Introduction to statistics using R

Seminar series - session 1

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Session1 - Learning objectives

- Understand what is “statistics”
- Get an idea of application range
- Understand the difference between **descriptive** and **inferential** statistics
- Measure central tendency, variability (R)
- Review data types
- What is a variable

What is “statistics”?

A collection of methods for:

- collecting,
- organizing,
- summarizing,
- analyzing,
- interpreting,

data

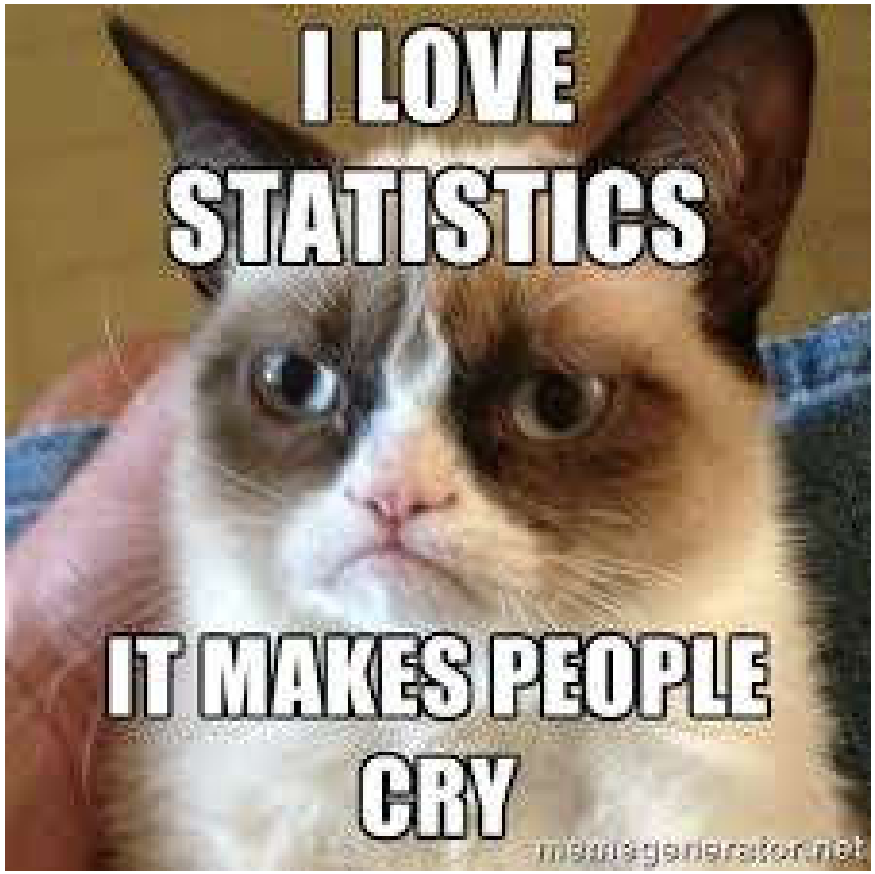
- and make decisions based on data

All steps in red: we can do with R software.

Why use statistics?

- Answer questions or test hypotheses
- Understand mechanisms and relationships between variables
- Ensure observed patterns are not due to chance
- Quantify phenomena
- Monitoring
- Predict future events
- Make informed decisions

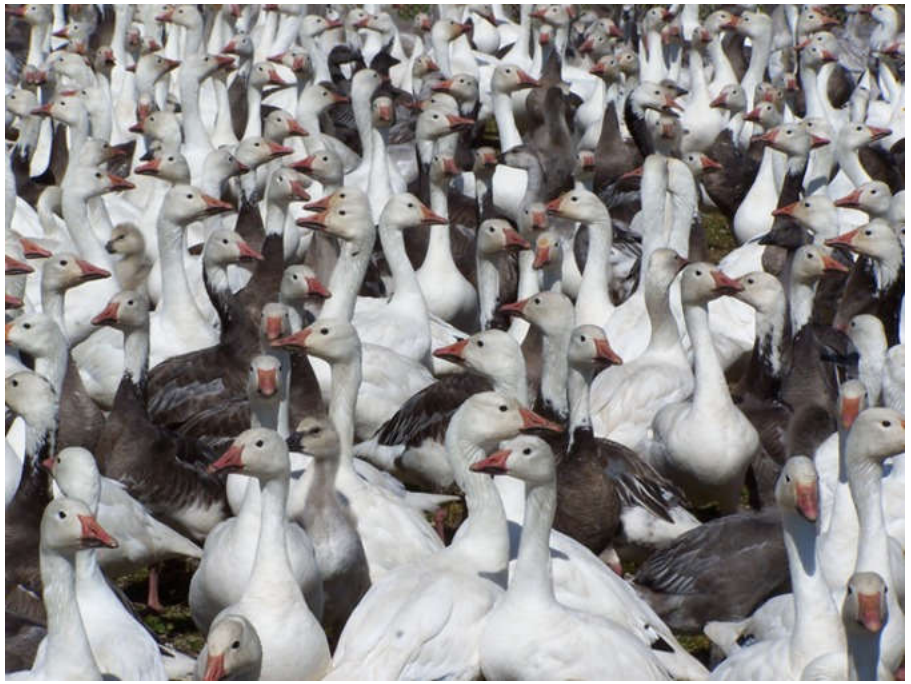
Some examples of why to use stats in Biology



Ex.1: test a hypothesis

Background:

- Arctic ecosystems: food is plenty in summer, scarce in winter

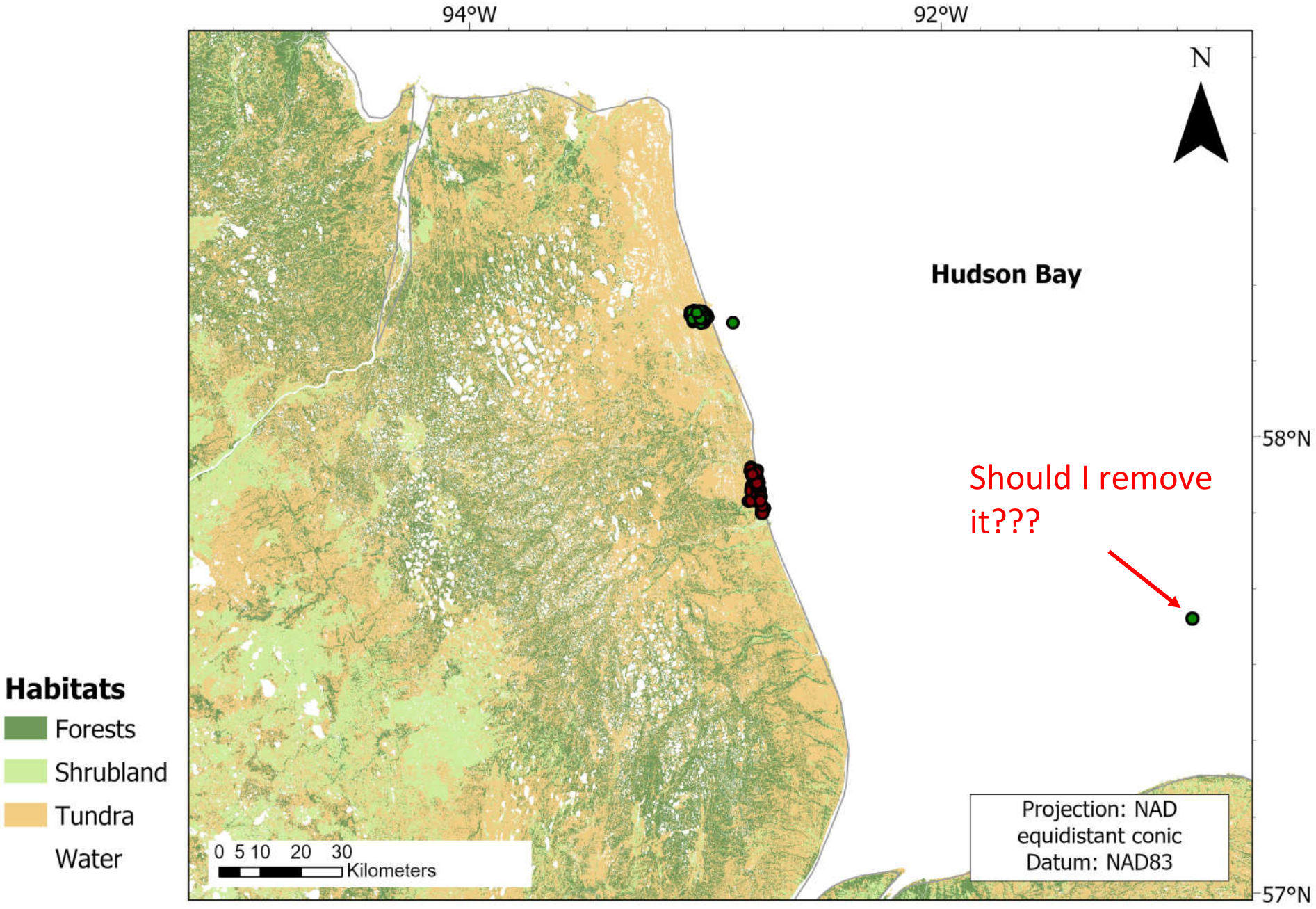


Ex.1: test a hypothesis

Hypothesis: Fox movement tactic changes seasonally

Collect data: Live trapping and satellite telemetry

Clean and organize the data



Analyze data

RStudio

File Edit Code View Plots Session Build Debug Profile Tools Help

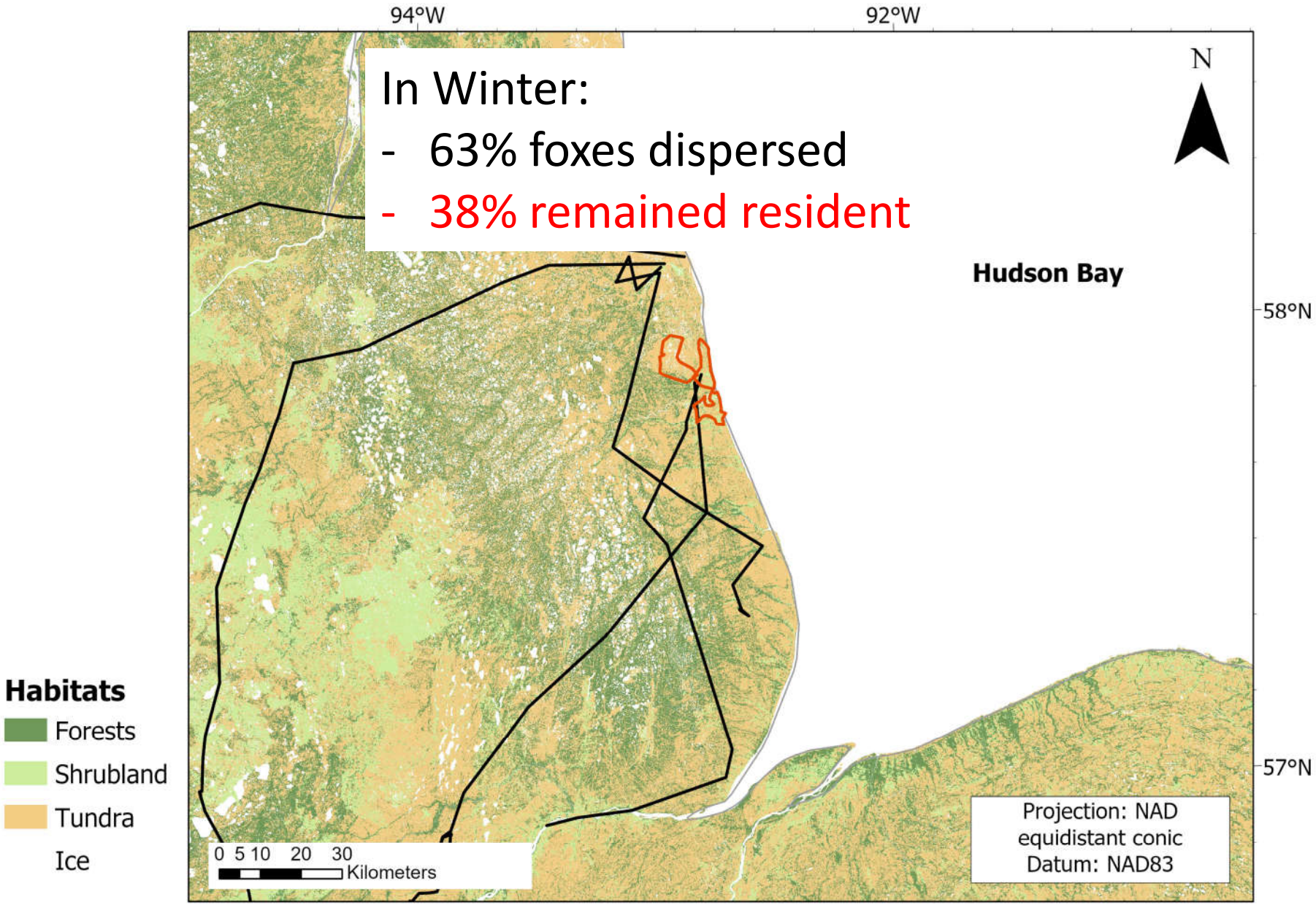
Go to file/function | Addins

grouse_gout.R | Parasite_summary.R | Gout_in_SG.md | Cloacal_prolapsus_KZ.R | Enjil_MC_EAB06.R | LoCoH_Churchill_winter_20182020.R | eab1.c

