Center for Academic Research & Training in Anthropogeny (CARTA)

Unique Features of Human Skin

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Chairs:
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ABSTRACTS

Skin: A Window into the Evolution of the Human Super-Organism

Richard Gallo, UC San Diego

All life must establish an external barrier that simultaneously interacts with and defends itself from the outside world. Skin is our most important barrier, and human skin has many functions that are in common with other animals but also unique to our species. General skin functions include sensing danger, regulation of internal temperature, maintaining fluid balance and mounting visual sexual displays. Human life also depends on the capacity of our skin to protect us from specific environmental dangers and pathogens unique to us. The central teachings of the medical specialty of Dermatology have been that health is defined by the capacity of skin to perform all these functions while constantly resisting entry of microbial pathogens. However, a recent revolution in understanding skin biology has revealed that normal skin functions are performed not only by cells of human origin, but also by specialized microbes that have co-evolved with us to live in a mutually beneficial relationship. This presentation will provide an overview of the multiple cell types, both human and microbial, that comprise the human skin super-organism. Understanding this relationship changes how we should think about evolution, gene transfer and the impact of current hygiene and antibiotic therapies.

The Genetics of Skin Pigmentation

Mark Shriver, Pennsylvania State University

How many genes determine human skin color? This question is deceptively simple and direct. Although there are over 100 genes that can lead to clinically-significant pigmentary disorders such as albinism, only four genes are responsible for most of the skin color differences between West African and European populations. The genes that underlie skin color differences between populations are usually also genes that can cause pigmentary disorders. Genes that affect skin color variation in humans also generally affect pigmentary variation in other species. Thus, evolutionary approaches to understanding which genes affect pigmentation can provide important insights into both normal development and pathophysiology. Likewise, genetic and genomic investigations can help illuminate where and when the genes that affect contemporary skin color levels changed and, ultimately, which evolutionary forces shaped the wide range of skin colors we see today.

The Skin and Ultraviolet Radiation: Effects on DNA and Carcinogenesis

James Cleaver, UC San Francisco

The hereditary syndromes xeroderma pigmentosum (XP) and Cockayne syndrome (CS) have mutations in the nucleotide excision repair (NER) pathway. XP shows an extremely high incidence of solar-induced skin cancer and in some cases neurological disease. CS shows photosensitivity, developmental disorders and neurological disease, but not cancer. XP is associated with mutations in components of the global genome repair (GGR) branch of NER that repairs regions of the genome that do not code for proteins and the non-transcribed strands of expressed protein-coding genes. CS is associated with mutations in components of the transcription coupled repair (TCR) pathway that repair the transcribed strand of protein-expressing genes. Studies of mutagenesis from UV light in XP and CS cells, and squamous cell carcinomas from XP patients, show that defective GGR predisposes to high mutation frequencies and solar-induced skin cancer, despite efficient TCR which does not protect XP patients; defects in TCR, however, only increases cell killing from UV light, but reportedly does not increase mutations in transcribed human chromosomal genes.

Human Skin: Sweating, Thermoregulation, and Water Balance

Michael Sawka, Georgia Institute of Technology

Humans are tropical animals, and given access to shade and adequate water, healthy persons can tolerate extended exposure to any naturally occurring climatic heat stress. This talk examines the role of skin in human thermoregulation as a potentially important evolutionary factor to modern man. Two strong selective factors for survival in early hominins were the ability to forage during peak daily heat when their predators were not a threat, and the capability for persistence hunting (track and pursue prey to cause hyperthermia-induced exhaustion of prey). Unlike most animals, humans can thermoregulate while performing physical exertion so that body core temperature elevates primarily as a function of metabolic rate (exercise intensity) and is only slightly influenced by the climate, if sufficient biophysical heat exchange is possible (e.g., convection, evaporation). Human phenotypes that contribute importantly to thermoregulation include: upright posture, large skin surface area, active skin vasodilation, eccrine sweating and sweat sodium reabsorption, and sensory information. Although these characteristics enhance thermoregulation, they often impose cardiovascular challenges during physical exertion. However, several skin sensory mechanisms help optimize the balance between thermoregulation and cardiovascular strain.

Ecology and Evolution of the Skin Microbiome

Rob Knight, UC San Diego

Like the microbiome at other human body sites, the human skin microbiome is remarkably diverse. Unlike our other microbiomes, the skin microbiome is in intimate contact with our physical environment, leading to a bidirectional transfer of microbes. Here I describe some of the functions of the human skin microbiome, how it and its complex chemical repertoire differ from that of other animals that have been studied including chimpanzees, dogs, amphibians and reptiles, and what we are starting to learn about how microbiomes evolve into specialized evolutionary niches. The findings have important implications for the idea that modern techniques such as antibiotics and C-sections, and keeping ourselves too sealed in energy-efficient buildings and cars, may contribute to immunological problems by cutting us off from the rich microbial environment with which we have coevolved.

