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In unpacking the Pandora's box of hygiene, the author looks into its
ancient evolutionary history and its more recent human history.
Within the box, she finds animal behaviour, dirt, disgust and many
diseases, as well as illumination concerning how hygiene can be
improved. It is suggested that hygiene is the set of behaviours that ani-
imals, including humans, use to avoid harmful agents. The author
argues that hygiene has an ancient evolutionary history; and that most
animals exhibit such behaviours because they are adaptive. In
humans, responses to most infectious threats are accompanied by sen-
tations of disgust. In historical times, religions, social codes and the
sciences have all provided rationales for hygiene behaviour. However,
the author argues that disgust and hygiene behaviour came first, and
that the rationales came later. The implications for the modern-day
practice of hygiene are profound. The natural history of hygiene needs
to be better understood if we are to promote safe hygiene and, hence,
win our evolutionary war against the agents of infectious disease.

Key Words: Dirt; Disgust; Evolution; Hygiene; Hygiene behaviour;
Natural history; Social codes

HYGIENE: FILTHY SECRETS?
Hygiene is a complex Pandora's box of a topic, full of doubt-
ful stuff we'd rather not confront. It contains filth and dis-
case, bugs, germs and grubby private habits. It contains ideas
about obsessive cleanliness, dirty old men, and coercive states
enforcing mental and racial hygiene. On the other hand, it
also contains images of sparkling kitchens and bathrooms;
scrubbed, perfumed and well-groomed people; and an endless
array of cleaning products. Hygiene sits uneasily between
filth and cleanliness; between the private and the public; and
between the scientific and the moral or religious domains of
society. While we all agree that hygiene is important,
improving it becomes difficult if we cannot agree on what it
means or understand where it comes from.

So what, then, is hygiene? Ask a mother at home with her
toddler and she will tell you hygiene is about cleanliness and
tidiness. Ask a microbiologist and she will tell you that
hygiene is about avoiding germs and disease. Ask an historian
and he will tell you that hygiene first meant health, and
gradually became more private and more specific over the
two millennia for which we have records. An anthropologist
might look at hygiene in one of two ways: the emic and the
etic – the emic being the perspective of the ordinary person
practicing their scrubbings and anointings, and the etic being
the perspective of the scientist, objectively studying and
categorizing human habits (1).

In the present article, I suggest that to make sense of all
these perspectives on hygiene, we need to understand its nat-
ural history. I propose that hygiene has its origins with our
earliest animal ancestors, and that its evolution can be traced
to the peculiar roles it plays today in our complex cultures. I
suggest that hygiene has biological origins as the set of behav-
iors that serves to avoid infection, and that it is exhibited by
most animals. I show that hygiene remains partly instinctive
in humans, driven by an innate sense of the need to avoid
that which disgusts. Finally, I suggest that by understanding
this history of hygiene, we can find powerful means to
improve it and, hence, help to defeat some of our ancient
natural enemies – the agents of infectious disease.

FOUR BILLION YEARS OF HYGIENE
Far from being uniquely human, I argue that the need for
hygiene arose almost as soon as animal life did. The earliest
single-celled organisms to evolve represented a temptation to
other organisms – parasites that wanted to use them for shel-
ter, as a consumable resource or as a reproductive aid. Of
course, we have no records of these earliest parasites, but per-
haps they were akin to the modern-day phage, which are now

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ubiquitous parasites on bacteria; “all the world's a phase”, as one microbiologist put it. Lysogenic phages insert themselves into their host's cellular machinery and use it to reproduce themselves (2). And as soon as the first thieving parasites evolved, the arms race began (3). Early unicellular life forms learned to defend themselves by building capsules that resisted attack and by developing cellular mechanisms for evicting invaders. Indeed, bacteria have evolved many specific genetic mechanisms to avoid the depredations of these viral phage parasites – for example, by phase varying the receptors that allow phage to attach to them (4).

