The Fundamentals of All Systems

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Book Chapter from book, *Systems Health: The Revolution in Medicine.*

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Since 1687, when Sir Isaac Newton first published his famous work, *Philosophiae Naturalis Principia*, modern science has been based on a simple and reasonably reliable assumption: If you want to understand anything, you need to take it apart. Many of us remember taking that first biology course in High School or Middle School. We began our study of trees by looking at leaves. This has been the accepted approach to all scientific and mechanical problems: Want to understand a watch, take it apart and examine the pieces. Want to figure out why an engine runs? Examine the pieces. Want to figure out how a human being functions? Look at the parts one at a time. In a Newtonian world, if you understand the parts, you can understand the whole. It's certainly easy to understand why this approach can be so appealing. Some things are simply too complex and huge to grasp any other way. It's complicated so we reduce it down to its parts. This approach is known as *reductionism*.

Reductionism has contributed greatly to human knowledge, but it has its limitations. It's easy to see these limitations in medicine when our bodies are approached as though they are broken up, as it were, into a group of organs and limbs, specialties and sub-specialties. A friend of mine recently visited her internist with a sinus infection. The internist sent her to an ENT (ear, nose throat specialist). The ENT examined her and made some recommendations for medication. My friend complained that a post-nasal drip making its way from the sinuses through her throat and into her lungs was giving her

a bad cough. The ENT said he was sorry but the cough involved the lungs, and he didn't treat anything below the neck.

As medical consumers, we know how exasperating this can be. We know that we can't always divide our bodies up into parts. We know that the foot bone is connected to the ankle bone and the ankle bone is connected to the shin bone and the shin bone is connected to the knee bone. Yet, if we have a foot pain and a knee pain, we have to visit at least two different doctors, who in all probability are not consulting with each other to determine if there is a connection. This is one of the problems associated with a reductionist approach to health.

21st Century science is beginning to realize that a reductionist approach gives only part of the entire picture—only a portion of the truth. When you connect a bunch of things, whether they are auto parts or human parts, something emerges that is greater and different than the sum of its parts. Take something as basic as a clock. If you take a clock apart, it's nothing more than a collection of odd assorted pieces. When it's put together in the right order, with the right connections, a clock assumes an almost magical function in terms of what it does and how a reliance on an accurate reading of time impacts your world. If this is true for a clock, imagine what happens when you are talking about a living organism, whether it is a tree, an animal, or a human being.

Holism is a direct pushback against a reductionism, particularly when it comes to health and wellness. Proponents of holism quote Aristotle, the first to clearly state, "The whole

is different from the sum of its parts." A holistic approach to health takes the human spirit as well as the mind-body connection into account. Men and women who want to take a more holistic approach to health frequently engage in practices like meditation and yoga; they are more careful about what they eat and look for ways to encourage spiritual as well as physical healing. Modern New Age movements have popularized holistic health practices. And to the shock and often annoyance of some of the medical establishment, these methods sometimes work.

Those who like to point out the failures of holistic health techniques tend to focus on the word "sometimes." This is a valid criticism. Practitioners of holistic healing can't always satisfactorily duplicate their results. They can't explain successes using the rigors of modern science, which requires standardization and reproducibility; when something works, they can't explain why. Instead of scientific explanations, what we see and hear is a fair amount of hand waving and conversations using buzz words like "meridians," "detox," and "energy." There is another larger issue: New Age healing extremists often go too far and throw science completely out the window. This approach encourages people to avoid modern medicine altogether and rely instead on peculiar diets, questionable herbal methods, and unreliable faith healers.

Here's the problem: When the complex system that is your body has a complex illness, a reductionist approach may not give you the healing you need; similarly a new holistic diet combined with meditation or any other alternative method will have its own limitations.

Complex problems require solutions that speak to the big picture, which is where a systems approach is most helpful. Systems Biology's "systems" approach to life helps us find the middle way between reductionism and holism. It helps us understand the whole as an interconnection of parts, not just the sum of is parts. It helps us recognize the values as well as the weaknesses in a Newtonian world model, which implies that there is always a certain linear cause and effect predictability.

