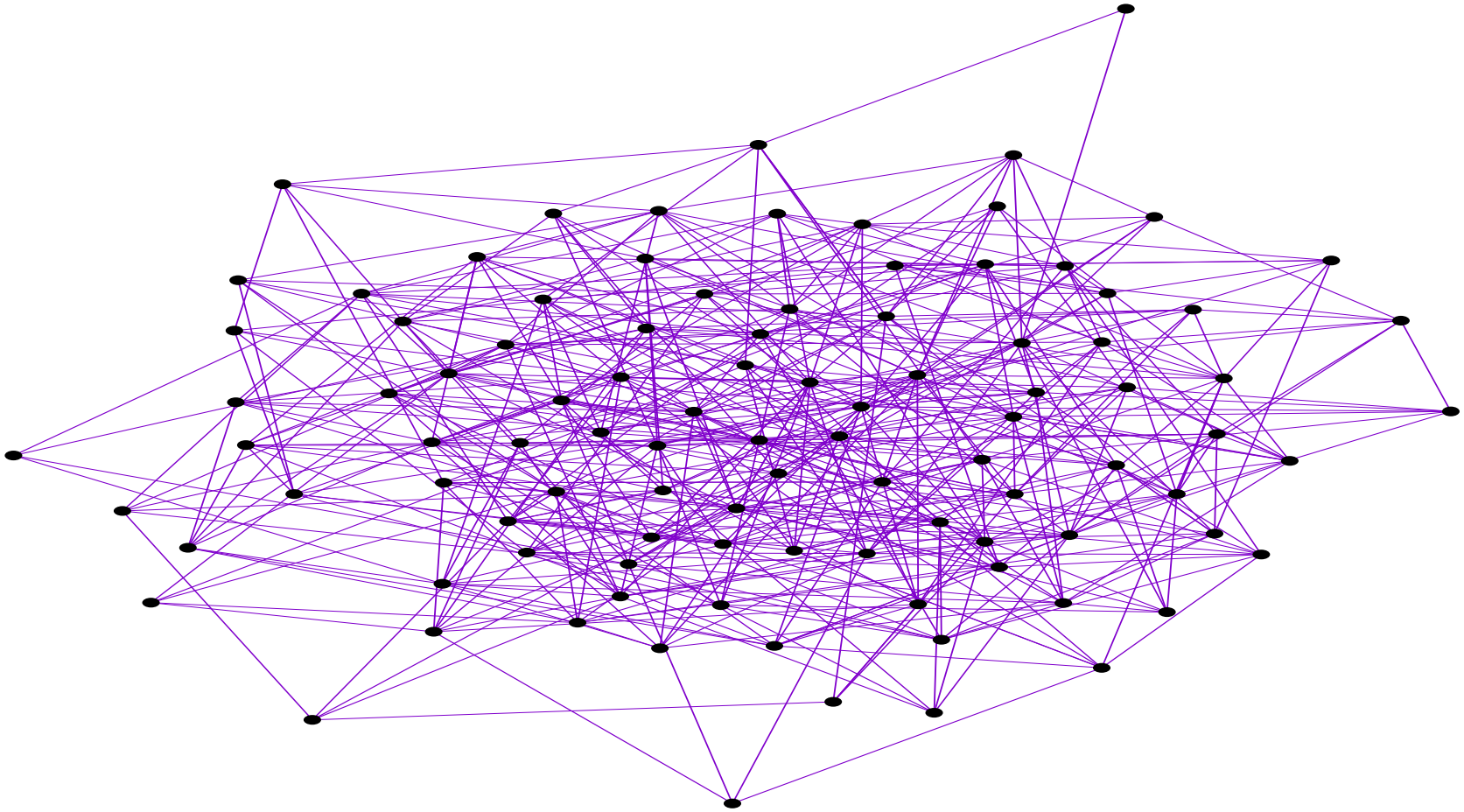
Lecture 7: Feedbacks



Intuitive Definitions

- Everyday language definitions
- Examples from Johnson/Emergence

http://www.sinc.co.uk/news/46/index.html

www.genniferflowers.com

Formal Definitions

- “The state of a model entity has an effect on the entity itself”
- Inherently temporal
- Difference equations / differential equations
- Agent based models
- Loops
- Complex Systems

