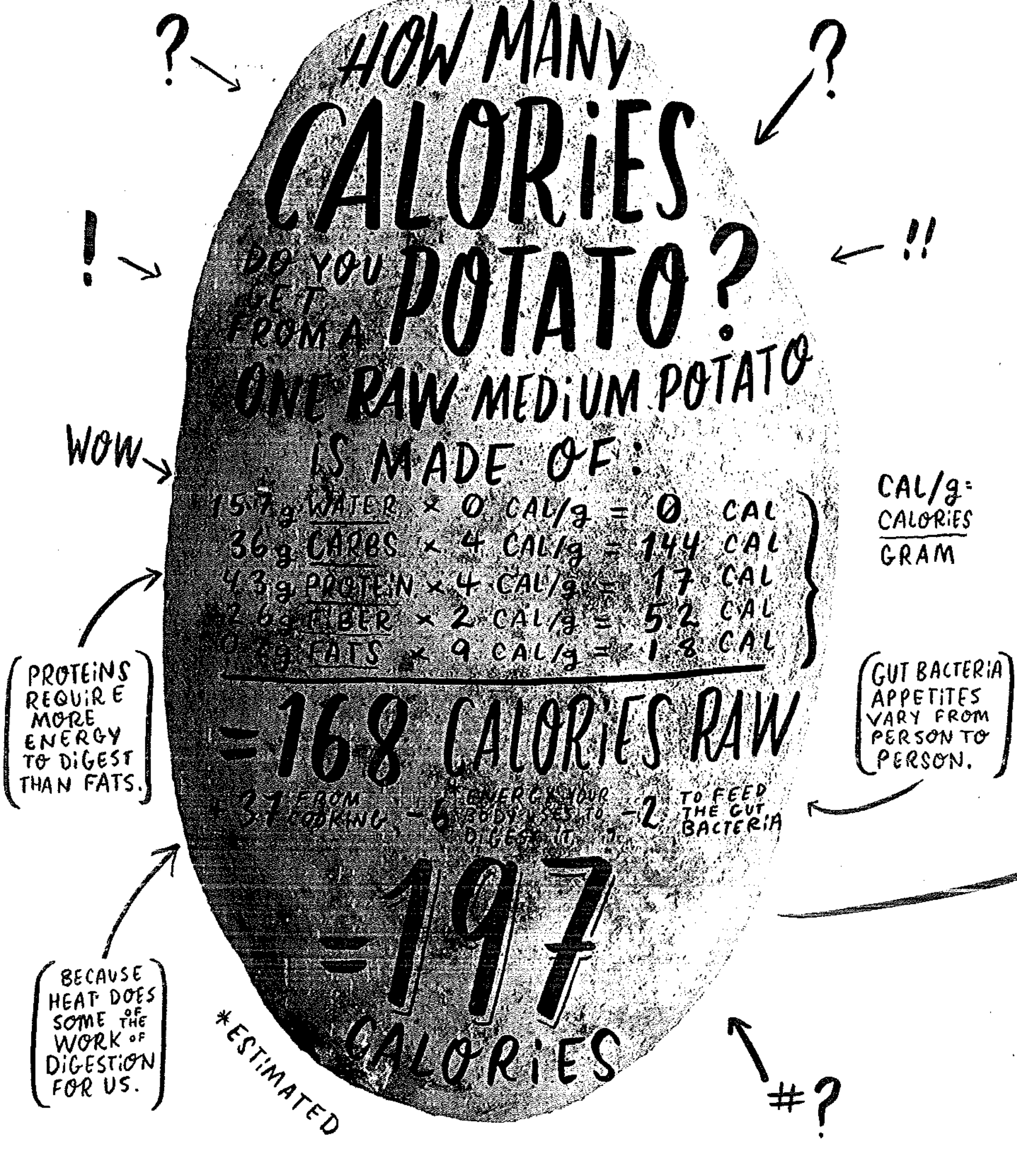

JUSTIN LIGHTLEY Getty Images (potato)

NUTRITION

everything you know about calories is wrong

Digestion is far too messy a process to accurately convey in neat numbers. The counts on food labels can differ wildly from the calories you actually extract, for many reasons

By Rob Dunn

AT ONE PARTICULARLY STRANGE MOMENT IN MY career, I found myself picking through giant conical piles of dung produced by emus—those goofy Australian kin to the ostrich. I was trying to figure out how often seeds pass all the way through the emu digestive system intact enough to germinate. My colleagues and I planted thousands of collected seeds and waited. Eventually, little jungles grew.

