

— FIVE —

System Traps . . . and Opportunities

Rational elites . . . know everything there is to know about their self-contained technical or scientific worlds, but lack a broader perspective. They range from Marxist cadres to Jesuits, from Harvard MBAs to army staff officers. . . . They have a common underlying concern: how to get their particular system to function. Meanwhile . . . civilization becomes increasingly directionless and incomprehensible.

—John Ralston Saul,¹ political scientist

Delays, nonlinearities, lack of firm boundaries, and other properties of systems that surprise us are found in just about any system. Generally, they are not properties that can or should be changed. The world is nonlinear. Trying to make it linear for our mathematical or administrative convenience is not usually a good idea even when feasible, and it is rarely feasible. Boundaries are problem-dependent, evanescent, and messy; they are also necessary for organization and clarity. Being less surprised by complex systems is mainly a matter of learning to expect, appreciate, and use the world's complexity.

But some systems are more than surprising. They are perverse. These are the systems that are structured in ways that produce truly problematic behavior; they cause us great trouble. There are many forms of systems trouble, some of them unique, but many strikingly common. We call the system structures that produce such common patterns of problematic behavior **archetypes**. Some of the behaviors these archetypes manifest are addiction, drift to low performance, and escalation. These are so prevalent I had no problem finding in just one week of the *International Herald Tribune* enough examples to illustrate each of the archetypes described in this chapter.

Understanding archetypal problem-generating structures is not enough. Putting up with them is impossible. They need to be changed. The destruction they cause is often blamed on particular actors or events, although it is actually a consequence of system structure. Blaming, disciplining, firing, twisting policy levers harder, hoping for a more favorable sequence of driving events, tinkering at the margins—these standard responses will not fix structural problems. That is why I call these archetypes “traps.”

But system traps can be escaped—by recognizing them in advance and not getting caught in them, or by altering the structure—by reformulating goals, by weakening, strengthening, or altering feedback loops, by adding new feedback loops. That is why I call these archetypes not just traps, but opportunities.

Policy Resistance—Fixes that Fail

I think the investment tax credit has a good history of being an effective economic stimulus,” said Joseph W. Duncan, chief economist for Dun & Bradstreet Corp. . . .

But skeptics abound. They say nobody can prove any benefit to economic growth from investment credits, which have been granted, altered, and repealed again and again in the last 30 years.

—John H. Cushman, Jr., *International Herald Tribune*, 1992²

As we saw in Chapter Two, the primary symptom of a balancing feedback loop structure is that not much changes, despite outside forces pushing the system. Balancing loops stabilize systems; behavior patterns persist. This is a great structure if you are trying to maintain your body temperature at 37°C (98.6°F), but some behavior patterns that persist over long periods of time are undesirable. Despite efforts to invent technological or policy “fixes,” the system seems to be intractably stuck, producing the same behavior every year. This is the systemic trap of “fixes that fail” or “policy resistance.” You see this when farm programs try year after year to reduce gluts, but there is still overproduction. There are wars on drugs, after which drugs are as prevalent as ever. There is little evidence that investment tax credits and many other policies designed to stimulate investment when the market is not rewarding investment actually work. No single policy yet has been able to bring down health care costs in the United States. Decades of “job creation” have not managed to keep unemployment permanently low. You probably can name a dozen other areas in which energetic efforts consistently produce non-results.

Policy resistance comes from the bounded rationalities of the actors in a system, each with his or her (or “its” in the case of an institution) own goals. Each actor monitors the state of the system with regard to some important variable—income or prices or housing or drugs or investment—and compares that state with his, her, or its goal. If there is a discrepancy, each actor does something to correct the situation. Usually the greater the discrepancy between the goal and the actual situation, the more emphatic the action will be.

Such resistance to change arises when goals of subsystems are different from and inconsistent with each other. Picture a single-system stock—drug supply on the city streets, for example—with various actors trying to pull that stock in different directions. Addicts want to keep it high, enforcement agencies want to keep it low, pushers want to keep it right in the middle so prices don’t get either too high or too low. The average citizen really just wants to be safe from robberies by addicts trying to get money to buy drugs. All the actors work hard to achieve their different goals.

If any one actor gains an advantage and moves the system stock (drug supply) in one direction (enforcement agencies manage to cut drug imports at the border), the others double their efforts to pull it back (street prices go up, addicts have to commit more crimes to buy their daily fixes, higher prices bring more profits, suppliers use the profits to buy planes and boats to evade the border patrols). Together, the countermoves produce a standoff, the stock is not much different from before, and that is not what anybody wants.

In a policy-resistant system with actors pulling in different directions, everyone has to put great effort into keeping the system where no one wants it to be. If any single actor lets up, the others will drag the system closer to their goals, and farther from the goal of the one who let go. In fact, this system structure can operate in a ratchet mode: Intensification of anyone's effort leads to intensification of everyone else's. It's hard to reduce intensification. It takes a lot of mutual trust to say, OK, why don't we all just back off for a while?

The results of policy resistance can be tragic. In 1967, the Romanian government decided that Romania needed more people and that the way to get them was to make abortions for women under age forty-five illegal. Abortions were abruptly banned. Shortly thereafter, the birth rate tripled. Then the policy resistance of the Romanian people set in.

Although contraceptives and abortions remained illegal, the birth rate slowly came back down nearly to its previous level. This result was achieved primarily through dangerous, illegal abortions, which tripled the maternal mortality rate. In addition, many of the unwanted children that had been born when abortions were illegal were abandoned to orphanages. Romanian families were too poor to raise the many children their government desired decently, and they knew it. So, they resisted the government's pull toward larger family size, at great cost to themselves and to the generation of children who grew up in orphanages.

One way to deal with policy resistance is to try to overpower it. If you wield enough power and can keep wielding it, the power approach can work, at the cost of monumental resentment and the possibility of explosive consequences if the power is ever let up. This is what

happened with the formulator of the Romanian population policy, dictator Nicolae Ceausescu, who tried long and hard to overpower the resistance to his policy. When his government was overturned, he was executed, along with his family. The first law the new government repealed was the ban on abortion and contraception.

The alternative to overpowering policy resistance is so counterintuitive that it's usually unthinkable. Let go. Give up ineffective policies. Let the resources and energy spent on both enforcing and resisting be used for more constructive purposes. You won't get your way with the system, but it won't go as far in a bad direction as you think, because much of the action you were trying to correct was in response to your own action. If you calm down, those who are pulling against you will calm down too. This is what happened in 1933 when Prohibition ended in the United States; the alcohol-driven chaos also largely ended.

That calming down may provide the opportunity to look more closely at the feedbacks within the system, to understand the bounded rationality behind them, and to find a way to meet the goals of the participants in the system while moving the state of the system in a better direction.

For example, a nation wanting to increase its birth rate might ask why families are having few children and discover that it isn't because they don't like children. Perhaps they haven't the resources, the living space, the time, or the security to have more. Hungary, at the same time Romania was banning abortions, also was worried about its low birth rate—fearing an economic downturn could result from fewer people in the workforce. The Hungarian government discovered that cramped housing was one reason for small family size. The government devised a policy that rewarded larger families with more living space. This policy was only partially successful, because housing was not the only problem. But it was far more successful than Romania's policy and it avoided Romania's disastrous results.³

The most effective way of dealing with policy resistance is to find a way of aligning the various goals of the subsystems, usually by providing an overarching goal that allows all actors to break out of their bounded rationality. If everyone can work harmoniously toward the same outcome (if all feedback loops are serving the same goal), the results

can be amazing. The most familiar examples of this harmonization of goals are mobilizations of economies during wartime, or recovery after war or natural disaster.

Another example was Sweden's population policy. During the 1930s, Sweden's birth rate dropped precipitously, and, like the governments of Romania and Hungary, the Swedish government worried about that. Unlike Romania and Hungary, the Swedish government assessed its goals and those of the population and decided that there was a basis of agreement, not on the size of the family, but on the quality of child care. Every child should be wanted and nurtured. No child should be in material need. Every child should have access to excellent education and health care. These were goals around which the government and the people could align themselves.

The resulting policy looked strange during a time of low birth rate, because it included free contraceptives and abortion—because of the principle that every child should be wanted. The policy also included widespread sex education, easier divorce laws, free obstetrical care, support for families in need, and greatly increased investment in education and health care.⁴ Since then, the Swedish birth rate has gone up and down several times without causing panic in either direction, because the nation is focused on a far more important goal than the number of Swedes.

Harmonization of goals in a system is not always possible, but it's an worth looking for. It can be found only by letting go of more narrow goals and considering the long term welfare of the entire system.

THE TRAP: POLICY RESISTANCE

When various actors try to pull a system stock toward various goals, the result can be policy resistance. Any new policy, especially if it's effective, just pulls the stock farther from the goals of other actors and produces additional resistance, with a result that no one likes, but that everyone expends considerable effort in maintaining.

THE WAY OUT

Let go. Bring in all the actors and use the energy formerly expended on resistance to seek out mutually satisfactory ways for all goals to be realized—or redefinitions of larger and more important goals that everyone can pull toward together.

The Tragedy of the Commons

Leaders of Chancellor Helmut Kohl's coalition, led by the Christian Democratic Union, agreed last week with the opposition Social Democrats, after months of bickering, to turn back a flood of economic migrants by tightening conditions for claiming asylum.

—*International Herald Tribune* , 1992⁵

The trap called the tragedy of the commons comes about when there is escalation, or just simple growth, in a commonly shared, erodable environment.

Ecologist Garrett Hardin described the commons system in a classic article in 1968. Hardin used as his opening example a common grazing land:

Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. . . . Explicitly or implicitly, more or less consciously, he asks, "What is the utility to me of adding one more animal to my herd?" . . .

Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1. . . . Since, however, the effects of overgrazing are shared by all, . . . the negative utility for any particular decision-making herdsman is only a fraction of -1. . . .

The rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another. . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each . . . is locked into a system that compels him to

increase his herd without limit—in a world that is limited. Ruin is the destination toward which all . . . rush, each pursuing his own best interest.⁶

Bounded rationality in a nutshell!

In any commons system there is, first of all, a resource that is commonly shared (the pasture). For the system to be subject to tragedy, the resource must be not only limited, but erodable when overused. That is, beyond some threshold, the less resource there is, the less it is able to regenerate itself, or the more likely it is to be destroyed. As there is less grass on the pasture, the cows eat even the base of the stems from which the new grass grows. The roots no longer hold the soil from washing away in the rains. With less soil, the grass grows more poorly. And so forth. Another reinforcing feedback loop running downhill.

A commons system also needs users of the resource (the cows and their owners), which have good reason to increase, and which increase at a rate *that is not influenced by the condition of the commons*. The individual herdsman has no reason, no incentive, no strong feedback, to let the possibility of overgrazing stop him from adding another cow to the common pasture. To the contrary, he or she has everything to gain.

The hopeful immigrant to Germany expects nothing but benefit from that country's generous asylum laws, and has no reason to take into consideration the fact that too many immigrants will inevitably force Germany to toughen those laws. In fact, the knowledge that Germany is discussing that possibility is all the more reason to hurry to Germany!

The tragedy of the commons arises from *missing (or too long delayed) feedback* from the resource to the growth of the users of that resource.

The more users there are, the more resource is used. The more resource is used, the less there is per user. If the users follow the bounded rationality of the commons ("There's no reason for *me* to be the one to limit my cows!"), there is no reason for any of them to

decrease their use. Eventually, then, the harvest rate will exceed the capacity of the resource to bear the harvest. Because there is no feedback to the user, overharvesting will continue. The resource will decline. Finally, the erosion loop will kick in, the resource will be destroyed, and all the users will be ruined.

Surely, you'd think, no group of people would be so shortsighted as to destroy their commons. But consider just a few commonplace examples of commons that are being driven, or have been driven, to disaster:

- Uncontrolled access to a popular national park can bring in such crowds that the park's natural beauties are destroyed.
- It is to everyone's immediate advantage to go on using fossil fuels, although carbon dioxide from these fuels is a greenhouse gas that is causing global climate change.
- If every family can have any number of children it wants, but society as a whole has to support the cost of education, health care, and environmental protection for all children, the number of children born can exceed the capacity of the society to support them all. (This is the example that caused Hardin to write his article.)

These examples have to do with overexploitation of renewable resources—a structure you have seen already in the systems zoo. Tragedy can lurk not only in the use of common resources, but also in the use of common sinks, shared places where pollution can be dumped. A family, company, or nation can reduce its costs, increase its profits, or grow faster if it can get the entire community to absorb or handle its wastes. It reaps a large gain, while itself having to live with only a fraction of its own pollution (or none, if it can dump downstream or downwind). There is no rational reason why a polluter should desist.

In these cases, the feedback influencing the rate of use of the common resource—whether it is a source or a sink—is weak.

If you think that the reasoning of an exploiter of the commons is hard to understand, ask yourself how willing you are to carpool in order to reduce air pollution, or to clean up after yourself whenever you make a mess. The structure of a commons system makes selfish behavior much more convenient and profitable than behavior that is responsible to the whole community and to the future.

There are three ways to avoid the tragedy of the commons.

- *Educate and exhort* . Help people to see the consequences of unrestrained use of the commons. Appeal to their morality. Persuade them to be temperate. Threaten transgressors with social disapproval or eternal hellfire.
- *Privatize the commons* . Divide it up, so that each person reaps the consequences of his or her own actions. If some people lack the self-control to stay below the carrying capacity of their own private resource, those people will harm only themselves and not others.
- *Regulate the commons* . Garrett Hardin calls this option, bluntly, “mutual coercion, mutually agreed upon.” Regulation can take many forms, from outright bans on certain behaviors to quotas, permits, taxes, incentives. To be effective, regulation must be enforced by policing and penalties.

The first of these solutions, exhortation, tries to keep use of the commons low enough through moral pressure that the resource is not threatened. The second, privatization, makes a direct feedback link from the condition of the resource to those who use it, by making sure that gains and losses fall on the same decision maker. The owner still may abuse the resource, but now it takes ignorance or irrationality to do

so. The third solution, regulation, makes an indirect feedback link from the condition of the resource through regulators to users. For this feedback to work, the regulators must have the expertise to monitor and interpret correctly the condition of the commons, they must have effective means of deterrence, and they must have the good of the whole community at heart. (They cannot be uninformed or weak or corrupt.)

Some “primitive” cultures have managed common resources effectively for generations through education and exhortation. Garrett Hardin does not believe that option is dependable, however. Common resources protected only by tradition or an “honor system” may attract those who do not respect the tradition or who have no honor.

