CT561: Systems Modelling & Simulation

3. Introduction to Feedback

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https://github.com/JimDuggan/SDMR

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Challenge 2.4

- A University attracts 30% of its total students as new students each year, and has an initial population of 1000
- It graduates 25% of all students
- For this:
    - Draw a stock and flow model
    - Add the net flow to the model
    - Formulate the equations
    - Build a model in Vensim with DT=0.25
    - Start the model in 2020, and complete in 2030

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Recap

- **Systems thinkers see the world as a collection of stocks along with the mechanisms for regulating the levels in the stocks by manipulating flows.**
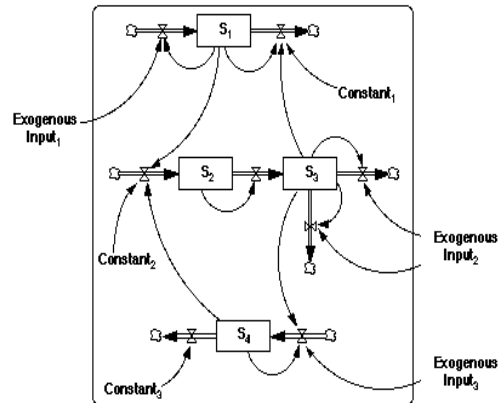

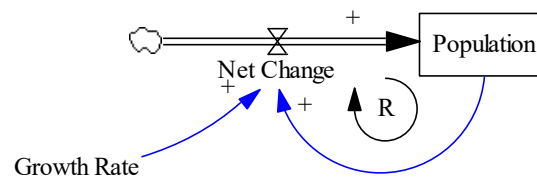Diagram source: J.D. Sterman,Business Dynamics: Copyright © 2001 by the McGraw-Hill Companies

Causality and Feedback

- Exploring causal relationships
  - Link polarity
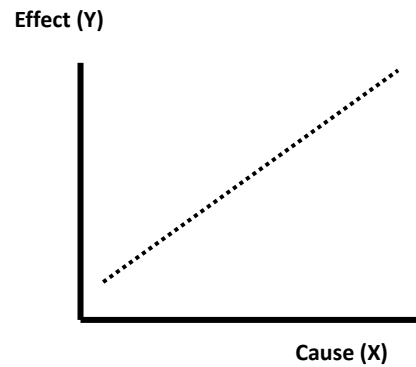 - Loop polarity
- Feedback loops
  - Positive
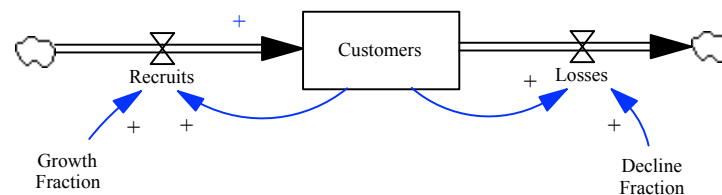 - Negative

Link polarity – Positive Link

A positive link means that:

- if the cause **increases**, the effect **increases** *above what it otherwise would have been,* and

- if the cause **decreases**, the effect **decreases** below what it would otherwise have been.

Effect (Y)

Cause (X)

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Examples

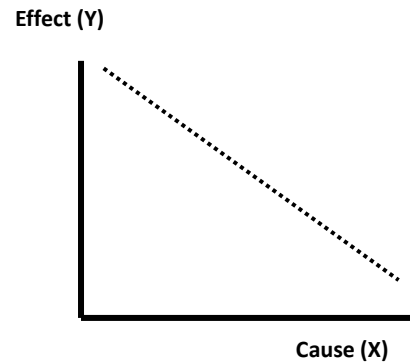| Recruits		↑	Customers		↑

The variables move in the same direction…

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Link polarity – Negative Link

A negative link means that:

- if the cause **increases**, the effect **decreases** *below what it would otherwise have been*, and

- if the cause **decreases**, the effect **increases** *above what it might otherwise have been*.
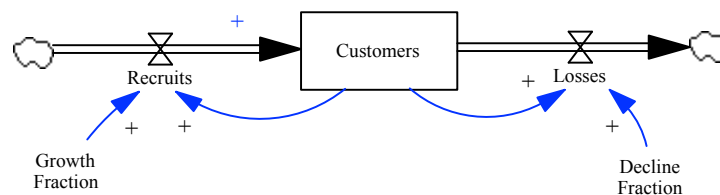
Effect (Y)

