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Systems Thinking: A Means to Understanding Our Complex World

by Linda Booth Sweeney

What is systems thinking? One great first step is to understand what it is *not.* Systems thinking is not *analysis.* If you're like most people, you probably had a teacher somewhere along the way who taught you that the best way to understand something was to *analyze* it—to break it down into bite-size, manageable pieces. So, for example, to write an essay, you were taught to break it down into its component parts: the introduction, the purpose, the body (with supporting facts, of course!), and the conclusion.

Many people approach lots of challenges this way, from learning how to juggle, to applying to college, to figuring out the best way to lose weight. This slice-and-dice approach is fine for some problems—for instance, when you want to organize your CD collection or understand how a clock works (you take it apart!). It's also helpful if you want to understand the basic elements of something; for instance, figuring out that water is really made up of hydrogen and oxygen atoms.

The problem arises when we use analysis *mindlessly,* assuming that the world stands still as we study it, that puzzling situations will stand still while we break them into their component pieces, and that the relationships between the pieces aren't important. As anyone who has tried to get a growing family out the door in the morning knows, problems *don't* stand still and inter-relationships *do* matter! Analysis therefore gives us a limited understanding of reality—and so it isn't the only skill we need to handle the big challenges in our lives.

By contrast, systems thinking helps *expand* our understanding. It shows us how to:

- see the world around us in terms of wholes, rather than as single events, or "snapshots" of life;
- see and sense how the parts of systems *work together,* rather than just see the parts as a collection of unrelated pieces;
- see how the relationships between the elements in a system influence the patterns of behavior and events to which we react;
- understand that life is always moving and changing, rather than static;
- understand how one event can influence another—even if the second event occurs a long time after the first, and "far away" from the first;
- know that what we see happening around us depends on where we are in the system;

- challenge our own assumptions about how the world works (our *mental models*)—and become aware of how they limit us;
- think about both the long-term and the short-term impact of our and others' actions;
- ask probing questions when things don't turn out the way we planned.

We can't *abandon* analytical thinking; after all, it really is important in dealing with certain kinds of tasks or simpler problems. But if we know how to *complement* analytical thinking with systems thinking, we'll have a much more powerful set of tools with which to approach life.

A Child's Early Steps Toward Systems Thinking

Children are actually natural systems thinkers. They start recognizing how systems work early in their lives. At about five months, a baby begins to play games with her parents. She learns to cry deliberately, and then waits to see if her doting parents will hurry over and pick her up. If they don't, she cries again, perhaps a little louder this time. These kinds of experiences give children a basic understanding of *one-way causality:* "If I cry, my parents will come and pick me up."

As the child grows into a teen, she extends her understanding of causality to her family and community: "If I stay out late, my parents will be mad, which means I may not be able to stay out late next weekend." She thus begins to learn about *mutual causality,* and to experience the nature of interdependence between herself and others, through being a member of a family, a sports team, a neighborhood, and so forth.

As she moves into adulthood, the young woman then finds a world of accelerating change, where new, faster technology and shrinking global borders collide to create an increasingly interconnected landscape. In such an environment, everything everywhere appears to be—and actually is—connected to everything else.

As adults, we all survive in this environment by trying to make sense of the phenomena we perceive around us. We then use our explanations to predict what may happen in the future. Yet our explanations often contain misconceptions about causes and outcomes and incomplete or overly simple assumptions about how the world works. When this happens, we struggle again and again with what seem like the same problems. We take actions that we think will address fundamental problems, but often they never do, or they actually make the original problem worse. How do we get off this problem-solving treadmill?

This is where systems thinking can help.

What Are Systems, Anyway?

How can we, as adults, help youngsters learn about complex systems, when many of us don't have formal training in systems thinking? One simple step is to understand the basic characteristics of systems. The following five questions can get you started.

Q: Is it a heap or a system?
Q: Is the whole greater than the sum of its parts?
Q: What's the purpose?
Q: Are the causes and effects shaped like a circle?
Q: Are we experiencing déjà vu?

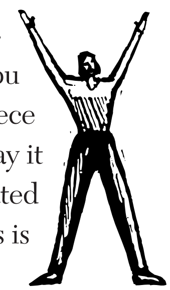
Is It a Heap or a System?

