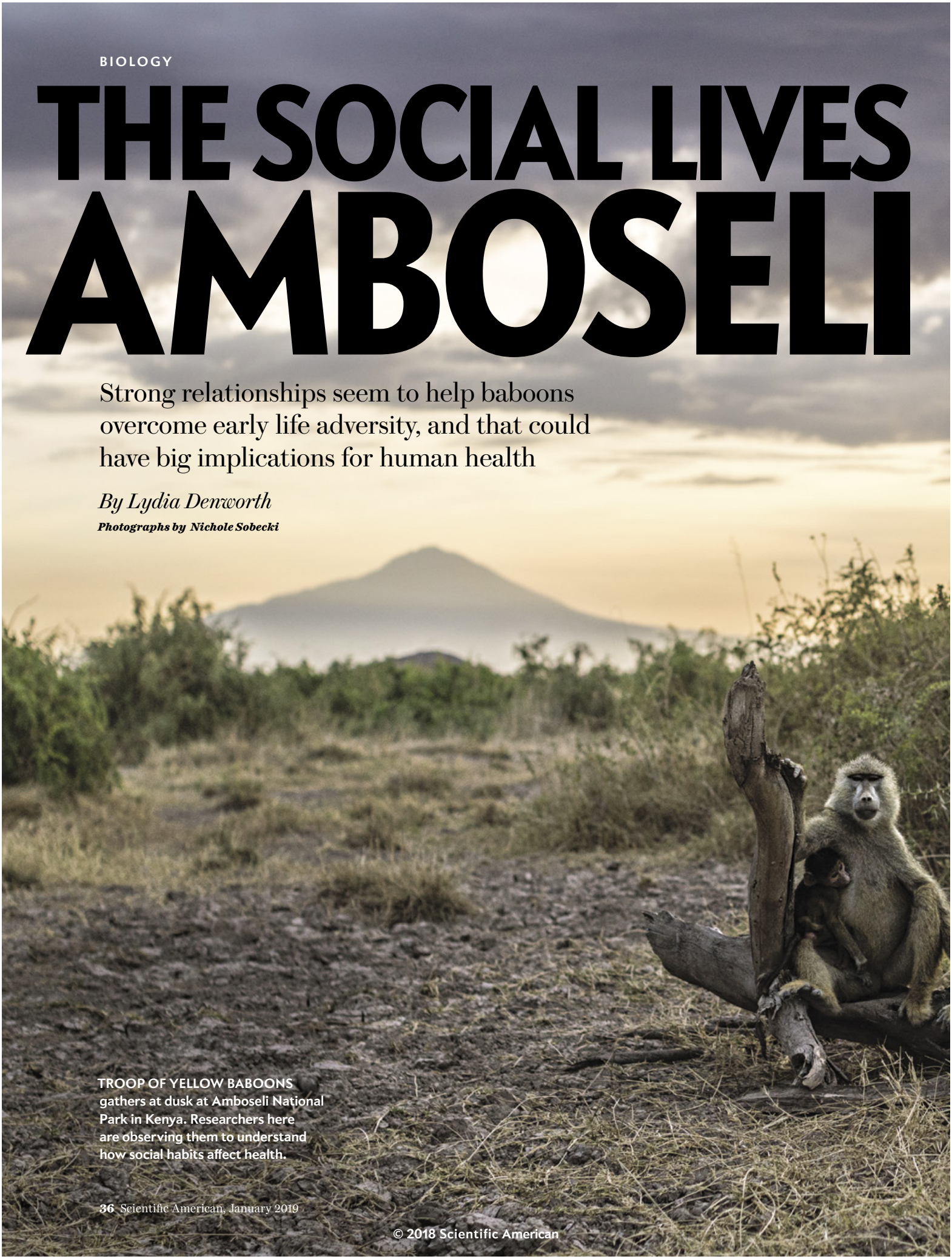
BIOLOGY

THE SOCIAL LIVES AMBOSELI

Strong relationships seem to help baboons overcome early life adversity, and that could have big implications for human health

