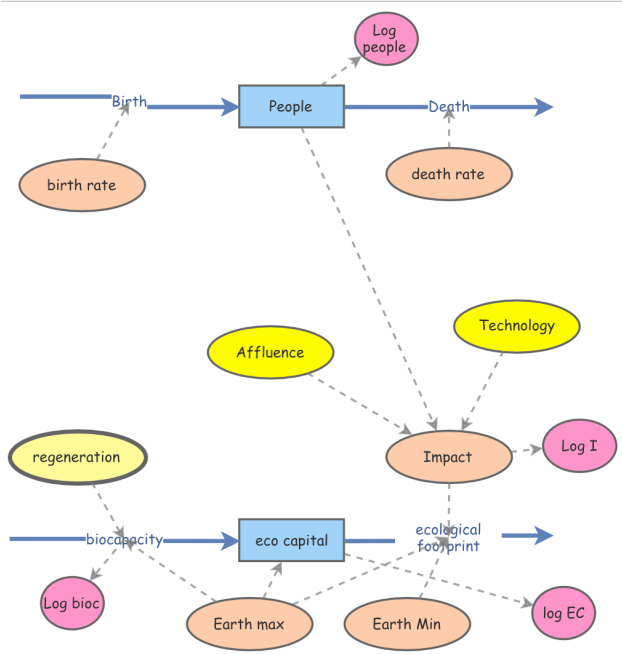
BIOL 4961 Human Population

Homework 3. Due Feb 23.

I=PAT



1. *Set up a model that looks like this.* (The coloring is your preference)

```
[birth rate] = 0.01
[death rate] = 0.008
[Birth] = [birth rate]*[People]
[death] = [death rate]*[People]
[People] = 1.5e9  (the human
population in 1900, approximately)
[Affluence] = slider (0.0, 1.0)
[Technology] = slider (0.0, 1.0)
[Impact] =[People]*[Affluence]*[Technology]
[ecological footprint] =
```

```
x <- [Impact]
If ([eco capital] < [Earth Min])
Then
  x <- 0
Else
  x<- [Impact]
End If
return x
```

```
[Earth Max]=1.5e10
[Earth Min]=0 (for now)
[eco capital] = [Earth Max]
[Regeneration] = slider(0., 1.0)
[biocapacity] =
```

```
## derivative of Type 3 Hollings ##
x <- [Earth max]-[eco capital]
x <- x/[Earth max]
x <- x*[regeneration]*[eco capital]
return x
##
```

2. Determine sensitivity.

Simulate 500 years.

Experiment with the sliders [Affluence], [Technology] and [regeneration] to get a feel for how the system behaves. What happens to [eco capital]? Why? What happens to [People]?

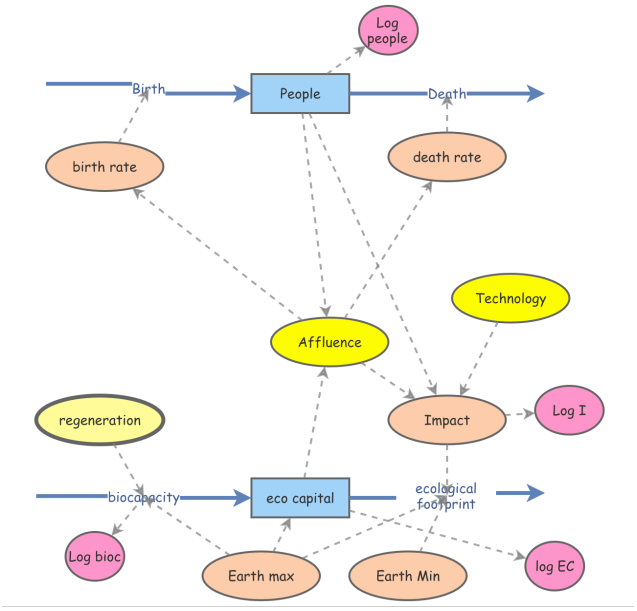
Run three Sensitivity Testing studies, one with each of the variables [Affluence], [Technology] and [regeneration]. Set the variable to a range over which you have seen sensitivity. Comment on how the outcome depends on the setting of each.

Compose a slide show in Powerpoint or KeyNote or Google Slides. Each slide should have a graph and caption. The caption should describe the graph. The rest is up to you. This slide show should not have "lecture notes". That is, all of the info is on the slides themselves.

- First slide should show the model, with caption.
- Second, third, fourth slides. Sensitivity tests, with captions.

3. Add feedback.

Turn off the slider for [Affluence] and make it a function of [eco capital] and [People]. Link it to [birth rate] and [death rate]. The model now looks like this:



Make [Affluence] a Hollings Type 3 function of [eco capital]/[People], which is natural resources per capita. Specifically,
[Affluence] =

```
x <- [eco capital]/[People]
b <- 0.5
k <- 5
y <- (x^k)/(x^k + b^k)
return y
```

Run a simulation to make sure everything works.

Set [birth rate] to be a function of [Affluence].
Search the web for information relating affluence (measured as income, GDP, or HDI) to fertility (TFR) or birth rate and convert it to birth rate. [Affluence] is bounded between 0.0 and 1.0. As [Affluence] approaches 1.0, birth rate goes down. Also as [Affluence] approaches zero, [birth rate] goes to zero, since infant mortality goes up. [birth rate] should reach a maximum of 0.03 when [Affluence] is 0.50. Write an equation that satisfies these conditions. Use Desmos.com/calculator to visualize equations.

[birth rate] =

```
x <- [Affluence]
y <- your function of x here
return y
```

Run a simulation to make sure everything works.

Set [death rate] to be a function of [Affluence].
Search the web for information relating affluence (measured as income, GDP, or HDI) to life expectancy (LEB) or death rate, and convert it to death rate. As [Affluence] approaches 1.0, death rate should go to a first world value of about 0.01. Also as [Affluence] approaches zero, [death rate] should go to 1.0, since [Affluence]=0 means *famine* and no one can survive a world with zero food! At intermediate values of [Affluence] the [death rate] decreases with increasing [Affluence]. Write a reasonable equation for this decrease based on whatever information you can find on the web. The simplest equation would be a line connecting 0.01 at [Affluence]=1.0 to 1.0 at [Affluence]=0.0. But

you might want the decrease in the death rate much more sharply than that. (Hint: Try taking it to a power.)

[death rate]=

```
x <- [Affluence]
y <- your function of x here
return y
```

Run a simulation to make sure everything works.

Congratulations! Now you have a system with feedback.

Add to your slide show.

- Your equation for birth rate as a function of Affluence.
- Your equation for death rate as a function of Affluence.
- Select variables to test sensitivity. Do at least two sensitivity tests. I suggest [regeneration] and [technology]. Show the "Runs chart" for each and comment on it.
- Add a final slide with comments on the nature of the feedback loop you generated. Positive or negative feedback? Stable or unstable? Is it realistic? Why or why not.