolian root emerged whether the researchers combined linguistic data or separately considered the 20 ancient languages and 83 modern ones.

As a further check, statistical simulations that assumed slow rates of language migration if people traveled along land routes or faster migration rates spurred by water crossings converged on a scenario in which Indo-European tongues originated among Anatolian farmers sometime between 8,000 and 9,500 years ago.

Farmers alone didn't propel the evolution of different Indo-European tongues, Atkinson says. His team's proposed trees suggest that new languages began to sprout within the five major Indo-European subfamilies from 4,500 to 2,000 years ago, after agriculture had spread across Europe. Kurgans or other expansionist Indo-European cultures could have instigated those later linguistic developments, Atkinson says.

Atkinson's statistical reconstruction is unpersuasive, comments UCLA linguist H. Craig Melchert. Researchers can confidently rebuild trees of Indo-European languages extending back no more than about 7,000 years, he says.

Many linguists and archaeologists suspect that Indo-European languages originated in what's now the southern Russian steppes, and that's unlikely to change as a result of the new study, says linguist Joe Eska of Virginia Tech in Blacksburg. Cognate swapping across languages could have occurred more often than assumed by Atkinson, undermining his conclusions, Eska says. ■

BERNARDO ARRIAZA

Prosperity led to preservation

A population boom may have led members of South America's Chinchorro culture to start mummifying their dead thousands of years before the ancient Egyptians started salt-drying their pharaohs for eternal life, ecologist Pablo Marquet of Pontificia Universidad Católica de Chile in Santiago and his colleagues conclude online August 13 in the *Proceedings of the National Academy of Sciences*. Chinchorro hunter-gatherers invented the earliest known mummification procedures (mummy coated in black manganese shown here) about 7,000 years ago, when increased rainfall along South America's Pacific coast boosted the availability of freshwater and seafood, spurring a rise in population. As the Chinchorro grew in number, groups spent big chunks of the year in the same camps. People would have regularly seen bodies mummified by dry heat poking out of shallow, eroding graves, Marquet says. Chinchorro encounters with these naturally mummified, undecomposed bodies may have led to a belief in the persistence of a person's soul via this process, motivating the invention of artificial mummification for religious reasons. —*Bruce Bower*

Life

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Mantis shrimp flub color vision test

Results suggest alternate way of detecting wavelengths

By Susan Milius

A mantis shrimp, which has one of the most elaborate visual systems ever discovered, turns out to be pretty lousy at distinguishing one color from another.

The puzzling underachievement may mean that the mantis shrimp brain perceives color in a way new to science, said Hanne Thoen of the University of Queensland in Brisbane, Australia. She presented results from her ongoing study August 6.

The stalked eyes of mantis shrimp species that live in shallow water can have up to 16 kinds of photoreceptor cells, 12 of which are specialized for different colors, including ultraviolets. People make do with four main kinds, three of which pick up colors.

Yet tests with pairs of increasingly similar colors found that the mantis shrimp *Haptosquilla trispinosa* flunks out when choices narrow to colors 15 nanometers apart in wavelength. At sweet spots in the color spectrum, people can distinguish between wavelengths only one or two nanometers apart.

"Hanne's results are a bit of a shock to us," said Thomas Cronin of the University of Maryland, Baltimore County, whose lab also studies mantis shrimp vision.

Thoen tested the color vision of mantis shrimp by training them to scoot toward a pair of optical fibers and punch at the one glowing a particular color. As she narrowed the color gap between the two fibers, the animals eventually no longer discerned a difference.

So far, Thoen has tested her mantis shrimp on six target colors and nearby wavelengths, ranging from a 425-nanometer purple to a 628-nanometer red. If the animals perform just as poorly at distinguishing colors in other wavelengths, then mantis shrimp may be using some unknown system of color perception.

ROY CALDWELL/UC BERKELEY

The mantis shrimp *Haptosquilla trispinosa* has complex color-detecting cells in its eyes but can't distinguish hues as well as researchers expected.

People and other animals studied so far distinguish colors through brainpower by interpreting activity in different kinds of light-receptor cells. Instead of doing fancy brainwork, mantis shrimp may just rely on what a particular specialized cell responds to most strongly. Wavelengths that tickle the purple-sensitive cells may be just plain purple regardless of whether they're more toward the blue or the ultraviolet.

Mantis shrimp species do see into the ultraviolet, which people don't. It's possible that a receptor-heavy visual system is working in this range too because the light-catching receptors don't overlap much in sensitivity, speculated Michael Bok of the University of Maryland, Baltimore County.

At the meeting, Bok described the workings of six kinds of cells that respond to UV light in the mantis shrimp *Neogonodactylus oerstedii*. Even though the receptors each detect a relatively small slice of the UV spectrum, Bok found that just two light-sensitive pigments provide the basis for all those receptors. Filters in the cells create the array of different sensitivities, he said. ■

MEETING NOTES

Galloping dung beetles

Pachysoma dung beetles in Africa have a gait never before described in insects—almost a gallop.

Biologists hadn't recognized the motion because it's hard to see scuttling beetle legs, said Jochen Smolka of Sweden's Lund University. He videotaped beetle sprints and analyzed them in slow replays.

Most insects move their six legs as two tripods. In one stride, the first and last legs on one side of the animal plus the middle one on the other side support the weight while the other legs step forward.

In *Pachysoma*, the front two leg pairs power the gait, Smolka reported August 8. When the front pairs support the body, the middle pair bounds forward. The middle legs do the supporting when the front ones bound. —*Susan Milius*

Hearing himself fly

The sounds of a male mosquito's own wingbeats may help him catch the faint whine of a flying female.

"Counterintuitive" is what Joseph C. Jackson of Scotland's University of Strathclyde called results he presented August 8 on mosquito hearing. Mosquito antennae are good for studying active listening: Nerve cells add their own mechanical oomph to signals of incoming sounds, which can amplify weak sounds or make hearing more selective.

When a male hears a female, there's a jump in his antennae's sensitivity. When listening to tones simulating his own wingbeats, that jump occurs sooner, Jackson found. Males should thus be able to lock on to even fainter sounds of females. —*Susan Milius*

Science & Society

Young scientists make the cut

Thirty finalists named in middle school competition

By Meghan Rosen

Forget the baking-soda volcano. With research ranging from the power of natural mosquito repellent to the adaptability of reef-building corals, a new crop of young science fair students are leaving old-school projects in the dust.

In September, 30 of these middle schoolers will head to Washington, D.C., to take part in the final stage of the Broadcom Math, Applied Science, Technology and Engineering for Rising Stars, or MASTERS, program. This is the second year of the national science competition, a program of the Society for Science & the Public that is sponsored by the Broadcom Foundation.

Announced on August 29, this year's finalists include one 12-year-old from Massachusetts who figured out how to use the ocean's waves to generate electricity. Another from California pitted an intelligent game-playing computer against human doctors and professors. But the competition doesn't just consider the creativity and scientific merit of a student's project; it also judges each finalist's ability to solve problems, communicate and work in teams.

While in Washington from September 28 to October 3, the sixth-, seventh- and eighth-grade finalists will compete in a series of project showcases, individual interviews and intellectually grueling team trials designed to test each student's math and science mettle.

"To build an innovative workforce of scientists and engineers for the future, our kids need hands-on experiences to develop their science, technology, engineering and math skills," says Paula Golden, executive director of Broadcom Foundation and director of community affairs for Broadcom Corp. The students have only 90 minutes to complete their tasks, but the competition's organizers believe the kids are up to the challenge.

"These students show that with support and encouragement, middle schoolers can come up with creative approaches to many of the challenges faced by society," says Elizabeth Marincola, president of the Society for Science & the Public, which publishes *Science News*.

2011 Broadcom MASTERS finalist Andrew Blonsky shows off a model for his project on algae's ability to remove carbon dioxide from car exhaust.

In 2011 and again in 2012, the Broadcom MASTERS competition received more than 1,460 entries from students nominated by SSP-affiliated science fairs throughout the country. In early August, judges shaved the student entries down to 300 semifinalists. In the final round, a panel of five scientists and engineers cut the group down to 30.

Winners will be announced October 2 at an awards ceremony at the Carnegie Institution for Science headquarters in Washington. The top prize is a $25,000 education award. Each finalist's school will also receive a $1,000 award.

THE FINALISTS

CALIFORNIA **Jessika Baral,** Fremont, Hopkins Junior High School; **Shashank Dholakia** and **Shishir Dholakia,** Santa Clara, Marian A. Peterson Middle School; **Elan Filler,** Rancho Palos Verdes, Rolling Hills Country Day School; **Raymond Gilmartin,** South Pasadena, South Pasadena Middle School; **Anna Lou,** Anaheim, Oxford Academy

CONNECTICUT **Maura Oei,** Hebron, Oei Home School

FLORIDA **Maria Elena Grimmett,** Jupiter, The Weiss School; **Shixuan Li,** Lynn Haven, Bay Haven Charter Academy; **Ceili Masterson,** Palm Bay, Stone Middle School; **Nicole Odzer,** North Miami Beach, Highland Oaks Middle School

ILLINOIS **Varun Iyer,** Springfield, Benjamin Franklin Middle School

KENTUCKY **Cassa Drury,** Louisville, St. Francis of Assisi

MASSACHUSETTS **Daniel Lu,** Carlisle, Carlisle Public Schools; **Ethan Messier,** Assonet, New England Christian Academy

MINNESOTA **Carolyn Jons,** Eden Prairie, Central Middle School Eden Prairie

MISSOURI **Samuel Coulson,** Weston, West Platte High School

NORTH CAROLINA **Chase Lewis,** Chapel Hill, Lewis School

NEW YORK **Katherine Fennell,** New York City, The Montessori Middle School; **David Li,** Commack, Commack Middle School

OHIO **Lisa Criscione,** Seven Hills, Incarnate Word Academy; **Olivia Henderson,** Loveland, St. Columban School

OREGON **Anirudh Jain**, Portland, Summa Academy North

PENNSYLVANIA **Sean Hnath,** Reading, Muhlenberg Middle School

TEXAS **Paige Gentry,** San Angelo, Irion County Intermediate School; **Maya Patel,** The Woodlands, McCullough Junior High School; **John Wilkins,** San Antonio, Keystone School

SOUTH CAROLINA **William Monts,** Bluffton, Cross Schools

UTAH **Mabel Wheeler,** Orem, Cherry Hill Elementary School

VIRGINIA **Camille Yoke,** Midlothian, Manchester Middle School

Finalists are listed by state, name, hometown and school.

BROADCOM MASTERS, ROBIN WEINER PHOTOGRAPHY

Molecules

For more Molecules stories, visit **www.sciencenews.org**

Lab-on-a-chip gives fast results

Nanowire setup may aid in detection of health emergencies

By Rachel Ehrenberg

Looking for a specific protein in a drop of blood is like trying to find a notorious white whale on the seven seas — it takes some time. But a new device quickly filters the ocean of molecules in a blood sample, capturing proteins that may warn of an impending heart attack or out-of-whack insulin levels.

Besides detecting potential emergencies, such devices could minimize the days a patient spends waiting for lab results, providing them in mere minutes.

Experiments showed that the lab-on-a-chip detected various levels of troponin T — a cardiac-regulating protein that can signal an impending heart attack — in less than 10 minutes, researchers report online August 2 in *Nano Letters*. In the future, people at home who are having chest pains might use the technology to quickly find out whether they need to get to an emergency room, says coauthor Fernando Patolsky of Tel Aviv University.

