# Course overview

## Course structure

* Lecture notes for each section will be available the afternoon before you need them
  + Check Avenue frequently for announcements and new information
  + All info will also be on the course resource page
    - <http://bio3ss.github.io/>
* The professor is Jonathan Dushoff
  + dushoff@mcmaster.ca
  + Office hours will be announced
  + Or ask questions electronically
    - We need a forum!
* Start and end on time
* Focus on conceptual understanding
* Make clear what terminology and facts must be learned
* Open to questions – both in class (within reason) and at office hours
* Responsive to questions on class forums (to be decided)
* Start and end on time
* Don’t talk while other students are talking, or while I am responding to student questions
* If you must talk at other times, be unobtrusive
* Don’t use the internet for non-class activities
* Attend the lecture, and the mandatory tutorials
* The primary text for this course is the lecture notes
* You will be given readings, which will be posted to Avenue
* Required material will be clearly outlined in the notes
* Required terminology will be presented in **bold**
* General ideas and approaches presented in class may also be required; you should take notes on these in your own words
* You will do best if you take notes
  + You should know by now what works for you
  + Or else that you need to keep working on it
* If a new concept is making sense to you right now, write something that will help you remember
* If there’s something specific I think you all need to write down, I will write it for you (or mark it as an answer)
* You can obtain extra credit by responding to in-class polls
  + Text from your cell phone, or answer on the web
* Poll: Why are you taking this class?

## People

* Loves math
* Lived in four countries
* Studies evolution and spread of infectious diseases
  + HIV, rabies, ebola, influenza, …
  + <https://mac-theobio.github.io/dushoff.html>
  + <https://twitter.com/jd_mathbio>
* Steve Cygu
* George Long
* Poll: What year are you in?
* Poll: What kind of career are you aiming for?

# Course content

## Learning goals

* Ecology and population ecology
* Quantitative thinking
* Dynamical modeling
* Poll: What is ecology?
* My answer
* Poll: What is population ecology?
* My answer
* Investigates the links between local, short-term processes, and large-scale, long-term outcomes
* Allows us to explore what assumptions we’re making, and how assumptions affect the link
* Population ecology uses math
  + Math is a critical tool for linking processes to outcomes
  + Math will play a central role in the course
* We will keep it *simple*
  + But we understand that simple does not always mean easy
* [Review the math supplement: https://bio3ss.github.io/materials/math.handouts.pdf](https://bio3ss.github.io/materials/math.handouts.pdf)
* People are evolved to be concrete thinkers, not conceptual thinkers
* A goal of this course is to build conceptual thinking skills

## Examples

* A nasty, mosquito-borne disease
* In some places (e.g., the southeastern US), it has been eradicated almost by accident
  + Mosquitoes are still present
* In other places it persists at high levels despite concerted efforts at elimination
* *What factors determine when and where malaria spreads?*
* Red squirrels are rapidly disappearing from England
  + Loss of suitable habitat?
  + Competition from gray squirrels introduced from North America?
  + Diseases carried by gray squirrels?
* <http://en.wikipedia.org/wiki/Eastern_grey_squirrels_in_Europe>
* Is the ocean too big for people to affect?
* What happened to the cod?
* [http://en.wikipedia.org/wiki/Collapse\_of\_the\_Atlantic\_northwest\_cod\_fishery](http://en.wikipedia.org/wiki/Collapse_of_the_Atlantic_northwest_cod_fishery )
* Poll: What population of organisms interests you?
* Start with one dandelion; it produces 100 seeds, of which only 4% survive to reproduce the next year.
  + How many dandelions after 3 years?

# Example populations

## Dandelions

* Start with one dandelion; it produces 100 seeds, of which only 4% survive to reproduce the next year.
* How many dandelions after 3 years?
  + [See spreadsheet on resource page: https://bio3ss.github.io/linear.html](https://bio3ss.github.io/linear.html)
* The spreadsheet is an implementation of a dynamical model!
* Make rules about how things change on a small scale
* Assumptions should be clear enough to allow you to calculate or simulate population-level results
* Challenging and clarifying assumptions is a key advantage of models

## Gypsy moths

* A pest species that feeds on deciduous trees
* Introduced to N. America from Europe   150 years ago
* Capable of wide-scale defoliation

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* Researchers studying a gypsy moth population make the following estimates:
  + The average reproductive female lays 600 eggs
  + 10% of eggs hatch into larvae
  + 10% of larvae mature into pupae
  + 50% of pupae mature into adults
  + 50% of adults survive to reproduce
  + All adults die after reproduction
* What happens if we start with 10 moths?
* Obviously, we will not get *exactly* 7.5 moths.
* If we consider moths as individuals, we need a **stochastic** model
* What do we mean by stochastic?

