More on Merde

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ABSTRACT Whereas food has always received much attention in conversation, commerce, and the literature, the subject of feces has been comparatively neglected. To fill this lacuna, a small book on comparative coprology was recently published (Lewin 1999). The present article aims to supplement this book with a review of overlooked or new items relating to biological and medical aspects of coprology, notably chemical and microbial components of human and animal feces, their uses as fertilizers, and a few other sociological impacts.

Introduction

Think of yourself as a sausage machine. At the front end you feed in meat (or potatoes or whatever you have for dinner), and it gets sliced and ground up, passed down the chute into a succession of hoppers where, in scientifically controlled succession, some substances are added and others are subtracted, and the residual mass is finally discharged as more or less cylindrical lumps at the lower end. But whereas in our everyday lives the input—food—forms the topic of daily discussions and the subject of untold numbers of published books and articles, the output tends not to be even mentioned in polite society (the Editor does not even allow me to use the English word for it), while relevant literature is almost non-existent.

Why should this be? I can suggest at least three reasons. Natural selection has taught animals to avoid their own feces which, if allowed to contaminate their food, would provide a vehicle for the reinfection by pathogenic germs and

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worms. Perhaps related to this, we are normally repelled by its smell, and in this we are not alone. So are cows, which tend to avoid grazing in patches of pastures treated with cow manure, where the smell evidently remains for three to 18 months, depending largely on climatic conditions (Marsh and Campling 1970). And maybe, at least in Western societies, we are so thoroughly potty-trained as infants that some of the conditioned reflexes and revulsions tend to stay with us throughout our adult lives.

Although it is unquestionably a matter with grave medical, sanitary, and agricultural importance, to my knowledge there has been only one book published during the past few centuries that deals specifically and comprehensively with the subject of human feces (Anon. 1748), but none until recently that treats the subject of human and animal coprology in all its various aspects. That is what I tried to do in *Merde* (1999). Of course, even in that slim volume I could not possibly cover more than a tiny fraction of what is known, or surmised, about feces. In the following article I have endeavored to present some additional items that I have encountered in the scientific literature or popular media, or that have been communicated to me by colleagues, afficionados of coprology, and other amateurs during the past couple of years.

Most of us tend to think of feces merely as waste products, to be dumped—out of sight and out of mind—from chamber-pots or flush toilets into the nearest natural body of water or, if none is near at hand, into a sewage farm. Much of the subject of human waste disposal has already been reviewed (Lewin 1999). But coprology has a variety of other interesting aspects. The specific physical features of animal droppings, for instance, have always been important for hunters and trappers, and typical scats are well illustrated in several handbooks (e.g., Bang and Dahlstrom 1974; Halfpenny and Biesiot 1986). In 1805, Meriwether Lewis, of the Lewis and Clark expedition, sent a collection of various animal droppings to President Jefferson at Monticello, and they probably finished up, along with all sorts of other exotica, in the Smithsonian Institution. In the following article I present a variety of coprological data which I think may be specifically of more or less biological and medical interest. (For some references to publications on scatology—a very different topic, dealing with expletives and words of opprobrium—see Ambler 1988.)

Scats, Turds, and Their Components

"It is conventional to assume that the feces produced have been derived from the food which is being eaten" (Kyriazakis 1999), and for the most part this is true. Analyses of animal scats obviously provide excellent information about the diet of the excretants. Thus, mammoth dung from the 13th to 11th millennium BC provides evidence that these unfortunate monsters, unlike most contemporary elephants, had to subsist largely on grasses, sedges, spruce twigs, and sage brush from the depauperate pastures and scrub lands on which they browsed. (In some caves in the Grand Canyon area, in Arizona, there is no dearth of mammoth dung for scientific study; its total weight has been estimated to exceed 300 tons.)

Scientists studying the stratigraphy of sediment cores from the bottom of an Antarctic lake have used the abundances of certain elements characteristic of penguin droppings to indicate how the populations of these birds had increased or declined within the past 3,000 years (Suh et al. 2000). Gross analyses of about a thousand wild bonobo feces indicated that only about 1 percent was of animal origin. Since sophistical chemical analyses of feces can provide details not only about the diet but also about the physiology and sexuality of the excretants, keepers in the San Diego Zoo are trying to assess the effects of stress on caged gorillas by chemical analyses of their feces. Even its color can be informative. The droppings of koalas, which feed solely on eucalyptus leaves, are typically bright green, indicating that their digestive enzymes do not destroy chlorophyll, while the conical droppings of emus that have fed on flame-heath fruits may become bright red. A senior constable in Australia was able to confirm the guilt of a thief by matching the yellow dog-feces on his shoes with samples scraped from a windowsill at the site of the robbery.

