Students in High School Algebra Build Pharmacokinetic Models Using System Dynamics

Diana Fisher, Ph.D.
System Science
Portland State University
fisherd@pdx.edu

Innovations in Collaborative Modeling Conference, MSU 2016

CC MODELING SYSTEMS

Definition of a System

A system is a set of things - people, cells, molecules, or whatever - interconnected in such a way that they produce their own pattern of behavior over time.

A system must consist of three kinds of things: *elements*, *interconnections*, and a *function* or *purpose*.

Donella Meadows

The purpose of most system dynamics studies is <u>insight</u>. The overarching goal is insight into the connections between system structure and system behavior captured in graphs of dynamic patterns over time.
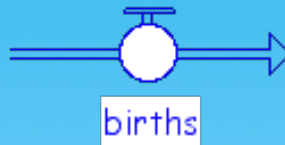
George Richardson

The Software: STELLA

Stock

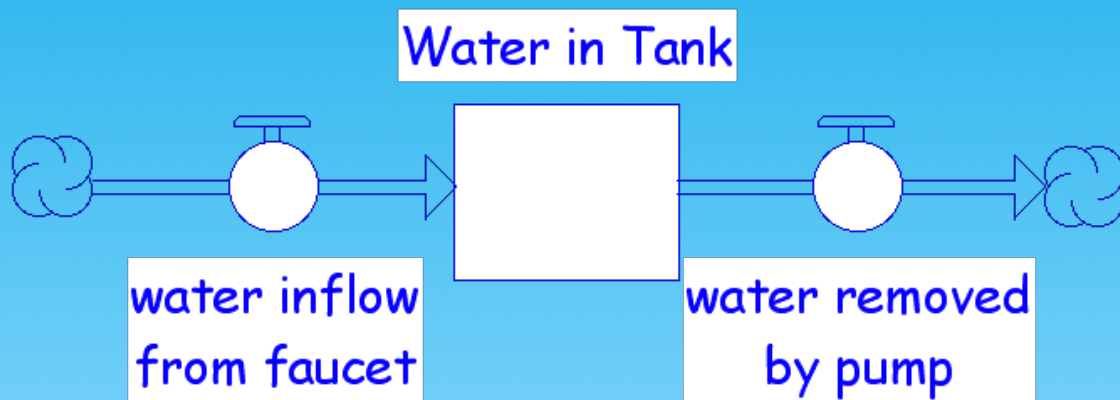Population

Flow

births

Converter

birth fraction

Connector

Example of Simple Model

Water in Tank

water inflow
from faucet

water removed
by pump

Linear Growth Model

Constant inflow

Money in Shoebox

deposits per month

Exponential Growth Model

Money in Bank

interest added
per year

interest
rate

Inflow is proportional to current amount of the stock value
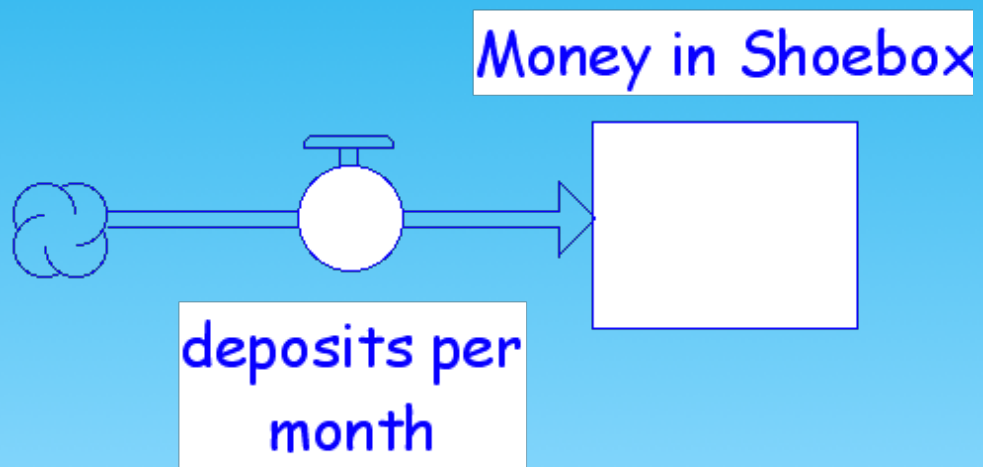
Drug Model 1

Emergency Room Problem
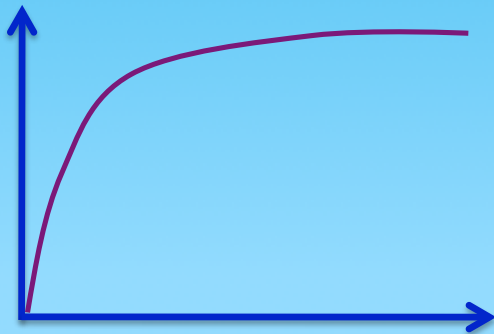
You are a medical resident (doctor) working in the emergency room and a patient comes in who needs immediate medical attention.

From your analysis you decide to connect this patient to an IV drip that will supply 1 g of therapeutic drug per minute.

This person, you estimate will metabolize the drug at about 0.55% per minute.

What is the pattern of drug level in the body over 24 hours?

