Tanjona Ramiadantsoa (with materials from Cara Brook)

Data and models

E2M2 2020
Valbio, Ranomafana
January 7th, 2020

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Department of Integrative Biology

Forewords

- I tend to talk fast, please interrupt and remind me all the time

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- This workshop is for you!!!

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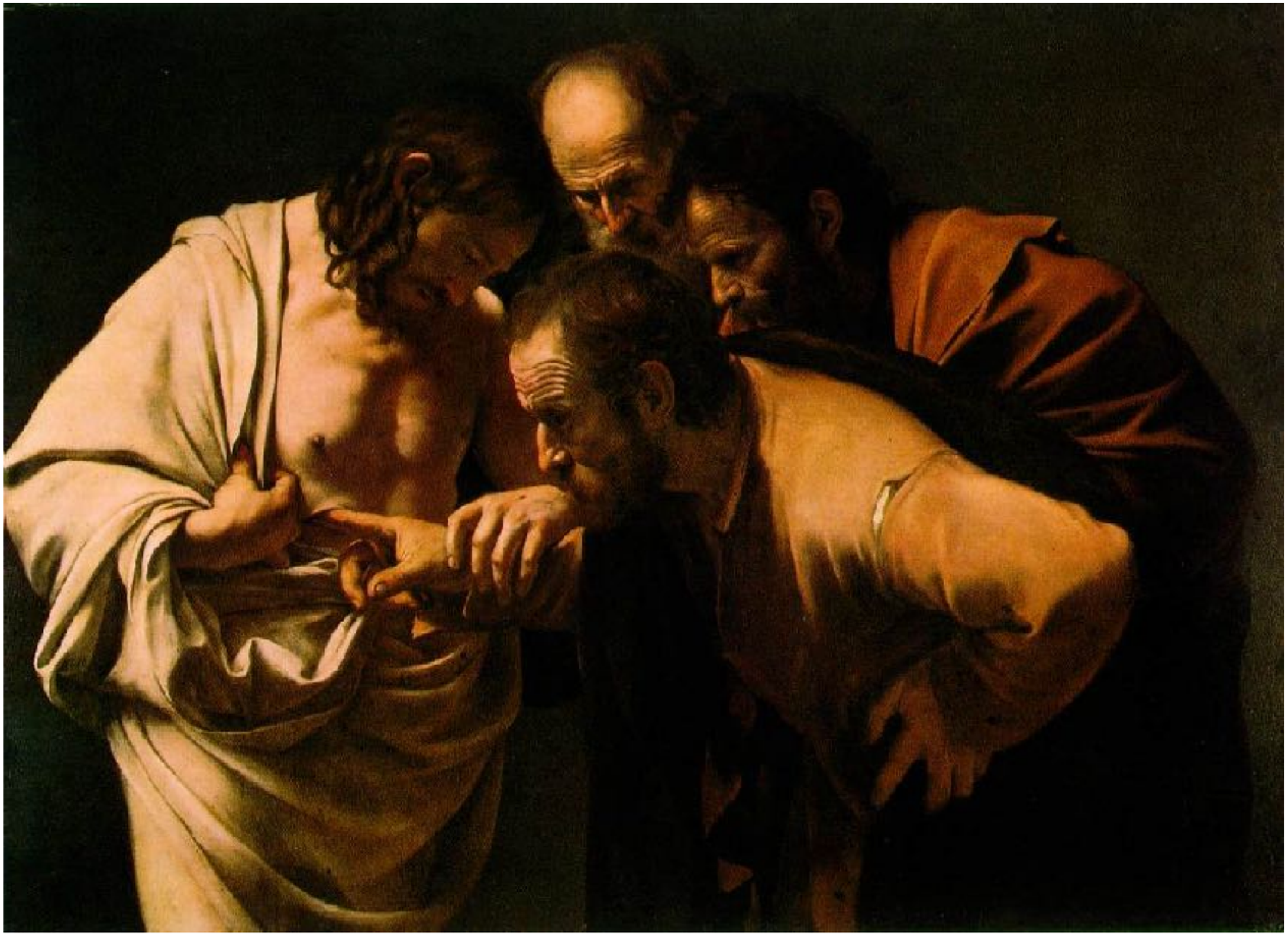
- I tend to talk fast, please interrupt and remind me all the time
- This workshop is for you!!!
- I use a lot of Disney and underwear references (no particular reason)

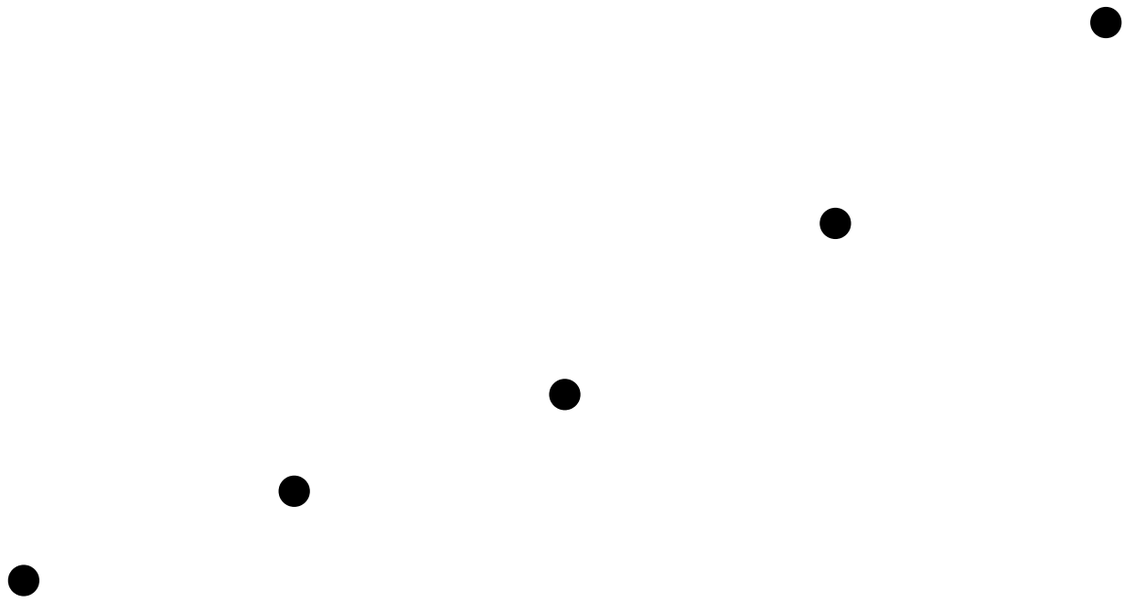
What is a scientist?

(St.) Thomas



The ability to correctly collect and interpret data makes a difference between the scientifically literate and illiterate

Is this data?



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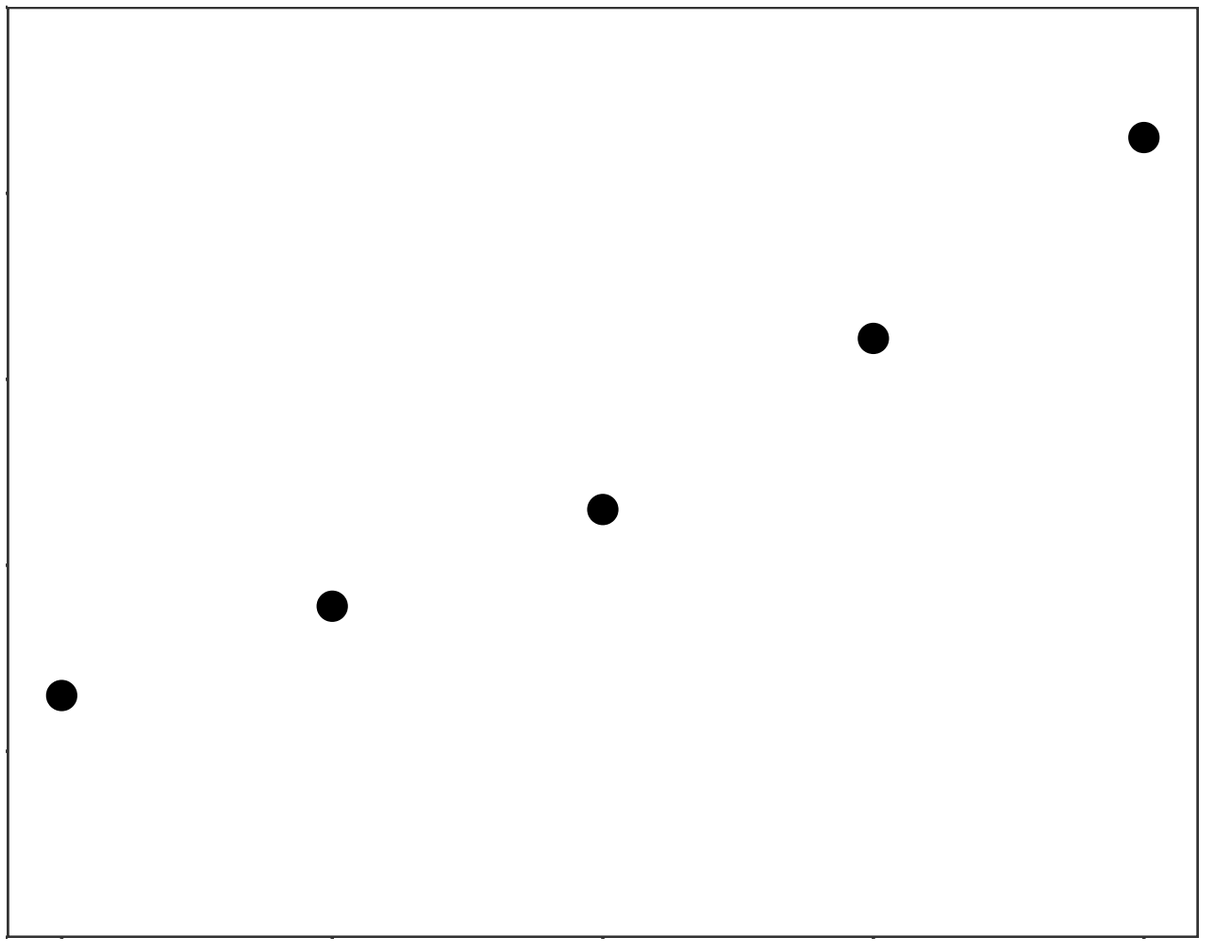
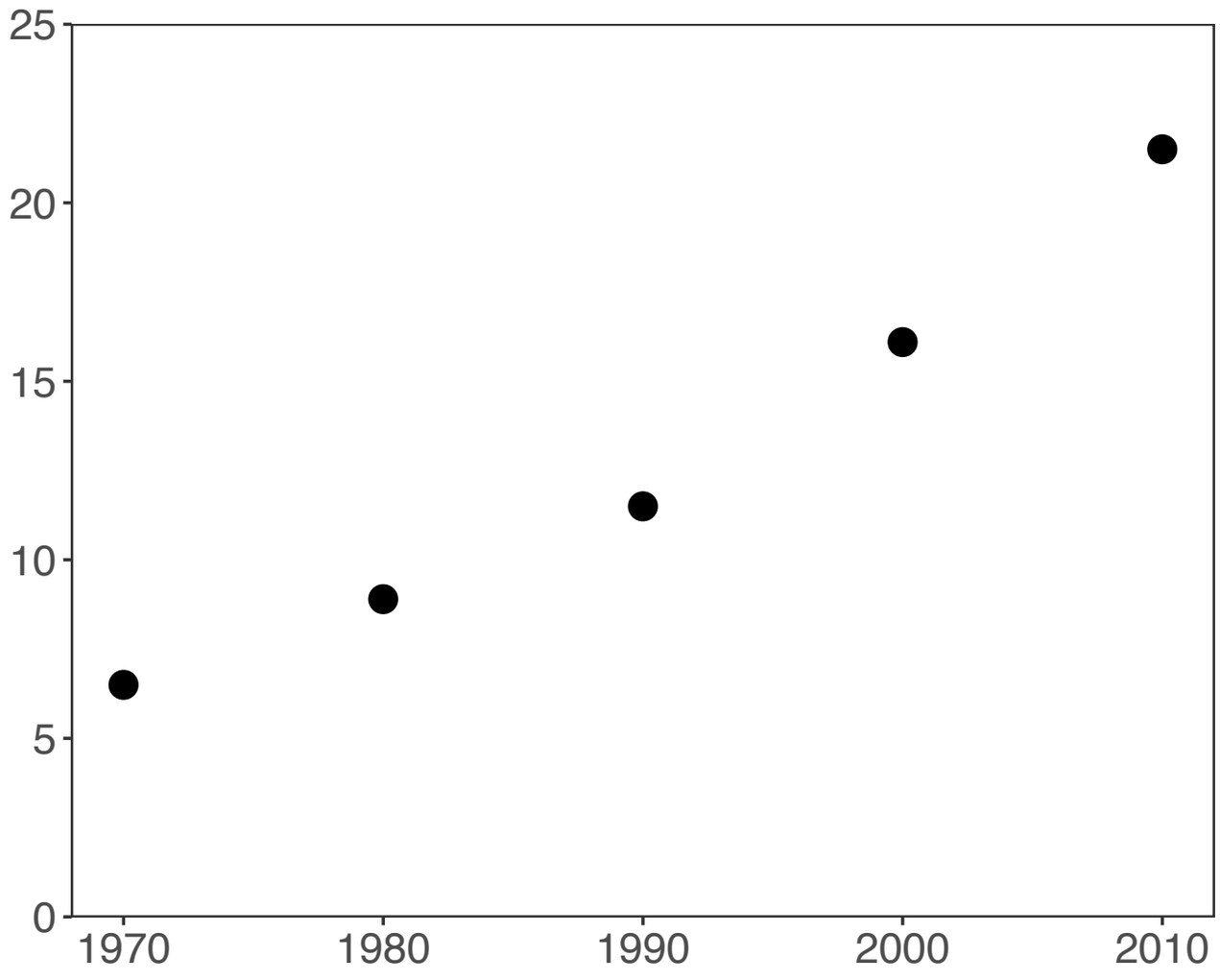


