

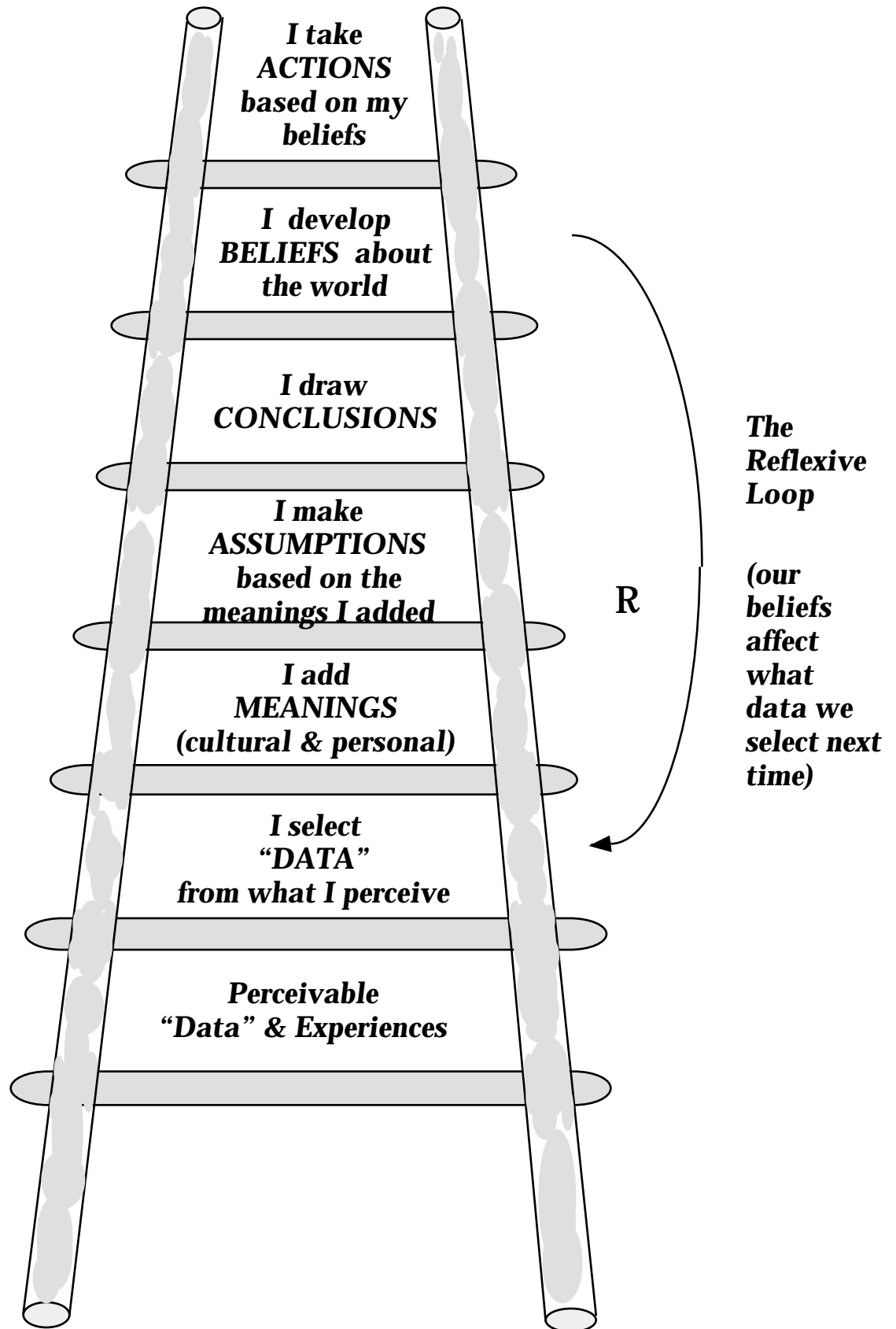
Introduction to Systems Concepts and Tools

Presentation by
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Waters Grant Project
Catalina Foothills School District
June 2000

Name_____

Ladder of Inference



Two Modes of Group Communication

Skillful Discussion

Intending to:

- make a decision
- reach an agreement
- identify priorities

Involves convergent thinking

Dialogue

Intending to:

- explore
- discover
- gain insight

Doesn't necessarily involve convergent thinking

What is System Dynamics?

Two parts:

- *system:*

*interdependencies, causality,
feedback*

- *dynamics:*

*how elements of the system
change over time*

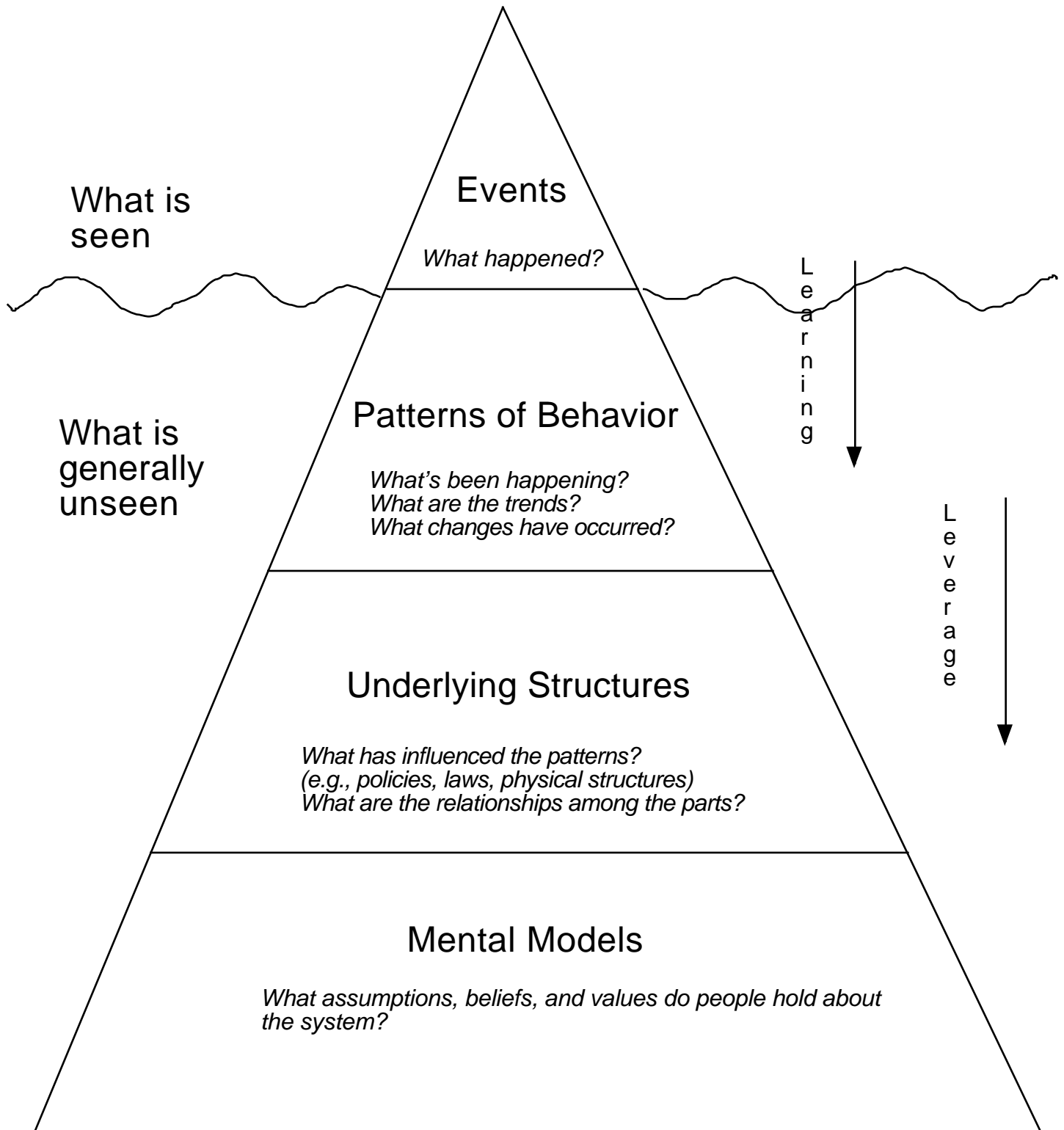
To Think and Act Systemically

- **identify that a system of interdependent parts exists within specified boundaries**
- **analyze and understand the interdependencies among parts of a system, particularly feedback relationships (how something that was initially an “effect” ultimately becomes a “cause”)**
- **analyze and understand the conditions that create/affect the interdependencies**
- **analyze and understand the cumulative effects over space and time that are caused by the interdependencies**

Relative to a goal:

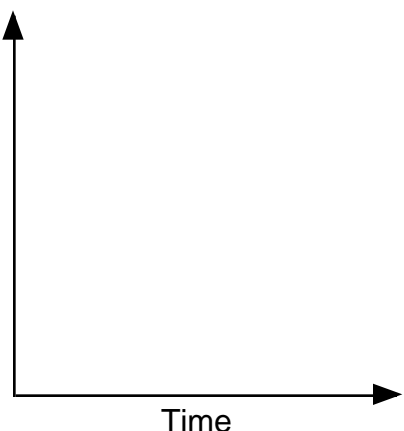
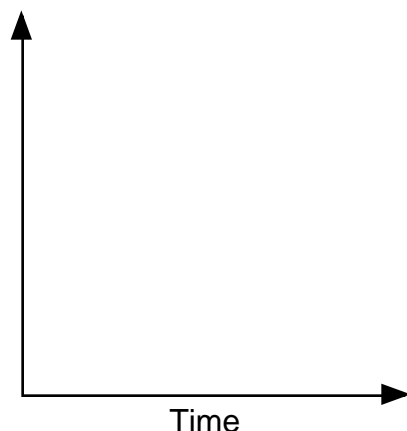
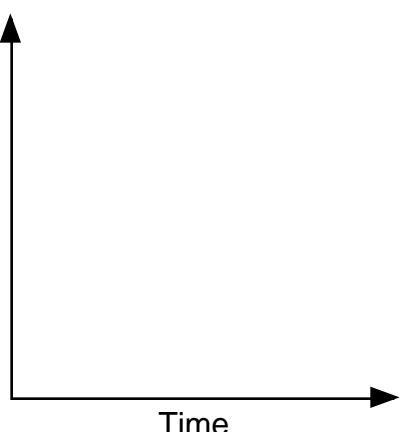
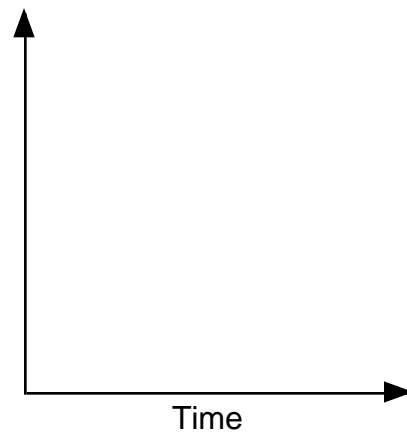
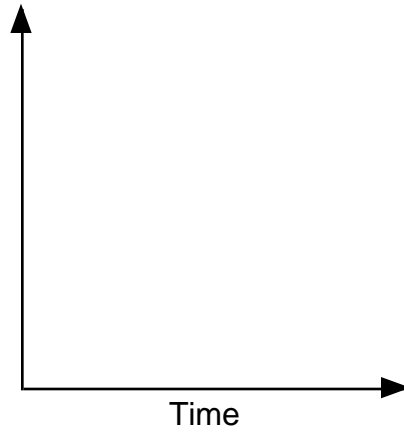
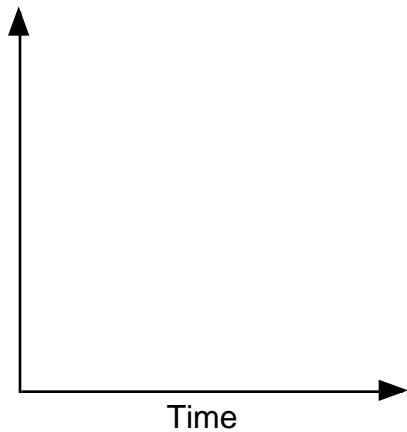
- **determine and understand the choices available within a system and the inherent trade-offs that result from those choices**
- **identify short and long-term effects of the trade-offs within a system**
- **make decisions and take action based on an understanding of the trade-offs and the accumulations over time within a system**