Predicting the Behavior

Drug in the Body

drug infused
with IV drip
per minute

drug lost
per minute

decay rate

CC MODELING SYSTEMS
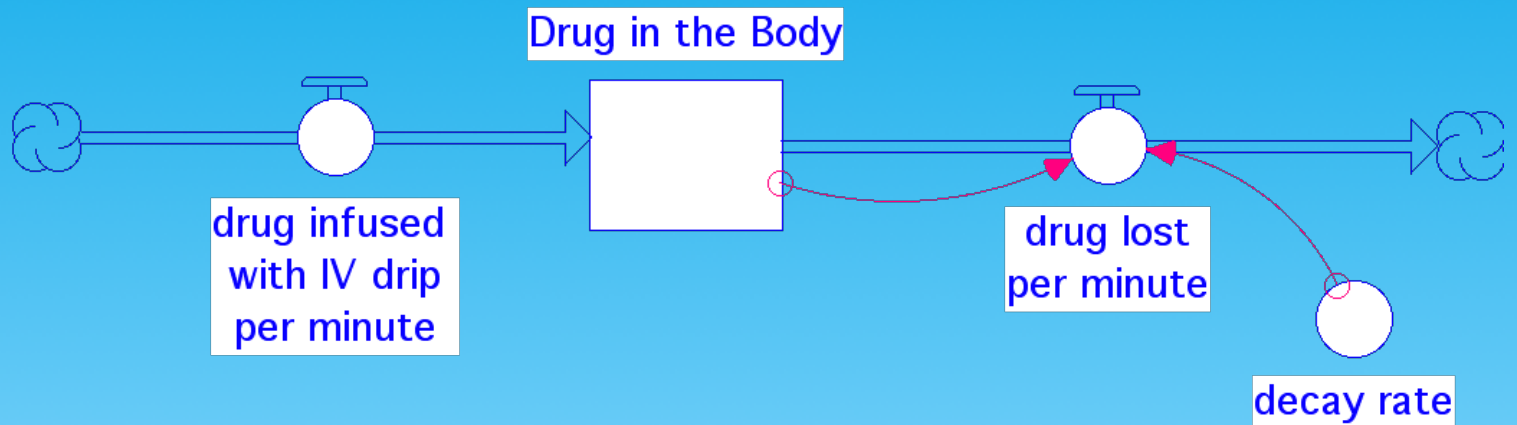
Drug Model 2

Emergency Room Problem

You are a still working in the emergency room.

A second patient arrives and you decide to give this patient a shot containing 500 mg of a therapeutic drug every 4 hours.

This person, you estimate will metabolize the drug at about 0.5% per minute.

What is the pattern of drug level in the body over 24 hours?

The Stock/Flow Diagram

Drug in the Body

giving drug
in shots

drug lost
per minute

decay rate
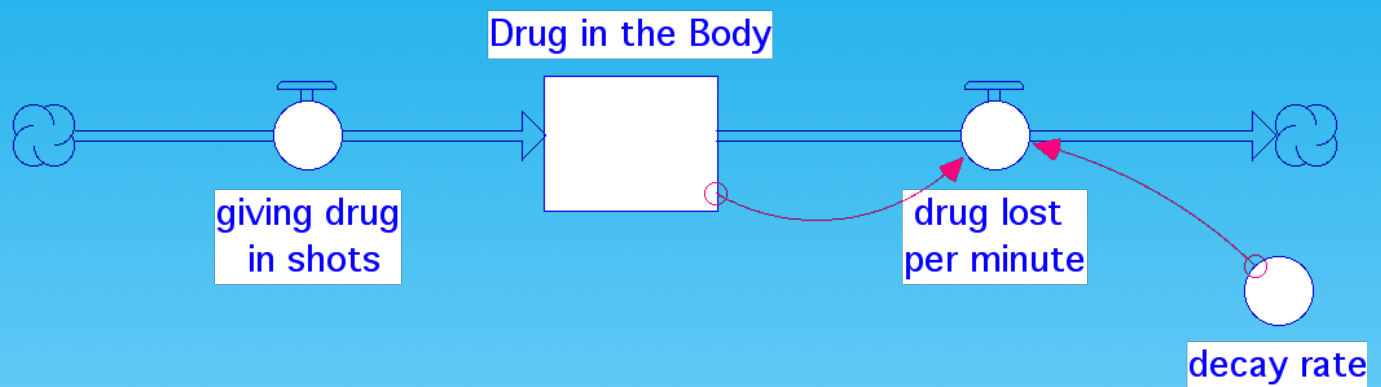
The Simulation Results

Drug in the Body

giving drug in shots

drug lost per minute

decay rate

TLmax

TLmin

Drug Model 3

Emergency Room Problem

It is a busy night in the emergency room.

A third patient arrives and you decide to give this patient 2 pills of 375 mg (each) of a therapeutic drug and tell them to continue taking 2 more every 4 hours.

