Human Population 2018

Lecture 7
The Biosphere
ECOME.
Boom-bust cycles.
Limits.
Regeneration of renewable resources.
Lamarckian evolution.

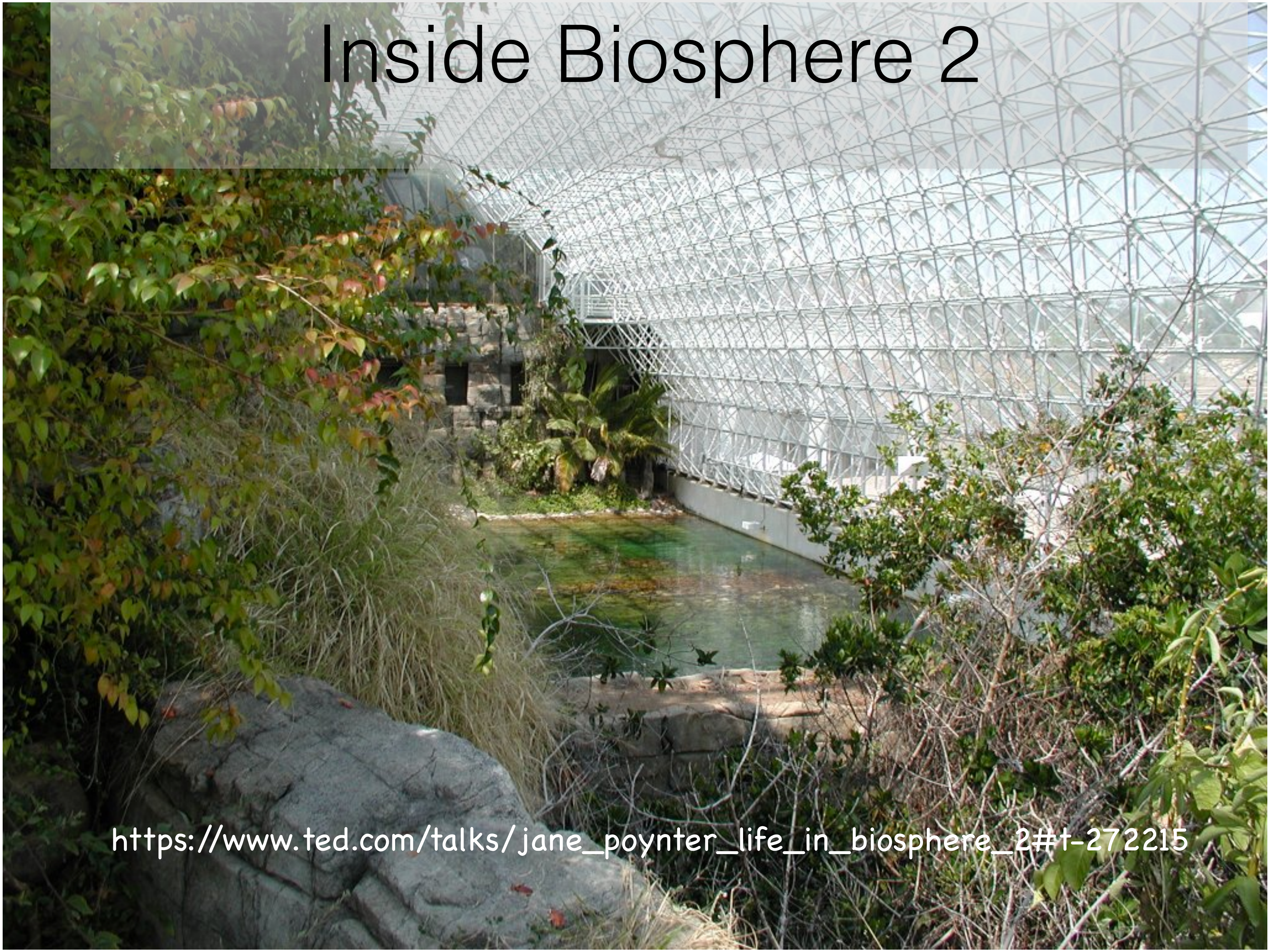
Questions on the reading?

pp 51-86

Sustainability
Sinks and sources
water
forests
ecosystem services

8 people lived in the biosphere, 1991-1993

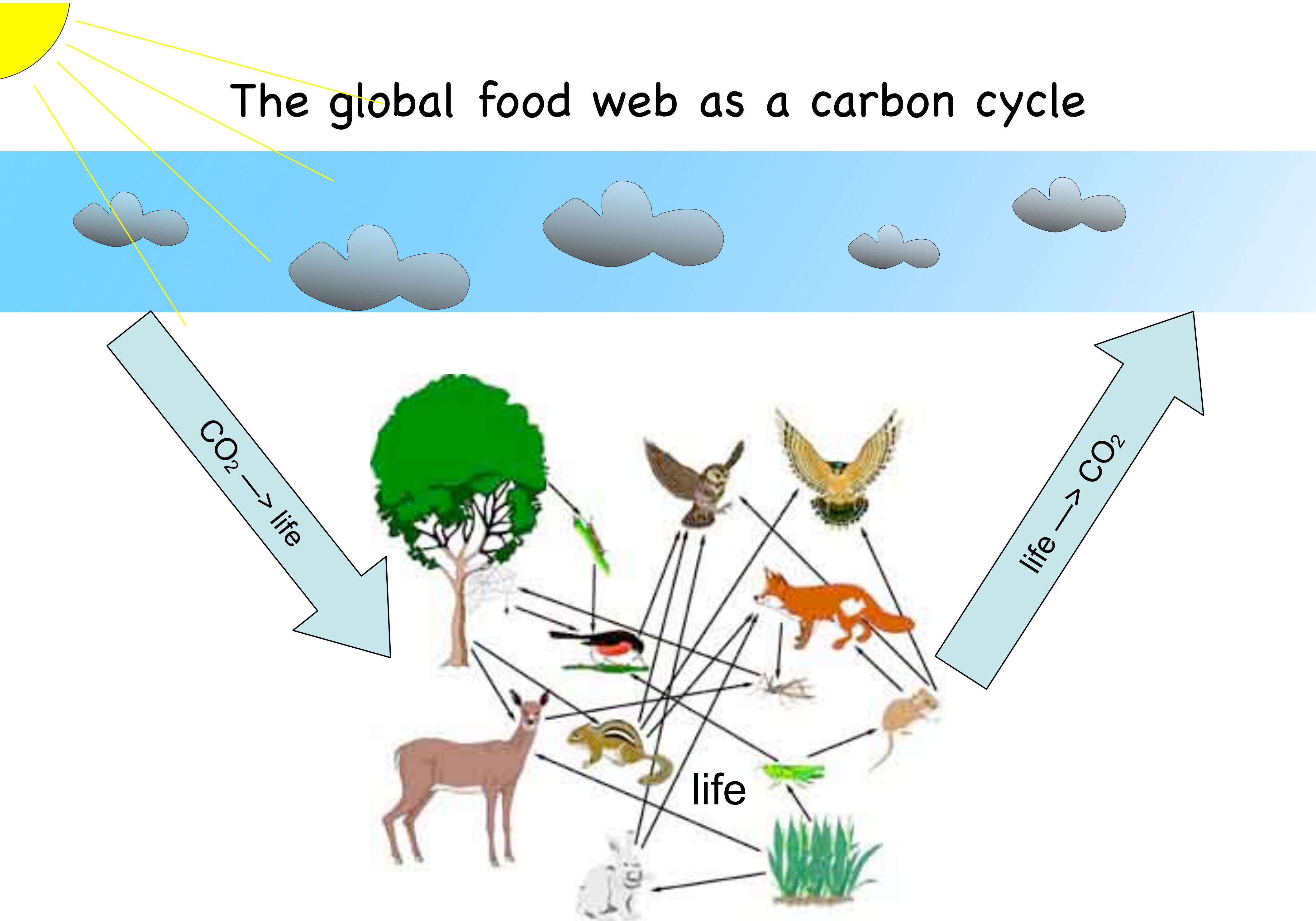
Inside Biosphere 2



https://www.ted.com/talks/jane_poynter_life_in_biosphere_2#t-272215

Life is a carbon cycle

The global food web as a carbon cycle

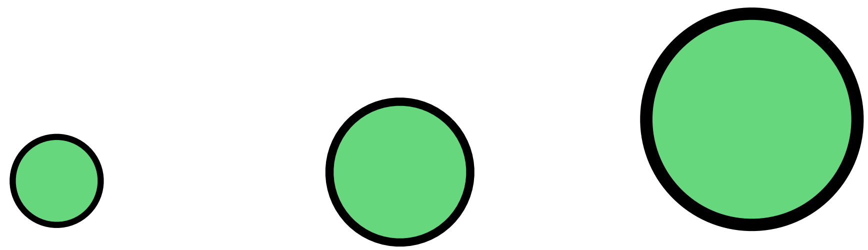


Bystroff C, DeLuca S, & McDaniel CN (2005) ECOME: A simple model for an evolving consumption web. *IEEE Computational Systems Bioinformatics Conference - Workshops* 8-11 Aug. 2005 pp 260 - 261

stocks are populations of animals and plants

How does it work?

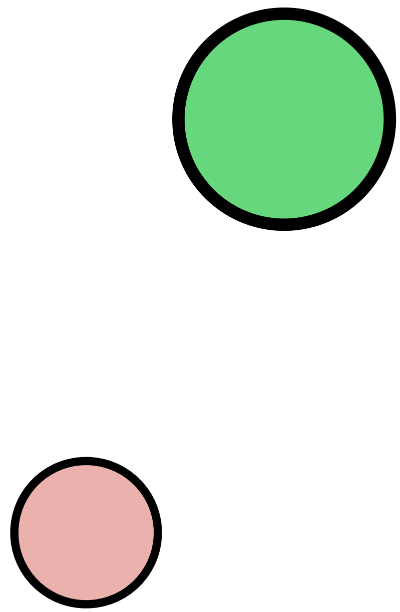
- Species are measured in units of “biomass”



area of circle = population

Bystroff C, DeLuca S, & McDaniel CN (2005) ECOME: A simple model for an evolving consumption web. *IEEE Computational Systems Bioinformatics Conference - Workshops* 8-11 Aug. 2005 pp 260 - 261 plants are green

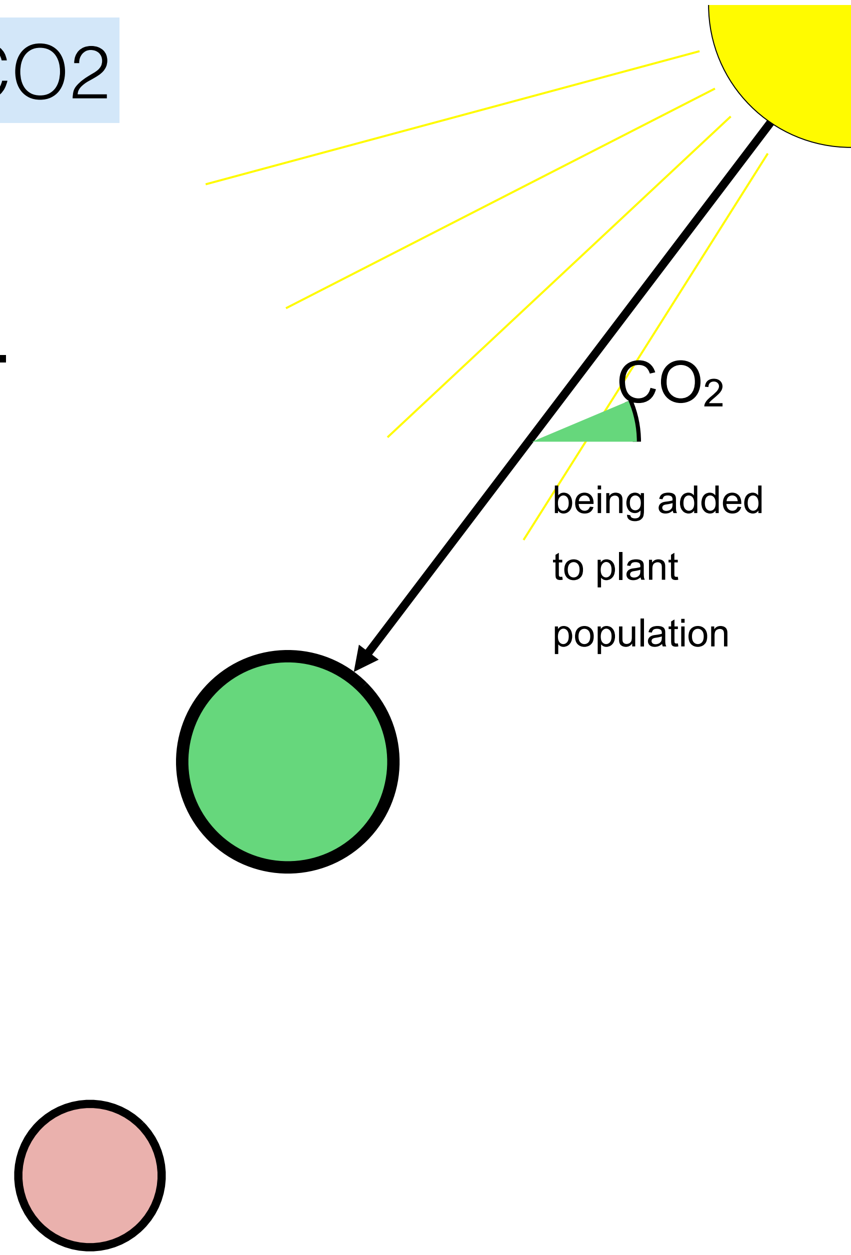
- Species can be autotrophs (green) or heterotrophs (red)



plants reduce CO2

- Plants catalyze* CO_2 --> CH

Plants grow <u>proportional</u> to biomass.