Iceberg...Seeing What's Below the Surface



CONCEPTS	TOOLS
<p><u>Change over time</u></p> <ul style="list-style-type: none"> • patterns and trends • accumulations 	<ul style="list-style-type: none"> • Behavior-over-time graphs (BOTGs) • Stock/flow diagrams • Ladder of Inference • Models - 3-D, mental, computer • Other simulations
<p><u>Feedback</u></p> <ul style="list-style-type: none"> • interdependencies • reinforcing and balancing relationships 	<ul style="list-style-type: none"> • Causal Loop Diagrams (CLDs) • Systems Archetypes • Stock/flow diagrams • Models -3D, mental, computer • Other simulations
<p><u>Leverage</u></p> <ul style="list-style-type: none"> • structure generates behavior • short & long term consequences • trade-offs • temporal and spatial boundaries 	<ul style="list-style-type: none"> • Iceberg • Ladder of Inference • Stock/flow diagrams • BOTGs • Models- 3D, mental, computer • Other simulations

Behavior-Over-Time Graphs (BOTGs) (Trends vs. Discrete Events)



The Story of Mrs. Jones and Her Vacuum Cleaner

Please read the following excerpt from a popular children's book. Note that the narrative is told from the point of view of a super-intelligent rat!

I was reminded of a story I had read at the Boniface Estate when I was looking for things written about rats. It was about a woman in a small town who bought a vacuum cleaner. Her name was Mrs. Jones, and up until then she, like all of her neighbors, had kept her house spotlessly clean by using a broom and a mop. But the vacuum cleaner did it faster and better, and soon Mrs. Jones was the envy of all the other housewives in town--so they bought vacuum cleaners, too.

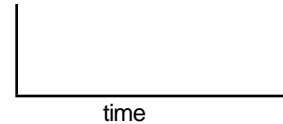
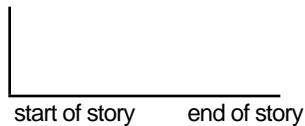
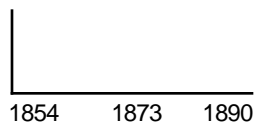
The vacuum cleaner business was so brisk, in fact, that the company that made them opened a branch factory in the town. The factory used a lot of electricity, of course, and so did the women with their vacuum cleaners, so the local electric power company had to put up a big new plant to keep them all running. In its furnaces the power plant burned coal, and out of its chimneys black smoke poured day and night, blanketing the town with soot and making all the floors dirtier than ever. Still, by working twice as hard and twice as long, the women of the town were able to keep their floors *almost* as clean as they had before Mrs. Jones ever bought a vacuum cleaner in the first place.

The story was part of a book of essays, and the reason I had read it so eagerly was that it was called "The Rat Race" (1)---which, I learned, means a race where, no matter how fast you run, you don't get anywhere. But there was nothing in the book about rats, and I felt bad about the title because, I thought, it wasn't a rat race at all, it was a People Race, and no sensible rats would ever do anything so foolish.

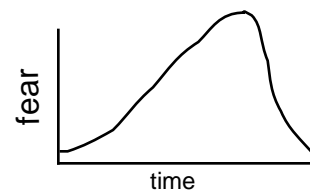
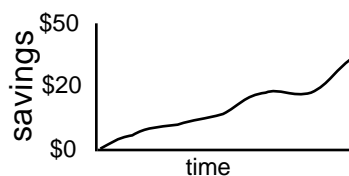
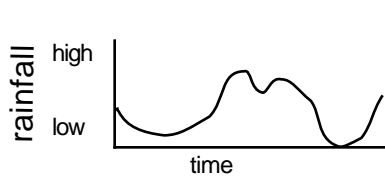
(1)O'Brien, Robert C. *Mrs. Frisby and the Rats of NIMH*. New York: Atheneum, 1971, pp 169-170.

Tips for Behavior-Over-Time-Graphs (BOTGs)

1. A BOTG shows the trend, or pattern of change, of a variable over time as opposed to discrete events.
2. On a basic line graph that is a BOTG:
 - the X axis is always labeled time
 - the X axis' beginning, medial, and ending times may be indicated or not, depending on your purpose:



3. The Y axis:
 - indicates the variable being graphed and must be labeled with that variable's name
 - label is particularly important when looking at graphs of different variables
 - should not include qualitative words such as more, less, increasing, bigger, etc. in the variable's name; it's difficult to understand less "More fear" over time
 - variable being graphed may be "hard" (like population or temperature) or "soft" (like love or stress)
 - may be quantified as much or little as possible, or not at all:



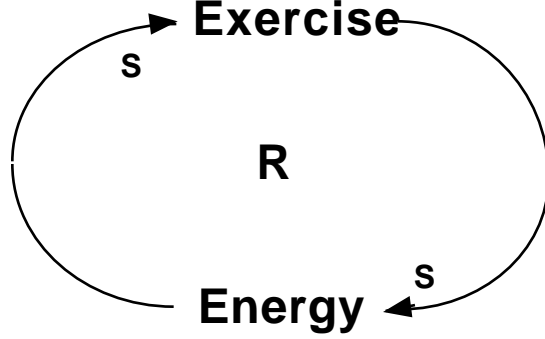
4. If students/staff choose to graph more than one variable on the same graph, they will need to differentiate between the lines on the graph by including a key of some sort.
5. Different interpretations of the stated variable are definitely possible, although generally peoples' graphs of the same variable will look fairly similar. If they are radically different, discussion of the differences should take place, and could be very interesting!
6. Discussion of when and where a trend or pattern of behavior starts, ends, or changes direction is recommended.
7. When discussing the graphs of different variables, the graphs could be compared for possible interdependencies and causal relationships between the variables.

