# Lecture 02

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## Review of Lecture 1

Covered

- Inductive vs deductive reasoning
- Formulating research questions
- Accuracy vs precision
- Data types and classifications
- Setting up R projects
- Installing and loading libraries
- Reading files into R
- Creating basic graphs

## Lecture 2: Project Design & Data Visualization

### The objectives:

1. Design a well-organized project
2. Implement good naming conventions
   - Controlled vocabulary
   - Including units in names
3. Create and use metadata effectively
4. Build tidy, well-structured spreadsheets
5. Understand data repositories
6. Create effective visualizations with ggplot2

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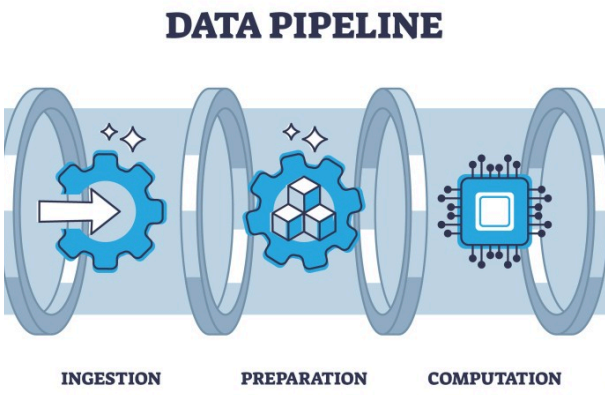
## Project Design: Step 1

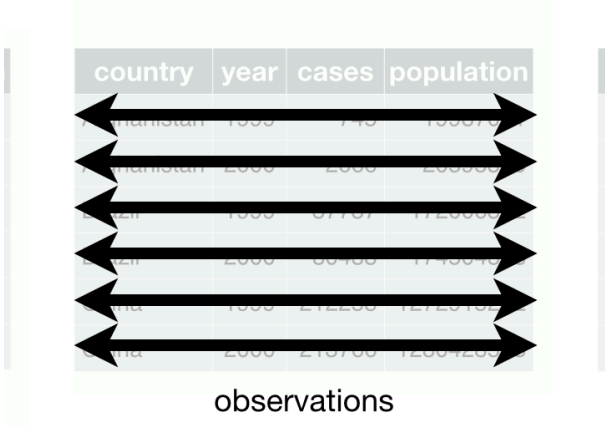
- Data: the raw material of science
- Wide variety of formats, sizes, complexity
- Data management and curation often under emphasized
- Good data management: owe it to our funding agencies, colleagues, supervisors, and study systems




## Lecture 2: Project Design: Step 1

1. **Determine data types** you'll collect
2. **Establish controlled vocabulary**
   - Example: `do_mgl` for dissolved oxygen in mg/L
   - Example: `drp_ugl` for dissolved reactive phosphorus in µg/L
3. **Plan your data flow** from collection to analysis
4. **Organize your project structure** (folders, files)
5. **Enter data promptly** after collection
6. **Save in multiple formats** (Excel and CSV)
7. **Ensure tidy data principles** from the start

> **Note**
>
> See Hadley Wickham's Tidy Data principles for best practices

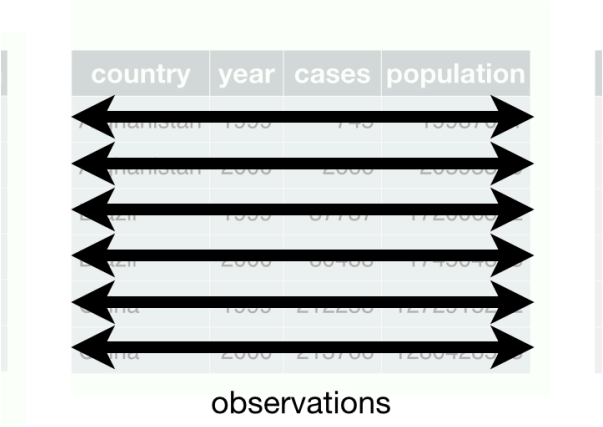



## Project Design: Step 2

Create a **Metadata Sheet** that includes:

- Variable descriptions
- Units of measurement
- Collection methods

- Instrument details
- Dates and locations
- Any other relevant contextual information




## Practice Exercise 1: Pine Data Organization

Practice Exercise 1: Pine Data Organization

Let's examine our pine needle data: - What naming conventions did you choose? - How did you organize the data? - How can you verify data formats (numeric vs categorical)? - What's your plan for organizing outputs and figures?

