SCIU4T4: Why study statistics?

Why study statistics?

- Importance of good statistics
- Statistical revolution
- Populations and samples
- Expectation and uncertainty
- Types of variables

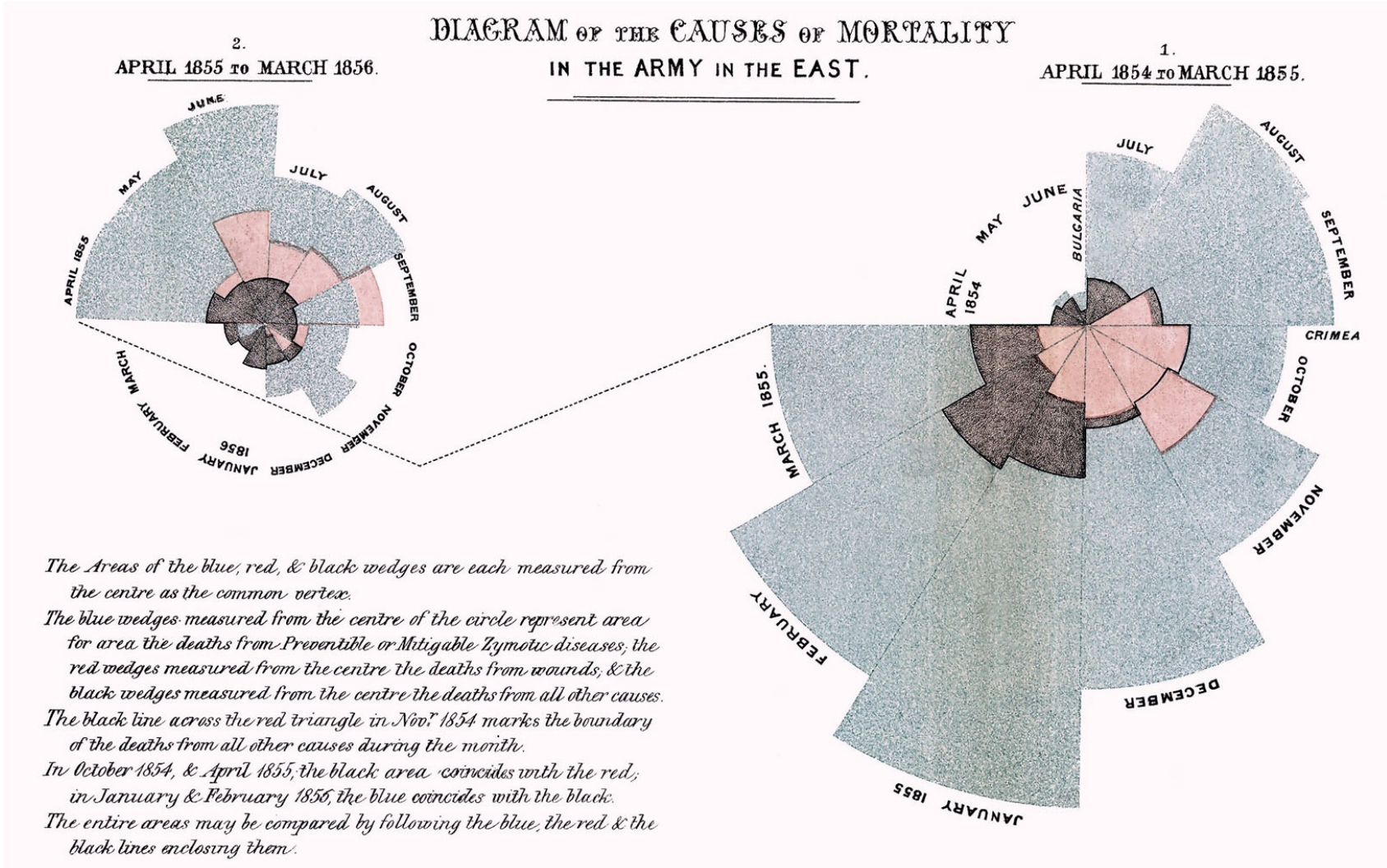
Florence Nightingale

- Pioneer of modern nursing and statistics
- Founded first secular nursing school 1860

Nurse during Crimean war (1853-1856)

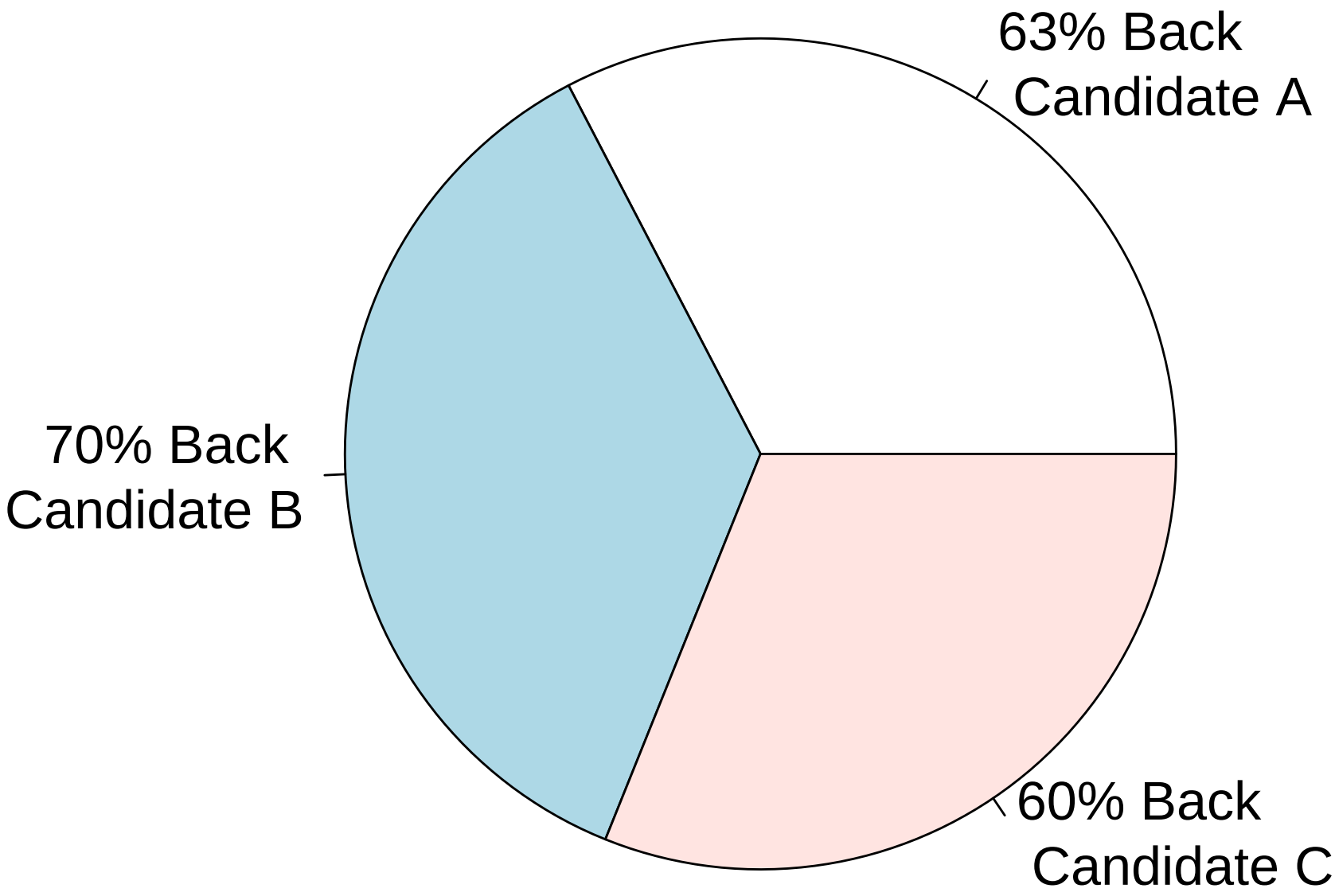
- 16k of 18k deaths due to sanitation
- Fatalities plummeted after improvements
- Persuaded parliament to reform hospitals

