FEATURE

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THINKING IN CIRCLES ABOUT OBESITY

BY TAREK K.A. HAMID

Systems thinking is a perspective and a set of conceptual tools that enables us to understand the structure and predict the behavior of complex systems. While already commonplace in engineering and in business, the use of systems thinking in personal health is less widely adopted. Yet health is precisely the setting where dynamic complexity is most problematic and where the stakes are highest. *Thinking in Circles About Obesity: Applying Systems Thinking to Weight Management* (Springer, 2009), aims to fill this gap. The book applies systems thinking to personal health in a form that's accessible to the general reader, with the hope that it will have a profound influence on how ordinary people think about and manage their health and well-being.

Systems Thinking . . . and Thinking About Systems

The great shock of 20th-century science has been that systems cannot be understood by analysis alone. While the performance of any system—whether it is an oil refinery, an economy, or the human body—obviously depends on the performance of its parts, it is never equal to the sum of the actions of its parts taken separately. Rather, it is a function of their *interactions*. Breaking a system into its component pieces and studying the pieces separately is, thus, an inadequate way to understand the whole.

Human weight and energy regulation provide a good case in point. They are parts of a complex psychobiological system that involves the behavioral act of eating, the processes of ingestion and assimilation of food, the storage and utilization of energy, as well as interactions with the external environment (cultural and physical). All these various factors are interconnected, pushing on each other and being pushed on in return. Appetite shapes body weight, and body weight influences appetite. Weight reflects activity levels (which are also shaped by the socioeconomic environment), and activity levels reflect weight. And on and on (see "Learning to Squint").

Understandably, putting systems pieces back together and recognizing the interactions between them can appear slippery and elusive. So much will be going on, and some of the things that are going on will cause still

LEARNING TO SQUINT

Why do we see straight lines when reality works in circles? For two primary reasons: visibility (what we see when we open our eyes) and time delays.

When we look with our eyes, we see "stuff." We see material things like people, food, tubs, and buildings. Feedback processes, on the other hand, are not physical objects; they are causal relationships between objects. To see them takes training and effort—more effort than simply opening our eyes and letting the appropriate chemical receptors be stimulated. We have to squint with our minds to see feedback relationships (from Barry Richmond, "Systems Thinking: Four Key Questions"—available at www.iseesystems.com).

In the case of human energy and weight regulation, the feedback relationships are hard to see, because many aspects of that physical system are opaque. The rise and fall of our energy stores, for example, are not as visible as the rising and falling water level in a tub. Further, because with energy and weight regulation we are part of the system ourselves, it is doubly hard to see the patterns of interactions.

In addition to the lack of visibility, another important reason we often fail to see the loops is the asymmetry in the delays associated with cause and effect (e.g., as when the effect of X on Y is immediate and directly apparent, but the feedback effect of Y on X is delayed by days or months). In many of the things we do, the consequences of our actions are not evident in the moment the action is being taken (as when smoking today leads to lung cancer many years in the future). Because we are conditioned to use cues such as temporal and spatial proximity of cause and effect to judge causal relationships, we often fail to close the causal loop.

The misperception of feedback, however, comes at a price. Misperceiving feedback often results in actions that generate unanticipated (often undesired) surprises, and when this happens, we are quick to claim these to be unfortunate side effects. But do not fool yourself. As John Sterman says in *Business Dynamics: Systems Thinking and Modeling for a Complex World* (Irwin McGraw-Hill, 2000), "Side effects are not a feature of reality but a sign that our understanding of the system is narrow and flawed."

He concludes: "To avoid [side effects] . . . requires us to expand the boundaries of our mental models so that we become aware of and understand the implications of the feedbacks created by the decisions we make. That is, we must learn about the structure . . . of the increasingly complex systems [that we are managing]."