Clearly, the plants that emus eat have evolved seeds that can survive digestion relatively unscathed. Whereas the birds want to get as many calories from fruits as possible—including from the seeds—the plants are invested in protecting their progeny. Although it did not occur to me at the time, I later realized that humans, too, engage in a kind of tug-of-war with the food we eat, a battle in which we are measuring the spoils—calories—all wrong.

Food is energy for the body. Digestive enzymes in the mouth, stomach and

JUSTIN LIGHTLEY *Getty Images (potato)*

Illustration by Joel Holland

intestines break up complex food molecules into simpler structures, such as sugars and amino acids that travel through the bloodstream to all our tissues. Our cells use the energy stored in the chemical bonds of these simpler molecules to carry on business as usual. We calculate the available energy in all foods with a unit known as the food calorie, or kilocalorie—the amount of energy required to heat one kilogram of water by one degree Celsius. Fats provide approximately nine calories per gram, whereas carbohydrates and proteins deliver just four. Fiber offers a piddling two calories because enzymes in the human digestive tract have great difficulty chopping it up into smaller molecules.

Every calorie count on every food label you have ever seen is based on these estimates or on modest derivations thereof. Yet these approximations assume that the 19th-century laboratory experiments on which they are based accurately reflect how much energy different people with different bodies derive from many different kinds of food. New research has revealed that this assumption is, at best, far too simplistic. To accurately calculate the total calories that someone gets out of a given food, you would have to take into account a dizzying array of factors, including whether that food has evolved to survive digestion; how boiling, baking, microwaving or flambéing a food changes its structure and chemistry; how much energy the body expends to break down different kinds of food; and the extent to which the billions of bacteria in the gut aid human digestion and, conversely, steal some calories for themselves.

Nutrition scientists are beginning to learn enough to hypothetically improve calorie labels, but digestion turns out to be such a fantastically complex and messy affair that we will probably never derive a formula for an infallible calorie count.

A HARD NUT TO CRACK

THE FLAWS in modern calorie counts originated in the 19th century, when American chemist Wilbur Olin Atwater developed a system, still used today, for calculating the average number of calories in one gram of fat, protein and carbohydrate. Atwater was doing his best, but no food is average. Every food is digested in its own way.

Consider how vegetables vary in their digestibility. We eat the stems, leaves and roots of hundreds of different plants. The walls of plant cells in the stems and leaves of some species are much tougher than those in other species. Even within a single plant, the durability of cell walls can differ. Older leaves tend to have sturdier cell walls than young ones. Generally speaking, the weaker or more degraded the cell walls in the plant material we eat, the more calories we get from it. Cooking easily ruptures cells in, say, spinach and zucchini, but cassava (*Manihot esculenta*) or Chinese water chestnut (*Eleocharis dulcis*) is much more resistant. When cell walls hold strong, foods hoard their precious calories and pass through our body intact (think corn).

Some plant parts have evolved adaptations either to make

Rob Dunn is a biologist at North Carolina State University and a writer whose articles have appeared in *Natural History*, *Smithsonian* and *National Geographic*, among other publications. His most recent book is *The Wild Life of Our Bodies* (Harper, 2011).

themselves more appetizing to animals or to evade digestion altogether. Fruits and nuts first evolved in the Cretaceous (between 145 and 65 million years ago), not long after mammals were beginning to run between the legs of dinosaurs. Evolution favored fruits that were both tasty and easy to digest to better attract animals that could help plants scatter seeds. It also favored nuts and seeds that were hard to digest, however. After all, seeds and nuts need to survive the guts of birds, bats, rodents and monkeys to spread the genes they contain.