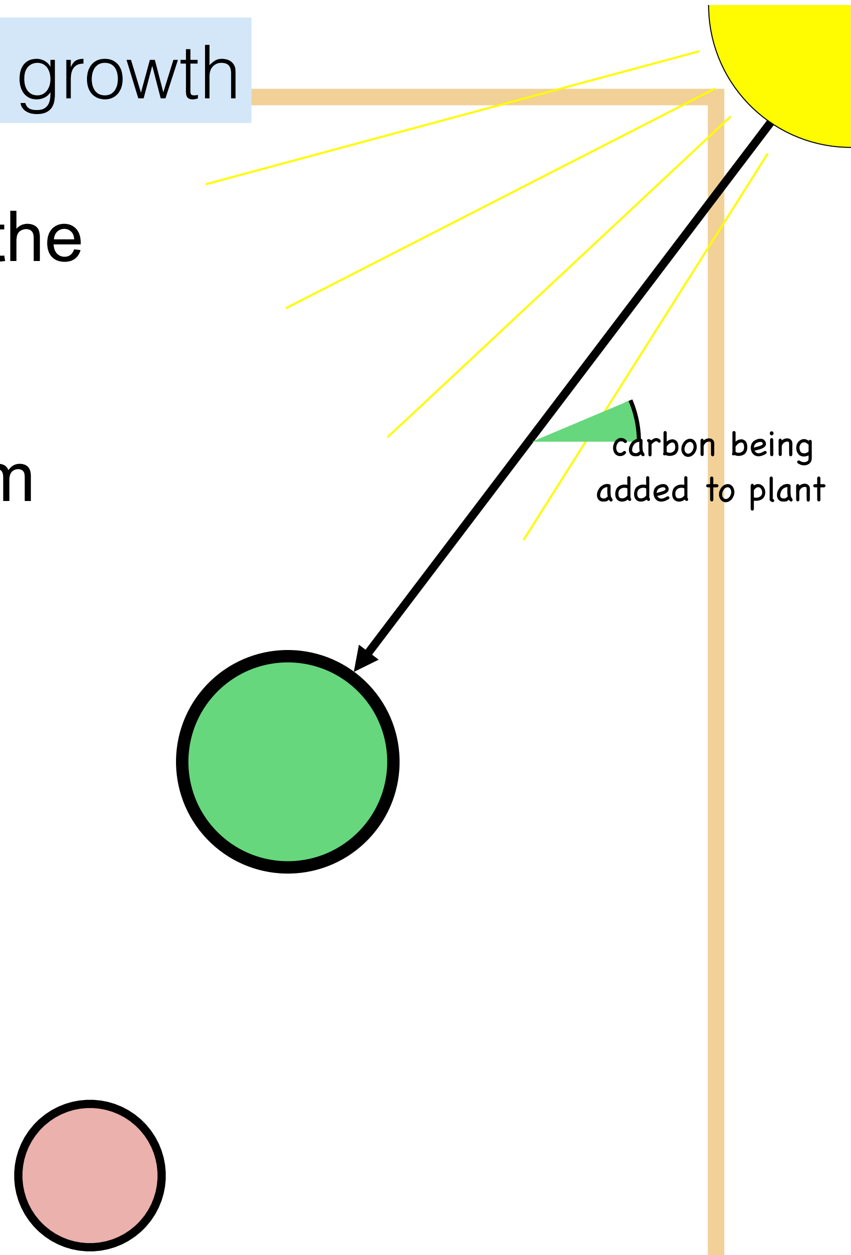


*RuBisCo is the enzyme responsible for this. In chloroplasts.

global limit on plant growth

- The sun's maximum total input to the food web is fixed.

All plants stop growing when the sum total biomass ≥ sun limit*



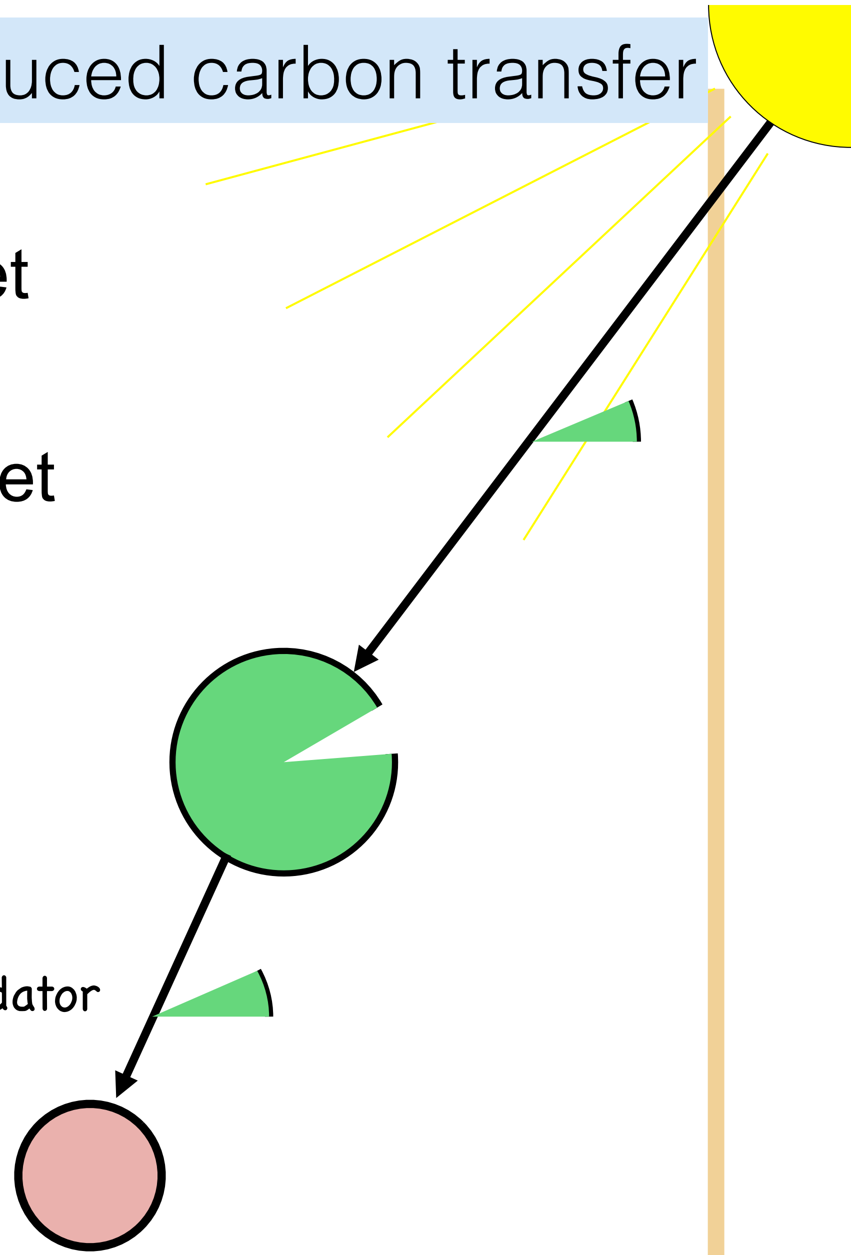
*This could have been modeled differently. In reality plants shade each other to death, competing for light. We're ignoring plant/plant competition. Is simplifying OK?

flows are predation (eating) = reduced carbon transfer

- Primary consumers (herbivores) get biomass from plants

Secondary consumers (carnivores) get biomass from other animals.

etc.

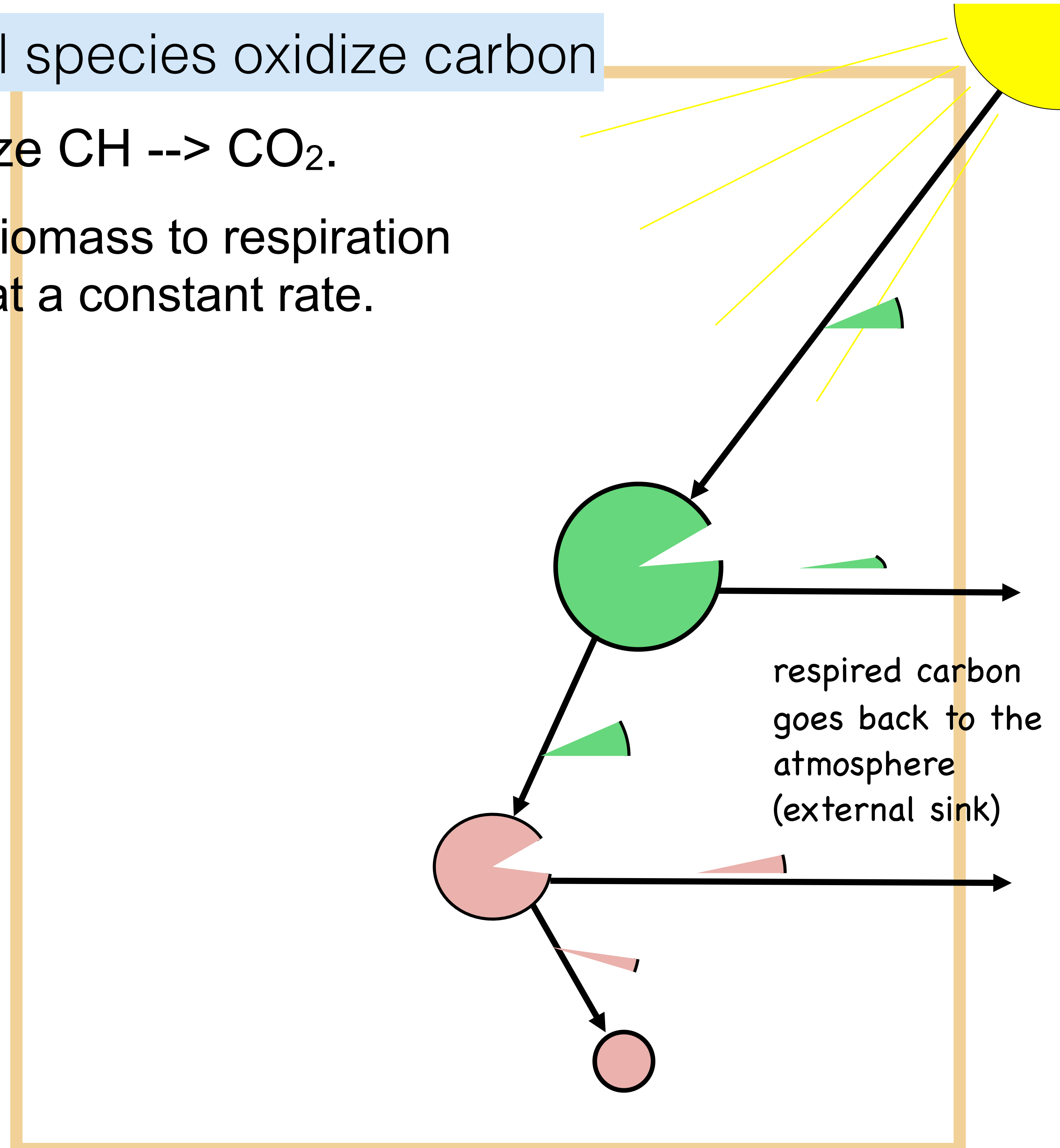


direction of arrow is prey --> predator

all species oxidize carbon

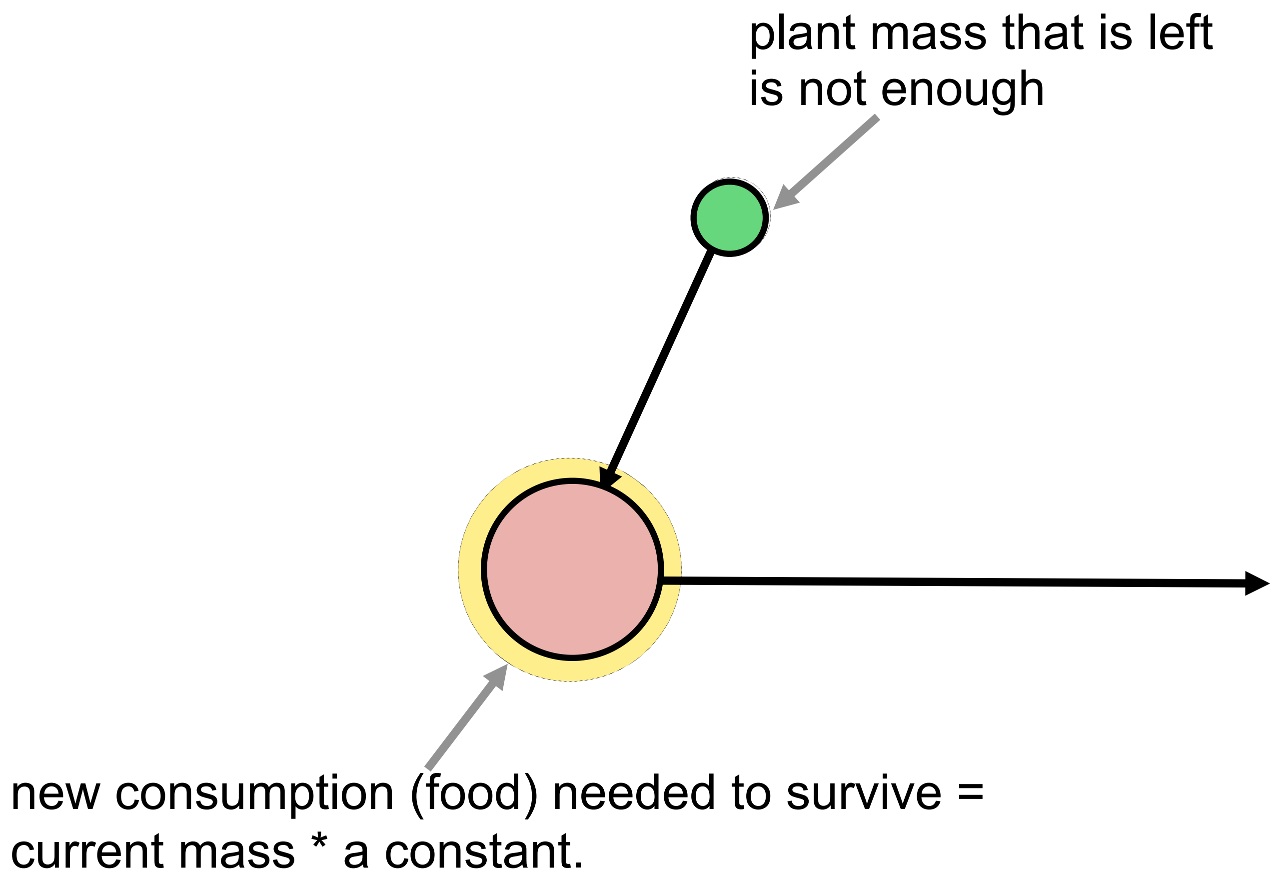
- All species catalyze CH --> CO_2.

i.e. All species lose biomass to respiration and decomposition, at a constant rate.



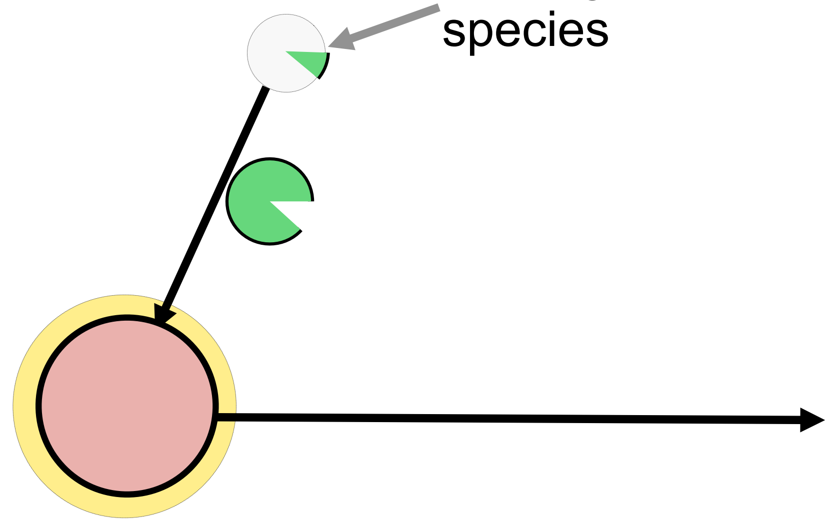
grow, or die!