This person, you estimate will absorb the drug from the stomach to the bloodstream at about 4.5% and metabolize the drug at about 0.55% per minute.
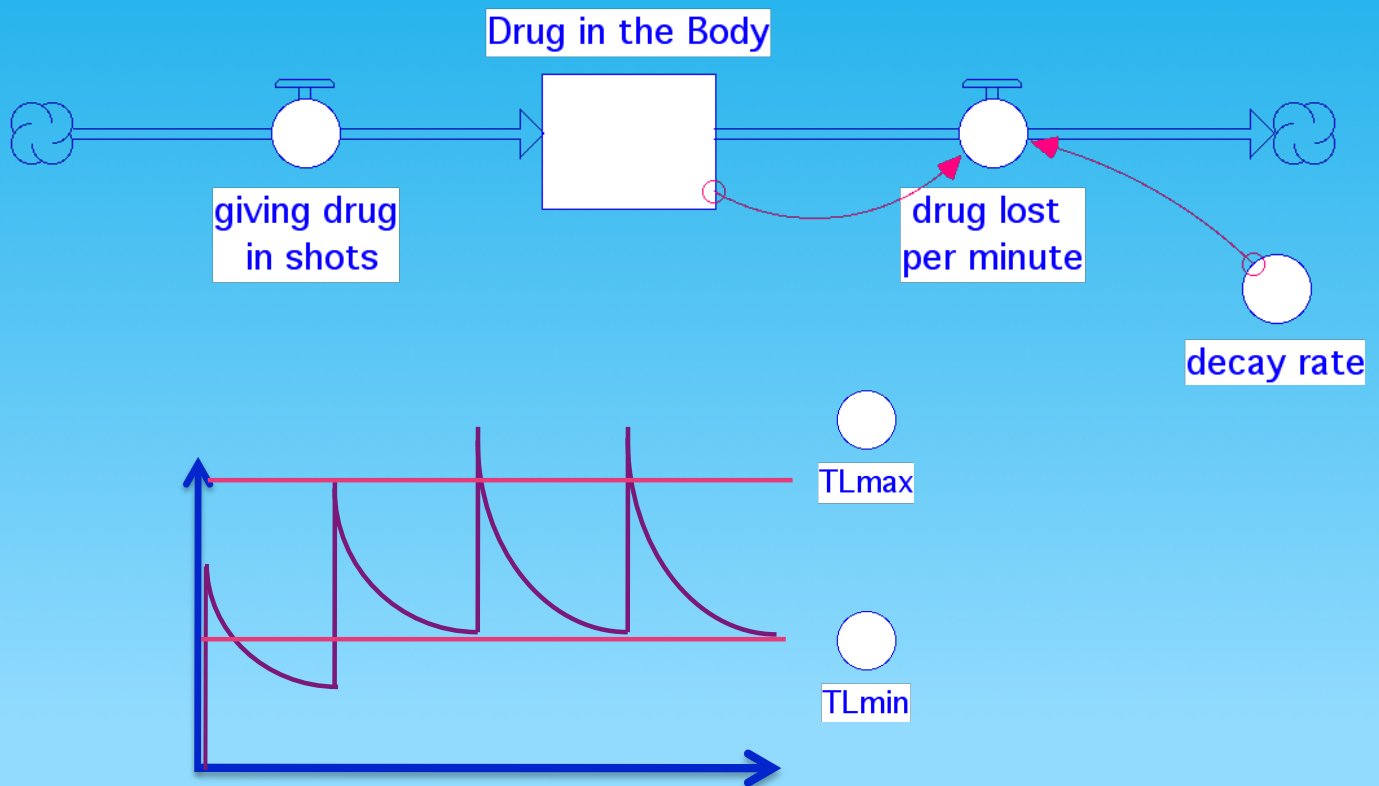
What is the pattern of drug level in the body over 24 hours?