In a 30 g sample of dried human feces found by the fireside of a 12th-century Pueblo settlement in Colorado, scientists have found chemical evidence for human myoglobin (a characteristic pigment of muscle tissue), with the almost irrefutable conclusion that at least some of the native Indians there must have engaged in cannibalism (Marlar et al. 2000). From some fecal samples, even the long and complex molecules of DNA can be isolated more or less intact. Chris Mulbey, in the Glacier National Park, Montana, collects and analyzes scats of bears (who drop about 10 a day), and from the nature of their DNA he can identify the individual animals that produced them. Under some conditions, DNA can remain more or less intact for hundreds or even thousands of years (Poinar 1999).

Among other informative components of feces are the steroids. In species of parrot in which males and females have such similar plumage that it is impossible for us mortals to determine a bird's sex, analyses of steroids in their excreta can provide the necessary discriminatory information. (Scientists sometimes encounter unexpected difficulties in obtaining samples for such analyses. When park rangers in New Zealand wanted determinations of the sex of their few surviving specimens of kakapo, a flightless parrot, they planned to send samples of the feces to an analytical laboratory in America. However, they were told that this would not be legal, since kakapos are on the endangered animal list and so neither they nor their droppings may be exported from New Zealand. On the other hand, in another case such studies have been unexpectedly facilitated. A bonobo at the San Diego Zoo learned to hand out between the bars of her cage fresh samples of her feces to a researcher who needed them in order to study the hormones they contained, and thereby to determine the reproductive condition of the animal.)

Recent studies of wild animal droppings have indicated that the coliform bacteria in their guts may or may not be resistant to antibiotics, according to their normal propinquity to human beings. Thus the gut bacteria of voles and deer from the wilds of Finland are still susceptible to most of our antibiotics (Oesterblad et al. 2001), whereas those of the same species of voles and wood mice in England (Gilliver et al. 1999), like those of urban baboons in India (Routman et al. 1985), are predominantly antibiotic-resistant.

Some fecal elements smell, but it should be noted that the main components of excreted gases are hydrogen and methane, which when pure are both odorless. Pig farts are mostly methane (Zhu, Fowler, and Fuller 1993), whereas those of many of us humans comprise a larger proportion of hydrogen. (Since these gases are lighter than air, we actually gain a few milligrams every time we fart.) What we are generally aware of, in the gases that we excrete all too frequently, are traces of smelly compounds such as skatole. Although one is rarely able to see evidence of gas production by animals, nice demonstrations are often provided by submerged hippos, manatees, and tapirs, when streams of bubbles emanating from their anus bear evidence of intestinal fermentation as in other vegetarians such as cows. (According to a shaman friend of Plotkin [2000], some South American tapirs, though normally vegetarian, seem to have developed a taste for fish, which they catch in the following way. They first browse on leaves of a plant called nekos, which contain a kind of narcotic, and then go to defecate into the nearest pond or stream, where they await the arrival of stupefied fishes at the water surface. I find this rather hard to believe, but I cite it for what it's worth.)

Whereas the feces of mammals and birds are all too familiar to us in many of our farms and city streets, those of invertebrates rarely obtrude on our consciousness (or on our shoes or buildings). This is partly because they are generally smaller and partly because the diets of many invertebrates contain less indigestible material than ours. The small droppings of spiders contain little but the breakdown products of nucleic acid metabolism, notably guanine, adenine, hypoxanthine and uric acid, while those of butterflies have even lower contents of solid matter ("liquid in, liquid out"). Earthworms, which ingest a lot of soil, pass a lot of dross through their guts, and caterpillars, which eat leaves consisting largely of indigestible cellulose, make lots of droppings, but these are exceptions. When there is a high proportion of indigestible matter, it may constitute an appreciable fraction of the animal's weight. This is probably why many beetles, like birds such as cormorants, often defecate to lighten their aerodynamic load before take-off. Limpets living on limestone rocks along the Adriatic coasts excrete granules of carbonate, about 50 micrometers in diameter, which contribute to the white sands of the shore (Clarke 1990), much in the same way as do those of parrot fish, which browse on limy corals in tropical reefs.

Feces of the blood-sucking bug *Rhodnius* contain compounds derived from haem, detoxicated and rendered insoluble before being excreted (Oliveira et al. 1999), in this respect qualitatively if not quantitatively like those of vampire bats which live on a similar diet of vertebrate blood.

