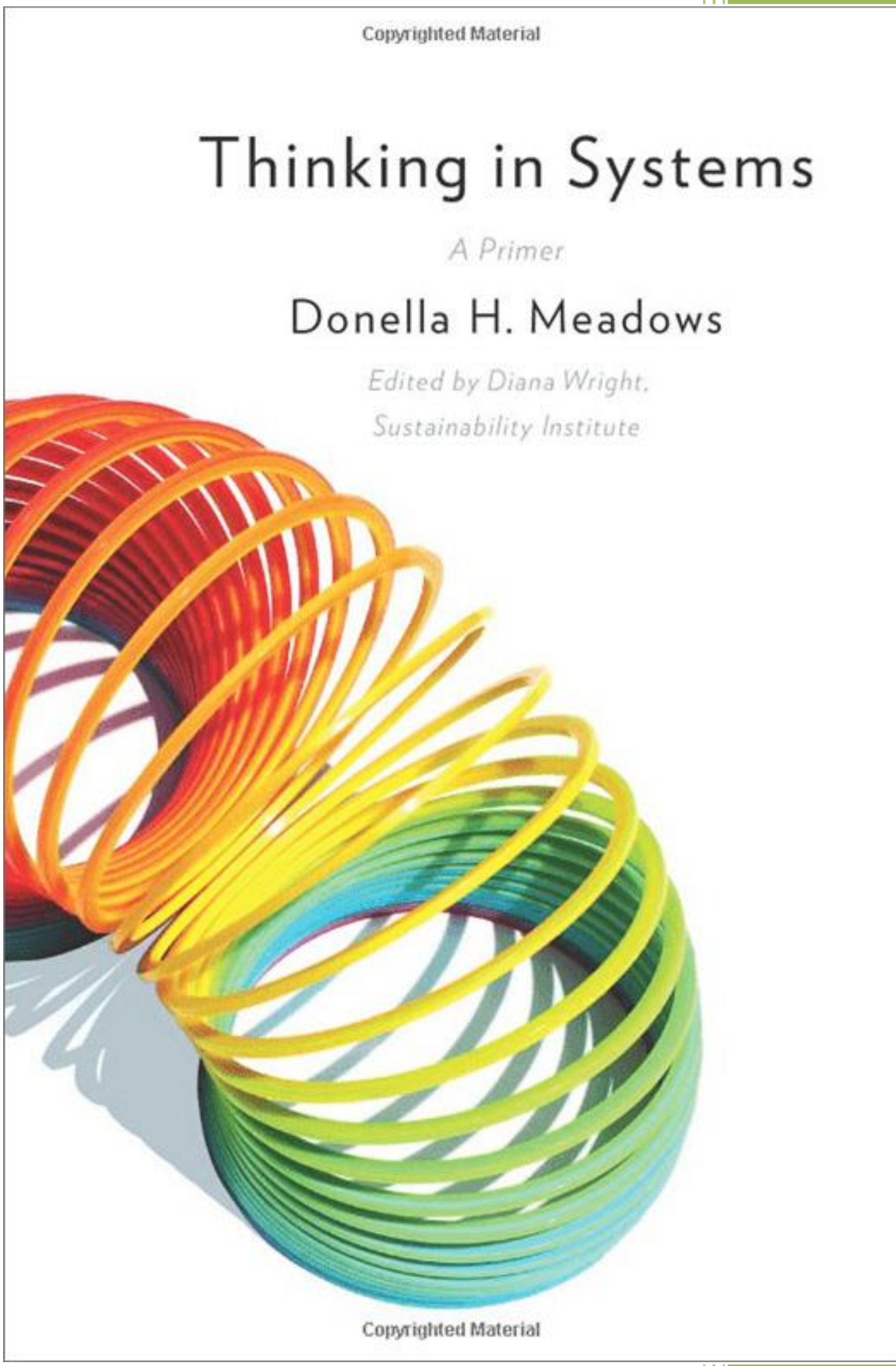

Summary by Kerem Tosun

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From the introduction:

Systems thinking is a way of thinking that considers relationships between structures of so-called "systems" and the behaviors they display. A key concept of systems thinking is that systems cause their own behavior, and the reaction of every system to external stimuli can differ. *Thinking in Systems: A Primer* will explore the various intricacies of systems thinking.