Waters Grant Project '97

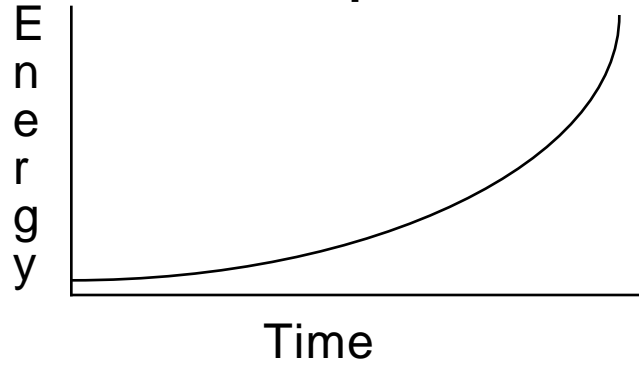
Catalina Foothills School District, 1911 E. Orange Grove Road, Tucson, AZ 85718

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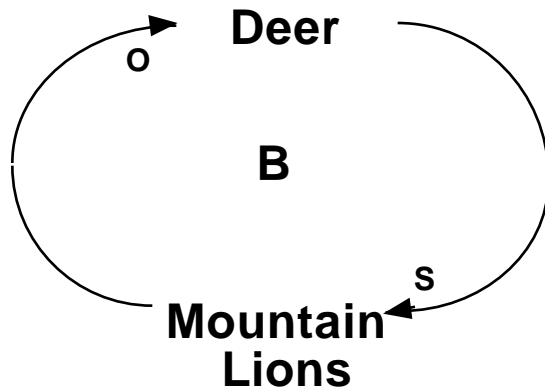
Reinforcing Causal Loop Diagram



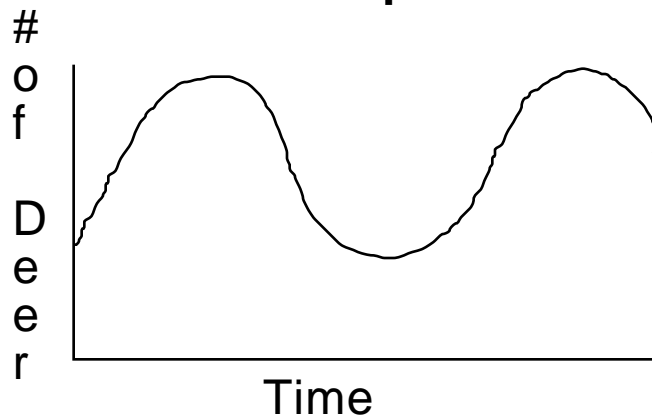
Behavior-Over-Time Graph of Reinforcing Loop



Balancing Causal Loop Diagram



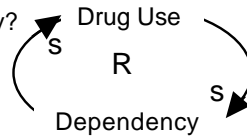
Behavior-Over-Time Graph of Balancing Loop



Tips for Causal Loop Diagrams (CLDs)

- CLDs show causal relationships and illustrate circular feedback within a system.
A cause becomes an effect, becomes a cause, becomes an effect, and so on.

- Does an effect in turn become a cause either directly or indirectly?
You should be able to read the loop around several times (does more drug use lead to more dependency, which leads to more drug use, etc.?).



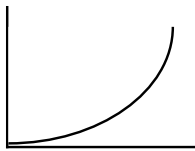
- You may choose to begin by creating behavior-over-time graphs (BOTGs) based upon information found in any given source.
Since CLDs are about the causes of change, it is often helpful to identify how key elements actually did change.

- All variables in a CLD must be able to increase or decrease.
Choosing your terms for the elements is one of the challenges of creating CLDs. For example, "Feelings" is a nebulous term for a loop...what does an increase in feelings really mean? Try "happiness," "sadness," or "frustration" instead.

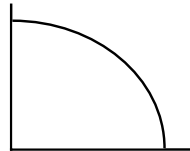
- Find a focus for the loop(s) from the identified BOTGs or directly from the given source. Pick an aspect A that makes another aspect B increase or decrease, which comes back to make A increase or decrease (the loop can also include aspects C, D, etc.).
Who is the audience? What is the purpose of your loop(s)? Pick one aspect of the system. Focus on a behavior that is changing over time...what are the causes? This/these become the other aspects of the loop(s).

- Remember "s" means a change in the same direction...not necessarily an increase.
Remember "o" means a change in the opposite direction...not necessarily a decrease.

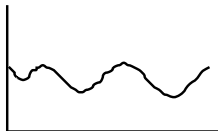
- Reinforcing loops grow more and more (get better and better) or decline more and more (get worse and worse).



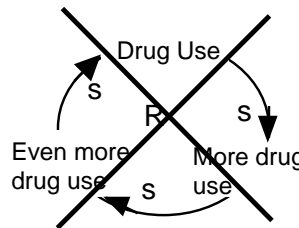
or



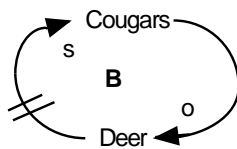
Balancing loops oscillate.



- Do not use the same variable more than once in your diagram.
- Do not use words such as more/less, increases/decreases as part of the variable name.