Among substances of more biochemical or physiological significance are certain components in the droppings of locusts, notably guaiacol, which has been found to promote aggregation leading ultimately to swarm formation. Careful studies have revealed that this substance is formed not by the insects themselves, but by bacteria in their guts (Dillon et al. 2000; Pener and Verusjhalmi 1998).

Coprophagy

Virtually all feces, from whatever kind of animal produces them, consist largely if not entirely of organic matter; indeed, fresh dung is high in protein (Holzman 1997). To assess the nutritive value of a diet of seaweeds eaten by marine lizards on the Galápagos Islands, scientists scraped samples of their feces off coastal rocks and subjected them to calorimetric analysis, and showed that the feces still contained much organic material. This means that although the stuff has been rejected by its excretant, it still retains potential as a food for some other creature which may be sufficiently hungry, sufficiently non-fastidious, and which would possess enzymes capable of digesting some of the residues in the dross. So who eats feces? People, obviously, don't, unless they are starved to the point of desperation, perhaps in a besieged city, or mentally deranged. (There is a biblical reference [Isaiah 36:12] to men on a wall eating their own dung. Maybe they had no choice.) Bourke (1891) unearthed records of a painter in Brussels who subsisted for 23 days on a diet of his own excrements; of a crazed girl in Germany who ate the droppings of pigeons and geese; and of another wretch who ate mouse droppings. Obviously these are not normally desirable components of human diet. However, consumption of fresh, warm camel feces has been recommended by Bedouins as a remedy for bacterial dysentery; its efficacy (probably attributable to the antibiotic subtilisin from *Bacillus subtilis*) was confirmed by German soldiers in Africa during World War II (Bernhardt 2000).

Of course, there are always jokers who violate taboos. A Maine hunting guide with a bent for practical joking used to feign eating a moose dropping, surreptitiously submitting a real olive before putting it into his mouth, and then encouraged unsuspecting tourists to do likewise. I have been told that a certain professor of medicine, in parasitology classes involving fecal smears, sometimes plays a similar trick on his students, using a tongue depressor and peanut butter. (I hope the story is apocryphal.) And long ago in Sri Lanka an acolyte used a similar device to mislead the chief monk of a Buddhist temple, who had reprimanded him for failing to close the doors to keep out stray dogs. In that case, the model dog droppings were fabricated from jaggery, a concoction of ground coconut and sugar.

Supplementing the diet of young animals with samples of parental feces is for many animals an essential biological act, serving to inoculate their offspring with useful component species of the gut flora—for instance, bacteria or protozoa which can produce enzymes permitting them to digest cellulose. Some millipedes in North America (*Narceus* sp.) put their droppings to good use in two ways. The female transfers her newly laid eggs directly to her cloaca, where they become covered with feces, so that when these are expelled, out come the eggs disguised as pellets of frass. Later, when the young millipedes hatch, by nibbling on their old eggshells they pick up a bacterial inoculum for their guts to help them digest cellulose. Naked mole-rats are among the animals that do this, as can be seen in photographs of such a mole-rat wallowing in the colony's underground toilet, and of a pup four weeks old and nearly weaned, begging for feces by nudging and tugging at the ano-genital area of a non-breeding adult (Mendes and Jarvis 1991). For this reason, keepers in the San Diego zoo deliberately add some adult fecal material to the diet of baby hyraxes. Some rodents, lacking the rumens of larger animals like cows, effectively double the lengths of their intestines by refecation, i.e. sending their ingested food through twice, to allow more time for digestive enzymes and gut bacteria to break down relatively refractory materials such as cellulose. Rabbits do this, eating their soft, night-time feces for breakfast and eliminating the harder droppings, which are more familiar to us, in the fields later in the day. Small Chilean rodents called degus, which defecate at more or less regular intervals, normally reconsume at least half of their nightly production and, when other food is unavailable, assuage the pangs of hunger by eating daytime feces too (Kenagy, Veloso, and Bozinovic 1999).

When other food is scarce, animals sometimes take recourse to eating the dung of other creatures. In Odzala, Africa, elephant dung is eaten by red river hogs, sitatunga deer, and (when it falls into a water-course) various kinds of fishes. Camel dung is sometimes consumed by crocodiles of a relict population in Saharan lakes. The caterpillars of moths that live on sloths feed on the dung that the animals deposit under their trees. Some hungry natives of the Congo supplement their meager diets by snacking on droppings of *Lobobunaea* caterpillars, which they manage to gather from among fallen leaves along jungle trails. Certain Amazonian ants seek out and collect special kinds of caterpillar droppings. And, for more refined tastes, female *Melania* butterflies in South American jungles suck juices from the droppings of ant-birds and thereby obtain essential amino-acids.

