UNRAVELING *the*

BY KRISTA ZALA

Eight centuries ago, the Four Corners region of the US Southwest was bustling. Regular rainfall coaxed crops from healthy soil, and the abundance of cottontails, jackrabbits, and mule deer made for choice meals. Tens of thousands of Ancestral Puebloans lived in adobe houses and cliff dwellings spread across an area the size of Napa County. Then, in the final decades of the 1200s, most everyone left. Drought, crop failure, and conflict all contributed to the society's collapse. But we don't exactly how the migration unfolded.

Clues from language, cultural artifacts, DNA, and human remains each provide pieces of the puzzle of human geographic history. Today, SFI researchers are re-examining these pieces, figuring out their collective significance, and applying novel insights to studies of civilizations past and present. Their research at the frontiers of genetics, linguistics, anthropology, and even economics is converging in a comprehensive approach to human migration. One early finding is that each migration story is unique.

ABOVE: DAN KITWOOD/GETTY IMAGES

"Most researchers assume that ancient migrations should leave consistent residues in human biology, language, and archaeology," says SFI Omidyar Fellow Scott Ortman, one of the archaeologists researching the history of the Four Corners. "But well-studied cases from the recent past show that they rarely do."

Ortman and others are confirming some old hunches and building cases for new accounts of migration. New techniques promise new evidence. Cheek swabs now produce enough DNA to help trace ancestral migrations. Computer models can help trace the evolution of human languages back to long before any word was ever written. By overlaying the improved evidence from many fields, some researchers hope to overhaul our understanding of migration and answer perhaps the most basic human question: Where did we come from?

Genes Reveal Clues

Modern humans first left Africa 60,000 years ago, ultimately spanning the globe in a series of colonizations reflected in our genomic diversity variation today. Where that original migration started

MYSTERIES *of* MIGRATION

The ≠Khomani San strike traditional poses. Their African homeland could be the spot where modern humanity began.

has been debated for decades. "Our belief used to be that the center of humans leaving Africa was in East Africa," SFI External Professor and Science Board Co-Chair Marcus Feldman says. "We've just never had enough people represented in our studies before."

Feldman is a geneticist at Stanford University and a pioneer in research on human origins and evolution. Using genetics and computational biology, he and a team recently moved humanity's starting point considerably farther south.

He and colleagues analyzed the genetic sequences from 25 populations of modern-day hunter-gatherers, pygmies, and farming societies throughout southern, central, and eastern Africa.

Cliff dwellings nestle in the sandstone of Colorado's Mesa Verde National Park, what was, prior to the 13th century AD, a Four Corners settlement.

The team looked at sites on chromosomes where a lone nucleotide has altered from the standard sequence in what's known as an SNP (single nucleotide polymorphism, pronounced *snip*). All chromosomes (except the Y chromosome in males) get cut and mixed at each generation; the older a population, the more frequently its sequences have been shuffled; and the more mutations that have accumulated, the greater the genetic diversity.

In analyzing hundreds of thousands of SNPs, the team found that hunter-gatherers' sequences vary the most, both within their groups and compared to other African populations. Two in particular, the click-speaking South African ≠Khomani and the Bushmen in Namibia, stand out as most diverse. The earliest common ancestor among ≠Khomani and other KhoeSan speakers in southern Africa today dates to 40,000 years ago. Some Bushmen groups have remained there ever since, and some may have disappeared a long time ago. Thus those small groups that originally left Africa most likely derived from ancestors of today's KhoeSan speakers in southern Africa.

Language Explains Roots

Language is nearly as easy to carry as genes. It's flexible too: When a group splits from its original population, the two lineages develop differently if they don't interact much. The French spoken in Quebec, for example, is a 17th-century offshoot of the old country's lexicon, pronunciation, and even taboos: Today, people from France find Quebeckers' swear words charming. Similarly, not far from the Santa Fe Institute, mountain villagers speak a derivation of 16th-century Spanish brought from old Spain.

The French and Spanish cases of divergence prompted by geographic separation represent just a few examples of how languages behave like species. On a larger scale, a movement is afoot to study historical linguistics, using models and techniques borrowed from molecular evolution. In the latter, researchers analyze thousands of genetic sequences to uncover how related, and how old, species are. The nascent linguistics methodology

crunches thousands of similar words within and between languages to chart their lineages.

This isn't the first time well-meaning scientists tried to subject language to statistical analysis. Decades ago, attempts to quantify language evolution used unsophisticated statistical methods, with incorrect results deterring historical linguists. Since those early tries, both computing and statistics have grown enough to handle the phenomenal task of charting the evolution of language.