Privatization works more reliably than exhortation, if society is willing to let some individuals learn the hard way. But many resources, such as the atmosphere and the fish of the sea, simply cannot be privatized. That leaves only the option of “mutual coercion, mutually agreed upon.”

Life is full of mutual-coercion arrangements, most of them so ordinary you hardly stop to think about them. Every one of them limits the freedom to abuse a commons, while preserving the freedom to use it. For example:

- The common space in the center of a busy intersection is regulated by traffic lights. You can’t drive through whenever you want to. When it is your turn, however, you can pass through more safely than would be possible if there were an unregulated free-for-all.
- Use of common parking spaces in downtown areas are parceled out by meters, which charge for a space and limit the time it can be occupied. You are not free to park wherever you want for as long as you want, but you have a higher chance of finding a parking space than you would if the meters weren’t there.

- You may not help yourself to the money in a bank, however advantageous it might be for you to do so. Protective devices such as strongboxes and safes, reinforced by police and jails, prevent you from treating a bank as a commons. In return, your own money in the bank is protected.
- You may not broadcast at will over the wavelengths that carry radio or television signals. You must obtain a permit from a regulatory agency. If your freedom to broadcast were not limited, the airwaves would be a chaos of overlapping signals.
- Many municipal garbage systems have become so expensive that households are now charged for garbage disposal depending on the amount of garbage they generate—transforming the previous commons to a regulated pay-as-you-go system.

Notice from these examples how many different forms “mutual coercion, mutually agreed upon” can take. The traffic light doles out access to the commons on a “take your turn” basis. The meters charge for use of the parking commons. The bank uses physical barriers and strong penal ties. Permits to use broadcasting frequencies are issued to applicants by a government agency. And garbage fees directly restore the missing feedback, letting each household feel the economic impact of its own use of the commons.

Most people comply with regulatory systems most of the time, as long as they are mutually agreed upon and their purpose is understood. But all regulatory systems must use police power and penalties for the occasional noncooperator.

THE TRAP: TRAGEDY OF THE COMMONS

When there is a commonly shared resource, every user benefits directly from its use, but shares the costs of its abuse with everyone else. Therefore, there is very weak feedback from the condition of the resource to the decisions of the resource users.

The consequence is overuse of the resource, eroding it until it becomes unavailable to anyone.

THE WAY OUT

Educate and exhort the users, so they understand the consequences of abusing the resource. And also restore or strengthen the missing feedback link, either by privatizing the resource so each user feels the direct consequences of its abuse or (since many resources cannot be privatized) by regulating the access of all users to the resource.

Drift to Low Performance

In this recession, the British have discovered that . . . the economy is just as downwardly mobile as ever. Even national disasters are now seized on as portents of further decline. The *Independent* on Sunday carried a front-page article on “the ominous feeling that the Windsor fire is symptomatic of the country at large, that it stems from the new national characteristic of ineptitude. . . .”

Insisted Lord Peston, Labor’s trade and industry spokesman, “We know what we ought to do, for some reason we just don’t do it.”

Politicians, businessmen, and economists fault the country as a place where the young receive substandard education, where both labor and management are underskilled, where investment is skimped, and where politicians mismanage the economy.

—Erik Ipsen, *International Herald Tribune* , 1992 ²Erik Ipsen,

Some systems not only resist policy and stay in a normal bad state, they keep getting worse. One name for this archetype is “drift to low performance.” Examples include falling market share in a business, eroding quality of service at a hospital, continuously dirtier rivers or air, increased fat in spite of periodic diets, the state of America’s public schools—or my onetime jogging program, which somehow just faded away.

The actor in this feedback loop (British government, business, hospital, fat person, school administrator, jogger) has, as usual, a performance goal or desired system state that is compared to the actual state. If there is a discrepancy, action is taken. So far, that is an ordinary balancing feedback loop that should keep performance at the desired level.

But in this system, there is a distinction between the actual system state and the perceived state. *The actor tends to believe bad news more than good news*. As actual performance varies, the best results are dismissed as aberrations, the worst results stay in the memory. The actor thinks things are worse than they really are.

And to complete this tragic archetype, *the desired state of the system is influenced by the perceived state*. Standards aren't absolute. When perceived performance slips, the goal is allowed to slip. "Well, that's about all you can expect." "Well, we're not doing much worse than we were last year." "Well, look around, everybody else is having trouble too."

The balancing feedback loop that should keep the system state at an acceptable level is overwhelmed by a reinforcing feedback loop heading downhill. The lower the perceived system state, the lower the desired state. The lower the desired state, the less discrepancy, and the less corrective action is taken. The less corrective action, the lower the system state. If this loop is allowed to run unchecked, it can lead to a continuous degradation in the system's performance.

Another name for this system trap is "eroding goals." It is also called the "boiled frog syndrome," from the old story (I don't know whether it is true) that a frog put suddenly in hot water will jump right out, but if it is put into cold water that is gradually heated up, the frog will stay there happily until it boils. "Seems to be getting a little warm in here. Well, but then it's not so much warmer than it was a while ago." Drift to low performance is a gradual process. If the system state plunged quickly, there would be an agitated corrective process. But if it drifts down slowly enough to erase the memory of (or belief in) how much better things used to be, everyone is lulled into lower and lower expectations, lower effort, lower performance.

There are two antidotes to eroding goals. One is to keep standards absolute, regardless of performance. Another is to make goals sensitive to the *best* performances of the past, instead of the worst. If perceived performance has an upbeat bias instead of a downbeat one, if one takes the best results as a standard, and the worst results only as a temporary setback, then the same system structure can pull the system up to better and better performance. The reinforcing loop going downward, which said “the worse things get, the worse I’m going to let them get,” becomes a reinforcing loop going upward: “The better things get, the harder I’m going to work to make them even better.”

If I had applied that lesson to my jogging, I’d be running marathons by now.

THE TRAP: DRIFT TO LOW PERFORMANCE

Allowing performance standards to be influenced by past performance, especially if there is a negative bias in perceiving past performance, sets up a reinforcing feedback loop of eroding goals that sets a system drifting toward low performance.

THE WAY OUT

Keep performance standards absolute. Even better, let standards be enhanced by the best actual performances instead of being discouraged by the worst. Use the same structure to set up a drift toward high performance!

Escalation

Islamic militants kidnapped an Israeli soldier Sunday and threatened to kill him unless the army quickly releases the imprisoned founder of a dominant Muslim group in the Gaza Strip. . . . The kidnapping . . . came in a wave of intense violence, . . . with the shooting of three Palestinians and an Israeli soldier who . . . was gunned down from a passing vehicle while he was on patrol in a jeep. In addition Gaza was buffeted by repeated clashes between stone-throwing demonstrators and Israeli troops, who

opened fire with live ammunition and rubber bullets, wounding at least 120 people.

—Clyde Haberman, *International Herald Tribune*, 1992 [8](#)

I already mentioned one example of escalation early in this book; the system of kids fighting. You hit me, so I hit you back a little harder, so you hit me back a little harder, and pretty soon we have a real fight going.

“I’ll raise you one” is the decision rule that leads to escalation. Escalation comes from a reinforcing loop set up by competing actors trying to get ahead of each other. The goal of one part of the system or one actor is not absolute, like the temperature of a room thermostat being set at 18°C (65°F), but is related to the state of another part of the system, another actor. Like many of the other system traps, escalation is not necessarily a bad thing. If the competition is about some desirable goal, like a more efficient computer or a cure for AIDS, it can hasten the whole system toward the goal. But when it is escalating hostility, weaponry, noise, or irritation, this is an insidious trap indeed. The most common and awful examples are arms races and those places on earth where implacable enemies live constantly on the edge of self-reinforcing violence.

Each actor takes its desired state from the other’s perceived system state—and ups it! Escalation is not just keeping up with the Joneses, but keeping slightly ahead of the Joneses. The United States and the Soviet Union for years exaggerated their reports of each other’s armaments in order to justify more armaments of their own. Each weapons increase on one side caused a scramble to surpass it on the other side. Although each side blamed the other for the escalation, it would be more systematic to say that each side was escalating itself—its own weapons development started a process that was sure to require still more weapons development in the future. This system caused trillions of dollars of expense, the degradation of the economies of two superpowers, and the evolution of unimaginably destructive weapons, which still threaten the world.

Negative campaigning is another perverse example of escalation. One candidate smears another, so the other smears back, and so forth, until the voters have no idea that their candidates have any positive features, and the whole democratic process is demeaned.

Then there are price wars, with one economic competitor underpricing another, which causes the other to cut prices more, which causes the first to cut prices yet again, until both sides are losing money, but neither side can easily back out. This kind of escalation can end with the bankruptcy of one of the competitors.

Advertising companies escalate their bids for the attention of the consumer. One company does something bright and loud and arresting. Its competitor does something louder, bigger, brasher. The first company outdoes that. Advertising becomes ever more present in the environment (in the mail, on the telephone), more garish, more noisy, more intrusive, until the consumer's senses are dulled to the point at which almost no advertiser's message can penetrate.

The escalation system also produces the increasing loudness of conversation at cocktail parties, the increasing length of limousines, and the increasing raunchiness of rock bands.

Escalation also could be about peacefulness, civility, efficiency, subtlety, quality. But even escalating in a good direction can be a problem, because it isn't easy to stop. Each hospital trying to outdo the others in up-to-date, powerful, expensive diagnostic machines can lead to out-of-sight health care costs. Escalation in morality can lead to holier-than-thou sanctimoniousness. Escalation in art can lead from baroque to rococo to kitsch.

Escalation in environmentally responsible lifestyles can lead to rigid and unnecessary puritanism.

Escalation, being a reinforcing feedback loop, builds exponentially. Therefore, it can carry a competition to extremes faster than anyone would believe possible. If nothing is done to break the loop, the process usually ends with one or both of the competitors breaking down.

One way out of the escalation trap is unilateral disarmament—deliberately reducing your own system state to induce reductions in your state. Within the logic of the system, this option is almost unthinkable. But it actually can work, if one does it with determination, and if one can survive the short-term advantage of the competitor.

The only other graceful way out of the escalation system is to negotiate a disarmament. That's a structural change, an exercise in system design. It creates a new set of balancing controlling loops to keep the competition in bounds (parental pressure to stop the kids' fight; regulations on the size and placement of advertisements; peace-keeping troops in violence-prone areas). Disarmament agreements in escalation systems are not usually easy to get, and are never very pleasing to the parties involved, but they are much better than staying in the race.

THE TRAP: ESCALATION

When the state of one stock is determined by trying to surpass the state of another stock—and vice versa—then there is a reinforcing feedback loop carrying the system into an arms race, a wealth race, a smear campaign, escalating loudness, escalating violence. The escalation is exponential and can lead to extremes surprisingly quickly. If nothing is done, the spiral will be stopped by someone's collapse—because exponential growth cannot go on forever.

THE WAY OUT

The best way out of this trap is to avoid getting in it. If caught in an escalating system, one can refuse to compete (unilaterally disarm), thereby interrupting the reinforcing loop. Or one can negotiate a new system with balancing loops to control the escalation.

Success to the Successful— Competitive Exclusion

Extremely rich people—the top slice of the top 1 percent of taxpayers—have considerable flexibility to expose less of their income to taxation. . . . Those who can have raced to take bonuses

now rather than next year [when taxes are expected to be higher], to cash in stock options, . . . and to move income forward in any way possible.

—Sylvia Nasar, *International Herald Tribune* , 1992⁹

Using accumulated wealth, privilege, special access, or inside information to create more wealth, privilege, access or information are examples of the archetype called “success to the successful.” This system trap is found whenever the winners of a competition receive, as part of the reward, the means to compete even more effectively in the future. That’s a reinforcing feedback loop, which rapidly divides a system into winners who go on winning, and losers who go on losing.

Anyone who has played the game of Monopoly knows the success-to-the-successful system. All players start out equal. The ones who manage to be first at building “hotels” on their property are able to extract “rent” from the other players—which they can then use to buy more hotels. The more hotels you have, the more hotels you can get. The game ends when one player has bought up everything, unless the other players have long ago quit in frustration.

Once our neighborhood had a contest with a \$100 reward for the family that put up the most impressive display of outdoor Christmas lights. The family that won the first year spent the \$100 on more Christmas lights. After that family won three years in a row, with their display getting more elaborate every year, the contest was suspended.

To him that hath shall be given. The more the winner wins, the more he, she, or it can win in the future. If the winning takes place in a limited environment, such that everything the winner wins is extracted from the losers, the losers are gradually bankrupted, or forced out, or starved.

Success to the successful is a well-known concept in the field of ecology, where it is called “the competitive exclusion principle.” This principle says that two different species cannot live in exactly the same ecological niche, competing for exactly the same resources. Because the two species are different, one will necessarily reproduce faster, or be able to use the resource more efficiently than the other. It will win a

larger share of the resource, which will give it the ability to multiply more and keep winning. It will not only dominate the niche, it will drive the losing competitor to extinction. That will happen not by direct confrontation usually, but by appropriating all the resource, leaving none for the weaker competitor.

Another expression of this trap was part of the critique of capitalism by Karl Marx. Two firms competing in the same market will exhibit the same behavior as two species competing in a niche. One will gain a slight advantage, through greater efficiency or smarter investment or better technology or bigger bribes, or whatever. With that advantage, the firm will have more income to invest in productive facilities or newer technologies or advertising or bribes. Its reinforcing feedback loop of capital accumulation will be able to turn faster than that of the other firm, enabling it to produce still more and earn still more. If there is a finite market and no antitrust law to stop it, one firm will take over everything as long as it chooses to reinvest in and expand its production facilities.

Some people think the fall of the communist Soviet Union has disproved the theories of Karl Marx, but this particular analysis of his—that market competition systematically eliminates market competition—is demonstrated wherever there is, or used to be, a competitive market. Because of the reinforcing feedback loop of success to the successful, the many automobile companies in the United States were reduced to three (not one, because of antitrust laws). In most major U.S. cities, there is only one newspaper left. In every market economy, we see long term trends of declining numbers of farms, while the size of farms increases.

The trap of success to the successful does its greatest damage in the many ways it works to make the rich richer and the poor poorer. Not only do the rich have more ways to avoid taxation than the poor, but::

- In most societies, the poorest children receive the worst educations in the worst schools, if they are able to go to school at

all. With few marketable skills, they qualify only for low paying jobs, perpetuating their poverty.¹⁰

- People with low income and few assets are not able to borrow from most banks. Therefore, either they can't invest in capital improvements, or they must go to local moneylenders who charge exorbitant interest rates. Even when interest rates are reasonable, the poor pay them, the rich collect them.
- Land is held so unevenly in many parts of the world that most farmers are tenants on someone else's land. They must pay part of their crops to the landowner for the privilege of working the land, and so never are able to buy land of their own. The landowner uses the income from tenants to buy more land.