For dung beetles, the droppings of mammals constitute their major items of diet. Sometimes they battle over choice bits, as illustrated by a sequence of photographs in a beautiful book by the Preston-Mofhams (2000). The French essayist Fabre (1912) presented a fascinating popular account of the activities of certain species in Provence, and latterly a whole book has been devoted to this subject (Hanski and Cambefort 1991; in 2000 Dr. Ilkka Hanski won a Balzan Prize worth half a million Swiss francs.) The adult beetles suck out juicier elements from the fresh dung, and then roll up some of the rest to make nurseries for their eggs, complete with stored food to nourish their grubs when they hatch. Dung beetles tend to be selective in their choices, each species specializing in the feces of only a few kinds of animals. Normally only the dungs of mammals are preferred. Floate (1998) in Lethbridge, Alberta, has adduced that some scarab beetles (*Aphodius* spp.), even more discriminatory, tend to avoid cattle dung contaminated with the vermifuge ivermectin. To make dung beetles feel more at home in their laboratory, and thereby more inclined to mate, Kotiaho, Simmons, and Tomkins (2001) smeared their artificial burrows with cow dung. But what did the beetles' ancestors do before the Cretaceus era, when there were no mammals? Probably they made do with dinosaur dung, as indicated by beetle burrows around Cretaceous coprolites dating from about 70 million years ago (Chin and Gill 1996).

Coprolites

Mary Anning of Lyme Regis (1799–1847) was the first to recognize the true nature of coprolites, as fossil dungs. Undoubtedly the biggest recorded so far is a fossilized turd measuring some 17 × 6 × 5 inches, attributed to *Tyrannosaurus rex*. (This seems to me somewhat odd, because that dinosaur was a carnivore, and the dungs of terrestrial carnivores today are generally much smaller than those of herbivores since their diets contain less roughage.) This of course was a rare find, but in some regions coprolites can be found in considerable quantities. The late Chester Stock, of Cal Tech, collected truckloads of giant sloth coprolites from a cave in Arizona, took them home and stored them in cardboard boxes in his basement, from which hoard he used to distribute specimens to his students. More recent coprolites, those deposited in caves by Neanderthal men (and presumably women), indicate that they ate mostly meat with very few vegetables. This was hardly a recommended diet for people today, but I suppose they had little choice. And at the lower end of the scale, we have some of the smallest coprolites, produced by insects that had evidently fed on the pollen of primitive flowering plants (Friis, Pedersen, and Crane 2000). Among human coprolites, probably the longest on record is a 20 cm specimen, with tapered ends, found in excavations under Lloyd's Bank in London; arguably the most valuable are some containing flakes of gold leaf, perhaps indicative of lucullan banqueting, excavated among the ruins at Pompeii.

Dispersal of Seeds and Spores

Just as flowering plants depend largely on insects for the dispersal of their pollen, so do seed plants depend on many kinds of birds and mammals for the dissemination of their seeds. Some South American mistletoe seeds (*Tristerix*) are distributed by a little marsupial (*Dromiciops*) through whose digestive system they pass, still sticky and still 98 percent viable (Amico and Aizen 2000). Edible fruits and pods (e.g., those of many tropical trees and shrubs such as sapota, longan, rambutan, and tamarind) contain hard, indigestible seeds dispersed by frugivorous birds, just as the indigestible spores of many fungi, including the mycorrhizal fungi that promote the growth of black spruce trees, are dispersed by animals such as red-backed voles (Terwilliger and Pastor 1999).

Brown lemurs of Madagascar can eat and excrete intact and still viable seeds more than half an inch wide, thereby helping to disperse the fruit trees that produce them. Likewise, in Australia many of the huge seeds of cycads (*Macrozamia*) eaten by emus may survive without being ground up by gizzard stones, and are thereby distributed by these big birds. When fruits of strangler figs are eaten by hornbills in Indonesia, for instance, the seeds remain viable in the droppings, providing in turn an inducement for ants to carry them up tree trunks and plant them where in due course they may be able to germinate.

