

JANUARY 2015

NATIONAL GEOGRAPHIC



HOW A TINY
12,000-YEAR-
OLD TEENAGER
BECAME

THE FIRST AMERICAN

The Firsts Issue

THE FIRST
ARTISTS

THE FIRST
YEAR OF LIFE

THE FIRST
CITY OF AFRICA

THE FIRST
GLIMPSE OF THE
HIDDEN COSMOS

EENIE
MEENIE
MINEY **GO**



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The wedding of Gbenga Adeoti and his bride, Funmi Olojede, featured traditional customs and attire of the Yoruba, Lagos's main ethnic group.

78 Africa's First City

In Lagos, Nigeria, a boom economy widens the rift between the wealthy and the poor.

By Robert Draper Photographs by Robin Hammond

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The First Artists

Credit them with a pivotal innovation in human history: the invention of symbolic expression.

By Chip Walter
Photographs by Stephen Alvarez

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The First Year

In the incredible learning machine that is a baby's brain, development depends on loving caretakers.

By Yudhijit Bhattacharjee
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A First Glimpse of the Hidden Cosmos

As scientists map the universe, what they can't see—dark energy and dark matter—is key.

By Timothy Ferris
Photographs by Robert Clark

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Tracking the First Americans

Genetic data and new archaeological discoveries offer clues to the mystery of early Americans' origin.

By Glenn Hodges

138 Proof | First Bird

The bald eagle may be a majestic national symbol—but it's also one tough bird.

By Klaus Nigge

On the Cover Geneticists say that Native Americans' ancestors were Asians who separated from other Asian populations and remained isolated for about 10,000 years. Art by Tomer Hanuka

Corrections and Clarifications Go to ngm.com/more.

Looking Ahead

This issue of *National Geographic* is built around the idea of “firsts”—discoveries, innovations, and actions that changed the world. As a first, it’s hard to top the bravery of Ruby Bridges, who tells us in our 3 Questions feature what it was like to be the first child to desegregate an American public elementary school in the South. We also use the term less formally, as in a photo essay on America’s “first” bird (the bald eagle) or a vibrant story on Africa’s “first” city (Lagos, Nigeria’s commercial center, which is driving the biggest economy on the continent).

So in an issue of firsts, how do we forecast what comes next? What will be the next “firsts” that will change us, our families, our communities, and our planet?

In an attempt to answer some of those questions, we went to the experts and futurists who contemplate coming changes both prosaic and profound. Take Paul Saffo, a Silicon Valley seer who, in 1994 (four years before the founding of Google), predicted that the future belonged to “those who control the filtering, search, and sensemaking tools we will rely on to navigate through the banal expanses of cyberspace.” Indeed.

Whether it’s about the anticipated demise of the combustion engine or a decrease in divorce, we hope you’ll find these experts’ ideas thought provoking as we enter 2015. One cautionary note: No predictor is always right. In what he calls his “worst forecast,” Saffo wrote in 1993 that “cyber-punks are to the 1990s what the beatniks were to the ’60s—harbingers of a mass movement waiting in the wings.” That’s one mass movement we still await. Onward to the next firsts—and Happy New Year!



Susan Goldberg, *Editor in Chief*



HOW WE WILL LIVE

WITHIN 5 TO 10 YEARS

Paul Saffo, *Technology Forecaster*

Driverless cars will share roadways with conventional cars. This will happen in urban areas first and will take a decade to fully diffuse. In the long run, people won’t own cars at all. When you need to go somewhere, you’ll have a subscription to an auto service, and it will show up at your door.

We’re moving away from a purchase economy. We will subscribe to access rather than pay money for possessions such as smartphones. We won’t buy software anymore; we’ll subscribe to it.

A new religion could emerge in the next decade or two, perhaps based around the environment. Digital technology is the solvent leaching the glue out of our global structure—including shaking our belief systems to the core.



HOW WE WILL LOVE

WITHIN 10 TO 20 YEARS

Pepper Schwartz
Professor, University of Washington

Divorce may decrease after the baby boomers, who have a high divorce rate, age into their 50s and 60s.

We will also see more people who are in love but do not share a domicile. Though definitely couples, these people are tied to different places because of a job or family, or because they love where they live. Maybe we will see people going back and forth between assisted living facilities.





HOW WE WILL HEAL

WITHIN 10 TO 20 YEARS

Bertalan Meskó
Medical Futurist
Author of *The Guide to the Future of Medicine*

The next decades of medicine and health care will be about using technologies and keeping the human touch in practicing medicine.

Everyone's genomes will be sequenced to access personalized treatments.

We'll measure almost any health parameters at home with diagnostic devices and smartphones.

The 3-D printing revolution will produce affordable exoskeletons and prosthetic devices.



HOW WE WILL AGE

WITHIN 20 YEARS

Byron Reese, *Tech Entrepreneur*

Author of *Infinite Progress: How the Internet and Technology Will End Ignorance, Disease, Poverty, Hunger, and War*

Since technology grows exponentially, not in a linear way, we will see dramatic improvements in our way of life in just a few years. Though it took us 4,000 years to get from the abacus to the iPad, in 20 years we will have something as far ahead of the iPad as it is ahead of the abacus. This means that soon we will be able to solve all problems that are fundamentally technical. These problems include disease, poverty, hunger, energy, and scarcity. If you can live a few years more, there is a real chance you will never die, since mortality may be just a technical problem we solve. All these advances will usher in a new golden age, freed from the scourges that have plagued humanity throughout our history.

"THERE IS A REAL CHANCE YOU WILL NEVER DIE, SINCE MORTALITY MAY BE JUST A TECHNICAL PROBLEM WE SOLVE." —Byron Reese



HOW WE WILL BE POWERED

WITHIN 50 YEARS

Michael Brune, *Executive Director, the Sierra Club*

Author of *Coming Clean: Breaking America's Addiction to Oil and Coal*

Within 50 years the world should be able to achieve a 100 percent clean energy economy. Within the next couple of decades, every time you turn on a light or power up your computer, every bit of that electricity will come from clean, renewable, carbon-free sources. Soon after that, solar and wind will displace nuclear as well, at which point we'll be getting 100 percent of our electricity from renewables. By 2030 we should be able to cut transportation oil use in half and then cut it in half again a decade later.

Once we're finally fossil-fuel free, we'll not only see our climate stabilize but we'll also rest secure knowing that we can get all our power from sources that are safe, secure, and sustainable. It's already within our grasp.

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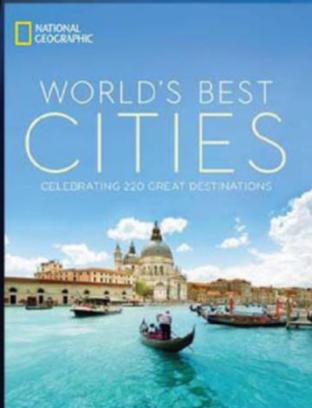
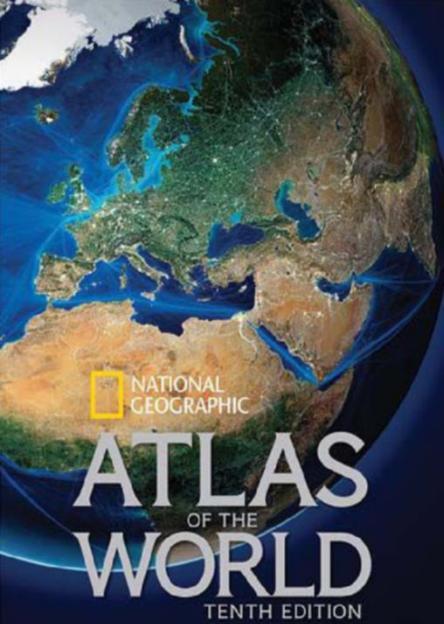
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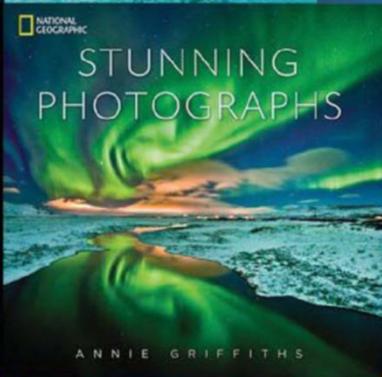
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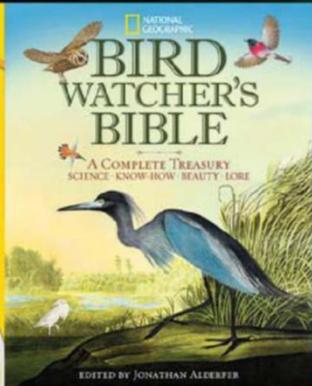
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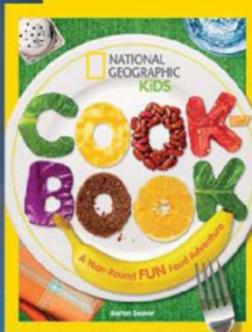


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3 Questions

Nominate someone for 3 Questions at nationalgeographic.com/3Q.



How I Felt to Be First

On November 14, 1960, six-year-old **Ruby Bridges** walked past an angry crowd to become the first child to integrate a public elementary school in the American South. Now a mother, grandmother, and activist, the lifelong New Orleans resident heads the Ruby Bridges Foundation and travels all over the United States to tell her story.

DID YOU EVER TALK TO YOUR MOTHER ABOUT HOW SHE FELT, SENDING YOU TO SCHOOL THAT FIRST DAY?

We never really spoke about it. My parents definitely displayed courage. I'm the mother of four. I'm very protective, but I just don't think that I possess that kind of courage. I know it was a different time, but as African Americans, my parents knew that if they wanted to see change in their lifetime, they had to step up to the plate to make that happen. And as we know, lots of people did that. Lots of people who made those bold sacrifices lost their lives. I remember driving up to the school, seeing all these people screaming. But in New Orleans that's what we do at Mardi Gras. I thought we'd stumbled upon a parade. And so I really wasn't afraid at all.

YOUR FOUNDATION'S MISSION IS TO "EMPOWER CHILDREN TO ADVANCE SOCIAL JUSTICE AND RACIAL HARMONY." HOW DO YOU HELP CHILDREN DO THIS?

I just draw from my own experience. I guess that six-year-old is still inside of me. Once my school was integrated and I was there with white kids and a few black kids, it really didn't matter to us what we looked like. Now I reach out to different communities and bring their kids together.

A STATUE OF YOU WAS RECENTLY DEDICATED AT YOUR FORMER SCHOOL. HOW DOES THAT MAKE YOU FEEL?

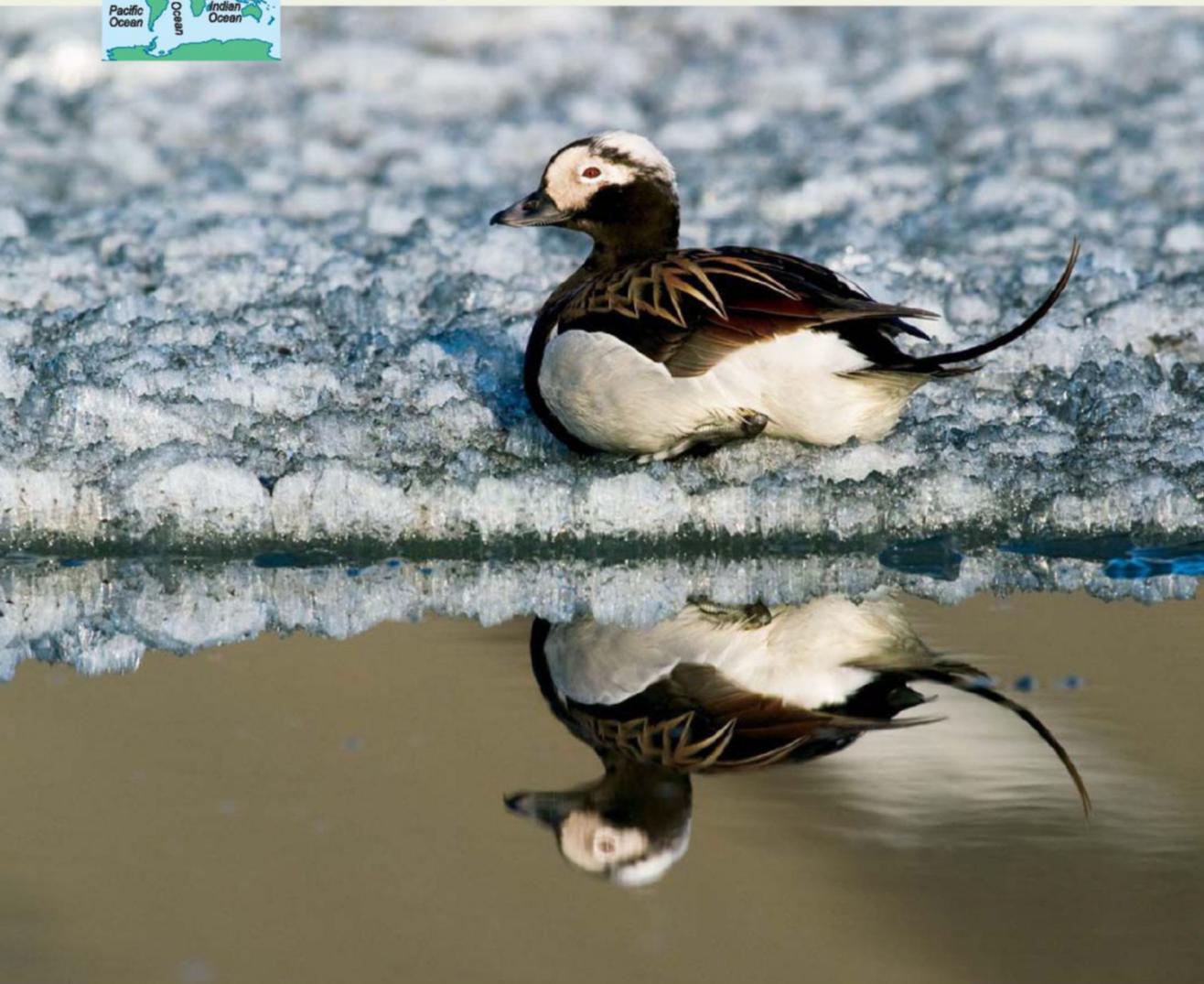
My school was hit by Hurricane Katrina, and they were going to tear it down. I worked hard to get it on the National Register of Historic Places. I'm really proud of that, and of the statue. I want to inspire kids. There are all kinds of monuments to adults—usually dead and usually white. But we don't often lift up the extraordinary work of children.



Long-tailed Duck (*Clangula hyemalis*)

Size: Body length (incl. tail), 37 - 60 cm (14.6 - 23.6 inches) **Weight:** 685 - 800 g (24 - 28 oz)

Habitat: Oceans of the Northern Hemisphere **Surviving number:** Estimated at 6.2 - 6.8 million



Photographed by Jasper Doest

WILDLIFE AS CANON SEES IT

Deep diver. When the long-tailed duck ventures beneath the waves in search of shrimp, krill, snails and mussels, it is able to reach depths as great as 200 feet. The male also shows his prowess in other ways during courtship, filling the skies with a distinctive call likened to that of a hoarse rooster. After mating, the male congregates with his fellows in a lake to molt his

plumage, leaving the female to brood on the nest. But every year fewer young are hatched as populations plunge due to habitat degradation, hunting, fishing bycatch and disease.

As Canon sees it, images have the power to raise awareness of the threats facing endangered species and the natural environment, helping us make the world a better place.



EOS System



EXPLORE



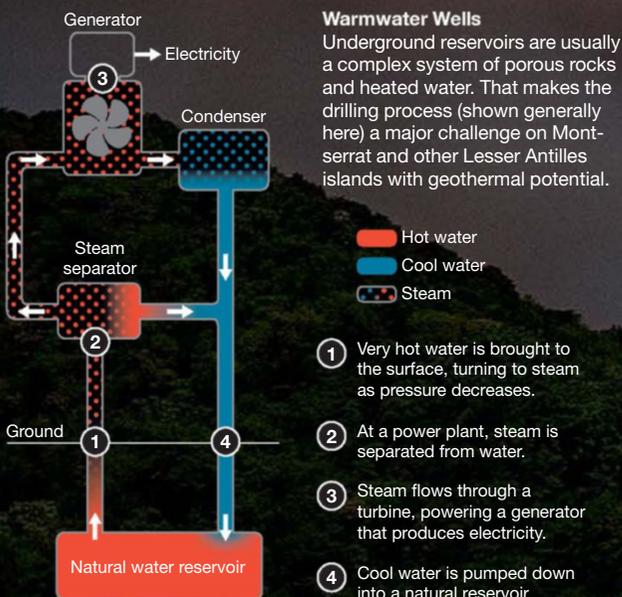
Planet Earth

A Geothermal First?

Can the “Emerald Isle of the Caribbean” be the first to go green? Montserrat is trying. Nearly 20 years after the Soufriere Hills volcano began erupting—rendering much of the island nation uninhabitable and exiling two-thirds of the population—the same geological forces could provide reliable, renewable geothermal energy.

Like much of the Caribbean, this British overseas territory runs on costly oil and gas imports. But as on other islands, plate tectonics and volcanic activity bring magma close enough to the surface for geothermal wells to tap into the heated reservoirs just below.

A single well can cost several million U.S. dollars, though. Last year, with U.K. funding, University of Auckland researcher Graham Ryan and an international team of scientists and engineers mapped two promising spots. Initial findings suggest there’s enough geothermal juice there to power the grid, warrant a third well—and maybe even sell to neighbors. —*Jeremy Berlin*





For people with a higher risk of stroke due to Atrial Fibrillation (AFib) not caused by a heart valve problem



ELIQUIS® (apixaban) is a prescription medicine used to reduce the risk of stroke and blood clots in people who have atrial fibrillation, a type of irregular heartbeat, not caused by a heart valve problem.

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 - bleeding that is severe or you cannot control
 - red, pink, or brown urine; red or black stools (looks like tar)
 - coughing up or vomiting blood or vomit that looks like coffee grounds
 - unexpected pain, swelling, or joint pain; headaches, feeling dizzy or weak
- ELIQUIS is not for patients with artificial heart valves.
- Spinal or epidural blood clots (hematoma). People who take ELIQUIS, and have medicine injected into their spinal and epidural area, or have a spinal puncture have a risk of forming a blood clot that can cause long-term or permanent loss of the ability to move (paralysis).

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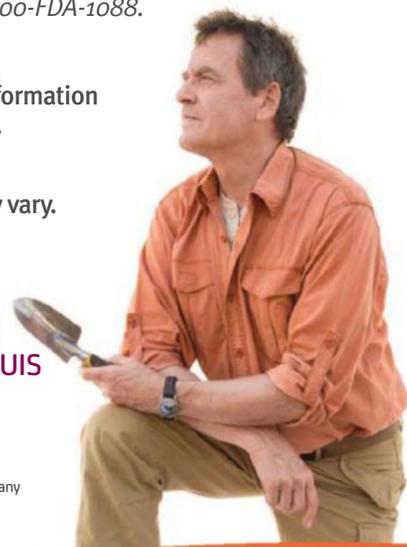
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IMPORTANT FACTS about ELIQUIS® (apixaban) tablets

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The information below does not take the place of talking with your healthcare professional. Only your healthcare professional knows the specifics of your condition and how ELIQUIS may fit into your overall therapy. Talk to your healthcare professional if you have any questions about ELIQUIS (pronounced ELL eh kwiss).

What is the most important information I should know about ELIQUIS (apixaban)?

For people taking ELIQUIS for atrial fibrillation: Do not stop taking ELIQUIS without talking to the doctor who prescribed it for you. Stopping ELIQUIS increases your risk of having a stroke.

ELIQUIS may need to be stopped, prior to surgery or a medical or dental procedure. Your doctor will tell you when you should stop taking ELIQUIS and when you may start taking it again. If you have to stop taking ELIQUIS, your doctor may prescribe another medicine to help prevent a blood clot from forming.

ELIQUIS can cause bleeding which can be serious, and rarely may lead to death. This is because ELIQUIS is a blood thinner medicine that reduces blood clotting.

You may have a higher risk of bleeding if you take ELIQUIS and take other medicines that increase your risk of bleeding, such as aspirin, nonsteroidal anti-inflammatory drugs (called NSAIDs), warfarin (COUMADIN®), heparin, selective serotonin reuptake inhibitors (SSRIs) or serotonin norepinephrine reuptake inhibitors (SNRIs), and other medicines to help prevent or treat blood clots.

Tell your doctor if you take any of these medicines. Ask your doctor or pharmacist if you are not sure if your medicine is one listed above.

While taking ELIQUIS:

- you may bruise more easily
- it may take longer than usual for any bleeding to stop

Call your doctor or get medical help right away if you have any of these signs or symptoms of bleeding when taking ELIQUIS:

- unexpected bleeding, or bleeding that lasts a long time, such as:
 - unusual bleeding from the gums
 - nosebleeds that happen often
 - menstrual bleeding or vaginal bleeding that is heavier than normal

- bleeding that is severe or you cannot control
- red, pink, or brown urine
- red or black stools (looks like tar)
- cough up blood or blood clots
- vomit blood or your vomit looks like coffee grounds
- unexpected pain, swelling, or joint pain
- headaches, feeling dizzy or weak

ELIQUIS (apixaban) is not for patients with artificial heart valves.

Spinal or epidural blood clots (hematoma).

People who take a blood thinner medicine (anticoagulant) like ELIQUIS, and have medicine injected into their spinal and epidural area, or have a spinal puncture have a risk of forming a blood clot that can cause long-term or permanent loss of the ability to move (paralysis). Your risk of developing a spinal or epidural blood clot is higher if:

- a thin tube called an epidural catheter is placed in your back to give you certain medicine
- you take NSAIDs or a medicine to prevent blood from clotting
- you have a history of difficult or repeated epidural or spinal punctures
- you have a history of problems with your spine or have had surgery on your spine

If you take ELIQUIS and receive spinal anesthesia or have a spinal puncture, your doctor should watch you closely for symptoms of spinal or epidural blood clots or bleeding. Tell your doctor right away if you have tingling, numbness, or muscle weakness, especially in your legs and feet.

What is ELIQUIS?

ELIQUIS is a prescription medicine used to:

- reduce the risk of stroke and blood clots in people who have atrial fibrillation.
- reduce the risk of forming a blood clot in the legs and lungs of people who have just had hip or knee replacement surgery.

(Continued on adjacent page)



PATIENT ASSISTANCE FOUNDATION

This independent, non-profit organization provides assistance to qualifying patients with financial hardship who generally have no prescription insurance. Contact 1-800-736-0003 or visit www.bmspa.org for more information.

IMPORTANT FACTS about ELIQUIS® (apixaban) tablets (Continued)

- treat blood clots in the veins of your legs (deep vein thrombosis) or lungs (pulmonary embolism), and reduce the risk of them occurring again.

It is not known if ELIQUIS is safe and effective in children.

Who should not take ELIQUIS (apixaban)?

Do not take ELIQUIS if you:

- currently have certain types of abnormal bleeding
- have had a serious allergic reaction to ELIQUIS. Ask your doctor if you are not sure

What should I tell my doctor before taking ELIQUIS?

Before you take ELIQUIS, tell your doctor if you:

- have kidney or liver problems
- have any other medical condition
- have ever had bleeding problems
- are pregnant or plan to become pregnant. It is not known if ELIQUIS will harm your unborn baby
- are breastfeeding or plan to breastfeed. It is not known if ELIQUIS passes into your breast milk. You and your doctor should decide if you will take ELIQUIS or breastfeed. You should not do both

Tell all of your doctors and dentists that you are taking ELIQUIS. They should talk to the doctor who prescribed ELIQUIS for you, before you have **any** surgery, medical or dental procedure. **Tell your doctor about all the medicines you take, including** prescription and over-the-counter medicines, vitamins, and herbal supplements. Some of your other medicines may affect the way ELIQUIS works. Certain medicines may increase your risk of bleeding or stroke when taken with ELIQUIS.

How should I take ELIQUIS?

Take ELIQUIS exactly as prescribed by your doctor. Take ELIQUIS twice every day with or without food, and do not change your dose or stop taking it unless your doctor tells you to. If you miss a dose of ELIQUIS, take it as soon as you remember, and do not take more than one dose at

the same time. **Do not run out of ELIQUIS. Refill your prescription before you run out.** When leaving the hospital following hip or knee replacement, be sure that you will have ELIQUIS (apixaban) available to avoid missing any doses. **If you are taking ELIQUIS for atrial fibrillation, stopping ELIQUIS may increase your risk of having a stroke.**

What are the possible side effects of ELIQUIS?

- See **“What is the most important information I should know about ELIQUIS?”**
- ELIQUIS can cause a skin rash or severe allergic reaction. Call your doctor or get medical help right away if you have any of the following symptoms:
 - chest pain or tightness
 - swelling of your face or tongue
 - trouble breathing or wheezing
 - feeling dizzy or faint

Tell your doctor if you have any side effect that bothers you or that does not go away.

These are not all of the possible side effects of ELIQUIS. For more information, ask your doctor or pharmacist.

Call your doctor for medical advice about side effects. You may report side effects to FDA at 1-800-FDA-1088.

This is a brief summary of the most important information about ELIQUIS. For more information, talk with your doctor or pharmacist, call 1-855-ELIQUIS (1-855-354-7847), or go to www.ELIQUIS.com.

Manufactured by:

Bristol-Myers Squibb Company
Princeton, New Jersey 08543 USA

Marketed by:

Bristol-Myers Squibb Company
Princeton, New Jersey 08543 USA

and

Pfizer Inc
New York, New York 10017 USA

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August 2014

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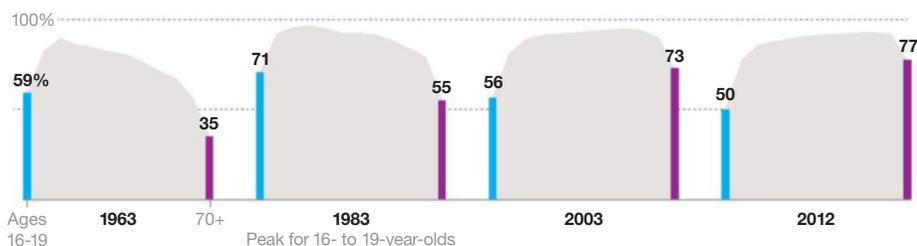
Today just over half of U.S. teens get their driver's license by age 18.