Those are only a few of the feedbacks that perpetuate inequitable distribution of income, assets, education, and opportunity. Because the poor can afford to buy only small quantities (of food, fuel, seed, fertilizer), they pay the highest prices. Because they are often unorganized and inarticulate, a disproportionately small part of government expenditure is allocated to their needs. Ideas and technologies come to them last. Disease and pollution come to them first. They are the people who have no choice but to take dangerous, low paying jobs, whose children are not vaccinated, who live in crowded, crime-prone, disaster-prone areas.

How do you break out of the trap of success to the successful?

Species and companies sometimes escape competitive exclusion by *diversifying*. A species can learn or evolve to exploit new resources. A company can create a new product or service that does not directly compete with existing ones. Markets tend toward monopoly and ecological niches toward monotony, but they also create offshoots of diversity, new markets, new species, which in the course of time may attract competitors, which then begin to move the system toward competitive exclusion again.

Diversification is not guaranteed, however, especially if the monopolizing firm (or species) has the power to crush all offshoots, or buy them up, or deprive them of the resources they need to stay alive. Diversification doesn't work as a strategy for the poor.

The success-to the-successful loop can be kept under control by putting into place feedback loops that keep any competitor from taking over entirely. That's what antitrust laws do in theory and sometimes in practice. (One of the resources very big companies can win by winning, however, is the power to weaken the administration of antitrust laws.)

The most obvious way out of the success-to the-successful archetype is by periodically "leveling the playing field." Traditional societies and game designers instinctively design into their systems some way of equalizing advantages, so the game stays fair and interesting. Monopoly games start over again with everyone equal, so those who lost last time have a chance to win. Many sports provide handicaps for weaker players. Many traditional societies have some version of the Native American "potlatch," a ritual in those who have the most give away many of their possessions to those who have the least.

There are many devices to break the loop of the rich getting richer and the poor getting poorer: tax laws written (unbeatably) to tax the rich at higher rates than the poor; charity; public welfare; labor unions; universal and equal health care and education; taxation on inheritance (a way of starting the game over with each new generation). Most industrial societies have some combination of checks like these on the workings of the success-to- the-successful trap, in order to keep everyone in the game. Gift-giving cultures redistribute wealth through potlatches and other ceremonies that increase the social standing of the gift giver.

These equalizing mechanisms may derive from simple morality, or they may come from the practical understanding that losers, if they are unable to get out of the game of success to the successful, and if they have no hope of winning, could get frustrated enough to destroy the playing field.

THE TRAP: SUCCESS TO THE SUCCESSFUL

If the winners of a competition are systematically rewarded with the means to win again, a reinforcing feedback loop is created by which, if it is allowed to proceed uninhibited, the winners eventually take all, while the losers are eliminated.

THE WAY OUT

Diversification, which allows those who are losing the competition to get out of that game and start another one; strict limitation on the fraction of the pie any one winner may win (antitrust laws); policies that level the playing field, removing some of the advantage of the strongest players or increasing the advantage of the weakest; policies that devise rewards for success that do not bias the next round of competition.

Shifting the Burden to the Intervenor—Addiction

You get some sense of what an incredible downward spiral we're in. Because more costs keep being shifted to the private sector, more private sector people stop insuring their employees. We are . . . now up to 100,000 Americans a month losing their health insurance.

An enormous percentage of them qualify for state Medicaid benefits. And since states can't run a deficit, they all go out and either underfund education, or underfund children's investment programs, or raise taxes, and that takes money away from other investments.

—Bill Clinton, *International Herald Tribune* , 1992^{[11](#)}

If you want to make a Somali angry, it is said, take away his khat. . .

Khat is the fresh tender leaves and twigs of the *catha edulis* plant.

. . . It is pharmacologically related to amphetamines. . . . Abdukadr Mahmoud Farah, 22, said he first started chewing khat when he

was 15. . . . “The reason is not to think of this place. When I use it, I get happy. I can do everything. I do not get tired.”

—Keith B. Richburg, *International Herald Tribune* , 1992¹²

Most people understand the addictive properties of alcohol, nicotine, caffeine, sugar, and heroin. Not everyone recognizes that addiction can appear in larger systems and in other guises—such as the dependence of industry on government subsidy, the reliance of farmers on fertilizers, the addiction of Western economies to cheap oil or weapons manufacturers to government contracts.

This trap is known by many names: addiction, dependence, shifting the burden to the intervenor. The structure includes a stock with in-flows and out-flows. The stock can be physical (a crop of corn) or *meta* -physical (a sense of well-being or self-worth). The stock is maintained by an actor adjusting a balancing feedback loop—either altering the in-flows or outflows. The actor has a goal and compares it with a perception of the actual state of the stock to determine what action to take.

Say you are a young boy, living in a land of famine and war, and your goal is to boost your sense of well-being so you feel happy and energetic and There is a huge discrepancy between your desired and actual state, and there are very few options available to you for closing that gap. But one thing you can do is take drugs. The drugs do nothing to improve your real situation—in fact, they likely make it worse. But the drugs quickly alter your *perception* of your state, numbing your senses and making you feel tireless and brave.

Similarly, if you are running an ineffective company, and if you can get the government to subsidize you, you can go on making money and continue to have a good profit, thereby remaining a respected member of society. Or perhaps you are a farmer trying to increase your corn crop on overworked land. You apply fertilizers and get a bumper crop without doing anything to improve the fertility of the soil.

The trouble is that the states created by interventions don't last. The intoxication wears off. The subsidy is spent. The fertilizer is consumed or washed away.

Examples of dependence and burden-shifting systems abound:

- Care of the aged used to be carried on by families, not always easily. So along came Social Security, retirement communities, nursing homes. Now most families no longer have the space, the time, the skills, or the willingness to care for their elderly members.
- Long-distance shipping was carried by railroads and short distance commuting by subways and streetcars, until the government decided to help out by building highways.
- Kids used to be able to do arithmetic in their heads or with paper and pencil, before the widespread use of calculators.
- Populations built up a partial immunity to diseases such as smallpox, tuberculosis, and malaria, until vaccinations and drugs came along.
- Modern medicine in general has shifted the responsibility for health away from the practices and lifestyle of each individual and onto intervening doctors and medicines.

Shifting a burden to an intervenor can be a good thing. It often is done purposefully, and the result can be an increased ability to keep the system in a desirable state. Surely the 100 percent protection from smallpox vaccines, if it lasts, is preferable to only partial protection from natural smallpox immunity. Some systems really need an intervenor!

But the intervention can become a system trap. A corrective feedback process within the system is doing a poor (or even so-so) job of maintaining the state of the system. A well-meaning and efficient intervenor watches the struggle and steps in to take some of the load.

The intervenor quickly brings the system to the state everybody wants it to be in. Congratulations are in order, usually self-congratulations by the intervenor to the intervenor.

Then the original problem reappears, since nothing has been done to solve it at its root cause. So the intervenor applies more of the “solution,” disguising the real state of the system again, and thereby failing to act on the problem. That makes it necessary to use still more “solution.”

The trap is formed if the intervention, whether by active destruction or simple neglect, undermines the original capacity of the system to maintain itself. If that capability atrophies, then more of the intervention is needed to achieve the desired effect. That weakens the capability of the original system still more. The intervenor picks up the slack. And so forth.

Why does anyone enter the trap? First, the intervenor may not foresee that the initial urge to help out a bit can start a chain of events that leads to ever-increasing dependency, which ultimately will strain the capacity of the intervenor. The American health-care system is experiencing the strains of that sequence of events.

Second, the individual or community that is being helped may not think through the long term loss of control and the increased vulnerability that go along with the opportunity to shift a burden to an able and powerful intervenor.

If the intervention is a drug, you become addicted. The more you are sucked into an addictive action, the more you are sucked into it again. One definition of addiction used in Alcoholics Anonymous is repeating the same stupid behavior over and over and over, and somehow expecting different results.

Addiction is finding a quick and dirty solution to the *symptom* of the problem, which prevents or distracts one from the harder and longer-term task of solving the real problem. Addictive policies are insidious, because they are so easy to sell, so simple to fall for.

Are insects threatening the crops? Rather than examine the farming the monocultures, the destruction of natural ecosystem controls that have led to the pest outbreak, just apply pesticides. That will make the bugs go away, and allow more monocultures, more destruction of ecosystems. That will bring back the bugs in greater outbursts, requiring more pesticides in the future.

Is the price of oil going up? Rather than acknowledge the inevitable depletion of a nonrenewable resource and increase fuel efficiency or switch to other fuels, we can *fix the price*. (Both the Soviet Union and the United States did this as their first response to the oil price shocks of the 1970s.) That way we can pretend that nothing is happening and go on burning oil—making the depletion problem worse. When that policy breaks down, we can go to war for oil. Or find more oil. Like a drunk ransacking the house in hopes of unearthing just one more bottle, we can pollute the beaches and invade the last wilderness areas, searching for just one more big deposit of oil.

Breaking an addiction is painful. It may be the physical pain of heroin withdrawal, or the economic pain of a price increase to reduce oil consumption, or the consequences of a pest invasion while natural predator populations are restoring themselves. Withdrawal means finally confronting the real (and usually much deteriorated) state of the system and taking the actions that the addiction allowed one to put off. Sometimes the withdrawal can be done gradually. Sometimes a nonaddictive policy can be put in place first to restore the degraded system with a minimum of turbulence (group support to restore the self-image of the addict, home insulation and high-mileage cars to reduce oil expense, polyculture and crop rotation to reduce crop vulnerability to pests). Sometimes there's no way out but to go cold turkey and just bear the pain.

It's worth going through the withdrawal to get back to an unaddicted state, but it is far preferable to avoid addiction in the first place.

The problem can be avoided up front by intervening in such a way as *to strengthen the ability of the system to shoulder its own burdens*. This option, helping the system to help itself, can be much cheaper and easier than taking over and running the system—something liberal

politicians don't seem to understand. The secret is to begin not with a heroic takeover, but with a series of questions.

- Why are the natural correction mechanisms failing?
- How can obstacles to their success be removed?
- How can mechanisms for their success be made more effective?

THE TRAP: SHIFTING THE BURDEN TO THE INTERVENOR

Shifting the burden, dependence, and addiction arise when a solution to a systemic problem reduces (or disguises) the symptoms, but does nothing to solve the underlying problem. Whether it is a substance that dulls one's perception or a policy that hides the underlying trouble, the drug of choice interferes with the actions that could solve the real problem.

If the intervention designed to correct the problem causes the self-maintaining capacity of the original system to atrophy or erode, then a destructive reinforcing feedback loop is set in motion. The system deteriorates; more and more of the solution is then required. The system will become more and more dependent on the intervention and less and less able to maintain its own desired state.

THE WAY OUT

Again, the best way out of this trap is to avoid getting in. Beware of symptom-relieving or signal-denying policies or practices that don't really address the problem. Take the focus off short-term relief and put it on long term restructuring.

If you are the intervenor, work in such a way as to restore or enhance the system's own ability to solve its problems, then remove yourself.

If you are the one with an unsupportable dependency, build your system's own capabilities back up before removing the intervention. Do it right away. The longer you wait, the harder the withdrawal process will be.

Rule Beating

CALVIN: OK, Hobbes, I've got a plan.

HOBBES: Yeah?

CALVIN: If I do ten spontaneous acts of good will a day from now until Christmas, Santa will have to be lenient in judging the rest of this last year. I can claim I've turned a new leaf.

HOBBES: Well, here's your chance. Susie's coming this way.

CALVIN: Maybe I'll start tomorrow and do 20 a day.

—*International Herald Tribune*, 1992¹³

Wherever there are rules, there is likely to be rule beating. Rule beating means evasive action to get around the intent of a system's rules—abiding by the letter, but not the spirit, of the law. Rule beating becomes a problem only when it leads a system into large distortions, unnatural behaviors that would make no sense at all in the absence of the rules. If it gets out of hand, rule beating can cause systems to produce very damaging behavior indeed.

Rule beating that distorts nature, the economy, organizations, and the human spirit can be destructive. Here are some examples, some serious, some less so, of rule beating:

- Departments of governments, universities, and corporations often engage in pointless spending at the end of the fiscal year just

to get rid of money—because if they don't spend their budget this year, they will be allocated less next year.

- In the 1970s, the state of Vermont adopted a land-use law called Act 250 that requires a complex approval process for subdivisions that create lots of ten acres or less. Now Vermont has an extraordinary number of lots just a little over ten acres.
- To reduce grain imports and assist local grain farmers, European countries imposed import restrictions on feed grains in the 1960s. No one thought, while the restrictions were being drafted, about the starchy root called cassava, which also happens to be a good animal feed. Cassava was not included in the restrictions. So corn imports from North America were replaced by cassava imports from Asia.¹⁴
- The U.S. Endangered Species Act restricts development wherever an endangered species has its habitat. Some landowners, on discovering that their property harbors an endangered species, purposely hunt or poison it, so the land can be developed.

Notice that rule beating produces the *appearance* of rules being followed. Drivers obey the speed limits, when they're in the vicinity of a police car. Feed grains are no longer imported into Europe. Development does not proceed where an endangered species is documented as present. The "letter of the law" is met, the spirit of the law is not. That is a warning about needing to design the law with the whole system, including its self-organizing evasive possibilities, in mind.

Rule beating is usually a response of the lower levels in a hierarchy to overrigid, deleterious, unworkable, or ill-defined rules from above. There are two generic responses to rule beating. One is to try to stamp out the self-organizing response by strengthening the rules or their enforcement—usually giving rise to still greater system distortion. That's the way further into the trap.

The way out of the trap, the opportunity, is to understand rule beating as useful feedback, and to revise, improve, rescind, or better explain the rules. Designing rules better means foreseeing as far as possible the effects of the rules on the subsystems, including any rule beating they might engage in, and structuring the rules to turn the self-organizing capabilities of the system in a positive direction.

THE TRAP: RULE BEATING

Rules to govern a system can lead to rule beating—perverse behavior that gives the appearance of obeying the rules or achieving the goals, but that actually distorts the system.

THE WAY OUT

Design, or redesign, rules to release creativity not in the direction of beating the rules, but in the direction of achieving the purpose of the rules.

