2 Unbalanced Act

Because eating is under conscious control—one can always decide not to put fork to mouth—weight has always been seen as a very individual, very personal thing. And being overweight, in turn, a matter of an individual's decisions—or, rather, of a failure to make decisions.[1] That is perhaps why most people believe that every overweight person can achieve slenderness and should pursue that goal, why obese people are stereotyped as lacking in self-control, and why being obese elicits scorn as often as sympathy.[2]

The inclination to explain health in terms of personal responsibility is deeply rooted in the Western culture, where both the power and responsibility of the individual are paramount.[3] And nowhere is this truer than in the United States. As Howard Leichter observes,[4]

> [T]he timelessness and persistence of holding the individual person responsible for his or her own health status has its genesis in one of the most distinguishing historical features of American culture and politics, namely the extraordinary emphasis on individuals' rights and responsibilities.

The *wellness movement*, which in the last few decades has taken hold of the health mentality of a large segment of the United States population, is rooted in this very concept of personal control over health. This is not surprising, as the notion of personal responsibility for our continual transformation, self-rejuvenation, and self-repair is certainly an appealing and almost irresistible one.[5] Perhaps the most striking expression of this focus on individual responsibility is Americans' quest for the perfect body. This obsession may explain why people with the "wrong" bodies are so poorly judged in American society, that is, considered self-indulgent, lazy, and lacking control, while those with the "right" bodies are seen as models of self-control.[6]

This individual-centered and (as we shall see) simplistic view of obesity's cause is not limited to laypeople. Health care professionals, it is disturbing to note, are among the chief offenders. Numerous studies of health care providers—dieticians, physicians, family doctors—reveal that many believe

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excess body weight simply reflects a lack of willpower, poor self-concept, and deep-seated psychological problems.[7] It is a disturbing finding because it has destructive results, including prejudice and discrimination toward the very patients for whom these professionals care.[8,9] In one study, for example, a survey of physicians found that they viewed their obese patients as weak-willed and even ugly and awkward. In another study, as many as 78 percent of the obese patients surveyed reported that they had "always, or usually, been treated disrespectfully by the medical profession because of [their] weight."[10]

"For every complex problem there is an [explanation] that is simple, direct, and . . . wrong."

—H.L. Mencken[11]

The individual-centered "theory" is an appealing proposition. For starters, it is a single-cause explanation and, hence, a simple one. And simple explanations can be very seductive to laypeople and experts alike. Cognitive theorists and philosophers argue that humans tend to seek simple causes for even the most complex problems.[12,13] Unfortunately, many of the simplifying short-cuts we habitually take have been shown to systematically lead to errors in judgment.

When explaining the causes of some behavior, for example, it is common for people to rely on factors that are most salient to them. The most salient thing in health behavior is the "actor" who is behaving. People are in the foreground; almost everything else—situational and environmental factors—is in the background. Hence the cognitive "trap."

> This over-readiness to explain behavior [not only in obesity, but for many dysfunctional behaviors] in terms of dispositional factors [such as abilities, traits, and motives] is so widespread and universal that it [has been] called "the fundamental attribution error."[14]

It is a tendency that often leads to attributions that are patently wrong. An example of biblical proportion is the one committed by the sailors in the Book of Jonah. "When a storm hit their ship, they didn't ascribe it to a seasonal weather pattern. They attributed the cause to Jonah's sinfulness, and responded by throwing him overboard."[15] In the case of health issues, the *fundamental attribution error* creates the bias of overattributing behavior to factors such as personal control, and grossly underweighing the influence of situational factors such as the socio-economic system in which we live.

As we have already seen in Chapter 1, experts are not impervious to such cognitive bias. In the past and still today, many in the health field have been engulfed by the overreadiness to explain health behavior in terms of individual-level drivers—the notion of i*ndividualization*.[16] From the proponents of the long-standing behavioral model of disease, who view disease as stemming from the individual's choices and behaviors, to the more recent genetic model, in which disease is considered strongly influenced by an individual's unique genetic makeup,[17] this cognitive bias remains strong.