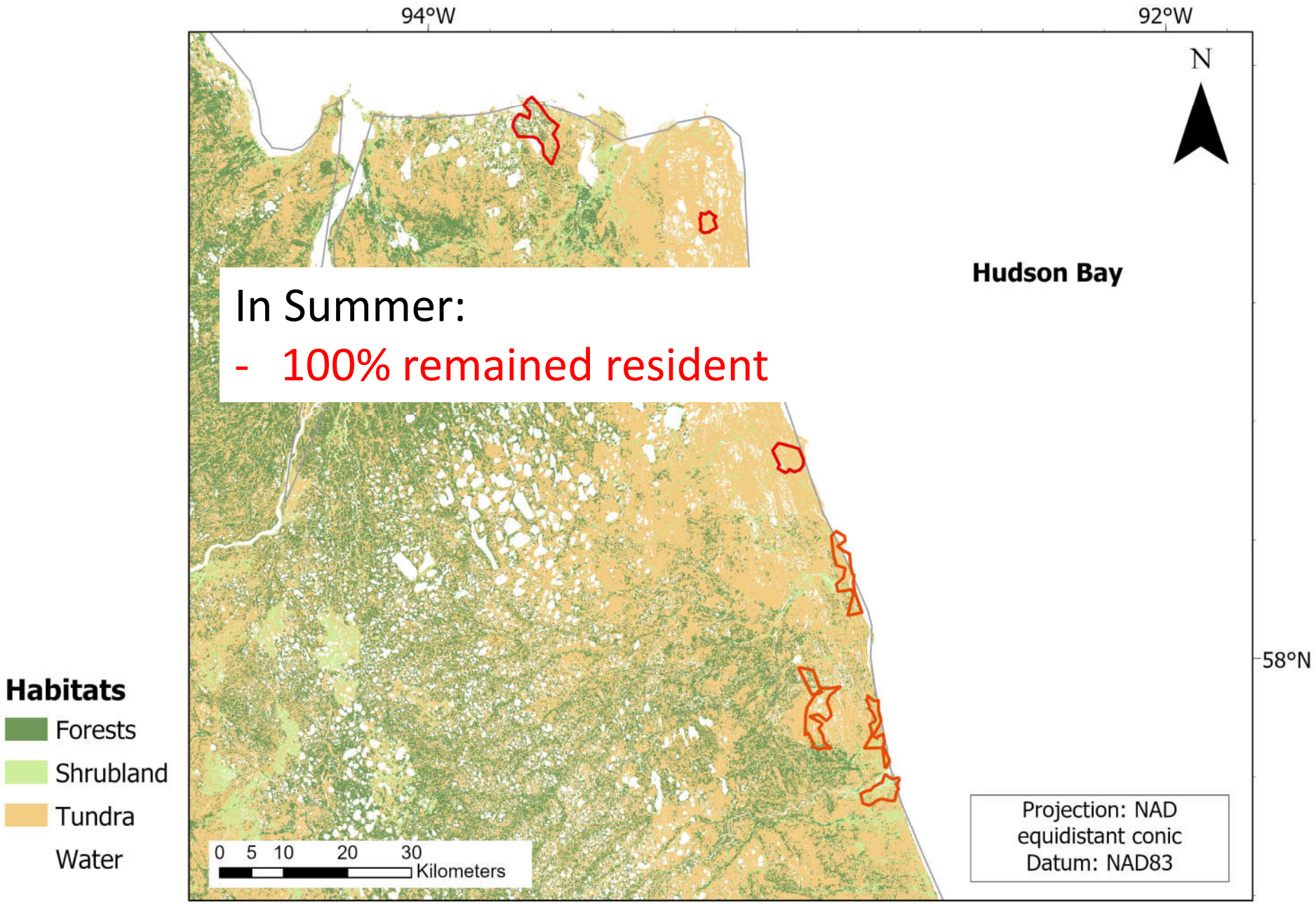
Source on Save | Run | Source

```
13  timestamp<-fox$date
14  xy2017<-SpatialPoints(fox[ , c("easting","northing")], proj4string=CRS("+proj=utm +zone=15 +datum=NAD83 +ellps=GRS80")
15  xy2017 <-coordinates(xy2017)
16  head(xy2017)
17  colnames(xy2017) <-c("x","y")
18
19  #merge the timestamp column to the SPDF
20  merge<-data.frame(fox)
21  head(merge)
22  df <- merge[,-(18)]
23  head(df)
24
25  head(as.character(df$date))
26  df.gmt<-as.POSIXct(strptime(merge[,"date"],"%d-%m-%y"))
27  df.gmt[1:3]
28
29
30  #---------------------------------------#
31  # create lxy object and investigate it #
32  #---------------------------------------#
33
34  #create and check lxy object
35  s.lxy <-xyt.lxy(xy=xy2017, dt=df.gmt, id=fox$Name, proj4string=CRS("+proj=utm +zone=15 +datum=NAD83 +ellps=GRS80"),
36                  show.dup.dt=TRUE,  show.bad.timestamps=TRUE)
37
38  #---------------------------------------#
39  # identify nearest neighbours - a-method #
40  #---------------------------------------#
41  #============#
42  # ***2018*** #
43  #============#
44
45  #subset individuals
46  U.lxy.2018 <-lxy.subset(s.lxy, id = "Uhtred")
47  MM.lxy.2018 <-lxy.subset(s.lxy, id = "MadMax2018")
48  FJ.lxy.2018 <-lxy.subset(s.lxy, id = "FoxyJim")
49  AB.lxy.2018 <-lxy.subset(s.lxy, id = "AnneBoleyn2018")
50  LR.lxy.2018 <-lxy.subset(s.lxy, id = "Little Red2018")
51
52  ##Parameter s will be set to 0 since time sn't relevant here. All hulls will purely be determined spatially
53
54
```

Quantify observations



Quantify observations



Interpret your results

Yes, fox movement tactic changes seasonally

Interpret your results

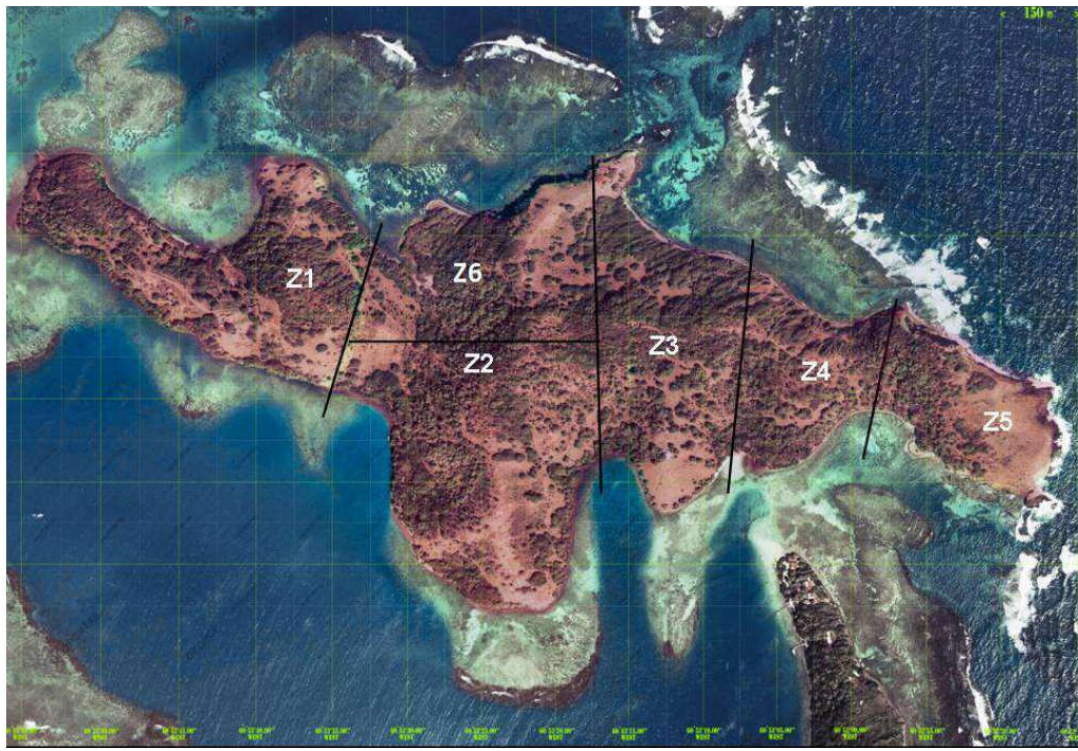
Fox movement tactic changes seasonally, **but why?**

Interpret your results

Fox movement tactic changes seasonally, **but why?**

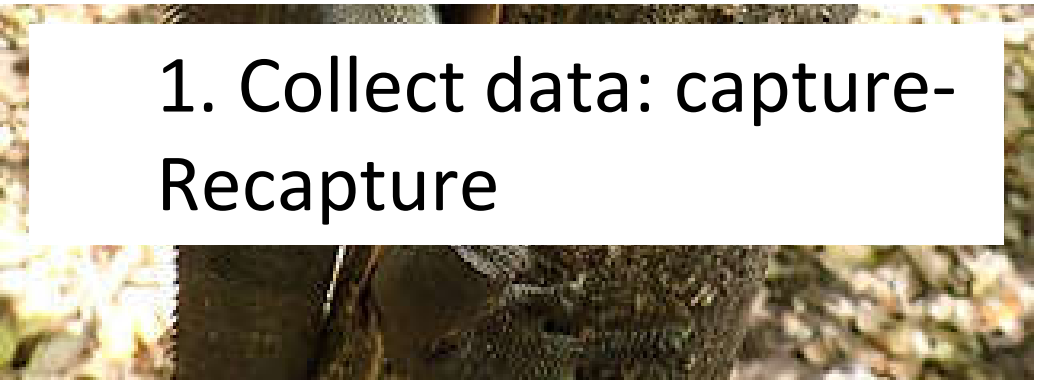
And hard to get…

So, not worth staying if you're starving!



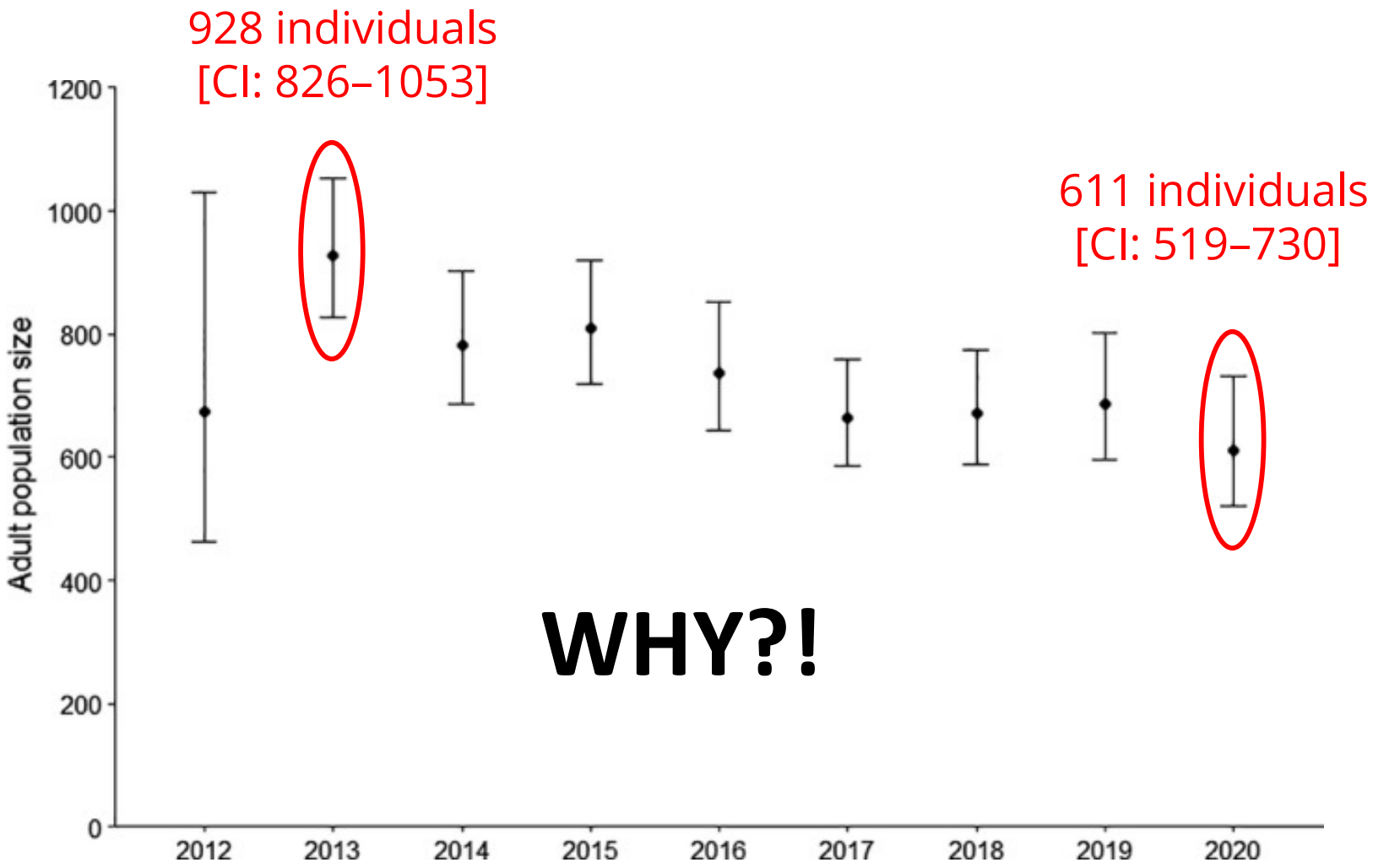
Population survey

1. Collect data: capture-Recapture



Ex.2: Managing endangered populations

Background: an endangered iguana population is declining



Ex.2: Understand a population decline and propose conservation measures

Background: an endangered iguana population is declining

Low fecundity?

Eggs not hatching?

Adult mortality?

Juvenile mortality?

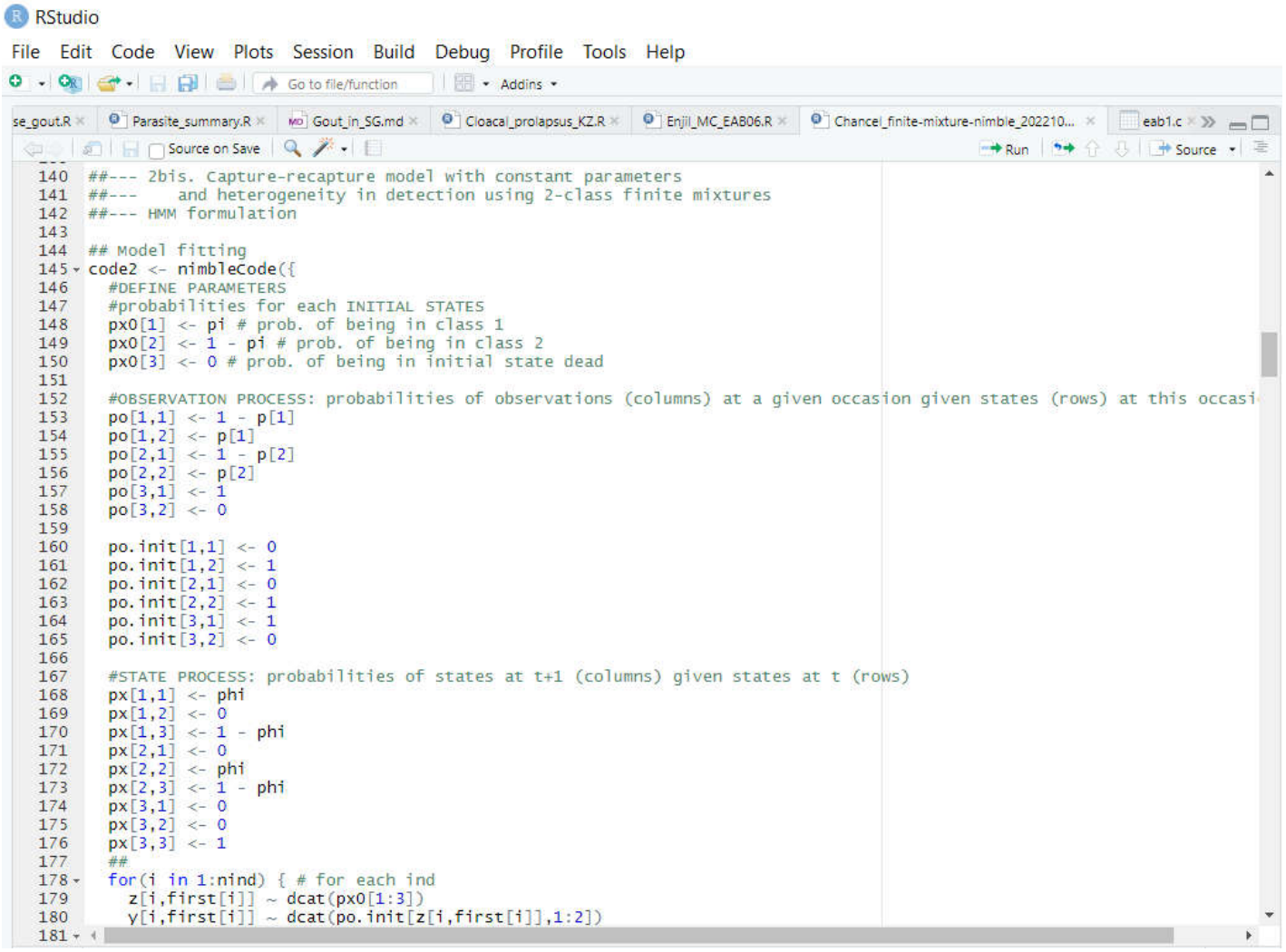
Demography analyses

1. Collect data: capture-Recapture
2. Organizing: create a capture history database

	Occasion 1	*Occasion 2*	*Occasion 3*	*Occasion 4*	*Occasion 5*
Animal 1	1	1	0	1	1
Animal 2	0	1	0	1	1
Animal 3	1	1	0	1	0