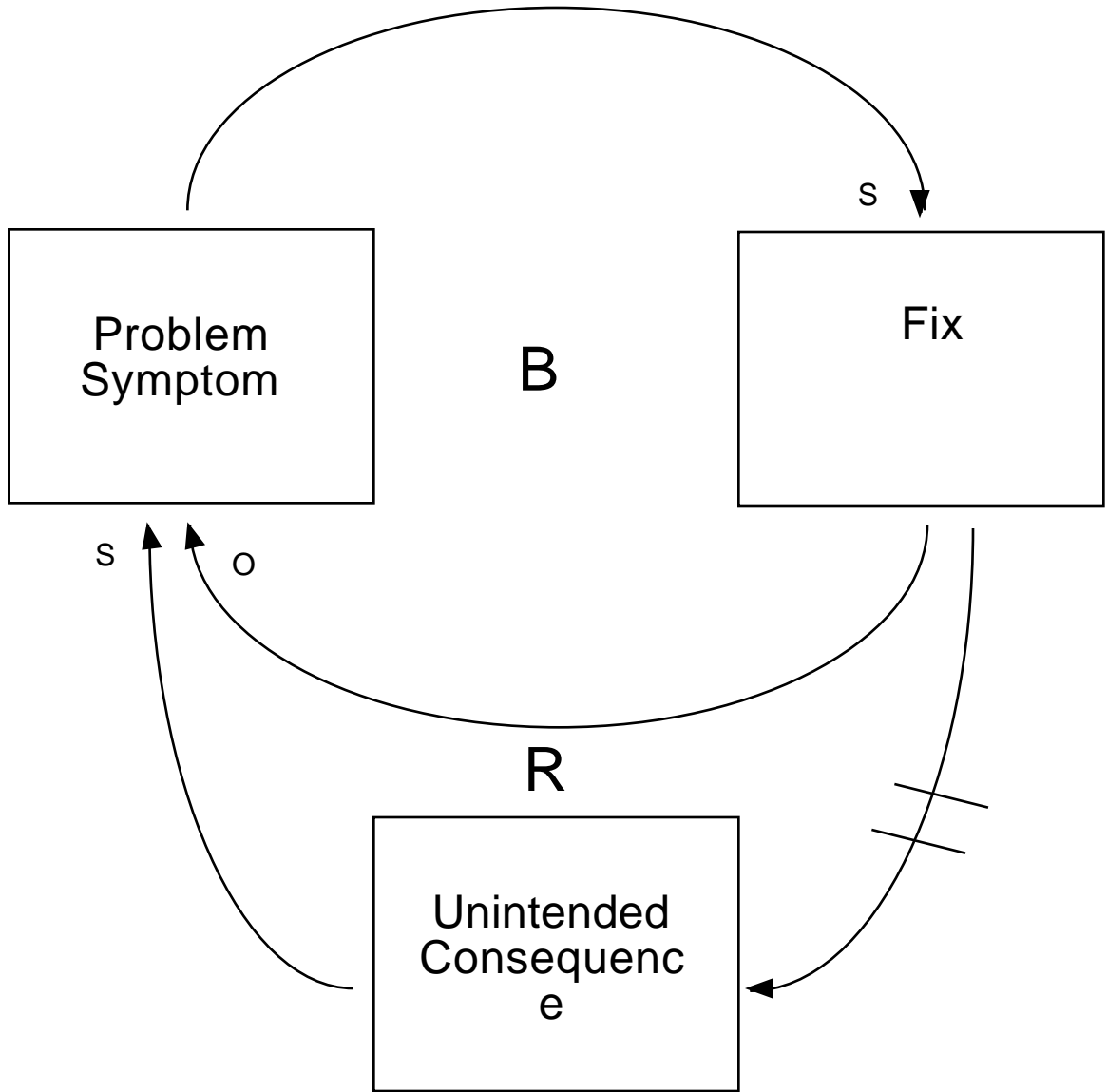


- If there is a significant amount of time between one variable and the next variable in the loop, a time delay can be indicated by drawing two short parallel line segments across the arrow that connects those two variables.