Biases—indeed most cognitive traps—thrive more easily and persist longer when there is subtlety and complexity, not when cause and effect are clear-cut, black-and-white affairs. In the domain of human health and disease, "grayness" and complexity remain, even today, the lay of the intellectual landscape.

There is no dispute, for example, that individual-level characteristics are important determinants of individual health and that our understanding of individual-level risk factors, from choices and behaviors to unique genetic makeup, has contributed greatly (and continues to contribute) to our understanding of health in populations. (A good example is the identification of lifestyle and biological factors associated with cardiovascular disease.) However, it has also become increasingly clear that a fixation on such determinants has limited our ability to examine and understand the full spectrum of disease causation.[18,19]

In the case of obesity, one consequence of the individual-centered fixation is the field's preoccupation with why individuals are obese and how to help them, rather than with why society is obese and how to help it.[20] Of the numerous diseases that have struck humanity throughout history, never has there been a disease as common as obesity. Many diseases were more deadly, for sure, but none as common. "[This] suggests that obesity develops through a mechanism which, unlike plague, tuberculosis, or AIDS, is induced by exposure to factors surrounding all of us in modern societies."[21] This may explain why, given the current environment, approaches to weight loss that focus on the individual have yielded less-than-impressive results.[22]

Another consequence of the individual-centered fixation is that individuals and the culture in general assume that they have more control than they actually do. Personal control is indeed important to human weight and energy regulation. However, we will see that control over our bodies must be considered within the context of environmental and cultural realities.

Part II provides a different conception of human health and disease, and, by extension, of the obesity problem. In contrast to the classical, individual-centered worldview, it is a systems-inspired worldview that adopts a much broader biopsychosocial perspective—one that looks beyond individuals' characteristics and behaviors for answers, to the symphony of behavior–biology–environment interactions.

The reason for this is scientific: our object of study demands it.[23]

Moving Beyond Individual-Centric Explanations

Obesity is not increasing because people are consciously trying to gain weight. Indeed, one of the major perplexities of this disease is that more and more people are getting fatter even in the face of broad publicity about the problem, tremendous pressure to be thin, and a titanic struggle by tens of millions of people to manage their weight. The fact that Americans spend some $50 billion annually on weight-loss products and services—services such as liposuction, which has become the most popular cosmetic surgery procedure in the country—shows that they can hardly be happy with the status quo.[24]

How, then, did we, as a society, get into this mess? To understand, we will need to go way back into our human history and evolution. An anthropological perspective, examining the problem and its root causes in the broader context of human history and cultural evolution, suggests that the obesity epidemic in Western cultures is caused by a mismatch between the modern living environment we share and a human physiology rooted in our evolutionary past.

"Civilization is but a filmy fringe on the history of man."

—William Osier

In the above quotation, Osier, the Canadian physician and historian, is saying that the past few millennia of human civilization represent a tiny fraction of the time since our human ancestors first appeared on earth.[25] Archaeological data suggest that it was not until approximately 12,000 years ago that some human groups started to shift from a food-foraging mode of existence to one of food production. This shift was driven primarily by ecological pressures from population growth and food scarcities, and it would prove to be of great consequence, as it was this relatively recent economic transformation that would ultimately allow for the evolution of complex societies and of civilization itself.[26]

But before that "filmy fringe" on our history and for hundreds of thousands of years, humans lived as hunter-gatherers dependent for their nourishment on the supply of game and on whatever fruits, nuts, berries, roots, leaves, and other vegetable matter was available.[27] While their diet was qualitatively adequate, food was scarce and the next meal unpredictable. In most prehistoric societies, starvation was a constant threat.[28]

Our understanding of life in the hunter-gatherer societies of antiquity is based not only on the abundant archaeological evidence that we have

accumulated, but also on the anthropological study of *contemporary* hunter-gatherer populations. In what would surely qualify as a *Believe It or Not* story, there are today, at the dawn of the 21st century, some contemporary nonindustrial societies that are, in fact, "good approximations" of Stone Age humans of about 20,000 years ago—and not one or two, but a hundred or more.