The Stock/Flow Diagram

Drug in the
Stomach

Drug in the
Bloodstream

taking
pills

drug absorption
per minute

drug elimination
per minute

absorption
rate

elimination
rate
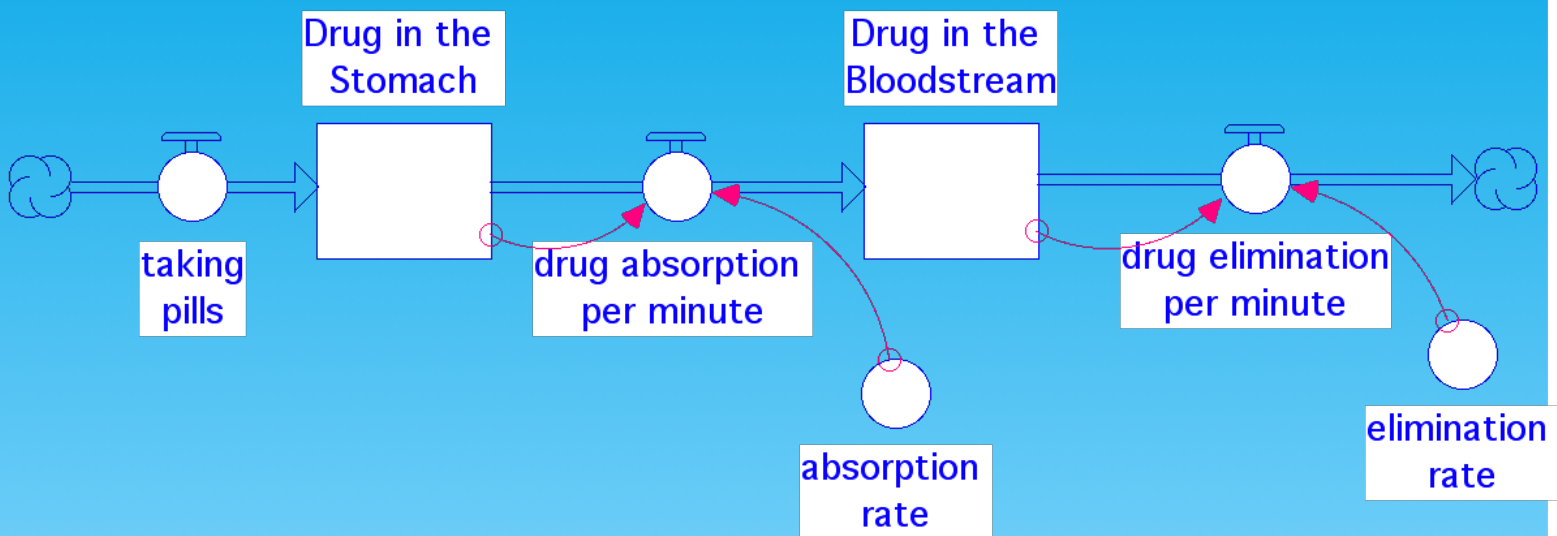
Drug Model 4

The Situation

We will consider the level of blood alcohol concentration in an adult male of about 150 pounds who has consumed six 12 ounce beers in two hours.

We will then use this model to experiment with other scenarios:

- different body weights
- different types of alcohol
- whether the drinker has food in his stomach
- male versus female drinker
- social drinker versus an alcoholic

More Details

Since the alcohol will enter the stomach and then be absorbed into the bloodstream, we will use the basic two compartment structure of drug model 3 as our starting point.

We will assume the person who is consuming the alcohol will be sipping the alcohol at a slow steady pace for two hours, so the inflow will be constant, and turned off after two hours.

The normal absorption rate will be about 7% per minute. The normal elimination rate will be 0.6% per minute.