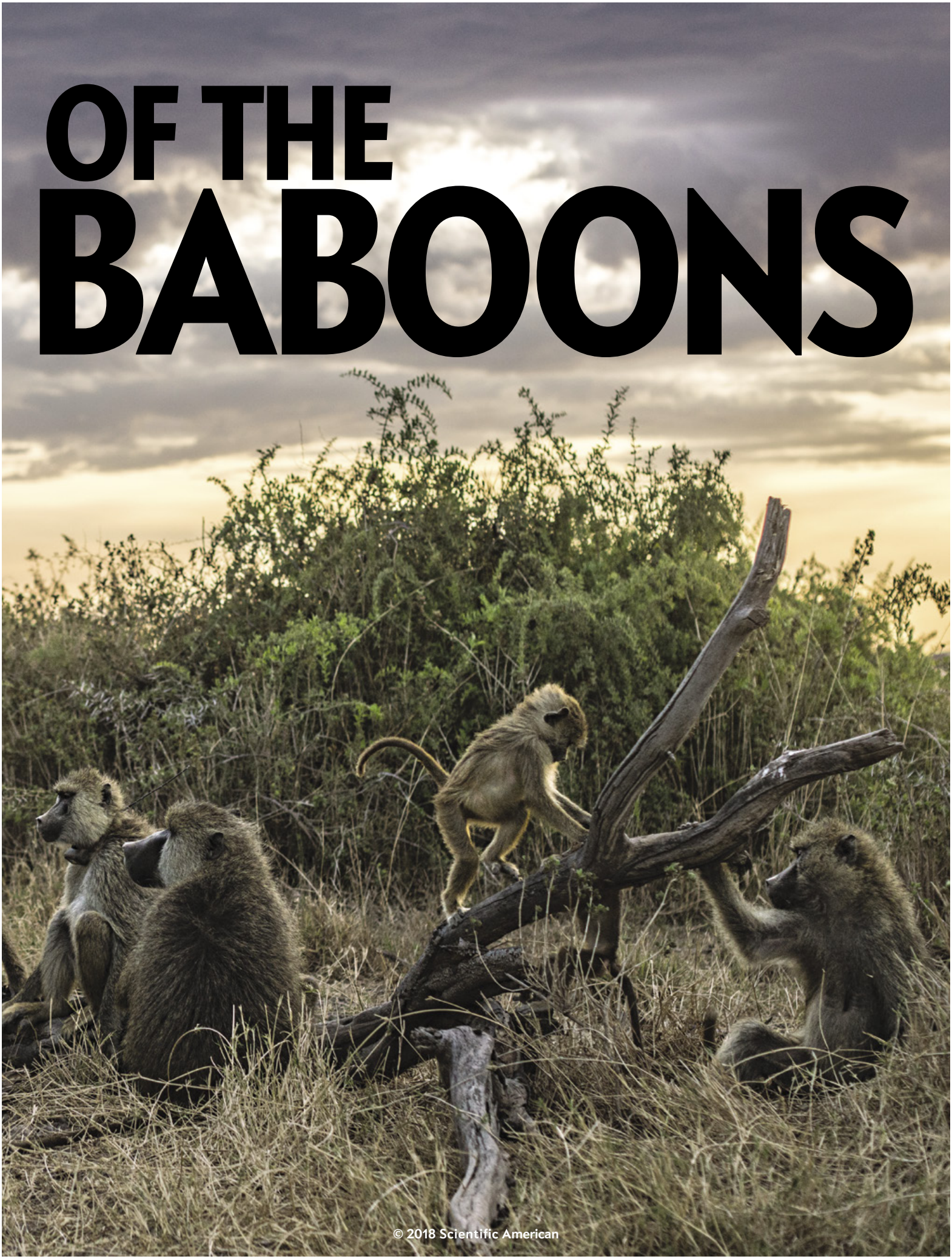
By Lydia Denworth

Photographs by Nichole Sobecki



TROOP OF YELLOW BABOONS gathers at dusk at Amboseli National Park in Kenya. Researchers here are observing them to understand how social habits affect health.

OF THE BABOONS



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It's just after daybreak on a plain at the edge of Amboseli National Park in southern Kenya. In a fever tree grove, a troop of nearly 70 yellow baboons is getting an easy start to the morning. A few late risers sleep on in the upper branches, but the others have been dropping down to the scrubby grass, one by one.