What do we need to make this a data?

Is this data?



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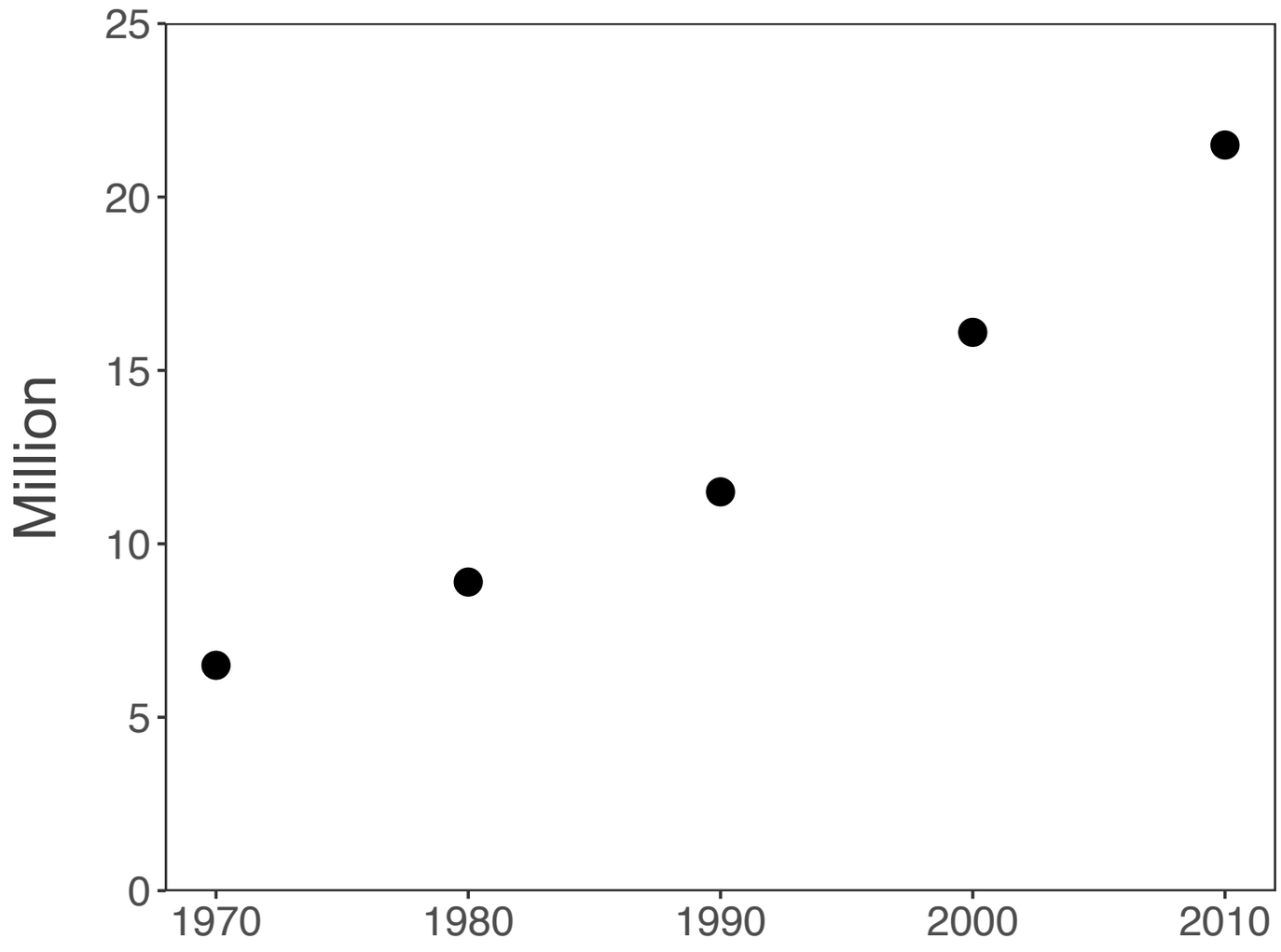

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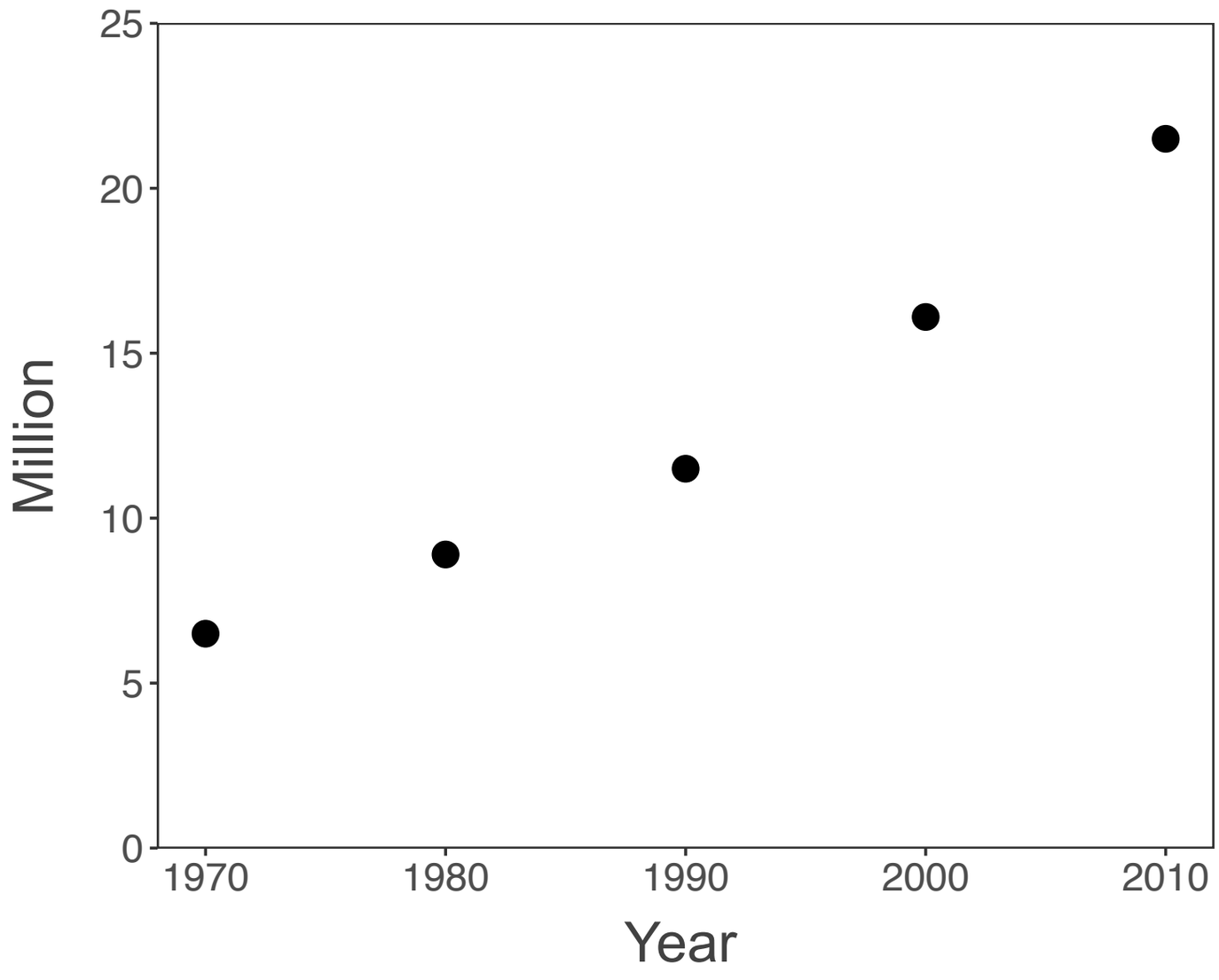
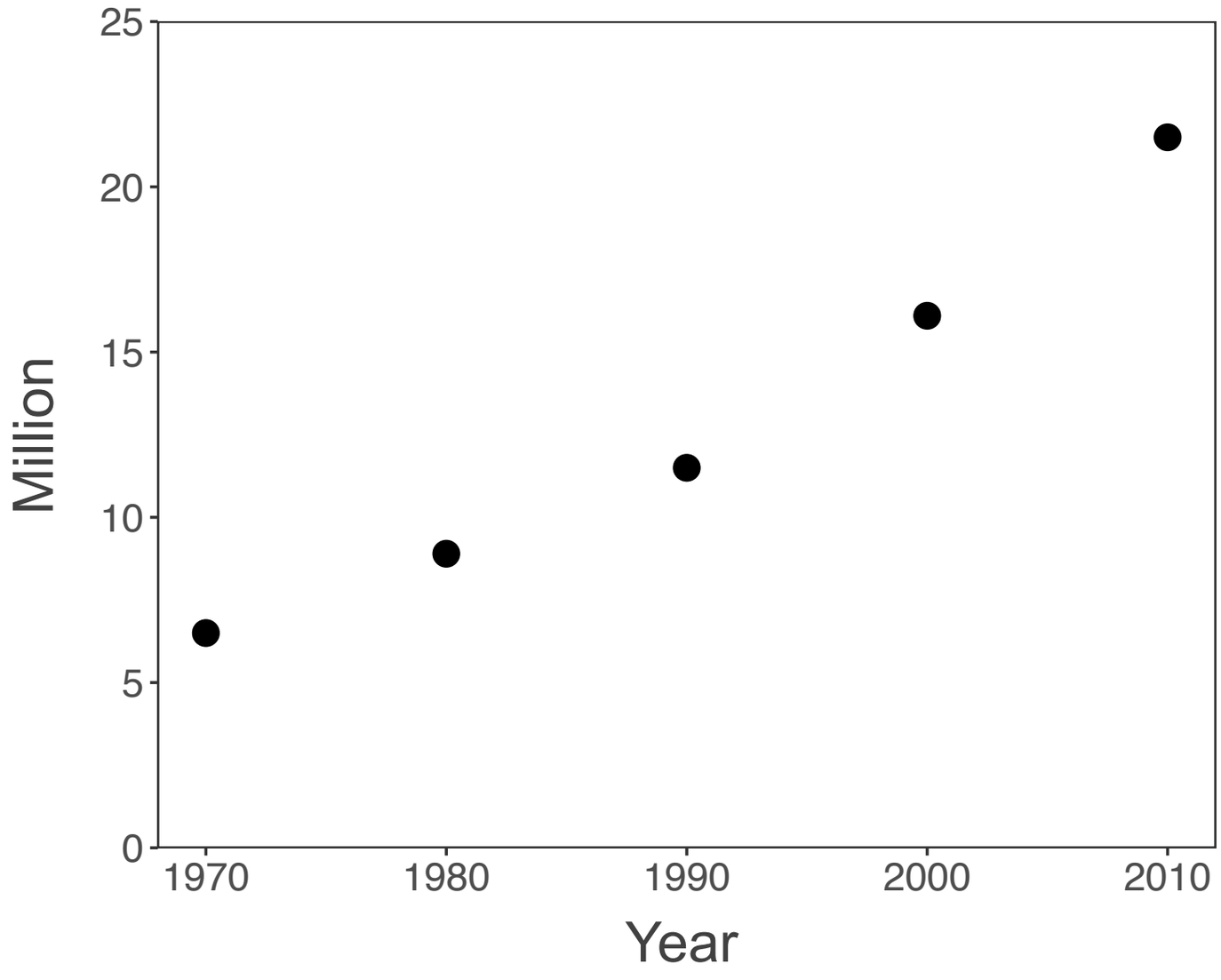