- Predator species collapse when prey is scarce, Part 1.



grow, or die!

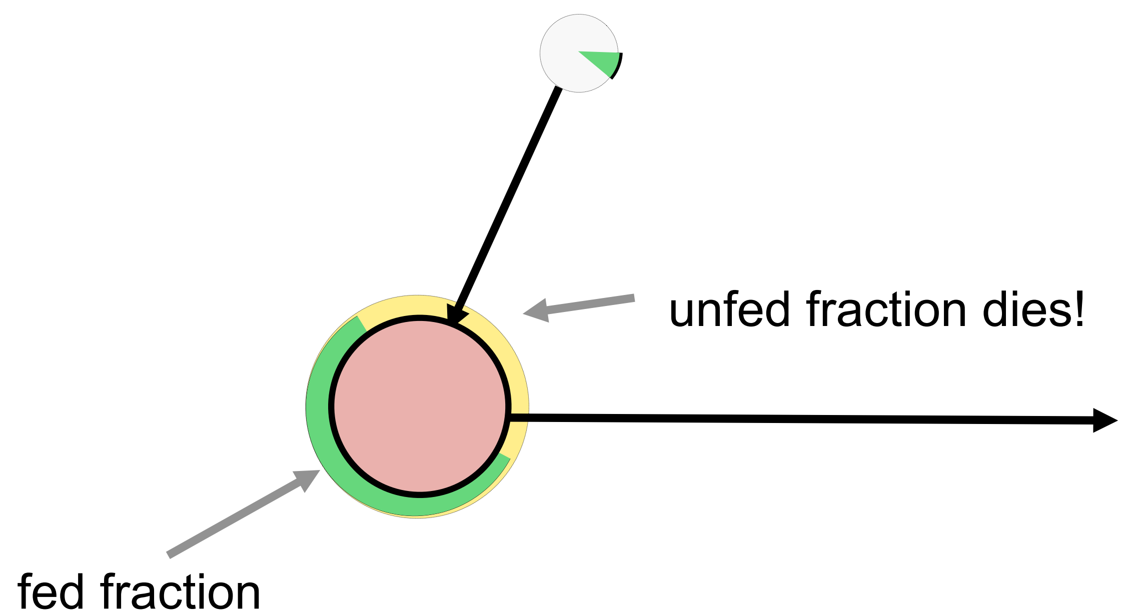
- Predator species collapse when prey is scarce, Part 2.



grow, or die!

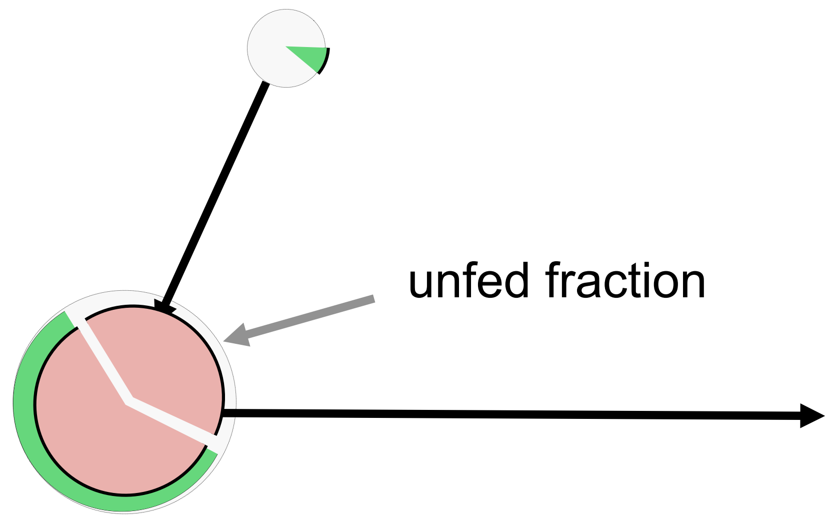
- Predator species collapse when prey is scarce, Part 3.

- Only fed fraction grows



grow, or die!

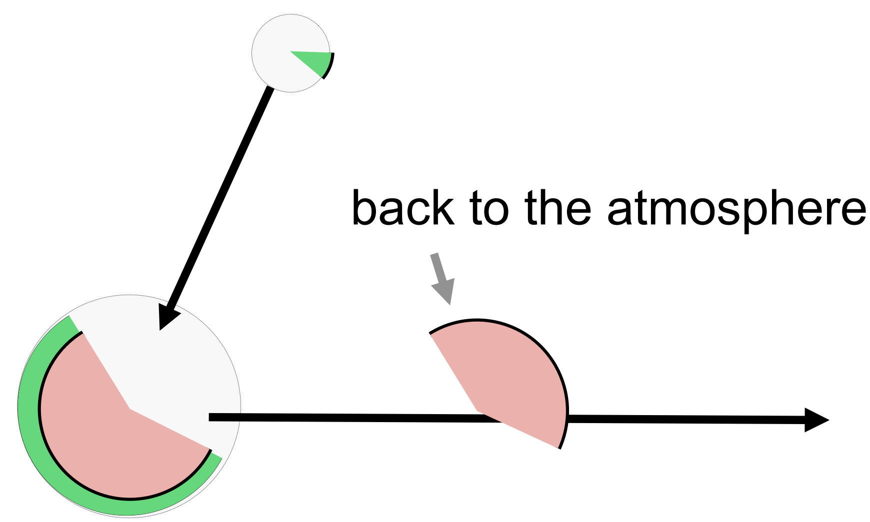
- Predator species collapse when prey is scarce, Part 4.



- Unfed fraction dies.

grow, or die!

- Predator species collapse when prey is scarce, Part 5.



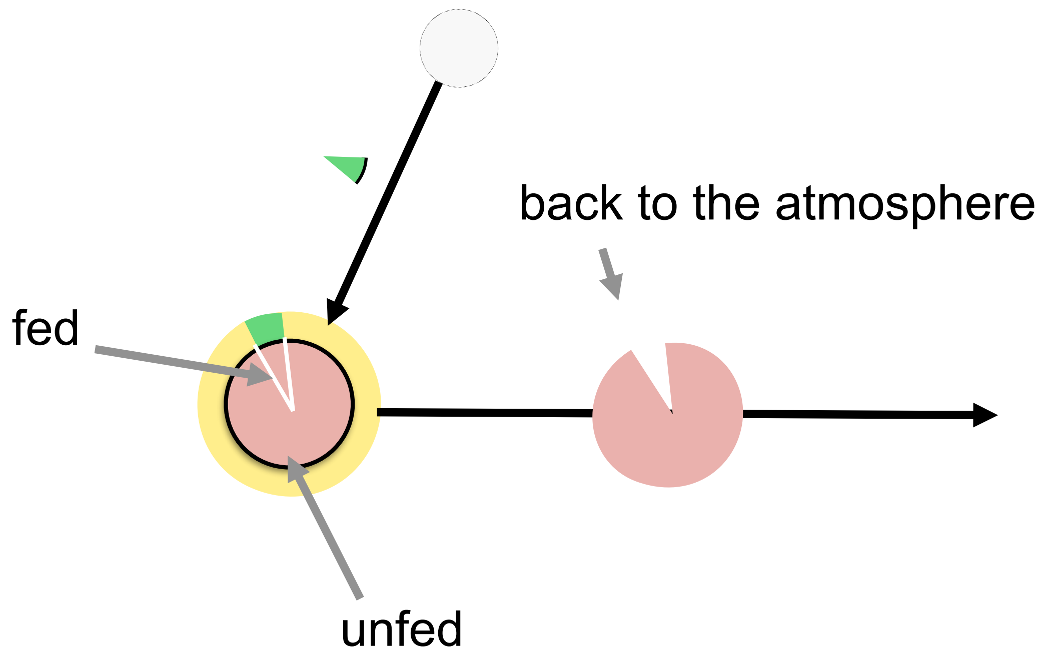
- ...becomes CO_2.

Collapse happens on the **next** cycle, since almost all the food is gone.

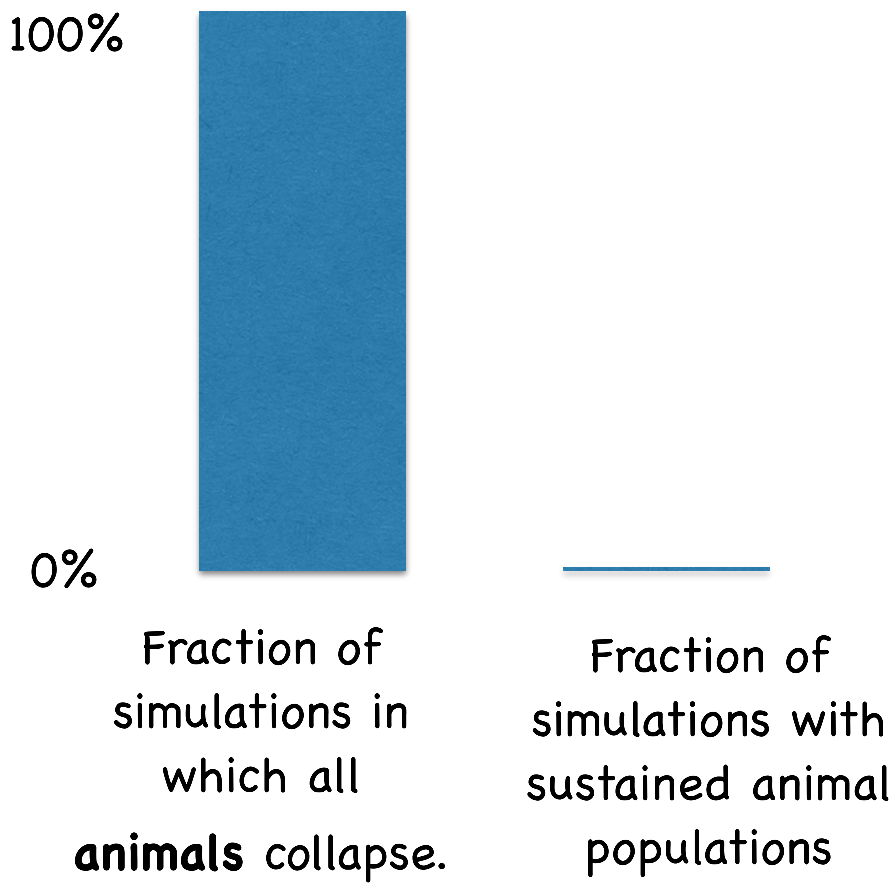
grow, or die!

- Predator species collapse when prey is scarce, Part 6.

Collapse happens on the **next** cycle, since all the food is gone.



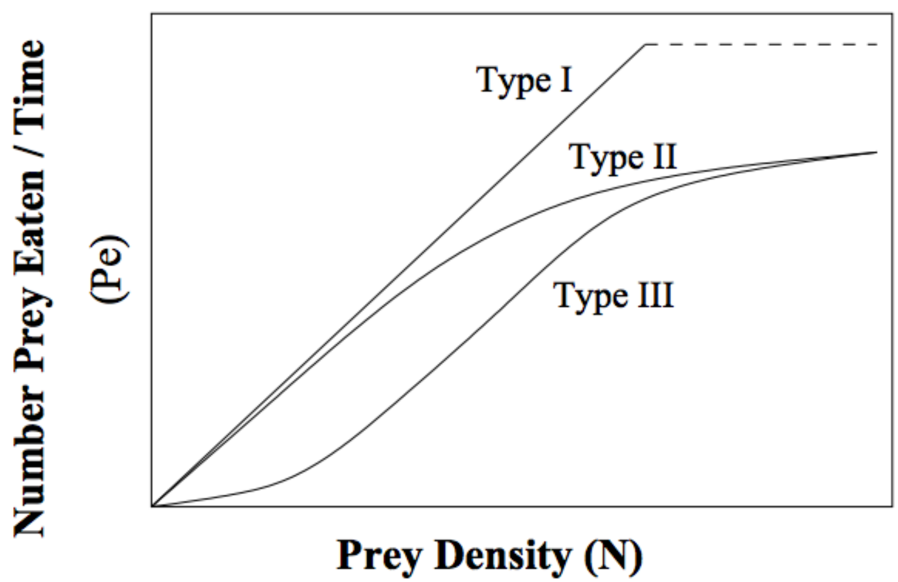
- **Results of ECOME simulations (no limits on predation.)**

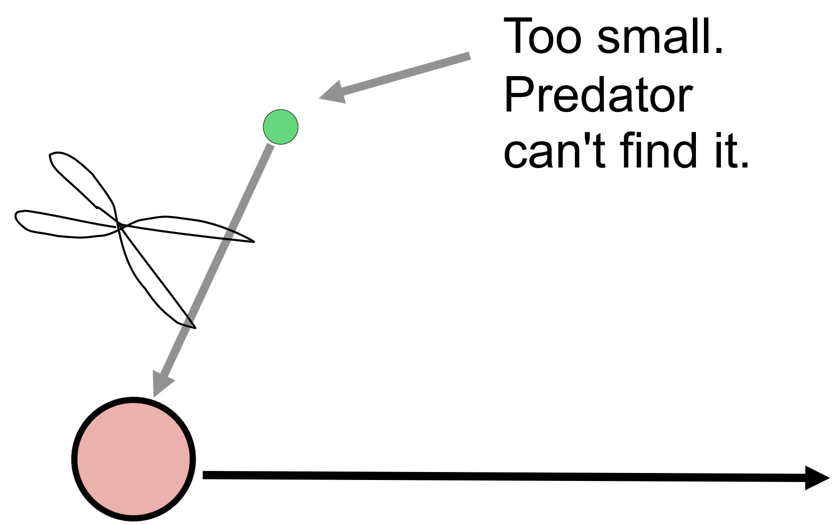


- **Holling response functions** modify predator/prey relationship.

Model prey availability as a function of prey density.