Part 1: System Structure and Behavior

Chapter 1: The Basics

"A system is an interconnected set of elements that is coherently organized in a way that achieves something" (Meadows, 11).

Note on language:

- "Function" is (generally) used on non-human systems.
- Purpose" is (generally) used on human systems.

Systems are composed of three essential parts: the elements, the interconnections between those elements, and the function or purpose of the system itself. Take the digestive system, for example. The elements include the stomach, liver, intestines, and enzymes. All of these elements are related to the flow of the food through them as well as the chemical signals being sent out. The human digestive system's purpose is to provide our bodies with the essential nutrients found in the foods we eat. It is essential to acknowledge the multiplicity of systems, that being, systems within other systems.

Important Quote:
"To ask whether elements, interconnections, or purposes are most important in a system is to ask an unsystemic question. All are essential. All interact. All have their roles. But the least obvious part of the system, its function or purpose, is often the most crucial determinant of the behavior. Interconnections are also critically important. Changing relationships usually changes systems behavior. The elements, the part of the system we are most likely to notice, are often (not always) least important in defining the unique characteristics o the system–*unless changing an element also results in changing relationships or purpose*" (17).

Systems thinkers approach real-world problems through this lens. Rather than trying to fix a problem by trying to solve just one part (element), systems thinkers look at the entire system to identify the root of the problem. This is the essence of systems thinking.

Understanding Systems Behavior over Time:

Stocks are the foundation of every single system. System stocks are the elements of the system. System Stocks can be: "a store, a quantity, an accumulation of material or information that has built up over time." The stock of a system constantly changes based on the inflow(s) and outflow(s). Think of the water in a bathtub. You can raise the water level by turning on the faucet or lower the water level by opening the drain (see Figures 5-7 on pg. 19-21). Dynamic equilibrium is achieved when inflow equals outflow, and the stock does not have a net change.

Important Quote:

"A stock takes time to change, because flows take time to flow" (23).

Change happens gradually, and any meaningful change will happen over a long period of time.

How Systems Run Themselves—Feedback

Systems thrive through consistent behavior through mechanisms called "feedback loops."

Types of feedback loops:

- Stabilizing Loops—Balancing Feedback (pg. 27)
    - Balancing Feedback Loops try to keep stock levels within a specific range.
    - They are goal-seeking or stability-seeking; they aim to reach a goal or stay within the range of that goal.
- Runaway Loops—Reinforcing Feedback (pg. 30)
    - Grows exponentially in either direction.
    - Think of interest in a bank account or the growth of a population.
    - In cases where runaway loops are not behaving as intended, stock can be added or taken away from the system to kick-start the snowballing nature of its growth in the right direction.

Chapter 2: A Brief Visit to the Systems Zoo

Within feedback loops, there is always a delay between the feedback delivered and the action taken by the system (remember: it takes time to change the stock).

Important Quote:

"The information delivered by a feedback loop—even nonphysical feedback–can only affect future behavior" (39).

Inherently, any input or adjustment to a system with a feedback loop will affect its future behavior, reiterating the concept that "stocks take time to change." It is important to note that delays in responding must be taken into account. These systems are reactionary, and sometimes when reactions are too slow, systems cannot sustain themselves.

Questions for evaluating the value of a model (pg. 47)

Systems can have multiple stocks, and each stock can have multiple balancing loops that can often compete. For a single stock with multiple loops, the various compete for dominance. The dominant loop is the one that ends up having the most significant effect on the behavior of the system. For example, population growth consists of two feedback loops: births and deaths. If births outweigh deaths, the population grows. If deaths outweigh births, the population decreases. If they equal each other, the population is at a dynamic equilibrium and remains constant.