Importance of good statistics



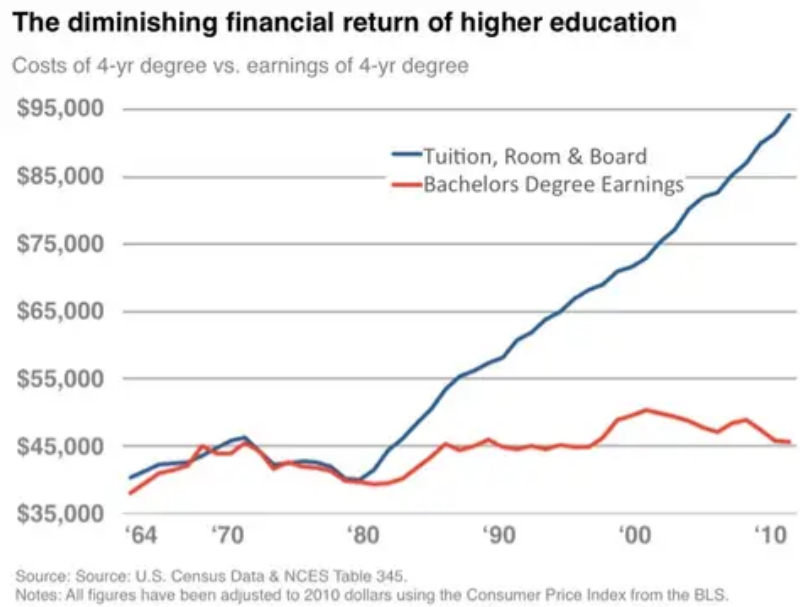
[1] **Image:** Notes on Matters Affecting the Health, Efficiency, and Hospital Administration of the British Army (Public domain).

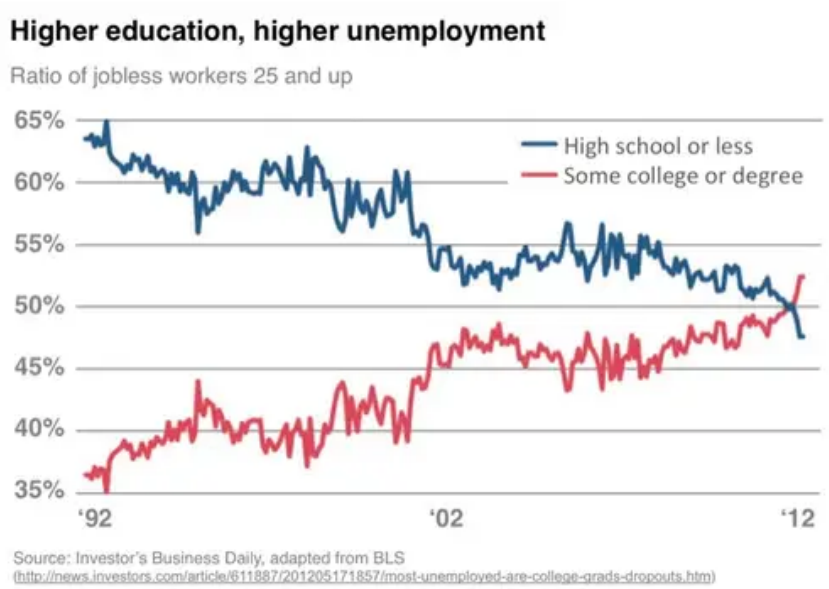
Importance of good statistics



[1]Source: A widely watched news channel

Importance of good statistics

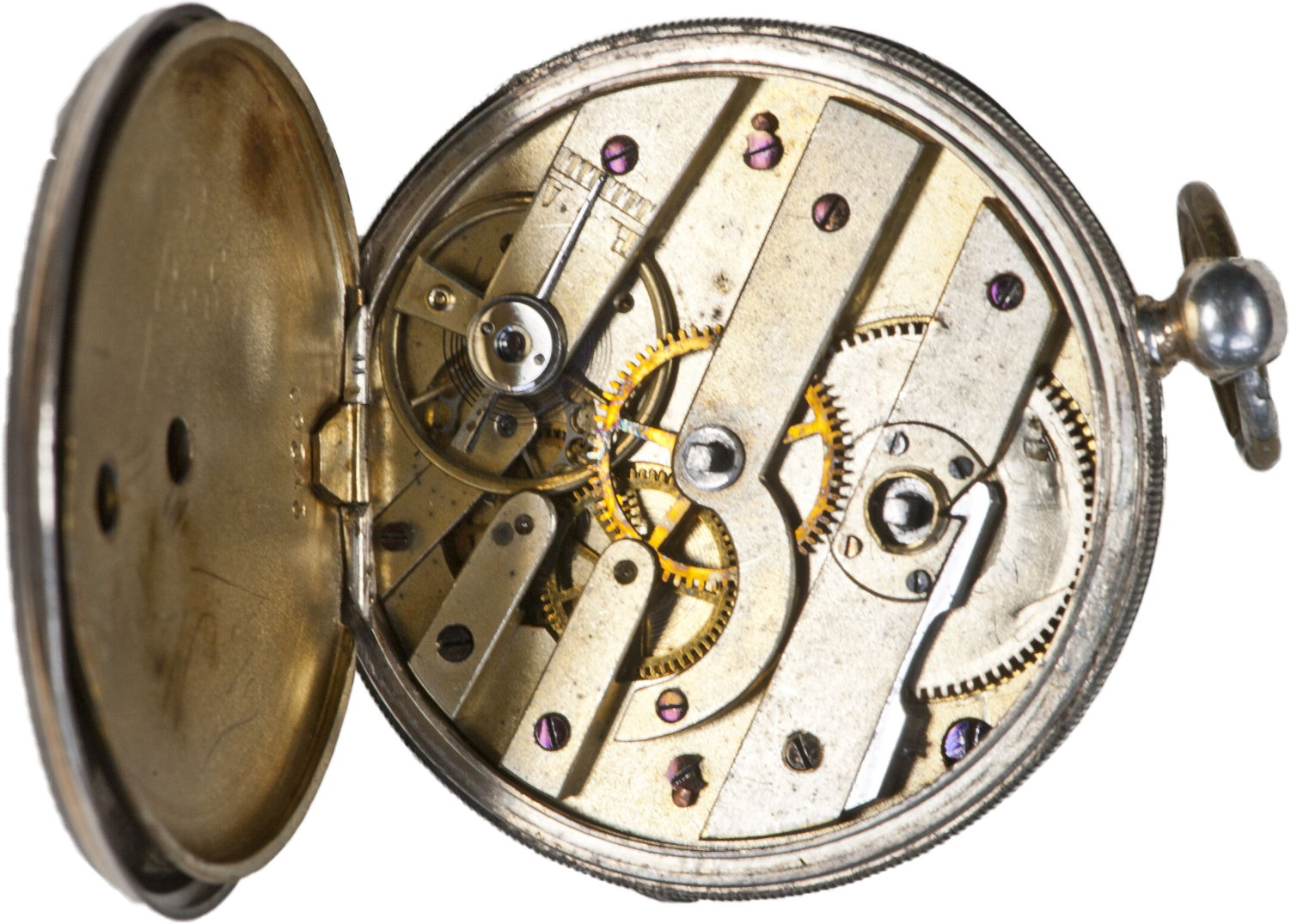




- Sometimes graphs do not tell the full story
- What about the earnings for people without a degree over time?

[1] Blake, D. 2012. These Two Charts Prove A College Education Just Isn't Worth The Money Anymore https://www.businessinsider.com/these-two-charts-prove-a-college-education-just-isnt-worth-the-money-anymore-2012-6.

Statistical revolution: Old view of a clockwork universe



[1] **Image:** Grobe, H. 2017. (Public domain).

Statistical revolution: Old view of a clockwork universe

- Newtonian physics success
- Formulas for laws of motion
- Precise measurement
- Eliminate measurement errors
- Apply to life sciences?

This old view of eliminating uncertainty was challenged in the early 1900s.[1]

[1] Salsburg, D. 2001. The lady tasting tea: How statistics revolutionized science in the twentieth century. Macmillan.

