Cartesian Thinking
System Thinking
Quantum Thinking
Cartesian Thinking

Never accept anything for true that we do not clearly know to be such.

Divide each part of the difficulties under examination into as many parts as possible.

Begin with the simplest and easiest and then work step-by-step to the more complex.

Make enumeration so complete and reviews so general that it might be assured that nothing is omitted.

Descartes (1619)
Quantum Thinking

“Reality is what we take to be true. What we take to be true is what we believe. What we believe is based upon our perceptions. What we perceive depends upon what we look for. What we look for depends on what we think. What we think depends on what we perceive. What we perceive determines what we believe. What we believe determines what we take to be true. What we take to be true is our reality”

Gary Zukav
Systems

Systems may be defined as groups of interacting, independent parts (agents, or subsystems, or lower hierarchies within the system under consideration) linked by exchanges of energy, matter, and/or information. Interdependence of parts is a diagnostic property of systems.

In systems, the whole is greater than the sum of its parts (emergence)
“Chaos” refers to an underlying connectedness that exists in apparently random events. Chaos science focuses on hidden patterns, nuance, the ‘sensitivity’ of things, and the ‘rules’ for how the unpredictable leads to the new”.

“Chaos theory tells us that systems tend to self-organize, preserving their internal equilibrium while retaining a measure of openness to the external world”

(J. Briggs and D. Peat)
Systems and Chaos

Some characteristics of chaotic systems:
- Dynamic with self organization (order out of chaos)
- Small things can have huge consequences (subtle influences)
- Many coupled negative and positive feedback loops
- Openness and bifurcation
- Creative, cooperative, sharing
- Non-linear and diverse
- Simple, complex, dialectical
- Synchronicity
- Fractal (patterns of chaos)
What makes a system?

- The parts or components
- The relationship between the parts
- The purpose of the system (subsystems may have several purposes conflicting or not)

“Nothing is completely itself without everything else”
(T. Berry)
Types of Systems

- **Isolated**: boundaries closed to import or export of both mass and energy
- **Closed**: boundaries closed to import or export of mass, but not of energy
- **Open**: exchange of both mass and energy with surroundings

“When we try to pick up anything by itself, we find it is attached to everything in the universe” (John Muir)
Simple and Complex Systems

**Simple**: few variables involved with limited and easily understandable relationships that are displayed over a short time period.

**Complex**: many variables, complex interactions between the variables. Characteristics: non-linearity, feed-back loop, discontinuities, sensitivity, dynamic equilibrium, emergent behavior, evolution, path-dependency, small changes here create big changes there (Edward Lorenz, 1979)
A Global View of System Thinking

- See the world around us in wholes instead of snapshots
- See and sense how the parts of systems work together
- See relationships between the elements from multiple levels of perspective rather than cause-effect chains (31)
- Help understand the dynamic and changing nature of life including the effect of time and delays (34)
- Help understand how one small event can influence another and unintended consequences (33)
- Help understand that what we see happening around us depends on where we are in the system
- Challenges our own assumptions (mental models)

(Linda Sweeney, 2001)
What is Systems Thinking?...

Nothing new…

- Greeks were describing reality in terms of wholes composed of related parts over 2,000 years ago.
- Native Americans tend to see reality in terms of indivisible wholes, circular loops of causality and inter-relationships, and interconnectedness
What is NOT Systems Thinking?…

- It is NOT analysis
- Analyzing something involves breaking it down into bite-size, manageable pieces.
- Analysis works fine for: organizing your CD collection, or finding out exactly how your clock works, or examining a water molecule.
- Problems arise when we use analysis *mindlessly!*
- Systems are dynamic, and there are relationships
What is NOT Systems Thinking?

**Detail complexity**—simulations with thousands of variables and complex arrays of details can actually distract us from seeing patterns and interrelationships. Traditional approach in tools for forecasting, planning and business analysis.

**Dynamic complexity**—Difficult to handle with traditional tools because of: subtle relationship between cause and effect, effects over time and space and interventions are not obvious. This is where the leverage lies.

Try not to fight “complexity with complexity”!
Systems Thinking Example

Arms Race- Problem of Dynamic Complexity

- **Interrelationships** (our actions to be more secure, and the threat they create to the countries of the former Soviet Union)
- **Delays** (between a U.S. decision to build up arms and the other country’s counter-buildup)
- **Patterns** of change (continuing escalation)
Nuclear Waste Repository

Atmosphere

Precipitation, water vapor, hydrologic cycle, energy, CO₂, O₂

Hydrosphere

Particulate mineral matter, H₂S, CO₂, H₂O

Geosphere

Biomass, nutrients, H₂O, CO₂, O₂

Biosphere

FROM: Figure 1.1, Industrial Ecology, Environmental Chemistry and Hazardous Waste, Stanley E. Manahan
Think Globally
Act Locally
NON-NATURAL SYSTEMS
(Built Environment - Anthrosphere)

VS.