These concepts become much more intricate when more stocks are introduced into the system. It is vital to consider renewable and non-renewable stocks. A prime example of this is energy. Non-renewable resources are stock limited, meaning the entirety of the stock is available, but there is only a set amount that humans can use. For renewable resources, there is no limit on how much humans can use them, but their rate of regeneration limits them. For our intents and purposes, fossil fuels are considered non-renewable resources, as their regeneration rate is very slow.

Part 2: Systems and Us

Chapter 3: Why Systems Work so Well

- Key Question: Why do systems work so well? (or why not?)
- Answer:
    1) Resilience
    2) Self-Organization
    3) Hierarchy

Resilience (pg. 76-78):

- Resilience measures a system's ability to shift and persist in variable conditions.
    - In simpler terms, resilience is how well a system can adapt to environmental changes.
- Systems can be resilient by employing various feedback loops to keep stock at acceptable levels or even by creating more complex systems (explored further later).

Important note:

- Resilience does not mean that a system does not change over time
    - Having the system change can be the normal condition that the system's resilience seeks.
    - Static stability is elementary, whereas resilience can be much harder to detect.
- Awareness of resiliency is beneficial to maintaining a system's resilience.
- In the absence of resilience, systems often fail.
    - For example, when the resilience of the cell duplication cycle fails, cancer cells can form.

Self-Organization (pg. 79-81):

- A system's potential to complexify itself is called self-organization.
- Systems can learn and evolve and complexify themselves to maintain resilience and survive.
- Self-organization most often thrives in disorder, and people often sacrifice it for the short-term comfort of productivity and stability.

- Self-organization can seem scary because it often challenges existing systems and power structures. Therefore, the change in self-organization, naturally, threatens many people.
- However, self-organization is crucial to the survival of a system.

- Even with straightforward rules of organization applied, self-organizational processes can create incredibly intricate systems.
    - For example, all life is based on DNA, RNA, and protein, but that life can range from the smallest single-celled organisms to blue whales.

Hierarchy (pg. 82-85):

- Hierarchy is the organization of the various structures and systems created by self-organization.
    - Think of ranking the systems within systems: cell, organ, organ system, creature, etc.
- Hierarchies provide stability and resilience and reduce the clutter of information communicated between parts of a system.

Important Quote:

"In hierarchical systems relationships within each subsystem are denser and stronger than relationships between subsystems" (83).

- This ensures that a system isn't overwhelmed by the sheer amount of information it stores and that each subsystem can have its own level of resilience.

Important Quote:
"Many systems are not meeting our goals because of malfunctioning hierarchies" (84).

- This quote introduced the topic of suboptimization, where a subsystem prioritizes its own self-interests over the system's interest as a whole.
- For any complex system to function, the system and its subsystems and the hierarchies within must be balanced to maintain resiliency, self-organization, and stability.

Chapter 4: Why Systems Surprise Us

- Key Question: Why do systems surprise us?
- Answer:
    1) Beguiling Events
    2) Linear minds in a Nonlinear World
    3) Nonexistent Boundaries
    4) Layers of Limits
    5) Ubiquitous Delays
    6) Bounded Rationality

Beguiling Events (pg. 87-91)

- Humans often see the world as a series of events, one by one following the other.
- Systems follow patterns and form behaviors rather than a series of events.
- One should focus on the reason behind something happening to identify that pattern/ behavior to understand the system (what is happening and why).

Linear minds in a Nonlinear World (pg. 91-94)

- Humans often like to linearize relationships, as it is much easier to understand linear relationships.
- However, most real-world processes and systems are nonlinear; therefore, their behavior can surprise our minds, which are used to linearity.
- Nonlinearities because they "change the relative strengths of feedback loops" (92).
    - They can suddenly cause a shift in the dominance or behavior of the feedback loop in play.

