# Thinking in systems

Inspired by the book:

"Thinking in systems"

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# the basic operating unit of a system- the feedback loop

the systems thinking lenses allow us to get/ build a foundation to do the following:

- See interconnections
- Ask "***what if***"? questions about possible future connections
- Be courageous and creative about systems redesign

# A system is an interconnected set of elements that is coherently organized in a way that achieves something

- An animal is a system;  a tree is a system;
- and thus we are systems

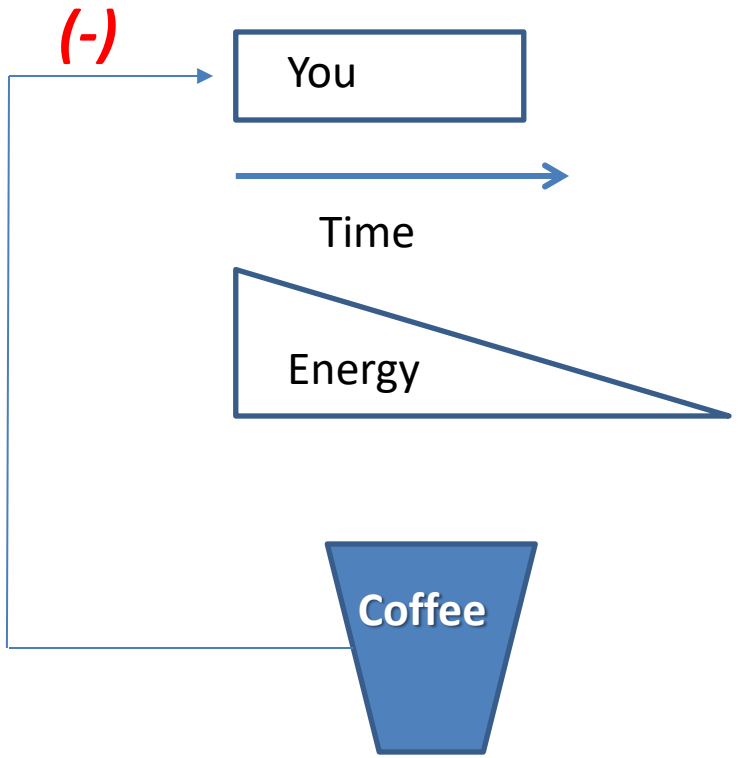
- Systems can be self organizing and to some extent, self-repairing
- Out of one system completely new never before imagined systems can arise- **Examples?**

- And engineering and basic science can involve systems if we are to integrate with and create smart systems

# stabilizing loops- balancing feedback

- An example of positive or negative feedback?
- Answer is:
- *(-)*
- Example: If you're a coffee drinker, when you feel your energy level run low, you may grab a cup of hot black stuff to perk you up again. You, as a coffee drinker, hold in your mind a desired stock level (energy for work). The purpose of this caffeine delivery system is to keep your actual stock levels near or at your desired level (you may have other purposes for drinking coffee as well…..)

# Stabilization by Coffee




Is it positive or negative feedback?
= negative, because it reverses the run-down of energy. How?

# Coffee-2

- in this coffee example, our decision to drink coffee solves the energy problem only at one level. Remember- all system diagrams are simplifications of the real world. We each choose how much complexity to look at. So, for the coffee decision, caffeine is only a short-term stimulant. It lets you run your motor faster, but it doesn't refill your personal fuel tank. Eventually the caffeine high wears off, leaving the body more energy-deficient than it was before. The drop (in caffeine, where? Resulting in drop in…..?) could reactivate the feedback loop and generate another trip to starbuck's. This is a decision making-process (see the discussion of addiction later). Or it could activate some longer-term and healthier feedback responses: eat some food, take a walk, get some sleep.

