NATIONAL GEOGRAPHIC

## DEPARTMENTS



POPULATION

**Marriage Across Color Lines**
Once illegal in many states, interracial marriages are on the rise in the U.S.

GEOGRAPHY

**State Rock Stars**
California was among the first to name—and the first to nearly disown—its state rock.

HISTORY

**Polar Dogs and Ponies**
An aeronautical chart of a New Zealand-to-Antarctica route honors four-legged explorers.

CULTURE

**Zeroing in on Corruption**
Indian officials who stick out a hand for extra cash are chastened with a zero-rupee note.

FOSSILS

**Prehistoric Big Birds**
An ancient flier's 17-foot wingspan offers clues to how supersize birds flew.

THE BIG IDEA



**On the Cover**
With 3-D data, experts helped shape this image of Machu Picchu, "lost city" of the Inca. The conical roof sits on the Temple of the Sun.

*Art by Dylan Cole*
*Sources: Instituto Nacional de Cultura, Peru; Center for Advanced Spatial Technologies, University of Arkansas; Cotsen Institute of Archaeology, UCLA; Vincent R. Lee*

**ngm.com**

**Online Adventures**
Take a virtual walk on New York's High Line (above). Read Hiram Bingham's account of his Machu Picchu discovery. Learn more about a photographer's volcanic encounter.

DIANE COOK AND LEN JENSHEL

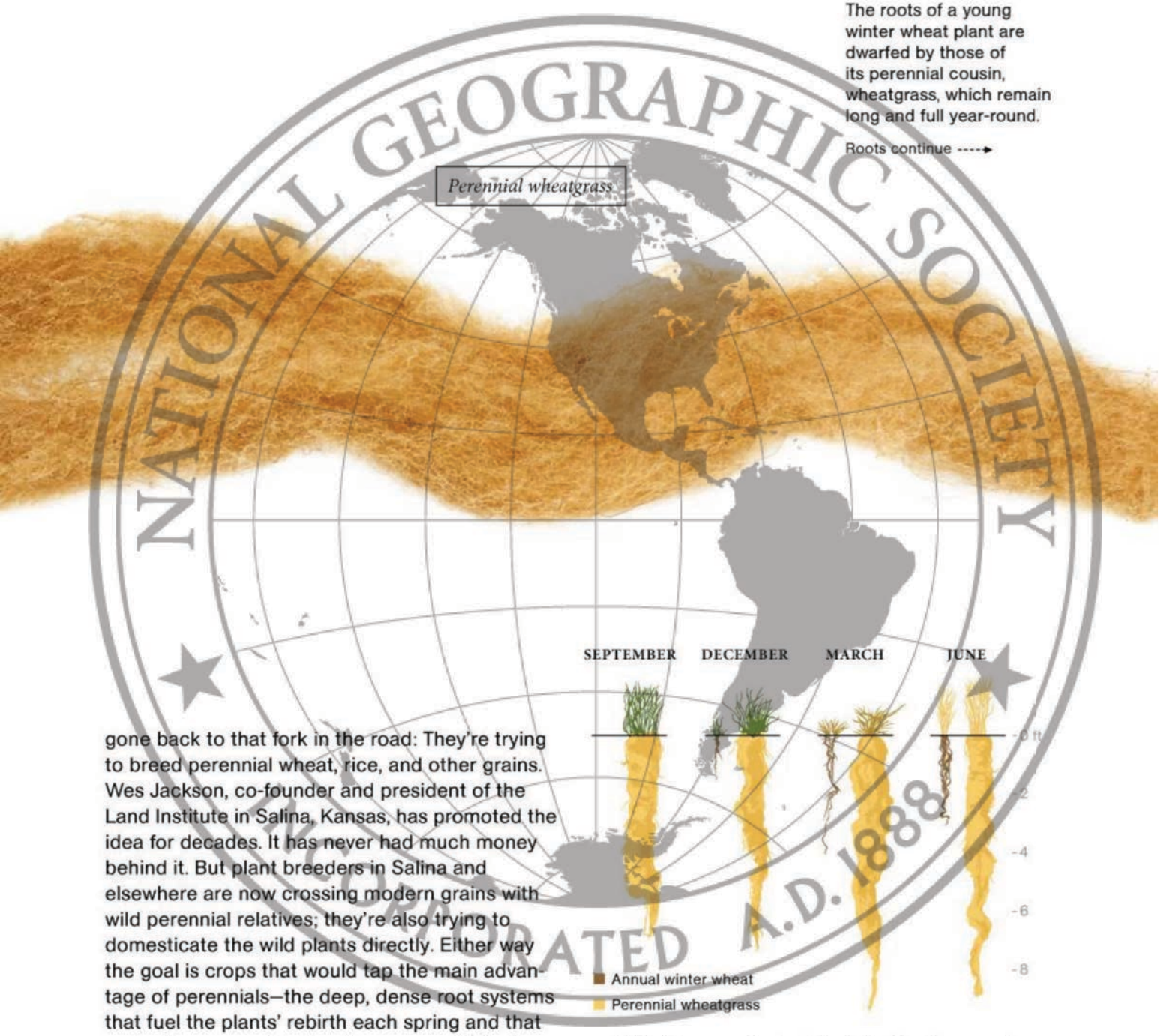
FOR SUBSCRIPTIONS, GIFT MEMBERSHIPS, OR CHANGES OF ADDRESS, CONTACT CUSTOMER SERVICE AT *NGMSERVICE.COM*, OR CALL 1-800-NGS-LINE (647-5463). OUTSIDE THE U.S. AND CANADA PLEASE CALL +1-813-979-6845.