The sugar-cube–sized device consists of two small compartments connected by a thin channel. In the first compartment is a densely packed forest of silicon nanowires coated with antibodies, molecules that latch onto specific proteins. These nanowires are very rough and full of holes, greatly increasing the surface area for attaching the antibodies.

"They are so rough and porous we can turn a 1-centimeter-square wafer into a 300-centimeter-square surface," says Patolsky, a biomedical chemist.

The second compartment also contains silicon nanowires, but these are laid flat and their ends are connected to tiny electrodes. After coating both sets of nanowires with antibodies for the specific protein that the researchers want to detect, a tiny drop of blood is added to the first compartment.

The thick nanowire forest allows the small target proteins in the blood to move through and be captured by the antibodies, while blocking larger things, such as cells, that can clog up the works.

A few minutes after the sample is added, the forest is rinsed with water, and researchers add a solution that detaches the target proteins from the antibodies. Then this concentrated stream of proteins is sent through the channel to the second compartment. The proteins are snatched up again by the antibodies on the flat nanowires, changing the amount of electrical current passing through the wires. The researchers read this change in current to determine how much of the target protein is present in the sample.

"It's clever," says Tarek Fahmy of Yale University. "They are doing separation and concentration on the same chip." ■

Body & Brain

For more Body & Brain stories, visit **www.sciencenews.org**

Alzheimer's protein could help MS

Amyloid-beta may thwart attack on central nervous system

By Laura Sanders

A much-maligned molecule that is devastating in the brain may have therapeutic potential outside it. The amyloid-beta protein, which piles up in the brains of people with Alzheimer's disease, reverses paralysis in mice with symptoms of multiple sclerosis.

The unexpected finding, published in the Aug. 1 *Science Translational Medicine*, could mean that A-beta or molecules like it may one day form the basis of a treatment for multiple sclerosis in people.

In MS, rogue immune cells penetrate the brain and spinal cord and attack myelin, a substance that is necessary to keep nerve cell signals moving at full speed. Damage and inflammation from this attack can leave a person with paralysis, numbness, vision problems and extreme fatigue.

A-beta is found in the brains of people with MS, but scientists do not know precisely what effect it has there, if any. To investigate that question, Lawrence Steinman of Stanford University and colleagues tried injecting A-beta into mice's abdomens, thinking it would worsen symptoms. "We expected that either nothing would happen or the disease would worsen because this is an infamous, villainous molecule," he says.

> "We expected that either nothing would happen or the disease would worsen because this is an infamous, villainous molecule."
>
> LAWRENCE STEINMAN

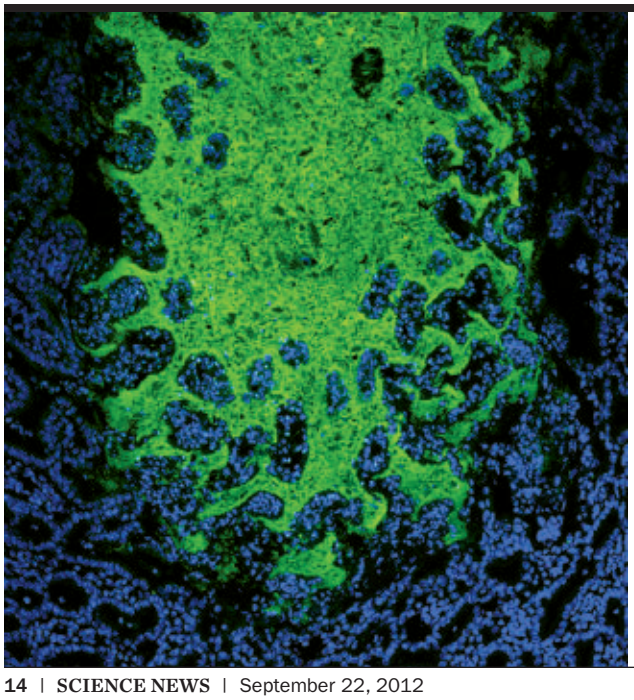
Instead, the mice got better. In several different kinds of mice designed to have symptoms similar to the human disease, A-beta injections into the body reduced paralysis and lowered brain inflammation. "The outcome was unmistakable," Steinman says.

To do its good work, A-beta didn't need to enter the brain, the researchers think. After the experiments, there was no evidence of the molecule piling up there. Instead, A-beta exerted its protective effects in the rest of the body, perhaps by calming down immune cells circulating in the blood and preventing them from waging war on the brain.

The data look convincing, but it's not clear exactly how A-beta works to ease multiple sclerosis symptoms, says biochemist Charles Glabe of the University of California, Irvine. More studies are needed to clarify how A-beta interacts with the immune system, he says.

Other proteins similar to A-beta in shape may bring the same benefit, and without the potential dangers associated with A-beta. Steinman and his colleagues are currently testing candidates.

Much more work needs to happen before such a treatment could be developed for use in people. "For these approaches, we have to learn what the drawbacks are," Steinman says. Dampening the immune system could heighten the risk of brain infection, for instance. And there's always a possibility that the results in mice won't hold up in humans. ■



COURTESY OF MICHAEL MOLLOY AND LILY KOO/NIAID BIOLOGICAL IMAGING FACILITY

Microbe misunderstanding

In a healthy gut, a thin layer of mucus-lined intestinal wall separates billions of beneficial bacteria from the immune system. But in the throes of an intestinal infection, the walls are breached and both infectious and beneficial microbes (green) penetrate the intestinal wall (blue). Immunologist Timothy Hand of the National Institute of Allergy and Infectious Diseases in Bethesda, Md., and his colleagues show online August 23 in *Science* that in mice these breaches cause immune cells to lose their tolerance for the beneficial bacteria. The immune system's T cells form long-lasting memory cells that harbor the ability to bring the beneficial bacteria under friendly fire in subsequent encounters. The new findings suggest a role for misdirected T cells in inflammatory bowel ailments such as Crohn's disease, in which there is evidence of barrier breaching and T cell dysfunction. In this way, gut infections might prime T cells for a subsequent destructive role and, Hand suggests, predispose some people to the diseases. —*Nathan Seppa*

14 percent Proportion of U.S. adults with at least one tattoo, 2008

21 percent Proportion of U.S. adults with at least one tattoo, 2012

Tattoo infections connected to ink

Mycobacteria discovered in manufacturers' supplies

By Nathan Seppa

Tattoos are getting bad ink, literally.

An outbreak of uncommon bacterial skin infections in upstate New York in late 2011 has been traced to a tainted batch of ink used in a tattoo parlor, researchers report August 22 in the *New England Journal of Medicine*. Potent antibiotics were needed to vanquish the culprit, *Mycobacterium chelonae*, a bacterium in the same family as those that cause tuberculosis and leprosy.

Around the same time that the patients in New York were being identified and treated, scientists from the Centers for Disease Control and Prevention and elsewhere began tracing the origins of similar tattoo-based infections. They found eight caused by *Mycobacterium* in Washington, Iowa and Colorado. Ink used in these states came from three separate suppliers, all different from the source of the New York infections.

Some of the microbes varied, too. Two confirmed infections in Iowa, two in Washington and one in Colorado were caused by *M. chelonae*. But three in Washington arose from the related bacterium *M. abscessus*. *Mycobacterium* infections can range from skin rashes to severe abscesses that require surgery, CDC researchers and their colleagues report August 22 in *Morbidity and Mortality Weekly Report*.

Mycobacterium can show up in tap water, sewage, dust and soil. It's unclear how the bacteria got into the ink from four different suppliers. Ink used in the New York tattoo parlor was subsequently recalled.

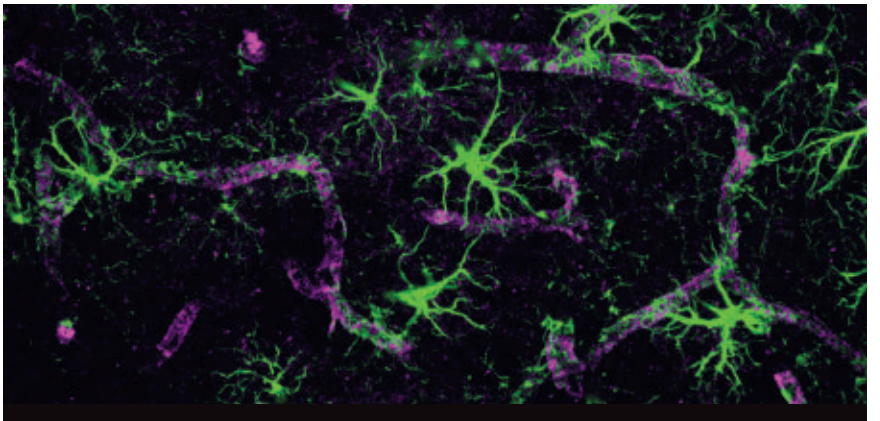
The New York study began when a dermatologist examining an infected tattoo couldn't discern its cause from a standard test. The doctor contacted health authorities, says Byron Kennedy, a physician and deputy director of the Monroe County Health Department. Kennedy and his colleagues contacted people in the county treated by the tattoo artist and uncovered 19 infections. Biopsies by dermatologists and lab tests at the University of Rochester confirmed *M. chelonae* infection in 14 of the patients, with probable infection in four others.

"This is a very complete, fair study that looked at the artist and the patients," says Myrna Armstrong, a nurse and researcher at Texas Tech University in Lubbock.

The microbe had previously appeared in a similar outbreak in France. The New York analysis is the first to nail down the microbial cause using DNA-level sleuthing and by examining an unopened ink bottle that turned out to contain the microbe, says Kennedy, who coauthored both new reports.

The antibiotics azithromycin and doxycycline proved effective in the New York patients, but lab tests showed the microbe might be resistant to cefoxitin and ciprofloxacin, potent antibiotics prescribed for a variety of infections. The CDC report notes that mycobacterial infections can require four months and two or more antibiotics to cure.

Despite these and other reports linking tattooing to an increased risk of hepatitis and other diseases, tattoos are as popular as ever. A Harris poll released in February found that 21 percent of U.S. adults have at least one tattoo, up from 14 percent in 2008. ■



J. ILIFF AND M. NEDERGAARD

Brain's sewer system revealed

The brain is a self-cleaning machine. A previously unknown plumbing system has been found to blast out waste by flushing it with the brain's cleaning solution—cerebrospinal fluid. Jeffrey Iliff of the University of Rochester Medical Center in New York and his colleagues watched cerebrospinal fluid flowing through the brains of living mice using an imaging technique called two-photon laser scanning microscopy. The fluid rushed into the brain by piggybacking on the outer surfaces of arteries. Fluid laden with toxins and waste was expelled through large drains. Channels (purple) on specialized brain cells called astrocytes (green) control the fluid flow, the team reports in the Aug. 15 *Science Translational Medicine*. Mice lacking these channels on their astrocytes had sluggish plumbing. Malfunctions of a similar plumbing system in humans could be behind conditions in which harmful proteins accumulate in the brain, such as Alzheimer's, Parkinson's and traumatic brain injury. —*Laura Sanders*

Genes & Cells

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Semen component may trigger hormone production and ovulation

Common protein identified in llamas also found in humans

By Meghan Rosen

Semen doesn't just ferry sperm. It also bears a mystery ingredient that turns on ovulation in some animals and may even pump up fertility in humans.

