Intro to Programming Part 4: modeling and simulations

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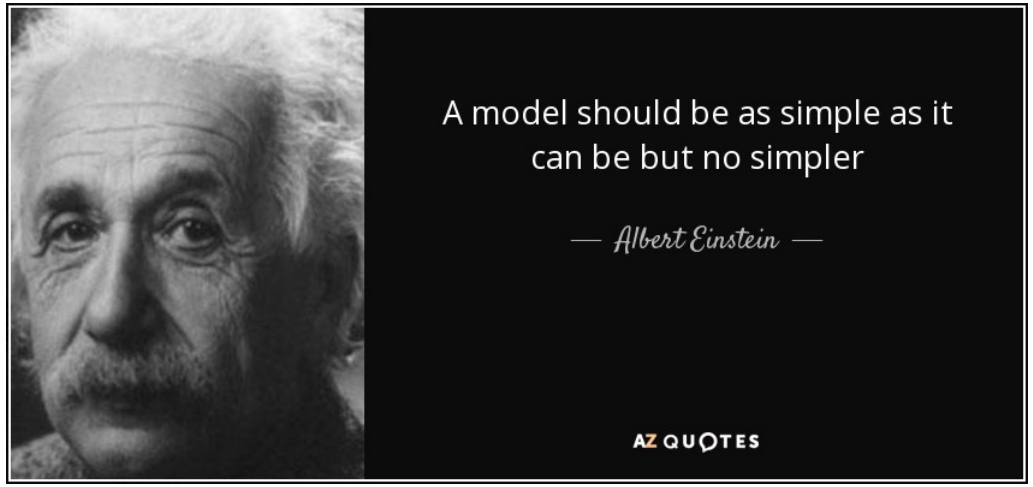
What is a model?

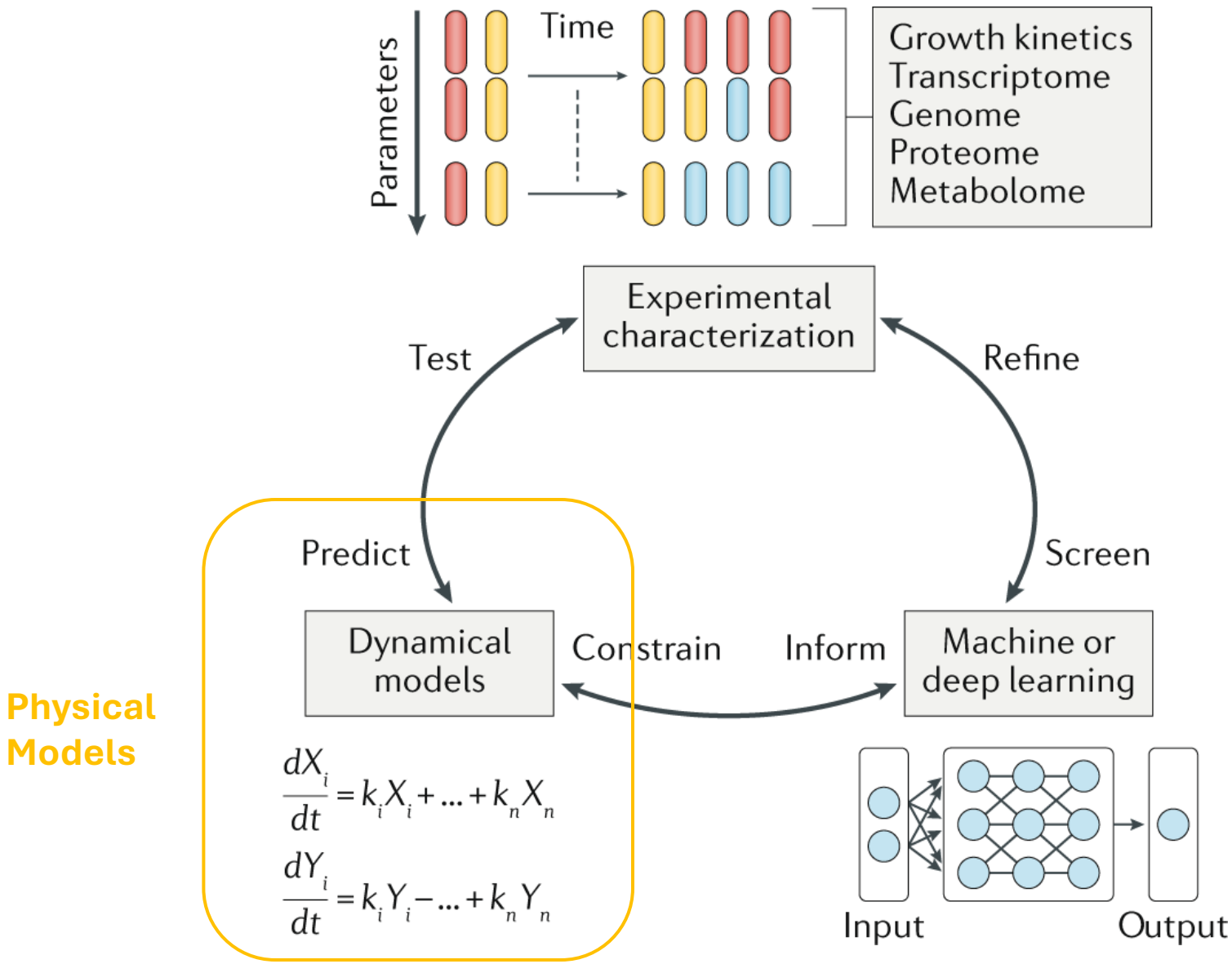
"Our simplified yet useful representation of reality."