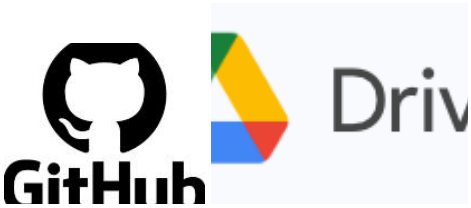
```
# Code to read and examine data
library(tidyverse)
library(patchwork)
library(flextable)

pine_df <- read_csv("data/pine_needles.csv")
pine_df
```

```
# A tibble: 48 × 6
   date    group       n_s   wind  tree_no length_mm
   <chr>   <chr>       <chr> <chr>   <dbl>     <dbl>
 1 3/20/25 cephalopods n     lee         1        20
 2 3/20/25 cephalopods n     lee         1        21
 3 3/20/25 cephalopods n     lee         1        23
 4 3/20/25 cephalopods n     lee         1        25
 5 3/20/25 cephalopods n     lee         1        21
 6 3/20/25 cephalopods n     lee         1        16
 7 3/20/25 cephalopods s     wind        1        15
 8 3/20/25 cephalopods s     wind        1        16
 9 3/20/25 cephalopods s     wind        1        14
10 3/20/25 cephalopods s     wind        1        17
# ℹ 38 more rows
```

## Lecture 2: Data Management: Step 3

**Storage and Backup Strategy**:

1. Store raw data and metadata securely
   - Save in both Excel and CSV formats
   - Consider write-protecting raw data files
2. Implement the 3-2-1 backup rule:
   - 3 total copies of data
   - 2 different storage media
   - 1 offsite location (cloud storage)
3. Establish a regular backup schedule

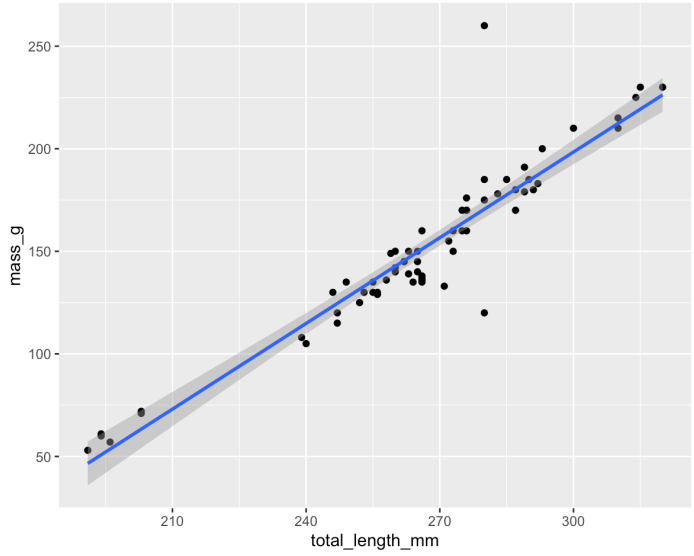



## Lecture 2: Data Management: Step 4

**Initial Data Inspection**:

1. Examine data in the Environment tab
2. Run summary() and glimpse() functions
3. Create exploratory visualizations
4. Check for outliers, errors, and missing data

```
# Specify how to handle missing values during import
pine_df <- read_csv("data/pine_needles.csv",
                    na = c("", "NA", "N/A", "missing", "null"))

# Get a quick summary
summary(pine_df)
```