TEAM TIP

Although this article focuses specifically on the issue of weight management, some of the lessons are relevant for organizational issues; for example, the idea of "learning to squint" to see feedback.

other things to go on. Making sense of it all becomes a daunting task. It's why one of the most important and potentially most empowering insights to come from the field of systems thinking is that certain patterns of structure recur again and again in many systems—whether physical, biological, or social—revealing an elegant simplicity underlying the complexity of systems (Peter Senge, *The Fifth Discipline: The Art & Practice of the Learning Organization*, Doubleday/Currency, 1990). And it's why learning to recognize these recurring building blocks is a powerful conceptual leverage that allows us to see through complexity into the underlying structures that drive system behavior (or misbehavior).

Stock and Flow Basics

All dynamic systems—the human body being a perfect example—can be modeled as *stocks* and *rates of flow* threaded together by information *feedback loops*. Stocks and flows constitute the two fundamentally different processes—accumulation and flow—that characterize how reality works and how systems change. You'll find these stock and flow structures in systems of all kinds. A familiar "plumbing" example is that of water in a bathtub. A bathtub is a (hydraulic) stock whose level changes as a function of the rates of water flowing in and draining out. And just like a bathtub, the level of energy stored in the human body constitutes a stock (primarily of fat), with food intake as its inflow rate and energy expenditure as its outflow rate.

Stock and flow structures are not limited to physical "stuff," however. For example, experimental research is demonstrating that the human capacity for self-regulation—a critical faculty for successful weight regulation—is a limited resource. In a manner analogous to the storage and depletion of physical energy, the human capacity for self-regulation can be conceptualized as a reservoir—or stock—that is consumed and replenished with the exertion of self-control and rest (M. Muraven, D. M. Tice, and R. F. Baumeister, "Self-control as a limited resource: Regulatory depletion patterns," *Journal of Personality and Social Psychology*, 74, 1998).

Behavior and Physiology Interactions

The strength of the systems approach lies in its capacity to integrate variables that otherwise would be isolated from each other. In the case of human weight and energy regulation, it allows us, for example, to examine (and better understand) the feedback interactions between the *physiological* and the *behavioral*.

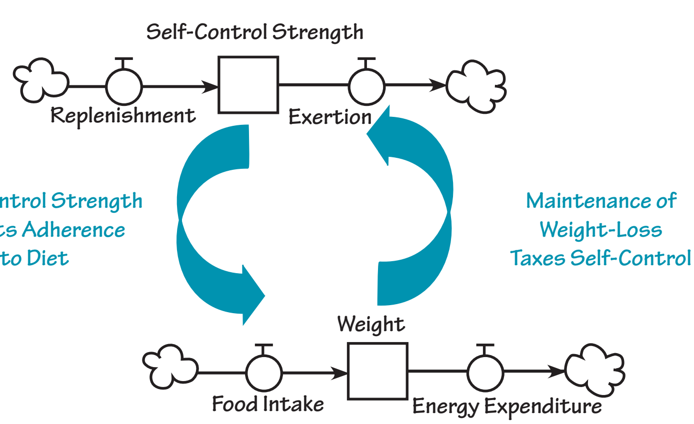
The diagram "Dieting Regulation System" integrates the two sets of stocks and flows in the human psychobiological system for feeding regulation discussed above: (1) the stock of human self-control, with its replenishment and exertion rates; and (2) the body's energy stock, with food intake as its inflow rate and energy expenditure as its outflow rate. As we shall see, these two sets of processes are not isolated phenomena. Indeed, it is the (mismanaged) interaction between these two stock and flow systems that gives rise to the weight-cycling dynamic—the "lose-gain" phenomenon widespread among and dreaded by dieters.

When the two stock and flow processes are combined into an integrated whole (see "Dieting Regulation System"), what we end up with is one of the classic archetypes for *oscillatory* behavior: that of two stocks (resources) interacting with one another such that the rise in one drains the other and vice versa.

Specifically, in this integrated psychobiological system for human feeding regulation, "Self-Control Strength" (which we can designate as stock 1) affects adherence to the diet and, hence, the regulation of the food intake rate into stock 2, "Weight." This regulatory function is not a free lunch—constraining food intake to decrease and/or maintain the weight stock at a certain level requires effort which, in turn, consumes self-control strength. This means that the state of the body-weight stock (stock 2) regulates the exertion rate (the outflow rate) of the self-control stock. Stock 1 acts as a catalyst for the *inflow* rate to stock 2, and, likewise, stock 2 returns the favor and acts as a catalyst for the *outflow* from stock 1.