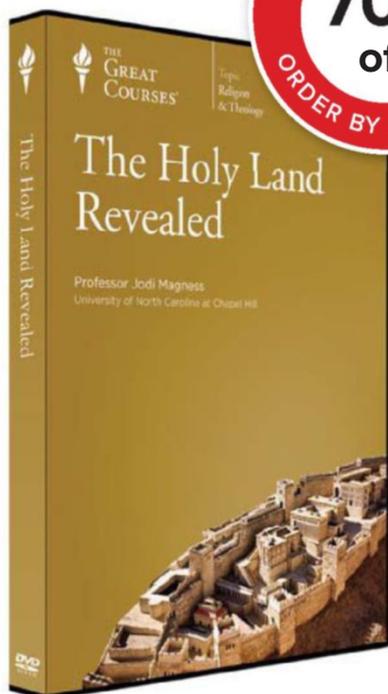
First Drive Delayed

If Jack Kerouac were writing today, he might title his book *Off the Road*. After six decades of growth in driving, America's love affair with the automobile has hit a ditch. More teens and young adults are waiting to get their first driver's license—or opting not to get one at all. In 2009 people ages 16 to 34 drove 23 percent fewer miles than in 2001. Some say they're too busy to get a license. Others cite cars' cost and hassle or the benefits of biking, walking, and taking mass transit.

A 2013 study by the University of Michigan Transportation Research Institute found vehicle registration down 6 percent since 2008, when the recession hit. But the decline may be about more than economics. Online and mobile technologies—which fuel telework, e-commerce, and ride sharing—are also factors, says a study by the U.S. Public Interest Research Group. “In 21st-century America, cars aren't freedom machines anymore,” says Cotten Seiler, author of *Republic of Drivers*. “They're just a way to get around.” Of course, since younger drivers average more auto accidents, fewer of them could mean safer roads. —*Jeremy Berlin*

Portion of age group with a license





Unearth Ancient Secrets from the Holy Land

With a rich history stretching back over 3,000 years, the Holy Land (the area in and around modern-day Israel) is a sacred land for three major faiths and the setting for defining events in religious history. And with the help of information uncovered at various archaeological sites, historians have shed intriguing new light on our understanding of this area—and its powerful role in religious history.

Comb through these remains for yourself with **The Holy Land Revealed**, an unforgettable experience that will add new dimensions to your understanding of the millennia-long story of this dynamic region. Delivered by archaeologist and Professor Jodi Magness, these 36 lectures give you an insider's look at ruins, artifacts, documents, and other long-buried objects that will take you deep beneath the pages of the Bible.

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2. The Arrival of the Israelites
3. Jerusalem—An Introduction to the City
4. The Jerusalem of David and Solomon
5. Biblical Jerusalem's Ancient Water Systems
6. Samaria and the Northern Kingdom of Israel
7. Fortifications and Cult Practices
8. Babylonian Exile and the Persian Restoration
9. Alexander the Great and His Successors
10. The Hellenization of Palestine
11. The Maccabean Revolt
12. The Hasmonean Kingdom
13. Pharisees and Sadducees
14. Discovery and Site of the Dead Sea Scrolls
15. The Sectarian Settlement at Qumran
16. The Dead Sea Scrolls and the Essenes
17. The Life of the Essenes
18. From Roman Annexation to Herod the Great
19. Herod as Builder—Jerusalem's Temple Mount
20. Caesarea Maritima—Harbor and Showcase City
21. From Herod's Last Years to Pontius Pilate
22. Galilee—Setting of Jesus's Life and Ministry
23. Synagogues in the Time of Jesus
24. Sites of the Trial and Final Hours of Jesus
25. Early Jewish Tombs in Jerusalem
26. Monumental Tombs in the Time of Jesus
27. The Burials of Jesus and James
28. The First Jewish Revolt; Jerusalem Destroyed
29. Masada—Herod's Desert Palace and the Siege
30. Flavius Josephus and the Mass Suicide
31. The Second Jewish Revolt against the Romans
32. Roman Jerusalem—Hadrian's Aelia Capitolina
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A First for Fish

Love them or hate them, genetically modified foods are making their way into grocery stores. Soybeans and corn have been for sale in the U.S. since the 1990s. Now, if the FDA gives the green light, the first GM edible animal, a farmed fish known as AquAdvantage salmon, could one day join their ranks.

Developed by Canadian scientists, the fish (right) is an Atlantic salmon with two tweaks to its DNA: a growth hormone gene from the large king salmon and genetic material from the eel-like ocean pout, to keep that growth hormone activated. The fish, which is female and sterile, should reach maximum size quickly in the land-based tanks where it would be raised. To help feed a hungry planet, the GM technology could be used in other species, says spokesman Dave Conley: “Many of its benefits have been downplayed or ignored.”

Still, the company was fined for environmental violations, and critics worry the fish could escape into the wild and create new problems. The FDA has yet to approve it for human consumption. If allowed, says Ocean Conservancy chief scientist George H. Leonard, “it’s imperative it be labeled, so consumers can vote with their wallets.” —*Catherine Zuckerman*



VANGUARD 1, FIRST SOLAR-POWERED SATELLITE

The size of a cantaloupe and weighing about three pounds, Vanguard 1 was the first solar-powered satellite and an important U.S. entry in the space race. Playing catch-up after the Soviet Union’s 1957 launches of Sputniks 1 and 2, the U.S. sent Vanguard 1 into orbit on March 17, 1958.



Soviet Premier Nikita Khrushchev derided the compact satellite as a “grapefruit.” Yet the much larger Sputniks fell from orbit and burned up on reentry in 1958, while Vanguard 1 remains aloft today. It stopped transmitting in 1964, after its last solar cells gave out. But it still holds the title of oldest artificial satellite in space and is projected to remain in orbit about 240 more years. —*Tim Wendel*

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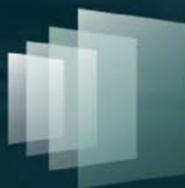
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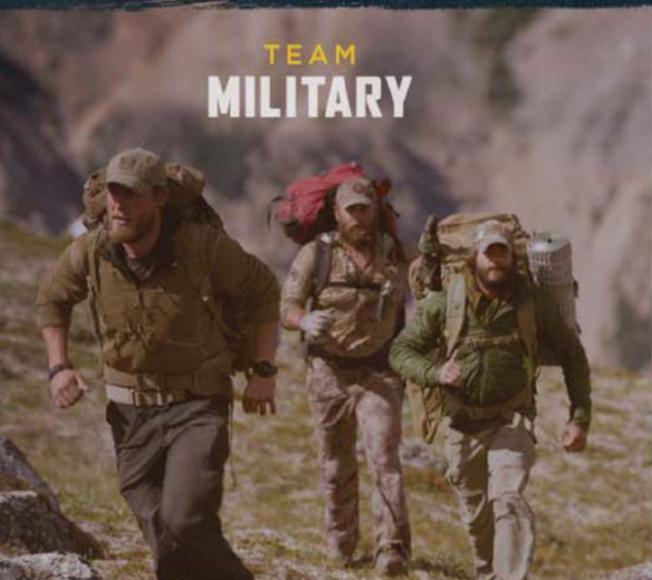
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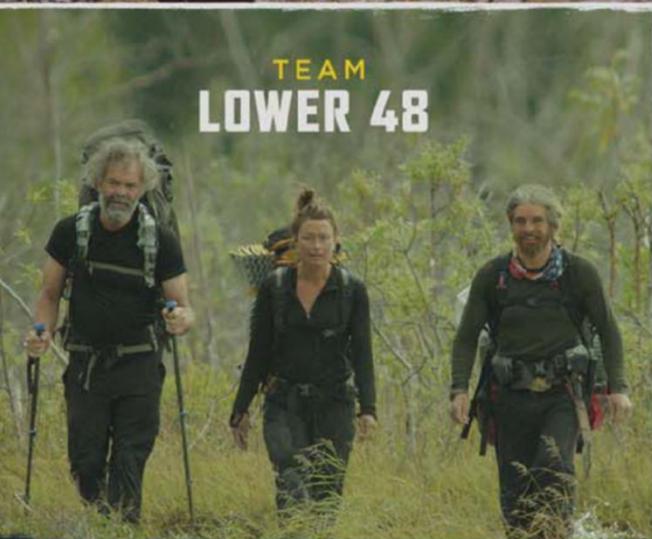
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Magellanic chicks conceived by artificial insemination thrive 13 weeks after hatching.

Hatching a First for Penguins

These captive Magellanic penguin chicks are pioneers: Theirs is the first penguin species to produce young via artificial insemination. Success took more than a decade, as researchers acquired detailed knowledge of Magellanics' reproductive biology. The near-threatened species was an ideal candidate for artificial insemination trials, says Justine O'Brien, scientific director of SeaWorld's reproductive programs. That's because the birds are easy to work with, and they're closely related to endangered species such as Galápagos and African penguins.

Now that the method has worked with Magellanics, researchers hope it can one day be employed with endangered penguin species. The ultimate goal, says O'Brien, is to use it to maintain genetically diverse captive penguin populations and perhaps even replenish depleted populations in the wild. —*Jane J. Lee*

WHO SPLIT FIRST?

The announcement jolted the gelatinous world: The comb jelly lineage was likely the first to split from the common ancestor of all animals. Scientists long believed that sponges broke off first, some 600 million years ago. Resolving the question could help explain how nervous systems evolved, says the University of Florida's Leonid L. Moroz. Comb jellies (right) have nerve cells; sponges don't. If comb jellies split first, they may have the oldest neurons of any extant species, says Heather Marlow of the European Molecular Biology Laboratory. —*JLL*





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of helping the
world *thrive*



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Learn more at cargill.com/150

1865

The first grain warehouse

Cargill was born into the uncertainty of post-Civil War America as a single storage site in Iowa. W. W. Cargill followed the construction of the new railroad, expanding his network to help farmers move their grain to market.



1991

The first to champion humane cattle practices

When we brought Dr. Temple Grandin's systematic ideas to life in our beef processing facilities, we helped define new ethical standards across the industry. A renowned expert in animal science, Grandin drafted a blueprint that promotes more peaceful and insightful handling methods, and in effect, safer and more nutritious products.



1940

The first hybrid transport ship

To transport food across vast lakes and down winding rivers, the world needed a better boat. Cargill entered the shipbuilding industry to create it, fusing the nimble towboat and big barge into a faster and more cost-efficient ship.



1998

The first floating, offshore port in India

In Kutch, India, import demand for fertilizer is high, used by farmers to withstand the region's long droughts. Because the Gulf of Kutch's waters are quite shallow, we designed a floating structure stationed miles from land. With integrated cranes, the port unloads vital resources from large vessels—later transferred to shore by ferry—while simultaneously loading other cargo for export.



1967

The first to deliver crops with newfound efficiency

We changed the food industry when we filled an entire train—all 115 cars—with Illinois corn, rendering it more affordable for consumers and profitable for farmers. On one of our earliest trips to Louisiana, we moved over 400,000 bushels for half the cost—and in record time.



2013

The first to achieve sustainable palm oil certification

Our Hindoll palm plantation was the first to achieve official Indonesia Sustainable Palm Oil (ISPO) certification. Not only is it cited as the model of sustainability for the industry nationwide, but also, it serves as the benchmark site for ISPO auditor training. Today, Cargill is actively moving toward another major first: a 100% sustainable supply chain for palm oil across the globe.



1st

THERE'S A FIRST TIME for everything. In fact we are so inundated by "firsts" that it's easy to lose sight of when the milestones took place. Some firsts happened earlier than you might think: The first successful cesarean in the United States was performed in 1794—by the patient's husband. Others occurred in an order that seems unexpected: The moon was mapped centuries before the ocean floor.

EARLIEST IDEAS 500 B.C.



Fire
One million years ago
Humans learn to control fire.



Wheel
3500 B.C.
Early wheels are used as pottery turntables and to transport goods via sledges.

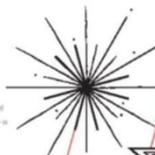
Domesticated livestock
9000 B.C.

Sheep and goats are tamed in the Middle East, then pigs and cattle.



Olympic Games
776 B.C.

Competitions are closely linked to festivals honoring the god Zeus.



Gunpowder
9th century A.D.
The Chinese discover gunpowder while looking for an immortality elixir.

A.D. 400 MIDDLE AGES 1400



University
859

The University of al-Qarawiyyin in Morocco is founded by a woman, Fatima al-Fihri.



Major literary work by a woman
1010

Murasaki Shikibu, a Japanese noblewoman, writes *The Tale of Genji*.

Eyeglasses
13th century

The first use of wearable spectacles is recorded in Italy.

Paper money
12th century

Chinese merchants begin using paper money to avoid having to carry heavy coins.

Chocolate to Europe
1519

The Aztec introduce chocolate to Hernán Cortés, who later takes cacao pods back to Europe.

Printing press
1439

This technology revolutionizes the manufacture of books.



Air pump
1650

Otto von Guericke invents the air pump, which he uses to study light and sound in a vacuum.

1350 RENAISSANCE 1650

Complete world map
1507

The Western Hemisphere is shown for the first time.



Submersible
1620

Dutch engineer Cornelis Drebbel reportedly waterproofs the craft with greased leather.

Piano
circa 1700

Bartolomeo Cristofori allegedly creates the modern piano.



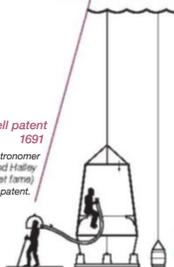
Scientific map of the moon
1679

Giovanni Cassini draws lunar landscapes seen through a telescope.

1650 ENLIGHTENMENT

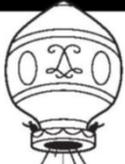
Diving-bell patent
1691

British astronomer Edmond Halley (of comet fame) receives the patent.



Sextant
mid-1700s

A tool is designed to measure longitude by measuring the angular distance between the moon and a nearby star.



Human flight
1783

Non-tethered human flight takes place in a hot-air balloon that rises 500 feet above Paris.

Photograph
1826

Taken in France, the first photo is titled "View From the Window at Le Gras."

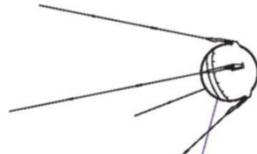
Skyscraper
1885

Chicago's steel-frame Home Insurance Building is built, ten stories high.



Satellite in space
1957

The Soviet Union launches the beach-ball-size Sputnik 1, the first artificial satellite to orbit Earth.



Man on the moon
1969

American Neil Armstrong's words as he becomes the first person to walk on the moon: "That's one small step for a man, one giant leap for mankind."

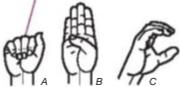


1760 INDUSTRIAL REVOLUTION 1900

1957 SPACE AGE 1980

Sign language
1770s

Abbé Charles Michel de l'Épée invents the first widely used sign language for the deaf.



Postage stamp
1840

The first stamp features Queen Victoria's profile and cost just a penny.

Phone call
1876

On the telephone he invented, Alexander Graham Bell's first words to his aide are "Mr. Watson, come here, I want to see you."



Aspirin
1897

German chemist Felix Hoffmann synthesizes aspirin in the lab—and two weeks later, heroin.

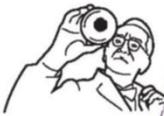
Electric wheelchair
1953

George Klein invents a motorized chair to assist quadriplegic veterans.



Lightning rod
1752

Benjamin Franklin and his son invent a way to protect buildings from lightning strikes.



Penicillin
1928

Alexander Fleming accidentally discovers the antibiotic in a petri dish.

INVENT 1800

1914 WAR & POSTWAR 1954

1971 INFORMATION AGE

U.S. C-section surgery
1794

Elizabeth Bennett and her baby girl are fine after Bennett's husband, a physician, performs nation's first successful C-section.



Adhesive bandage
1920

Earle Dickson, a cotton buyer, invents this for his accident-prone wife.



Oral contraceptive
1951

Chemist Carl Djerassi creates the pill by synthesizing hormones from yams.

Organ transplant
1954

First successful procedure moves a kidney from one twin to another.



Permanent artificial heart
1982

The Jarvik-7 is successfully implanted in a human, who lives another 112 days.

Smartphone
1993

IBM's Simon is the first cellular phone to have "personal digital assistant" features such as email.



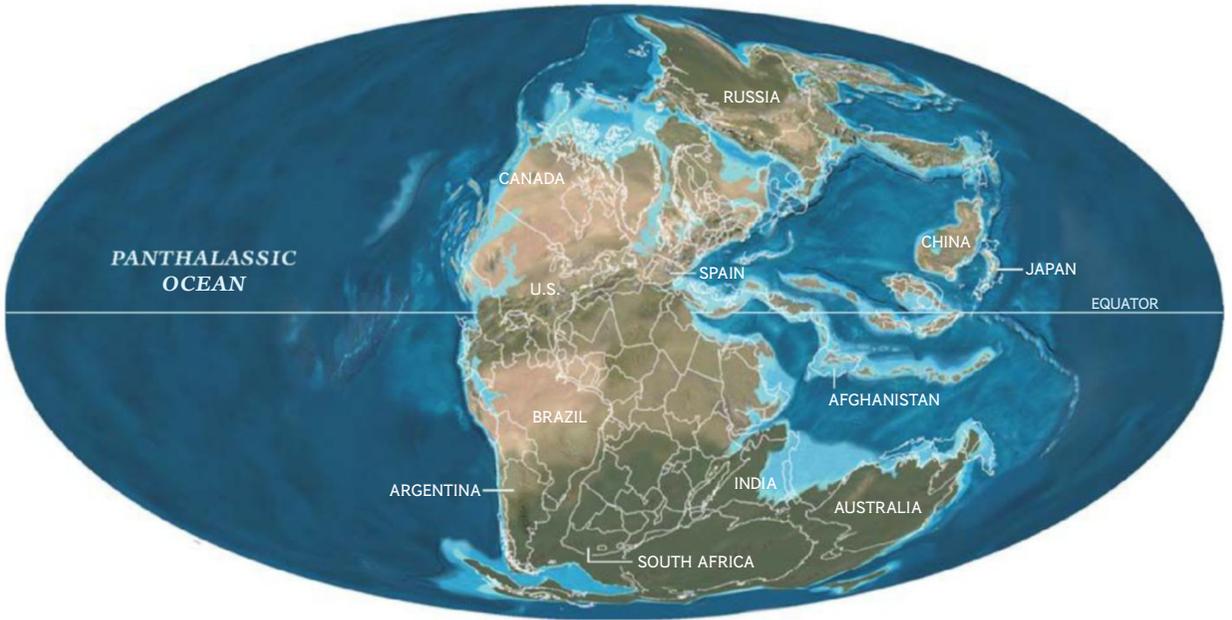
Voyager 1
2013

The spacecraft is the first human-made object to venture into interstellar space.

Cloned mammal
1996

Dolly the sheep is cloned from a mammary cell and named for Dolly Parton.





Present-day country boundaries and shorelines are superimposed on the Pangaea of 250 million years ago. Some areas of the modern world aren't seen; their continental crust formed later.

First Came Pangaea

Hot off the presses in 1915, Alfred Wegener's book *The Origin of Continents and Oceans* sent tremors through the foundations of earth science. The German meteorologist was the first to weave together multidisciplinary evidence to support a then controversial theory of continental drift.

While perusing a world atlas in 1910, Wegener pondered whether the shapes of the continents corresponded by mere coincidence. He later pieced them into a single "primordial continent" he called Pangaea, Greek for "all Earth." Wegener theorized that this massive landform had existed until roughly 250 million to 200 million years ago, when today's continents began to creep apart.

For biologists, this explained the related plant and animal species on lands divided by oceans. For paleontologists, the theory fit with mesosaur fossils found in both South Africa and Brazil. To geologists, Wegener pointed out similar land formations on separate continents and suggested, among other things, that South Africa's Cape Fold Belt range once joined up with Argentina's Sierra de la Ventana.

Wegener's work was rejected by leading geologists who had a stake in long-standing, competing theories of Earth's evolution. Critics complained that he had failed to explain the exact mechanism that would have driven the drifting motion. Wegener agreed with that point, writing in 1929 that "the Newton of drift theory has not yet appeared." The next year Wegener died, at age 50. It would take 30 more years—and geophysicists' conclusion that plate tectonics results in continental drift—for Wegener's theory to be vindicated. —Karen de Seve

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— C.S. from Fort Worth, TX



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The First Time

For humans, sexual initiation can be a big deal—obsessed about, romanticized. The loss of virginity, it's said, leaves one forever changed.

"Tell me about it," says the male hump-winged grig. The first female he mates with takes not just his innocence but bites of his body.

Grigs are cricket-like insects whose annual mating season involves what behavioral ecologist Scott Sakaluk calls "an unusual form of sexual cannibalism." To entice a female grig, a male makes a call by rubbing his forewings together, an act called stridulation. The male then seals the deal by letting the female munch on his hind wings during sex and lap up the hemolymph, the bug version of blood. "One night he's a virgin. The next night he's been chewed on," Sakaluk says.

Why do some males get several of these grisly trysts (which are seldom, if ever, fatal) but others get none? The call is key. When Sakaluk's colleague Geoff Ower compared the insects' calls, he found "fundamental differences" between the sound made by grigs that had mating success and those that did not.

Being a sex snack can sap the strength a male grig needs for stridulation, Sakaluk says. By the end of mating season, "there's only a few left calling. Those are the males that have gotten superlucky—and they are chewed right down to the nub." —*Patricia Edmonds*

HABITAT

Forests of northwestern U.S. and southwestern Canada

STATUS

Vulnerable

OTHER FACTS

In the insect order that grigs share with grasshoppers and katydids, there are three North American grig species.

The mating of hump-winged grigs involves "an unusual form of sexual cannibalism."



PHOTO: PIOTR NASKRECKI

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VISIONS





Costa Rica

Waking up on a tree branch near Guayacán de Siquirres, a red-eyed tree frog peers through a gold-striped, semitransparent eyelid. The scarlet eyes on this toxic, three-inch-long amphibian might be an example of startle coloration—a defense strategy some animals use to ward off predators.

PHOTO: INGO ARNDT





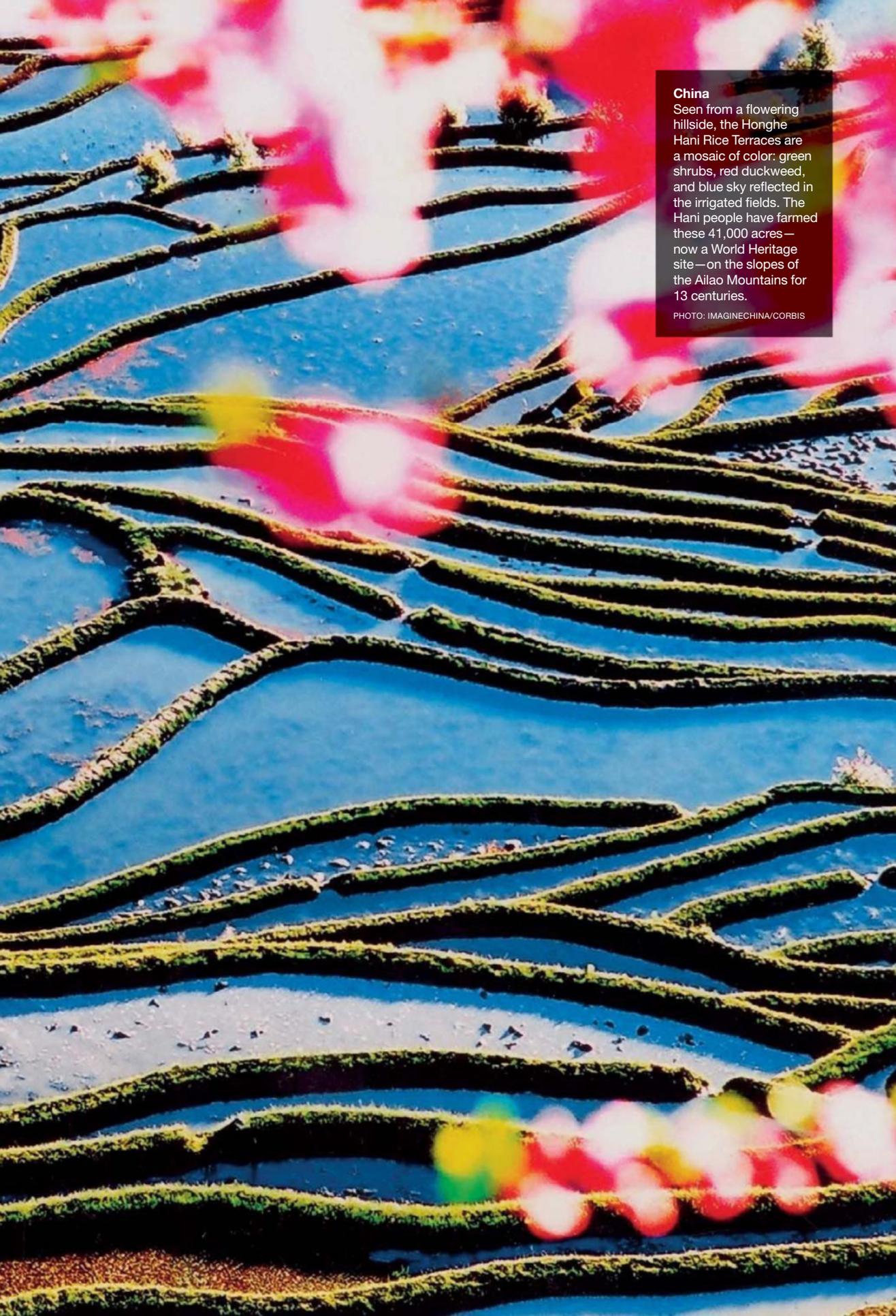
Bulgaria

Fatme Inus wears face paint, tinsel, and many-hued sequins on her wedding day in Ribnovo. The colorful tradition, which symbolizes status change, is called *gelina*. It's practiced by Bulgarian-speaking Muslims — also known as Pomaks — whose wedding celebrations span two days and involve hundreds of villagers.

PHOTO: SEAN GALLUP,
GETTY IMAGES



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China

Seen from a flowering hillside, the Honghe Hani Rice Terraces are a mosaic of color: green shrubs, red duckweed, and blue sky reflected in the irrigated fields. The Hani people have farmed these 41,000 acres — now a World Heritage site — on the slopes of the Ailao Mountains for 13 centuries.

PHOTO: IMAGINECHINA/CORBIS

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The Settlements include two Classes covering Shingles made: (1) between 1999 and 2007 at GAF’s plant in Mobile, Alabama and (2) between 1998 and 2009 at other GAF manufacturing plants.

Am I included?

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What do the Settlements provide?

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You may be eligible to receive: (1) replacement shingles (comparable to the Shingles installed) and/or (2) a cash payment. The Settlements will not reduce the benefits you may be entitled to under any existing GAF warranty.

The attorneys representing the Classes are asking the Court for attorneys’ fees (up to \$6,890,000 in total) and costs and expenses (up to \$1,115,000 in total). Counsel will also request an incentive payment for the Class Representatives. The payment of costs and expenses, and the incentive awards, will be paid by GAF and will not reduce the benefits under the Settlements.

The attorneys representing the Class covering Shingles made in Mobile are also asking for a portion of the additional benefits going to Class Members with property outside South Carolina. These fees will not be paid by GAF and would in these instances reduce the benefits to some Class Members.

How can I make a claim?

In order to get benefits, you need to file a claim. You can find out how to file a claim by visiting www.RoofSettlement.com or calling 1-866-759-6518. You can file a claim over the next seven years after the effective date of the Settlements.

What are my rights?