Not surprisingly, they have all been the focus of intensive study by anthropologists. A cross-cultural ethnographic survey of a sample of more than a hundred such societies found seasonal food shortages for all of them, the same type of pattern that archaeological studies of excavated skeletal remains have revealed about the prehistoric hunter-gatherer societies. Shortages occur annually or even more frequently for roughly half of the societies, and the shortages are "severe" (approaching starvation-level) in nearly a third of them.[29]

That is the bad news. The good news, however, is that these best approximation surrogates for our human ancestors experience slow population growth, enjoy high-quality diets, maintain high levels of physical fitness, and are generally healthy. They are healthier, in fact, than many of the third-world populations currently undergoing the process of economic modernization or westernization.[30]

This is no accident. The interaction between any species and its food supply is one of the most important influences affecting biological adaptation and cultural evolution.[31] Because the struggle for survival of the human species has been driven by a lack, not an excess, of food, the human body has developed over the years to defend itself actively against this threat,[32] and it has succeeded.

In the hunter-gatherer mode of existence, where a high level of physical activity was required for daily subsistence and the food supply was inconsistent, the challenge to the body energy-control system was to provide a strong drive to eat to keep pace with energy expenditure and to rest when physical exertion was not required.[33] Because starvation was not only real but also a periodic threat, the greatest survival rates were among those who not only ate voraciously when food was plentiful, but who also stored the excess energy efficiently as a buffer against future food shortages.[34] Such individuals built up stores of fat that increased their survival prospects during famines, and they passed on these traits to their progeny, who, similarly, were more likely to survive.[35] For the females, whose reproductive fitness depended on their ability to withstand the nutritional demands of pregnancy and lactation, greater energy reserves provided a selective advantage over their lean counterparts in withstanding the stress of food shortage, not only for themselves but also for their fetuses and nursing children.[36,37]

It should not surprise, then, as Sharman Russell writes in his informative book, *Hunger: An Unnatural History*, that since human beings evolved to

survive chronic threats of famine, we have grown afflicted by "chronic, troubling urges to gorge, grab, and hoard."

Our taste buds are also rooted in our evolutionary past. When, thousands of years ago, humans were hunting wild game and gathering wild plants for food, their primary food sources contained limited sugar, fat, and salt. But because these are essential to the proper functioning of the human body, it was always good for people to eat as much of them as they could find. In another adaptive response to human dietary needs, evolution equipped us with a nearly insatiable appetite for fat, salt, and sugar to encourage us to eat these foods. These strong taste preferences have been genetically passed on to us over the generations—and to good effect, until now.

> Fatty foods helped our ancestors weather food shortages. Salt helped them maintain an appropriate water balance in their cells, helping avoid dehydration. Sugar and the sweetness associated with it helped them distinguish edible berries from poisonous ones. By giving us the taste for fat, sugar, and salt, our genetics led us to prefer the foods that were most likely to keep us alive. It also led us to want to eat a wide variety of foods. The more types of foods we could eat, the more we were likely to consume the wide range of unknown nutrients we needed. Our natural inclination for variety made sure we got enough of these nutrients without us needing to know the difference between vitamin C, riboflavin, and a complex carbohydrate.[38]

In this evolutionary context, the usual range of human metabolic variation would have produced many individuals with a predisposition to become fat, but chronic food scarcity and vigorous physical exertion ensured that they never would.[39] Skeletal remains indicate that our human ancestors were typically more lean and muscular than we are today, and studies of contemporary hunter-gatherer populations are consistent with this finding. For example, studies of the !Kung San tribe in the Kalahari Desert show them to be lean, with skin fold thicknesses approximately half those of age-matched North Americans and suffering no obesity problem.[40,41]

This suggests that, despite seasonal fluctuations in food availability and a mode of existence characterized by vigorous physical exertion, the caloric intake and output of our hunter-gatherer ancestors were balanced over time.[42] Eating whatever animals they could kill or scavenge and whatever fruit and vegetable matter they could take from plants, early humans kept enough fat stores to make it through the occasional lean times, but not so much that it slowed them down significantly. Further, control of their body weight was largely accomplished through innate physiological processes and required little conscious effort. They did not have to think about how much to eat in order to maintain a desirable weight. Their bodies told them.[43]

Our current predicament, it turns out, is a direct byproduct of our early successes. Let's see how.