Nonexistent Boundaries (pg. 95-99)

- There is no single boundary for a system.
- It is possible to draw one single boundary that encompasses every system in the universe.

Important Quote:

"There are no separate systems. The world is a continuum. Where to draw a boundary around a system depends on the purpose of the discussion" (97).

- Systems thinkers imagine and invent boundaries that suit the needs of the question they are asking.
- We become surprised when we draw narrow boundaries, as the system will (frequently) produce a result we did not anticipate.
- Conversely, when boundaries are drawn too large, the system analysis becomes too complex and inefficient.

Important Quote:

"Boundaries are of our own making, and they can and should be considered for each new discussion, problem, or purpose."

Layers of Limits (pg. 100-103)

- We don't like to think of limits.
- Systems surprise us because we like to think that one thing leads to another, whereas in systems, one thing can lead to many outcomes happening all at once.
- Justus von Liebig's "law of the minimum" describes how systems are limited.
    - If you are missing nitrogen, no amount of phosphorus fertilizer you use will increase plant growth because what you need is nitrogen, not phosphorus.

Important Quotes:

- "At any given time, the input that is most important to a system is the one that is most limiting" (101).
- "Ultimately, the choice is not to grow forever but to decide what limits to live in" (102).

Key Concepts:

- As systems evolve and develop, more limits are introduced, and the limiting factors also change.
- There will always be limits to growth.

Ubiquitous Delays (pg. 103-105)

- All systems have delays in their delivery of information from feedback loops.
- Time and time again, we are surprised by the length and variability of these delays.
- When there are long delays, foresight into the future behavior of a system is essential.

Bounded Rationality (pg. 105-110)

- People often make rational decisions for short-term benefits only to cause future problems.
    - Such as people traveling to Bali and then complaining about all the tourists, etc.
- Bounded rationality describes rational decisions that are made upon imperfect information.
- When we make decisions based on bounded rationality, and the outcome isn't what we expected, we are surprised
    - it is impossible to have perfect information, as that would require knowledge of future events, which is impossible.

Chapter 5: System Traps . . . and Opportunities

- Systems that yield problematic behavior(s) are called archetypes

Key Concept/ Important Quote:

"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 margin—these standard responses will not fix structural problems. That is why I call these archetypes 'traps' " (112).

The Archetypes:

1. Policy Resistance—Fixes that Fail
2. The Tragedy of the Commons
3. Drift to Low Performance
4. Escalation
5. Success to the Successful—Competitive Exclusion
6. Shifting the Burden to the Intervenor—Addiction
7. Rule Beating
8. Seeking The Wrong Goal

Policy Resistance—Fixes that Fail (pg. 112-116)

Important Quotes:

- "Behavior patterns that persist over long periods of time are undesirable" (112)
- "Policy resistance comes from the bound rationality of the actors in a system" (113).
- The countermoves of the various actors in a system produce a standoff, and the stock remains unchanged.
    - The more effort one actor puts in, the more the other actors put in to counter that, and as all the actors escalate, the stock practically stays the same.
- A way to deal with policy resistance is to attempt to overpower the other actors, but this rarely works.

- Calming down and taking a step back to assess the root of the problem you are trying to fix is often helpful.
- Harmonizing goals is not always possible between the various actors in a system. However, it is a notable option, but it can only be found by letting go of other goals and considering the long-term benefits that option would yield to the system.

