UNIT 1: Introduction

Outline

Outline

Communication

- Lecture notes for each section will be available the afternoon before you need them
  - Check AtL 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 on facebook group
    - Bio 3SS Winter 2018
    - I am not your friend

Expectations of professor

- 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 (Facebook and AtL)

Expectations of students

- 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

Texts

- The primary text for this course is the lecture notes
- You will be given readings, which will be posted to AtL
- You are required to have an Ecology textbook
  - Molles and Cahill, Second Canadian edition is recommended
  - If you would like to use a different textbook, let your TA know, so we can attempt to provide readings.

Structure of presentation

- Required material will be clearly outlined in the notes
  - * This is an answer: it was omitted from the notes for discussion purposes, you should probably write it in
  - *This is a comment: I omitted from the notes because I thought it wasn't necessary for you to study. If you write it in, make a note to yourself that it's a comment.*
- 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

Taking notes

- 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)

Polling

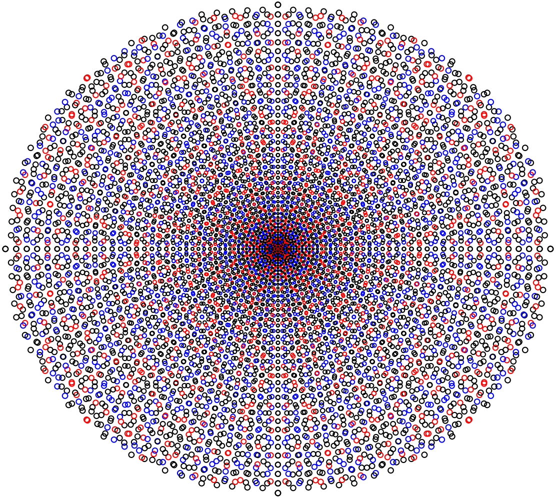
- You can obtain extra credit by responding to in-class polls
  - Text from your cell phone, or answer on the web
- Poll: Why are you taking this class?

Outline

Dushoff

- Loves math
- Lived in four countries
- Studies evolution and spread of infectious diseases
  - HIV, rabies, ebola, influenza, ...
  - See notes for more info.

Pythagorean triples



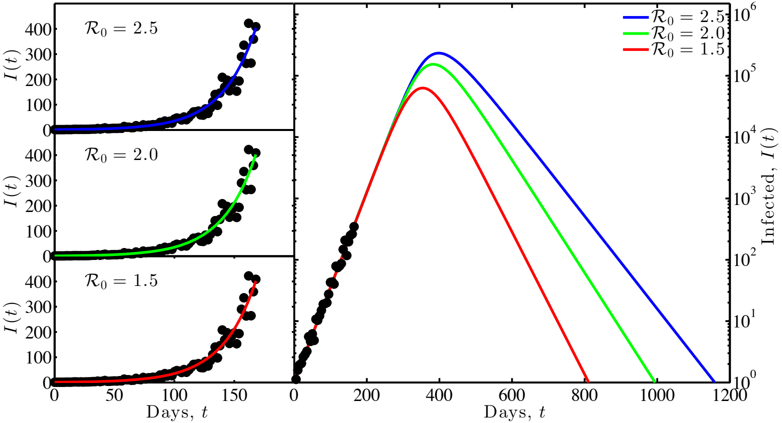
Which country?

Which country?

Which country?

Which country?

Ebola research



TAs

- Morgan Kain
  - Current: ecology and evolution of infectious diseases
  - Forest ecology, animal behaviour
    - Focused on statistical approaches
- Michael Li
  - Research: Disease forecasting and control
  - Interests: Math, science, business, politics, philosophy.
    - How everything is connected

Students

- Poll: What year are you in?
- Poll: What kind of career are you aiming for?

Outline

Outline

Learning goals

- Ecology and population ecology
- Quantitative thinking
- Dynamical modeling

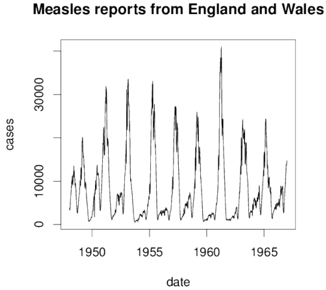
- Poll: What is ecology?
- My answer
  - * The study of how organisms interact with each other and with the environment
  - * Ecology is not environmentalism

- Poll: What is population ecology?
- My answer
  - * The study of how organisms interact with each other and with the environment at the population scale
  - * Larger spatial scale, longer temporal scale
  - * We use *dynamical models* to link from the individual level to the population level

Dynamical modeling

- 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

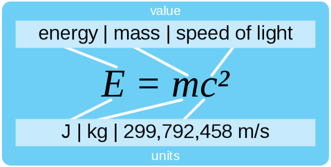


Math

- 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

Humans and abstract thought

- People are evolved to be concrete thinkers, not conceptual thinkers
- A goal of this course is to build conceptual thinking skills

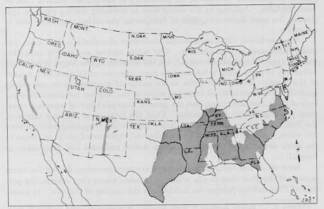


$c^2 = 89{,}875{,}517{,}873{,}681{,}800\ m^2/s^2$

Outline

Malaria

- 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?*



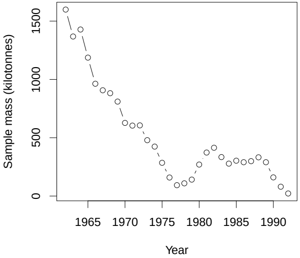
Map 4.—Areas of the continental United States believed to be malarious in 1934–35.

Red squirrels

- Red squirrels are rapidly disappearing from England
  - Loss of suitable habitat?
  - Competition from gray squirrels introduced from North America?
  - Diseases carried by gray squirrels?

Cod fisheries

- Is the ocean too big for people to affect?
- What happened to the cod?



Populations

- Poll: What population of organisms interests you?

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?
        - * 64?
        - * 125?

Outline

Outline

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?
  - * 64?
  - * 125?
  - See spreadsheet on resource page
- The spreadsheet is an implementation of a dynamical model!

Dynamical models

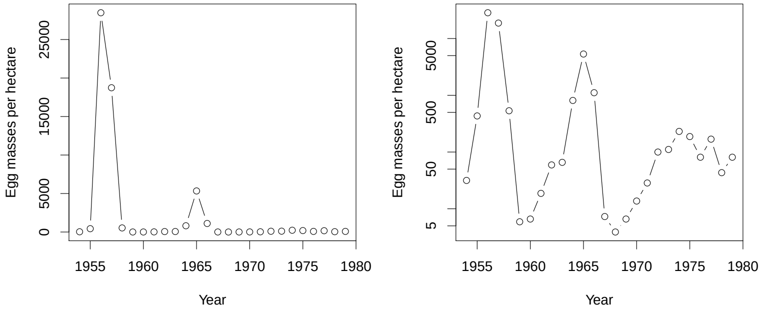
- Make rules about how things change on a small scale
- Assumptions should be clear enough to allow you to calculate or simulate population-level resuls
- Challenging and clarifying assumptions is a key advantage of models

Outline

Gypsy moths

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

Gypsy moth fopulations



Moth calculation

- 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
- Poll: What happens if we start with 10 moths?
  - * We end up with 15 moths
  - * On average