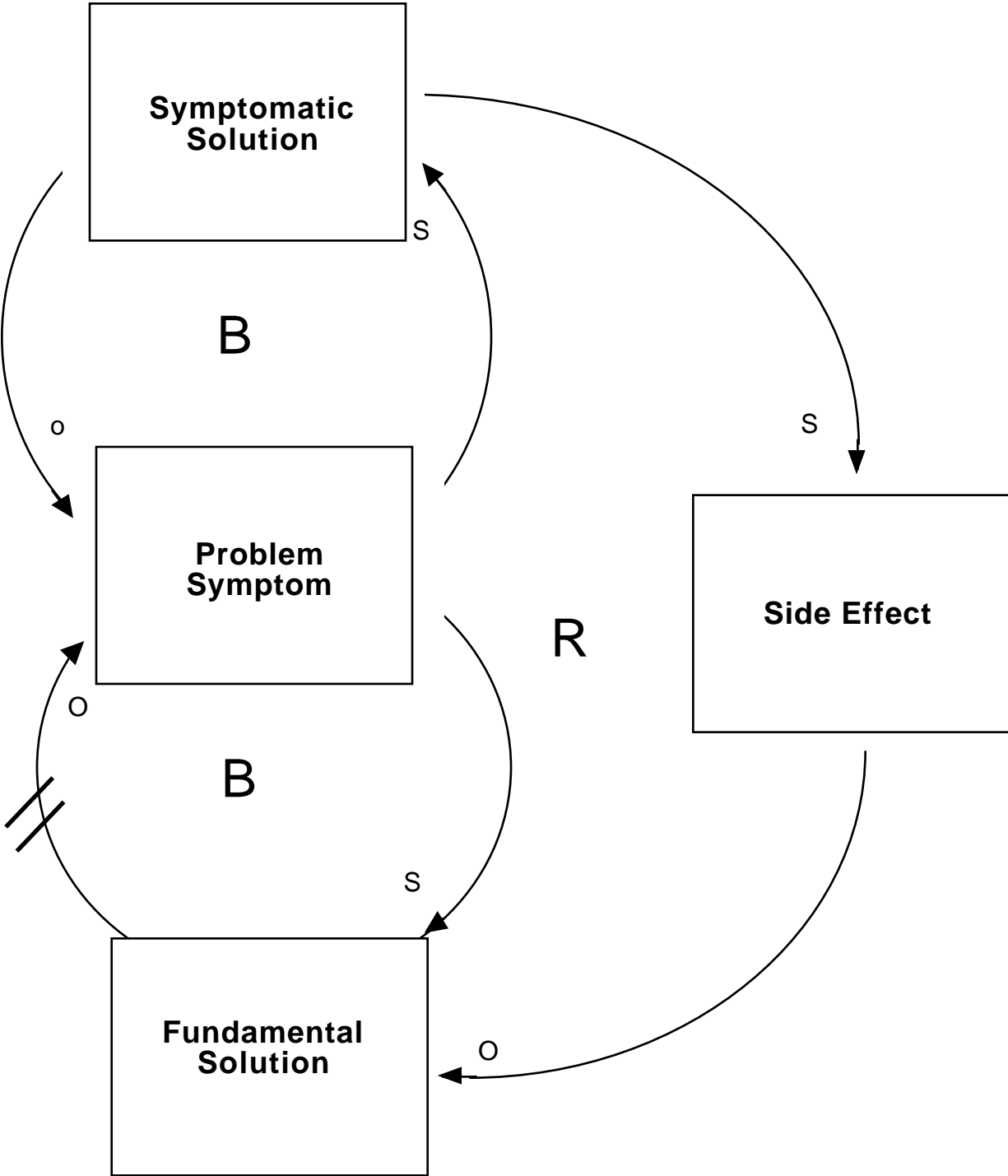


- Potential variables for CLDs are not always included within the scope of a given source.
Causality may be linear within the scope of the given source, but you might know of, or be able to hypothesize, information beyond the information supplied which might let you identify circular causality.

