

# Summarizing Categorical Data: Tables and Plots

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## Today's plan

1. Summarizing categorical data (tables + bar plots)
2. R basics: writing and running code in Quarto

# Summarizing categorical data

- Last week we looked at:
  - Variable types
  - Summarizing numerical variables
- Today, we focus on summarizing and *describing* categorical variables.

# What do we mean by categorical?

- Values are labels or categories
- Counts and proportions matter more than averages
- Examples from biomedicine:
  - Treatment group
  - Diagnosis
  - Sex
  - Response category (e.g., improved / unchanged / worsened)
- **Nominal** – labels, no order
- **Ordinal** – labels, with order

# Example dataset: FAMuSS

## Functional SNPs Associated with Muscle Size and Strength (FAMuSS)

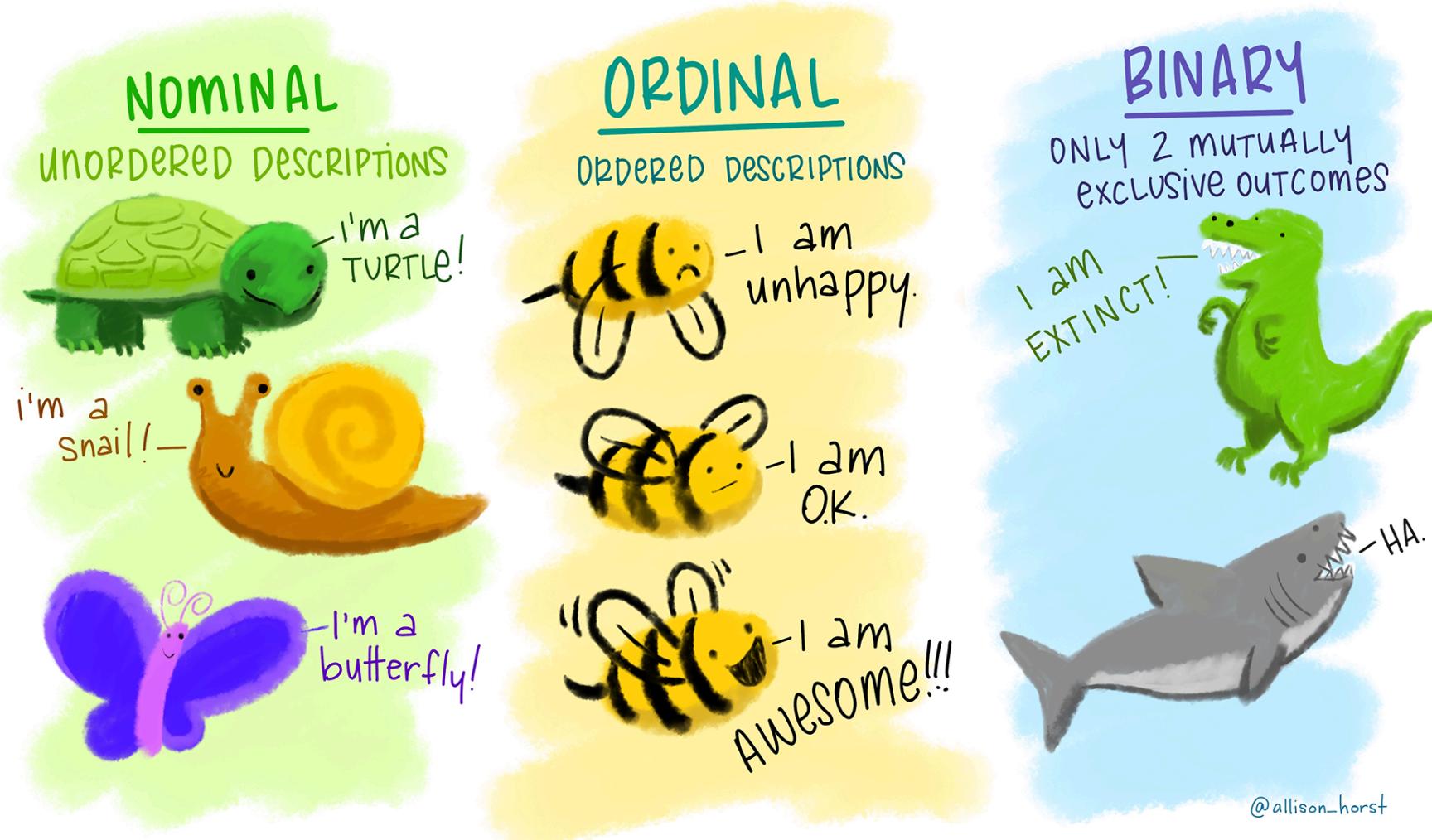
- Study goal: examine how **demographic, physiological, and genetic factors** are associated with muscle strength
- Strength measured in:
  - Dominant arm
  - Non-dominant arm
  - Before and after resistance training
- Key gene of interest:
  - **ACTN3** ("the sports gene")
- Data frame with **595 participants**