Positive and Negative Feedbacks

- Positive: reinforcing
  - Chain reactions

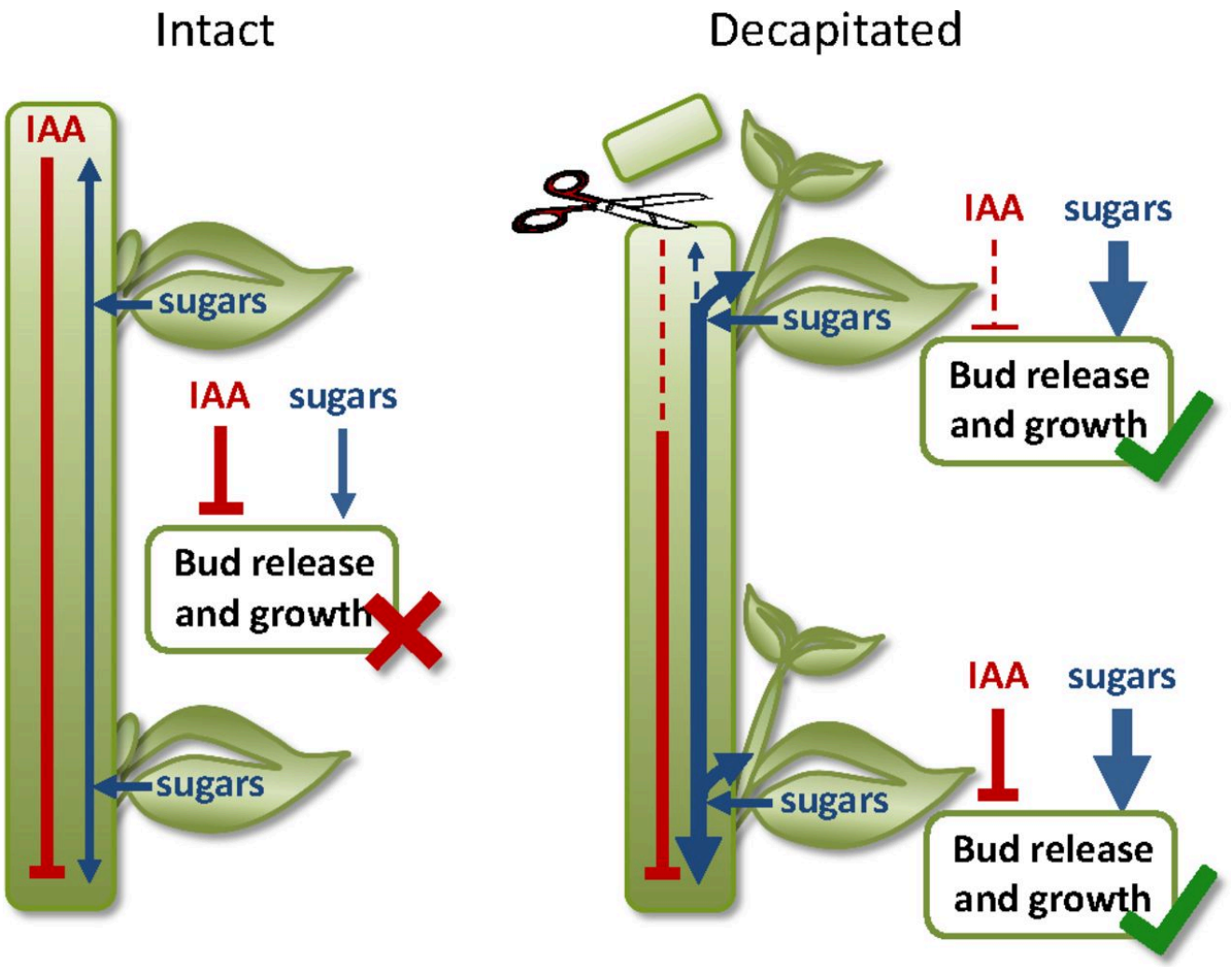
- Negative: regulating, damping/inhibiting
  - “homeostasis”

Some Examples From Biology….