Statistical revolution: A new perspective

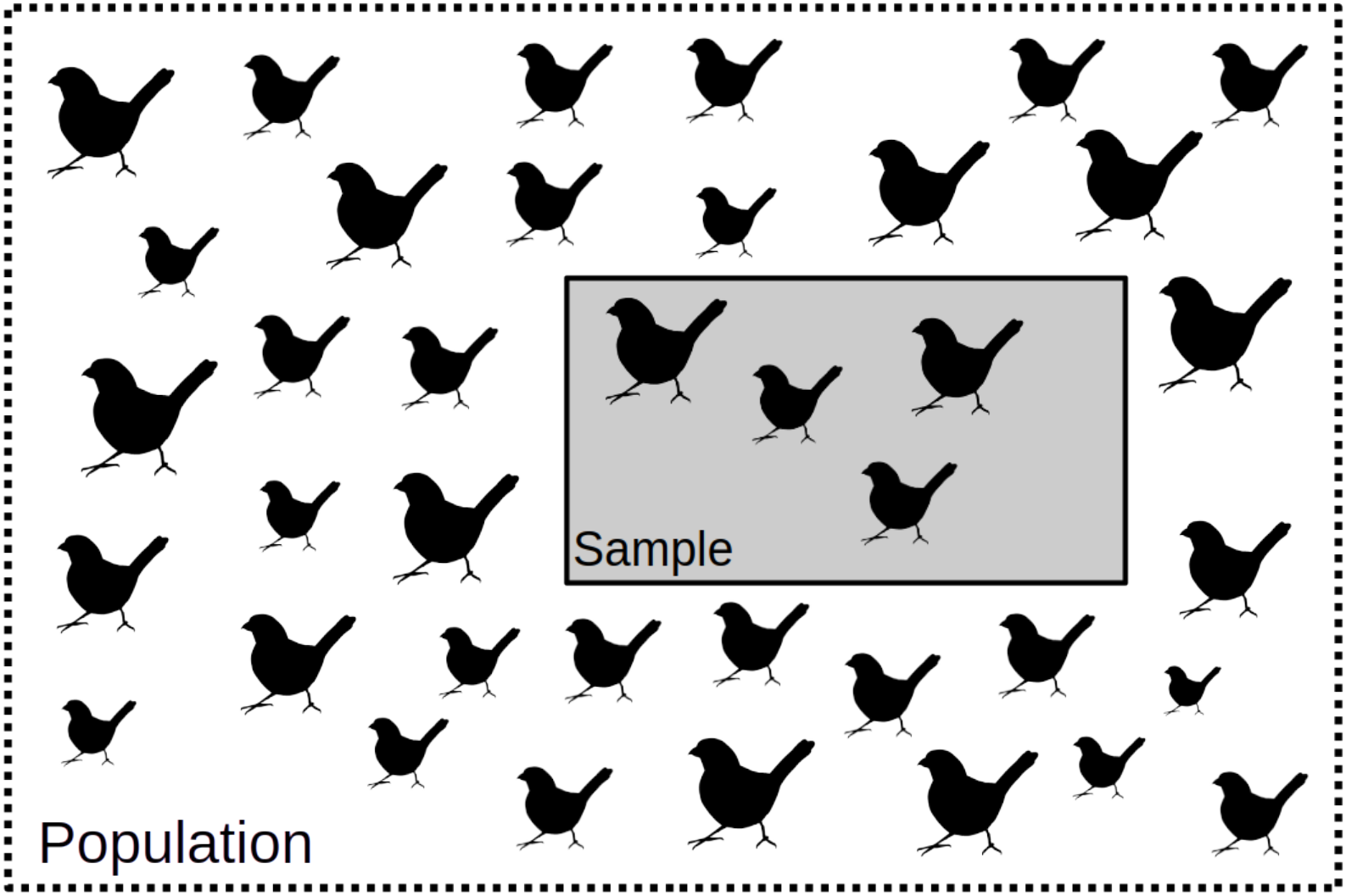


Figure 1: Samples are taken from a subset of a population

Statistical revolution: A new perspective

"In statistics, population always means the **totality of individual observations about which inferences are to be made, existing anywhere in the world or at least within a definitely specified sampling area limited in space and time**"[1]

[1] Sokal, Robert R, and F James Rohlf. 1995. Biometry. 3rd ed. W H Freeman & Company, New York, USA.

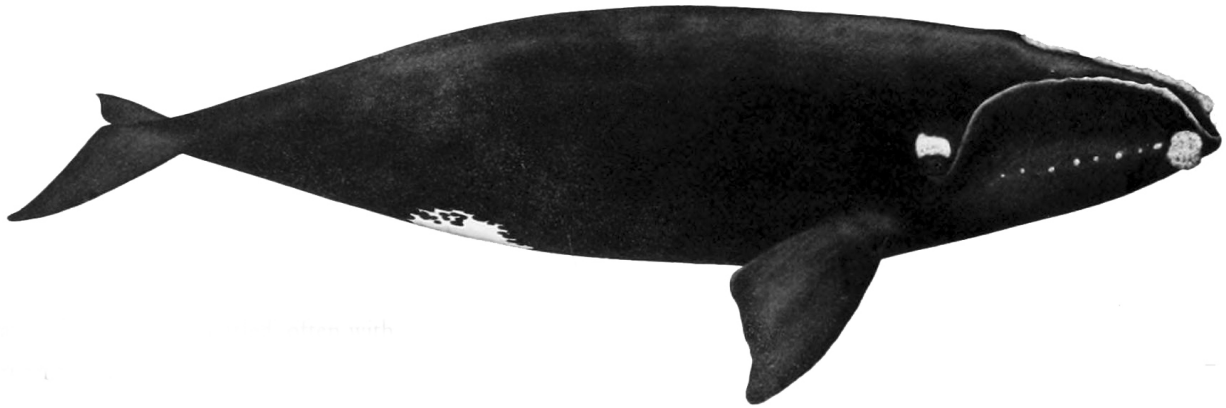
Populations and samples

Statistical population:

- Not necessarily a *biological* population
- Not necessarily an *actual* population
- Might be theoretical, not concrete

[1] **Image:** Wilson, A. 2019. (Public domain)

Populations and samples



North Atlantic right whale (*Eubalaena glacialis*)