### Variables we will focus on today:

- `sex` (Female, Male)
- `race` (African Am, Asian, Caucasian, Hispanic, Other)
- `actn3.r577x` (CC, CT, TT genotype)

(We will use other variables later in the course.)

# One categorical variable (Section 1.5)



Artwork by @allison\_horst

## Frequency tables

- A frequency table shows the **count** in each category
- Often the first summary we compute for categorical data
- **Questions** it helps answer:
  - How many observations are in each category?
  - Are some categories rare?

## Relative frequency tables

- A relative frequency table shows **proportions** instead of counts
- Proportions often make comparisons easier
- Especially useful when:
  - Group sizes differ
  - We want to compare across studies or samples

## FAMuSS example

Counts

| actn3.r577x | n   |
|-------------|-----|
| CC          | 173 |
| CT          | 261 |
| TT          | 161 |
| Total       | 595 |

Proportions

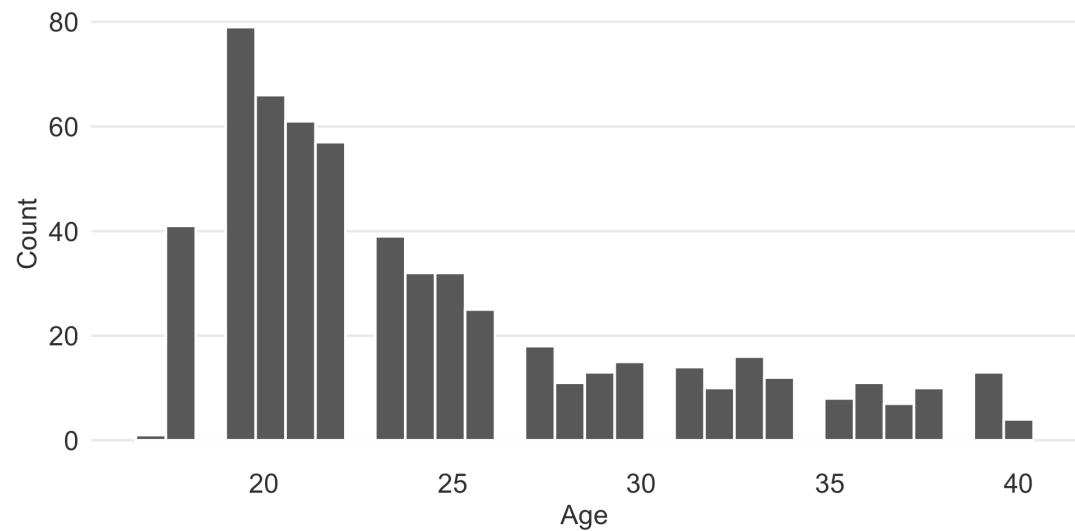
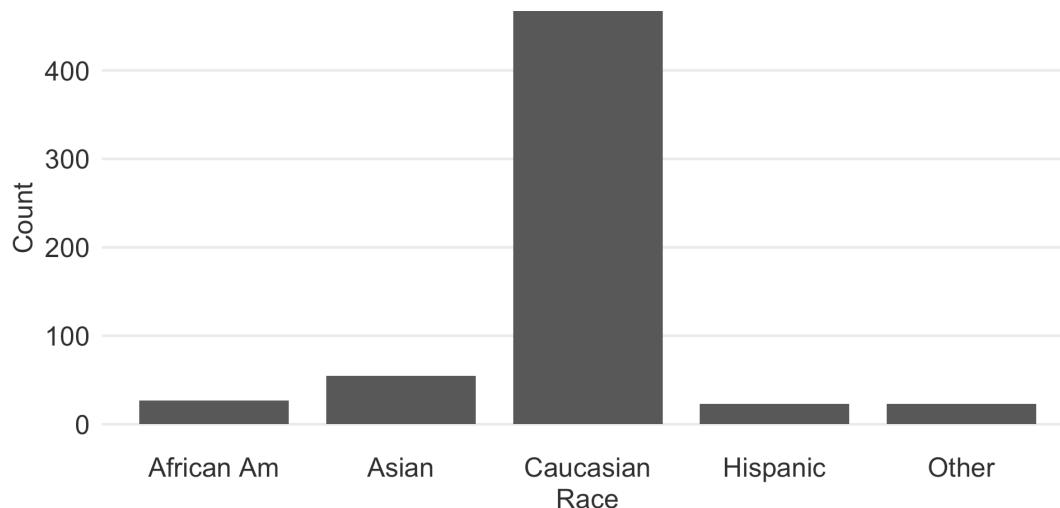
| actn3.r577x | n   | percent |
|-------------|-----|---------|
| CC          | 173 | 29.1%   |
| CT          | 261 | 43.9%   |
| TT          | 161 | 27.1%   |
| Total       | 595 | 100.0%  |

