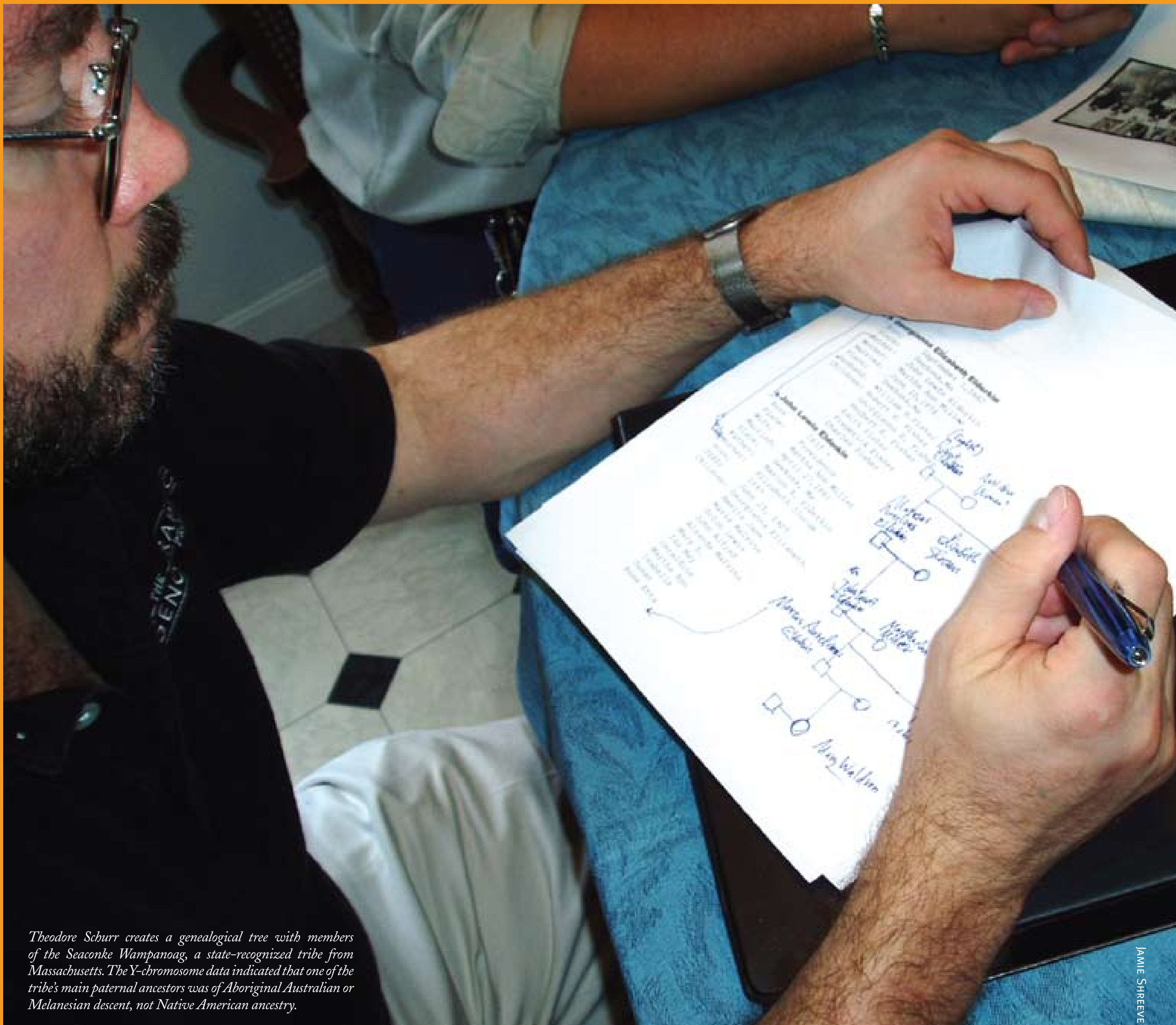

Theodore Schurr creates a genealogical tree with members of the Seaconke Wampanoag, a state-recognized tribe from Massachusetts. The Y-chromosome data indicated that one of the tribe's main paternal ancestors was of Aboriginal Australian or Melanesian descent, not Native American ancestry.

Jamie Shreeve

THE WORLD WANDERERS

Molecular Anthropologist Uses DNA to Track Migrations of Homo Sapiens

by Peter Nichols

"[F]or mortals, nothing is worse than wandering." This lament fell from the lips of Odysseus, Homer's far-wandering, homeward-yearning hero who was near the end of a 10-year Mediterranean voyage following the Trojan War.