- Predict the future.
- Predict different outcomes.



“Modeling”: To build, analyze, test, and critique models (of biology).

Gunawardena, J. Models in biology: ‘accurate descriptions of our pathetic thinking’. *BMC Biol* **12**, 29 (2014). https://doi.org/10.1186/1741-7007-12-29



Physical Models

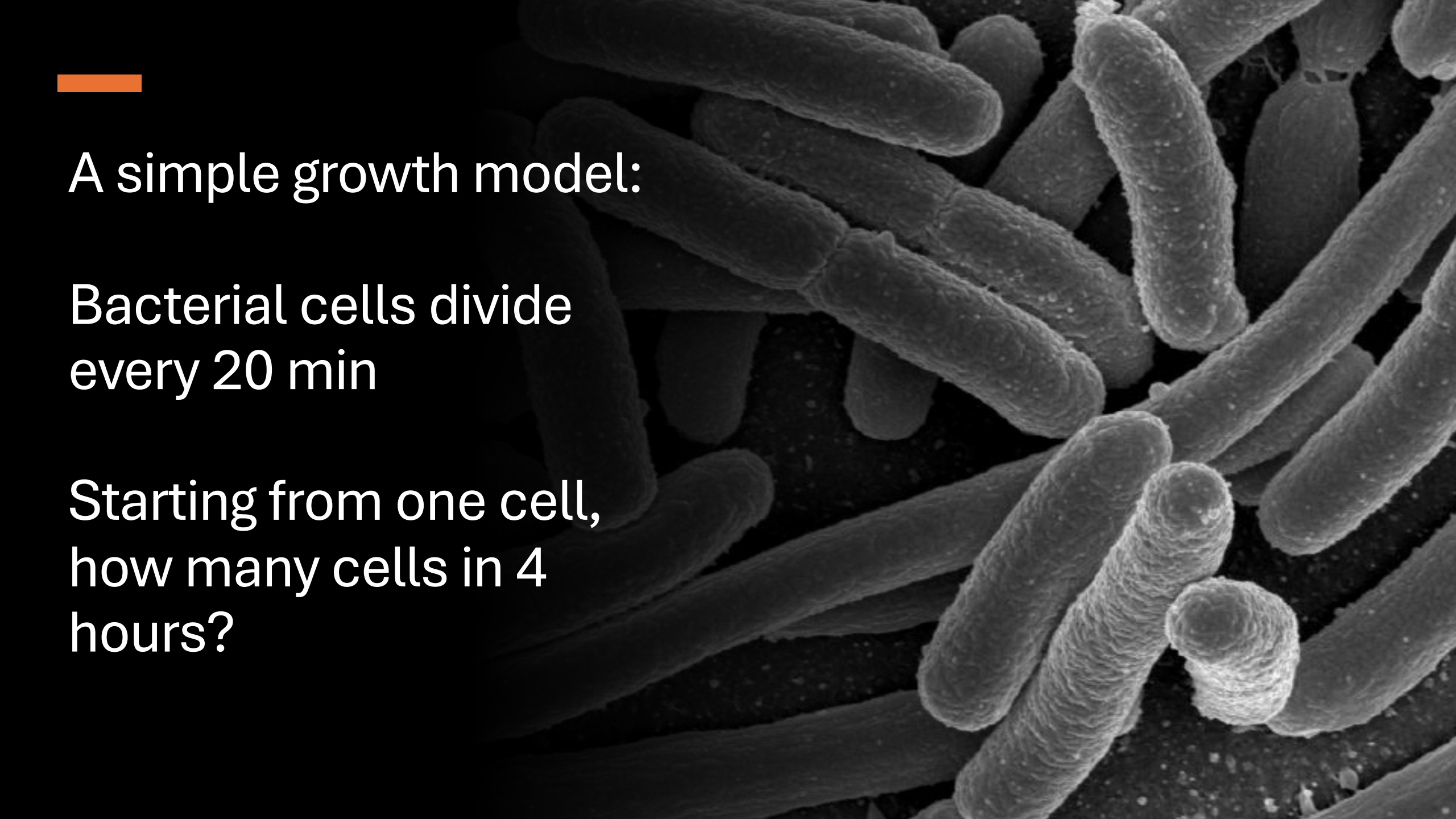
Experiments
+
Physical models
+
Machine learning models