Seeking the Wrong Goal

The government formally acknowledged Friday what private economists have been saying for months: Japan will not come close to hitting the 3.5 percent growth target government planners set a year ago. . . .

GNP grew in 1991 by 3.5 percent and in 1990 by 5.5 percent. Since the beginning of this fiscal year . . . the economy has been stagnant or contracting. . . .

Now that the forecast . . . has been lowered sharply, pressure from politicians and business is likely to grow on the Finance Ministry to take stimulative measures.

—*International Herald Tribune* , 1992¹⁵

Back in Chapter One, I said that one of the most powerful ways to influence the behavior of a system is through its purpose or goal. That's because the goal is the direction-setter of the system, the definer of

discrepancies that require action, the indicator of compliance, failure, or success toward which balancing feedback loops work. If the goal is defined badly, if it doesn't measure what it's supposed to measure, if it doesn't reflect the real welfare of the system, then the system can't possibly produce a desirable result. Systems, like the three wishes in the traditional fairy tale, have a terrible tendency to produce exactly and only what you ask them to produce. Be careful what you ask them to produce.

If the desired system state is national security, and that is defined as the amount of money spent on the military, the system will produce military spending. It may or may not produce national security. In fact, security may be undermined if the spending drains investment from other parts of the economy, and if the spending goes for exorbitant, unnecessary, or unworkable weapons.

If the desired system state is good education, measuring that goal by the amount of money spent per student will ensure money spent per student. If the quality of education is measured by performance on standardized tests, the system will produce performance on standardized tests. Whether either of these measures is correlated with good education is at least worth thinking about.

In the early days of family planning in India, program goals were defined in terms of the number of IUDs implanted. So doctors, in their eagerness to meet their targets, put loops into women without patient approval.

These examples confuse effort with result, one of the most common mistakes in designing systems around the wrong goal. Maybe the worst mistake of this kind has been the adoption of the GNP as the measure of national economic success. The GNP is the gross national product, the money value of the final goods and services produced by the economy. As a measure of human welfare, it has been criticized almost from the moment it was invented:

The gross national product does not allow for the health of our children, the quality of their education or the joy of their play. It does not include the beauty of our poetry or the strength of our

marriages, the intelligence of our public debate or the integrity of our public officials. It measures neither our wit nor our courage, neither our wisdom nor our learning, neither our compassion nor our devotion to our country, it measures everything in short, except that which makes life worthwhile.¹⁶

We have a system of national accounting that bears no resemblance to the national economy whatsoever, for it is not the record of our life at home but the fever chart of our consumption.¹⁷

The GNP lumps together goods and bads. (If there are more car accidents and medical bills and repair bills, the GNP goes up.) It counts only marketed goods and services. (If all parents hired people to bring up their children, the GNP would go up.) It does not reflect distributional equity. (An expensive second home for a rich family makes the GNP go up more than an inexpensive basic home for a poor family.) It measures effort rather than achievement, gross production and consumption rather than efficiency. New light bulbs that give the same light with one-eighth the electricity and that last ten times as long make the GNP go down.

GNP is a measure of *throughput* —flows of stuff made and purchased in a year—rather than capital stocks, the houses and cars and computers and stereos that are the source of real wealth and real pleasure. It could be argued that the best society would be one in which capital stocks can be and used with the lowest possible throughput, rather than the highest.

Although there is every reason to want a thriving economy, there is no particular reason to want the GNP to go up. But governments around the world respond to a signal of faltering GNP by taking numerous actions to keep it growing. Many of those actions are simply wasteful, stimulating inefficient production of things no one particularly wants. Some of them, such as overharvesting forests in order to stimulate the economy in the short term, threaten the long term good of the economy or the society or the environment.

If you define the goal of a society as GNP, that society will do its best to produce GNP. It will not produce welfare, equity, justice, or efficiency unless you define a goal and regularly measure and report the state of welfare, equity, justice, or efficiency. The world would be a different place if instead of competing to have the highest per capita GNP, nations competed to have the highest per capita stocks of wealth with the lowest throughput, or the lowest infant mortality, or the greatest political freedom, or the cleanest environment, or the smallest gap between the rich and the poor.

Seeking the wrong goal, satisfying the wrong indicator, is a system characteristic almost opposite from rule beating. In rule beating, the system is out to evade an unpopular or badly designed rule, while giving the appearance of obeying it. In seeking the wrong goal, the system obediently follows the rule and produces its specified result—which is not necessarily what anyone actually wants. You have the problem of wrong goals when you find something stupid happening “because it’s the rule.” You have the problem of rule beating when you find something stupid happening because it’s the way around the rule. Both of these system perversions can be going on at the same time with regard to the same rule.

THE TRAP: SEEKING THE WRONG GOAL

System behavior is particularly sensitive to the goals of feedback loops. If the goals—the indicators of satisfaction of the rules—are defined inaccurately or incompletely, the system may obediently work to produce a result that is not really intended or wanted.

THE WAY OUT

Specify indicators and goals that reflect the real welfare of the system. Be especially careful not to confuse effort with result or you will end up with a system that is producing effort, not result.

INTERLUDE • *The Goal of Sailboat Design*

Once upon a time, people raced sailboats not for millions of dollars or for national glory, but just for the fun of it.

They raced the boats they already had for normal purposes, boats that were designed for fishing, or transporting goods, or sailing around on weekends.

It quickly was observed that races are more interesting if the competitors are roughly equal in speed and maneuverability. So rules evolved, that defined various classes of boat by length and sail area and other parameters, and that restricted races to competitors of the same class.

Soon boats were being designed not for normal sailing, but for winning races within the categories defined by the rules. They squeezed the last possible burst of speed out of a square inch of sail, or the lightest possible load out of a standard-sized rudder. These boats were strange-looking and strange-handling, not at all the sort of boat you would want to take out fishing or for a Sunday sail. As the races became more serious, the rules became stricter and the boat designs more bizarre.

Now racing sailboats are extremely fast, highly responsive, and nearly unseaworthy. They need athletic and expert crews to manage them. No one would think of using an America's Cup yacht for any purpose other than racing within the rules. The boats are so optimized around the present rules that they have lost all resilience. Any change in the rules would render them useless.

PART THREE

Creating Change—in Systems and in Our Philosophy.

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— SIX —

Leverage Points— Places to Intervene in a System

IBM . . . announced 25,000 new job cuts and a large reduction in spending on research. . . . Spending on development research is to be lowered by \$1 billion next year. . . . Chairman John K. Akers . . . said IBM was still a world and industry leader in research but felt it could do better by “shifting to areas for growth,” meaning services, which need less capital but also return less profit in the long run.

—Lawrence Malkin, *International Herald Tribune* , 1992¹

So, how do we change the structure of systems to produce more of what we want and less of that which is undesirable? After years of working with corporations on their systems problems, MIT’s Jay Forrester likes to say that the average manager can define the current problem very cogently, identify the system structure that leads to the problem, and guess with great accuracy where to look for leverage points—places in the system where a small change could lead to a large shift in behavior.

This idea of leverage points is not unique to systems analysis—it’s embedded in legend: the silver bullet; the trimtab; the miracle cure; the secret passage; the magic password; the single hero who turns the tide

of history; the nearly effortless way to cut through or leap over huge obstacles. We not only want to believe that there are leverage points, we want to know where they are and how to get our hands on them. Leverage points are points of power.

But Forrester goes on to point out that although people deeply involved in a system often know intuitively where to find leverage points, more often than not they push the change in the *wrong direction* .

The classic example of that backward intuition was my own introduction to systems analysis, the World model. Asked by the Club of Rome—an international group of businessmen, statesmen, and scientists—to show how major global problems of poverty and hunger, environmental destruction, resource depletion, urban deterioration, and unemployment are related and how they might be solved, Forrester made a computer model and came out with a clear leverage point: growth.² Not only population growth, but economic growth. Growth has costs as well as benefits, and we typically don't count the costs—among which are poverty and hunger, environmental destruction, and so on—the whole list of problems we are trying to solve with growth! What is needed is much slower growth, very different kinds of growth, and in some cases no growth or negative growth.

The world's leaders are correctly fixated on economic growth as the answer to virtually all problems, *but they're pushing with all their might in the wrong direction* .

Another of Forrester's classics was his study of urban dynamics, published in 1969, which demonstrated that subsidized low-income housing is a leverage point.³ World Bank, The less of it there is, the *better off* the city is—even the low-income folks in the city. This model came out at a time when national policy dictated massive low-income housing projects, and Forrester was derided. Since then, many of those projects have been torn down in city after city.

Counterintuitive —that's Forrester's word to describe complex systems. Leverage points frequently are not intuitive. Or if they are, we too often use them backward, systematically worsening whatever problems we are trying to solve.

I have come up with no quick or easy formulas for finding leverage points in complex and dynamic systems. Give me a few months or years and I'll figure it out. And I know from bitter experience that, because they are so counterintuitive, when I do discover a system's leverage points, hardly anybody will believe me. Very frustrating—especially for those of us who yearn not just to understand complex systems, but to make the world work better.

It was in just such a moment of frustration that I proposed a list of places to intervene in a system during a meeting on the implications of global trade regimes. I offer this list to you with much humility and wanting to leave room for its evolution. What bubbled up in me that day was distilled from decades of rigorous analysis of many different kinds of systems done by many smart people. But complex systems are, well, complex. It's dangerous to generalize about them. What you read here is still a work in progress; it's not a recipe for finding leverage points. Rather, it's an invitation to think more broadly about system change.

As systems become complex, their behavior can become surprising. Think about your checking account. You write checks and make deposits. A little interest keeps flowing in (if you have a large enough balance) and bank fees flow out even if you have no money in the account, thereby creating an accumulation of debt. Now attach your account to a thousand others and let the bank create loans as a function of your combined and fluctuating deposits, link a thousand of those banks into a federal reserve system—and you begin to see how simple stocks and flows, plumbed together, create systems way too complicated and dynamically complex to figure out easily.

That's why leverage points are often not intuitive. And that's enough systems theory to proceed to the list.

12. Numbers—Constants and parameters such as subsidies, taxes, standards

Think about the basic stock-and-flow bathtub from Chapter One. The size of the flows is a matter of numbers and how quickly those numbers can be changed. Maybe the faucet turns hard, so it takes a while to get the water flowing or to turn it off. Maybe the drain is blocked and can

allow only a small flow, no matter how open it is. Maybe the faucet can deliver with the force of a fire hose. Some of these kinds of parameters are physically locked in and unchangeable, but many can be varied and so are popular intervention points.

Consider the national debt. It may seem like a strange stock; it is a money hole. The rate at which the hole deepens is called the annual deficit. Income from taxes shrinks the hole, government expenditures expand it. Congress and the president spend most of their time arguing about the many, many parameters that increase (spending) and decrease (taxing) the size or depth of the hole. Since those flows are connected to us, the voters, these are politically charged parameters. But, despite all the fireworks, and no matter which party is in charge, the money hole has been deepening for years now, just at different rates.

To adjust the dirtiness of the air we breathe, the government sets parameters called ambient-air-quality standards. To ensure some standing stock of forest (or some flow of money to logging companies), it sets allowed annual cuts. Corporations adjust parameters such as wage rates and product prices, with an eye on the level in their profit bathtub—the bottom line.

The amount of land we set aside for conservation each year. The minimum wage. How much we spend on AIDS research or Stealth bombers. The service charge the bank extracts from your account. All of these are parameters, adjustments to faucets. So, by the way, is firing people and getting new ones, including politicians. Putting different hands on the faucets may change the rate at which the faucets turn, but if they're the same old faucets, plumbed into the same old system, turned according to the same old information and goals and rules, the system behavior isn't going to change much. Electing Bill Clinton was definitely different from electing the elder George Bush, but not all that different, given that every president is plugged into the same political system. (Changing the way money flows in that system would make much more of a difference—but I'm getting ahead of myself on this list.)

Numbers, the sizes of flows, are dead last on my list of powerful interventions. Diddling with the details, arranging the deck chairs on the Titanic. Probably 90—no 95, no 99 percent—of our attention goes to parameters, but there's not a lot of leverage in them.

It's not that parameters aren't important—they can be, especially in the short term and to the individual who's standing directly in the flow. People care deeply about such variables as taxes and the minimum wage, and so fight fierce battles over them. But changing these variables *rarely changes the behavior of the national economy system*. If the system is chronically stagnant, parameter changes rarely kick-start it. If it's wildly variable, they usually don't stabilize it. If it's growing out of control, they don't slow it down.

Whatever cap we put on campaign contributions, it doesn't clean up politics. The Fed's fiddling with the interest rate hasn't made business cycles go away. (We always forget that during upturns, and are shocked, shocked by the downturns.) After decades of the strictest air pollution standards in the world, Los Angeles air is less dirty, but it isn't clean. Spending more on police doesn't make crime go away.

Since I'm about to get into some examples where parameters are leverage points, let me stick in a big caveat here. Parameters become leverage points when they go into ranges that kick off one of the items higher on this list. Interest rates, for example, or birth rates, control the gains around reinforcing feedback loops. System goals are parameters that can make big differences.

These kinds of critical numbers are not nearly as common as people seem to think they are. Most systems have evolved or are designed to stay far out of range of critical parameters. Mostly, the numbers are not worth the sweat put into them.

Here's a story a friend sent me over the Internet to makes that point:

When I became a landlord, I spent a lot of time and energy trying to figure out what would be a "fair" rent to charge.

I tried to consider all the variables, including the relative incomes of my tenants, my own income and cash-flow needs, which expenses were for upkeep and which were capital expenses, the equity versus the interest portion of the mortgage payments, how much my labor on the house was worth, etc.

I got absolutely nowhere. Finally I went to someone who specializes in giving money advice. She said: “You’re acting as though there is a fine line at which the rent is fair, and at any point above that point the tenant is being screwed and at any point below that you are being screwed. In fact, there is a large gray area in which both you and the tenant are getting a good, or at least a fair, deal. Stop worrying and get on with your life.”⁴

11. Buffers—The sizes of stabilizing stocks relative to their flows

Consider a huge bathtub with slow in- and outflows. Now think about a small one with very fast flows. That’s the difference between a lake and a river. You hear about catastrophic river floods much more often than catastrophic lake floods, because stocks that are big, relative to their flows, are more stable than small ones. In chemistry and other fields, a big, stabilizing stock is known as a buffer.