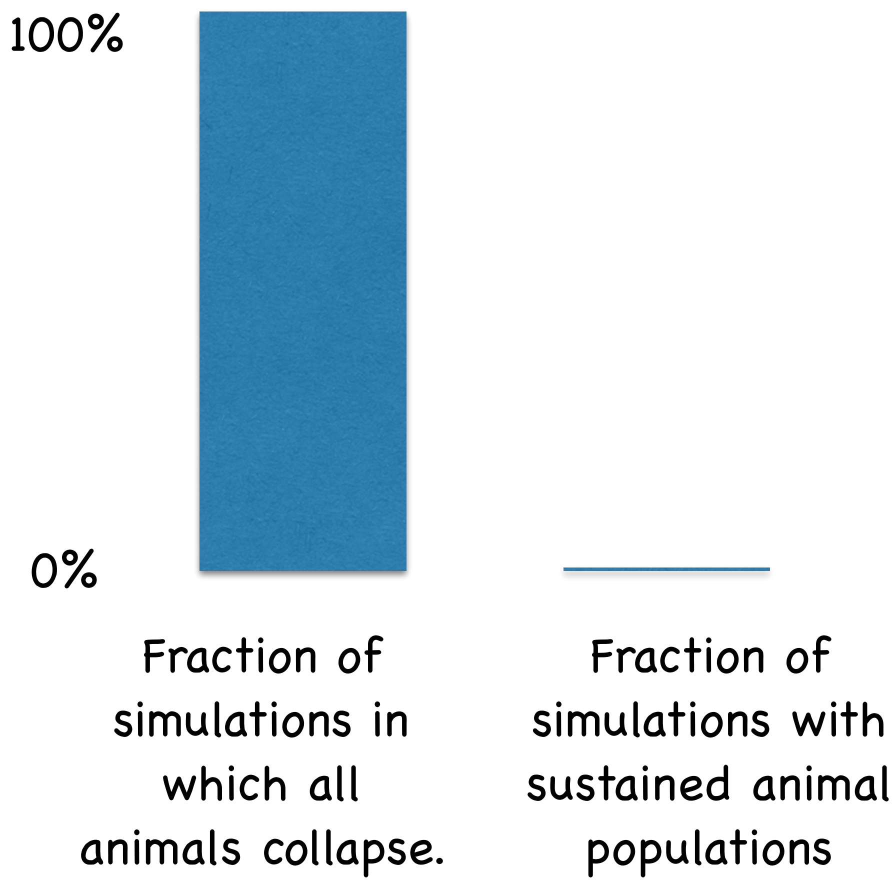
$$Pe = N/(K + N)$$





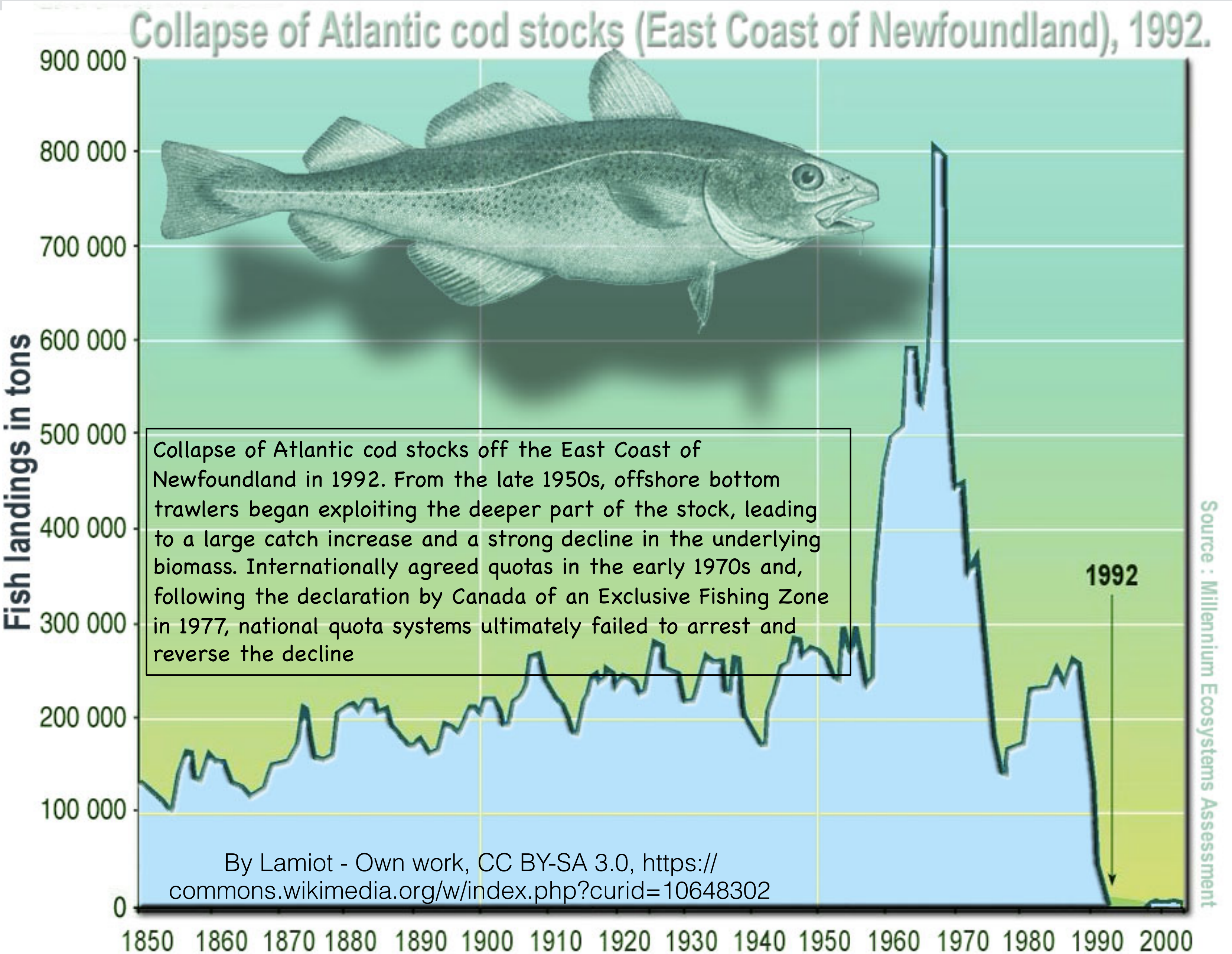
http://www.indiana.edu/~oso/lessons/BioMath/hd-root.pdf

- **Results of ECOME simulations with <u>Hollings functions</u> to limit predation.**



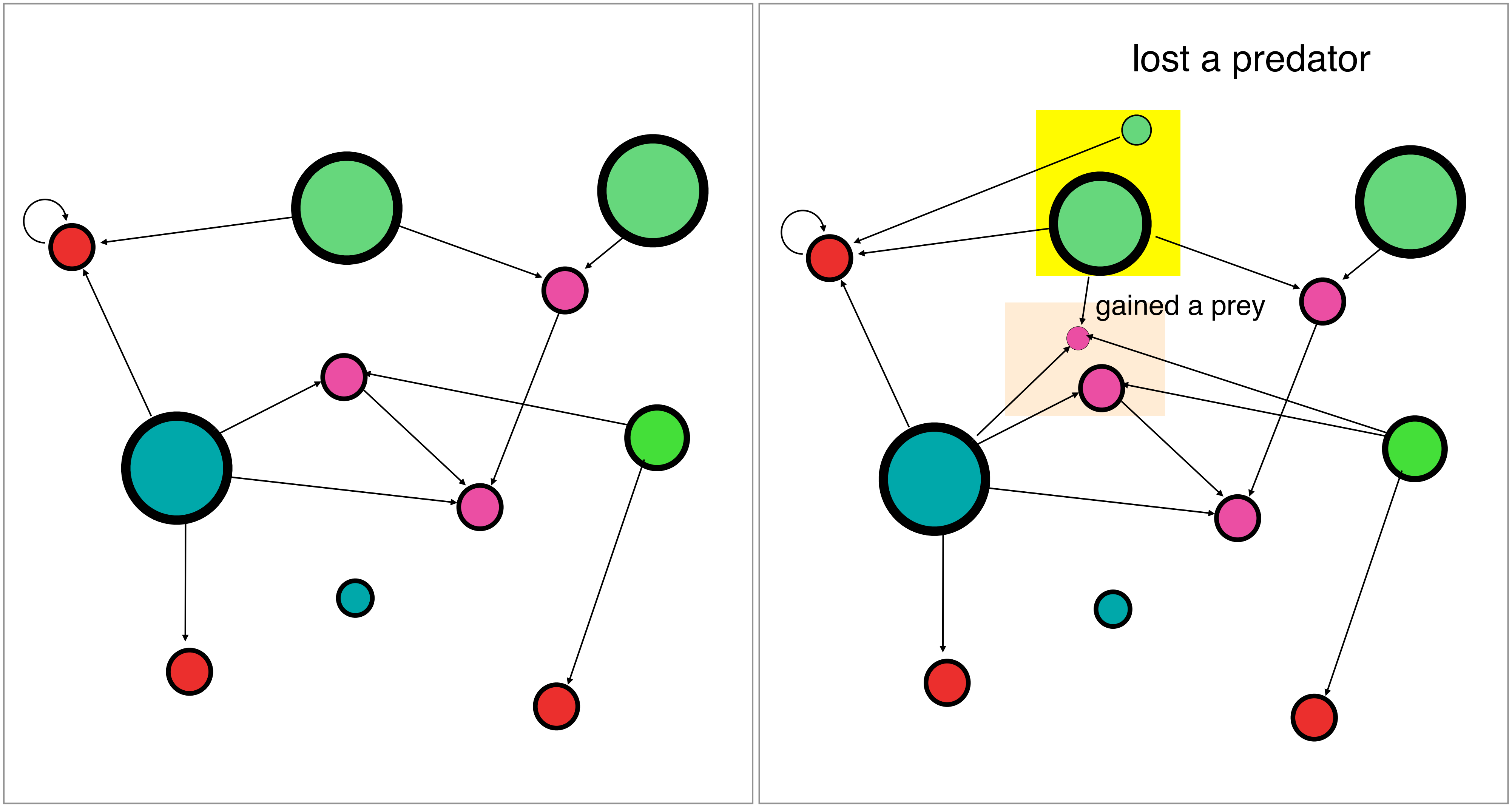
Hollings functions favor prey over predators. Plants dominate. Animals collapse.

Canadians versus Cod. Holling response function Type 3 applied to commercial fishing, but...



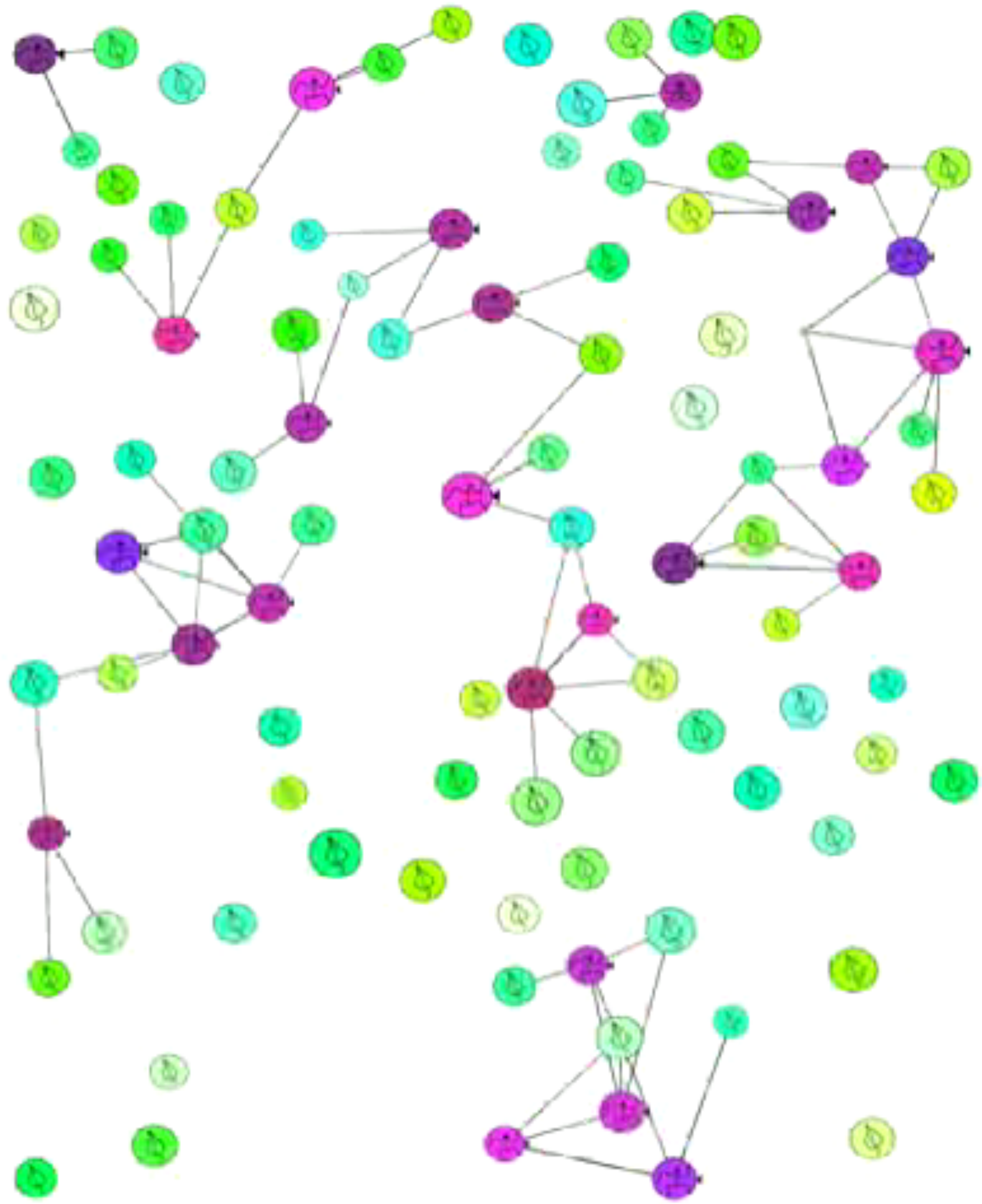
What if we allow evolution?

- New species chooses prey randomly, proportional to biomass.
- New species adapts against a predator.