Cause (X)

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Example

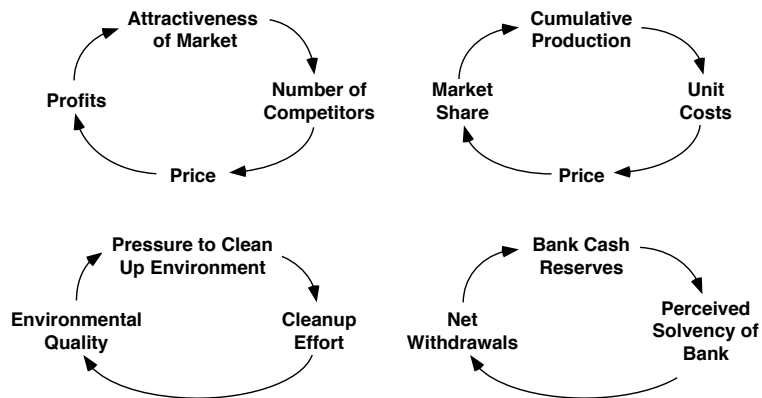| Losses		↑	Customers		↓

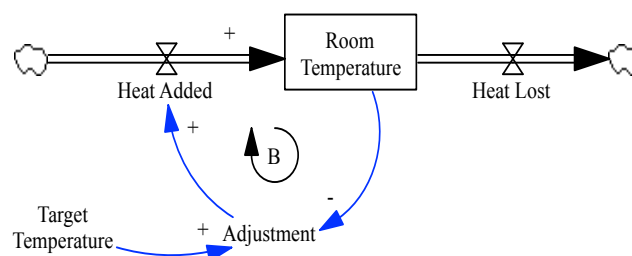*The variables move in opposite directions…*

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Challenge 3.1

- Add links to the following diagrams

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Feedback - Definition

A closed chain of causal connections from a stock, through a set of decisions or rules or physical laws or actions that are dependent on the level of the stock, and back again through a flow to change the stock.

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Loop Polarity

The loop is broken down into a set of the causal links, and the impact of a change in one variable is traced through the causal chain, and back to the original variable.
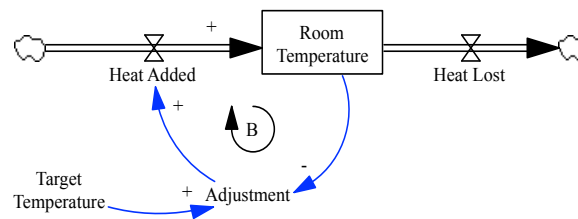
Room Temperature	↓	Adjustment	↑
Adjustment	↑	Heat Added	↑
Heat Added	↑	**Room Temperature**	↑

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Calculating Loop Polarity?

The Fast Way

- Count the number of negative links in the loop
- If this number is even (including zero)
  - Positive Feedback
- If this number is odd
  - Negative Feedback

The Correct Way

- Trace the effect of a small change in one of the variables as it propagates around the loop
- If the loop reinforces the original change, it's a positive loop
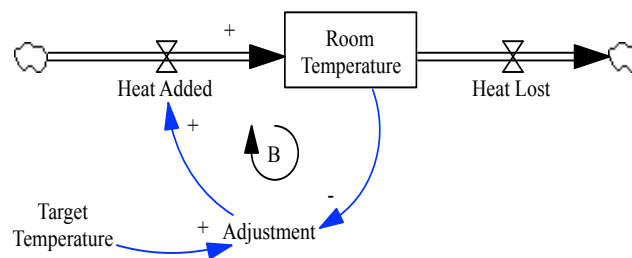- If it opposes the original change, it's a negative loop

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Balancing Loop

Balancing feedback loops are goal-seeking structures in systems and are:

- – sources of stability and
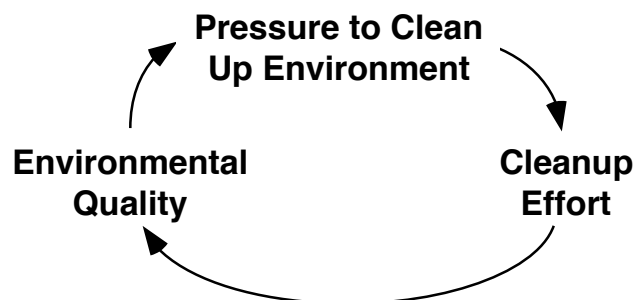- – sources of resistance to change.