Plant Physiology (!)

- Regulation of bud dormancy
  - Auxin (IAA) and Sugars
  - Actively growing buds inhibit other buds' growth
  - Removal of apical bud releases lower buds
  - Newly released buds inhibit others
  - Adaptive e.g. for herbivory

Apical dominance is controlled by sugar and hormone responses.

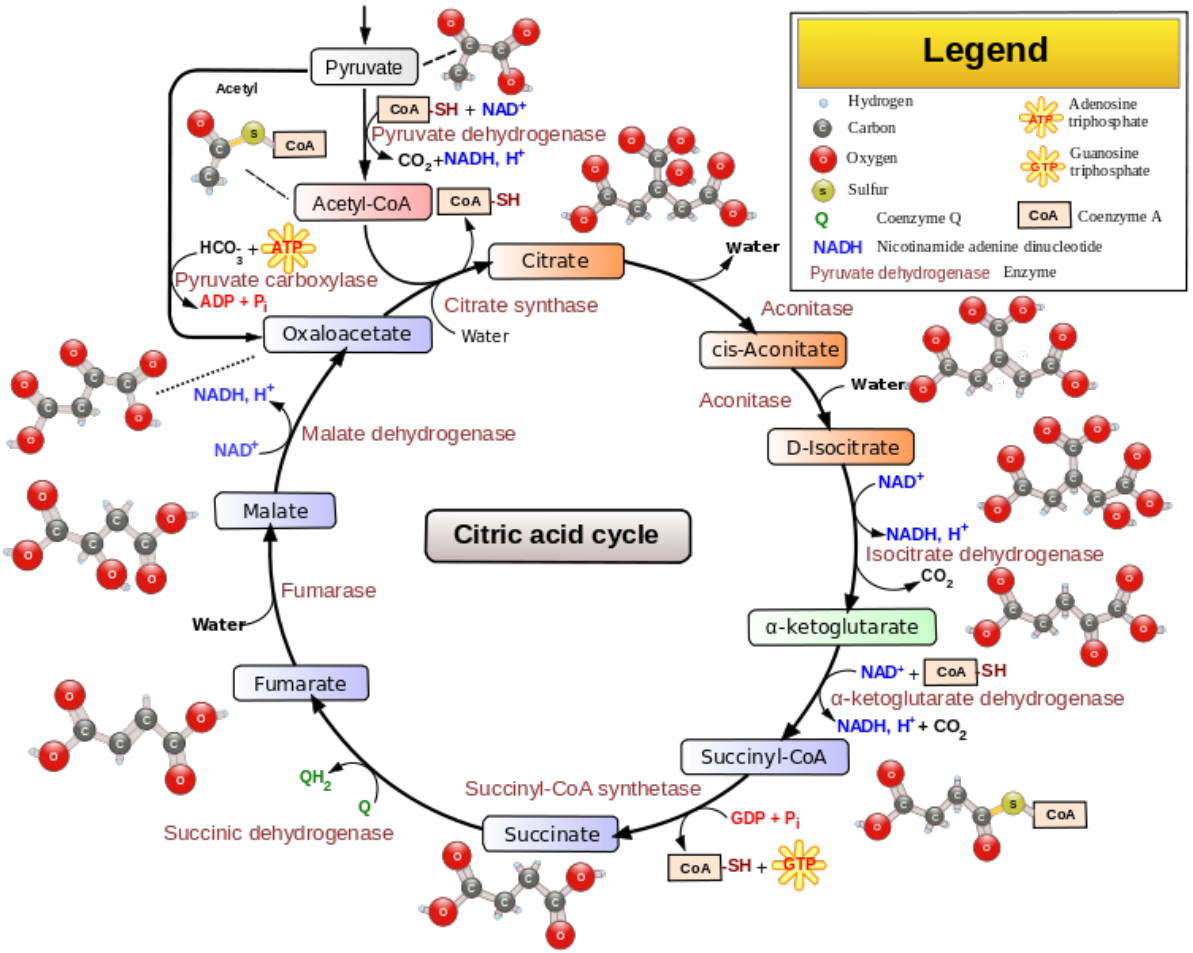


Michael G. Mason et al. PNAS 2014;111:6092-6097

Biochemistry

- The Citric Acid Cycle
  - Many steps
  - Reaction rates regulated by concentrations of products

High citrate concentration inhibits further glycolysis



http://biocyc.org/META/NEW-IMAGE?type=PATHWAY&object=TCA

Sexual Selection

- Selection for morphological traits affecting mating success.
- Female choice (typically).
- Positive feedback loop.

Tim Clutton-Brock**, Sexual Selection in Males and Females,** *Science 21 December 2007: Vol. 318 no. 5858 pp. 1882-1885*

Sexual Selection: Extreme Phenotypes

Bird-of-paradise

pbs.org

Sexual Selection: Extreme Phenotypes

www.bio.miami.edu

Examples From Social Science

- Product ratings/recommendations
- Urban Development
- Others?

