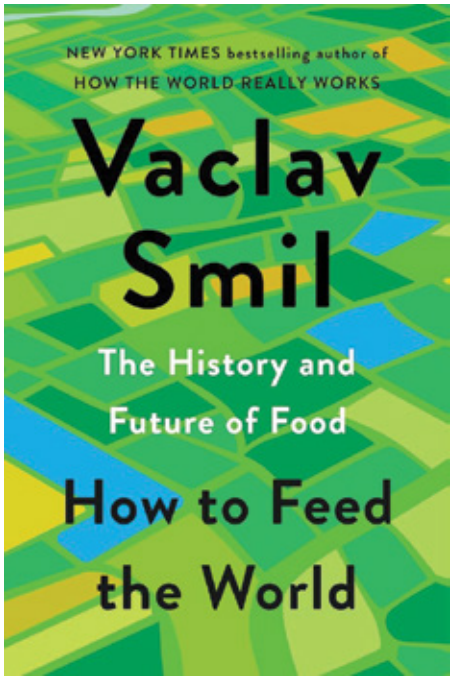

Gates Notes

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How to Feed the World

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Why Do We Eat Some Animals and Not Others?

The statistics are clear: an overwhelming majority of this book's readers are not vegetarians (in affluent countries, no more than about 5 percent are), and this means that they must make repeated choices about what kind of meats (and in what quantities) to con- sume.1 But no matter if you have clear dietary preferences (chicken above beef) or if you are omni-carnivorous, chances are that you have never asked some fundamental questions concerning meat con- sumption. Why have we domesticated such a small number of animals to produce meat (and milk and eggs and wool), and to help us in transportation and other work? As we will see, we chose the limited number of animals that we did because of a cocktail of considerations including size, metabolism, social organization, behavior, and feeding habits (or, as ecologists would say, trophic levels).

Perhaps the best place to start is to ask: what species of animals would our ancestors have preferred for domestication if they had today's best scientific understanding regarding animal metabolism and trophic levels? The answer is exactly the same animals as they did select, starting about 11,000 years ago with, in fairly quick succession, goats and sheep, followed by pigs (10,500 years ago), and cattle (10,000 years ago), all within a crescent-shaped area in what is now southern and eastern Turkey, northern Iraq, and northwestern Iran.2 Other domestications came considerably later: donkeys and yaks about 7,000 years ago, water buffalo and camels 6,000 years ago, llamas and alpacas 5,500 years ago, and horses only around 2,500 bce.3 The history of food production

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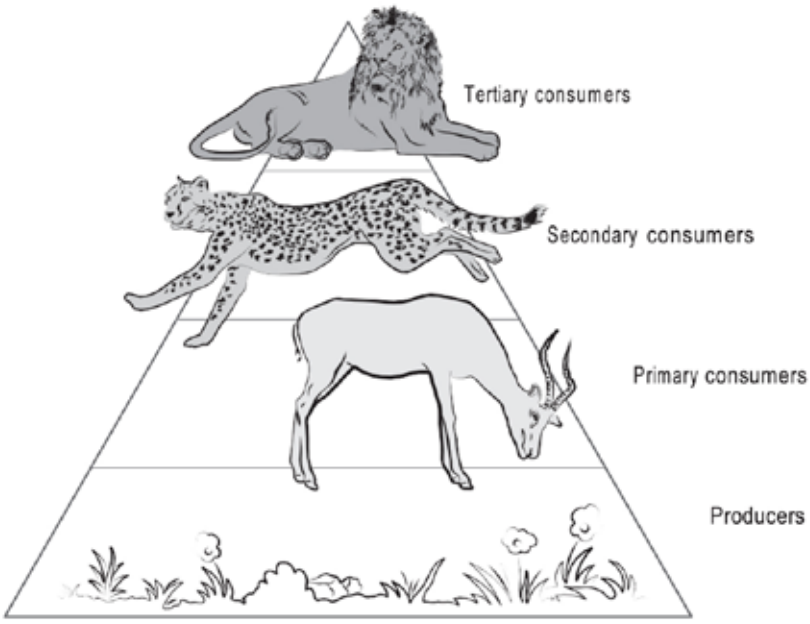
has a way of selecting the best methods, and this shouldn't be sur- prising: long periods of observation, experience, and trials were bound to end with the same outcomes as those dictated by formal scientific understanding



Trophic levels: the terrestrial pyramid of life.