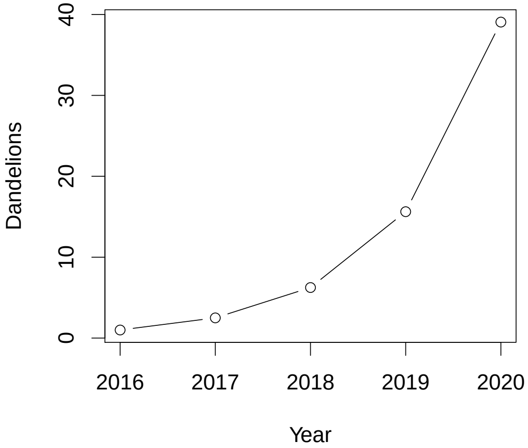
Moth calculation

- Researchers studying a gypsy moth population make the following estimates:
  - The average reproductive female lays 600 eggs
    - * Assume half are female
  - 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?
  - * If 5 are female, we end up with an average of 7.5 moths

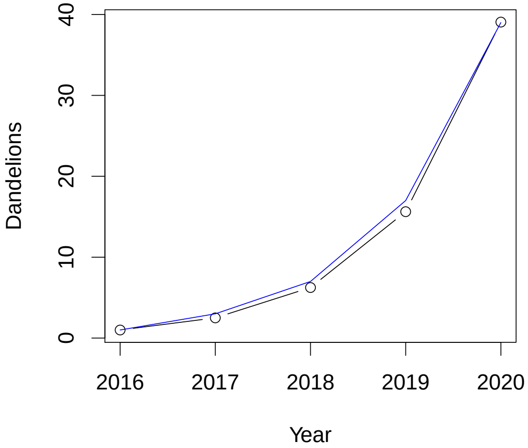
Stochastic version

- 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?
  - * The model has randomness, to reflect details that we can't measure in advance, or can't predict

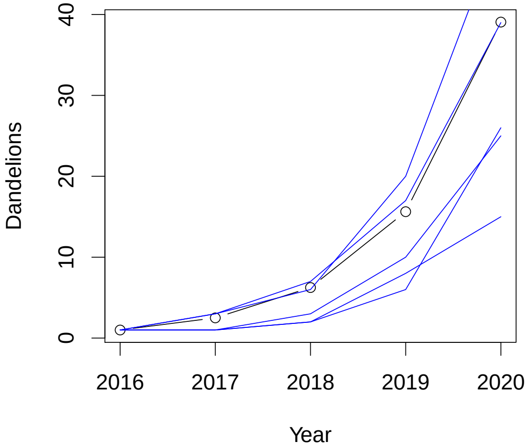
Stochastic model



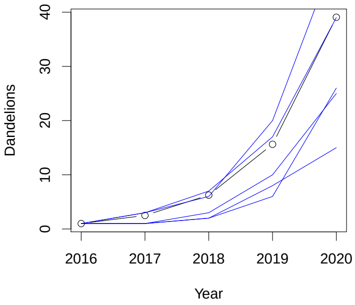
Stochastic model



Stochastic model



Stochastic model



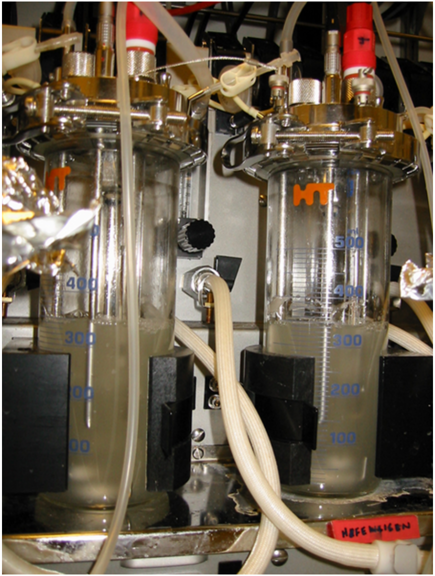
- A stochastic model has randomness in the model.
- If we run it again with the same parameters and starting conditions, we get a different answer

Outline

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/ hr
  - They die at a rate of 0.01/ hr
- 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?

Bacteria in a tank



Bacteria, rescaled

- 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?

Units

- 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

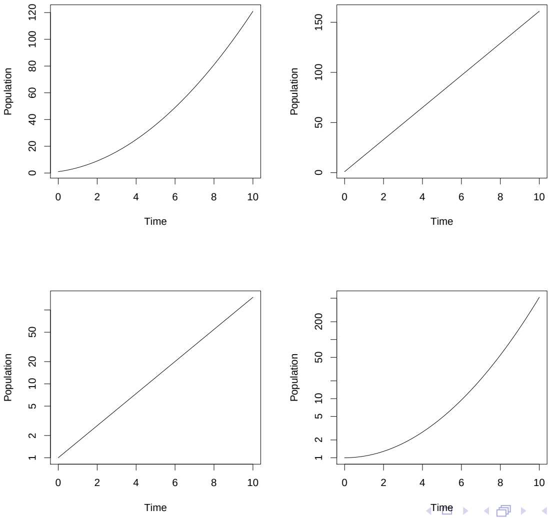
Bacteriostasis

- 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?

Outline

Exponential growth

- What is exponential growth?
- Which of these is an example?



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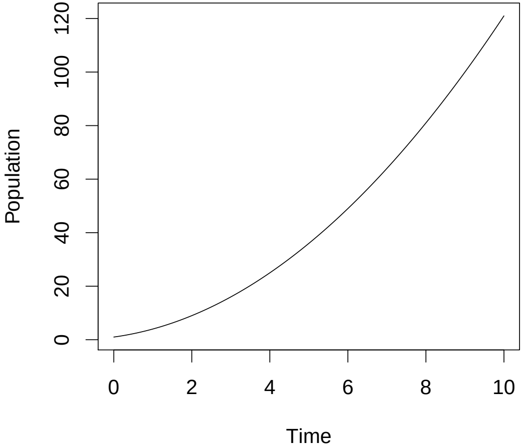

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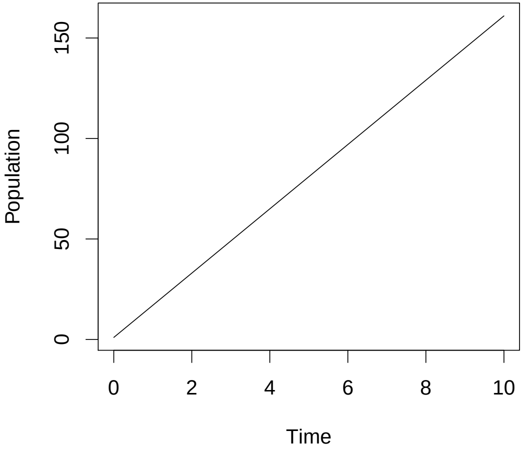

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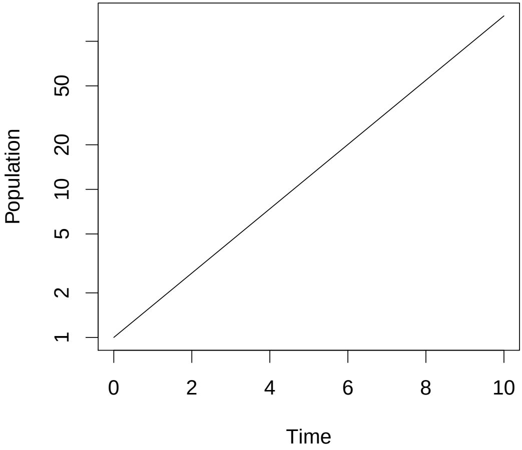

