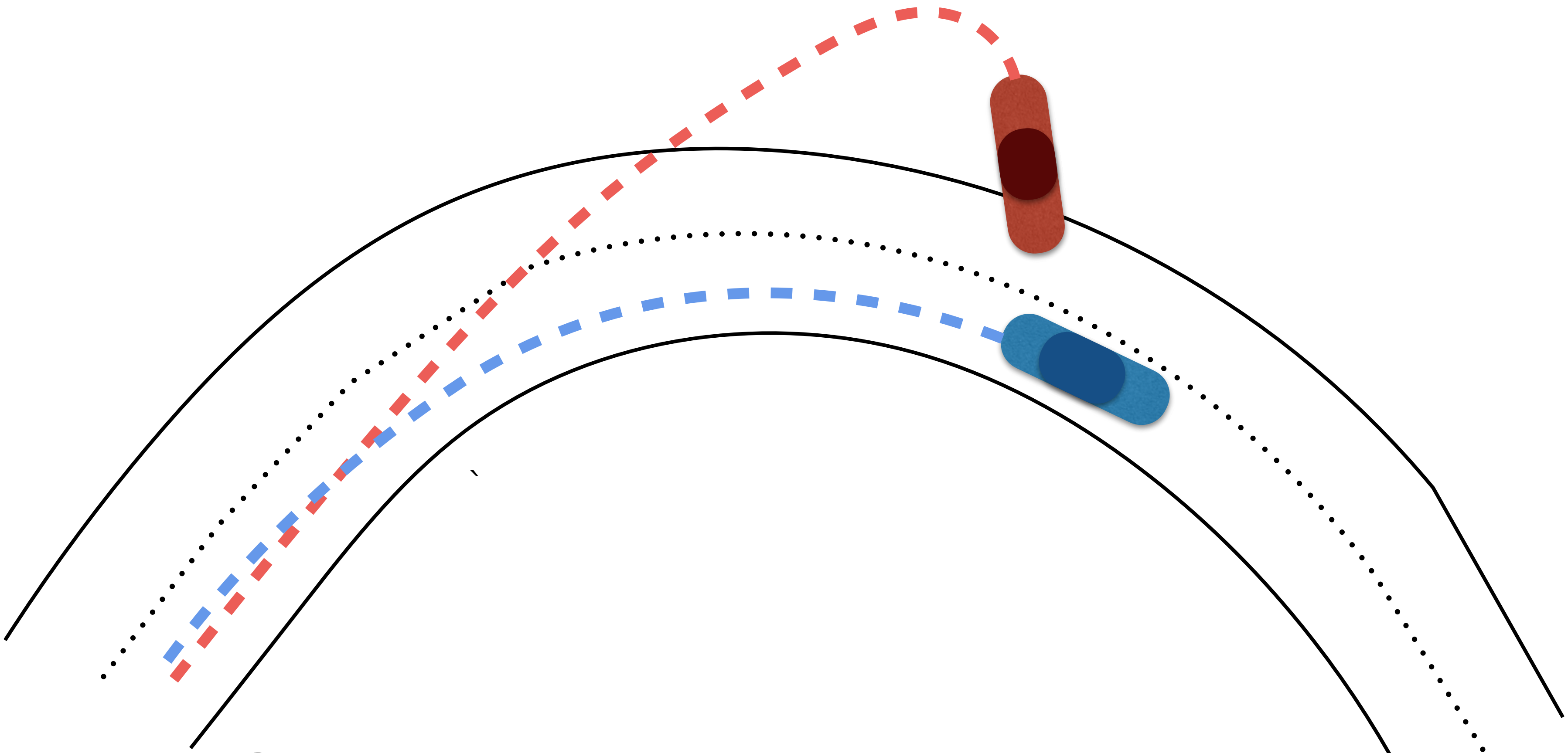
Human Population
2018

Lecture 2
Overshoot

Are we in overshoot?

Read todays questions.......
pp 1-16
Overshoot

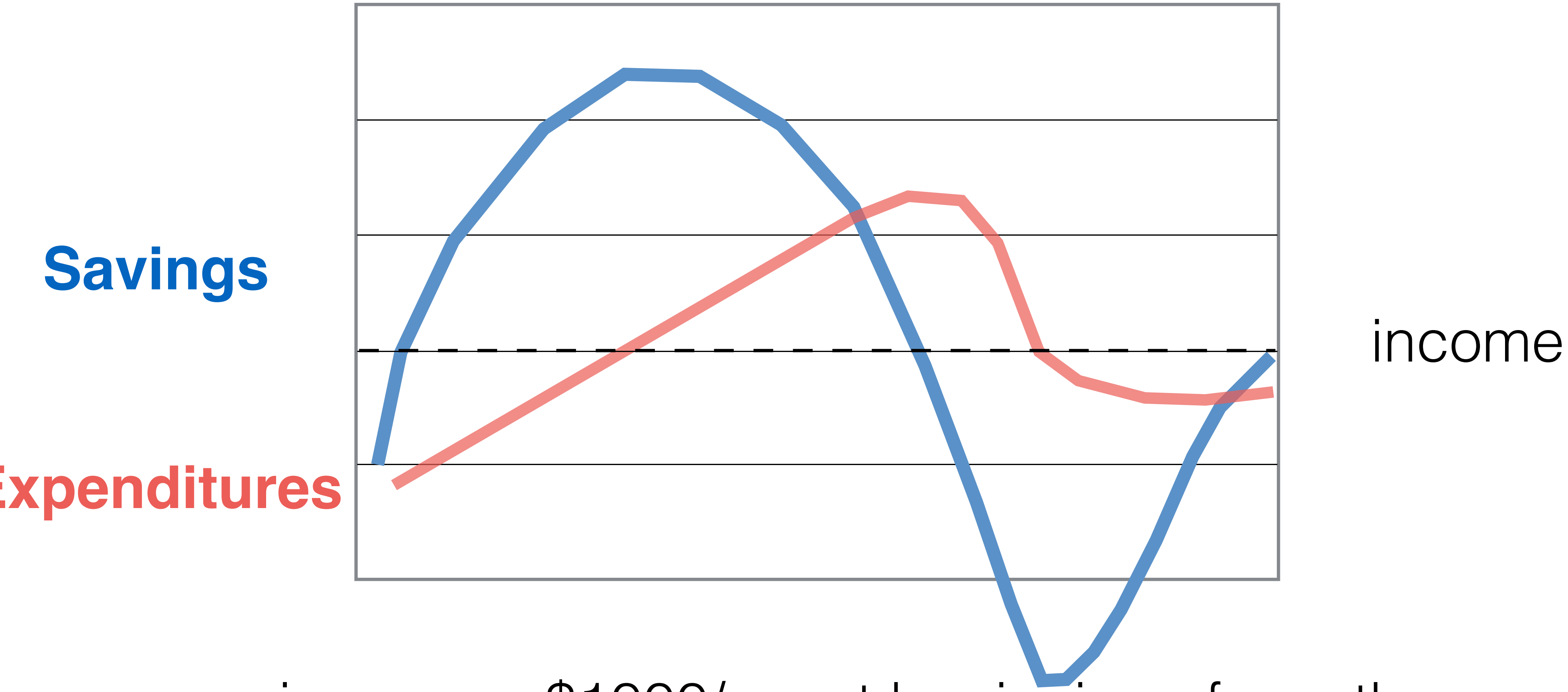
Overshooting a turn



Cause: curve + momentum + delay

Consequence: loses race

Overshooting a budget

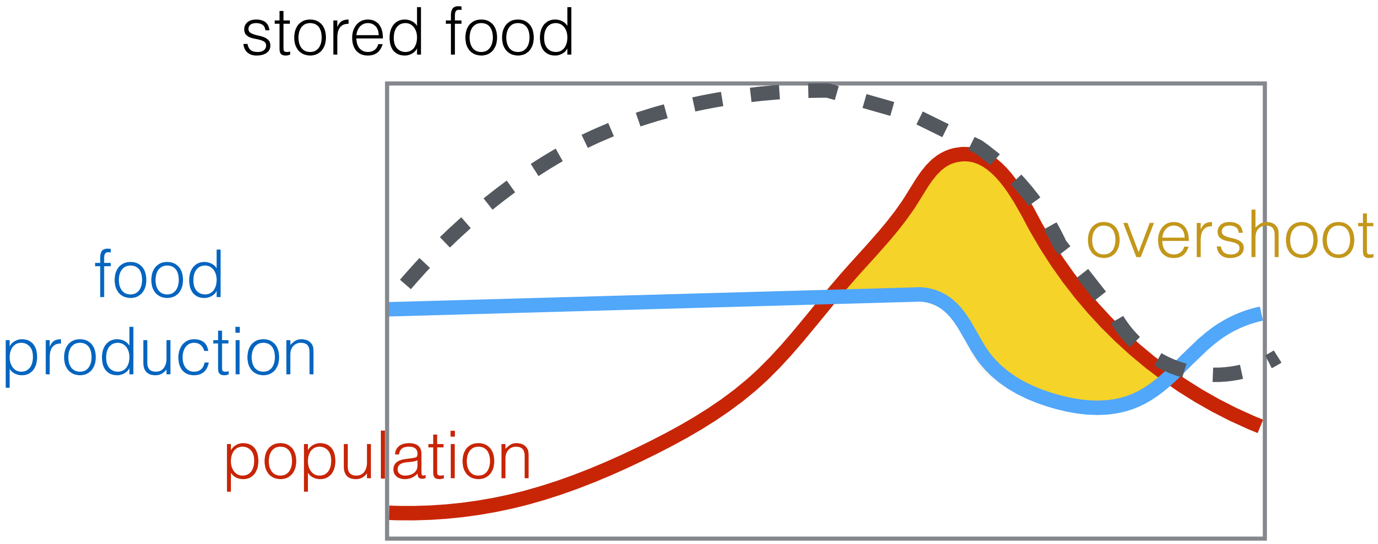


income = $1000/mo at beginning of month
expenditures at end of month (credit card)

causes: growth + limit + delay.

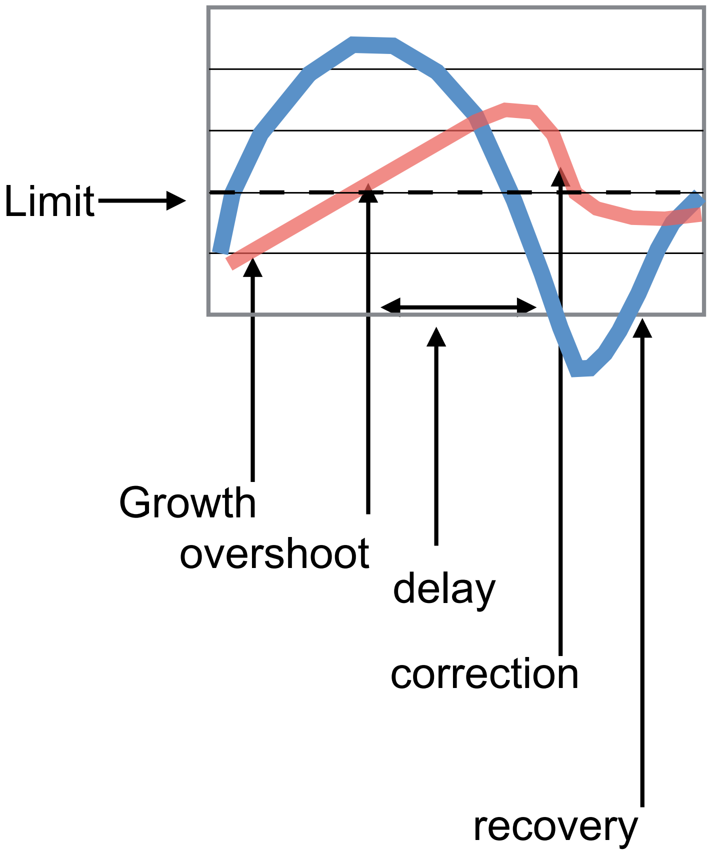
consequences: debt payments, lower income, lower expenditures.

