CDS 230
Modeling and Simulation I

Module 1

An Introduction to Modeling and Simulation

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Schedule fixed

Week of	Chapter	Topic	Assignment
Aug 23	-	**MODULE 1 - Introduction** ● Welcome and Course Overview ● An Introduction to Modeling and Simulation	Homework 0
Aug 30	1, 2	**MODULE 2 - Getting Started with Python** ● Setting Up Your Python Environment ● Variables and Basic Data Types in Python ● Simple Physics Models	Homework 1
Sep 6		**Labor Day - No class on Monday** **MODULE 3 - Control Flow** ● Comparisons, Logic, and Conditional Statements	
Sep 13	3	**MODULE 4 - Strings** ● Strings	Homework 2
Sep 20	3, 4, 5	**MODULE 5 - Collections and Iteration** ● Lists, Tuples, Dictionaries, and Sets ● Loops	Homework 3
Sep 27	6, 11	**MODULE 6 - Making Your Code Organized** ● Functions ● Classes and Object Oriented Programming	
Oct 4	9, 10	**MODULE 7 - Using Third Party Packages** ● NumPy ● Matplotlib	Homework 4
Oct 11		● Example Problems (Oct 12 - **Tuesday**) **MIDTERM EXAM** ● Oct 13 (from 10:30 am - 11:45 am) ● In class	Mid-semester survey

FERPA form and Homework 0

202170.84874 CDS-230-002 (Fall 2021)

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FERPA Release Form

Attached Files: FERPA_HB1release_CDS_AY21-22.pdf   (99.816 KB)
                   FERPA_HB1release_CDS_AY21-22.docx   (94.623 KB)

FERPA release form to access third party tools including DataCamp and Loom. You should fill out, sign, and upload the form. It's totally fine to use this form even if you're not a CDS student.

Homework 0 (BONUS)

Find an online video of a simulation model which you find interesting (+15 pts) and tell your classmates why you liked it (+15 pts).

Rule: Before posting your answer as a new thread, make sure no other classmates posted the same video. In such cases, only the early submission is counted.

This is an optional homework which will be counted as BONUS.

Due: Sep 1, 2021 at 10:30 AM

This lecture in a nutshell

1. **What** is a model?

2. **Why** do we need models?

3. **How** to develop models?

What is a model?

Source: https://www.thebalancecareers.com/how-to-become-a-male-runway-model-2379357

What is a model, anyway?

- "something built or drawn esp. to show how something much larger would look"

- "a representation of something in words or numbers that can be used to tell what is likely to happen if particular facts are considered as true"

- "a description or analogy used to help visualize something (such as an atom) that cannot be directly observed"

- "a system of postulates, data, and inferences presented as a mathematical description of an entity or state of affairs"
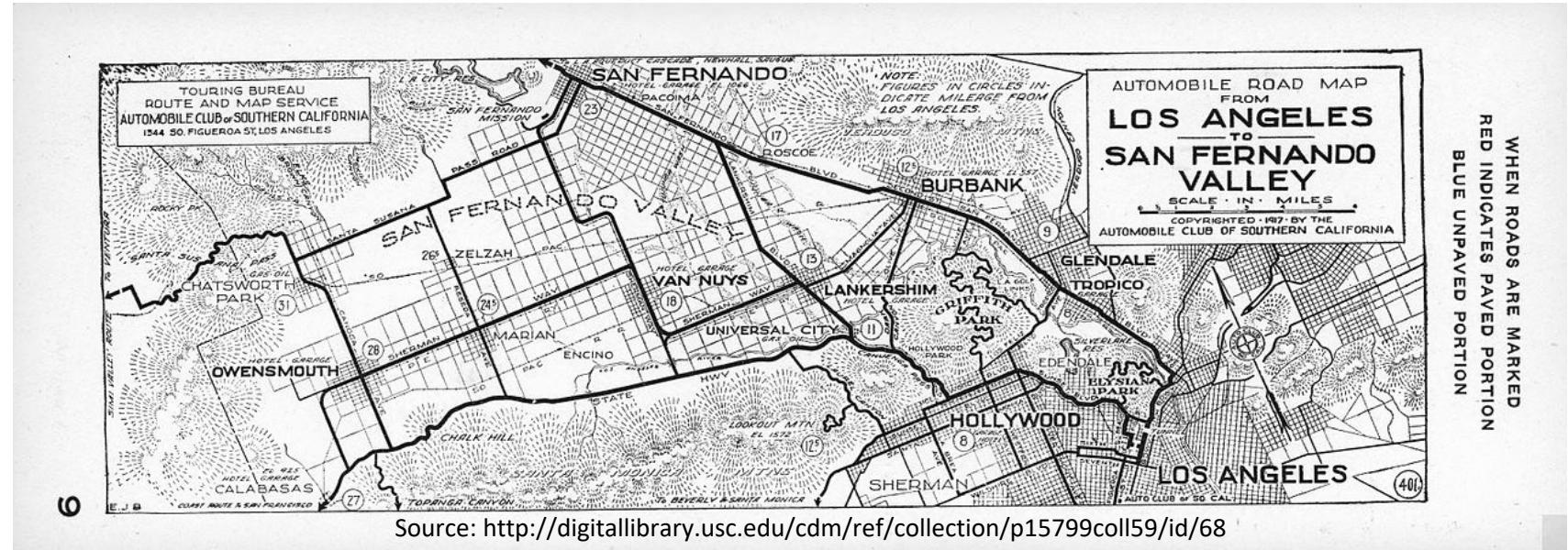
Models

- **Represents** something real or imaginary.
- Built for a **purpose**
- Has **detail** or **abstraction level**
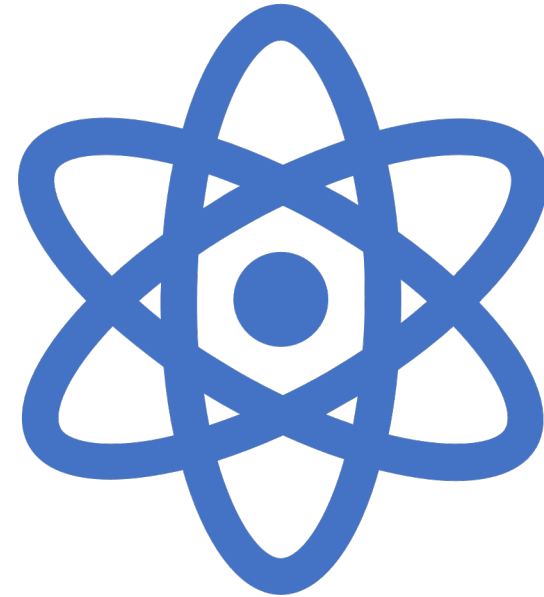
Models used or seen in daily life

- Printed maps

Source: http://digitallibrary.usc.edu/cdm/ref/collection/p15799coll59/id/68

- Weather forecasters

DAY		DESCRIPTION	HIGH / LOW	PRECIP	WIND	HUMIDITY
TODAY JAN 23		Mostly Cloudy	44°/32°	0%	SE 3 mph	51%
FRI JAN 24		Cloudy	51°/46°	20%	ENE 8 mph	77%
SAT JAN 25		AM Rain	52°/30°	80%	WNW 10 mph	72%
SUN JAN 26		Partly Cloudy	47°/29°	10%	W 10 mph	60%
MON JAN 27		Partly Cloudy	46°/30°	10%	NW 9 mph	63%

Source: https://weather.com/weather/5day/l/e8321c2fb1f8234f40bf92ce494921d94e657d54cc2c01f1882755e04b761dee

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Models used or seen in daily life

- Model cars

- Scarecrows

Source: https://pixabay.com/photos/model-car-ford-ford-capri-model-2093815/
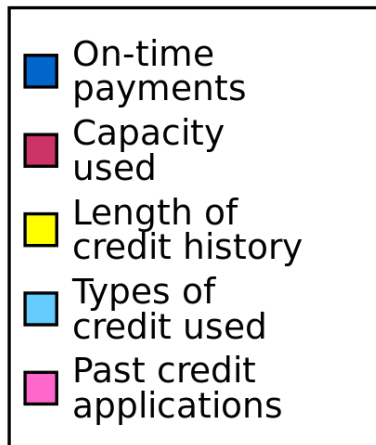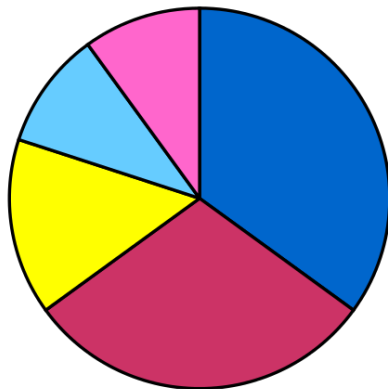