Is this data?

Number of views for Justin Bieber's "Baby" video on Youtube



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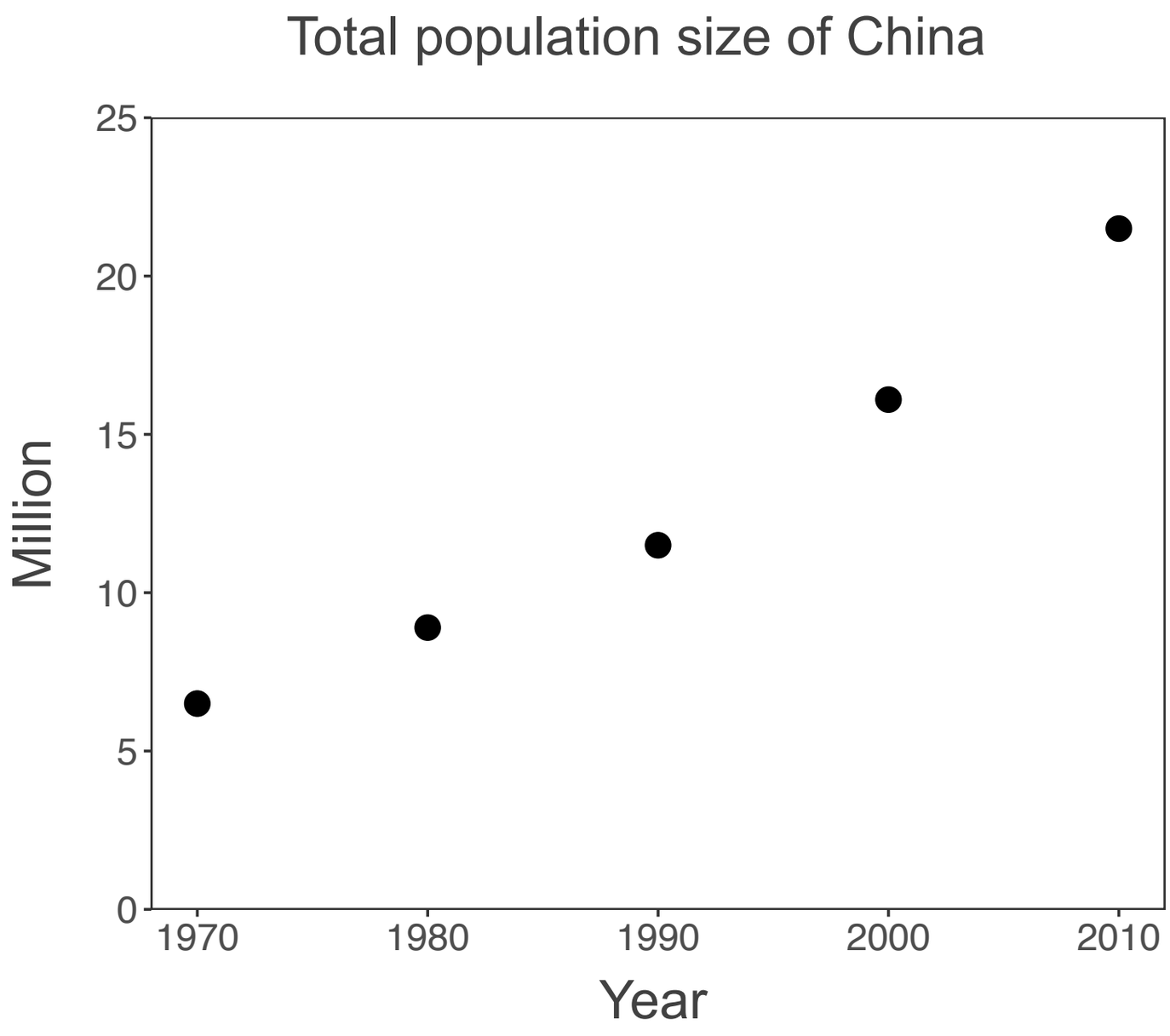
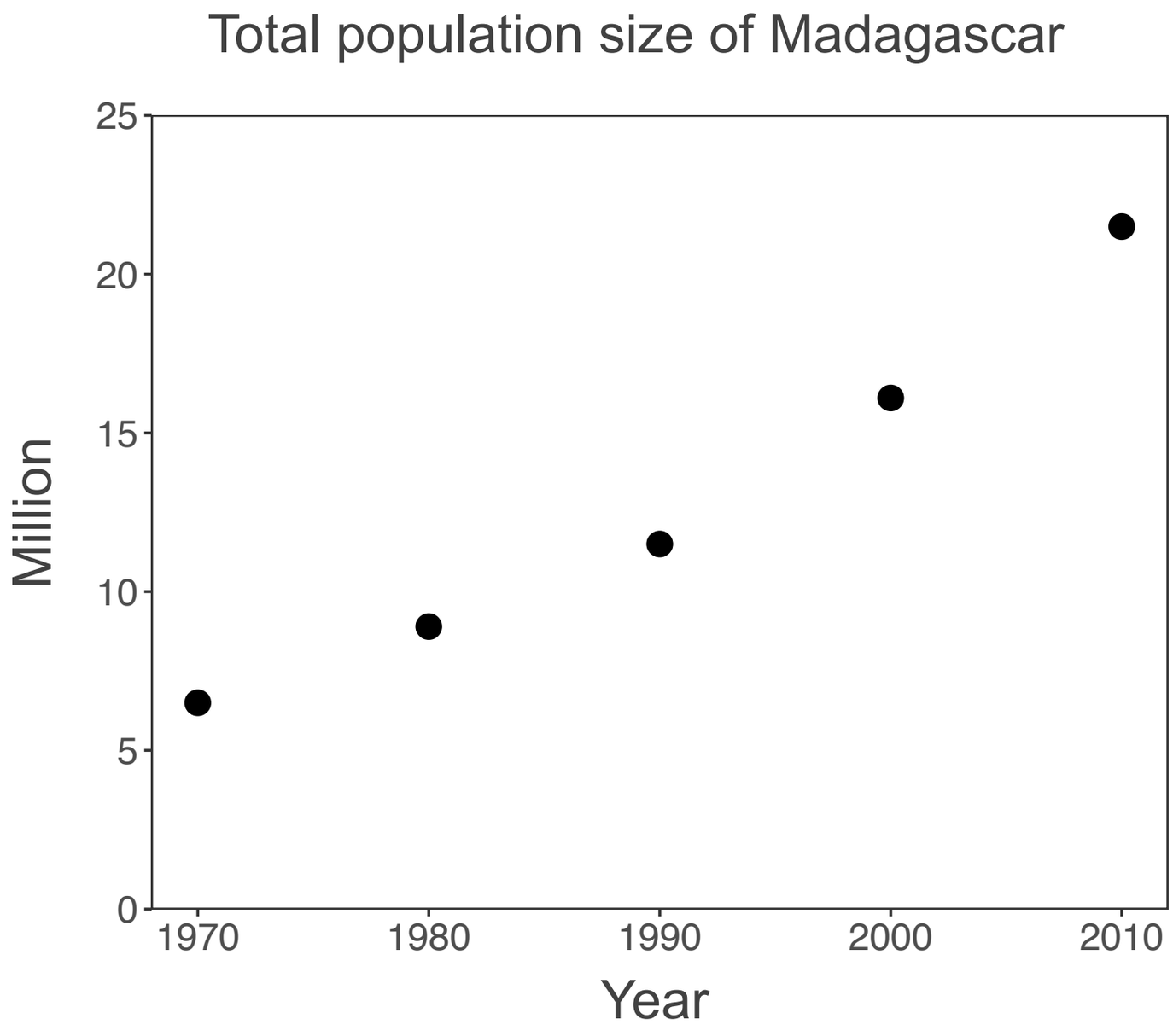
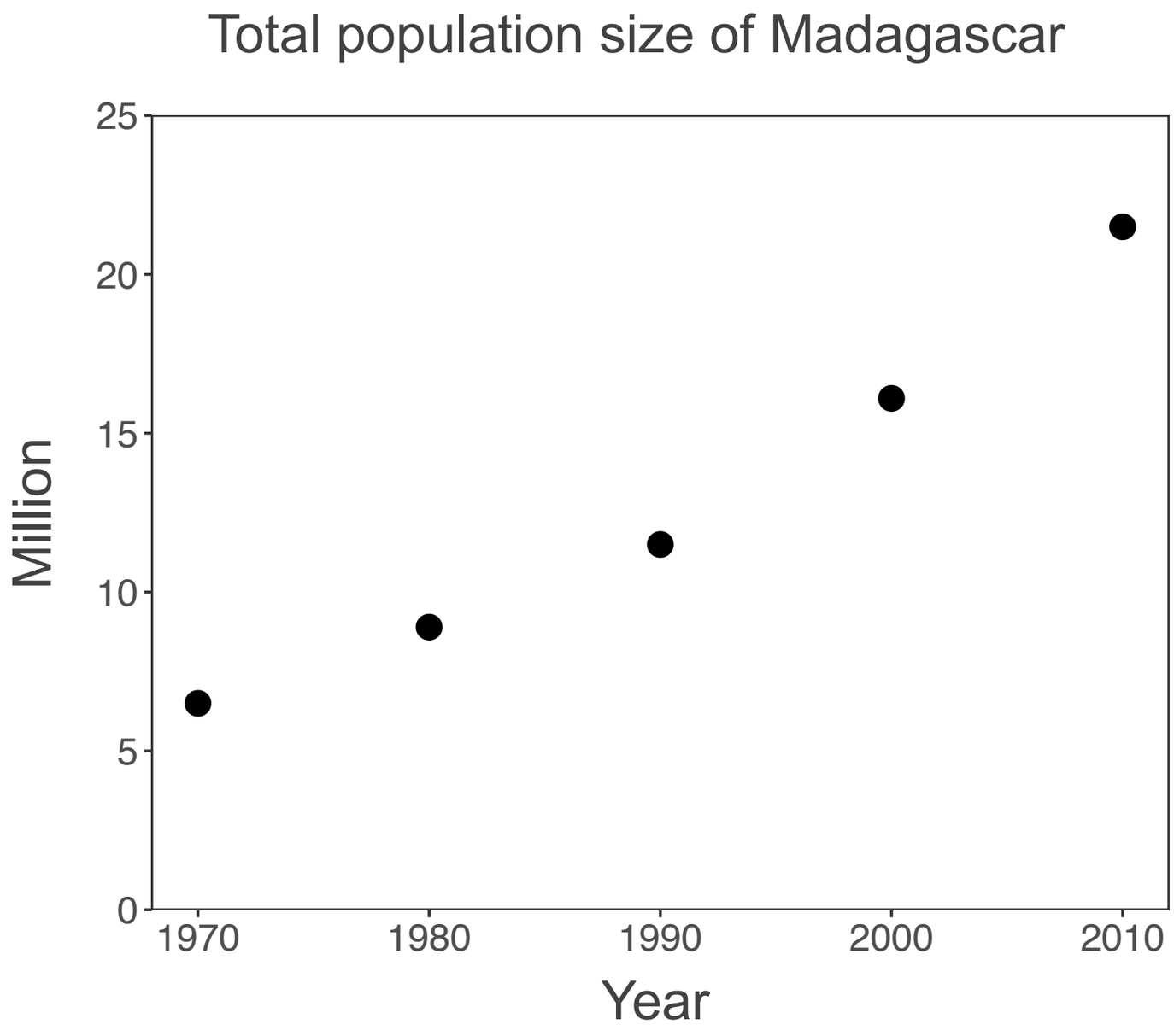