Hiawatha, a six-year-old female, is picking through the coat of her older sister, Hoja, removing dirt and bugs. "It's like somebody waking up, taking a shower, brushing your teeth and combing your hair," Kinyua Warutere, a senior field assistant for the Amboseli Baboon Research Project, says quietly. "Before they set out, they'll socialize in such a way. Mothers will groom kids. Friends will groom friends."

Some of the kids are already playing. The smallest, Huawey, is younger than two months and a little wobbly. He still has the distinctive black coat and bright pink facial features of an infant, although soon his fur will turn golden and then grayish brown. He rolls around with a playmate, and they bat at each other's heads like kittens. Every couple of minutes, though, Huawey retreats to his mother, Hiawatha, and tucks himself under her arm for a moment before venturing out again.

The fate of Huawey and his playmates is of particular interest to Susan Alberts, who stands by a mud-spattered 4×4 peering through binoculars. An evolutionary biologist at Duke University and co-director of the project, Alberts has been studying this group of baboons for 34 years. Since the Amboseli project was founded in 1971 by primatologists Jeanne and Stuart Altmann, its goal has been to dig for the deep evolutionary roots of social behavior in the lives of these animals. The focus of the team's latest work is the long-term consequences of what happens early in life.

The odds are already long for Huawey and his peers. They must navigate what Alberts calls "the Darwinian gauntlet." Thirty to 50 percent of wild baboons do not survive their first year, mostly because of nutritional stress, disease and predators. But some individuals have it harder than others—if they are born in a drought, say, or orphaned. In the first prospective, longitudinal study of its kind, published in 2016, the Amboseli researchers found that early adversity reduces life expectancy dramatically, by as much as half.

Recently, however, the Amboseli researchers have found a potential source of protection from early adversity: strong, stable relationships with other baboons. Now they are trying to figure out how much agency an individual baboon has to use relation-

IN BRIEF

For nearly 50 years researchers at the Amboseli Baboon Research Project have been recording the behaviors of wild baboons, using precise observational tools. The data reveal that baboons that have early adversity tend to die younger than those that do not.

There is new evidence, however, that a baboon might be able to overcome a tough early life by building strong relationships with others in its community. Amboseli researchers suggest that stable social connections might play a role in biological health.

These new ideas in evolutionary science could change our understanding of (and approach to) public health. Humans with childhood adversity tend to get sicker: Could strong relationships help rescue people from their rough starts?

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FIELD RESEARCHER Longida Siodi uses an antenna to find baboons, some of which wear tracking collars (*1*). Members of Yoda's Group are located on the plain (*2*). Project manager Raphael Mututua searches for the baboons he will be studying that day (*3*).

ships to bend the trajectory of its fate. This is a critical question not just for baboons but for people with rough starts in life, too.

There are obviously significant differences between baboons and humans. But the parallels in the fundamental elements that shape a life are striking—from the earliest environment to the social relationships of adulthood and patterns of mortality. Indeed, research into developmental origins of human health has found that low birth weight and poor maternal nutrition lead to a higher risk of a range of health problems later in life. And retrospective studies find that early psychological traumas such as abuse and loss of a parent are also associated with a greater likelihood of psychological and medical problems in adulthood.

With fewer confounding variables and shorter (but not too short) life spans, the baboons offer an intriguing opportunity to bridge research in evolution and human health—and to better understand the origins of illness and how to protect against it. As Elizabeth Archie, an associate director at Amboseli and a behavioral ecologist at the University of Notre Dame, says: "The fact that we see a relationship between social support and longevity in animals where they don't have hospitals or someone to drive them to hospitals means that there must be something else fundamentally biological going on." Being well, in other words, is not just about access to health care. Understanding that fact could have sweeping implications for public health.

GROWING ROOTS IN AMBOSELI

WHEN THE ALTMANNS FIRST CAME to Africa in 1963, few primatologists were working in the wild. They spent months searching Kenya and Tanzania before choosing Amboseli as a field site. Stretching across 150 square miles, the acacia woodland and open grassland offered good visibility and thousands of baboons to observe, along with elephants, zebras and giraffes. After they set up a permanent field site in 1971, Jeanne Altmann, who originally studied mathematics and ultimately assumed responsibility for the project, thought hard about how to rigorously record observational data. She developed a methodical technique in which researchers follow individual animals in a certain order for a set period, carefully logging what each does and with whom. Her eventual paper on sampling methods, published in 1974, made possible the valid measurement of behavior in the wild. It has become a bible in primatology.