*Annual grains feed the world,*
*but they create perennial problems.*
*Some think we need a*

# Perennial Solution

HUMANS MADE AN UNWITTING but fateful choice 10,000 years ago as we started cultivating wild plants: We chose annuals. All the grains that feed billions of people today—wheat, rice, corn, and so on—come from annual plants, which sprout from seeds, produce new seeds, and die every year. "The whole world is mostly perennials," says USDA geneticist Edward Buckler, who studies corn at Cornell University. "So why did we domesticate annuals?" Not because annuals were better, he says, but because Neolithic farmers rapidly made them better—enlarging their seeds, for instance, by replanting the ones from thriving plants, year after year. Perennials didn't benefit from that kind of selective breeding, because they don't need to be replanted. Their natural advantage became a handicap. They became the road not taken.

Today an enthusiastic band of scientists has




gone back to that fork in the road: They're trying to breed perennial wheat, rice, and other grains. Wes Jackson, co-founder and president of the Land Institute in Salina, Kansas, has promoted the idea for decades. It has never had much money behind it. But plant breeders in Salina and elsewhere are now crossing modern grains with wild perennial relatives; they're also trying to domesticate the wild plants directly. Either way the goal is crops that would tap the main advantage of perennials—the deep, dense root systems that fuel the plants' rebirth each spring and that make them so resilient and resource efficient—without sacrificing too much of the grain yield that millennia of selection have bred into annuals.

We pay a steep price for our reliance on high yields and shallow roots, says soil scientist—and National Geographic emerging explorer—Jerry Glover of the Land Institute. Because annual root crops mostly tap into only the top foot or so of soil, that layer gets depleted, forcing farmers to rely on large amounts of fertilizers to maintain high yields. Often less than half the fertilizer in the Midwest gets taken up by crops; much of it washes into the Gulf of Mexico, where it fertilizes algae blooms that cause a vast dead zone around the mouth of the Mississippi. Annuals also promote heavy use of pesticides or *(Continued)*

PHOTOS: REBECCA HALE, NGM STAFF
GRAPHIC: LAWSON PARKER, NGM STAFF. SOURCE: LAND INSTITUTE

**Perennials are thrifty.** *Their long roots hold on to soil, water, and fertilizer, which means less pollution.*

tillage because they leave the ground bare much of the year. That allows weeds to invade.

Above all, leaving the ground bare after harvest and plowing it in planting season erodes the soil. No-till farming and other conservation practices have reduced the rate of soil loss in the U.S. by more than 40 percent since the 1980s, but it's still around 1.7 billion tons a year. Worldwide, one estimate put the rate of soil erosion from plowed fields at ten to a hundred times the rate of soil production. "Unless this disease is checked, the human race will wilt like any other crop," Jackson wrote 30 years ago. As growing populations force farmers in poor countries onto steeper, erodible slopes, the "disease" threatens to get worse.

Perennial grains would help with all these problems. They would keep the ground covered, reducing erosion and the need for pesticides, and their deep roots would stabilize the soil and make the grains more suitable for marginal lands. "Perennials capture water and nutrients 10 or 12 feet down in the soil, 11 months of the year," Glover says. The deep roots and ground cover would also hold on to fertilizer—reducing the cost to the farmer as well as to the environment.

The perennial wheat-wheatgrass hybrid now growing at the Land Institute can already be made into flour. Yields are too low to compete with annual wheat in Kansas—but maybe not in Nepal, which has steeper slopes and a harsher climate, and where a researcher is now testing perennial hybrids in small plots. Amber waves of perennial grain may be decades away, but the emergence of cheap DNA sequencing is allowing plant breeders to work much faster than they used to. Buckler thinks that for a tiny fraction of the billions spent annually on corn research, one could create field-testable perennial corn in as little as ten years. "I think we should take a shot at revolutionizing agriculture," he says. *—Robert Kunzig*