Overshooting the food supply



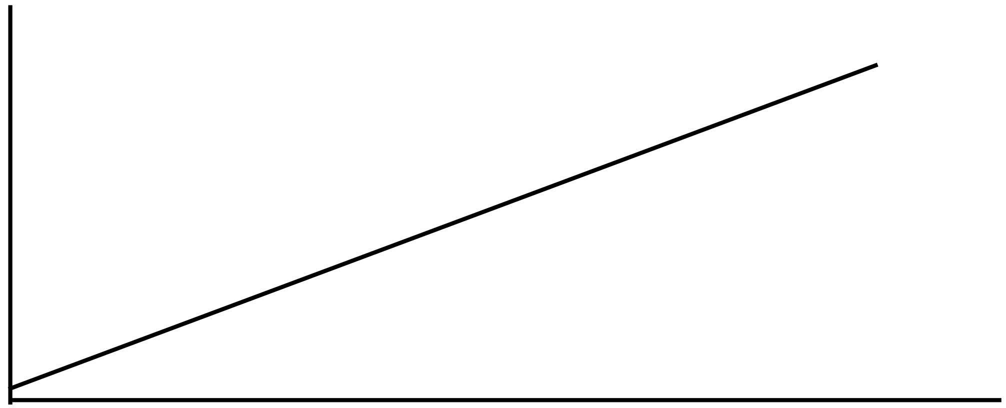
Overshoot

- Components of overshoot
  - – Growth
  - – Limits to growth
  - – Delays
- Result
  - – crash, correction



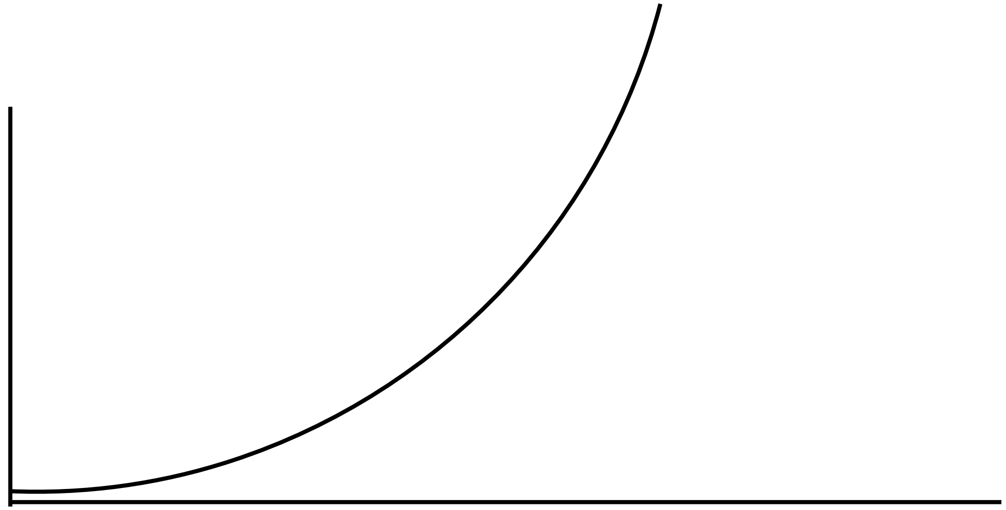
Examples of Growth

- Linear growth
  - filling of a bathtub
  - no-interest savings account when you add $10 per month
  - constant acceleration



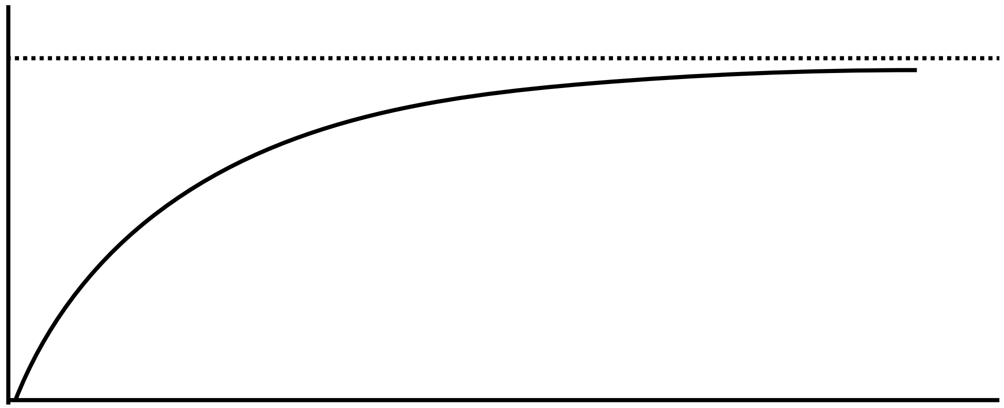
Examples of Growth

- Exponential growth
  - – rabbits without predators and plenty of food.
  - – interest on a loan that you are not paying back!



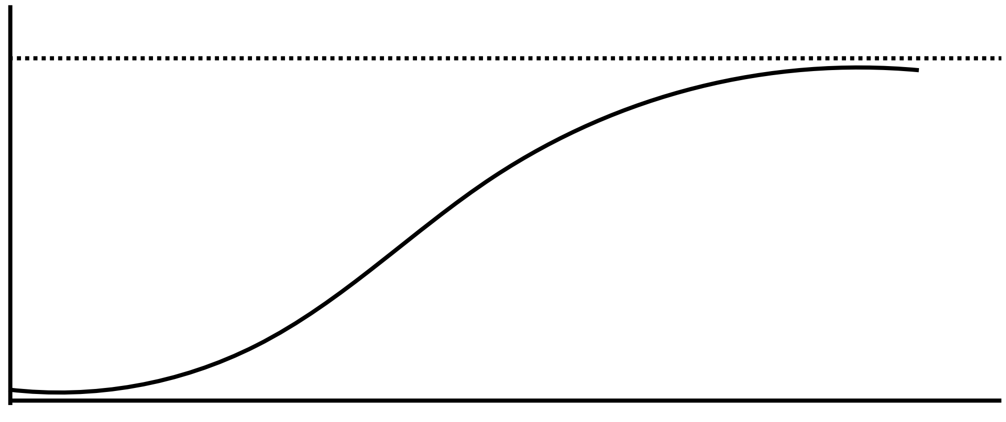
Examples of Growth

- Limited growth
  - enzyme activity as a function of substrate concentration.
  - tree height versus tree age



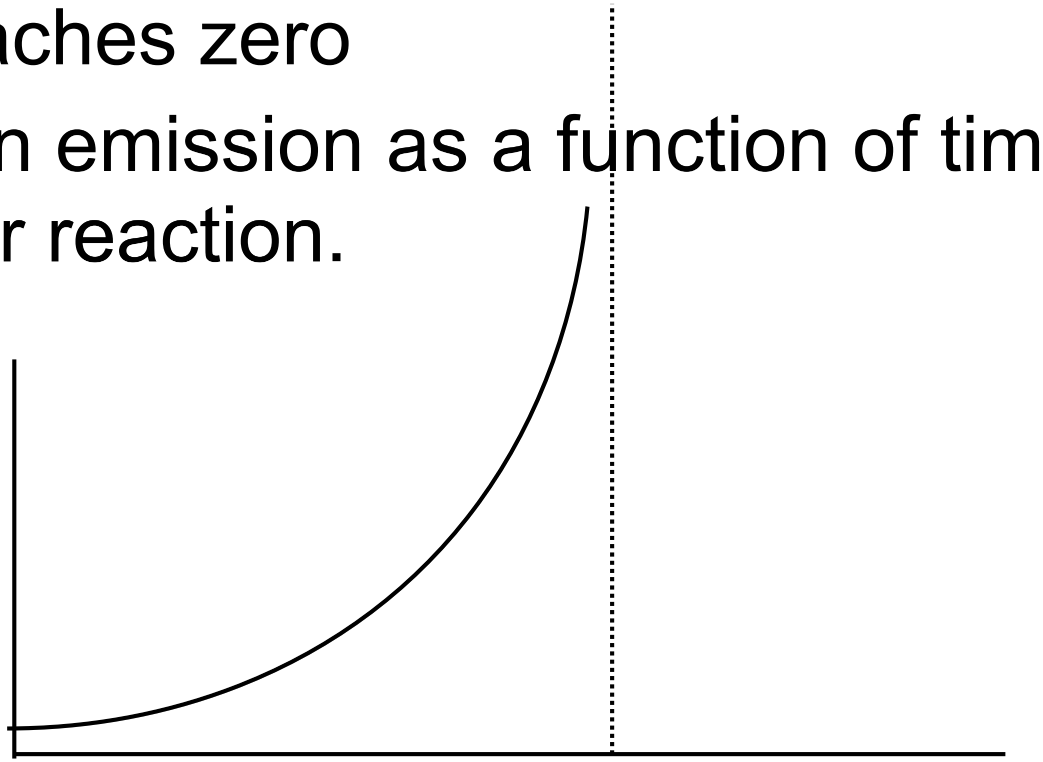
Examples of Growth

- Logistic growth
  - Exponential combined with limited growth
  - rabbits without predators and limited supply of food.
  - enzyme activity (cooperative enzyme)



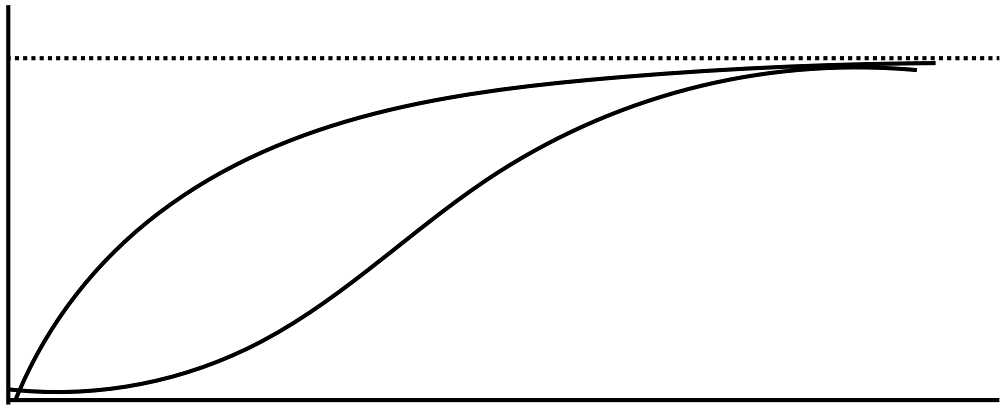
Examples of Growth

- Hyperbolic growth
  - pressure of an ideal gas as volume approaches zero
  - neutron emission as a function of time after nuclear reaction.