Demography analyses

1. Collect data: capture-Recapture
2. Organizing: create a capture history database
3. Analyzing: Demography models



Demography analyses

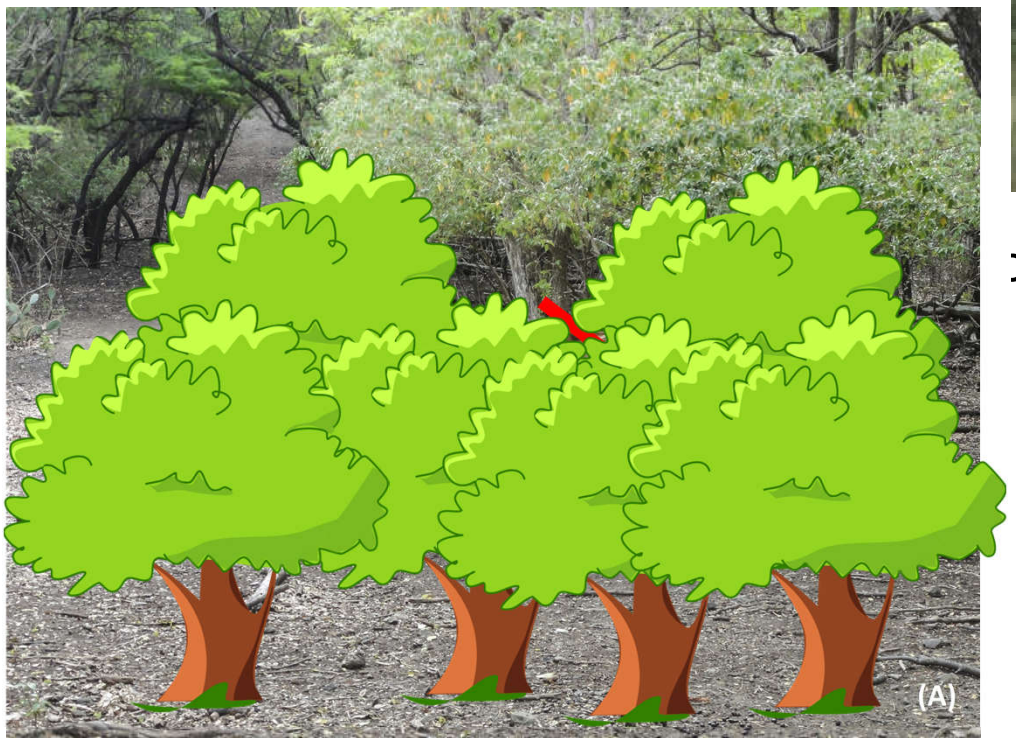
4. Interpreting results:

Adult survival = 0.85 HIGH

Recruitment = 0.09 LOW

Demography analyses

5. make decisions: improve survival of immatures



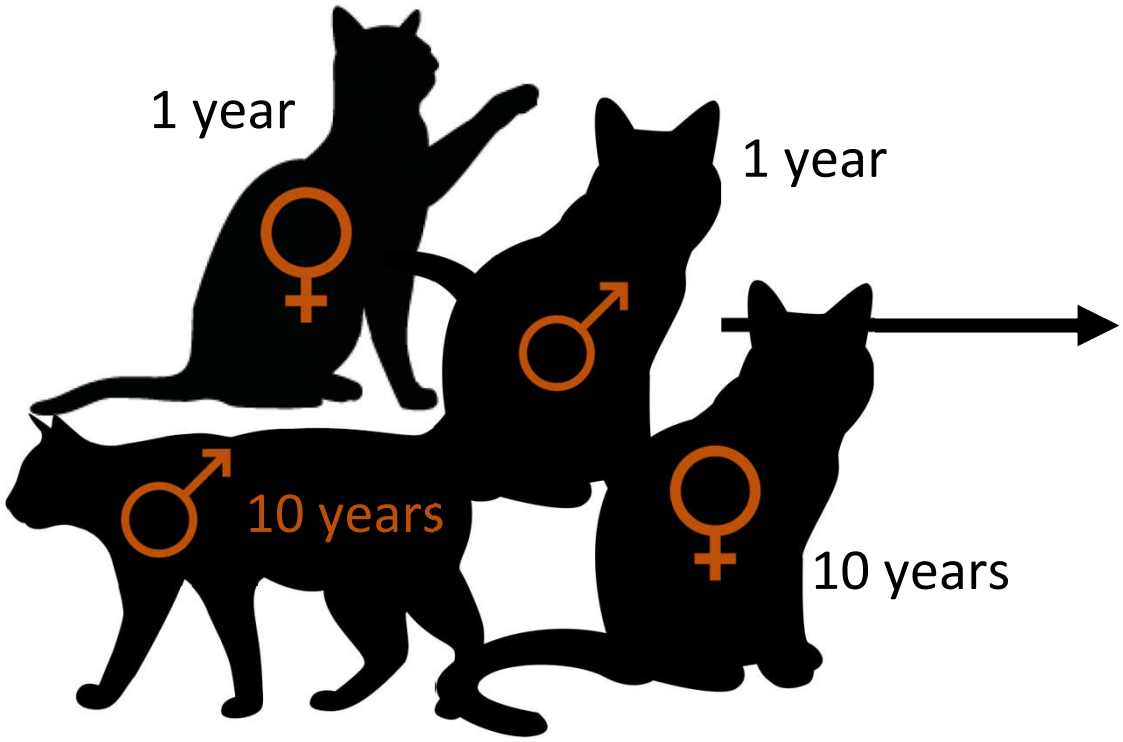
ontrol predators

Ex.3: Monitoring patient's health

Paramètres	Résultat	Unités
ALP	**100**	U/l
ALT	**123**	U/l
UREA	**0.45**	g/l
GLU	**1.18**	g/l
CRE	**13.9**	mg/l
TBIL	**0.6**	mg/l
TP	**85**	g/l
UR/C	**32.38**	

???

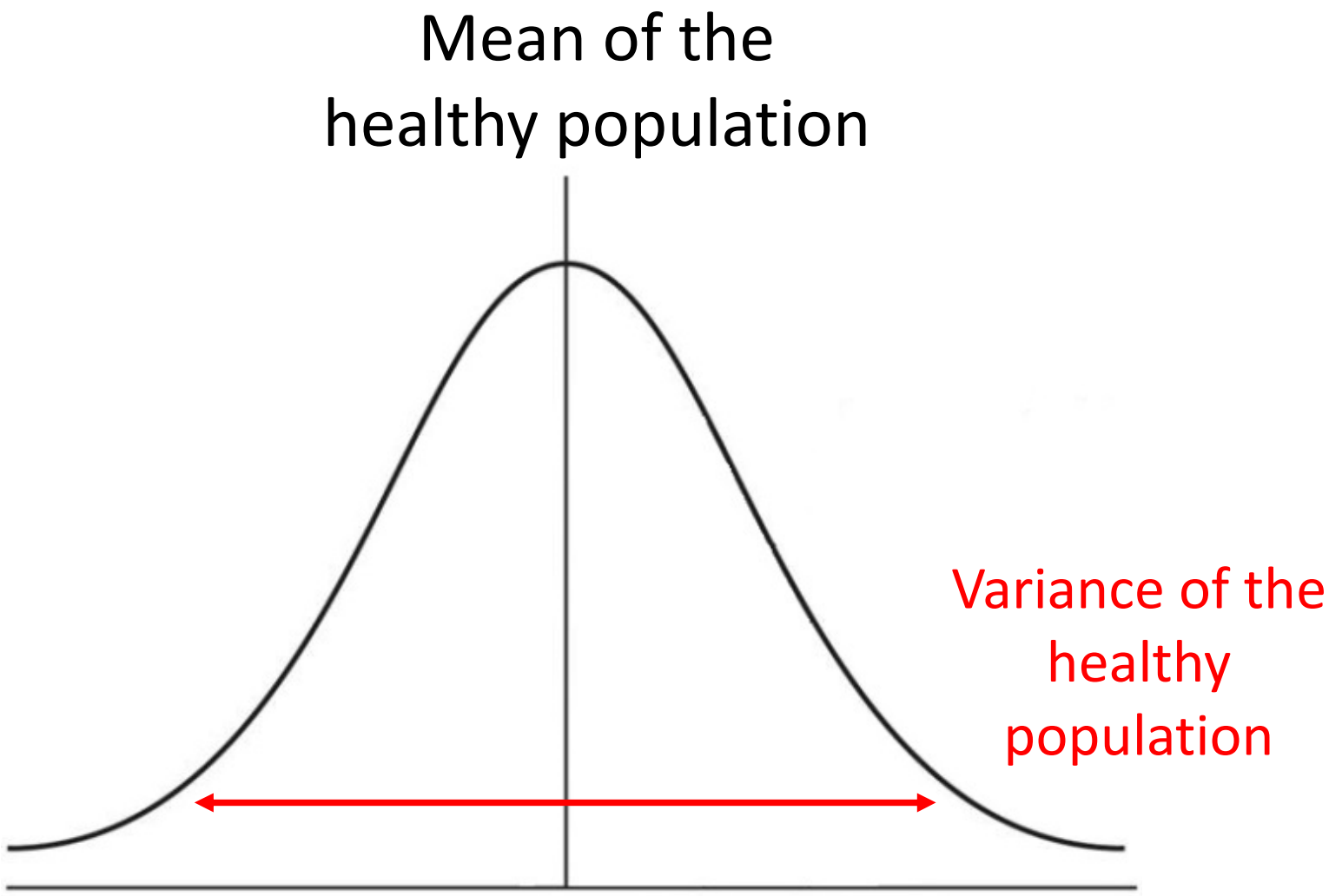
Ex.3: Monitoring patient's health



Sample healthy individuals

Collect data

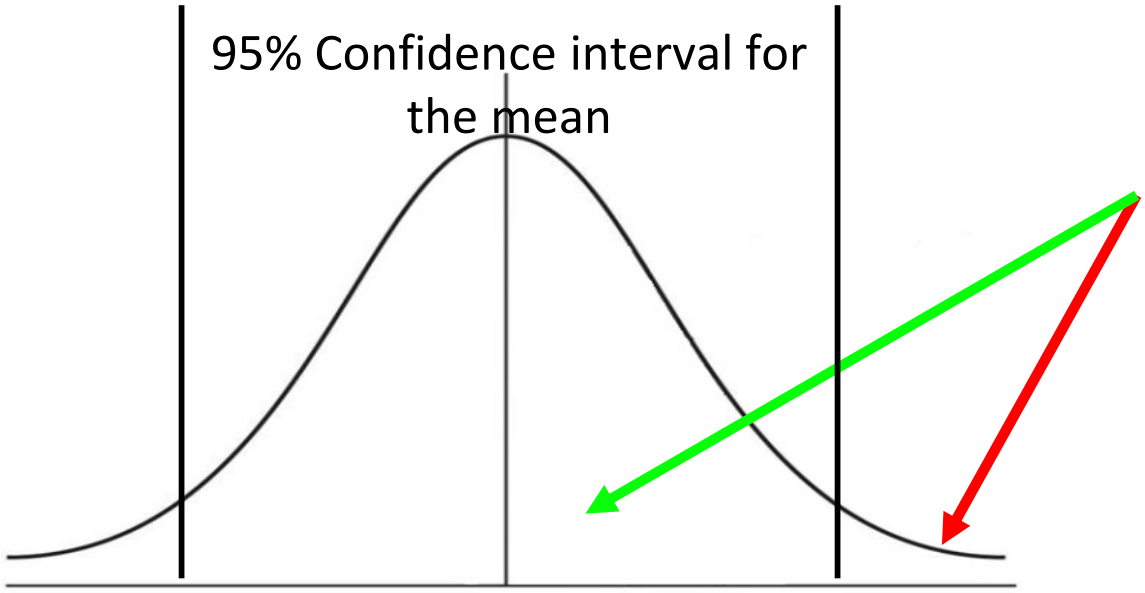
Estimate parameters of a population based on the statistics of the sample



Summarize data

Some examples: Monitoring patient's health

Paramètres	Indi	Alrm.	Résultat	Unités	Normalités	<----------N----------+>
ALP			**100**	U/l	10- 130	
ALT	+		**123**	U/l	10- 90	
UREA			**0.45**	g/l	0.19- 0.60	
GLU			**1.18**	g/l	0.60- 1.50	
CRE			**13.9**	mg/l	3.1- 14.0	
TBIL			**0.6**	mg/l	0.0- 9.9	
TP	+		**85**	g/l	58- 78	
UR/C			**32.38**		0.00- 0.00	



How different is my patient from the healthy population?

The usual steps

1. Everything starts with a QUESTION or HYPOTHESIS
(or at least it should 😉)

2. Decide WHAT data to collect and HOW to collect them

Collect, organize

Collect data

Prepare data set

Think about structure!

Enter data

Clean data

Summarize

Descriptive statistics

Plots

Analyze

Compare groups

Determine relationship between variables

The usual steps

1. Everything starts with a QU
(or at least it should 😉)

2. Decide WHAT data to collect a

Describe distributions:
Characterize the variability around central tendency

Collect, organize	Summarize	Analyze
Collect data	Descriptive statistics	Compare groups
Prepare data set	Plots	Determine relationship between variables
Think about structure!		
Enter data		
Clean data		