Quantitative Clues

The biosphere contains nearly 6,500 mammalian and almost 10,000 avian species, and yet the Food and Agriculture Organization's annual statistics count only 16 categories of domesticated animals.4 Most are single species (with numerous varieties); three categories combine two similar species (camels: dromedary and Bactrian; and camelids: llamas and alpacas); two contain two different species (rabbits and hares; geese and guinea fowl). Of these 16 groups, 12 are mammals and 4 are birds, and their total numbers are distrib- uted in a highly skewed manner. Larger ruminants dominate the mammalian count with more than 4 billion heads: about 1.5 billion cattle, 1.25 billion sheep, 1.1 billion goats, some 200 million water buffalo, and 40 million camels.5 Pigs rank next, at nearly a billion; horses, asses, mules, and camels add up to only about 130 million; and in 2020 there were fewer than 200,000 caged rabbits (and hares) and fewer than 20,000 domesticated rodents (mostly Andean guinea pigs). Among birds, chickens—after a rapid global diffusion—are vastly more numerous than any other domesticated avian species: about 33 billion in 2020, compared to some 1.1 billion ducks, and less than half a billion each of turkeys and geese.6

All of these animals are herbivores, although pigs, as well as ducks and geese, are opportunistically

omnivorous. Less than 5 percent of a wild pig's diet consists of insects and small animals, and domesti- cated pigs will feed on garbage of any kind or on carcasses of animals, while ducks will eat, if they come across them, insects, small fish, and crustaceans, and so would geese, but both species are overwhelmingly herbivorous.7 The biosphere's macroscopic pyramid of life—which you might remember, however vaguely, from school—rests on the photosynthetic productivity of plants (primary producers, the first trophic level), and the most abundant mammals will be herbivores (primary consumers at the second trophic level) able to feed directly on various plant parts.8 The number of secondary consumers (the third trophic level, including foxes and bears)—carnivores eating primary consumers and omnivores eating plants and primary consumers—and their total zoomass will be necessarily smaller.

Tertiary consumers (the fourth trophic level) can also be omniv- orous, but the carnivorous species eat both primary and secondary consumers: lions will kill antelopes but they will also kill and, when hungry, eat cheetahs (although, there are exceptions to everything, and they do not eat the leopards or hyenas that they kill). Tertiary consumers are much more common in the ocean, with sharks and tuna the most massive examples. The aggregate zoomass of all blue- fin tuna in the ocean is much smaller than that of the carnivorous mackerel (secondary consumers) on which they feed and vastly smaller than that of herring (primary consumers), which are also their common prey.

Not only are the most numerous domesticated mammals—cattle, sheep, and goats—herbivorous, they are ruminants, capable of digesting abundantly available lignocellulosic phytomass (see the first chapter), and hence have at their disposal vastly more biomass than most of the mammals who are unable to digest those com- pounds. But being a herbivore (and especially a ruminant) is not enough to be selected for domestication: size and behavior are both very important.

Size Matters

Size matters in two important ways: in feeding animals and in taking care of them. The specific basal metabolism (the energy required at rest per unit of body weight) of warm-blooded animals decreases with increasing body size.9 A 400-kilogram cow will need only about 60 percent as much energy per kilogram of body mass as a 40-kilogram sheep, and the sheep will need only about 25 per- cent as much energy as a 400-gram rat, and the rat has a far lower specific metabolism than a 20-gram mouse.