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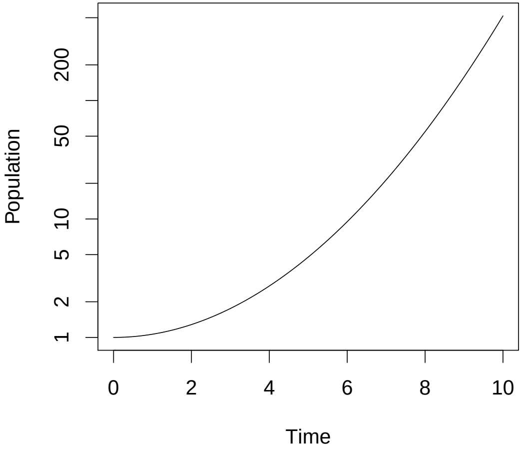
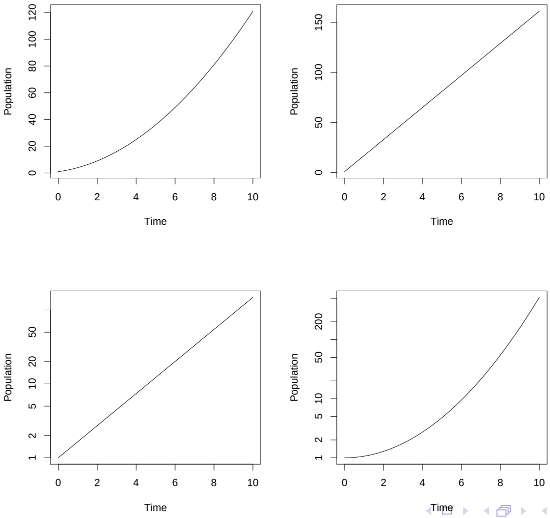


Exponential growth

- Poll: What is exponential growth?
- Poll: Which of these is an example?



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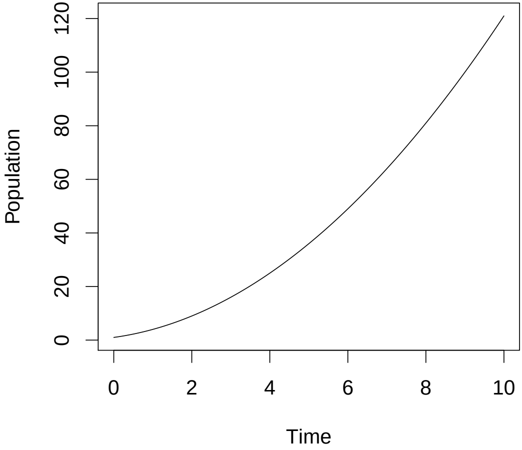

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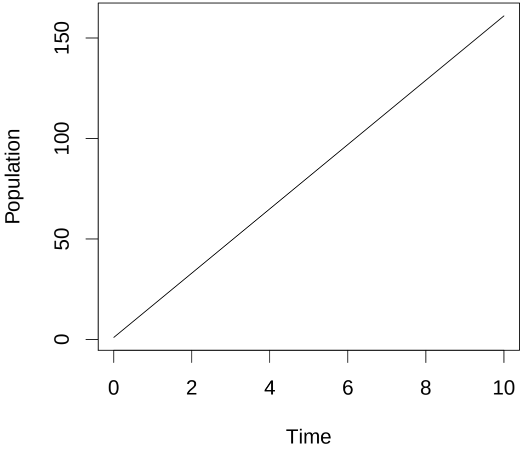

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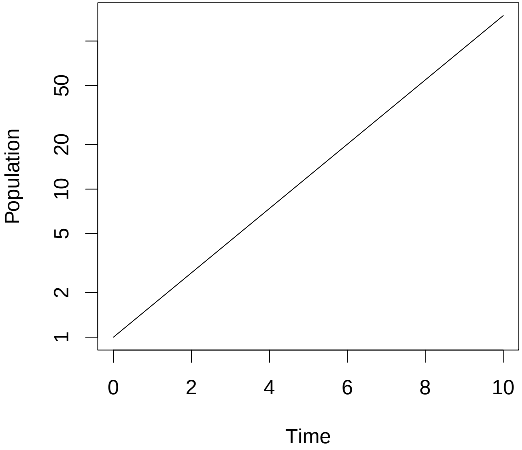

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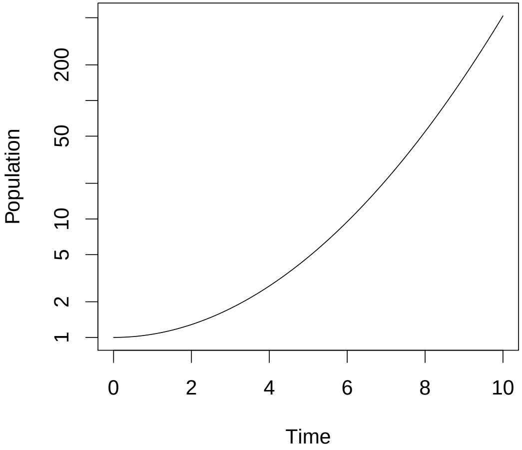
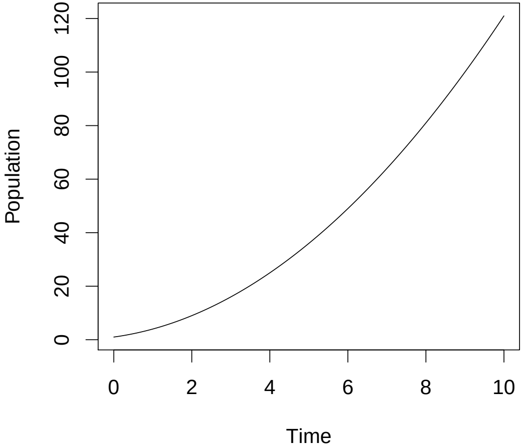
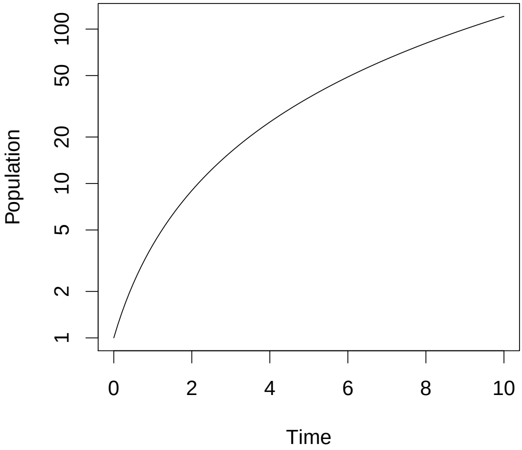