Examples of Limits

-
  - supply of food.
  - size of storage shed.
  - size of Earth.
  - total food production of Earth
  - monthly salary



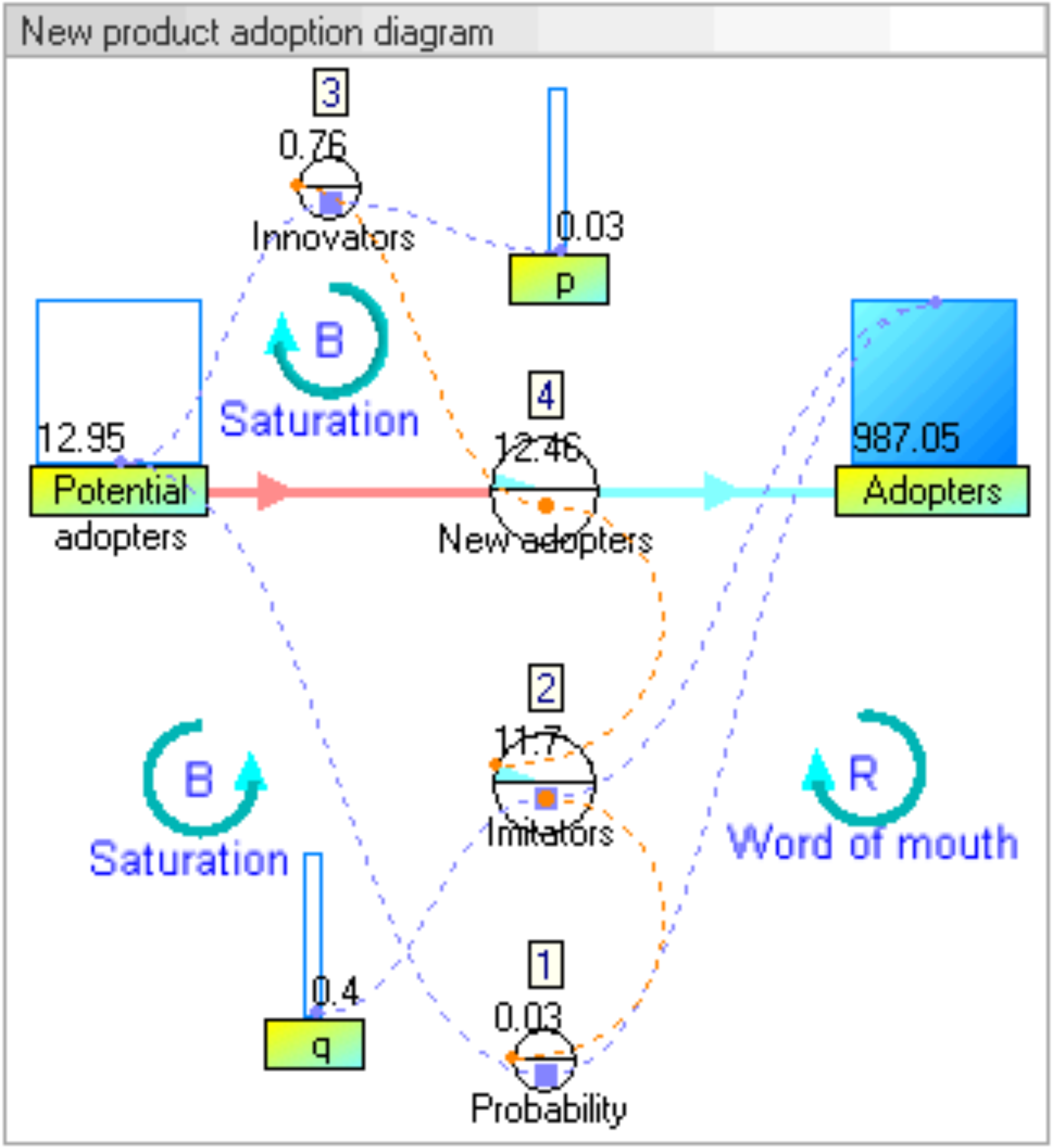
Examples of Delays

- Physical
  - Slow absorption of CO2 by the ocean.
  - Delayed warming of permafrost, sea ice.
  - Slow diffusion of pollutants
- Human
  - The slow pace of Science.
  - Slow public acceptance
  - Slow adoption of countermeasures

Systems Dynamics

- **a "bottom-up" approach to modeling, understanding and predicting the behavior of complex systems. Numerical models of physical systems in the time domain.**

- **System** -- a set of interacting entities.
  - Consists of **Stocks**, **Flows**, and **Variables**.
  - Open system -- a system that allow Flows to or from an external Sink or Source (external Stocks). Total sum of all Stocks may start from zero or go to zero.
  - Closed system -- a system that does not allow external Sources and Sinks. No net change in total of all Stocks.



https://en.wikipedia.org/wiki/System_dynamics

ImageMaker

- **Systems dynamics web app**

- **Stocks**
  Stocks are quantities, physical or otherwise. Quantities can be *measured*, may have *units*, may be *added* to, may be *subtracted* from.

- **Flows**
  Flows *send* quantities of a Stock to another Stock, or to the Sink, or from the Source.

- **Variables**
  Numbers or functions that interact with Flows and Stocks.

insightmaker.com

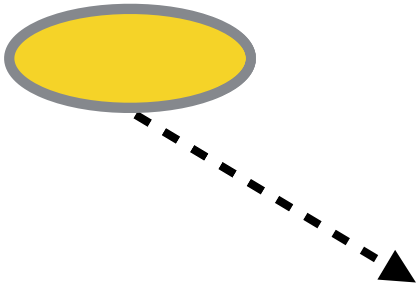
Stock

- **Stocks**
  Must be *quantifiable*. Should have *units.* May be *added* to, or *subtracted* from. May contain a built-in *Delay* (conveyer stock).
- **Flow** into a stock comes from its **Source**
  - A Source may be another Stock or **External**.
- **Flow** out of a stock goes to its **Sink**
  - A Sink may be another Stock or **External**.

Flow

- **Flow**
  - May have *rate units* (or no units)
    - Rate units have reciprocal time (y^{-1} , tons/y, etc)
  - May connects two **Stocks** or one.
  - May be forward-only or reversible.
  - Starts at **Source**, ends at **Sink**.
  - May be "external" (no sink or no source)
- Pair of stocks pair may have more than one **Flow**, each under different controls. (Sometime the same effect may be achieved with one Flow having multiple input Variables.)

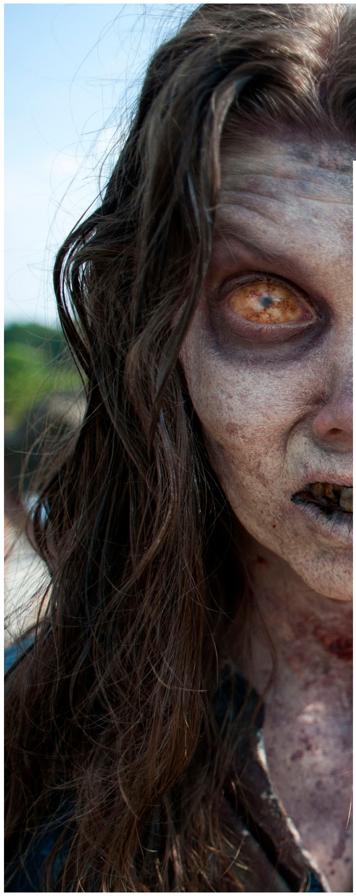
Variables and links

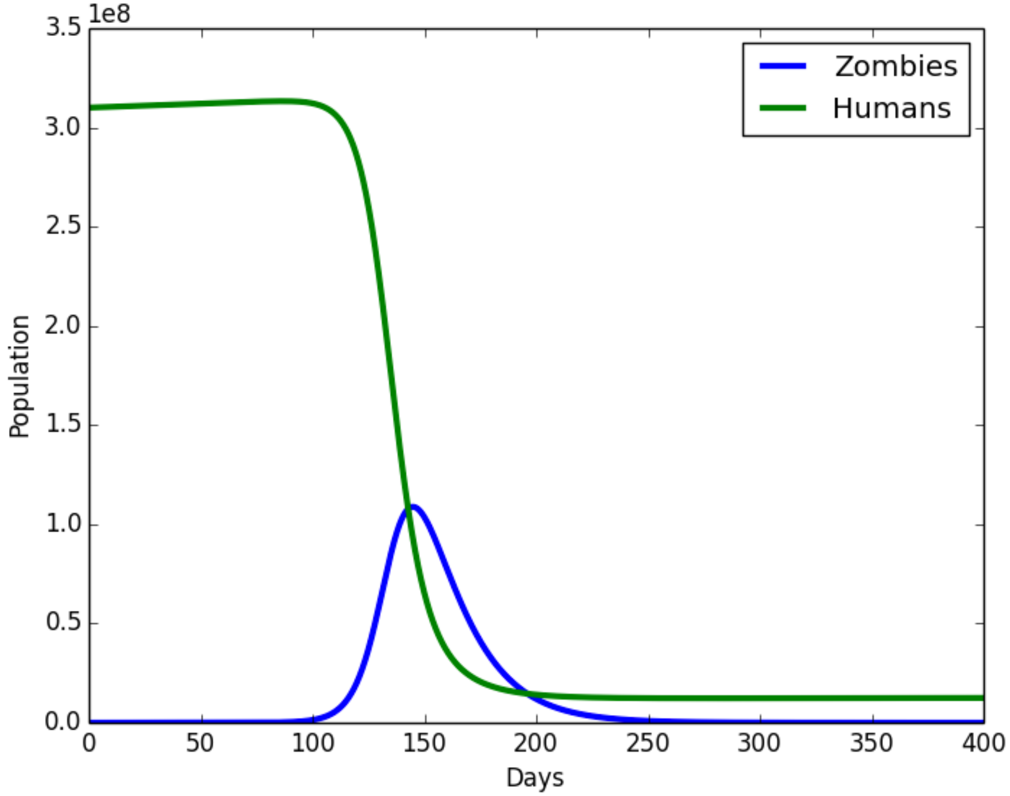


- **Variables**
  containers for numbers, equations, even programs.
- **Links**
  indicates dependency.
- **Equations** in Flows and Variables can be made dependent on the values of Stocks and/or Variables.