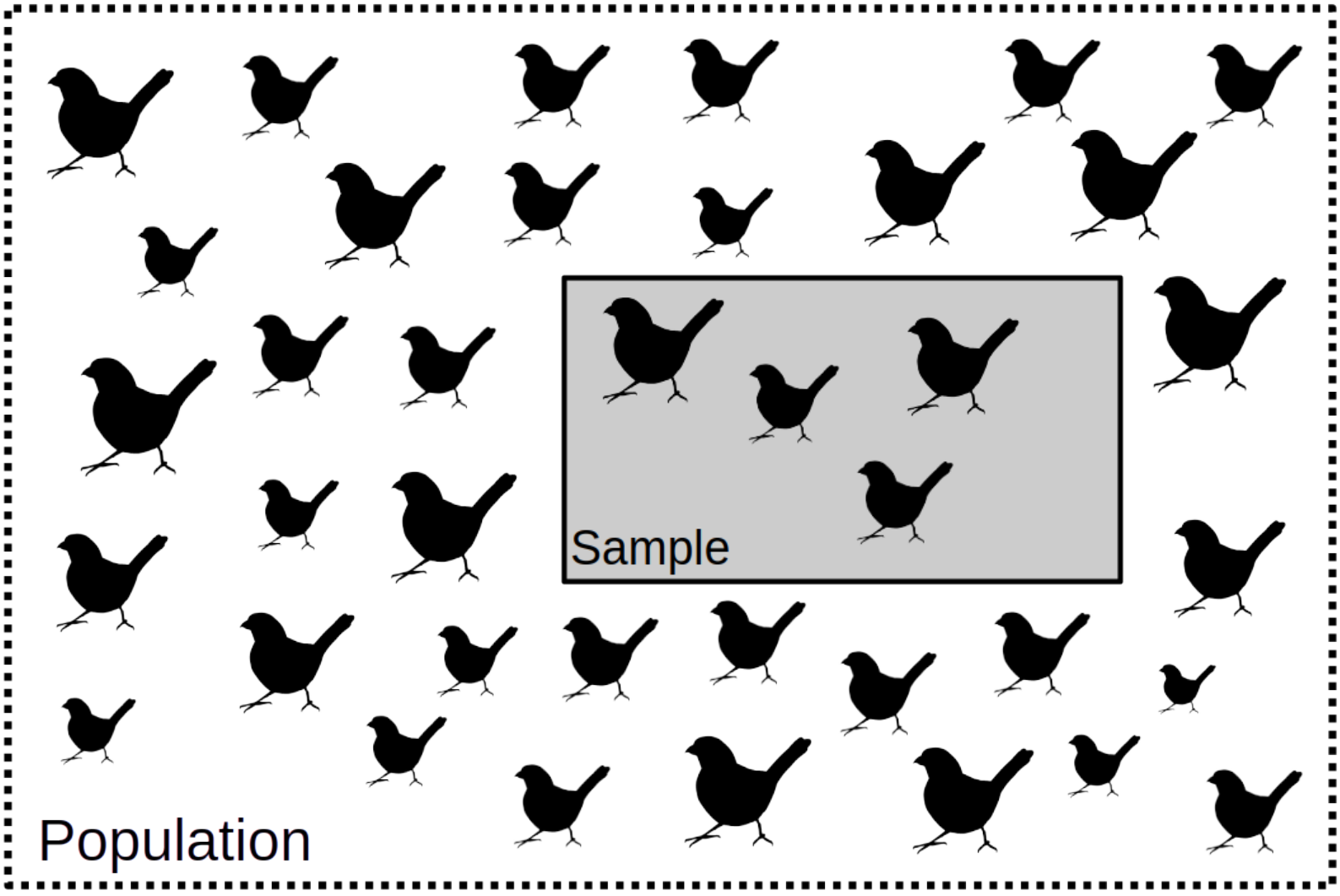
- Estimated 338 left[1]
- Conservation requires estimating traits
- Average value might not be *expected* value[2]

[1] NOAA (2023). North Atlantic right whale (*Eubalaena glacialis*): Western Atlantic Stock.

[2] van Veelen, M. (2025). The general version of Hamilton's rule. Elife, 14, RP105065.

[3] **Image:** NOAA. 1987. (Public domain).

General idea of frequency statistics



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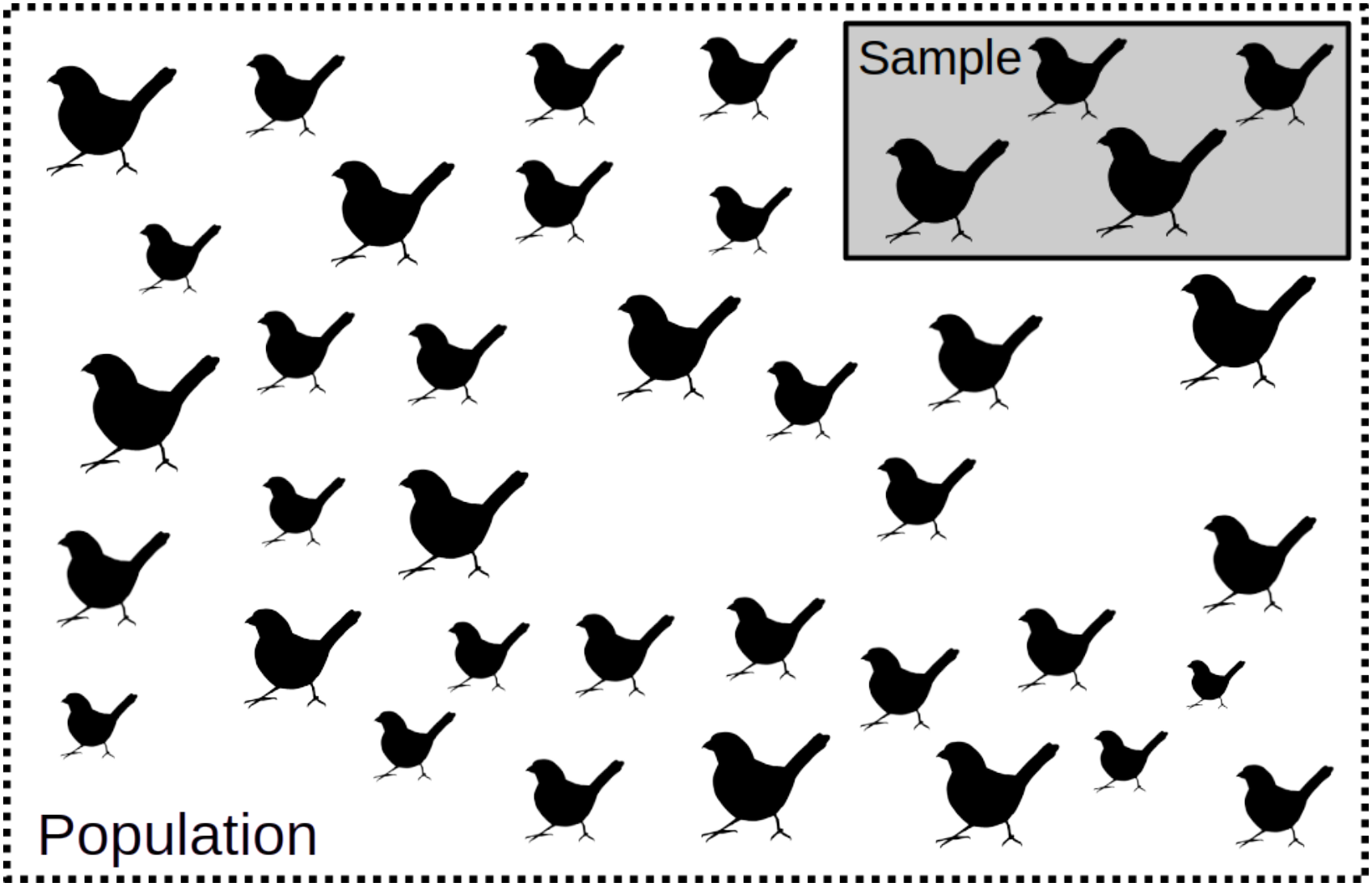
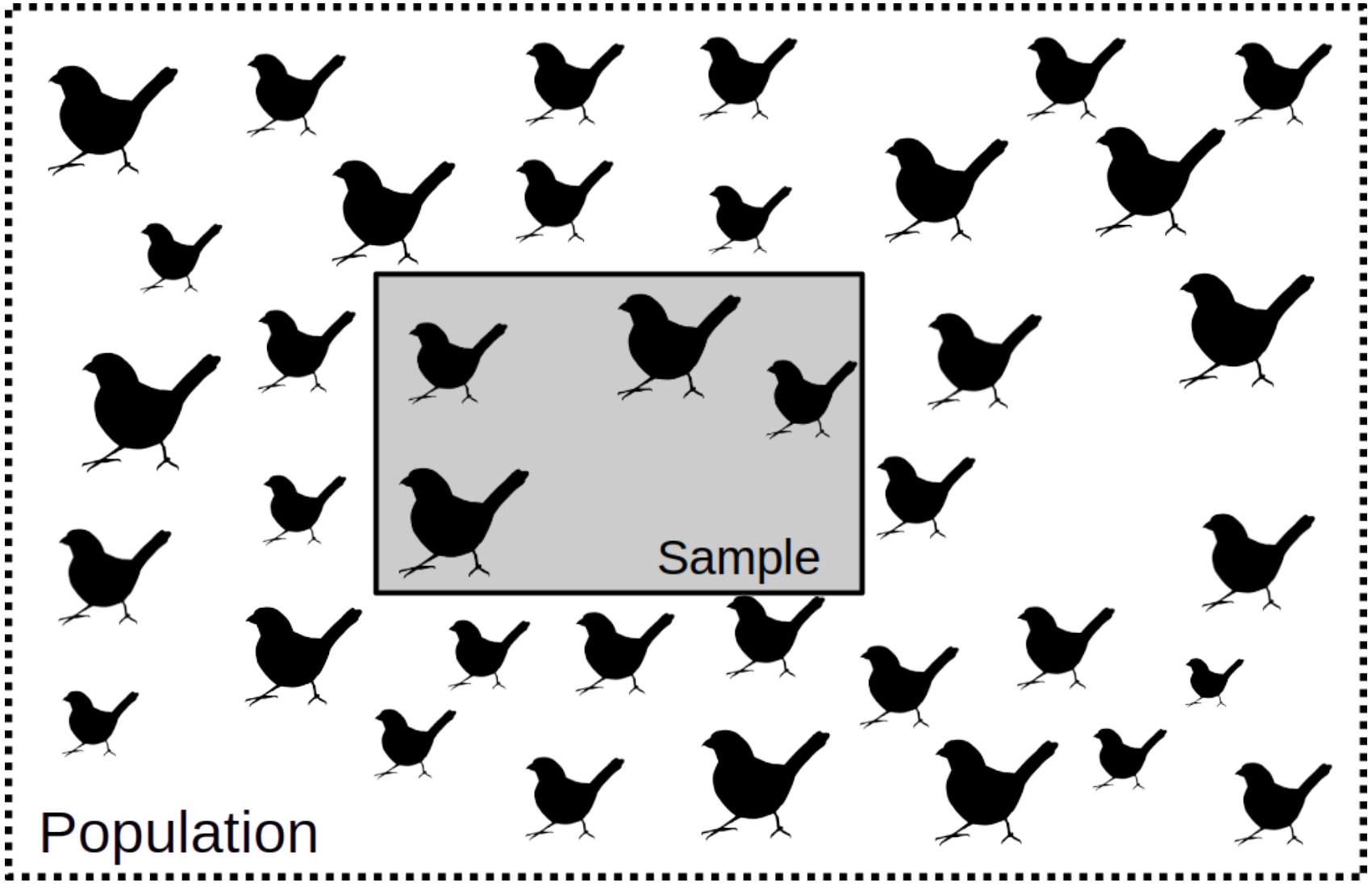