## Practice Exercise 2: Try plotting a histogram

Practice Exercise 2: Try plotting a histogram of your data

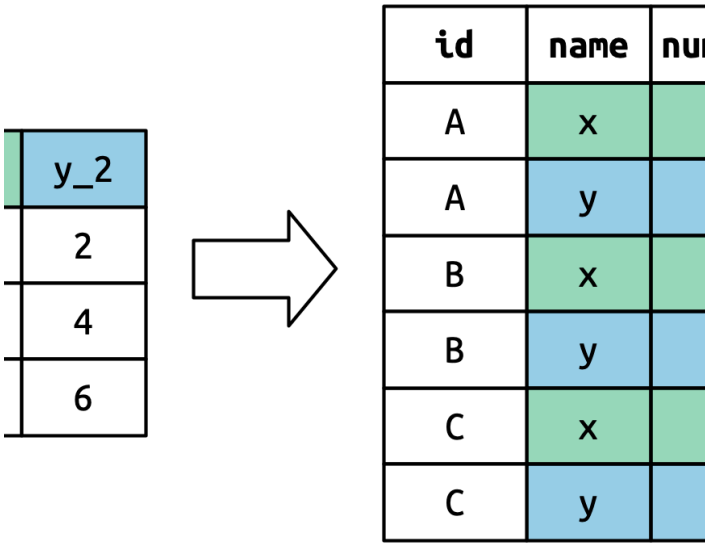
Create a histogram of pine needle lengths to check the distribution:

```
# Write your code here to make a plot
# How do you examine the data - what are the ways you think and lets try it!
```

## Lecture 2: Data Management: Step 5

**Data Cleaning**:

1. Correct errors and inconsistencies
2. Replace missing values with proper NA codes
3. Document all changes made to raw data
4. Save a clean, master version (consider making read-only)
5. Keep notes on data cleaning procedures




## Lecture 2: Data Management: Step 6

**Analysis and Visualization Workflow**:

1. Create exploratory visualizations
2. Summarize and transform data as needed
3. Document all analysis steps
4. Save outputs systematically

A good way to organize script files is number them in the order they get run.

ewater_import_clean.R
ewater initial raw means figures.R
ewater_means_mixed_anova.R
ewater_anova_mixed_graphs with a fu
ewater_anova_mixed_graphs.R
ewater_graphs_functions.R
ewater_figs_jeq_formatting.R
mary statistics.R

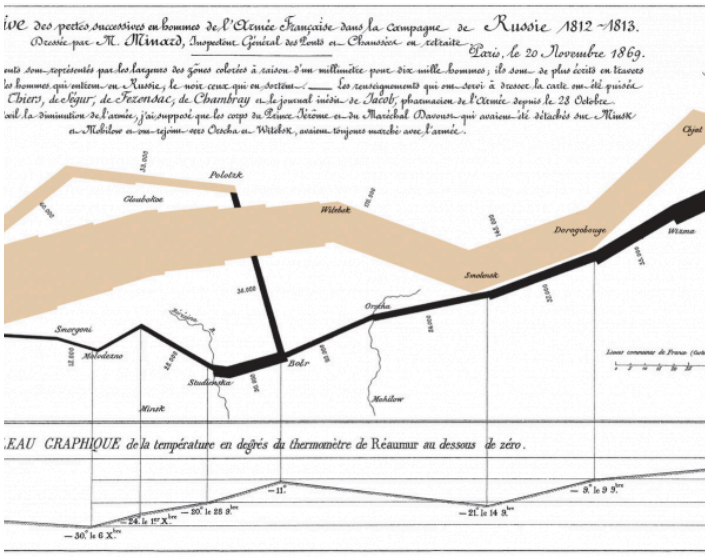
# Lecture 2: Effective Data Visualization

## Why make plots?

### Get in a group and discuss

- What is the purpose of a data visualization?
- What elements are essential in an effective plot?
- What characteristics define a "good" plot?
- What common mistakes make plots ineffective?

Napoleon's Disastrous Invasion of Russia Detailed in an 1869 Data Visualization: It's Been Called "the Best Statistical Graphic Ever Drawn"