A



A on the log scale



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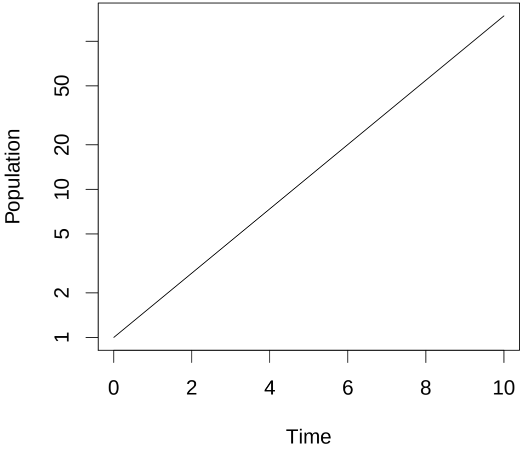
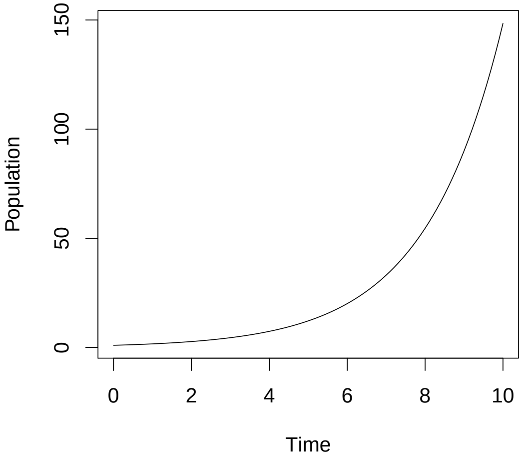


C on the linear scale



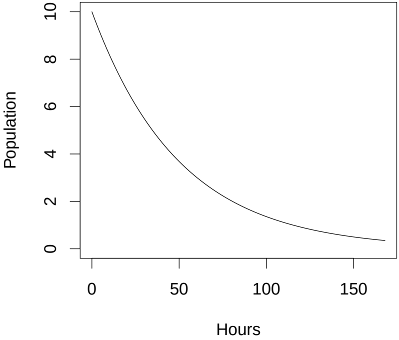
Types of growth

- arithmetic/linear:
  - * *Add* a fixed amount in a given time interval
  - * Total growth rate is constant
- geometric/exponential:
  - * *Multiply* by a fixed amount in a given time interval
  - * Per-capita growth is constant
  - * Only C is exponential, mathematically speaking.
- other:
  - Many possibilities, we may discuss some later

Exponential decline?

- Poll: What does exponential decline look like?
  - * Decline is proportional to size
  - * Declines more and more *slowly* (on linear scale)

Exponential decline



- Decline is proportional to size
- Declines more and more *slowly* (on linear scale)

Terminology

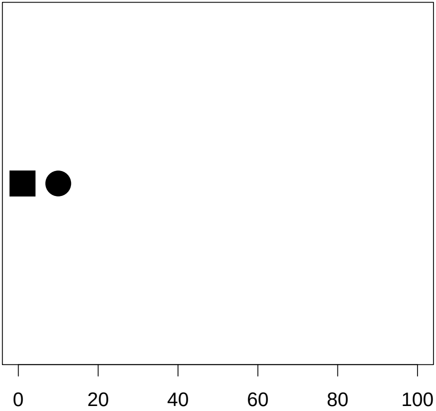
- Sometimes people distinguish
  - **arithmetic** from **linear** growth, or
  - **geometric** from **exponential** growth
- Based on:
  - * **discrete** vs. **continuous** time
- We won't worry much about this.

Outline

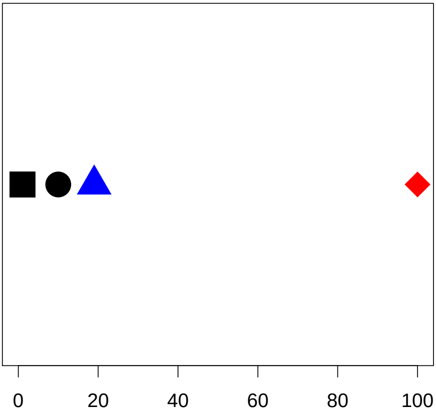
Scales of comparison

- Poll: 1 is to 10 as 10 is to what?
  - * If you said 100, you are thinking multiplicatively
  - * If you said 19, you are thinking additively

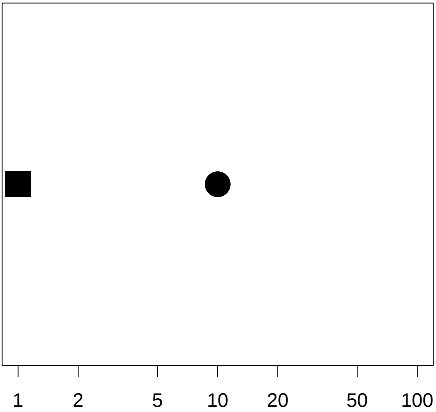
Scales of display



Scales of display



Scales of display



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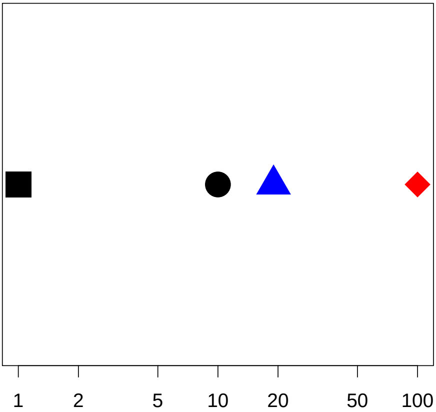

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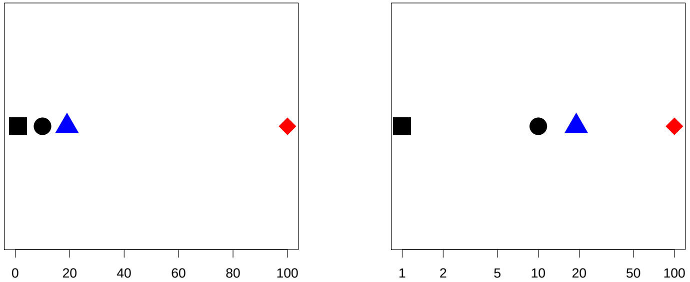
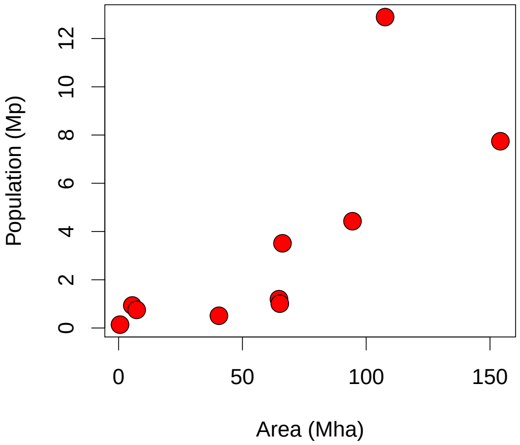


There is only one log scale; it doesn't matter which base you use!

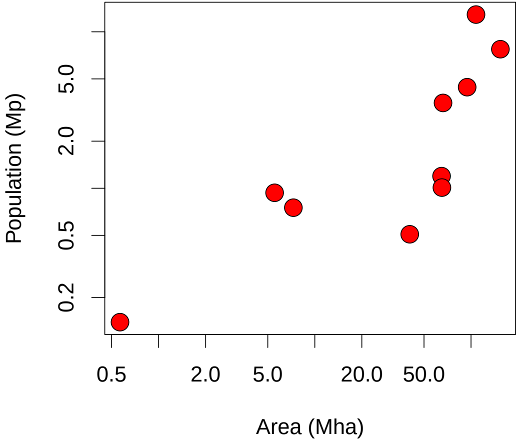
Canadian provinces

- 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?