Total population size of China
Million
25
20
15
10
5
0
1970
1980
1990
2000
2010
Year

Is this data?


Total population size of Madagascar
Million
25
20
15
10
5
0
1970
1980
1990
2000
2010
Year

Is this data?



Source: World Bank (accessed 2017)

Notes

- Asking what is a data can become extremely philosophical
- A data should have at least one explanatory (X) and one response variable (Y) and be precise
- More practically, data are evidences to **support claims**

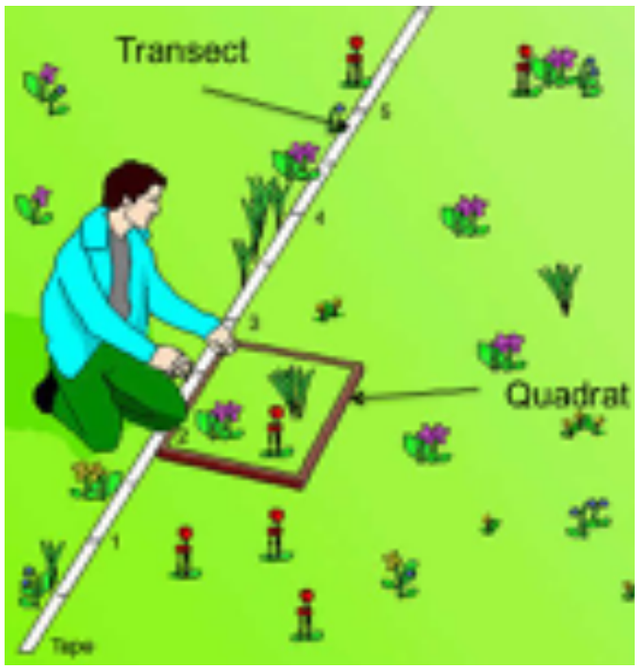
Data: X and Y values

- **Numerical**
  - A variable is numerical when you can transform it with mathematical operation
  - Examples: integer, real number, multi-dimensional number

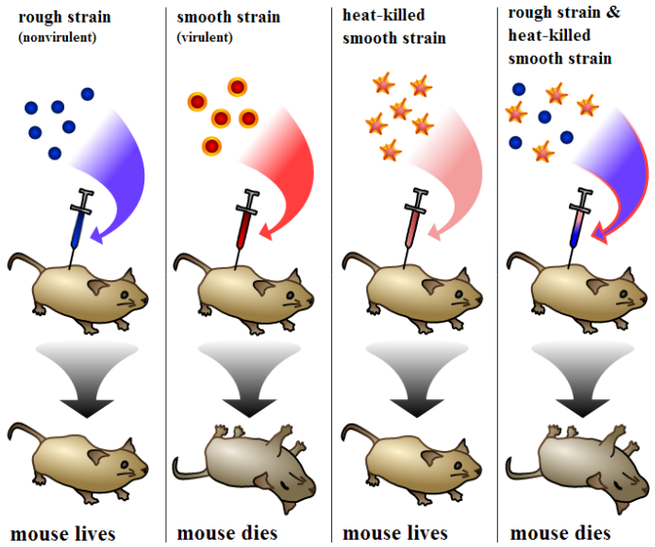
- **Categorical ('factors' in R language)**
  - A variable is categorical when it is not numerical but a categorical can be numerical?
  - Examples: colors, (blood) types, species name

Source of data

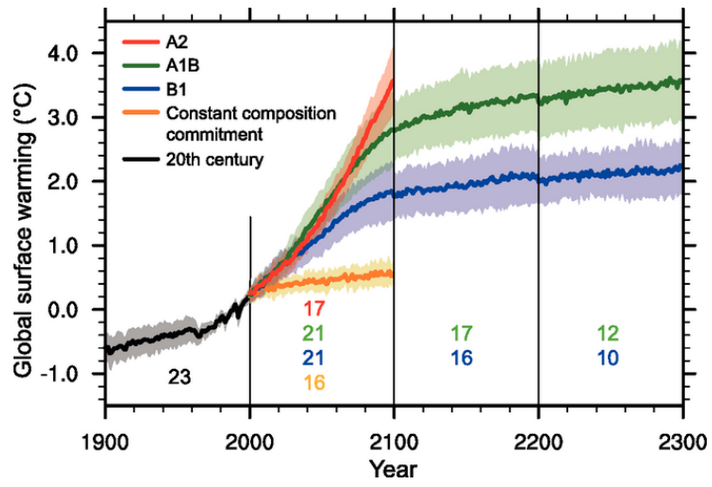
Observational



Experimental



Simulated



Empirical data

What is X and what is Y?

Things to consider

- Data acquisition
  - Impossible
  - Theoretically possible but practically unfeasible
- Data quality and quantity
  - Trade-off with time, money, human effort …
- Reproducibility
  - Spatial and temporal
- Measurement errors
- Open access?

Thoughts on data?

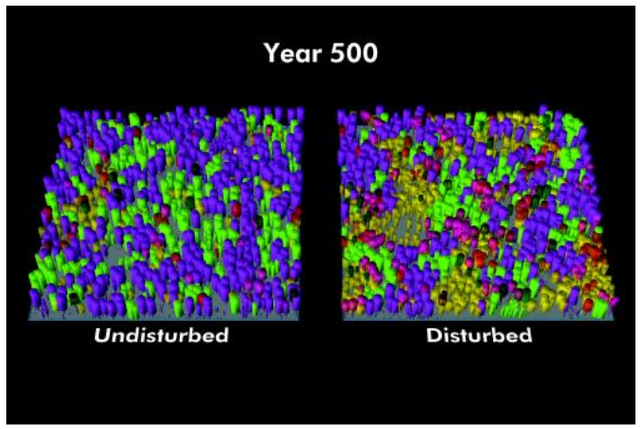
Models

Is this a model?

Human

Car

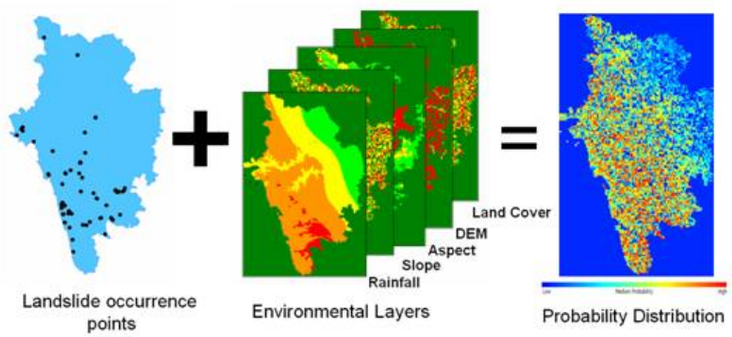
Forest simulator



Ecology & Evolution

Zoonotic pathogen

Niche mapping



Models

A model := a simplified representation of a phenomenon

During E2M2, you will learn steps for a modeling project

Steps to a modeling project

- Research question
- Formulate a hypothesis
- Test the hypothesis with data
- (Models are scientific procedures to generate data and / or analyze data)