Evolved Asymmetry of Our Physiology

As mentioned, feeding behavior was a function that humans accomplished largely unconsciously and automatically. Given that obesity was not a common health problem throughout most of human history, it is not unreasonable that people instinctively believe that the body's regulatory system strives to maintain stability at some "natural" body weight, defending against both weight loss and weight gain.[44] Such a system would be symmetrical, defending against both positive and negative energy balances that threaten to cause weight change.

Unfortunately, this is a fundamental misconception that, because it remains quite common, seriously undermines (as we shall see in later sections) prevention efforts.

In reality, humans display a system of weight regulation that is *asymmetrical*. Because survival in a food-scarce environment is more acutely threatened by starvation than by obesity, evolution has selected our physiology and behavior to favor overconsumption rather than underconsumption. That is, our regulatory system has been organized by evolutionary selection to galvanize in a more robust way in response to deficient energy intake and stores than to excess energy.[45]

Before we see how this is accomplished, let's contemplate for just a moment the alternative: that of a *symmetrical* system that defends *equally* against weight loss or gain, while striving to maintain stability at some "normal" body weight. In a food-scarce environment, such a system would have probably led to extinction, because lower-than-average food levels would have led to a drop in weight to below "target." That's the downside. But an abundance of food would have exceeded the regularity system's "needs" (and capacity) to store it, leading to a maximum weight equal only to the target weight. This provides no upside to balance the downside.

Professor Sam Savage of Stanford University provides an interesting analogy that demonstrates how such a symmetric model would similarly lead to bankruptcy (cash starvation?) in business. Consider a hypothetical case of an entrepreneur considering building a manufacturing facility for a new product. She did extensive market analysis for her new product and expects average annual demand to be 100,000 units. A further analysis of construction and operating costs suggests that building and running a manufacturing facility with a 100,000 capacity would yield a healthy $10 million annual profit. What would happen if the demand of 100,000 units is indeed the correct average, but with year-to-year fluctuations between say 50,000 ("famine" market conditions) and 150,000 units ("feast" market conditions)? Intuitively, most people would expect that profit would still average out to $10 million: Some years it would be below, but those years would be

compensated for by other years when it is above. Right? Wrong! Lower-than-average demand clearly leads to profits of less than $10 million. That's the downside. But greater demand exceeds the capacity of the new plant, leading to a ceiling on profit of $10 million. There is no upside to balance the downside. The result: an average profit much lower than the "target," perhaps leading to bankruptcy (extinction).

How Asymmetry Is Achieved by Our Physiology

The energy dynamic between organisms and their environments, that is, energy expended in the search for and consumption of food in relation to energy acquired and used for biological processes, is absolutely critical to survival and reproduction. This dynamic has important adaptive consequences for any organism's evolution.[46] Thus, it is not at all surprising that nature has worked so hard to make us succeed in a food-scarce environment. Indeed, we *have* succeeded, and this section explains how: how in humans, multiple redundant physiological systems evolved to ensure sufficient energy balance for survival and reproduction; and how humans display a system of weight and energy regulation that is *asymmetrical* not only in energy input (favoring overconsumption over underconsumption of food), but also in energy expenditure and storage.

Asymmetry in Energy Intake

In humans, feeding is controlled by two regulatory subsystems, one short-term and the other long-term. The short-term component controls the onset and cessation of feeding on a meal-to-meal basis. During the course of a meal, the body relies on an extensive array of receptors along the gastrointestinal tract to relay information to the brain about the amount and nutrient content of the food, such that the meal can be terminated when sufficient food has been consumed.[47,48]