The molecule, called nerve growth factor, kick-starts egg release and revs up pregnancy-protective hormones in llamas, researchers report online August 20 in the *Proceedings of the National Academy of Sciences*. Llama semen is loaded with NGF, says study coauthor and veterinarian Gregg Adams of the University of Saskatchewan in Saskatoon, Canada. The protein is also found in the semen of cattle and humans.

"If we find that NGF is also effective in women, it will obviously have huge implications for treating male infertility conditions," says reproductive biologist Raj Duggavathi of McGill University's campus in Sainte-Anne-de-Bellevue, Canada. "It could be a big boost for couples."

NGF is well-known to biologists but not in the context of reproduction. Nerve cells typically spit the protein out to tell neighboring cells to grow.

Previous findings that semen could trigger ovulation in llamas challenged conventional wisdom that the physical movements of sex were what stimulated egg drop in the animals, says Adams. Unlike humans, cows, horses and sheep, which ovulate on a regular cycle, some animals rely on a little action to get their eggs moving.

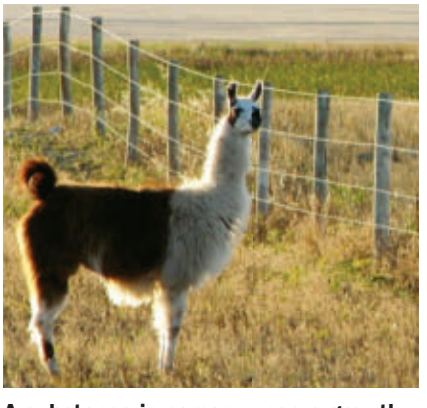
Adams' team had shown that sperm-free semen injected into llamas' leg muscles could set off ovulation all on its own — no bump-and-grind required.

What's more, in llamas and other animals, the seminal substance nurtured growth of a little yellow gland in the ovary called the corpus luteum. The gland churns out hormones essential for maintaining a pregnancy. Humans rely on it early in gestation, before the placenta plumps up and takes over. A fizzled-out corpus luteum with low-flowing hormones can lead to miscarriage in women.

Adams' team has known since 2005 that some ingredient in llama semen juices up ovulation, but until now, they didn't know what it was.

To pinpoint NGF's identity, the researchers collected semen from five llamas, filtered out the sperm and zeroed in on that special semen substance by injecting increasingly pure portions into female llamas' legs. The team then followed a step-by-step process to rule out potential molecular suspects.

The molecule's size, structure and biochemical properties clued researchers in to its identity. "When we found out that it was NGF, we scratched our heads and said, 'That's strange — NGF isn't supposed to work this way,'" Adams says. Instead of signaling nearby cells, semen NGF goes all the way through the blood vessels to the brain, where it delivers the message to get busy cranking out more hormones.



A substance in semen — nerve growth factor — can trigger ovulation in female llamas, like this one from the research herd at the University of Saskatchewan.

COURTESY OF G. ADAMS/ UNIV. OF SASKATCHEWAN

The team confirmed that the llama semen substance was NGF by using a technique usually seen in fertility clinics: injections followed by ultrasounds. Researchers gave llamas shots of either the purified semen substance or NGF from mouse salivary glands — a classic source of the protein — and checked the animals' reproductive organs with daily ultrasounds. Both substances made ovulation rates shoot up.

The work is the first to link NGF to reproductive function. "It's a blockbuster paper," says reproductive biologist Bruce Murphy of the University of Montreal.

Next, Adams' team plans to investigate NGF's role in human semen to see if the molecule is connected to fertility in people as well as llamas. Because women, unlike llamas, don't need semen to ovulate, it's not clear yet if NGF is also important for people, says reproductive biologist Dan Bernard of McGill University in Montreal. "It's still early." But, he says, "I think the fact that they've identified the protein will put this work on the map." The findings should provide fertile ground for other researchers in the field.

Even though women ovulate regularly, sometimes their bodies gear up for egg release at odd times during their cycle. "I want to know what happens if seminal plasma is absorbed at that time," Adams says. If a timely dose of semen does nudge an egg's release, he says, "It could be why we sometimes call couples who practice the rhythm method 'parents.'"

In addition to tweaking ovulation timing, NGF could boost growth of the pregnancy-protecting corpus luteum in humans. If NGF can cultivate the gland the way it does in llamas, cattle and mice, it's possible that frequent sex — and thus a steady supply of semen — during early pregnancy could help prevent miscarriage. The idea "is not crazy at all," Adams says. ■

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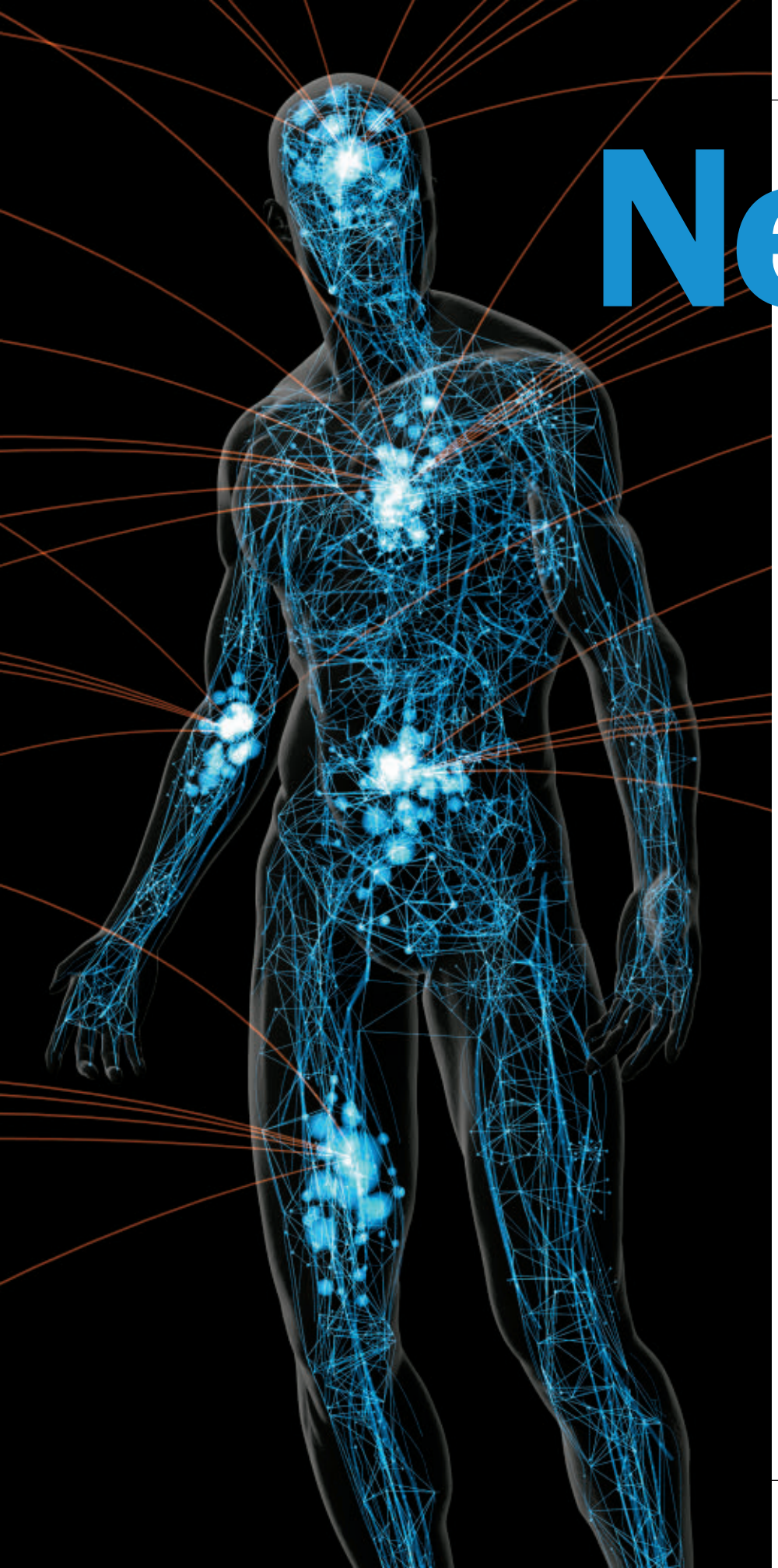


When Netwo

Once studied solo, systems display surprising behavior when they interact

By Elizabeth Quill

Half a dozen times each night, your slumbering body performs a remarkable feat of coordination.

During the deepest throes of sleep, the body's support systems run on their own timetables. Nerve cells hum along in your brain, their chitchat generating slow waves that signal sleep's nether stages. Yet, like buses and trains with overlapping routes but unsynchronized schedules, this neural conversation has little to say to your heart, which pumps blood to its own rhythm through the body's arteries and veins. Air likewise skips into the nostrils and down the windpipe in seemingly random spits and spats. And muscle fluctuations that make the legs twitch come and go as if in a vacuum. Networks of muscles, of brain cells, of airways and lungs, of heart and vessels operate largely independently.

Every couple of hours, though, in as little as 30 seconds, the barriers break down. Suddenly, there's synchrony. All the disjointed activity of deep sleep starts to connect with its surroundings. Each network — run via the group effort of its own muscular, cellular and molecular players — joins the larger team.

This change, marking the transition from deep to light sleep, has only recently been understood in detail — thanks to a new look at when and how the body's myriad networks link up to form an übernetwork.

ARTWORK BY BRYAN CHRISTIE DESIGN

rks Network

"As I go from one state to another, immediately the links between the physiological systems change," says Plamen Ivanov, a biophysicist at Boston University. "It is quite surprising."

And it's not just in bodies. Similar syncing happens all the time in everyday life. Systems of all sorts constantly connect. Bus stops pop up near train stations, allowing commuters to hop from one transit network to another. New friends join your social circle, linking your network of friends to theirs. Telephones, banks, power plants all come online — and connect online.

A rich area of research has long been devoted to understanding how players — whether bodily organs, people, bus stops, companies or countries — connect and interact to create webs called networks. An advance in the late 1990s led to a boom in network science, enabling sophisticated analyses of how networks function and sometimes fail. But more recently investigators have awakened to the idea that it's not enough to know how isolated networks work; studying how networks interact with one another is just as important. Today, the frontier field is not network science, but the science of networks of networks.

"When we think about a single network in isolation, we are missing so much of the context," says Raissa D'Souza, a physicist and engineer at the University of California, Davis. "We are going to make predictions that don't match real systems."

Like their single-network counterparts, networks of networks show up everywhere. By waking up in the morning, going to work and using your brain, you are connecting networks. Same when you introduce a family member to a friend or send a message on Facebook that you also broadcast via Twitter. In fact, anytime you access the Internet, which is supported by the power grid, which gets its instructions via communications networks, you are relying on interdependent systems. And if your 401(k) lost value during the recent recession, you're feeling the effects of such systems gone awry.

Findings so far suggest that networks of networks pose risks of catastrophic danger that can exceed the risks in isolated systems. A seemingly benign disruption can generate rippling negative effects. Those effects can cost millions of dollars, or even billions, when stock markets crash, half of India loses power or an Icelandic volcano spews ash into the sky, shutting down air travel and overwhelming hotels and rental car companies. In other cases, failure within a network of networks can mean the difference between a minor disease outbreak or a pandemic, a foiled terrorist attack or one that kills thousands of people.