The Starting Stock/Flow Diagram

Alcohol
in Stomach

Alcohol in
Rest of the Body

drinking alcohol

amt absorbed
per minute

amt eliminated
per minute

elimination
rate

absorption rate
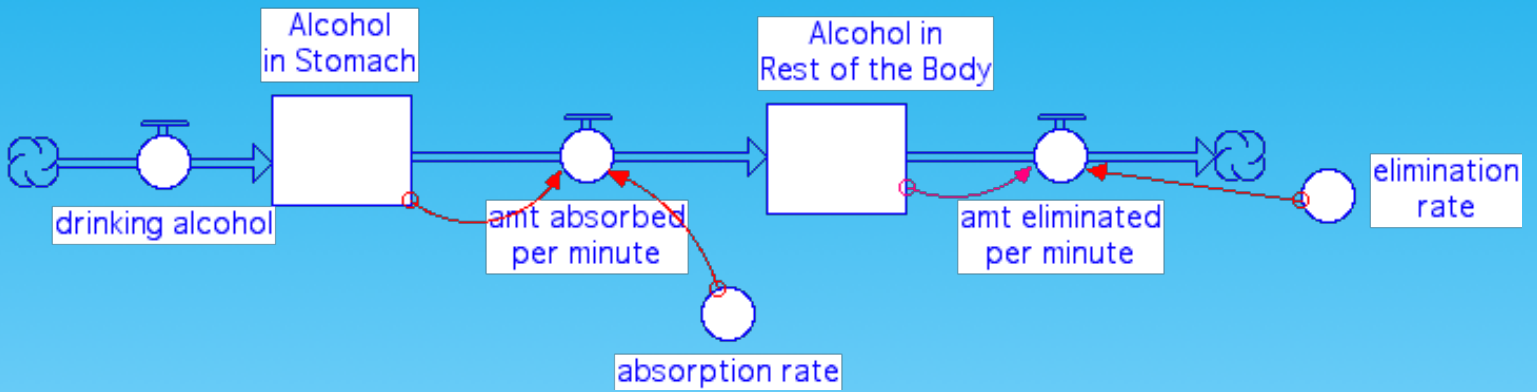
The Starting Behavior of the Stocks
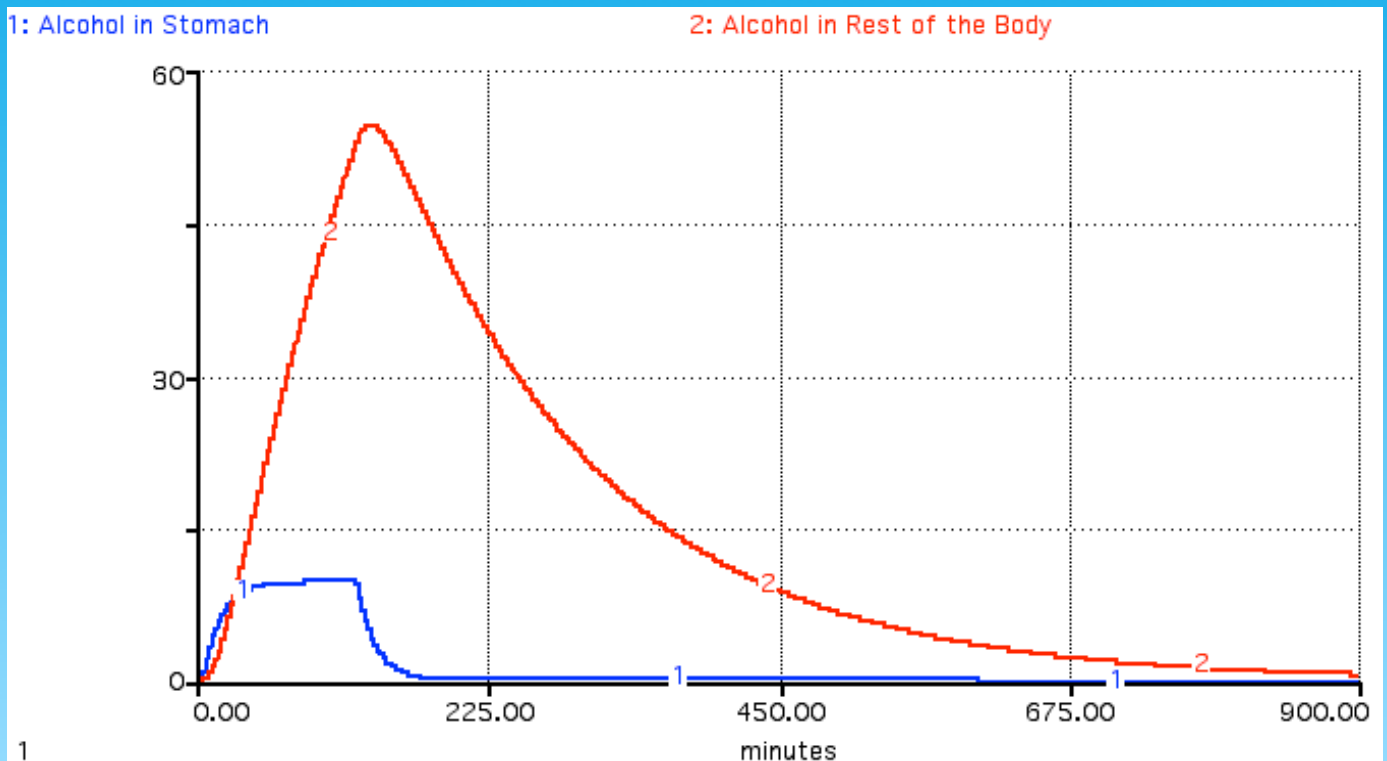
More Accurate Model Produces Much More Accurate Behavior
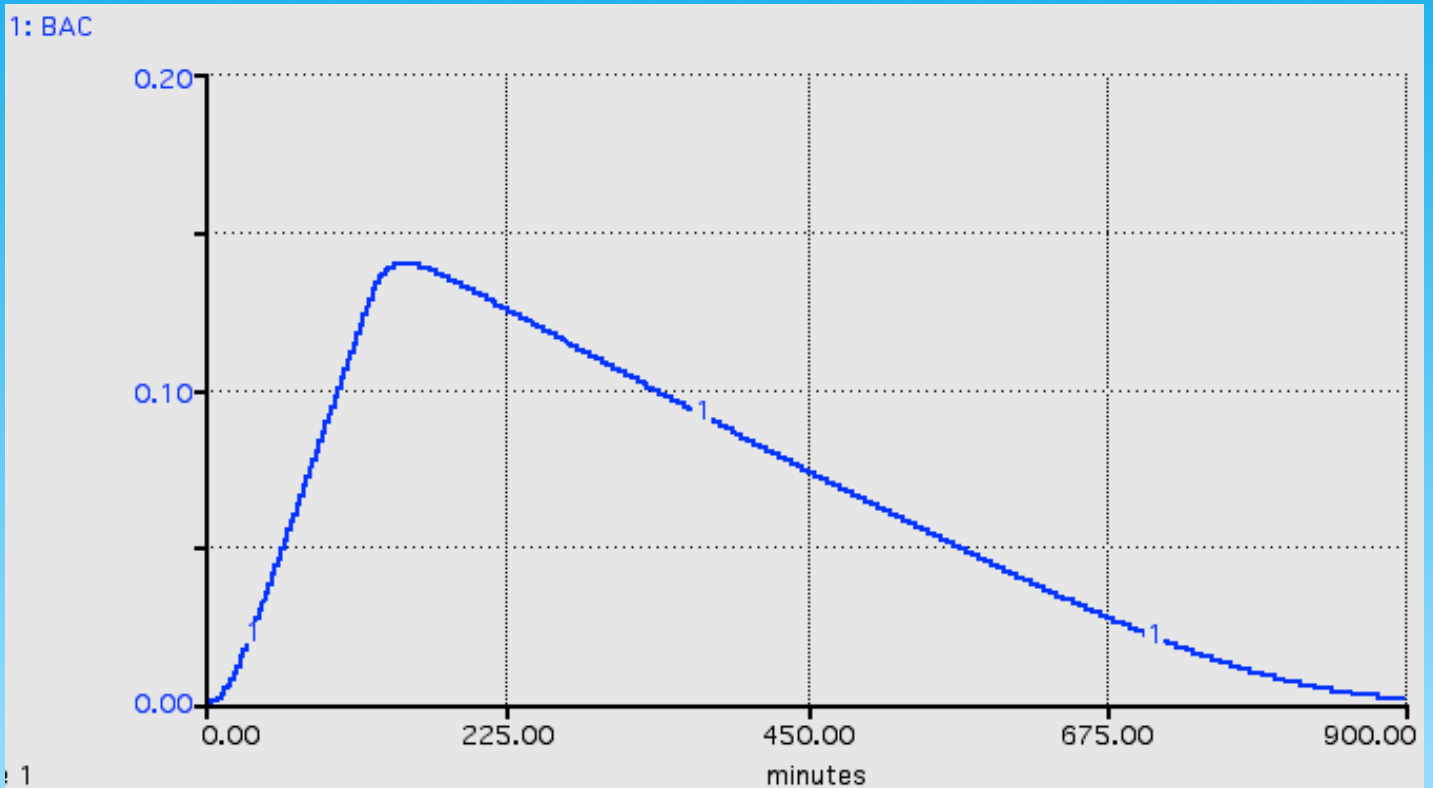
Resources

1. Online Courses in STELLA Modeling

    www.ccmodelingsystems.com

2. STELLA Software

    www.iseesystems.com

    Books of Lessons: www.iseesystems.com/store/k12.aspx

3. Creative Learning Exchange

    www.clexchange.org

4. Contact: Diana Fisher

    fisherd@pdx.edu

Thank You

Extra

A Year-Long
System Dynamics Modeling Course
for Students Grades 9 - 12

Prepare students to identify and analyze problems in the world from which they can gain understanding by building and analyzing System Dynamics models.