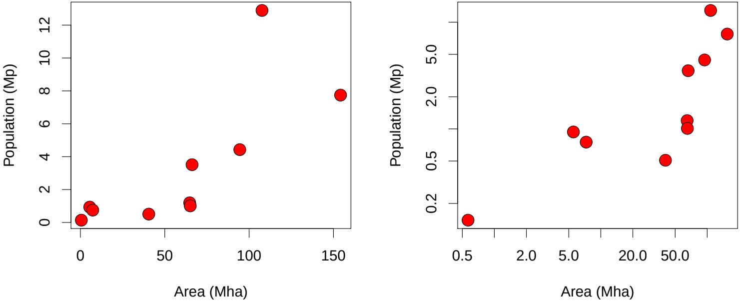
Canadian provinces



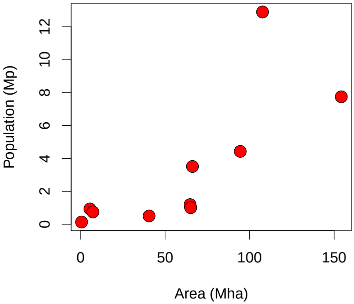
Canadian provinces

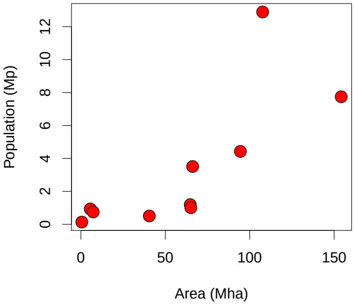


Canadian provinces

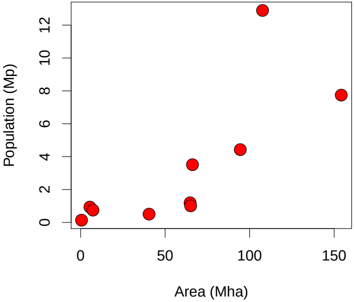


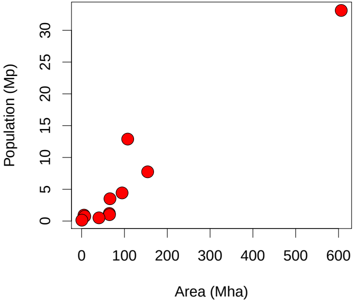
Canadian provinces plus Canada?



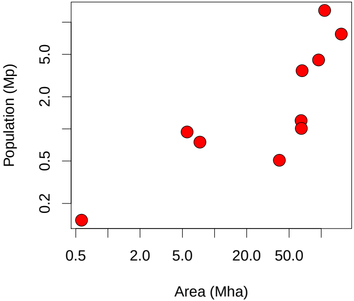


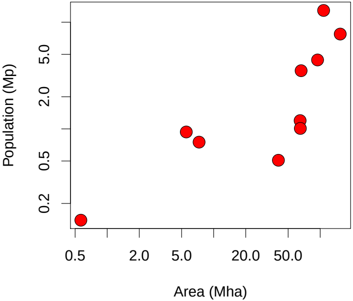
Canadian provinces plus Canada



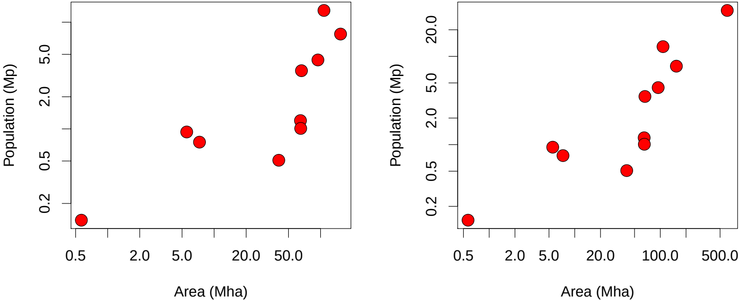


Canadian provinces plus Canada?

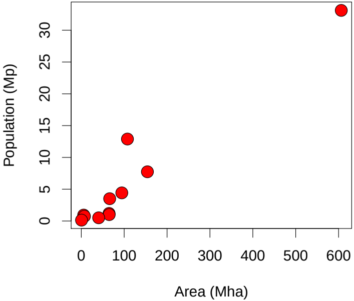


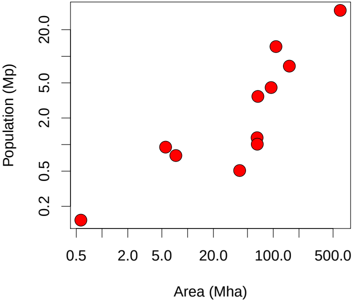


Canadian provinces plus Canada



Canadian provinces plus Canada





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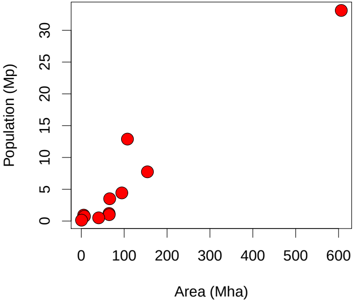

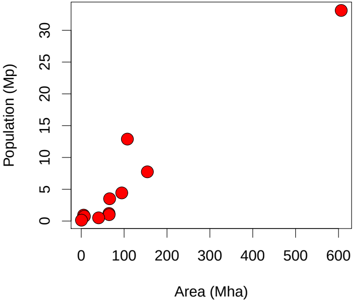

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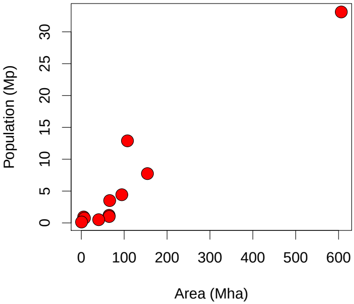
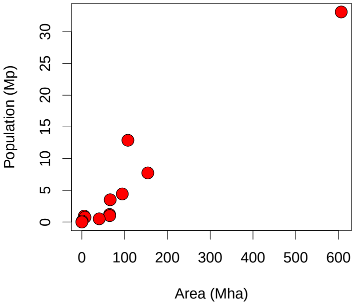
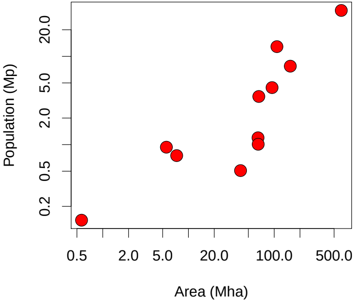
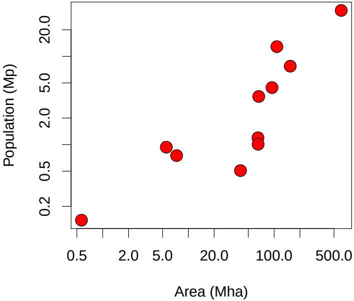


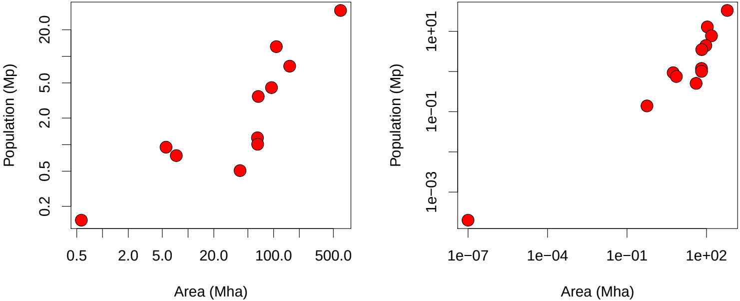


Canada plus room 1105?