# Bar plots for categorical data

- Bar plots visualize counts or proportions
- Each bar represents a category
- Bar height reflects frequency or proportion

**Bar plots** are used for **categorical** data

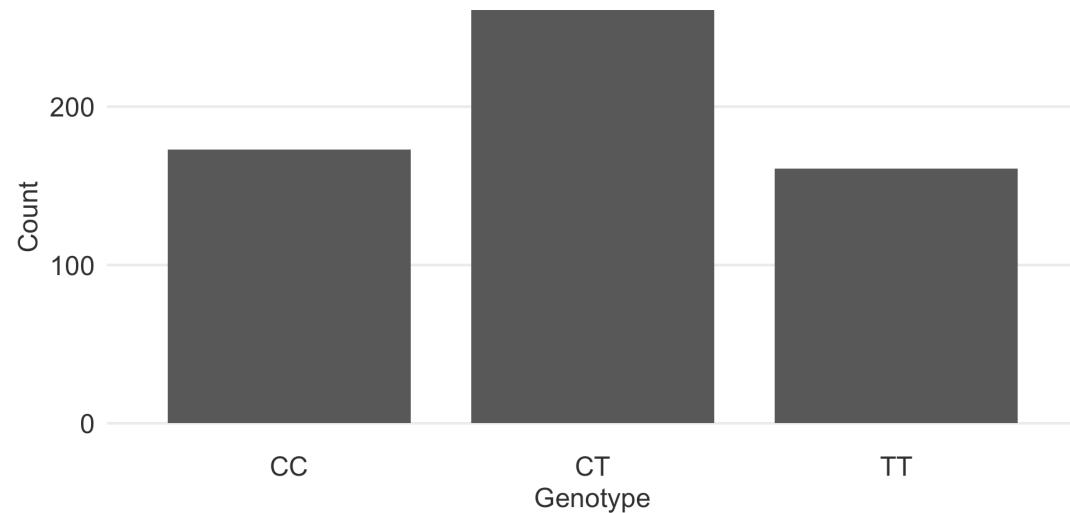
**Histograms** are used for **numerical** data