Fertilizers and Other Uses

We come now to the matter of farmyard wastes. The cost of setting up a special facility to treat and dispose of pig feces in Singapore has been estimated at about US$40 per pig. When one considers that in North Carolina alone there are about 2 million pigs, producing predominantly liquid waste, this constitutes no mean problem for the state economy. Much of it is sprayed on agricultural soils, where the ammonia and other odorous elements arising therefrom are generally unappreciated by people living in their vicinity. Furthermore, accidents may exacerbate the problem. In June 1995, almost 100 million liters from a large swine-waste lagoon overflowed into the New River, to be followed by other, smaller spills later in the summer. In addition to the noxious odors, and the disastrous effects on the wildlife downstream, the high counts of fecal coliform bacteria and many other pathogens in such swine and poultry waste present serious threats to human health.

In a chatty book published more than a century ago, Harris (1883) discussed different kinds of manures, chiefly from cows, sheep, pigs, and horses, and presented a useful table comparing the nitrogen, phosphorus, and potash contents of human night-soil with the averages for these four farm animals, indicating that our feces, containing 25 percent of dry matter, score twice as high as animal wastes for nitrogen and three times as high for phosphorus. He concluded that, from the farming standpoint, "although it is an unpleasant job . . . it pays well to empty the vaults (presumably the cesspits) at least twice a year." Other useful information on pig manure and chicken droppings produced on American farms, and their impacts on local ecologies, has been presented more recently by Mallin (2000).

Sewage can of course be treated and marketed as fertilizers. Bradford Corporation Sewage Works used to sell—and maybe still does—treated sewage as "Yorkshire bounty." In nature even untreated feces are generally beneficial, in one way or another. Charles Darwin emphasized the important role of earthworms in turning over and fertilizing the ground, although sometimes one can have too much of a good thing. In some Amazonian pastures, worms annually contribute as much as 100 tons of casts per hectare, forming in some seasons a relatively impermeable stratum that tends to impede aeration of the underlying soil (Chauvel et al. 1999). It is a common observation that grass grows more exuberantly under trees and overhead cables on which birds customarily perch. And in some parts of Africa, where queleas (social weaver-birds) flock in almost astronomical numbers, enough guano can be gathered under their roosts to provide local farmers, who otherwise suffer seriously from their depredations, with an excellent source of fertilizer (Ward 1965).

A much more familiar fertilizer is, of course, horse manure, sometimes referred to as horse-apples. Door-to-door peddlers of this commodity used to sell it in London at four pence per bag—or sixpence if, as they claimed, it was hand-picked. It is liberally applied in the gardens of the Queen Mother in Balmoral, Scotland, and in countless other gardens and farms in Britain and elsewhere. Likewise, some poor women used to gather dog droppings by the basketful from city streets in England to sell to fellmongers or tanners (Coman 1999).

Manures have other uses, too. In many parts of the world, cattle droppings constitute the main fuel for cooking food and heating households. Long before the exploitation of North Sea oil as a source of fuel around the north of Britain, dried cowpats ("coos' scones" or "longo") were burned together with seaweed and peat by Scottish crofters (Fenton 1978), while buffalo turds were used in this way by native Americans. Even today, some campers may find it expedient to cook on cow-pats, though they are well advised to probe them with a stick before collecting them for their fire to ensure that they do not retain their original sloppiness. However, this feature can be employed to good effect. To keep down the dust of earthen floors in Nepal, cow-dung is often employed as a sort of varnish. Even in England it is sometimes used, for instance on the outer walls of houses in the fen country in East Anglia, to encourage the growth of lichens and thereby confer an "olde-worlde" look to the buildings. In Malawi recently, a special paper is being made from a mixture of recycled paper and dried elephant dung. (Elephants produce lots of dung; while being weighed in a zoo, one eight-ton bull deposited a fecal mass weighing 85 pounds.) Some samples of hyena dung have been found to contain so much chewed-up bone that the dried and powdered material could be used as a sort of face-powder. And even insect droppings have been used, for instance, in folk medicine. In some Chinese traditional pharmacies one can buy a mixture of cockroach droppings with various herbs for about $2 per pound, to alleviate constipation (maybe), while for the same purpose an infusion of the stick-insect *Eurycnema* has been recommended, particularly since it is supposed to be rich in vitamin E. I have it on good authority that some bakers in France add (or used to add) small amounts of pigeon droppings to their dough in order to provide wild yeasts that promote its rising. And in the botanic gardens in Sydney, Australia, python dung has been employed in attempts to discourage depredation by fruit bats (how effectively, I don't know).