Systems consist of two or more parts, but so do "heaps," such as a bowl of mixed nuts. So how do you know if you've got a plain old heap of something, or a system? Here's a basic way to tell:

With a *heap,* nothing changes if you take away or add parts. For instance, imagine that you have a bowl of nuts. What happens if you remove all the cashews or add hazelnuts? Answer: You still have just a bowl of nuts.

With a *system,* things definitely change if you take away or add parts. For example, suppose you removed the battery from your car. The car wouldn't start! A car is an example of a mechanical system. Living systems—including human systems like our families, classrooms, neighborhoods, and nations—are far more complicated. When you take away or add parts to *those,* you get some very complex changes. (Imagine what life would be like if your town's police force or waste-disposal department completely disappeared one day!)

Children and adults can learn to distinguish between heaps and systems by doing the simple exercise described above: Just ask whether anything important would change if you took away or added parts, or if the parts can operate on their own. You will find that systems always have a distinctive arrangement between their key elements; thus the wisdom behind the old saying "If you cut a cow in half, you don't get two cows." For example, if you remove a piece of fruit from a bowl, it still functions as a piece of fruit. But if you remove your hand from your body, the hand certainly won't work in the same way it used to. That's because every part of the "body" system has certain capacities that it loses when separated from its system. What makes these capacities work is the interaction among the system's parts. (This is why analysis doesn't work when you want to understand a system as a whole.)



Is the Whole Greater Than the Sum of Its Parts?

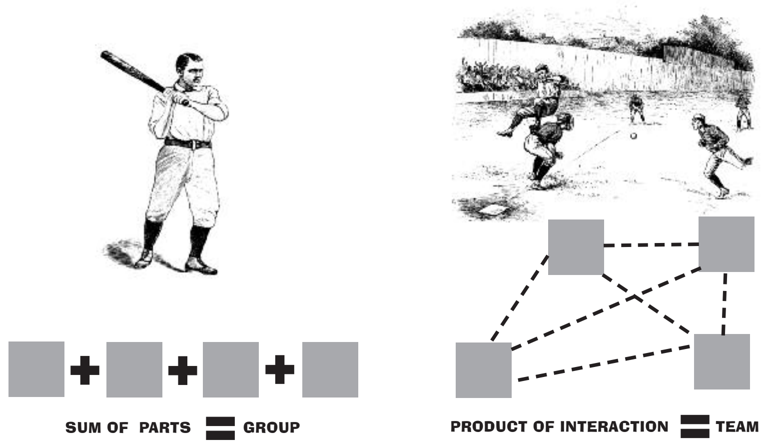
All living systems consist of a huge number of tightly connected interactions. How do these complex interconnections play out in our daily lives? We've all heard the saying, "The whole is greater than the sum of its parts." In systems thinking, this means that the many interactions among the parts in a system give rise to qualities or properties that you just can't measure merely by adding up those parts. For example, when fishermen overharvested sea perch on California's coastline, orcas—whales that had fed on the perch—began to prey on otters instead, even though they and the otters had coexisted peacefully for centuries. This is just one example of how the whole (the ecosystem) is affected when the interactions between the parts (the animals in the ecosystem) are affected.

As another example, imagine that you not only took the battery out of your poor car; you also completely took the car apart. If you weighed all the pieces and added up the numbers, you'd know how much the entire car weighs when it's assembled correctly. But, you wouldn't know how *fast* the car goes or how comfortable a ride you'd have on a bumpy road. *Speed* and *comfort* are created by the *interactions* of the car's parts and thus are "greater than the sum" of all the car's separate parts. *Speed* is an example of what is called an "emergent property"—a property or behavior that arises only out of the interactions within a specific set of parts.

If your children play in an orchestra, act with a drama troupe, or are members of a sports team, they are learning about emergent properties all the time. They know that the all-star team is not always the best team in the league. Why? Each person on the team may have exceptional batting or throwing skills, but when you put the players together, they don't necessarily make the best *team.*

What does make a team great? It's the quality of the *interactions* among the players—which comes only from lots of practice, time spent in getting to know one another, and good old experience.

Systems thinkers have a healthy respect for emergent properties: for understanding them, intervening in them (e.g., when children on a long car trip start to get antsy), and sometimes, as in the case of team spirit, fostering them.