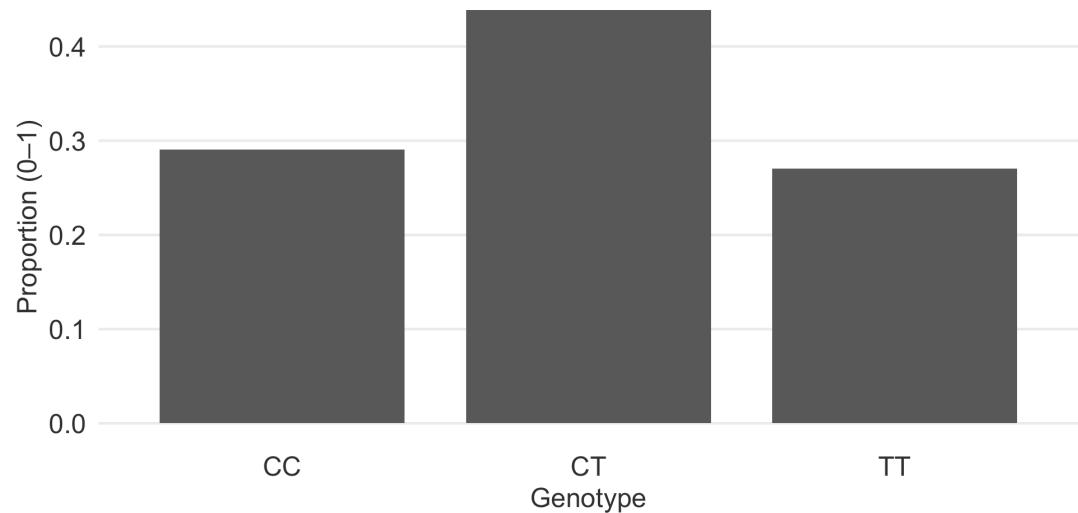
# Visualizing a categorical variable: bar plots

Height = count or proportion

Counts



Proportions



## Two categorical variables (Section 1.6.2)

- So far, we have summarized **one categorical variable at a time**
  - Counts
  - Proportions
  - Bar plots
- Often, we want to understand the relationship between **two categorical variables**
- **Examples:**
  - Genotype and sex
  - Treatment group and response
  - Exposure and disease status

## Contingency tables

- When we have **two categorical variables**, we summarize them with a **contingency table** (also called a **two-way table**)
- Each cell shows the **count** for a combination of categories
- Rows represent one variable
- Columns represent the other variable

## Contingency table example (counts)

- Example question:
  - Does the distribution of genotypes differ by sex?
- These are **counts**, not proportions
- Totals appear along the margins

| sex    | CC  | CT  | TT  | Total |
|--------|-----|-----|-----|-------|
| Female | 106 | 149 | 98  | 353   |
| Male   | 67  | 112 | 63  | 242   |
| Total  | 173 | 261 | 161 | 595   |

# Marginal totals vs conditional distributions

- Marginal totals

- Summarize **one variable at a time**
- Ignore the other variable
- Found in the **row totals** or **column totals**

| sex/actn3.r577x | CC  | CT  | TT  | Total |
|-----------------|-----|-----|-----|-------|
| Female          | 106 | 149 | 98  | 353   |
| Male            | 67  | 112 | 63  | 242   |
| Total           | 173 | 261 | 161 | 595   |

- Conditional distributions

- Describe one variable **within levels of the other**
- Require computing **proportions**

## Row proportions vs column proportions (1/2)

- Which one you use depends on the **question**
- **Row proportions**
  - Condition on the **row variable**
  - Each row sums to 1 (or 100%)
- **Example question:** Among females, what proportion have genotype CC?