Of Lice and Men: The Molecular Evolution of Human Lice

Mark Stoneking, Max Plank Institute for Evolutionary Anthropology

Lice are ubiquitous parasites, as they infest practically all mammals and even birds. However, while most mammals are parasitized by just one type of lice, humans are blessed with three different kinds of lice, informally known as the head louse, the body louse, and the pubic louse. Moreover, these lice are all obligate parasites of humans, meaning that they cannot live on other animals, and they cannot exist for more than ~24 hours away from the human body without feeding. Thus, these human lice are intimately associated with humans, and the spread of human lice around the world reflects human migrations, so by studying genetic variation in lice we might learn more about such human migrations. However, it turns out that human lice are potentially even more fascinating in that the differences among the three types of human lice probably reflect important developments during human evolution. During my talk I will discuss why this is likely to be the case, and what we can learn about these important developments by studying the molecular evolution of human lice.

Subcutaneous Fat in Humans

Chris Kuzawa, Northwestern University

Humans are unusually fat as a species, and this trait is particularly evident at birth, when our newborns enter the world with a large layer of “baby fat.” One proposal to explain our large fat stores is that they evolved as a “brain battery,” or backup energy supply to buffer our costly brains, which are vulnerable to energy shortfall. Although humans are especially fat at birth, we lose much of our abundant fat stores after weaning, and human adiposity reaches its lowest level during childhood when brain costs are at their peak. If our large brains help explain the evolution of human baby fat, what accounts for these developmental changes in adiposity, and our relatively lean state by childhood? In this talk, I will argue that human body fat co-evolved not just with the energetically-demanding and vulnerable brain, but also with the cultural strategies that humans use to buffer offspring intake. The human infant’s need for ample baby fat traces to the fact that the main causes of nutritional stress at this age are infections, which force a reliance on onboard energy by reducing appetite and impairing digestion. As the child’s immune system matures, nutritional stress now traces to ecological factors that influence the group’s food availability, which are buffered through social and cultural strategies like food sharing, fall back foods, and cooperative childcare. Thus, our brainy newborns are forced to rely upon their own onboard energy reserves due to common infections, but by childhood we are less reliant upon this resource as a result of another uniquely human buffering system: food sharing and our cooperative strategy of caring for and feeding our young.

Evolution of Hair Follicles, Mammary Glands, and Sweat Glands in Humans and Other Mammals

Sarah E. Millar, University of Pennsylvania

Skin appendages such as hair follicles, mammary glands and sweat glands develop during embryonic life through a series of interactions between surface epithelial cells and underlying mesenchymal cells. In each case, these events are regulated by similar sets of conserved cell-cell signaling pathways. These observations suggest that diverse appendages may have evolved from a common precursor. Most evidence from evolutionary studies suggests that this precursor was a simple glandular structure whose initial function was to prevent organismal dehydration and permit greater independence from an aquatic environment. Secretions from such glands, containing water, salts and anti-microbial peptides, may have first been used to help hydrate and protect thin-walled eggs, and later developed a nutrient function to support the growth of hatchlings. Consistent with this hypothesis, the gene encoding the anti-microbial enzyme lysozyme became duplicated during evolution, and the duplicated copy evolved into a-lactalbumin, a whey protein unique to the mammary gland. Specialization of simple glands resulted in the formation of eccrine sweat glands, and hair follicles with associated apocrine sweat glands and sebaceous glands. In some mammals, such as the echidna (spiny anteaters), mammary secretions are conveyed to the young via specialized hairs, suggesting that hair may first have evolved for this purpose, and that mammary glands may have originally developed from apocrine glands associated with hair follicles. In line with this, mammary glands and hair follicles are both unique to mammalian species, and, while marsupials and eutherian mammals have specialized nipples developed to deliver milk, in koala bears each nipple retains a tuft of hairs. Most mammals, including humans, have hairless nipples, which may have been a subsequent evolutionary adaptation to facilitate feeding. I will summarize our current state of knowledge of the molecular events that control hair follicle, mammary gland and sweat gland development, and will highlight major questions still remaining. Using the mammary gland as an example, I will discuss how evolutionary pressures may have driven specific changes in molecular pathways to permit organ diversification, and further refinements in glandular number and location that permitted efficient feeding of newborn mammals including humans.

Naked, Colorful Skin and Its Role in Human Social Interactions

Nina Jablonski, Pennsylvania State University

The evolution of mostly naked skin in the human lineage heralded major changes in the biological and social functions of skin. The evolution of enhanced barrier functions of the epidermis made it possible for functionally naked skin to repel water, resist abrasion, and combat harmful microbes and ectoparasites. Naked skin also changed the nature of human social interactions, both at a distance and at close quarters, although many of the details of exactly what happened when are not yet known. With raising of the hackles precluded, displays of fear, anger, and excitement became focused more strongly on facial expressions. With the loss of most body hair, grooming became more focused on scalp hair and the face, and huddling for thermoregulation probably became more important. Erogenous zones and increased sensitivity of facial skin promoted infant-mother and pair bonding. Naked integument almost certainly became a canvas for social expression early in the history of *Homo sapiens*, if not earlier, and the communication functions of temporarily and permanently decorated skin have only increased over the millennia. As visually oriented primates, humans attend closely to the appearance of skin and make assessments of age, health, and group membership based on it.