Altmann also pushed to do two things that were highly unusual. The first was to pay attention to female animals when male aggression—and the assumption that violent competition deter-

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NOTES ON social interactions among members of Acacia's Group (*1*). Feces from a yellow baboon from Yoda's Group—to test for hormone levels and track lineage within the troop (*2*).

mined an animal's fate—tended to steal the limelight. "There was this attitude, sometimes explicit, sometimes implicit, that males were where all the action of evolution was," she said when we met in the summer of 2017 in her office at Princeton University, where Altmann is a professor emerita of ecology and evolutionary biology. Yet baboon society is organized along matrilineal lines. Females usually stay in one group all their lives, whereas males move at sexual maturity. "I felt that particularly in mammals and even more so in primates, including humans, females had not only control over their own lives—to the extent that anybody does—but also over the next generation. Why should that be irrelevant to evolution?" Altmann also knew that she needed to be in for the long haul, collecting data on the same groups of animals for generations. "It was so obvious that the outcomes came down the road," she says. "The real action was in lifetimes."

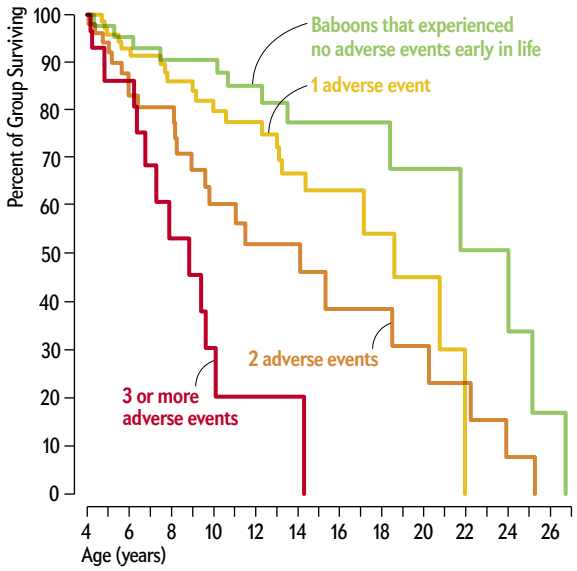
The team of scientists at Amboseli today represents its own matriline—an academic one. Altmann remains a director. Alberts came to Amboseli a year out of college in 1984 and was one of Altmann's first graduate students before becoming a director. The two associate directors, Archie and Jenny Tung, an evolutionary biologist at Duke, were Alberts's graduate students. Between them, they study everything from the demographics of the six groups they follow to the microbiome and genetics of the animals. Of the three Kenyan senior field assistants, Warutere is the most junior, with only 23 years of experience. Project manager Raphael Mututua and second-in-command Serah Sayialel both started work for the project in the 1980s. Even the camp staff—drivers and a cook—are old-timers.

The benefits of such deep institutional knowledge are evident in the field. Warutere, like Mututua and Sayialel, knows every animal on sight—even on the move or glimpsed in the trees. As we watch the troop start its day, he uses a small, yellow binder to record field notes on births, deaths, visible wounds and reproductive states, which females advertise by the variable swelling and color of their posteriors. When the census is done, Warutere begins to collect data in exactly the manner Altmann devised years ago. He observes individual baboons for 10 minutes at a time, noting what they are doing—eating, resting, grooming, and so on—and with whom. He and his colleagues ensure that every animal is observed for the same total amount of time.

Multiply this morning's data by two sessions a day, six days a week, 52 weeks a year and 48 years, and the result is a database that is nearly unmatched in any other wild population. It includes some 1,800 animals across six and a half generations. Yet the records are also intimate. The coded spreadsheets retell the stories of thousands of individual interactions such as those we have just witnessed among Hoja, Hiawatha and Huawey.

How Early Adversity Affects Survival

An analysis of the lives and deaths of 196 wild female baboons from Amboseli showed that sources of early adversity add up—with far-reaching implications for longevity. Females that experienced three or more harsh conditions early in life, such as drought, having siblings close in age or the death of a mother, died an average of 10 years earlier than those that got off to an easier start.