Understanding these life-and-death scenarios means abandoning some well-established ideas developed from single-network studies. Scientists now know that networks of networks don't always behave the way single networks do. In the wake of this insight, a revolution is under way. Researchers from various fields are rushing to figure out how networks link up and to identify the consequences of those connections.

Investigators including Ivanov are analyzing a deluge of data to understand how networks cooperate to make bodies function. Other researchers are probing the Earth around them to identify the links that keep the planet in balance. But it's not all rainbows and butterflies. Much of the recent focus has been on the potential dangers that come with connection. In one landmark study, researchers at Boston University and elsewhere have developed math for explaining the way networks of networks can suddenly break down. Studying the bad along with the good may lead to a sort of "how to" for designing integrated systems that not only perform well in normal times, but also keep working when things go wrong.

Cascades of failure

A series of CNN news clips posted on YouTube highlight the vulnerability of interdependent systems. In what Wolf Blitzer repeatedly reminds the viewer is only an "exercise," former U.S. government officials convene to respond to a simulated cyberattack. The War of the Worlds–esque report begins with a Russian computer infecting a smartphone with a virus. After jumping to other smartphones, the bug makes its way into U.S. computers. From there it crashes communication networks, which in turn take out power stations. The ensuing blackout shuts down transportation networks. Each failure leads to yet more failures as the effects of a single infection bounce back and forth between systems. Having no control over the Russian computer system and no authority to shut down smartphones, the U.S. government is powerless.

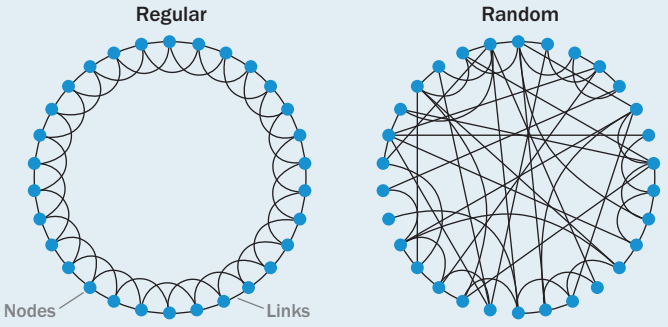
Shlomo Havlin of Bar-Ilan University in Israel sometimes shows portions of these clips during talks he gives on networks of networks. "If you have damage in one system, it can lead to damage in another system," Havlin says. But he points out that concerns about such rippling damages are not entirely new. Several reports — such as the CNN coverage — have highlighted worries about how fragile interdependent systems

Network milestones

A major breakthrough in the study of networks occurred when researchers discovered that a lot of real-world networks take a similar form. Dubbed "small-world," these single networks are characterized by clustering and shortcuts. Another refinement in thinking is now taking place as attention turns to interacting networks.

Single networks

A network consists of nodes (dots) connected by links (lines). Scientists characterize networks using properties such as size (number of nodes) and average degree (average number of links). In regular networks, each node has the same number of links. In random networks, the number of links per node is random. Small-world networks are a sort of intermediary and often more relevant to the real world.



might be. "What was not known was a systematic way to study this, a framework," Havlin says.

He first became interested in the problem when a program reviewer from the U.S. Defense Threat Reduction Agency visited the Boston University physics department in 2009. The agency was funding Havlin and H. Eugene Stanley, along with Boston colleagues Gerald Paul and Sergey Buldyrev, to work on questions plaguing single networks. The reviewer mentioned a new topic that interested the agency: How resilient are interacting networks when something goes amiss? Proposals were due in a couple of weeks. Despite the short time frame, the team, later joined by Bar-Ilan colleague Roni Parshani, decided to tackle the issue.

Overnight Havlin came up with a way of thinking about it. Single networks are typically represented by dots joined by lines. The dots, called nodes, are the players in the network. The lines, called edges or links, represent connections between those players. Havlin's insight was to connect some of the nodes in one network with nodes in another via a new type of line. His new lines, called dependency links, signal places where a node in one network relies on a node in the other to function — say, a computer that can't get by without its sole power source. These key dependencies could allow a failure to propagate between systems.

Once Havlin outlined a way of thinking about the problem, Buldyrev worked through the math. It wasn't simple. He had to use equations to explain each state of each network as the random removal of one node triggered the removal of other nodes. Buldyrev, whom Paul calls "a mathematical genius," cracked it. Answering the program reviewer's initial question took only about a week.

"One morning, I came in and Shlomo was — not quite dancing on the table — but he was very, very excited," Paul says.

In their analysis of connected networks, the researchers found a type of mathematical behavior that couldn't have been predicted from knowledge of single networks. When a node is removed from a single network, the failure tends to propagate gradually, the network coming apart bit by bit by bit. But removing nodes in a network of networks means the breakdown can occur abruptly. As nodes go offline, the system initially appears to be working properly. But all of a sudden, a threshold is reached. Lose one more node and — poof — the whole thing falls to pieces.

"Even if one more node fails, the network collapses completely," Havlin says. "It makes the network a much more risky place."

Stanley likens the single-network scenario to a drunken prisoner trying to escape with a pair of wire clippers. As the prisoner makes random cuts along a fence, a hole develops that gradually gets bigger and bigger. After a little while, maybe, the prisoner can stick an arm through, and with a few more snips, a head. Eventually enough snips may allow the prisoner's whole body to fit through. But in the case of networks of networks, the prisoner cuts just one or two wires and then appears to hit on a magical one that makes the whole fence disintegrate. The prisoner can walk to freedom.

"It's as if someone threw a switch," Stanley says. "But there is no switch."

After tweaking the math and running some simulations, the researchers submitted a paper to *Nature*. Since its publication, in 2010, more than 100 other papers have cited it.

Other teams have also found unexpected behavior in networks of networks. In 2009, D'Souza and a colleague showed that connecting a large portion of nodes in a network of networks takes fewer links than would be required for a similar single network. Other scientists have revealed that imposing travel restrictions may not reduce the spread of an epidemic as much as would be expected because of the interconnected nature of human mobility networks. And in 2008, Italian researchers reported that a power station shutdown led to a failure in the Internet communication network, causing the breakdown of more power stations and triggering an electrical blackout affecting much of Italy. In its *Nature* paper, the Boston group used this disaster as a real-world example to model how failures can cascade back and forth between networks.

What set the *Nature* paper apart from the others was that it offered a simple mathematical model to explain real-world phenomena. That finding meshed with others to give network-of-networks science a theoretical foundation.

"They have really figured out the framework of how to think about it," says

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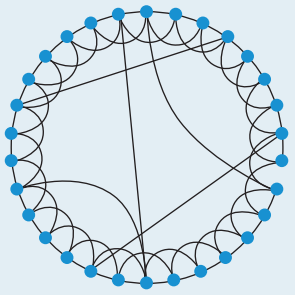
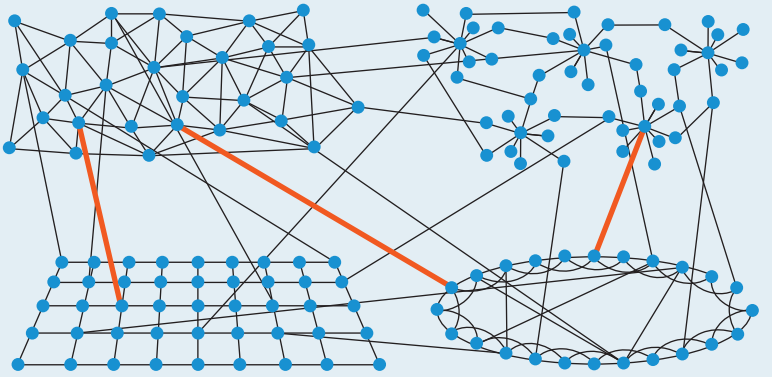


Networks of networks
In practice, networks often link up. Though scientists don't yet know what form these übernetworks typically take, some of the same quantitative properties still apply. Links here come in at least two forms: connectivity (similar to links in single networks, shown in black) and dependency (interactions that can be the difference between life and death for a node, shown in orange).



Albert-László Barabási of Northeastern University in Boston, who made seminal contributions to studies of single networks. "They came along and said, let me show how you calculate this and what are the consequences of coupling these networks."

Since the discovery, the Boston cadre — along with a battalion of graduate students — has extended its framework to study the vulnerability of three or more interconnected systems. In another study, the researchers have found that terrorist-caused damage to an important power hub may differ from more arbitrary damage caused by, say, a rat chewing through an electrical wire.

Like a social scene in which all the popular kids hang out together, in some networks well-connected nodes are more likely to link up with other well-connected nodes. Stanley, grad student Di Zhou and colleagues have found that if one network in an interdependent system has this property, dubbed assortativity, then the whole system is more vulnerable to disturbance.

These early findings were unexpected based on studies of solo networks, leaving scientists wondering what other secrets networks of networks might hold. "There are many questions that appear immediately," Havlin says.

It's a small world

A similar burst of activity in network science occurred in 1998, after Cornell University's Steven Strogatz and then-colleague Duncan Watts published a groundbreaking paper, also in *Nature*. Titled "Collective dynamics of 'small-world' networks," it explained why the world seems so tiny.

At the time, "small-world phenomena" had already gained a degree of notoriety. In the 1960s, psychologist Stanley Milgram showed that a randomly selected person living in Nebraska could be connected via acquaintances to a target person in Massachusetts through just a few (typically six) other people. Students from Albright College in Reading, Pa., made the idea widely known in the mid-1990s when they invented a game known as Six Degrees of Kevin Bacon, based on the actor's appearances in so many movies. With the links defined as coappearances in any single film, Bacon could supposedly be connected to any other Hollywood celebrity in no more than six steps. In the network of actors, moving from the node of Kevin Bacon to the node of, say, Hilary Swank would pass you over fewer than six films. (In fact, it's hard to name an actor who is more than two or three degrees from Kevin Bacon. Try for yourself at www.oracleofbacon.org.)

Small-world, or Watts-Strogatz, networks exhibit two features: They are highly clustered, meaning the nodes clump together like cliques of middle school girls. And shortcuts connect those cliques, akin to a cheerleader who occasionally hangs out with a member of the nerdy group.

Much like the simple framework developed more recently by the Boston group, the Cornell duo's findings had implications for how a network behaves. "Systems synchronize much faster, epidemics spread much more rapidly," Strogatz says. "In the case of game theory — where you have people, companies, countries playing prisoner's dilemma — we were able to show that the small-world structure would make a difference in how that game evolved."

But what really launched the Watts-Strogatz revolution was the way features in their model matched multiple real-world networks. An electric power grid, actors connected to Kevin Bacon and the nerve cells in a worm were all in on a secret that scientists had only just uncovered.

"The legacy is the introduction of the idea of looking at the comparative anatomy of networks," Strogatz says. "What we were able to show was there were universal principles that applied to different networks that scientifically were completely unrelated but mathematically were following the same architectural principles."

Almost immediately, researchers from diverse disciplines abandoned existing projects and redirected their intellectual firepower to develop network math for proteins, planes, power stations and pathogens. Friends, film actors and financial players also got their fair share of attention. Over the last dozen years or so, this flood of effort has led to a better understanding of how nodes of all types come together to form networks and what happens when one gets plucked out.

But work so far has focused mostly on the comparative anatomy of single

networks. Surprising behavior uncovered in networks of networks presents a new and still puzzling question: Do the übernetworks behind blackouts, stock market crashes, transportation gridlock and even sudden deteriorations in health — a particular worry of Stanley's — conceal a deeper shared anatomy?