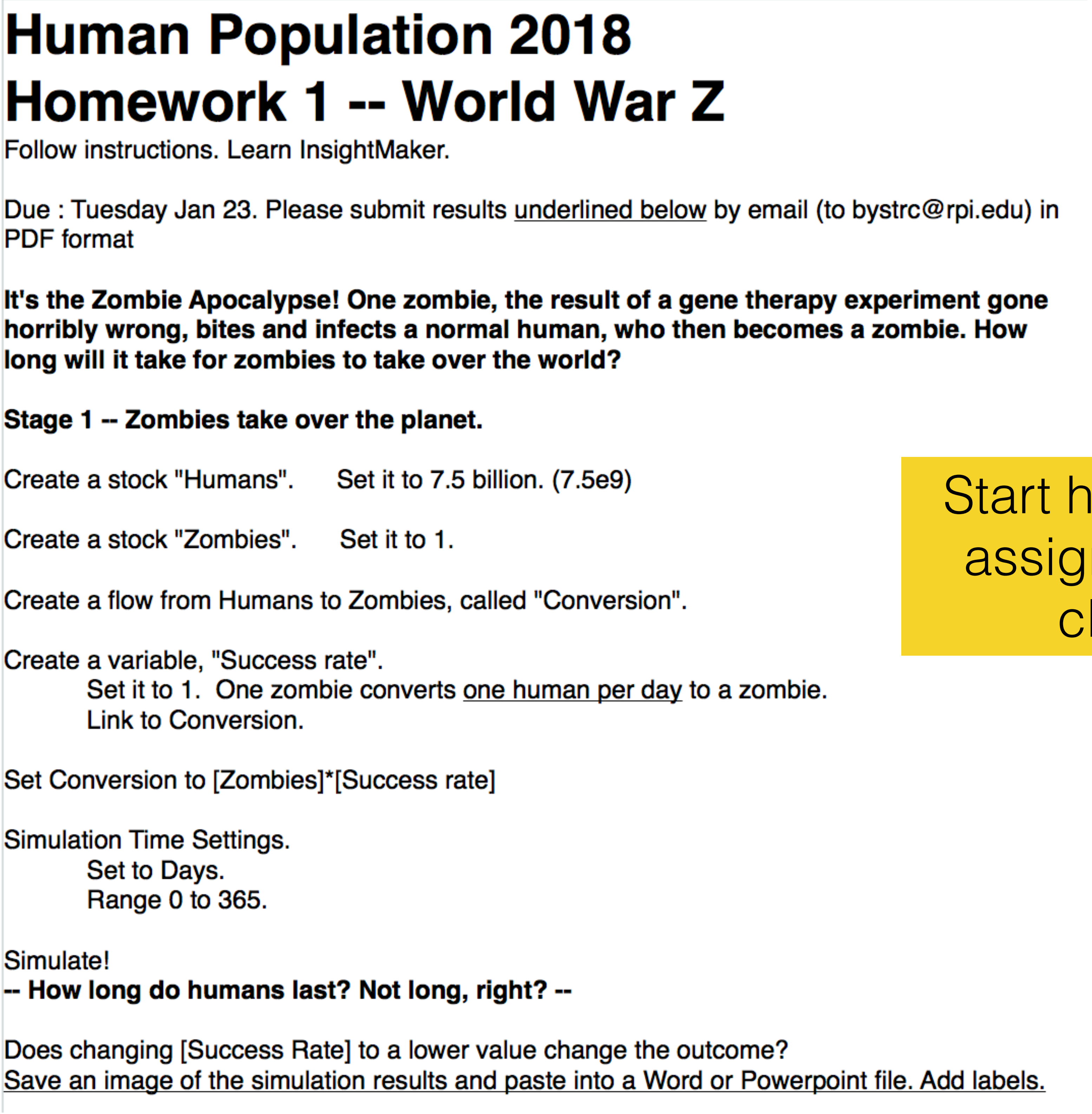
A Variable can use another Variable or Stock only if it is **link**ed.

Zombie apocalypse





http://www.livescience.com/57407-zombie-apocalypse-would-take-100-days.html



Human Population 2018

Homework 1 -- World War Z

Follow instructions. Learn InsightMaker.

Due : Tuesday Jan 23. Please submit results underlined below by email (to bystrc@rpi.edu) in PDF format

It's the Zombie Apocalypse! One zombie, the result of a gene therapy experiment gone horribly wrong, bites and infects a normal human, who then becomes a zombie. How long will it take for zombies to take over the world?

Stage 1 -- Zombies take over the planet.

Create a stock "Humans". Set it to 7.5 billion. (7.5e9)

Create a stock "Zombies". Set it to 1.

Create a flow from Humans to Zombies, called "Conversion".

Create a variable, "Success rate".
Set it to 1. One zombie converts one human per day to a zombie.
Link to Conversion.

Set Conversion to [Zombies]*[Success rate]

Simulation Time Settings.
Set to Days.
Range 0 to 365.

Simulate!
-- How long do humans last? Not long, right? --

Does changing [Success Rate] to a lower value change the outcome?
Save an image of the simulation results and paste into a Word or Powerpoint file. Add labels.

Start homework assignment in class.

Setting up an equation

Click on the "=" of Variable.*

Write the formula to be calculated in the box.

References and linked variables, with brackets [].

Click to add that variable to the formula.

Math operators are standard:

+

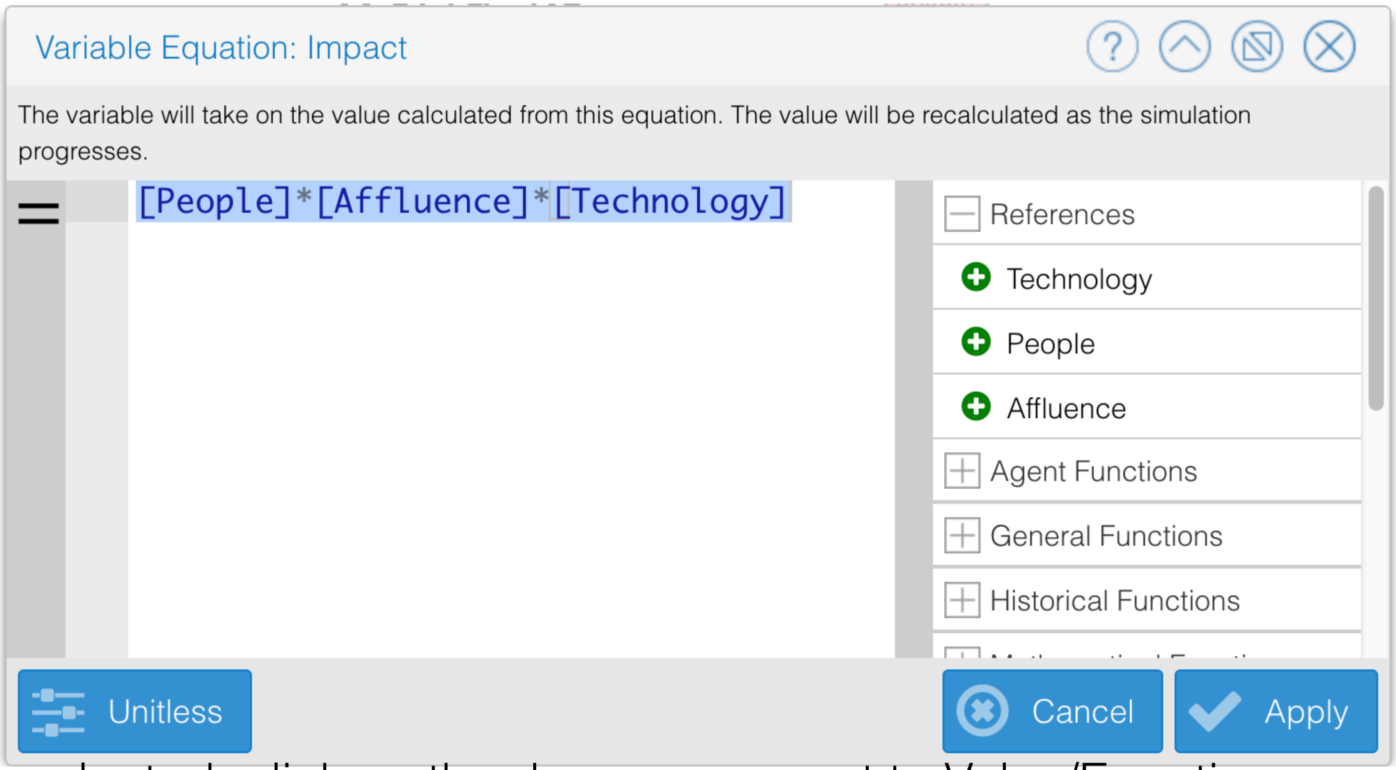
-

/

*

^

Apply.



The variable will take on the value calculated from this equation. The value will be recalculated as the simulation progresses.

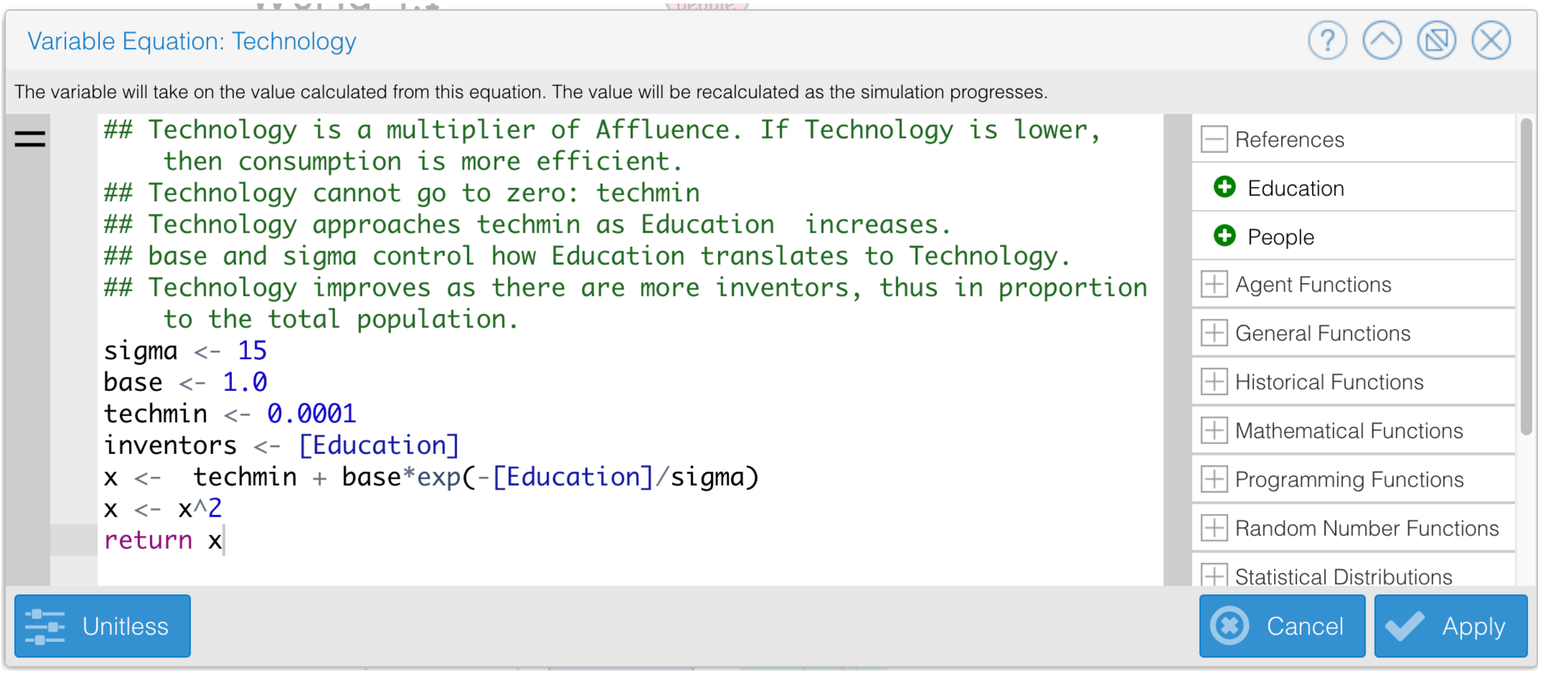
= [People]*[Affluence]*[Technology]

*or if the Variable is already selected, click on the down arrow next to Value/Equation=

More complex programming

You can define new variables within a Variable using left-arrow "<-", for example: "y **<-** 2 + 2"

If you do, you *must* specify the value that the Variable holds, using "**return**" as in the example below.
Here the value of the Variable is the final value of "x".
(Any text after a **#** is a comment. Ignored.)