SOURCE: "CUMULATIVE EARLY LIFE ADVERSITY PREDICTS LONGEVITY IN WILD BABOONS," BY JENNY TUNG ET AL., IN *NATURE COMMUNICATIONS*, VOL. 7, ARTICLE NO. 11181; APRIL 19, 2016

Graphic by Amanda Montañez

OUT IN THE FIELD: Mututua and Siodi observe Acacia's Group of yellow baboons at dusk in early November (*1*). One of the baboons from Acacia's Group eats in a tree (*2*).

THE POWER OF BEGINNINGS

AFTER MORE THAN FOUR DECADES of accumulating details about the lives of the baboons, the scientists in Amboseli began to think their research might have relevance to a growing field within human epidemiology: the developmental origins of health. Theories about the impact of early environments on adult disease had been gaining influence since the 1980s. But they remained untested. And in humans, it is difficult to disentangle the effects of early adversity from differences in health habits and access to health care.

The idea that developmental origins might matter appeared in 1986, when the late British epidemiologist David Barker published the first of a series of papers highlighting a link between malnutrition in utero and adult disease such as diabetes, hypertension and heart attacks. Among other things, Barker found that higher rates of type 2 diabetes in British adults in their 60s were associated with low birth weights. Barker and his colleagues came up with the idea that fetal undernutrition might be setting up long-term risk for chronic diseases that we traditionally associate with overweight adults, explains anthropologist Chris Kuzawa of Northwestern University. A handful of other unfortunate natural experiments suggested something similar. At the end of World War II, for instance, residents of a region of the Netherlands under German occupation faced a famine during the winter of 1944–1945, when a railway strike cut off access to food. The long-running Dutch Hunger Winter study of the survivors has shown effects on cardiovascular disease, metabolism and cognitive function in Dutch adults born during that season of starvation.

In light of such findings, in 1992 Barker and C. Nicholas Hales, a biochemist at the University of Cambridge, developed the thrifty phenotype hypothesis, which suggested that an organism faced with harsh early conditions must compromise aspects of development in the interests of short-term survival (fetal under-

nutrition, for instance, might alter glucose metabolism). About a decade later they noticed that in some species, notably insects, early conditions could actually be used to predict adult environments. They refined their hypothesis and renamed it "predictive adaptive response," which suggests that adapting to difficult early conditions better prepares an organism for similar conditions later in life. The theory emphasizes that a mismatch—early malnutrition followed by plenty of food—would be a recipe for disease. The idea rapidly caught on among experts in public health. "It's hard to overstate how widely accepted these models are," Alberts said in a recent presentation.

Variation in adaptive responses depends on the notion of developmental plasticity, which is the ability of an organism to find more than one way to cope with and adapt to its environment. The best demonstrations of the principle are in short-lived animals, such as a species of Siberian vole. Based on cues from maternal melatonin received while in utero, voles born early in the summer mature and reproduce quickly, whereas those born as days shorten experience slower development and do not reproduce until the sun returns.

Other researchers inadvertently stumbled on the long shadow cast by early psychological and social stresses. In the 1980s Vincent J. Felitti was a physician running an obesity clinic in California. He had a patient whose weight appeared to be related to sexual abuse she had suffered as a child. That spurred Felitti to seek connections between childhood family dysfunction and adulthood disease and risky behavior.

Felitti joined forces with Robert Anda, then at the Centers for Disease Control and Prevention, and others, and they launched the Adverse Childhood Experiences (ACE) Study in 1995. It established seven categories of formative experiences, such as abuse, living amid domestic violence, and having family members who were imprisoned or suicidal. Among the more than 9,500 adults who answered the questionnaire, there was a strong relation between the number of categories to which someone had been exposed and that person's likelihood of engaging in substance abuse, suicide attempts and other risky behavior. Exposure to four or more categories resulted in a fourfold to 12-fold increase in risk. The study also found an increased risk of heart disease, cancer and other biomedical diseases.