If you do nothing, you will be bound by the Settlements and the Court’s decisions. If you want to keep your right to sue GAF, you must exclude yourself from the Classes by **March 16, 2015**. If you stay in the Classes, you may object to the Settlements by **March 16, 2015**. The Court will hold a hearing on **April 22, 2015** to consider whether to approve the Settlements. You or your own lawyer may appear at the hearing at your own expense, but you do not have to attend.

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WHAT IS THIS SETTLEMENT ABOUT? Plaintiff claims that Defendants, Botanical Laboratories, Inc., Schwabe North America, Inc., and Botanical Laboratories, LLC's ("Defendants"), Wellesse Joint Movement Glucosamine did not provide certain health benefits as advertised, including joint health benefits, mobility, flexibility, and lubrication. Defendants strongly deny the allegations made in the lawsuit. The Court has not decided who is right and who is wrong. Instead, the parties decided to settle the dispute.

WHAT DOES THE SETTLEMENT PROVIDE? Each Settlement Class Member who submits a valid claim form may be entitled to receive cash payment of up to \$15.00 to \$18.00 for each bottle of Wellesse Joint Movement Glucosamine purchased prior to October 8, 2014, not to exceed one hundred dollars (\$100) in total recovery. Defendants will make payments of \$3.1 million into a Settlement Fund to reimburse Settlement Class Members for the Wellesse Joint Movement Glucosamine they purchased, to pay for costs and expenses of settlement administration not to exceed \$580,000.00, an award of attorneys' fees not to exceed \$930,000.00, and a service award to the Class Representatives, not to exceed \$3,500.00. In the event that the dollar amount of approved claims submitted by Settlement Class Members exceeds the amount remaining in the Settlement Fund after payment of costs and expenses of settlement administration, the Court's award of attorneys' fees, and a service award to the Class Representatives, payments on approved Claims to Settlement Class Members shall be reduced pro rata. In the event that the dollar amount of approved claims submitted by Settlement Class Members does not meet or exceed the amount remaining in the Settlement Fund after payment of costs and expenses of

settlement administration, the Court's award of attorneys' fees, and a service award to the Class Representatives as well as the tallied amount of all Authorized Claims, the Settlement Administrator shall divide the remaining cash amount equally by the number of Authorized Claimants and shall pay each such Authorized Claimant his or her share of the remaining cash amount.

AM I A CLASS MEMBER? You're a Class Member if you purchased a Wellesse Joint Movement Glucosamine product anywhere in the nation at any time prior to October 8, 2014.

WHAT ARE MY LEGAL OPTIONS? To ask for cash and remain in the Class, you must mail, fax, or submit online a completed claim form by February 19, 2015. If you do not wish to participate in the settlement, you may exclude yourself from the Class by February 19, 2015, or you may stay in the Class and object to the settlement by February 19, 2015. Visit www.WELLESSEJMGSETTLEMENT.com for important information about these options.

HEARING ON THE PROPOSED SETTLEMENT: The Court will hold a Final Approval Hearing on March 19, 2015 at 11:00 a.m., to determine whether the proposed settlement is fair, reasonable, and adequate, to approve attorneys' fees and expenses, and any service award for the Class Representatives. The Final Approval Hearing will take place at U.S. District Court, Southern District of California, 940 Front Street, San Diego, CA 92101. You do not have to attend the hearing.

HOW CAN I GET MORE INFORMATION? For more information or to view all relevant documents in the litigation, or if you have questions, visit www.WELLESSEJMGSETTLEMENT.com, or call 1-877-902-6937.

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Editor's Choice

Daily Dozen Editors pick 12 photos from those submitted online each day. Here are our favorites this month.



EDITOR'S NOTE

“I love the visceral, youthful, and joyful feeling Ujjal captured [below]. The way he waited for a specific gesture adds emotional punch to what might have been an ordinary moment.”

—*Jessie Wender, National Geographic senior photo editor*



Bogdan Comanescu

Caransebes, Romania

Comanescu was in the Danube Delta and met an 86-year-old fisherman named Artiom. The man sat on his *lejanca*, a traditional bed that's an extension of the oven. Comanescu framed the fisherman in a mirror surrounded by family photos.

Ujjal Dey

Hyderabad, India

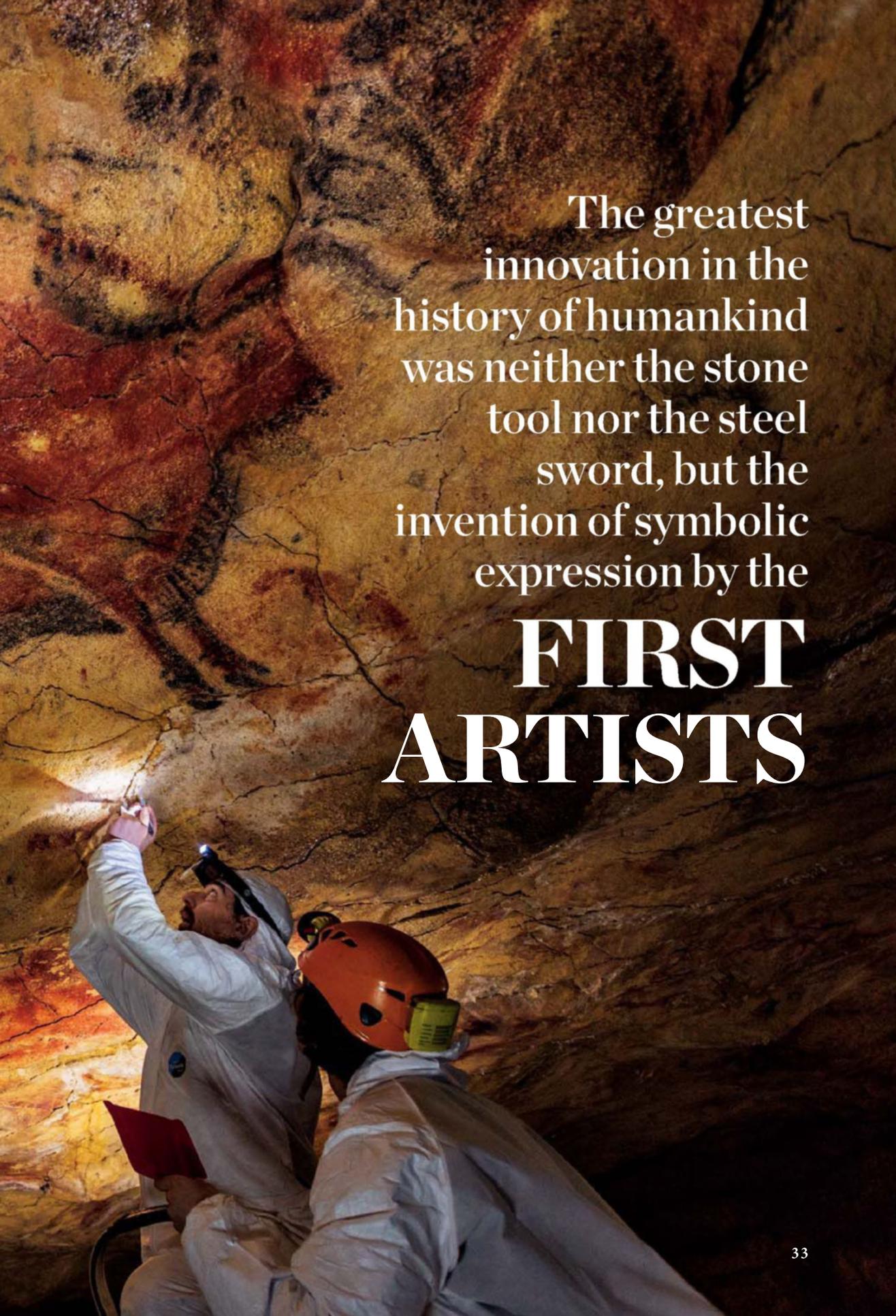
In a park in his hometown Dey liked to watch kids play in the water fountains. One summer day right before sunset, he went inside the fountain and pointed his camera toward the sun, then waited for one of the children to jump.



39,000
years ago

Scientists scrape samples for dating from the polychrome ceiling in Spain's Altamira Cave, festooned with animals painted 19,000 to 15,000 years ago. Abstract symbols on the ceiling can be traced back at least another 20,000 years.

ALTAMIRA MUSEUM, MINISTRY OF EDUCATION, CULTURE, AND SPORT

The image shows two researchers in white protective suits and headlamps examining ancient cave paintings on a rock wall. The rock surface is covered in various colors of ochre, red, and black, with some faint, dark markings that appear to be early human art. The researchers are positioned in the lower left, looking up at the wall. One researcher is pointing at a specific area on the wall, while the other is looking on. The lighting is focused on the wall, creating a dramatic effect against the dark background of the cave.

The greatest
innovation in the
history of humankind
was neither the stone
tool nor the steel
sword, but the
invention of symbolic
expression by the

FIRST ARTISTS



ACTUAL SIZE

35,000

Uncovered in 2008, the Venus figurine from Hohle Fels Cave in Germany is the oldest undisputed image of a human being. The loop above her torso suggests the carving was meant to be worn as a pendant.



25,000

Delicately carved from mammoth tusk, the Lady of Brassempouy was discovered in southwest France in 1894. Whether a "lady" or a youth, it is among the oldest representations of a human face.

HILDE JENSEN, TÜBINGEN UNIVERSITY, GERMANY (LEFT); SISSE BRIMBERG, NATIONAL GEOGRAPHIC CREATIVE, AT MUSÉE DES ANTIQUITÉS NATIONALES, FRANCE



ACTUAL SIZE



100,000

Perched near Africa's southern tip, Blombos Cave has yielded some of the earliest evidence of symbolic expression, including shell beads, engraved ocher, and ocher-processing kits that are 100,000 years old.



By Chip Walter

Photographs by Stephen Alvarez

It is as if we are walking into the throat of an enormous animal. The tongue of a metal path arcs up and then drops downward into the blackness below. The ceiling closes in, and in some places the heavy cave walls crowd close

enough to touch my shoulders. Then the flanks of the limestone open up, and we enter the belly of an expansive chamber.

This is where the cave lions are.

And the woolly rhinos, mammoths, and bison, a menagerie of ancient creatures, stampeding, battling, stalking in total silence. Outside the cave, where the real world is, they are all gone now. But this is not the real world. Here they remain alive on the shadowed and creviced walls.

Around 36,000 years ago, someone living in a time incomprehensibly different from ours walked from the original mouth of this cave to the chamber where we stand and, by flickering firelight, began to draw on its bare walls: profiles of cave lions, herds of rhinos and mammoths, a magnificent bison off to the right, and a chimeric creature—part bison, part woman—conjured from an enormous cone of overhanging rock. Other chambers harbor horses, ibex, and aurochs; an owl shaped out of mud by a single finger on a rock wall; an immense bison formed from ocher-soaked handprints; and cave bears walking casually, as if in search of a spot for a long winter's nap. The works are often drawn with nothing more than a single and perfect continuous line.

In all, the artists depicted 442 animals over perhaps thousands of years, using nearly 400,000 square feet of cave surface as their canvas. Some animals are solitary, even hidden, but most congregate in great mosaics like the one I am

looking at now, in the deepest part of the cave.

Hidden by a rock slide for 22,000 years, the cave came to light in December 1994, when three spelunkers named Eliette Brunel, Christian Hillaire, and Jean-Marie Chauvet scrambled through a narrow crevice in a cliff and dropped into the dark entry. Since then, what is now known as the Cave of Chauvet-Pont-d'Arc has been ferociously protected by the French Ministry of Culture. We are among the rare few who have been allowed to make the same journey the ancient artists did. The age of these drawings makes youngsters of Egypt's storied pyramids, yet every charcoal stroke, every splash of ocher looks as fresh as yesterday. Their beauty whipsaws your sense of time. One moment you are anchored in the present, observing coolly. The next you are seeing the paintings as if all other art—all civilization—has yet to exist.

How did such human accomplishment come to be, so long ago, seemingly out of nowhere? Until recently it was thought that the drawings found on the walls of well-known Upper Paleolithic caves in southern Europe like Altamira, Lascaux, and Chauvet were the expression of a superior kind of human—us—who had arrived on the continent, driving out the brutish, artless Neanderthals who had been living and evolving there for hundreds of thousands of years.

It turns out that the story is a good deal more complicated, and more interesting. It begins, as stories often do, in Africa.



National Geographic grantee Christopher Henshilwood and his team dig for clues to the origins of modern human behavior at Klipdrift Shelter, which, like Blombos Cave, has yielded early art. Modern humans roamed the region as far back as 165,000 years ago.

CHRISTOPHER HENSHILWOOD unwinds his six-foot-five frame, dusts his hands, and gazes out over the Indian Ocean. He stands at the very tip of Africa, and except for the immense, sea-battered rocks 80 feet below, nothing lies between his boots and Antarctica but 1,500 miles of rolling, white-capped sea.

“Not a bad day,” he says, in a baritone you might call godlike, if God had a South African accent.

True, it has not been a bad day. Henshilwood, of the University of the Witwatersrand, South Africa, and the University of Bergen, Norway, and his colleagues have been excavating all morning here at a site known as Klipdrift Shelter, adding some stone tools and other new finds to the mounting evidence that modern human beings have inhabited these hills and shallow caves off and on for more than 165,000 years. Yet Henshilwood has had better days. Some of his most memorable discoveries have come from Blombos Cave, 28 miles east of Klipdrift, near an area where he used to play as a kid. One day in 2000

his team dug out a small block of engraved red ocher a bit smaller than a flip phone. Ocher is common in this part of Africa and has been used for millennia for everything from body paint to a food preservative. This piece, though, was different: Roughly 75,000 years in the past, some clever person had carefully etched on it a pattern of overlapping, parallel, triangular markings.

No one knows the meaning of those marks, which have since been found on 13 other pieces of ocher. A signature? Calculations? A primeval grocery list? Whatever their elusive purpose, they were 35,000 years older than any other undisputed evidence of symbolic behavior known at the time.

Controversy dogged the discovery at first. Some scientists attacked the little rock as a one-off, nothing but random scratchings or idiosyncratic doodling. “They said it was

Chip Walter's most recent book is Last Ape Standing. Stephen Alvarez photographed Paris's underground in the February 2011 issue of National Geographic.



meaningless,” says Henshilwood. “They said everything negative you could possibly think.” In time, however, others regarded it as a breakthrough.

Soon more examples of symbol and ornament were uncovered. Henshilwood’s team discovered the shells of little sea snails called *Nassarius* that were some 75,000 years old and perforated, with evidence they had been strung together. Other finds were even older. *Nassarius* beads have been dated to 82,000 years ago at a site called Grotte des Pigeons (Pigeon Cave) in Taforalt, Morocco. At the opposite end of the Mediterranean, similar beads from two Israeli caves, Qafzeh and Skhul, were dated to 92,000 and at least 100,000 years ago. Back in South Africa, a 2010 team led by the University of Bordeaux’s Pierre-Jean Texier reported finding 60,000-year-old engraved ostrich eggshells in

Diepkloof Rock Shelter north of Cape Town. Meanwhile, Blombos itself kept yielding treasures: finely carved and decorated bone tools, and evidence that as long as 100,000 years ago the cave’s inhabitants had methodically ground ocher into fine powder and mixed it with other ingredients to make a paste. Stored in abalone shells—the earliest known containers—it could have been used as a decorative paint for bodies, faces, tools, or clothing. In 2009 Henshilwood reported finding more ocher and rocks marked with deliberate cross-hatchings, also dating as far back as 100,000 years.

Compared with the jaw-dropping beauty of the art created in Chauvet Cave 65,000 years later, artifacts like these seem rudimentary. But creating a simple shape that stands for something else—a symbol, made by one mind, that can be shared with others—is obvious only after the fact. Even more than the cave art, these first concrete expressions of consciousness represent a leap from our animal past toward what we are today—a species awash in symbols, from the signs that guide your

■ **Society Grant** The research on early art in South Africa and cave art in Spain was funded in part by your National Geographic Society membership.



65,000 | 75,000

A block of red ochre (above) found in Blombos Cave in 2000 bears a pattern of cross-hatchings and parallel lines etched by a human hand 75,000 years ago. At left, Henshilwood holds a red ochre crayon found in nearby Klipdrift Shelter in 2013. “This is where it all began,” says Henshilwood.

progress down the highway to the wedding ring on your finger and the icons on your iPhone.

There’s something else telling about these early African and Middle Eastern eruptions of symbolism: They come, and then they go. The beads, the paint, the etchings on ochre and ostrich egg—in each case, the artifacts show up in the archaeological record, persist in a limited area for a few thousand years, and then vanish. The same applies to technological innovations. Bone harpoon points, found nowhere else before 45,000 years ago, have been uncovered in the Democratic Republic of the Congo in sediments nearly twice that old. In South Africa two relatively complex stone and bone tool traditions appear—the Still Bay 75,000 years ago and the Howieson’s Poort 65,000 years ago. But the latter lasted just 6,000 years, the former 4,000. Nowhere has a tradition been found to spread across space and through time, gathering richness and diversity, until just before 40,000 years ago, when art began to appear more commonly across Africa, Eurasia, and Australasia. As far east as the

Indonesian island of Sulawesi (Celebes), stenciled handprints—once thought of as an invention of the European Upper Paleolithic—were recently shown to be almost 40,000 years old.

It seems unlikely, therefore, that some genetic “switch” flipped in our African ancestors to produce the capacity for a new, higher-order level of cognition that, once it evolved, produced a lasting change in human behavior.

So how do we explain these apparently sporadic flare-ups of creativity? One hypothesis is that the cause was not a new kind of person but a greater density of people, with spikes in population sparking contact between groups, which accelerated the spread of innovative ideas from one mind to another, creating a kind of collective brain. Symbols would have helped cement this collective brain together. When populations again fell below critical mass, groups became isolated, leaving new ideas nowhere to go. What innovations had been established withered and died.

Such theories are difficult to prove—the past holds its secrets close. But genetic analyses





A young Himba woman applies ochre to another's hair on a riverbank in northwestern Namibia. Prized for its warm red hue, ochre is widely used as body ornamentation today, as it was by ancient humans.

of modern populations do point to a surge in population in Africa 100,000 years ago. A 2009 study conducted by Adam Powell, Stephen Shennan, and Mark G. Thomas of University College London also provides some statistical support for the power of larger populations to generate innovation. And research by Joseph Henrich, now at the University of British Columbia, suggests that as populations shrink, they have an increasingly difficult time holding on to the innovations they invented in the first place. The inhabitants of the island of Tasmania had been making bone tools, cold-weather clothing, and fishing equipment for 15,000 years before these advances disappear from the archaeological record some 3,000 years ago. Henrich argues that when sea levels rose 12,000 to 10,000 years ago and isolated Tasmania from the rest of the world, the indigenous population of perhaps 4,000 individuals was simply not large enough to keep the cultural traditions alive.

Why Africa's archaeological record grows dim for 150 centuries is by no means clear. Perhaps pestilence, natural catastrophe, or a sharp swing in climate caused populations to collapse. Yet Francesco d'Errico, an archaeologist at the University of Bordeaux, points out that although harsh conditions might spell doom for some cultures, others might be spurred on by them. There is no set formula.

"Each region of the globe produced cultures with a number of different trajectories," says d'Errico. "You could have situations where some short-term chaotic disaster might wipe out a culture in one area, but in another, people were able to take advantage of the challenge." He likens it to a recipe. "Even if the ingredients are the same, you don't necessarily get the same outcome."

"LET ME SHOW YOU SOMETHING." Nicholas Conard glances over his shoulder, then carefully spins the dial on an enormous safe in his office, housed in a 16th-century German castle at Tübingen University. From the safe he extracts four small pine boxes and sets them gingerly on the table in front of me. Within each sits a tiny carving: a horse, a mammoth, a bison, and a lion. All

are from a German cave called Vogelherd. They display a grace and beauty and playfulness that would make any artist today proud. Yet they are 40,000 years old—predating the painted masterpieces of Chauvet by 5,000 years.

"Jaw-dropping," says Conard, the university's scientific director of prehistory. "Every piece is different. But when you look at them, it's obvious they form a coherent whole."

The humans who made these objects were part of a population that left the African homeland some 60,000 years ago, taking a route through the Middle East and what is now

HOW DID SUCH HUMAN ACCOMPLISHMENT COME TO BE, SO LONG AGO, SEEMINGLY OUT OF NOWHERE?

Turkey, along the western fringe of the Black Sea, and up the Danube River Valley. As far as we know, nowhere along that journey did they leave signs of an artistic inclination, not even a piece of marked ocher. But once settled some 43,000 years ago in the Lone and Ach River Valleys of southern Germany, they suddenly began to create—not crude etchings but fully realistic animal figurines carved out of mammoth tusk.

The sources of most of these objects are four caves: Hohle Fels and Geissenklösterle in the Ach Valley, and Hohlenstein-Stadel and Vogelherd in the Lone. Not much more than indentations in the rock face, the caves could easily be missed today by someone driving the backcountry roads that wind through Germany's southwestern mountains. Lush and green today, the Ach and Lone Valleys 40,000 years ago, at the beginning of a period known as the Aurignacian, were frigid steppe landscapes, dotted with herds of horses, reindeer, and mammoths. In spite of the harsh conditions, the richness of the archaeological sites indicates that population sizes in the



While Europe is home to famous examples of Paleolithic art such as the paintings at Chauvet, Lascaux, and Altamira, evidence of modern behavior is far older in Africa and the Middle East.

Aurignacian were growing. The increases could help explain an apparent flare-up of creativity, not unlike those seen earlier in Africa. Maybe the difficulties these European settlers faced, says Conard, led them to share customs that spread from one group, and generation, to the next. In hard times prized carvings and tools could have smoothed the way toward intertribal marriages, trade, and alliances and helped spread new techniques for hunting, building shelters, and making clothing.

In Hohlenstein-Stadel, Conard's team recently uncovered some objects whose messages are so sexually explicit they might require a parental warning. One is a carving of a woman with exaggerated breasts and genitalia, found in 2008 (page 34). At least 35,000 years old, the Venus of Hohlenstein-Stadel is the most ancient figure yet discovered that is indisputably human. (Two much earlier figurines from Morocco and what is now Israel may be natural rocks that vaguely resemble the human form.) Earlier the team had found a polished rod of siltstone, about eight inches long and an inch

in diameter, with a ring etched at one end—likely a phallic symbol. A few feet away from the Venus figurine, Conard's team uncovered a flute carved from a hollow griffon vulture bone, and in Geissenklösterle Cave found three other flutes, one made of ivory and two fashioned from a swan's wing bone. They are the oldest known musical instruments in the world. We don't know whether these people had drugs. But they clearly had the sex and rock and roll.

Of all the findings to emerge from this period in Germany, none is more fascinating than the Löwenmensch (Lionman) of Hohlenstein-Stadel Cave, a fantastical sculpture nearly 40,000 years old. The original Löwenmensch fragments—some 200 of them—were discovered in 1939, on the eve of World War II, by Robert Wetzel, a professor of anatomy at Tübingen University, and a geologist named Otto Völzing. Wetzel had hoped to work on the pieces of mammoth tusk when the war ended, but they sat untouched in a box for 30 years. Then, in 1969, archaeologist Joachim Hahn (Continued on page 56)



36,000

Discovered in 1994, the Horse Panel and the other stunning creations in the Cave of Chauvet-Pont-d'Arc provide "an extraordinary testimony to man's first steps in the adventure of art," says France's Minister of Culture Fleur Pellerin.



40,000 Part human, part lion, the foot-tall figurine from Germany's Hohlenstein-Stadel Cave was pieced together from some 200 fragments found in 1939. Recent excavations have added new pieces to the chimeric creation.

YVONNE MÜHLEIS, STATE OFFICE FOR CULTURAL HERITAGE IN RP STUTTGART



36,000

Later Paleolithic artists mostly depicted herbivores, but the Chauvet painters often featured fierce predators, like these in the famous Great Panel. In June 2014 UNESCO voted to designate Chauvet Cave as a World Heritage site.

PANORAMA COMPOSED OF EIGHT IMAGES



THE BIRTH OF ART



The first anatomically modern people evolved in Africa some 200,000 years ago, but undisputed evidence of modern human behavior—body ornaments, symbols scratched on ochre, more complex tools—does not begin to appear for another 100,000 years. Stenciled handprints, such as the one above from El Castillo Cave in Spain, at least 37,000 years old, send a timeless message: Like you, I am human. I am alive. I was here.



MIDDLE PALEOLITHIC/MIDDLE STONE AGE

First impressions

When did art begin? Some scientists regard strikingly simple axes produced at least a half million years ago as expressive function. But objects created purely for their symbolic or aesthetic purposes are much younger, appearing first in Africa and the Middle East.

Human and animal figures

Objects like the volcanic rock from Israel (left) and a similar one from Morocco dated to between 500,000 and 300,000 years ago, may be the earliest depictions of the human form—or merely natural objects with suggestive curves.

VENUS OF BEREKHAT RAM
ISRAEL
ACTUAL SIZE

265,000 YEARS AGO



Pigments and cave art

Pigments turn up at archaeological sites as old as 300,000 years, but their use is unknown. Processing kits discovered in South Africa in 2008, including pigments, shell containers, and tools, were likely used to produce colorful paints for body decoration or skin protection.

ABALONE SHELL CONTAINER
BLOMBO'S CAVE, SOUTH AFRICA
1 IN

100,000



HANDPRINT
LEANG TIMPUSENG CAVE

40,000

Personal expression

Sea snail shell beads, with carefully drilled holes, may have been strung on clothes or necklaces. A delicate, engraved eggshell (right) required practiced artistry. Found from Israel to South Africa, such ornaments constitute the first clear evidence of self-expression.

SHELL BEAD
BLOMBO'S CAVE, SOUTH AFRICA
0.5 IN

75,000



ENGRAVED OSTRICH
KLIPDRIFT SHELTER,
SOUTH AFRICA
1 IN

63,000

HANDPRINT (AT LEFT): STEPHEN ALVAREZ, DEPARTMENT OF EDUCATION, CULTURE, AND SPORTS, MEDAD SUCHOWOLSKI, ISRAELI MUSEUM; WILHELM JENSEN, TÜBINGEN UNIVERSITY, GERMANY; M. WITWATERSRAND, SOUTH AFRICA, AND UNIVERSITY OF BERGEN, NORWAY; GRETHE MOELLER, PERIODIC TABLE, STEPHEN ALVAREZ, AT IZIKO MUSEUMS OF SOUTH AFRICA. STEPHEN ALVAREZ, MARIAN VANHAARLEM, AT IZIKO MUSEUMS OF SOUTH AFRICA.

Asymmetrical stone hand
 impressions of style as well as
 for ornamental value are
 found in the East.

UPPER PALEOLITHIC/LATE STONE AGE

Creative expansion

Beginning some 43,000 years ago, abstract and realistic art becomes more widespread in Africa and Eurasia, appearing as far east as Indonesia by 40,000 years ago. Early Spanish cave art could be the work of Neanderthals. But by the time of the great paintings of Chauvet Cave, only modern humans remained.