For any such stock and flow system, if and how fast total depletion of a stock occurs depends on the initial size of the stock and the magnitude of the imbalance between the inflow and outflow. In the case of self-regulation, we know from personal experience that most people are capable of exerting modest levels of self-control and sustaining the effort day in and day out. This suggests that the amount of self-control needed for our daily social functioning—for example, stopping at a stop sign, standing in line even when

DIETING REGULATION SYSTEM



This diagram integrates two sets of stocks and flows in the human psychobiological system for feeding regulation: (1) the stock of human self-control, with its replenishment and exertion rates; and (2) the body's energy stock, with food intake as its inflow rate and energy expenditure as its outflow rate. The interaction between these two systems gives rise to the weight-cycling dynamic widespread among and dreaded by dieters.

in a hurry, holding our tempers, and so forth—is low enough that normal periods of rest can compensate for the moderate depletion rate.

But what about when we have to (or choose to) exert *more-than-modest* levels of self-control? Resisting stronger impulses, such as not eating even when persistently hungry, obviously requires more self-control than resisting less appealing temptations or weaker impulses, such as speeding on the highway. Would normal rest be enough, then, to compensate for the faster depletion rate? Or is the human capacity for self-regulation a limited resource that intense exertion depletes relatively quickly—akin say to our bodies' limited glycogen stores that fuel intense physical activity?

Over the last 20 years, a wide range of studies have been conducted to assess self-regulatory depletion in humans. (Many of these studies were conducted by Dr. Roy Baumeister and his group at Case Western Reserve University.) The results generally point toward the following conclusions: The capacity for self-regulation, just like muscular strength, is a limited resource that is subject to temporary depletion. Furthermore, the research results suggest that, for most people, this resource is rather scarce.

So, how effective are dieters at managing their limited capacity for self-regulation? The record indicates that successful long-term "losers" remain a minority, and that the vast majority of dieters are trapped in a recurring cycle of weight loss and regain—*Yo-Yo dieting* is the colloquial term for this process. In this all-too-familiar pattern, dieters seeking lofty weight-loss goals are able to slash off large amounts of weight by eating very little or even starving themselves, but then run out of regulatory gas and end up, after a period of short-lived success, regaining the weight—often with "interest."

But why?

Where More Is Less

When embarking on a diet, most overweight individuals tend to set weight-loss goals that reflect their image of what their ideal body weight should be—based, perhaps, on personal notions of aesthetics, advertised "poster" success stories, or standard height/weight charts read in a book or magazine article. The greater the weight-loss goal, the greater the caloric deficit must be. The greater the caloric deficit, the more acute the person's hunger and the greater the self-control needed to override the deprivation and sustain the diet—that is, the greater the drain rate on the dieter's self-control capacity (stock). That's obvious. But what is often less obvious is how much harder doing so becomes over time.

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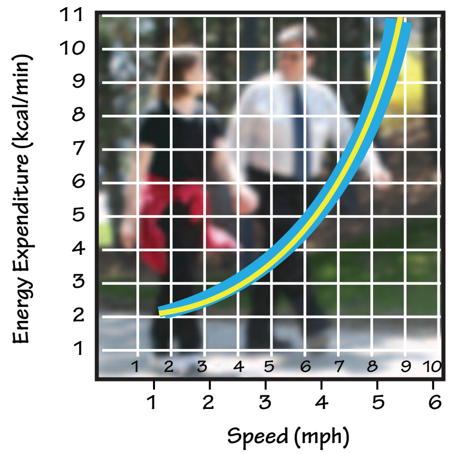
Dieters can seriously underestimate the escalation in hardship because, as psychologists have found, most people intuitively view causality in *linear* terms, expecting effect to be always proportional to cause. That is to say, we to tend to think that if *A* causes *B* to happen, then *2As* must cause *2Bs* to happen.