General idea of frequency statistics



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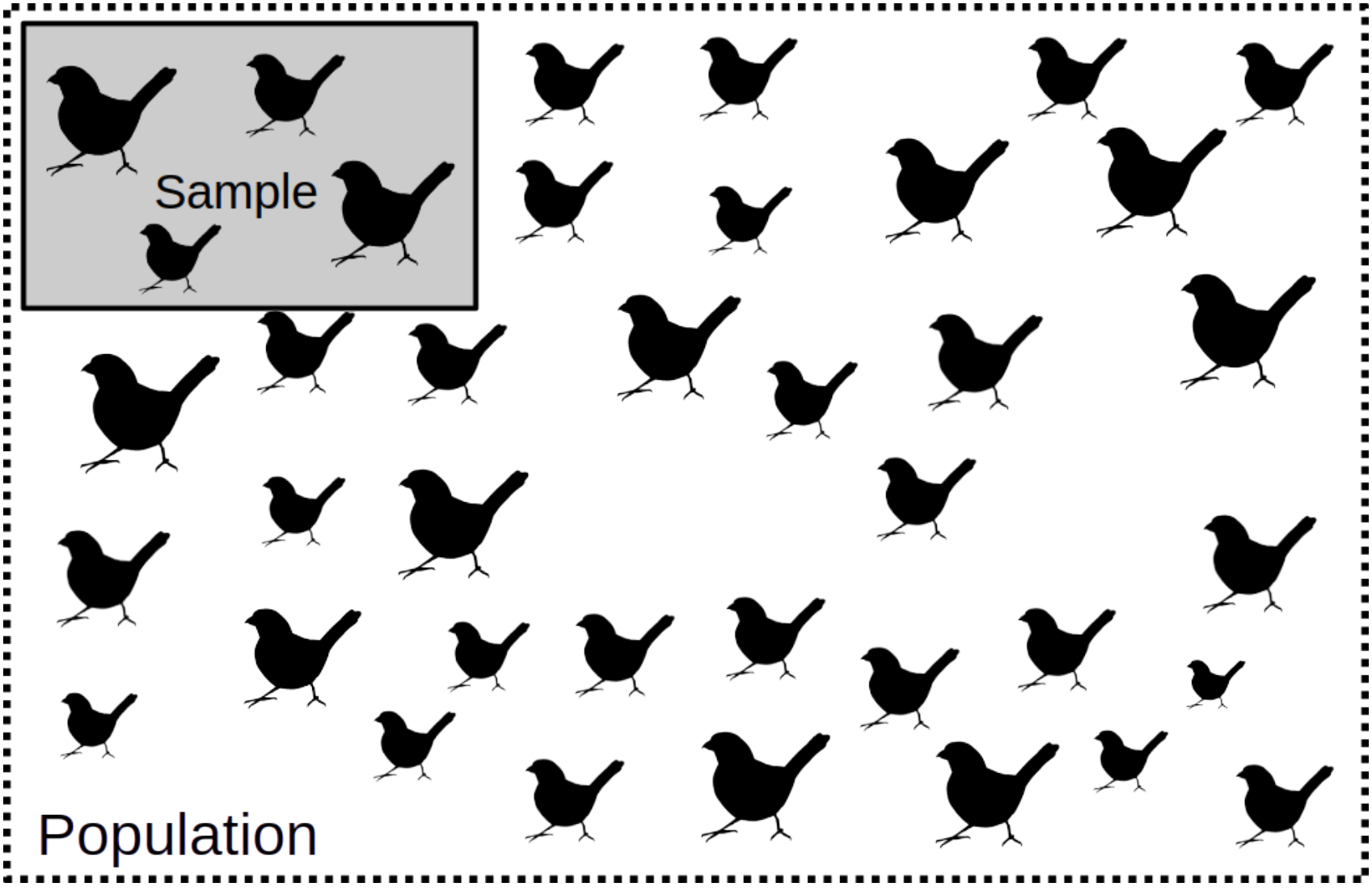

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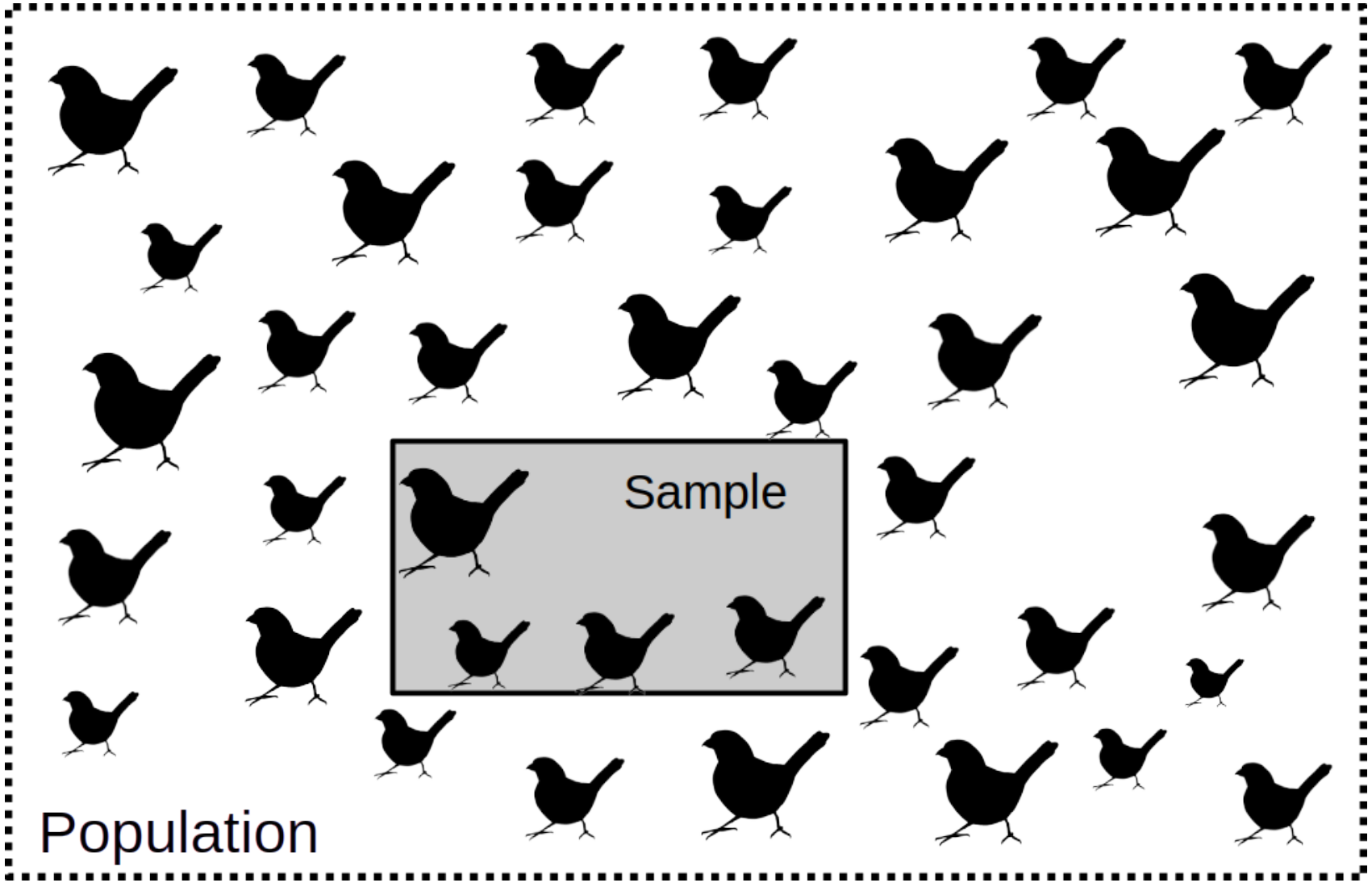