Here's an example: In the Newtonian World Model, of linear action and reaction, when A gives rise to B which gives rise C, we can anticipate that the end result of A interacting with B will always give rise to C. But what happens when another factor (D) enters the picture? We can't always anticipate D, and we can't always predict exactly what will happen. In short, just because you have a gene for diabetes doesn't mean that you will eventually have diabetes. Just because you have a highly evolved "smart" or even "brilliant" gene doesn't mean that you're going to equal Einstein. Conversely, if you are limited in the "smart" gene category, this is no guarantee that you are doomed endlessly to repeat seventh grade. This means that we are not victims of our genes. Nature is not, by definition, destiny. Nature rather unfolds as it and its offspring interact with one another to redefine Nature itself!

Life Is An Interconnected System Of Systems

Many new biological experiments are demonstrating how, beyond our genes, life is dynamic and defines itself moment by moment as an interconnected system of systems,

where we need to see the whole **and** the parts. We are a system and the nature of our own holistic existence emerges from the interconnections and interactions of the parts. Our genes are one component or part in that cosmic drama. The other parts include our environment, lifestyle, and social interactions, all of which interact to define us at a particular point in time. Recent biological experiments are demonstrating this phenomenon of interconnection.

Consider the phenomenon of stress and one's response to stress. Some of us are more relaxed and easy-going, while others are very anxious and stressed; some of us can even become highly aggressive. In earlier work, a gene called the GR gene, which produces the GR protein, was found to be key controller of how we responded to stress. The more GR protein one had, the better one is able to detect cortisol, the molecule that drives our flight or fight response. Higher levels of GR protein indicate one can better modulate cortisol, and thereby be more relaxed. Lower levels of GR protein mean that one does not detect cortisol well, and would, therefore, end up being more anxious, stressed and aggressive.

In this single system paradigm, where we assume that the genetic system controls everything, those with the GR gene are destined to be relaxed, happy and less impacted by changing conditions and stressors, while those, with the no GR gene are destined to be anxious and stressed and more likely to have heart disease and diabetes.

However, an experiment at McGill University demonstrated the reality of the systems nature of life. In this experiment, a set of mice was inbred; all had the GR gene in place. It was expected that all these mice, whose internal system contained the GR gene, were destined to be relaxed, happy and stress free. However, this was not found to be the case.

Some mice were relaxed and others were anxious. What was going on?

Further observation showed that the mere existence of the GR gene did not mean that one would be relaxed. A systems approach is necessary to understand this phenomenon. Let us enter this mouse world, and define the following three systems:

(System I) Environment, in which the mice live.

(System II) Mother mice

(System III) Pups, or the baby mice.

These three systems interact to produce behavior of the individual systems and the whole. In this experiment, the Environment which included their surroundings e.g. the population of all other mice, the temperature, the weather, etc., itself a system affected the maternal behavior. If the Environment was relaxed, food was plenty, and there were minimal predators, the Mothers licked their pups more frequently during the first week after birth. However, if the Environment was harsh, food was scarce, or there were predators, the Mothers rarely licked their pups during the first week of birth.

Clearly the Environment, System I, affected the Mothers' System II, behavior. System I and System II were interconnected.

The Pups, System III, which were licked during the first week after birth, grew up to exhibit the GR gene; they were docile, relaxed, and generally less stressed. The Pups, which were not licked during the same period, grew up not exhibiting the GR gene; they were more anxious, stressed and aggressive. System II, the Mothers, clearly affected System III, the Pups behavior. System II and System III were interconnected.

When one steps back and looks at the whole System I, System II and System III were all interconnected, with the genetic component being only one factor. What was the underlying systems biology of all of this?

The Environment, System I, which itself is affected by the population of System II (Mothers) and System III (Pups), sets a switch, which is dynamic, that results in the Mothers licking or non-licking behavior. It turns out that when any Pup is born, chemicals, known as methyl groups, surround the GR gene and keep it turned off. When a Mother licks a Pup, a series of chemical reactions take place in the Pup's brain. These chemical reactions activate molecular pathways that extend across the cytoplasm and nucleus to deactivate the methyl groups that were surrounding the GR gene. The molecular pathways, literally resulting from the licking action, **turn on** the GR gene! This turning on of the GR gene now results in the Pups exhibiting docile behavior.

However, if minimal licking takes place, molecular pathways are not activated and the GR gene remains inactive.

There are now many other experiments that are showing over and over again how overall system behavior is not just a function of one component but the interaction of multiple systems.