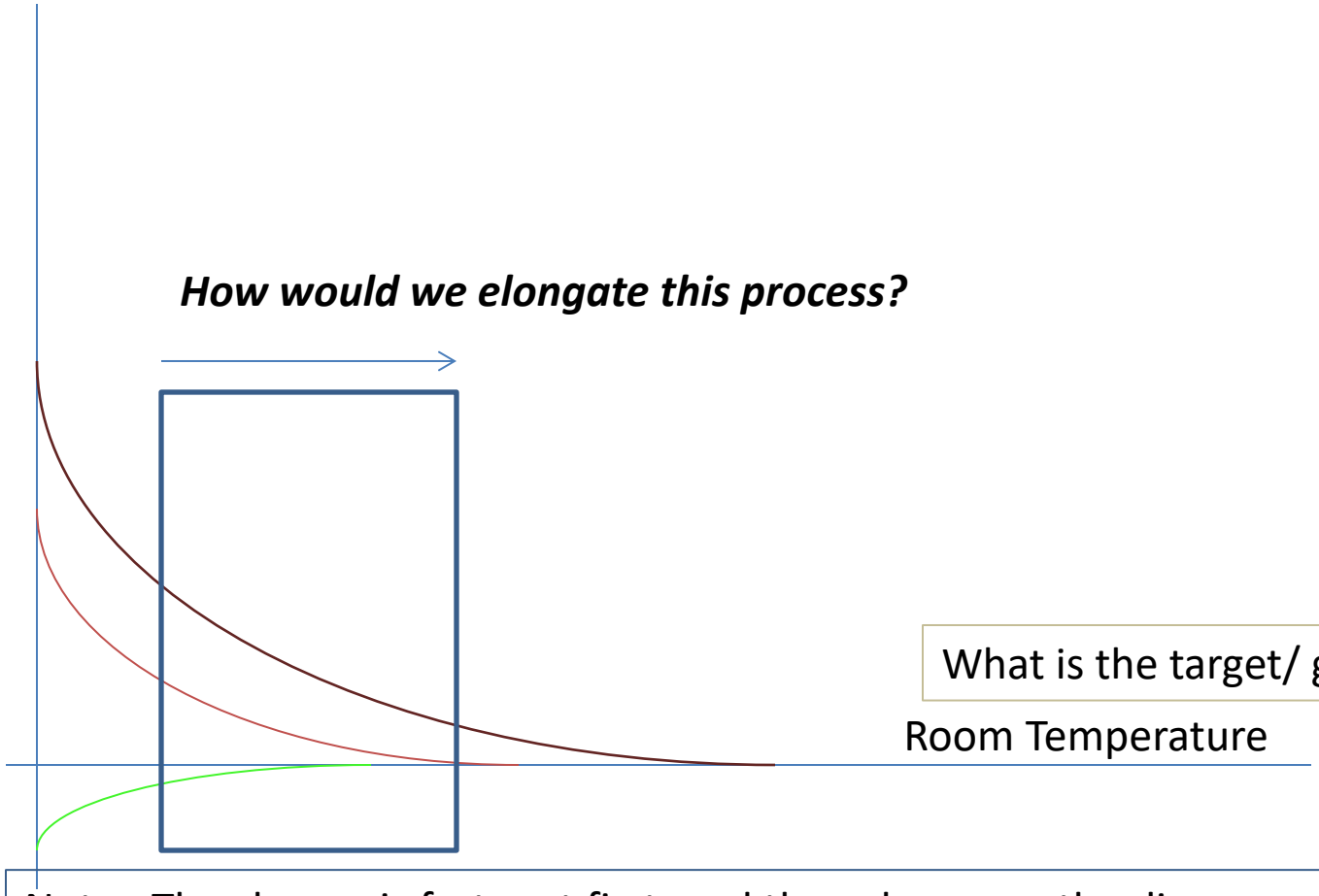
# Balancing feedback loops are goal-seeking or stability seeking

- Each tries to keep a stock at a given value or within a range of values. A balancing feedback loop opposes whatever direction of change is imposed on the system (so is it a negative feedback loop?).

