The Naked Truth

Recent findings lay bare the origins of human hairlessness—and hint that naked skin was a key factor in the emergence of other human traits

BY NINA G. JABLONSKI

Among primates, humans are unique in having nearly naked skin. Every other member of our extended family has a dense covering of fur—from the short, black pelage of the howler monkey to the flowing copper coat of the orangutan—as do most other mammals. Yes, we humans have hair on our heads and elsewhere, but compared with our relatives, even the hairiest person is basically bare.

How did we come to be so demudded? Scholars have pondered this question for centuries. Finding answers has been difficult, however: most of the hallmark transitions in human evolution—such as the emergence of upright walking—are recorded directly in the fossils of our predecessors, but none of the known remains preserves impressions of human skin. In recent years, though, researchers have realized that the fossil record does contain indirect hints about our transformation from hirsute to hairless. Thanks to these clues and insights gleaned over the past decade from genomics and physiology, I and others have pieced together a compelling account of why and when humans shed their fur. In addition to explaining a very peculiar quirk of our appearance, the scenario suggests that naked skin itself played a crucial role in the evolution of other characteristic human traits, including our large brain and dependence on language.

Hairy Situations

To understand why our ancestors lost their body hair, we must first consider why other species have coats in the first place. Hair is a type of body covering that is unique to mammals. Indeed, it is a defining characteristic of the class: all mammals possess at least some hair, and most of them have it in abundance. It provides insulation and protection against abrasion, moisture, damaging rays of sunlight, and potentially harmful parasites and microbes. It also works as camouflage to confuse predators, and its distinctive patterns allow members of the same species to recognize one another. Furthermore, mammals can use their fur in social displays to indicate aggression or agitation: when a dog “raises its hackles” by involuntarily elevating the hairs on its neck and back, it is sending a clear signal to challengers to stay away.

Yet even though fur serves these many important purposes, a number of mammal lineages have evolved hair that is so sparse and fine as to serve no function. Many of these creatures live underground or dwell exclusively in the water.
FURRY VS. NAKED

Naked human skin is better at ridding the body of excess heat than is fur-covered skin. Mammals possess three types of glands for the purpose: apocrine, eccrine and sebaceous. In most mammals the outermost layer of the skin, known as the epidermis, contains an abundance of apocrine glands. These glands cluster around hair follicles and coat the fur in a layer of oily sweat. Evaporation of this sweat, which cools the animal by drawing heat away from the skin, occurs at the surface of the fur. But the more the animal perspires, the less effectively it eliminates heat because the fur becomes matted, hampering evaporation. In the human epidermis, in contrast, eccrine glands predominate. These glands reside close to the skin surface and discharge thin, watery sweat through tiny pores. In addition to evaporating directly from the skin surface, this eccrine sweat vaporizes more readily than apocrine sweat, thus permitting improved cooling.

In subterranean mammals, such as the naked mole rat, hairlessness evolved as a response to living in large underground colonies, where the benefits of hair are superfluous because the animals cannot see one another in the dark and because their social structure is such that they simply huddle together for warmth. In marine mammals that never venture ashore, such as whales, naked skin facilitates long-distance swimming and diving by reducing drag on the skin’s surface. To compensate for the lack of external insulation, these animals have blubber under the skin. In contrast, semiaquatic mammals—otters, for example—have dense, waterproof fur that traps air to provide positive buoyancy, thus decreasing the effort needed to float. This fur also protects their skin on land.

The largest terrestrial mammals—namely, elephants, rhinoceroses and hippopotamuses—also evolved naked skin because they are at constant risk of overheating. The larger an animal is, the less surface area it has relative to overall body mass and the harder it is for the creature to rid its body of excess heat. (On the flip side, mice and other small animals, which have a high surface-to-volume ratio, often struggle to retain sufficient heat.) During the Pleistocene epoch, which spans the time between two million and 10,000 years ago, the mammoths and other relatives of modern elephants and rhinoceroses were “woolly” because they lived in cold environments, and external insulation helped them conserve body heat and lower their food intake. But all of today’s megaherbivores live in sweltering conditions, where a fur coat would be deadly for beasts of such immense proportions.

Human hairlessness is not an evolutionary adaptation to living underground or in the water—the popular embrace of the so-called aquatic ape hypothesis notwithstanding [see box on opposite page]. Neither is it the result of large body size. But our bare skin is related to staying cool, as our superior sweating abilities suggest.

Sweating It Out

Keeping cool is a big problem for many mammals, not just the giant ones, especially when they live in hot places and generate abundant heat from prolonged walking or running. These animals must carefully regulate their core body temperature because their tissues and organs, specifically the brain, can become damaged by overheating.

