

Thinking in Systems

A Primer

Donella H. Meadows

*Edited by Diana Wright,
Sustainability Institute*



The Basics

I have yet to see any problem, however complicated, which, when looked at in the right way, did not become still more complicated.

—POUL ANDERSON¹

More Than the Sum of Its Parts

A system isn't just any old collection of things. A **system*** is an interconnected set of elements that is coherently organized in a way that achieves something. If you look at that definition closely for a minute, you can see that a system must consist of three kinds of things: *elements*, *interconnections*, and a *function or purpose*.

For example, the elements of your digestive system include teeth, enzymes, stomach, and intestines. They are interrelated through the physical flow of food, and through an elegant set of regulating chemical signals. The function of this system is to break down food into its basic nutrients and to transfer those nutrients into the bloodstream (another system), while discarding unusable wastes.

A football team is a system with elements such as players, coach, field, and ball. Its interconnections are the rules of the game, the coach's strategy, the players' communications, and the laws of physics that govern the motions of ball and players. The purpose of the team is to win games, or have fun, or get exercise, or make millions of dollars, or all of the above.

A school is a system. So is a city, and a factory, and a corporation, and a national economy. An animal is a system. A tree is a system, and a forest is a larger system that encompasses subsystems of trees and animals. The earth

* Definitions of words in bold face can be found in the Glossary.

is a system. So is the solar system; so is a galaxy. Systems can be embedded in systems, which are embedded in yet other systems.

Is there anything that is not a system? Yes—a conglomeration without any particular interconnections or function. Sand scattered on a road by happenstance is not, itself, a system. You can add sand or take away sand and you still have just sand on the road. Arbitrarily add or take away football players, or pieces of your digestive system, and you quickly no longer have the same system.

When a living creature dies, it loses its “system-ness.” The multiple interrelations that held it together no longer function, and it dissipates, although its material remains part of a larger food-web system. Some people say that an old city neighborhood where people know each other and communicate regularly is a social system, and that a new apartment block full of strangers is not—not until new relationships arise and a system forms.

A system is more than the sum of its parts. It may exhibit adaptive, dynamic, goal-seeking, self-preserving, and sometimes evolutionary behavior.

You can see from these examples that there is an integrity or wholeness about a system and an active set of mechanisms to maintain that integrity. Systems can change, adapt, respond to events, seek goals, mend injuries, and attend to their own survival in lifelike ways, although they may contain or consist of nonliving things. Systems can be self-organizing, and often are self-repairing over at least some range of disruptions. They are resilient, and many of them are evolutionary. Out of one system other completely new, never-before-imagined systems can arise.

Look Beyond the Players to the Rules of the Game

You think that because you understand “one” that you must therefore understand “two” because one and one make two. But you forget that you must also understand “and.”

—Sufi teaching story

The elements of a system are often the easiest parts to notice, because many of them are visible, tangible things. The elements that make up a tree are roots, trunk, branches, and leaves. If you look more closely, you

THINK ABOUT THIS

How to know whether you are looking at a system or just a bunch of stuff:

- A) Can you identify parts? . . . and
- B) Do the parts affect each other? . . . and
- C) Do the parts together produce an effect that is different from the effect of each part on its own? . . . and perhaps
- D) Does the effect, the behavior over time, persist in a variety of circumstances?

see specialized cells: vessels carrying fluids up and down, chloroplasts, and so on. The system called a university is made up of buildings, students, professors, administrators, libraries, books, computers—and I could go on and say what all those things are made up of. Elements do not have to be physical things. Intangibles are also elements of a system. In a university, school pride and academic prowess are two intangibles that can be very important elements of the system. Once you start listing the elements of a system, there is almost no end to the process. You can divide elements into sub-elements and then sub-sub-elements. Pretty soon you lose sight of the system. As the saying goes, you can't see the forest for the trees.

Before going too far in that direction, it's a good idea to stop dissecting out elements and to start looking for the *interconnections*, the relationships that hold the elements together.

The interconnections in the tree system are the physical flows and chemical reactions that govern the tree's metabolic processes—the signals that allow one part to respond to what is happening in another part. For example, as the leaves lose water on a sunny day, a drop in pressure in the water-carrying vessels allows the roots to take in more water. Conversely, if the roots experience dry soil, the loss of water pressure signals the leaves to close their pores, so as not to lose even more precious water.

As the days get shorter in the temperate zones, a deciduous tree puts forth chemical messages that cause nutrients to migrate out of the leaves into the trunk and roots and that weaken the stems, allowing the leaves to

fall. There even seem to be messages that cause some trees to make repellent chemicals or harder cell walls if just one part of the plant is attacked by insects. No one understands all the relationships that allow a tree to do what it does. That lack of knowledge is not surprising. It's easier to learn about a system's elements than about its interconnections.

In the university system, interconnections include the standards for admission, the requirements for degrees, the examinations and grades, the budgets and money flows, the gossip, and most important, the communication of knowledge that is, presumably, the purpose of the whole system.

Many of the interconnections in systems operate through the flow of information. Information holds systems together and plays a great role in determining how they operate.

Some interconnections in systems are actual physical flows, such as the water in the tree's trunk or the students progressing through a university. Many interconnections are flows of information—signals that go to decision points or action points within a system. These kinds of interconnections are often harder to see, but the system reveals them to those who look. Students may use informal information about the probability of getting a good grade to decide what

courses to take. A consumer decides what to buy using information about his or her income, savings, credit rating, stock of goods at home, prices, and availability of goods for purchase. Governments need information about kinds and quantities of water pollution before they can create sensible regulations to reduce that pollution. (Note that information about the existence of a problem may be necessary but not sufficient to trigger action—information about resources, incentives, and consequences is necessary too.)

If information-based relationships are hard to see, *functions or purposes* are even harder. A system's function or purpose is not necessarily spoken, written, or expressed explicitly, except through the operation of the system. The best way to deduce the system's purpose is to watch for a while to see how the system behaves.

If a frog turns right and catches a fly, and then turns left and catches a fly, and then turns around backward and catches a fly, the purpose of the frog has to do not with turning left or right or backward but with catching flies. If a government proclaims its interest in protecting the environment but allocates little money or effort toward that goal, environmental protection is not, in fact, the government's purpose. Purposes are deduced from behavior, not from rhetoric or stated goals.