| sex/actn3.r577x | CC  | CT  | TT | Total |
|-----------------|-----|-----|----|-------|
| Female          | 106 | 149 | 98 | 353   |
| Male            | 67  | 112 | 63 | 242   |

| sex/actn3.r577x | CC   | CT   | TT   | Total |
|-----------------|------|------|------|-------|
| Female          | 0.30 | 0.42 | 0.28 | 1.00  |
| Male            | 0.28 | 0.46 | 0.26 | 1.00  |

## Row proportions vs column proportions (2/2)

- Column proportions
  - Condition on the **column variable**
  - Each column sums to 1 (or 100%)
- **Example question:** Among those with genotype CC, what proportion are female?

| sex/actn3.r577x | CC  | CT  | TT  |
|-----------------|-----|-----|-----|
| Female          | 106 | 149 | 98  |
| Male            | 67  | 112 | 63  |
| Total           | 173 | 261 | 161 |

| sex/actn3.r577x | CC   | CT   | TT   |
|-----------------|------|------|------|
| Female          | 0.61 | 0.57 | 0.61 |
| Male            | 0.39 | 0.43 | 0.39 |
| Total           | 1.00 | 1.00 | 1.00 |

# Interpreting contingency tables

- Always ask:
  - What are the **rows**?
  - What are the **columns**?
  - What is being **held fixed**?
- Interpretation depends on:
  - The research question
  - Which variable you condition on

## Common interpretation pitfalls

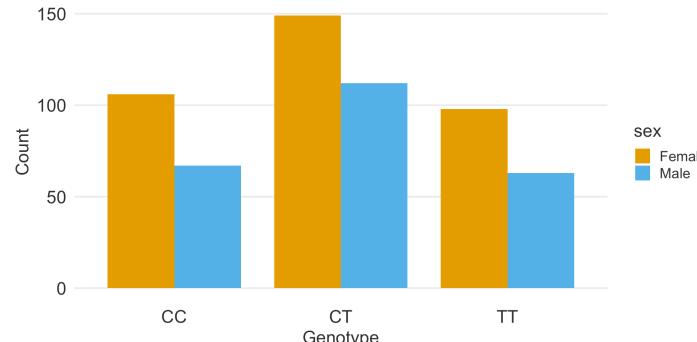
- Confusing marginal totals with conditional distributions
  - Marginal totals describe the sample overall
  - Conditional distributions describe relationships (what happens within groups)
- Comparing counts when group sizes differ
- Forgetting which variable is being conditioned on

## Visualizing two categorical variables

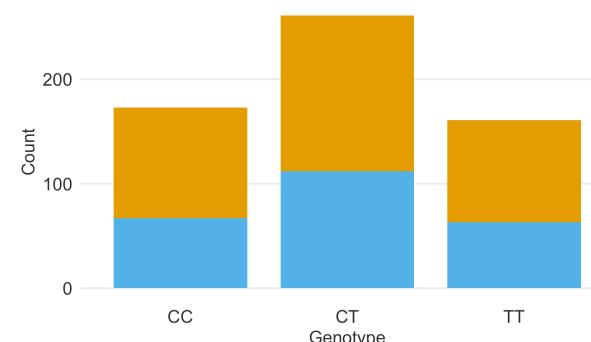
- Contingency tables show the numbers
- Plots help reveal patterns