But can the deployment of cellular defences against parasitization be said to be an example of hygiene? Perhaps it might rather make sense to save the term ‘hygiene’ for behaviour or movement that is directed at avoiding disease. Which was the first animal to do this? We don't know the answer, but because the task of avoiding parasites came early in evolution, evolving behaviours to avoid them probably started very early too. We know that Cnidarians – some of the simplest multicellular animals – can eject toxins from their body cavities in an early form of emesis (5). Simple animals, such as the nematode worm, demonstrate disease avoidance behaviours. With only 302 neurons, Caenorhabditis elegans can distinguish between innocuous and pathogenic Bacillus thuringiensis, and actively avoids the latter (6). Bullfrog tadpoles avoid other tadpoles with candidiasis (7), and lobsters avoid other lobsters with viral infections (8). Whitefish (Coregonus species) have likewise evolved mechanisms to sense and respond to the presence of Pseudomonas fluorescens, a virulent egg parasite, and to avoid it (9). Ants groom themselves to remove fungal pathogens (10), and bats groom to remove ectoparasites (11), as do other mammals, fish and birds. Some chimpanzees have been seen engaging in penile hygiene after mating (12), and mother chimps have been observed wiping the behinds of their infants (13). Birds and mammals keep their nests free of fecal material, while raccoons, badgers, lemurs and tapirs use latrines. Sheep avoid grazing near fecal remains, and one reason that reindeer and caribou migrate is to avoid parasite buildup in heavily dunged fields (14).

So who taught the animals hygiene? Who taught them about the germ theory of disease and how to avoid the places where parasites are found? No one, of course. Rather, their teacher was evolution. Animals that were good at behaving in ways that avoided the ravages of micro- and macro-organisms were better at passing on their 'hygiene genes' than those who didn't exhibit such behaviours. Gradually, hygienic behaviours were selected for, often becoming an instinctive part of the behavioural repertoire, much like 'flight' or 'freeze' became instinctive responses to the threat of predation.

So, do humans have these hygiene instincts? After a series of research projects looking into hygiene motivation around the world (eg, India, Africa, Netherlands and the United Kingdom), we found evidence for this idea (15). When interviewed about the ‘why’ of their hygiene habits, we found that people found it hard to explain their reactions to certain stimuli. Faced with feces, bodily fluids, rotten food and creepy-crawlies, people would say, “I can’t explain it – they are just yuk!” It seemed that there was a powerful sense of disgust involved, which compelled people to avoid nasty, sticky, oozing, teeming stuff. We hypothesized that disgust in humans evolved to serve hygiene; in other words, to do the job of making people avoid disease. We suggested that such behaviours happen largely independent of conscious decision-making, and that disgusting cues should almost automatically lead to hygiene behaviours.

**THAT'S DISGUSTING!**

We tested our hypothesis that disgust evolved to help humans avoid disease in a Web-based experiment on the British Broadcasting Corporation's Web site. The site showed pictures appearing in random order, and participants were asked to rate how disgusting they were on a scale of one to five. Within the series were seven pairs of photos made to be similar in appearance, but with a manipulation to heighten the disease relevance of one of the pictures. Hence, for example, a bowl of goo that was bright blue was contrasted with greeny, red-flecked goo to look like bodily fluids. An empty tray was contrasted with a full one, and disgust scores for a photo of a healthy-looking person were compared with the scores for an image of the same person manipulated to look spotty and feverish. The study was completed by more than 40,000 participants from 165 countries.

The results were consistent with the hypothesis; all of the images with disease relevance scored as more disgusting than those with none (16). Disgust scores declined with the age of the respondent and were significantly higher overall in women (which may be due to women’s enhanced role in child care – that is, she needs to have enough disgust to protect both herself and her dependent infant). We concluded that disgust is likely to be common to humans in all cultures, and that it serves to help us avoid those things that were associated with the risk of disease in our evolutionary past. Thus, disgust is a component of our hygiene instincts. (It is still possible to participate in the experiment by visiting <www.bbc.co.uk/science/humanbody/mind/surveys/disgust>.)

**HYGIENE IN HISTORY**

If hygiene is a natural function of the human psyche, originating from before we were human, then we would expect to find that, far from revelling in muck and dirt, prehistoric man would have behaved hygienically. He would have groomed himself to remove parasites and kept his living areas free from the humid wastes that can encourage their growth, survival and transmission. He would have defecated away from living areas and avoided close contact with the bodily fluids of others (except when there were overriding reasons to do so, such as when mating or caring for a child). He would have tended to avoid those of his fellows with signs of sickness (unless they were related) and also strangers (because they might have been carrying novel diseases).