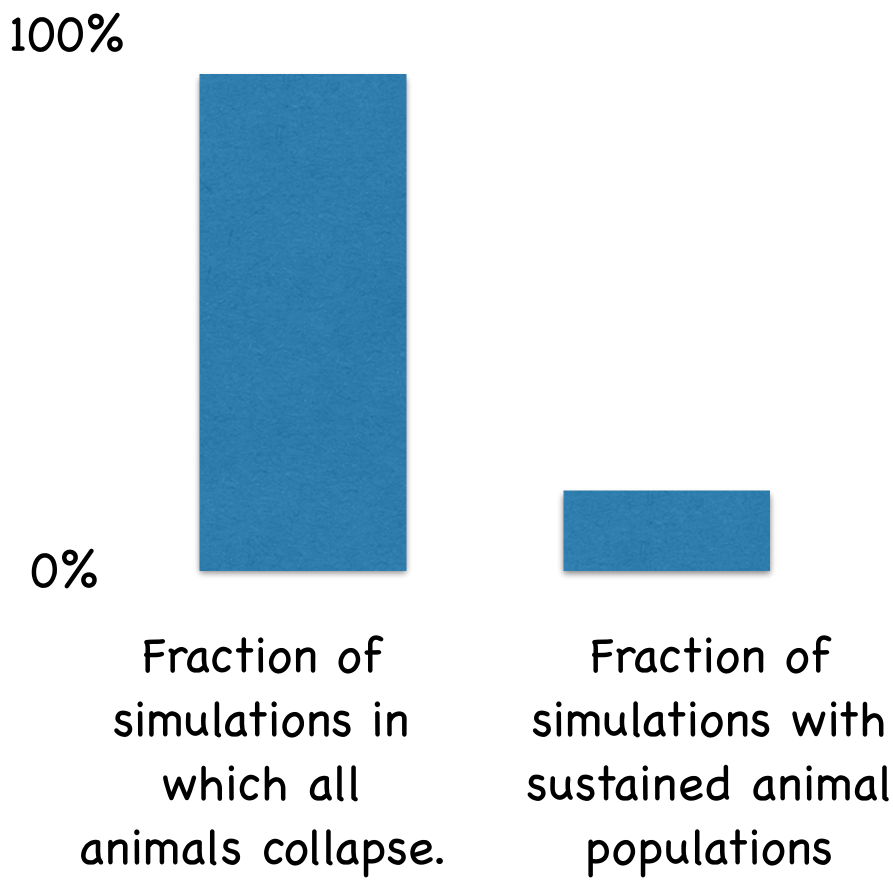


http://www.bioinfo.rpi.edu/bystrc/ecome/local.mpeg

ECOME: boom/bust cycles



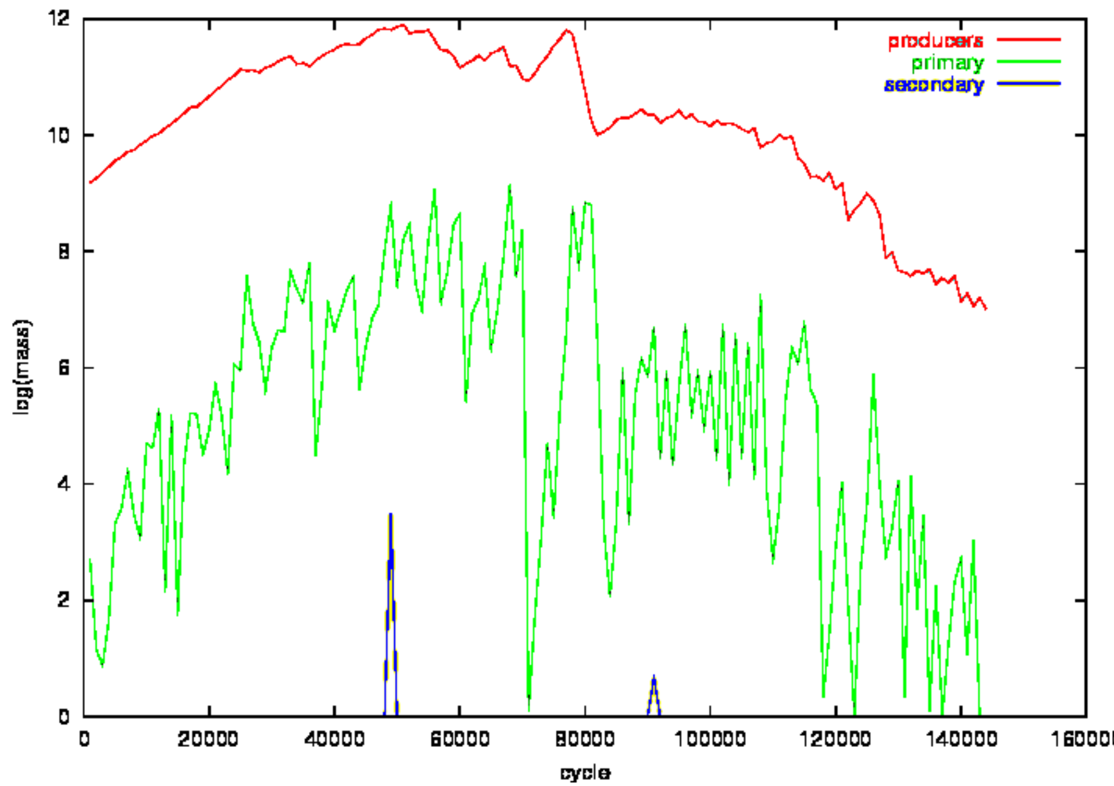
- **Results of ECOME simulations with <u>evolution.</u>**



Why are populations inherently *unstable?*

- Predators consume in proportion to population
- Prey recover in proportion to population

- As population of predators increases, predation increases, therefore prey decreases, therefore prey recovery decreases, leading to collapse.

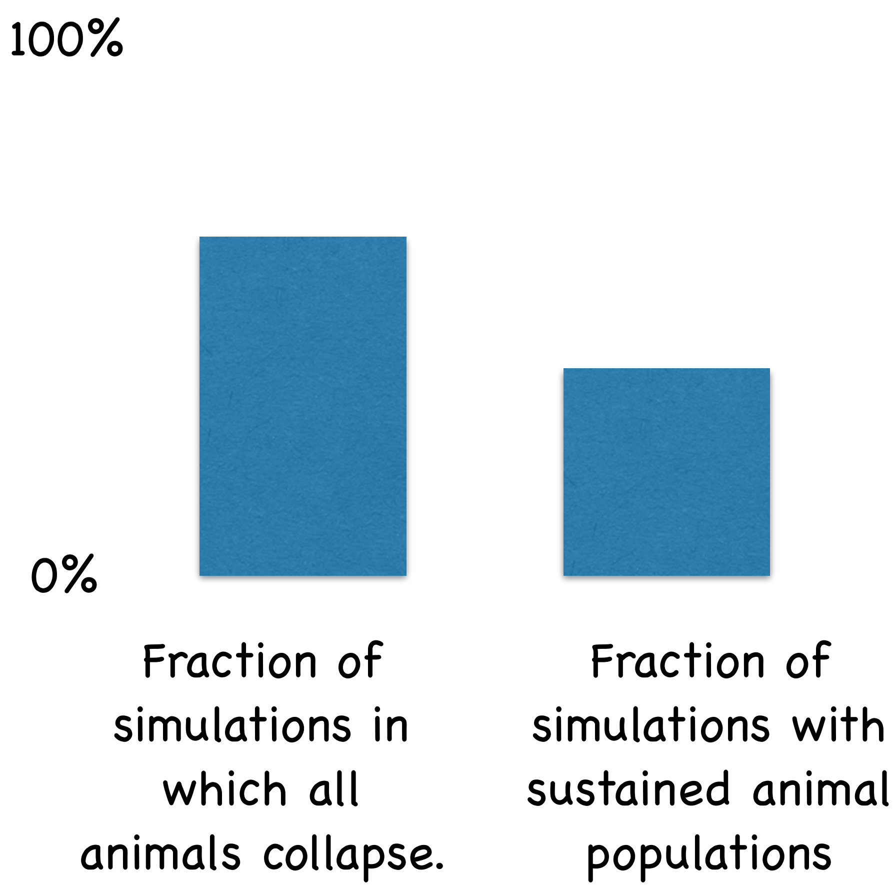


ECOME log(biomass) vs time.

How does evolution make ecosystems *dynamically stable?*

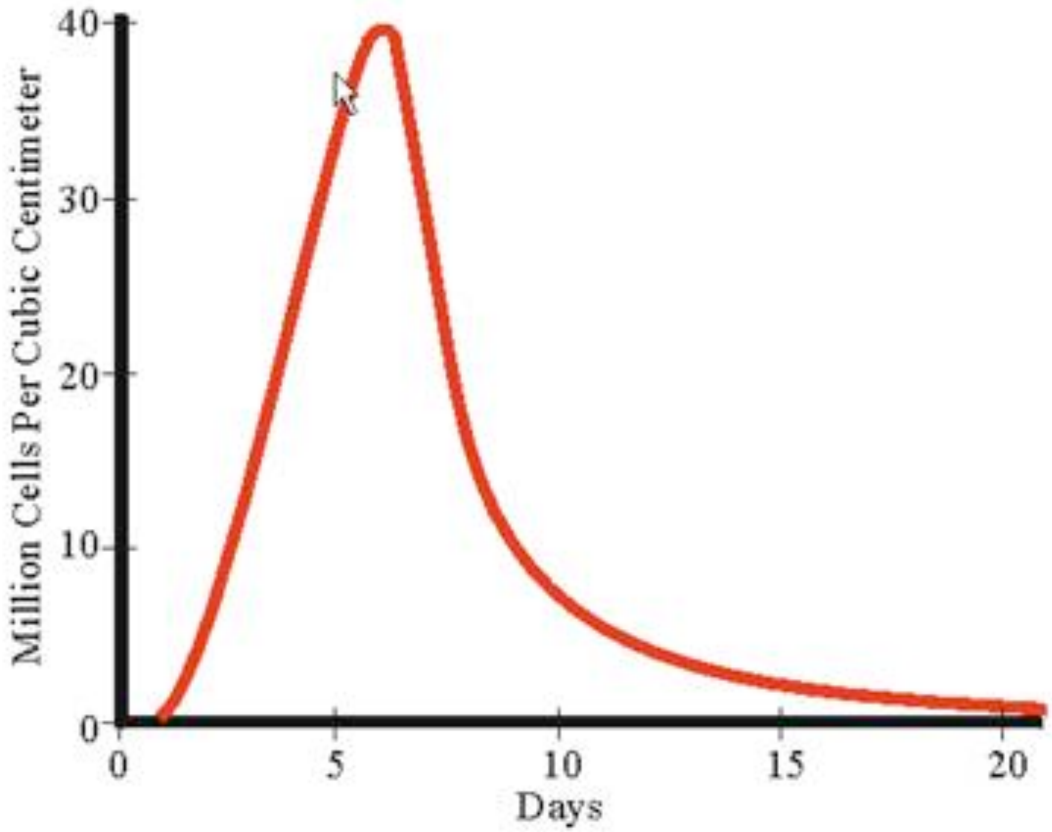
- Evolution cuts predator/prey relationships, makes new predator/prey relationships.
- Newly evolved species have fewer predators, increase in population.
- Older species have more predators, are more subject to collapse.
- Collapse of old species releases resources for new species.
- Inherent collapse still happens, but newly evolved species escape.

- **Results of ECOME simulations with <u>large systems</u> and <u>evolution.</u>**

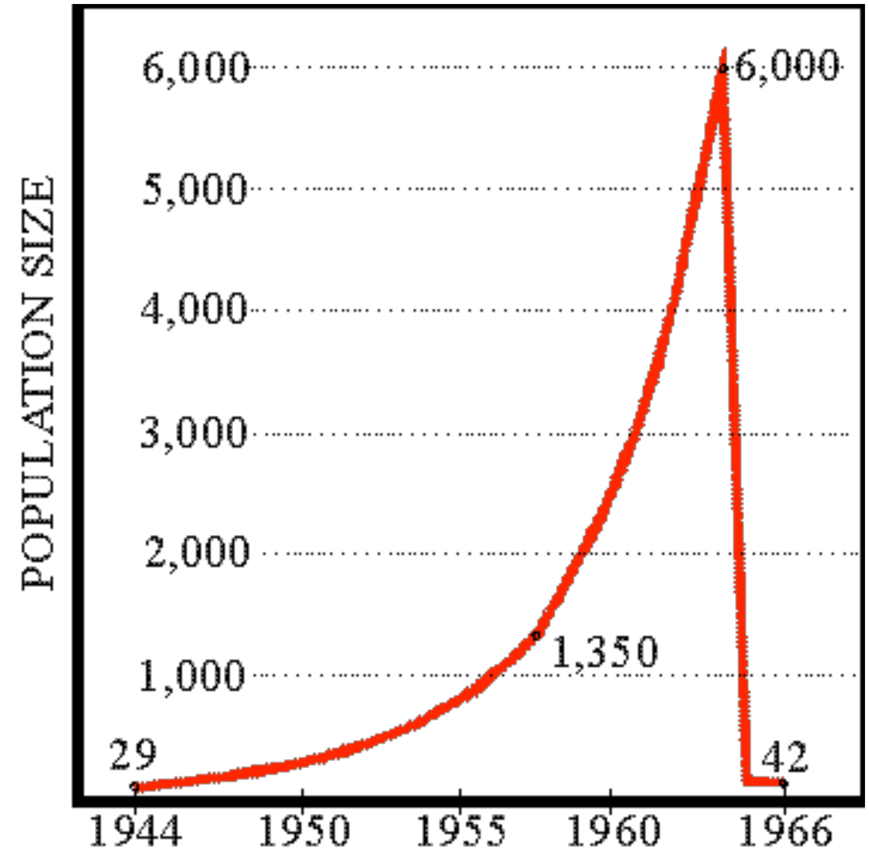


boom/bust upon depletion of food resources

Yeast in 10% sugar solution



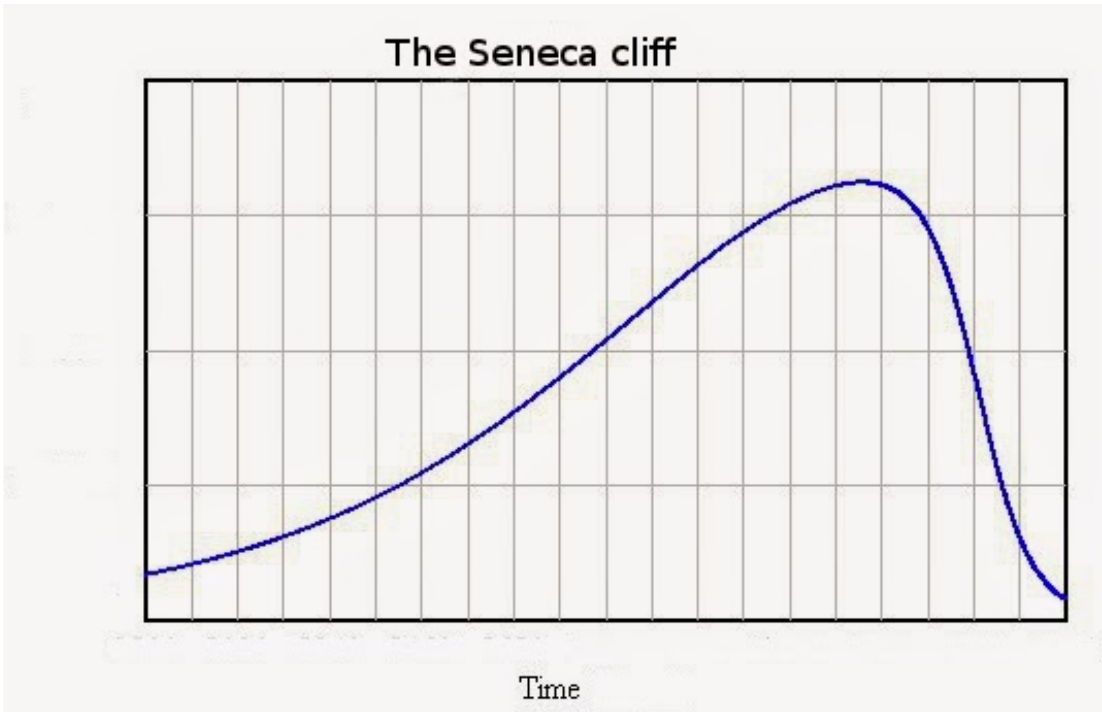
Large mammal with no predators



Assumed population of the St. Matthew Island reindeer Herd. Actual counts are indicated on the population curve.