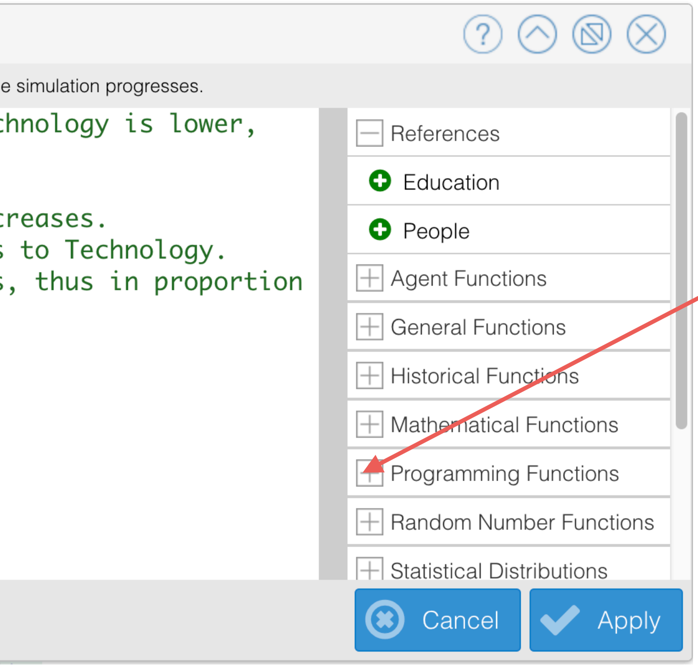
Variable Equation: Technology

The variable will take on the value calculated from this equation. The value will be recalculated as the simulation progresses.

```
## Technology is a multiplier of Affluence. If Technology is lower,
    then consumption is more efficient.
## Technology cannot go to zero: techmin
## Technology approaches techmin as Education  increases.
## base and sigma control how Education translates to Technology.
## Technology improves as there are more inventors, thus in proportion
    to the total population.
sigma <- 15
base <- 1.0
techmin <- 0.0001
inventors <- [Education]
x <-  techmin + base*exp(-[Education]/sigma)
x <- x^2
return x
```

Plug and play programming

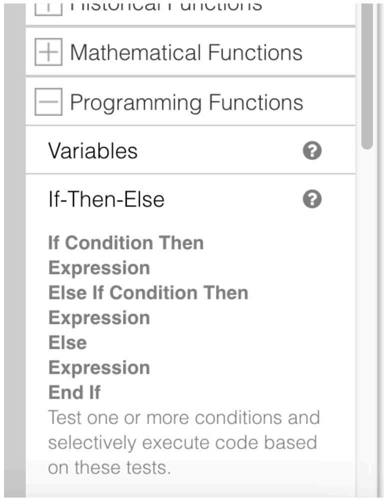
To make "programming" more accessible, InsightMaker provides an array of listed functions and functionalities. Each can be entered into the calculation box by clicking it.



e simulation progresses.

```
chnology is lower,

creases.
s to Technology.
s, thus in proportion
```

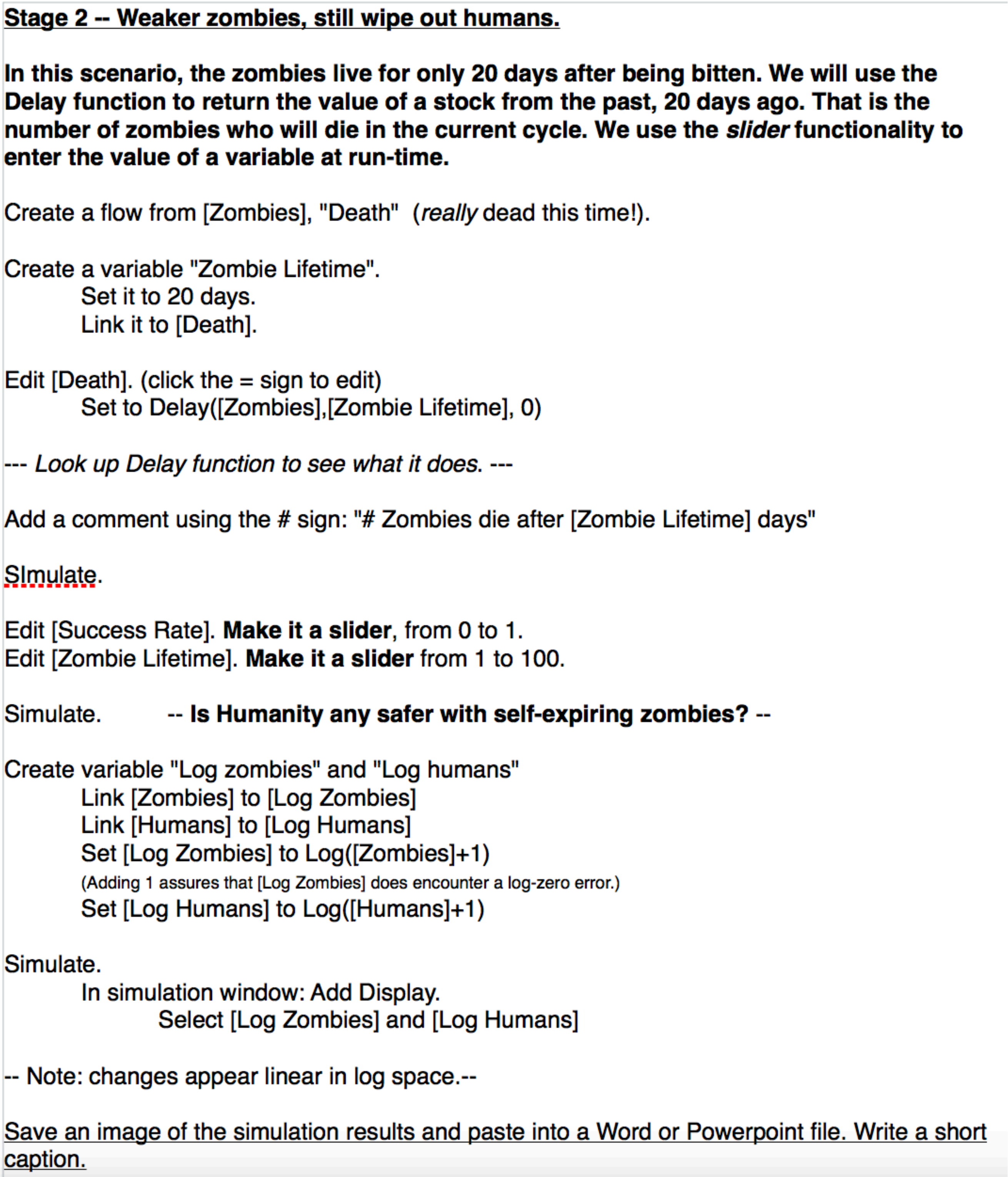


```
If Condition Then
Expression
Else If Condition Then
Expression
Else
Expression
End If
```

Test one or more conditions and selectively execute code based on these tests.

Example: If-then-else block.

"Expression" means any number of lines of equations.



Stage 2 -- Weaker zombies, still wipe out humans.

In this scenario, the zombies live for only 20 days after being bitten. We will use the Delay function to return the value of a stock from the past, 20 days ago. That is the number of zombies who will die in the current cycle. We use the *slider* functionality to enter the value of a variable at run-time.

Create a flow from [Zombies], "Death" (*really* dead this time!).

Create a variable "Zombie Lifetime".
  Set it to 20 days.
  Link it to [Death].

Edit [Death]. (click the = sign to edit)
  Set to Delay([Zombies],[Zombie Lifetime], 0)

--- *Look up Delay function to see what it does.* ---

Add a comment using the # sign: "# Zombies die after [Zombie Lifetime] days"

SImulate.

Edit [Success Rate]. **Make it a slider**, from 0 to 1.
Edit [Zombie Lifetime]. **Make it a slider** from 1 to 100.

Simulate. -- **Is Humanity any safer with self-expiring zombies?** --

Create variable "Log zombies" and "Log humans"
  Link [Zombies] to [Log Zombies]
  Link [Humans] to [Log Humans]
  Set [Log Zombies] to Log([Zombies]+1)
  (Adding 1 assures that [Log Zombies] does encounter a log-zero error.)
  Set [Log Humans] to Log([Humans]+1)

Simulate.
  In simulation window: Add Display.
    Select [Log Zombies] and [Log Humans]

-- Note: changes appear linear in log space.--

Save an image of the simulation results and paste into a Word or Powerpoint file. Write a short caption.

Do Stage 2.
Delay function.

Holling's Response function

Holling set up an experiment in which subjects were blindfolded and stood in front of a large table with small sandpaper disks on it. A second person stood with a stopwatch while the subject searched blindly for the disks, counting how many disks were found in a given time.

Naturally, where then were fewer disks, fewer disks were found. As more disks were added, more were found, linearly. This is Holling's response function Type I.

$y = bx$

If enough disks were placed on the table, a limit was reached beyond which the subject could not go. (The speed of removing the disk and putting in on a pile was limiting.) This was Holling's response function Type II.

$y = bx/(1 + bx)$

If Holling added a disk of a different color (blue versus red), and repeated the experiment, then the subject (who is blindfolded and can't see the color) initially found less of the red disks than expected by their number, because at low numbers they were outnumbered by the blue disks. This is Holling's response function Type 3.

Type 3 models any situation in which low numbers make finding the "prey" object less likely than expected by Type I or II. These work:

$y = bx^2/(1 + bx^2)$ ..or..