The stabilizing power of buffers is why you keep money in the bank rather than living from the flow of change through your pocket. It’s why stores hold inventory instead of calling for new stock just as customers carry the old stock out the door. It’s why we need to maintain more than the minimum breeding population of an endangered species. Soils in the eastern United States are more sensitive to acid rain than soils in the west, because they haven’t got big buffers of calcium to neutralize acid.

You can often stabilize a system by increasing the capacity of a buffer.¹⁰ But if a buffer is too big, the system gets inflexible. It reacts too slowly. And big buffers of some sorts, such as water reservoirs or inventories, cost a lot to build or maintain. Businesses invented just-in-time inventories, because occasional vulnerability to fluctuations or screw-ups is cheaper (for them, anyway) than certain, constant inventory costs—and because small-to vanishing inventories allow more flexible response to shifting demand.

There's leverage, sometimes magical, in changing the size of buffers. But buffers are usually physical entities, not easy to change. The acid absorption capacity of eastern soils is not a leverage point for alleviating acid rain damage. The storage capacity of a dam is literally cast in concrete. So I haven't put buffers very high on the list of leverage points.

10. Stock-and-Flow Structures—Physical systems and their nodes of intersection

The plumbing structure, the stocks and flows and their physical arrangement, can have an enormous effect on how the system operates. When the Hungarian road system was laid out so all traffic from one side of the nation to the other had to pass through central Budapest, that determined a lot about air pollution and commuting delays that are not easily fixed by pollution control devices, traffic lights, or speed limits.

The only way to fix a system that is laid out poorly is to rebuild it, if you can. Amory Lovins and his team at Rocky Mountain Institute have done wonders on energy conservation by simply straightening out bent pipes and enlarging ones that are too small. If we did similar energy retrofits on all the buildings in the United States, we could shut down many of our electric power plants.

But often physical rebuilding is the slowest and most expensive kind of change to make in a system. Some stock-and-flow structures are just plain unchangeable. The baby-boom swell in the U.S. population first caused pressure on the elementary school system, then high schools, then colleges, then jobs and housing, and now we're supporting its

retirement. There's not much we can do about it, because five-year-olds become six-year-olds, and sixty-four-year-olds become sixty-five-year-olds predictably and unstoppably. The same can be said for the lifetime of destructive CFC molecules in the ozone layer, for the rate at which contaminants get washed out of aquifers, for the fact that an inefficient car fleet takes ten to twenty years to turn over.

Physical structure is crucial in a system, but is rarely a leverage point, because changing it is rarely quick or simple. The leverage point is in proper design in the first place. After the structure is built, the leverage is in understanding its limitations and bottlenecks, using it with maximum efficiency, and refraining from fluctuations or expansions that strain its capacity.

9. Delays—The lengths of time relative to the rates of system changes

Delays in feedback loops are critical determinants of system behavior. They are common causes of oscillations. If you're trying to adjust a stock (your store inventory) to meet your goal, but you receive only delayed information about what the state of the stock is, you will overshoot and undershoot your goal. The same is true if your information is timely, but your response isn't. For example, it takes several years to build an electric power plant that will likely last thirty years. Those delays make it impossible to build exactly the right number of power plants to supply rapidly changing demand for electricity. Even with immense effort at forecasting, almost every electricity industry in the world experiences long oscillations between overcapacity and undercapacity. A system just can't respond to short-term changes when it has long term delays. That's why a massive central-planning system, such as the Soviet Union or General Motors, necessarily functions poorly.

Because we know they're important, we see delays wherever we look. For example, the delay between the time when a pollutant is dumped on the land and when it trickles down to the groundwater; or the delay between the birth of a child and the time when that child is ready to have a child; or the delay between the first successful test of a new technology and the time when that technology is installed throughout

the economy; or the time it takes for a price to adjust to a supply-demand imbalance.

A delay in a feedback process is critical *relative to rates of change in the stocks that the feedback loop is trying to control*. Delays that are too short cause overreaction, “chasing your tail,” oscillations amplified by the jumpiness of the response. Delays that are too long cause damped, sustained, or exploding oscillations, depending on how much too long. Overlong delays in a system with a threshold, a danger point, a range past which irreversible damage can occur, cause overshoot and collapse.

I would list delay length as a high leverage point, except for the fact that delays are not often easily changeable. Things take as long as they take. You can’t do a lot about the construction time of a major piece of capital, or the maturation time of a child, or the growth rate of a forest. It’s usually easier *to slow down the change rate*, so that inevitable feedback delays won’t cause so much trouble. That’s why growth rates are higher up on the leverage point list than delay times.

And that’s why slowing economic growth is a greater leverage point in Forrester’s World model than faster technological development or freer market prices. Those are attempts to speed up the rate of adjustment. But the world’s physical capital stock, its factories and boilers, the concrete manifestations of its working technologies, can change only so fast, even in the face of new prices or new ideas—and prices and ideas don’t change instantly either, not through a whole global culture. There’s more leverage in slowing the system down so technologies and prices can keep up with it, than there is in wishing the delays would go away.

But if there is a delay in your system that *can* be changed, changing it can have big effects. Watch out! Be sure you change it in the right direction! (For example, the great push to reduce information and money-transfer delays in financial markets is just asking for wild gyrations.)

8. Balancing Feedback Loops—The strength of the feedbacks relative to the impacts they are trying to

correct

Now we're beginning to move from the physical part of the system to the information and control parts, where more leverage can be found.

Balancing feedback loops are ubiquitous in systems. Nature evolves them and humans invent them as controls to keep important stocks within safe bounds. A thermostat loop is the classic example. Its purpose is to keep the system stock called "temperature of the room" fairly constant near a desired level. Any balancing feedback loop needs a goal (the thermostat setting), a monitoring and signaling device to detect deviation from the goal (the thermostat), and a response mechanism (the furnace and/or air conditioner, fans, pumps, pipes, fuel, etc.).

A complex system usually has numerous balancing feedback loops it can bring into play, so it can self-correct under different conditions and impacts. Some of those loops may be inactive much of the time—like the emergency cooling system in a nuclear power plant, or your ability to sweat or shiver to maintain your body temperature—but their presence is critical to the long term welfare of the system.

One of the big mistakes we make is to strip away these "emergency" response mechanisms because they aren't often used and they appear to be costly. In the short term, we see no effect from doing this. In the long term, we drastically narrow the range of conditions over which the system can survive. One of the most heartbreaking ways we do this is in encroaching on the habitats of endangered species. Another is in encroaching on our own time for personal rest, recreation, socialization, and meditation.

The strength of a balancing loop—its ability to keep its appointed stock at or near its goal—depends on the combination of all its parameters and links—the accuracy and rapidity of monitoring, the quickness and power of response, the directness and size of corrective flows. Sometimes there are leverage points here.

Take markets, for example, the balancing feedback systems that are all but worshipped by many economists. They can indeed be marvels of

self correction, as prices vary to moderate supply and demand and keep them in balance. Price is the central piece of information signaling both producers and consumers. The more the price is kept clear, unambiguous, timely, and truthful, the more smoothly markets will operate. Prices that reflect *full* costs will tell consumers how much they can actually afford and will reward efficient producers. Companies and governments are fatally attracted to the price leverage point, but too often determinedly push it in the wrong direction with subsidies, taxes, and other forms of confusion.

These modifications weaken the feedback power of market signals by twisting information in their favor. The *real* leverage here is to keep them from doing it. Hence, the necessity of antitrust laws, truth-in-advertising laws, attempts to internalize costs (such as pollution fees), the removal of perverse subsidies, and other ways of leveling market playing fields.

Strengthening and clarifying market signals, such as full-cost accounting, don't get far these days, because of the weakening of another set of balancing feedback loops—those of democracy. This great system was invented to put self-correcting feedback between the people and their government. The people, informed about what their elected representatives do, respond by voting those representatives in or out of office. The process depends on the free, full, unbiased flow of information back and forth between electorate and leaders. Billions of dollars are spent to limit and bias and dominate that flow of clear information. Give the people who want to distort market-price signals the power to influence government leaders, allow the distributors of information to be self-interested partners, and none of the necessary balancing feedbacks work well. Both market and democracy erode.

The strength of a balancing feedback loop is important *relative to the impact it is designed to correct*. If the impact increases in strength, the feedbacks have to be strengthened too. A thermostat system may work fine on a cold winter day—but open all the windows and its corrective power is no match for the temperature change imposed on the system. Democracy works better without the brainwashing power of centralized mass communications. Traditional controls on fishing were sufficient until sonar spotting and drift nets and other technologies made it

possible for a few actors to catch the last fish. The power of big industry calls for the power of big government to hold it in check; a global economy makes global regulations necessary.

Examples of strengthening balancing feedback controls to improve a system's self-correcting abilities include:

- preventive medicine, exercise, and good nutrition to bolster the body's ability to fight disease,
- integrated pest management to encourage natural predators of crop pests,
- the Freedom of Information Act to reduce government secrecy,
- monitoring systems to report on environmental damage,
- protection for whistleblowers, and
- impact fees, pollution taxes, and performance bonds to recapture the externalized public costs of private benefits.

7. Reinforcing Feedback Loops—The strength of the gain of driving loops

A balancing feedback loop is self-correcting; a reinforcing feedback loop is self-reinforcing. The more it works, the more it gains power to work some more, driving system behavior in one direction. The more people catch the flu, the more they infect other people. The more babies are born, the more people grow up to have babies. The more money you have in the bank, the more interest you earn, the more money you have in the bank. The more the soil erodes, the less vegetation it can support, the fewer roots and leaves to soften rain and runoff, the more soil erodes. The more high-energy neutrons in the critical mass, the more they knock into nuclei and generate more high-energy neutrons, leading to a nuclear explosion or meltdown.

Reinforcing feedback loops are sources of growth, explosion, erosion, and collapse in systems. A system with an unchecked reinforcing loop ultimately will destroy itself. That's why there are so few of them. Usually a balancing loop will kick in sooner or later. The epidemic will run out of infectible people—or people will take increasingly stronger steps to avoid being infected. The death rate will rise to equal the birth rate—or people will see the consequences of unchecked population growth and have fewer babies. The soil will erode away to bedrock, and after a million years the bedrock will crumble into new soil—or people will stop overgrazing, put up check dams, plant trees, and stop the erosion.

In all those examples, the first outcome is what will happen if the reinforcing loop runs its course, the second is what will happen if there's an intervention to reduce its self-multiplying power. Reducing the gain around a reinforcing loop—slowing the growth—is usually a more powerful leverage point in systems than strengthening balancing loops, and far more preferable than letting the reinforcing loop run.

Population and economic growth rates in the World model are leverage points, because slowing them gives the many balancing loops, through technology and markets and other forms of adaptation (all of which have limits and delays), time to function. It's the same as slowing the car when you're driving too fast, rather than calling for more responsive brakes or technical advances in steering.

There are many reinforcing feedback loops in society that reward the winners of a competition with the resources to win even bigger next time—the “success to the successful” trap. Rich people collect interest; poor people pay it. Rich people pay accountants and lean on politicians to reduce their taxes; poor people can't. Rich people give their kids inheritances and good educations. Antipoverty programs are weak balancing loops that try to counter these strong reinforcing ones. It would be much more effective to weaken the reinforcing loops. That's what progressive income tax, inheritance tax, and universal high-quality public education programs are meant to do. If the wealthy can influence government to weaken, rather than strengthen, those measures, then the government itself shifts from a balancing structure to one that reinforces success to the successful!

Look for leverage points around birth rates, interest rates, erosion rates, “success to the successful” loops, any place where the more you have of something, the more you have the possibility of having more.

6. Information Flows—The structure of who does and does not have access to information

In Chapter Four, we examined the story of the electric meter in a Dutch housing development—in some of the houses the meter was installed in the basement; in others it was installed in the front hall. With no other differences in the houses, electricity consumption was 30 percent lower in the houses where the meter was in the highly visible location in the front hall.

I love that story because it’s an example of a high leverage point in the information structure of the system. It’s not a parameter adjustment, not a strengthening or weakening of an existing feedback loop. It’s a new loop, delivering feedback to a place where it wasn’t going before.

Missing information flows is one of the most common causes of system malfunction. Adding or restoring information can be a powerful intervention, usually much easier and cheaper than rebuilding physical infrastructure. The tragedy of the commons that is crashing the world’s commercial fisheries occurs because there is little feedback from the state of the fish population to the decision to invest in fishing vessels. Contrary to economic opinion, the *price* of fish doesn’t provide that feedback. As the fish get more scarce they become more expensive, and it becomes all the more profitable to go out and catch the last few. That’s a perverse feedback, a reinforcing loop that leads to collapse. It is not price information but population information that is needed.

It’s important that the missing feedback be restored to the right place and in compelling form. To take another tragedy of the commons example, it’s not enough to inform all the users of an aquifer that the groundwater level is dropping. That could initiate a race to the bottom. It would be more effective to set the cost of water to rise steeply as the pumping rate begins to exceed the recharge rate.

Other examples of compelling feedback are not hard to find. Suppose taxpayers got to specify on their return forms what government services their tax payments must be spent on. (Radical democracy!) Suppose any town or company that puts a water intake pipe in a river had to put it immediately *downstream* from its own wastewater outflow pipe. Suppose any public or private official who made the decision to invest in a nuclear power plant got the waste from that facility stored on his or her lawn. Suppose (this is an old one) the politicians who declare war were required to spend that war in the front lines.

There is a systematic tendency on the part of human beings to avoid accountability for their own decisions. That's why there are so many missing feedback loops—and why this kind of leverage point is so often popular with the masses, unpopular with the powers that be, and effective, if you can get the powers that be to permit it to happen (or go around them and make it happen anyway).

5. Rules—Incentives, punishments, constraints

The rules of the system define its scope, its boundaries, its degrees of freedom. Thou shalt not kill. Everyone has the right of free speech. Contracts are to be honored. The president serves four-year terms and cannot serve more than two of them. Nine people on a team, you have to touch every base, three strikes and you're out. If you get caught robbing a bank, you go to jail.

Mikhail Gorbachev came to power in the Soviet Union and opened information flows (glasnost) and changed the economic rules (perestroika), and the Soviet Union saw tremendous change.

Constitutions are the strongest examples of social rules. Physical laws such as the second law of thermodynamics are absolute rules, whether we understand them or not or like them or not. Laws, punishments, incentives, and informal social agreements are progressively weaker rules.

To demonstrate the power of rules, I like to ask my students to imagine different ones for a college. Suppose the students graded the teachers, or each other. Suppose there were no degrees: You come to college

when you want to learn something, and you leave when you've learned it. Suppose tenure were awarded to professors according to their ability to solve real world problems, rather than to publish academic papers. Suppose a class got graded as a group, instead of as individuals.