Develop skill in model building, in analyzing model design and output/feedback, and in explaining what they learn.

(Course taught for 20 years to students grades 9-12.)

A Few of the

Original SD Models Produced

by High School Students

www.ccmodelingsystems.com

Hybrid Cars

age 18

Diagram labels:

- Desired Production
- Shipping Time
- Hybrid Production
- Hybrid Inventory
- Active Hybrid Vehicles
- Actual Production
- Supplying
- Order Fulfillment
- Becoming Obsolete
- Normal Hybrid Inventory
- Ideal Utilization
- Actual Lifespan of Factory
- Gap Between Inventory Order Fulfillment
- Average LIfespan of Car
- Effect of Ratio of Actual Production to Capacity on Factory Life
- Effect of Inventory Ratio on Desired Production
- Target Delivery Time
- Desired Shipment Rate
- Normal LIfespan of Factory
- Unmet Demand
- Time to Construct
- Constructed Capital
- Production Capacity
- Closing
- Hybrid Demand Backlog
- Fulfilling Demand
- Constructing
- Startup
- Desired Production
- New Demand
- Normal Oil Price
- Normal Rate of Construction
- Time to Startup
- Effect of Capcity Availability on Closures
- Effect of Oil Price on Demand
- Change
- Effect of Capacity Availability on Construction Starts
- Ratio of Desired Production to Capacity
- Desired Production
- Normal Customer Order Rate
- Price of Oil
- Real and Perceived Availability Gap
- Ideal Utilization
- Effect of Price on Desired Production
- Changing Oil Price
- Perceived Backlog of Hybirds
- Effect of Price on Demand
- Actual Customer Order Rate
- Effect of Perceived Backlog on Demand
- Change in Perception
- Ratio of Actual to Normal Price
- Normal Backlog
- Effect of Backlog on Price
- Delay in Availability Perception
- Price of Hybrid
- Normal Price of Hybrid