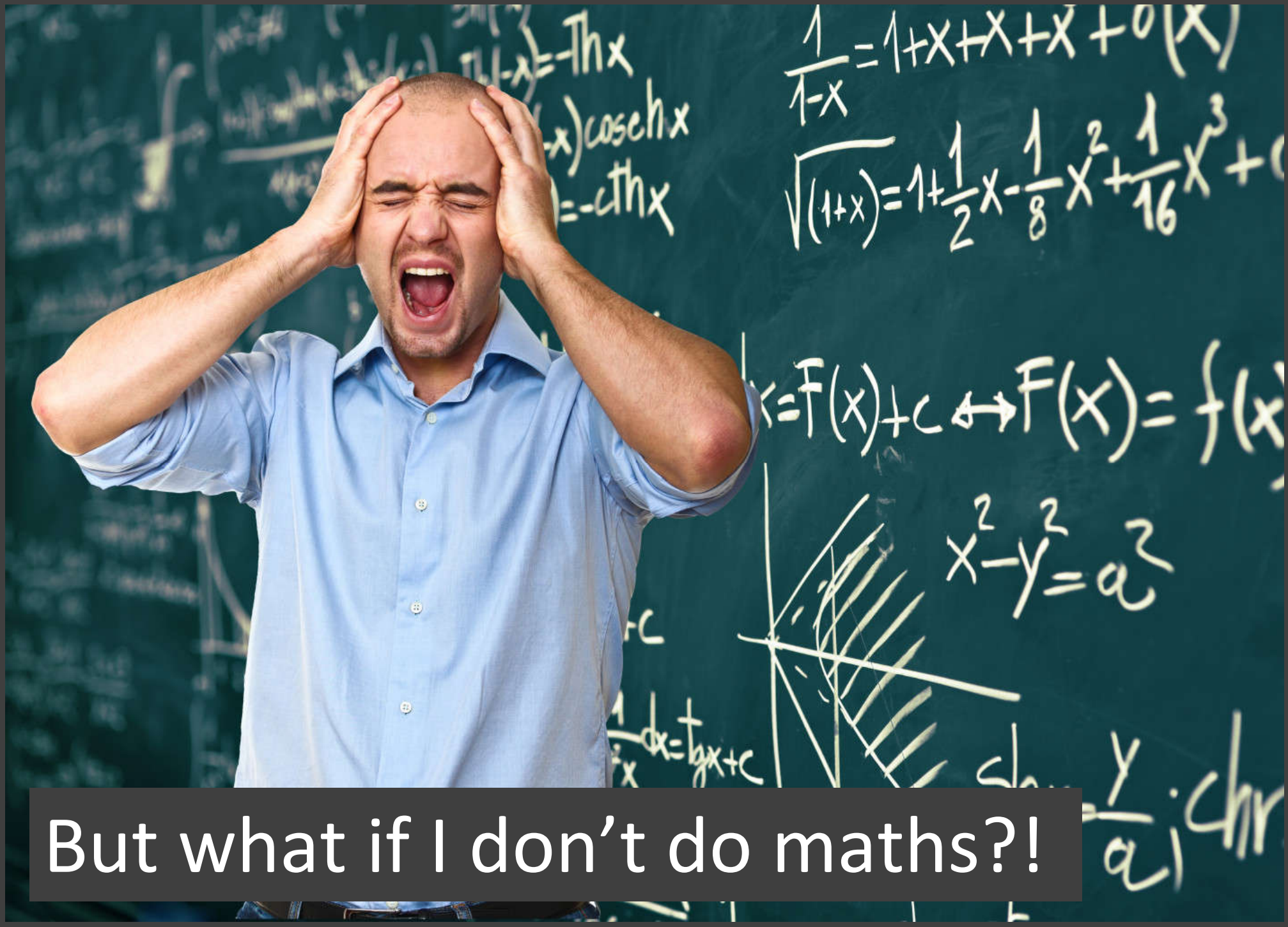
The usual steps

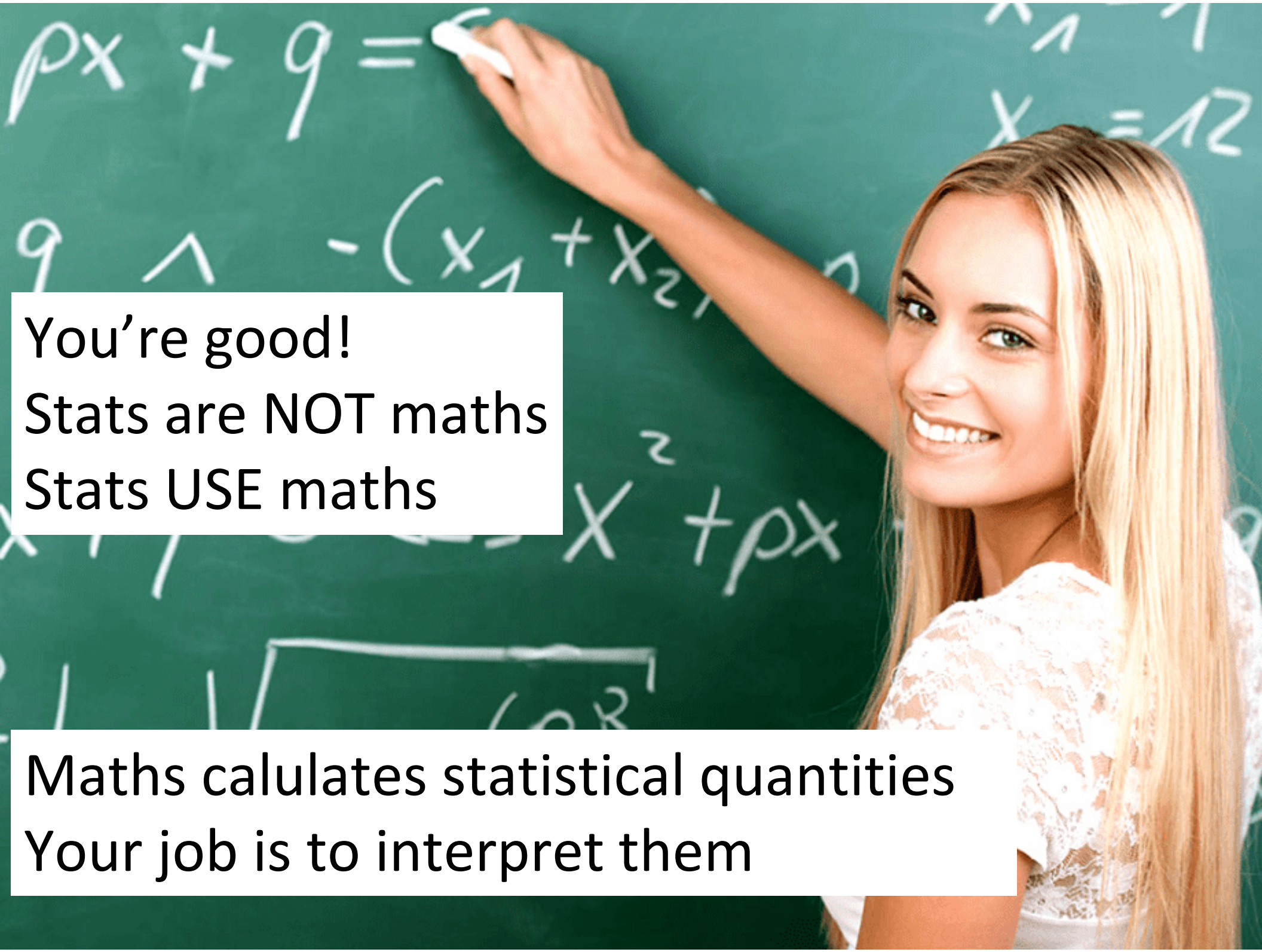
1. F… …OTHESIS

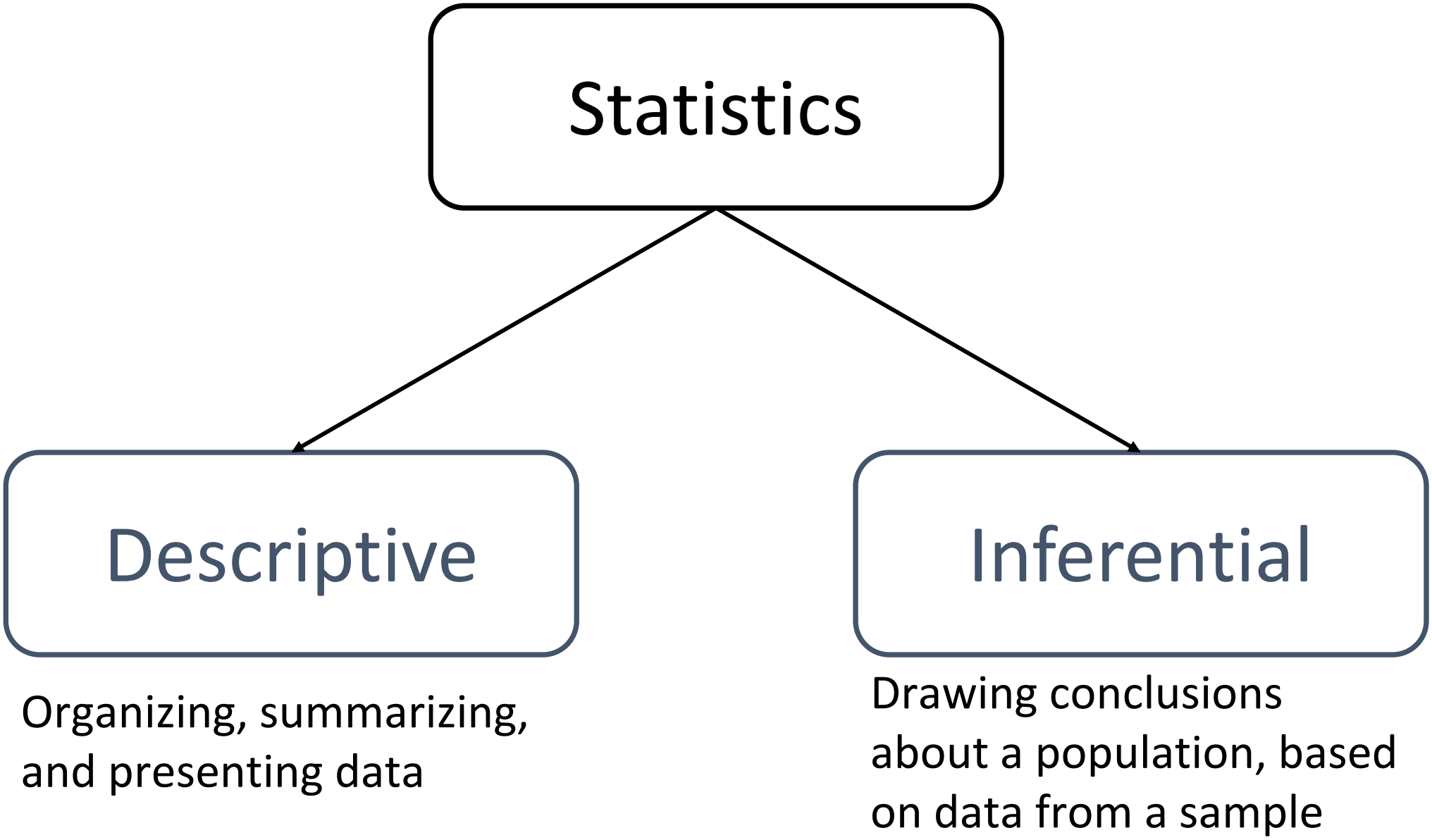
Make inferences about populations based on samples:
Use a mathematical model applied from the theory of probability

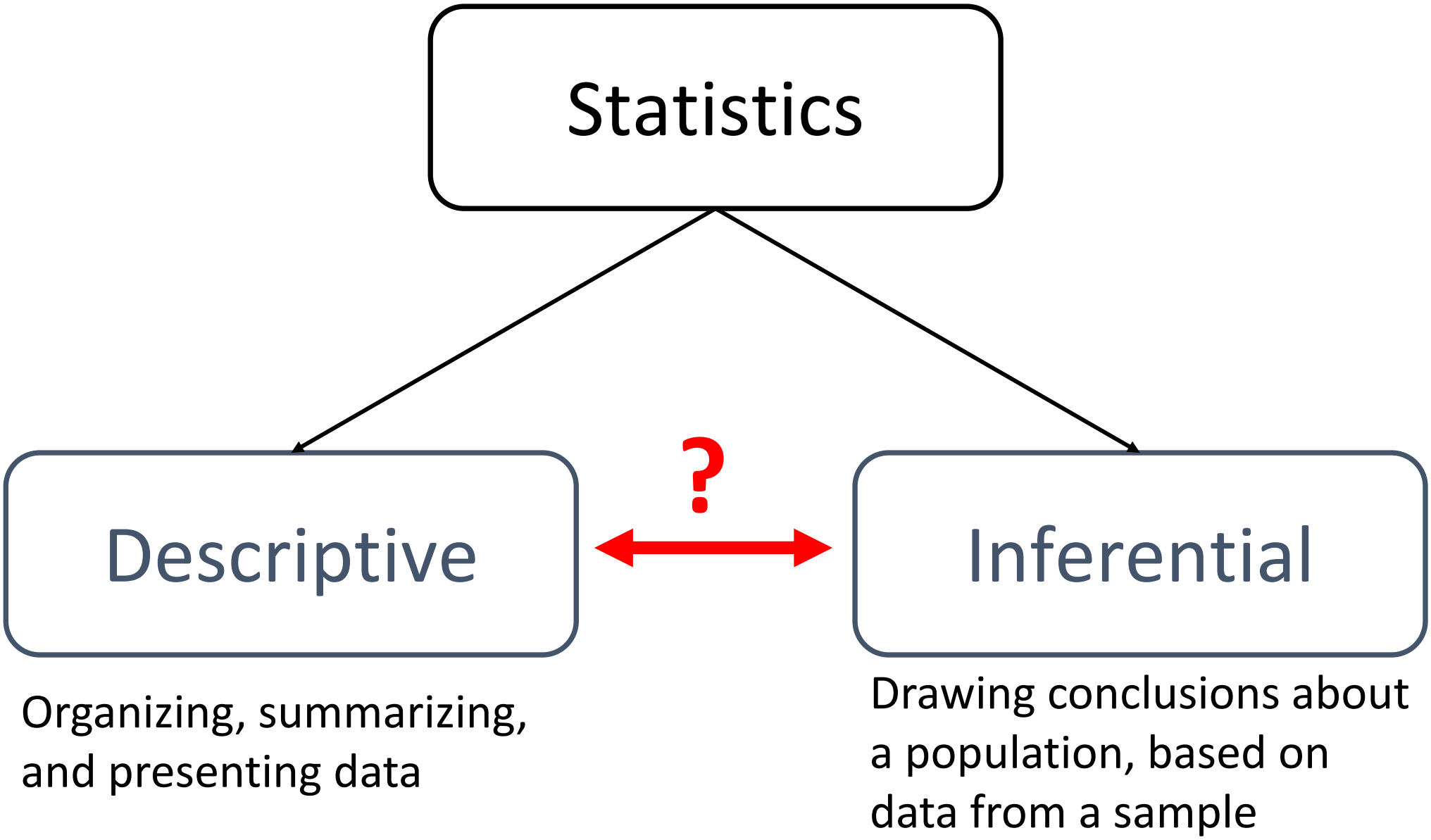
…ct them

Collect, organize	…anize	Analyze
Collect data	Descriptive statistics	Compare groups
Prepare data set	Plots	Determine relationship between variables
Think about structure!		
Enter data		
Clean data		


But what if I don’t do maths?!


You’re good!
Stats are NOT maths
Stats USE maths
Maths calulates statistical quantities
Your job is to interpret them


Statistics
Descriptive
Inferential
Organizing, summarizing, and presenting data
Drawing conclusions about a population, based on data from a sample


