ASSIGNMENT 3

3.1.

Identify reinforcing loops responsible for growth in the following examples (could be more than one loop). Give your answers in terms of causal loop diagrams. Remember to denote link polarity with + and – signs, and include the R-letter to denote that the loop is reinforcing. (Do not use verbs in your variable names, links and polarities indicate in what direction the variables will change).
Drawing by hand is fine.

- Population growth
- A quarrel (include level of anger and provoking comments)
- A war between two countries (provocation and retaliation)
- Economic growth (include machines, labor, technology, production)
- Spread of an epidemic (consider those infected and the infection rate)
- Market growth for a new product (assume that production costs and product prices vary (decrease) with accumulated production).

3.2.

In a bacteria culture, there is a net fractional growth rate of 3.5 % per minute (instantaneous growth rate). Assume that the initial number of bacteria is 1000.

a) Write the equations for net growth in the number of bacteria (difference, differential, integral).

b) Use a structure graph from stock to net flow to reason about how the stock of bacteria will develop over time. Make sure you number the axis and that you are accurate. Hints: remember that the structure graph is not a behavior-over-time graph! For any value of the stock, you can see how large the net flow is, and consequently you can reason about how the stock will develop from the stock value you consider. The stock needs time to change from one point in time to the next.

c) Use the 70-rule to find out how many minutes it takes for the bacteria culture to double in numbers.

d) Model the bacteria system in Stella. Simulate the model where time runs in minutes, and find out how many bacteria there will be after 1 hour (60 minutes), 6 hours and 24 hours. Use Runge-Kutta 4 (RK4) and set DT=4. Which is the largest DT that gives the correct answer measured by the second decimal for the number of bacteria after 1 hour.

e) For a time-horizon of 60 minutes, find the exact number of bacteria by using the formula for development over time for a linear reinforcing system. Try out different time steps DT when using the Euler integration method. Reason about the need for accuracy given that there is uncertainty in the estimate of the instantaneous growth rate.

f) Would you say development after a 24 hours simulation is realistic? Perform a structural test and explain what may be wrong with the model?

g) Assume from now on that a predator is present, which eats bacteria. Include eating by this predator in your Stella model. This predator eats exactly 17.5 bacteria per minute - as long as there are bacteria available. Thus, the eating by the predator does not vary with the stock of bacteria. Use a revised structure graph for net growth to explain what happens if there are 1000 bacteria initially. Test your answer by simulating in Stella.

h) Solve the differential equation $y' = by - d$ and represent the solution taking into account the initial value of $y(0)$. Investigate the dynamic properties of solution for different initial values $y(0)$.

j) What happens if there are only 400 bacteria initially? Use the structure graph to explain your answer. Test your answer by simulating in Stella.

i) Identify an unstable equilibrium point (repellor) for this system with a predator present?