But the effort needed to accomplish a task often increases *exponentially*, not linearly, as the difficulty of the task increases. This principle is not unique to dieting, but applies to many tasks, both cognitive and physical. And it is, perhaps, easier to grasp in physical tasks such as, say, muscular exertion. Consider, for example, walking, which for most people is their major physical activity in a relatively sedentary lifestyle. "Escalating Energy Expenditure" portrays how energy expenditure escalates as walking speed increases, at speeds ranging from one to 10 km per hour (0.62 to 6.2 mph). It shows that as speed increases, energy expenditure rises, not in a linear fashion, but exponentially.

At low walking speeds—at the one- to two-mph pace of normal daily activities—the exertion of muscular energy (the stock's outflow rate) is modest enough that the drain on

ESCALATING ENERGY EXPENDITURE



The effort needed to accomplish a task often increases exponentially, not linearly, as the difficulty of the task increases. For example, energy expenditure escalates as walking speed increases.

energy reserves can be adequately compensated for by daily rest and food intake (the inflow rate). It is, in other words, a level of exertion that is sustainable, meaning that if we chose to, we could sustain this level of physical activity for extended periods of time without depleting our muscular energy stock. In fact, we can sustain it for very extended periods, as in the case of Deborah De Williams. On Friday, October 15, 2004, De Williams arrived back in her hometown of Melbourne after having set a world record as the first woman to walk around Australia—traveling in a clockwise direction along Australia's National Highway 1. She completed the 9,715-mile walk in 343 days (which also earned her a second world record for the "longest walk in the shortest time"). Deborah De Williams had walked close to 30 miles per day, at a speed of two miles per hour. That translates into walking 15 hours a day, every day for almost a year—a sustained stock, if there ever was one.

As the speed versus energy-expenditure plot in "Escalating Energy Expenditure" shows, walking faster can quickly increase the rate of energy expenditure. Once our rate of energy expenditure exceeds our ability to replace it, our energy reserves deplete over time. How fast? Consider what it takes to run a marathon. The human energy "stock" (even the best stocked) is barely large enough to sustain a 26-mile marathon run (quite a bit less than De Williams' 9,715 miles.) And those resilient enough to endure that challenge will most certainly arrive with empty tanks.