I am told that in some gift shops in western Canada one can buy necklaces of moose droppings, and even gold-plated "moose nuggets." Plastic-coated koala feces (presumably from Australia) have been made into earrings for ladies in

Japan, while dried and flattened cowpats have been mounted for the faces of wall clocks. Probably since time immemorial, however, animal feces have been employed as physical expressions of disapproval. In recent years Mayor Giuliani of New York was pelted by street mobs with elephant dung (where on earth did they get it from, in that supposedly civilized city?), while in other American cities protesters piled horse manure at the doors of clinics where abortions could be carried out. Police authorities in Switzerland, following this lead, have recently confronted mobs protesting the World Economic Conference in Davos with the prospect of being sprayed with cow manure, evidently with good deterrent effect. However, one may question whether this could be regarded as a justifiable use for so valuable a product.

Nuisances

Feces in the wrong place can of course constitute nuisances. Clotted on wool from around a sheep's anus, the material is technically called *dag*—hence the Australian derogatory expression "daggy." In 1840, some 12 cart-loads of horse dung had to be removed every day from Regent Street, in London, and in later years, as horse-drawn vehicles became more numerous, the problem became worse. And whereas horses tend to leave their droppings in the streets, in urban settings dogs, like pedestrians, tend to favor pavements. In some places, legislation and common decency have considerably reduced this problem. For instance, one of our neighbors in La Jolla, who goes for daily walks with one large dog and one small dog, considerately carries with her a large shovel, a small shovel, a large plastic bag and a small plastic bag. However still today some 14,000 tons of canine feces per annum have to be removed from the sidewalks of Mexico City alone. The problem is not confined just to pavements. The ninth Duke of Marlborough, who married an American dog-lover, Gladys Deacon, finally grew so disgusted by the droppings left around Blenheim Palace by her 80 dogs (which had not been house-trained) that he divorced her.

Birds, too, can sometimes make nuisances of themselves. Owls as well as bats sometimes enter churches, perhaps mistaking them for barns (as has been reported from Burton-on-Trent in England) and leave regurgitated pellets and feces even in those sacred precincts. And birds that gather in enormous numbers, as do the starlings that flock from the countryside into the city of London at nightfall, to roost and deposit their droppings in the relative quiet of parks, riversides and roadside trees, constitute a major problem. But who is to stop them?

Health and Disease

As the court physician asserted in the film *The Madness of King George*, "I've always found the stool more eloquent than the pulse." You don't have to be any kind of medicine man to put such information to use. The two Japanese outlaws, Hiroo Onoda and Kozuka Kinshichi, who survived in hiding on Luban Island in the Philippines for some 30 years after the end of World War II, used to examine their feces every day to check on their state of health before burying them to conceal their whereabouts. If they could have read French, they might have profited by information presented in *Manuel de coprologie clinique* (Goiffon 1921), which contains a summary table "Interpretation of a coprological examination, limited to macroscopic and microscopic examination observations and a few reactions," accompanied by a color chart and some 36 illustrations in the text. This seminal publication was followed, some nine years later, by *Coprologie microscopique* (Langeron and Rondeau du Noyer 1930), with sections on technical methods, normal and abnormal elements, and various kinds of parasites (protozoans, worms, arthropods, and fungi). To my knowledge, no comparable work has been published in English, or indeed in any other language. (Incidentally, it has been noted that when rats nibble on cat feces and thereby become infected with *Toxoplasma gondii*, a protozoan parasite of small mammals and birds, they become more timid [Berdoy, Webster, and MacDonald 2000]. Maybe they feel too sick to be aggressive.)

However, fecal afflictions have received considerable attention and some publications in the Anglo-Saxon literature. Whorton's entertaining book on constipation (2000) is based largely on information gleaned from the American Medical Association's Chicago collection on historical health fraud and alternative medicine. In 10 well-annotated chapters, the scholarly doctor deals with such subjects as the "white man's burden," constipation and civilization, and the never-ending quest for regularity. Today, Professor Gwee Kok An and other gastroenterologists in the National University Hospital of Singapore are surveying the incidence of "irritable bowel syndrome" among some 2,000 residents in the Bedok and Pasir Ris areas, where this embarrassing complaint has apparently tripled during the past decade, to see whether there is any merit to the use of certain Chinese herbal mixtures that have been touted to alleviate it.