Here's how this short-term subsystem works: as a meal is consumed, the presence of food in the gastrointestinal (GI) tract causes mechanoreceptors in the stomach to stretch, sending a message to the brain about the amount of food ingested. At the same time, the different nutrients of ingested food interact with chemoreceptors along the small intestine, triggering the release of GI hormones (such as cholecystokinin) to signal the nutrient content of the ingested meal. These neuronal and hormonal signals are decoded in the brain's feeding-control center (within the hypothalamus) to track the amount of food eaten and its nutrient content and to orchestrate the feelings of hunger/satiation that drive us to continue or to stop eating.[49]

A feeding episode—a meal—provides energy substrate to meet the immediate metabolic needs of the body. After a large meal, the unused portion of ingested food energy is stored, primarily in the body's depot of fat reserves. The function of the second long-term regulatory component is to monitor the depletion/repletion of these reserves—a function, it turns out, that's critical not only to our survival but also to our convenience.

To stay alive, humans, like all living organisms, need to continuously expend energy—literally every second of every day, whether we are awake or asleep. We must do that both to fuel physical activity and to sustain the body's basic metabolic and internal housekeeping functions. Our capacity to store energy long-term is what allows us to expend energy *continuously*, without having to constantly infuse energy into our bodies.

Consider for a moment how inconvenient it would be if that were not the case. It would be like running a retail business with some product on hand to sell but no additional inventory. Without the capacity to store energy long-term, energy output to sell but energy input would have to be tightly coupled; that is, for every calorie of energy *output* we expend, we would need a simultaneous infusion of a calorie of energy *input*. Since staying alive requires a continual exertion of energy, we would have to spend all our time finding and consuming food.

Thankfully, our energy stores—in a manner very much analogous to the role inventory plays in business—*decouple* energy-in and energy-out, so that energy expenditure can be continuous while energy input (feeding) does not have to be. That is what allows us to limit caloric consumption to just a few feeding episodes per day, with each one not only fulfilling our immediate energy needs, but also providing a little extra to supply our energy needs between meals and overnight, when there is no energy infusion.

Beyond the obvious convenience that this provides us on a day-to-day basis, our capacity to store energy is also key to our survival in a food-scarce environment. As with many other species that contend with a highly variable food supply, humans' energy regulation system is designed to maintain our energy reserves *at substantial enough levels* to provide a buffer against prolonged periods of food shortages.[50]

By contrast, species that live in an environment with a surplus of immediately available food—as many marine animals do, for example—do not need to maintain substantial energy stores.[51] The most striking example here might be the oyster. "[The oyster] only has to open its shell and filter the abundance of surrounding nutrients in sea water. [That's why the] oyster never gets fat; it is living in the midst of its food supply, and does not need to store energy."[52]

For species without constant access to food, conserving excess energy, primarily in the form of adipose tissue, is a necessary survival characteristic.

(*Adipose*, which is another word for fatty, comes from the Latin *adipatus*, meaning "greasy."[53]) These species include humans—and the polar bear.

> The main energy source of the polar bear is seal meat. The bear can only catch seals during the winter when the animals surface at the breathing openings in the ice. During the summer, with less ice, the polar bear cannot catch the seals, which are much more skilful swimmers than are bears. Throughout the winter the bears accumulate a massive amount of adipose tissue by preferentially selecting to eat the fat-rich parts of the seals such as the brains of the lean seal pups. The stored fat is then used for survival during the summer.[54]

Like the polar bear, human beings developed the ability to store energy in the form of fat during periods of surfeit to cope with the inevitability of periods of famine. In the words of Sharman Russell, this allowed our ancestors to survive not just a bad day of hunting, but a bad week of hunting, and not just a bad crop, but a bad year of crops.[55] Understanding how this is accomplished is important because it has direct bearing on obesity's etiology.

To regulate our energy stores at desired levels, the brain must perform two vital functions. First, it must sense the size of the fat stores and, second, it must be able to adjust hunger, satiety, and energy expenditure accordingly.[56] To do that, the brain relies on a lot of help from the body's fat mass.

In recent years it has become clear in recent years that the body's fat depot is not the passive receptacle of fat that it was once thought to be. Rather, the body's fat cells are highly active tissue that spins out a steady supply of nearly a dozen hormones—collectively known as adipokines—that carry messages to the brain and the rest of the body.[57] Because the concentrations of these hormonal secretions are proportional to the size of the body's fat mass, they serve as reliable signals to the brain about changes in (and the status of) the size of the body's aggregate fat stores.