CC MODELING SYSTEMS

www.ccmodelingsystems.com

Hybrid Cars

age 18

Hybrid Cars

Shipping Time

Desired Production

Active Hybrid Vehicles

Actual Production

Order Fulfillment

Becoming Obsolete

Supplying

Normal Hybrid Inventory

Order Fulfillment

Average Lifespan of Car

Ideal Utilization

Actual Lifespan of Factory

Effect of Inventory Ratio on Desired Production

Gap Between Inventory Order Fulfillment

Target Delivery Time

Factory Capacity

Effect of Ratio of Actual Production to Capacity on Factory Life

Normal Lifespan of Factory

Unmet Demand

Desired Shipment Rate

Time to Construct

Constructing

Closing

Hybrid Demand Backlog

Fulfilling Demand

Normal Rate of Construction

Effect of Capacity Availability on Closures

Backlog and Perceived Backlog

Desired Production

Effect of Capacity Availability on Construction Starts

Ratio of Desired Production to Capacity

Normal Customer Order Rate

Real and Perceived Availability Gap

Ideal Utilization

Effect of Price on Desired Production

Effect of Price on Demand

Actual Customer Order Rate

Effect of Perceived Backlog on Demand

Perceived Backlog of Hybirds

Change in Perception

Normal Backlog

Effect of Backlog on Price

Ratio of Actual to Normal Price

Delay in Availability Perception

Price of Hybrid

Normal Price of Hybrid

CC MODELING SYSTEMS

www.ccmodelingsystems.com

Workforce Pressure

age 18

Workforce Pressure

age 18

Cervical Cancer

ages 16

www.ccmodelingsystems.com
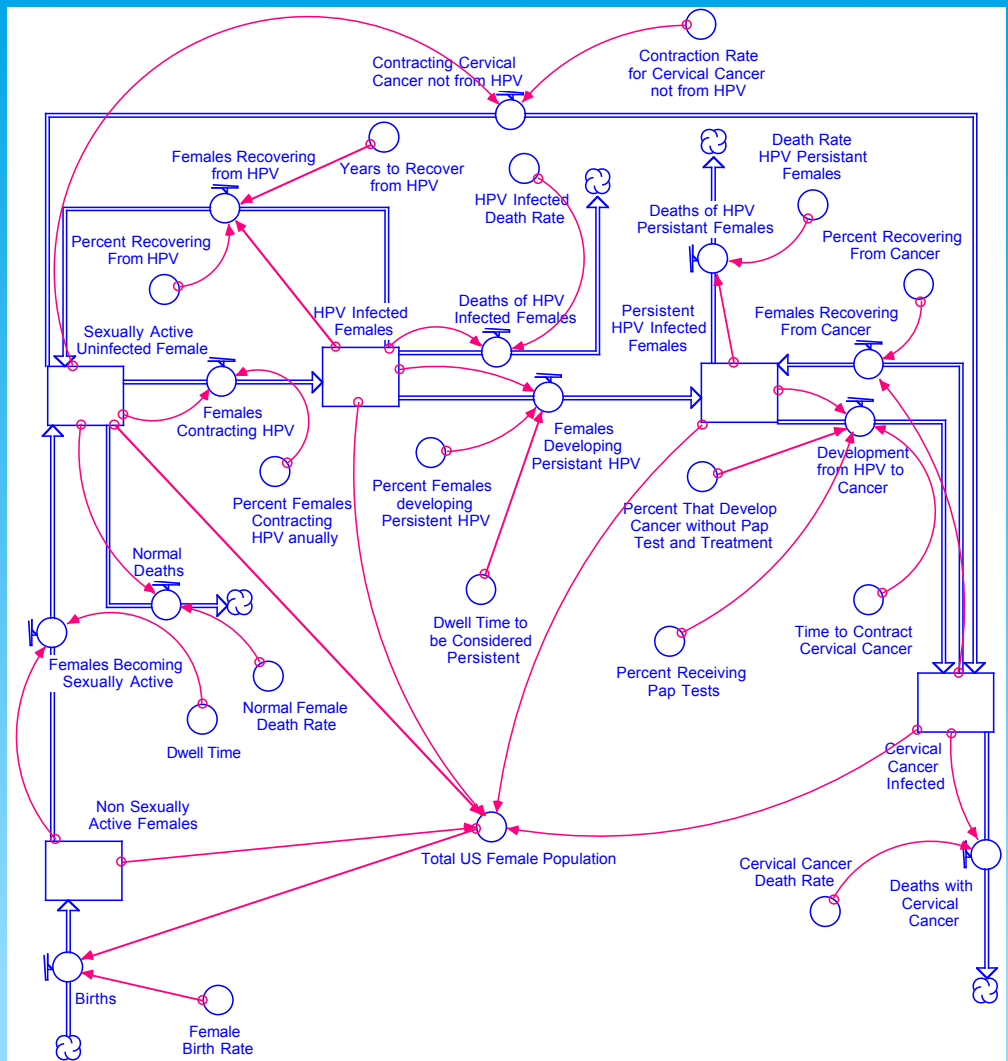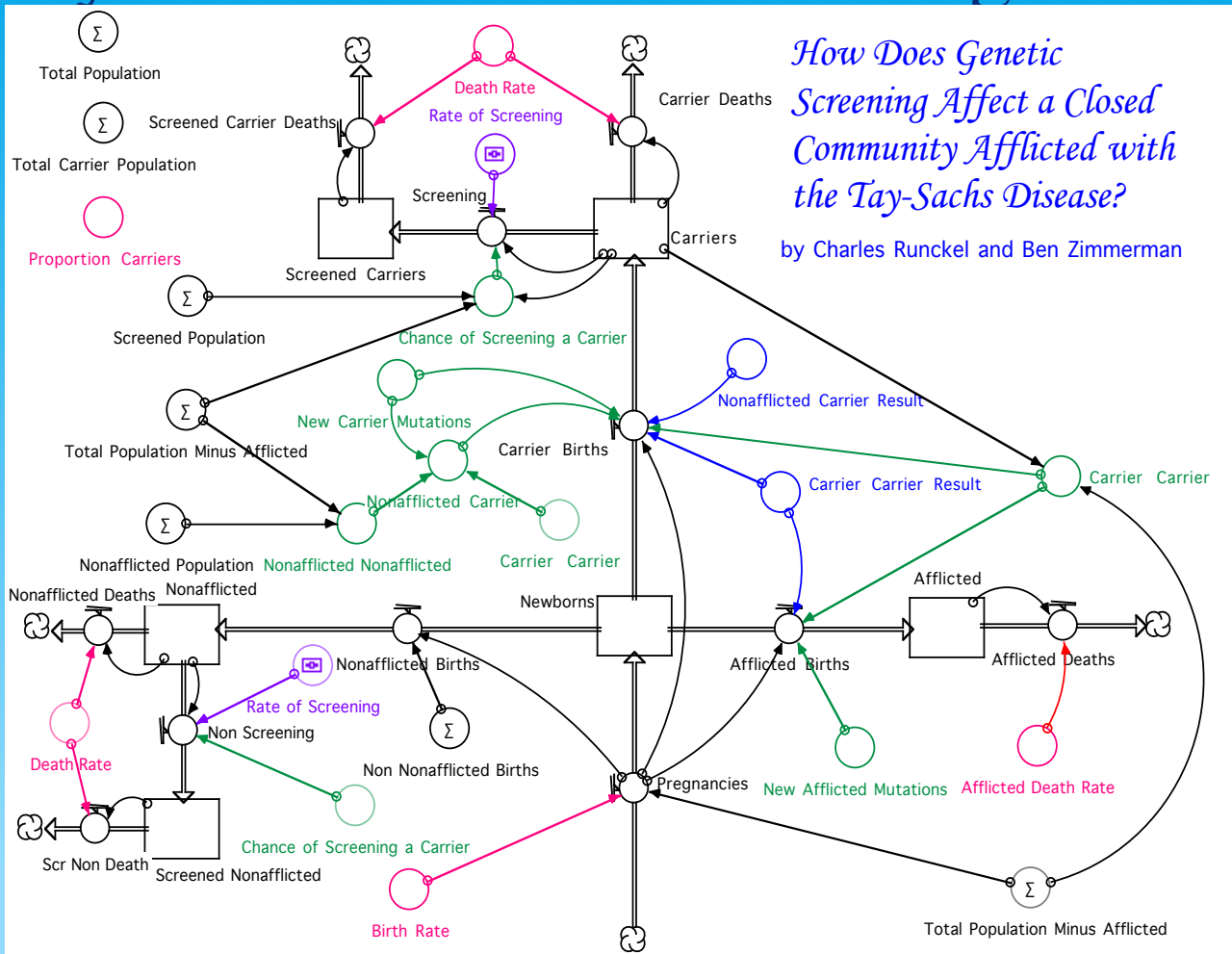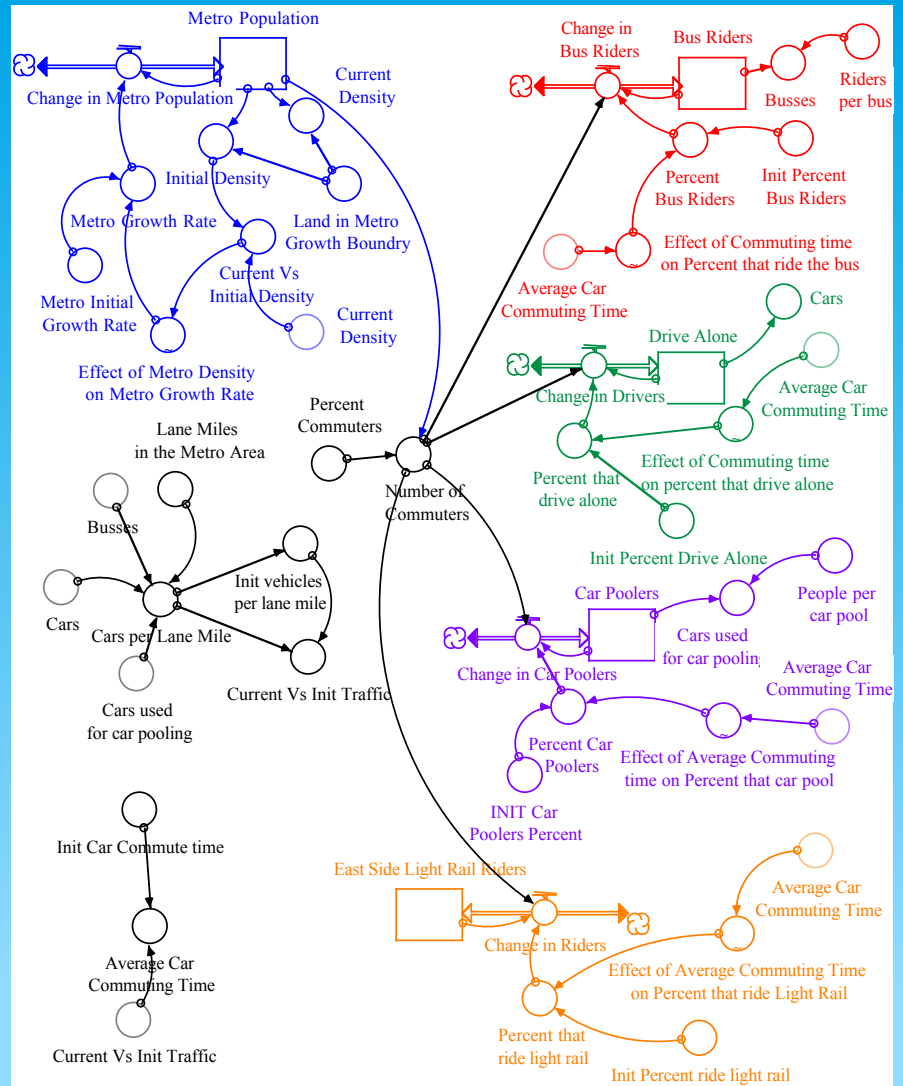
Tay-Sachs Genetic Screening