Mammals employ a variety of tactics to avoid burning up: dogs pant, many cat species are most active during the cooler evening hours, and many antelopes can off-load heat from the blood in their arteries to blood in small veins that has been cooled by breathing through the nose. But for primates, including humans, sweating is the primary strategy. Sweating cools the body through the production of liquid on the skin’s surface that then evaporates, drawing heat energy away from the skin in the process. This whole-body cooling mechanism operates according to the same principle as an evaporative cooler (also known as a swamp cooler), and it is highly effective in preventing the dangerous overheat-
cooling diminishes as an animal’s coat becomes wet and matted with this thick, oily sweat. The loss of efficiency arises because evaporation occurs at the surface of the fur, not at the surface of the skin itself, thus impeding the transfer of heat. Under conditions of duress, heat transfer is inefficient, requiring that the animal drink large amounts of water, which may not be readily available. Fur-covered mammals forced to exercise energetically or for prolonged periods in the heat of day will collapse from heat exhaustion.

Humans, in addition to lacking fur, possess an extraordinary number of eccrine glands—between two million and five million—that can produce up to 12 liters of thin, watery sweat a day. Eccrine glands do not cluster near hair follicles; instead they reside relatively close to the surface of the skin and discharge sweat through tiny pores. This combination of naked skin and watery sweat that sits directly atop it rather than collecting in the fur allows humans to eliminate excess heat very efficiently. In fact, according to a 2007 paper in Sports Medicine by Daniel E. Lieberman of Harvard University and Dennis M. Bramble of the University of Utah, our cooling system is so superior that in a marathon on a hot day, a human could outcompete a horse.

**Showing Some Skin**

Because humans are the only primates that lack coats and have an abundance of eccrine glands, something must have happened since our hominid lineage diverged from the line leading to our closest living relative, the chimpanzee, that favored the emergence of naked, sweaty skin.

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**Why the Aquatic Ape Theory Doesn’t Hold Water**

Among the many theories that attempt to explain the evolution of naked skin in humans, the aquatic ape theory (AAT)—which posits that humans went through an aquatic phase in their evolution—has attracted the most popular attention and support. First enunciated by English zoologist Sir Alister Hardy in a popular scientific article in 1960, the AAT later found a champion in writer Elaine Morgan, who continues to promote the theory in her lectures and writings. The problem is, the theory is demonstrably wrong.

The AAT holds that around five million to seven million years ago tectonic upheavals in the rift Valley of East Africa cut early human ancestors off from their preferred tropical forest environments. As a result, they had to adapt to a semiaquatic life in marshes, along coasts and in floodplains, where they lived for about a million years. Evidence of this aquatic phase, Morgan argues, comes from several anatomical features humans share with aquatic and semiaquatic mammals but not with savanna mammals. These traits include our bare skin, a reduced number of apocrine glands, and fat deposits directly under the skin.

The AAT is untenable for three major reasons. First, aquatic mammals themselves differ considerably in the degree to which they exhibit Morgan’s aquatic traits. Thus, there is no simple connection between, say, the amount of hair an animal has and the environment in which it lives. Second, the fossil record shows that watery habitats were thick with hungry crocodiles and aggressive hippopotamuses. Our small, defenseless ancestors would not have stood a chance in an encounter with such creatures. Third, the AAT is overly complex. It holds that our forebears shifted from a terrestrial way of life to a semiaquatic one and then returned to living on terra firma full-time. As John H. Langdon of the University of Indianapolis has argued, a more straightforward interpretation of the fossil record is that humans always lived on land, where the driving force behind the evolution of naked skin was climate change that favored savanna grasslands over woodlands. And from a scientific perspective, the simplest explanation is usually the correct one.—**N.J.**
Although the fossil record does not preserve any direct evidence of ancient human skin, scientists can estimate when nakedness evolved based on other fossil clues. Protohumans such as the australopithecines (left) probably led relatively sedentary lives, as today's apes do, because they lived in or near wooded environments rich in plant foods and freshwater. But as woodlands shrank and grasslands expanded, later ancestors, such as Homo ergaster (right), had to travel ever farther in search of sustenance—including meat. This species, which arose by 1.6 million years ago, was probably the first to possess naked skin and eccrine sweat, which would have offset the body heat generated by such elevated activity levels.

Perhaps not surprisingly, the transformation seems to have begun with climate change.