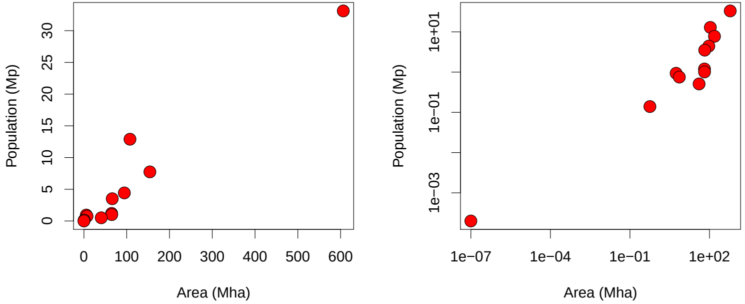




Canada plus room 1105



Canada plus room 1105



Predation comparison

Predation comparison

- 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 (500 lbs heavier)?

Different scales

- The log scale and linear scale provide different ways of looking at the same data
- Equally valid
- What are some advantages of each?

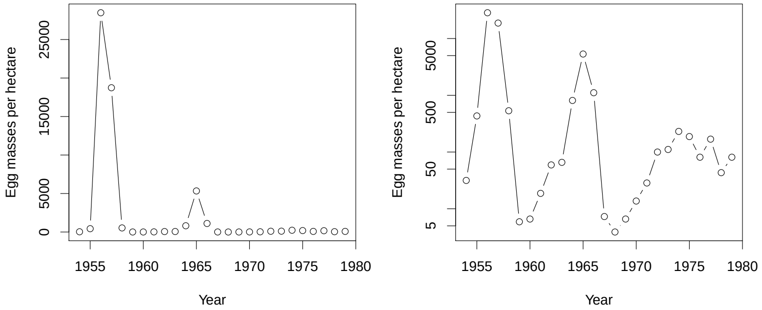
Advantages of arithmetic view

- * When there is no natural zero (or the natural zero is irrelevant)
  - * Often the case for time or geography
- * When zeroes (or negative numbers) can occur
- * When we are interested in adding things up

Advantages of geometric view

- * When comparing physical quantities, or quantities with natural units
- * When comparing proportionally

Gypsy-moth example



Scales in population biology

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

Outline

Speeding in Taiwan

- A life experience
- Some clarifications
  - I was reading the sign wrong
  - I didn't actually know how to say speed
  - The whole thing never happened

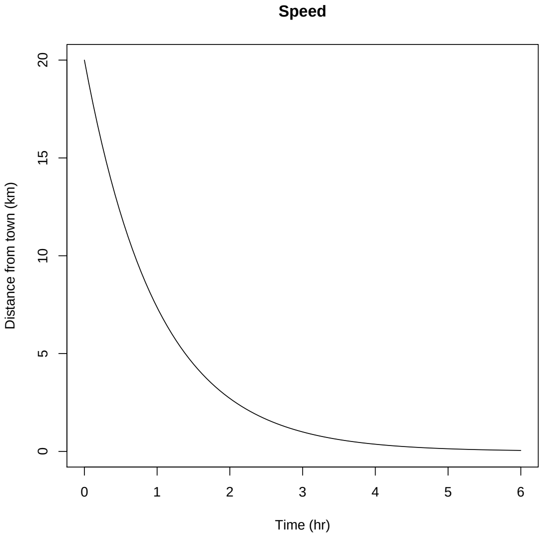
Speeding in Taiwan

- Moral:
  - Units (km is *not* a speed)
  - Exponential decay
- Imagine now that I follow the signs exactly and unrealistically.
- Poll: Do I ever arrive in the (ideal) town of Speed?
  - * No. I am always an hour away!
  - * But I do get extremely close (after several hours)
- Does anyone remember Zeno's paradox?
  - * Don't worry about it, then

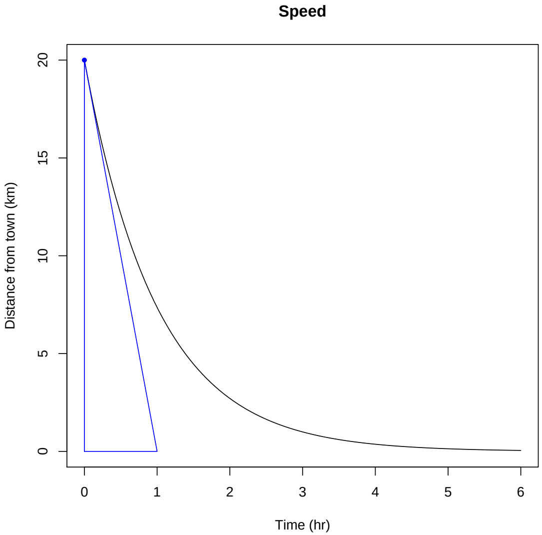
Characteristic times

- 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)
- *I'm always 1 hour away from the town of Speed*

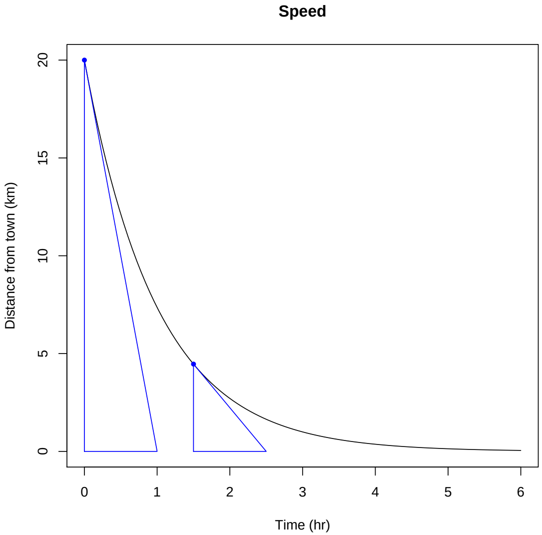
Characteristic times



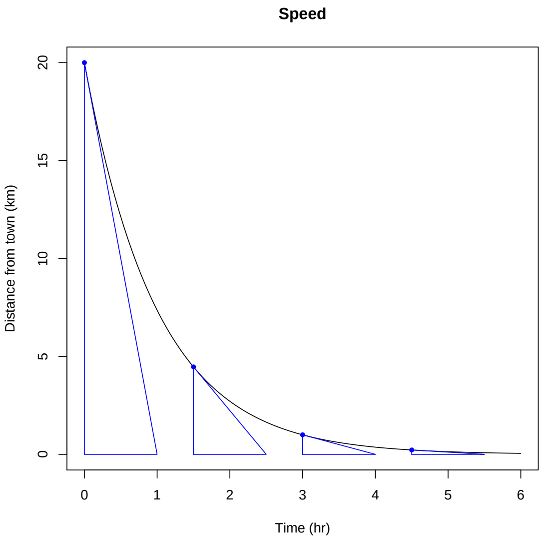
Characteristic times



Characteristic times



Characteristic times



Bacteriostasis

- 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?