How Does Genetic Screening Affect a Closed Community Afflicted with the Tay-Sachs Disease?

by Charles Runckel and Ben Zimmerman

ages 16

Total Population

Screened Carrier Deaths

Total Carrier Population

Proportion Carriers

Death Rate
Rate of Screening

Carrier Deaths

Screening

Screened Carriers

Carriers

Screened Population

Chance of Screening a Carrier

New Carrier Mutations

Carrier Births

Nonafflicted Carrier Result

Carrier Carrier Result

Carrier Carrier

Total Population Minus Afflicted

Nonafflicted Carrier

Nonafflicted Population   Nonafflicted Nonafflicted

Carrier Carrier

Afflicted

Nonafflicted Deaths   Nonafflicted

Newborns

Afflicted Births

Afflicted Deaths

Death Rate

Rate of Screening

Nonafflicted Births

Non Screening

Non Nonafflicted Births

New Afflicted Mutations

Afflicted Death Rate

Scr Non Death

Screened Nonafflicted

Chance of Screening a Carrier

Pregnancies

Total Population Minus Afflicted

Birth Rate

Portland Traffic

ages 15

Resources

Some Student Work

Model Diagrams, Papers, Some Video Presentations

http://www.ccmodelingsystems.com/student-projects-highlights.html

http://www.ccmodelingsystems.com/student-projects-videos.html

http://www.ccmodelingsystems.com/student-projects-other.html