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Challenge 3.2
Calculate Link and Loop Polarity

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Another type of feedback…
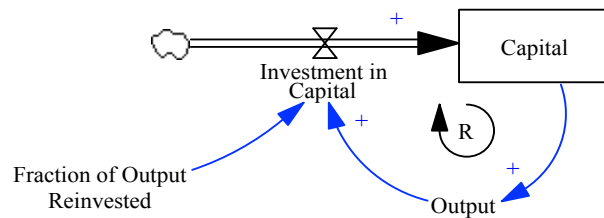
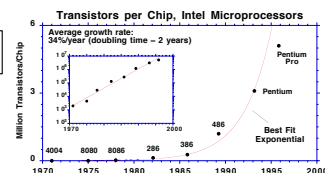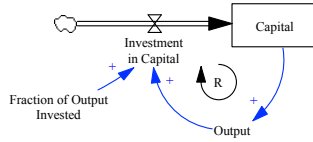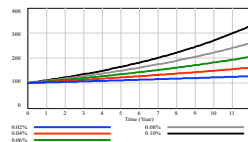| Capital	↑	Output	↑
Output	↑	Investment in Capital	↑
Investment in Capital	↑	**Capital**	↑

Reinforcing Loops

- **"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."
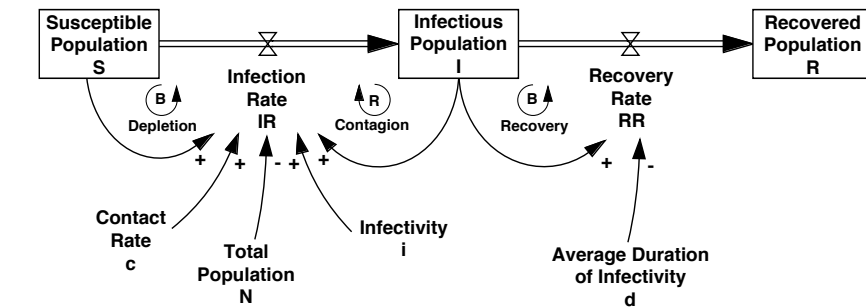
Infectious Disease Example

Cause	Direction	Effect	Direction
Infectious Population	⬆	Infection Rate	⬆
Infection Rate	⬆	Infectious Population	⬆

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Population Growth Example

Cause	Direction	Effect	Direction
Population	⬆	Net Change	⬆
Net Change	⬆	Population	⬆
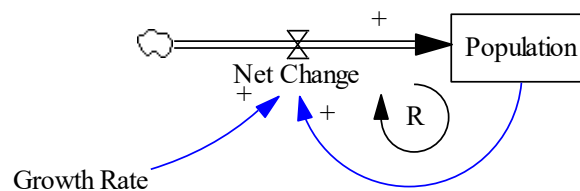
"The second kind of feedback loop is amplifying, reinforcing, self-multiplying, snowballing—a vicious or virtuous circle that can cause healthy growth or runaway destruction." Meadows (2008)

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Positive Feedback (Sterman 2000)
Bill Gates quotes…

- "The biggest advantage we have is that good developers like to work with good developers."
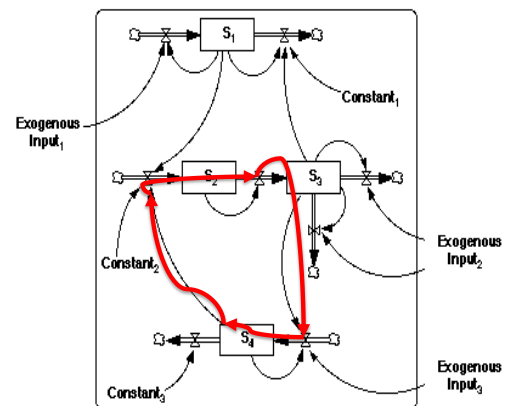- "The growth [Windows NT] continues to amaze us and it's a positive feedback loop. As we got more applications, NT Servers get more popular. As it's gotten more popular, we've got more applications."