Stanley believes they might. When he walks down the stairs, he has a habit of holding the railing. Breaking a hip, he says, could trigger a series of disconnections in his body's network of networks.

It's widely known that an elderly person who fractures a hip faces a greatly increased chance of dying within the next year, even if repair surgery is successful. What's not yet clear, though, is whether the cascading behavior outlined by the Boston team is behind this abrupt decline in health. An answer may emerge as scientists find out what networks of networks in the body, in finance and in nature have in common.

Plumbing networked networks

Of all the world's network-of-networks problems, climate change is one of the most challenging to untangle. How much global temperatures will increase over the next century depends on patterns of behavior in the air, the ocean, the land and among all the organisms living on the planet. Natural cycles are influenced by human-driven networks — the economics governing greenhouse gas emissions, the political drive behind energy alternatives and the social recognition of global warming as a problem in need of a solution.

In a recent study, physicist Jonathan Donges of Germany's Potsdam Institute for Climate Impact Research plotted hundreds of thousands of data points related to air pressure to study networks in just the atmosphere. By tracking how the data changed over time, he identified a series of horizontal networks that wrap around the Earth, layering on top of one another like Russian nesting dolls. The Arctic serves as the link, acting as a sort of atmospheric border patrol that controls mingling between the horizontal layers, he and colleagues reported last year in *European Physical Journal B*.

"The Arctic seems to be important in coupling atmospheric dynamics on the surface and in higher layers up in the atmosphere," Donges says.

If networks of air molecules sound complicated, consider the network of goings-on in your cells, where the nodes and their links come in different forms. Within each cell of your body there is a constant dance among DNA, RNA and proteins. DNA encodes networks of 20,000-plus genes; at any one time many are being decoded into complementary strands of messenger RNA, which form their own networks as they guide the production of proteins. Those proteins can do-si-do with other proteins, interacting within their own network in a very physical way, or can connect with other networks by pulling genes onto or off the dance floor.

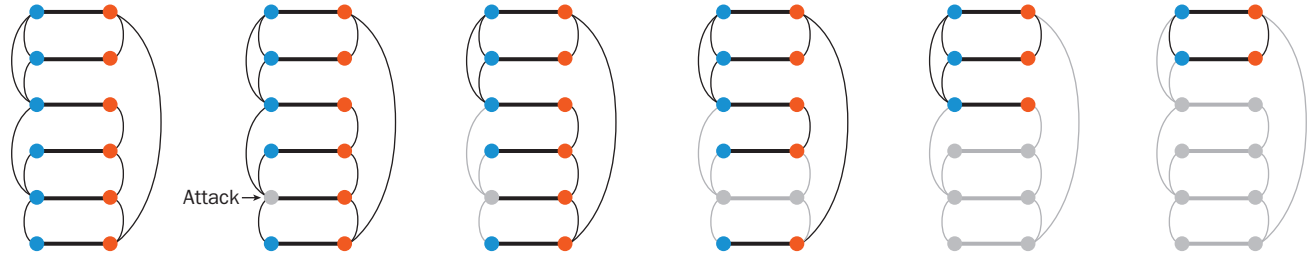
"You cannot look at these networks in isolation," says Tom Michoel of the University of Edinburgh's Roslin Institute. "Everything there is interconnected."

Michoel tries to understand networked networks by studying small-scale patterns that show up more often than expected in a particular system, and thus say something about its overall functioning. Consider a common workplace pattern, in which an intermediary can serve as a point of contact between a boss and an employee. Michoel found many examples of a similar pattern in yeast cells. One of two linked-up networks included interactions that regulated gene activity, in which a protein (the boss) chemically tags a gene that codes for another protein (the intermediary). The other contained more direct protein-protein interactions (between the intermediary and an employee).

By looking at how the small-scale patterns clustered and overlapped, Michoel discerned that one boss interacts with one intermediary but that each intermediary represents many employees, sort of like a union spokesperson acting on behalf of union members. Without the übernetwork analysis, there was no way to understand the distinct roles of bosses and intermediaries, Michoel says. Important large-scale interactions would have remained hidden.

Exposing unknown interactions is not the only issue. Strengths of the connections linking networks are also impor-

Back-and-forth failures When networks depend on other networks, such as a communications network that relies on a power grid, failure can cascade back and forth between the two. This behavior may explain sudden breakdowns in interacting systems. Thus, the effects of an attack on a single node can reduce an übernetwork (below) that starts with 12 operating nodes to just four. SOURCE: S.V. BULDYREV *ET AL*/*NATURE* 2010



Two networks (blue and orange) interact via dependency links (bold).

An attack on the blue network takes out a blue node.

Links connecting the attacked node to other blue nodes no longer function.

An orange node that had depended on the attacked node fails, along with all of its links.

Blue nodes detached from their network and dependent orange nodes exit.

Orange nodes detached from their network and dependent blue nodes exit.

T. DUBÉ

tant. The volume of buses traveling a route, for example, may ramp up during rush hour. Or in your social networks, you may see a coworker almost every day but a high school friend just once a year.

In his investigation of sleep cycles, Ivanov showed that changing how tightly two networks are coupled can affect physiology. Links don't have to be newly created or severed to matter.

A former student of Stanley's, Ivanov spent more than a decade collecting data on heart rate, breathing rate, muscle tone and eye movement to find out how the body's networks interact during the various stages of sleep. Much like Donges' approach with the atmosphere, Ivanov inferred links and the nature of those links by analyzing how measurable markers from each system parallel each other in time. His team found out how the networks hook and unhook, but also how those hookups vary.

Ivanov believes his problem, as well as other network-of-networks puzzles that show up in the body, is a bit more challenging than the ideal scenario tackled by Stanley and Havlin's group.

"We could have failure even if a particular link between nodes doesn't disappear," Ivanov says. "We could still have all links present, but with different strengths, and the system can come to arrest."

Such considerations inject further complications into the emerging field, suggesting just how much more there is to be learned.

Physicist and computational scientist Alessandro Vespignani of Northeastern University, who studies epidemics and other spreading processes in networks, compares the current state of knowledge to what the Romans knew about Africa 2,000 years ago. The Romans had a pretty good map of the world, but they didn't journey deep into Africa. "There are lions, that was the only information," Vespignani says.

Right now, scientists have a map of the future of network science, and networks of networks offer an exciting new area, but people are only beginning to travel there. "We need to define new mathematical tools," Vespignani says. "We need to gather a lot of data. We need to do the exploratory work to really chart the territory."

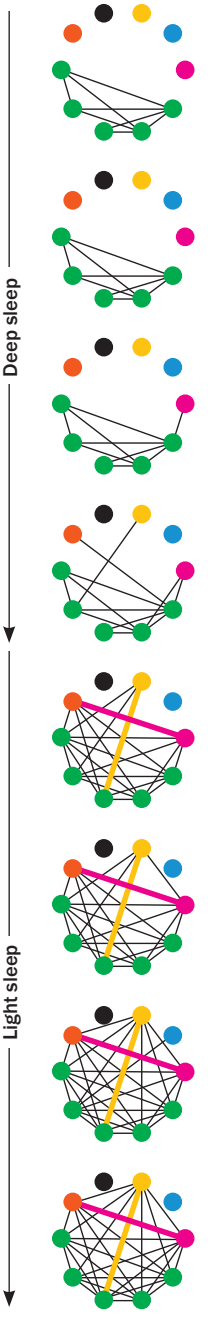
Linked resilience

D'Souza of UC Davis has made early strides in mapping a landscape different from the one where the Boston team planted its flag. When she and colleagues became interested in networks of networks, they focused on success rather than failure.

"We weren't looking in the realm of something so catastrophic that the node goes away forever," D'Souza says. "We are more interested in a dynamical thing that will keep the network still working."

In a recent study, her team looked at how two linked power grids might interact, say a grid that covers much of the eastern United States and another that services the West. She constructed links between the grids that are similar to the links between individual nodes within each grid: The nodes interact, but the survival of one doesn't depend entirely on the other. She calls them connectivity links.

Each node in each network was assigned a capacity, akin to the load a power plant can handle before it becomes overwhelmed by that demand. Links represent ways for a power plant to hand off its load. If a plant can't meet a given demand, it can pass some on to another linked power plant, which can pass it on to another and then another. As the researchers gradually add demand, like sand being added to a pile, they look for "avalanches" of load. Load will take off running across nodes the way that sand added to a pile will eventually start tumbling down the sides. Fittingly, network scientists call these avalanches "sandpile cascades."



Sleep shifts During the transition from deep to light sleep, networks in the body suddenly join up. Each small circle stands for a measurement of a bodily system, and the lines show which systems are acting in concert over a four-minute period. From an interacting networks perspective, deep sleep is quite distinct from light sleep, which more resembles waking.

- Eye activity
- Leg movements
- Chin muscle tone
- Respiratory activity
- Heart rate
- Brain activity at various frequencies

SOURCE: A. BASHAN *ET AL*/*NATURE COMMUNICATIONS* 2012

In analyzing the mathematics of these cascades, D'Souza and her colleagues showed that having two networks can help take some of the burden off a single network, minimizing the threat of large avalanches. "A little bit of coupling was incredibly beneficial," D'Souza says. "The second network acted as a reservoir where the first could shed some load."

But add too many connections between the networks and larger avalanches become possible, the team reported in March in the *Proceedings of the National Academy of Sciences*.

Connected power grids are a good example of networks that cooperate, says D'Souza. Adding power lines to one network may boost the transmitting capabilities of the second. But such networks may also turn competitive, if, for example, an improvement in one puts the other at an energy-supplying disadvantage.

D'Souza's efforts have highlighted other flavors that networks of networks can come in, too. In your social web, you probably have overlapping networks, in which you simultaneously belong to a

T. DUBÉ

friend group and a family group. Or there may be networks in which the nodes are the same, but the links differ; think of banks that borrow money from each other in one network and invest in each other in another.

Then there are systems in which one network is actually built on top of another, the way hyperlinked Web pages sit atop electric, fiber-optic and wireless communication channels. These "overlay networks" also show up in the brain. Its physical architecture, the very anatomy of the brain, provides the structural network from which function — thought, memory, reason — emerges.

"Functional activity for me is more of a fleeting, fast-changing, difficult to characterize and for that reason much more ethereal construct in some ways," says Olaf Sporns of Indiana University. Sporns is a major player in the Human Connectome Project, which seeks to understand how all the nerve cells in the brain interact. "The structure of the brain, the anatomy is something that, if we have good enough instruments, we can measure," he says. "It is actual wiring."

Brain scientists agree that the functional network must somehow be rooted in the structural network. But exactly how one gives rise to the other isn't clear. What's more, the networks feed off each other, adding the element of evolution to an already hard-to-follow labyrinth of nodes and links. The architecture sculpts, constrains and molds the function, and the function leaves experiential traces on the structure over time.

Sporns proposes that these dynamics represent a constant balancing act between the wiring cost in the anatomical network and the desire for efficient outcomes in the functional network. "This process of negotiating, and renegotiating trade-offs," Sporns and a colleague wrote in May in *Nature Reviews Neuroscience*, "continues over long (decades) and short (millisecond) timescales as brain networks evolve, grow and adapt to changing cognitive demands."

As the brain changes in time, so does the behavior of the body — influencing all the larger networks in which a person plays a part.

That can expand the puzzles facing scientists. Questions extend to how a network of networks reacts to what's happening within, and how people adapt to the system, says Vespignani. "If I know there is a blackout, I will do certain things. If I know there is an economic crisis, I will go to the bank and ask to get all my money back. If there is an epidemic, I will stay home."