What's the Purpose?

Most systems have a distinct "point," or purpose in relationship to the larger system in which they are embedded. In many social systems, we see subsystems whose purposes can conflict sometimes; for instance, the teachers in your kids' school may sometimes be at cross-purposes with the guidance department, or with the administration.

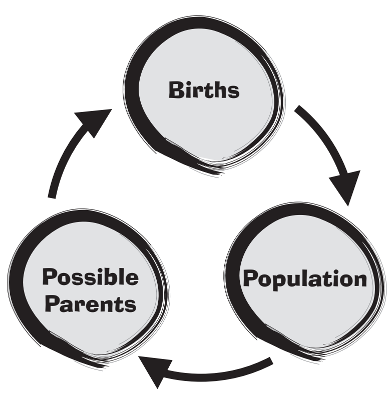
The simple question we might often forget to ask is this: "What is the purpose of this system?," whether it be a clique in school, a committee on the school board, or a department in an organization. By understanding the various and sometimes conflicting purposes within a system, you can begin gaining insight into why the system functions as it does—and how you might help it function better. (For example, regular meetings between teachers and school administrators might help them clear up conflicts.)

Are the Causes and Effects Shaped Like a Circle?

We can think of cause and effect, or causality, as coming in several "shapes." The shape can be linear, as in the story of the old lady who swallowed a fly:

Many people—children and adults—assume that this is how things happen: One thing causes the next, like a set of falling dominos. In the case of dominos, this is indeed the nature of causality.

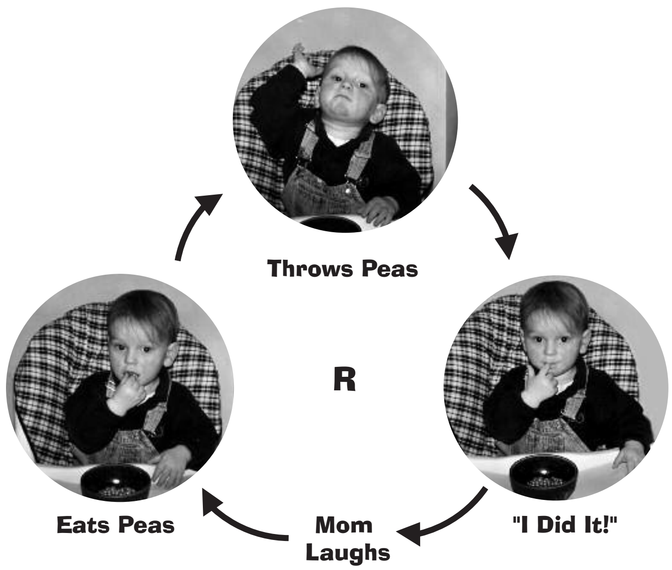
Systems thinkers have another notion of causality: feedback loops, which have a circular shape. The simplest way to think of these is to imagine that one event causes another event, and that second event comes back around to influence that *first* cause. It's like this: A causes B, B causes C, and C causes A. For example, the more children who are born, the greater the population. And the greater the population, the greater number of possible parents. And the greater number of possible parents, the greater the number of births … and so on (assuming a relatively stable environment).



This idea is by no means new: Many indigenous cultures see the world in terms of circular causality. In a well-known speech, Black Elk, a holy man of the Oglala Sioux, once said:

> ***"Everything an Indian does is in a circle, and that is because the power of the world always works in circles, and everything tries to be round."***

How do we see these circular loops in everyday life? Here's an example: My little son Jack likes green peas (which makes his mother very happy!). When he was about one, he would eat a few peas and then, because it must have seemed like a fun thing to do, he would throw some peas on the floor. Then he'd say, "I did it!" Being the novice mother I was, I laughed, thinking that the whole thing was funny. What did he do? He then ate *more* peas, threw *more* peas, and said, even *more* happily, and proud of himself, "I did it!!!" Of course, I'd laugh even more—and then he'd throw peas even more!



This is a simple example of what systems thinkers call a *reinforcing* feedback loop (other examples include teachers' expectations of student performance, population growth, and compound interest building in your savings account. Reinforcing loops cause dramatic growth or collapse (like the stock-market crash in the U.S. in the 1930s). They're usually easy to spot because they're so extreme. When you hear people say things like "The situation's totally out of control" or "Things are just snowballing," chances are there are reinforcing loops at work.