Source: https://commons.wikimedia.org/wiki/File:Little_Bo_Peep_Scarecrow.JPG

Models used or seen in daily life

- Credit score calculators

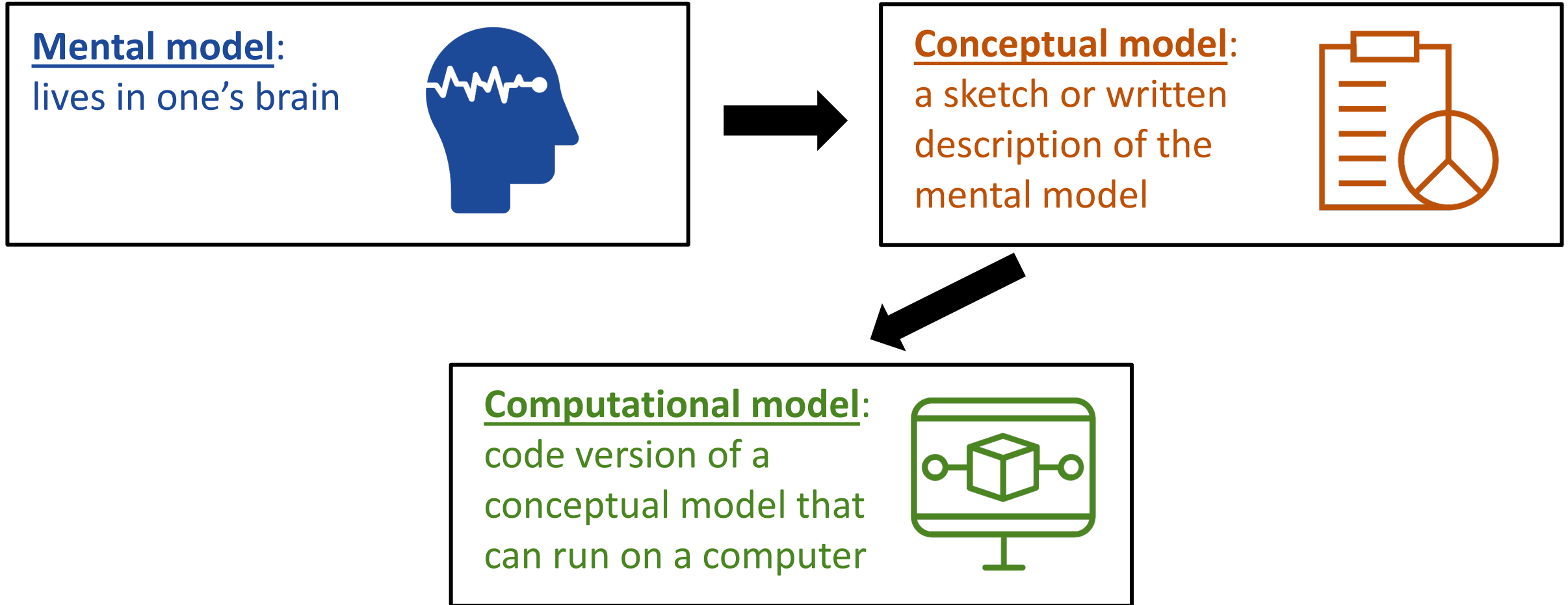- GPS navigation devices

CREDIT SCORE FACTORS

- On-time payments
- Capacity used
- Length of credit history
- Types of credit used
- Past credit applications

Source: https://commons.wikimedia.org/wiki/File:Credit-score-chart.svg

Source: https://pixabay.com/vectors/gps-navigation-garmin-device-304842/

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Models can be of different types

Mental model: lives in one's brain

Conceptual model: a sketch or written description of the mental model

Computational model: code version of a conceptual model that can run on a computer

An example model

Routing to grocery store

Mental model

1. Go to car
2. Drive to grocery store

Conceptual model

Current location

Parking lot

Grocery store
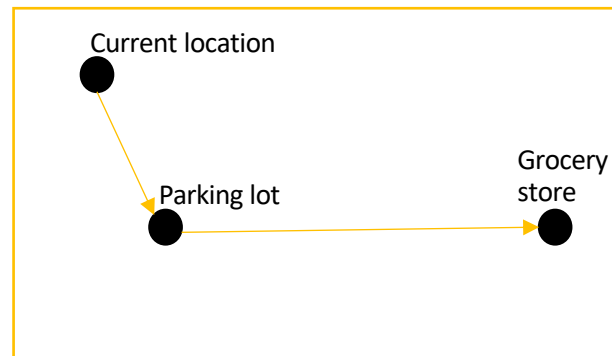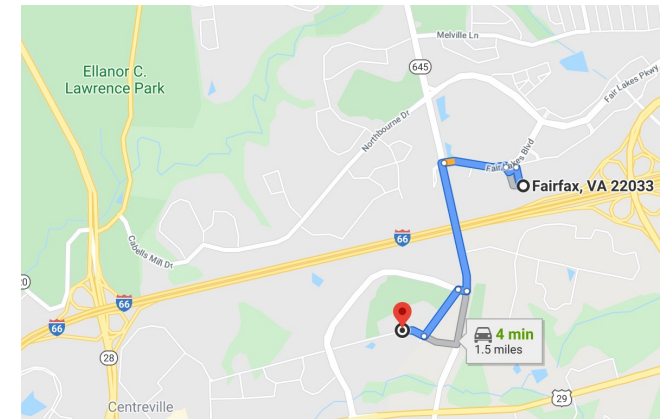
Computational model