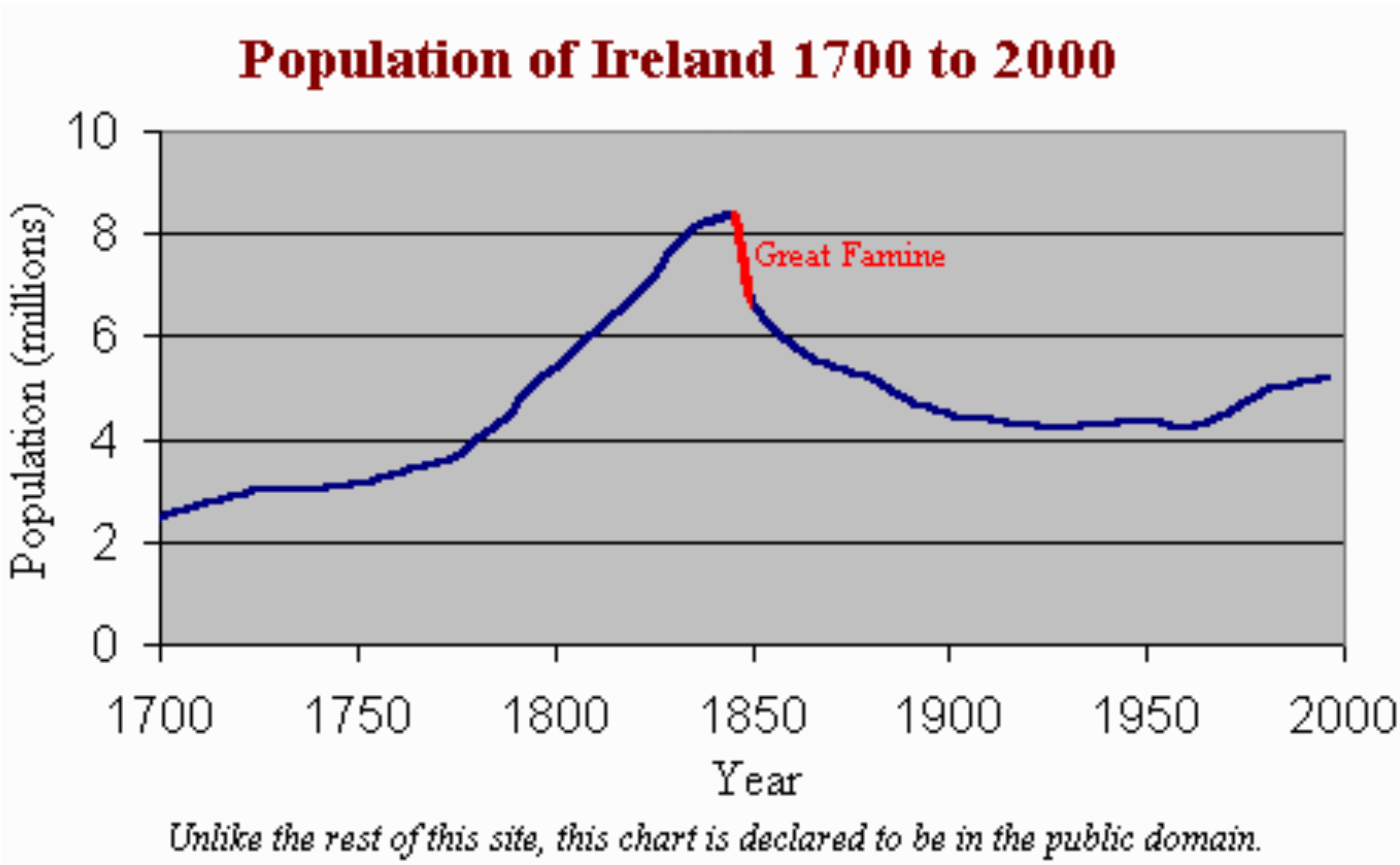
Michael Mills, Dept of Psychology, LMU

The Seneca Cliff



- "**It would be some consolation for the feebleness of our selves and our works if all things should perish as slowly as they come into being; but as it is, increases are of sluggish growth, but the way to ruin is rapid**." Lucius Anneaus Seneca*, Letters to Lucilius, n. 91. Rome, 4BC-65AD.

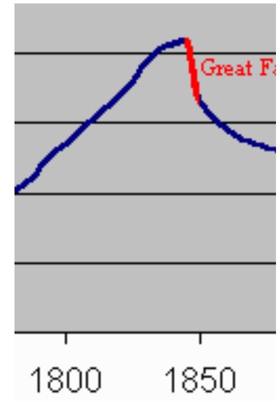
Irish Potato Famine

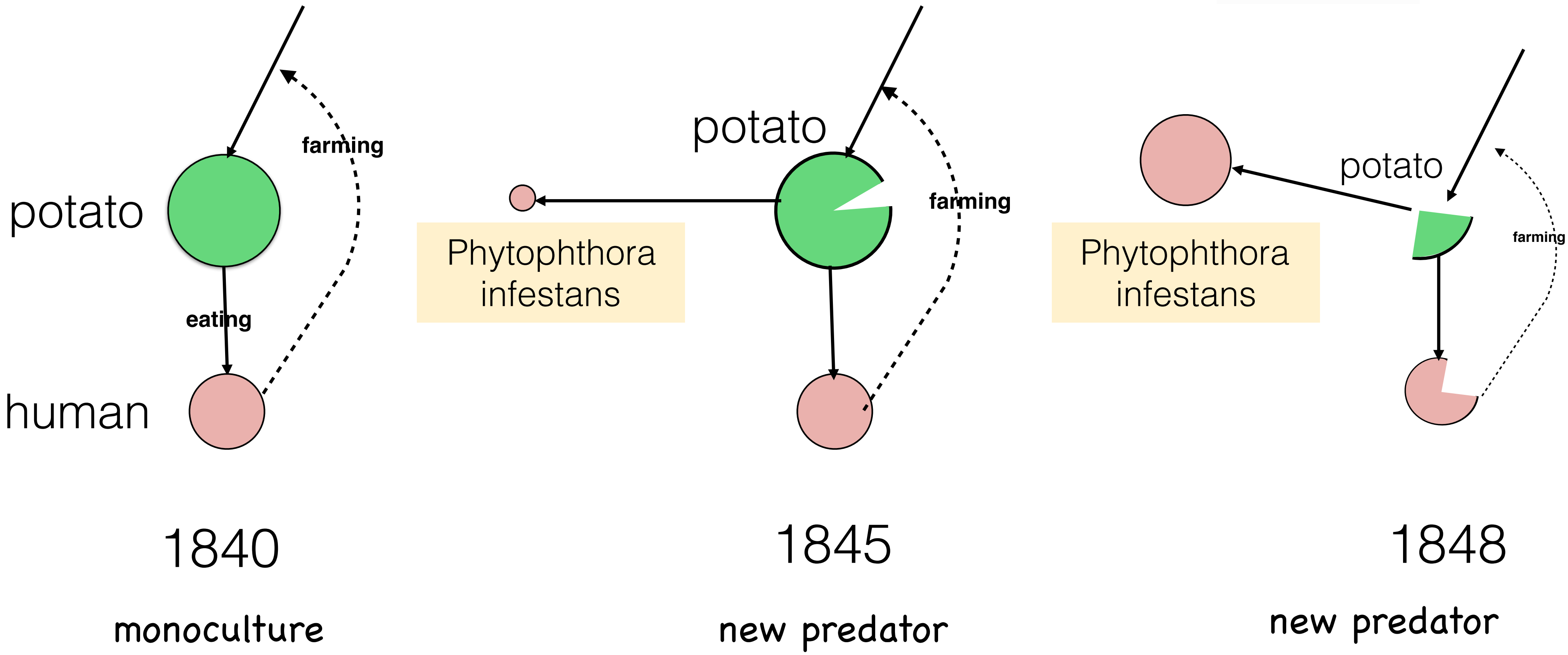


A Seneca Cliff?

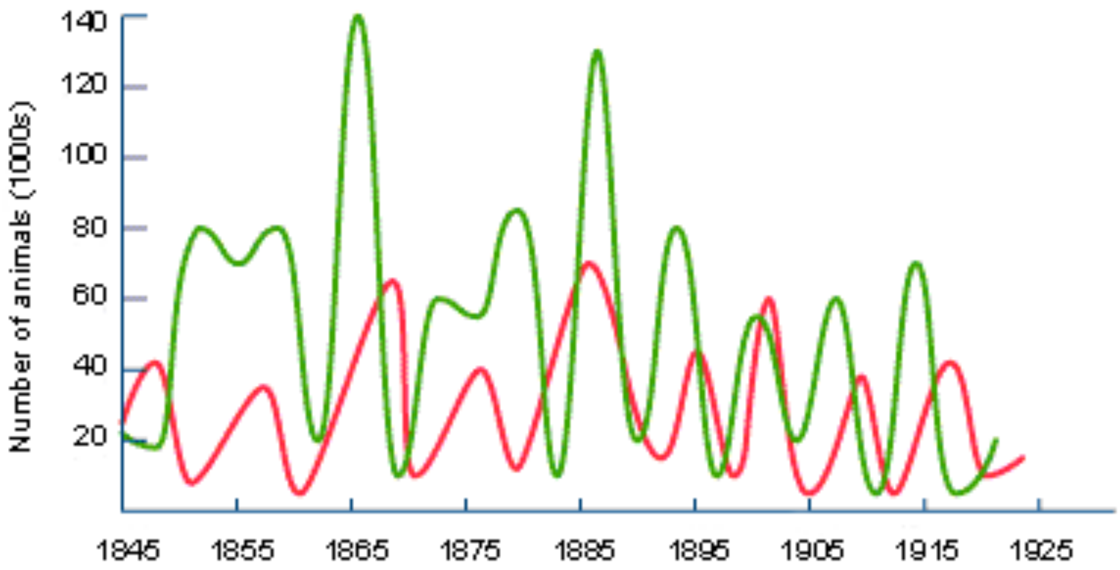
Seneca cliff in Irish Potato famine

- What caused the famine?
- Why did famine happen so quickly?





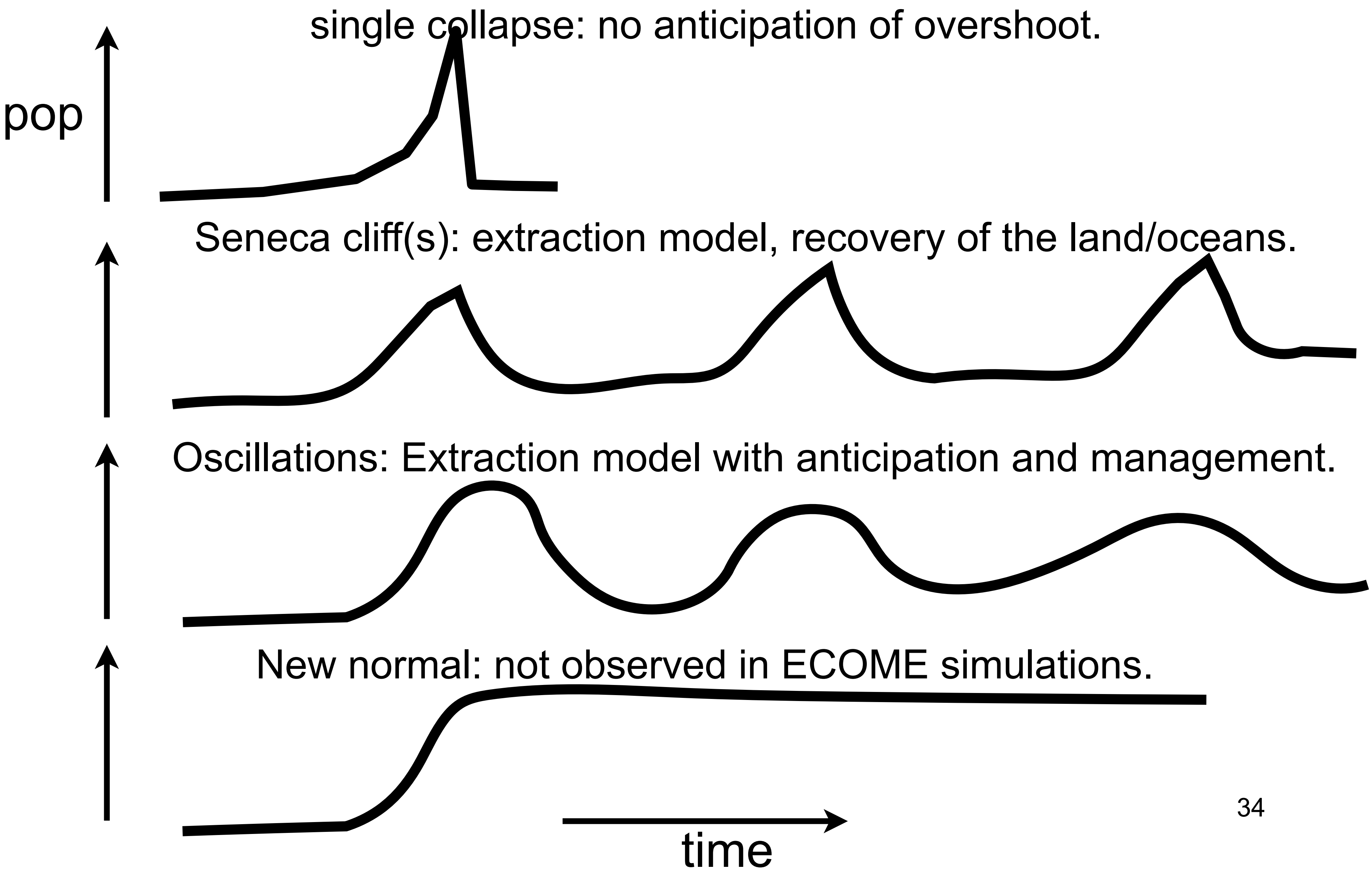
Boom/bust oscillations though co-evolution of predator and prey



Hollings function (hiding) prevents total collapse of the hare.
Relatively rapid growth rate if the hare prevents collapse of the lynx.