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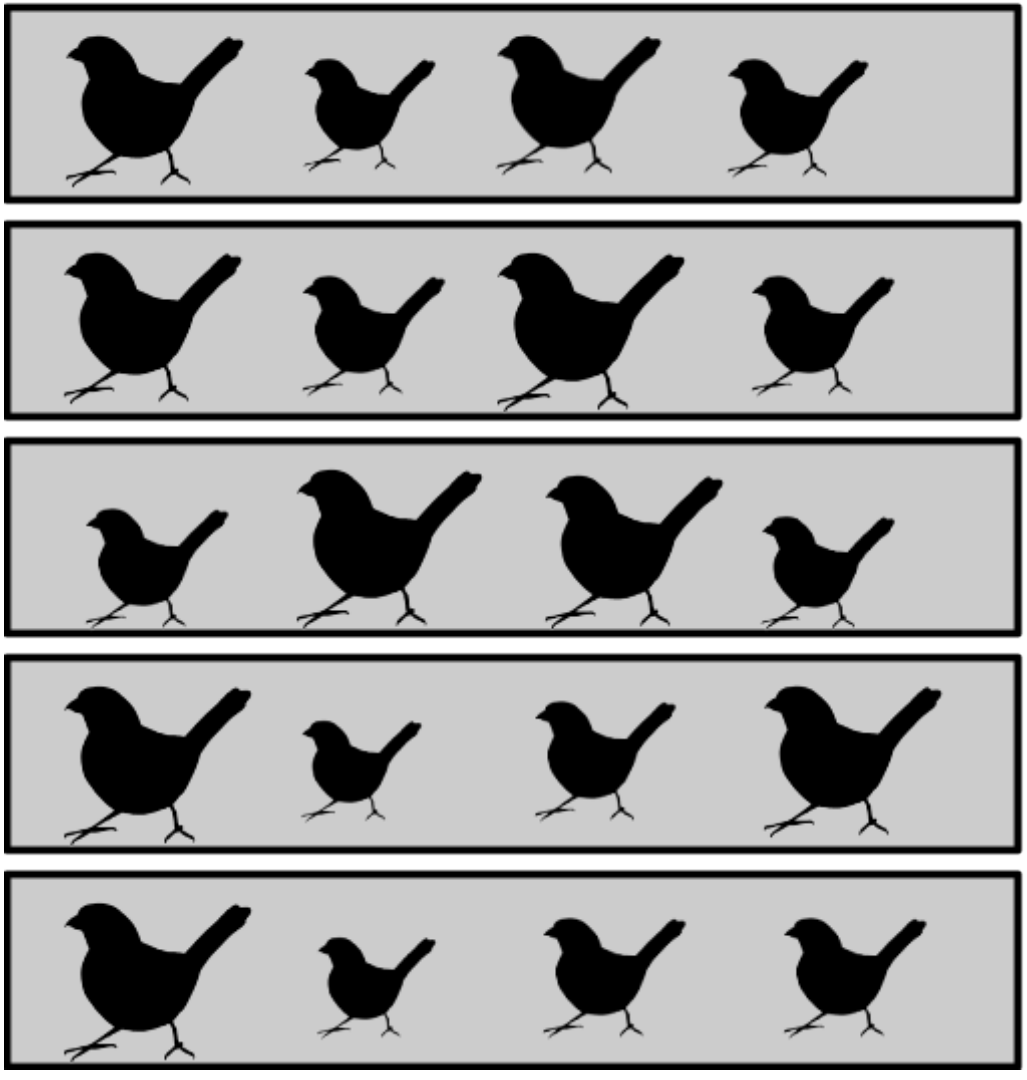
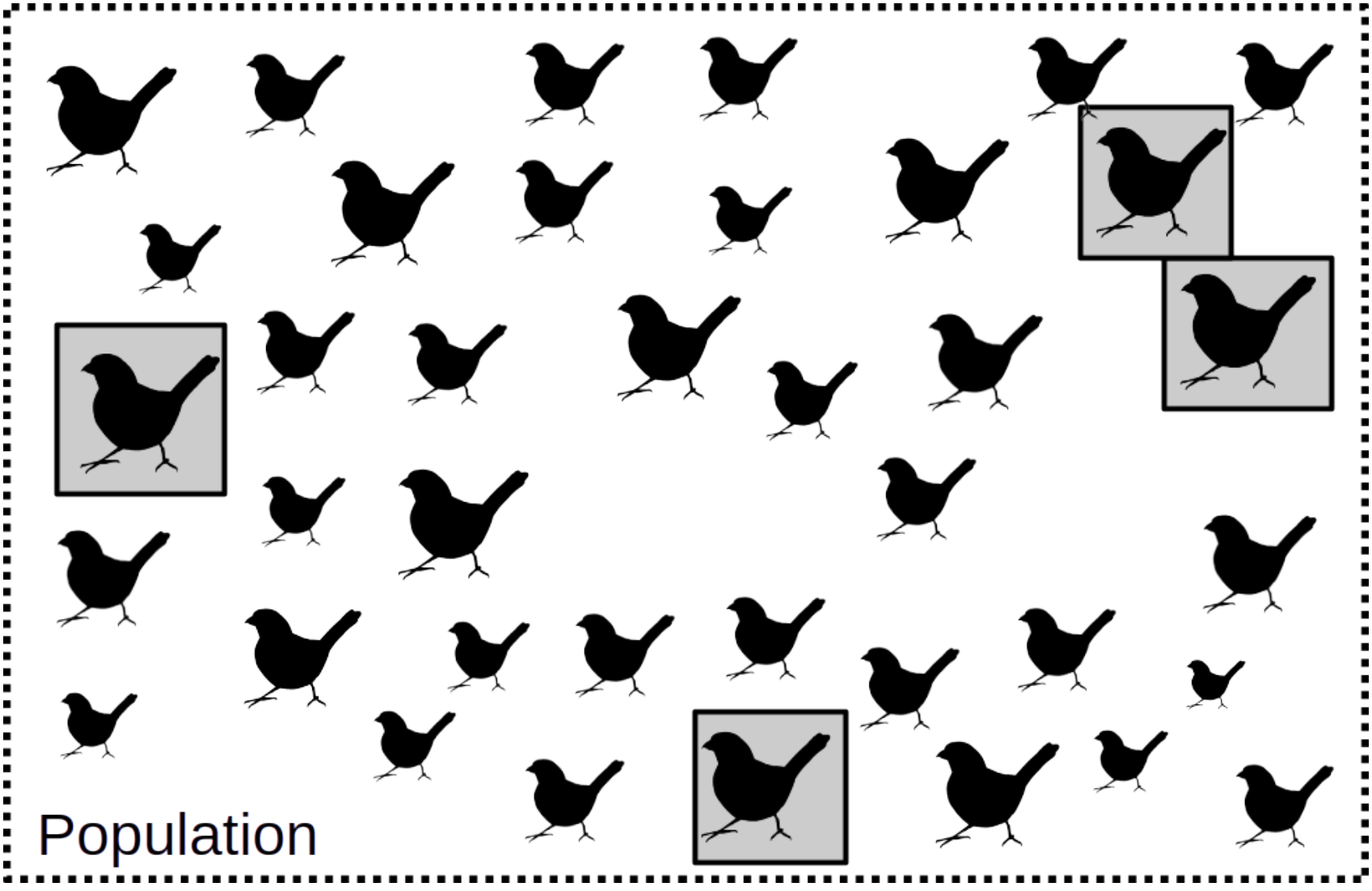