Two broad classes of models

Statistical

Correlative

Mechanistic

Causative

Statistical vs. mechanistic model

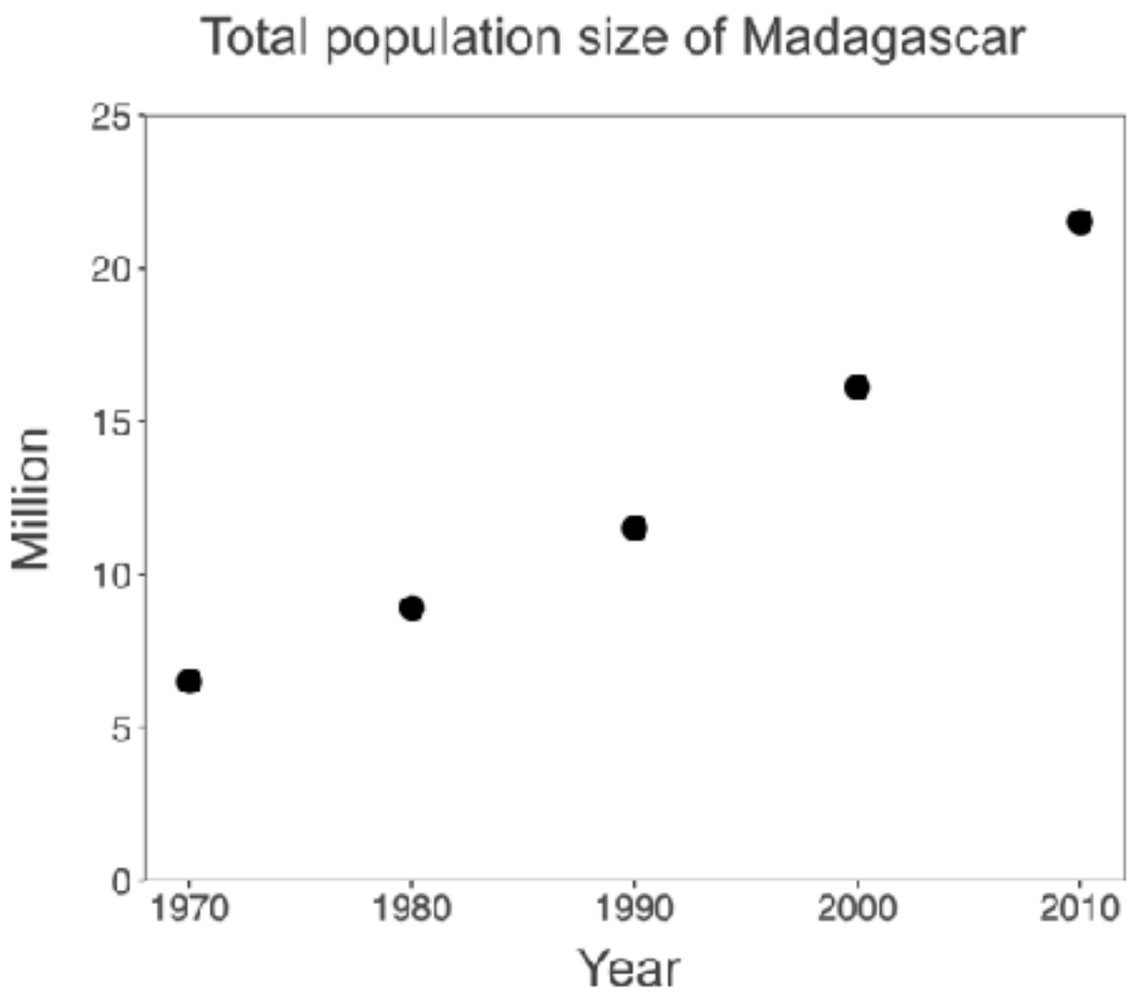
- Statistical:
  - You ask: What?
- Mechanistic
  - You ask: How?

Statistical vs. mechanistic model

- Statistical:
  - You ask: What?
  - Require data collection
- Mechanistic
  - You ask: How?
  - Make your own data

Statistical vs. mechanistic model

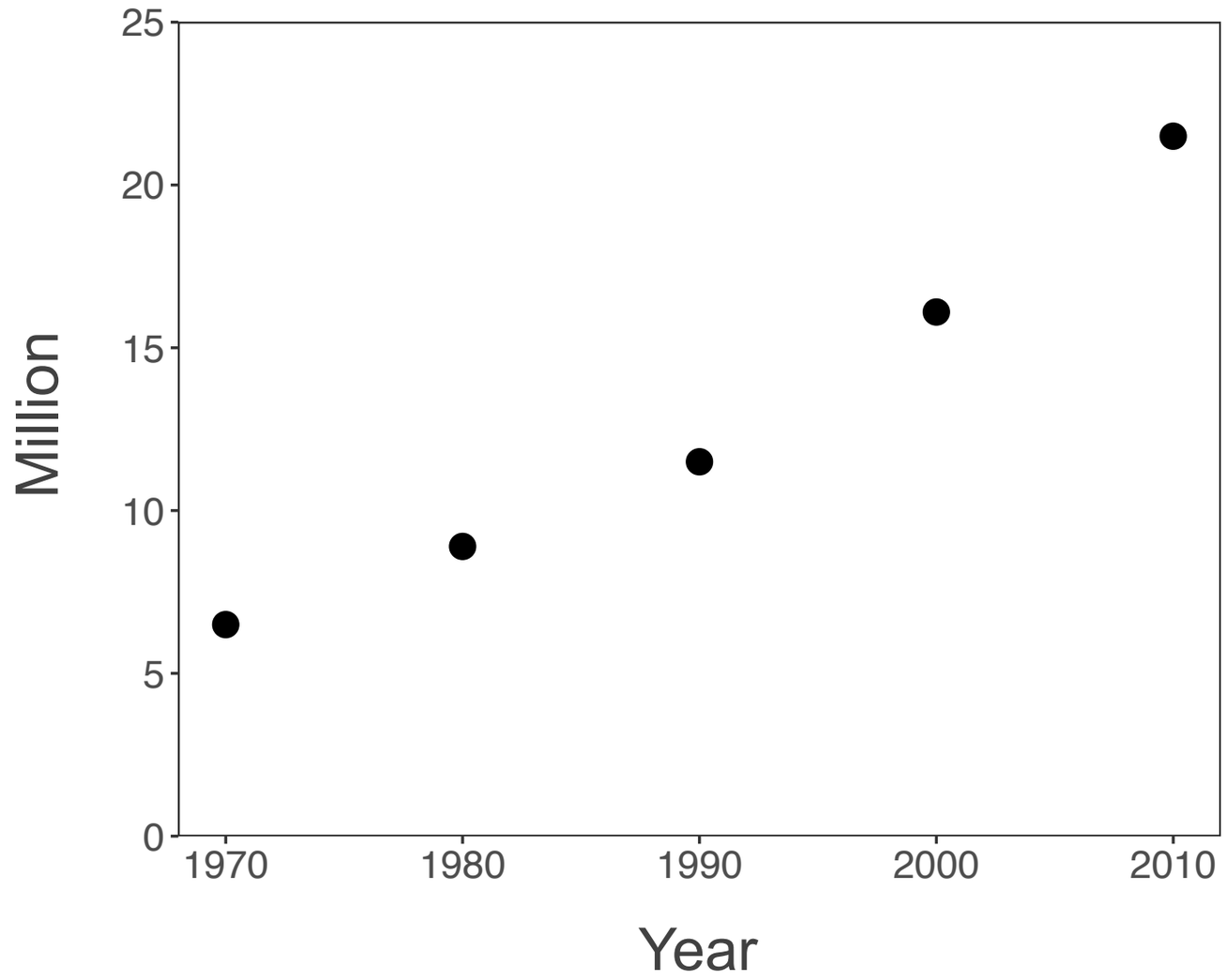
- Statistical:
  - You ask: What?
  - Require data collection
  - Fit a function to the data (estimate parameter values)
- Mechanistic
  - You ask: How?
  - Make your own data
  - Process generating a phenomenon (explore the effect of changing parameter values)



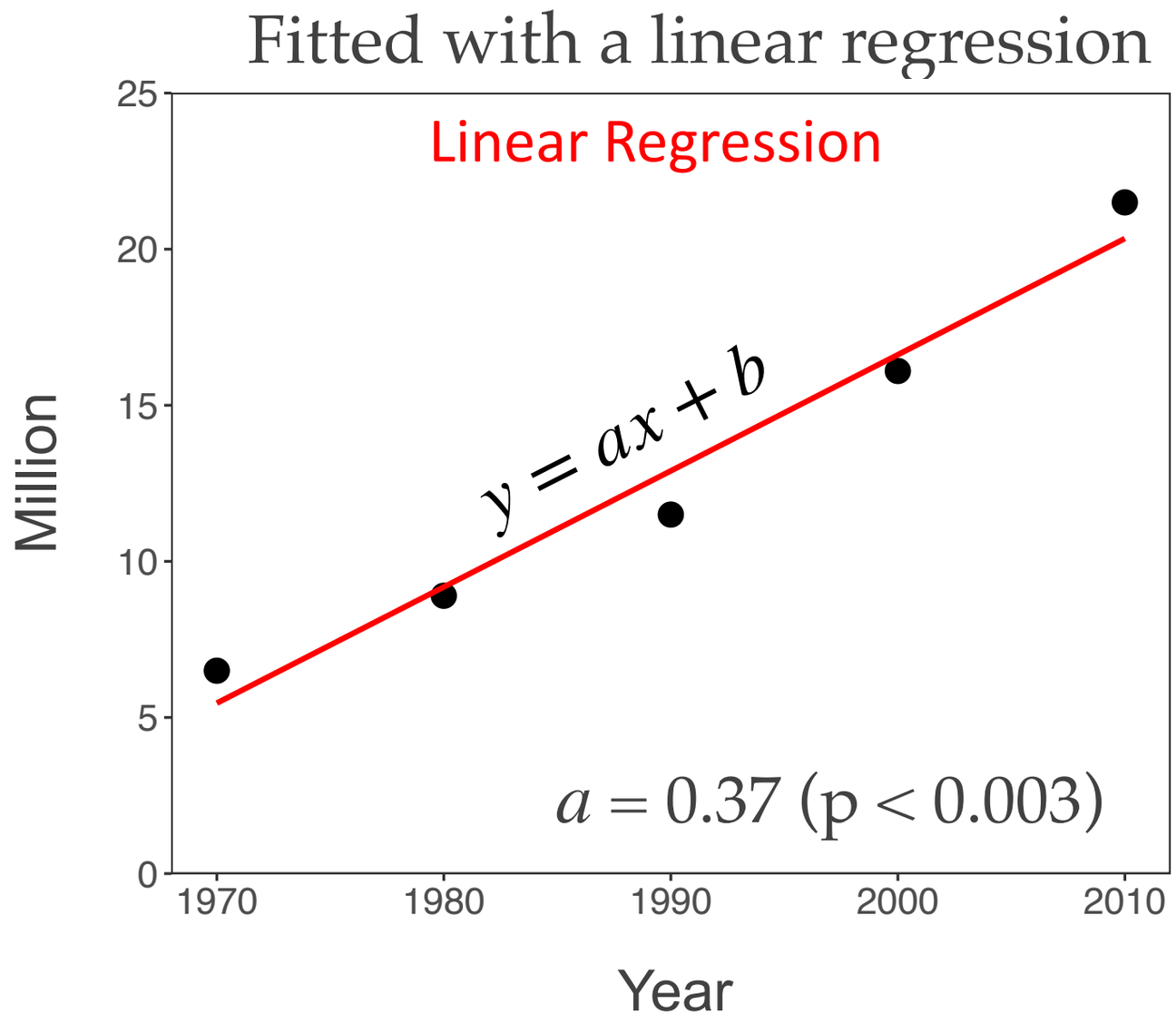
During E2M2, you will look at the figure in two ways: empirical or simulated data