Any time the brain detects a change in the status of the body's energy reserves—say a drop below desired levels—it triggers compensatory actions to adjust caloric intake and energy expenditure. An increase or decrease in caloric intake, for example, can be induced by adjusting the frequency or size of meals. This is achieved through the release of brain peptides (such as neuropeptide Y) from nerve terminals in the hypothalamus that serve to enhance or decrease the potency of the short-term satiety (or meal-ending) signals to the brain. In other words, the size of the fat reserves can turn up or turn down the *sensitivity* of the brain to the meal-generated satiety signals, which, as explained above, are part of the short-term regulatory subsystem. It is an elegant system, and it works.

> [A]n individual who has recently eaten insufficient food to maintain its weight will be less sensitive to meal-ending signals and, given the opportunity, will consume larger meals on the average. Analogously, an individual who has enjoyed excess

food and consequently gained some weight will, over time, become more sensitive to meal-terminating signals.[58]

This system of feeding regulation is asymmetric. This asymmetry results from the fact that the neuronal and endocrine factors generated when fat stores decrease (as a result of a prolonged negative energy balance) and that stimulate feeding are more potent than are the inhibitory signals generated when fat stores increase (as a result of overfeeding).

This was demonstrated more than twenty years ago in a clever series of experiments designed to reveal the differences in how humans compensate for increases/decreases in the energy content of their diet. In the experiments, Mattes et al.[59] surreptitiously diluted and then boosted the energy content of meals offered to free-living experimental subjects and observed how they compensated. What they found was rather surprising. When their subjects received lunches containing 66 percent fewer calories than their customary midday meal, the subjects compensated for the lunchtime deficit by ingesting additional nonlunch calories. As a result, their total energy intakes did not decrease. In contrast, when the subjects were covertly provided lunches containing 66 percent more calories than their customary midday meal, they did not adjust their nonlunch energy intake downward to compensate. As a result, total energy intake was significantly higher.

Humans, it thus appears, are "wired" to compensate for caloric dilution but not the reverse, exhibiting more tolerance for increases in caloric intake. Over the eons, this tendency served humans well since survival was more acutely threatened by starvation than by obesity.

The 1994 discovery of leptin by molecular biologists provided strong experimental support for this asymmetry in our regulatory system and significantly advanced our understanding of its biological underpinnings. Leptin is an amino acid protein synthesized in fat cells and secreted into the bloodstream in concentrations that are proportional to total fat stores. As such, it serves as a primary signaling mechanism to the brain about how much fat the body has stored. It has recently been shown experimentally that "when a person's fat stores shrink, so does [the body's] leptin production. In response, appetite increases while metabolism decreases."[60] The system, however, does not work quite the same in the other direction; that is, a rise in leptin does not necessarily lead to appetite reduction. The results "expose" the brain's true intentions in deploying leptin: it deploys it to track how much fat the body has stored *not to keep us from getting fat, but to keep us from getting too thin*.[61]

In summary, several principles may be deduced about human appetite regulation: (1) Feeding is controlled by two regulatory subsystems, one short-term and the other long-term. (2) The two systems are physiologically interdependent. (3) The two systems are not symmetric.

These principles provide prospective dieters with two crucial insights:

> *Firstly . . . biological processes exert a strong defense against under-eating which serves to protect the body from an energy (nutritional) deficit. Therefore, under-eating must normally be an active and deliberate process. Secondly, in general biological defenses against over-consumption are weak or inadequate. This means that over-eating may occur despite efforts of people to prevent it.*[62]

Asymmetry in Energy Expenditure

To adequately manage our energy reserves, it is not enough for the body's regulatory systems to manage the amount of energy input into the body. Just as in managing the financial budget of a business or a household, one needs to keep an eye on both sides of the ledger—what is coming in and what is going out—similarly with human energy regulation, the system needs to oversee how energy is stored and consumed. This subsection discusses energy consumption, and the next subsection explains how the body manages the status of its energy stores.