The Tragedy of the Commons (pg. 116-121)

- This archetype is very easy to understand and is also caused by the bounded rationality of the actors involved.
- Basically, in a commonplace, the benefits one gain from adding something to the commonplace (for example, more animals to the shared herding ground) trump the immediate losses.
- However, no one benefits when every actor does this because the commonplace deteriorates.
- This can also be seen with the immediate advantage of using fossil fuels with the consequence of an increased greenhouse gas effect and the depletion of resources.
- It is the overexploitation of renewable resources to the point where the resource cannot renew itself to keep up.
- There are three ways to avoid this tragedy:

    1. Educate and encourage the actors not to harm the commons for a better long-term effect.
    2. Privatize the commons so that the benefits and consequences equal each other for individual actors and the actions of one actor do not affect all the actors.
    3. Regulate the commons by placing common limits (think of traffic laws that all drivers obey so that roads remain safe).

Drift to Low Performance (pg. 121-123)

- In this archetype, the negative results of the past dominate over the positive ones the system recorded.
- Drift to low performance happens gradually through the fixation on the past negative results.
- There are two ways to fix this archetype.

    1. Set absolute standards of performance that ignore performance
    2. Make goals sensitive only to the positive results recorded (ignore the negatives and use the positives to create a drift to high performance)

Escalation (pg. 124-126)

- Escalation is a double-edged sword:
    - It is good if applied towards a positive goal, like a cure for cancer.
    - It is bad if applied toward escalating violence, hostility, conflict, etc.
- Escalation is a reinforcing feedback loop: it is an exponential process.
- The best way out of an escalating process is to avoid getting in it in the first place.
- Another way is to disarm mutually, step back, and de-escalate from then on.

Success to the Successful—Competitive Exclusion (pg. 126-130)

- This system is set up so that winners (as a part of their reward) gain advantages to help them continue winning, thereby making the losers more likely to keep losing.
- An example of this is the poverty cycle. In most all societies, poorer children receive a worse education than wealthier children and thereby qualify for less ser paying jobs, continuing a cycle of poverty.
- The way out of this feedback loop is to diversify the competition by giving losers more chances to become winners.
    - Level the playing field by equity, not equality (increase advantages for the weak).

Shifting the Burden to the Intervenor—Addiction (pg. 131-135)

- Addiction encompasses far more than being addicted to a drug. Addiction can present itself in and in much larger systems in forms like over-dependence/ reliance on goods.

Important Quote:

“Addiction is finding a quick and dirty solution to the symptom of the problem, which prevents one from the harden and long-term task of solving the real problem” (133).

- Breaking the cycle of addiction is painful:
    - It can manifest in physical pain like withdrawal or economic pain for reducing oil consumption by a government.
- The best way out of addiction is to avoid the trap altogether.

- However, suppose one is already in an addictive process. In that case, the best solution is to get out as quickly as possible by shifting focus from the short-term relief provided to the long-term restructuring of the system.

Rule Beating (pg. 136-137)

- Rule beating describes the evasive action(s) of getting around a system's rules.
- Rule beating leads to distortion and neutral behaviors in the system.
  - When it gets out of hand, it can cause "destructive behavior."
- The way out of rule beating is to design new rules to fit the goal of a system better so that rule-beating is discouraged.
  - This is often achieved by adding more creative space to the system.

Seeking The Wrong Goal (pg. 138-141)

- If a goal is defined poorly, people can misinterpret the actual goal of a system and seek the wrong goal, producing results that negatively affect the overall welfare of a system.
- It is crucial to precisely define the goals of a system so that they yield positive results.
- It is crucial not to associate the effort put into a system with the results yielded, or else the system might work to produce effort and not the desired results.

Part 3: Creating Change—in Systems and in Our Philosophy

Chapter 6: Leverage Points—Places to Intervene in a System

- Leverage Points are places in a system where even minimal changes significantly impact system behavior

Important Quote:

"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" (145).