Statistical model

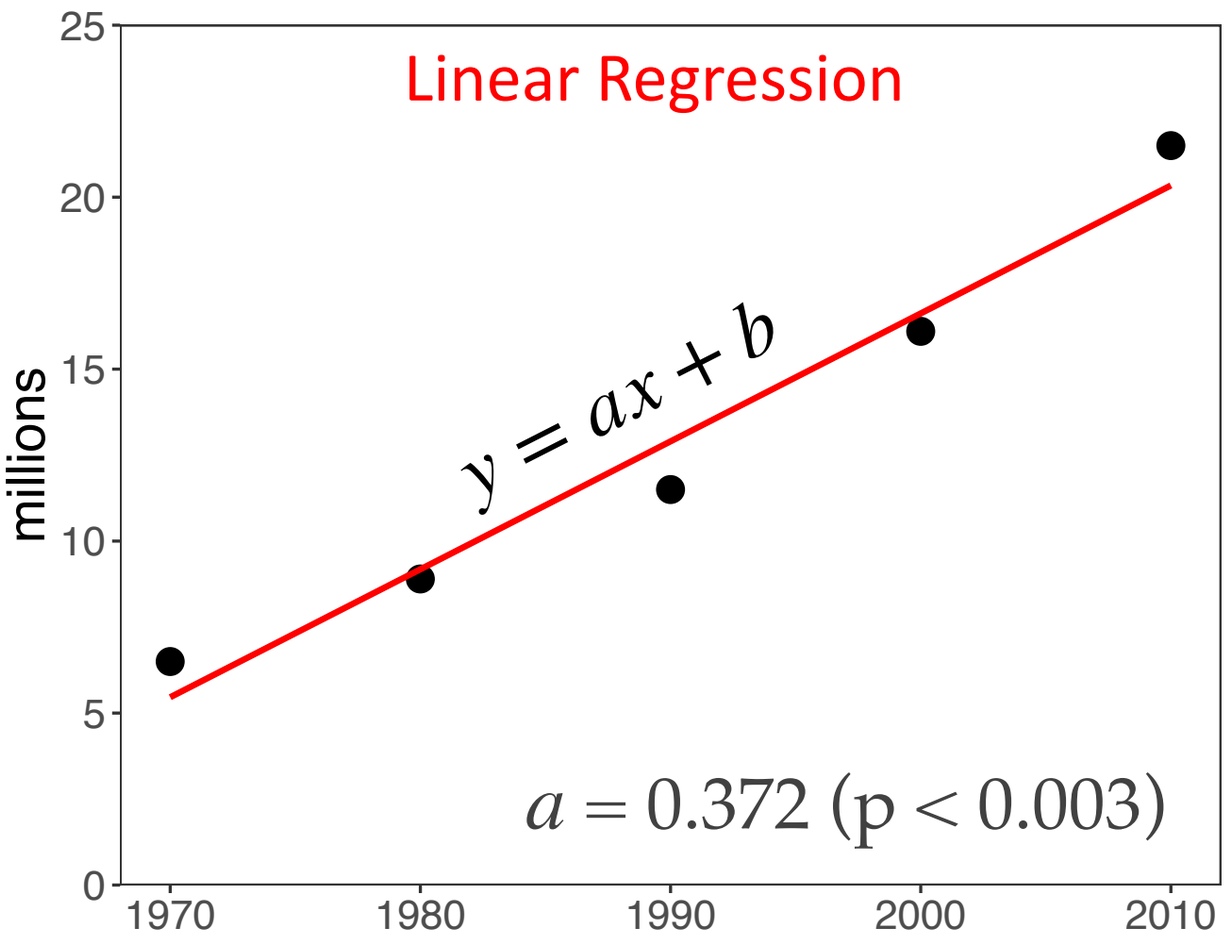
This is an empirical data

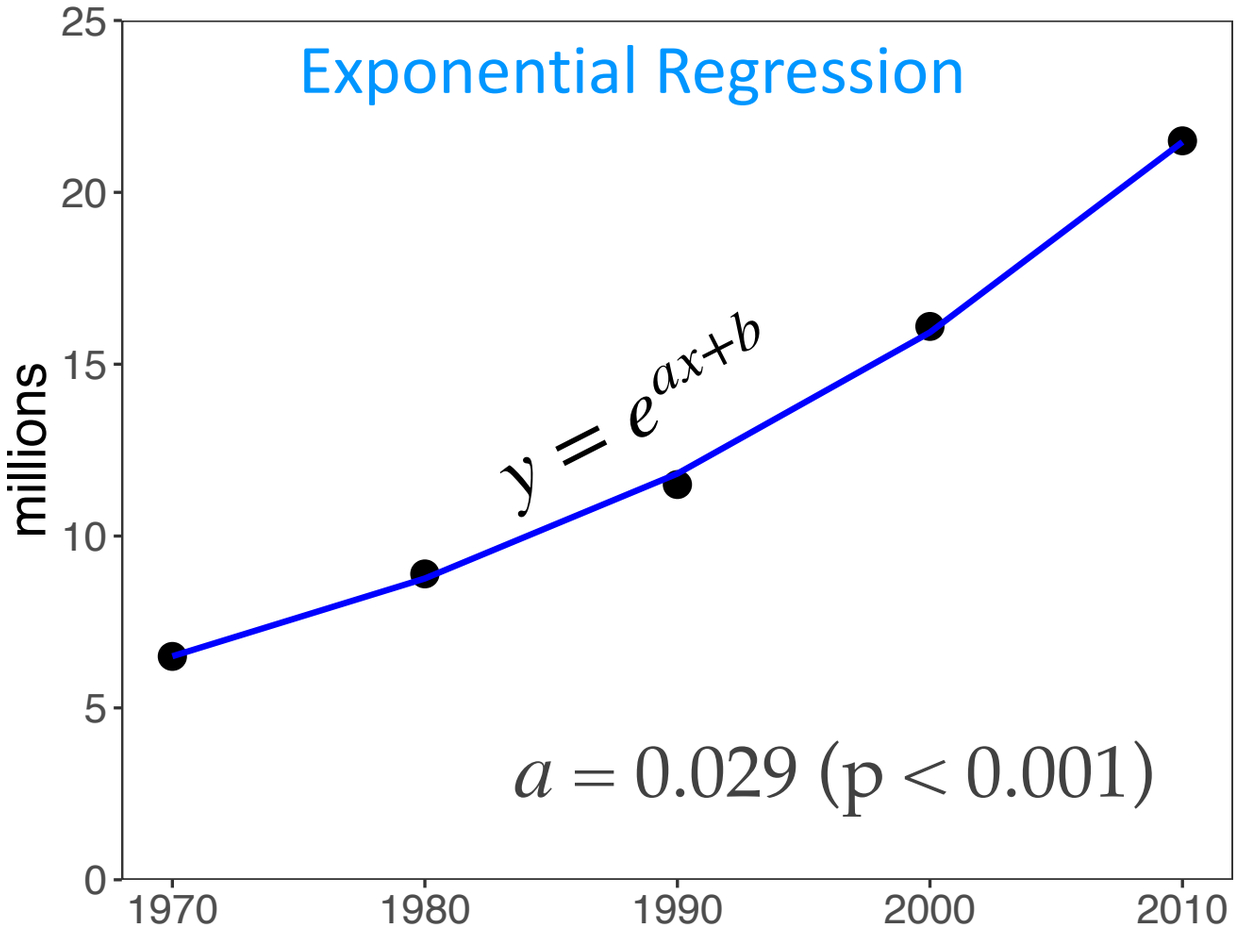


Using a statistical model



Two statistical models





That was wrong!!!

What is the research question? What is the hypothesis?

A model is a tool not an endpoint

Remember the steps

- Research question
- Formulate a hypothesis
- Test the hypothesis with the data
- (Models are tools to test your hypothesis)

During this week, you will **spend a lot of time** writing research questions and formulating hypotheses

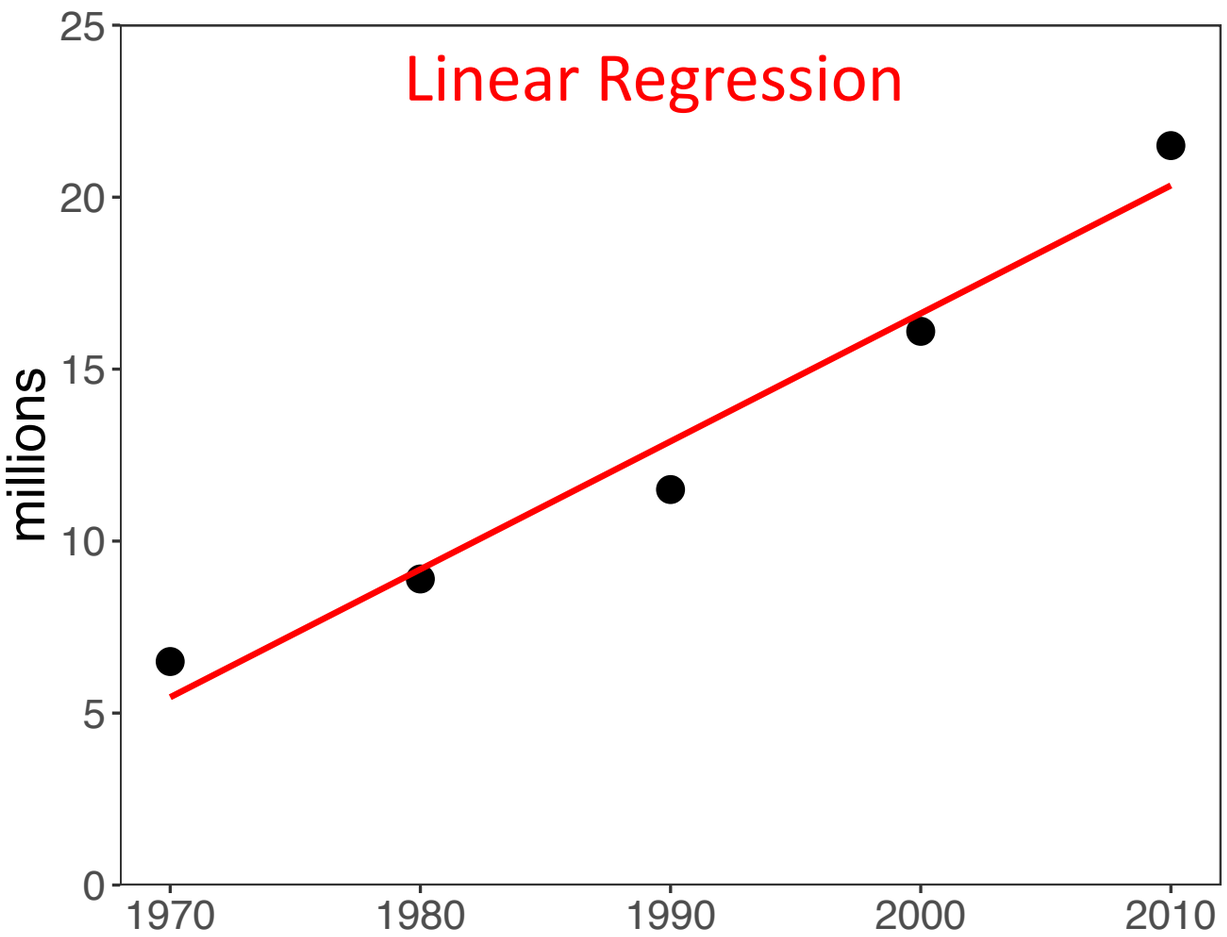
Tuesday, Jan 7: "Understanding Your System"