Statistics
Descriptive
?
Inferential
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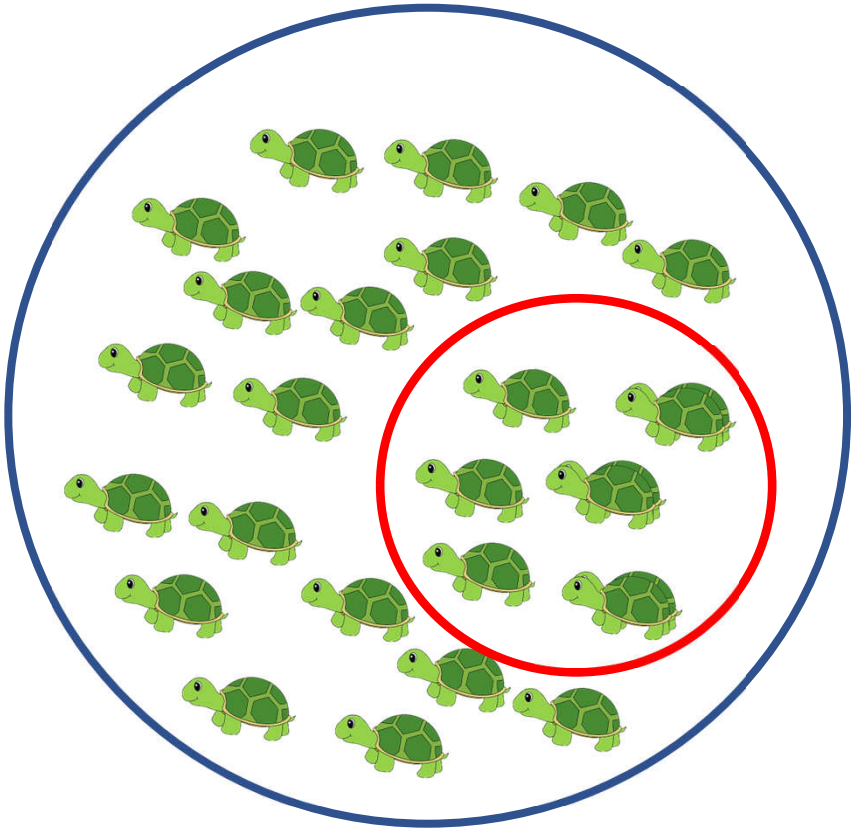
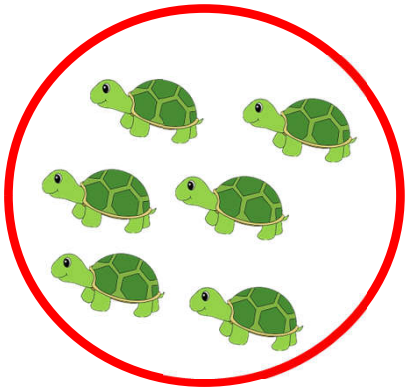
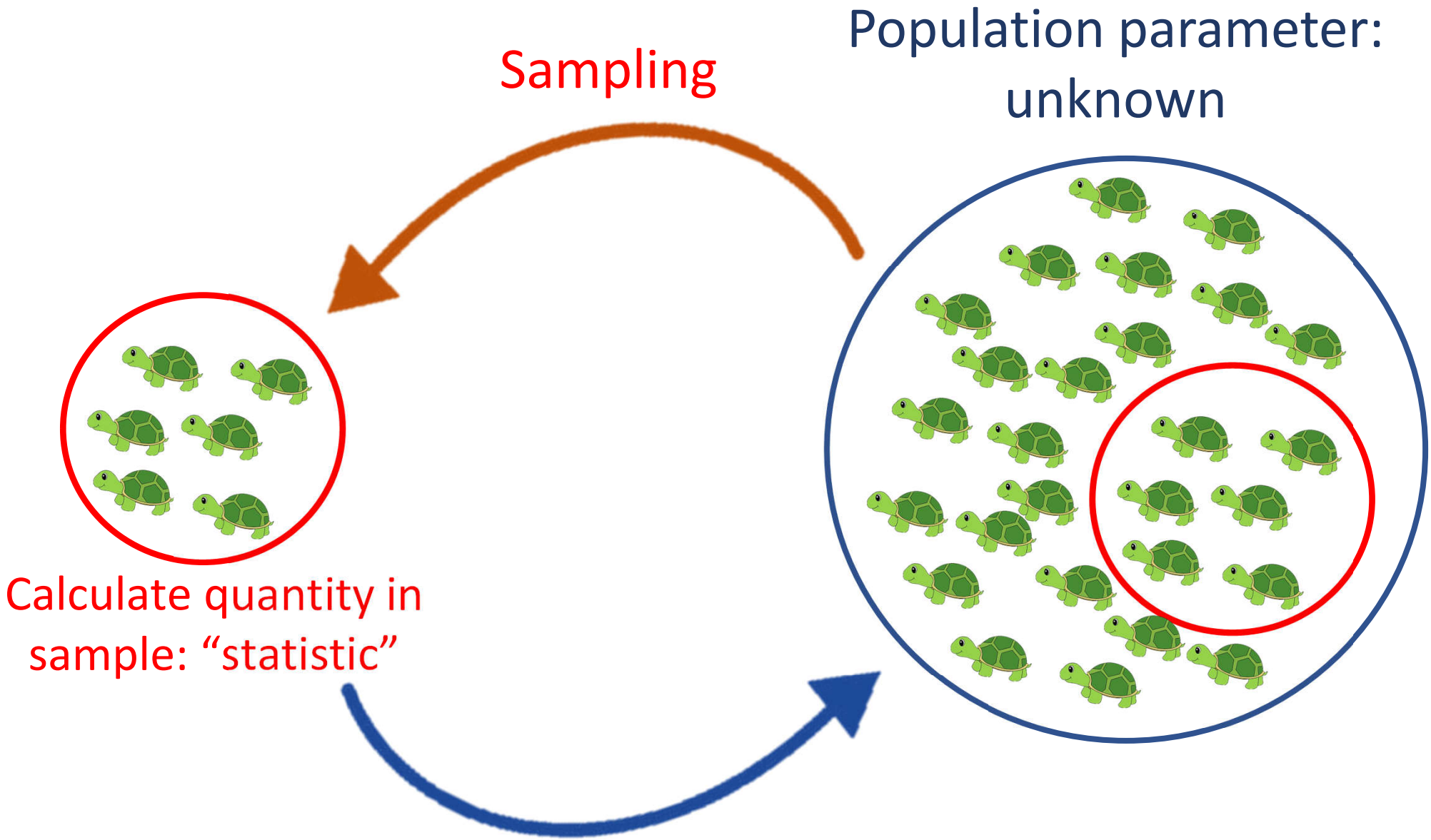


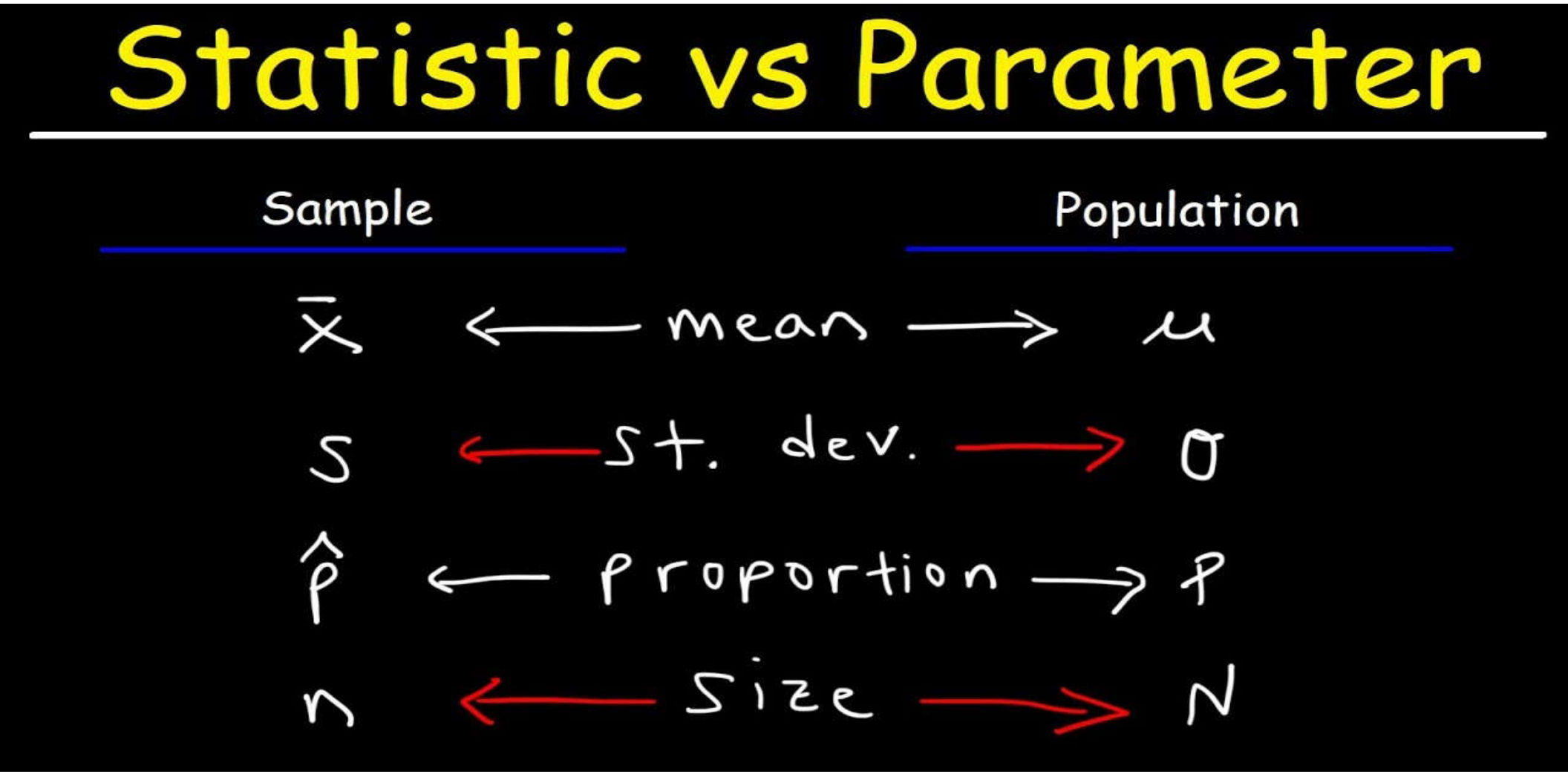
Population: impossible to observe all outcomes

Sample: n individuals independently obtained and characteristic of your population



Your data


Sampling
Population parameter: unknown
Calculate quantity in sample: “statistic”
Make inferences: approximate true population values with estimators



A note on semantics:

- Statistic describes a sample
- Parameter describes a population

A note on semantics

Descriptive statistics

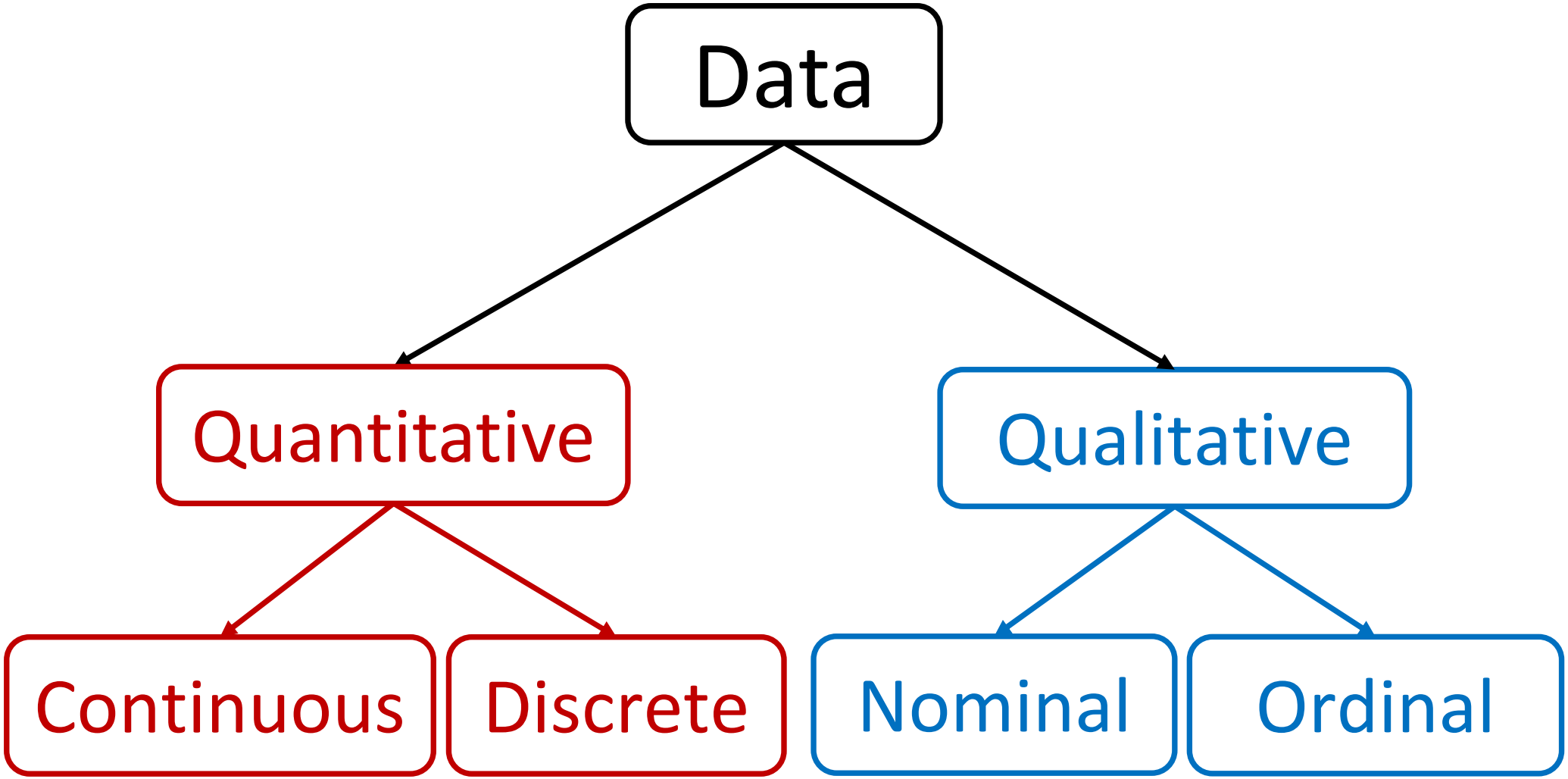
Learning objectives:

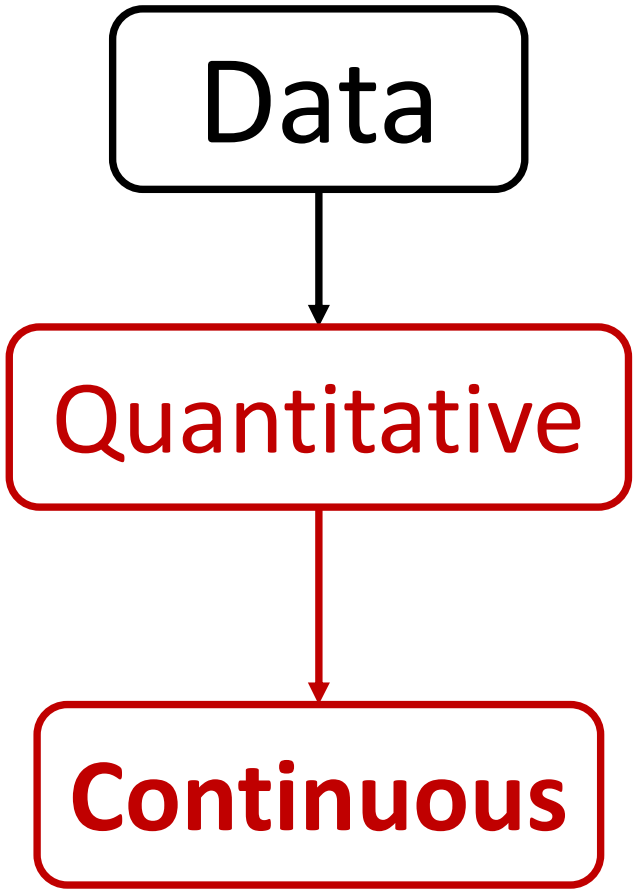
- Define descriptive statistics
- Different data types
- Measure **central tendency**
- Measure **variability**
- Define variable

Descriptive statistics

Measure quantities of statistical populations that summarise or describe an aspect of the population

No generalization beyond your data

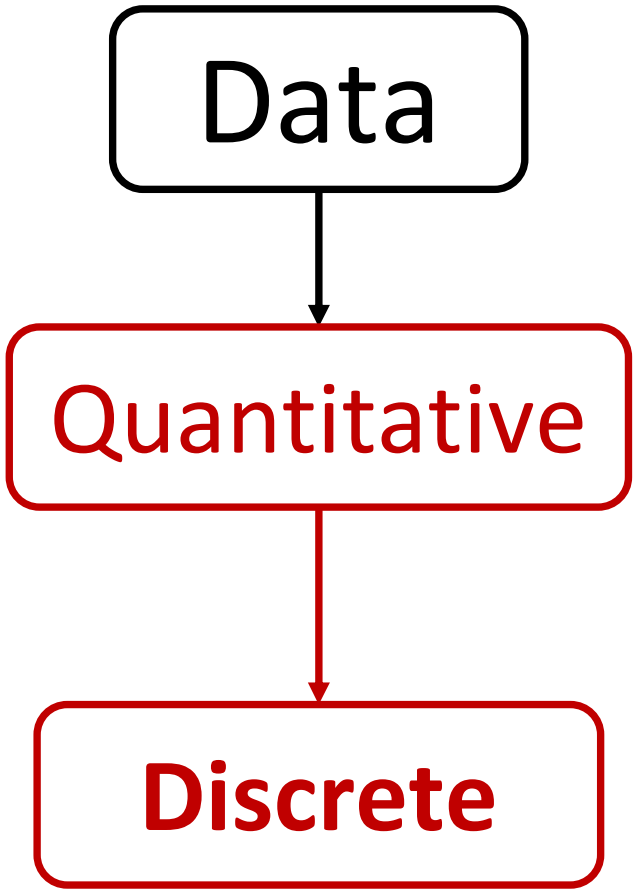

Data
Quantitative
Qualitative
Continuous
Discrete
Nominal
Ordinal



- Theoretically: **infinite** number of values within a range
- In practice: limited by measurement accuracy

Ex.:

- Wingspan
- Body mass
- Animal growth
- Skull length
- precipitation



- **Limited** number of values within a range
- Often but not always integers

Ex.:

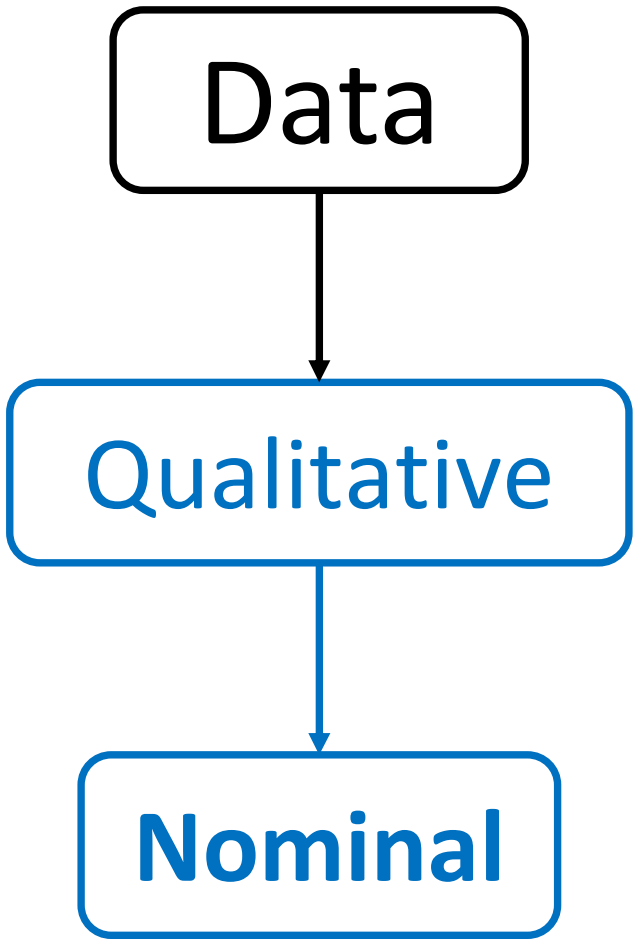
- Number of rain days in a month
- Number of viable chick per clutch
- Number of dens occupied by red foxes

Continuous vs discrete

The distinction can be blurred:

- # of cells per ml blood: integer therefore discrete, but thousands of cells so behave as continuous

- Distance is continuous, but if you measure flushing distance of geese to the nearest 5m it will behave as discrete



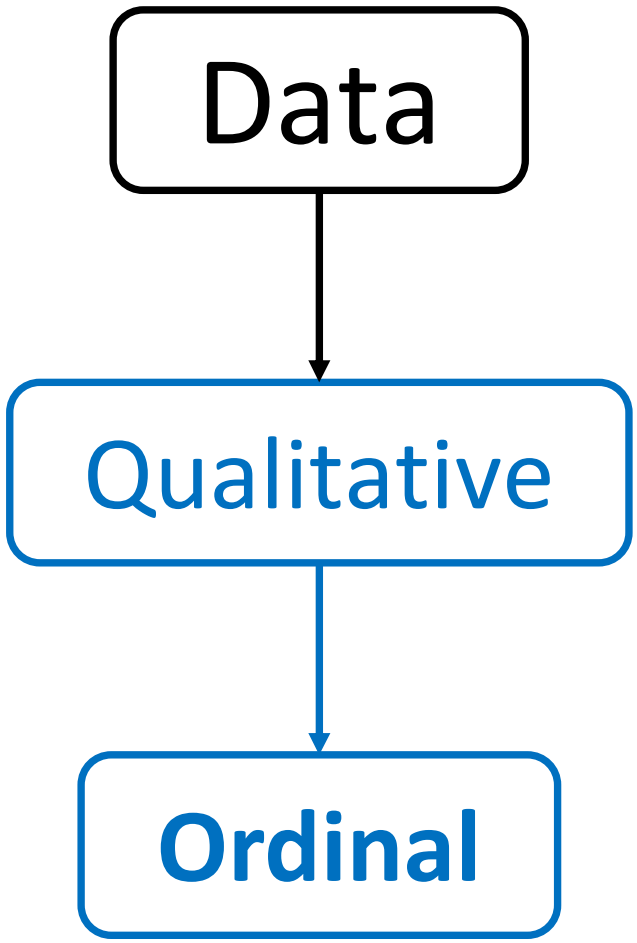
- Partition data into classes
- NOT ordered
- Also called factors with levels
- Special case: binary data
- Also called categorical data

Ex.:

- Fur color (black, grey, spotted)
- Species (lynx, wolf, fox)

Ex. binary:

- Occurrence (present, absent)
- Sex (Male, Female)



- Partition data into classes
- Intrinsically ordered
- Also called “Ranked” data

Ex.:

- Body condition index (High, medium, low)
- Index of growth rate (slow, medium, fast)
- Timing of molt (before, during after migration)

One more type you will likely need…

Derived or computed data

- Calculated from 2 (or more) raw data:
  - Ratio
  - Proportion
  - Percentage
  - rate

Derived or computed data

- Loss of accuracy (rounding)
- Loss of information

5/10 = 0.5

500/1000 = 0.5

But are they the same?

2% of my 50 animals are sick…

But, really, that is only 1 animal

Derived or computed data

- Awkward to model (often bounded – ex. Proportion: [0-1], percentage: 0-100%)

- Yet we often use derived data in biology: we'll see tricks to deal with them later

Describe your data with numbers

- Central tendency and spread
- What is a typical value of my dataset?
- How scattered is my data?
- How do my data typically differ from the mean?
- How skewed is my data?

Quantitative data

Quantitative data
1. Central tendency

Describing and summarizing the data – central tendency

- The arithmetic mean or average:
  - by far the most commonly used
  - sample $\overline{X} = \frac{\sum X}{N}$
  - μ for population

central tendency

- The median:
  - The next most common measure
  - Middle value of ranked data
  - I will not scare you off with an equation ;)

central tendency

- The geometric mean:
  - Good for right-skewed datasets (example lognormal data)
  - $\mathrm{GeometricMean} = \sqrt[n]{x_1 x_2 \ldots x_n}$
  - Always smaller than the arithmetic mean

central tendency

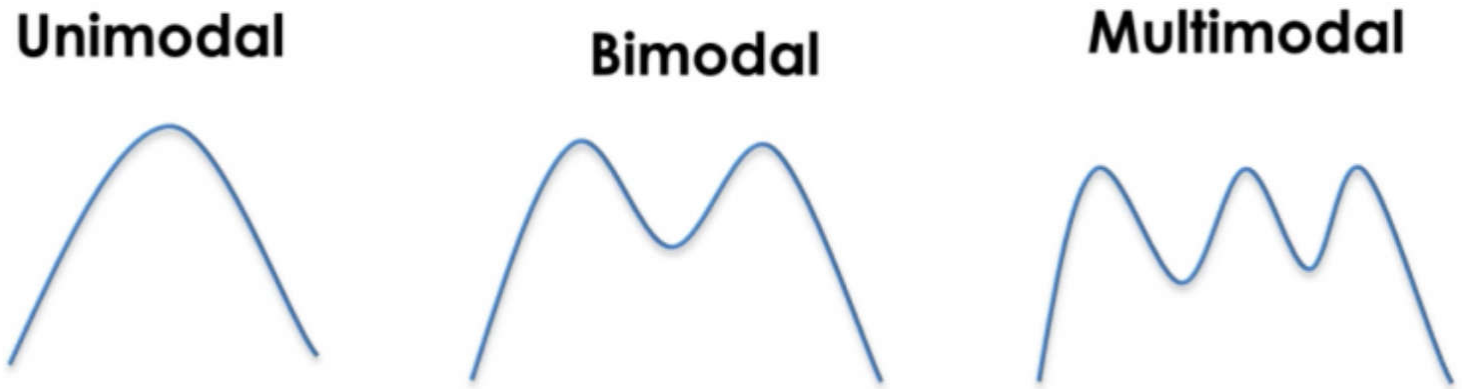
- The harmonic mean:
  - $$\text{Harmonic Mean Formula} = \frac{n}{\left(\frac{1}{X_1} + \frac{1}{X_2} + \frac{1}{X_3} \ldots\ldots\ldots \frac{1}{X_n}\right)}$$
  - Hence, impossible to use if some x = 0
  - Rarely used
  - But gives higher weight to smaller values than other means

central tendency

- The weighted mean:
  - Higher weight to certain values
  - weighted mean = x_1*weight$_1$ + x_2*weight$_2$ + … + x_n*weight$_n$
  - Used when some values are more likely or more important than others

central tendency

- The Mode:
  - The most frequent value of the dataset
  - Can be used with categorical data
  - Useful with very large datasets or data with low accuracy
  - Some datasets don’t have a mode, while others have >1 (multimodal)

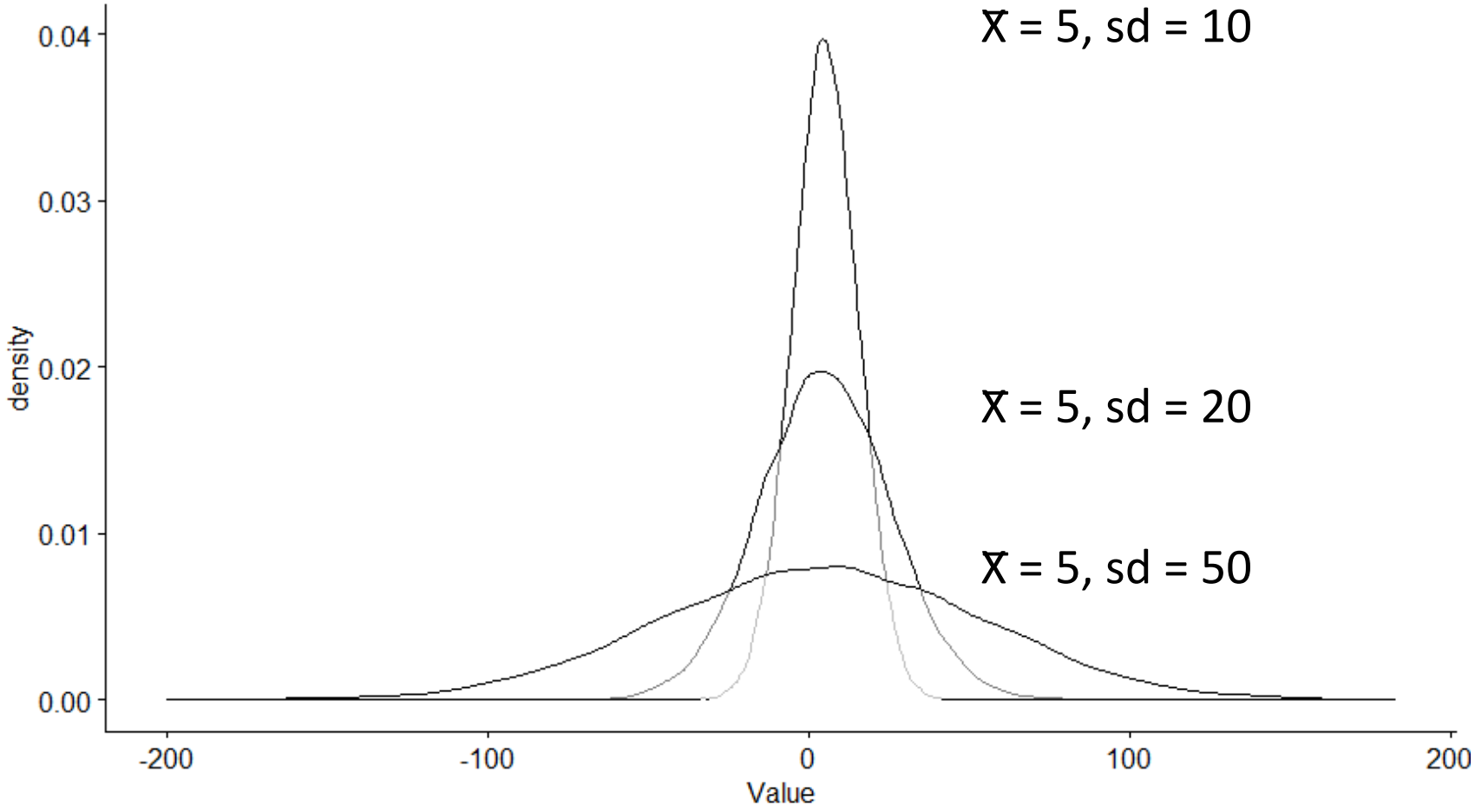



Intermission

Quantitative data
1. Variability

Describing and summarizing the data – variability

- Spread, dispersion



Describing and summarizing the data – variability

- Many ways to characterize dispersion, but choose according to:
  - Data
  - Central tendency measure (ex. Mean)
  - Your question

Variability

- Range:
  - The simplest one
  - [min. value – max. value]
  - Sensitive to outliers!

Variability

- Variance
  - Estimate s^2 of the true variance of the population (σ^2)
  - $$s^2 = \frac{\sum (x - \bar{x})^2}{n - 1}$$
  - Rarely used as a descriptive stat
- Standard deviation (SD)
  - Estimate (s) of the true standard deviation (σ)
  - Square root of Variance
  - Often used, but not ideal to compare different datasets

Variability

- Standard Error (SE):
  - Commonly used
  - $$SE = \frac{\sigma}{\sqrt{n}}$$
  - If you compare samples, confidence intervals are better
- Confidence intervals (CI):
  - The most useful measure of dispersion
  - You can customize (90% CI, 95% CI) depending on the needs
  - 95% CI of the mean: “you are 95% sure that the interval contains the true mean of the population”
  - Measure of confidence

Variability

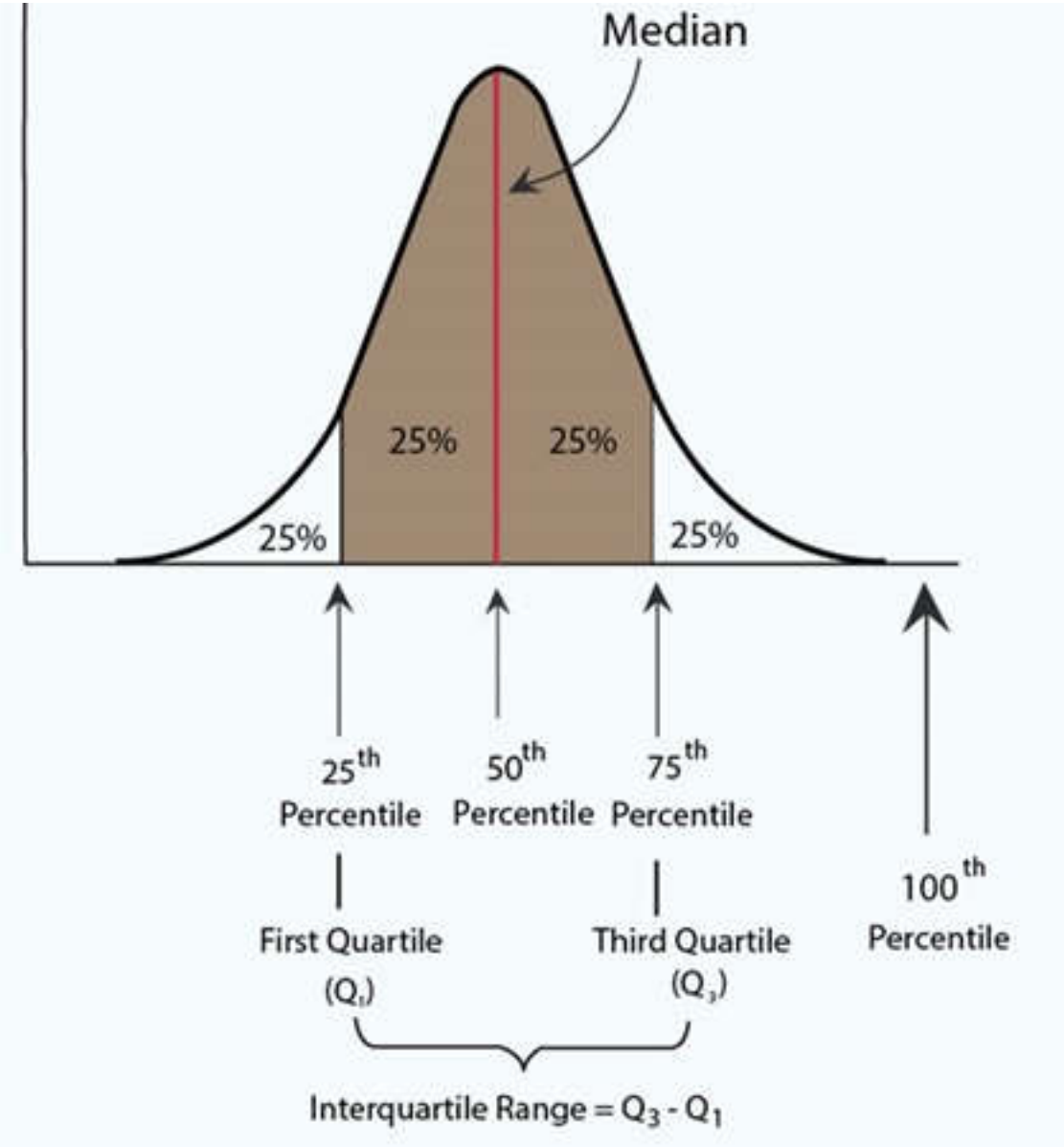
- Coefficient of variation (CV):
  - Widely used in labs to assess the precision and repeatability of an assay
  - $$CV = \frac{\sigma}{|\mu|} \quad *100$$
  - Relative measure of variation