# Hot coffee or cold coffee?

- Here's another balancing feedback loop that involves coffee- working thru physical laws: a hot cup of coffee will gradually cool down to room temperature. Its rate of cooling depends on the difference between the temperature of the coffee and the temperature of the room. The greater the difference, the faster the coffee will cool. The loop works the other way too- if you make iced coffee on a hot day, it will warm up until it has the same temperature as the room. The function of this system is to bring the discrepancy between the coffee's temperature and room's temperature to zero, no matter what the direction of the discrepancy.

# Coffee:  Hot or cold?




Note:  The change is faster at first, and then slower, as the discrepancy between the stock and the goal decreases.

# balancing feedback loops

- **definition**: balancing feedback loops are equilibrating or goal-seeking structures in systems and are both sources of stability and sources of resistance to change.
- Example: your body adjusts its blood-sugar concentration

# runaway loops- reinforcing feedback (is this positive or negative feedback?)

- *Quote: "I'd need rest to refresh my brain, and to get rest it's necessary to travel, and to travel one must have money, and in order to get money you have to work…. I am in a vicious circle…from which it is impossible to escape."—H. Balzac 19th century novelist and playwright.*

- *Quote: "here we meet a very important feature. It would seem as if this were circular reasoning; profits fell because investment fell, and investment fell because profits fell." -J. Tinbergen, economist*.

# Positive feedback loops

- The second kind of feedback loop is amplifying, reinforcing, self-multiplying, snowballing- a vicious or virtuous circle that can cause healthy growth or runaway destruction. It is called a reinforcing feedback loop (also know as positive feedback). It generates more input to a stock the more that is already there (and less input the less that is already there).
- **A reinforcing feedback loop enhances whatever direction of change is imposed on it. For example**:
- -1) when we were kids, the more my brother pushed me, the more I pushed back, so the more he pushed back, so the more I pushed back
- -2) the more rabbits there are, the more rabbit parents there are to make baby rabbits. The more baby rabbits there are, the more grow up to become rabbit parents, to have even more baby rabbits
- -3) the more soil is eroded from the land, the less plants are able to grow, so the fewer roots there are to hold the soil, so the more the soil is eroded, so less plants can grow
- -4) the more I practice the piano, the more pleasure I get from the sound, and so the more I play the piano, which gives me more practice (also exercise and tone of the body, which can work in reverse with weight gain and not wanting to exercise).

# Reinforcing loops

- reinforcing loops are found wherever a system element has the ability to reproduce itself or to grow as a constant fraction of itself (or to be revealed or recruited from a storage site).

- Examples?
- (glutamate release or influx of a predator or prey from a neighboring environment; growling stomach and smell of food?)

# Reinforcing loops

- the more money you have in the bank, the more interest you can earn, which is added to the money already in the bank, where it earns even more interest-
- This is not simple linear growth. It is not constant over time. The growth of the bank account at lower interest rates may look linear in the first few years, but, in fact, growth goes faster and faster. The more there is, the more is added
- This kind of growth is called “exponential” it’s either good news or bad news, depending on what is growing- money in the bank, people with HIV/AIDS, pests in the cornfield, a national economy, or weapons in an arms race.

- **definition**: reinforcing feedback loops are self-enhancing, leading to exponential growth or to runaway collapses over time. They are found whenever a stock has the capacity to reinforce or reproduce itself.

# What influences systems?
## (if A causes B is it possible that B also causes A?)

- Instead of seeing only how A causes B, think about how B may also influence A, and how A might reinforce or reverse itself.
- Examples: 1) when you hear that the Federal Reserve has done something to control the economy, you may see that the economy must have done something to affect the Federal Reserve.
- 2) When someone says that population growth causes poverty, ask how poverty may cause population growth.
- --We **need** to be systems thinkers.

# Positive feedback thought problem

- After investing $100 in a savings account that earns 100%! per year, if compounding every month, how long does it take to double your money?

# Balancing of stock levels-1

- So far we have thought of one feedback loop at a time.
- In real systems, feedback loops rarely come singly.
- Instead, they are linked together, often in complex, weblike patterns.
- Look at one component of the system (one stock) and that one stock is likely to have several reinforcing and balancing loops of differing strengths pulling it in several directions.