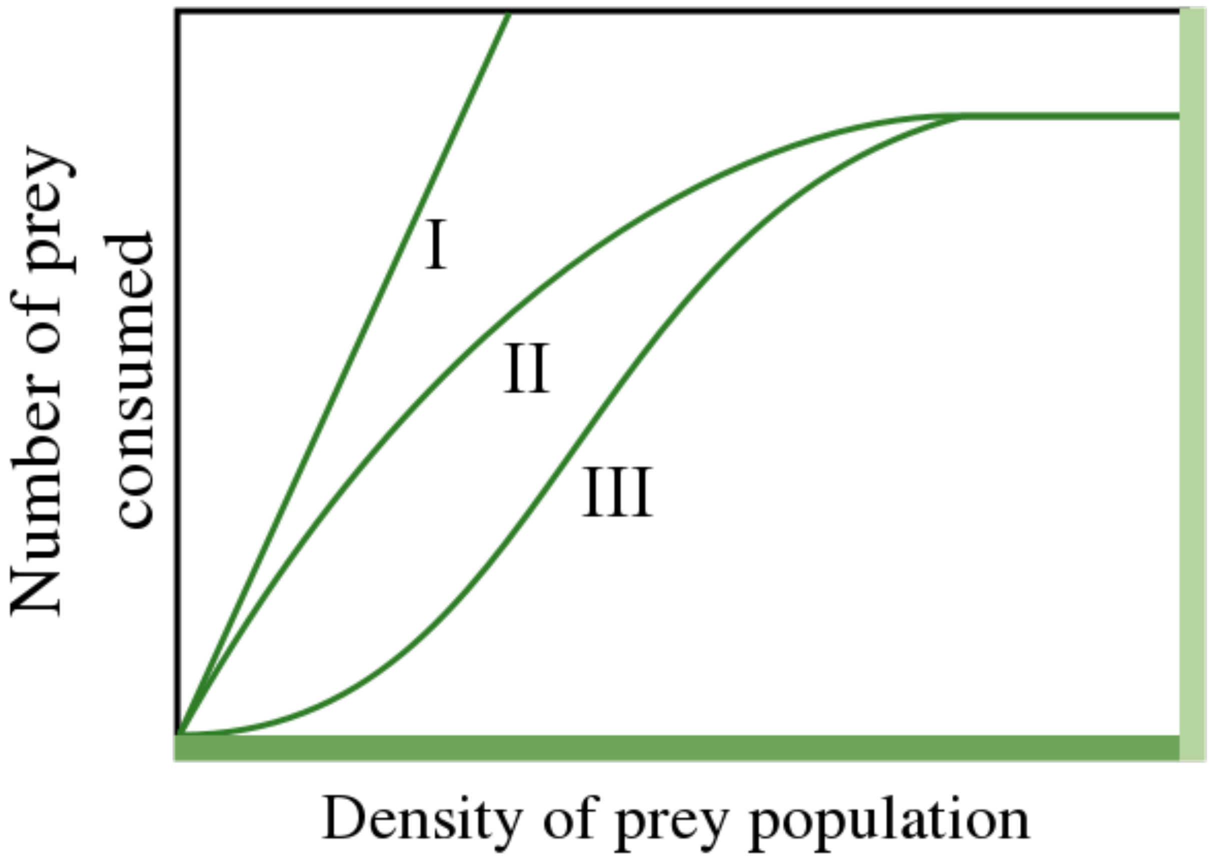
$y = x^2/(b^2 + x^2)$ ..or..

$y = x^k/(b^k + x^k)$.

Holling, C. S. (May 1959). "The components of predation as revealed by a study of small-mammal predation of the European pine sawfly". The Canadian Entomologist. 91 (5). pp. 293–320.

Holling's Response function

As the density of prey decreases, the number of prey consumed decreases (I) linearly, or (II) saturating, or (III) logistic.



Graphing calculator

- Go to https://**www.desmos.com**/calculator
- Try writing equations:

y=bx Holling's Type 1

$$y = \frac{bx}{(1 + bx)}$$

Holling's Type 2

$$y = \frac{bx^2}{\left(1 + bx^2\right)}$$

Holling's Type 3

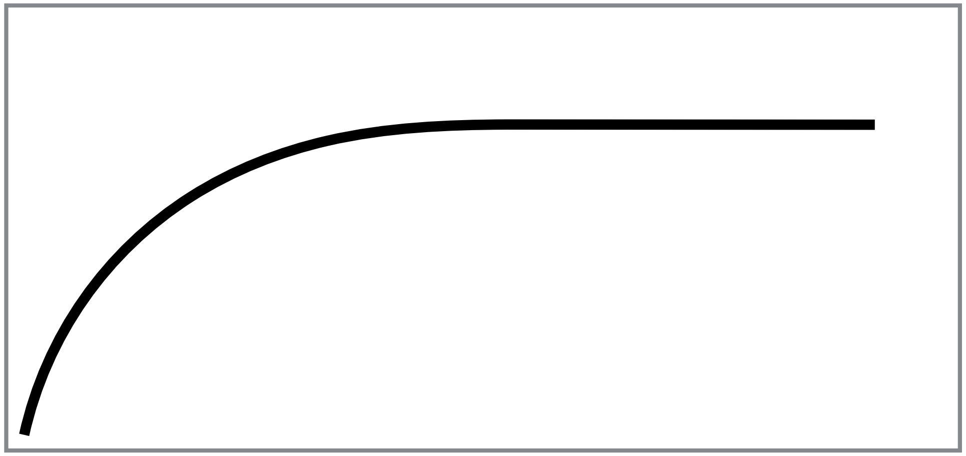
$$y = \frac{x^k}{\left(x^k + b^k\right)}$$

Holling's Type 3 with variable sharpness

Examples of Holling Type 2

in human ecology

- Food production from farms per year, versus number of farmers
- Forest growth versus forest density



Holling Type 2

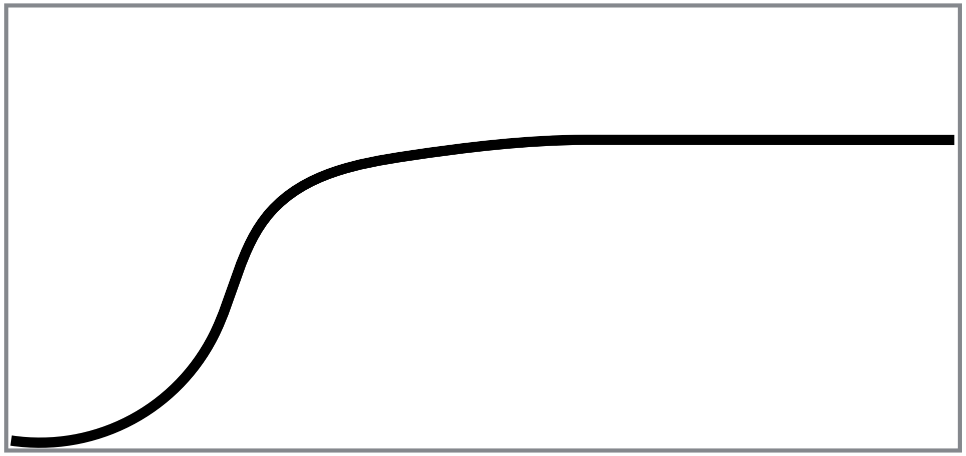
$$y = \frac{bx}{(1 + bx)}$$

Examples of Holling Type 3

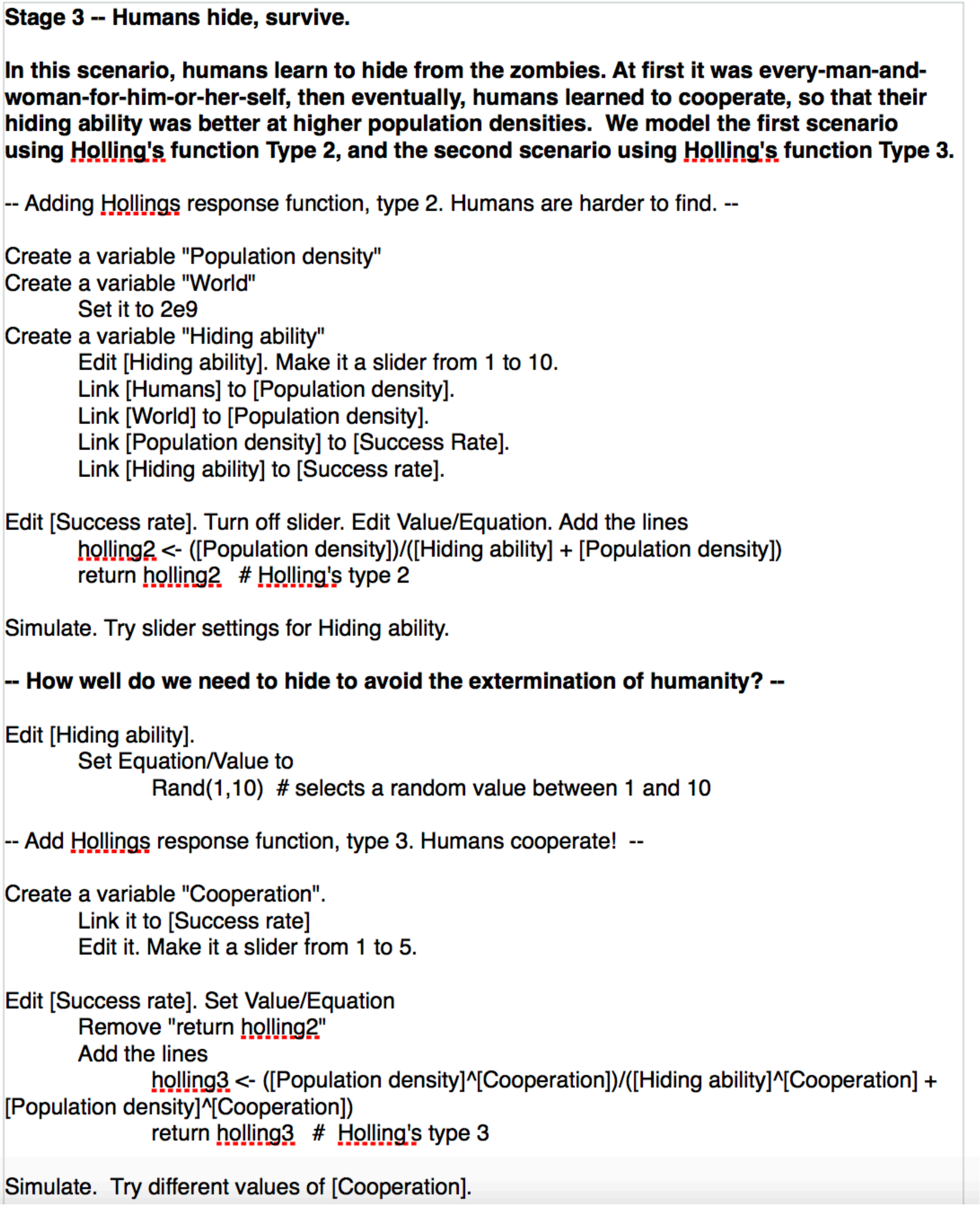
in human ecology

- Ability to field a baseball team versus number of players available.
- Life expectancy, versus calories/day.

$$y = \frac{bx^2}{\left(1 + bx^2\right)}$$



$$y = \frac{x^k}{\left(x^k + b^k\right)}$$



Stage 3 -- Humans hide, survive.

In this scenario, humans learn to hide from the zombies. At first it was every-man-and-woman-for-him-or-her-self, then eventually, humans learned to cooperate, so that their hiding ability was better at higher population densities. We model the first scenario using Holling's function Type 2, and the second scenario using Holling's function Type 3.

-- Adding Hollings response function, type 2. Humans are harder to find. --

Create a variable "Population density"
Create a variable "World"
    Set it to 2e9
Create a variable "Hiding ability"
    Edit [Hiding ability]. Make it a slider from 1 to 10.
    Link [Humans] to [Population density].
    Link [World] to [Population density].
    Link [Population density] to [Success Rate].
    Link [Hiding ability] to [Success rate].

Edit [Success rate]. Turn off slider. Edit Value/Equation. Add the lines

```
        holling2 <- ([Population density])/([Hiding ability] + [Population density])
        return holling2   # Holling's type 2
```

Simulate. Try slider settings for Hiding ability.

-- How well do we need to hide to avoid the extermination of humanity? --

Edit [Hiding ability].
    Set Equation/Value to

```
                Rand(1,10)  # selects a random value between 1 and 10
```

-- Add Hollings response function, type 3. Humans cooperate! --

Create a variable "Cooperation".
    Link it to [Success rate]
    Edit it. Make it a slider from 1 to 5.