As we try to imagine restructured rules and what our behavior would be under them, we come to understand the power of rules. They are high leverage points. Power over the rules is real power. That's why lobbyists congregate when Congress writes laws, and why the Supreme Court, which interprets and delineates the Constitution—the rules for writing the rules—has even more power than Congress. If you want to understand the deepest malfunctions of systems, pay attention to the rules and to who has power over them.

That's why my systems intuition was sending off alarm bells as the new world trade system was explained to me. It is a system with rules designed by corporations, run by corporations, for the benefit of corporations. Its rules exclude almost any feedback from any other sector of society. Most of its meetings are closed even to the press (no information flow, no feedback). It forces nations into reinforcing loops “racing to the bottom,” competing with each other to weaken environmental and social safeguards in order to attract corporate investment. It's a recipe for unleashing “success to the successful” loops, until they generate enormous accumulations of power and huge centralized planning systems that will destroy themselves.

4. Self-Organization—The power to add, change, or evolve system structure

The most stunning thing living systems and some social systems can do is to change themselves utterly by creating whole new structures and behaviors. In biological systems that power is called evolution. In human economies it's called technical advance or social revolution. In systems lingo it's called self-organization.

Self-organization means changing any aspect of a system lower on this list—adding completely new physical structures, such as brains or wings or computers—adding new balancing or reinforcing loops, or new rules. The ability to self-organize is the strongest form of system

resilience. A system that can evolve can survive almost any change, by changing itself. The human immune system has the power to develop new responses to some kinds of insults it has never before encountered. The human brain can take in new information and pop out completely new thoughts.

The power of self-organization seems so wondrous that we tend to regard it as mysterious, miraculous, heaven sent. Economists often model technology as magic—coming from nowhere, costing nothing, increasing the productivity of an economy by some steady percent each year. For centuries people have regarded the spectacular variety of nature with the same awe. Only a divine creator could bring forth such a creation.

Further investigation of self-organizing systems reveals that the divine creator, if there is one, does not have to produce evolutionary miracles. He, she, or it just has to write marvelously clever *rules for self-organization*. These rules basically govern how, where, and what the system can add onto or subtract from itself under what conditions. As hundreds of self-organizing computer models have demonstrated, complex and delightful patterns can evolve from quite simple sets of rules. The genetic code within the DNA that is the basis of all biological evolution contains just four different letters, combined into words of three letters each. That pattern, and the rules for replicating and rearranging it, has been constant for something like three billion years, during which it has spewed out an unimaginable variety of failed and successful self-evolved creatures.

Self-organization is basically a matter of an evolutionary raw material—a highly variable stock of information from which to select possible patterns—and a means for experimentation, for selecting and testing new patterns. For biological evolution, the raw material is DNA, one source of variety is spontaneous mutation, and the testing mechanism is a changing environment in which some individuals do not survive to reproduce. For technology, the raw material is the body of understanding science has accumulated and stored in libraries and in the brains of its practitioners. The source of variety is human creativity (whatever *that* is) and the selection mechanism can be whatever the

market will reward, or whatever governments and foundations will fund, or whatever meets human needs.

When you understand the power of system self-organization, you begin to understand why biologists worship biodiversity even more than economists worship technology. The wildly varied stock of DNA, evolved and accumulated over billions of years, is the source of evolutionary potential, just as science libraries and labs and universities where scientists are trained are the source of technological potential. Allowing species to go extinct is a systems crime, just as randomly eliminating all copies of particular science journals or particular kinds of scientists would be.

The same could be said of human cultures, of course, which are the store of behavioral repertoires, accumulated over not billions, but hundreds of thousands of years. They are a stock out of which social evolution can arise. Unfortunately, people appreciate the precious evolutionary potential of cultures even less than they understand the preciousness of every genetic variation in the world's ground squirrels. I guess that's because one aspect of almost every culture is the belief in the utter superiority of that culture.

Insistence on a single culture shuts down learning and cuts back resilience. Any system, biological, economic, or social, that gets so encrusted that it cannot self-evolve, a system that systematically scorns experimentation and wipes out the raw material of innovation, is doomed over the long term on this highly variable planet.

The intervention point here is obvious, but unpopular. Encouraging variability and experimentation and diversity means "losing control." Let a thousand flowers bloom and *anything* could happen! Who wants that? Let's play it safe and push this lever in the wrong direction by wiping out biological, cultural, social, and market diversity!

3. Goals—The purpose or function of the system

Right there, the diversity-destroying consequence of the push for control demonstrates why the goal of a system is a leverage point superior to the self-organizing ability of a system. If the goal is to bring

more and more of the world under the control of one particular central planning system (the empire of Genghis Khan, the Church, the People's Republic of China, Wal-Mart, Disney), then everything further down the list, physical stocks and flows, feedback loops, information flows, even self-organizing behavior, will be twisted to conform to that goal.

That's why I can't get into arguments about whether genetic engineering is a "good" or a "bad" thing. Like all technologies, it depends on who is wielding it, with what goal. The only thing one can say is that if corporations wield it for the purpose of generating marketable products, that is a very different goal, a very different selection mechanism, a very different direction for evolution than anything the planet has seen so far.

As my little single-loop examples have shown, most balancing feedback loops within systems have their own goals—to keep the bathwater at the right level, to keep the room temperature comfortable, to keep inventories stocked at sufficient levels, to keep enough water behind the dam. Those goals are important leverage points for pieces of systems, and most people realize that. If you want the room warmer, you know the thermostat setting is the place to intervene. But there are larger, less obvious, higher-leverage goals, those of the entire system.

Even people within systems don't often recognize what whole-system goal they are serving. "To make profits," most corporations would say, but that's just a rule, a necessary condition to stay in the game. What is the point of the game? To grow, to increase market share, to bring the world (customers, suppliers, regulators) more and more under the control of the corporation, so that its operations becomes ever more shielded from uncertainty. John Kenneth Galbraith recognized that corporate goal—to engulf everything—long ago. ⁶—It's the goal of a cancer too. Actually it's the goal of every living population—and only a bad one when it isn't balanced by higher level balancing feedback loops that never let an upstart power-loop-driven entity control the world. The goal of keeping the market competitive has to trump the goal of each individual corporation to eliminate its competitors, just as in ecosystems, the goal of keeping populations in balance and evolving has to trump the goal of each population to reproduce without limit.

I said a while back that changing the players in the system is a low-level intervention, as long as the players fit into the same old system. The exception to that rule is at the top, where a single player can have the power to change the system's goal. I have watched in wonder as—only very occasionally—a new leader in an organization, from Dartmouth College to Nazi Germany, comes in, enunciates a new goal, and swings hundreds or thousands or millions of perfectly intelligent, rational people off in a new direction.

That's what Ronald Reagan did, and we watched it happen. Not long before he came to office, a president could say "Ask not what government can do for you, ask what you can do for the government," and no one even laughed. Reagan said over and over, the goal is not to get the people to help the government and not to get government to help the people, but to get government off our backs. One can argue, and I would, that larger system changes and the rise of corporate power over government let him get away with that. But the thoroughness with which the public discourse in the United States and even the world has been changed since Reagan is testimony to the high leverage of articulating, meaning, repeating, standing up for, insisting upon, new system goals.

2. Paradigms—The mind-set out of which the system—its goals, structure, rules, delays, parameters—arises

Another of Jay Forrester's famous systems sayings goes: It doesn't matter how the tax law of a country is written. There is a shared idea in the minds of the society about what a "fair" distribution of the tax load is. Whatever the laws say, by fair means or foul, by complications, cheating, exemptions or deductions, by constant sniping at the rules, actual tax payments will push right up against the accepted idea of "fairness."

The shared idea in the minds of society, the great big unstated assumptions, constitute that society's paradigm, or deepest set of beliefs about how the world works. These beliefs are unstated because it is unnecessary to state them—everyone already knows them. Money measures something real and has real meaning; therefore, people who are paid less are literally worth less. Growth is good. Nature is a stock

of resources to be converted to human purposes. Evolution stopped with the emergence of *Homo sapiens*. One can “own” land. Those are just a few of the paradigmatic assumptions of our current culture, all of which have utterly dumbfounded other cultures, who thought them not the least bit obvious.

Paradigms are the sources of systems. From them, from shared social agreements about the nature of reality, come system goals and information flows, feedbacks, stocks, flows, and everything else about systems. No one has ever said that better than Ralph Waldo Emerson:

Every nation and every man instantly surround themselves with a material apparatus which exactly corresponds to . . . their state of thought. Observe how every truth and every error, each a thought of some man’s mind, clothes itself with societies, houses, cities, language, ceremonies, newspapers. Observe the ideas of the present day . . . see how timber, brick, lime, and stone have flown into convenient shape, obedient to the master idea reigning in the minds of many persons. . . . It follows, of course, that the least enlargement of ideas . . . would cause the most striking changes of external things.²Ralph Waldo Emerson,

The ancient Egyptians built pyramids because they believed in an afterlife. We build skyscrapers because we believe that space in downtown cities is enormously valuable. Whether it was Copernicus and Kepler showing that the earth is not the center of the universe, or Einstein hypothesizing that matter and energy are interchangeable, or Adam Smith postulating that the selfish actions of individual players in markets wonderfully accumulate to the common good, people who have managed to intervene in systems at the level of paradigm have hit a leverage point that totally transforms systems.

You could say paradigms are harder to change than anything else about a system, and therefore this item should be lowest on the list, not second to- highest. But there’s nothing physical or expensive or even slow in the process of paradigm change. In a single individual it can happen in a millisecond. All it takes is a click in the mind, a falling of scales from the eyes, a new way of seeing. Whole societies are another

matter—they resist challenges to their paradigms harder than they resist anything else.

So how do you change paradigms? Thomas Kuhn, who wrote the seminal book about the great paradigm shifts of science, has a lot to say about that. ⁸Clyde Haberman, You keep pointing at the anomalies and failures in the old paradigm. You keep speaking and acting, loudly and with assurance, from the new one. You insert people with the new paradigm in places of public visibility and power. You don't waste time with reactionaries; rather, you work with active change agents and with the vast middle ground of people who are open-minded.

Systems modelers say that we change paradigms by building a model of the system, which takes us outside the system and forces us to see it whole. I say that because my own paradigms have been changed that way.

1. Transcending Paradigms

There is yet one leverage point that is even higher than changing a paradigm. That is to keep oneself unattached in the arena of paradigms, to stay flexible, to realize that *no* paradigm is “true,” that every one, including the one that sweetly shapes your own worldview, is a tremendously limited understanding of an immense and amazing universe that is far beyond human comprehension. It is to “get” at a gut level the paradigm that there are paradigms, and to see that that itself is a paradigm, and to regard that whole realization as devastatingly funny. It is to let go into not-knowing, into what the Buddhists call enlightenment.

People who cling to paradigms (which means just about all of us) take one look at the spacious possibility that everything they think is guaranteed to be nonsense and pedal rapidly in the opposite direction. Surely there is no power, no control, no understanding, not even a reason for being, much less acting, embodied in the notion that there is no certainty in *any* worldview. But, in fact, everyone who has managed to entertain that idea, for a moment or for a lifetime, has found it to be the basis for radical empowerment. If no paradigm is right, you can

choose whatever one will help to achieve your purpose. If you have no idea where to get a purpose, you can listen to the universe.

It is in this space of mastery over paradigms that people throw off addictions, live in constant joy, bring down empires, get locked up or burned at the stake or crucified or shot, and have impacts that last for millennia.

There is so much that could be said to qualify this list of places to intervene in a system. It is a tentative list and its order is slithery. There are exceptions to every item that can move it up or down the order of leverage. Having had the list percolating in my subconscious for years has not transformed me into Superwoman. The higher the leverage point, the more the system will resist changing it—that's why societies often rub out truly enlightened beings.

Magical leverage points are not easily accessible, even if we know where they are and which direction to push on them. There are no cheap tickets to mastery. You have to work hard at it, whether that means rigorously analyzing a system or rigorously casting off your own paradigms and throwing yourself into the humility of not-knowing. In the end, it seems that mastery has less to do with pushing leverage points than it does with strategically, profoundly, madly, letting go and dancing with the system.

— SEVEN —

Living in a World of Systems

The real trouble with this world of ours is not that it is an unreasonable world, nor even that it is a reasonable one. The commonest kind of trouble is that it is nearly reasonable, but not quite. Life is not an illogicality; yet it is a trap for logicians. It looks just a little more mathematical and regular than it is.

—G. K. Chesterton,¹20th century writer

People who are raised in the industrial world and who get enthused about systems thinking are likely to make a terrible mistake. They are likely to assume that here, in systems analysis, in interconnection and complication, in the power of the computer, here at last, is the key to prediction and control. This mistake is likely because the mind-set of the industrial world assumes that there is a key to prediction and control.

I assumed that at first too. We all assumed it, as eager systems students at the great institution called MIT. More or less innocently, enchanted by what we could see through our new lens, we did what many discoverers do. We exaggerated our findings. We did so not with any intent to deceive others, but in the expression of our own expectations and hopes. Systems thinking for us was more than subtle, complicated mind play. It was going to *make systems work* .

Like the explorers searching for the passage to India who ran into the Western Hemisphere instead, we had found something, but it wasn't what we thought we had found. It was something so different from what we had been looking for that we didn't know what to make of it. As we got to know systems thinking better, it turned out to have greater worth than we had thought, but not in the way we had thought.

Our first comeuppance came as we learned that it's one thing to understand how to fix a system and quite another to wade in and fix it. We had many earnest discussions on the topic of "implementation," by which we meant "how to get managers and mayors and agency heads to follow our advice."

The truth was, we didn't even follow our advice. We gave learned lectures on the structure of addiction and could not give up coffee. We knew all about the dynamics of eroding goals and eroded our own jogging programs. We warned against the traps of escalation and shifting the burden and then created them in our own marriages.

Social systems are the external manifestations of cultural thinking patterns and of profound human needs, emotions, strengths, and weaknesses. Changing them is not as simple as saying "now all change," or of trusting that he who knows the good shall do the good.

We ran into another problem. Our systems insights helped us understand many things we hadn't understood before, but they didn't help us understand *everything*. In fact, they raised at least as many questions as they answered. Like all the other lenses humanity has developed with which to peer into macrocosms and microcosms, this one too revealed wondrous new things, many of which were wondrous new mysteries. The mysteries our new tool revealed lay especially within the human mind and heart and soul. Here are just few of the questions that were prompted by our insights into how systems work.