So, even if you were to confine mice in very small cages (and hence reduce their energy needs close to their basal or resting metabolism), they would still need almost five times as much feed per unit of weight as a small goat, nearly ten times as much as a large pig—and all that to get too much skin (smaller animals have relatively larger body surface areas) and mere grams of meat per animal. This is why mice were caught and eaten by some societies (Romans ate dormice, glires, fattened in jars, gutted, and stuffed with minced pork) but were never really domesticated.10 And this is also why the annual meat output from the smallest domesticated mammals—guinea

pigs (they need only about a third as much feed per unit of body mass as a mouse) and rabbits—has remained limited.

Guinea pigs (yielding less than a kilogram of meat per carcass) have never made it globally as a source of food and their rearing remains confined to its original region of domestication as they are fed food scraps in Andean kitchens.11 Rabbits are larger, with three- month-old animals having live weight mostly between 1.5 and 2 kilograms, and heavier (up to six months old) rabbits for roasting weighing 2.5–3.5 kilograms. With carcass weight being about 50 percent of the live weight, a small rabbit yields less than a kilogram of meat, still too small to become a global favorite: their produc- tion is highly concentrated in just a handful of countries dominated by China and including North Korea, Egypt, Italy, and Russia.12

What's for DInner?

As you can see, metabolic considerations and typical meat yields favor larger mammals—animals found in plentiful numbers whose carcasses provide enough meat for at least an entire family. Goats and sheep have all the desirable attributes facilitating domestica- tion.13 They are the right sizes: most adult sheep weigh between 50 and 120 kilograms, and larger varieties of adult goats can match that range. Small goats, common in parts of Asia, weigh only 25–40 kilo- grams. Both species are ruminants and are able to adapt to harsh climates (arid, cold), and goats, in particular, eat thorny plants and climb steeply inclined surfaces with their split hooves and rubber- like soles. And their suitability for domestication is further enhanced by their social behavior. Sheep have an intensely gregarious social instinct resulting in a strong flock mentality, and goat flocks can even mingle with sheep, cows, and horses.14

While Islam, Hinduism, and Judaism label pigs as unclean ani- mals, a proscription that reduces the pool of potential pork consumers by about 3 billion people—or nearly two-fifths of humanity—pork is still by far the most consumed mammalian meat.15 About 110 million tons of it was produced in 2020, which is about 60 percent more than beef and 3.5 times as much as goat and sheep meat combined. As with sheep and goats, a combination of attributes facilitated the domestication of wild pigs. Mass-wise they are compromise mammals (not too small, not too large) and their body mass range overlaps our body weights (mostly between 60 and 150 kilograms). Pigs are also adaptable to a range of climates (from the tropics to the sub-Arctic), their omnivory makes them easy to feed, they are social animals that can be herded like sheep, and like sheep (and unlike goats), fats make up a relatively high share of their carcasses—a welcome attribute in societies whose traditional diets were short of fats.16

Cattle, much like sheep and goats, are ruminants (more grazers than browsers, preferring grasses to leaves and branches) with dis- tinct social structures.17 They recognize human faces, and when properly handled they are docile and readily herded. But they weigh considerably more than sheep, goats, and pigs, which has the advan- tage of providing plenty of meat per animal. Although their heavy bones and skin reduce their edible carcass weight to only about 40 percent of live weight (for pigs this ratio is about 60 percent), their large size means that a mature animal will yield at least 150 kilo- grams (for low-weight Indian cows) and up to 350 kilograms of meat for large European breeds.

But this high meat yield per animal carries high metabolic costs: to reach such substantial slaughter weights takes long periods of feeding, and although the basal metabolism of larger mammals is lower than that of smaller species, this advantage is negated by their much larger body mass: cows of heavy cattle breeds can weigh more than 700 kilograms; the heaviest bulls can weigh more than a ton.18 As a result, even modern meat breeds, fed carefully balanced mix- tures in large feedlots, go to slaughter only after at least two years of this practice. We will assess the energy requirements of specific feeding regimes later in this chapter, but for now, it is clear that producing beef is less efficient and more environmentally demand- ing than producing pork.