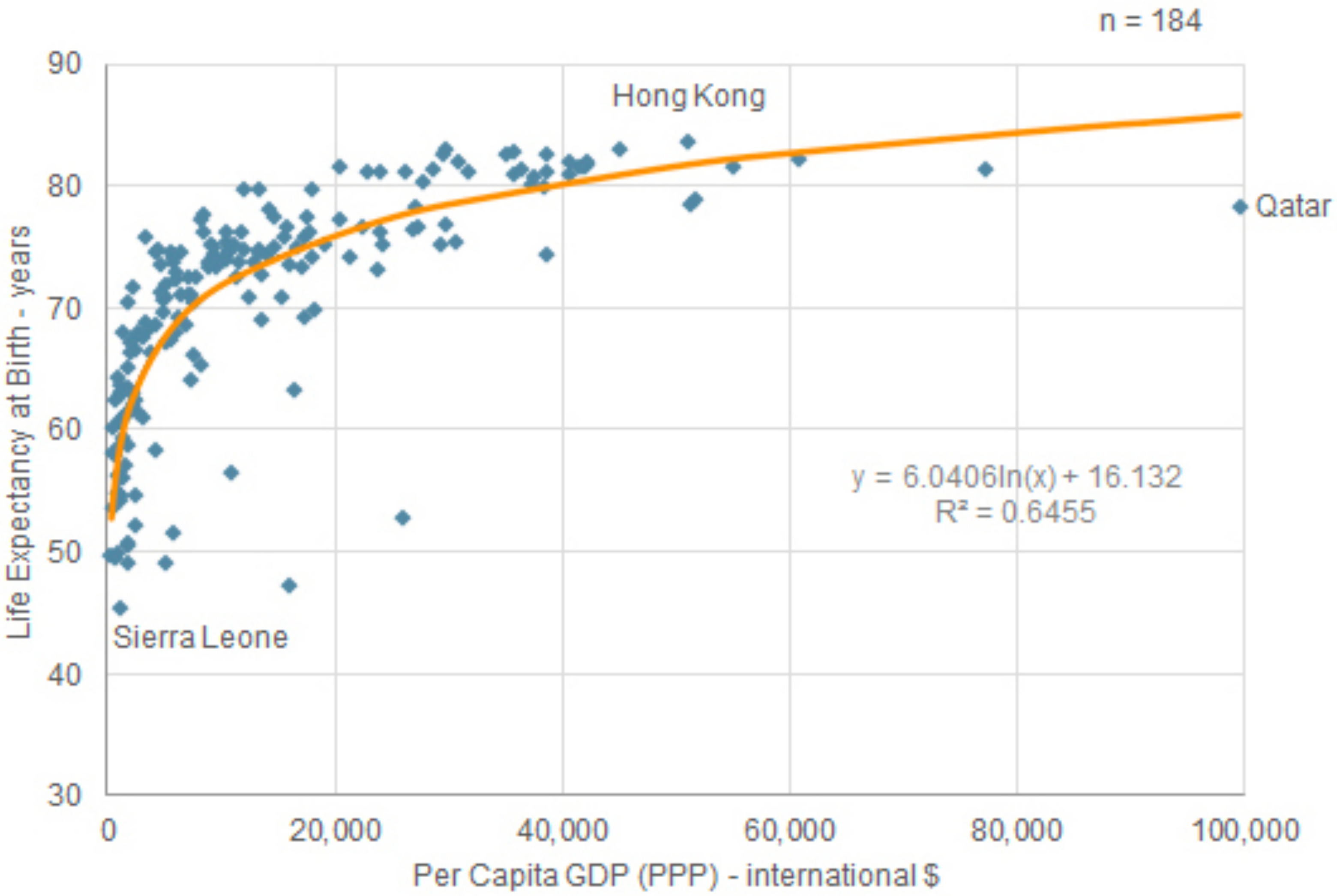
Edit [Success rate]. Set Value/Equation
    Remove "return holling2"
    Add the lines

```
                holling3 <- ([Population density]^[Cooperation])/([Hiding ability]^[Cooperation] +
[Population density]^[Cooperation])
                return holling3   #  Holling's type 3
```

Simulate. Try different values of [Cooperation].

Do Stage 3.
math

Fitting data to functions



https://blog.euromonitor.com/2014/03/fresh-food-consumption-around-the-world.html

How do I fit data to a curve?

- Enter the data into EXCEL, then use "trendline"
    - https://www.extendoffice.com/documents/excel/2642-excel-best-fit-line-curve-function.html#excel2010

Easy. Uses a set of pre-defined curves.

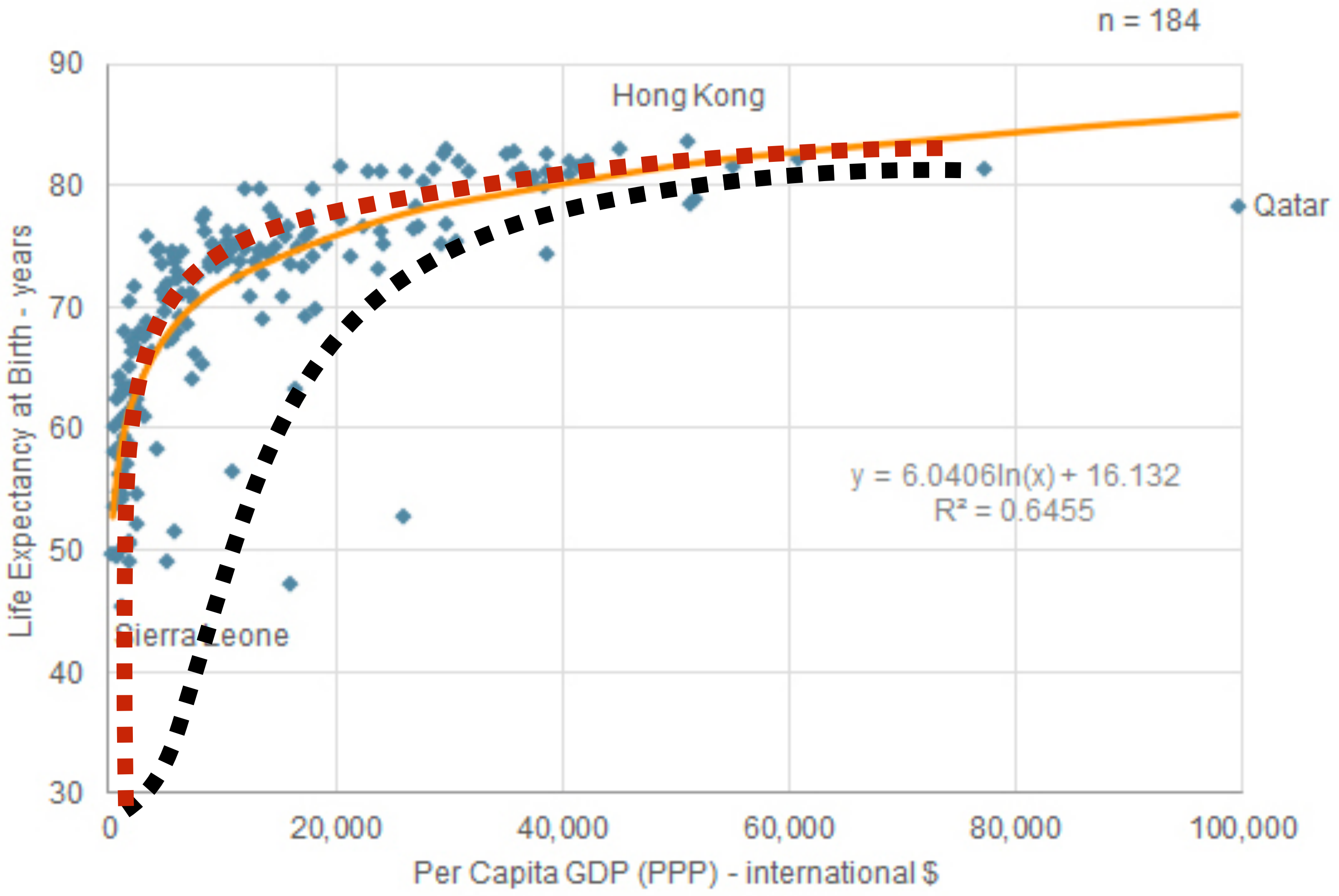
- Or "Solver"
    - https://www.solver.com/solver-tutorial-using-solver

Requires expert Excel skills. Allows fitting to just about any function.

- Alternative: "eyeball" fitting.
    - Use www.desmos.com/calculator

Sometimes it is good enough.

Trying Holling Type 2, Type 3 instead of Log.



Philosophy of curve fitting

- **The equation should make "theoretic sense"**
  - For example, if you are fitting data that can't go greater than 100%, the curve function should not go above 100%
  - If your data can't be negative, your curve can't be negative.
  - etc.. etc.
- **If the data has fundamental underlying math, use it.**
  - Example: use an exponential equation to fit exponential growth.
- **The curve should have the fewest possible curves.**
  - Don't fit the noise.
- **Make the residual flat.**
  - Subtract the curve from the data. Is it flat noise?

Sensitivity analysis

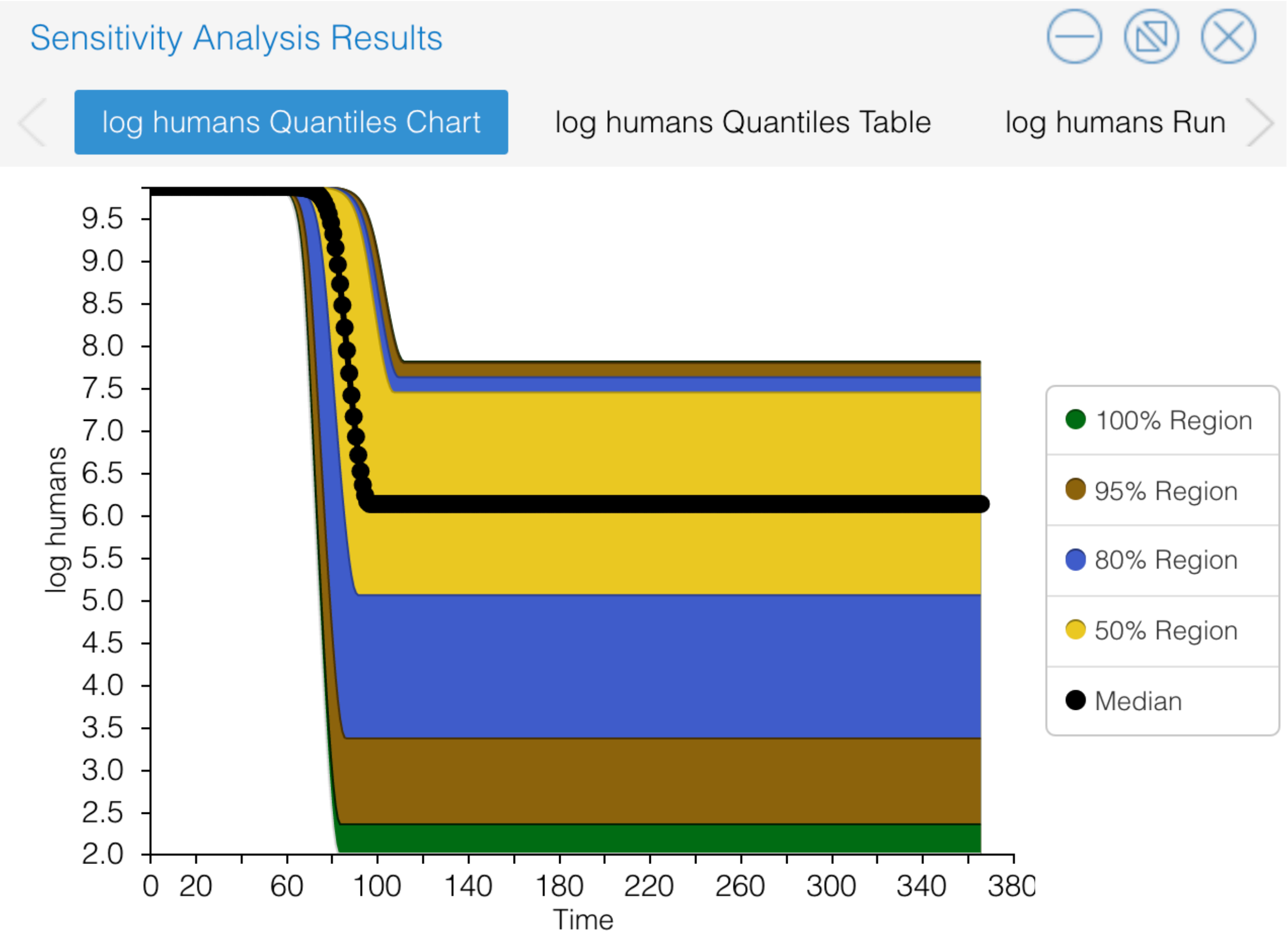
- Asks the question: **how much does the result change when I change variable *x*?**
- Set Variable x to a random number at the start of the simulation using Fix(Rand(min,max)