Lopatkin, A.J., Collins, J.J. Predictive biology: modelling, understanding and harnessing microbial complexity. *Nat Rev Microbiol* **18**, 507–520 (2020). https://doi.org/10.1038/s41579-020-0372-5

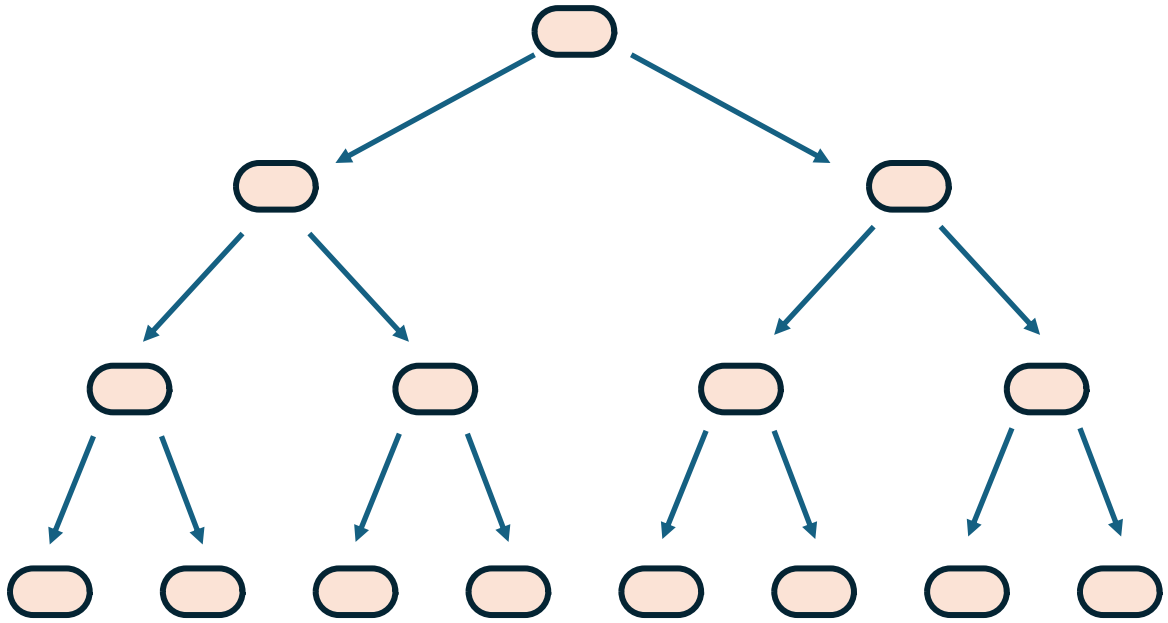
A simple growth model:

Bacterial cells divide every 20 min

Starting from one cell, how many cells in 4 hours?