In the baboons of Amboseli, Alberts, Tung and their colleagues saw an opportunity to test these ideas. In 2015 the team evaluated the predictive adaptive response hypothesis using data they had collected in 2009—a year of such terrible drought that 98 percent of Amboseli's wildebeests died. The researchers focused on adult female baboons born in previous years of either low rainfall or high rainfall. Because reproductive success is the most critical measure in evolutionary biology, they compared the fertility of these individuals in 2009 with one another. As expected, all animals were less likely to reproduce during a bad drought. But in a direct contradiction of the predictive adaptive response model—which would suggest that being born in a dry year prepares a female for drought, making her fertility less susceptible to its effects—those born in low rainfall years did not fare better than the high rainfall group. In fact, they did worse. Alberts and her colleagues propose that something nearly opposite to the predictive adaptive response is at work: a developmental constraints model. It predicts that "being born in a poor early environment gives you a deficit in *all* environments," Alberts says.

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The team also designed a baboon version of the ACE Study. Because baboons are nonseasonal breeders, no two have the same experience. "Everybody's born at a different time, and so many aspects of the early environment are highly particular to your mother," Alberts says. Published in 2016 in *Nature Communications,* the study analyzed the life histories of 196 females and considered six categories of early adversity from the first four years of life: drought; group size (which affects competition and fertility); maternal dominance rank and social integration; a sibling born within 18 months; and death of the mother.

The results were unequivocal. Baboons with three or more sources of adversity died an average of 10 years earlier than those with one or none (the median life span of the group was 18.5 years). Those that suffered the most adversity were also the most socially isolated adults. "That's an astonishing effect," Alberts says. "It explains 12 percent of the variation in life span, which is a lot for a fitness component."

Northwestern's Kuzawa, who oversees a long-term study of the developmental origins of human health in the Philippines, was pleased to see Amboseli's empirical tests of the predictive adaptive response model, which he had always found limited. Early life conditions may predict adult conditions for a short-lived animal such as the vole, for whom environmental factors at birth are more like-

AMBOSELI Baboon Research Project is studying animals from Acacia's Group (*1, 3*), Yoda's Group (*2*) and others. The baboons give an opportunity to bridge research in evolution and human health.

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ly to stay the same into reproduction, Kuzawa says. But the model is not necessarily valid in humans, who live into their 70s and beyond. "You see the same ideas get repeated, and there's actually no evidence for it," he says. Baboons, which can live for up to 30 years, are more comparable. That is why Kuzawa calls the Amboseli project "a unique resource for looking at these long-term effects."

RESILIENCE FROM RELATIONSHIPS

FOR PEOPLE WHO FACE early adversity while they are young, the big question is: How much can later circumstances compensate for the effects of a rough start? The recent Amboseli studies may offer some clues. Not every unfortunate baboon came to an unfortunate end. Indeed, there was enough variation in longevity to suggest that some animals do alter their fate. The Amboseli researchers have found signs that strong relationships help animals push back against the damaging effects of early adversity. Being born in a drought, for example, is mitigated by having a high-ranking mother. Females' grooming relationships with males, as opposed to females, were less affected by early adversity, suggesting a possible buffer. Maternal early experience echoes down the baboon generations. "If your mother dies and she had no early adversity, your survival is compromised, but it's not terrible compared with kids whose mothers are still alive," Alberts says. "But if your mother dies and she had early adversity, you're toast."

These findings fit with earlier pioneering work from Amboseli on the functional significance of social bonds. By the mid-1990s the project had complete data (birth, reproduction, death) on about 100 female baboons and was reaping the rewards of Jeanne Altmann's long-range approach. Altmann and Alberts teamed up with evolutionary anthropologist Joan Silk, now at Arizona State University, to investigate just how much social relationships might figure in an animal's prospects for reproductive success.

Silk had spent a year at Amboseli as a postdoctoral researcher. In the late 1990s and early 2000s, when a few primatologists started saying that animals have friends, she wondered if they really did and if it mattered. Conventional wisdom held that the critical variable in hierarchical monkey societies was dominance rank. But Silk was intrigued by emerging evidence that human social relationships were linked with health. A pivotal 1988 paper in *Science* by sociologist James House and his colleagues at the University of Michigan had concluded that a lack of connection could be as deadly as obesity and smoking.