Studies suggest that peanuts, pistachios and almonds are less completely digested than other foods with similar levels of proteins, carbohydrates and fats, meaning they relinquish fewer calories than one would expect. A new study by Janet A. Novotny and her colleagues at the U.S. Department of Agriculture found that when people eat almonds, they receive just 129 calories per serving rather than the 170 calories reported on the label. They reached this conclusion by asking people to follow the same exact diets—except for the amount of almonds they ate—and measuring the unused calories in their feces and urine.

Even foods that have not evolved to survive digestion differ markedly in their digestibility. Proteins may require as much as five times more energy to digest as fats because our enzymes must unravel the tightly wound strings of amino acids from which proteins are built. Yet food labels do not account for this expenditure. Some foods such as honey are so readily used that our digestive system is hardly put to use. They break down in our stomach and slip quickly across the walls of our intestines into the bloodstream: game over.

Finally, some foods prompt the immune system to identify and deal with any hitchhiking pathogens. No one has seriously evaluated just how many calories this process involves, but it is probably quite a few. A somewhat raw piece of meat can harbor lots of potentially dangerous microbes. Even if our immune system does not attack any of the pathogens in our food, it still uses up energy to take the first step of distinguishing friend from foe. This is not to mention the potentially enormous calorie loss if a pathogen in uncooked meat leads to diarrhea.

WHAT'S COOKING?

PERHAPS THE BIGGEST PROBLEM with modern calorie labels is that they fail to account for an everyday activity that dramatically alters how much energy we get from food: the way we simmer, sizzle, sauté and otherwise process what we eat. When studying

IN BRIEF

Almost every packaged food today features calorie counts in its label. Most of these counts are inaccurate because they are based on a system of averages that ignores the complexity of digestion.

Recent research reveals that how many calories we extract from food depends on which species we eat, how we prepare our food, which bacteria are in our gut and how much energy we use to digest different foods.

Current calorie counts do not consider any of these factors. Digestion is so intricate that even if we try to improve calorie counts, we will likely never make them perfectly accurate.

the feeding behavior of wild chimpanzees, biologist Richard Wrangham, now at Harvard University, tried eating what the chimps ate. He went hungry and finally gave in to eating human foods. He has come to believe that learning to process food—cooking it with fire and pounding it with stones—was a milestone of human evolution. Emus do not process food; neither, to any real extent, do any of the apes. Yet every human culture in the world has technology for modifying its food. We grind, we heat, we ferment. When humans learned to cook food—particularly, meat—they would have dramatically increased the number of calories they extracted from that food. Wrangham proposes that getting more energy from food allowed humans to develop and nourish exceptionally large brains relative to body size. But no one had precisely investigated, in a controlled experiment, how processing food changes the energy it provides—until now.

Rachel N. Carmody, a former graduate student in Wrangham's lab, and her collaborators fed adult male mice either sweet potatoes or lean beef. She served these foods raw and whole, raw and pounded, cooked and whole, or cooked and pounded and allowed the mice to eat as much as they wanted for four days. Mice lost around four grams of weight on raw sweet potatoes but gained weight on cooked potatoes, pounded and whole. Similarly, the mice retained one gram more of body mass when consuming cooked meat rather than raw meat. This reaction makes biological sense. Heat hastens the unraveling, and thus the digestibility, of proteins, as well as killing bacteria, presumably reducing the energy the immune system must expend to battle any pathogens.

Carmody's findings also apply to industrial processing. In a 2010 study people who ate 600- or 800-calorie portions of whole-wheat bread with sunflower seeds, kernels of grain and cheddar cheese expended twice as much energy to digest that food as did individuals who consumed the same quantity of white bread and "processed cheese product." Consequently, people snacking on whole wheat obtained 10 percent fewer calories.