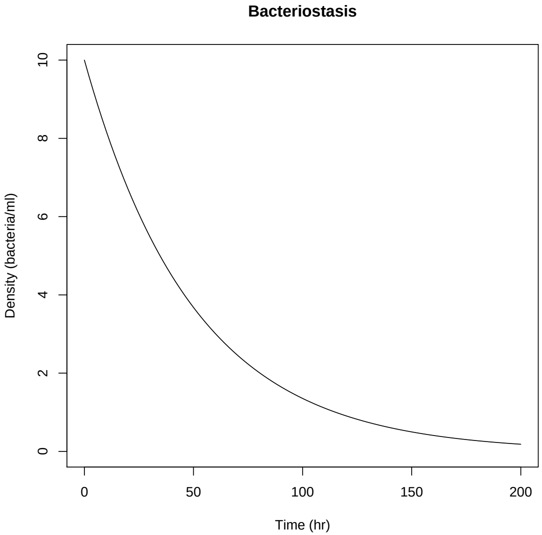
Bacteriostasis answers

- Bacteria wash out at the rate of 0.02/hr
  - * This can only make sense with concrete units if we think of it as an instantaneous rate – more soon
  - * $N = N_0 exp(-rt)$
- Start with 10 bacteria/ml:
  - * After one hour, 9.802 bacteria/ml
  - * After one week, 0.347 bacteria/ml

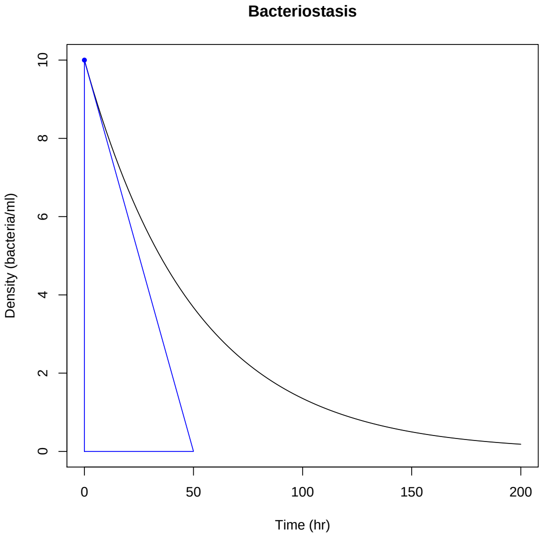
Bacteriostasis analysis

- Rate of exponential decline is $r = 0.02/\,\mathrm{hr}$
- Characteristic time is $T_c = 1/r = 50\,\mathrm{hr}$
- If experiment time $t \ll T_c$, then proportional decline $\approx t/T_c$
- The answer makes sense for short times and for long times
- *We will come back to this*

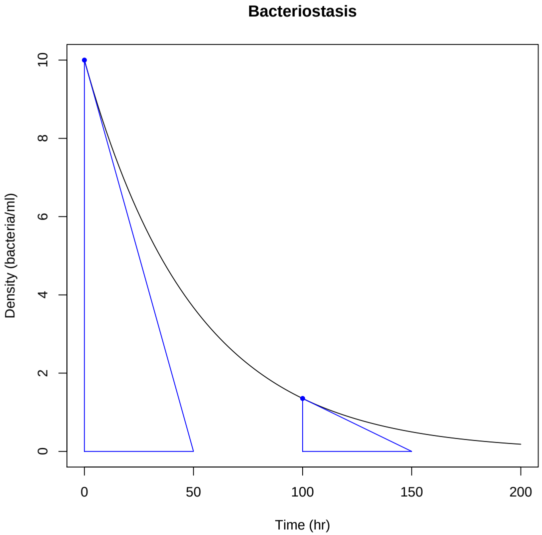
Characteristic times



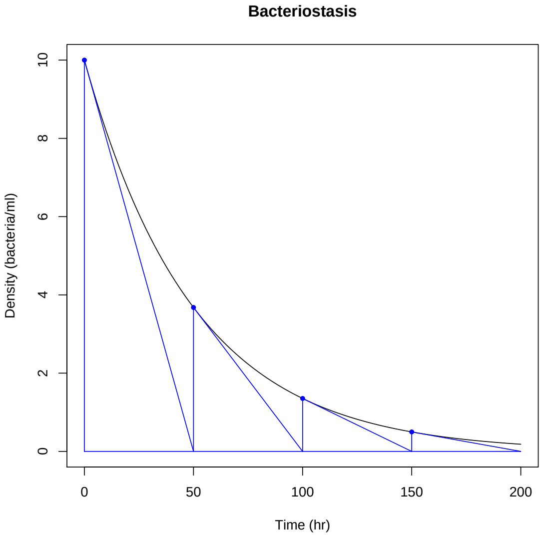
Characteristic times



Characteristic times



Characteristic times



Euler's e

- The reason mathematicians like e 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?
  - * e times closer

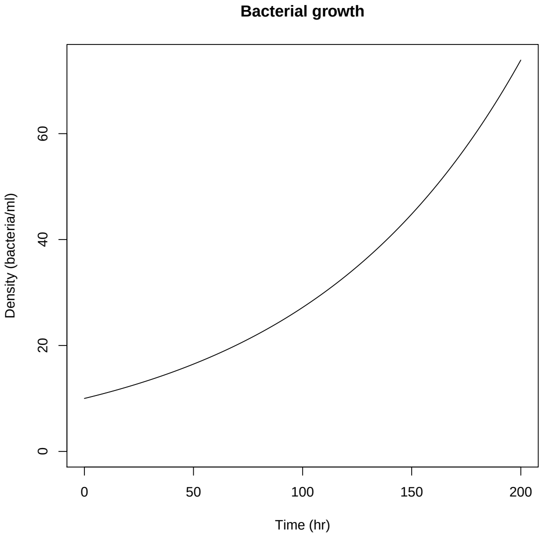
Euler's e

- e or $1/e$ 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?

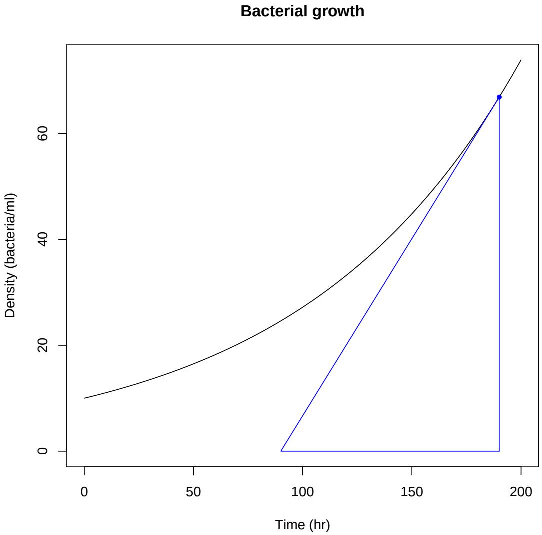
Exponential growth

- 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 $N = N_0 \exp(rt) = N_0 \exp(t/T_c)$