From the many years that I've studied modern, conventional systems of science and engineering, as well as traditional and ancient systems of medicine, I wish I could tell you that I've discovered some quick fix that would allow you miraculously to achieve real health. I wish I knew some guaranteed cure-alls like "drink nothing but carrot juice for a month" or slather your body in some esoteric herbal tincture. But I don't. I know that real health is about connection. It's about understanding how to navigate the complex system of your body within the complex system of your environment. What my studies have taught me is that be it modern or ancient science, the real solutions that make any sense come from a systems approach to life. It is therefore important that we now probe deeper into systems, their nature, what they are, and how they work, so we can truly understand how to manage life; otherwise, our understanding of life will either be just holistic or just reductionist. What we want is a systems approach to life that captures reality as it is.

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What Is A System?

Let's first begin by understanding what a System is. When terms like mechanical systems, electrical systems, and systems engineers get thrown around, it can sound daunting. In reality, systems are fairly straightforward. Here's what you need to know:

Everything is a system

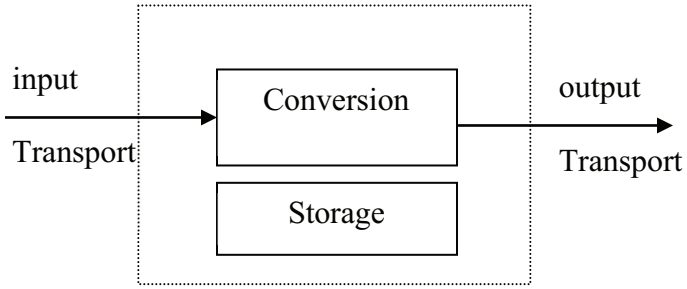
The lovely yellow daffodil pushing through the earth in early spring is a system. So is the airplane flying overhead. Your tea kettle is a system. You are a system. So is everything inside you. Your cardiovascular system, for example, is a part of the larger system that is you. There are simple *open systems* and more complex *feedback systems*.

All open systems have three basic components.

- Transport (or Input & Output)
- Conversion (or Processing)
- Storage (or Structure)

Consider the simple tea kettle. It is an open system. When you turn on the stove, heat from the flame (the input) is *transported* into the tea kettle to produce hot water (the output. Cold water in the tea kettle is *converted* to hot water. The tea kettle serves as *storage* for the water. This is an example of your basic open system: one turns on the flame and a few minutes later the water gets hot.

Illustration of an Open System.

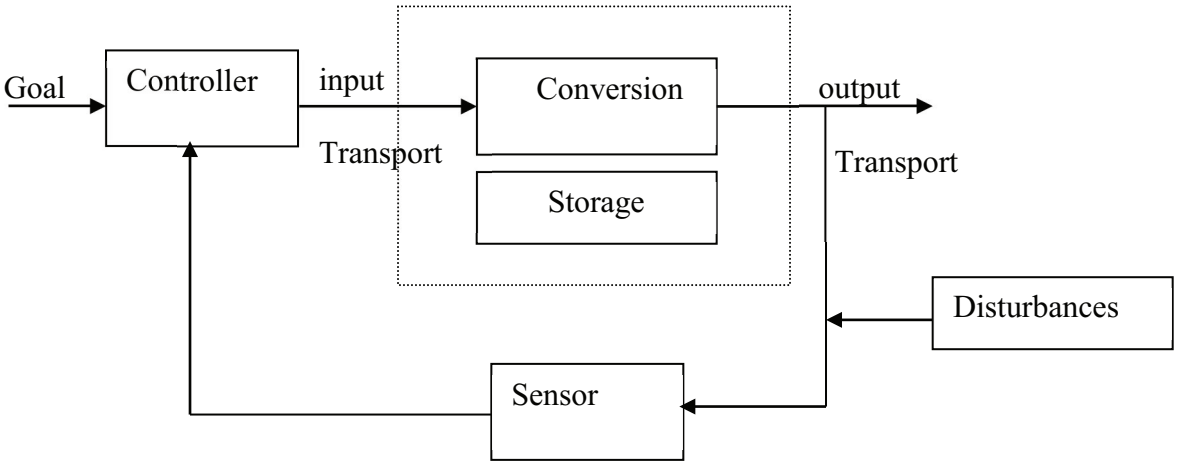


The more interesting, and truly *intelligent* systems, in life, are feedback systems. Feedback systems enable "intelligence" to manifest. A feedback system has four additional components beyond the open system. These components are:

- Goal
- Controller
- Sensor
- Disturbances

The reason a feedback system is called a "feedback" system is because a feedback system begins with a purpose to achieve a particular *goal*. In a feedback system, the output from the open system is literally "fed back" (looped back as in the diagram below) to a *sensor* which "senses" the value of the output. This value is fed back to a *controller*. The controller assesses the original *goal* with the current output, and then calculates a new input. This new input is used to generate a new output, which is then fedback, until the desired goal is achieved while being aware of any *disturbances* from changes in the environment. As we can see, the open system is a subset of the feedback system.