- Although many systems thinkers can intuitively identify leverage points, they often spark change in the wrong direction.
- Systems can become insanely complex, and so can their behaviors. That's why leverage is mostly not intuitive ad why it is wanton to generalize systems and their behaviors when dealing with leverage points.
- Intervening in systems can be tricky, but there is a list of places to intervene in a system (ranked from least to most potent in terms of intervention):

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

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

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

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

8) Balancing Feedback Loops—The strength of feedback relative to the impacts they are trying to correct

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

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

5) Rules—Incentives, punishments, constraints

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

3) Goals—The purpose or function of the system

2) Paradigms—The mindset out of which the system—its goals, structure, rules, delays, parameters—arises

1) Transcending Paradigms

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

- The numbers: the size of flow and stock are not very powerful leverage points because they rarely (if ever) cause change.

Important Quote:

"People care deeply about such variables as taxes ad the minimum wage… but changing these variables rarely changes the behavior of the national economy's system" (148).

- Changing parameters often have individuals on a short-term basis, but seldom the system's behavior as a whole (which is causing the problem in the first place).

Buffers—The sizes of stabilizing stocks relative to their flows

- Buffers offer stability to systems.
- However, if a buffer is too big, it can create an inflexible system (which is undesirable).
- Also, it is extremely difficult (or sometimes impossible) to change buffers, rendering them weak leverage points.

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

Important Quote:

"The only way to fix a system that is laid out poorly is to rebuild it, if you can" (150).

- Rebuilding is possible. However, it is often slow and expensive. Therefore (in most cases), it is not a particularly strong leverage point.

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

Important Quote:

"A delay in a feedback process is critical *relative to the rates of change in the stock that the feedback loop is trying to control*" (152).

- Delay length is powerful when it can be changed, but delays are frequently innate and cannot be changed.

Balancing Feedback Loops—The strength of feedback relative to the impacts they are trying to correct

- Balancing feedback loops are the star of information and control parts of systems which are more important leverage points than any physical part of the system.

Important Quote:

"The strength of balancing feedback loops are important relative to the impact it is designed to correct" (154).

- The real leverage that balancing feedback loops provide is their self-correcting ability that keeps a system working properly.
  - An important and often overlooked contributor to this stability is the emergency response mechanisms in the case of massive systemwide malfunctions.

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

Important Quote/ Distinction:

"A balancing feedback loop is self-correcting; a reinforcing feedback loop is self-reinforcing" (155).

- Reinforcing loops cause growth (climaxing in explosion) and erosion (climaxing in collapse).
  - As a result of their catastrophic projections (in either direction), they often require balancing loops to regulate their growth.
- Population and economic growth rates are essential points because slowing their processes gives the plethora of balancing loops and systems affected by them the time they need to function correctly.

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

- Missing information flows are one of the most prevalent causes of malfunction within systems.
- Adding information to a system is much easier and cheaper than correcting the physical parts of a system and is, therefore, more valuable.
- However, it is paramount that the correct information is restored to the correct place, or it does not benefit the system.

Rules—Incentives, punishments, constraints

Important quote:

"The rules of the system define its scope, its boundaries, its degrees of freedom" (158).

- Rules are made to be followed and have accompanying consequences so that they are followed, but rules can be and are often broken.
  - Absolute rules (like the laws of motion) are an expedition and cannot be broken.
- Rules are very high leverage points. The power to change the rules grants one immense power over the system.

Important Quote:

"If you want to understand the deepest malfunction of systems, pay attention to the rules and to who has power over them" (158).

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

- Self-Organization (from Ch. 4) is changing any of the previously mentioned aspects of a system.
- Self-organization is the most potent form of self-resiliency in systems.

Important Quote:

"A system that can evolve can survive almost any change by changing itself (159).

- The key leverage point for self-organization (a system's ability to evolve) comes from increasing chaos, freedom, experimentation, variability, and diversity.
    - However, humans (flawed as they are) like to play it safe and lack the trust and bravery to trust in systems.