One could perhaps argue about what might be worse than wandering, but not with the claim that the human species has spent much of its restless history—and prehistory—drifting across vast stretches of forests and seas, treeless plains and blue ice fields.

Wandering is a basic motif of the human condition and a fact, well-established by science, of the human adventure. Homo sapiens as Homo viator. For better or for worse, the long-term, big-picture view is that we are a tribe of nomads—at home nowhere and ceaselessly on the way to someplace else. It's even written in our genes.

Genetics is usually thought of as a future-gazing science, a body of knowledge that holds the promise of wonder drugs and miracle cures to come. But DNA is also a book of history. Our DNA tells us that today's humans are the descendants of ancestors who set out from Africa 70,000 years ago on a long migration that spanned the Earth. No matter where we call home today, all 6.7 billion of us are the children of primeval parents who—2,000 generations back—wandered out of Africa. As groups of humans moved into different corners and continents of the globe, distinct mutations accumulated in the DNA of different populations. For those who know how to read it, the genetic alphabet tells the story of humankind's long wanderings.

Theodore Schurr is a molecular anthropologist, one of a new breed of cross-disciplinary scholar-scientists who combine ethnographic and archeological fieldwork with laboratory research. An associate professor of anthropology, Schurr is consulting curator in the Physical Anthropology and American Sections at Penn's Museum of Archaeology and Anthropology. He also directs the Laboratory of Molecular Biology, housed in the biology department's Goddard Labs, where DNA samples he collects in the field are analyzed. Schurr is in the business of tracing back in time the migrations of existing and extinct peoples and the links among various tribes, clans and other groupings by interpreting inherited genetic "markers," combined with archaeological clues left behind by a community's culture.

"Molecular anthropology emerged maybe 20 years ago," he explains, "with the realization that researchers could use genetics to understand kinship, migration and even the origins of primates and humans." It's a science of movement and ancestry and connection.

Every time a human is conceived, the genetic alphabet of parents and all their forebears gets copied, shuffled and recombined to create a new and unique person. The transaction involves billions of moving molecular parts. When genes replicate, 'mistakes' or random mutations—the variation that drives evolution—sometimes go uncorrected. These additions, deletions or repeats in the gene code get replicated and transmitted down a lineage of descendants. The genetic stuff in the Y chromosome, which sons inherit from fathers, and mitochondrial DNA, which all children inherit from their mothers, does not get recombined with the genes of the other parent but is passed down almost unchanged. That base of stability makes these paternal or maternal lineages ideal for following markers in the code as they move along the genealogical forks and branches of a family tree.

"By looking at genetic markers in the mitochondrial DNA and the Y chromosome," Schurr explains, "we're able to track the historical changes in the branches of the genealogies that connect all women and all men in the world." Finding common biological markers in seemingly unrelated populations on different continents, for instance, points to an earlier connection between the two groups. And the appearance and transmission of new markers in a lineage can pinpoint a period of time in a population's history. Many mutations in mitochondrial DNA correlate with geographic regions where they first occurred, providing clues for the reconstruction of ancient migration patterns based on the distribution of these mutations in a population.

As often happens, new technologies give scientists innovative tools to answer old questions. "The stories molecular anthropologists tell are ones that are very, very old," Schurr comments. "They're part of the narrative we all share but talk about in non-genetic ways: Where do I come from? Who am I related to? What do I share with people across the valley?" He is currently working to answer these and other questions regarding the peoples of North America. Where did the original settlers, whom we call "indigenous," come from? How long ago did they arrive? And how did they spread across the continent? The answers, in order, are southern Siberia and Mongolia about 15,000 to 20,000 years ago by crossing the Bering Land Bridge and wandering down the American continents along coastal migration routes.

Schurr has the answers at his fingertips because he's been studying genetic variations in Asian, Siberian and Native American populations for the last 20 years. He currently heads up the North American Regional Center of the Genographic Project. The five-year, $40-million undertaking, begun in 2005, is an ambitious voyage of discovery, encompassing 11 regions, hundreds of thousands of DNA samples (mostly cheek swabs) and thousands of scientists from around the world. Primary funding comes from National Geographic and IBM. The research venture uses front-line gene-science technology and computational equipment to analyze historical patterns of DNA collected from the world's population, with a strong emphasis on indigenous and traditional peoples.

FOR BETTER OR FOR WORSE, THE LONG-TERM, BIG-PICTURE VIEW IS THAT WE ARE A TRIBE OF NOMADS—AT HOME NOWHERE AND CEASELESSLY ON THE WAY TO SOMEPLACE ELSE.