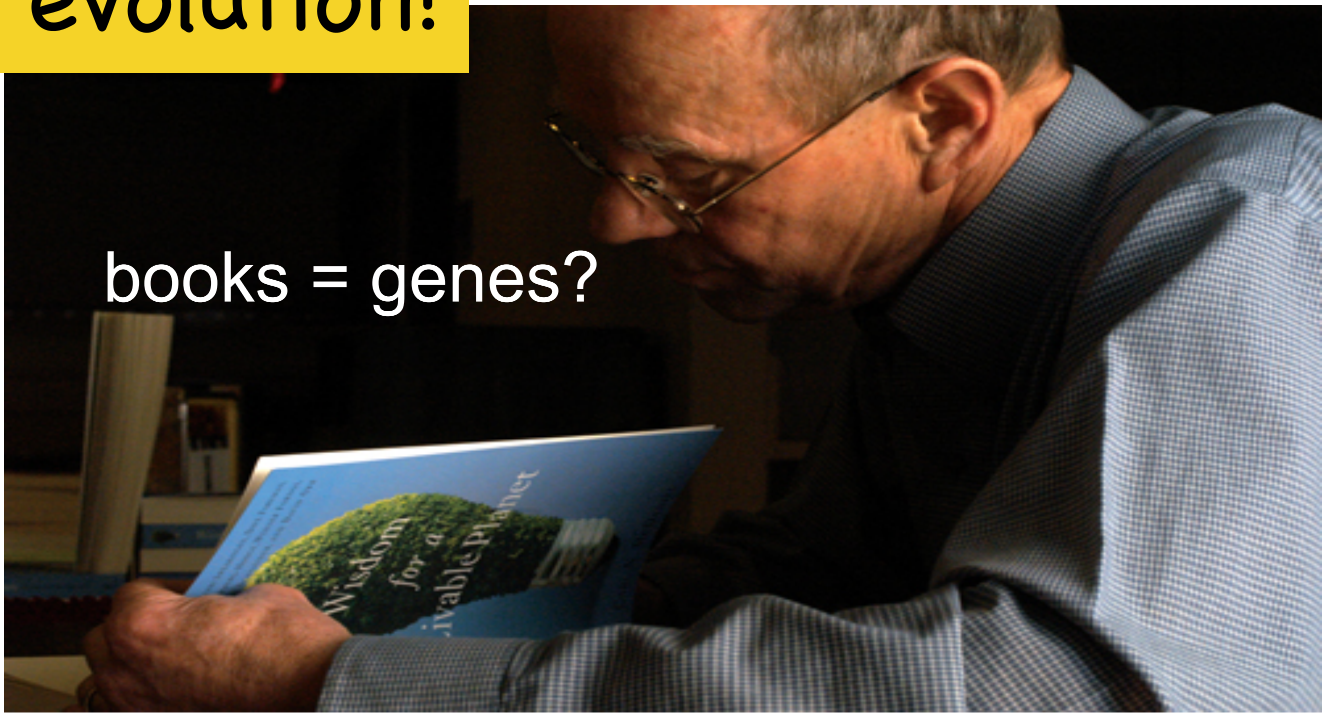
http://io.uwinnipeg.ca/~simmons/16cm05/1116/16popbio.htm

Prediction for humans?

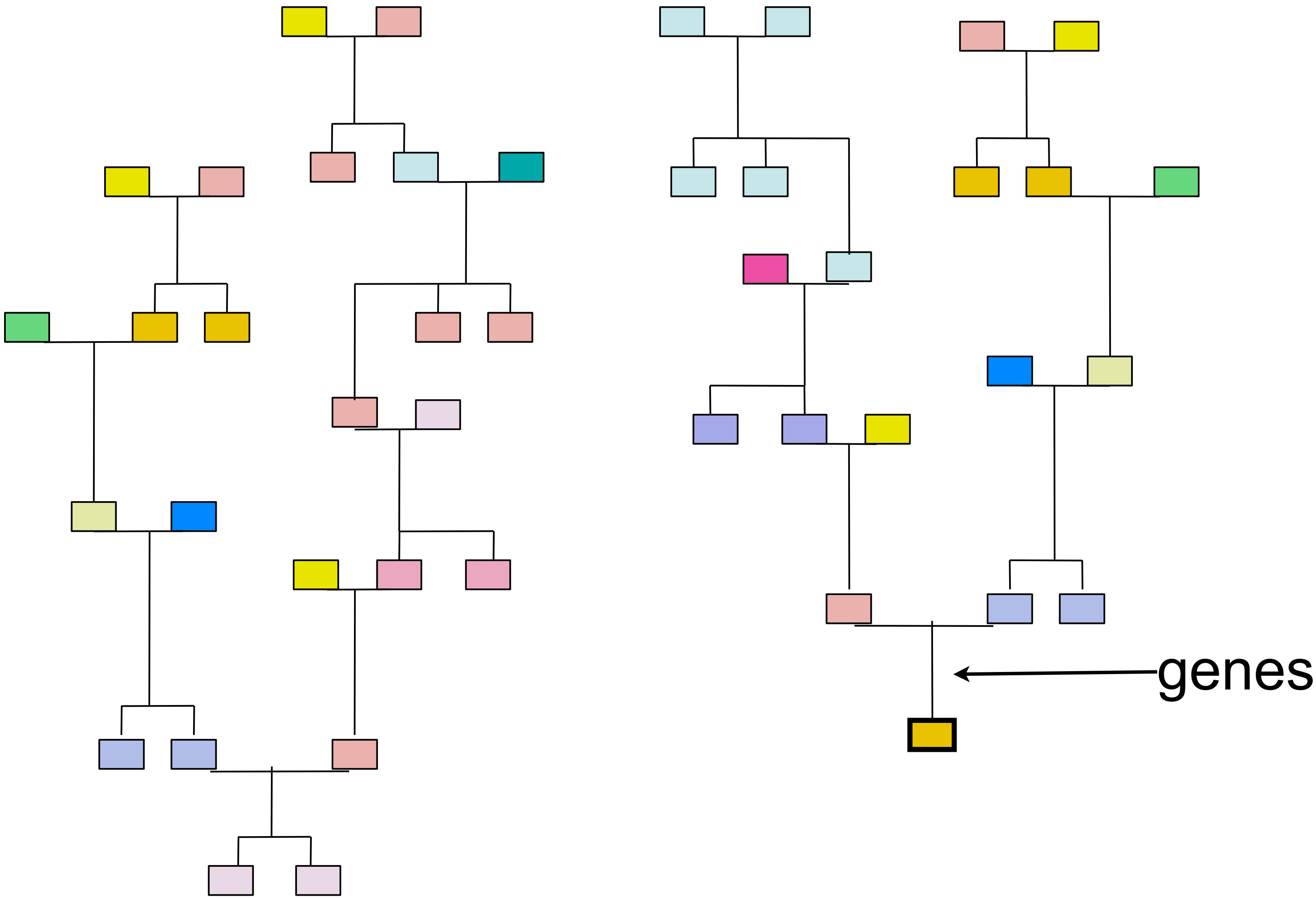


What makes humans different?

Humans evolve by passing down **knowledge** instead of **genes**. Cultural evolution is faster than genetic evolution!

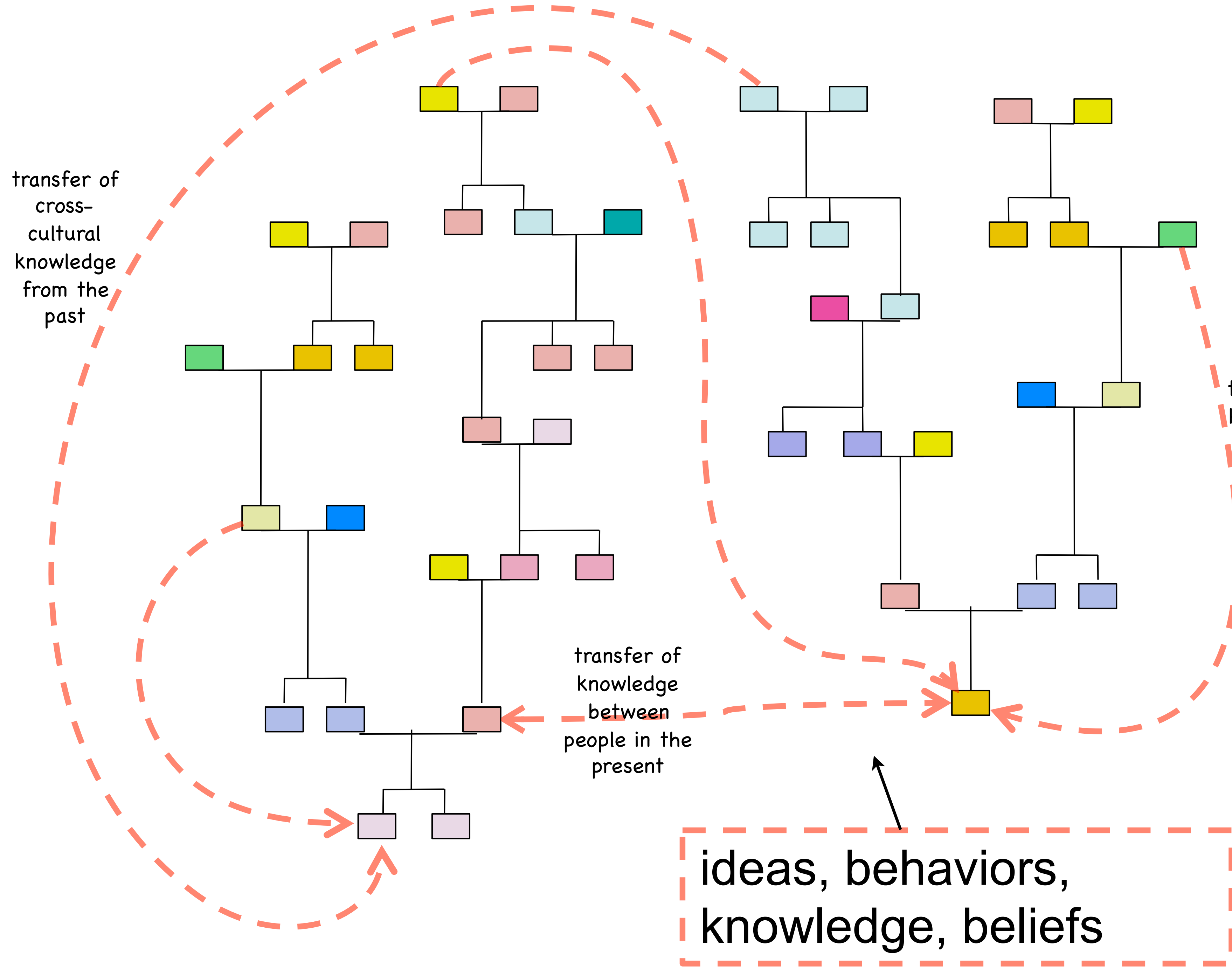


Genetic evolution is Darwinian

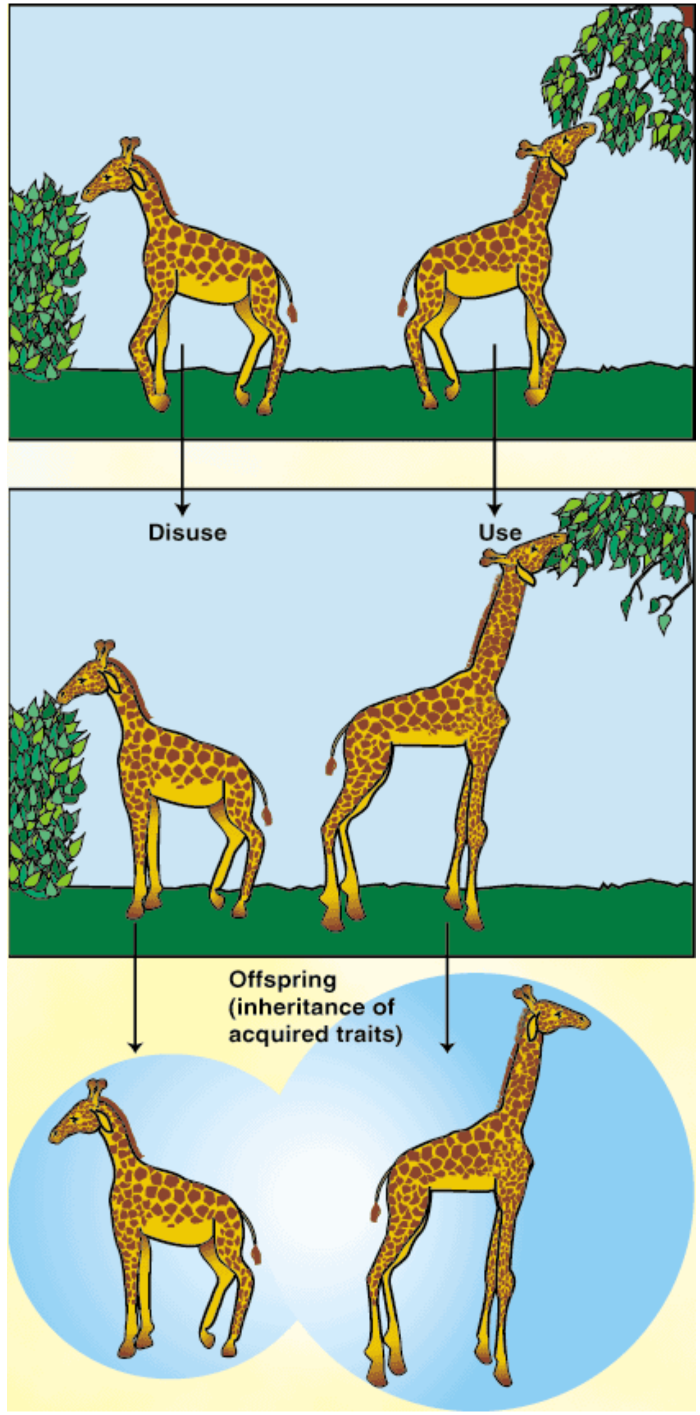


Animal/plant traits are inherited genetically, mostly.

Cultural inheritance is <u>Lamarckian</u>

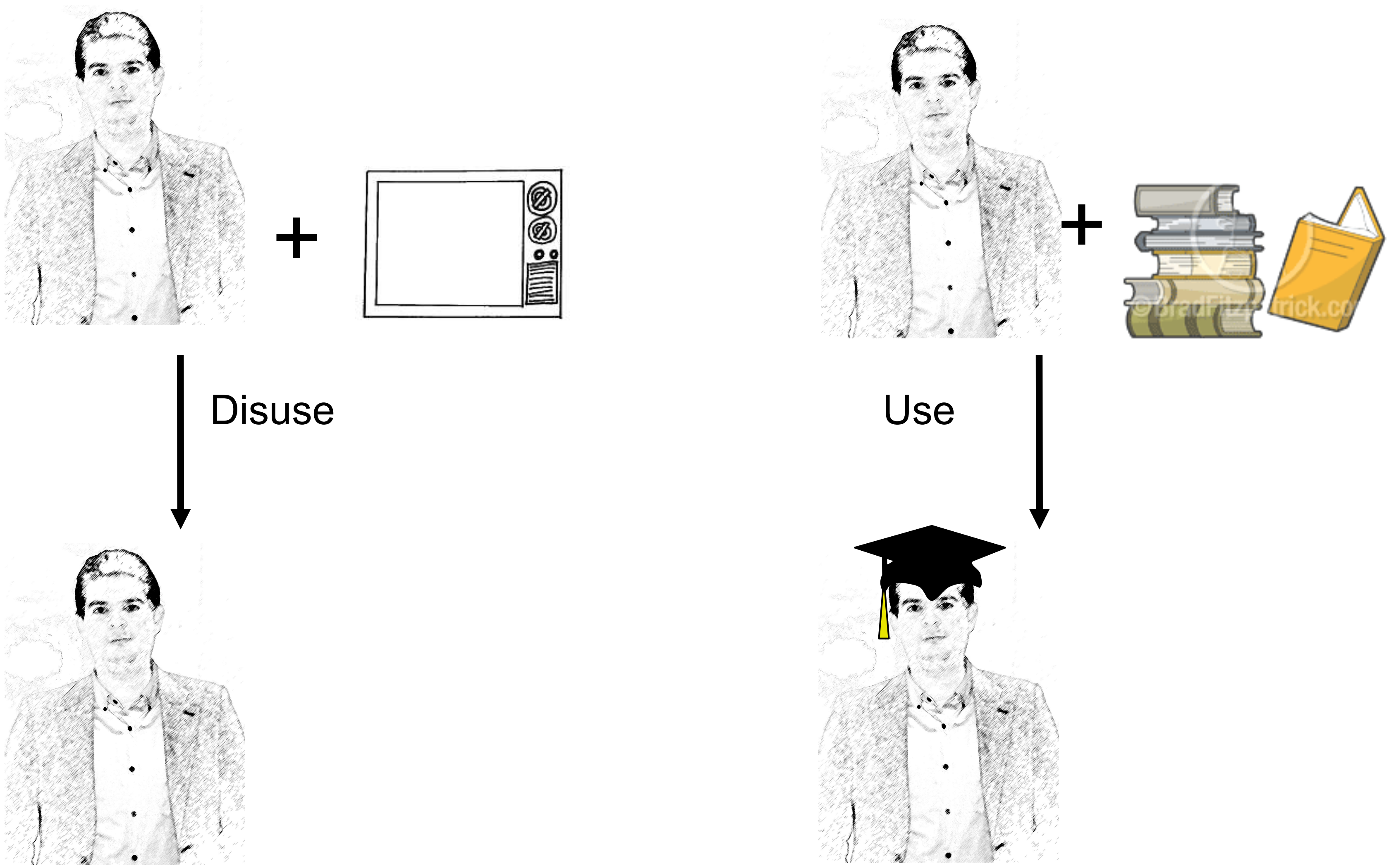


Lamarckian evolution



(not true)

Lamarckian evolution



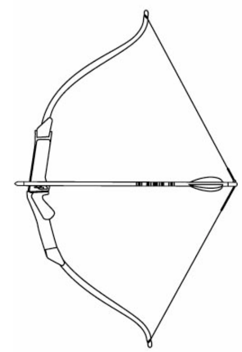
(true!)