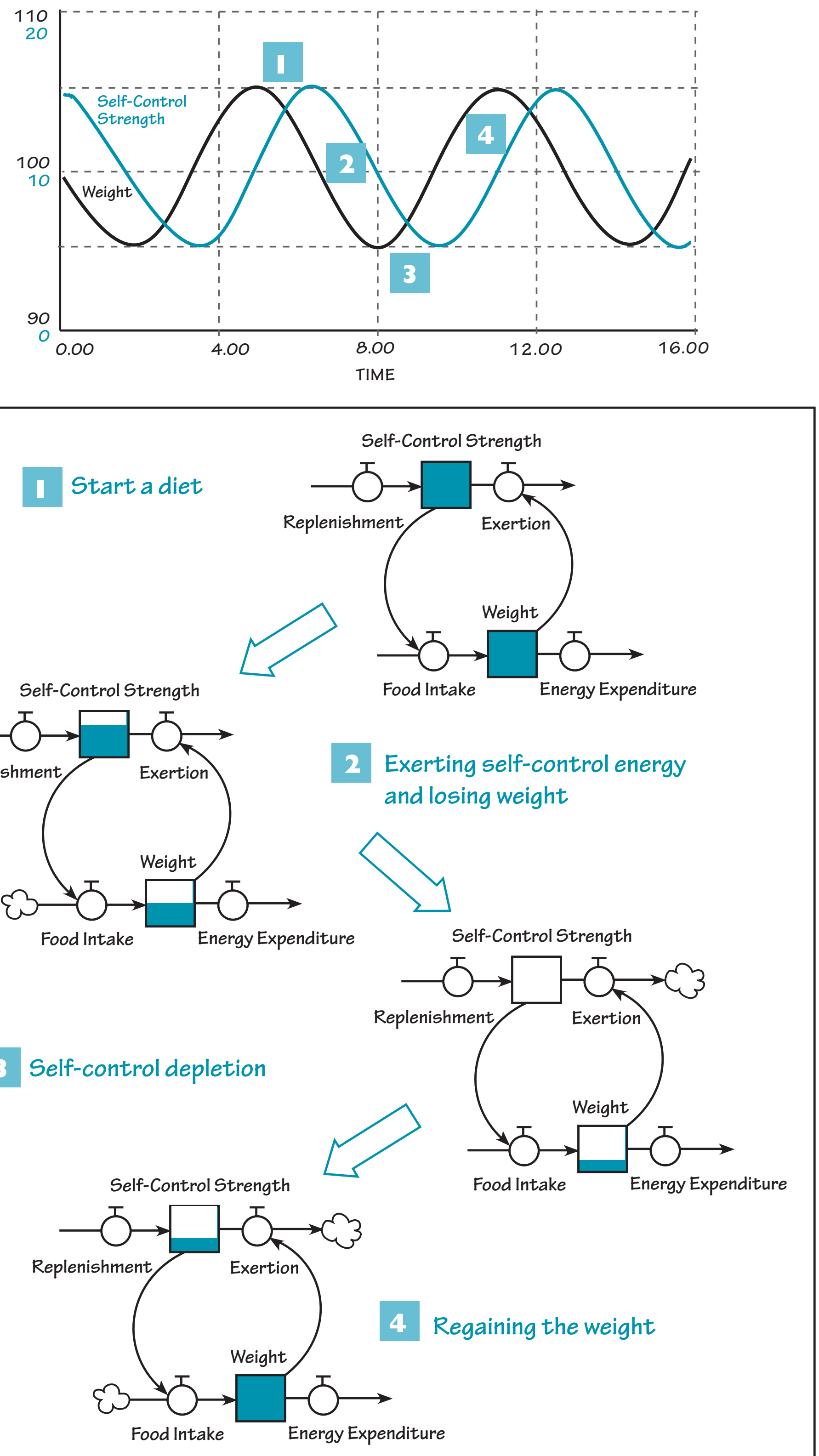
Not unlike walking or running, the self-regulatory effort in weight loss escalates not linearly, but exponentially, with the difficulty of the goal. Our body's weight set point seems to have a certain give to it, so that a person can stay a bit below it with relatively little effort. Larger weight losses, on the other hand, are difficult to tolerate. Fat-cell theory provides one possible mechanism for this physiological non-linearity. As the enlarged fat cells of an overweight dieter (which had expanded in size during weight gain to accommodate excess energy storage) shrink back to their normal size (or slightly below it) subsequent to modest weight loss, the physiological signals to overeat and regain the weight are often easy to override. But if the weight-loss effort persists and the fat cells deplete to below-normal levels, the "volume" of the physiological message to the brain's appetite-control center increases, eventually becoming a scream: "EAT, EAT, EAT."

Understanding How Weight Cycling Happens

To understand how unrealistic goals can induce weight-cycling behavior, in the lower part of "The Lose-Gain Cycle," we "walk through" one such cycle by following the numbered arrows down from top to bottom. At the start of a diet cycle, both stocks—"Self-Control Strength" and "Weight"—would typically be relatively full (such as at point 1). Voluntary restriction of one's food intake when starting a diet causes "Weight"—stock 2—to gradually drop. Because the dieting process consumes self-control energy, the dieter drops to point 2 in the figure with both stocks partially depleted.

But this particular dieter doesn't stop there. Her futile persistence to shed an unrealistic amount of weight causes her to keep going, depleting

THE LOSE-GAIN CYCLE



At the start of a diet cycle, both stocks—"Self-Control Strength" and "Weight"—are relatively full (point 1). Voluntary restriction of food intake causes "Weight" to gradually drop. Because the dieting process consumes self-control energy, the dieter drops to point 2 with both stocks partially depleted. As she continues to lose weight, she depletes both stocks further, hitting bottom at point 3. With depleted self-control, the dieter's grip on the feeding inflow "spigot" loosens, and the weight stock invariably refills—propelling her back to the top of the cycle (point 4).

both stocks further. When that process ultimately depletes her self-control strength, she hits bottom—at point 3 in the cycle. While, from a weight-loss standpoint, reaching that juncture may be cause for celebration, unfortunately for her, she will not stay at that point. With a depleted stock 1, the dieter's grip on the feeding inflow "spigot" loosens. And with adherence to the diet progressively weakening as a result, the weight stock invariably refills—propelling her back to the top of the cycle, at point 4.