Populations that have remained relatively isolated for long periods provide a clear geographic context for making more reliable inferences about the genetic patterns of ancestry and inheritance. If a group remains in one place, so does its genes, whose unique markers can be identified and tracked when they get passed on to other groups. Once these closed-off tribes enter into the world's genetic melting pot, the geographic context and genetic trail become muddied, so the project has prioritized collection of DNA from these scattering and disappearing peoples.

From these explorations, the Genographic Project hopes to build up a data set that captures a genetic profile of our species at this moment in time. "We're attempting to put together the story of humankind—its migration out of Africa and its expansion across the world over the past 70 millennia," says Schurr. "We have some broad brush-stroke pictures of this migration history, but the details that we will obtain through this study will give us much greater clarity on the timing, the migratory routes and settlement patterns."

Kids from Voyampolia Village in Kamchatka, Russia, where Schurr worked with researchers on a study of Koryak and Itel'men people.

Schurr (left) working with villagers on the Anatolia Genetic History Project in the Cankiri Region, near Ankara, Turkey.

Schurr has been painting in the details of that larger portrait in several parts of the world ever since he was a grad student taking biological samples and family genealogies in remote villages on the Kamchatka Peninsula in northeastern Russia. Molecular anthropologists look at genetic data in light of cultural, geographic and other information to reconstruct a population's history. Biological and anthropological findings together paint a more complete picture, each approach informing or supporting the other, filling in gaps, providing context, adding evidence like pigment to a canvas. "Comparing the genetic analysis with the narrative that comes from the fieldwork allows us to test hypotheses about history, about origins and about connections between people," he stresses. "Without the anthropology, we don't have nearly as much power to interpret our genetic evidence."

In Schurr's informal characterization, fieldwork amounts to "hanging out and collecting the facts on the ground." Those facts can include historical and trade records, oral histories, genealogical data, tribal histories, lists of languages spoken by relatives and ancestors, as well as local archival information on births, deaths and marriages. In Tymlat, a coastal fishing village in Kamchatka, Schurr was part of a research team that came to investigate the history and pre-history of the Koryaks and Itel'men who lived there. The team went with villagers on their daily rounds to fishing huts, cemeteries, administrative offices and local museums. The researchers also hung out in homes and the *bany* (public bathhouse).

"You need to see things from the local perspective to really understand the bigger pattern," he asserts. "Until you actually work in these communities and talk to the people about their history and their own genealogies and so forth, you don't really understand exactly what you have."

Analyzing the genes of Koryaks and Itel'men revealed that they are not closely related to Native Americans but have stronger genetic affinities with eastern Siberian and East Asian populations. These findings support the view that Paleoasiatic tribes originating in mainland Siberia expanded into the Kamchatka peninsula 6,000 to 8,000 years ago, while the genetic traces of earlier groups that gave rise to Eskimos and Aleuts had been absorbed by the ancestral Koryaks and Itel'men.

In addition to research in Kamchatka and North America, Schurr has carried out work on populations in Turkey, Mongolia, Siberia, Melanesia, Nepal, South Africa, India, Central America, Europe, Lebanon and elsewhere. He's been a consultant for the genetic interpretation of Vietnam War MIA remains, and he's advised the genetic genealogy company Family Tree DNA in developing genetic tests for people interested in tracing their biological ancestry. In a legal fight between scientists and Native American groups over Kennewick Man, one of the oldest fossil skeletons found in the U.S., Schurr gave expert testimony on the limits of what genetic information can reveal about individual ancestry without the context of cultural data, which was entirely absent in this case.

The Genographic Project's growing files on gene variation among groups of people maps and chronicles with increasing clarity the great odyssey of the human race. After meandering in Africa for 130,000 years, Homo sapiens, impelled perhaps by climate change, embarked upon its outward journey. Schurr speculates that humans moved out in two migrations. One snaked along the southern coast of Asia through India and on to Australia, having colonized much of East Asia by 60,000 years ago. The second migration headed into Western and Central Asia and peopled the Eurasian land mass about 43,000 years ago. Even after these regions were settled, transient bands of humans continued roaming the globe, crossing oceans and mountain ranges, trekking across continents and leaving behind genetic markers before moving on again. The last part of the Earth to be colonized was the New World, although its earliest settlers came, not from Europe to the east, but from the west.