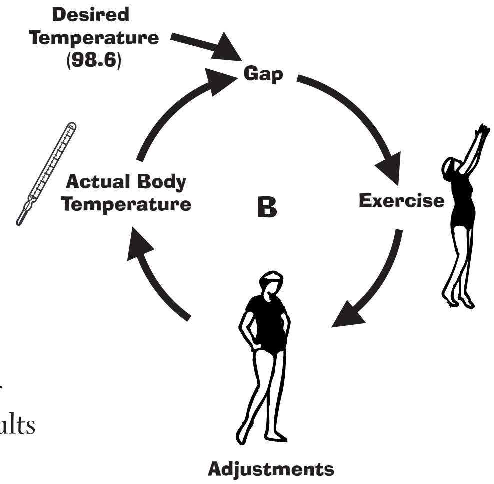
Depending on the situation, a reinforcing loop can be either vicious (amplifying to make something greater) or virtuous (amplifying in the opposite direction, e.g., making something less).

But as the old systems adage goes, "Nothing grows forever." Luckily, there's another kind of feedback loop that helps to keep things under control in general. (Otherwise, Jack would be throwing more and more peas into infinity, and I'd be laughing more and more—with no end in sight to the cycle!) Systems thinkers call this other kind of loop *balancing.* Balancing loops put limits on dramatic growth and collapse, and ensure that a system fulfills its purpose.

For example, in the case of Jack's throwing peas, the balancing came from the fact that Jack eventually ran out of peas to throw. I also provided a balancing action: I quickly learned to stop laughing and changed the goal of the "game" by encouraging him to see how many peas he could stack in a bowl instead of throw on the floor.

Another simple example is your body's temperature-control system—whose purpose is to keep your body temperature at 98.6 degrees Fahrenheit.

When you exercise, your body heats up. To keep your temperature close to 98.6 degrees Farenheit, your sweat glands produce perspiration. Air moving across sweaty skin creates a cooling effect that helps brings your temperature back in balance. And if you get chilled, your muscles start shivering, and the friction of your shaking muscles warms your body back up to 98.6 degrees. Balancing loops aren't as noticeable as reinforcing loops, but there are lots of them out there. Because they tend to keep things steady, we can sometimes detect them when we try to change something but get no results (e.g., when we *try* to lose weight!).



Are We Experiencing Déjà Vu?

Another interesting thing about systems is that they tend to behave in similar ways in very *different* kinds of settings. For instance, let's go back to that age-old problem of playground fights. One bully insults another, who then comes back with an even more inflammatory retort. The next thing you know, someone throws a punch—and an all-out brawl erupts. Now think of companies competing in the business world. One draws more customers by slashing prices. Its main competitor, concerned about being left behind, slashes *its* prices even more—prompting the first company to try to offer even lower prices. Even though these two situations look very different on the surface, both involve a build-up, or an escalation, of tensions or competitiveness.

Systems thinkers have identified a whole set of common "stories" like this—which they call "systems archetypes"—that occur in very different settings. For instance, in an archetype called "Fixes That Fail," you do something to try to solve a problem—but the problem eventually just gets worse (like drinking coffee to perk you up when you're tired, but then when bedtime comes, you're restless and don't sleep as well, and you get even *more* tired over time).

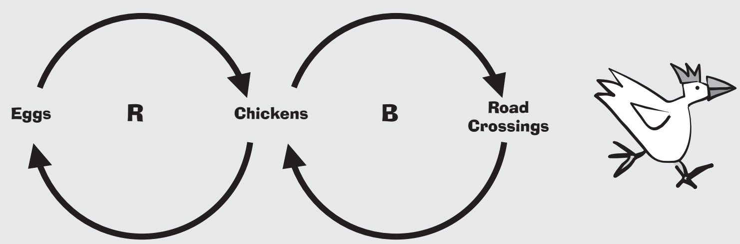
With another archetype, "Limits to Success," you get something really great going, but then it seems to level off—such as persuading more and more neighbors to help out at the annual town fair—but then suddenly seeing their help taper off. What has happened? A reinforcing loop (efforts to make the town fair successful) is connected to a balancing loop (a limit to the time, energy, or resources that folks in town can provide). If you have that "I'm spinning my wheels" feeling, you may be experiencing this archetype.