# Bar plots example: Sex by genotype

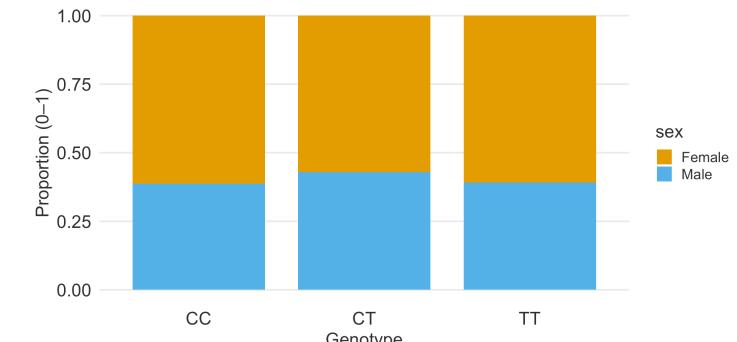
Grouped bar plot



Stacked bar plot

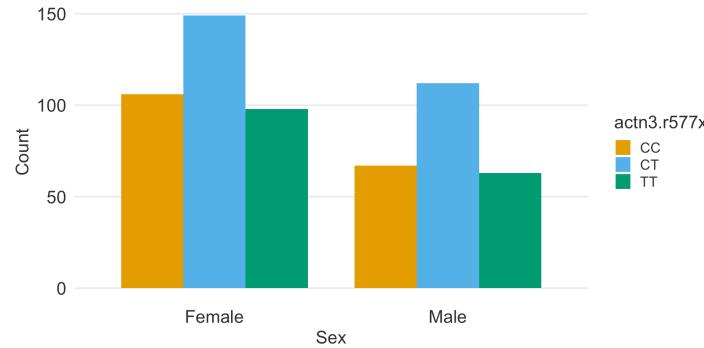


Percent stacked bar plot

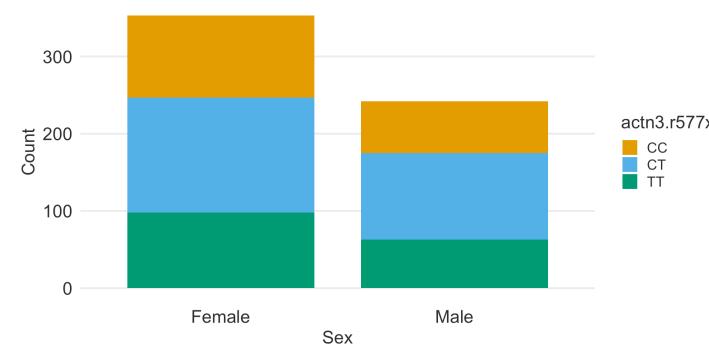


## Bar plots example: Genotype by sex

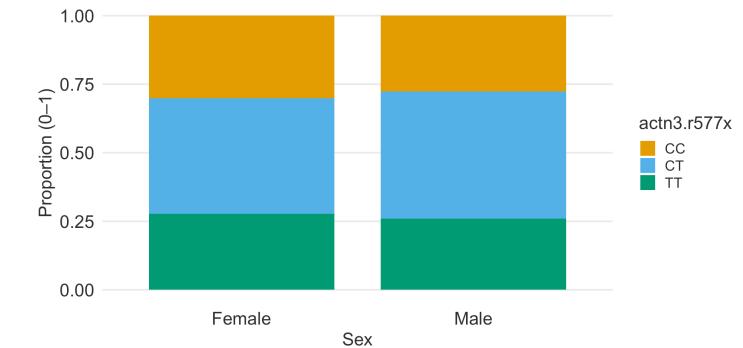
Grouped bar plot



Stacked bar plot



Percent stacked bar plot



## Special case: two-by-two tables

- A **two-by-two table** is a contingency table with:
  - Two levels of one variable
  - Two levels of another variable
- Very common in biomedical research:
  - Exposure (Yes / No) × Outcome (Yes / No)
  - Treatment (Drug / Control) × Response (Improved / Not improved)
  - Test result (Positive / Negative) × Disease status (Present / Absent)
- Today:
  - Focus on **structure and interpretation**
- Later:
  - Risk, odds, probability, and inference