Repeated re-sampling

- What is our expectation?
- What is our uncertainty?

Want to get best estimate of *true* expected measurement and contain uncertainty.

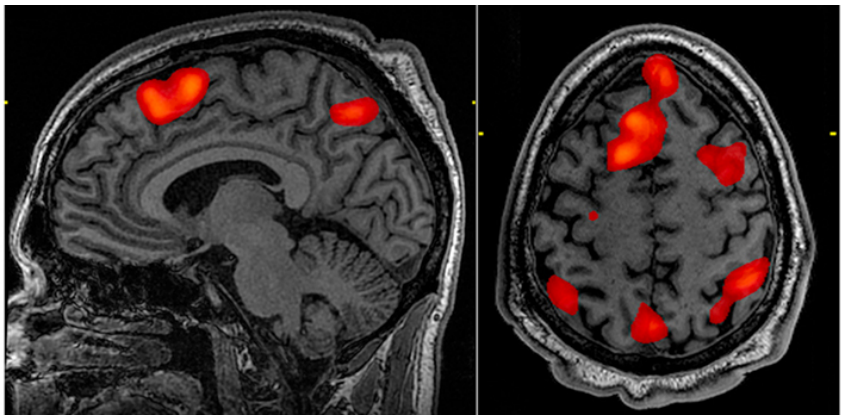
Bias and unrepresentative sample



Bias and unrepresentative sample

Neuroscience: fMRI scans before & after task

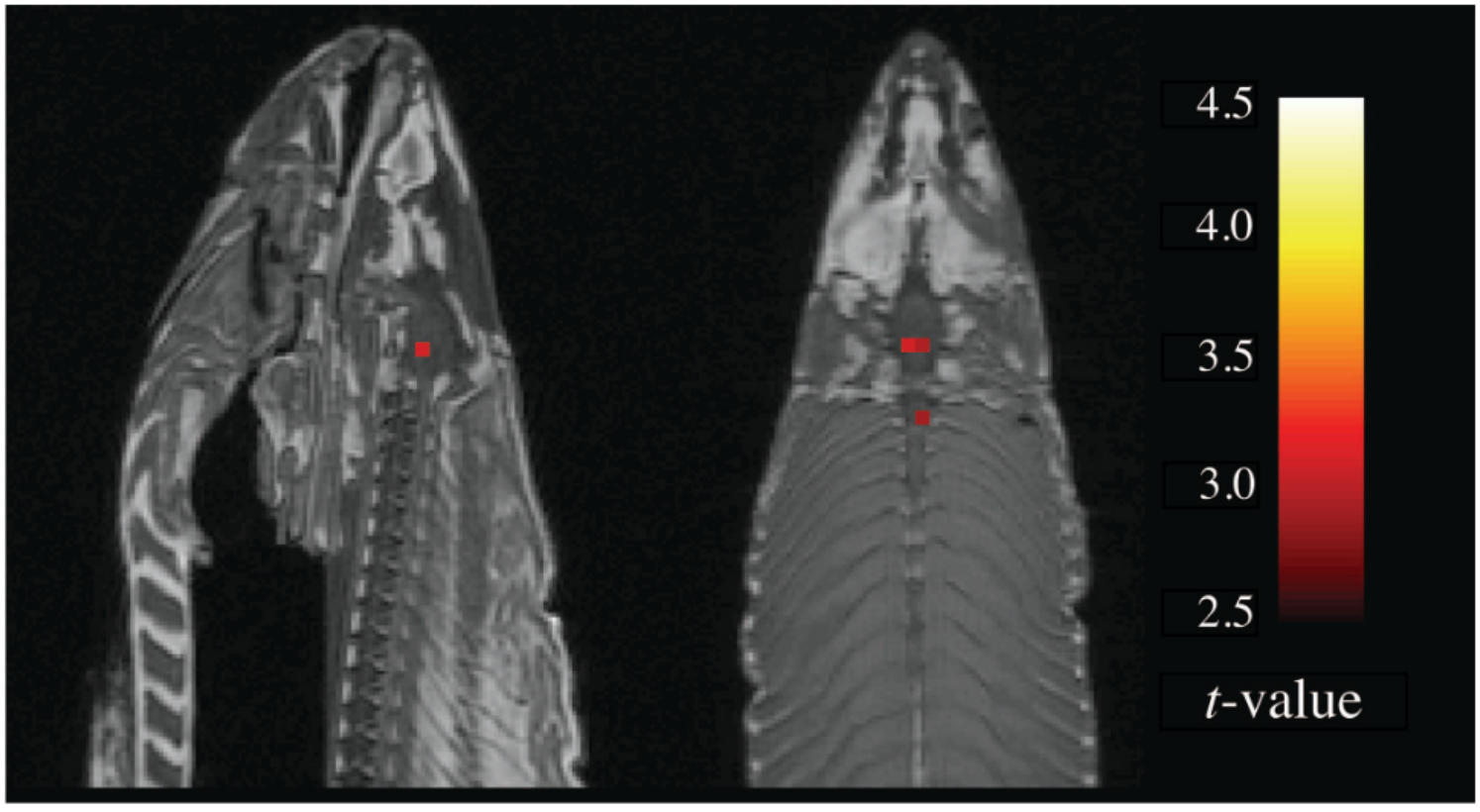
- What parts of brain most active during task?
- Compare thousands of areas of the brain
- Subject shown pictures of human social activity
- Cluster of brain areas showed high activity
- Typical analysis approach highly significant



[1] Reinhart, A. 2015. Statistics done wrong: The woefully complete guide. No starch press.

[2] **Image:** Graner, J. 2010. (Public domain).

Bias and unrepresentative sample



207 different analysis methods in 241 fMRI studies

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[1]Reinhart, A. 2015. Statistics done wrong: The woefully complete guide. No starch press.

[2]Bennett, CM, et al. 2010. J of Serendipitous and Unexpected Results. 1:1-5.