Illustration of a Feedback System.



An airplane provides a good example of a feedback system.

If you were interested in understanding systems at MIT, your advisor would highly recommend that you take a class called *Control Systems and Feedback*. In this course, you would learn the basics of what has been discussed above, and towards the end of the semester, you would be given the classic airplane example as a model system to understand highly complex systems, including the human body.

In this chapter, I've chosen to share this airplane example, since it will serve a wonderful purpose of explaining to you how all complex intelligent systems operate. Moreover, we will refer back to this example in subsequent chapters to demonstrate how the Siddhars' model of life itself was a complex feedback system, though they used a very different terminology. Furthermore, from a practical standpoint, this example will enable you understand how to receive feedback from your environment and body to navigate yourself to your particular goals for health and well-being, no different than how a pilot navigates a plane across many disturbances to a desired destination.

The Airiplane: A Classic Intelligent Feedback System

During flight, an airplane has various goals. One goal is to maintain a certain speed, say 600 miles per hour. The controller, in this case, is the pilot. Feedback is provided from the sensors, which are instruments that provide the actual speed (the output) of the plane. The controller, the pilot, assesses the difference between the desired goal of 600 miles per hour, and the actual speed, and will decide a new input (an increase or decrease in the amount of stored fuel to be converted by the engines to create more thrust). If the current speed is only 500 miles per hour, for example, the controller will send a new input to deliver more fuel to the engines. The iutput, after the engines convert the fuel, may be an increase in the speed to 590 miles per hour, for instance. Once again, the controller, the pilot, will send more fuel as an input, until the speed stabilizes at 600 miles per hour. Sometimes, the controller may overshoot and send too much input, and will have to reduce the fuel. This feedback process is iterative, and the controller is constantly observing the output from the feedback process relative to the goal, and makes constant adjustments to the input to achieve the desired goal.

Sometimes disturbances from the environment (or another system) will occur. These disturbances need to be observed and also fed back to the Controller. Consider the simple case of a disturbance, such as a headwind of 100 miles per hour. Clearly, in this case the weather is another system that provides such a wind disturbance. In this case, that disturbance will need to be accounted for in determining the input to the engines. The

pilot will have to increase the input accordingly and proportionately to achieve the goal of 600 miles per hour.

In summary, for the airplane example:

- Goal: maintain speed of 600 m.p.h.
- Controller: the pilot
- Input: fuel
- Output: actual speed
- Sensor: the airplane's "speedometer", which measures air speed
- Conversion: The airplane's engines, which convert fuel to thrust
- Storage: the fuel tanks
- Disturbances: wind

You Are A Feedback System

You, like the airplane, are also a complex feedback system that contains a large group of other systems. You are the controller of your system. Within you are systems, which also have multiple control mechanisms to keep you moving forward. For example, you have twelve organs. Each is a system of sytems. Each organ is composed of different tissue systems. Each tissue is composed of different cells. These systems are interconnected within you and, in turn, within the external systems of your environment.

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How Your System Works

Goal: We all have of large number of short-term and long-term goals, ranging from catching the bus, finding a cab or maneuvering the car out of traffic on a crowded highway, to losing weight, getting more exercise, giving up alcohol or sugar, finding a better job, improving a current relationship, or finding new love.

Controller: That's you! Like the pilot on the plane, you have to stay alert to observe what is going on around you. You observe your outputs relative to your goals, and make adjustments by changing inputs (what foods you eat, how much exercise you get, what supplements you take, etc.). Your aim is achieve your goals. Based on changing conditions and disturbances, you need to adjust your inputs. Do you feel upset? Would listening to music help? You have been diagnosed with hypertension. Do you need medication? You have an upset tummy. Should you change your diet? You're flying too high; you're flying too low; you're flying in the wrong direction! You need to make some fast adjustments and start fiddling with your controls! This "fiddling" and adjustment is what intelligent systems do to achieve their goal. Intelligent systems, such as yourself, use your internal "sensors" to sense your current outputs (or your current state). Then, based on your intended goals, and how far you are away from them, based on assessing your current state, you make adjustments moment-by-moment, day-by-day or week-by-week, for example, until your goals are achieved.