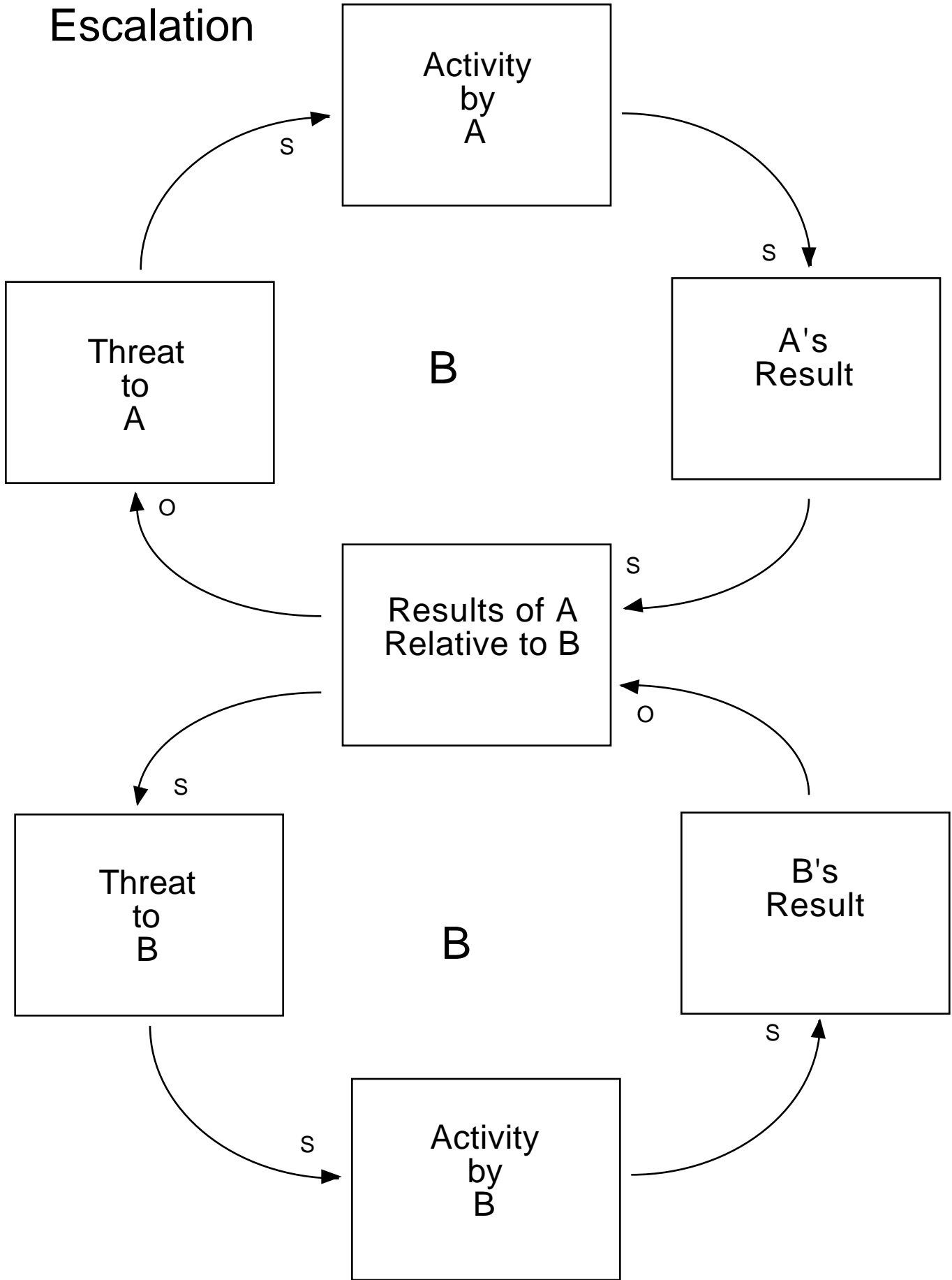
Fixes that Fail



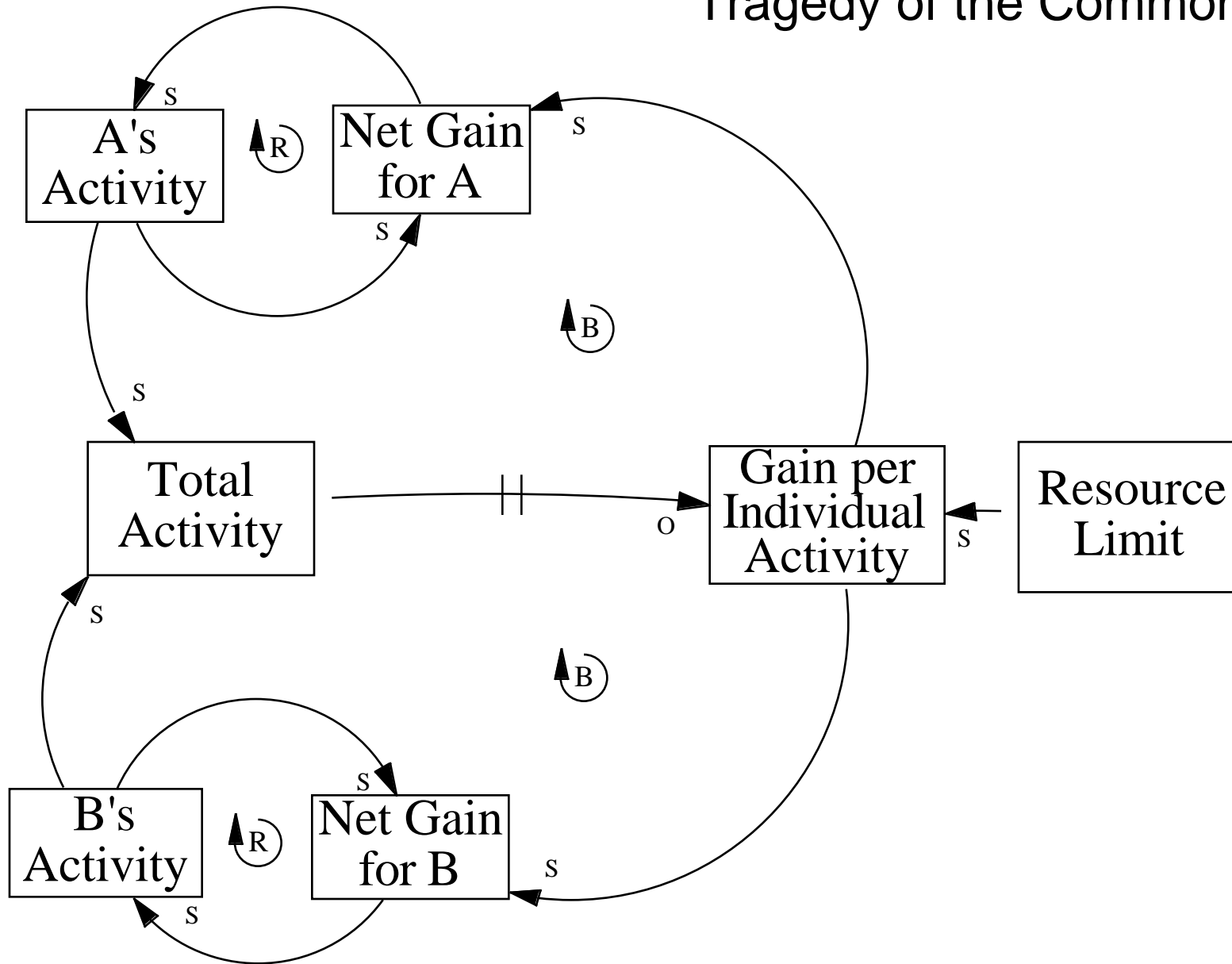
Shifting the Burden



Escalation



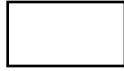
Tragedy of the Commons



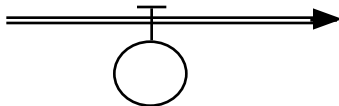
“Stocks and Flows”

STELLA Building Blocks

Definitions and Examples



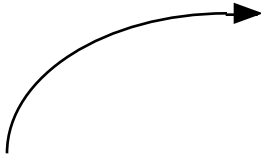
- **Stock** - An accumulation (physical or non-physical) that grows or decays over time. A “noun” in the system.
 - a) Water in the Bathtub
 - b) Money
 - c) Sick People
 - d) Radioactive Isotopes
 - e) Innocence



- **Flow** - An action, a process, or a decision that directly changes a stock. Flows can either be *inflows* or *outflows*. A “verb” in the system.
 - a) Faucet inflow/Draining
 - b) Depositing/Withdrawing
 - c) Infecting/Curing
 - d) Fusion/Decaying
 - e) Innocence increasing/Innocence decreasing*