Goals—The purpose or function of the system

- Goals are tricky to identify and understand (especially as systems become large and more complex). However, they outclass self-organization because every previous leverage point will conform itself and its behavior to whatever the goal demands.
- In most cases, switching out the actors in a system won't affect systems behaviors unless that actor is at the top with the power to change the goal of a system.
    - Nazi Germany (under the leadership of Adolf Hitler) is a prime example of how an entire system will change when a goal changes and how much power those few people (who can change the goal of a system) have.

Paradigms—The mindset out of which the system—its goals, structure, rules, delays, parameters—arises

- Paradigms are the unwritten ideas and rules agreed upon and shared by society.

- Examples:
    - Money is real and has value.
    - Land can be "owned."
    - There is a "fair" and an "unfair."
- Paradigm change is not physical, expensive, or slow: it can happen in a fraction of a second for an individual.
- However, societies resist paradigm changes harder than anything else.
- Nevertheless, changing a paradigm is tremendously powerful and happens much more than you might think.

Important quote:

"Systems modelers say that we can change paradigms by building a model of the system, which takes us outside the system and forces to see it whole" (164).

Transcending Paradigms

- One transcends the confinement of paradigms to realize that no paradigm is absolute (that they are things society has accepted to be "true").
- This is the most powerful leverage point because you can choose paradigms that fit your purpose/ goals and the ones that benefit you.

Chapter 7: Living In a World of Systems

An incomplete list of what to do when encountering and interacting with systems:

Get the Beat of the System

- Before you disturb the system, observe it and learn its behaviors and history.
- "This guideline is deceptively simple. Until you make it a practice, you won't believe how many turns it helps you avoid" (171).

Honor, Respect, and Distribute Information

- "Information is power" (173).
- Systems work best when provided with timely, accurate, and complete information.
- Do not block or hinder the flow of information.

Use Language with Care and Enrich It with Systems Concepts

- "Honoring information above all avoiding language pollution—making the cleanser possible use we can of language. Second, it means expanding our language so we can talk about complexity" (174).
- Keep language as concrete, meaningful, and truthful as possible when communicating information.
- Enlarge language to keep it consistent with enlarged understandings of systems.
    - Don't overcomplicate when you do not need to, but do not oversimplify and misrepresent the system.

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

- Not everything is quantifiable, nor should everything be assigned a number.
- People can count, but they can also assess quality.
- "Be a quality detector" (176).

Make Feedback Policies for Feedback Systems

- Make policies that change based on the system's state (self-adjusting policies).
- These policies work best in uncertain systems such as a market economy.

Go For the Good of the Whole

- "Aim to enhance total systems properties, such as growth, stability, diversity, resilience and sustainability—whether they are easily measured or not" (178).

Listen to the Wisdom of the System

- Help the structures that help the system run itself rather than ignore them and add something.
- Before trying to improve the system, focus on the value of what is already in the system.

Locate Responsibility in the System

- It's a guideline for the analysis and designing of a system.
- For analysis, it is about finding ways the system creates its behavior.
- Intrinsic responsibility that the system designs quickly sends the consequence of decisions to the decision maker(s).
- Intrinsic responsibility is seemingly missing in many systems around us (currently).

Stay Humble—Stay a Learner

- Try new things out, make mistakes, embrace those mistakes and learn from them.

Celebrate Complexity

- The universe is marvelously complex, messy, and in a constant state of disorder.
- Our minds like uniformity—straight lines and whole numbers—but celebrate the self-organization of systems and disorder.

Expand Time Horizons

- "We experience now the consequences of action set in motion yesterday and decades ago and centuries ago" (183).
- Don't be fixated on the immediate future, but consider both your actions' short-term and long-term consequences.

Defy the Disciplines

- "Follow a system wherever it leads" (183).
- To fully understand a system, you will have to challenge yourself in disciplines you are likely unfamiliar with.

- Do not shy away from learning.

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” (184).

Don’t Erode the Goals of Goodness

- Try to escape the myriad of systems stuck in a “drift to low performance,” try to find the good in things, and use those to motivate yourself.