BISON (IVORY)
 ZARAYSK, RUSSIA
 4 IN



HORSE (IVORY)
 VOGELHERD CAVE, GERMANY
 2 IN

35,000



LION HEAD (IVORY)
 VOGELHERD CAVE,
 GERMANY
 1 IN

35,000

First portrait
 HEAD (IVORY)
 DOLNI
 VESTONICE,
 CZECH
 REPUBLIC
 2 IN

26,000



First ceramic
 figure
 VENUS OF
 DOLNI
 VESTONICE,
 CZECH
 REPUBLIC
 4.5 IN

26,000



Handprints—prehistoric selfies?—made by blowing pigments are a common feature of Upper Paleolithic art in caves in Europe. The earliest known example is from a cave on the Indonesian island of Sulawesi (Celebes).

CAVE, INDONESIA



LIONS FROM GREAT PANEL
 CAVE OF CHAUVET-PONT-D'ARC, FRANCE

36,000



ANIMAL ON PAINTED TABLET
 APOLLO 11 CAVE, NAMIBIA

27,000



RED COW AND HORSE
 LASCAUX CAVE, FRANCE

19,000



Neanderthals had style too. A fox tooth, drilled perhaps to hang from a necklace, is one of many ornaments from deposits in a cave that also yielded Neanderthal tools.

EGGSHELL

FOX TOOTH ORNAMENT
 GROTTTE DU RENNE,
 FRANCE
 1 IN

43,000



First instrument

GRIFON VULTURE BONE FLUTE
 HOHLE FELS CAVE, GERMANY
 8.6 IN (BELOW)

40,000



BEADS (IVORY) DOLNI
 VESTONICE, CZECH REPUBLIC
 UP TO 0.7 IN

26,000

FLYING BIRD PENDANT (IVORY)
 MALTA, RUSSIA
 4.6 IN

20,000



First writing

Early writing, as on this cuneiform tablet recording barley distribution, does not appear until well after the beginning of agriculture.



CUNEIFORM WRITING
 ON CLAY TABLET, IRAQ
 2 IN

5,000

OF THE GOVERNMENT OF CANTABRIA, SPAIN; TOP ROW (FROM LEFT):
 MIDDLE ROW: CHRISTOPHER HENSHLWOOD, UNIVERSITY OF THE
 DERSEN, MAXIME AUBERT, GRIFFITH UNIVERSITY, AUSTRALIA; BOTTOM ROW:
 ERN

TOP ROW (FROM LEFT): H. ZWIETASCH, WÜRTTEMBERG STATE MUSEUM, STUTTGART, GERMANY; MORAVIAN MUSEUM/ANTHROPOS INSTITUTE, CZECH REPUBLIC (2); H. AMIRKHANOV,
 S. LEV, ZARAYSK KREMLIN MUSEUM, RUSSIA; MIDDLE ROW: STEPHEN ALVAREZ R. F. RIPPIN, UNIVERSITY OF BERGEN, NORWAY; SISSE BRIMBERG, NATIONAL GEOGRAPHIC CREATIVE;
 BOTTOM ROW: HILDE, JENSEN, TÜBINGEN UNIVERSITY, GERMANY (FLUTE); MORAVIAN MUSEUM/ANTHROPOS INSTITUTE (BEADS); KIRIL SHAPCOVALOV © STATE HERMITAGE MUSEUM,
 ST. PETERSBURG (PENDANT); METROPOLITAN MUSEUM OF ART/ART RESOURCE, NY (TABLET)

pulled them out and began to piece them together like a three-dimensional puzzle.

As he did, an extraordinary work of art emerged. At nearly a foot high, the Löwenmensch dwarfs all other carvings so far discovered in the German valleys. But what makes it particularly interesting, says Claus-Joachim Kind, an archaeologist at the State Office for Cultural Heritage in Baden-Württemberg, is that it depicts for the first time a creature that was completely imaginary, part man and part lion. Its creation required not only an unusually inventive mind, but also impressive technical skills and an enormous amount of time—an estimated 400 hours. “This is not something you do in the evening after work,” says Kind.

You can feel the power of the figure when you look at it, the seamless melding of a stately human and a ferocious animal. Does the sculpture reflect a wish to bestow a lion’s power on a human? Or could it represent a shaman’s special ability to straddle the spiritual worlds of human and animal? Hohlenstein-Stadel is the only cave in the region where archaeologists have found no everyday tools, bones, or rubbish. It is deeper than the other caves too. It’s not difficult to imagine that within its chambers early hunters venerated the Lionman and that Hohlenstein-Stadel Cave was an early locus of prehistoric religion. This was “a holy place,” says Kind.

Conard thinks these people possessed minds as fully modern as ours and, like us, sought in ritual and myth answers to life’s mysteries, especially in the face of an uncertain world. Who governs the migration of the herds, grows the trees, shapes the moon, turns on the stars? Why must we die, and where do we go afterward? “They wanted answers,” he says, “but they didn’t have any science-based explanations for the world around them.”

SOON AFTER MODERN HUMANS arrived in Europe, the continent’s long-term residents began to die out. The Neanderthals had emerged in Eurasia some 200,000 years earlier. Very little evidence remains that they engaged in symbolic behavior. But the traditional view of Neanderthals as

brutish beings incapable of such behavior has been slowly chipped away. Having never reached the population densities that may have triggered the appearance of symbolism in Africa, Neanderthals may never have had much need for it, or revealed it in ways we don’t yet understand.

For decades the debate over the Neanderthals’ ability to rise to the standards of their successors centered on a site in France called Grotte du Renne, where artifacts normally associated with Upper Paleolithic modern humans—bone tools,

**IT IS ALMOST AS IF
SOME ANIMALS WERE
ALREADY IN THE ROCK,
WAITING TO BE
REVEALED BY THE
ARTIST’S CHARCOAL
AND PAINT.**

distinctive stone blades, and pierced and grooved animal teeth probably worn as pendants—were found along with Neanderthal remains. Some researchers reasoned that although the Neanderthals may have been responsible for this tool tradition (known as the Châtelperronian), they were still a species capable only of emulating the fancy craftsmanship of their new modern human neighbors, not inventing it on their own.

The more we learn about Neanderthals, including their ability to interbreed with our direct ancestors, the more the “copycat” explanation for the Châtelperronian sounds like special pleading. The record for Neanderthal symbolic behavior elsewhere may be faint, but it is discernible. Some scholars argue that Neanderthal skeletons found in France and Iraq were deliberately buried. Cut marks recently found on bird-wing bones hint that Neanderthals used feathers for ornaments up to 50,000 years ago, and a crisscross pattern engraved at least 39,000 years ago in the rock of a Neanderthal cave in Gibraltar suggests they could think abstractly. And a single red disk painted

on a wall in El Castillo Cave in Spain was recently dated to about 41,000 years ago, tantalizingly close to a time when only Neanderthals are known to have been in western Europe. Perhaps they, not us, were the first cave artists.

But most of the cave paintings in southern France and Spain were created after the Neanderthals disappeared. Why there? Why then? One clue is the caves themselves—deeper and more extensive than the ones in the Ach and Lone River Valleys of Germany or the rock shelters of Africa. Tito Bustillo in northern Spain is a half mile from one end to the other. El Castillo and other caves on Monte Castillo dive, twist, and turn into the ground like enormous corkscrews. France's Lascaux, Grotte du Renne, and Chauvet run football fields deep into the rock, with multiple branches and cathedral-like chambers.

Perhaps the explosion of creativity we see on the walls of these caverns was inspired in part by their sheer depth and darkness—or rather, the interplay of light and dark. Illuminated by the flickering light from fires or stone lamps burning animal grease, such as the lamps found in Lascaux, the bumps and crevices in the rock walls might suggest natural shapes, the way passing clouds can to an imaginative child. In Altamira, in northern Spain, the painters responsible for the famous bison incorporated the humps and bulges of the rock to give their images more life and dimension. Chauvet features a panel of four horse heads drawn over subtle curves and folds in a wall of receding rock, accentuating the animals' snouts and foreheads. Their appearance changes according to your perspective: One view presents perfect profiles, but from another angle the horses' noses and necks seem to strain, as if they are running away from you. In a different chamber a rendering of cave lions seems to emerge from a cut in the wall, accentuating the hunch in one animal's back and shoulders as it stalks its unseen prey. As our guide put it, it is almost as if some animals were already in the rock, waiting to be revealed by the artist's charcoal and paint.

In his book *La Préhistoire du Cinéma*, filmmaker and archaeologist Marc Azéma argues that some of these ancient artists were the world's first

animators, and that the artists' superimposed images combined with flickering firelight in the pitch-black caves to create the illusion that the paintings were moving. "They wanted to make these images lifelike," says Azéma. He has recreated digital versions of some cave images that illustrate the effect. The Lion Panel in Chauvet's deepest chamber is a good example. It features the heads of ten lions, all seemingly intent on their prey. But in the light of a strategically positioned torch or stone lamp, these ten lions might be successive characterizations of just one lion, or perhaps two or three, moving through a story, much like the frames of a flip-book or animated film. Beyond the lions stands a cluster of rhinoceroses. The head and horn of the top one are repeated staccato-like six times, one image above the other, as if thrusting upward, its whole body shuddering with multiple outlines.

Azéma's interpretation fits with that of eminent prehistorian Jean Clottes—the first scientist to enter Chauvet, only days after its discovery. Clottes believes the images in the cave were intended to be experienced much the way we view movies, theater, or even religious ceremonies today—a departure from the real world that transfixed its audience and bound it in a powerful shared experience. "It was a show!" says Clottes.

Thousands of years later you can still feel the power of that show as you walk the chambers of the cave, the sound of your own breath heavy in your ear, the constant drip, drip of the water falling from the walls and ceilings. In its rhythm you can almost make out the thrum of ancient music, the beat of the dance, as a storyteller casts the light of a torch upon a floating image, and entralls the audience with a tale. □

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Twins Felix and Viva Torres, seven-and-a-half months old, take in the sights and sounds of Greenwich Village in New York City. They hear two languages spoken at home.



A baby's brain
needs love
to develop.
What happens in

THE FIRST YEAR

is profound.



Ginny Mooney comforts her adopted daughter, Lena, in Fayetteville, Arkansas, after physical and speech therapy. The six-year-old has behavioral and cognitive deficits, partly from neglect in a Ukrainian orphanage. She is swaddled for her comfort.



By Yudhijit Bhattacharjee
Photographs by Lynn Johnson

In the late 1980s, when the crack cocaine epidemic was ravaging America's cities, Hallam Hurt, a neonatologist in Philadelphia, worried about the damage being done to children born to addicted mothers. She and her colleagues, studying children from low-income families, compared four-year-olds who'd been exposed to the drug with those who hadn't. They couldn't find any significant differences. Instead, what they discovered was that in both groups the children's IQs were much lower than average. "These little children were coming in cute as buttons, and yet their IQs were like 82 and 83," Hurt says. "Average IQ is 100. It was shocking."

The revelation prompted the researchers to turn their focus from what differentiated the two groups toward what they had in common: being raised in poverty. To understand the children's environment, the researchers visited their homes with a checklist. They asked if the parents had at least ten books at home for the children, a record player with songs for them, and toys to help them learn numbers. They noted whether the parents spoke to the children in an affectionate voice, spent time answering their questions, and hugged, kissed, and praised them.

The researchers found that children who received more attention and nurturing at home tended to have higher IQs. Children who were more cognitively stimulated performed better on language tasks, and those nurtured more warmly did better on memory tasks.

Many years later, when the kids had entered their teens, the researchers took MRI images of their brains and then matched them up with the records of how warmly nurtured the children had been at both four and eight years old. They found a strong link between nurturing at age four and the size of the hippocampus—a part of the brain associated with memory—but found no correlation between nurturing at age eight and the hippocampus. The results demonstrated just how critically important an emotionally supportive environment is at a very young age.

The Philadelphia study, published in 2010, was one of the first to demonstrate that childhood experience shapes the structure of the developing brain. Since then, other studies have shown a link between a baby's socioeconomic status and the growth of its brain. Despite coming prewired with mind-boggling capacities, the brain depends heavily on environmental input to wire itself further. Scientists are now discovering precisely how that development is molded by the interplay between nature and nurture.

Peering inside children's brains with new imaging tools, scientists are untangling the mystery of how a child goes from being barely able to see when just born to being able to talk, ride a tricycle, draw, and invent an imaginary friend by the age of five. The more scientists find out about how children acquire the capacity for language, numbers, and emotional understanding during this period, the more they realize that the baby brain is an incredible learning machine. Its future—to a great extent—is in our hands.

If the metamorphosis of a cluster of cells into



Natasha Alvarez floats in a swimming hole in Lancaster, Pennsylvania, hoping that a stress-free pregnancy will help her child's brain development in utero.

a suckling baby is one of life's great miracles, so is the transformation of that wobbly infant into a walking, talking toddler capable of negotiating bedtime. While researching this story, I have watched that miracle unfold before my eyes as my daughter has gone from a fidgety bundle with only a piercing cry signaling hunger to a feisty three-year-old who insists on putting on her sunglasses before stepping out of the house. The blossoming of her mental and emotional abilities has been a string of marvels, deepening my amazement at how deftly a baby's brain comes to grasp the world.

The milestones she has passed would be recognizable to any parent. At two she knew enough to realize that she didn't have to hold my hand when walking on the sidewalk; she would reach for my hand only when we were about to cross the street. Around the same age, she also learned to block the drain in the bathtub with the ball of her foot—turning what was to be a quick shower into a playful bath. Before she turned three, she was holding lengthy conversations and coming up with rhymes: "If the

candy tastes bad, Willy Wonka will be sad."

Despite millennia of child rearing, we have only a limited understanding of how babies take such gigantic strides in cognitive, linguistic, reasoning, and planning ability. The lightning pace of development in these early years coincides with the formation of a vast skein of neural circuits. At birth the brain has nearly a hundred billion neurons, as many as in adulthood. As the baby grows, receiving a flood of sensory input, neurons get wired to other neurons, resulting in some hundred trillion connections by age three.

Different stimuli and tasks, such as hearing a lullaby or reaching for a toy, help establish different neural networks. Circuits get strengthened through repeated activation. The sheath encasing nerve fibers—made of an insulating material called myelin—thickens along oft-used pathways, helping electrical impulses

*Yudhijit Bhattacharjee is writing a nonfiction book, *The Spy Who Couldn't Spell*. Lynn Johnson's feature, "Vanishing Voices," in the July 2012 issue, was on the world's disappearing languages.*





Tiffany Painter spends a tender moment with her six-month-old son, Taevon, at their home in Pittsburgh, Pennsylvania. After a breakfast of rice cereal, fruit, and juice, Taevon will watch music videos while his mother takes online courses to further her education.

In Patricia Kuhl's lab at the University of Washington, researchers study brain activity in babies less than a year old using a magnetoencephalography device, which measures the magnetic field around a baby's scalp, to reveal the pattern of neurons firing.

travel more quickly. Idle circuits die through the severing of connections, known as synaptic pruning. Between the ages of one and five, and then again in early adolescence, the brain goes through cycles of growth and streamlining, with experience playing a key role in engraving the circuits that will endure.

HOW NATURE AND NURTURE combine to shape the brain is nowhere more evident than in the development of language ability. How much of that comes hardwired, and how do babies acquire the rest? To learn how researchers are answering that question, I visit Judit Gervain, a cognitive neuroscientist at Paris Descartes University who has spent the past decade probing the linguistic acumen of children, ranging in age from days to a few years. We meet on the steps of Robert-Debré Hospital in Paris, where Gervain is readying an experiment on newborns.

I follow her into a room down the hall from the maternity ward. The morning's first subject is wheeled in on a cart, swaddled in a pink polka-dot blanket, with dad in tow. A research assistant slips a skullcap studded with button-like sensors onto the infant's head. The plan is to image the baby's brain while playing a variety of audio sequences, like *nu-ja-ga*. But before any observations can begin, the baby emits a series of high-pitched cries, making it known he isn't going to submit. The assistant hurriedly removes the cap, and the dad cradles the baby.

After they leave, Gervain, who had just become a mother a few months earlier, tells me that such failures are not uncommon. Another newborn—also accompanied by dad—is wheeled in. Gervain's assistant follows the same protocol, and this time the observing goes off without a hitch. The baby sleeps through it.

Gervain and her colleagues have used a similar setup to test how good newborns are at discriminating between different sound patterns. Using near-infrared spectroscopy, the researchers imaged the brains of babies while they heard audio sequences. In some, the sounds were repeated in an ABB structure, such as *mu-ba-ba*; in others, an ABC structure, such as *mu-ba-ge*. The researchers

found that brain regions responsible for speech and audio processing responded more strongly to the ABB sequences. In a later study they found that the newborn brain was also able to distinguish between audio sequences with an AAB pattern and those with an ABB pattern. Not only could babies discern repetition, they also were sensitive to where it occurred in the sequence.

Gervain is excited by these findings because the order of sounds is the bedrock upon which words and grammar are built. "Positional information is key to language," she says. "If something is at the beginning or at the end makes a big difference: 'John killed the bear' is very different from 'The bear killed John.'"

That the baby brain responds from day one to the sequence in which sounds are arranged suggests that the algorithms for language learning are part of the neural fabric infants are born with. "For a long time we had this linear view. First, babies are learning sounds, then they are understanding words, then many words together," Gervain says. "But from recent results, we know that almost everything starts to develop from the get-go. Babies are starting to learn grammatical rules from the beginning."

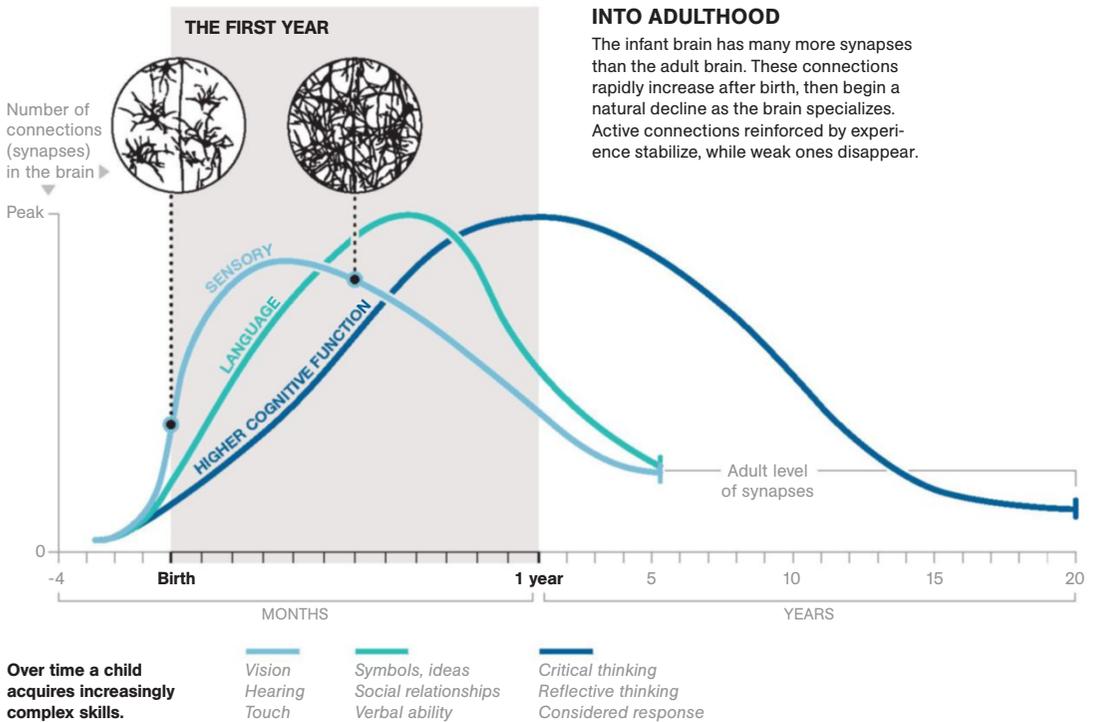
Researchers led by Angela Friederici, a neuropsychologist at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig, Germany, have found evidence of such comprehension in an experiment with four-month-old German babies exposed to an unfamiliar language. The children first heard a series of Italian sentences representing two types of construction: "The brother can sing" and "The sister is singing." After three minutes they listened to another set of Italian sentences, some of which were grammatically incorrect, along the lines of "The brother is sing" and "The sister can singing." During this phase the researchers measured the infants' brain activity using tiny electrodes placed on the scalp. In the first round of testing the babies showed a similar brain response to both correct and incorrect sentences. A few rounds of training later, the infants exhibited very different activation patterns when they heard erroneous constructions.

In just 15 minutes the babies appeared to have



Neural Network

The brain begins developing in the womb and achieves dramatic levels of growth during the first few years of life. During this time positive experiences contribute to building a strong brain architecture.





Julien Inzodda conducts a tutorial on spices in her kitchen in Pittsburgh to stimulate her 20-month-old daughter, Allie. It's a playful opportunity for the toddler to learn about color, texture, and taste. Allie's favorite is the pepper sauce, which she describes as "hot, hot, hot."





In the neonatal intensive care unit at Texas Children's Hospital in Houston, five-month-old Lucas Guidry watches as mom Sydney (center) holds up a mirror. Children born prematurely or with an illness are at risk for cognitive delays.

absorbed what was correct. “Somehow they must have learned it, despite not comprehending the meaning of the sentences,” Friederici tells me. “At this point it’s not syntax. It’s phonologically encoded regularity.”

Researchers have shown that children around two and a half years old are savvy enough to correct grammatical mistakes made by puppets. By the age of three most children seem to master a considerable number of grammatical rules. Their vocabulary burgeons. This flowering of language ability comes about as new connections are made among neurons, so that speech can be processed on multiple levels: sound, meaning, and syntax. Scientists have yet to unveil the precise map followed by the infant brain on the path to linguistic fluency. But what’s clear, in the words of Friederici, is this: “The equipment alone is not enough. You also need input.”

On my way to Leipzig to interview Friederici, my attention is drawn to a mother and her young son, engaging in conversation on a shuttle bus at the Munich airport. “What do you see in the distance?” the mother asks as the bus takes us

from the terminal to the aircraft. “I see a lot of planes!” the kid exults, bouncing. Seated in a row ahead of me on the flight, the two keep up an unflaggingly spirited exchange. The woman stops to answer the boy’s every question as she reads him one picture book after another, drawing on what seems like a limitless reservoir of enthusiasm. When we land, I learn that the mom, Merle Fairhurst, is a cognitive neuroscientist who studies child development and social cognition. It isn’t surprising that she is determined to apply the emerging research on how stimulation can help the developing brain.

More than two decades ago Todd Risley and Betty Hart, both child psychologists then at the University of Kansas in Lawrence, recorded hundreds of hours of interactions between children and adults in 42 families from across the socioeconomic spectrum, following the kids from the age of nine months to three years.

Studying the transcripts of these recordings, Risley and Hart made a surprising discovery. Children in well-off families—where the parents were typically college-educated

professionals—heard an average of 2,153 words an hour spoken to them, whereas children in families on welfare heard an average of 616 words. By the age of four this difference translated to a cumulative gap of some 30 million words. Parents in poorer homes tended to make shorter, more perfunctory comments, like “Stop that,” and “Get down,” whereas parents in wealthier homes had extended conversations with their kids about a variety of topics, encouraging them to use their memory and imagination. The kids in low socioeconomic families were being raised on a poor linguistic diet.

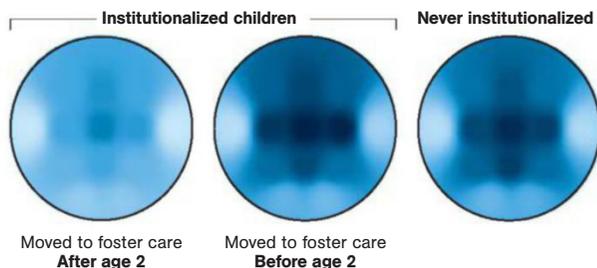
The amount of talking parents did with their children made a big difference, the researchers found. The kids who were spoken to more got higher scores on IQ tests at age three. They also

in a foreign language, while getting better at discriminating between native language sounds. Japanese children, for example, are no longer able to distinguish between “l” and “r” sounds.

In their study the researchers exposed nine-month-olds from English-speaking families to Mandarin. Some of the children interacted with native Chinese-speaking tutors, who played with them and read to them. “The babies were entranced by these tutors,” Kuhl says. “In the waiting room they would watch the door for their tutors to come in.” Another group of children saw and heard the same Mandarin-speaking tutors through a video presentation. And a third group heard only the audio track. After all the children had been through 12 sessions, they were tested on their ability to discriminate

Critical Years

The amount of brain activity in the earliest years affects how much there is later in life. These EEG scans of eight-year-olds show that institutionalized children who were not moved to a nurturing foster care environment before they were two years old have less activity than those who were.



performed better in school at ages nine and ten.

Exposing children to more words would seem simple enough. But language delivered by television, audio book, Internet, or smartphone—no matter how educational—doesn’t appear to do the job. That’s what researchers led by Patricia Kuhl, a neuroscientist at the University of Washington in Seattle, learned from a study of nine-month-old children.

Kuhl and her colleagues were exploring a key puzzle of language acquisition: how babies hone in on the phonetic sounds of their native language by the age of one. In the first few months of their lives, babies show a knack for discriminating between sounds in any language, native or foreign. Between six and 12 months of age, however, they start losing the ability to make such distinctions

between similar phonetic sounds in Mandarin.

The researchers expected the children who’d watched the videos to show the same kind of learning as the kids tutored face-to-face. Instead they found a huge difference. The children exposed to the language through human interactions were able to discriminate between similar Mandarin sounds as well as native listeners. But the other infants—regardless of whether they had watched the video or listened to the audio—showed no learning whatsoever.

“We were blown away,” Kuhl says. “It changed our fundamental thinking about the brain.” The result of this and other studies led Kuhl to propose what she calls the social gating hypothesis: the idea that social experience is a portal to linguistic, cognitive, and emotional development.





Tyler Quebodeaux, a single parent, struggles to raise his three children, aged 20 months to four years, in Springfield, Oregon. Quebodeaux is attending a program at the University of Oregon to learn how to provide better nurturing and stimulation for his kids.



At a Waldorf School on Whidbey Island northwest of Seattle, children play on bales of straw while teachers supervise. The school's philosophy is that free play is essential for physical, cognitive, linguistic, and social development in young children.



AFTER GAINING POWER in Romania in the mid-1960s, the communist leader Nicolae Ceausescu implemented drastic measures to transform the country from an agricultural society into an industrial one. To increase the population, the regime limited contraception and abortion, and imposed a tax on couples older than 25 who were childless. Thousands of families moved from villages to cities to take jobs at govern-

ment factories. These policies led many parents to abandon their newborn children, who were then placed in a state-run institution called a *leagan*—the Romanian word for “cradle.”