Some scientists speculate that currently available theoretical approaches for übernetworks may be too simplistic to be useful. One economist went so far as to warn of the dangers of applying the Boston team's results too widely, assuming everything is a nail just because you have a hammer. Most researchers, though, offer a more measured take.

Toward better systems

While physicists and mathematicians strive for simplicity, engineers like Leonardo Dueñas-Osorio of Rice University favor a more data-driven simulation approach, enriching tools from network science with realities from physical systems.

"When you have a complex problem, abstractions of the analytical kind can help you narrow down where to focus," Dueñas-Osorio says. "Then you need to add refinement, make things more realistic."

Both approaches — theoretical and simulation-based — have some real-world payoff. With equations that are mathematically tractable, "you can do a lot of insightful derivations," he says. "Those are very valuable, but sometimes you only achieve those at the expense of simplifying the systems."

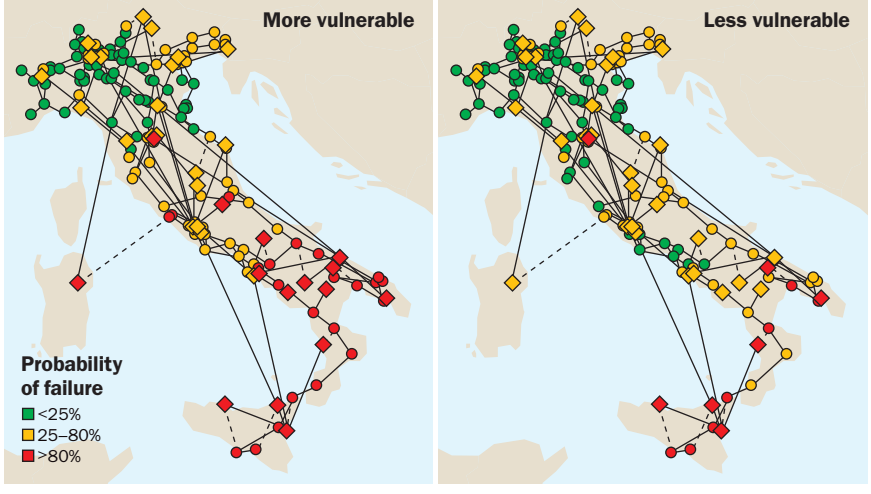
Dueñas-Osorio and others instead build network models that pin every node into its proper geographic location and give each one a different likelihood of failing, depending on factors such as its age or activity level. Many of these researchers get their data on the ground.

During a trip to Chile after a 2010 earthquake there, Dueñas-Osorio collected information about what transformers failed and what pipes broke. He talked to utility companies to track service interruptions. "This information allows us to get a sense of how strong the connections are between systems," he says.

Such data also reveal ways in which systems are suboptimal and could be improved. Some areas hard-hit by natural disasters don't have enough connections — with, for example, only one power plant supporting a pumping station.

Efforts by Havlin and colleagues have

Saving nodes In a simulation of coupled networks in Italy (circles represent a power grid, diamonds a communications network), protecting just four nodes made a system less vulnerable. At left, all communications servers are coupled to the power grid; at right, four are decoupled. Colors show the probability that a node fails after 14 servers fail. SOURCE: C.M. SCHNEIDER *ET AL*/ARXIV.ORG 2011



MAP: GEOATLAS/GRAPHI-OGRE, ADAPTED BY T. DUBÉ

yielded other tips for designing better systems. Selectively choosing which nodes in one network to keep independent from the second network can prevent "poof" moments. Looking back to the blackout in Italy, the researchers found that they could defend the system by decoupling just four communications servers. "Here, we have some hope to make a system more robust," Havlin says.

This promise is what piques the interest of governments and other agencies with money to fund deeper explorations of network-of-networks problems. It's probably what attracted the attention of the Defense Threat Reduction Agency in the first place. Others outside the United States are also onboard. The European Union is spending millions of euros on Multiplex, putting together an all-star network science team to create a solid theoretical foundation for interacting networks. And an Italian-funded project, called Crisis Lab, will receive 9 million euros over three years to evaluate risk in real-world crises, with a focus on interdependencies among power grids, telecommunications systems and other critical infrastructures.

Eventually, Dueñas-Osorio envisions that a set of guidelines will emerge not just for how to simulate and study networks of networks, but also for how to best link networks up to begin with. The United States, along with other countries, have rules for designing independent systems, he notes. There are minimum requirements for constructing buildings and bridges. But no one says how networks of networks should come together.

Ivanov hopes to develop a similar rulebook for the human body that shows actual designs. Many doctors' offices display diagrams of the body that outline the different systems — the circulatory system, the respiratory system, the musculoskeletal system. But no diagrams show how those systems interact with one another, and that knowledge might be just as crucial for fighting disease.

As more data come in, the goals of those working on human-built systems and natural systems may merge. More important than whether biological, social and technological systems exhibit similar mathematical properties may be whether they should. Can people design better systems by learning from the systems that exist in nature?

Sporns predicts the answer could be yes. "These systems naturally, just by virtue of being here, actually having survived, have been optimized to a certain extent," he says. "They are existing proof that you can have complex networks that are structurally buildable and realizable and sustainable, at the same time dynamically competent, resilient against perturbations and evolvable."

How to maximize sustainability, resilience and evolvability in networks of networks are questions that are still largely open. Geneticists seek answers in the genes, physiologists in the broader body and ecologists in the interactions that govern all living things. Connections forming among these growing webs of knowledge, as well as with engineers' models and theorists' frameworks, will provide much-needed fuel for a burgeoning intellectual endeavor.

If the efforts prevail, one day preventing blackouts, interrupting epidemics and handling a complicated commute may be as easy as waking up in the morning. ■

Explore more

- *Nature Physics* special issue, January 2012: www.nature.com/nphys/insight/complexity

Network catastrophes While researchers have not yet analyzed them in detail, some recent real-world incidents highlight what can happen if disaster strikes within a network of networks.

India blackout, 2012
Power grids collapsed in India earlier this year, leaving hundreds of millions of people without power. The outage triggered transportation failures as local and long-distance trains stopped running. Some sources speculate that the grid was overloaded because a weak monsoon had farmers using more electricity to pump water to fields.

Eyjafjallajökull eruption, 2010
Iceland's Eyjafjallajökull volcano erupted in 2010, spewing ash that shut down air travel throughout Europe. But travelers weren't the only ones affected: Manufacturers, medical suppliers and crop producers couldn't move their goods. The effects of the grounding rippled into the fuel, hotel and car rental industries.

Swine flu pandemic, 2009
When a swine flu outbreak hit Mexico in 2009, officials responded with travel bans and other control measures. But a drop in international air traffic to and from Mexico didn't prevent a pandemic. Viruses travel through a complex global mobility übernetwork that is made up of long-distance flights as well as local commutes, and interacts with social and economic networks.

FROM TOP: © AP, CORBIS; STOCKTREK IMAGES/RICHARD ROSCOE/GETTY IMAGES; ENEAS DE TROYA/FLICKR

Planetary Peekaboo

Astronomers aren't playing games when it comes to spotting an exoEarth

By Nadia Drake

ANCHORAGE, Alaska — On a bright June evening, residents of Anchorage packed the theater in Cyrano's Off-Center Playhouse, ready to sample some otherworldly dispatches.

The messages were beamed to Earth by NASA's Kepler spacecraft, which circles the sun spying on planets orbiting distant stars. Planet-hunting members of the mission's science team, in town for an American Astronomical Society meeting, served as translators for the evening, telling tales of far-off worlds that put a twinkle in the spacecraft's eye.

At the time of the summer get-together, the Kepler team had officially confirmed the existence of 72 exoplanets, a tally that stumped some audience members during a game of science trivia.

"When I first wrote this question, the answer was 61," said Anchorage resident Wendy Withrow, the event's emcee. "And it wasn't that long ago."

The Kepler craft is delivering results at an extraordinary rate, with a stable of planetary candidates that now tops 3,000. At times, every week seems to herald the confirmation of a new world, another planet joining a cosmic menagerie that includes molten spheres, two-starred orbs and siblings snuggled so close together that each occasionally rises in the other's sky.

Since the June meeting, Kepler scientists have announced another five confirmations, upping the exoplanets on the confirmed list to 77. Soon, the team expects to pin down an additional 800 or so, which would double the total number of planets discovered by any search, ever.

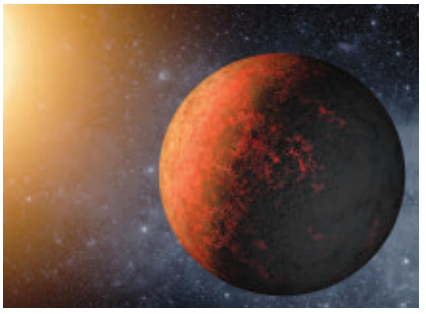
With such vast returns, it's hard to believe that Kepler's goal — to make a major stride in determining how special Earth is — once balanced on the brink of impossibility. Until NASA granted the team a four-year extension in April, failure was almost certain. The stars in Kepler's eye proved rowdier than expected, blinking and winking and muddying the signatures of orbiting planets.

"When Kepler was launched, the objective was to determine the frequency of Earth-sized planets in the habitable zone. We actually changed that statement as the years evolved; we dropped 'in the habitable zone,'" says Natalie Batalha of San José State University in California. "Now we're adding that back in."

Barring any more unexpected malfunctions (*SN Online: 8/14/12*), the team is in business through September 2016. And researchers are working to clear the hurdles standing in the way of quantifying exoEarths — small planets living in life-friendly zones around their stars.

Reaching the finish line will still be a rocky journey. The scientists have to improve their detection techniques to better pick possible exoplanets from among the thousands of blinking lights spilling from the Kepler field of view.

NASA AMES, JPL-CALTECH



Kepler has found Earth-sized exoplanets (illustration of Kepler-20e, above) and planets with Earthlike orbits (Kepler-22b, left). But an orb that fits both criteria still eludes mission scientists.

Researchers are also working on tools to characterize planets once they are confirmed: Are they rocky, like Earth? Ultimately, the team might actually figure out how frequently Earths spangle the skies viewed by Kepler, but whether that number will apply to the entire galaxy is not so clear.

"Are there other habitable planets out there, and how common are they?" asks Geoff Marcy of the University of California, Berkeley. "This is a really profoundly beautiful question. It's one of those questions that transcends science. It's in the realm of philosophy."

Winning the lottery

Kepler finds Earthly cousins by engaging in a staring contest with a patch of sky stuffed with more than 150,000 stars. The spacecraft watches for blinks occurring when a planet dims a star's light by passing in front of it, or transiting. A planet in an Earthlike orbit would dim its star just once each Earth year — and scientists look for multiple dimming events, requiring years of observing time.

"We can't look away, because we might miss one of the transits," Nick Gautier of the Jet Propulsion Laboratory in Pasadena, Calif., told the audience at Cyrano's.

Sighting the blinking kicks off a complex process meant to distinguish a real-deal planet-bearing star from a star just showing off its inherent twinkles. But Kepler's star field is overly rambunctious, with natural brightness fluctuations much greater than expected for stars like the sun, says Jon Jenkins of the SETI Institute in Mountain View, Calif. "It was a big surprise to us that the typical solar-like star is noisier than the sun," says Jenkins, Kepler's lead analytical guru. "The sun really isn't a 'solarlike star.'"