By using fossils of animals and plants to reconstruct ancient ecological conditions, scientists have determined that starting around three million years ago the earth entered into a phase of global cooling that had a drying effect in East and Central Africa, where human ancestors lived. With this decline in regular rainfall, the wooded environments favored by early hominids gave way to open savanna grasslands, and the foods that our ancestors the australopithecines subsisted on—fruits, leaves, tubers and seeds—became scarcer, more patchily distributed and subject to seasonal availability, as did permanent sources of freshwater. In response to this dwindling of resources, our forebears would have had to abandon their relatively leisurely foraging habits for a much more consistently active way of life just to stay hydrated and obtain enough calories, traveling ever longer distances in search of water and edible plant foods.

It is around this time that hominids also began incorporating meat into their diet, as revealed by the appearance of stone tools and butchered animal bones in the archaeological record around 2.6 million years ago. Animal foods are considerably richer in calories than are plant foods, but they are rarer on the landscape. Carnivorous animals therefore need to range farther and wider than their herbivorous counterparts to procure a sufficient amount of food. Prey animals are also moving targets, save for the occasional carcass, which means predators must expend that much more energy to obtain their meal. In the case of human hunters and scavengers, natural selection favored the apelike proportions of the australopithecines, who still spent some time in the trees, into a long-legged body built for sustained striding and running. (This modern form also no doubt helped our ancestors avoid becoming dinner themselves when out in the open.)

But these elevated activity levels came at a price: a greatly increased risk of overheating. Beginning in the 1980s, Peter Wheeler of Liverpool John Moores University in England published a series of papers in which he simulated how hot ancestral humans would have become out on the savanna. Wheeler's work, together with research my colleagues and I published in 1994, shows that the increase in walking and running, during which muscle activity builds up heat internally, would have required that hominids both enhance their eccrine sweating ability and lose their body hair to avoid overheating.

When did this metamorphosis occur? Although the human fossil record does not preserve skin, researchers do have a rough idea of when our forebears began engaging in modern patterns of movement. Studies conducted inde-
Homo ergaster was the first hominid to possess long, striding legs, seen here in the 1.6-million-year-old Turkana Boy skeleton. Such elongated limbs facilitated sustained walking and running.

Going furless was not merely a means to an end; it had profound consequences for subsequent phases of human evolution. Rogers's estimate thus provides a minimum age for the dawn of nakedness.

Skin Deep
Less certain than why and when we became naked is how hominids evolved bare flesh. The genetic evidence for the evolution of nakedness has been difficult to locate because many genes contribute to the appearance and function of our skin. Nevertheless, hints have emerged from large-scale comparisons of the sequences of DNA “code letters,” or nucleotides, in the entire genomes of different organisms. Comparison of the human and chimp genomes reveals that one of the most significant differences between chimp DNA and our own lies in the genes that code for proteins that control properties of the skin. The human versions of some of those genes encode proteins that help to make our skin particularly waterproof and scuff-resistant—critical properties, given the absence of protective fur. This finding implies that the advent of those gene variants contributed to the origin of nakedness by mitigating its consequences.

The outstanding barrier capabilities of our skin arise from the structure and makeup of its outermost layer, the stratum corneum (SC) of the epidermis. The SC has what has been described as a bricks-and-mortar composition. In this arrangement, multiple layers of flattened
dead cells called corneocytes, which contain the
protein keratin and other substances, are the
bricks; ultrathin layers of lipids surrounding
each of the corneocytes make up the mortar.

Most of the genes that direct the development
of the SC are ancient, and their sequences are
highly conserved among vertebrates. That the
genesis underlying the human SC are so distinc-
tive signifies, therefore, that the advent of those
genese was important to survival. These genes en-
code the production of a unique combination of
proteins that occur only in the epidermis, includ-
ing novel types of keratin and involucrin. A num-
ber of laboratories are currently attempting to
unravel the precise mechanisms responsible for
regulating the manufacture of these proteins.

Other researchers are looking at the evolution
of keratins in body hair, with the aim of deter-
mining the mechanisms responsible for the
sparseness and fineness of body hair on the sur-
f ace of human skin. To that end, Roland Moll of
Philips University in Marburg, Germany, and
his colleagues have shown that the keratins pre-
 sent in human body hair are extremely fragile,
which is why these hairs break so easily com-
pared with those of other animals. This finding,
detailed in a paper Moll published in 2008, sug-
gests that human hair keratins were not as im-
portant to survival as the hair keratins of other
primates were over the course of evolution and
thus became weak.

Another question geneticists are eager to an-
swer is how human skin came to contain such an
abundance of eccrine glands. Almost certainly
this accumulation occurred through changes in
the genes that determine the fate of epidermal
stem cells, which are unspecialized, in the em-
bryo. Early in development, groups of epidermal
stem cells in specific locations interact with cells
of the underlying dermis, and genetically driven
chemical signals within these niches direct the
differentiation of the stem cells into hair follicles,
eccrine glands, apocrine glands, sebaceous
glands or plain epidermis. Many research groups
are now investigating how epidermal stem cell
 niches are established and maintained, and this
work should clarify what directs the fate of em-
byronic epidermal cells and how more of these
cells become eccrine sweat glands in humans.