# Balancing of stock levels-2

- A single flow may be adjusted by the contents of 3 or five or twenty stocks.
- It may fill one stock while it drains another and feeds into decisions that alter yet another.
- The many feedback loops in a system tug against each other, trying to make stocks grow, die off, or come into balance with each other.
- As a result, complex systems do much more than stay steady or explode exponentially or approach goals smoothly- as we shall see……

# Balancing of stock levels-3

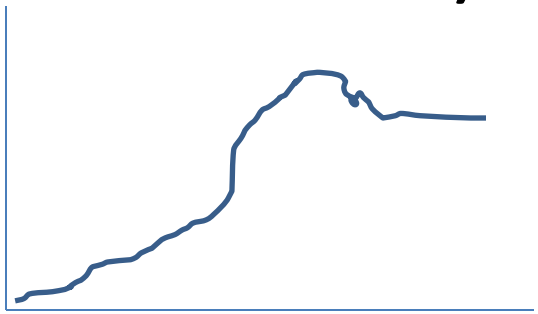
- Some systems thoughts (homework examples):
- In a predator prey system, what influences the stock level of sheep?- define the system and who is positive and who is negative.
- In Starbuck's shop in Ruston, LA. What influences the stock of income to that shop for a given day?  Again, define some + and – players as a starting point.

# Oscillations in a system- the fishing fleet- 01

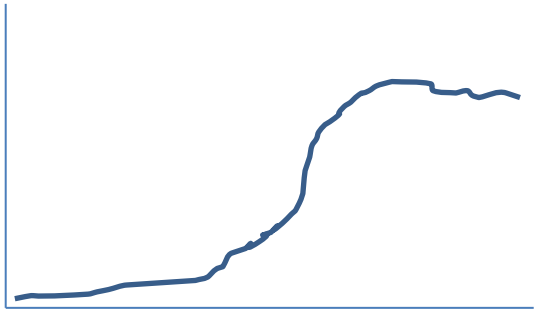
- Imagine a fishery economy that is affected by 3, non-linear relationships: 1) price: (scarcer fish are more expensive; 2) regeneration rate (scarcer fish don't breed much, nor do crowded fish); 3) yield per unit of capital (efficiency of the fishing technology and practices).
- This system can produce many different sets of behaviors because parts of the system can regenerate (it is a renewable resource; ***unless we destroy it***!):

# Fishery system dynamics (and handout)

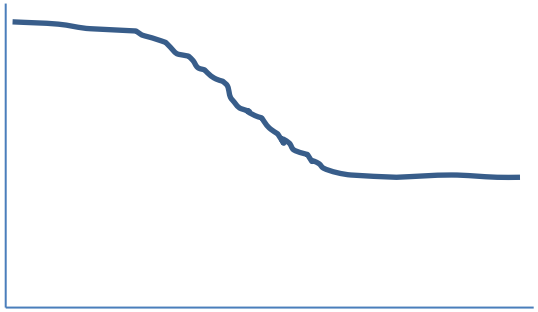
A: Harvest Rate



B: Capital Stock



C: Resource Stock



Time

# Notes on the Fishery Dynamics

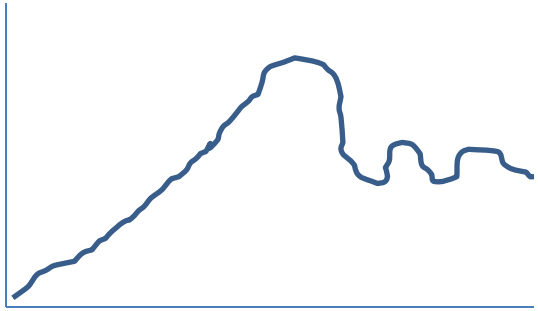
- We see that the capital and fish harvest rise exponentially at first. The fish population (the resource stock) falls, but that stimulates the fish reproduction rate. For decades (in this example), the resource can go on supplying an exponentially increasing harvest rate.
- Eventually, the harvest rises too far and the fish population falls low enough to reduce the profitability of the fishing fleet.
- The balancing feedback of falling harvest reducing profits brings down the investment rate quickly enough to bring the fishing fleet into equilibrium with the fish resource.
- The Fleet can't grow forever, but it can maintain a high and steady harvest rate forever.