It was only after Ceausescu was deposed in 1989 that the outside world saw the horrific conditions in which these children were living. As babies, they were left in cribs for hours. Typically their only human contact was when a caregiver—each responsible for 15 to 20 children—came to feed or bathe them. As toddlers, they hardly received any attention. The system of institutionalized care was slow to change, and in 2001, U.S. researchers began a study of 136 children from six institutions to investigate the impact of neglect on their development.

The researchers—led by Charles Zeanah, a child psychiatrist at Tulane University; Nathan Fox, a developmental psychologist and neuroscientist at the University of Maryland; and Charles Nelson, a neuroscientist at Harvard—were struck by the children’s aberrant behaviors. Many of the kids, less than two years old when the study began, showed no attachment to their caregivers. When upset, they wouldn’t go to the caregivers. “Instead, they showed these almost feral behaviors that we had never seen before—aimlessly wandering around, hitting their heads against the floor, twirling and freezing in one place,” Fox says.

When the researchers conducted an EEG test of the children’s brains, they found that these signals were weaker than the signals recorded from similarly aged children in the general population. “It was as if a dimmer switch had been used to turn their brain activity down,” Fox says. He and his colleagues then placed half of the kids with foster families that they picked with the help of social workers. The remaining kids

The baby brain is an incredible learning machine. Its future—to a great extent—is in our hands.

stayed at the institutions. The foster families received a monthly stipend, books, toys, diapers and other supplies, as well as periodic visits by the social workers.

Fox and his colleagues followed the children over the next several years and saw dramatic differences emerge between the groups. At age eight the children placed with foster families at age two or earlier showed EEG brain patterns that were indistinguishable from those of typical eight-year-olds. The kids who had remained at the institutions continued to have weaker EEGs. Although all the children in the study had smaller brain volumes than similarly aged kids in the general population, the ones who received foster care had more white matter—axons connecting neurons—than the institutionalized kids. “It suggests that there were more neuronal connections made in the children who experienced the intervention,” Fox explains.

The most striking difference between the two sets of children—evident by the age of four—was in their social abilities. “We find that many of the children who were put into our intervention, particularly the children who were taken out of institutions early, could now relate to their caregiver in the way that a typical child would,” Fox says. “There’s enough plasticity in the brain early in life that allows children to overcome

negative experiences.” And that, Fox says, is the best news: Some of the debilitating effects of early deprivation can be addressed with appropriate nurturing, as long as it is provided within a critical period of development.

A PARENTAL TRAINING PROGRAM led by neuroscientist Helen Neville at the University of Oregon in Eugene aims to do just that. The researchers sign up participants from among families enrolled in Head Start, a U.S. government program that gives a leg up to preschoolers from low-income families. Parents or care providers come in for a class every week over a two-month period. In the first few classes they get tips on lowering the stress involved in the day-to-day care of children. As any parent can testify, these stresses can at times be overwhelming to even the most Zen-like among us, and they can feel even more burdensome to parents dealing with financial worries. “You find yourself on edge because you don’t have certain things,” says Patricia Kycek, a Eugene mom who’s taken the classes.

Parents learn to emphasize positive reinforcement, expressing praise for specific accomplishments. “We encourage them to shift the focus from scolding your child every time they are doing something wrong to noticing every time they are doing something right,” explains Sarah Burlingame, a former parent instructor. In later weeks parents learn how to stimulate the child. In one activity that they are encouraged to try at home, the parent asks the child to pick out various objects—a spoon, a bottle, a pen—and guess which will float and which will sink. Then the child gets to test each prediction in a bucket of water or in the bathtub.

The children receive training in attention and self-control in a 40-minute session every week. They work on focusing on a task in the midst of distractions—for instance, coloring inside the lines of figures while other kids bounce balloons all around. Instructors also teach them to better identify their emotions through a game called Emotional Bingo, in which children match states like “happy” and “sad” with facial expressions. In some later

classes the kids learn to practice calming techniques, like taking a deep breath when they are upset.

At the end of the eight weeks the researchers evaluate the kids on language, nonverbal IQ, and attention. Through a questionnaire given to the parents, they also assess how the kids are doing behaviorally. In a paper published in July 2013, Neville and her colleagues reported that kids in Head Start who received the intervention showed significantly higher increases on these measures than those who did not. Parents reported experiencing much lower stress in managing their children. “When you change parenting and stress level goes down, that leads to increased emotional regulation and better cognition for the kids,” Neville says.

Tana Argo, a young mother of four, decided to go through the program to make sure she wouldn’t subject her children to the kind of neglect that she had suffered as a child. “I grew up with a lot of stress and drama,” she says. “I told myself, I’m going to remember this with my kids. This won’t happen to my kids.”

What she learned—she says—has altered the family’s dynamic, creating more time for play and learning. When I visit her at home one afternoon, she describes how happy she felt a few days earlier when she saw her four-year-old daughter—the youngest—plop down on the carpet to thumb through a children’s encyclopedia. As I’m leaving, I notice the encyclopedia resting on top of a stack of books, most of them for children. In the best of circumstances, that stack would perhaps serve as a wall against the generational dominoes of poverty and neglect, helping Argo’s kids build a future that she never had a shot at. □

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TELEVISION

Test Your Brain

Now you know how a baby’s brain works, but what about your own? Learn why you forget your keys, what your dreams mean, and more on the National Geographic Channel series, *Brain Games*.

VIDEO



Bursting with a
get-rich spirit
that has made
Nigeria's economy
the continent's
largest, Lagos
is Africa's

FIRST CITY

Almaz relishes the growing cultural scene in Lagos. Here she poses at the African Artists' Foundation. "Lagos is a very bubbly society," she says. "If you want to make something happen really, really bad, come to Lagos. It will happen, trust me."







At the end of the workday, vans crowd into Idumota Market on Lagos Island to pick up workers returning home to the mainland, where most Lagosians live.





Young businessmen of the Cigar Club of Lagos, who are part of the city's rapidly growing upper class, savor a moment of relaxation at a hotel on Victoria Island.



Vendors hawk goods at one of many markets on Lagos Island, demonstrating the entrepreneurial fervor that has made Nigeria's economy Africa's most vibrant.





Lakowe Lakes Golf and Country Estate, a gated residential community, offers a posh retreat for the wealthy not far from the frenzied commercial center.



By Robert Draper

Photographs by Robin Hammond

WHEN HE WAS 15 YEARS OLD,

David Adeoti worked in an Internet café in blue-collar Satellite Town, where it was almost possible to see the gleaming towers of Lagos Island less than ten miles to the east.

Satellite Town was a step up for Adeoti. His birthplace was off to the north in Orile, a wretched village of flooded streets and collapsing buildings. Technology had provided his way out. The Internet café in Satellite Town was run as a side business by a banker, who saw that the boy had a natural facility for computers—even the shop's ancient desktops, which operated at lurching speeds. The banker paid Adeoti a little more than \$200 a month to run the place. Adeoti spent his money on courses at a technical institute, determined that the Internet café would not be the end of the line for him.

One day in 2010 the shop's customers looked up from the computers to see who had just walked in the door with the mannered British accent. His name was Jason Njoku, a bespectacled 30-year-old Londoner who had relocated to his ancestral homeland of Nigeria. Njoku asked Adeoti if he could scan some documents. While Adeoti operated the scanner, the genteel visitor mentioned that he was trying to find investors for a new business venture and asked the

Internet café manager if he enjoyed his job. They exchanged cell phone numbers. A few months later Adeoti inquired about a job and was invited to find six young men wedged behind desks with computer cables snaked around their feet as they typed. This, Njoku informed Adeoti, was his new business: an indigenous version of Netflix that would stream movies to Nigerian computers and bring Nigerian movies to the world. Njoku needed someone like Adeoti to convert "Nollywood" DVDs into a YouTube format. As was evident by the cramped environs, the project was perilously low on money. Adeoti signed on anyway, thinking, It's going to sell itself.

When I met David Adeoti in spring 2014, he was 24 and wearing an elegant knit shirt and designer jeans while sitting behind a Mac laptop in the sleek three-story office that now houses iROKOTv in Lagos. Njoku's company has about 80 employees, with additional offices in Johannesburg, London, and New York City. Adeoti makes twice the salary he made as the manager at the Internet café. But all this exposure to money and movies had whetted his appetite for more of both. "I plan on starting my own business—something in the film industry," he told me. He was saving money to travel to Hollywood. He wants to be a cinematographer—and perhaps one day, a Nollywood studio executive.

"It's a very far distance from middle class to

*Robert Draper's last story for the magazine was on rethinking Rome's Emperor Nero. Robin Hammond's book *Condemned: Mental Health in African Countries in Crisis* has won numerous awards.*



Tobi Ajike, 6, and brother Tomi, 7, attend private school close to their home in Mende Villa Estate in an upscale area of mainland Lagos. Their father is an architect, their mother a businesswoman. Asked to describe his city, Tobi says, "My Lagos is wonderful, beautiful, lovely, very busy."

being rich,” Adeoti said. With a widening grin, he added, “But the middle class, we strive. Everyone is very desperate to be very rich these days.”

Almost anywhere else in the developing world, such a sentiment would seem pitifully delusional. In Lagos, Nigeria’s commercial center, “Be Very Rich” has all but become the city’s motto. The country recently recalculated its gross

African nation teeming with industrious strivers like Adeoti but also with poverty, despair, and violence. If anything, the miracle of Lagos is that its economy gallops onward even when fettered by the same federal incompetence that allows terrorism to go unchecked. A lesser city would be crippled. Then again, in a sense so is Lagos.

“Nigeria’s problem and Lagos’s problem is its

LAGOS HAS LONG NURTURED an elite class only marginally inconvenienced by the squalor enveloping the city as a whole.

domestic product to take into account sectors of the economy that barely existed two decades ago. As a result, Nigeria determined that its GDP surpassed South Africa’s in 2012 to become the continent’s largest economy. About 15,700 millionaires and a handful of billionaires live in Nigeria, more than 60 percent of them in Lagos.

As with other African metropolises, oil-enriched Lagos has long nurtured an elite class only marginally inconvenienced by the squalor enveloping the city as a whole. Now the upper class is expanding, and despite persistent income inequality, so is the middle class. The growth of the latter in Nigeria, according to a 2013 survey by Ciuci Consulting, a strategy and marketing firm in Lagos, is driven by the expanding banking, telecommunications, and services sectors, particularly in Lagos. Nigeria’s middle class grew from 480,000 in 1990 to 4.1 million in 2014, or 11 percent of households. Seemingly overnight, Lagos has transformed itself into a city of Davids clamoring to become Goliaths.

This is a great African success story. And how lovely it would be to tell this bright, uplifting tale while ignoring altogether the dark and demoralizing saga of Nigeria’s grotesque terrorists, which has blocked the boomtown narrative from the world’s consciousness like a lunar eclipse. But Lagos does not exist in a parallel universe, any more than the Islamic extremist group Boko Haram does. Both are indigenous to Nigeria, a vast West

image. That’s the chief problem. You’d think you were in a war zone in Afghanistan when you read what you read about here! But tell me: Have you felt any threat?”

No, I confessed to Kola Karim, the dashing 45-year-old multimillionaire and CEO of Shoreline Energy International, a food/energy/telecommunications/construction conglomerate with more than 3,000 employees. I felt quite safe in Lagos—a pleasant surprise, given that I had boarded my flight to the city on the same day that dozens were killed in a bomb blast at a bus depot in the capital city of Abuja. It was the latest in a string of terrorist episodes for which Boko Haram had taken credit. But Lagos had been spared from such incidents, so far. The violence felt a country away—like a bad dream washed from memory after a morning’s shower.

“Look, I was invited to the White House a few weeks ago,” Karim went on, his British-educated diction edged with exasperation. “There were 21 of us—young global leaders of the World Economic Forum. I told them, ‘You’re always viewing things from a national security angle rather than commercial viability. You invite African businessmen over, and all you want to know about is al Qaeda. Why are you wasting my time to come all the way here to listen to the same old gibberish?’”

Karim makes it his business to evangelize about the Lagos miracle in which he has played a notable

Lagos, Nigeria's largest city and its commercial center, lies on the Atlantic Ocean and hugs Lagos Lagoon. The main business districts are on Lagos and Victoria Islands.



role. Later in the day a French TV station would be filming Karim playing polo as a way of showcasing the city's prosperity. The following week he would be at the Milken Institute in Santa Monica, giving a speech about Africa's power sector. Karim has delivered similar talks at Harvard and Yale, part of what he refers to as his "moral duty to promote Nigeria and Lagos." When I joked that he could be making big money on the speaking circuit, the Lagos entrepreneur solemnly replied, "I will start charging money when the world has heard our story."

Here is the story, in brief. Following centuries of tribal rule by territorial kings and emperors and 99 years of British colonial rule, Nigeria achieved independence in 1960 and was intermittently ruled by military heads of state until 1999, when it at last achieved a rickety state of democracy. Among its 36 states, Lagos—which includes the sprawling port city of the same name—was ever the country's center of power, even when the federal capital was relocated in 1991 to Abuja, a 450-mile drive away. Still, Lagos deteriorated under decades of military rule. Its schools, roads, and hospitals went to seed. Western investors kept their distance. When Karim returned from England to his birthplace in 1996 to build on the

family cocoa business, there were very few of his kind, "because," he told me, "it wasn't an open economy, and financial services were few. Back then the total capital of a bank was maybe two million dollars. Imagine you want to do business in Lagos. How much can a bank like that possibly lend you? Fast-forward to today—they'll lend you up to \$500 million!"

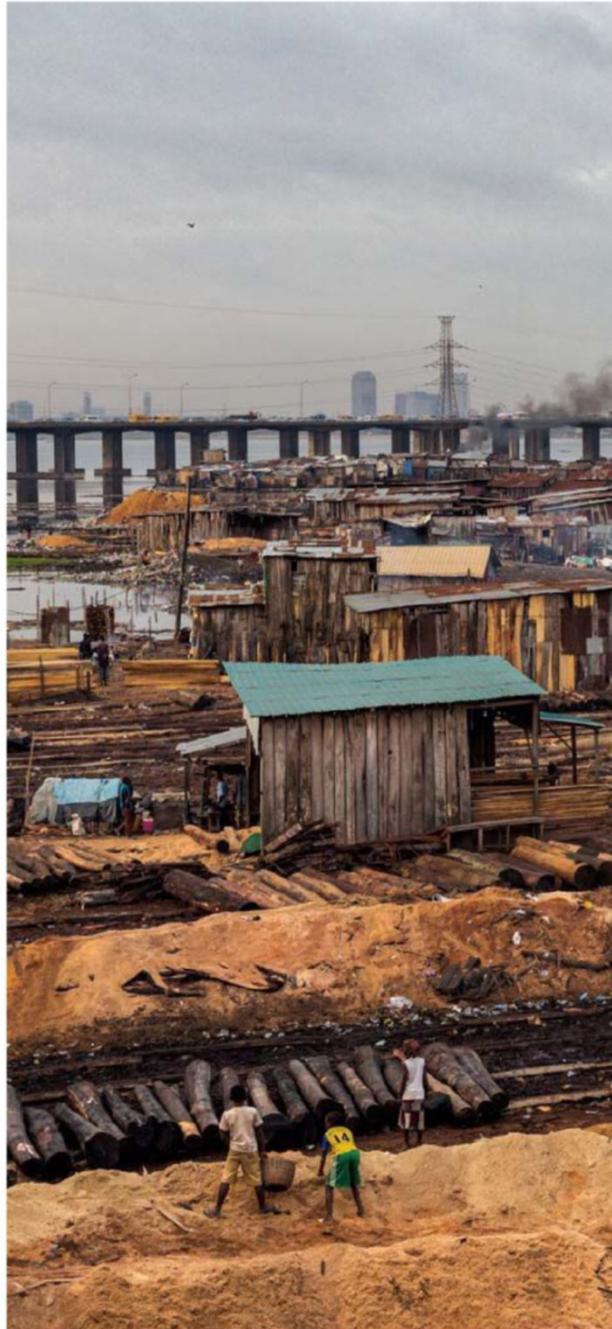
What happened to Lagos stemmed from a convergence of two phenomena. First, after knowing only political incompetence, the newly democratized Lagosians elected a pair of remarkably consequential state governors: former accountant Bola Tinubu in 1999, and in 2007 his handpicked successor, Babatunde Fashola, who has been credited with helping quash an Ebola outbreak in Lagos. The two executives restored some fiscal sanity to Lagos while investing in bridges and expressways. Meanwhile a reverse diaspora transpired as native Nigerians began to return home. When the worldwide recession foreclosed opportunity in Europe and America, Lagos offered itself as a new frontier for ambitious entrepreneurs. One of them, Lanre Akinlun, told me, "Back in the U.K., all of my friends started moving back to Lagos. When they'd return to visit, we'd meet in a bar, and they'd buy a

round of shots. But then later they'd come back and order up bottles of the most expensive stuff. I told myself, OK, something's going on here."

On the Atlantic coast and consisting of a slab of mainland around a lagoon and several islands, Lagos today is an ad hoc ecosystem thrashing with wealth seekers. Tourism is largely absent here—one comes to Lagos strictly to do business—and yet at the same time it is a strangely inviting place, a city of optimists.

That is not to suggest that life in Lagos is a smooth ride. As with all boomtowns, the city is at pains to keep up with itself. Lagos's population is growing so fast and is so transient that it's impossible to estimate the number of inhabitants more precisely than between 13 million and 18 million. The hubs of commerce are the two small islands of Lagos and Victoria, and only the very wealthy can afford to live there. While developers swoop down on every last sliver of marshland, forest, and landfill (and in the case of the ultra-elite planned city of Eko Atlantic, 3.5 square miles of land recovered from the ocean), ambitious Lagosians struggle to reconcile their status consciousness with the absurd price of central housing and the 20 percent interest that banks commonly charge for mortgage loans. Invariably, Lagosians settle on a flat somewhere on the mainland, which means enduring commutes through grinding traffic that can exceed two hours each way. Or it means waiting out the gridlock over beers and cigars with fellow young Turks at a bar somewhere on the islands—a fraternal spectacle as endemic to Lagos as the traffic snarls themselves.

I sat one late afternoon in one of those bars with a half dozen well-dressed bankers in their 30s, a daily congregation of gentlemen who have perfected the art of boozy time-wasting. One of them, an especially talkative fellow, told me that a flat on the island would cost four times the amount he had paid for his house on the mainland. "If I had the right kind of income, of course I'd live on the island," he said. "If I lived on the island, I'd go home, check my boys' homework assignments, play some computer games with them, maybe take my wife out for dinner. During the week I can't do that."





Thousands live and work in the sawmill district on mainland Lagos, a patchwork of workshops and shanties that twice in recent years has been devastated by fires. The towers where Nigeria's wealth is made loom across Lagos Lagoon behind the Third Mainland Bridge.



Girls wash dishes and boil peanuts (top) to sell at a decaying housing complex, one of many cheaply built, low-cost neighborhoods constructed by the Lagos state government more than three decades ago. In a tiny classroom tucked into a row of shops, Innocent Lewis teaches adults how to type on keyboards, to improve their job prospects.

The young banker then laughed off his predicament and called out for another round.

A RECENT SURVEY of middle-class Nigerians conducted by Renaissance Capital, an investment bank, found that 76 percent of them are optimistic about the country's future. Sunniness of outlook has deep roots in Nigeria, particularly

a young man who, at 18, became an unpaid apprentice to an electrician and worked odd jobs to survive. For a time he slept in a bus stop. He owned what he was wearing and nothing else. After about four years Chiagozie scraped together enough money to rent a tiny house in the mixed-income neighborhood of Ojota, where he had apprenticed. "Save, save, save: I've

AN AD HOC ECOSYSTEM

thrashing with wealth seekers, Lagos is a strangely inviting place, a city of optimists.

so in Lagos, a land of traders and settlers, and thus of industrious disposition. Lagosians believe themselves to be pluckier than the average West African. This is, if anything, a modest self-assessment. The man I hired to drive me around during my three weeks in Lagos, Daniel Sunday, took me one day to the neighborhood where he was born and raised: Makoko, a fetid shantytown on stilts in Lagos Lagoon that is mordantly referred to as the "Venice of Africa." Sunday told me that he left the shabby family home when he was a teenager and found work as a bus conductor. He slept on his boss's floor and after a few years had accumulated enough money to buy his first car. Now he was married, with a residence on the mainland, and for two hours each morning he uncomplainingly chauffeured customers like me around the commercial districts. The motto on Sunday's business card was "In God I Trust."

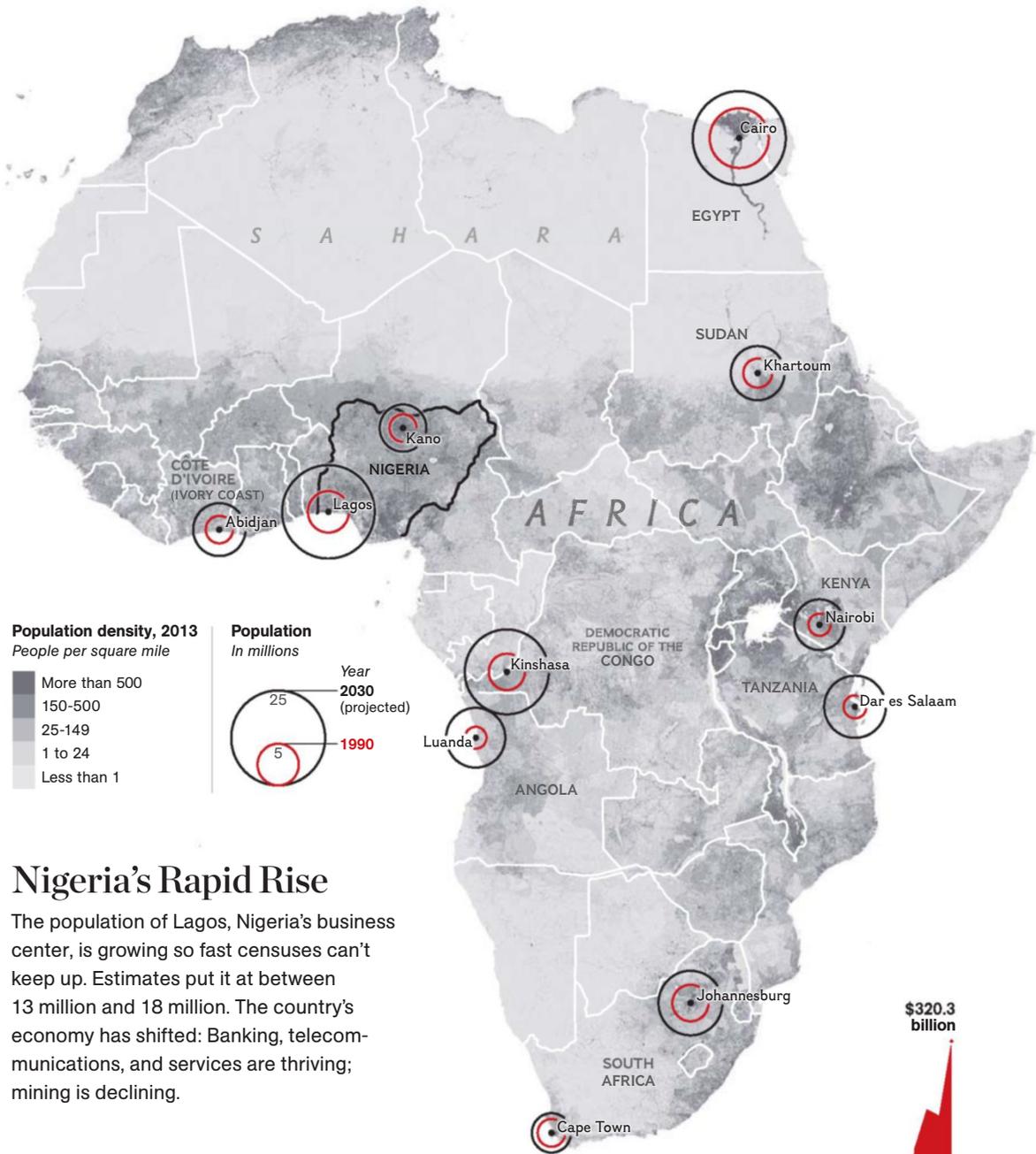
"If you give a Nigerian an opportunity, he will do his best," a 36-year-old man named Onyekachi Chiagozie proclaimed one hot afternoon as he proudly showed me his mobile electrician's workshop. In truth, the hollowed-out van with the cracked windshield wasn't much to look at. Chiagozie had bought the used van for about \$4,300, and with it he could drive his tools all over the city, an enabler and beneficiary of Lagos's construction boom.

All of this was an improbable outcome for

made the sacrifice, and it's started to pay off," he recalled. "I registered my company. People in the area knew me. I'd fix this socket or see why that light wasn't turning on. The customers grew to trust me. Then they started getting me good jobs. Wiring whole houses. Fixing ATMs and air conditioners. And because in Lagos it's very expensive to have an office, I decided to have the first mobile workshop in the country."

The owner of the whimsically named Varied Pace Enterprises, Chiagozie beamed as he told me that he was now married, with a three-bedroom house in Ojota and a tract of land outside the city that he deemed a prudent investment. He shepherded me through the neighborhood, pointing out the houses that he and his two apprentices were currently wiring. The slum child had broken through. Another Lagos success story—but an unfinished one, for this was not nearly enough. "I've been making money," the electrician told me, "but the money is better across the bridge, on the island. And I don't know the right people there yet."

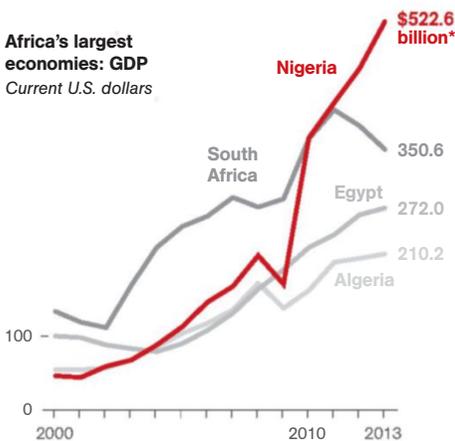
Banke Meshida Lawal knows the right people. When I visited her at her beauty salon, BM Pro, on Lagos Island, the young makeup artist was applying a full makeover to a wealthy client who would soon be attending a wedding in Chicago. Because Lawal herself could not break away from her business to fly over for the event, a colleague was videotaping the procedure, and a



Nigeria's Rapid Rise

The population of Lagos, Nigeria's business center, is growing so fast censuses can't keep up. Estimates put it at between 13 million and 18 million. The country's economy has shifted: Banking, telecommunications, and services are thriving; mining is declining.