This new finding makes pegging a signal as a candidate planet much more difficult, so Jenkins and about two dozen other team members are working on improvements that will filter out excess stellar noise. To do this, the team is fine-tuning its computer software, teaching the software to be a bit more discriminating in what it lets through.

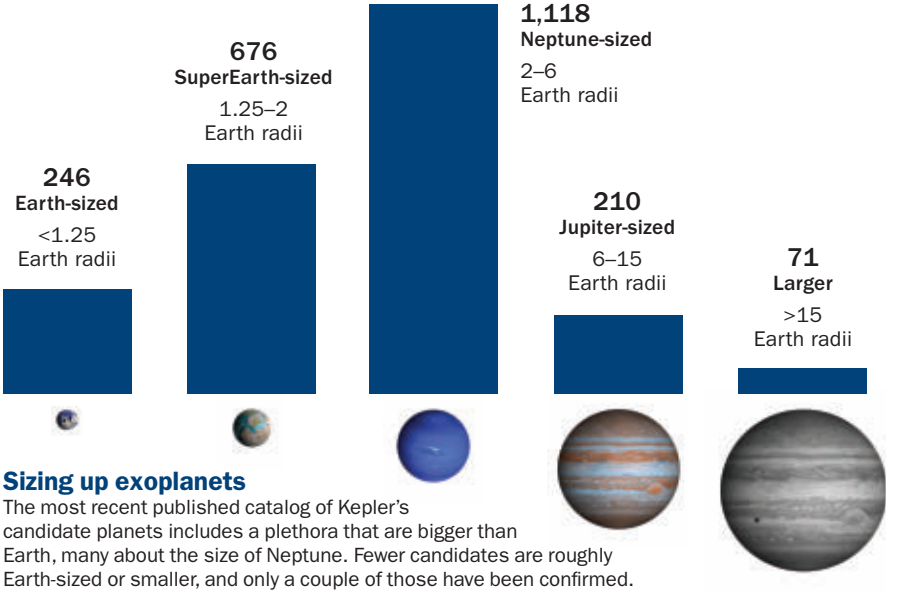
Jenkins likens the tuning process to selectively listening to the tenor in a barbershop quartet. "As long as you're listening to the tenor, you can screen out the bass and the baritone because they don't interfere," he says. But you also have to make the system's ear more sensitive by removing barriers that can introduce the equivalent of static to the listening process. "We've made significant progress, but we still have to continue to beat those down in order to be able to find the smallest planets that are of the most interest to us," Jenkins says.

As the mission has progressed, scientists have found more and more small candidates. But there are worries those climbing numbers may come to a halt.

At the astronomy meeting, scientists presented preliminary analyses of the candidate census so far. Hot Jupiters — large planets closely orbiting a parent star — are often found by themselves and are scarce in the Kepler field, probably because they don't much care to live around the type of star Kepler looks at. Smaller planets don't appear to be as picky: There's a whole load of planets bigger than Earth but smaller than Neptune, and they live around a variety of types of stars. An additional report pointed to roughly a dozen candidates smaller than Mars awaiting confirmation.

Scientists have long assumed that smaller planets are more abundant than larger ones, but the current Kepler census suggests that the pattern might not hold in all cases. "We see the now-familiar rise in planet occurrence as you go to smaller planet sizes, down to two Earth radii," said Andrew Howard of the University of Hawaii at Manoa. "And then something interesting happens: The occurrence actually falls."

No one knows why — or whether the falloff is real. "One possibility is that we're seeing something profound about planetary science," Howard said. The other: Kepler's current trove isn't representative of what is actually out



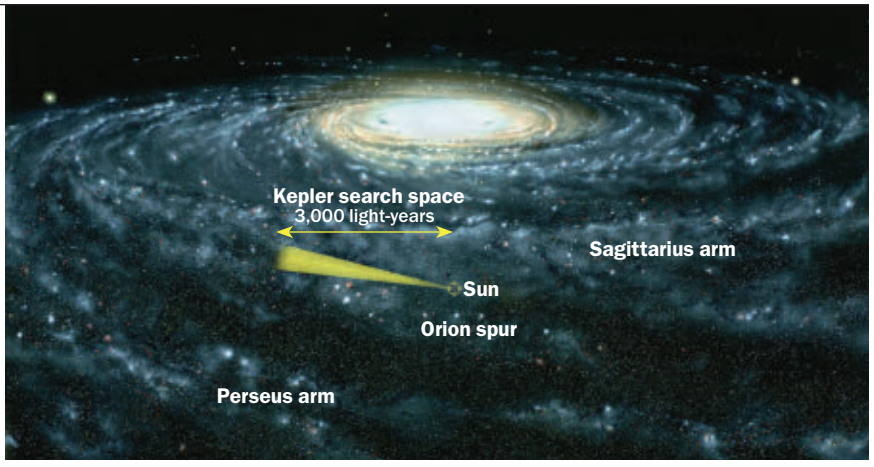
Sizing up exoplanets
The most recent published catalog of Kepler's candidate planets includes a plethora that are bigger than Earth, many about the size of Neptune. Fewer candidates are roughly Earth-sized or smaller, and only a couple of those have been confirmed.

FROM TOP: NASA AMES, JPL-CALTECH; WENDY STENZEL/KEPLER MISSION/NASA. ADAPTED BY E. FELICIANO

there — either because of the stars themselves, or because listening techniques are biased toward bulked-up basses.

If the number of Earth-sized planets does drop off, scientists will have to work even harder to find them. Already, two of these exo-treasures have rolled off the Kepler pipeline: Kepler-20e and Kepler-20f, announced in December. But these planets sit too close to their parent star for liquid water and life to survive.

Other planets, Kepler-22b announced last December (*SN Online: 12/6/11*) and one orbiting the binary star system Kepler-47 reported in *Science* in August, sit in their stars' habitable zones but are too big to qualify as Earth-sized.



A stellar view The Kepler mission searches for planets around stars that sit along the Orion spur of the Milky Way. Most of the stars are from 500 to 3,000 light-years away. Though this region of space is expected to be similar to the solar neighborhood, scientists aren't yet sure whether Kepler's exoplanet findings will hold for the entire galaxy.

Planet ingredients

Though spying Earth-sized planets in habitable zones fulfills Kepler's goals, it won't be enough to convince scientists that they have found a true Earth 2.0. Kepler can determine only the radius of a planet, so the team needs a different way to measure a planet's mass — and thus its density and composition.

Traditionally, a star's wobble has been used to measure mass, in what's known as the radial velocity method. Marcy presented preliminary data at the astronomy meeting suggesting that planets begin to transition from bloated, watery mini-Neptunes to rocky Earths when they are somewhat smaller than two Earths. But he hasn't surveyed enough planets to know for sure.

Since smaller planets tug less on a parent star, measuring the star's wobbles requires a supersensitive, stable instrument. "The U.S. currently doesn't have one," says Marcy, who performs radial velocity follow-up measurements on the planets for which it is possible. "It's a huge embarrassment."

Instead of traditional radial velocity follow-ups, a newer method called transit timing variations might help scientists calculate the mass of a small planet. For this method to work, a transiting Earth-sized planet in a system with at least one Neptune-like sibling is "a golden combination," Marcy says. Even without transiting its parent star, a larger planet would cause slight variations in the smaller planet's transit times. These variations would allow astronomers to measure the larger planet's mass, from which they could calculate the smaller planet's mass.

"A very small handful of people are doing this, and they're in very high demand right now," Batalha says, adding that characterizing planets needs to become a priority.

"Can you have an Earth-sized planet that's like a big cotton ball? Maybe you could. Are they all rocky planets like Earth? They might be icy, dirty snowballs," she says. "We're in this candy store with all these planets, and it would make me very sad if we didn't have the technology to characterize them."

The Kepler spacecraft will search for new exoplanets through September 2016.

To Earth and beyond

Despite the obstacles still to be overcome, scientists think they're close to achieving their goal. "We're going to know, within two years, the following thing: Whether Earth-sized planets are common or rare, in Earthlike orbits," Marcy says.

Of course, the broader implications of the Earthy frequency determined by Kepler will depend on how well the census reflects the galaxy as a whole. Because the telescope stares at stars that hover above the Milky Way's plane, it's unlikely that the patch will be representative of real estate nearer the galactic bulge, for example. Still, the Kepler patch is "supposedly like the solar neighborhood," says Jack Lissauer of NASA's Ames Research Center in Mountain View, Calif.

Though a destination in itself, finding the frequency of Earthy worlds is just one part of a much broader, millennia-old question: Are we alone, or is there other life in the universe? Ultimately, scientists want to profile exoEarths, however common they may be, by studying atmospheres, sniffing around for potential biosignatures and searching for signs of intelligent life.

The Kepler mission is just the start of that journey. Step by step, the team is leaping over the hurdles that come with plunging into the unknown, and managing to turn up surprises along the way. As the evening wound down at Cyrano's, Anchorage resident Todd Sherwood offered his opinion of the Kepler team's work: "It's like close encounters of the 12th kind." ■

Explore more

■ www.kepler.nasa.gov

The invention of the year is great news for your ears

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Perfect Choice HD feature comparison

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Setting Memory	YES	Few
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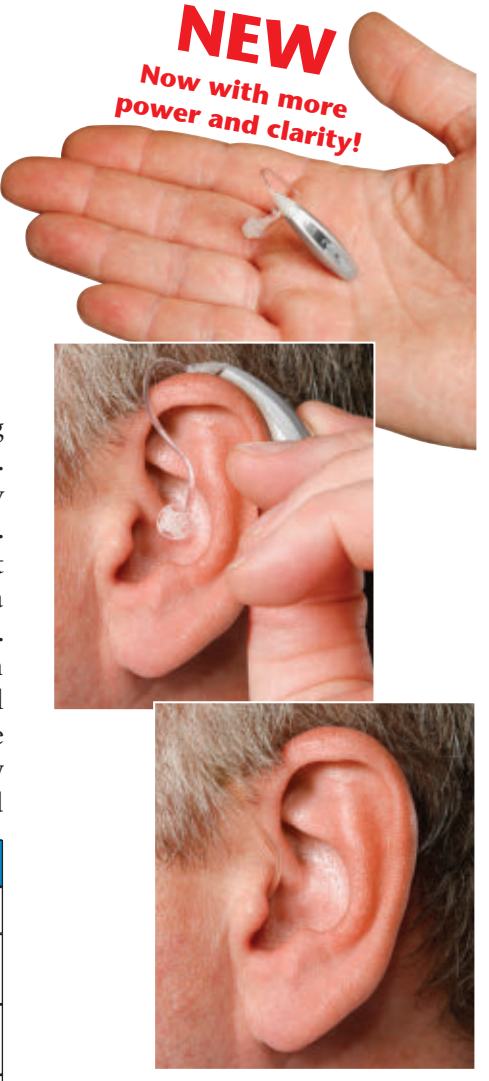

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The Ravenous Brain

Daniel Bor

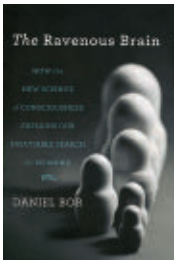
In this dispatch from the front lines of consciousness research, neuroscientist Bor offers an introspective interpretation of what the human mind is and what it's good for.

Consciousness, Bor argues, is a "chronic mental hunger," the brain's demand for more and more information about the world. This insatiable appetite has propelled humans to the moon, ushered in medical advances and compelled countless commuters to reach for sudoku puzzles.