A systems insight . . . can raise more questions!

Systems thinkers are by no means the first or only people to ask questions like these. When we started asking them, we found whole disciplines, libraries, histories, asking the same questions, and to some

extent offering answers. What was unique about our search was not our answers, or even our questions, but the fact that the tool of systems thinking, born out of engineering and mathematics, implemented in computers, drawn from a mechanistic mind-set and a quest for prediction and control, leads its practitioners, inexorably I believe, to confront the most deeply human mysteries. Systems thinking makes clear even to the most committed technocrat that getting along in this world of complex systems requires more than technocracy.

Self-organizing, nonlinear, feedback systems are inherently unpredictable. They are not controllable. They are understandable only in the most general way. The goal of foreseeing the future exactly and preparing for it perfectly is unrealizable. The idea of making a complex system do just what you want it to do can be achieved only temporarily, at best. We can never fully understand our world, not in the way our reductionist science has led us to expect. Our science itself, from quantum theory to the mathematics of chaos, leads us into irreducible uncertainty. For any objective other than the most trivial, we can't optimize; we don't even know what to optimize. We can't keep track of everything. We can't find a proper, sustainable relationship to nature, each other, or the institutions we create, if we try to do it from the role of omniscient conqueror.

A new information feedback loop at *this* point in this system will make it *Why do people actively sort and screen information the way they do? How do they determine* behave much better. But the decision makers are resistant to the *what to let in and what to let bounce off, what to reckon with and what to ignore or disparage?* information they need! They don't pay attention to it, they don't believe it, *How is it that, exposed to the same information, different people absorb different messages,* they don't know how to interpret it. *and draw different conclusions?*

If *this* feedback loop could just be oriented around *that* value, the *What are values? Where do they come from? Are they universal, or culturally determined?* system would produce a result that everyone wants. (Not more energy, *What causes a person or a society to give up on attaining "real values" and to settle for cheap* but more energy services. Not GNP, but material sufficiency and *substitutes? How can you key a feedback loop to qualities you can't measure, rather than to* security. Not growth, but progress.) We don't have to change anyone's *quantities you can?*

values, we just have to get the system to operate around real values.

Here is a system that seems perverse on all counts. It produces *Why is it that periods of minimum structure and maximum freedom to create are so* inefficiency, ugliness, environmental degradation, and human misery. But *frightening? How is it that one way of seeing the world becomes so widely shared that* if we sweep it away, we will have no system. Nothing is more frightening *institutions, technologies, production systems, buildings, cities, become shaped around that* way of seeing? *How do systems create cultures? How do cultures create systems? Once a*

than that. (As I write, I have the former communist system of the Soviet Union in mind, but that is not the only possible example.) *culture and system have been found lacking, do they have to change through breakdown and chaos?*

The people in this system are putting up with deleterious behavior *Why are people so easily convinced of their powerlessness? How do they become so cynical because they are afraid of change. They don't trust that a better system about their ability to achieve their visions? Why are they more likely to listen to people who tell is possible. They feel they have no power to demand or bring about them they can't make changes than they are to people who tell them they can?* improvement.

For those who stake their identity on the role of omniscient conqueror, the uncertainty exposed by systems thinking is hard to take. If you can't understand, predict, and control, what is there to do?

Systems thinking leads to another conclusion, however, waiting, shining, obvious, as soon as we stop being blinded by the illusion of control. It says that there is plenty to do, of a different sort of "doing." The future can't be predicted, but it can be envisioned and brought lovingly into being. Systems can't be controlled, but they can be designed and redesigned. We can't surge forward with certainty into a world of no surprises, but we can expect surprises and learn from them and even profit from them. We can't impose our will on a system. We can listen to what the system tells us, and discover how its properties and our values can work together to bring forth something much better than could ever be produced by our will alone.

We can't control systems or figure them out. But we can dance with them!

I already knew that, in a way. I had learned about dancing with great powers from whitewater kayaking, from gardening, from playing music, from skiing. All those endeavors require one to stay wide awake, pay close attention, participate flat out, and respond to feedback. It had never occurred to me that those same requirements might apply to intellectual work, to management, to government, to getting along with people.

But there it was, the message emerging from every computer model we made. Living successfully in a world of systems requires more of us than our ability to calculate. It requires our full humanity—our rationality, our ability to sort out truth from falsehood, our intuition, our compassion, our vision, and our morality.²

I want to end this chapter and this book by trying to summarize the most general “systems wisdoms” I have absorbed from modeling complex systems and from hanging out with modelers. These are the take-home lessons, the concepts and practices that penetrate the discipline of systems so deeply that one begins, however imperfectly, to practice them not just in one’s profession, but in all of life. They are the behavioral consequences of a worldview based on the ideas of feedback, nonlinearity, and systems responsible for their own behavior. When that engineering professor at Dartmouth noticed that we systems folks were “different” and wondered why, these, I think, were the differences he noticed.

The list probably isn’t complete, because I am still a student in the school of systems. And it isn’t a list that is unique to systems thinking; there are many ways to learn to dance. But here, as a start-off dancing lesson, are the practices I see my colleagues adopting, consciously or unconsciously, as they encounter new systems.

Get the Beat of the System

Before you disturb the system in any way, watch how it behaves. If it’s a piece of music or a whitewater rapid or a fluctuation in a commodity price, study its beat. If it’s a social system, watch it work. Learn its history. Ask people who’ve been around a long time to tell you what has happened. If possible, find or make a time graph of actual data from the system—peoples’ memories are not always reliable when it comes to timing.

This guideline is deceptively simple. Until you make it a practice, you won’t believe how many wrong turns it helps you avoid. Starting with the behavior of the system forces you to focus on facts, not theories. It keeps you from falling too quickly into your own beliefs or misconceptions, or those of others.

It’s amazing how many misconceptions there can be. People will swear that rainfall is decreasing, say, but when you look at the data, you find that what is really happening is that variability is increasing—the droughts are deeper, but the floods are greater too. I have been told with great authority that the price of milk was going up when it was

going down, that real interest rates were falling when they were rising, that the deficit was a higher fraction of the GNP than ever before when it wasn't.

It's especially interesting to watch how the various elements in the system do or do not vary together. Watching what really happens, instead of listening to peoples' theories of what happens, can explode many careless causal hypotheses. Every selectman in the state of New Hampshire seems to be positive that growth in a town will lower taxes, but if you plot growth rates against tax rates, you find a scatter as random as the stars in a New Hampshire winter sky. There is no discernible relationship at all.

Starting with the behavior of the system directs one's thoughts to dynamic, not static, analysis—not only to "What's wrong?" but also to "How did we get there?" "What other behavior modes are possible?" "If we don't change direction, where are we going to end up?" And looking to the strengths of the system, one can ask "What's working well here?" Starting with the history of several variables plotted together begins to suggest not only what elements are in the system, but how they might be interconnected.

And finally, starting with history discourages the common and distracting tendency we all have to define a problem not by the system's actual behavior, but by the lack of our favorite solution. (The problem is, we need to find more oil. The problem is, we need to ban abortion. The problem is, we don't have enough salesmen. The problem is, how can we attract more growth to this town?) Listen to any discussion, in your family or a committee meeting at work or among the pundits in the media, and watch people leap to solutions, usually solutions in "predict, control, or impose your will" mode, without having paid any attention to what the system is doing and why it's doing it.

Expose Your Mental Models to the Light of Day

When we draw structural diagrams and then write equations, we are forced to make our assumptions visible and to express them with rigor. We have to put every one of our assumptions about the system out where others (and we ourselves) can see them. Our models have to be

complete, and they have to add up, and they have to be consistent. Our assumptions can no longer slide around (mental models are very slippery), assuming one thing for purposes of one discussion and something else contradictory for purposes of the next discussion.

You don't have to put forth your mental model with diagrams and equations, although doing so is a good practice. You can do it with words or lists or pictures or arrows showing what you think is connected to what. The more you do that, in any form, the clearer your thinking will become, the faster you will admit your uncertainties and correct your mistakes, and the more flexible you will learn to be. Mental flexibility—the willingness to redraw boundaries, to notice that a system has shifted into a new mode, to see how to redesign structure—is a necessity when you live in a world of flexible systems.

Remember, always, that everything you know, and everything everyone knows, is only a model. Get your model out there where it can be viewed. Invite others to challenge your assumptions and add their own. Instead of becoming a champion for one possible explanation or hypothesis or model, collect as many as possible. Consider all of them to be plausible until you find some evidence that causes you to rule one out. That way you will be emotionally able to see the evidence that rules out an assumption that may become entangled with your own identity.

Getting models out into the light of day, making them as rigorous as possible, testing them against the evidence, and being willing to scuttle them if they are no longer supported is nothing more than practicing the scientific method—something that is done too seldom even in science, and is done hardly at all in social science or management or government or everyday life.

Honor, Respect, and Distribute Information

You've seen how information holds systems together and how delayed, biased, scattered, or missing information can make feedback loops malfunction. Decision makers can't respond to information they don't have, can't respond accurately to information that is inaccurate, and can't respond in a timely way to information that is late. I would guess

that most of what goes wrong in systems goes wrong because of biased, late, or missing information.

If I could, I would add an eleventh commandment to the first ten: *Thou shalt not distort, delay, or withhold information* . You can drive a system crazy by muddying its information streams. You can make a system work better with surprising ease if you can give it more timely, more accurate, more complete information.

For example, in 1986, new federal legislation, the Toxic Release Inventory, required U.S. companies to report all hazardous air pollutants emitted from each of their factories each year. Through the Freedom of Information Act (from a systems point of view, one of the most important laws in the nation), that information became a matter of public record. In July 1988, the first data on chemical emissions became available. The reported emissions were not illegal, but they didn't look very good when they were published in local papers by enterprising reporters, who had a tendency to make lists of "the top ten local polluters." That's all that happened. There were no lawsuits, no required reductions, no fines, no penalties. But within two years chemical emissions nationwide (at least as reported, and presumably also in fact) had decreased by 40 percent. Some companies were launching policies to bring their emissions down by 90 percent, just because of the release of previously withheld information.³

Information is power. Anyone interested in power grasps that idea very quickly. The media, the public relations people, the politicians, and advertisers who regulate much of the public flow of information have far more power than most people realize. They filter and channel information. Often they do so for short-term, self-interested purposes. It's no wonder our that social systems so often run amok.

Use Language with Care and Enrich It with Systems Concepts

Our information streams are composed primarily of language. Our mental models are mostly verbal. Honoring information means above all avoiding language pollution—making the cleanest possible use we can of language. Second, it means expanding our language so we can talk about complexity.

Fred Kofman wrote in a systems journal:

[Language] can serve as a medium through which we create new understandings and new realities as we begin to talk about them. In fact, we don't talk about what we see; *we see only what we can talk about* . Our perspectives on the world depend on the interaction of our nervous system and our language—both act as filters through which we perceive our world. . . . The language and information systems of an organization are not an objective means of describing an outside reality—they fundamentally structure the perceptions and actions of its members. To reshape the measurement and communication systems of a [society] is to reshape all potential interactions at the most fundamental level. Language . . . as articulation of reality is more primordial than strategy, structure, or . . . culture.⁴

A society that talks incessantly about “productivity” but that hardly understands, much less uses, the word “resilience” is going to become productive and not resilient. A society that doesn't understand or use the term “carrying capacity” will exceed its carrying capacity. A society that talks about “creating jobs” as if that's something only companies can do will not inspire the great majority of its people to create jobs, for themselves or anyone else. Nor will it appreciate its workers for their role in “creating profits.” And of course a society that talks about a “Peacekeeper” missile or “collateral damage,” a “Final Solution” or “ethnic cleansing,” is speaking what Wendell Berry calls “tyrannese.”

My impression is that we have seen, for perhaps a hundred and fifty years, a gradual increase in language that is either meaningless or destructive of meaning. And I believe that this increasing unreliability of language parallels the increasing disintegration, over the same period, of persons and communities.

. . .

He goes on to say:

In this degenerative accounting, language is almost without the power of designation, because it is used conscientiously to refer to nothing in particular. Attention rests upon percentages, categories,

abstract functions. . . . It is not language that the user will very likely be required to stand by or to act on, for it does not define any personal ground for standing or acting. Its only practical utility is to support with “expert opinion” a vast, impersonal technological action already begun. . . . It is a tyrannical language: tyrannese.⁵

The first step in respecting language is keeping it as concrete, meaningful, and truthful as possible—part of the job of keeping information streams clear. The second step is to enlarge language to make it consistent with our enlarged understanding of systems. If the Eskimos have so many words for snow, it’s because they have studied and learned how to use snow. They have turned snow into a resource, a system with which they can dance. The industrial society is just beginning to have and use words for systems, because it is only beginning to pay attention to and use complexity. *Carrying capacity* , *structure* , *diversity* , and even *system* are old words that are coming to have richer and more precise meanings. New words are having to be invented.

My word processor has spell-check capability, which lets me add words that didn’t originally come in its comprehensive dictionary. It’s interesting to see what words I had to add when writing this book: *feedback* , *throughput* , *overshoot* , *self-organization* , *sustainability* .

Pay Attention to What Is Important, Not Just What Is Quantifiable

Our culture, obsessed with numbers, has given us the idea that what we can measure is more important than what we can’t measure. Think about that for a minute. It means that we make quantity more important than quality. If quantity forms the goals of our feedback loops, if quantity is the center of our attention and language and institutions, if we motivate ourselves, rate ourselves, and reward ourselves on our ability to produce quantity, then quantity will be the result. You can look around and make up your own mind about whether quantity or quality is the outstanding characteristic of the world in which you live.

As modelers we have exposed ourselves to the ridicule of our scientific colleagues more than once by putting variables labeled “prejudice,” or “self-esteem,” or “quality of life” into our models. Since computers

require numbers, we have had to make up quantitative scales by which to measure these qualitative concepts. “Let’s say prejudice is measured from -10 to $+10$, where 0 means you are treated with no bias at all, -10 means extreme negative prejudice, and $+10$ means such positive prejudice that you can do no wrong. Now, suppose that you were treated with a prejudice of -2 , or $+5$, or -8 . What would that do to your performance at work?”