The great thing about these old teaching stories is that they let you recognize—and therefore better manage—common problems that occur in lots of different situations. And they also tend to show up in some favorite stories!

Counting Chickens in a Complex World

There are only two types of loops—reinforcing and balancing. The interaction (usually nonlinear) of these loops creates all dynamics that we experience in all systems. Indeed, some of the most confounding behaviors we face arise when multiple reinforcing and balancing loops interact.

Say we want to look at that age-old dilemma of chicken-and-egg populations. Assuming we have at least one rooster, the population of chickens likely goes up and down over time. But looking at the reinforcing loop between the number of chickens and the number of eggs laid will give us only part of the story. For example, suppose that in this case, the roost is actually located right next to a highway. As the chicken population grows, there is more chance of road crossings (a balancing loop that leads to fewer chickens). If this balancing loop were the only one operating (because the farmer decided to sell all the eggs), then over time, there would eventually be no more chickens left.



So, because most knotty problems we find ourselves trying to understand arise out of some interaction of balancing and reinforcing loops, our challenge is twofold: 1) to be aware of our own oversimplified perceptions of feedback and 2) to discover and be able to explain these interactions to others.

Source: John Sterman, *Business Dynamics: Systems Thinking and Modeling for a Complex World.* 2000. New York: Irwin/McGraw-Hill. Reprinted with permission.

Ready for More?

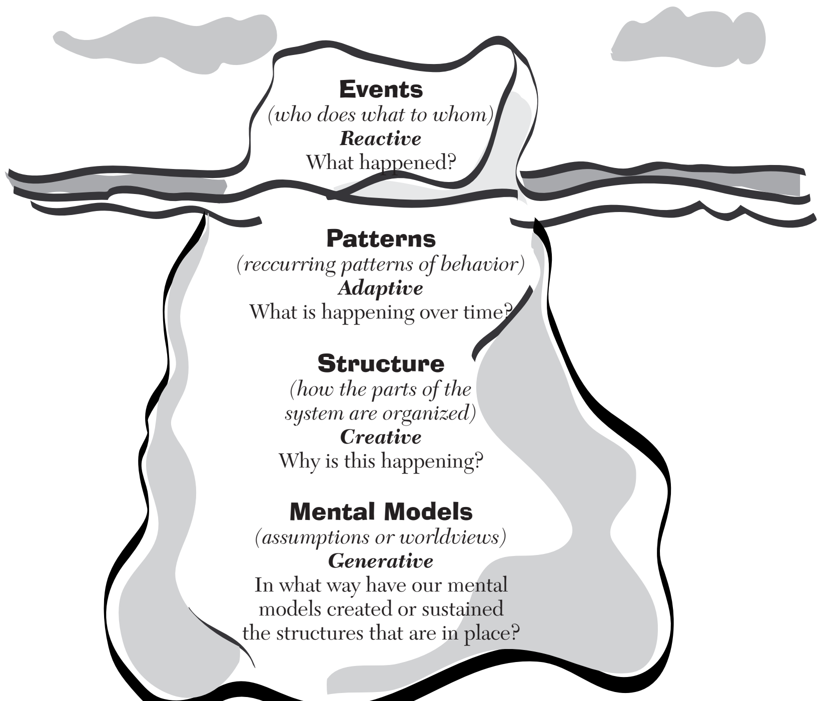
Still with me? Good! You've now got a basic idea of what systems are and how they behave. Want to go a little further? Here are some other tried-and-true ways to think about systems.

- "Lowering the Water Line": Seeing How a System's Structure Influences Behavior
- "Oops—I Didn't Mean to Do That!": Understanding Unintended Consequences
- The Systems Thinker's Clock: A Different Look at Time
- Ferreting out Delays
- Thinking Like a Bathtub

Lowering the Water Line: Seeing How a System's Structure Influences Behavior

One of the most profound and practical habits I've learned from systems thinking is to consciously look at a system from multiple perspectives—actually, from multiple *levels* of perspective. To use an example a teacher might face, if Johnny is late to school, he might lose his recess privilege that day. But this "event" often doesn't tell the whole story. Systems thinking tells us to stop and look below the surface, to see how the structure (the relationships between the parts in the system) drives the patterns of behaviors we see. These patterns influence the events to which we react.