Even if two people eat the same sweet potato or piece of meat cooked the same way, they will not get the same number of calories out of it. Carmody and her colleagues studied inbred mice with highly similar genetics. Yet the mice still varied in terms of how much they grew or shrank on a given diet. People differ in nearly all traits, including inconspicuous features, such as the size of the gut. Measuring people's colons has not been popular for years, but when it was the craze among European scientists in the early 1900s, studies discovered that certain Russian populations had large intestines that were about 57 centimeters longer on average than those of certain Polish populations. Because the final stages of nutrient absorption occur in the large intestine, a Russian eating the same amount of food as a Pole is likely to get more calories from it. People also vary in the particular enzymes they produce. By some measures, most adults do not produce the enzyme lactase, which is necessary to break down lactose sugars in milk. As a result, one man's high-calorie latte is another's low-calorie case of the runs.

People differ immensely as well in what scientists have come to regard as an extra organ of the human body—the community of bacteria living in the intestines. In humans, two phyla of bacteria, Bacteroidetes and Firmicutes, dominate the gut. Researchers have found that obese people have more Firmicutes in their intestines and have proposed that some people are obese, in part, because the extra bacteria make them more efficient at metabolizing food: so instead of being lost as waste, more nutrients make their way into the circulation and, if they go unused, get stored as fat. Other microbes turn up only in specific peoples. Some Japanese individuals, for example, have a microbe in their intestines that is particularly good at breaking down seaweed. It turns out this intestinal bacterium stole the seaweed-digesting genes from a marine bacterium that lingered on raw seaweed salads.

Because many modern diets contain so many easily digestible processed foods, they may be reducing the populations of gut microbes that evolved to digest the more fibrous matter our own enzymes cannot. If we continue to make our gut a less friendly environment for such bacteria, we may get fewer calories from tough foods such as celery.

Few people have attempted to improve calorie counts on food labels based on our current understanding of human digestion. We could tweak the Atwater system to account for the special digestive challenges posed by nuts. We could even do so nut by nut or, more generally, food by food. Such changes (which have unsurprisingly been supported by the Almond Board of California, an advocacy group) would, however, require scientists to study each and every food the same way that Novotny and her colleagues investigated almonds, one bag of feces and jar of urine at a time. Judging by the FDA's regulations, the agency would be unlikely to prevent food sellers from adjusting calorie counts based on such new studies. The bigger challenge is modifying labels based on how items are processed; no one seems to have launched any efforts to make this larger change.

Even if we entirely revamped calorie counts, however, they would never be precisely accurate because the amount of calories we extract from food depends on such a complex interaction between food and the human body and its many microbes. In the end, we all want to know how to make the smartest choices at the supermarket. Merely counting calories based on food labels is an overly simplistic approach to eating a healthy diet—one that does not necessarily improve our health, even if it helps us lose weight. Instead we should think more carefully about the energy we get from our food in the context of human biology. Processed foods are so easily digested in the stomach and intestines that they give us a lot of energy for very little work. In contrast, veggies, nuts and whole grains make us sweat for our calories, generally offer far more vitamins and nutrients than processed items, and keep our gut bacteria happy. So it would be logical for people who want to eat healthier and cut calories to favor whole and raw foods over highly processed foods. You might call it the way of the emu. ■

MORE TO EXPLORE

Postprandial Energy Expenditure in Whole-Food and Processed-Food Meals: Implications for Daily Energy Expenditure. Sadie B. Barr and Jonathan C. Wright in *Food & Nutrition Research,* Vol. 54; 2010.

Discrepancy between the Atwater Factor Predicted and Empirically Measured Energy Values of Almonds in Human Diets. Janet A. Novotny, Sarah K. Gebauer and David J. Baer in *American Journal of Clinical Nutrition,* Vol. 96, No. 2, pages 296–301; August 1, 2012.

SCIENTIFIC AMERICAN ONLINE
To watch an Instand Egghead video about why traditional calorie counts are inaccurate, visit ScientificAmerican.com/sep2013/calories