Variability

- Interquartile Range (IQR):
  - Non-parametric measure of dispersion
  - Works with ranked data
  - Use it if you describe the central tendency with a median
  - Unaffected by outliers or sample size: so more useful than the range on that aspect!
  - Useful to identify the skewness of a dataset
  - Difference between 75^{th} and 25^{th} percentile of the data

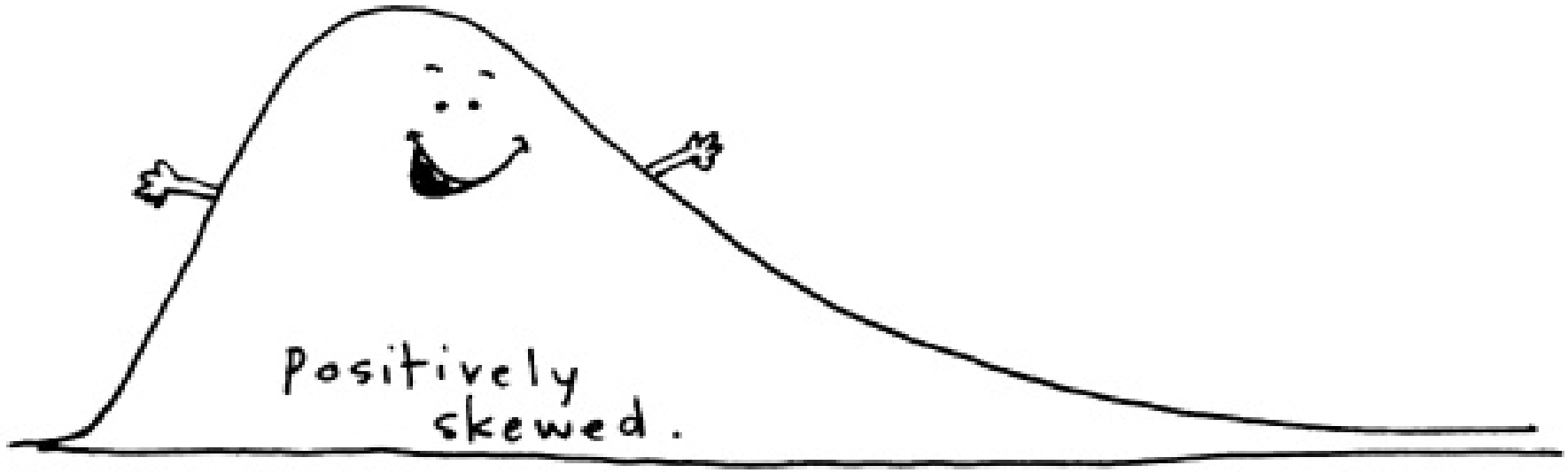
Variability

- Interquartile Range:



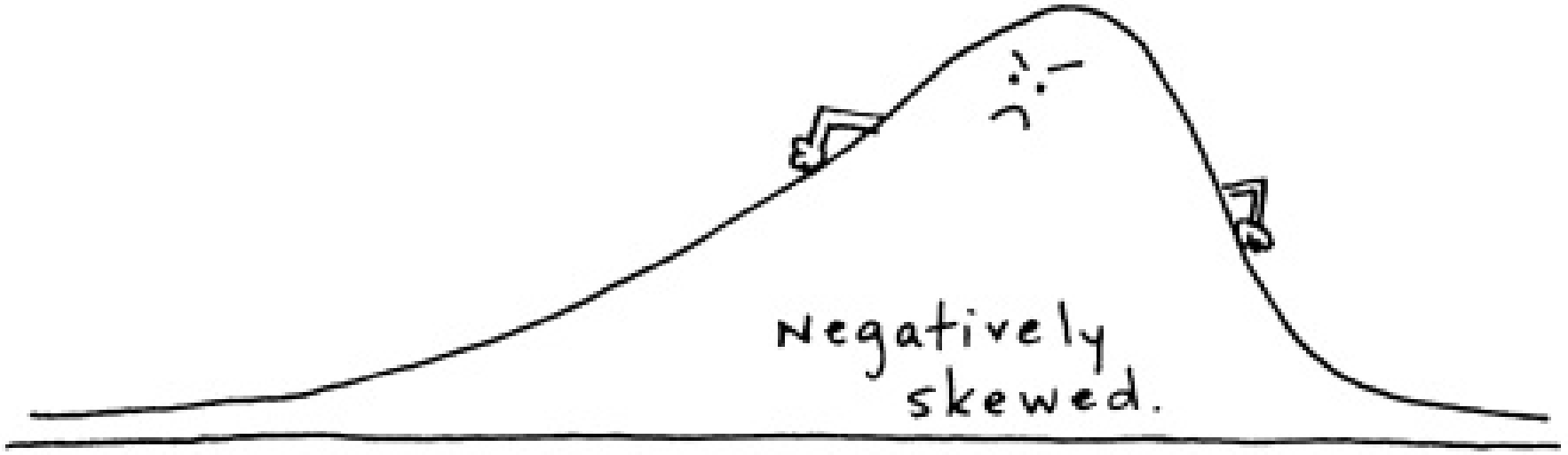
Describing and summarizing the data – other summary statistics

- Skewness: symmetry of the dataset
  - Perfect symmetry: skewness = 0
  - Tail to the right (right-skewed): skewness>0



Describing and summarizing the data – other summary statistics

- Skewness: symmetry of the dataset
  - Tail to the left (left-skewed): skewness<0



Describing and summarizing the data – other summary statistics

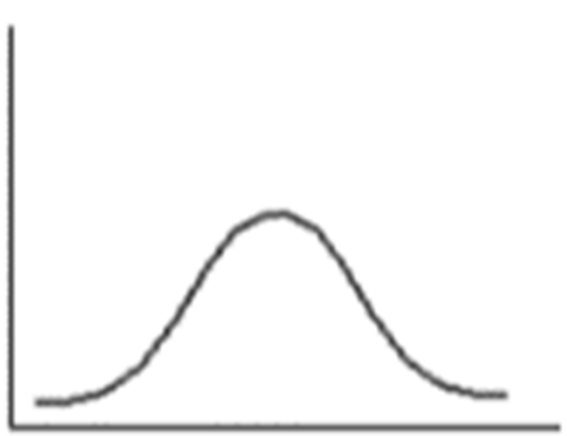
- Skewness: symmetry of the dataset
  - When the dataset is skewed: mean closer to the tail than the median (remember the lognormal R example)
  - **Not really useful to calculate skewness for small data set (i.e., n<30)**

Describing and summarizing the data – other summary statistics

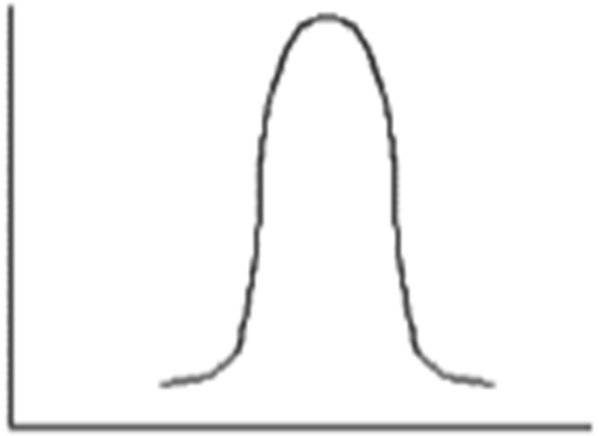
- Kurtosis: flatness of the data
  - Always in comparison to normal distribution
  - Only meaningful for large dataset
  - 2 big words: *leptokurtic* and *platykurtic*

Describing and summarizing the data – other summary statistics

- Kurtosis: flatness of the data
  - *Leptokurtic:* data more concentrated around the mean



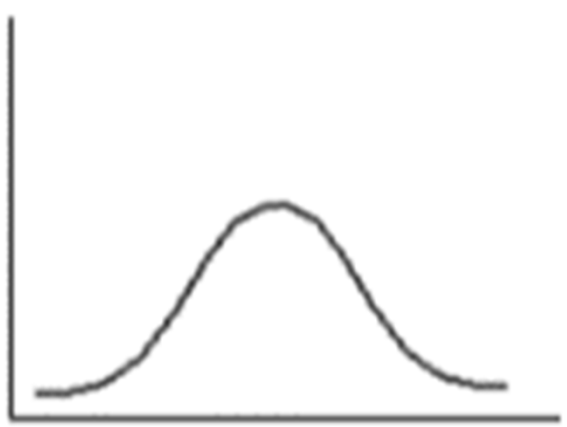
Normal curve



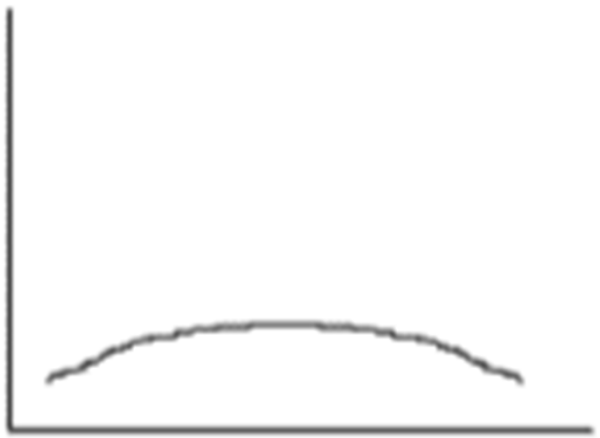
Leptokurtic curve

Describing and summarizing the data – other summary statistics

- Kurtosis: flatness of the data
  - *Platykurtic:* thinner tails than Normal distribution, so less extreme values



Normal curve



Platykurtic curve


Intermission

Qualitative data

Describing categorical data

- Frequency
- Proportions and percentages
- Marginals (total counts across columns or rows in contingency tables)

- Coefficient of unalikeability (how often observations differ from each other)

- Visualization (which we'll see in a future workshop)

Ordinal categorical data

- Central tendency:
  - Median
  - Mode

The mean assumes equal spacing between categories, so cannot be used.

- Variability:
  - Range
  - Variation ratio (the simplest)

Standard deviation, Standard error and variance all depend on the mean, and thus cannot be used.

Nominal categorical data

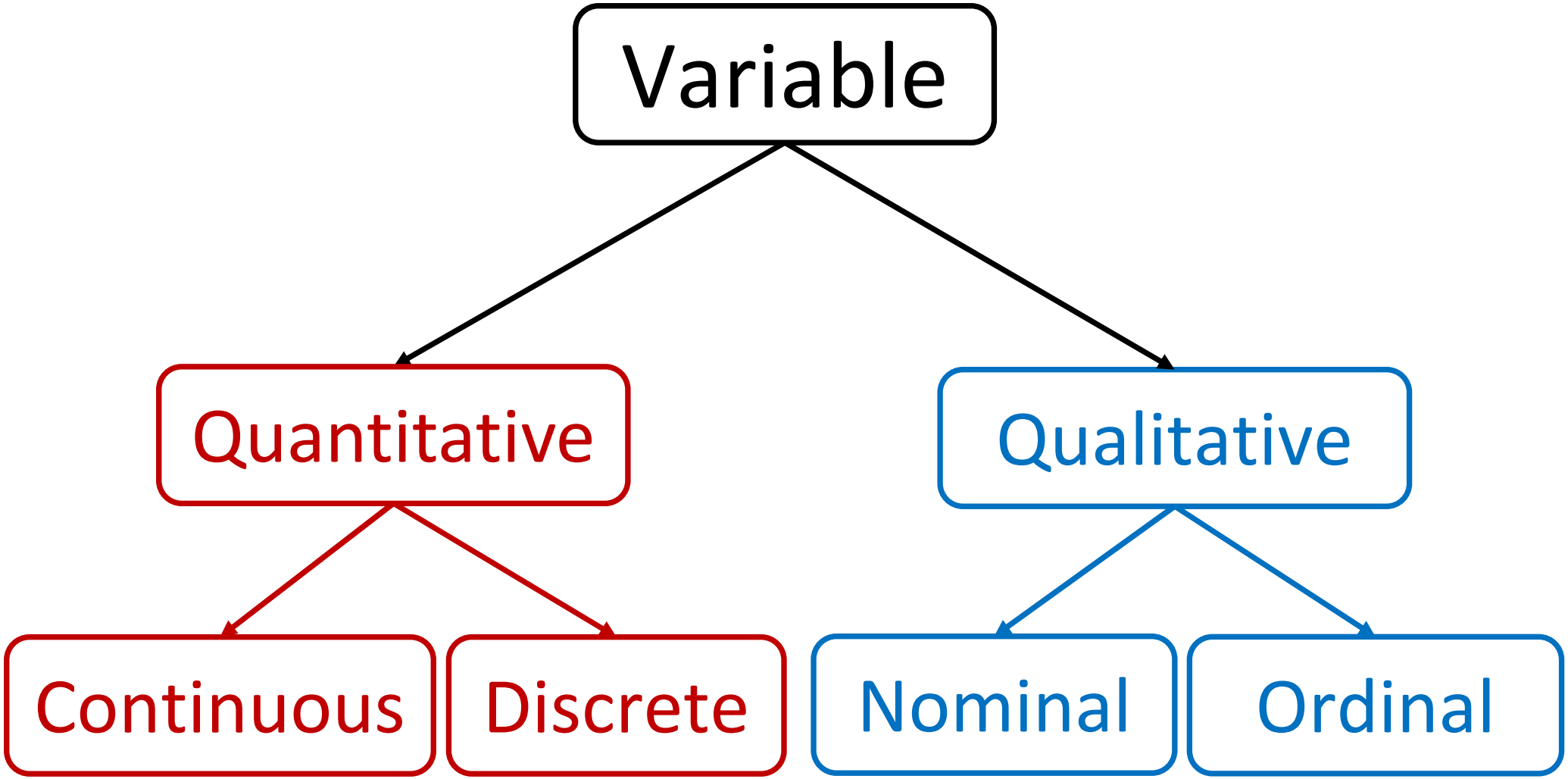
- Central tendency:
  - Mode is the most common

- Spread:
  - Rarely reported
  - > 50 indices of qualitative variation
  - Variation ratio (the simplest)


Intermission

What is a variable?