Think of this idea as an iceberg, where only 10 percent of the ice is "above the water line" and 90 percent of it is beneath the surface. In Johnny's case, the "event" is that he is late. If we look below the water line, we might see a certain pattern of behavior; that is, Johnny is late every Tuesday and Thursday morning. If we go down one more level, by asking Johnny and his family why this is happening, we might find that on Tuesday and Thursday mornings, Johnny's mother has to drive another sibling to preschool, which often makes Johnny late for class. If the teacher and



the parent actually move their conversation and exploration to this level, they might come up with any number of creative solutions to the problem.

Without a doubt, the things that most preoccupy us and are easiest to react to are events—a fire breaks out; we pull off a "miracle" to get a project done on time; the stock market jumps up or down, oil prices skyrocket. And as a general rule, not only do we tend to focus *first* on events, but we then look at the immediate actions we need to take, rather than think about how the situations fit into a larger pattern or what may be causing them in the first place.

At the same time, it's important to remember that reacting at the event level is quite appropriate in certain situations. For example, if someone is running in front of a car, shouting or even pushing them out of the way is the right thing to do! But as in my own neighborhood, if you see that people are getting hit on the same corner a few times a month, then it would be useful to "lower the water line" and look at what set of interactions might be causing the pattern of accidents. So, for example, you might discover that kids are crossing the street at a time of day when the sun is most blinding, a problem that could be addressed by providing children and adults with bright orange flags to wave as they cross the street.

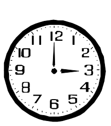
"Oops—I Didn't Mean to Do That!"*: Understanding Unintended Consequences*

Often when we have a problem, we look for a fast way to fix it. While our solution may ease the problem for a little while, it might also have some consequences that we never intended—and that even make the original problem worse eventually.

You may experience this phenomenon in your own life. For example, suppose you want to spend more time with your kids because you believe that quality time together will help make them happy. So, you play with them after work, keeping them up past their bedtimes. They get more time with you, but as an unintended consequence, they're cranky and tired the next morning—hardly the happy individuals you wanted them to be!

The more you know about systems thinking, the more you can *anticipate* unintended consequences instead of being caught off-guard by them. Sometimes, the *actions* that cause the consequences can seem relatively insignificant. For instance, suppose it's a hot and muggy Saturday afternoon, and the kids are restless. You decide to take them to the local beach to try to cool down. You pack everybody up and drive over to the lake—and discover that everyone else in town had exactly the same idea! Families are crammed towel-to-towel all along the beach, and the designated swimming area is so full that no one can actually swim. Everybody's getting annoyed—including your kids, who are even more irritable than before! You're irritated, too—but you probably don't realize that you're just as much a part of the crowding problem as all the other people who decided to come to the beach. (This kind of situation is so common that systems thinkers have identified it as another systems archetype, known as "Tragedy of the Commons.")

In addition to helping us anticipate or even avoid *unintended* consequences, systems thinking can encourage us to reinforce *intended* consequences. For example, an initial success often leads to more success. By investing in early successes (for instance, putting money in a bank account, or spending time with our children), we get dividends later on. Focusing on intended consequences can help us monitor when things go awry. It also helps us develop the patience we need to see our early efforts pay off.



The Systems Thinker's Clock: A Different Look at Time

Systems thinkers view time very differently from how most people do. For one thing, they understand that most living systems don't demonstrate a full "cycle" of their behavior over short time periods. To understand and work with such a system, you have to look at its behavior over a longer time frame. For instance, after years of *perestroika,* the Soviet Union's economic situation changed very little. But as systems thinker Donella Meadows explained, "People are calling it failure, not understanding how long it takes for a nation's capital plant, exhausted soils, and disaffected workforce to revitalize." As another example, it's common for leaders to take credit for any improvements in the economy that occur during their administration. But, those economic changes were likely set in motion way before they took office—perhaps as long as two or three administrations ago.

But thinking long term can involve even longer "time horizons" than just a few changes in leadership. For example, before the Nashua Indians (a native people who lived in New Hampshire) made any decision, they weighed its potential impact on *seven generations* to follow. Or for you gardeners, you know this from the cycles of seed planting, incubation, growth, fruit bearing, eating, and decay.