Africa's largest economies: GDP
Current U.S. dollars



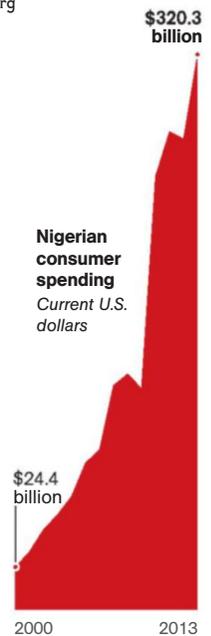
Nigeria's middle class

4.1 million
middle-class Nigerian households in 2014

11%
of current population

7.6 million
additional middle-class households expected by 2030

Nigerian consumer spending
Current U.S. dollars



*GDP REVISED FROM 2010 ONWARD TO REFLECT IMPROVED DATA SOURCES AND METHODOLOGY

RYAN MORRIS, NGM STAFF. SOURCES: STANDARD BANK GROUP; WORLD BANK; LANDSCAN; UNITED NATIONS POPULATION DIVISION

copy would be sent to one of Lawal's beauty reps in the United States, who would replicate the makeover on the wedding day. Lawal's onetime fee was more than what it had cost Chiagozie to buy his mobile electrician's workshop.

The makeup artist shares with the electrician a fierce entrepreneurial motor, though she began with a leg up on the ladder. Lawal's father was a university lecturer, her mother a radiologist. While studying English at the University of Lagos, she began doing other students' makeup for a small fee. "There was nothing like makeup artistry back then—it was unheard of," she told me. "But when I was traveling to the U.K. on holiday, I'd buy all sorts of makeup, and I was addicted to the girly teenage magazines like *Marie Claire* and *Cosmo*. My background was in fine arts, and that helped me to put together colors and draw lines." During her postcollegiate year of youth service mandated by the Nigerian government, Lawal decided to open a little cubicle in the affluent neighborhood of Ikoyi. In 2000 she did the makeup for the women in the wedding of the new president's son. Press coverage followed. She moved to a larger studio. More celebrities requested her services, which now included hair and nails. Today BM Pro has four branches and 32 employees. Banke Meshida Lawal has what Onyekachi Chiagozie wants. She occupies the dead center of island prosperity.

"I know that what I do is ostentatious. It's luxury," Lawal told me. "Anyone can get by doing their own makeup themselves. But if they want that something special—make it go *pow*, give it that extra thing—they come to me. This is a cash economy, and there are people here willing to pay the cash."

Smiling somewhat ruefully, the makeup artist added, "The gap is so great between rich and poor. I'm just glad to be on the receiving end of the cash."

ON A SUNNY EASTER MORNING I climbed aboard a motorboat docked at Victoria Island and rode an hour along the coast outside of Lagos until the driver deposited me at the edge of a dirt trail that led to a beach house crammed with

200 dancing, cognac-swilling young Lagosians. Everyone was dressed entirely in white, as instructed by the party invitation—at least until a hard rain pummeled the patio, at which point many stripped down to their swimsuits and jumped in the pool. They all seemed to know one another from the same nightclubs, or the same business deals, or the same university back in London, or Lawal's beauty salon. Few if any of them likely fraternized with aspiring laborers like Chiagozie or knew the hard path he had taken to the middle class.

I stood beside the hip-hop deejay for several hours, observing this landscape of impervious beauty and affluence—a tableau that could just as easily be taking place halfway around the globe, in the Hollywood Hills or the Hamptons. Where it could not be taking place, I found myself thinking, was more than 700 miles northeast, in the forests of northern Nigeria, where roughly the same number of individuals—young schoolgirls—were being held hostage after Boko Haram had kidnapped them six days earlier.

The moneyed and the maraudered. Within a few days the *New York Times T Magazine* would publish a lavish spread in celebration of the former ("In Lagos, the 1% Takes Stock") even as #bringbackourgirls hashtag activism sounded alarms on behalf of the latter. How do the two worlds coexist? How does Lagos prosper when upper Nigeria roils with chaos?

It takes effort to discern any connection. But after a couple of weeks moving through the city, I began to form questions: If Nigeria is the largest exporter of petroleum in Africa, how can there be continual fuel scarcity, such that Lagosians periodically sit in gas lines for up to four hours? Why does every building in the city—not just the low-income hovels on the mainland but also the sleekest hotels on Lagos Island—rely on generators to supply round-the-clock power? Why do residents continue to pay for electricity that never arrives? Why do the city's police set up evening checkpoints on the bridges and shake down commuters for cash? Why do the top academics at the University of Lagos carry on with strikes lasting entire semesters? (Continued on page 104)



Wasiu "Hello Sir" Ishola, 38, calls himself a hustler. For money and goodwill, he has names tattooed all over his body. Some of his customers are vacationing professional soccer players from Europe. "Lagos is the place where I see money and where people are merciful," he says.



Kilani "Big Ben" Ebenezer started his high-end menswear line in 2012. Two years later his bold, patterned designs won him recognition as best male designer at the 2014 Lagos Fashion Awards. "Lagos is a land flowing with milk and honey," he says. "Only shine your eyes and see clearly."



In Nigeria it's common to ask guests to wear color-coordinated outfits, called *aso ebi*, at social events, such as this wedding at the Yoruba Tennis Club.





Fisherman Monday Enikanoselu, 16, was born and lives in Makoko, a slum in Lagos Lagoon that began as a fishing village of shacks on stilts. He wears eczema cream on his face and a knockoff Louis Vuitton belt. "Lagos will be good to me," he says. "Lagos shall profit us all."



Stephanie Igben, 15, resplendent in a bridesmaid dress, is finishing senior secondary school but has no plans yet to continue her education. Her father is a driver and her mother a business-woman. She hopes to be an actress. "To me, Lagos is a land of opportunities," she says.

What's wrong with this picture?

Corruption is what's wrong—and because much of it exists on the federal level, Lagos is largely powerless to overcome it. The striking professors and the underpaid police are federal employees. That petro-titan Nigeria must import fuel to attempt to meet consumer demand is the result of the petroleum ministry

a job with contractors," he said. "But some of them aren't engineers. They're teachers, or something else, and they just happen to have a brother who works in the government. So when a contract comes their way, they hire a subcontractor. And the subcontractor is able to pocket a lot of money by using inferior materials. And they won't hire me, because I insist on using the

LAGOS MAY NEVER BE STOPPED, but it can be slowed. It is not immune to the forces paralyzing less fortunate regions of Nigeria.

sitting helplessly by while the country's refineries deteriorate and gas marketers hold back production to jack up prices. And the chronic power outages throughout the city are also the fault of the bureaucrats in Abuja, according to Abike Dabiri-Erewa, who serves in the Nigerian House of Representatives. "And they're not tapping the gas that's there. So the problem is that the plants aren't being powered," the Lagos representative told me.

Dabiri-Erewa was once a TV reporter. As a federal lawmaker, she witnesses firsthand the kind of wanton corruption that the government-owned Nigerian Television Authority would never have allowed her to cover. "It is a real phenomenon," she said somberly. "And it's done with impunity. Someone working in the government owns a private jet. A civil servant steals a billion naira [six million dollars] in pension funds, and he's walking about freely. Not one federal official has been punished for corruption—not one! Here in Lagos there's lots of everyday ingenuity. You see people surviving by selling oranges or phone cards. Still, all of this corruption has to be demoralizing for the average Nigerian."

It does more than demoralize: The unscrupulousness comes at the expense of hardworking Lagosians—unless, of course, they're willing and able to play the game. Chiagozie told me that bureaucratic corruption routinely affected his livelihood. "Most electricians like me are seeking

best material. If I were to use inferior material, the building might collapse, and then the government would arrest me and take my license away and make me pay for the damage. This happens all the time."

When I asked Kola Karim if the federal government's sorry reputation made Western investors wary of doing business in Lagos, the worldly CEO elaborately dismissed it as a non-issue. Companies partnered with companies, not with bureaucrats, he maintained. "What does government do for you anyway, apart from charging you more taxes?" he said. "Look, it's not about who rules anymore. Lagos is a train that has left the station. And you can only slow it down—you can't stop it. So it doesn't matter who comes next. This is the fun of democracy! It's not about [President] Goodluck Jonathan! It's about progress! Forget politics!"

I left the offices of Shoreline pondering these words of Karim, a genuine patriot who generously donates time and money to Nigerian causes. It's difficult to begrudge him his yellow Ferrari and his vacation homes in Miami and Marbella, on Spain's Mediterranean coast, and the fact that his children, who live in London, stand little chance of being kidnapped by Boko Haram. Still, Karim said it himself: Lagos may never be stopped, but it can be slowed. It is not immune to the forces paralyzing less fortunate regions of Nigeria. And when I observed to



Students at the elite St. Saviour's primary school romp with family and friends at the annual "Fun Day" celebration. The school in the affluent Ikoyi neighborhood teaches England's national curriculum. A shopper (above) peruses the grocery aisles at the South Africa-based Shoprite in the three-year-old Ikeja City Mall.

Dabiri-Erewa that Boko Haram's attacks had spared Lagos, she waved her hand frantically and shook her head. This was not, after all, a far-flung terrorist outfit targeted by American drone missiles. Boko Haram was born in Nigeria and is devastatingly effective. "As we're speaking now, we don't know where they're going to strike next," she said. "And while they're planning, the federal government seems to have no clue."

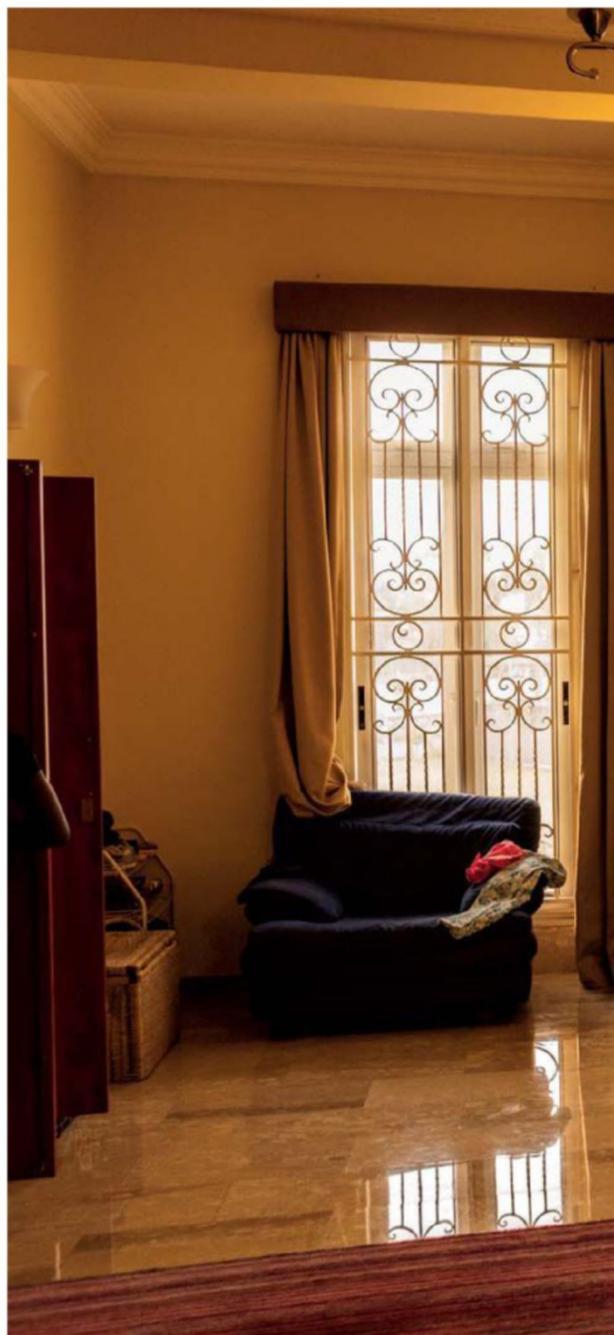
THE CITY REMAINS, for now, safe and a home for the bold, where even those who could be forgiven for despairing are instead eyeing the next rung on Lagos's golden ladder. I was told about a hustling fellow named T. J. who apparently had a knack for acquiring—how, it wasn't entirely clear—a reliable inventory of fashionable used clothes, which he sold in a grubby stall on Market Street, within walking distance of the Nigerian Stock Exchange. The lanky entrepreneur greeted me, sized me up, and then proceeded to pull out several plastic garbage bags filled with men's shirts.

"Even when I was small, I believed there was something behind me, driving me," T. J. said as he riffled through the shirts to find something appropriate for me. "I'm an incurable optimist. I don't believe in negativity. My customers, they love this about me. I cannot call myself a pastor, but I speak the truth. And the truth is, I love this country. People here are suffering. I'm suffering. And the government, they won't do the right thing. But it's all about attitude. I can feed myself. And one day I'll do something else."

Still digging in his bag of used clothes, the salesman said, "Right now I'm just trying to find the leverage." □

MORE ONLINE

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A spacious bedroom in the Okafor family's home on Banana Island. The artificial island in Lagos Lagoon, named for its shape, is one of the city's most expensive neighborhoods and is popular with foreigners working for major corporations. The Okafors, who grew up in Lagos, trained as lawyers but are now in business.

The background of the page is a dark, deep red and orange nebula, with wispy, glowing structures that resemble flames or interstellar dust. The colors transition from dark red on the left to bright orange and yellow on the right, creating a sense of depth and movement.

What we can see is
only a tiny fraction of
what exists. To catch the

FIRST GLIMPSE

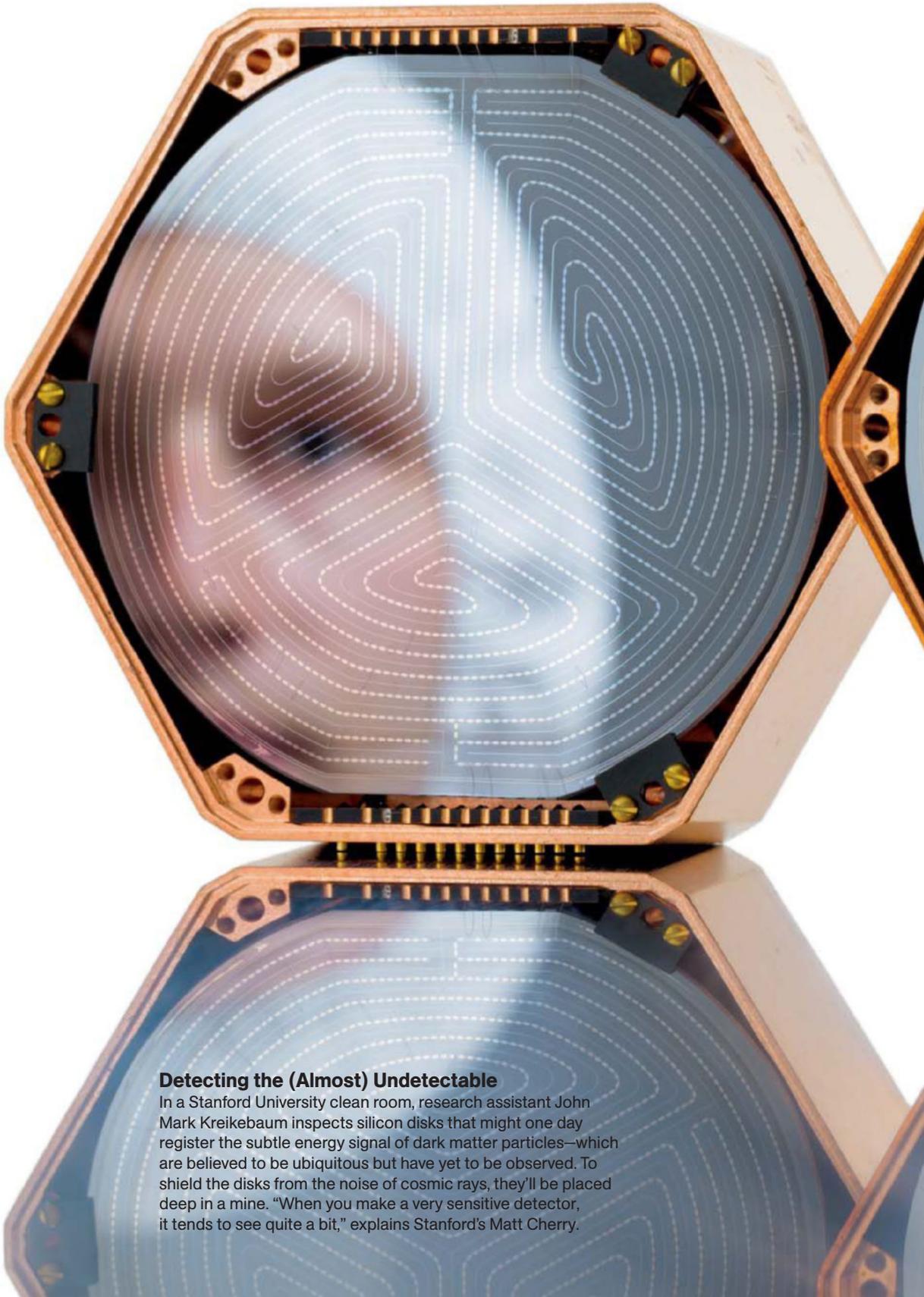
of the shadow universe
around us, scientists are
learning to detect the
other stuff: dark matter
and dark energy.



Death of an Early Star

One of the first stars in the universe explodes, bursting through its halo of invisible dark matter and seeding space with carbon, oxygen, and other elements. This computer simulation shows that stars might never have formed, and certainly not so soon—100 million years after the big bang—without the gravitational force generated by abundant dark matter. Its nature is uncertain.

TOM ABEL AND RALF KAEHLER, STANFORD KAVLI INSTITUTE
FOR PARTICLE ASTROPHYSICS AND COSMOLOGY



Detecting the (Almost) Undetectable

In a Stanford University clean room, research assistant John Mark Kreikebaum inspects silicon disks that might one day register the subtle energy signal of dark matter particles—which are believed to be ubiquitous but have yet to be observed. To shield the disks from the noise of cosmic rays, they'll be placed deep in a mine. “When you make a very sensitive detector, it tends to see quite a bit,” explains Stanford’s Matt Cherry.



By Timothy Ferris
Photographs by Robert Clark

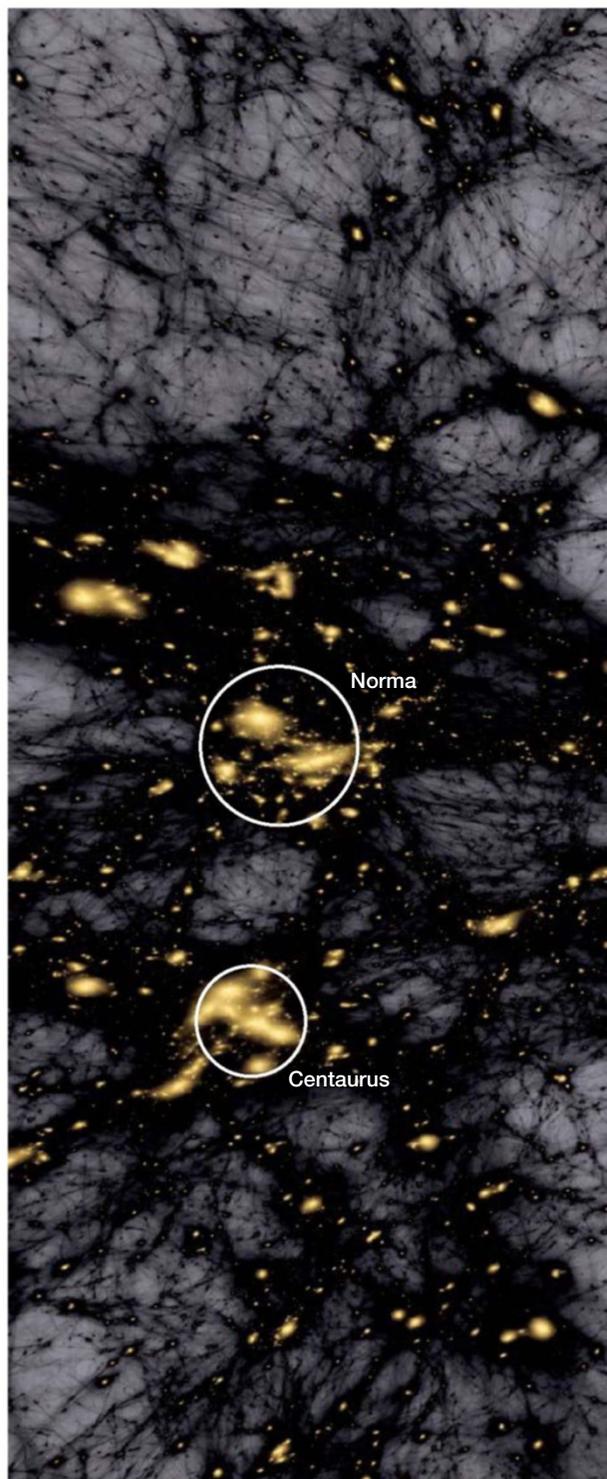
It used to be said that cosmologists, the scientists who study the universe as a whole, are “often in error but never in doubt.”

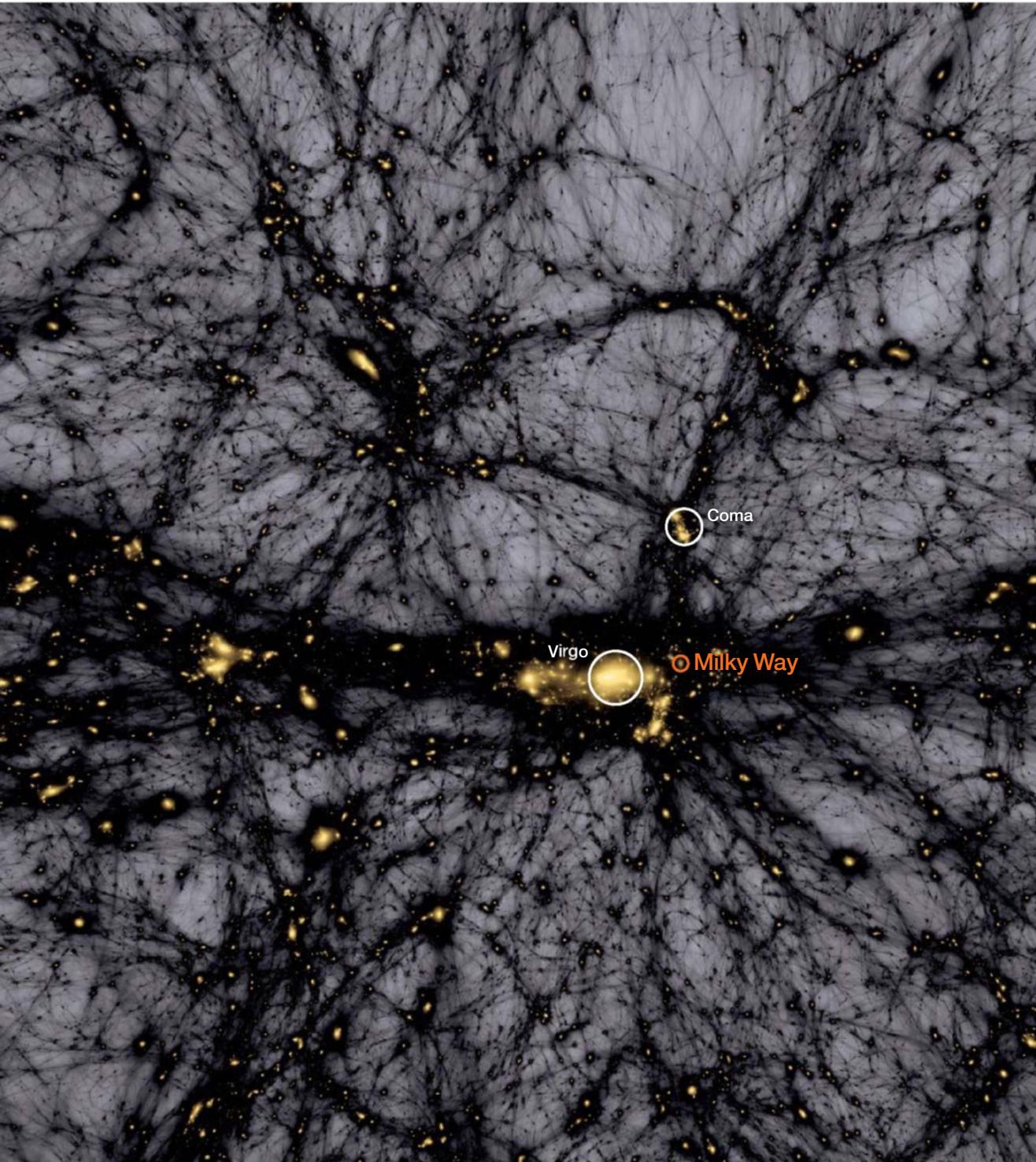
Nowadays they’re less often in error, but their doubts have grown as big as all outdoors.

After decades of research involving new and better telescopes, light detectors, and computers, cosmologists can now state with some assurance that the universe was born 13 billion, 820 million years ago, most likely as a bubble of space smaller than an atom. For the first time they’ve mapped the cosmic background radiation—light released when the universe was only 378,000 years old—to an accuracy of better than a tenth of one percent.

But they have also concluded that all the stars and galaxies they see in the sky make up only 5 percent of the observable universe. The invisible majority consists of 27 percent dark matter and 68 percent dark energy. Both of them are mysteries. Dark matter is thought to be responsible for sculpting the glowing sheets and tendrils of galaxies that make up the large-scale structure of the universe—yet nobody knows what it is. Dark energy is even more mysterious; the term, coined to denote whatever is accelerating the rate at which the cosmos expands, has been called a “general label for what we do not know about the large-scale properties of our universe.”

As a result, cosmologists today find themselves in something like the ignorance that





The Invisible Scaffolding of Space

We can't see dark matter, but its gravity sculpts what we do see from our vantage point inside the Milky Way galaxy. This supercomputer simulation, which looks at our cosmic neighborhood from the outside, is a realistic, data-driven reconstruction of the web of dark matter that guided galaxies to their present positions. Where huge dark tendrils cross, bright galaxies cluster; the Virgo cluster alone includes thousands.

SIMULATION AND RECONSTRUCTION: STEFFEN HESS AND FRANCISCO-SHU KITaura, LEIBNIZ INSTITUTE FOR ASTROPHYSICS POTSDAM. VISUALIZATION: TOM ABEL AND RALF KAEHLER

A History Shaped by Dark Forces

The big bang

13.8 billion years ago

Our universe blossoms from a hot, dense state smaller than an atom. Within milliseconds it inflates enormously.

Composition of the universe

Dark matter forms

First seconds of the universe

Dark matter also emerges in the first second. Interacting with particles of normal matter only through gravity, it begins to pull them together.



Stars light up

100 million years after the big bang

Clouds of hydrogen assembled by the gravity of dark matter collapse to form the first scattered stars. Nuclear fusion inside them creates heavier elements—and lights space.