NATURAL SYSTEMS
(Biosphere- Hydrosphere-Geosphere – Atmosphere)

- Cartesian
- Somewhat predictable
- Designed as closed systems
- Built to last

- Non-Cartesian
- Diverse
- Non-linear
- Open
- Coupled
- Dissipative
- Chaotic
- Changing
Why Things Fail?

- **Slowness of human thinking.** We feel obliged to economize and simplify.
- **Slow speed in absorbing new material.** We don’t think about problems we don’t have.
- **Self protection.** We need to have things easier and under control to preserve our expectation of success.
- **Limited understanding of systems:** complexity, dynamics, mistaken hypotheses and ignorance.

“We have been turned loose in the industrial age equipped with the brain of prehistoric times”
Failures

- Failure to anticipate a problem
- Failure to perceive a problem that has actually arrived
- Failure to attempt to solve a problem once it has been identified
- Failure to find a viable solution to the problem

(in “Collapse: How Societies Choose to Fail or Succeed”, by Jared Diamond)
What is Systems Thinking?…

“Since relationships are the essence of the living world, one would do best… if one spoke a language of relationships to describe it. This is what stories do…. What is important in a story, what is true in it, is not the plot, the things, or the people in the story, but the relationships between them.”

Fritjof Capra
If You Give a Mouse a Cookie

Author: Laura Joffe Numeroff, illustrated by Felicia Bond
Publisher: HarperCollins, New York, 1985
Format: Picture book, fiction
Age Range: 3–7

Systems Thinking Concepts
Simple interconnectedness, circular feedback, unintended consequences, time horizons, solutions that create new problems

The Old Ladies Who Liked Cats

Author: Carol Greene, pictures by Loretta Krupinski
Format: Picture book
Age Range: 9–12 (though this range seems too limited to me; I know readers younger than 9 who enjoy reading this book as well)

Systems Thinking Concepts
Simple interconnectedness, the impact of delays, unintended consequences, goal-seeking behaviors or equilibrium, how a seemingly rational decision can have disastrous large-scale results

The Cat in the Hat Comes Back

Author: Dr. Seuss
Publisher: Random House, New York, 1958
Format: Picture book
Age Range: 4–8 (but open-ended possibilities for grown-ups, too)

Systems Thinking Concepts
Simple interconnectedness, unintended consequences, the archetypal systems story of "Fixes That Fail"

Zoom

Author: Istvan Banyai
Publisher: Viking Children's Books, New York, 1995
Format: Picture book, nonfiction
Age Range: All

Systems Thinking Concepts
Understanding the impact of our own perceptual filters, multiple levels of perspective, "nested systems," systems boundaries
Linear Causality

A → B → C

Cause → Effect

Circular Causality

Feedback: shows how actions can reinforce (positive feedback) or counteract (balance through negative feedback) each other.

Variables are organized in a circle or loop of cause-effect relationship called a “feedback process”
“I am filling a glass of water”

From *The 5th Discipline* by Peter Senge (1990)
The hand on the faucet is controlling the rate of flow of water into the glass.
The level of water in the glass is controlling the hand.

The intent to fill a glass of water creates a system that causes water to flow in when the level is low, then shuts the flow off when the glass is full. The structure causes the behavior.
Positive or Reinforcing Feedback Loops (R)

A reinforcing loop is one in which the interaction are such that each action adds to the other. Any situation where action produces a result that promotes more of the same action is representative of a reinforcing loop. These loops amplify or add to change. *Vicious vs. virtuous.*
Negative or Balancing Feedback Loops (B)

A balancing loop is one in which actions attempt to bring two things to agreement. Any situation where one attempts to solve a problem or achieve a goal or objective is representative of a balancing loop. These loops negate change and create stability. They often display goal seeking behavior.
Feedback Processes

Reinforcing (R) or Amplifying

- Cause dramatic growth or collapse
- Amplifies change
- Snowballing effect
- Make something greater or less
- Accelerating growth or decline
- “Vicious cycles”, “self fulfilling prophecies”, “Virtuous cycles”, “Bandwagon effect”, “rats are jumping ship”

Balancing (B) or Stabilizing

- Operates when there is a goal oriented behavior (implicit or explicit)
- Keep things under control
- Limit dramatic growth
- Ensure that systems fulfills its purpose
- Seeks equilibrium and stability
- Self correction to keep goal or target
Reinforcing Feedback
Balancing Feedback