A sudden bout of diarrhea may afflict anyone, from a drug smuggler caught red-handed to even a philosopher. When Wittgenstein, visiting A. E. Housman in Trinity College, Cambridge, urgently needed to visit a toilet, his request to use Housman's private facility was unaccountably denied. Chronic diarrhea may be the inheritance of a blameless babe new-born to a heroin-addicted mother. Graver still worldwide are the diarrheal diseases like cholera and typhoid caused by bacteria transmitted by drinking water contaminated by feces. Among many notables, both high and lowly, who succumbed to water-borne typhoid were Willie, son of President Lincoln, and the wife of the notorious wild western highwayman, Wyatt Earp. According to a United Nations report published in March 2000, the homes of half of the world's populations lack adequate sanitary facilities and, largely as a consequence, infant mortality from typhoid and cholera has now reached 3 million per annum. Another nasty diarrheal disease is caused by *Cryptosporidium*, which may infect other animals besides humans. Near the San Antonio and Calaveras reservoirs, which provide water for households in and around San Francisco, some two thousand feral pigs constitute a potential source of cryptosporidiosis in that area.

In addition to protozoa like *Giardia*, and the bacteria mentioned above, viruses too can be involved in diarrheal diseases. It is noteworthy that bacterial viruses (bacteriophages) were discovered in 1917 when Felix d'Herelle found evidence for a filterable agent in the feces of a dysentery patient (Ho 2001). It has been found that *Vibrio dysenteriae* causes diarrhea only if the bacterium itself is infected with a virus. These days, duck feces in Hong Kong are periodically checked for signs of resurgent influenza viruses, and some legal documents in the Department of the Interior have been considered unfit to touch because they were contaminated by mouse droppings that might carry the dreaded Hanta virus.

Myths and Legends

Lastly, we might mention a few myths and legends about feces of one sort or another. There is an apocryphal account of someone called Tobit, who fell asleep under a wall on which sparrows perched, and was apparently blinded when some of their droppings fell into his eyes. (Did he sleep with his eyes open?) He recovered his eyesight only some four years later when his son applied a preparation of fish gall (Dancy 1972; Halpern 1988).

According to an African story, God decreed that the hippopotamus spray out its feces so that he could determine whether or not it had been eating fish (which had been proscribed when he had permitted it to live in the water). More recently, Ngabhi Diamini, the Speaker of the Parliament of Swaziland, was asked to resign after being caught stealing cow dung from the royal herd, which could have had special powers and might have been used for witchcraft. And finally, an unsubstantiated RAF story: after the Queen had visited an air force station, conserved samples of the royal stools were reputedly dried, varnished, and displayed to commemorate her visit. If true, this would certainly be without her approval.

References

Ambler, R. 1988. The descent of human feces. *J. Irreproducible Results* 30:25–26. (Exceptional bibliography.)

Amico, G., and M. A. Aizen. 2000. Mistletoe seed dispersal by a marsupial. *Nature* 408: 929–30.

Anon. 1748. *Human ordure, botanically considered.* London: Carpenter. (Not seen; referred to in Whorton 2000.)

Bang, P., and P. Dahlstrom. 1974. *Animal tracks and signs.* London: Collins.

Berdoy, M., J. P. Webster, and D. W. MacDonald. 2000. Fatal attraction in rats infected with *Toxoplasma gondii*. *Proc. R. Soc. B.* 267:1591–94.

Bernhardt, J. 2000. Bacillus subtilis: Beschreibung under Charakterisierung. <http://microbiol.biologie.un-greifswald.de>.

Bourke, J. G. 1891. *Scatalogic rites of all nations.* Washington, DC: Lowdermilk. Rep. Johnson Reprint, 1968.

Chauvel, A., et al. 1999. Pasture damage by an Amazonian earthworm. *Nature* 398:32–33.

Chin, K. and B. D. Gill. 1996. Dinosaurs, dung beetles, and conifers: Participants in a Cretaceous food web. *Palaios* 11:280–85.

Clarke, A. 1990. Fecal egestion and ammonia excretion in the Antarctic limpet Nucella concinna (Strebel 1908). *J. Exper. Mar. Biol. Ecol.* 138:227–46.

Coman, B. J. 1999. Modern rectitude, pure finders and the broad-toothed rat. *Quadrant* (April):35–39.

Dancy, J. C. 1972. *The shorter books of the Apocrypha.* Cambridge: Cambridge Univ. Press.

Dillon, R. J., C. T. Vennard, and A. K. Charnley. 2000. Exploitation of gut bacteria in the locust. *Nature* 403:851.

Fabre, J. H. 1912. The Sisyphus beetle: The instinct of paternity. In *Social life in the insect world.* 136–49. London: Fisher Unwin.