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Input: The inputs to your system are many: oxygen, water, food, vitamins, medications, herbs, sleep, exercise, environmental toxins, stimulation from friends, social connections, spiritual connections, emotions, music, television, books, classes, the internet, etc.

Output: The outputs of your system include your current weight, cholesterol levels, CO2, excretions, toxins, thoughts, creating things, emotions, laughter, tears, work, etc.

Conversion: Your body is constantly converting inputs into outputs. Your digestive system, for example, converts food to produce nourishment for the cells in your body. Your lungs convert the air you breathe to provide oxygen for your blood. Your brain converts sounds, images, smells, etc. to make decisions.

Storage: Not everything you take in is immediately excreted. The various systems in your body have the capacity to store much of your input. Some toxins, for example, are stored far longer than we would like. Your fat cells provide storage for excess glucose in the form of glycogen, and let's not forget your brain, which has the capacity to store large amounts of information. Your skeletal structure is used to "store" and provide structure for your body.

Sensors: Each moment your five senses (and potentially six) receive visual, auditory, tactile (touch), olfactory (smell), gustorial (taste) feedback, and provide these sensations to you, the controller, to make decisions. However, at the organ, tissue and molecular levels, a myriad of systems of systems is used to provide many sensory mechanisms to

assess your body's current outputs. Your hormones serve as systemic sensory and signalling mechanism across the internal systems of your body providing feedback across organs. Cytokines, chemical signals, provide feedback at the cellular level. These sensory systems are key to enabling your controller to achieve the goals you desire.

Disturbances: Who can count the many things that take place in the course of everyday life, altering your system? You ate too much sugar yesterday or drank too much coffee or wine. Today you need to do something to balance it out. Your best friend needs help moving, which means you have to change your plans and goals for the day. You have a fever and a cough. Do you have a simple cold or something more serious? Do you need to see a doctor? You had an argument with a significant other. Both your head and your heart are pounding; you can't concentrate, and you head straight for the M&Ms.

Life is dynamic and changing. Nothing is constant. You are constantly moving. Remember that Woody Allen line about relationships—the one where he turns to his girlfriend, played by Diane Keaton and says, "A relationship….is like a shark…. It has to constantly move forward or it dies….I think what we got on our hands is a dead shark."

Like the shark, we all have to keep moving, adjusting and adapting, if we want to survive.

Systems that function successfully know how to detect changes and make adjustments that will help propel them towards the final goal. When it comes to health and wellness, this is an essential truth that must be kept in mind. This reality is why most fad diets can't

work long term. They are not based on the an intelligent systems feedback approach of input, output, sensors, conversion, storage, disturbances, and a controller that makes adjustments. They don't take into account system elements like disturbances and changing conditions. Raw food diets, blood type diets, and the Atkins diets are neither flexible nor adaptable. It makes no sense to tell a person who is living in an environment where parasites are an issue, to eat raw foods. People who have religious, ethical, or dietary reasons for wanting to avoid meat can't follow a primarily meat based Atkins program. To force people with certain blood types to follow specific dietary programs, paying little attention to what they enjoy eating or changes in their environment, such as weather and geographical conditions, is also inflexible.

Diet is not the only element that needs adjusting. Exercise programs also need to be streamlined to fit specific human systems. Yoga and meditation are wonderful, but some people need to avoid these practices unless adjustments are made to fit their systems. People with certain constitutions should avoid certain yoga postures; some meditation techniques may cause depression for some people. Similarly, some people will benefit from heavy resistance training, while others may do better with tai chi. When we take a systems approach, we acknowledge that our favorite form of summer exercise may not be appropriate for winter or vice versa. People with asthma for example may have to avoid walking outdoors during some weeks or even seasons of the year.

Integrative medicine and holistic approaches are certainly headed in the right direction. But what is needed is a systems medicine that combines the best elements of traditional

medicine and modern medicine at the energetic and molecular levels. Such a medicine will use rational thinking and scientific rigor to incorporate the knowledge acquired by the East from thousands of years of patient observation. Such an approach to health will enable us to develop, understand, and confidently understand and accept new modes of healing, which would not be possible by East or West alone.

This new approach is **Systems Health**. Systems Health will:

1. Recognize your unique nature along with your body's *natural system state*
2. Give you flexibility to adjust inputs depending upon likes, dislikes, goals, and changing conditions.

The approach I'm describing will provide a true convergence of the best of Eastern and Western approaches to health and wellness. I believe, it will also give us a more expansive outlook into our study of life.