The body's total energy expenditure can be divided conceptually into three components. The smallest component (about 10 percent of daily energy expenditure) is the amount of energy expended in processing the food we eat—its digestion and absorption. A second component is the energy expended for muscular work. This typically accounts for 15 to 20 percent of daily energy expenditure, but can increase by a factor of two or more with heavy physical exertion.[63] The third and largest component is basal energy expenditure, also known as resting energy expenditure (REE), which is the maintenance energy required to keep us alive. This is the amount of energy required for the basic maintenance of the cells, maintaining body temperature, and sustaining the essential physiological functions (e.g., keeping the lungs inhaling and exhaling air, the bone marrow making new red blood cells, the heart beating 100,000 times a day, the kidneys filtering waste, etc.). In most of us the REE makes up about 60 to 70 percent of total energy expenditure.

As with the energy input side, the body's regulatory system for energy expenditure evolved to protect us against the frequent peril of food shortages and associated energy deficits, rather than energy surplus. The system evolved to complement the overconsumption bias (explained above) with the capacity to reduce the body's metabolic rate in response to negative energy balance and a bias toward conserving energy when physical activity is not required.[64] As Polivy and Herman[65] argue, it is an effective strategy that best ensures that the body's fuel reserves are conserved in lean times:

> If there is a dearth of food available, the organism is better served by physiological adjustments that render what *is* available more useful—by means of what has come to be known as a *thrifty* metabolism—rather than by promptings to acquire more

> food when there simply is no more to be acquired, or when the energy expended in acquiring more might well exceed the energy content of the food itself. In short, in an ecology of scarcity, we are better served by metabolic adjustments than by behavioral adjustments.

As soon as the body senses an energy deficit, basal metabolism drops quite dramatically in order to conserve energy and restrain the rate of tissue loss. This is achieved chiefly through hormonal mechanisms that operate to decrease the metabolic activity at the cellular level, in essence enhancing the tissues' metabolic efficiency, as though the body were changing its light bulbs to fluorescent lights to save energy.[66] This homeostatic mechanism acts as a first line of defense against energy imbalance—a buffer, if you will, that helps spare the body's fat reserves in lean times. While, today, that may be bad news for dieters (because it limits weight loss), the survival value of an energy-sparing regulatory process that aims to limit tissue depletion during food scarcity is obvious.

The body's regulatory mechanisms work in reverse when confronted with a positive energy balance. Sort of. When a period of sustained positive energy balance induces weight gain, the body's basal or REE does rise. But experimental studies of human energy regulation have demonstrated that in this less-threatening case, the body's biological signals are relatively "muted."[67] That is, while the body does adjust its REE level upward when in positive energy balance, the adjustments do not increase energy expenditures enough to fully compensate for the imbalance.

The system clearly is not as robustly organized to galvanize in response to surplus energy balances (which are not particularly threatening to survival) as it is in responding to deficits (which are very threatening). This asymmetric bias in energy expenditure is in sync with the one we saw earlier on the energy intake side. Working in concert, these two limbs of our body's energy regulation system have effectively evolved us into what we are today: "exquisitely efficient calorie conservation machines."[68]

Asymmetry in Energy Storage

The third and final component in the energy equation is energy storage. Our primary source of energy is the food we eat. The human diet provides three energy-yielding macronutrients: protein, carbohydrate, and fat. The primary task of proteins is to provide the major building blocks for the synthesis of body tissue.[69] By contrast, fat and carbohydrate serve as the primary fuels to the body, fueling biological work and our physical activity, and replenishing our reserves. They are not equivalent, however—not by a long shot.

By a large margin, the primary form in which the body stores excess food energy is fat in the fat cells called adipocytes. This is no coincidence since fat is the more efficient way to store energy. When stored as fat, energy is stored at about 9 kilocalories (kcal) per gram of adipose tissue, which is almost 2½ times as many calories of energy as each gram of glycogen (the form in which carbohydrates are stored in the body). "In lean adults, fat reserves typically amount to some 10 kg, an energy reserve of 90,000 kcal, enough to survive about two months of near total food deprivation."[70] By contrast, the average person has only about 2,500 calories of carbohydrate reserves, stored mostly in liver and muscle.