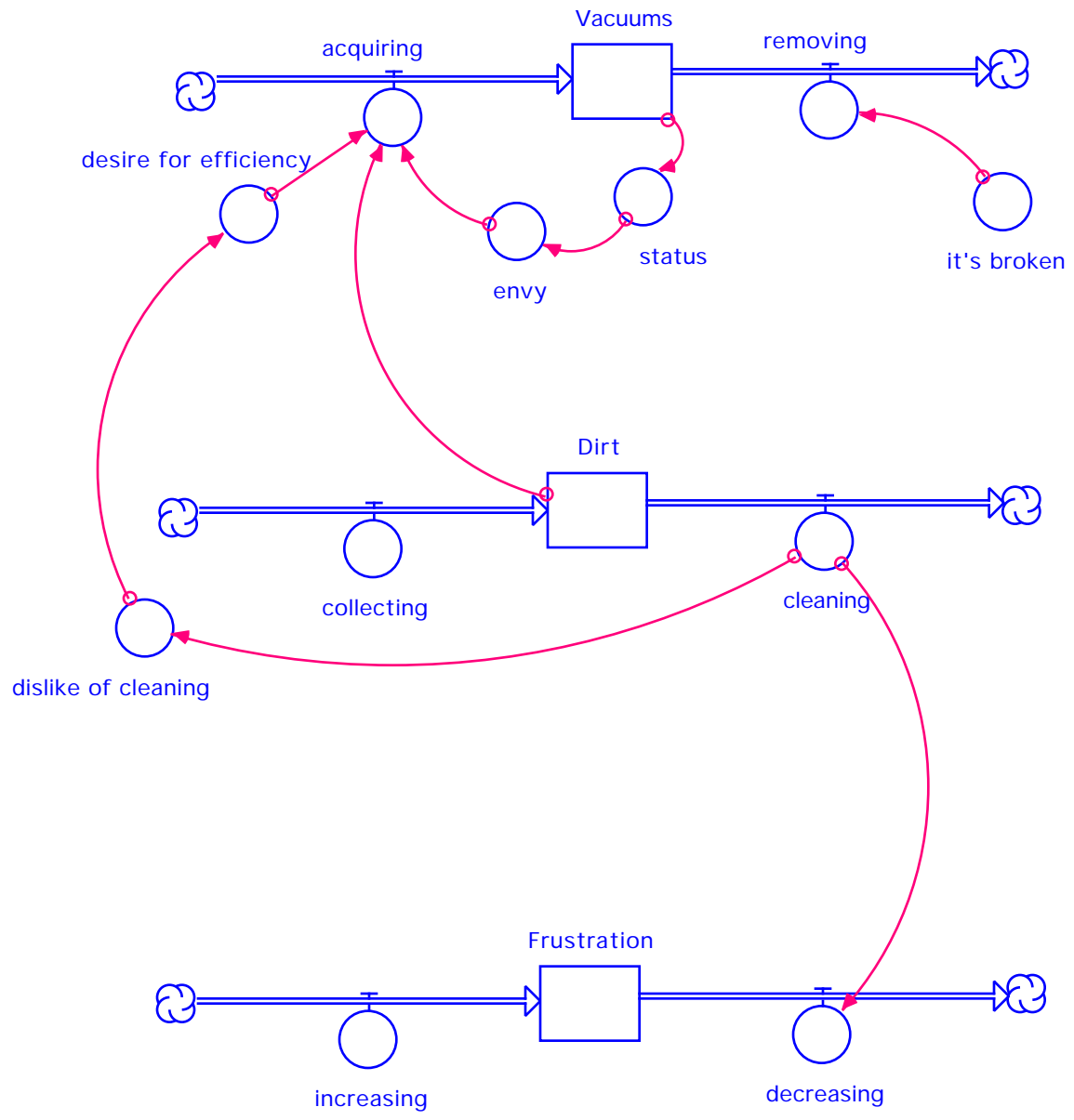
- **Converter** - Converters hold information or relationships that affect the rate of the flows or that affect the content of another converter.
 - a) Desired water level
 - b) Interest rate
 - c) Use of antibiotics
 - d) Rate of decay
 - e) Sordid life experiences



- **Connector** - Used to indicate that changes in one element cause changes in another element. *Never points to a stock* (only flows change stocks).

Tips

- The choice of a stock is an important part of the building of a model. Look for something that is measurable if you “stopped time.” For example, water in a bathtub would be measurable, but the rate of inflow from a faucet would not be measurable.
- When choosing a name for a STELLA element, look for something that can be measured at higher and lower values. Try to keep words like “more” and “less” out of the name. For example, “Level of Stress” is preferable to “More Stress.”



Tips for Stock/Flow Diagrams/Maps

1. **Stock/Flow Diagrams or Maps** show interdependencies and feedback within a system by identifying major accumulations and the factors that increase and decrease them over time.

2. Definitions:



• **stock**- represents an accumulation, concrete or abstract, that increases or decreases over time; the “noun(s)” in the system



• **flow**- represents actions or processes; transports “stuff”, concrete or abstract, that directly adds to or takes away from the accumulation in a stock; can be either an inflow or an outflow; the “verb(s)” in the system



• **converter**- holds information or relationships that affect the rate of the flows, or that affect the content of another converter



• **connector**- indicates that changes in one element cause changes in another element; only changes a stock by going through an accompanying flow

3. Depending on the group, you may want to explain and draw this “bathtub analogy” before mapping:

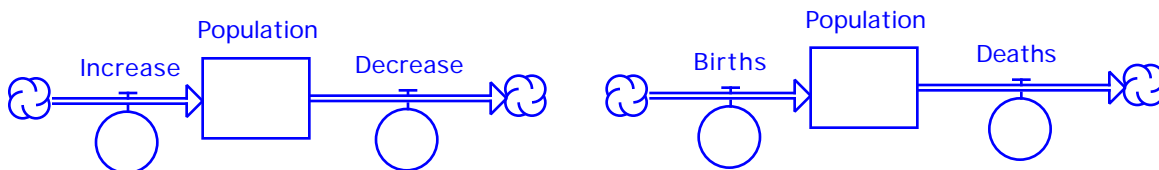
- a stock is like a bathtub which can be filled or drained
- an inflow is like a pipe that goes into the stock (tub) and fills it according to how much the spigot on the pipe (inflow) is opened/closed
- an outflow is like the drain that allows the accumulation to flow out according to how much the drain spigot (outflow) is opened/closed
- a converter is like a wrench that adjusts the spigot on a flow by way of the connector

4. For group mapping, you may choose to draw the map freehand and display it, or use the STELLA program and project it.

5a. One way to generate possible **stocks** to use in a map is to have the group create and discuss BOTGs from the article/story/information under consideration, then choose the BOTG(s) they wish to study as the stock(s) in the map (perhaps the most important accumulations). *

b. Another way is simply to choose the stocks you wish to emphasize ahead of time, making sure at some point to have the group create the BOTG that represents the trend of each stock’s accumulation/drain over time.

6. The **inflow** and **outflow** can be labeled simply as “Increase” and “Decrease” or as concrete or abstract “stuff” flowing into and/or out of the stock. The unit of measure used for the stock must also be used to measure the inflow and outflow. Remember: if you stop time in the system, nothing will remain in the flows, but the accumulation will remain in the stock.



7. **Converters** may be chosen from the remaining BOTGs generated in 5a above, or directly from the article/story/information. It is sometimes helpful to aggregate information in converters, e.g. tornado, fire, flooding, and earthquake could be aggregated in a converter labeled “natural disasters.”

8. A **connector** must point to the element that is being affected.

9. Once you have set up your stock(s), flows, converters, and connectors, make sure you look for the **feedback** that makes a system dynamic! Ask questions such as: Does the accumulation in the stock affect its inflow? outflow? converters? other stocks’ inflow/outflow/converters?

* When choosing a name for any element in a S/F map, try to keep words like “more” and “less” out of the name; e.g. “Level of Stress” is preferable to “More Stress”.