Hygiene behaviours do not fossilize, so evidence has to be sought elsewhere. Neanderthals apparently used seashell tweezers to pluck hair (17), and early cave paintings show beardless men, suggesting that grooming began early, perhaps to remove facial parasites. Hygiene artifacts, such as combs, are among the earliest material goods recovered. A ceremonial ivory comb in the collection of the Metropolitan Museum of New York dates back to predynastic Badarian Egypt 3200 BCE. Excavations of the earliest city states of the Indus basin dating from 3000 BC found drainage and toilet structures. Burying the dead can also be thought of as early human
hygiene behaviour (although there were probably further reasons for all of these practices, other than just instinctive disease avoidance).

Cleansing aids have a long history. I suspect that the early cavewoman probably discovered that she could remove stubborn stains with the washed-out residue of animal fat and ash from roasting meat. However, the first recorded use of soap is in Phoenician times, although the use of oil and a scraper, known as a strigil, was a more common way of cleaning the skin in the Greek and Roman eras. Roman plumbing and toilet facilities are, of course, legendary.

If early humans kept themselves and their surroundings clean, did they also avoid diseased others? An ancient Mesopotamian text shows how an exorcist explained the sickness of a patient: “He has come into contact with a woman of unclean hands … or his hands have touched one of unclean body” (18). A Babylonian letter from the 17th century BC counsels not sharing a chair, a bed or a cup with a lady suffering from a disease (19). It is not clear from these texts whether the concern was the avoidance of contagion or of immoral women. Perhaps the gut feeling of disgust provided the motive to avoid the sick, and the search for a rational explanation for why this was a good thing to do came later.

Certainly, humans have continued to find rationales for what they ‘felt’ to be ‘right’ through to the present day. Sometimes, the explanations were supernatural or religious, sometimes moral, sometimes naturalistic or scientific. Purification rituals are a common feature of religions (20). In Mesopotamian times, ‘Kippur’ was purification through the application and wiping off of a flour paste. It came to mean purification in general, as in the Hebrew word ‘Kippur’. The Laws of Manu, part of the four sacred Vedas of Hindu scripture circa 200 BC, prescribed the avoidance of the 12 impurities of the body viz “Oily exudations, semen, blood, urine, feces, the mucus of the nose, ear wax, phlegm, tears, the rheum of the eyes and sweat ...” (The Laws of Manu [5:135]).

Christian morality became inextricably linked with hygiene. What was clean and ‘pure’ was what was morally right: “Wash me clean of my guilt, purify me from my sin” (Psalms 51:2).

The Koran agreed: “God loves those that turn to him in repentance and strive to keep themselves clean” (2:223).

Greek history relates both supernatural and naturalistic rationales for hygienic behaviour. The word ‘miasma’ originally meant ‘stain’ or sins that offended the Gods, but came to mean ‘stain’ or sins that offended the Gods, but came to mean ‘miasma’ or ‘cultural body’, a more common way of cleaning the skin in the Greek and Roman eras. Roman plumbing and toilet facilities are, of course, legendary.

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Greek history relates both supernatural and naturalistic rationales for hygienic behaviour. The word ‘miasma’ originally meant ‘stain’ or sins that offended the Gods, but came to be used as a term for the foul airs and atmospheres that caused disease. It was the Greeks, however, who coined the word ‘hygiene’. Originally, the Goddess Hygieia, granddau-
also led us to other ancient motives for cleanliness: to care for and nurture children, to avoid social disapprobation, to do what others are doing, to be more attractive. Such motives can also be harnessed in the service of hygiene promotion.)

Although we humans are proud of our rationality, we cannot explain the whole of our behaviour through conscious, logical calculation. Because human symbolic thought arrived relatively recently and the understanding of germs is very recent (and not yet ubiquitous), hygienic behaviour cannot be explained purely as a conscious response to disease threats. Rather, the scrubbings, purgings, tidyings and separations we make are a product of our natural history. They have their origins with our most ancient ancestors, the first animals, who practiced hygiene to avoid being eaten from within by parasites. These animals knew nothing about the germ theory of disease. In the same way, societies throughout history have been hygienic without the discoveries of Pasteur or the molecular biologists. Science continues to zero in on, to make more precise, what we ‘feel’ to be right: dirt causes disease. But as a species, we are naturally hygienic – in fact, we ‘knew’ that all along.

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