SFI External Professor Mark Pagel, an evolutionary biologist at the University of Reading, and colleagues took some steps a few years ago. The team used lexicons of three major language groups—Bantu in Africa, Indo-European, and Austronesian—to create evolutionary trees depicting the patterns and paces of language change and emergence. They found that, much the way species can speedily evolve in new settings, young languages burst with innovation in their infancy before slowing to relative stasis.

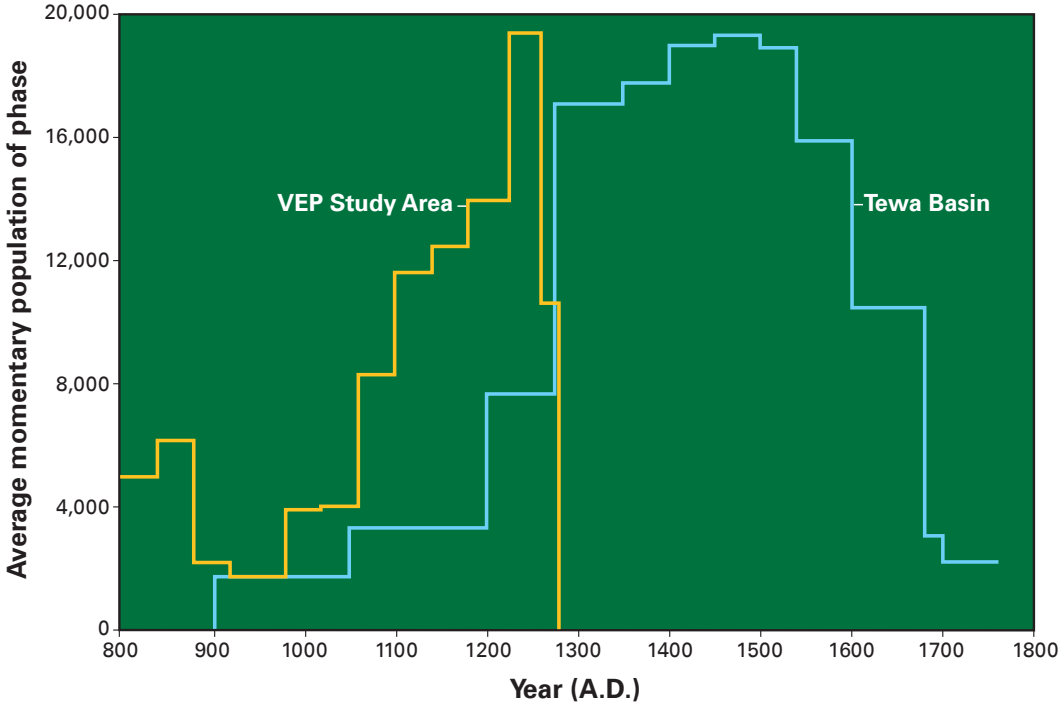
Subsequent work confirmed that a word's importance determines its resistance to change. Peripheral words like *bird* change faster than everyday words like *two*, where disagreement on meaning could lead to conflict.

Back at the global scale, so many languages have deep-rooted similarities that they hint at a common ancestor, posits SFI Professor Tanmoy Bhattacharya, a statistical physicist at Los Alamos National Laboratory, who has turned his data-analysis skills to studying dynamics of change in language. "Today, we don't care about answers that are *probably* so," says Bhattacharya. "We want to know *how* probably."

He, Pagel, and other SFI affiliates recently joined efforts to create two major systems that examine patterns of sound change and meaning change. Project members with SFI ties include SFI External Professor and physicist Eric Smith, External Professor and geneticist Jon Wilkins, Postdoctoral Fellow and network physicist Hyejin Youn, anthropologist Daniel Hrushcka of Arizona State University, and linguists William Croft and Ian Maddieson at the University of New Mexico.

In the first project, the team is quantifying sound changes in language by aligning corresponding sounds in similar words belonging to related languages. Drawing from the 29 closely related languages of the Turkic family, the team can construct an evolutionary tree of tongues, complete with probabilities of sound change for every branch.

In the second project, the team is looking



Population histories for the Four Corners (VEP) and northern Rio Grande (Tewa Basin) regions suggest a massive migration from the former to the latter during the 13th century AD.