Models can vary in their certainty

Stochastic
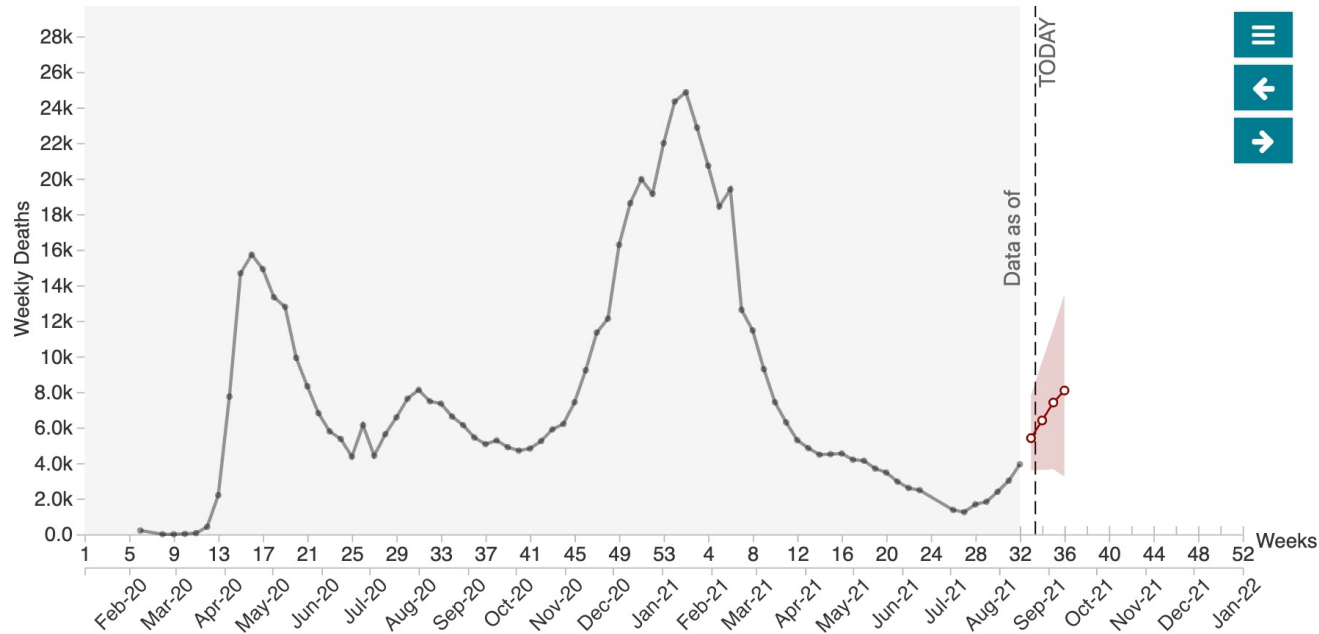
Deterministic

Source: https://covid.cdc.gov/covid-data-tracker/#forecasting_weeklydeaths
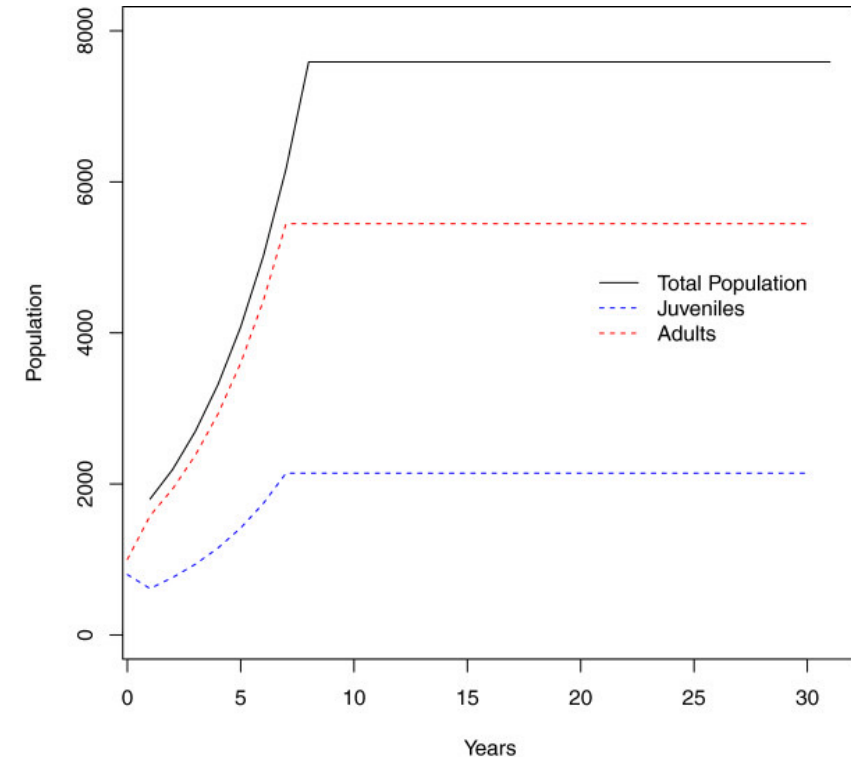
Source: Erickson, R. A., Thogmartin, W. E., & Szymanski, J. A. (2014). BatTool: an R package with GUI for assessing the effect of White-nose syndrome and other take events on Myotis spp. of bats. *Source code for biology and medicine*, *9*(1), 1-10.

We can combine models

Source: https://www.cdc.gov/coronavirus/2019-ncov/science/forecasting/forecasting-us.html
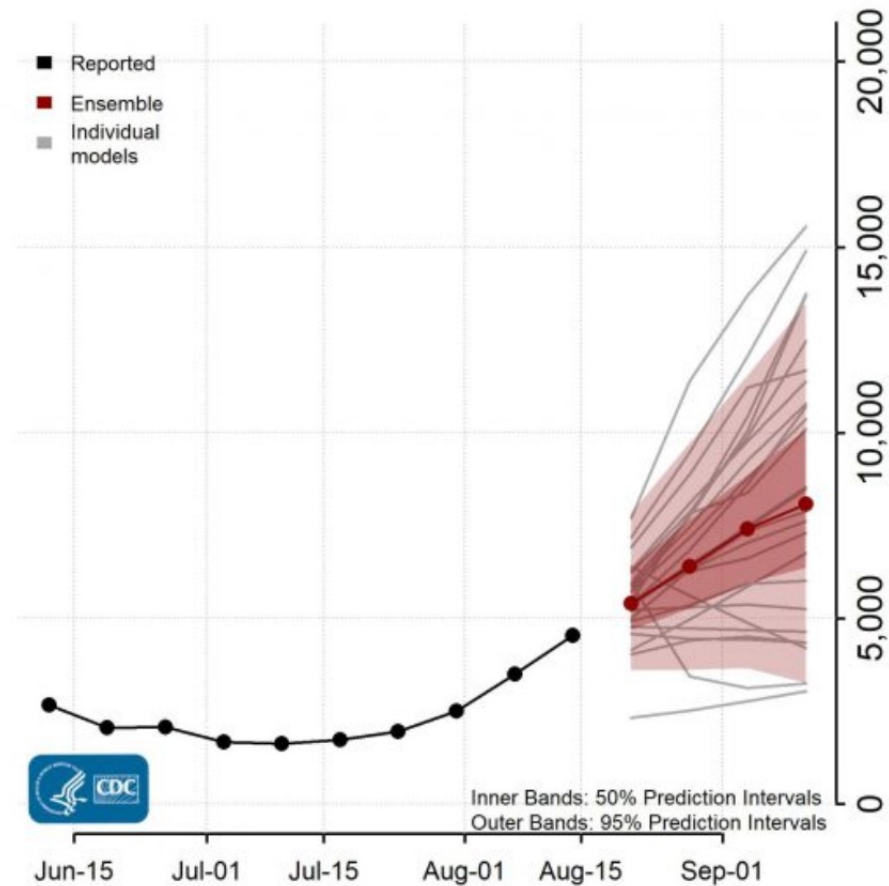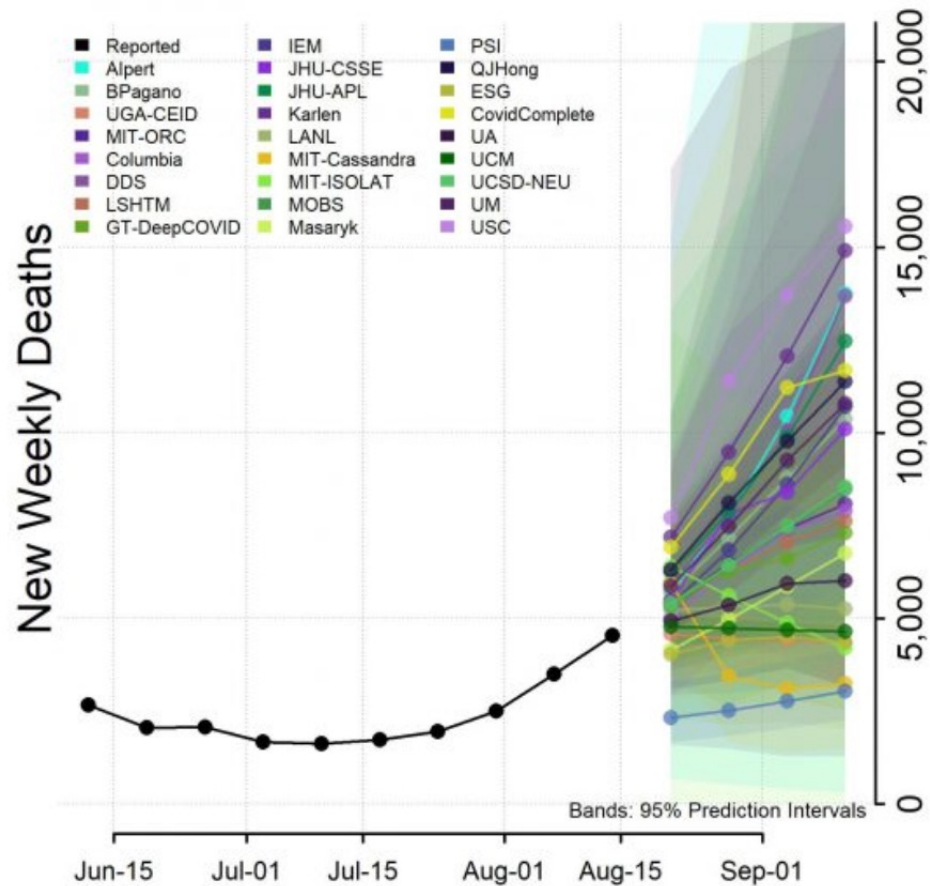
Computational models

- Monte Carlo models
- Agent-based models
- Discrete event models
- Mathematical models
  - Continuous time
  - Discrete time
- Network models
- Cognitive models
- …

Why do we need models?

5 reasons among many

Why do we need models?

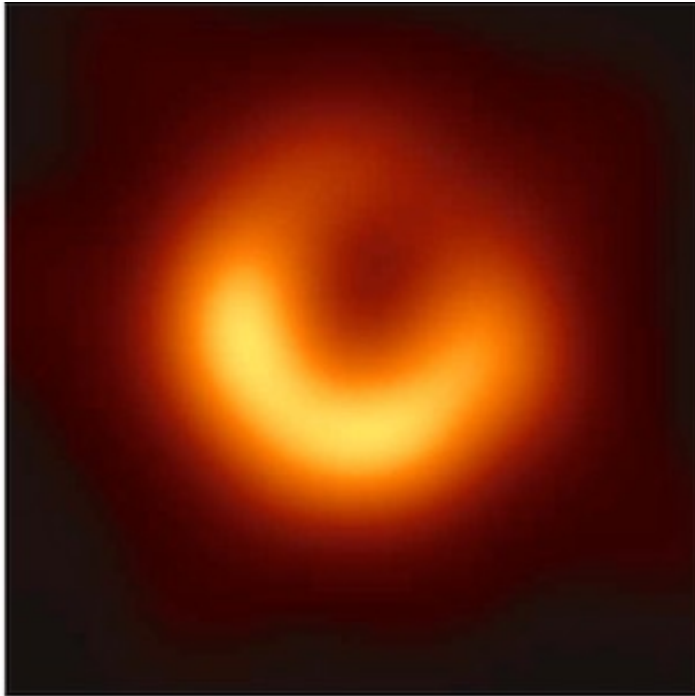1. To test theories

What is this? Any guess?