## A quick note on numeric variables

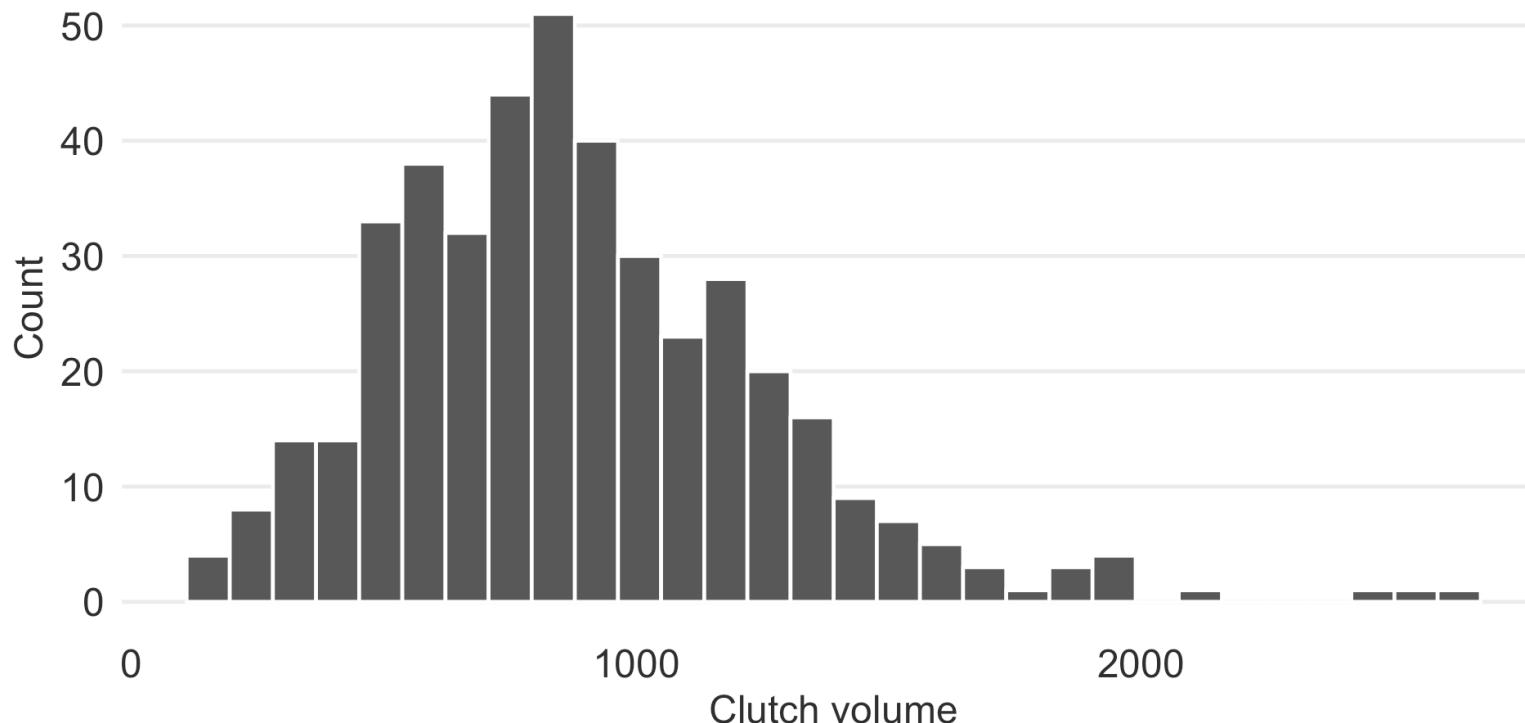
Last week, we summarized numeric variables using:

- mean and standard deviation
- median and IQR

We can also **summarize numeric variables visually**, just like we did for categorical data.

## Visualizing a numeric variable: histogram

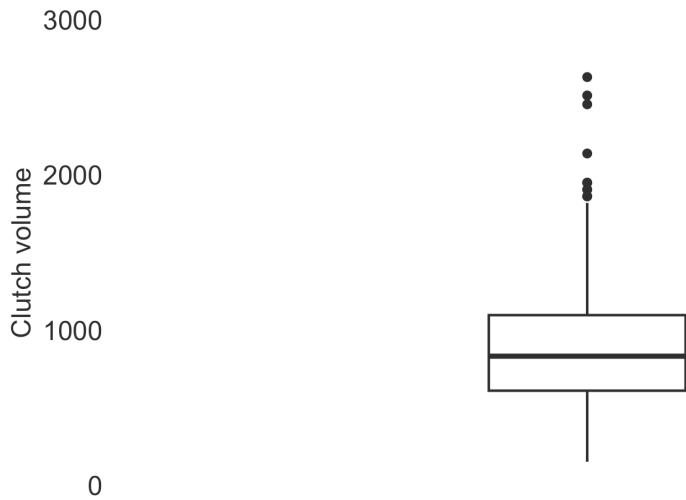
- Histograms show the **distribution** of a numeric variable
- Useful for seeing:
  - shape (symmetric vs skewed)
  - outliers
  - clusters