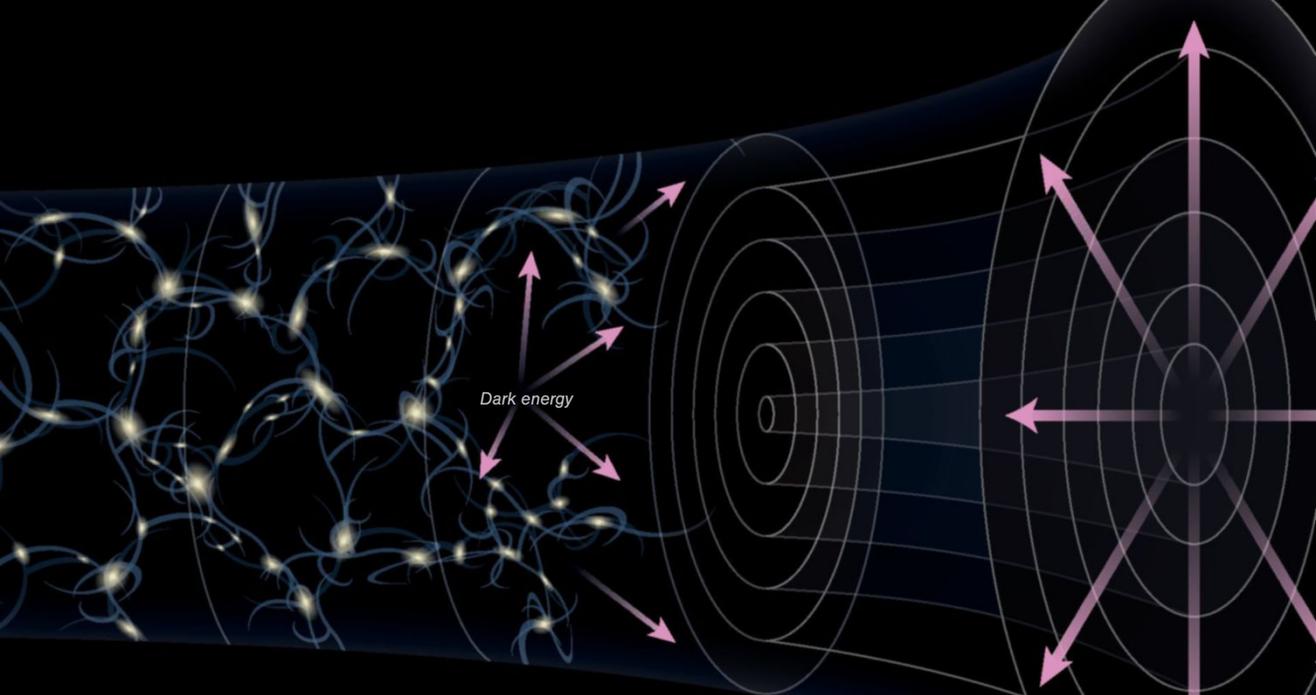
afflicted Thomas Jefferson in 1804, when he enjoined Lewis and Clark to keep an eye out for woolly mammoths. Jefferson and his contemporaries knew that North America from the Mississippi River to the Pacific Ocean was big and important, but they had only vague notions of what might live there.

The first inkling of dark matter's pervasive presence came in the 1930s from the Swiss astronomer Fritz Zwicky. While working at the Mount Wilson Observatory in southern California, Zwicky measured the speeds at which galaxies in the Coma cluster, 321 million light-years from Earth, orbit the center of the cluster. He calculated that unless the cluster contained much more mass than was visible, the galaxies would long since have flown off into space. That

Timothy Ferris wrote about solar storms for the magazine in June 2012. Robert Clark photographed an ancient Peruvian tomb for the June 2014 issue.

the Coma cluster had survived for billions of years could only mean, he surmised, “that dark matter is present in the universe in far greater density than visible matter.” Subsequent investigations have indicated that galaxies never would have formed in the first place had not the gravity generated by dark matter gathered primordial materials together when the universe was young.

Dark matter can't just be inconspicuous normal matter, because there isn't enough of that. Trillions of dim, normal matter objects surely are out there—among them black holes, dwarf stars, cold gas clouds, and rogue planets ejected from their birthplaces—but in no plausible scenario do they add up to five times the mass of the bright stuff. Hence scientists think that dark matter must be made of more exotic materials. Theorists working in what's called supersymmetric quantum physics have conjured up lots of unobserved varieties of matter, one or more of which might turn out to be dark matter. But



The expansion slows

1 billion years after the big bang

Stars clump into galaxies, galaxies into clusters along a scaffolding of dark matter. The mass of all matter, most of it dark, is so great that its gravity slows cosmic expansion.



Dark energy rises

4-8 billion years after the big bang

After slowing for billions of years, the expansion accelerates again. Why? A mysterious repulsive force, dubbed dark energy, has begun to counteract the pull of dark matter.



Ever onward

Today

The universe hurtles outward toward an uncertain future.



*Percentages do not add up to 100 due to rounding.

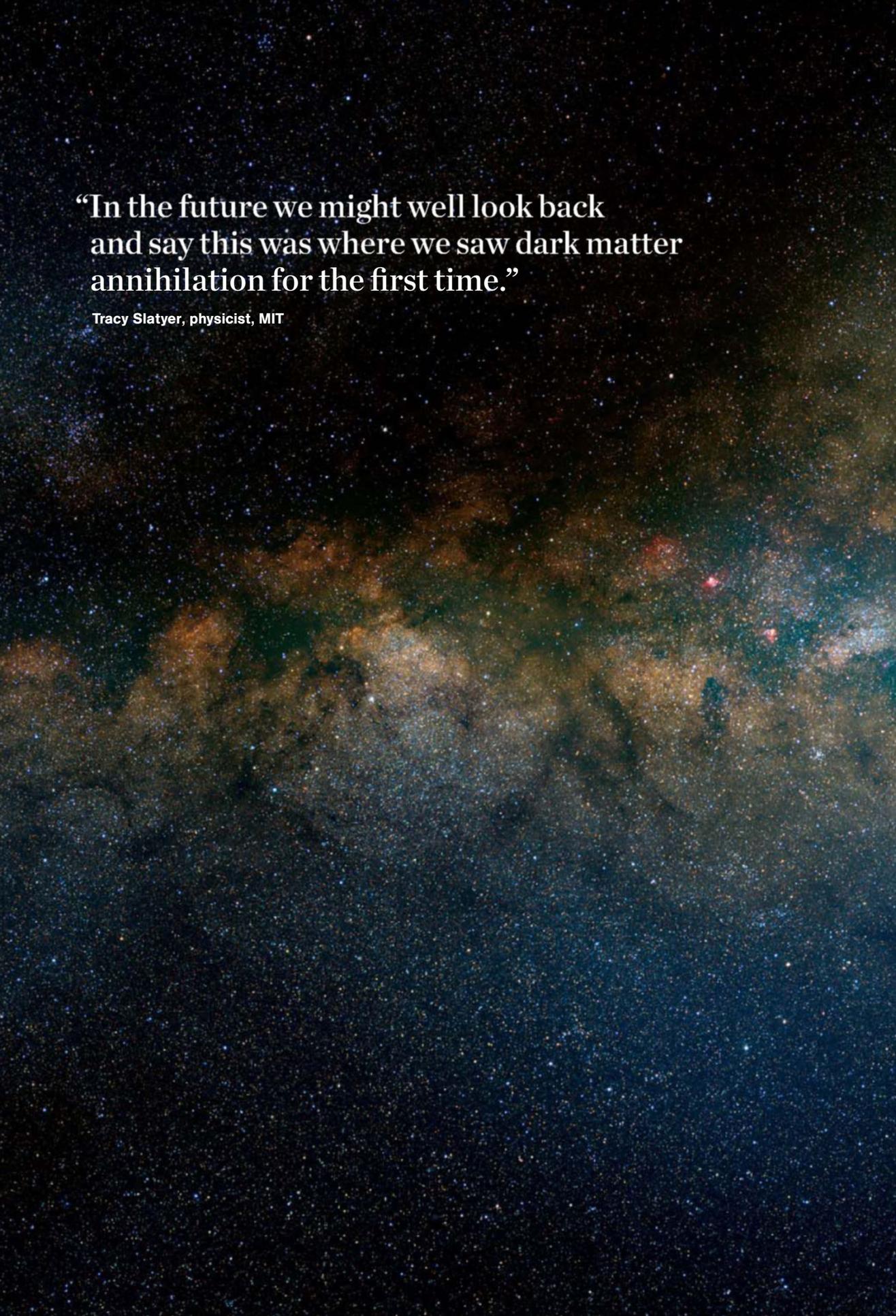
recent experimental results obtained with CERN's Large Hadron Collider, near Geneva, Switzerland, ruled out some versions of supersymmetry. The mood among the theorists, says one of them, is "fairly somber." Rather than speculate about the precise identity of dark matter, most scientists on the hunt just say they're looking for WIMPs, or "weakly interacting massive particles."

Evidence of just how weakly dark matter interacts not just with normal matter but also with itself has turned up three billion light-years from Earth, in the Bullet cluster—which is actually two galaxy clusters in the act of colliding. Astronomers mapping the Bullet with the aid of NASA's Chandra X-ray Observatory found massive clumps of hot gas at its center, which they attributed to collisions of clouds of normal matter. But when the astronomers charted the Bullet's gravitational field, they discovered two more huge concentrations of mass, one for each of the original clusters, farther from the center

of the collision. They concluded that although the normal matter frames of the two clusters were colliding and merging as spectacularly as two munitions trains, their heavier cargoes of dark matter were sailing through the carnage uninvolved and unscathed.

Dark matter's aloofness makes it challenging for experimenters to catch—even if, as some scientists estimate, dark matter particles are so commonplace that billions of them pass through every human being every second. The dark matter detectors currently operating are so technologically sophisticated as to resemble Fabergé eggs constructed for the delectation of future archaeologists.

One of them, the two-billion-dollar Alpha Magnetic Spectrometer, is perched on the International Space Station and hunts for evidence of dark matter particles colliding near the center of our galaxy. Most of the detectors, however, look for interactions between particles of dark matter



**“In the future we might well look back
and say this was where we saw dark matter
annihilation for the first time.”**

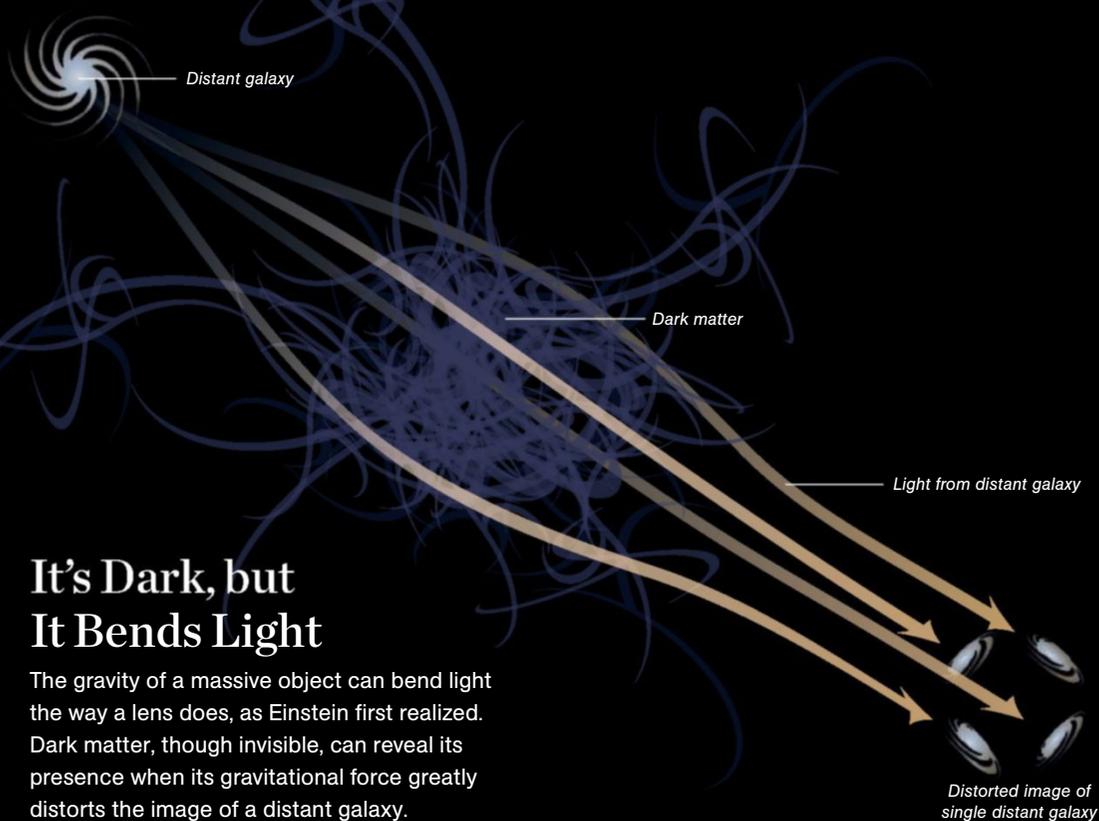
Tracy Slatyer, physicist, MIT



Message From the Milky Way

A NASA telescope orbiting Earth has detected unusually intense gamma rays coming from the center of our galaxy. The gamma rays are represented by the patch of bright colors superimposed on this picture of the Milky Way. What made them? Physicist Tracy Slatyer of MIT and her colleagues have a suspect: dark matter particles, smashing into and annihilating one another near the galaxy's core.

NASA GODDARD SPACE FLIGHT CENTER/A. MELLINGER, CENTRAL MICHIGAN UNIVERSITY, AND T. LINDEN, UNIVERSITY OF CHICAGO



It's Dark, but It Bends Light

The gravity of a massive object can bend light the way a lens does, as Einstein first realized. Dark matter, though invisible, can reveal its presence when its gravitational force greatly distorts the image of a distant galaxy.

and normal matter here on Earth. They're buried deep underground, to minimize intrusions by high-velocity normal matter particles flying in from space. Some consist of a supercooled set of crystals or a tank of liquid xenon or argon surrounded by detectors and onionskin layers of shielding materials, ranging from polyethylene to copper to lead. (Recently mined lead tends to be mildly radioactive, so two experiments—one in Soudan, Minnesota, and the other in L'Aquila, Italy—use the melted-down ballast of ancient Roman shipwrecks. Mined thousands of years ago, the old lead emits less radioactivity.)

America's Large Underground Xenon detector, the most sensitive of its kind, is situated in Lead, South Dakota, right off Main Street and 4,850 feet down by elevator. It started operating in 2013 but came up empty-handed; it's currently resuming the search at a higher sensitivity. Other searches produced ghostly clues, but none has found definitive evidence of dark

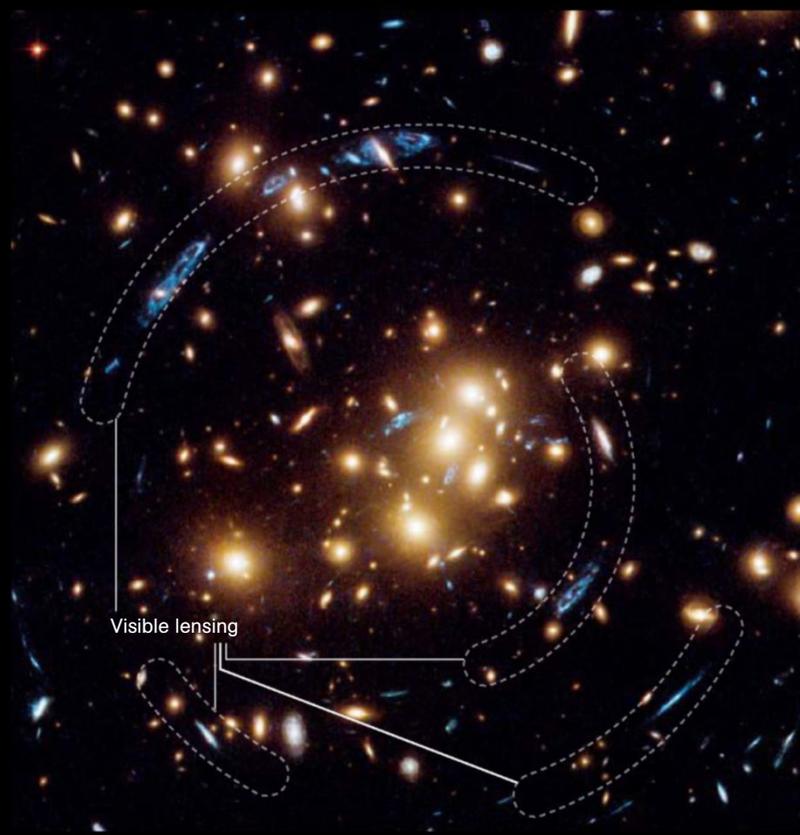
matter. The Large Hadron Collider, scheduled to resume operations in 2015 after a shutdown for maintenance and upgrades, may attain high enough energy levels to produce a few dark matter particles. But the odds are difficult to estimate, because the masses of the sought-after particles are not well understood. WIMP hunting is not for wimps.

WEIRD AS THE DARK MATTER RIDDLE may be, it looks almost pedestrian in comparison with the mysterious phenomenon of dark energy, which physicist Steven Weinberg calls the "central problem for physics" and astrophysicist Michael Turner nominates as the "most profound mystery in all of science."

Turner coined the term "dark energy" after two teams of astronomers announced in 1998 that the rate at which the universe was expanding appeared to be accelerating. The astronomers reached this conclusion by studying a particular

A Dark Matter Lens

The blue shapes outlined here are really distorted images of galaxies that lie far behind the bright cluster at the center. Dark matter in the cluster (not shown) warped the distant galaxies' light as it traveled toward Earth.

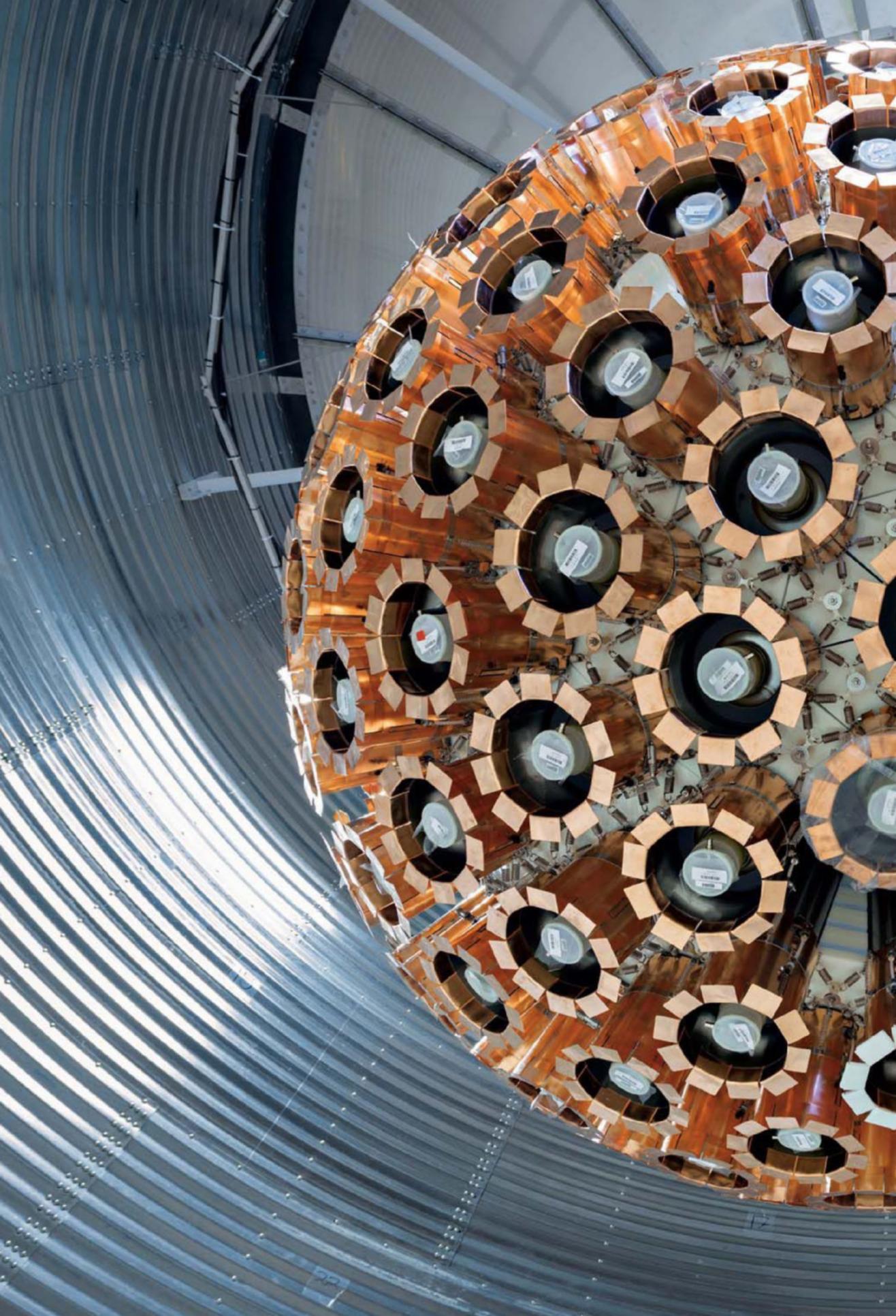


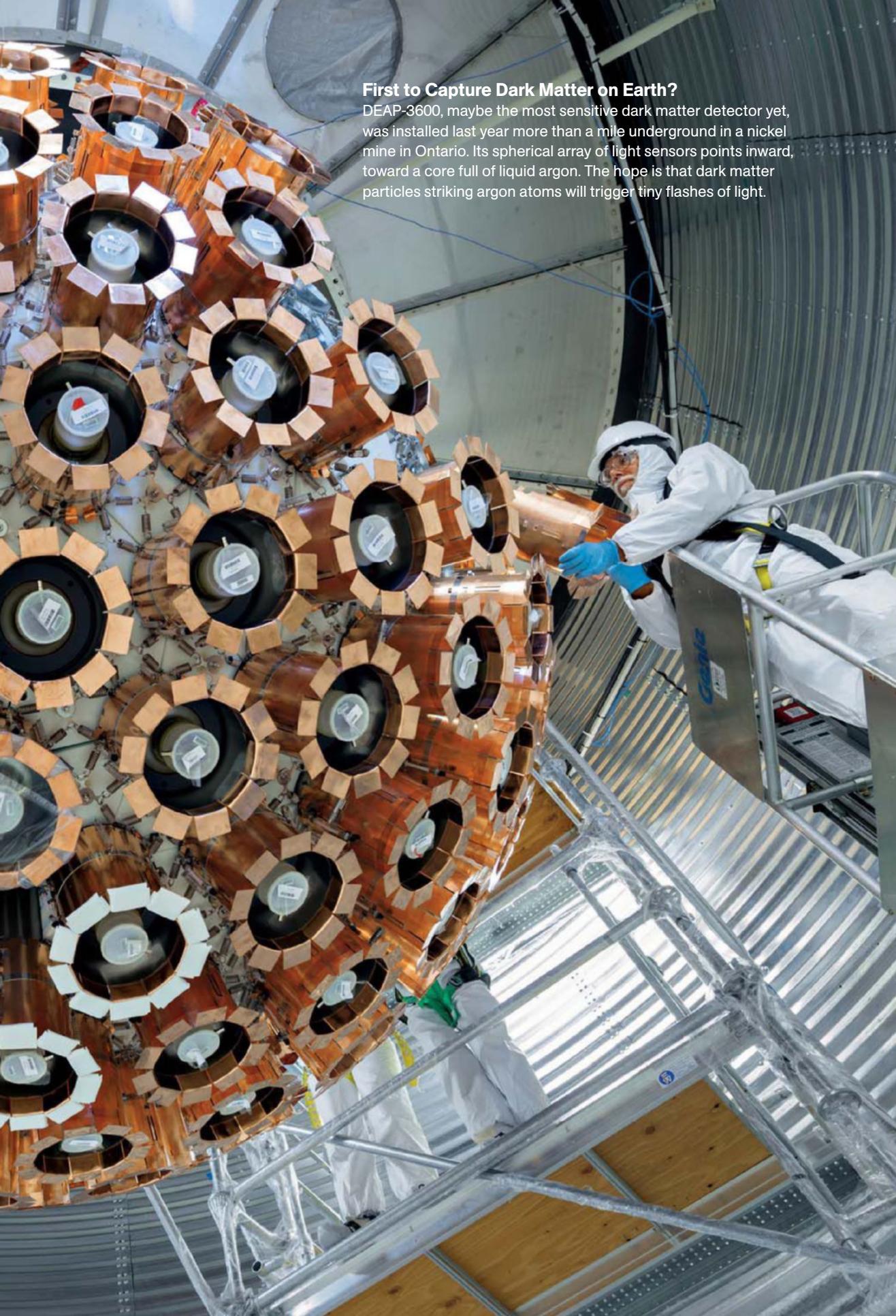
class of exploding stars that are bright enough to be seen far away and consistent enough in brightness to make them useful in charting the distances of remote galaxies. The mutual tug of gravity among all galaxies serves as a brake on the expansion of the universe, and so astronomers expected it to be slowing down. Instead they found just the opposite: The universe is expanding ever faster as time goes by and has been doing so for the past five to six billion years.

Observers today are busily mapping the universe with unprecedented precision, looking for evidence of just when dark energy emerged and whether it has since remained constant in strength or is growing even stronger. They have the advantage of being able to peer into the past: When researchers study a galaxy billions of light-years from Earth, they see it as it looked billions of years ago. They are limited, though, by the capacity of their telescopes and digital detectors. Now, as in the past, writing

more accurate cosmological history requires building better gear.

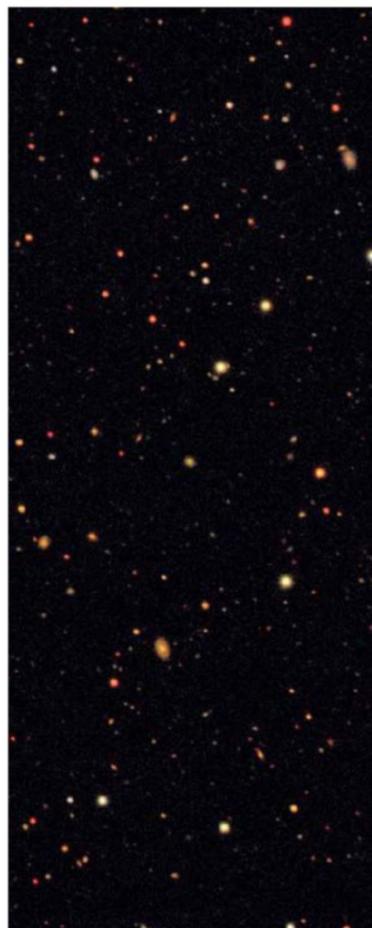
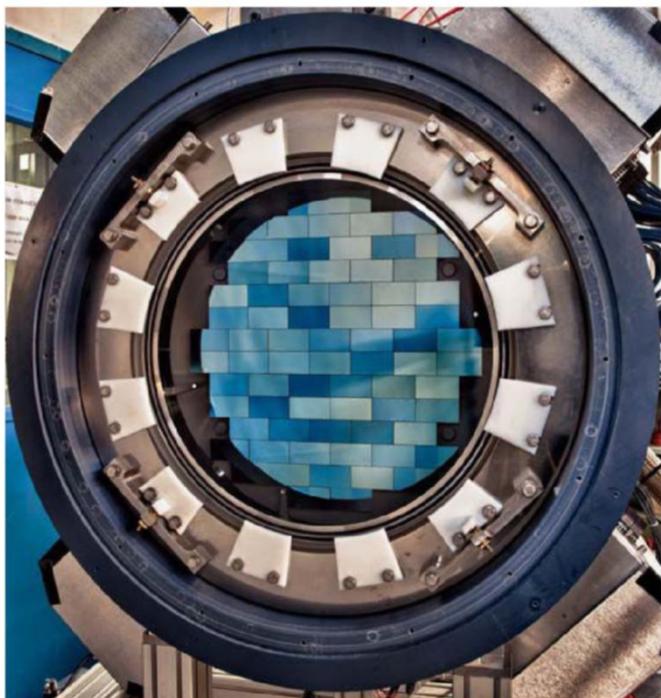
That call is being answered by projects such as the Baryon Oscillation Spectroscopic Survey, which employs a 2.5-meter telescope at Apache Point in New Mexico to map cosmic distances at an unprecedented one percent accuracy. Meanwhile the Dark Energy Survey, using the Blanco four-meter telescope in the Chilean Andes, is collecting data on 300 million galaxies. The European Space Agency's Euclid space telescope, scheduled for launch in 2020, is designed to make precise measurements of cosmic dynamics over the past ten billion years. Expectations run high as well for the Large Synoptic Survey Telescope (LSST), currently under construction in north-central Chile, a few miles from the Blanco telescope. A squat, photographically "fast" 8.4-meter instrument equipped with the largest digital camera ever made, the LSST is designed to repeatedly image the depths of the





First to Capture Dark Matter on Earth?