Source: https://www.jpl.nasa.gov/edu/news/2019/4/19/how-scientists-captured-the-first-image-of-a-black-hole/
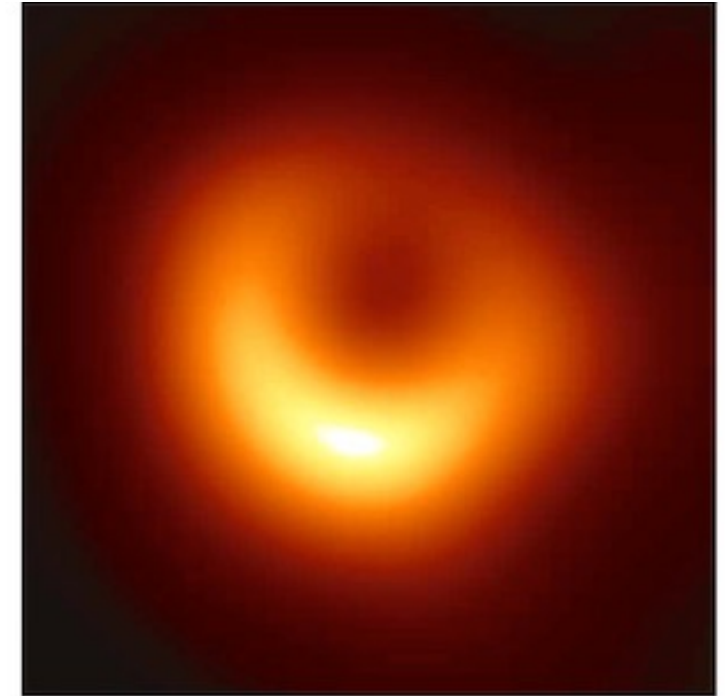
A donut?

A partly eaten donut?

Looking at the sun during a solar eclipse?

First ever picture of a black hole from the galaxy M87 obtained using The Event Horizon Telescope.

How about this?

Real Black Hole (M87)

Simulation of Black Hole (M87)

40 micro arcsec
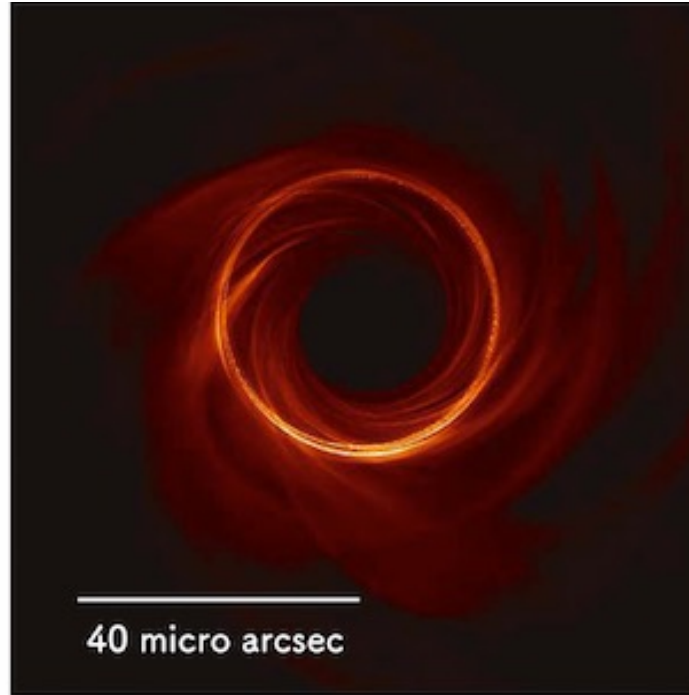
Blurred Simulation

Source: https://www.cfca.nao.ac.jp/en/pr/20190410

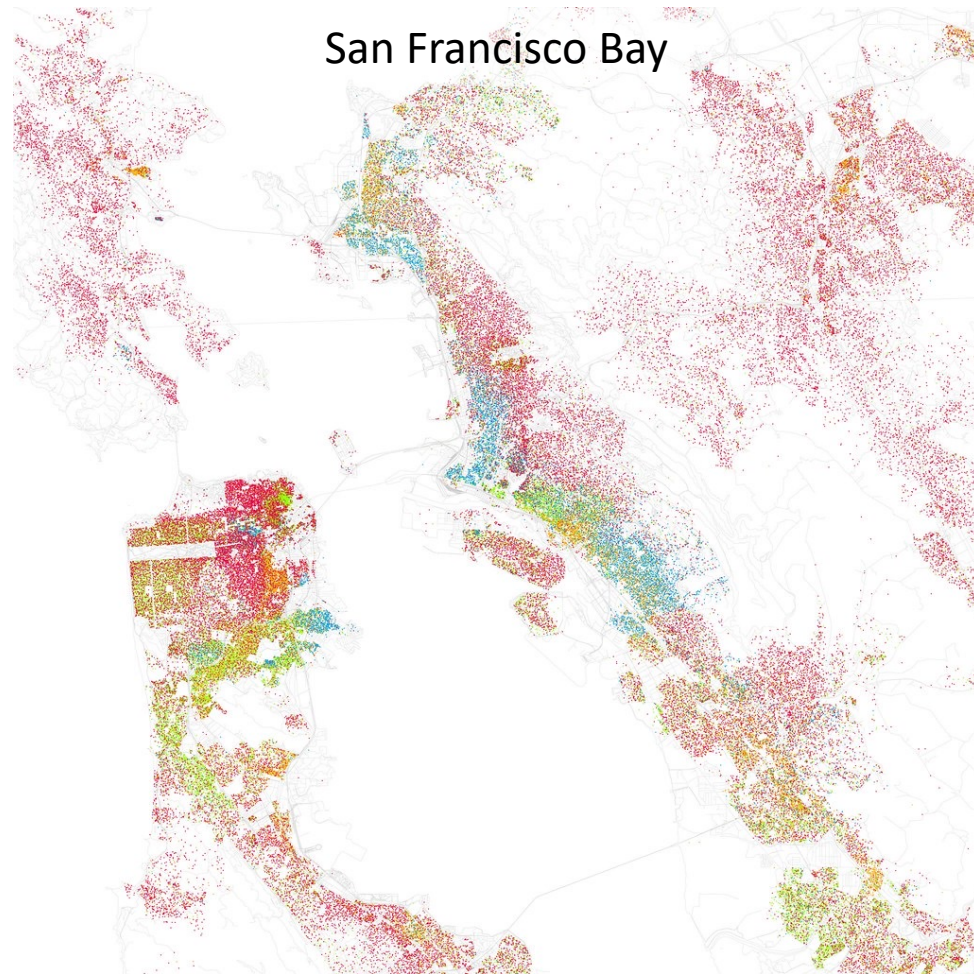Watch: https://www.youtube.com/watch?v=S_GVbuddri8

Why do we need models?

1. To test theories.
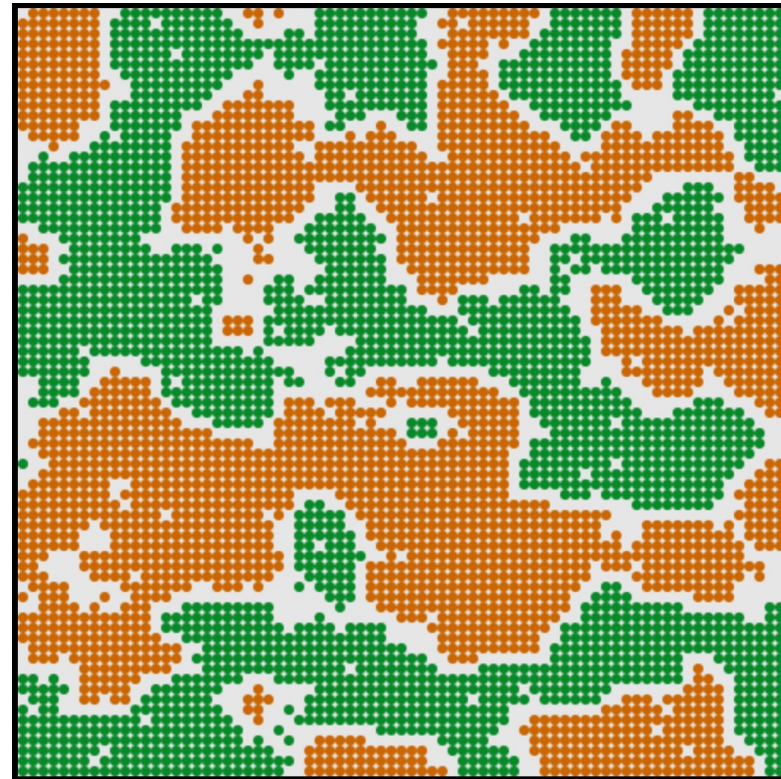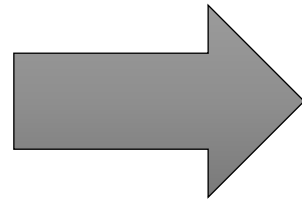
2. To explain a phenomena

Anyone likes maps?