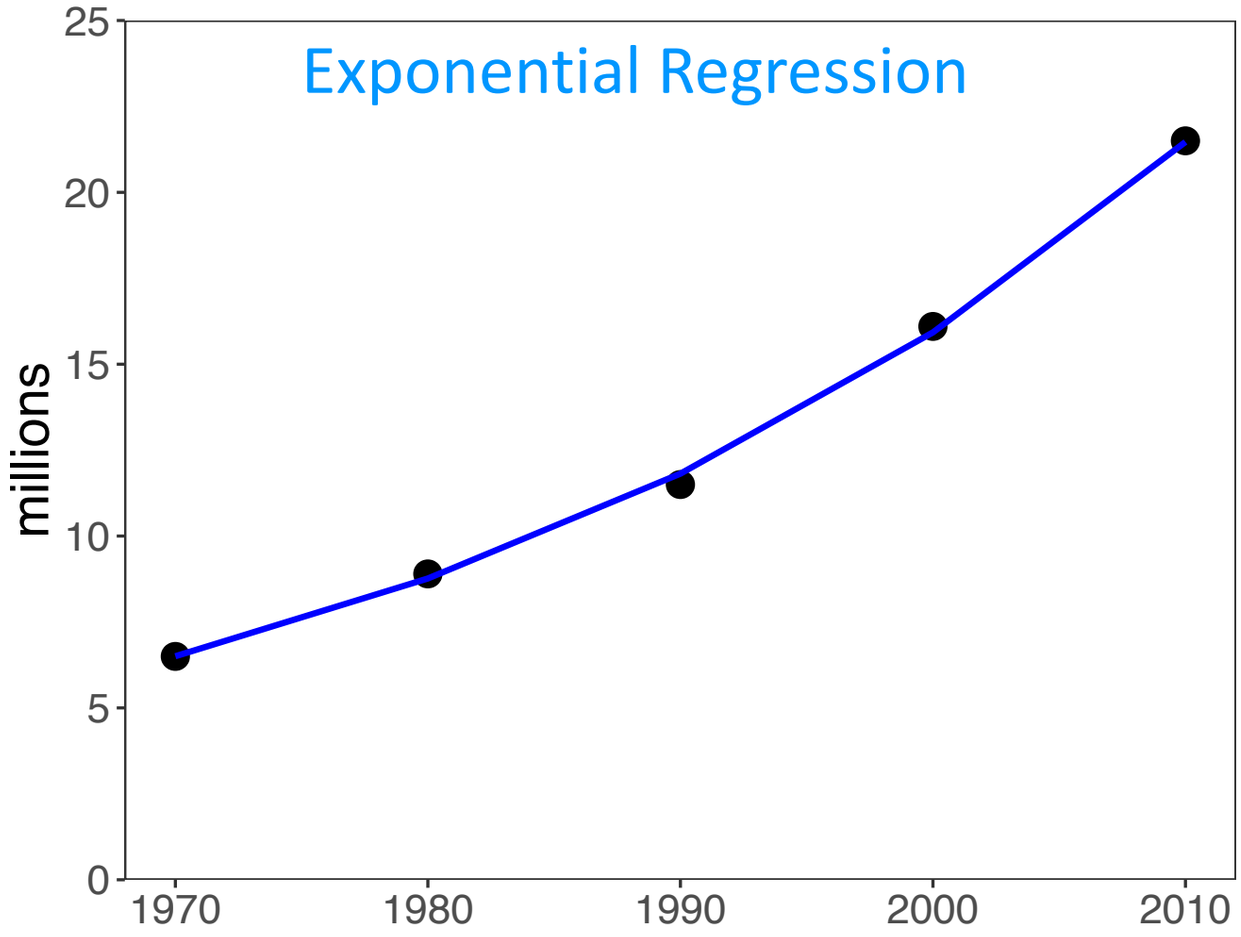
- 6:30-8:00am: Breakfast
- 8:00-8:30am: Road Map and Daily Agenda. Brief Introductions **(Cara)**
- 8:30-9:00: Lecture: Ecology Meets Epidemiology **(Cara)**
- 9:00 - 10:00am: Lecture: What are We Doing Here? Data and Models **(Tanjona)**
- 10:00-10:30am: Coffee Break
- 10:30-12:00pm: Reviewing Key Concepts in Mathematics **(Tanjona)**
- 12:00-1:00pm: Lunch
- 1:00-2:00pm: Introductions: 2-min student/mentor/instructor introductions **(Sarah)**
- 2:30-4:00pm: Formulating research questions **(Cara)**
    - For HW, write your own research question
- 4:00-4:30pm: Coffee Break
- 4:30-6:30pm: Lecture/Tutorial: Study Design and Data Collection **(Sarah)**
- 6:30-7:30pm: Dinner

tics **(Andres, Fara)**

- 12:00-1:00pm: Lunch
- 1:00-2:30pm: Exercise + Discussion: Dynamical Fever **(Christian, Fara, Mentors)**
- 2:30-3:00pm: Coffee Break
- 3:00-4:30pm: Lecture/Tutorial: Introduction to Compartmental Models and Differential Equations **(Cara)**
- 4:30-5:00pm: Small Group Sessions: Refining research questions for modeling **(all instructors lead small groups)**
    - All students should have a workable statistical and mechanistic question by the end of the session
    - For HW, assign: Creating a model world to address a research question
- 5:00-6:30pm: Mid-session feedback **(Program Evaluator)**
- 6:30-7:30pm: Dinner

Transition to mechanistic models

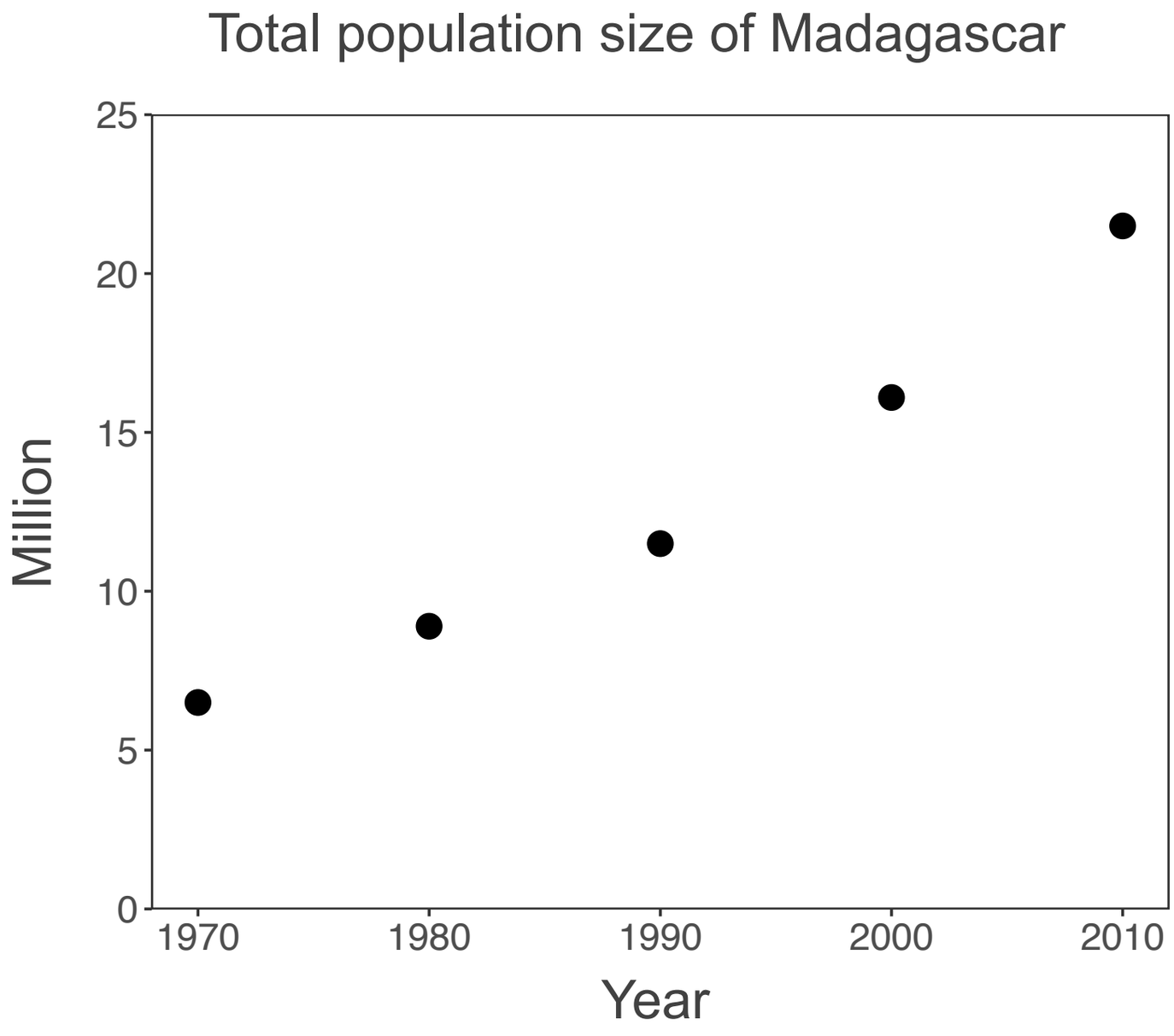




Tells nothing about why population is increasing

Mechanistic model

This is a simulated data



Source: World Bank (accessed 2017)

Mechanistic

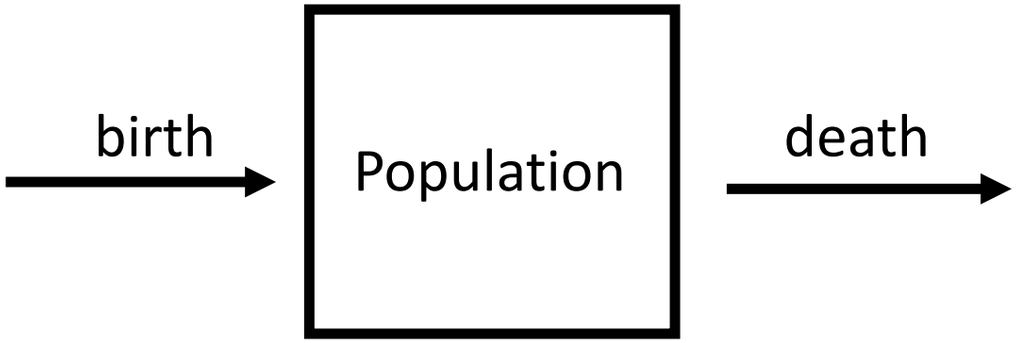
- Mechanistic model allows you to **make your own data**, generate data through time
- You think about the type of processes that can generate the phenomenon you are interested in
- Translate the processes into mathematical equations (your equation is your model)
- Solve the equation!

Mechanistic model

- Research question: How does a population change if birth and death rates are constant?
- Formulate a hypothesis: Population increases exponentially if birth > death, and goes extinct if birth < death
- Build the model that translate your hypothesis into equation
- Assess if the solution of the equation agrees with the observation in the research question