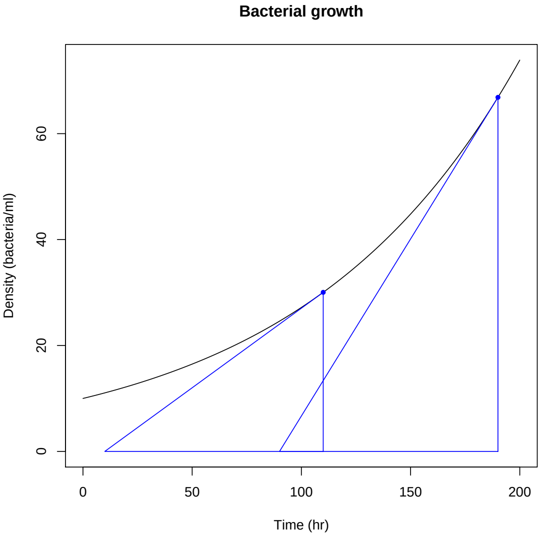
Characteristic times



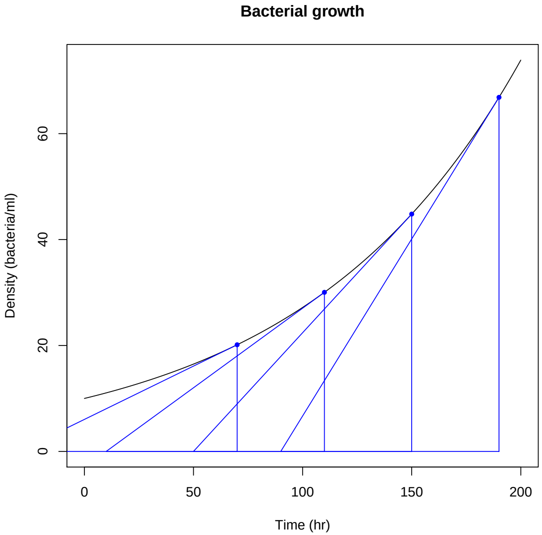
Characteristic times



Characteristic times

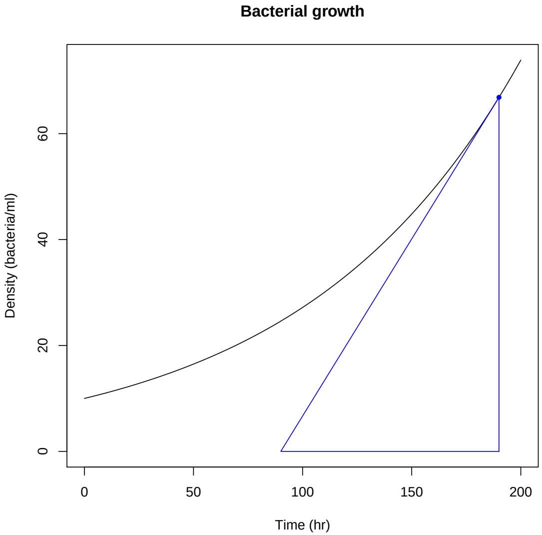


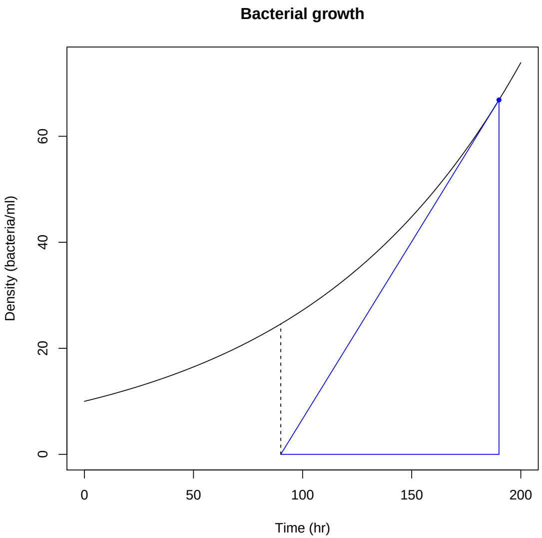
Characteristic times



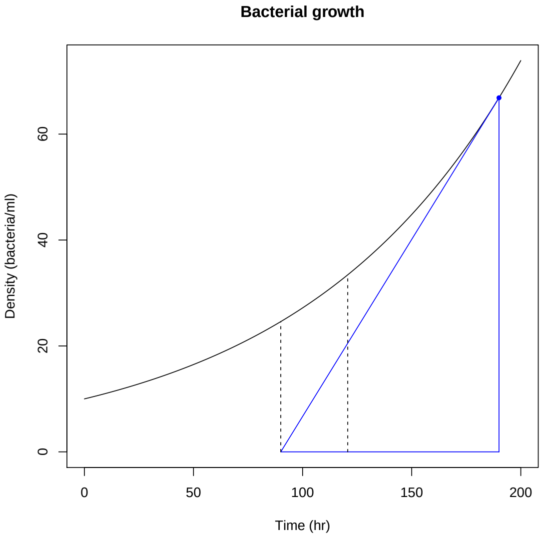
Doubling time

- Some people prefer to think about doubling times.
- These make just as much sense as characteristic times, but don't have the direct link to the instantaneous change.
  - It takes T_c time to increase by a factor of e
  - It takes $\log_e(2)\,T_c \approx 0.69\,T_c$ to increase by a factor of 2
  - We can write $T_d = \log_e(2)\,T_c$
- You should be able to do this calculation


Bacterial growth
Density (bacteria/ml)
0
20
40
60
0
50
100
150
200
Time (hr)

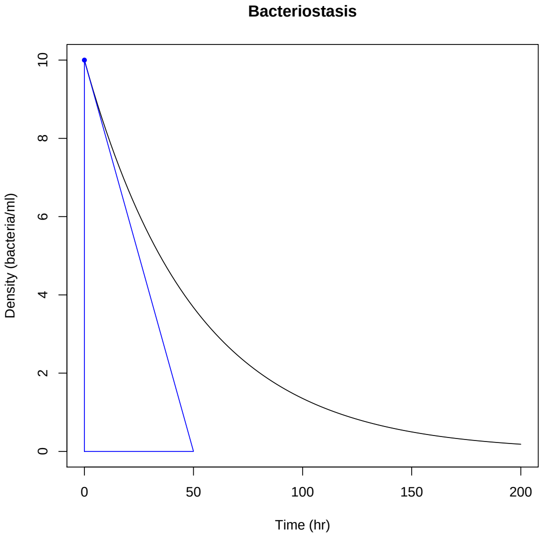

Bacterial growth
Density (bacteria/ml)
0
20
40
60
0
50
100
150
200
Time (hr)

Characteristic time and doubling time

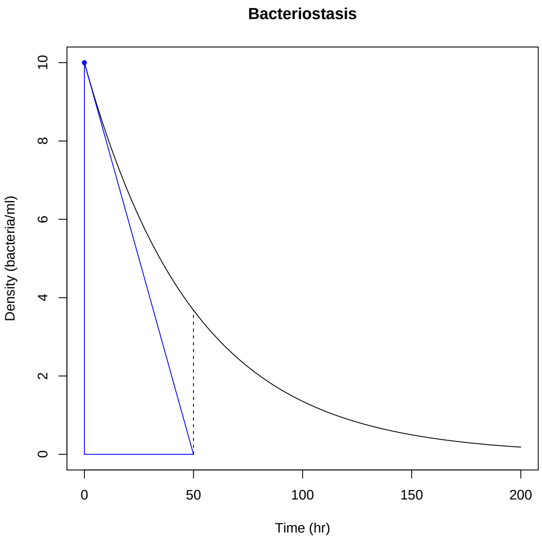


Half life

- The half life plays the same role for exponential decline as the doubling time does for exponential growth:
  - $T_h = \log_e(2)\, T_c$
  - It takes T_c time for a declining population to decrease by a factor of e
  - It takes $\log_e(2)\, T_c \approx 0.69\, T_c$ to decrease by a factor of 2
  - We can write $T_h = \log_e(2)\, T_c$



Bacteriostasis
Density (bacteria/ml)
0
2
4
6
8
10
0
50
100
150
200
Time (hr)


Bacteriostasis
Density (bacteria/ml)
0
2
4
6
8
10
0
50
100
150
200
Time (hr)

Characteristic time and half life