HUMAN CULTURE evolved by Lamarckian mechanisms

1. EDUCATION: Humans evolve beneficial traits without speciating.

2. COMMUNICATION: Humans trade without boundaries, consume from anywhere.

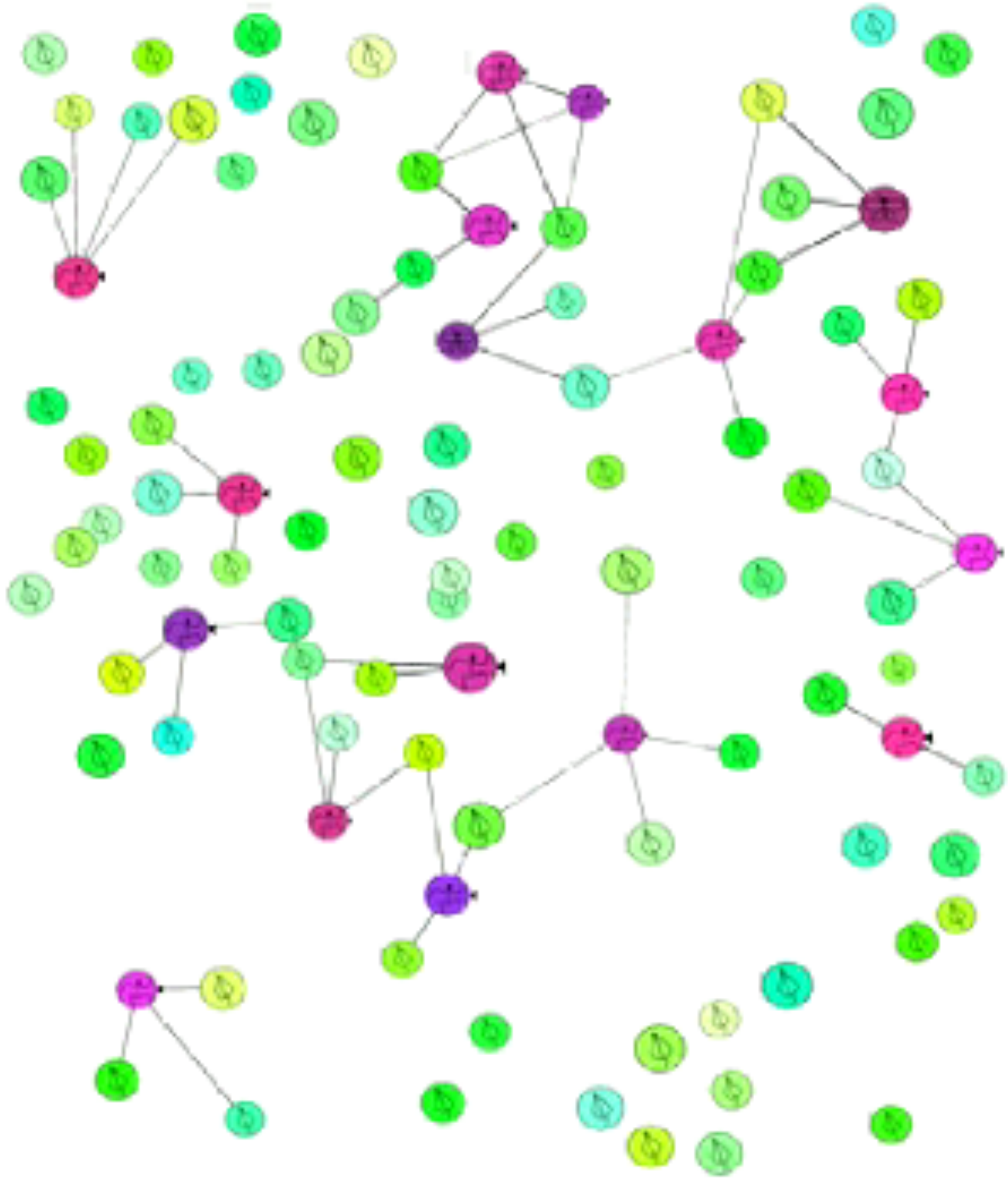
3. DEFENSE: Humans eliminate their own predators.



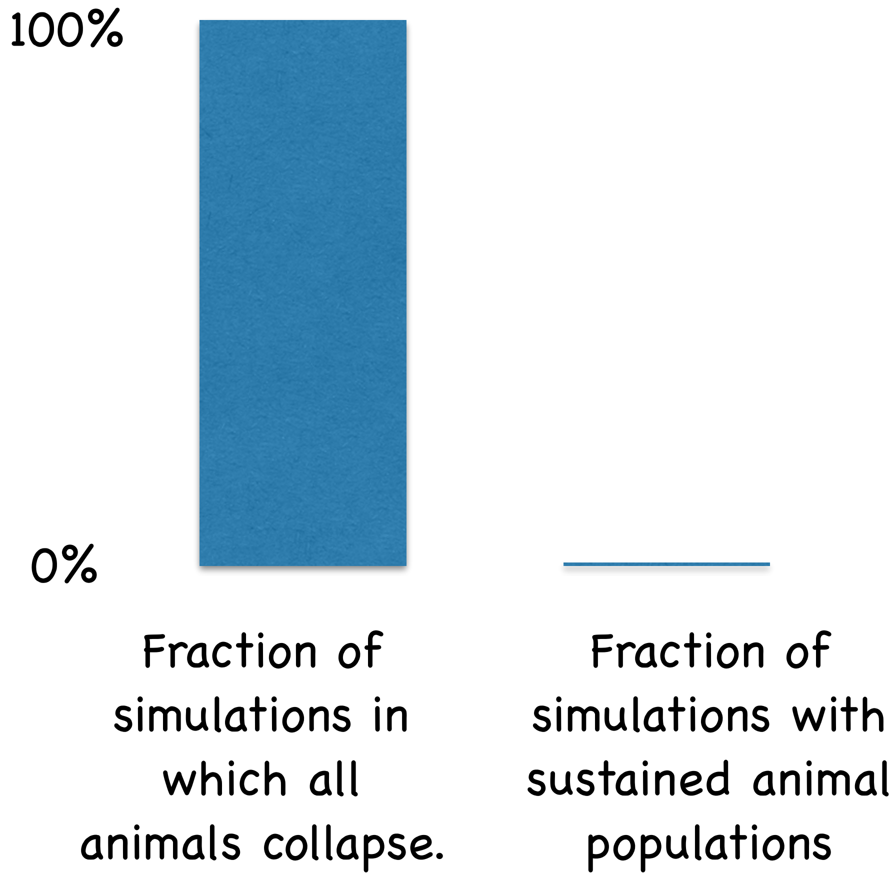
4. POPULATION CONTROL: Humans control their growth rate?

http://www.bioinfo.rpi.edu/bystrc/pub/mpeg/culture3c.mpeg

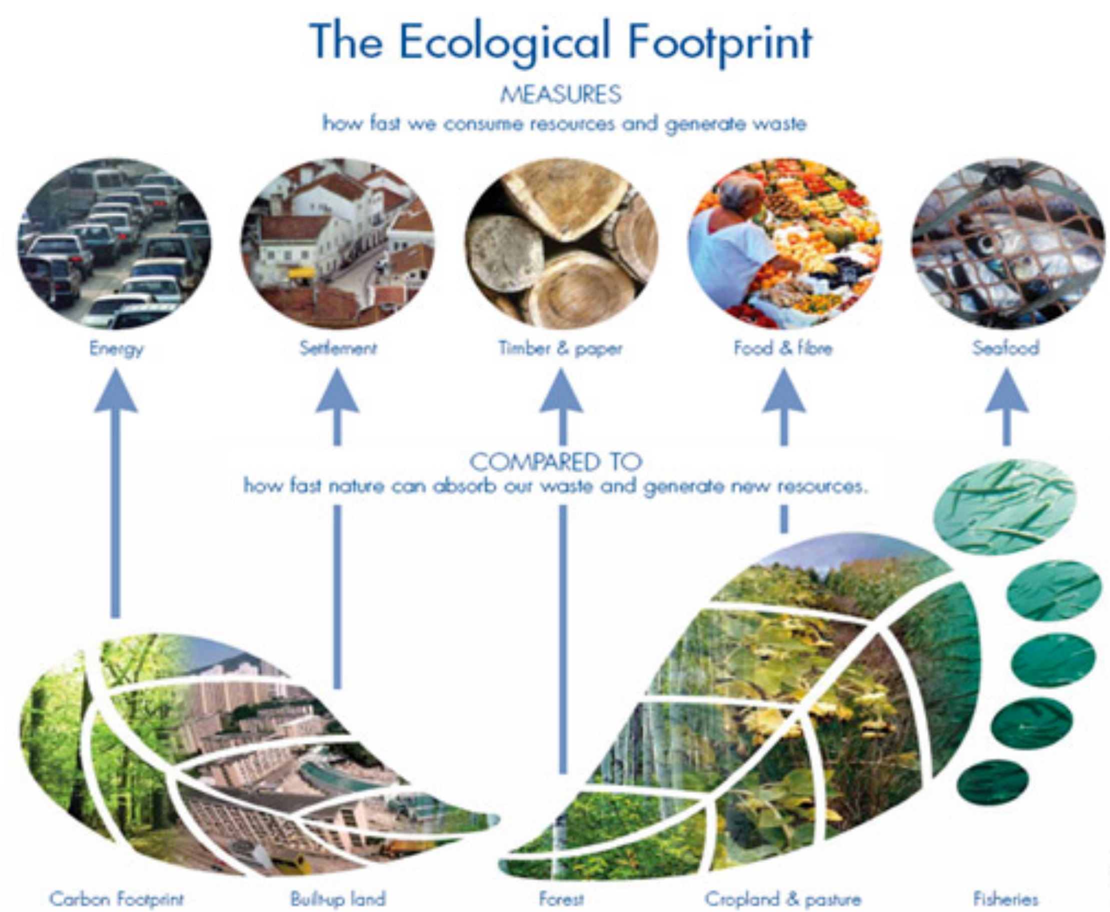
ECOME: Introducing hyper-evolution



- **Results of ECOME simulations with <u>Humans</u> and <u>Lamarckian</u> <u>evolution.</u>**

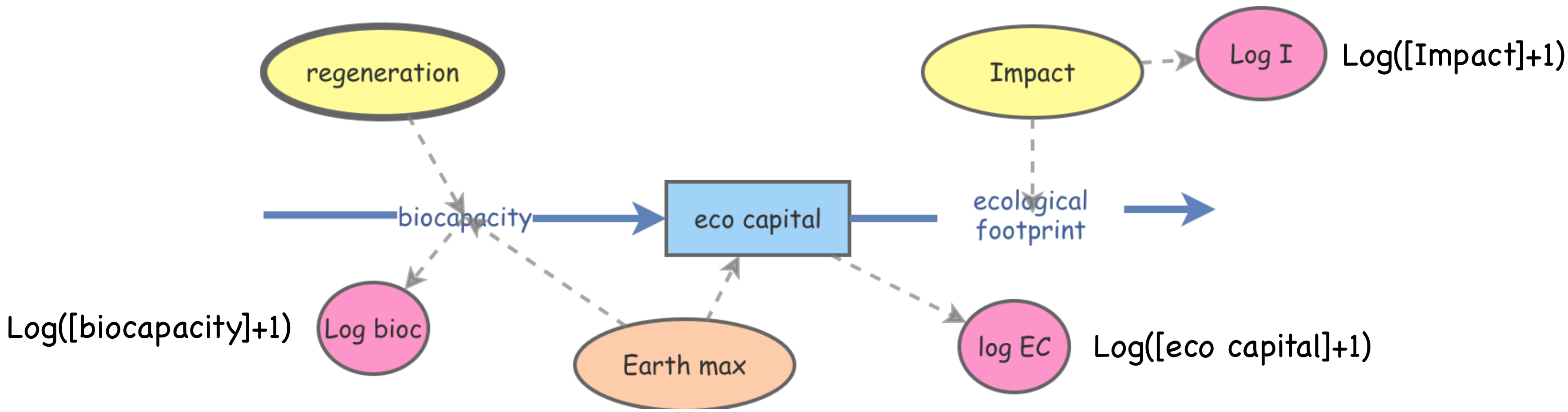


Modeling the global ecological footprint



http://www.footprintnetwork.org/

in-class exercise: modeling nature under human impact



model

regeneration: slider from 0 to 1 (growth rate of [eco capital]).

Earth Max: set to 1.2e10

Impact: Fix(Rand(6e8,7.5e8))

ecological footprint: [Impact]

biocapacity : (([Earth Max]-[eco capital])/[Earth Max])*[regeneration]*[eco capital]

Hollings Type 2

simulation settings

Years, zero to 500, Pause interval 50, Display [log EC]

Do sensitivity analysis on [Impact], then on [regeneration]

1. regeneration: 0.20, Fix(Rand(6e8,7.5e8))
2. regeneration: Fix(Rand(0.15,0.25)), Impact: 7e8

Your ecological footprint

http://www.footprintnetwork.org/resources/footprint-calculator/

Calculate your ecological footprint.
Share with the class.