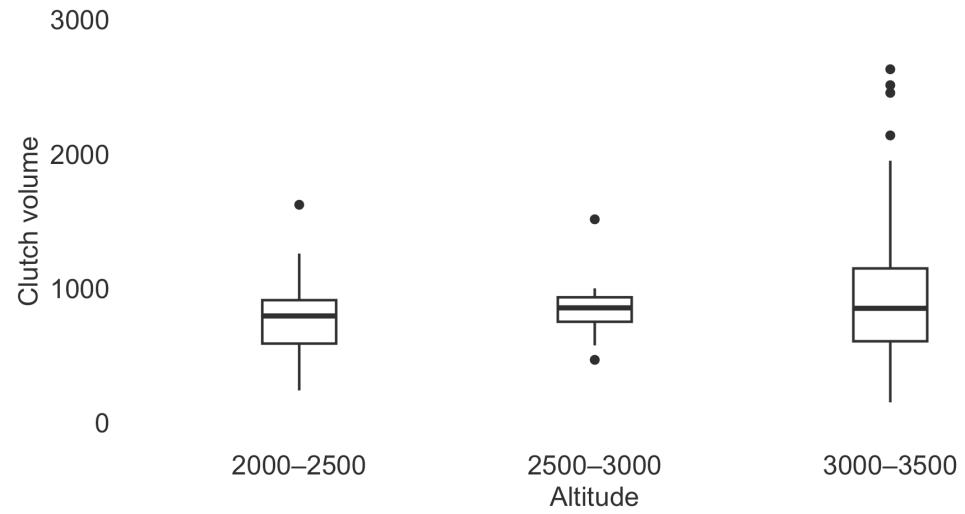
# Visualizing a numeric variable: box plot

- Box plots summarize a numeric variable using:
  - median
  - IQR
  - potential outliers

Box plot

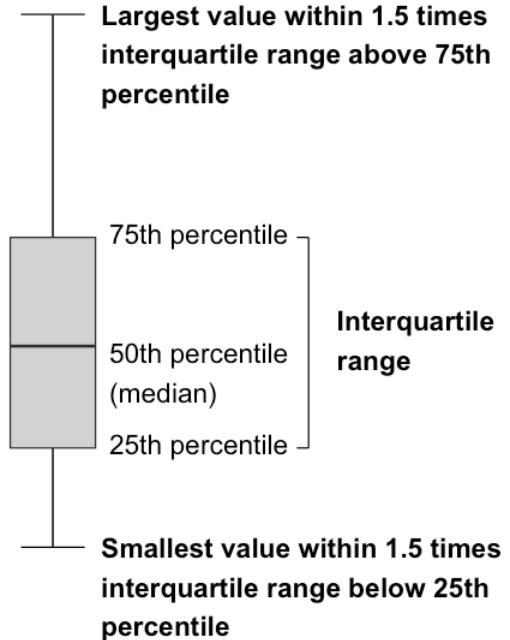


Box plot by groups



# Box plot legend

Boxplot legend



- Potential outlier; value more than 1.5 times and less than 3 times the interquartile range beyond either end of the box

## Wrap-up

Today you learned how to:

- Summarize categorical variables (counts + proportions)
- Compare two categorical variables (contingency tables)
- Interpret row vs column percentages
- Use bar plots, histograms, and box plots as quick visual summaries