Doubling every 20 minutes is a “chain reaction”



Time [min]	Generation	Nr. of cells N
0	1	1
20	2	2
40	3	4
60	4	8

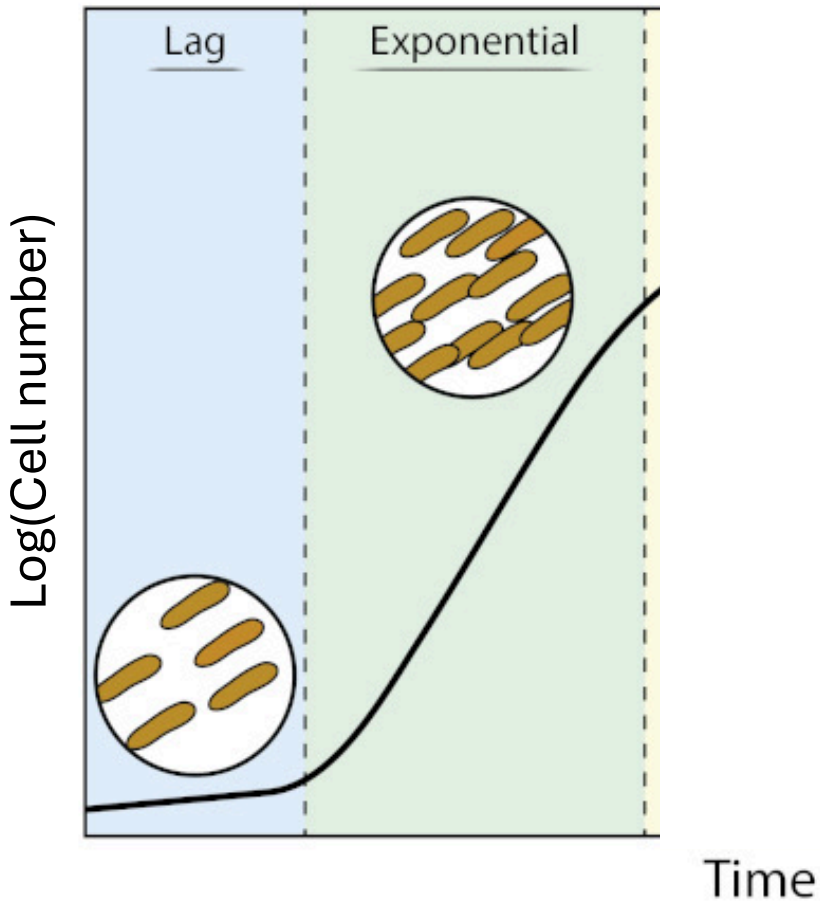
Cell number in next generation $= 2C$

C: current cell number

Predicting the number of cells vs. time

1. using Google Spreadsheets
2. using Python and for loops

Bacterial division leads to exponential growth



Until resources are consumed…

Bonus Q:
How can you model resource consumption?

JoVE Science Education Database. Microbiology. Growth Curves: Generating Growth Curves Using Colony Forming Units and Optical Density Measurements. JoVE, Cambridge, MA, (2023).