# Oscillations around a stable system

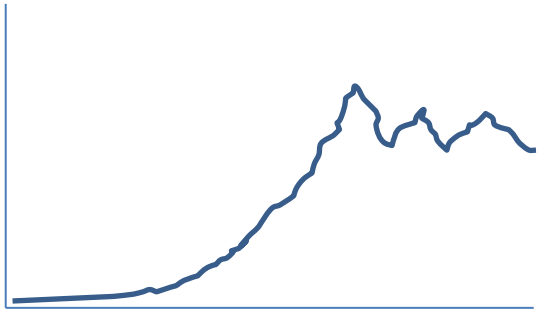
- Just a minor change in the strength of the controlling balancing feedback loop through yield per unit of capital, however, can make a surprising difference.
- Suppose that in an attempt to raise the catch in the fishery, the industry comes up with a technology to improve the efficiency of the boats (sonar, for example, to find the scarcer fish)
- As the population declines, the fleet's ability to pull in the same catch per boat is maintained, just a little longer.
- However, this technical change, which increases the productivity of all fishermen, throws the system into instability: Oscillations appear!

# Fishery system dynamics (and handout-2- Oscillations)

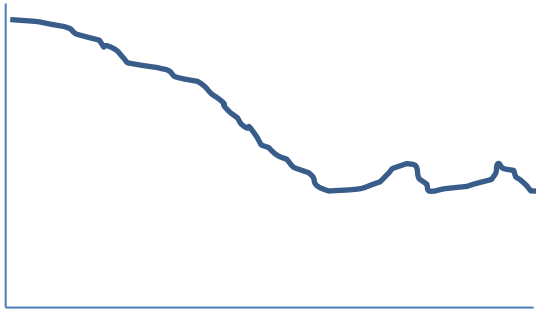
A: Harvest Rate



B: Capital Stock



C: Resource Stock



Time

# Definitions for these dynamics

- **Nonrenewable resources** are stock-limited. The entire stock is available at once, and can be extracted at any rate (limited mainly be extraction capital). But since the stock is not renewed, the faster the extraction rate, the shorter the lifetime of the resource.
- **Renewable resources** are flow-limited. They can support extraction or harvest indefinitely, but only as a finite flow rate equal to their regeneration rate. If they are extracted faster than they regenerate, they may eventually be driven below a critical threshold and become, for all practical purposes, nonrenewable.

# Why systems work so well

- So some of these systems work quite well, regaining their composure and proceeding on about their business of maintaining a room's temperature, or bringing into balance the size of a fishing fleet, for example, with the productivity of a fishery resource.
- If pushed too far, however, systems may well fall apart or exhibit heretofore unobserved behavior.
- When systems work well, we see a kind of harmony in their functioning. Think of a community kicking into high gear to respond to a storm.
- People work long hours to help victims, talents and skill emerge; once the emergency is over, life goes back to "normal".

# Why do systems work so well?

- Consider the properties of highly functional systems.
- You may have observed one of three characteristics:
- 1. resilience
- 2. self-organization
- 3. hierarchy

# resilience

- Systems need to be managed not only for productivity or stability, they also need to be managed for resilience:
- the ability to recover from perturbation, the ability to restore or repair themselves.

# Self-organization

- Systems often have the property of self-organization- the ability to structure themselves, to create new structure, to learn, diversify, and complexify.
- --Even complex forms of self-organization may arise from relatively simple organization rules-
- Or may Not.

# Hierarchy

- Hierarchical systems evolve from the bottom up.
- --The purpose of the upper layers of the hierarchy is to serve the purposes of the lower layers.
- (examples?- and when this does not work?)

# End

- Think in systems!