NOTE: The **Fix()** function causes the random number function to run once only, in cycle one. Every other cycle will use the same random number.

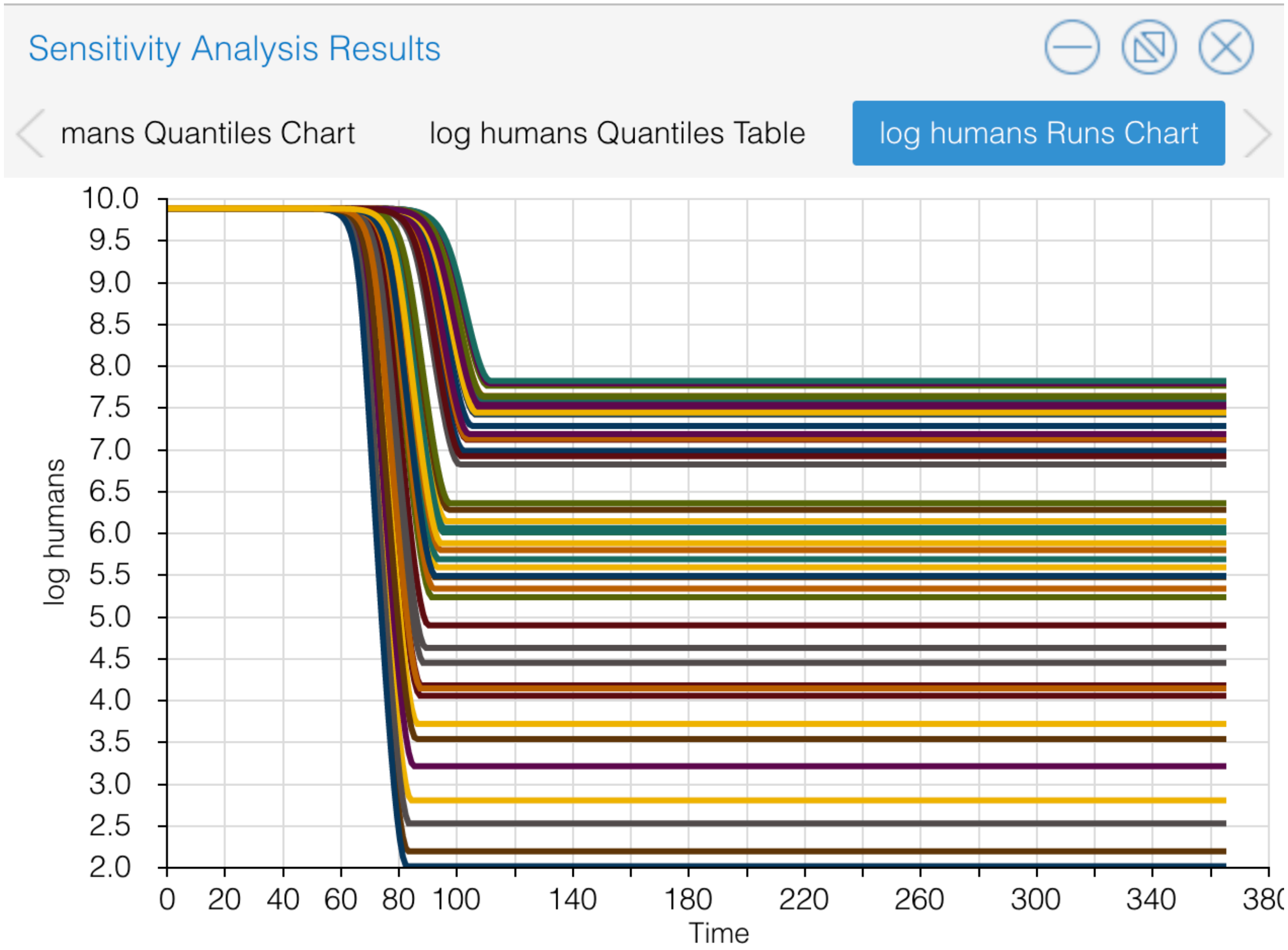
NOTE: IM is finicky about numbers. They can't end in "."

Rand(0,1.)	illegal
Rand(0.,1.0)	illegal
Rand(0.0,1.0)	OK

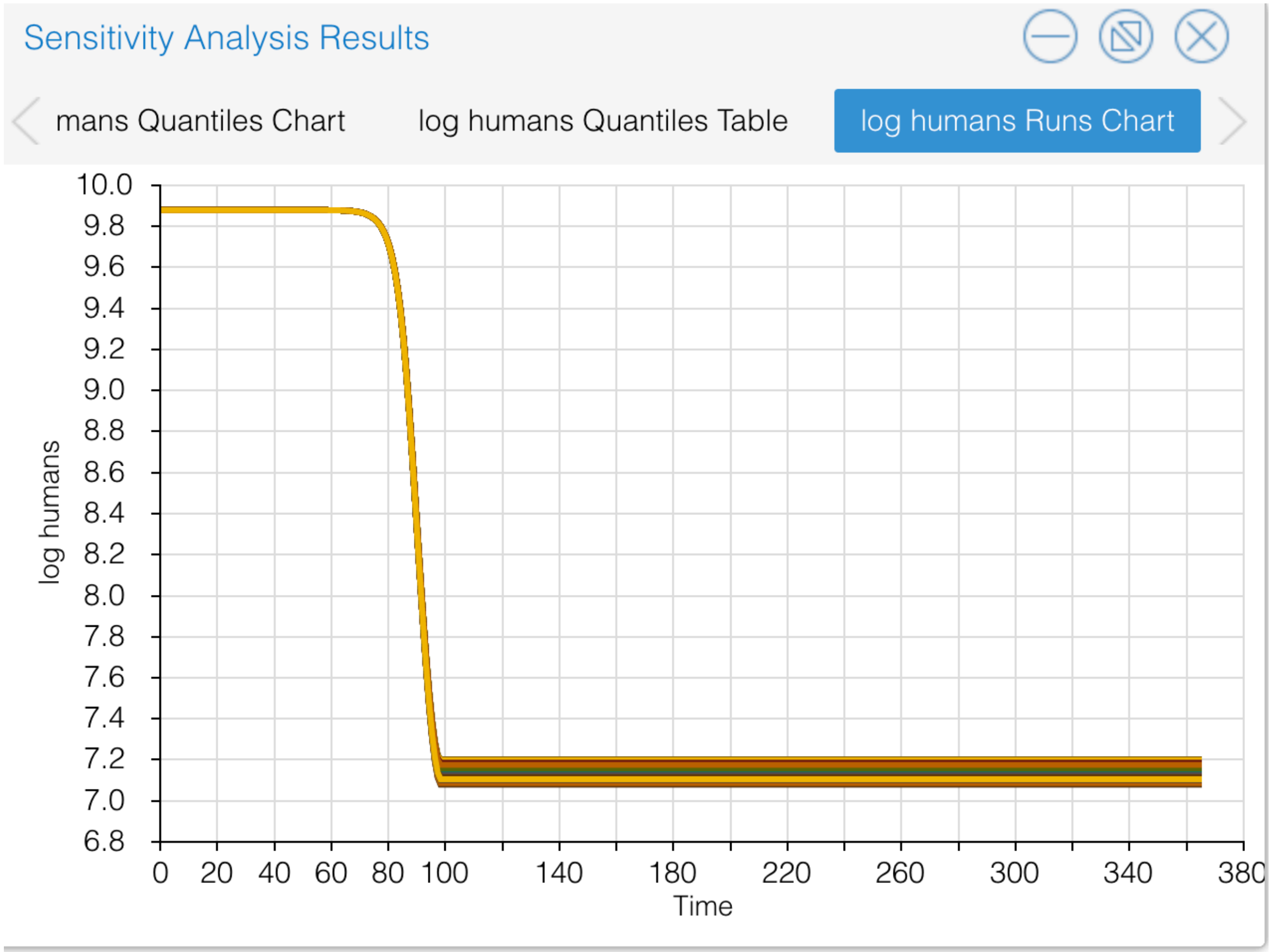
Quartiles chart



Runs chart


Sensitivity Analysis Results
mans Quantiles Chart
log humans Quantiles Table
log humans Runs Chart
log humans
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
0
20
40
60
80
100
140
180
220
260
300
340
38
Time

Runs chart for an "*insensitive*" Variable.



If the results all superimpose on each other when calculated over a range x=Rand(min,max), then we can say the system is "*insensitive*" to variable x over the range (min,max).

-- SENSITIVITY TESTING --

Edit [Cooperation]. Set Value/Equation =
    Fix(Rand(1,5))

Tools I Sensitivity Testing...
    Set confidence regions to 50, 70, 90
    Set runs to 50
    Check Plot Each Run.
    Monitor: [log Humans], [log Zombies]
    Ran analysis.

Save an image of the simulation results and paste into a Word or Powerpoint file. Write a short caption.

Stage 4 -- Humans sound the alarm.

It is a character trait of humans that we adapt quickly. We are not always in hiding mode. When the zombies start to multiply, we start to pay attention and we quickly learn to hide. But what if we wait too long?

-- Use PAUSE function to change parameters on the fly --

Settings
    Set Pause interval to 5 days

Edit [Cooperation]. Make it a slider from 1 to 5.

Edit [Hiding ability]. Make it a slider from 1 to 10.

Start sliders at lowest levels. (DefCon "Green")

Simulate!
    Simulation will pause.
    Hit Play until [Zombies] have reached a dangerous level. (DefCon "Red")
    Adjust sliders to increase [Hiding ability] and [Cooperation].

-- What happens? Can humanity be saved if we delay? --
Play the simulation to the end, whenever that happens.

Next time

Turn in homework 1 (by email)
Read LtG
Submit a question!