Some Formal, Mathematical Examples…

Simplest Possible Feedback Model
Examples:
1-variable, aspatial

- Exponential population growth

$$x_{t+1} = \alpha x_t$$

- Logistic population growth

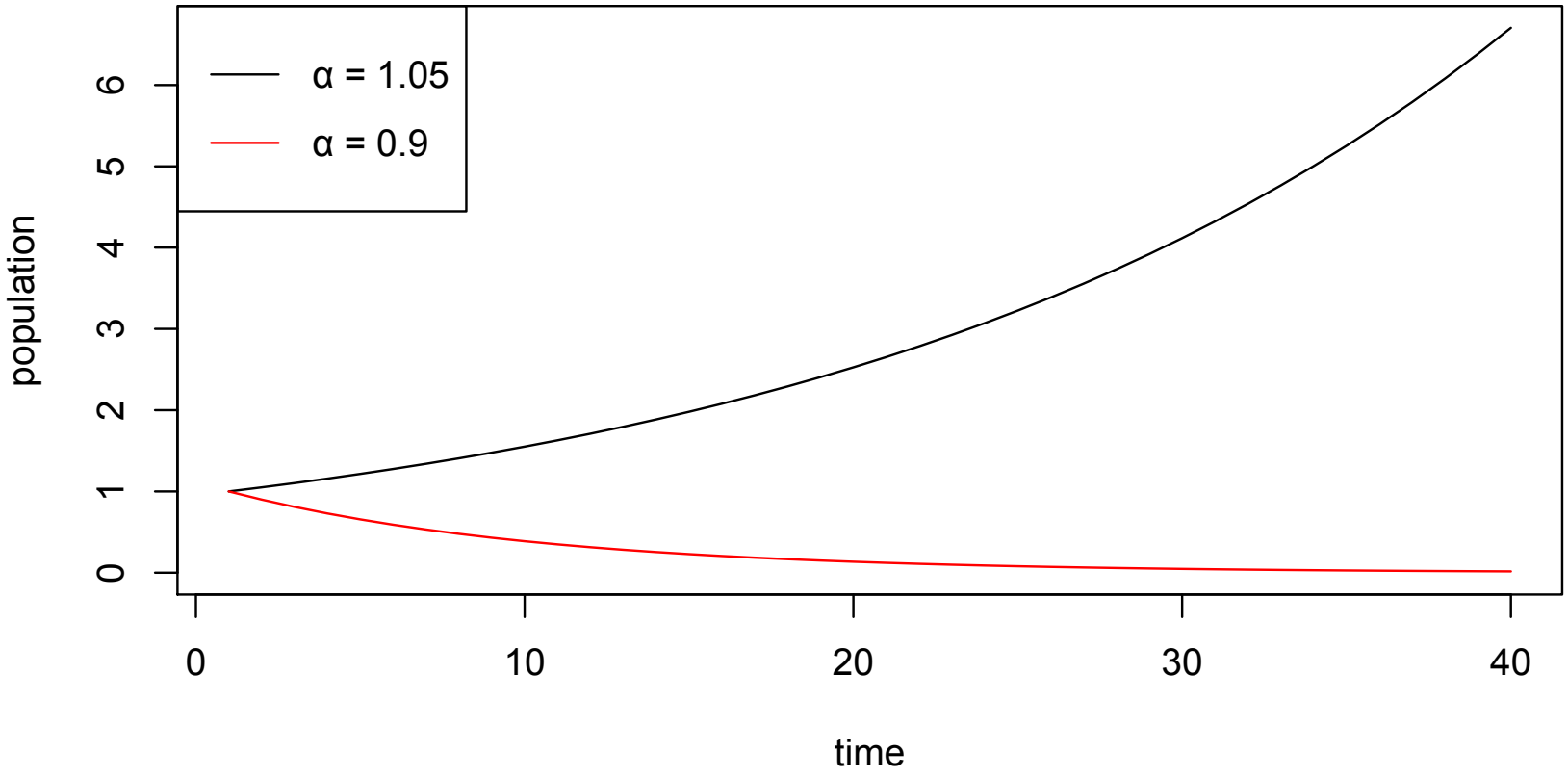
$$x_{t+1} = \alpha x_t (1 - x_t)$$

Exponential Population Growth

$$x_{t+1} = \alpha x_t$$

Positive feedback (when $\alpha > 1$)