Fenton, A. 1978. *Northern Isles: Orkney and Shetland.* Edinburgh: John Donald.

Floate, K. D. 1998. Does a repellent effect contribute to reduced levels of insect activity in dung from cattle treated with ivermectin? *Bull. Entomol. Res.* 88:291–97.

Friis, E. M., K. R. Pedersen, and P. R. Crane. 2000. Reproductive structure and organization of basal angiosperms from the early Cretaceous of West Portugal. *Int. J. Plant Sci.* 161 (suppl. 6):169–82.

Gilliver, M. A., et al. 1999. Antibiotic resistance found in wild rodents. *Nature* 401: 233–34.

Goiffon, R. 1921. *Manuel de coprologie clinique.* Paris: Masson.

Halfpenny, J. C., and E. A. Biesiot. 1986. *A field guide to mammal tracking in western America.* Boulder: Johnson Books.

Halpern, B. 1988. *The first historians: The Hebrew Bible and history.* San Francisco: Harper and Row.

Hanski, I., and Y. Cambefort, eds. 1991. *Dung beetle ecology.* Princeton: Princeton Univ. Press.

Harris, J. 1883. *Talks on manures.* New York: Orange Judd.

Ho, K. 2001. Bacteriophage therapy for bacterial infections: Rekindling a memory from the pre-antibiotic era. *Perspect. Biol. Med.* 44:1–16.

Holzman, D. C. 1997. Nature's own pooper-scoopers keep Earth livable for all of us. *Smithsonian* 28:116–22.

Kenagy, G. J., C. Veloso, and F. Bozinovic. 1999. Daily rhythms of food intake and feces reingestion in the degu, an herbivorous Chilean rodent: Optimizing digestion through coprophagy. *Physiol. Biochem. Zool.* 72:78–86.

Kotiaho, J. S., L. W. Simmons, and J. L. Tomkins. 2001. Towards a resolution of the lek paradox. *Nature* 410:684–86.

Kyriazakis, I., ed. 1999. *A quantitative biology of the pig.* Wallingford: CABI.

Langeron, M., and M. Rondeau du Noyer. 1930. *Coprologie microscopique.* Paris: Masson.

Lewin, R. A. 1999. *Merde.* New York: Random House.

Mallin, M. A. 2000. Impacts of industrial animal production on rivers and estuaries. *Am. Scientist* 888:26–37.

Marlar, R. A., et al. 2000. Biochemical evidence of cannibalism at a prehistoric Puebloan site in southwestern Colorado. *Nature* 407:74–78.

Marsh, R., and R. C. Campling. 1970. Fouling of pastures by dung. *Herbage Abst.* 40: 123–30.

Mendes, R. A., and J. U. M. Jarvis. 1991. *The biology of the naked mole-rat.* Princeton: Princeton Univ. Press.

Oesterblad, M., et al. 2001. How wild are wild mammals? *Nature* 409:37–38.

Oliveira, M. F., et al. 1999. Haem detoxification by an insect. *Nature* 400:517–18.

Pener, M. P., and V. Verusjhalmi. 1998. The physiology of locust phase polymorphism: An update. *J. Insect Physiol.* 44:365–77.

Plotkin, M. J. 2000. *Medicine quest: In search of nature's healing secrets.* New York: Viking.

Poinar, H. N. 1999. DNA from fossils: The past and the future. *Acta Paediatr.* 88:133–40.

Preston-Mofham, K., and R. Preston-Mofham. 2000. *The natural world of bugs and insects.* China: PRC Publishers.

Routman, E., et al. 1985. Antibiotic resistance and population structure in Escherichia coli from free-ranging African yellow baboons (*Papio cynocephalus*). *Appl. Environ. Microbiol.* 50:749–54.

Suh, L., Z. Xie, and J. Zhao. 2000. A 3,000-year record of penguin populations. *Nature* 407:858.

Terwilliger, J., and J. Pastor. 1999. Small mammals, ectomycorrhizae, and conifer succession in beaver meadows. *Oikos* 85:83–94.

Ward, P. 1965. Feeding ecology of the black-faced dioch *Quelea quelea* in Nigeria. *Ibis* 107:173–214.

Whorton, J. C. 2000. *Inner hygiene: Constipation and the pursuit of health in modern society.* Oxford: Oxford Univ. Press.

Zhu, J. Q., V. R. Fowler, and M. F. Fuller. 1993. Assessment of fermentation in growing pigs given unmolassed sugar-beet pulp: A stoichiometric approach. *Brit. J. Nutr.* 69: 511–25.