# Lecture 2: Tables vs. Visualizations

## How readable are tables?

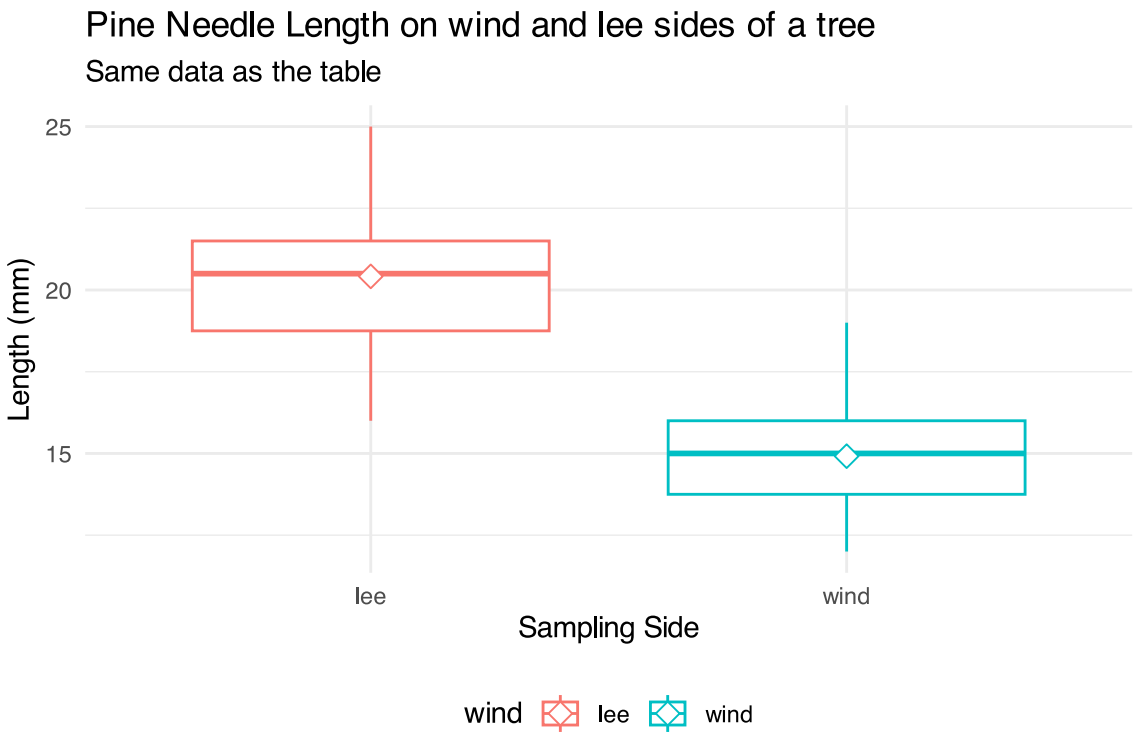
We will get to what these number mean and how to make them in the next lecture.

- Tables
  - are they useful in a presentation?

| wind | n | mean_mm | sd_mm | min_mms | max_mm |
|---|---|---|---|---|---|
| lee | 24 | 20 | 2.45 | 16 | 25 |
| wind | 24 | 15 | 1.91 | 12 | 19 |

## Lecture 2: Displaying data

- **how does a table compare to a plot?**
- Does this help?
- What is this plot?
  - if you don't explain does the audience know?




## Lecture 2: Principles of Effective Graphics

According to Tufte (2001), good scientific graphics:

1. **Show the data** without distortion
2. **Maximize data-ink ratio** (minimize non-data elements)
3. **Make large datasets coherent** and understandable
4. **Encourage comparison** between elements
5. **Reveal multiple layers** of information
6. **Serve a clear purpose** in telling your story
7. **Integrate with statistical methods** appropriately

```
# A tibble: 4 × 7
  group       mean_mm sd_mm     n se_mm conf_low conf_high
  <chr>         <dbl> <dbl> <int> <dbl>    <dbl>     <dbl>
1 cephalopods    18    3.86    12 1.11      15.5      20.5
2 crayfish       18    3.86    12 1.11      15.5      20.5
```

```
3 salmon         16.3  3.94    12 1.14      13.8      18.8
4 snail          18.3  2.27    12 0.655     16.9      19.8
```