Exponential Population Growth



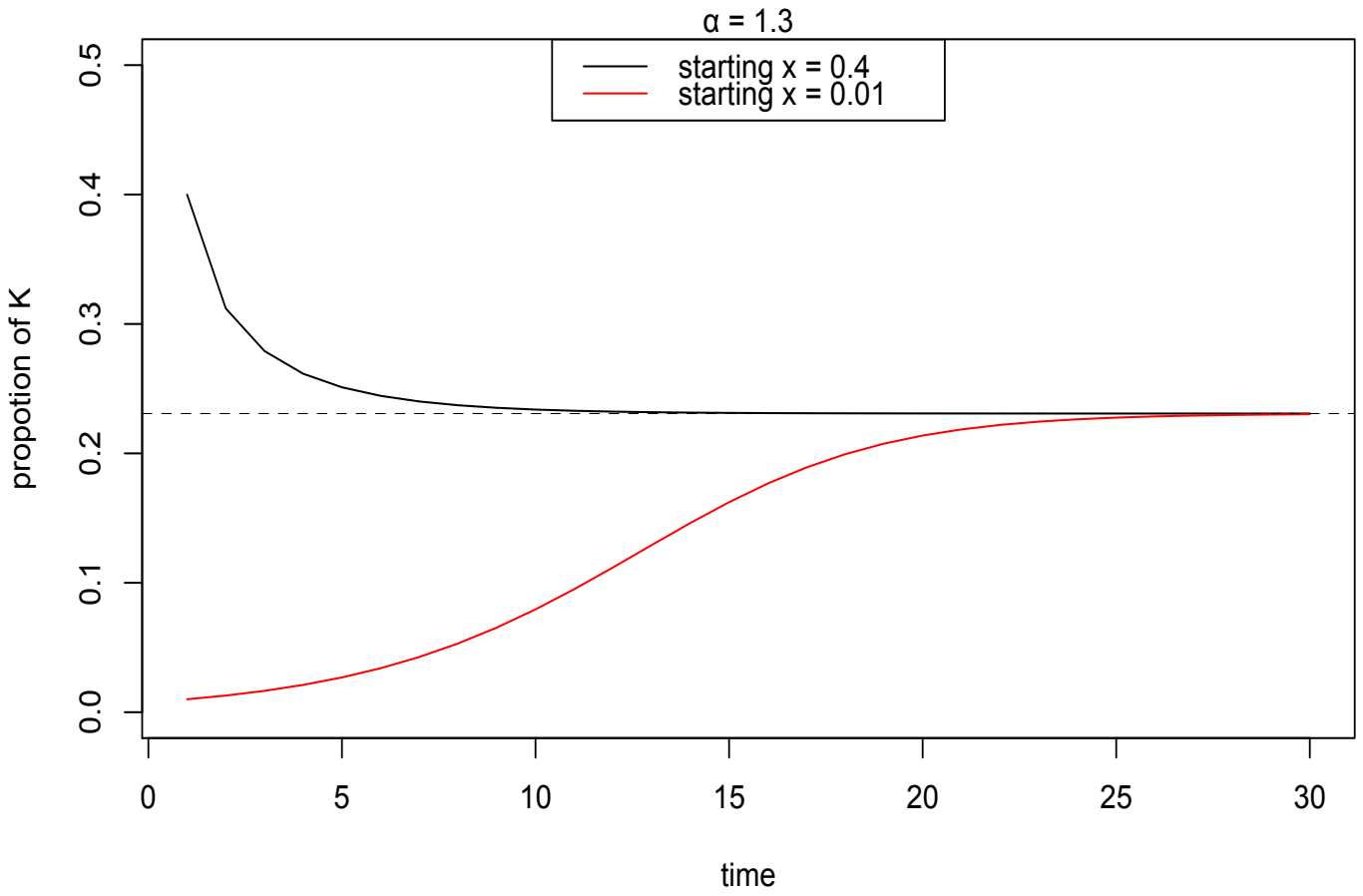
Logistic Population Growth

$$x_{t+1} = \alpha x_t (1 - x_t)$$

Positive

Negative

Logistic Population Growth



Logistic Population Growth

- At equilibrium:

$$x_{t+1} = x_t$$

- Perturbations

More complex feedback: 2-variables, coupled model

- Predator/Prey Interaction: the Lotka-Volterra Equations

Prey: $$\frac{dx}{dt} = \alpha x - \beta xy$$

Predator: $$\frac{dy}{dt} = \delta xy - \gamma y$$

Prey Model

$$\frac{dx}{dt} = \alpha x - \beta xy$$

Reproduction: Depends on x

Predation: Depends on x and y

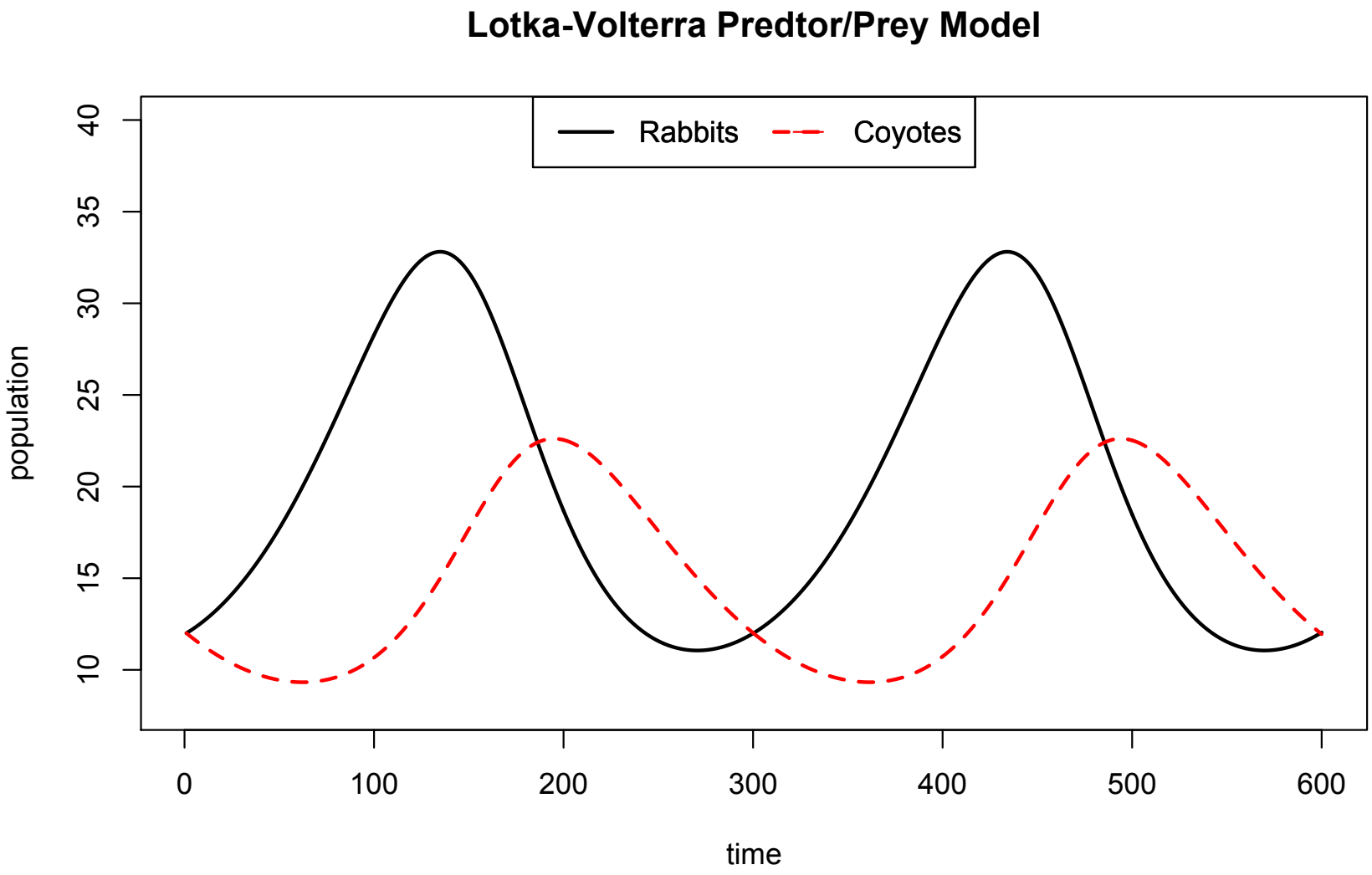
Predator Model

$$\frac{dy}{dt} = \delta xy - \gamma y$$

Reproduction:
Depends on y
and availability of x

Mortality:
Depends on y

Feedback can lead to cycles



Feedbacks in Spatial Models

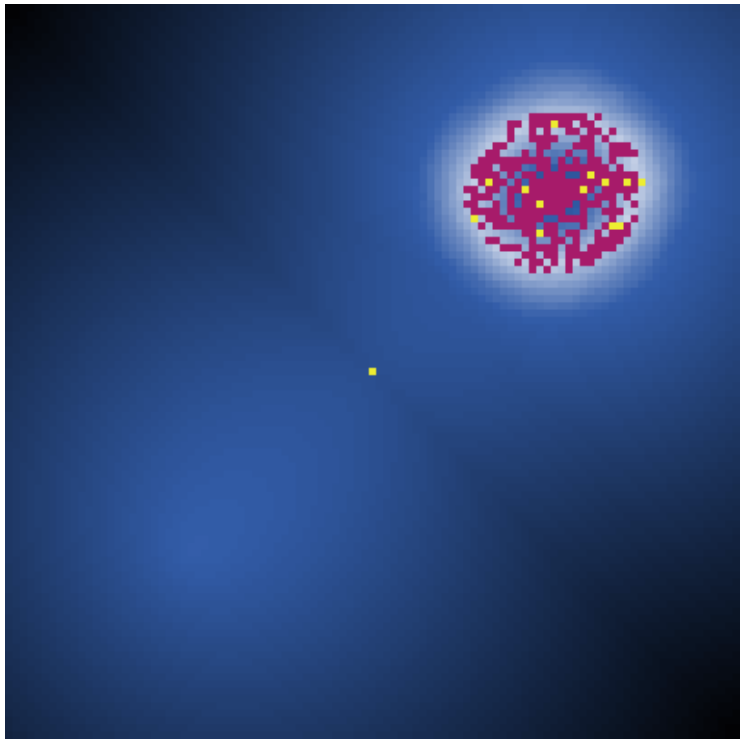
- Attempt to create a simple spatial predator/ prey model of Lotka-Volterra dynamics: What happens?