Washington D.C.

Detroit

Source: https://www.fastcompany.com/1690097/infographic-day-how-segregated-your-city

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More maps?

San Francisco Bay

San Antonio

Source: https://www.fastcompany.com/1690097/infographic-day-how-segregated-your-city
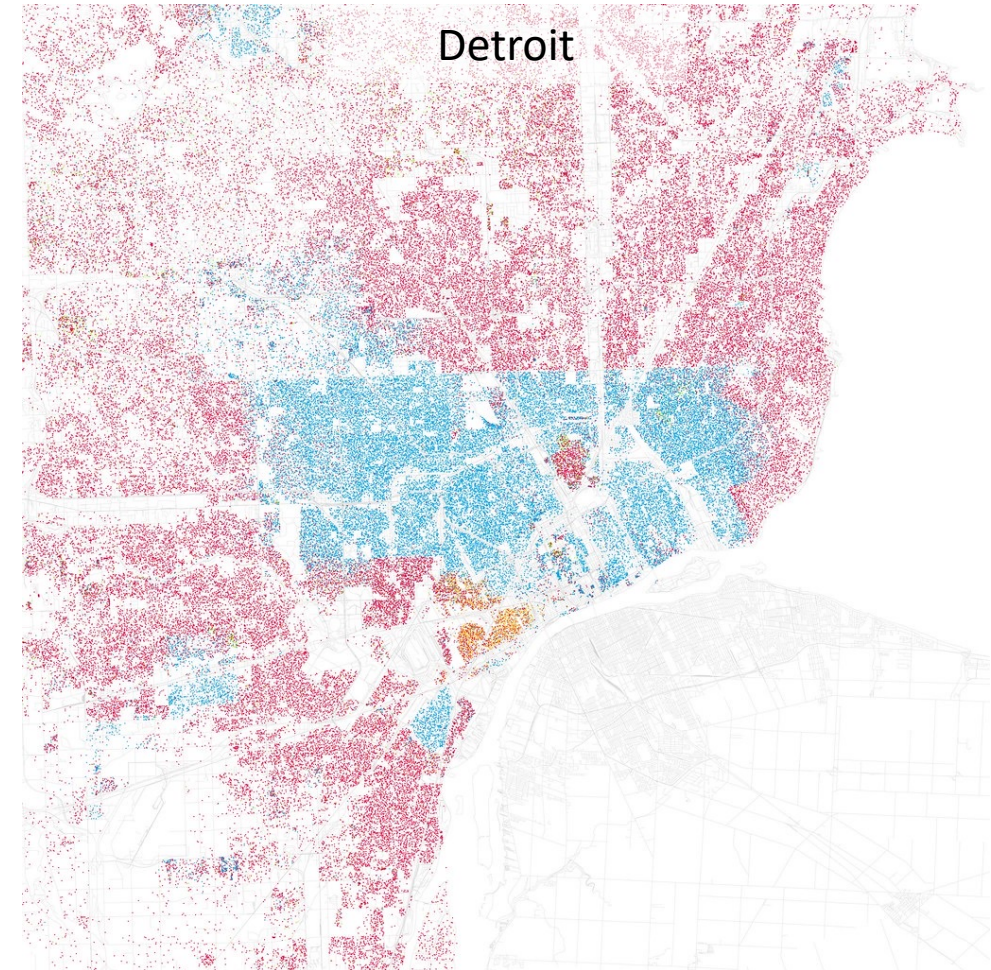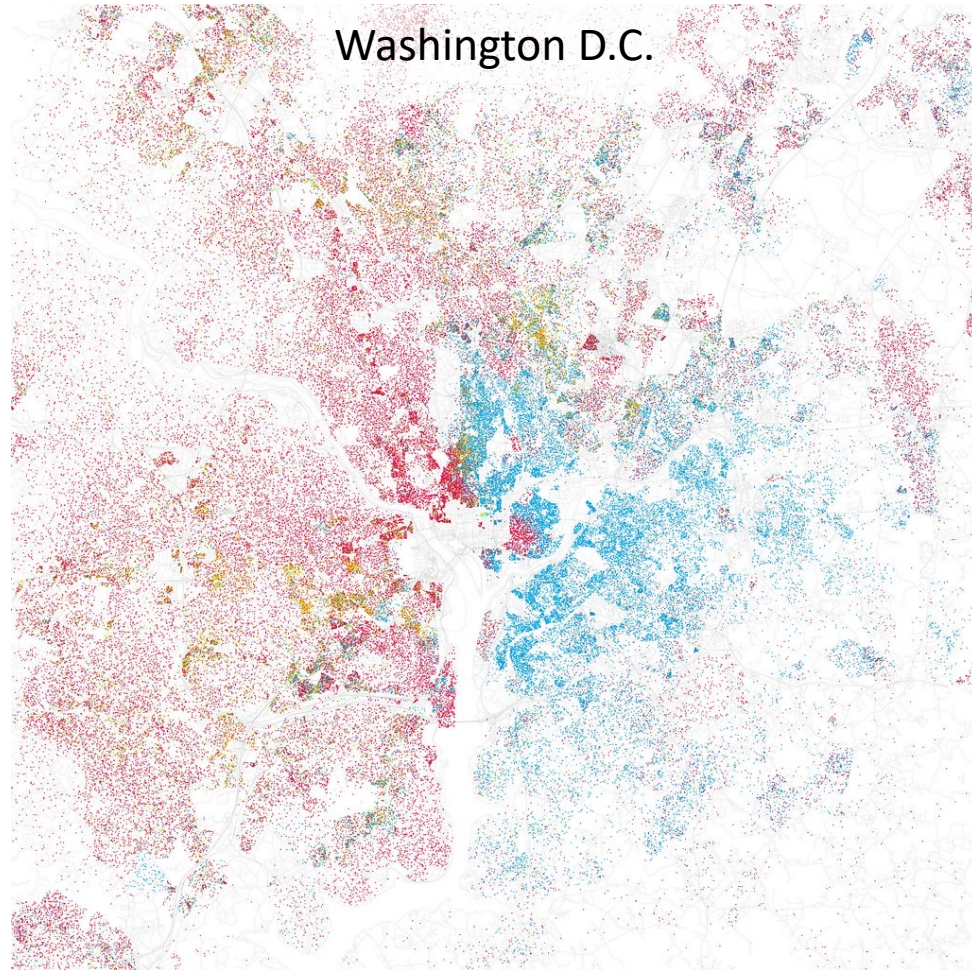
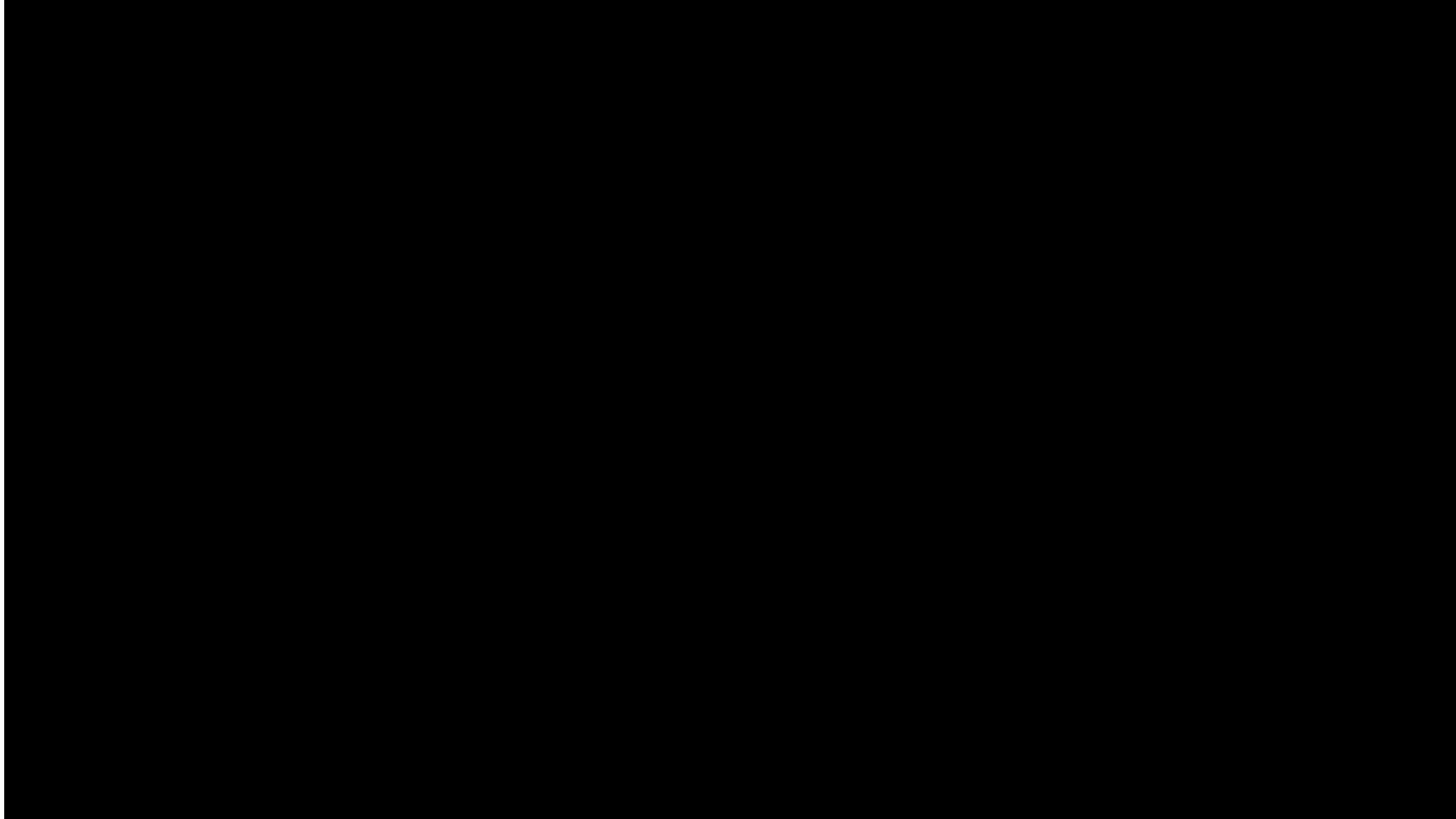# An explanation to why cities are segregated