- Any property that you can **measure** or **control**
- Likely changes between objects
- **Data** results from observations or measurements you make on one or more variables


Variable
Quantitative
Qualitative
Continuous
Discrete
Nominal
Ordinal

Choosing the right variable

- In hypothesis testing the choice of variable is key

Examples:

- You're interested in occurrence of a bird per site

  Presence/absence of bird in each site

  number of bird seen per site

- You want to know bird abundance by habitats, but some habitats are more present than others

  number of birds per unit habitat area

A reminder on semantics

Accuracy vs Precision

A reminder on semantics

Precision

High Low

High

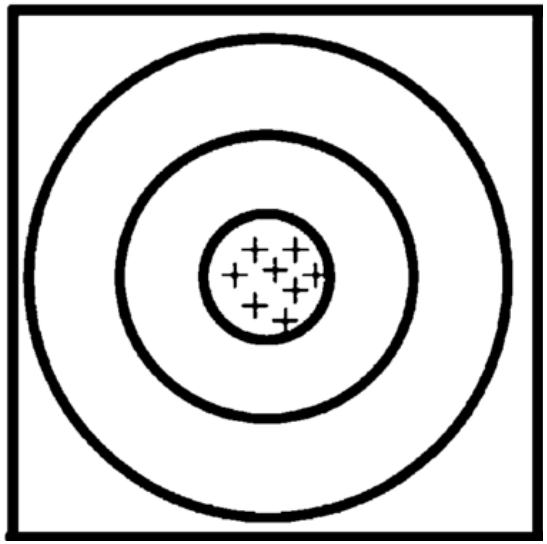
Accuracy

Low

A reminder on semantics

Precision

High Low



High

Accuracy

Low

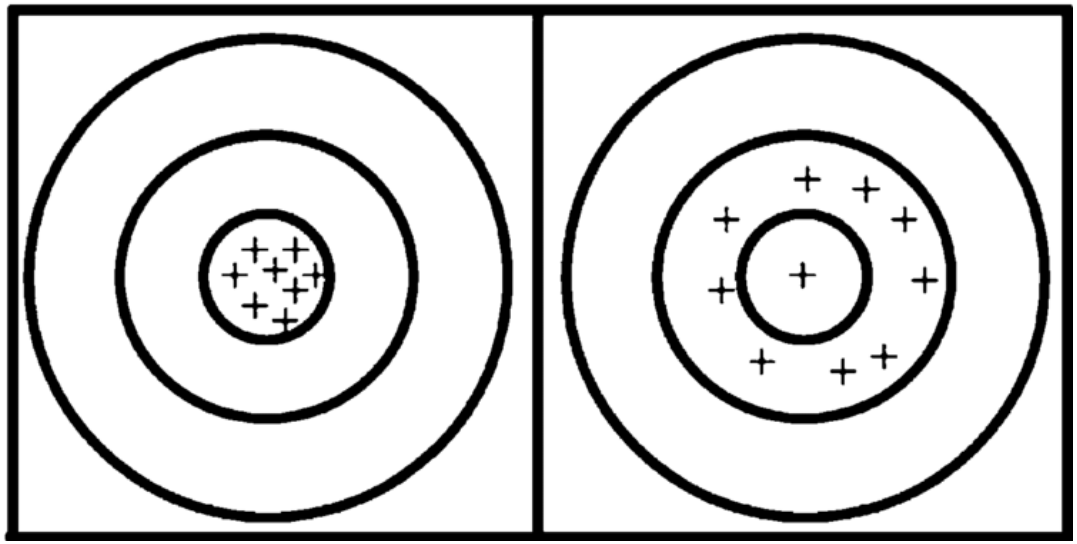
A reminder on semantics

Precision

High Low

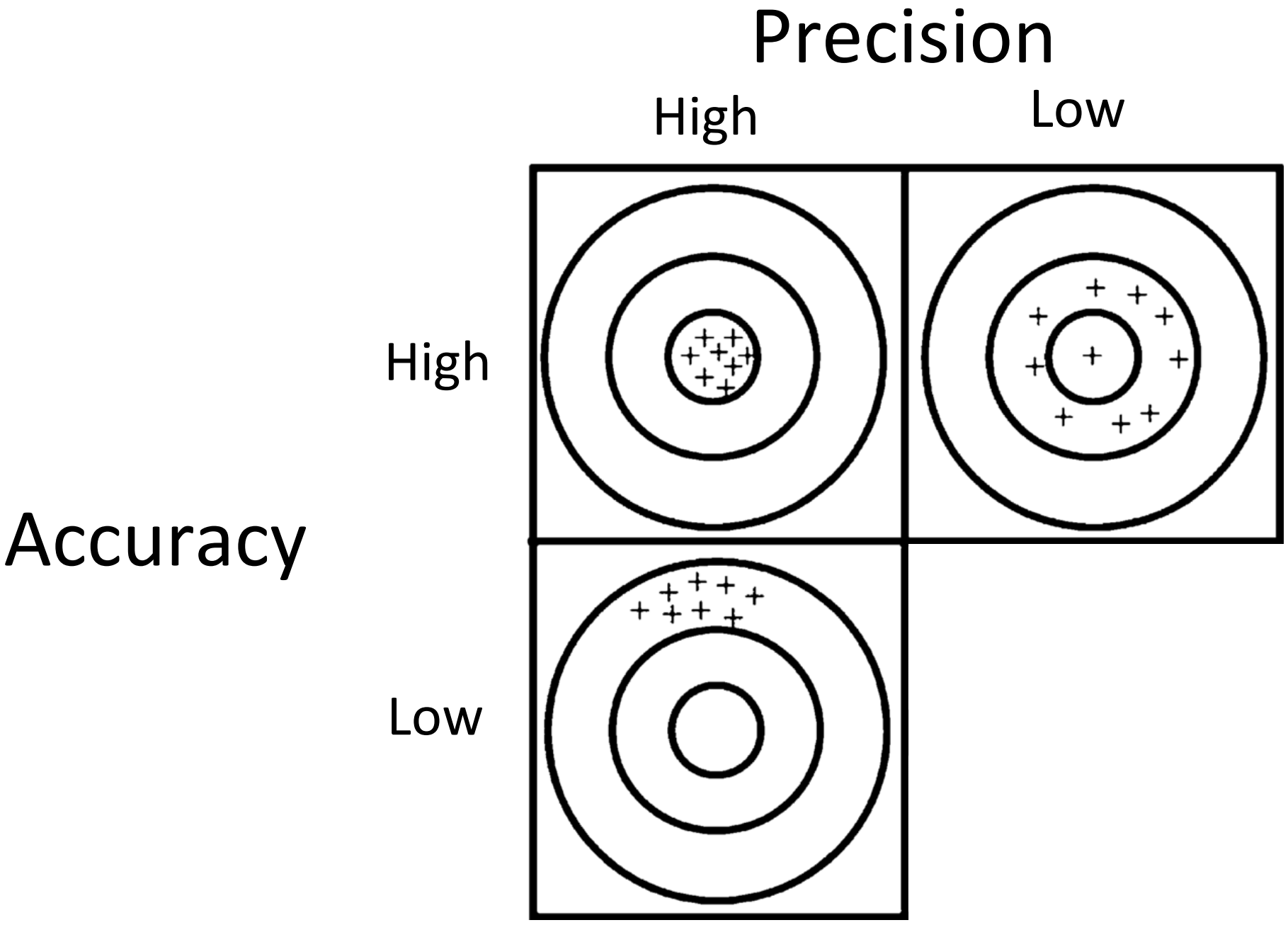
Accuracy

High

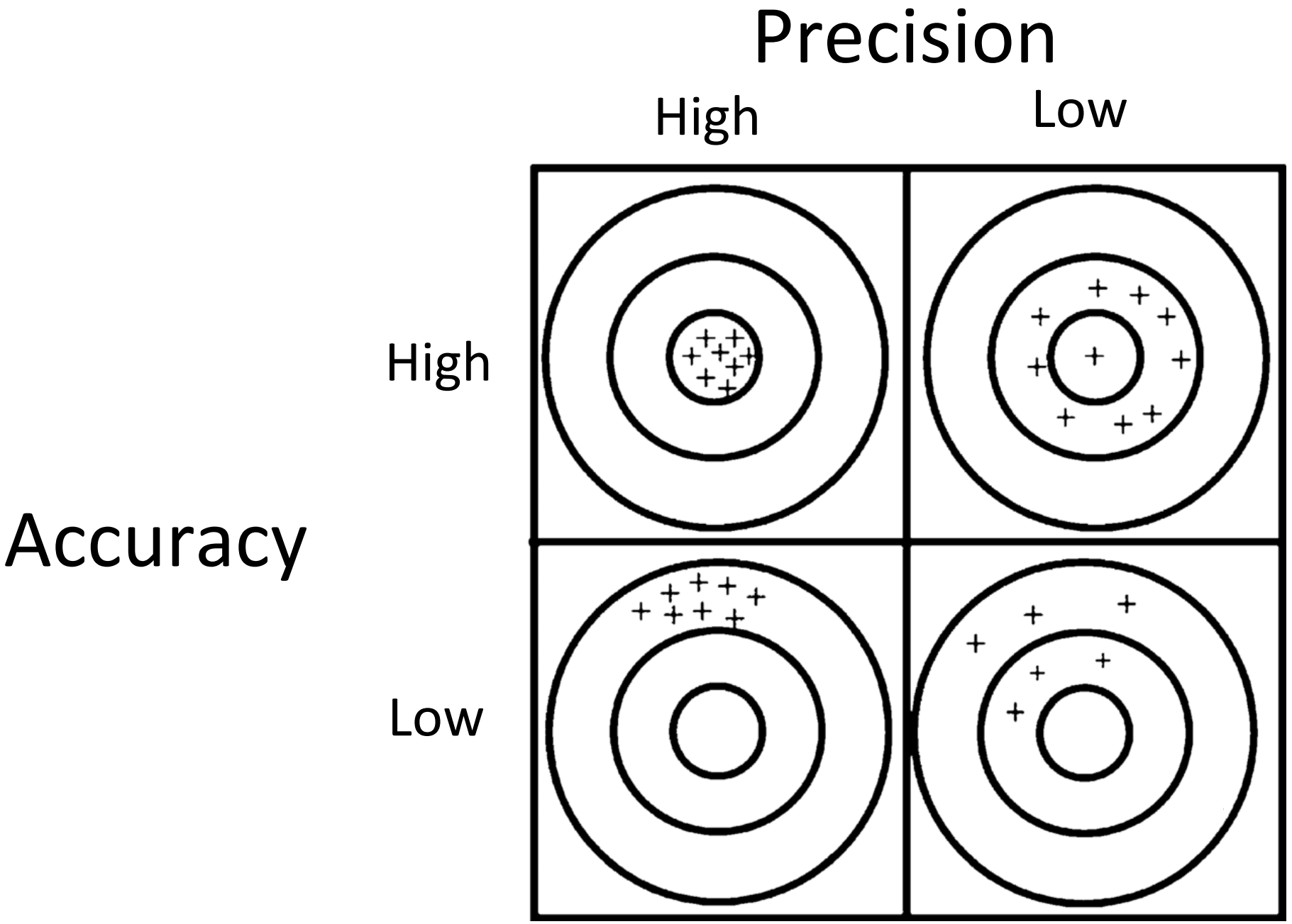


Low

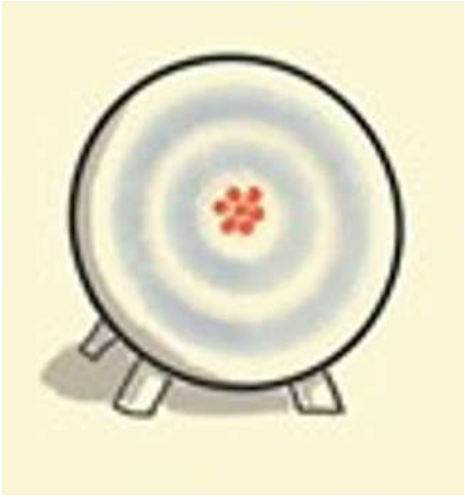
A reminder on semantics



A reminder on semantics

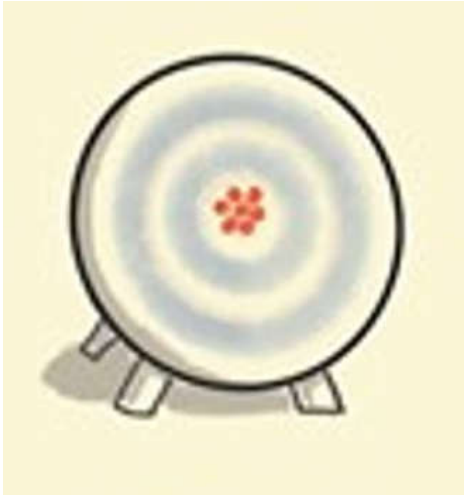


A reminder on semantics



Accuracy relates to the quality of the results

A reminder on semantics



Precision relates to the quality of the process by which the results are obtained

Hypothesis testing: two types of variables

- Explanatory variable (or “independent”, or “predictors”): expected cause
- Response variable (or “dependent variables”): expected effect

In general, researchers observe changes in explanatory variables to explain effects on the response variable they measure.

Hypothesis testing: two types of variables

The R way to write a model:

$$Y \sim X1 + X2$$

Hypothesis testing: two types of variables

The R way to write a model:

$$Y \sim X1 + X2$$

Explanatory variable 1

Hypothesis testing: two types of variables

The R way to write a model:

$$Y \sim X1 + X2$$

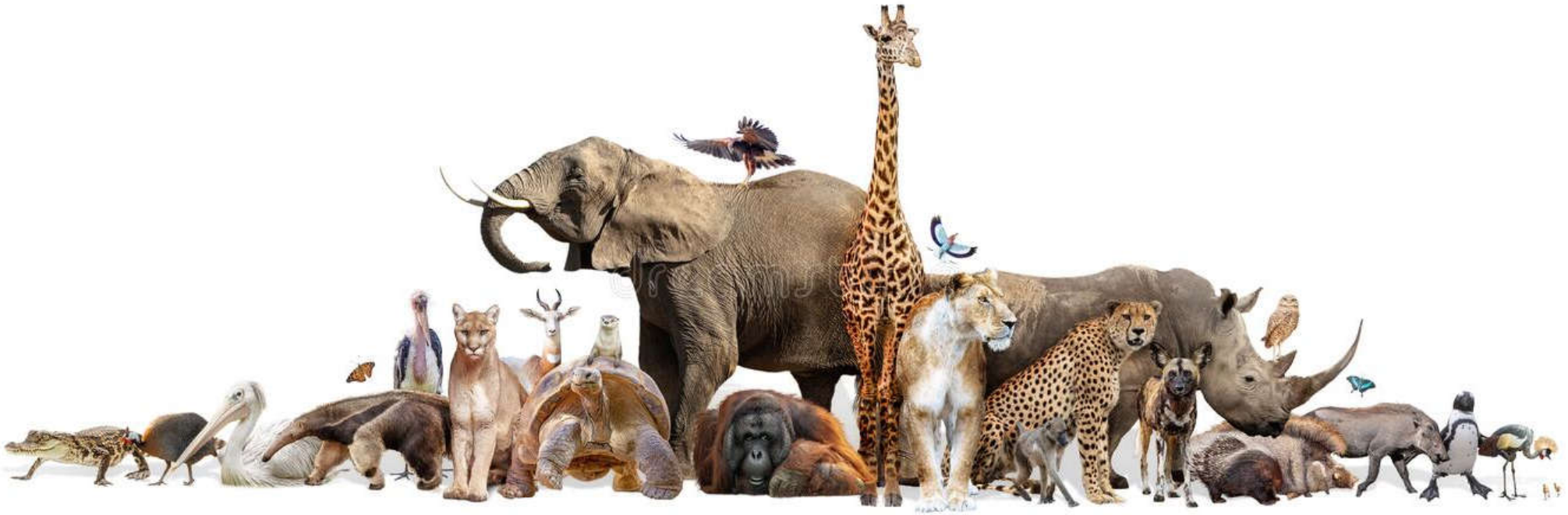
Explanatory variable 2

Hypothesis testing: two types of variables

The R way to write a model:

$$Y \sim X1 + X2$$

Response variable



Your turn to work:

Find the explanatory and response variables

Your turn to work

- You want to know the effect of protein content in pellets on chick growth

Your turn to work

- You want to know the circadian rhythm of leopard cats

Your turn to work

You are comparing Argali sheep's response to predators with different hunting modes

Questions?