DEAP-3600, maybe the most sensitive dark matter detector yet, was installed last year more than a mile underground in a nickel mine in Ontario. Its spherical array of light sensors points inward, toward a core full of liquid argon. The hope is that dark matter particles striking argon atoms will trigger tiny flashes of light.



A Survey of Cosmic Repulsion

Dark matter pulls stuff together; dark energy drives it apart. The Dark Energy Survey's 570-megapixel camera (above), mounted on a telescope in Chile, is designed to image 300 million galaxies in five years, including NGC 1365 (right). Peering out eight billion light-years, it could see how fast the cosmos was expanding billions of years ago—when its acceleration by dark energy is thought to have begun.

observable universe, covering the southern night sky up to ten times each month.

With such tools, cosmologists hope to reconstruct the history of dark energy's emergence and influence by directly measuring the cosmic expansion rate throughout the past. At issue may be nothing less than the future of the universe—and of its study. If we live in a “runaway universe” increasingly dominated by dark energy, most galaxies eventually will be driven beyond one another's sight, leaving far-future cosmologists with little to observe but their immediate neighborhood and the blackness of space.

In the nearer future, making sense of dark energy may require radical improvements in the way we conceive of space itself. The voids between the planets and stars were long thought to be sheer nothingness, although Isaac Newton admitted that he couldn't imagine how gravity could keep the Earth spinning around the sun

if the space between them was utterly vacuous. In the 20th century, quantum field theory came to the rescue by demonstrating that space is never really empty but instead is suffused with quantum fields, which are literally everywhere. The protons, electrons, and other particles often described as the building blocks of matter are themselves excitations of quantum fields. Space looks empty when the fields languish near their minimum energy levels. But when the fields are excited, space comes alive with visible matter and energy. The mathematician Luciano Boi compares space to the water in a quiet Alpine pond: invisible when calm but evident when a breeze ripples its surface. “Empty space is not empty,” the American physicist John Archibald Wheeler once said. “It is the seat of the most rich and surprising physics.”

Dark energy may prove him to have been prophetic on the largest possible scale. To



understand how cosmic space balloons—and why it now seems to be ballooning ever faster—physicists rely mainly on Einstein’s general theory of relativity, composed a century ago. That theory works well on the large scale but bows out at the microscopic level, where quantum theory reigns and the underlying cause of accelerating cosmic expansion is thought to reside. Explaining dark energy may require something new: a quantum theory of space and gravitation.

Scientists are confronted by the embarrassing fact that they don’t know just how much energy, dark or otherwise, space contains. When quantum theorists try to calculate how much energy resides in, say, a quart of seemingly empty space, they get a big number. But astronomers calculating the same quantity from their dark energy observations get a small number. The difference between the two numbers is staggering: It’s ten to the 121st power, a one followed by 121 zeroes,

an amount far exceeding the number of stars in the observable universe or grains of sand on the planet. That’s the largest disparity between theory and observation in the entire history of science. Clearly something fundamentally important about space—and therefore about everything, since galaxies, stars, planets, and people are made mostly of space—remains to be learned.

Yet just such conundrums have opened the doors of discovery before. Einstein’s general relativity theory was invented in part to solve tiny discrepancies between the predicted and the observed orbits of the planet Mercury. Quantum physics sprang in part from little puzzlements about how heat is radiated. How much may be learned, then, by resolving today’s much deeper confusions about dark matter and dark energy? As the physicist Niels Bohr used to say, “No paradox, no progress.” □



Set upside down to keep its teeth in place, the skull of a young woman found in an underwater cave in Mexico has put a face on the New World's first inhabitants.

New finds, theories,
and genetic discoveries
are revolutionizing our
understanding of the

FIRST AMERICANS



Divers who discovered her bones named her Naia. A facial reconstruction reveals that the first Americans didn't look much like later Native Americans, though genetic evidence confirms their common ancestry.

RE-CREATION: JAMES CHATTERS, APPLIED PALEOSCIENCE; TOM MCCLELLAND
PHOTO: TIMOTHY ARCHIBALD

By Glenn Hodges

The first face of the first Americans belongs to an unlucky teenage girl who fell

to her death in a Yucatán cave some 12,000 to 13,000 years ago. Her bad luck is science's good fortune. The story of her discovery begins in 2007, when a team of Mexican divers led by Alberto Nava made a startling find: an immense submerged cavern they named Hoyo Negro, the "black hole." At the bottom of the abyss their lights revealed a bed of prehistoric bones, including at least one nearly complete human skeleton.

Nava reported the discovery to Mexico's National Institute of Anthropology and History, which brought together an international team of archaeologists and other researchers to investigate the cave and its contents. The skeleton—affectionately dubbed Naia, after the water nymphs of Greek mythology—turned out to be one of the oldest ever found in the Americas, and the earliest one intact enough to provide a foundation for a facial reconstruction. Geneticists were even able to extract a sample of DNA.

Together these remnants may help explain an enduring mystery about the peopling of

the Americas: If Native Americans are descendants of Asian trailblazers who migrated into the Americas toward the end of the last ice age, why don't they look like their ancient ancestors?

By all appearances, the earliest Americans were a rough bunch. If you look at the skeletal remains of Paleo-Americans, more than half the men have injuries caused by violence, and four out of ten have skull fractures. The wounds don't appear to have been the result of hunting mishaps, and they don't bear telltale signs of warfare, like blows suffered while fleeing an attacker. Instead it appears that these men fought among themselves—often and violently.

The women don't have these kinds of injuries, but they're much smaller than the men, with signs of malnourishment and domestic abuse.

To archaeologist Jim Chatters, co-leader of the Hoyo Negro research team, these are all indications that the earliest Americans were what he calls "Northern Hemisphere wild-type" populations: bold and aggressive, with hypermasculine males and diminutive, subordinate females. And this, he thinks, is why the earliest Americans' facial features look so different from those of

Former Geographic staff writer Glenn Hodges explores life's big questions at soundingline.org.



The bones of at least 26 Ice Age animals—including those of an elephant-like gomphothere (above)—litter the floor of Hoyo Negro, the flooded cave where divers found Naia's remains. The cavern was mostly dry during Naia's short life. She may have fallen to her death while exploring the cave's dark passages (right).

later Native Americans. These were risk-taking pioneers, and the toughest men were taking the spoils and winning fights over women. As a result, their robust traits and features were being selected over the softer and more domestic ones evident in later, more settled populations.

Chatters's wild-type hypothesis is speculative, but his team's findings at Hoyo Negro are not. Naia has the facial features typical of the earliest Americans as well as the genetic signatures common to modern Native Americans. This signals that the two groups don't look different because the earliest populations were replaced by later groups migrating from Asia, as some anthropologists have asserted. Instead they look different because the first Americans changed after they got here.

Chatters's research is just one interesting development in a field of study that has been

exploding in fresh directions over the past two decades. New archaeological finds, novel hypotheses, and a trove of genetic data have shed fresh light on who the first Americans were and on how they might have come to the Western Hemisphere. But for all the forward motion, what's clearest is that the story of the first Americans is still very much a mystery.

FOR MOST OF THE 20TH CENTURY it was assumed that the mystery had been more or less solved. In 1908 a cowboy in Folsom, New Mexico, found the remains of an extinct subspecies of giant bison that had roamed the area more than 10,000 years ago. Later, museum researchers discovered spearpoints among the bones—clear evidence that people had been present in North America much earlier than previously believed. Not long after, spearpoints dating to 13,000 years ago were found near Clovis, New Mexico, and what became known as Clovis points were subsequently found at dozens of sites across North America where ancient hunters had killed game.

■ **Society Grants** This research was generously supported with funds made possible in part by your National Geographic Society membership.



1 32,000 YEARS AGO

Asian ancestors

Humans from Eurasia and East Asia first populate western Beringia by 32,000 years ago.

2 25,000-15,000 YEARS AGO

Beringian standstill

A population with two-thirds East Asian and one-third Eurasian DNA becomes isolated in Beringia. Genetic mutations result in new, unique DNA markers that are found in modern Native Americans but not Asians.



LINES OF EVIDENCE

Paths to a new world

Fresh discoveries are redefining our understanding of when and how humans first migrated into the Americas. Archaeological evidence now firmly suggests human occupation began some 15,500 years ago, not 13,000 years ago, as previously thought. In 2014 advances in DNA analysis enabled the first sequencing of a full Paleo-American genome, at the Anzick site in western Montana—confirmation that the ancestors of modern Native Americans did indeed originate from a population in Asia.

MARTIN GAMACHE, NGM STAFF; AMANDA HOBBS

SOURCES: DAVID G. ANDERSON, UNIVERSITY OF TENNESSEE; JAMES CHATTERS, APPLIED PALEOSCIENCE; E. JAMES DIXON, UNIVERSITY OF NEW MEXICO; ARTHUR S. DYKE, GEOLOGICAL SURVEY OF CANADA; MICHAEL H. GRAHAM, MOSS LANDING MARINE LABORATORIES; JOHN W. IVES AND KISHA SUPERNANT, UNIVERSITY OF ALBERTA; WILLIAM F. MANLEY, UNIVERSITY OF COLORADO; MICHAEL WATERS, TEXAS A&M UNIVERSITY; PALEOINDIAN DATABASE OF THE AMERICAS; WESTERN CANADIAN FLUTED POINT DATABASE

3 16,000 YEARS AGO

Coastal route

Deglaciation along the northwest Pacific coast opens a migration route into the Americas. Genetic evidence suggests that fewer than 5,000 individuals disperse south.

Kelp forest ecosystem, modern distribution

ASIA

Sea level: -308 ft (-94 m)
Present-day shoreline

NORTH AMERICA

Manis
ca 13,800 years ago

Lindsay
ca 14,250

Paisley Caves
ca 14,350

Channel Islands

Schaefer and Heblor
ca 14,500 and ca 14,800

Meadowcroft
15,000-14,000

Page-Ladson
ca 14,400

Debra L. Friedkin
15,500-13,200

5 14,000-13,000 YEARS AGO

Land route

An interior ice-free corridor opens some 2,000 years after the coastal route, enabling further migration across the continent.

Serpentine Hot Springs
12,400-12,000 years ago

Cordilleran Ice Sheet
Columbia River
Klamath River

Sea level: -210 ft (-64 m)
Present-day shoreline

Anzick
ca 12,650

Charlie Lake Cave
ca 12,350

Folsom
Clovis

Hoyo Negro
ca 12,800

6 13,000 YEARS AGO

Reverse migration

Archaeological finds suggest that a northward flow through the corridor predominated, possibly because people were following big game. By 12,000 years ago boreal forest began to colonize the corridor, making it less attractive to large herbivores.

Quantity of fluted spearpoints dating from 13,000 to 12,000 years ago

Absent Abundant

7 13,000 YEARS AGO

Clovis culture

Hunters develop a distinctive type of fluted spearpoint and expand across most of North America. For archaeologists, these Clovis points later became the first definitive evidence of early human occupation in the Americas. More recently, discoveries at Paisley Caves, Monte Verde, the Friedkin site, and others have pushed back initial migration estimates by as much as 2,500 years.

4 15,000 YEARS AGO

Rapid expansion

Remains at sites like Monte Verde, Chile, suggest that humans migrated along the coast and reached the southern tip of South America in just a few hundred years.

Huaca Prieta
ca 14,100

SOUTH AMERICA

Arroyo Seco 2
ca 14,000

Monte Verde
14,500-14,250



Given that Asia and North America were connected by a broad landmass called Beringia during the last ice age and that the first Americans appeared to be mobile big-game hunters, it was easy to conclude that they'd followed mammoths and other prey out of Asia, across Beringia, and then south through an open corridor between two massive Canadian ice sheets. And given that there was no convincing evidence for human occupation predating the Clovis hunters, a new orthodoxy developed: They had been the first Americans. Case closed.

That all changed in 1997 when a team of high-profile archaeologists visited a site in southern Chile called Monte Verde. There Tom Dillehay of Vanderbilt University claimed to have discovered evidence of human occupation dating to more than 14,000 years ago—a thousand years before the Clovis hunters appeared in North America. Like all pre-Clovis claims, this one was controversial, and Dillehay was even accused of planting artifacts and fabricating data. But after reviewing the evidence, the expert team concluded it was solid, and the story of the peopling of the Americas was thrown wide open.

How did people get all the way to Chile before the ice sheets in Canada retreated enough to allow an overland passage? Did they come during an earlier period of the Ice Age, when this inland corridor was ice free? Or did they come down the Pacific coast by boat, the same way humans got to Australia some 50,000 years ago? Suddenly the field was awash in new questions and invigorated by a fresh quest for answers.

In the 18 years since the Monte Verde bombshell dropped, none of these questions have been resolved. But the original question—Was Clovis first?—has been answered repeatedly, with several sites in North America making their own claims to pre-Clovis occupation. Some of these places have been known and studied for years and have gained fresh credibility in the wake of Monte Verde's acceptance, but there have been new finds as well. One location in particular, the Debra L. Friedkin site in central Texas, might even be the earliest place of demonstrable human habitation in the Western Hemisphere.

IN 2011 ARCHAEOLOGIST Michael Waters of Texas A&M University announced that he and his team had unearthed evidence of extensive human occupation dating to as early as 15,500 years ago—some 2,500 years before the first Clovis hunters arrived. The Friedkin site lies in a small valley in the hill country about an hour north of Austin, where a tiny perennial stream now called Buttermilk Creek, along with some shade trees and a seam of chert, a type of rock useful for toolmaking, made the area an attractive place for people to live for thousands of years.

“There was something unique about this

A SITE IN CENTRAL TEXAS MIGHT BE THE EARLIEST PLACE OF HUMAN HABITATION IN THE WESTERN HEMISPHERE.

valley,” Waters says. It was long thought that the earliest Americans were primarily big-game hunters, following mammoths and mastodons across the continent, but this valley was an ideal place for hunter-gatherers. People here would have eaten nuts and roots, crawdads and turtles, and they would have hunted animals such as deer and turkeys and squirrels. In other words, people probably weren't here on their way to somewhere else; they were here to live.

But if Waters is right that people were settled here, in the middle of the continent, as early as 15,500 years ago, when did the first arrivals cross into the New World from Asia? That's unclear, but it appears that people may have been settled in other parts of the continent at the same time. Waters says the pre-Clovis artifacts he's found at Buttermilk Creek—more than 16,000 of them, including stone blades, spearpoints, and chips—resemble artifacts found at sites in Virginia, Pennsylvania, and Wisconsin.

“There's a pattern here,” he says. “I think the data clearly show that people were in North

America 16,000 years ago. Time will tell if that represents the initial occupation of the Americas or if there was something earlier.”

Either way, the newest archaeological evidence comports with an increasingly important line of evidence in our understanding of the peopling of the Americas. In recent years geneticists have compared the DNA of modern Native Americans with that of other populations around the world and concluded that the ancestors of Native Americans were Asians who separated from other Asian populations and remained isolated for about 10,000 years, based on mutation rates in human DNA. During that time they developed unique genetic signatures that only Native Americans currently possess.

These genetic markers have been found not only in the DNA recovered from Nai’s skeleton but also in the remains of a child buried some 12,600 years ago in western Montana, on a piece of land now called the Anzick site. Last year Danish geneticist Eske Willerslev reported that an analysis of the child’s remains had yielded, for the first time, a full Paleo-American genome.

“Now we’ve got two specimens, Anzick and Hoyo Negro, both from a common ancestor who came from Asia,” Waters says. “And like Hoyo Negro, the Anzick genome unquestionably shows that Paleo-Americans are genetically related to native peoples.”

Though some critics point out that two individuals are too small a sample to draw definitive conclusions, there’s strong consensus on the Asian ancestry of the first Americans.

So how and when did the earliest inhabitants of the New World get here? That remains an open question, but given that people made it all the way to southern Chile more than 14,000 years ago, it would be surprising if they hadn’t journeyed by boat.

THE CHANNEL ISLANDS off the southern California coast are rugged and wild, home to a national park, a national marine sanctuary, and a training post for U.S. Navy SEALs. The archipelago also harbors thousands of archaeological sites, most of them still undisturbed.

In 1959, while exploring Santa Rosa Island, museum curator Phil Orr discovered a few bones of a human he named Arlington Springs man. At the time, the bones were judged to be 10,000 years old, but 40 years later researchers using improved dating techniques fixed the age at 13,000 years—among the oldest human remains ever discovered in the Americas.

Thirteen thousand years ago the northern Channel Islands—then fused into a single island—were separated from the mainland by five miles of open water. Clearly Arlington Springs man and his fellow islanders had boats capable of offshore travel.

Jon Erlandson of the University of Oregon has been excavating sites on these islands for three decades. He hasn’t found anything as old as Arlington Springs man, but he has found strong evidence that people who lived here slightly later, some 12,000 years ago, had a well-developed maritime culture, with points and blades that resemble older tools found on the Japanese islands and elsewhere on the Asian Pacific coast.

Erlandson says that the Channel Island inhabitants might have descended from people who traveled what he calls a kelp highway—a relatively continuous kelp-bed ecosystem flush with fish and marine mammals—from Asia to the Americas, perhaps with a long stopover in Beringia. “We know there were maritime peoples using boats in Japan 25,000 to 30,000 years ago. So I think you can make a logical argument that they may have continued northward, following the Pacific Rim to the Americas.”

Beaches along the Pacific coast still teem with elephant seals and sea lions, and it’s easy to imagine hunters in small boats moving swiftly down the coastline, feasting on the abundant meat. But imagination is no substitute for hard evidence, and as yet there is none. Sea levels are 300 to 400 feet higher than at the end of the last glacial maximum, which means that ancient coastal sites could lie under hundreds of feet of water and miles from the current shoreline.

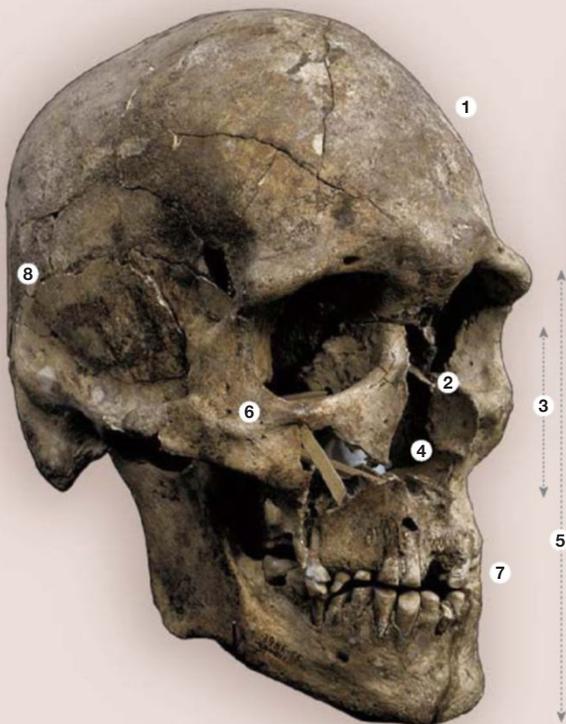
Perhaps ironically, the best evidence for a coastal migration might be found inland, as people traveling along the coast would likely have

Clues to an ancient mystery

Judging from their skulls, Paleo-Americans looked markedly different from modern Native Americans. Why? Archaeologist Jim Chatters theorizes that the first Americans were bold pioneers whose behaviors and physical traits changed as they became more settled.

Paleo-American

Male, about 12,000 years old; Horn Shelter, Texas



Modern Native American

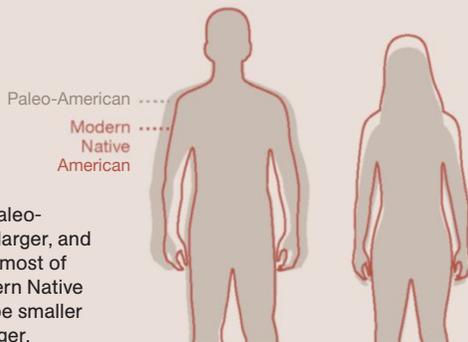
Male, less than 1,000 years old; central Texas



- 1 Larger, rugged skull
- 2 Wider-set eyes
- 3 Shorter, broad upper face
- 4 Broader nose
- 5 Longer, narrower skull
- 6 Inward-angled cheekbones
- 7 Outward-projecting face
- 8 Less rounded occipital

Men and women, then and now

Skeletal remains suggest that Paleo-American men ate better, grew larger, and lived much longer than women, most of whom died before age 26. Modern Native American men have tended to be smaller than their ancestors, women larger.





Stone tools discovered at a 15,500-year-old campsite in what is now central Texas provided clinching evidence that the first Americans arrived at least 2,500 years earlier than previously thought. Chert was an essential rock for toolmaking because of the way it flakes.





Tribal leaders gather in Montana to rebury the 12,600-year-old bones of a boy known as the Anzick child. His DNA confirmed that today's Native Americans are direct descendants of the first Americans.



explored rivers and inlets along the way. There is already suggestive evidence of this in central Oregon, where projectiles resembling points found in Japan and on the Korean Peninsula and Russia's Sakhalin Island have been discovered in a series of caves, along with what is surely the most indelicate evidence of pre-Clovis occupation in North America: fossilized human feces.

In 2008 Dennis Jenkins of the University of Oregon reported that he'd found human coprolites, the precise term for ancient excrement, dating to 14,000 to 15,000 years old in a series of shallow caves overlooking an ancient lake bed near the town of Paisley. DNA tests have identified the Paisley Caves coprolites as human, and Jenkins speculates that the people who left them might have made their way inland from the Pacific by way of the Columbia or Klamath Rivers.

What's more, Jenkins points to a clue in the coprolites: seeds of desert parsley, a tiny plant with an edible root hidden a foot underground. "You have to know that root is down there, and you have to have a digging stick to get it," Jenkins says. "That implies to me that these people didn't just arrive here." In other words, whoever lived here wasn't just passing through; they knew this land and its resources intimately.

That seems to be an emerging theme. It appears to be the story not just at Paisley Caves but at Monte Verde and the Friedkin site in Texas as well. In each of these cases people seemed to have been settled in, comfortable with their environment and adept at exploiting it. And this suggests that long before the Clovis culture began spreading across North America, the Americas hosted diverse communities of people—people who may have arrived in any number of migrations by any number of routes. Some may have come by sea, others by land. Some may have come in such small numbers that traces of their existence will never be found.

"There's a whole lot of stuff that we don't know and may never know," says David Meltzer, an archaeologist at Southern Methodist University. "But we're finding new ways to find things and new ways to find things out." □





First Bird

Story and Photographs by

KLAUS NIGGE

The eagle is a national symbol, not just for Americans, but for Germans like me and many other people too. Photographers tend to portray the birds as these majestic animals, always soaring in a blue sky with their plumage perfectly in place.

In the Aleutian Islands in Alaska I found bald eagles that were wilder and tougher than that. They were dirty, they were wet, and they fought with each other, which is not what we expect from our national symbols. But maybe a bird that can deal with strong weather and difficult comrades makes a better source of inspiration.

Around the village of Unalaska and nearby Dutch Harbor, the largest fishing port in the United States, the eagles are very much used to people. Fish are everywhere, and the eagles hang around, looking for leftovers. They go to fishing boats, where they search on the decks after the boats come in. They go to where the fishermen clean their nets. They sit on the roofs of processing plants.

To make these photographs, I would go to the wild places outside of town where these habituated eagles congregated. There I could face the eagles eye to eye. I could get close to them without using a blind. They were always fully aware of me. I had to be careful, I had to study them, and I had to know what they liked and what they didn't like. You might have found me lying on my belly, surrounded by 40 eagles.

I have been to the Aleutians seven times, and I will go again. I am an eagle man—I like eagles so much.

You see, they can fly, and I cannot. □

Days of heavy rain, a common phenomenon in the Aleutian Islands, have drenched this bald eagle. The raptors are not as active when it rains.



Two bald eagles aim for the same post. According to Nigge, the one that lands first in such squabbles usually vacates the perch in order to avoid being raked by the incoming bird's open talons.



"The bald eagle is an opportunist," says Nigge. "He's a scavenger. Even if food is stinky and old, he'll take it." At right, eagles still await a free meal near the home of a woman who used to feed them roadkill and fish scraps. Below, an eagle inspects the ground for food left by other birds. Once in danger of extinction in most of the lower 48 states, bald eagles were removed from the endangered species list in 2007. Their range now extends across most of North America.







Near Unalaska there's a small stream where eagles often gather. Here one aims for something floating in shallow water. "You can see how much he wants to get it," says Nigge. "His eyes, so sharp, point to one place."



In the Loupe

With Bill Bonner, National Geographic Archivist



A Failed First

Though they planted the Union Jack (at far left) upon arrival at the South Pole in January 1912, members of Robert Falcon Scott's British Antarctic expedition had found Norwegian flags already flying there. Roald Amundsen's rival expedition had reached the Pole first—and then departed—a little more than a month before. But Edward Wilson, Scott, Edgar Evans, Lawrence Oates, and Henry Bowers (left to right) still marked their accomplishment with this photo. A look through the loupe reveals how they all made it into the frame: A string to trigger the camera is visible, grasped in Wilson's mitten.

The portrait was one of their last. None of them survived the journey home. Within a month Evans had died. A month later Oates, frostbitten, left the group and never was seen again. The frozen bodies of the rest were found in their tent, along with the negative for this photograph, in November 1912. —Margaret G. Zackowitz



PHOTO: HERBERT G. PONTING, NATIONAL GEOGRAPHIC CREATIVE

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