OF LICE AND MEN
In recent years researchers have looked to lice for clues to why
humans lost their body hair. In 2003 Mark Pagel of the University
of Reading in England and Walter Bodmer of John Radcliffe Hospital
in Oxford proposed that humans shed their fur to rid their bodies
of disease-spreading lice and other fur-dwelling parasites and to
advertise the health of their skin. Other investigators have studied
head and body lice for insight into
how long after becoming bare-
skinned our ancestors began to
cover up with clothing.

Although body lice feed on
blood, they live on clothing. Thus,
the origin of body lice provides a
minimum estimate for the dawn
of hominid garb. By comparing gene
sequences of organisms, investi-
gators can learn roughly when the
species arose. Such analyses in lice
indicate that whereas head lice
have plagued humans from the
start, body lice evolved much
later. The timing of their appear-
ance hints that humans went
naked for more than a million
years before getting dressed.

Not Entirely Nude
However it was that we became naked apes, evolu-
tion did leave a few body parts covered. Any
explanation of why humans lost their fur there-
fore must also account for why we retain it in
some places. Hair in the armpits and groin prob-
bly serves both to propagate pheromones (chemi-
cals that serve to elicit a behavioral response
from other individuals) and to help keep these
areas lubricated during locomotion. As for hair
on the head, it was most likely retained to help
shield against excess heat on the top of the head.
That notion may sound paradoxical, but having
dense hair on the head creates a barrier layer of
air between the sweating scalp and the hot sur-
f ace of the hair. Thus, on a hot, sunny day the
hair absorbs the heat while the barrier layer of air
remains cooler, allowing sweat on the scalp to
evaporate into that layer of air. Tightly curled
hair provides the optimum head covering in this
regard, because it increases the thickness of the
space between the surface of the hair and the
scalp, allowing air to blow through. Much
remains to be discovered about the evolution of
human head hair, but it is possible that tightly curled hair was the original condition in modern humans and that other hair types evolved as humans dispersed out of tropical Africa.

With regard to our body hair, the question is why it is so variable. There are many populations whose members have hardly any body hair at all and some populations of hirsute folks. Those with the least body hair tend to live in the tropics, whereas those with the most tend to live outside the tropics. Yet the hair on these non-tropical people provides no warmth to speak of. These differences in hairiness clearly stem to some extent from testosterone, because males in all populations have more body hair than females do. A number of theories aimed at explaining this imbalance attribute it to sexual selection. For example, one posits that females prefer males with fuller beards and thicker body hair because these traits occur in tandem with virility and strength. Another proposes that males have evolved a preference for females with more juvenile features. These are interesting hypotheses, but no one has actually tested them in a modern human population; thus, we do not know, for instance, whether hairy men are in fact more vigorous or fecund than their sleeker counterparts. In the absence of any empirical evidence, it is still anybody's guess why human body hair varies the way it does.

**Naked Ambitions**

Going furless was not merely a means to an end; it had profound consequences for subsequent phases of human evolution. The loss of most of our body hair and the gain of the ability to dissipate excess body heat through eccrine sweating helped to make possible the dramatic enlargement of our most temperature-sensitive organ, the brain. Whereas the australopithecines had a brain that was, on average, 400 cubic centimeters—roughly the size of a chimp's brain—*H. ergaster* had a brain twice that large. And within a million years the human brain swelled another 400 cubic centimeters, reaching its modern size. No doubt other factors influenced the expansion of our gray matter—the adoption of a sufficiently caloric diet to fuel this energetically demanding tissue, for example. But shedding our body hair was surely a critical step in becoming brainy.

Our hairlessness also had social repercussions. Although we can technically raise and lower our hackles when the small muscles at the base of our hair follicles contract and relax, our body hairs are so thin and wispy that we do not put much of a show compared with the displays of our cats and dogs or of our chimpanzee cousins. Neither do we have the built-in advertising—or camouflage—offered by zebra stripes, leopard spots, and the like. Indeed, one might even speculate that universal human traits such as social blushing and complex facial expressions evolved to compensate for our lost ability to communicate through our fur. Likewise, body paint, cosmetics, tattoos and other types of skin decoration are found in various combinations in all cultures, because they convey group membership, status and other vital social information formerly encoded by fur. We also employ body postures and gestures to broadcast our emotional states and intentions. And we use language to speak our mind in detail. Viewed this way, naked skin did not just cool us down—it made us human.

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