Challenge 3.3
Calculate Link and Loop Polarity
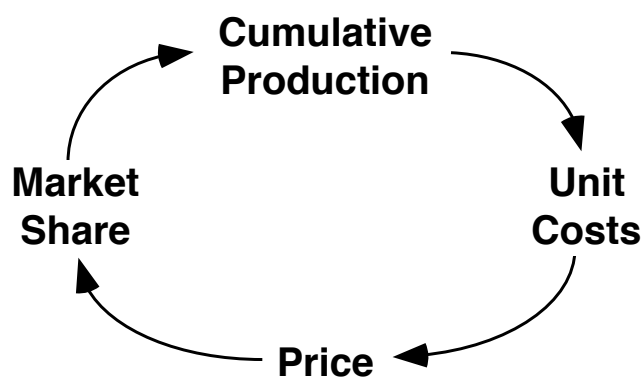
Feedback Summary

- A complex system is an interlocking structure of feedback loops, and this loop structure is found many real-world processes (Forrester 1969).
- A feedback loop is a closed chain of causal links from a stock, through a flow, and back to the original stock again.
- There are two classes of feedback loops. **Negative feedback** counteracts the direction of change, whereas **positive feedback** amplifies change and drives exponential growth.
- Loop polarity is calculated by examining the individual link polarities in a circular causal chain. If there are an odd number of negative links, the loop polarity in negative, otherwise the loop polarity is positive.
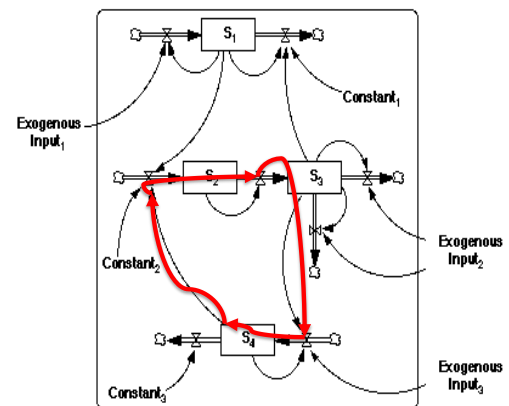
Challenge 3.3 – Part (a)

Construct a stock and flow model from the following description of student workload.
- The *assignment backlog* is increased by *new assignments* and reduced by *completions*.
- *Additional rework* also increases the assignment backlog.
- As the *assignment backlog* increases, so too does the *work pressure*
- There are two student responses to increasing work pressure:
  - The *time per assignment* is reduced
  - The *workweek* is increased
- As the time per assignment increases:
  - The *completions* reduce
  - The *Additional rework* reduces
- As the workweek increases:
  - *Completions* increase
  - *Fatigue* increases
- As *fatigue* increases, so too does *time per assignment*.

Part (b)

- Show the feedback loops and calculate their polarity, by tracing an increase in a variable all the way around a feedback loop, and observing its direction of change.

- Discuss how the feedback loops can help identify the implications of leaving assignments to the last possible minute, rather than working on them in a consistent way throughout a semester.

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Challenge 3.4

Construct a stock and flow model from the following description of an insurance claims work process:

- *Claims* (the stock) are increased by the *Arrival Rate* and reduced by the *Completion Rate*.
- As *Claims* increase, so to does the *Schedule Pressure*
- In response to increasing *Schedule Pressure*, *Overtime* is increased
- As *Overtime* increases, so too does the *Completion Rate*.
- An increase in *Overtime* leads (after a delay) to increased *Fatigue*.
- Increased *Fatigue* reduces the *Completion Rate.*

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Part(b)

Based on the stock and flow model in part(a):

- Show the feedback loops and calculate their polarity, by tracing an increase in a variable all the way around a feedback loop, and observing its direction of change.

- Discuss how the feedback loops can help identify the consequences of having a higher *Arrival Rate* than *Completion Rate.*