CHART RE-CREATION: JAN UNDERWOOD/INFOBURRITO.COM

to trace how words have expanded, shrunk, or shifted their meanings. "If you learn that a word in, say, Basque means both 'water' and 'hazelnut,' would you be surprised?" asks Bhattacharya. "Across the world's languages, what patterns do you expect?" By measuring shifts in sound and meaning, the team hopes to build a system that scientifically analyzes language relationships. Ideally, the system will automate the routine work of processing countless data points, relieving the linguistics experts to interpret the results and advise on particular and peculiar instances.

Faces as Indicators

Back in the Southwest, Ortman, the archaeologist, is putting genes, language, and culture together. He noticed the shrinking Four Corners towns coincided with swelling populations in the northern Rio Grande area, but confirming the link required evidence. With no DNA of the study subjects available, Ortman chose a proxy: craniofacial data. Skull measurements can indicate people's relatedness; across a population, the genetic structure and even the mating network emerge.

Ortman analyzed records from remains of 1,200 people found at a hundred sites across the Ancestral Pueblo world and found that, indeed, the northern Rio Grande population had originated in the Four Corners. He also found that residues of Four Corners society survived and persist in present-day Rio Grande pueblo languages. Oddly, however, the migrants chose the architectural and ceramic styles of their new home over those of their old one.

The Four Corners collapse represents just one of thousands of migrations. Societal features all jostle for prominence when cultures mingle, and the melee rarely settles into consistent patterns. Trouble arises when researchers assume they will find the same patterns of change, in specific cases or in general. The lure of simplicity runs the risk of badly misrepresenting human history.

Traditionally, archaeologists have categorized elements of ancient cultures based on researchers' own backgrounds. The problem with this, Ortman continues, is that humans vary dramatically in how they classify and value experience, and such assumptions influence decision making. So to understand the cultural dimension of human history at the same level of precision as genetics or linguistics, the first step is to figure out how to identify, classify, and count the conceptions of the people who actually created the archaeological record. Ortman is working on a scientific approach for doing just that.

Metaphors Offer Answers

People everywhere rely on metaphors to explain ideas. Analogies permeate languages. In English, for example, one collection of sayings for piquing interest uses fishing metaphors: *Okay, I'll bite. He took the bait. They swallowed it hook, line, and sinker. He knows how to reel people in.*

Concepts from everyday living are captured in language and can even be applied to other forms of expression, such as architecture or painting. Ortman's framework offers a means to describe cultures based on the distinctions the people themselves make.

To understand cultural elements at the Four Corners, Ortman is looking at the myriad ways Ancestral Puebloans utilized container metaphors to conceptualize their experience. He has quantified various elements that were important to the

Ultimately, human nature may be to join the migration once it starts: When enough people move away, the urge to **stay in the familiar place** is overcome by the urge to **stay amid the familiar culture.**

people, including the bits of weaving imagery that appear on pots, the bits of pottery designs that appear in mural paintings, and the aspects of container technology that structured architecture and social organization. On a grander scale, the method also provides a basis for tracking how and why salient aspects of a culture change through time.

So why did the Four Corners people leave?

Ortman joins SFI External Professor Tim Kohler, an archaeologist at Washington State University, in making a model society that might point to some plausible reasons. They and researchers in hydrology, ecology, economics, and computer science have built an agent-based model to simulate the Ancestral Puebloans' lives. In it, each household is an agent. Given initial conditions of climate and environment, the model simulates hundreds of years of people living their daily lives—collecting water and fuel, hunting and farming, exchanging meat and maize through good years and bad—to see how the inhabitants might have used their wild and domestic resources.

The team also drew from archaeological data from 9,000 sites to understand where farmers chose to live and use the local resources, how goods exchange influenced the forming and dissipating of villages, and why so many people left. By playing the model and data off each other, they learned that, beyond the basic water and land considerations, housing rules seemingly changed between waves of settlement, as households at later stages were built at less than optimal sites. The team also learned that maize levels dropped, but not necessarily enough to drive so many people away. Warfare, too, may have kept people huddled in villages for safety, even as some fled.

So, despite the tough times, more people left than needed to. Ultimately, human nature may be to join the migration once it starts: When enough people move away, the urge to stay in the familiar place is overcome by the urge to stay amid the familiar culture. The unknown is less intimidating if you face it with allies. ◀

PICTOGRAPH #2, ACRYLIC ON CANVAS, 48"X 48", DAN NAMINGHA © 2011

In his paintings, Hopi/Tewa artist Dan Namingha utilizes ancient symbols often found on petroglyphs in the Four Corners region, including the spiral, which can depict migration. Courtesy of Niman Fine Art.