Our fat stores allow us to store energy efficiently and in a compact form, making it possible for us to carry a substantial energy reserve without being slowed down. That is an enormous benefit when an individual (or an animal) must be highly motile to survive.

The two fuels are functionally different, as well. Carbohydrate-based fuel provides faster energy transfer and can be used anaerobically; that is, it can be metabolized to produce energy without the simultaneous use of oxygen. This makes it the ideal fuel to use for activities that need immediate bursts of energy (i.e., whenever we perform at a rate that exceeds the capacity of the heart and lungs to supply oxygen to the muscles), such as when we are trying to catch a bus or escape a charging rhino.

As already discussed, fat tissue is not just a static "spare tire" of energy around our waist. Rather, it is a highly dynamic tissue that is continuously secreting active substances (e.g., leptin) that play important roles in the body's weight-regulating system. As we have already seen, when it comes to its fat reserves, the human body is decidedly biased, with defenses against the depletion of its fat reserves that are more potent than the inhibitory signals it generates when fat reserves increase (as a result of overfeeding). There is a second asymmetry in the regulation of fat stores in humans: *when body fat is shed during weight loss, the size, but not the number, of fat cells dwindles.*[71]

The total amount of fat in a person's body is dependent on two factors: the number and the size of the fat cells in the body. When a person experiences a positive energy balance and starts to gain weight, initially the excess energy gets stored in the body's existing stock of fat cells, increasing their size. Fat cells can expand in size quite a bit, but they have a biological limit. When the cells approach maximal or "peak" size, a process of adipocyte proliferation is initiated, increasing the body's fat cell count. Thus, obesity develops when a person's fat cells increase in number, in size, or, quite often, both. *Once fat cells are formed, however, the number seems to remain fixed even if weight is lost.*[72,73]

This means that over time, and given the chance, an individual's total adipocytes are biased to creep upward in number. Worse yet, as the new cells fill up with fat, they work to achieve and then maintain nominal size. (The details

of this mechanism are explained in Part III.) Long-term fat-cell proliferation results not only in an elevation of body weight, but also in the *defense* of that body weight,[74] and that is what makes *losing* excess weight so difficult.

Conclusion

Throughout much of human history, feeding behavior was set on "cruise-control," largely accomplished unconsciously and automatically, requiring little deliberate effort. Given that obesity was never a common health problem, it is quite understandable that people instinctively believe their body's feeding and energy regulation system is symmetrical, defending against both weight loss and weight gain. Unfortunately, this is but an illusion—and a risky one that may lull people into a false sense of invulnerability and seriously undermine obesity prevention.

In reality, as explained above, our weight regulation system is *asymmetric*. The fact that obesity was not a realistic possibility for our hunter-gatherer ancestors was a result of the "fit" between this asymmetrical design and their food-scarce environment—not the goal of the body's weight and energy regulation system.

Today, we are both lucky and unlucky. Most of us have ready access to food, but the very physiological adaptations that worked so effectively to keep us alive and in good form in a hunter-gatherer environment are resulting in a maladaptive response in our modern food-rich, activity-poor environment. With food becoming increasingly plentiful and the opportunities for physical exertion quickly diminishing, a persisting imbalance of energy intake and output is occurring in an ever-increasing proportion of the population.[75] It is an opportunity that was not anticipated by biology. Given the capacity of the human body to adjust to excess calorie intake by adding body fat, the potential for weight gain in today's population is enormous.[76]

But is it just a matter of time before the gears of evolutionary change recalibrate our weight and energy regulation processes to fit our new environment? Unfortunately, the answer is probably no. In the case of obesity,

> there do not appear to be strong biological mechanisms to oppose [it] once it is present. Even if the high levels of obesity seen today were sustained over generations within a population, there would be no selective pressure to remove [it]. . . . [T]hat's because most chronic diseases associated with obesity generally occur well after reproductive age is reached.[77]

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