This two-stock feedback structure, while admittedly far too simplified to capture the full complexity and idiosyncrasies of human weight regulation, does in fact capture the essential elements that underlie human weight-cycling behavior. Interestingly, this particular two-stock structure—two resources (stocks) interacting with one another such that the rise in one drains the other and vice versa—is fundamentally the same structure that underlies cyclic behavior in many other familiar systems, such as the pendulum clock and a child's Slinky toy. And if we were to mathematically represent the variables in these systems and their interrelationships, the variables would assume different names—rather than body weight, feeding, and energy expenditure, we would have, for example, pendulum or spring mass, force, and momentum—but the differential equations that capture their dynamic interactions will have similar forms.

While weight cycling is surely a source of frustration to many dieters, the risks associated with repeated cycles of weight loss and regain far exceed mere disappointment. A substantial body of epidemiologic research clearly shows that repeated cycles of weight loss and regain increase the risks of chronic diseases (particularly coronary heart disease) and even premature death—independent of obesity itself.

Learning to "Manage Our Stocks"

Like any other limited (and exhaustible) resource, self-regulatory capacity needs to be managed and must not be squandered. But squandering it, not managing it, is what most dieters habitually do. The unrealistic goals that people set escalate self-regulatory exertion and over time induce regulatory depletion and ultimately relapse (not unlike a marathoner who sprints early, only to run out of gas later).

This particular two-stock structure is fundamentally the same structure that underlies cyclic behavior in many other familiar systems.

Unfortunately, setting more realistic goals rarely coincide with most dieters' personal agendas. Nor are they encouraged to. The diet industry thrives for two reasons—big promises and repeat customers. The big promises attract the customers in the first place, and the magnitude of the promises virtually guarantees that they cannot be maintained. It makes for a very attractive business model. (J. Polivy and C.P. Herman, "If at first you don't succeed: False hopes of self-change," *American Psychologist*, 57(9), 2002).

Thankfully, however, things may be changing.

A growing understanding of the biological factors that regulate body weight and of the cognitive difficulty of maintaining large weight losses is prompting a redefinition of the "successful" goals of obesity treatment. Slowly but surely, moderation is becoming the overriding theme in weight-loss efforts. A major impetus for this shift has been the growing evidence that moderate weight losses of only 10–15 percent of initial weight, even among substantially overweight individuals, are associated with a significant improvement in nearly all parameters of health—including blood pressure, heart morphology and functioning, lipid profile, glucose tolerance (among diabetics), sleep disorders, and respiratory functioning. And these findings are now prompting a growing number of federal agencies and health organizations to call for setting more realistic weight goals rather than striving for an "ideal" weight.

To this system thinker, that's music to the ear. ▪

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NEXT STEPS

Here are some topics for additional exploration; many of these are covered in depth in *Thinking in Circles About Obesity*:

1. While linear thinking is convenient (and, in some cases, may serve as a "good enough approximation"), in reality, it is almost always invalid. Changes in system outputs are not always proportional to changes in input, and things rarely happen in straight lines. Until a few years ago when mathematical analysis was our only tool, "assuming away" nonlinearity was justifiable—some say a necessity. It no longer is. With the advent of modern computers and the availability of inexpensive simulation techniques, we are now able to develop realistic and faithful models of our real-world nonlinear systems. Today there is no excuse (whether in managing a business or one's health) to make simplifying linearity assumptions when dealing with complex phenomena.
2. While already commonplace in engineering and in business, the use of systems thinking in personal health is less widely adopted. Yet this is precisely the setting where complexities are most problematic, and where the stakes are perhaps highest.
3. We all need to realize that in managing our health (and our bodies), we are decision makers who are managing a complex and dynamic system. Effective self-regulation requires more than motivation—it requires understanding and skill.