Feedbacks in Spatial Models

- Attempt to create a simple spatial predator/prey model of Lotka-Volterra dynamics: What happens?
- Why model?
  - Expose prevailing wisdom as incompatible with available data
  - Challenge the robustness of prevailing theory through perturbations
  - Discover new questions
  - Among others…

Feedbacks in Spatial Models

- Urban Development: The Brown et al. model
  - Spatial pattern of development affects subsequent development.
  - Path dependence



A Complex System: Mount Pine Beetles

beatthebeetles.com

news.ubc.ca

MPB Life Cycle Overview

Attack

www.lccdnet.org

Adults Emerge

beatthebeetles.com

Reproduce

sdda.sd.gov

Egg/Larva

apkxda.com

System Drivers

- Climate: Temperature, Precipitation, Wind
- Fire: Severity
- Beetle Communication: Pheromones
- Temporal: Successional Stage
- Spatial: Environmental Heterogeneity
- Forest Policy: Fire Supression, Age Structure

Feedbacks

- Pheromones: Aggregation and Repulsion
- Competitors
- Climate
- Age Structure

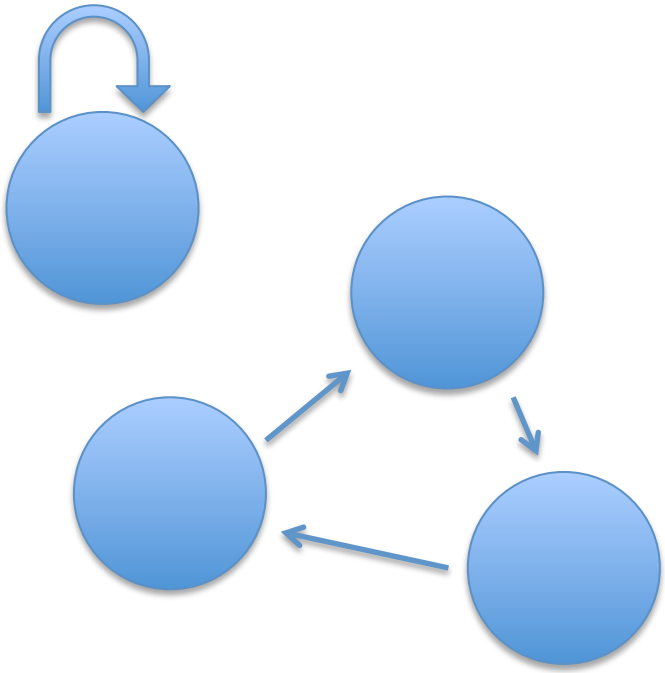
MPB
Endemic vs. Epidemic Phase

- Endemic: stable, low population size

- Epidemic: population explosions

Mechanics of Feedbacks

- Direct
  - Entity affects self directly
- Indirect
  - Feedback via intermediaries
- Cross-Scale
  - Processes occurring at different spatial/temporal scales



Stochasticity

- What is stochasticity?
- How is stochasticity implemented in models?
- How is it related to uncertainty?

Next Lab

- Read Brown et al. through section 2.3