- http://hamdikavak.com/sims/segregation/

Birds

Source: https://www.youtube.com/watch?v=bb9ZTbYGRdc
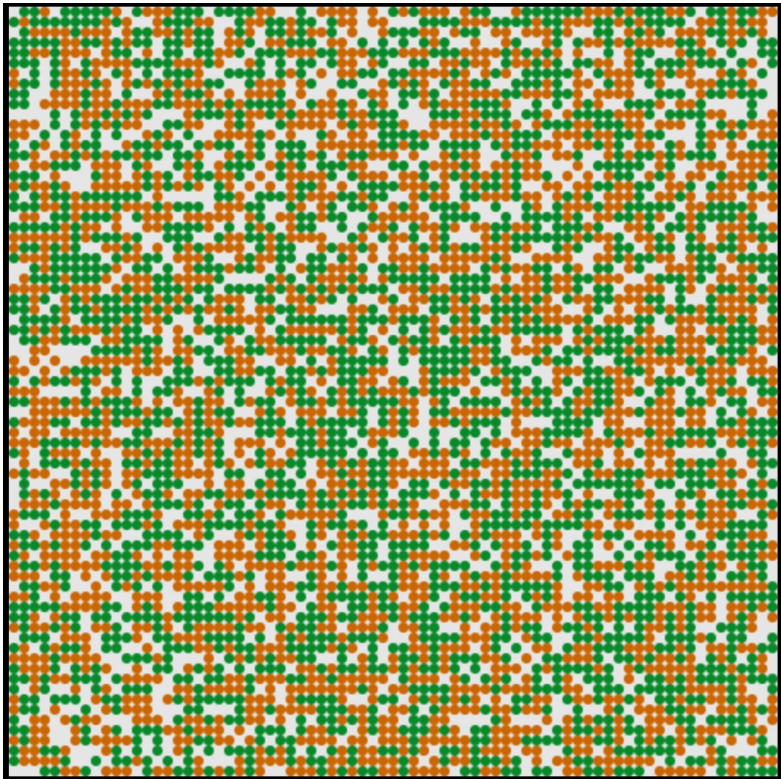
An explanation to how birds flock

- http://hamdikavak.com/sims/flocking/
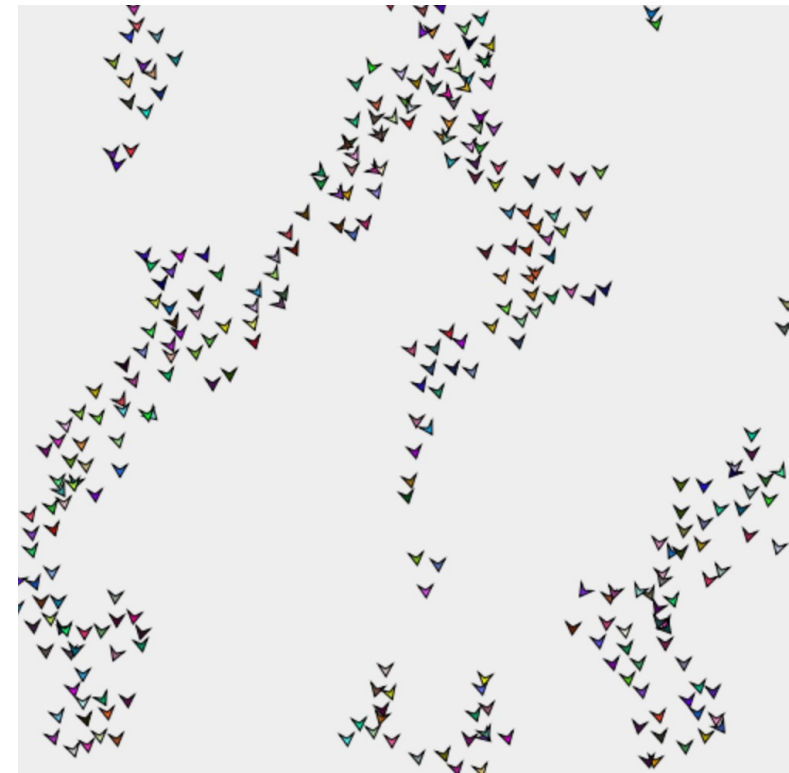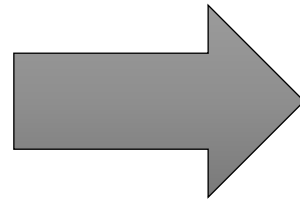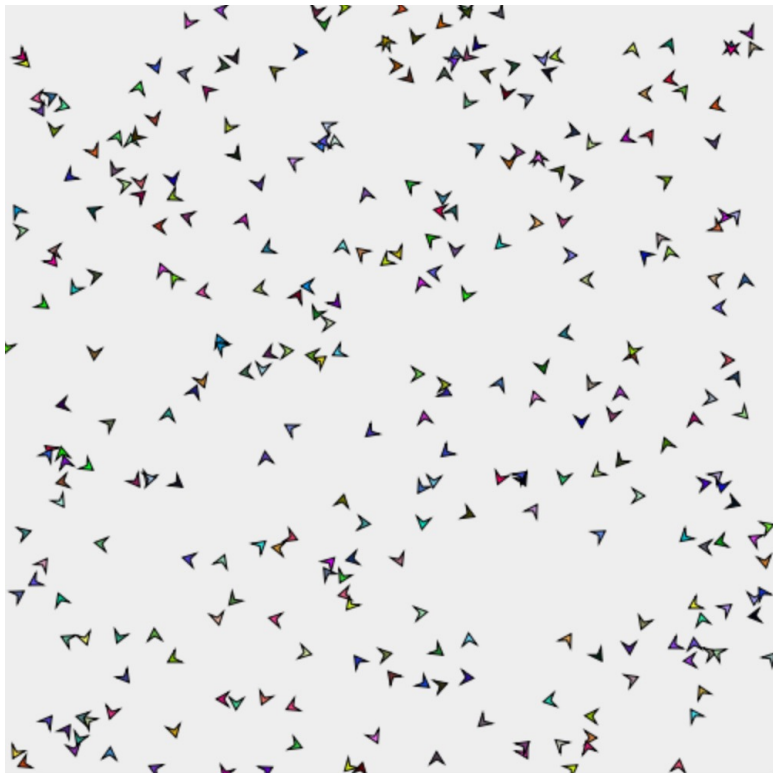
Traffic shockwave jam in real-world

- 22 cars equally spaced on a 230m single lane circle.
- Drivers asked to cruise steadily at 30km/h.
- 1st traffic moved freely.
- Disturbances/clusters soon appear.
- Causing cars to slow/stop.
- Cars at front of cluster can accelerate at 40km/h.
- But these join another jam.