Bor sees this hunger in action as he watches his baby daughter learn to walk. She gleefully toddles around the room and is delighted when she figures out how to step backward, her burgeoning consciousness greedily finding patterns and making connections.

At the other end of the spectrum, a waning consciousness can signal illness such as depression, anxiety disorder, chronic pain or schizophrenia. The book opens with Bor's father experiencing a minor stroke that leaves him with limited awareness of his left side. This constricted form of consciousness changed the father's personality, providing Bor's initial impetus to study neuroscience.

During aging, the insatiable brain becomes less so, Bor writes. "We are less ravenous for new jewels of wisdom, and our entire existence, examined through the perspective of the thousands of chunks we've acquired, can become routine." Meditation and some forms of brain training may help, he suggests, by putting the mind in a childlike state.



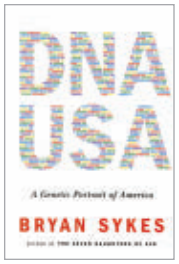
Bor's knack for bolstering personal examples with laboratory studies makes this a thought-provoking read. His ideas are tantalizing, but not as definitive as he occasionally makes them seem. Scientists still have a lot of tinkering and testing to do before they are even close to understanding consciousness. — *Laura Sanders*

Basic Books, 2012, 352 p., $27.99

DNA USA: A Genetic Portrait of America

Bryan Sykes

A human geneticist has dipped his DNA testing kit into the great melting pot, exploring the genetic history, genealogy and anthropology of Americans. Sykes travels across the country meeting ordinary people and creating portraits of their chromosomes that reflect from whence their ancestors hailed. All the volunteers are given pseudonyms drawn from Hollywood movies, but the stories of their heritage are engagingly real.

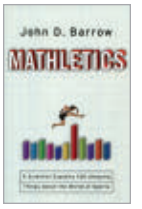


As the author of *The Seven Daughters of Eve* and other books, Sykes is an old hand at writing about genetics for the general public. His experience shows as he deftly introduces highly technical information in reader-friendly ways.

He spends most of the first third of this new book on the ancestry of various immigrant groups, telling their tales through DNA found in mitochondria and on the Y chromosome. Mitochondrial DNA is passed from mother to child, and Y chromosomes trace paternal lines. Sykes has studied human history extensively through these two genetic lenses. Consequently, he focuses there and doesn't tackle recent genetic tests that sample all of a person's DNA until Chapter 11.

During his journey, Sykes encounters people who embrace DNA testing as a way to clear up messy genealogical records. He also meets skeptics, who see the technology as a way to discredit their cultural heritage. Sykes doesn't shy away from these criticisms, presenting a well-balanced view of the disparate attitudes. — *Tina Hesman Saey*

W.W. Norton & Co., 2012, 369 p., $27.95



Mathletics

John D. Barrow

See what math reveals about sports, from the possibility of speeding up Usain Bolt to the physics of high jumping's backward flop. *W.W. Norton & Co., 2012, 298 p., $26.95*

Finding the Arctic

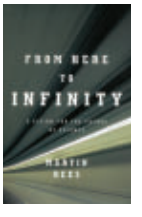
Matthew Sturm

A climate researcher intertwines the story of his own snowmobile expedition with the history of life and exploration in the Arctic. *Univ. of Alaska, 2012, 258 p., $24.95*

The Case of the Green Turtle

Alison Rieser

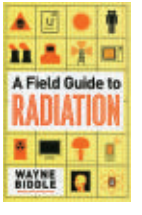
The story of efforts to save green sea turtles, including by farming them, illustrates conflicts common to conservation work. *Johns Hopkins, 2012, 338 p., $45*



From Here to Infinity

Martin Rees

An astrophysicist proposes ways for scientists and the public to tackle problems together, from climate change and energy to health care and population growth. *W.W. Norton & Co., 2012, 144 p., $23.95*



A Field Guide to Radiation

Wayne Biddle

From "absorbed dose" to zirconium-95, this alphabetical collection of essays makes an interesting guide to the nuclear age. *Penguin, 2012, 258 p., $16*

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Cartilage risk

I enjoyed Nathan Seppa's article ("Cartilage creation," *SN: 8/11/12, p. 22*) about attempts to generate new cartilage from somatic stem cells. He writes that cartilage evolved "in ancestors who lived shorter lives, carried less body weight and roamed an unpaved world." Implications: The risk of osteoarthritis increases with age, body weight and impact on concrete, such as a long-term runner might experience. Is there solid scientific experience for all three of these putative risk factors?
William Check, San Francisco, Calif.

Yes. First, osteoarthritis stemming from cartilage wear and tear is most common in the elderly. Second, studies show that extra pounds add to stress on weight-bearing joints, particularly the knees. Third, it's certain that modern humans spend a lot of time in a paved world. Joint compression is natural and necessary for nutrient transfer in cartilage tissue, which isn't supplied by blood or driven by circulatory pressure. But too much compression — through abrupt injury or long-term pounding — creates stress, inflammation and other damage. MIT's Alan Grodzinsky puts it this way: "With compression above a certain rate and amplitude, you cross a threshold into microdamage" of cartilage tissue and the cells that make it.
— Nathan Seppa

On Turing's life and death

Out of the whole of Tom Siegfried's well-written article on Alan Turing ("A mind from math," *SN: 6/30/12, p. 26*), I especially want to commend Siegfried both for his honesty and for the language he chose to speak of Turing's death. It is so important, even in a science magazine in a math-history article, not to shy away from social truth and to name what is evil as evil.
David H. Kehret, via e-mail

Send communications to: Editor, Science News, 1719 N Street, NW, Washington, D.C. 20036 or **editors@sciencenews.org**. Letters subject to editing.

The Science Life

To see thermal video of a lava lake on Kilauea, visit **www.sciencenews.org/kilauea**

By keeping close watch on lava fields and fissures at Hawaii's Kilauea, volcanologist Matt Patrick works to predict lava flows and eruptions.

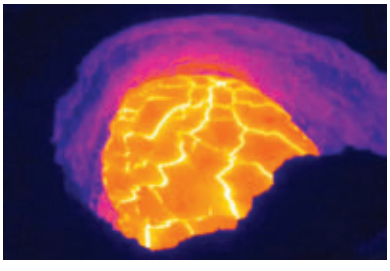
The volcano watcher

Matt Patrick's office is perched not far from the summit of Hawaii's busiest volcano: Kilauea. When it erupts, he has a good view. Of course, it's his job to see every possible vista of the peak, whether it's flying over in a helicopter, hiking to fissures and along lava fields or checking webcams, seismometers and satellites. Working at the U.S. Geological Survey's Hawaiian Volcano Observatory, Patrick is part of a team that monitors the volcano's every tremor, eruption, burp of gas and lava path. This diligence helps researchers track potential danger and understand the details of a volcano's inner workings.

"Working on an active volcano is a pretty special opportunity," Patrick says. And for the first time in at least 200 years, there's major action at two different places on Kilauea. "We've had eruptions going on at the summit and East Rift Zone, going on for years," he says. "And with the quality of data we're collecting, it gets better every day."

One of Patrick's specialties is the use of thermal cameras, which see through eruption fumes and can show clearly where a lava field is newest and thus most likely to continue flowing. Before joining the observatory in 2007, he used thermal images to spot signs of upcoming eruptions on Alaskan and Russian volcanoes and to track eruptions at Italy's Stromboli. Now he spies on Halemaumau, the eruption crater resting at Kilauea's summit. The work is revealing that the crater's lava lake and the East Rift Zone may be physically connected.

He remembers one evening in 2011 when data pointed to an imminent eruption in the rift zone. A helicopter flight confirmed a fissure opening. Patrick and a colleague had hiked to the eruption site by midnight. Nothing happened, so they started hiking back. An hour passed. "Suddenly we saw the sky turn bright orange. We heard a jetting sound. We were able to see the spot we were just at had become a fountain." —*Kristina Bartlett Brody*



One busy volcano

Matt Patrick of the Hawaiian Volcano Observatory used thermal cameras to capture the rapid draining of a lava lake (thermal image above) within the Halemaumau crater on Kilauea's summit. His monitoring is revealing a hydraulic connection between the lava lake and the volcano's active East Rift Zone and suggests that changes in the lake's levels may be linked to eruptions.

Kilauea is one of the most active volcanoes on Earth today and can be active for decades at a time. Eruptions have been persistent along the volcano's flank since 1983, and at the summit since 2008.

The observatory also monitors Mauna Loa and four other Hawaiian volcanoes that are quiet now but could erupt again. Mauna Loa eruptions can produce lava flows that move kilometers within hours—much faster than Kilauea's lava streams. "You could even outcrawl the lava," Patrick says of Kilauea.

TOP: JIM KAUAHIKAUA/USGS; OTHERS: HVO/USGS

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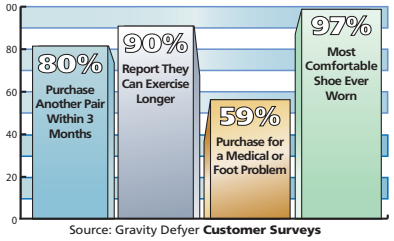

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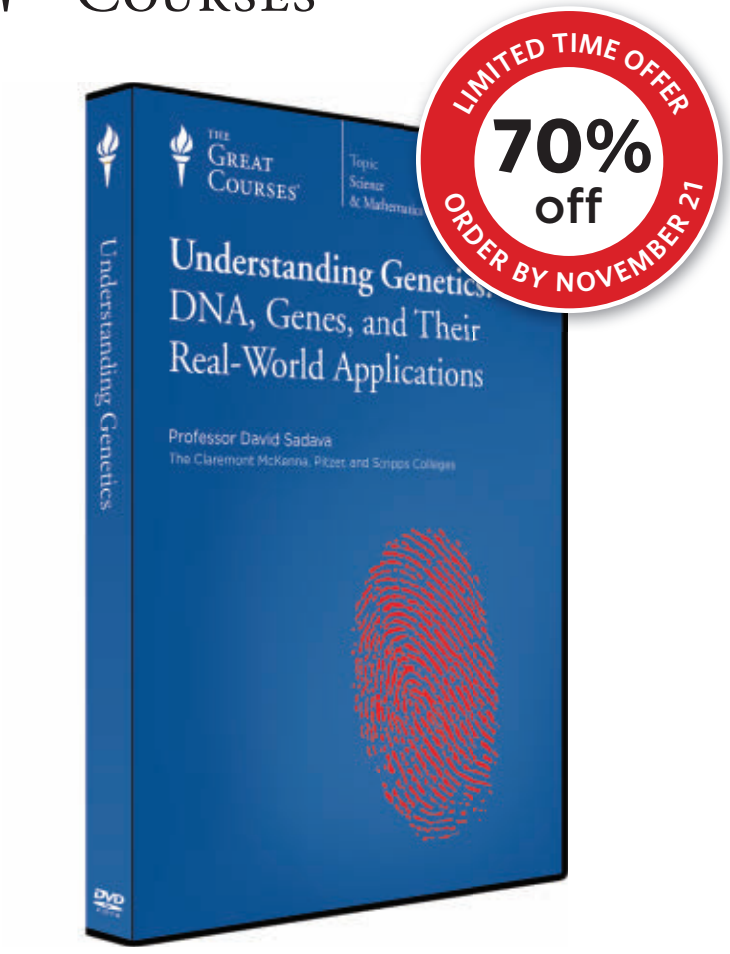

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