# Massachusetts Institute of Technology
# ESD.00 Introduction to Engineering Systems

## Spring, 2011

## Assignment # 2

Distributed: Lecture 2
Due: Lecture 4

This assignment aims to develop your systems thinking and modeling skills. Complex socio-technical systems exhibit behavior that usually cannot be determined through simple extrapolations of past experiences. There can be many feedback processes and delays that collectively produce often unexpected and counter-intuitive outcomes.  In order to better understand the behavior of such systems, it is useful to create explicit models that can clarify our understanding of the underlying causal structure, help in explaining observed behavior, and possibly aid in predicting future outcomes under various policies and actions.
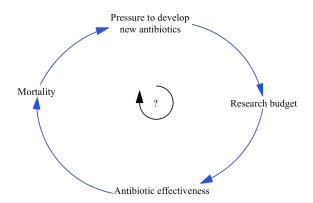
**A. Understanding Policy Resistance:**

For both A1 and A2, use of VenSim is not required. You may, if you wish, make the causal diagrams in neat and legible hand drawings.

A1. Evolution of anti-biotic resistance
Mortality resulting from bacterial infections increases pressure for developing new drugs. The new drugs are used effectively for sometime in fighting pathogen-induced mortality.

a) The diagram below shows a high-level, partial representation of the problem. Label the link polarities, and indicate the type of loop (reinforcing or balancing) that results. Give the loop a name.

b) Indicate any time delays on links you may think are needed. Briefly explain your reasons.

c) Consider the additional description of the problem:

Pathogens are not equally susceptible to any particular antibiotic. An increased use of the antibiotic leads to selective survival of pathogen strains that were immune or resistant to the drug. With ever expanding use of the drugs, the susceptibility of humans increases to the drug-resistant strains and the effectiveness of the antibiotic declines.

Another cause for evolution of resistant strains has been the improper use of antibiotics. Many people do not follow the proper protocol and do not finish the entire course of treatment. By stopping the treatment early (before all the bacteria are killed in the body), the chances of resistant strains surviving are increased which can then be communicated to other people and hence allow for propagation of such strains. The end result is again a reduction in the effectiveness of the antibiotics.

Augment the CLD shown in part (a) with the following four variables:

1. Use of antibiotics
2. Emergence of resistant strains
3. Compliance of antibiotic protocol
4. Opportunity for resistance to develop

Use variables 1 and 2 in one loop, and 3 and 4 in another loop. Name each loop, and label each polarity. If you wish, you may include another two or three additional variables (but no more) in your CLD.


A2. AYCE dining and Nutritious eating

The MIT Dining system is undergoing changes that include new meal plans, with revised prices, options and rules. The new system will include pre-paid, All-You-Care to-Eat (AYCE) dining at a few undergraduate dorms. One important issue that has been discussed regarding the new AYCE program is its effects on nutritious eating. There are differing thoughts on how AYCE may actually affect food choices by students. There are two excerpts included below. Read the two viewpoints carefully, and construct a causal loop diagram that describes this issue.

**Viewpoint #1:**
"Approximately 75 percent of undergraduates want MIT to offer some dining plan configuration with AYCE meals. Certain students, such as athletes, may find this option especially appealing. And, according to surveys, undergraduates would eat a broader variety of foods if AYCE were available.

A brief AYCE pilot study in Simmons Hall bears out this assertion. During the pilot, Simmons residents drank five times more milk and twice as much juice and ate considerably more fruits and vegetables than they did with a la carte service. Better still, AYCE creates a demand for a more balanced variety of foods without significantly increasing costs."

**Viewpoint #2:**
"Prepaid all-you-can-eat (AYCE) dining is required to ensure student nutrition. HDAG [House Dining Advisory Group] fails to realize that AYCE dining makes students eat whatever they want, not what is healthy. HDAG's favorite statistic, a statistic they love to repeat to end discussion, is that during an AYCE dinner trial in Simmons students got several times more milk and twice as much juice than normal. But this ignores the bigger picture. With a la carte dining, students often get free water with their dinner. On the other hand, with AYCE dining, students will get juice and soda and pile desserts on their plate. One of the unhealthiest meals I have eaten was at an AYCE dining hall, because I took everything that looked tasty."