SHOCKWAVE TRAFFIC JAMS
RECREATED FOR FIRST TIME

Footage courtesy of
University of Nagoya,
Nagoya, Japan

Source: http://www.youtube.com/watch?v=Suugn-p5C1M
New Scientist Article: http://technology.newscientist.com/article/dn13402

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Traffic shockwave jam simulated

- Example:
- Models the movement of cars on a road.
- Each car follows a simple set o rules:
  - If there's a car close ahead, it slows down.
  - If there's no car ahead, it speeds up.
- Demonstrates how traffic jams can form without any obvious incident.
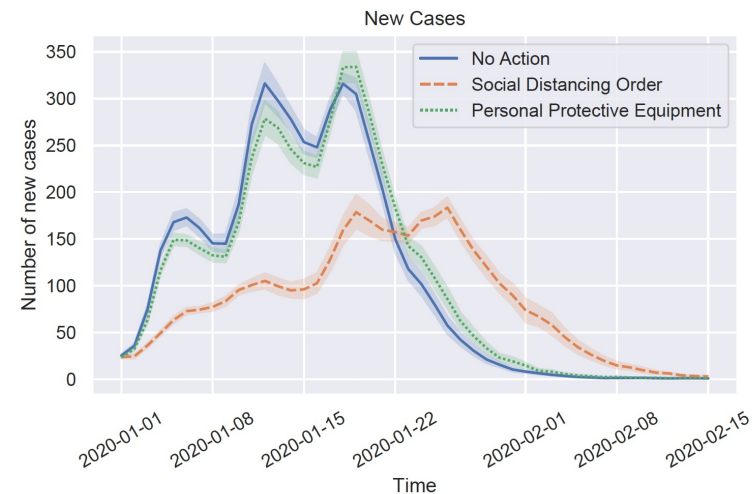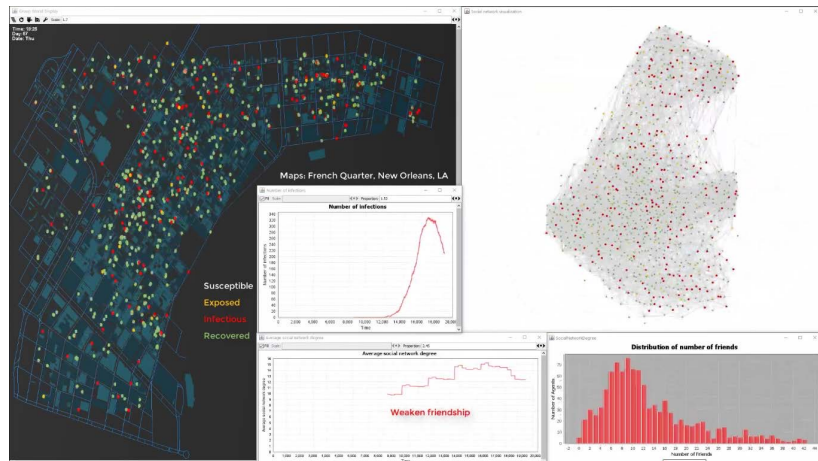- Simple rules can explain phenomena.
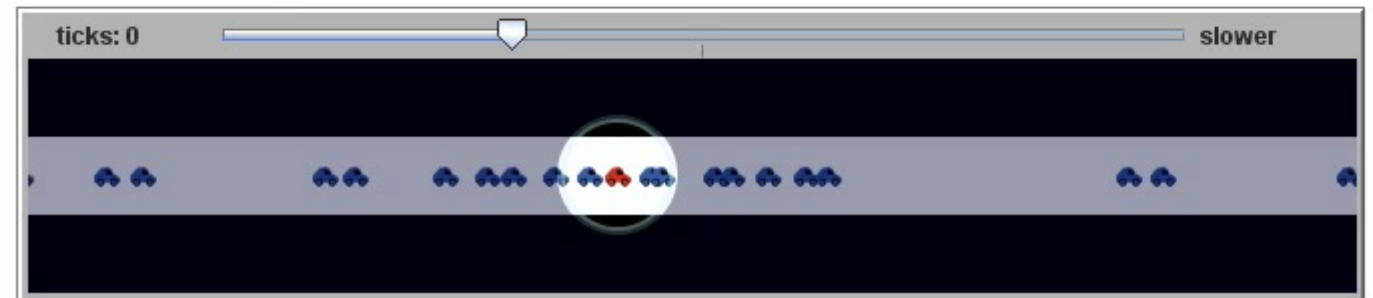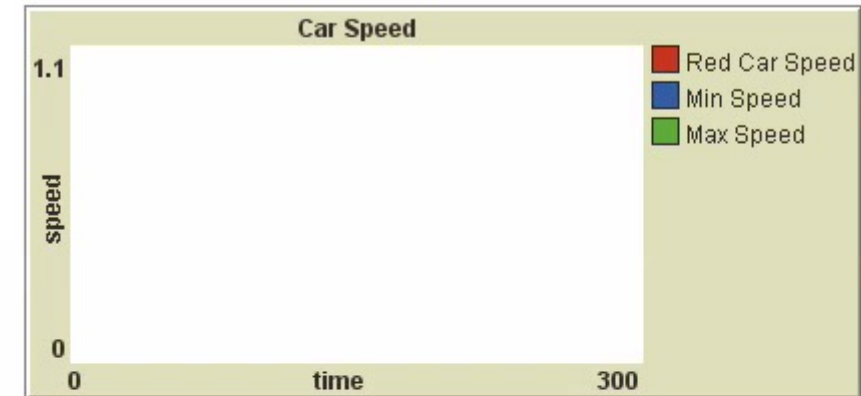
Source: NetLogo

Why do we need models?

1. To test theories

2. To explain a phenomena

3. To predict a phenomena
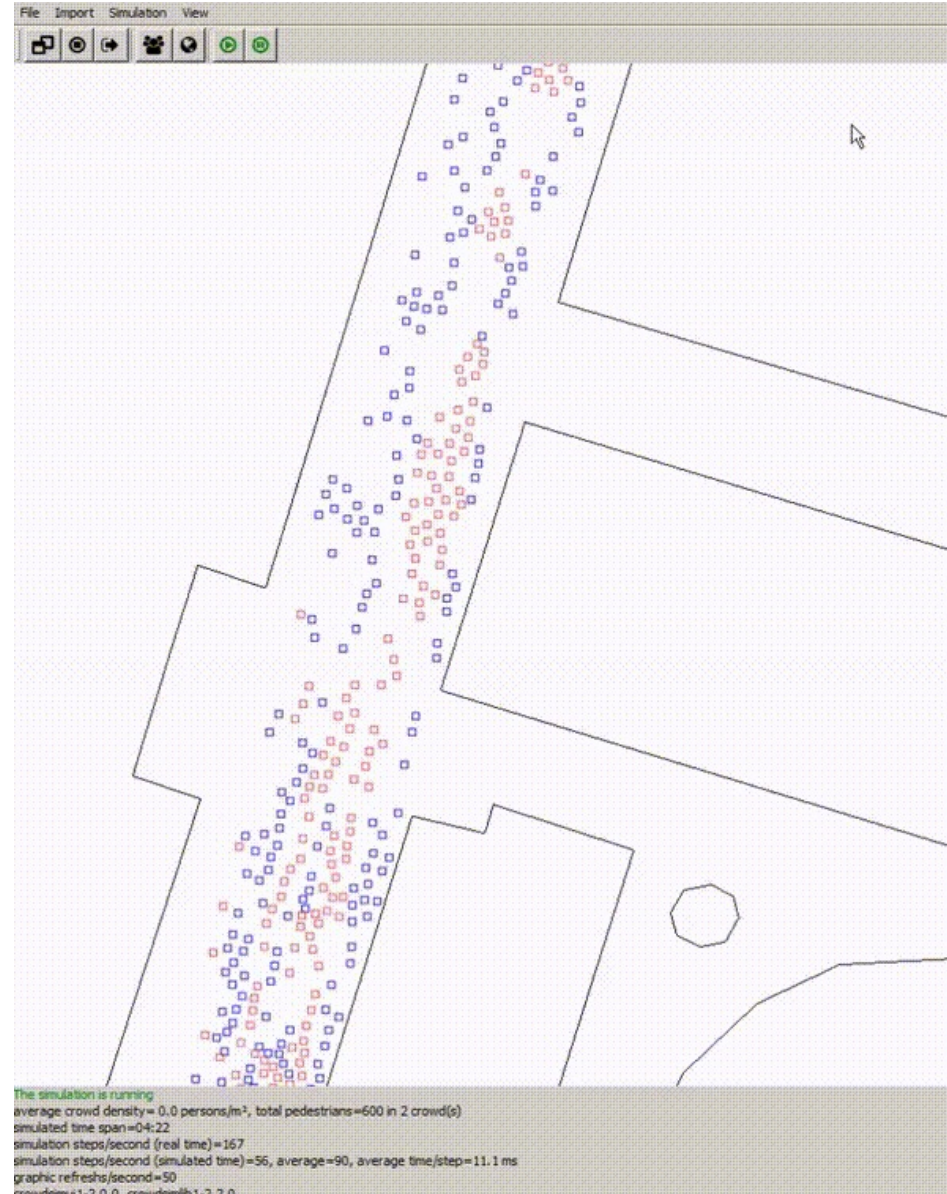
Disease spread prediction

- A simple disease model
  - https://www.shodor.org/featured/DiseaseModel
- Ebola model
  - https://www.khanacademy.org/science/health-and-medicine/current-issues-in-health-and-medicine/ebola-outbreak/pi/modelling-an-epidemic
- COVID-19 models

Why do we need models?