So Silk, Alberts and Altmann turned to Amboseli's database. Alberts had already created something they called the sociality index, a measure that reflected the strength of social bonds based on proximity, grooming and other social behaviors—basi-

cally how often females interacted nicely. They measured that against the number of surviving infants. To their surprise, social integration predicted reproductive success more than dominance rank or any other variable they measured. That result, which Silk calls "stunning," was published in 2003 in *Science*.

To be sure the finding was not unique to Amboseli, Silk did a similar analysis with Robert Seyfarth and the late Dorothy Cheney, evolutionary biologists at the University of Pennsylvania, using data from their baboon research at Moremi Game Reserve in Botswana. "The results from both studies were striking in their convergence," Seyfarth says. By 2014 further studies at both Amboseli and Moremi had found that social connectedness was linked not just to reproduction but to longevity.

Overall, the negatives of getting a bad start still tend to outweigh the positive effects of social connection among the baboons. But because social relationships do have some protective power in extending life spans, the team at Amboseli is now asking, as Archie puts it, "Can friendship rescue you?" If it can, the reasons why are likely to be found in biology. "What's happening at the molecular and physiological level?" asks Tung, who focuses on the interplay between genes and behavior. "How does [social behavior] get under the skin and influence how the genome functions?"

Applying evolutionary science to public health could provide important clues to figuring out the causes of disease.

Tung's most intriguing finding so far, published in 2016 in *Science,* came not from the baboons but from a group of captive rhesus macaques. Her Duke laboratory manipulated the animals' social status by creating and then rearranging groups of females. When the scientists tested cells from different animals to see how they handled infection, they found clear differences in immune gene regulation according to social status. "We think that social integration and social isolation probably do have direct effects on how our immune system functions," Tung says.

Although Tung cannot manipulate the wild baboon groups, she is now using fecal samples, collected in Dixie cups, to look for similar patterns. Led by Archie, the team is sequencing the microbiomes of those 20,000 samples. So far the researchers have found that the baboon microbiome is socially structured—animals in the same group have more similar gut microbes. Furthermore, within a group animals that groom one another more often are more similar than those that do not. Once the sequencing is done, they will look for aspects of the microbiome that predict an animal's health, survival or reproductive success.

The new ideas about developmental plasticity arising from the work of the Amboseli Baboon Research Project are stirring debate as well as excitement. When the scientists published a review in 2017 in *Evolution, Medicine, & Public Health,* it generated five commentaries in response, including one from Kuzawa, who questioned the researchers' definition of "early life," which they extend from conception to reproductive maturity. Others argued that they did not give enough attention to the role of parents as mediators of early conditions. And a few researchers remain unconvinced that animal models are useful for thinking about disease in people.

Nearly everyone agrees, however, that applying evolutionary science to public health could provide important clues to figuring out the causes of disease and developing better interventions. A 2017 review in the *Lancet* noted: "It is no exaggeration to suggest that ... [it] could revolutionise the discipline." It will deepen our understanding, the authors explain, of why poverty and deprivation have such a powerful impact on health and life span and emphasizes that factors such as bad health habits do not explain everything. After all, Alberts says, "baboons don't have health habits."

At the end of our morning in the field, Alberts and I perch on a rocky hillside above the baboons with zebras and wildebeest grazing in the distance. She sums up the project's work by drawing a chart in my notebook. It consists of three boxes in a row. She marks the first "EA" for early adversity, the middle "ASC" for adult social connectedness, and the third "H + S" for health and survival. Then she adds arrows between the boxes—each pointing to the right—to show the influence of adversity on connectedness and of connectedness on survival. Based on the new research, she inserts a third arrow, which arcs high above the boxes from early adversity directly to health and survival, skipping over connectedness. This represents how too much adversity swamps the help provided by strong relationships.

The arrows are all-important. Clearly, early adversity must precede survival. But how does connectedness fit in? How much healthier does it make you? It is still possible that healthier individuals are more likely to connect in the first place.

Alberts hands back my notebook and says, "I think that all those arrows are real." She means that each element exerts its influence in the way she has laid out. If she is right, connectedness has the power to alter the course of an individual's life in the face of early adversity. Even if that does not prove true, Alberts is convinced the baboons have more to tell us about ourselves. "When a phenomenon that we are very concerned about in humans has evolutionary roots," she says, "it has huge consequences for how we think we're going to fix the problems that arise from it." SA

MORE TO EXPLORE

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