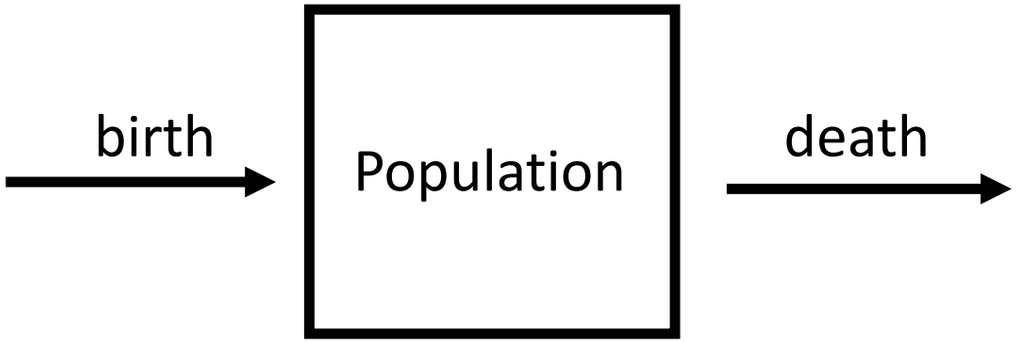
Mechanistic model

Compartmental model



Mechanistic model

Compartmental model

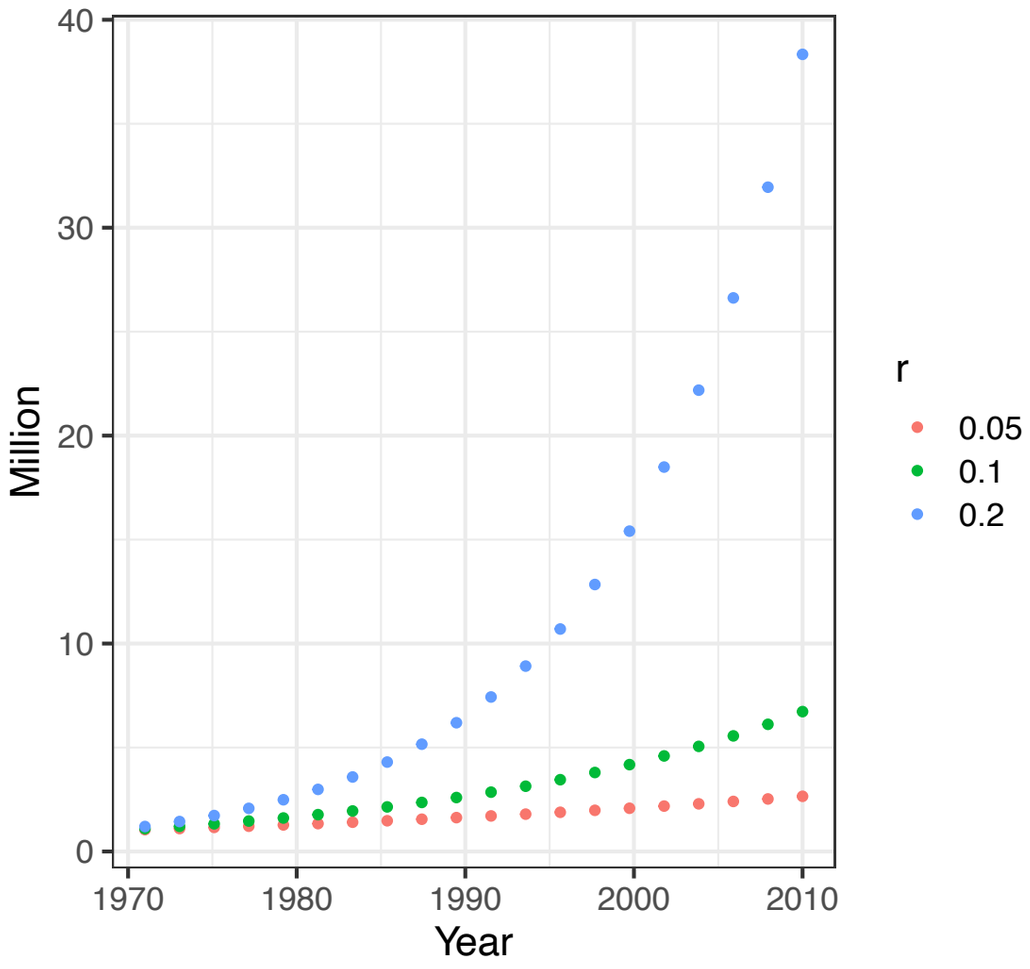


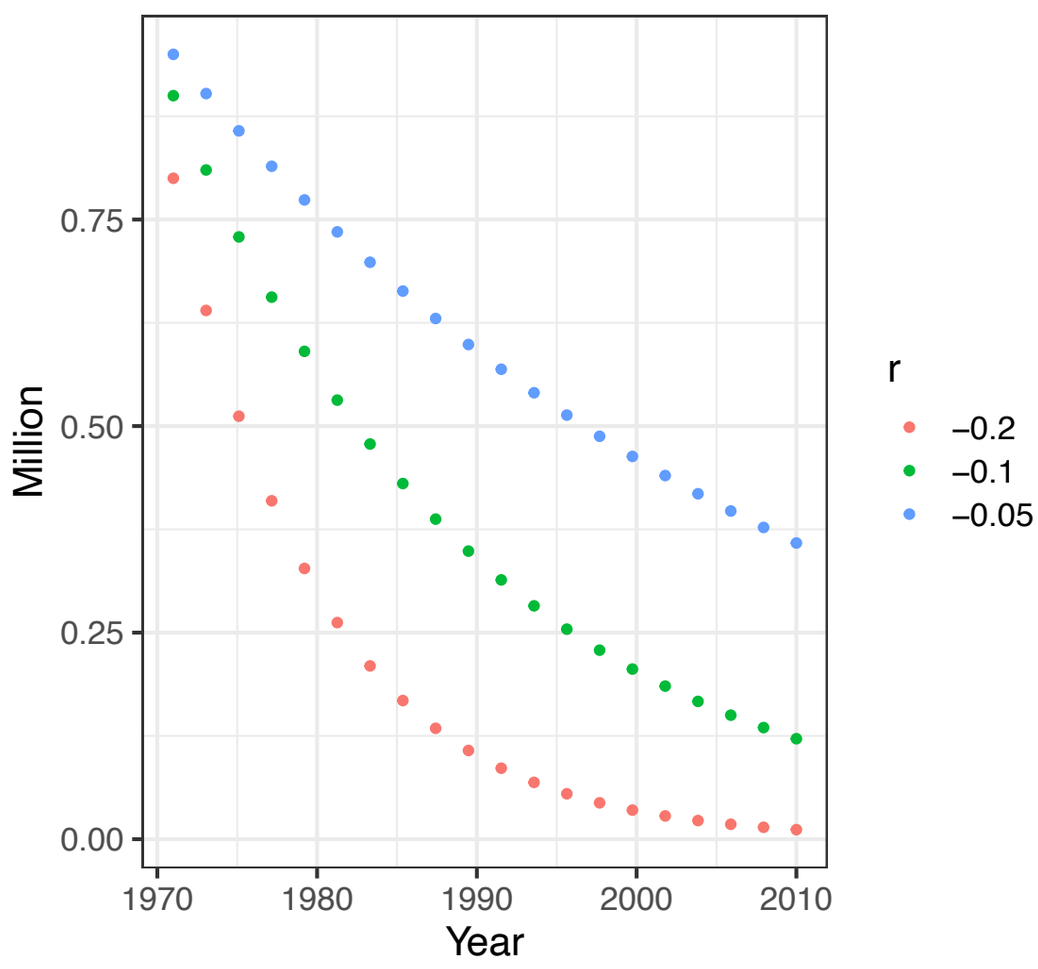
In terms of equation :

$$p_{t+1} = p_t + bp_t - dp_t = (1 + r)p_t$$

Comparing with the hypothesis

- Population increases exponentially if birth > death
- Population goes extinct if birth < death





Mechanistic model

- Research question: How does a population change if birth and death rates are constant?
- Formulate a hypothesis: Population increases exponentially if birth > death, and goes extinct if birth < death
- Build the model that translate your hypothesis into equation: $p_{t+1} = (1 + b - d)p_t = (1 + r)p_t$
- Assess if the solution of the equation agrees with the observation in the research question: it agrees

Two broad classes of models

Statistical

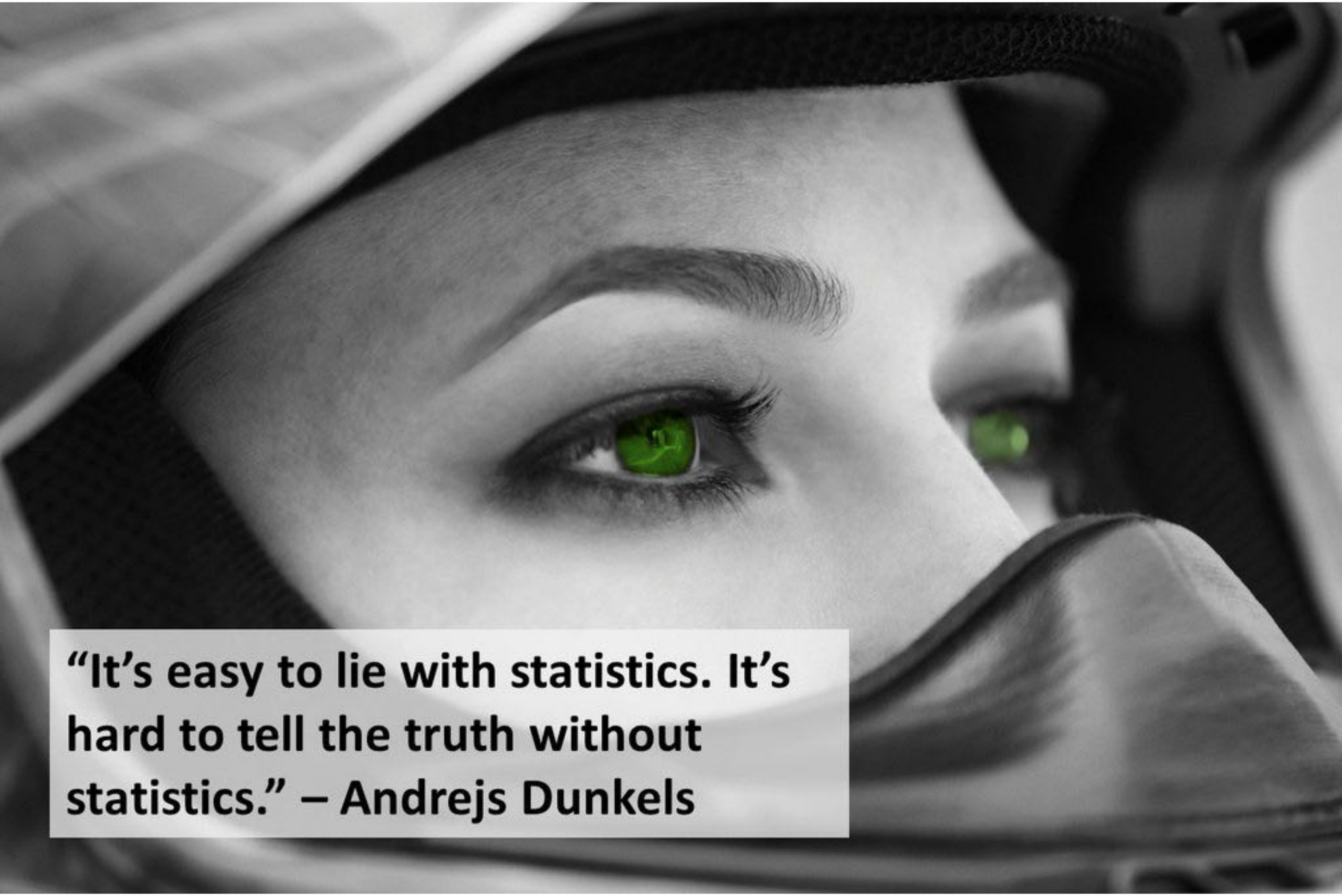
Correlative

Mechanistic

Causative

Statistical model: beware!!!

- Statistical models are based on specific assumptions
  - Make sure your data does not violate these assumptions
  - What happened if you violate those assumptions?
- There are so many statistical models
  - There is not necessarily a single best approach
- Advances in computational powers, statistical packages, and data size often attracts people to use **complex statistical** models which **are not necessarily better**


“It’s easy to lie with statistics. It’s hard to tell the truth without statistics.” – Andrejs Dunkels

Mechanistic model: beware !!!

- Parameters used in the mechanistic models sometimes are not measurable
- Simulations can be computationally intensive
- Advances in computational power often inspire the development of **more complex models** which are **not necessarily better**

Coralie Fritsch

Principle

- When building a model, you include elements that you feel is most important (parsimony) to explain a phenomenon
- The details depend on how similar do you want your model to reproduce the real-world data

R is just a tool

R is a good (not the best) program
for mechanistic and statistical modeling

Take homes

- Research question and hypothesis are more important that models
- Any data needs context: the X and Y should be clear
- Models are rigorous tools to assess how the data support the claim
  - There are figuratively an infinite number of models
  - Statistical model works with question starting with **what**
  - Mechanistic model **generates data** and works with question starting with **how**

E2M2

- Ask questions
- Perform classical statistical model
- Create simple mechanistic model
- Use R as a tool