How can we develop a systems thinker's view of time? We can start by simply being aware of the enormous number of forces in our society and how long they really take to exert their effects. The next time you're reading the newspaper, choose a story and think about how the impact of those events will unfold over the next week, months, years, decades—even generations.

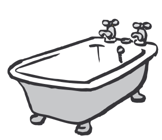
Ferreting out Delays

Another way to learn to take the long view is to practice ferreting out delays. For instance, as frustrated parents of teenagers try to keep in mind, the lessons that you teach your kids about the value of family and community may not "sink in" until the kids reach adulthood.

These kinds of delays (that is, the time lag between your actions and evidence of their effects) can be the biggest reason that unintended consequences happen. Why? Because when we don't see instant results from our actions, we often continue to tinker with the system, coming up with more "fixes" even though we've already taken appropriate action. (We just don't know whether our steps were effective because the results haven't yet made themselves evident.)

For example, if you're like many people, you may battle every day with the hot/cold control in your shower. When the shower water feels too cold, you turn the temperature control to "Warm." But it takes a while (a delay) for the water to warm up. Shivering, you turn the control up even more—to "Hot." But then, when the water finally warms up, it's *too* hot—and you practically scald yourself. So, you turn the control back down to "Cool"—and start the cycle all over again: It takes a while for the water to cool down, so you twist the dial to "Cold." But when you finally get a response, the water's *too* cold. And so on. . . .

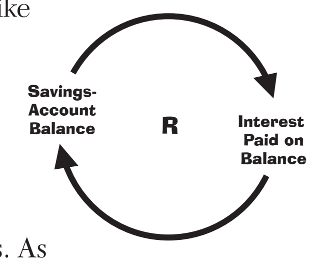
Understanding delays can help you avoid this kind of ineffective fiddling with the system. The more you know about delays, the more chance you have of avoiding the kinds of results you had no intention of getting!



Thinking Like a Bathtub

So far, we've been exploring a way to think about systems that focuses on interrelationships, circular causes and outcomes, the impact of delays, and so on. You even saw some simple diagrams that show how causes and effects can influence each other (for instance, the picture of Jack on p. 5). If you want to know something even more interesting about systems thinking, let's take a closer look at another one of these diagrams.

In this diagram, there's something more to the feedback loop showing the relationship between your savings-account balance and the paying of interest on that balance. Let's take a closer look. You can imagine your account balance as a kind of bathtub—the money in it just keeps getting higher and higher (as long as you don't make any withdrawals, of course!). So, the balance is something that *accumulates.* On the other hand, the paying of interest on



the account is more like a faucet that flows faster the higher your balance gets. Thus it's like an action, or a process. Systems thinkers would describe your account balance as a *stock* and your interest payments as a *flow.* Each of them influences the other.

Thinking like a bathtub and faucet—that is, thinking of systems as consisting of stocks and flows—is helpful because it lets us understand the more subtle relationships in the system.

Again, systems thinker Donella Meadows offers an intriguing perspective on this. As she explains, we need to understand the difference between the national deficit (a flow—the rate at which we borrow) and the national debt (a stock—the accumulated debt). Reducing the deficit, Meadows points out, will not reduce the level of debt. It will slow down the *rate* at which the debt accumulates—but the debt itself will still keep accumulating.

This is a subtle point, but it's important to understand. Most people assume that to increase a stock, you have to increase the flow into that stock (e.g., to accumulate more money in the bank, you have to increase the rate at which you deposit money). But—and here's the surprising part—you can also increase a stock by *reducing the outflow.* As Meadows explains, we can make our nation wealthier by repairing and maintaining old equipment as well as by investing in new equipment.

Linda Booth Sweeney is a researcher, consultant, and systems educator (www.lindaboothsweeney.net/). She was a research associate for M.I.T.'s Organizational Learning Center (now SoL) and is now a founding partner in the SoL Education Partnership, as well as a content expert for SEED—Schlumberger Excellence in Educational Development. Linda is the author of several books and numerous articles, including her most recent book, *Connected Wisdom: Living Stories about Living Systems*. She received her doctorate from Harvard University in 2004.

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