"The big picture for the Americas has changed a number of times in the last two decades," Schurr remarks, "and will continue to change with the accumulation of new archeological and genetic evidence." Current thinking holds that westward-moving Old World migrations halted somewhere in northeastern Asia, perhaps on the Beringian land mass, for several thousand years. These ancestral Native Americans then moved south at the peak of the last ice age, using watercraft to navigate around the ice sheets to unglaciated regions in North America. "We have defined the founding maternal and paternal lineages that were brought in this major expansion event," Schurr maintains, "and we are tracing their spread in North and South America, which while sharing a common migration history, have become genetically distinctive from each other over the past 10,000 years."

By the end of Homer's epic poem, long-suffering Odysseus finally made his way home to the kingdom of Ithaca. But if the story told by molecular anthropology is any guide, the fate of homeless humanity appears to be a never-ending pilgrimage that has but one final resting place. It might be, as some have warned, that the whole

DNA COLLECTOR

Sarah Tishkoff (standing) and workers collecting blood samples in the Arusha region of Tanzania.

Sarah Tishkoff collects human DNA the way old-time naturalists like Darwin gathered up beetles and bird skins. Both collectors use their specimens to support big theories about how life came to be as it is now. Darwin saw in his assortment of life forms the story of how life evolved. In her genetic database, Tishkoff sees the continuing migratory and evolutionary saga of Homo sapiens.

Tishkoff is the David and Lyn Silfen University Associate Professor, one of the University's Penn Integrates Knowledge faculty members. She has a joint appointment in the biology department of the School of Arts and Sciences and the genetics department of the School of Medicine.

Tishkoff travels deep into Africa's bush country to draw blood from diverse tribes and peoples—more than 7,000 DNA samples from 100-plus ethnic groups. The white blood cells are extracted in the field using a portable centrifuge hooked up to her Land Rover's battery, and the material is preserved in pellets, which are carried back to her campus lab for analysis. Slight variations in DNA sequences among the groups provide clues about when and where

Earth is our home, and we should take good care of it. Still, the big money being poured into space travel and the tales told by science fiction writers suggest a future that imagines humanity blasting off to wander far among the stars.

Schurr ponders a different future. DNA is called the "code of life," the blueprint for building and maintaining an organism. It also tells molecular anthropologists about the interwoven meetings and departures and ceaseless peregrinations of our ancestors. But Schurr describes connections of another sort, inscribed deep within the human genome, written perhaps between the lines of data that tell the story of long-wandering humanity. It's a code to live by, a lesson on how humans might find their way on the journey.

"We are remarkable in our diversity," he observes, "what we say, what we do, how we look, how we behave. Despite our differences, we're all part of the same family tree. Our branch, Homo sapiens, is relatively recent, which makes us very similar to each other—99.9 percent of our DNA is the same. It's a profound thing to find out through this kind of research, and it suggests to me the possibility of developing a mutual understanding, a shared empathy and a concern for all the members of our species." ◆

Accordionist and boy in Guanjuato, Mexico, where Schurr's group plans to conduct research on indigenous peoples in the near future.

our species arose in Africa, how populations differentiated and spread across the continent and beyond, and what ways evolution continues to shape discrete populations in different ways.

"We found very old mitochondrial DNA lineages, among the oldest in Africa, in several groups we sampled," Tishkoff reports. The genetic material was from peoples in East Africa. The DNA samples showed an accumulation of many mutations, which is a rough measure of the time since a lineage first appeared. Analysis suggests that the 'African Eve' who gave rise to this line of descendants (mitochondrial DNA is inherited from the mother) lived 170,000 years ago, a timeline that corresponds to the oldest human fossils found there.

Tishkoff's DNA research also uncovered the genetic signature of recent evolution in humans. In most mammals, the gene that allows them to digest lactose, the sugar in milk, gets turned off after weaning. Many European peoples are known to be lactose tolerant—cattle herding emerged there some 8,000 years ago. Tishkoff discovered three separate mutations in African groups, all independent from the European mutation, that keep the lactose-digesting gene active in adults. The principle mutation was found in groups from Kenya and Tanzania, who, DNA scrutiny shows, arose around 4,000 years ago, the time when pastoral peoples arrived on the scene. The adaptation attunes the human organism in these tribes more perfectly to the environment of their culture.

Tishkoff is also at work on a project that looks at variations in the human genome across a large set of African peoples. That collection of genetic data will give her the evidence to make further inferences about the movements of African populations and might even help to identify the genetic basis of diseases like diabetes and hypertension, which are widespread among Africans and African Americans.

—PN