1. To test theories

2. To explain a phenomena

3. To predict a phenomena

4. To test dangerous scenarios

Pedestrian movement

Evacuation Scenarios

- Office fire
  - https://www.youtube.com/watch?v=st8HRgHOErw
- Panic evacuation
  - https://www.youtube.com/watch?v=SCm0mKPdY3M

Why do we need models?

1. To test theories

2. To explain a phenomena

3. To predict a phenomena

4. To test dangerous scenarios

5. Entertainment

Entertainment

- Games and movies

So, what is
modeling and **simulation**?

Modeling

- Is the process of developing a model

Thing to be modeled → Data collection, thinking, … → Mental model → conceptualizing → Conceptual model → coding → Computational model → validation
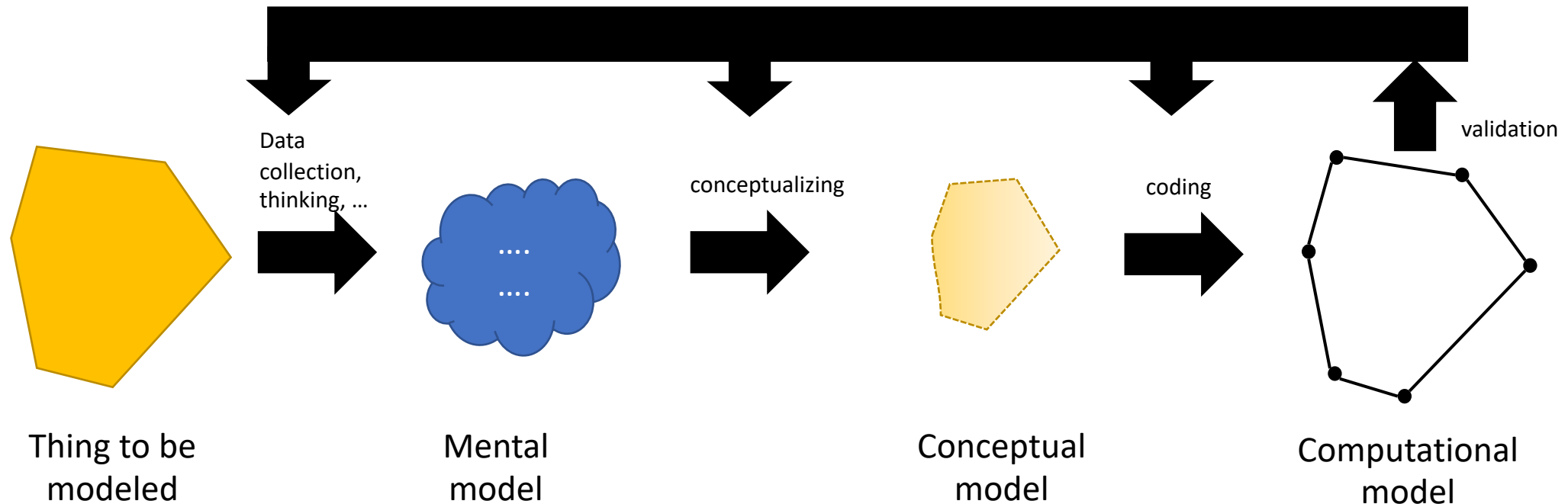
This is a simplified version of a modeling process

Simulation

- Running a model over time

Source: http://christinemcleavey.com/adding-simulation-mechanics/

Modeling and Simulation

Thing to be modeled → Thinking, observing, researching… → Mental model → conceptualizing → Conceptual model → coding → Computational model → simulate →

1. To test theories
2. To explain a phenomena
3. To predict a phenomena
4. To test dangerous scenarios
5. Entertainment

validation
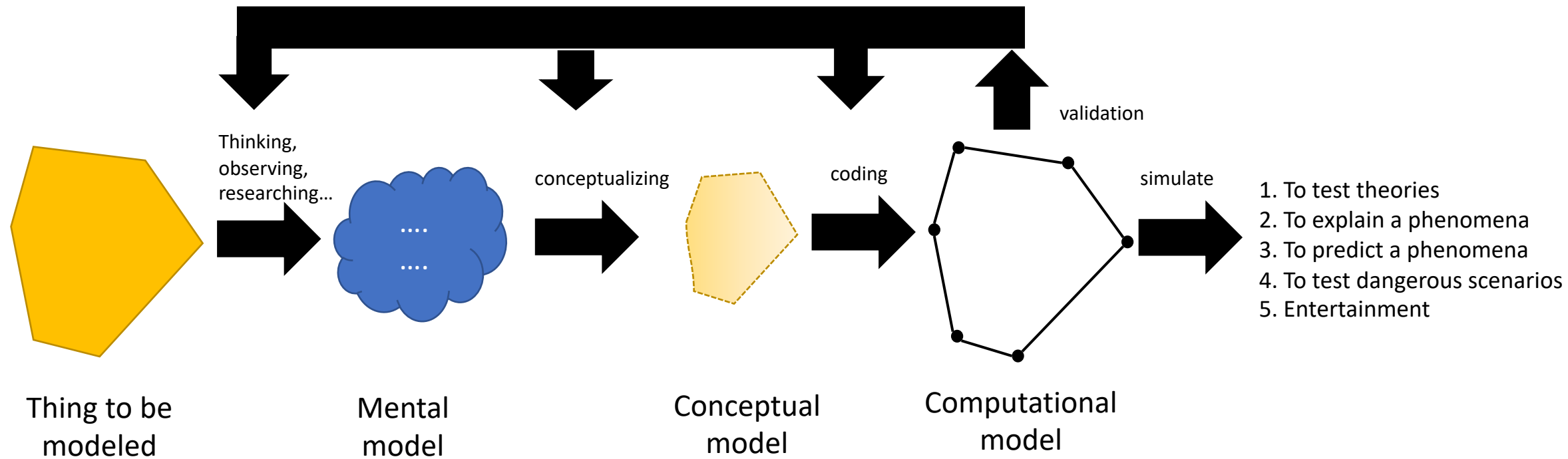
Modeling and Simulation (our focus)

Thinking, data collection, researching...

conceptualizing

coding

simulate

validation

Thing to be modeled

Mental model

Conceptual model

Computational model

1. To test theories
2. To explain a phenomena
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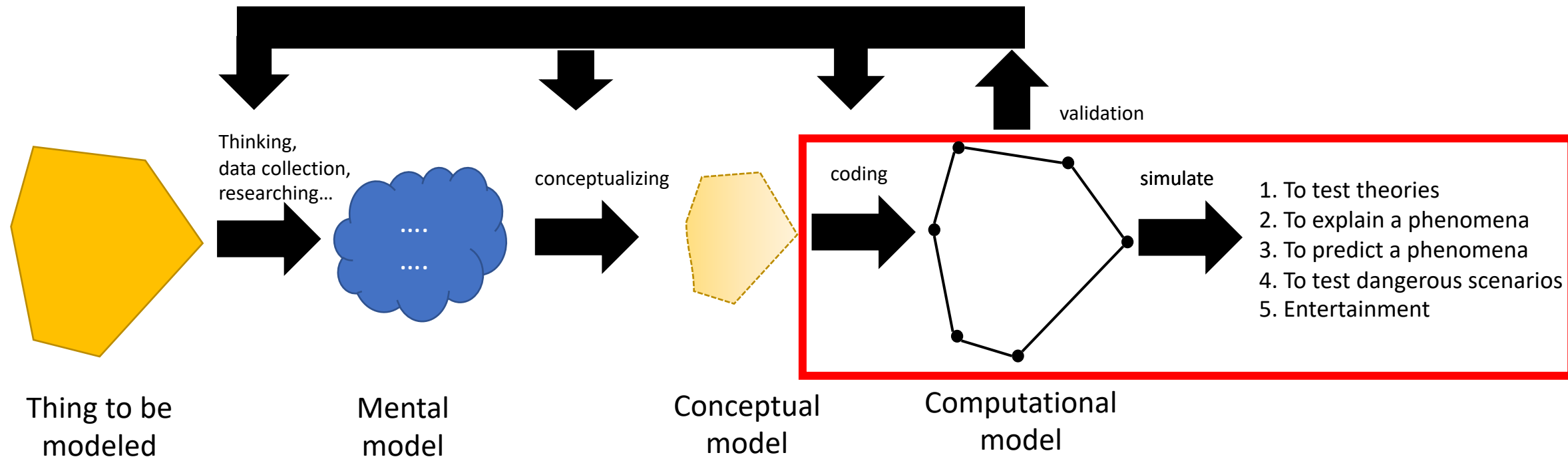
Sources

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- Downey, A. B. (2017). *Modeling and Simulation in Python, Version 3.4.0*. Green Tea Press. Needham, Massachusetts.

- Sokolowski, J. A., & Banks, C. M. (2010). *Modeling and simulation fundamentals: theoretical underpinnings and practical domains*. John Wiley & Sons.

- Robinson, S. (2014). *Simulation: The Practice of Model Development and Use, 2nd edition*. John Wiley and Sons, Ltd.

- Frigg, R., & Hartmann, S. (2006). Models in science.