The relationship between prejudice and performance actually had to be put in a model once.⁶ The study was for a firm that wanted to know how to do better at treating minority workers and how to move them up the corporate ladder. Everyone interviewed agreed that there certainly was a real connection between prejudice and performance. It was arbitrary what kind of scale to measure it by—it could have been 1 to 5 or 0 to 100 —but it would have been much more unscientific to leave “prejudice” out of that study than to try to include it. When the workers in the company were asked to draw the relationship between their performance and prejudice, they came up with one of the most nonlinear relationships I’ve ever seen in a model.

Pretending that something doesn’t exist if it’s hard to quantify leads to faulty models. You’ve already seen the system trap that comes from setting goals around what is easily measured, rather than around what is important. So don’t fall into that trap. Human beings have been endowed not only with the ability to count, but also with the ability to assess quality. Be a quality detector. Be a walking, noisy Geiger counter that registers the presence or absence of quality.

If something is ugly, say so. If it is tacky, inappropriate, out of proportion, unsustainable, morally degrading, ecologically impoverishing, or humanly demeaning, don’t let it pass. Don’t be stopped by the “if you can’t define it and measure it, I don’t have to pay attention to it” ploy. No one can define or measure justice, democracy, security, freedom, truth, or love. No one can define or measure any value. But if no one speaks up for them, if systems aren’t designed to produce them, if we don’t speak about them and point toward their presence or absence, they will cease to exist.

President Jimmy Carter had an unusual ability to think in feedback terms and to make feedback policies. Unfortunately, he had a hard time explaining them to a press and public that didn't understand feedback.

He suggested, at a time when oil imports were soaring, that there be a tax on gasoline proportional to the fraction of U.S. oil consumption that had to be imported. If imports continued to rise, the tax would rise until it suppressed demand and brought forth substitutes and reduced imports. If imports fell to zero, the tax would fall to zero.

The tax never got passed.

Carter also was trying to deal with a flood of illegal immigrants from Mexico. He suggested that nothing could be done about that immigration as long as there was a great gap in opportunity and living standards between the United States and Mexico. Rather than spending money on border guards and barriers, he said, we should spend money helping to build the Mexican economy, and we should continue to do so until the immigration stopped.

That never happened either.

You can imagine why a dynamic, self-adjusting feedback system cannot be governed by a static, unbending policy. It's easier, more effective, and usually much cheaper to design policies that change depending on the state of the system. Especially where there are great uncertainties, the best policies not only contain feedback loops, but meta-feedback loops—loops that alter, correct, and expand loops. These are policies that design *learning* into the management process.

An example was the historic Montreal Protocol to protect the ozone layer of the stratosphere. In 1987, when that protocol was signed, there was no certainty about the danger to the ozone layer, about the rate at which it was degrading, or about the specific effect of different chemicals. The protocol set targets for how fast the manufacture of the most damaging chemicals should be decreased. But it also required monitoring the situation and reconvening an international congress to change the phase-out schedule, if the damage to the ozone layer turned out to be more or less than expected. Just three years later, in

1990, the schedule had to be hurried forward and more chemicals added to it, because the damage was turning out to be much greater than was foreseen in 1987.

That was a feedback policy, structured for learning. We all hope that it worked in time.

Go for the Good of the Whole

Remember that hierarchies exist to serve the bottom layers, not the top. Don't maximize parts of systems or subsystems while ignoring the whole. Don't, as Kenneth Boulding once said, go to great trouble to optimize something that never should be done at all. Aim to enhance total systems properties, such as growth, stability, diversity, resilience, and sustainability—whether they are easily measured or not.

Listen to the Wisdom of the System

Aid and encourage the forces and structures that help the system run itself. Notice how many of those forces and structures are at the bottom of the hierarchy. Don't be an unthinking intervenor and destroy the system's own self-maintenance capacities. Before you charge in to make things better, pay attention to the value of what's already there.

A friend of mine, Nathan Gray, was once an aid worker in Guatemala. He told me of his frustration with agencies that would arrive with the intention of "creating jobs" and "increasing entrepreneurial abilities" and "attracting outside investors." They would walk right past the thriving local market, where small-scale business people of all kinds, from basket makers to vegetable growers to butchers to candy sellers, were displaying their entrepreneurial abilities in jobs they had created for themselves. Nathan spent his time talking to the people in the market, asking about their lives and businesses, learning what was in the way of those businesses expanding and incomes rising. He concluded that what was needed was not outside investors, but inside ones. Small loans available at reasonable interest rates, and classes in literacy and accounting, would produce much more long term good for the community than bringing in a factory or assembly plant from outside.

That's a guideline both for analysis and design. In analysis, it means looking for the ways the system creates its own behavior. Do pay attention to the triggering events, the outside influences that bring forth one kind of behavior from the system rather than another. Sometimes those outside events can be controlled (as in reducing the pathogens in drinking water to keep down incidences of infectious disease). But sometimes they can't. And sometimes blaming or trying to control the outside influence blinds one to the easier task of increasing responsibility within the system.

"Intrinsic responsibility" means that the system is designed to send feedback about the consequences of decision making directly and quickly and compellingly to the decision makers. Because the pilot of a plane rides in the front of the plane, that pilot is intrinsically responsible. He or she will experience directly the consequences of his or her decisions.

Dartmouth College reduced intrinsic responsibility when it took thermostats out of individual offices and classrooms and put temperature-control decisions under the guidance of a central computer. That was done as an energy-saving measure. My observation from a low level in the hierarchy was that the main consequence was greater oscillations in room temperature. When my office got overheated, instead of turning down the thermostat, I had to call an office across campus, which got around to making corrections over a period of hours or days, and which often overcorrected, so One way of making that system more, rather than less, responsible might have been to let professors keep control of their own thermostats and charge them directly for the amount of energy they use, thereby privatizing a commons!

Designing a system for intrinsic responsibility could mean, for example, requiring all towns or companies that emit wastewater into a stream to place their intake pipes *downstream* from their outflow pipe. It could mean that neither insurance companies nor public funds should pay for medical costs resulting from smoking or from accidents in which a motorcycle rider didn't wear a helmet or a car rider didn't fasten the

seat belt. It could mean Congress would no longer be allowed to legislate rules from which it exempts itself. (There are many rules from which Congress has exempted itself, including affirmative action hiring requirements and the necessity of preparing environmental impact statements.) A great deal of responsibility was lost when rulers who declared war were no longer expected to lead the troops into battle. Warfare became even more irresponsible when it became possible to push a button and cause tremendous damage at such a distance that the person pushing the button never even sees the damage.

Garrett Hardin has suggested that people who want to prevent other people from having an abortion are not practicing intrinsic responsibility, unless they are personally willing to bring up the resulting child!²

These few examples are enough to get you thinking about how little our current culture has come to look for responsibility within the system that generates an action, and how poorly we design systems to experience the consequences of their actions.

Stay Humble— Stay a Learner

Systems thinking has taught me to trust my intuition more and my figuring- out rationality less, to lean on both as much as I can, but still to be prepared for surprises. Working with systems, on the computer, in nature, among people, in organizations, constantly reminds me of how incomplete my mental models are, how complex the world is, and how much I don't know.

The thing to do, when you don't know, is not to bluff and not to freeze, but to learn. The way you learn is by experiment—or, as Buckminster Fuller put it, by trial and error, error, error. In a world of complex systems, it is not appropriate to charge forward with rigid, undeviating directives. “Stay the course” is only a good idea if you're sure you're on course. Pretending you're in control even when you aren't is a recipe not only for mistakes, but for not learning from mistakes. What's appropriate when you're learning is small steps, constant monitoring, and a willingness to change course as you find out more about where it's leading.

That's hard. It means making mistakes and, worse, admitting them. It means what psychologist Don Michael calls "error-embracing." It takes a lot of courage to embrace your errors.

Neither we ourselves, nor our associates, nor the publics that need to be involved . . . can learn what is going on and might go on if we act as if we really had the facts, were really certain about all the issues, knew exactly what the outcomes should/ could be, and were really certain that we were attaining the most preferred outcomes. Moreover, when addressing complex social issues, acting as if we knew what we were doing simply decreases our credibility. . . . Distrust of institutions and authority figures is increasing. The very act of acknowledging uncertainty could help greatly to reverse this worsening trend.⁸

Error-embracing is the condition for learning. It means seeking and using—and sharing—information about what went wrong with what you expected or hoped would go right. Both error embracing and living with high levels of uncertainty emphasize our personal as well as societal vulnerability. Typically we hide our vulnerabilities from ourselves as well as from others. But . . . to be the kind of person who truly accepts his responsibility . . . requires knowledge of and access to self far beyond that possessed by most people in this society.⁹

Celebrate Complexity

Let's face it, the universe is messy. It is nonlinear, turbulent, and dynamic. It spends its time in transient behavior on its way to somewhere else, not in mathematically neat equilibria. It self-organizes and evolves. It creates diversity *and* uniformity. That's what makes the world interesting, that's what makes it beautiful, and that's what makes it work.

There's something within the human mind that is attracted to straight lines and not curves, to whole numbers and not fractions, to uniformity and not diversity, and to certainties and not mystery. But there is something else within us that has the opposite set of tendencies, since we ourselves evolved out of and are shaped by and structured as

complex feedback systems. Only a part of us, a part that has emerged recently, designs buildings as boxes with uncompromising straight lines and flat surfaces. Another part of us recognizes instinctively that nature designs in fractals, with intriguing detail on every scale from the microscopic to the macroscopic. That part of us makes Gothic cathedrals and Persian carpets, symphonies and novels, Mardi Gras costumes and artificial intelligence programs, all with embellishments almost as complex as the ones we find in the world around us.

We can, and some of us do, celebrate and encourage self-organization, disorder, variety, and diversity. Some of us even make a moral code of doing so, as Aldo Leopold did with his land ethic: “A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise.”¹⁰

Expand Time Horizons

One of the worst ideas humanity ever had was the interest rate, which led to the further ideas of payback periods and discount rates, all of which provide a rational, quantitative excuse for ignoring the long term.

The official time horizon of industrial society doesn't extend beyond what will happen after the next election or beyond the payback period of current investments. The time horizon of most families still extends farther than that—through the lifetimes of children or grandchildren. Many Native American cultures actively spoke of and considered in their decisions the effects on the seventh generation to come. The longer the operant time horizon, the better the chances for survival. As Kenneth Boulding wrote:

There is a great deal of historical evidence to suggest that a society which loses its identity with posterity and which loses its positive image of the future loses also its capacity to deal with present problems, and soon falls apart. . . . There has always been something rather refreshing in the view that we should live like the birds, and perhaps posterity is for the birds in more senses than one; so perhaps we should all . . . go out and pollute something cheerfully. As an old taker of thought for the morrow, however, I cannot quite accept this solution. . . .¹¹

In a strict systems sense, there is no long term, short-term distinction. Phenomena at different time-scales are nested within each other. Actions taken now have some immediate effects and some that radiate out for decades to come. We experience now the consequences of actions set in motion yesterday and decades ago and centuries ago. The couplings between very fast processes and very slow ones are sometimes strong, sometimes weak. When the slow ones dominate, nothing seems to be happening; when the fast ones take over, things happen with breathtaking speed. Systems are always coupling and uncoupling the large and the small, the fast and the slow.

When you're walking along a tricky, curving, unknown, surprising, obstacle-strewn path, you'd be a fool to keep your head down and look just at the next step in front of you. You'd be equally a fool just to peer far ahead and never notice what's immediately under your feet. You need to be watching both the short and the long term—the whole system.

Defy the Disciplines

In spite of what you majored in, or what the textbooks say, or what you think you're an expert at, follow a system wherever it leads. It will be sure to lead across traditional disciplinary lines. To understand that system, you will have to be able to learn from—while not being limited by—economists and chemists and psychologists and theologians. You will have to penetrate their jargons, integrate what they tell you, recognize what they can honestly see through their particular lenses, and discard the distortions that come from the narrowness and incompleteness of their lenses. They won't make it easy for you.

Seeing systems whole requires more than being “interdisciplinary,” if that word means, as it usually does, putting together people from different disciplines and letting them talk past each other. Interdisciplinary communication works only if there is a real problem to be solved, and if the representatives from the various disciplines are more committed to solving the problem than to being academically correct. They will have to go into learning mode. They will have to admit ignorance and be willing to be taught, by each other and by the system.

It can be done. It's very exciting when it happens.

Expand the Boundary of Caring

Living successfully in a world of complex systems means expanding not only time horizons and thought horizons; above all, it means expanding the horizons of caring. There are moral reasons for doing that, of course. And if moral arguments are not sufficient, then systems thinking provides the practical reasons to back up the moral ones. The real system is interconnected. No part of the human race is separate either from other human beings or from the global ecosystem. It will not be possible in this integrated world for your heart to succeed if your lungs fail, or for your company to succeed if your workers fail, or for the rich in Los Angeles to succeed if the poor in Los Angeles fail, or for Europe to succeed if Africa fails, or for the global economy to succeed if the global environment fails.

As with everything else about systems, most people already know about the interconnections that make moral and practical rules turn out to be the same rules. They just have to bring themselves to believe that which they know.

Don't Erode the Goal of Goodness

The most damaging example of the systems archetype called "drift to low performance" is the process by which modern industrial culture has eroded the goal of morality. The workings of the trap have been classic, and awful to behold.

Examples of bad human behavior are held up, magnified by the media, affirmed by the culture, as typical. This is just what you would expect. After all, we're only human. The far more numerous examples of human goodness are barely noticed. They are "not news." They are exceptions. Must have been a saint. Can't expect everyone to behave like that.

And so expectations are lowered. The gap between desired behavior and actual behavior narrows. Fewer actions are taken to affirm and instill ideals. The public discourse is full of cynicism. Public leaders are

visibly, unrepentantly amoral or immoral and are not held to account. Idealism is ridiculed. Statements of moral belief are suspect. It is much easier to talk about hate in public than to talk about love. The literary critic and naturalist Joseph Wood Krutch put it this way:

Thus though man has never before been so complacent about what he *has* , or so confident of his ability to *do* whatever he sets his mind upon, it is at the same time true that he never before accepted so low an estimate of what *he is* . That same scientific method which enabled him to create his wealth and to unleash the power he wields has, he believes, enabled biology and psychology to explain him away—or at least to explain away whatever used to seem unique or even in any way mysterious. . . . Truly he is, for all his wealth and power, poor in spirit. ¹²

We know what to do about drift to low performance. Don't weigh the bad news more heavily than the good. And keep standards absolute.

Systems thinking can only tell us to do that. It can't do it. We're back to the gap between understanding and implementation. Systems thinking by itself cannot bridge that gap, but it can lead us to the edge of what analysis can do and then point beyond—to what can and must be done by the human spirit.