[3]Carp, J. 2012. The secret lives of experiments: methods reporting in the fMRI literature. Neuroimage, 63:289-300. 10.1016/j.neuroimage.2012.07.004

Predicting one variable from another

- **Dependent variable**
  - Response variable
  - Shown on Y axis
- **Independent variable**
  - Explanatory variable
  - Shown on X axis

Predicting one variable from another

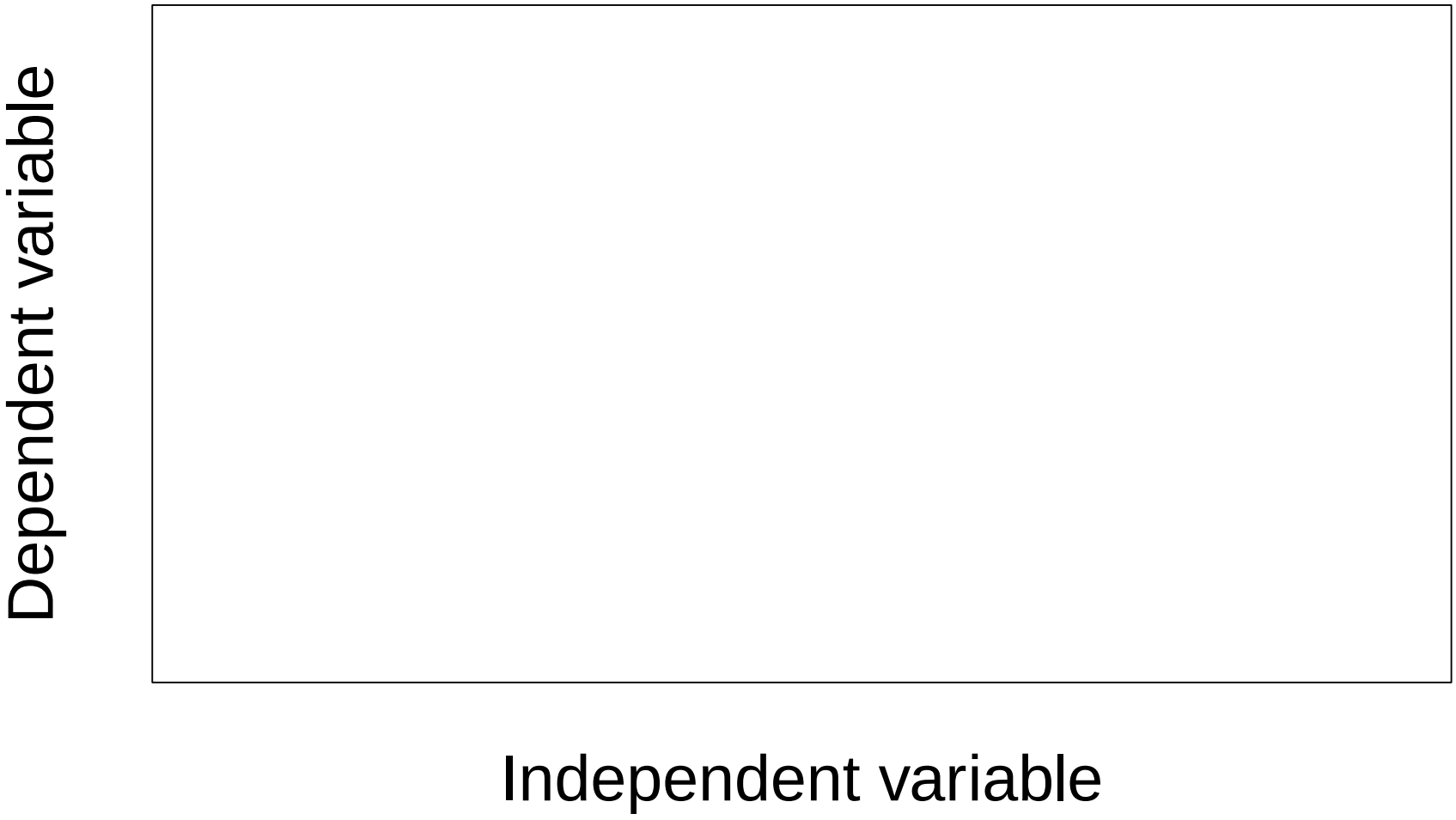
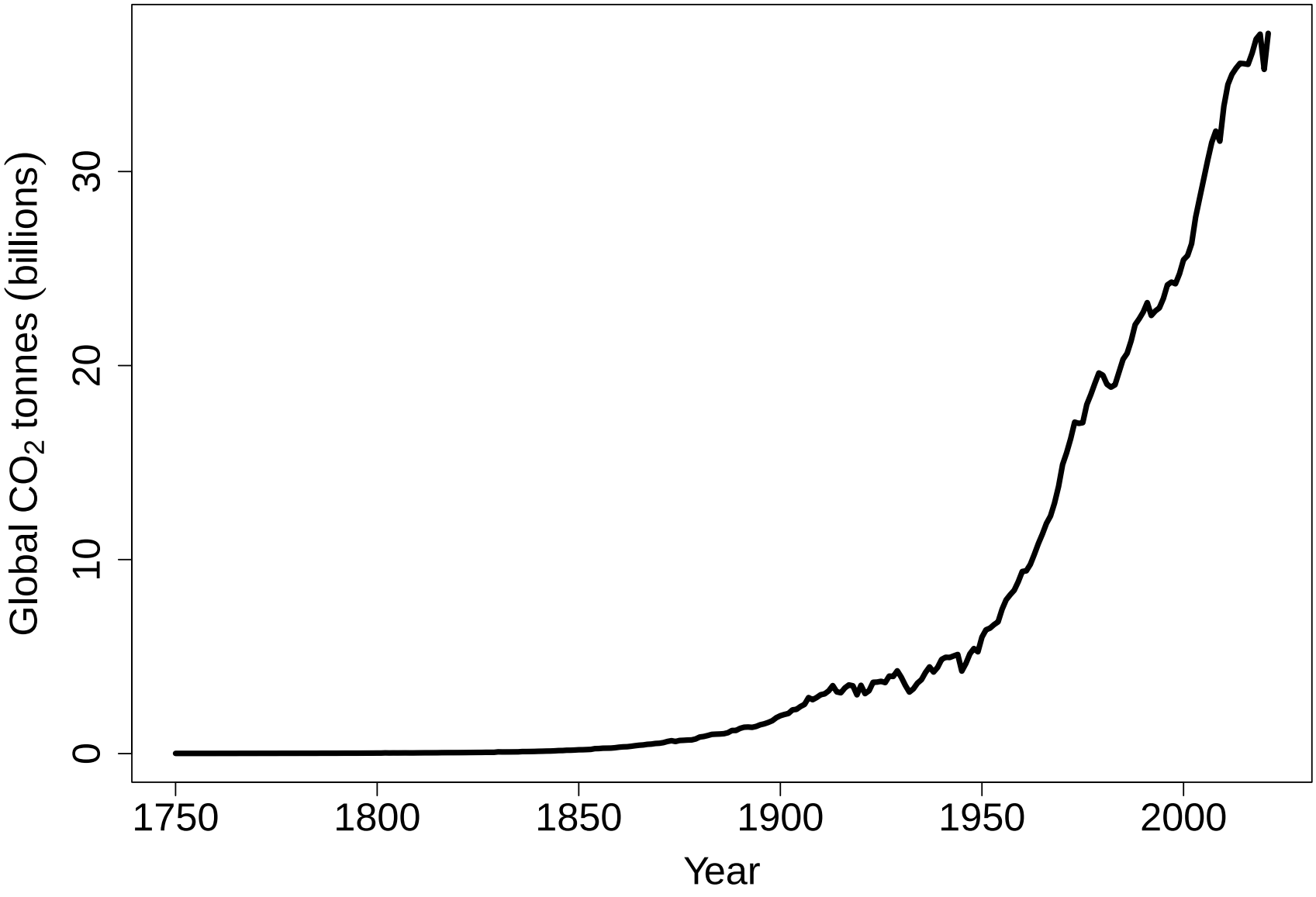


Figure 2: Dependent variable on the vertical (Y) axis, and independent variable on the horizontal (X) axis.

Predicting one variable from another



Types of variables: definitions

- **Categorical:** Fixed number of options
  - Nominal: No inherent order
  - Ordinal: Inherent order
- **Quantitative:** Numbers meaningful
  - Discrete: Limited number of values
  - Continuous: Any real number

Types of variables: examples

- **Categorical:** Fixed number of options
  - Nominal: Tundra, Boreal, Tropical
  - Ordinal: Disagree, Neutral, Agree
- **Quantitative:** Numbers meaningful
  - Discrete: Number of offspring
  - Continuous: Body mass

Types of variables: fig wasps collected from fruit

Species	Fruit	Count	Fruit length (mm)
Het1	F1	0	15
Het1	F2	0	14
Het1	F3	0	16
Het1	F4	1	15
Het1	F5	0	14
Het2	F1	0	15
Het2	F2	2	14
Het2	F3	3	16

Types of variables: implications

- Different variables handled in different ways
- Need to use the right plot or test for a variable type