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* A stochastic model has randomness in the model.
* If we run it again with the same parameters and starting conditions, we get a different answer

## Bacteria

* Imagine we have some bacteria growing in a big tank, constantly dividing and dying:
  + They divide (forming two bacteria from one) at a rate of $0.04/\hr$
  + They wash out of the tank at a rate of 0.02/
  + They die at a rate of 0.01/
* Rates are **per capita** (i.e., per individual) and **instaneous** (they describe what is happening at each moment of time)
* We start with 10 bacteria/ml
  + How many do we have after 1 hr?
  + What about after 1 day?
* Imagine we have some bacteria growing in a big tank:
  + They divide (forming two bacteria from one) at a rate of 0.96/day
  + They wash out of the tank at a rate of 0.48/day
  + They die at a rate of 0.24/day
* If we start with 10 bacteria/ml, how many do we have after 1 day?
* When we attach units to a quantity, the meaning is concrete
  + 0.24/day *must* mean exactly the same thing as 0.01/hr
  + The two questions above *must* have the same answer

## Coronavirus

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* arithmetic/linear:
* geometric/exponential:
* other:
  + Many possibilities, we may discuss some later
* Poll: What is exponential decline?
* Sometimes people distinguish
  + **arithmetic** from **linear** growth, or
  + **geometric** from **exponential** growth
* Based on:
* We won’t worry much about this.

## Log and linear scales

* Poll: 1 is to 10 as 10 is to what?

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There is only one log scale; it doesn’t matter which base you use!

* How many people know the Canadian provinces song?
* Poll: Which Canadian province is the most unusual in terms of area?
* Poll: Which Canadian province is the most unusual in terms of population?

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* A 300 lb lion is attacking a 600 lb buffalo!
* Poll: This is analogous to a 15 lb red fox attacking: a beaver, an elk
  + A 30 lb beaver (twice as heavy)?
  + A 315 lb elk (300 lbs heavier)?
* The log scale and linear scale provide different ways of looking at the same data
* Equally valid
* What are some advantages of each?

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* The linear scale looks at differences at the population scale
* The log scale looks at differences at the individual scale (per capita)

## Time scales

* If something is declining exponentially, the rate of change (units [widgets/time]) is always proportional to the size of the thing ([widgets]).
* The constant ratio between the rate of change and the thing that is changing is:
  + the **characteristic time** (something/change), or
  + the **rate of exponential decline** (change/something)
* What if we add an agent to the tank that makes the birth and death rates nearly zero?
* Now the bacteria are merely washing out at the rate of 0.02/hr
* If we start with 10 bacteria/ml, how many do we have after:
  + Poll: 1 hr?
  + Poll: 1 wk?
* Bacteria wash out at the rate of 0.02/hr
* Start with 10 bacteria/ml:
* Rate of exponential decline is $r = 0.02/\hr$
* Characteristic time is $T\_c = 1/r = 50 \hr$
  + Number of bacteria / rate of change
* If experiment time , then proportional decline
* The reason mathematicians like is that it makes this link between instantaneous change and long-term behaviour
* If I drive for an hour, how much closer do I get to the ideal town of Speed?
* or is the approximate answer to a lot of questions like this one
  + If I compound 1%/year interest for 100 years, how much does my money grow?
  + If two people go deal out two decks of cards simultaneously, what is the probability they will never match cards?
  + If everyone picks up a backpack at random after a test, what’s the probability nobody gets the right backpack?
* We can think about exponential growth the same way as exponential decline:
  + Things are always changing at a rate that would take a fixed amount of time to get (back) to zero
  + This is the characteristic time
  + Exponential growth follows
* Some people prefer to think about half lives.
* Half life is similar to characteristic time, but doesn’t have the direct link to the instantaneous change.
  + It takes time to decrease by a factor of
  + It takes to decrease by a factor of 2
  + We can write
* You should be able to do this calculation
* The doubling time plays the same role for exponential growth as the half life does for exponential decline:
  + It takes time for a declining population to decrease by a factor of
  + It takes to decrease by a factor of 2
  + We can write
* Exponential growth is a specific thing
  + At least in math and science
* Often tied to a specific mechanism
* Units can help us think clearly
  + or notice our mistakes

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