Mathematical ecology:

Modeling the population dynamics of rabbits and foxes

1. Rabbits multiply.
2. Fox feed on rabbits.

Modeling the Rabbit-Fox interactions

Rabbit pop. in next generation $= R$

Current

g_1: Growth rate of rabbits

g_2: Growth rate of foxes

Modeling the Rabbit-Fox interactions

Rabbit pop. in next generation

$$= R + g_1 R - d_1 RF$$

Rabbit growth

Rabbit death

Fox pop. in next generation

$$= F + g_2 RF - d_2 F$$

Fox growth

Fox death

g_1: Growth rate of rabbits

g_2: Growth rate of foxes

d_1: Death rate of rabbits

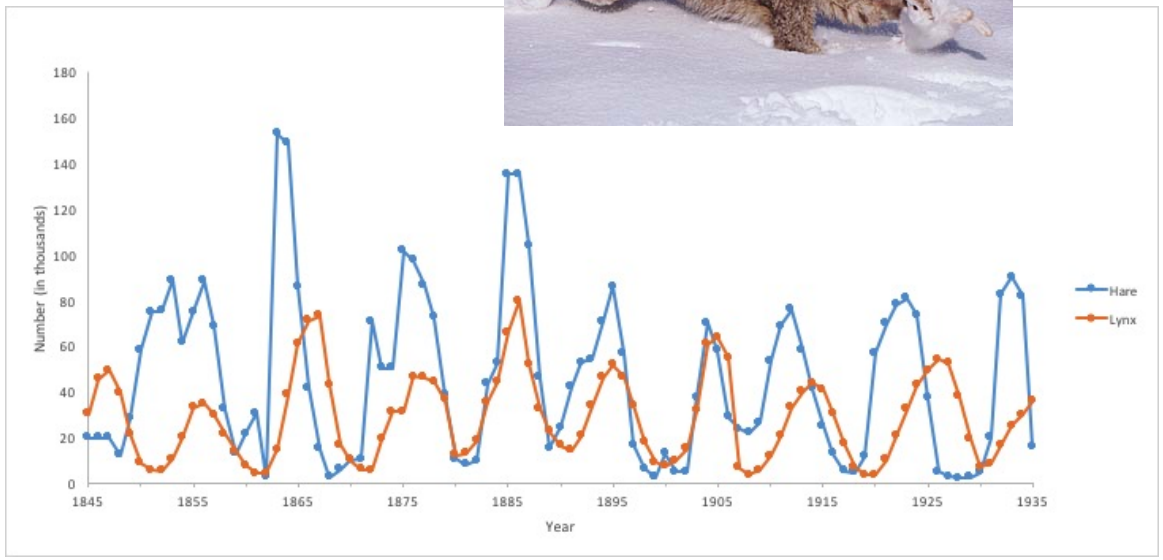
d_2: Death rate of foxes

Predicting the population dynamics of rabbits and foxes

1. using Google Spreadsheets
2. using Python and for loops

Modeling oscillations in the field and in our bodies

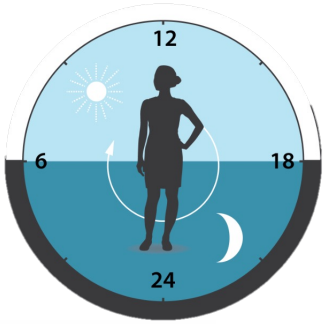
Hare and Lynx

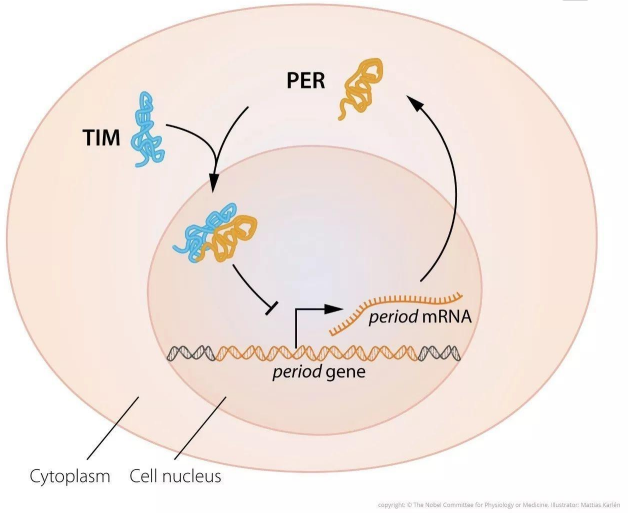


https://www2.nau.edu/lrm22/lessons/predator_prey/predator_prey.html

Circadian clock

~24 hours





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