First, make a diagram that depicts the first viewpoint, i.e. how the system is expected to work as envisioned by the first viewpoint. Then augment the diagram to include the second viewpoint of what may happen.

Make sure you:

1. Identify key variables
2. Identify how they are related (think through cause-effect etc.)
3. Create map of interactions (i.e. a CLD), label polarities etc.
4. What policy/action would you recommend to ensure that effects as described in opinion #2 are reduced? Indicate how your recommendation would work in the CLD.
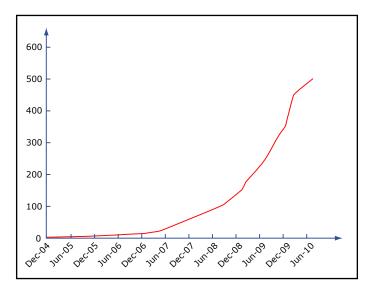
## B. Exponential Growth

Exponential growth describes a wide variety of systems around us. Ranging from populations and economies (social systems), to microprocessor performance (technical systems), one can use the exponential function to describe their growth dynamics.

Facebook users have been growing rapidly since its inception in 2004. In July 2010, the user base reportedly surpassed 500 million. The figure below shows one account of the number of users of Facebook over the years. Assume that the number of users, $U(t)$, can be described as an exponential function: $U(t) = U_o \exp(gt)$, where $U_o$ is the initial number of users and $g$ is the fractional growth rate.

i) Estimate the average doubling time $t_d$. (Hint: do this approximately by inspection of the tabular data).

ii) If we assume $U_0$ = 1 million users, and a fractional growth rate of 1.14 [1/yr], when will there be a billion users?

iii) What factors may limit growth? Discuss briefly.



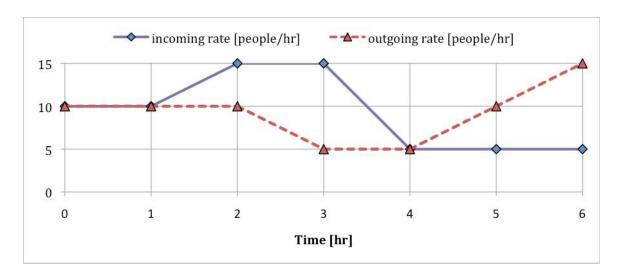| Year | Million Users (U) |
|---|---|
| Dec-04 | 1.0 |
| Dec-05 | 5.5 |
| Dec-06 | 12.0 |
| Dec-07 | 55.0 |
| Dec-08 | 110.0 |
| Dec-09 | 350.0 |

Image by MIT OpenCourseWare.

## C. Stocks and Flows: Graphical Integration

Consider a hospital waiting room, where incoming (non-emergency related) patients arrive. As the patients arrive (with some 'incoming rate'), they have to wait until the hospital staff attends to them. Each patient is then sent off for further procedures as necessary. The rate at which the patients are attended to (and thus leave the waiting room) is the 'out-going rate'. We can model the system as a simple stock and flow structure:



Image by MIT OpenCourseWare.

Consider the scenario as described in the figure below:

Assume the initial number of waiting patients (at time 0) is 5. Without using a computer, answer the following:

i)  What is the highest number of patients in the room at any point in time? When does the highest number of waiting patients occur? Assume that you can treat number of people as continuous (rather than discrete).

ii) Suppose that the number of hospital staff, **s**, that attends to the patients depends on the patients in the room. If the number of patients increase, more staff is called in to attend to them in order to increase the 'out-going rate'. The staff members have productivity, **e**, at which they process waiting patients. The units of **e** are # of patients processed/staff member per hour. Assume that there are no delays. Expand the stock-flow structure above to include **s**, and **e,** and show how they are connected.

iii) Write an equation that describes your stock-flow diagram. Denote the number of patients as **P(t)**, incoming rate with **I(t),** outgoing rate with **O(t).** Assume that you can treat number of people as a continuous variable (rather than discrete). You do not need to solve the equation.

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