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A natural history of hygiene

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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 animals, 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 sensations 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 doubtful stuff we'd rather not confront. It contains filth and disease, 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

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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 natural 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 behaviours 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 the natural 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 parasitic that wanted to use them for shelter, as a consumable resource or as a reproductive aid. Of course, we have no records of these earliest parasites, but perhaps they were akin to the modern-day phage, which are now ubiquitous parasites on bacteria; "all the world's a phage", as one microbi-

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ologist 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 macroparasites 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 greenish, red-flecked goo to look like bodily fluids. An empty train 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 to 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 stub-

born 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, 'Kippuru' 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 twelve impurities of the body viz "Oily exudations, semen, blood, urine, feces, the mucous of the nose, ear wax, phlegm, tears, the rheum of the eyes and sweat ..." (135 {?}).

4 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 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, granddaughter of Apollo, headed a local healing cult, which spread across the Hellenic world following the plagues of 429 BC and 427 BC. Hippocrates (460 BC to 377 BC) exhorted that to stay healthy, one needed order and balance in all things and, above all, to stay away from the 'Airs, Waters and Places' that contained the dangerous miasmas that were responsible for disease (21). The miasma idea hopped from the Greeks via Galen and the monasteries to medieval science:

"...bad, rotten and poisonous vapors from elsewhere: from swamps, lakes and chasms, for instance, and also (which is even more dangerous) from unburied or unburnt corpses – which might well have been a cause of the epidemic..." (Report on the Cause of the Plague, University of Paris Medical Faculty, 1348).

It then moved into the nineteenth century in the United Kingdom:

"Disease caused by '...atmospheric impurities produced by decomposing animal and vegetable substances, by damp and filth, and close and overcrowded dwellings.' (Edwin Chadwick's 'Report into the Sanitary Conditions of the Labouring Population of Great Britain' – 1842).

Gradually, a modern science of hygiene developed. The work of Leeuwenhoek, Koch and Pasteur made visible the microbial agents of disease. Snow showed how they could be transmitted in populations. Florence Nightingale and Mary Seacole applied science (and a good deal of nonscientific morality, religion and common sense) to disease prevention and control, and Roger Stanier initiated molecular evolutionary studies of disease-causing organisms. Etic science moved forward, homing in on the enemy, but this was not the whole story; the direction taken by science and its progress was largely driven by innate emic wisdom. Science was following common sense, trying to prove what we always 'knew' was bad and disgusting, without knowing why we felt that way. The history of hygiene science could thus be said to be one of zeroing in on explanations for what we already felt in our gut and deep in the ancient animal centres of our brains.

Today, we know much about the behaviour of thousands of disease-causing organisms and about human cellular defences. But we still do not understand human disease avoidance behaviour – a strange omission because changing behaviour is surely our most potent way of preventing disease.

THE HYGIENE CHALLENGE TODAY

5 Does the insight that hygiene behaviour is driven not by rationality, but by deep and ancient urges within us, which are not entirely under our conscious control, have any implications for hygiene today? [If hygiene is, as I suggest, the set of behaviours that serves to avoid infection, does condom or bednet use qualify as hygiene? This is certainly behaviour that serves to avoid infection, but is not commonly thought of as hygiene, nor is it inspired by disgust. Scientific understanding of disease has allowed us to invent novel protective technologies with which we have no ancient evolved relationship; hence, disgust is not elicited and the hygiene category does not 'feel right'. However, biologically speaking, they should still be classed as hygiene behaviour.] {placement?} While over two million children still die from infectious intestinal diseases every year (22), the need to find solutions is pressing. We have proposed that it is possible to harness the deeper motivations that drive behaviour in the service of hygiene. While health education – that is, teaching people about germs – may play a role in eliciting safer behaviour, it may be more effective to build on our already hard-wired instincts to avoid contamination (23). In a recent attempt to reduce the toll of diarrhoeal diseases among children in Ghana by getting people to wash their hands with soap (24), we developed a campaign to make people feel that not washing hands with soap was disgusting. The television advertisement, for example, showed a strange stain on a mother's hands after coming from the toilet, which was then transferred to her child's food. Despite not using rational arguments about germs or disease, the campaign led to 41% more Ghanaians reporting washing hands with soap in national samples (Scott, submitted) {update}. (The advertisement can be viewed at <www.globalhandwashing.org>). Recognizing the importance

of ancient, evolved motivations may help us to zero in on more effective public health interventions designed to improve hygiene. [Our explorations of hygiene 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.] {placement?}

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

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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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