Diagram:
- Adjust clothing
- Body temperature
- Temperature gap
- Desired body temperature

Graph:
- Desired body temperature over time
- Body temperature over time
Delays = interruptions between actions and their consequences

Balancing Process with a Delay: A Sluggish Shower

Diagram showing the relationship between current water temperature, desired water temperature, shower tap setting, and the resulting time graph with actual water temperature lagging behind desired water temperature.
“Today, system thinking is needed more than ever because we are becoming overwhelmed by complexity. Perhaps for the first time in history, humankind has the capacity to create far more information than anyone can absorb, to foster far greater interdependency than anyone can manage, and to accelerate change far faster than anyone’s ability to keep pace”

(Peter Senge)
Systems Archetypes

- Balancing process with delay
- Limits to growth
- Shifting the burden
- Eroding goals
- Escalation
- Success to the successful
- Tragedy of the commons
- Fixes that fail
- Growth and under-investment
Limits to Growth Archetype
Size of engineering staff → R&D budget → New products → Product development time → Management burden to senior engineers → Delay → Management complexity → Senior engineers' ability to manage → Revenues
Shifting the Burden Archetype

Diagram:
- Symptomatic "Solution"
- Problem Symptom
- Fundamental Solution
- Delay
- Side Effect
Flow and Stock

- **Stock**: Anything that accumulate and can be measured at one point in time (water in bathtub, population, etc.)
- **Flow**: Anything that changes over time (number of births, inflation rate, etc.)
Quantum Thinking

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Gary Zukav
“Our beliefs reinforce our perceptions and our perceptions reinforce our beliefs”
Reality

**Fiction**
- Cartesian
- Linear
- Predictable
- Independent parts
- Closed systems
- To be controlled

**Fact**
- Non-Cartesian
- Non-linear
- Chaotic
- Interconnectedness
- Open, Dissipative
- Emergence, Self-organization, Autopoiesis
Bohr's Principle of Complementarity:
Things, events, etc. are always potentially present. They become present when we decide to look at them (quantum probability functions collapse). The problem is that once we decide to look at one aspect of something, the less we know about the other aspects.
Heisenberg Uncertainty Principle:
The simple process of observation changes what we perceive due to our own interaction. Reality depends on what we choose to measure, or more specifically, which set of lenses we choose to look through.
“If a man talks in the forest and a woman is not there to hear it, is he wrong?”

Anonymous
Systems

Systems may be defined as groups of interacting, independent parts (agents, or subsystems, or lower hierarchies within the system under consideration) linked by exchanges of energy, matter, and/or information. Interdependence of parts is a diagnostic property of systems.

The whole is greater than the sum of its parts
Nuclear Waste Repository

Atmosphere

Hydrosphere

Geosphere

Biosphere

Precipitation, water vapor, hydrologic cycle, energy, CO₂, O₂

Particulate mineral matter, H₂S, CO₂, H₂O

CO₂, O₂, Water vapor

Biomass, nutrients, H₂O, CO₂, O₂

Water, salts

Energy, nitrogen

Nutrients, organic matter

FROM: Figure 1.1, Industrial Ecology, Environmental Chemistry and Hazardous Waste, Stanley E. Manahan
System Approach

- Leibnizian Approach: truth is analytic
- Lockean Approach: truth is experimental
- Kantian Approach: truth is synthetic
- Hegelian Approach: truth is conflictual
What is a System?

Ques: Heap or a System?

…Nuts

…Sand
What is a System?

Ques: Whole greater than sum of parts?

.....overfishing sea perch...
...........orcas began preying on otters.....

.....took your car apart, weighed everything...
............speed and comfort....emergent properties
What is a System?

Ques: What’s the purpose of the system?

….teachers in a school may sometimes disagree with the administration……
What is a System?

Ques: Are causes and effects shaped like a circle?

... the old lady who swallowed a fly.....(not)

.......# births, population, possible parents....

...reinforcing feedback loop (spiralling up or spiralling down)....

....... body temperature --balancing feedback loop
What is a System?

Ques: Are we experiencing déjà vu?
(Systems behave similarly in different settings)

…bullies in the playground….slashing prices game between competitors ….
What is Systems Thinking?...

Do we live moment to moment?
OR
Do we seek to understand how problems come about and how new challenges might unfold?

- Question overly simple explanations of events
- Look for patterns in how things happen
- Redesign systems so they work better

Systems Thinking--Linda Booth Sweeney
Ways to Think About Systems…

- Lowering the water line – the iceberg
- “Oops, didn’t mean to do that…” understanding unintended consequences
- A system thinker’s clock - A different look at time
- Ferreting out delays
- Thinking like a bathtub