## Lecture 2: Creating Effective Graphics

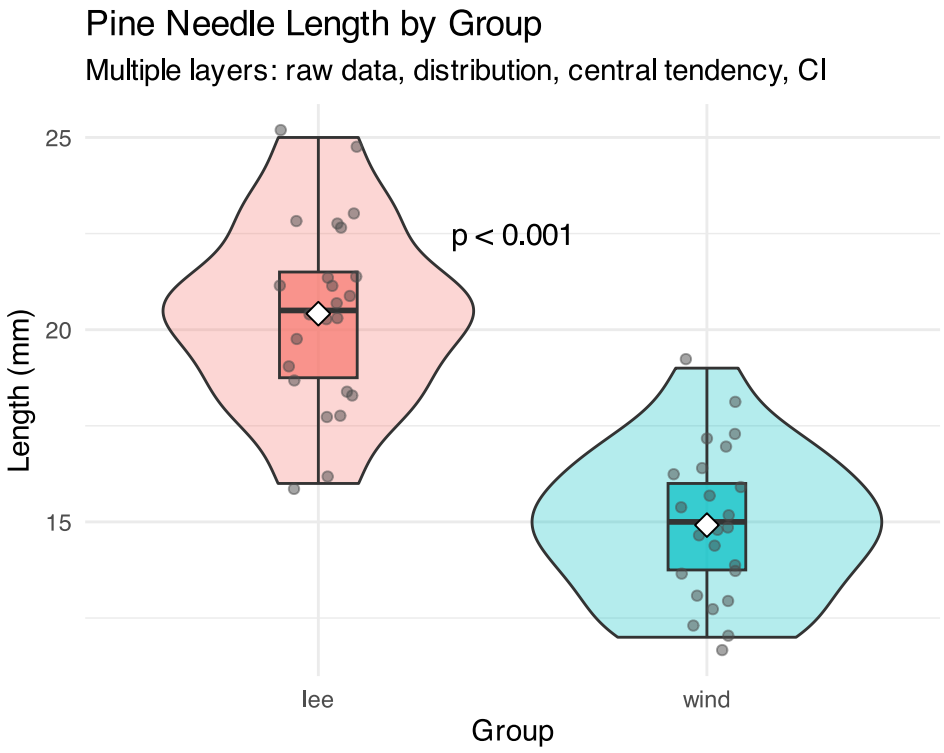
According to Tufte (2001), good scientific graphics:

- To implement these principles:
  - Focus on the data, not decorative elements
  - Ensure proportional representation of numbers
  - Provide clear and informative labels
  - Remove unnecessary elements ("chart junk")
  - Revise and refine visualizations iteratively

## Lecture 2: Displaying data - Good Graphics

To make good graphics:

- Above all, focus on data
- Do not distort data
- Graphical representation of numbers → directly proportional to numbers
- Strive for clarity through labeling
- Maximize data-ink ratio
  - Remove non-data ink
  - Reduce redundant data ink
- Revise and redraw

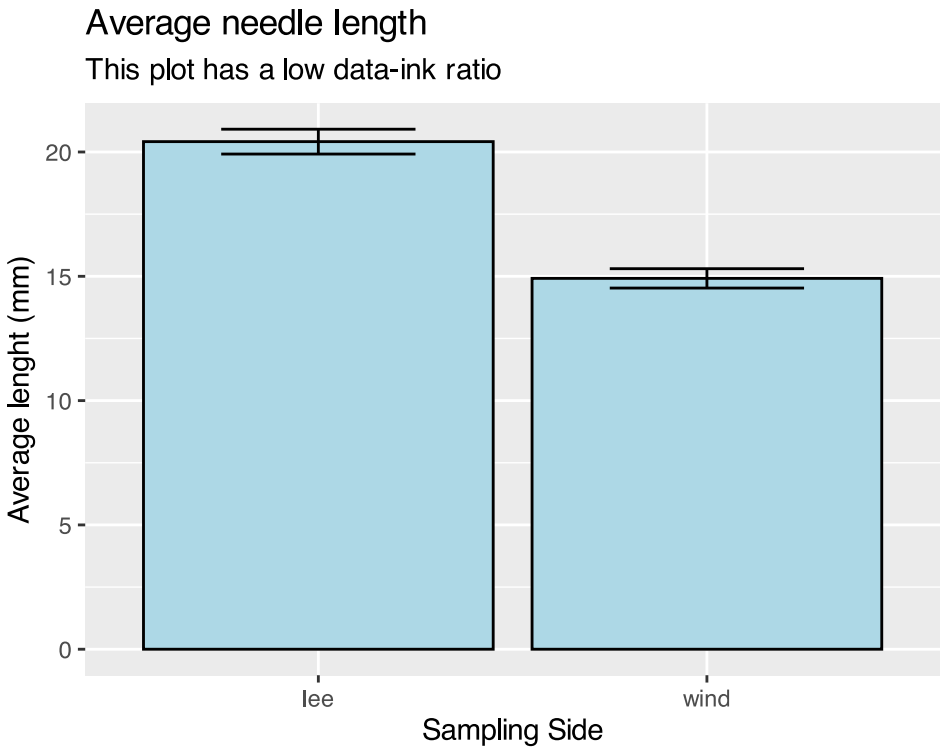



## Lecture 2: Displaying data - Poor Example

What do you think?

Does this -

- Focus on data
- Distort data
- Is it directly proportional to numbers
- Is labeling clear
- Maximize data-ink ratio
  - Remove non-data ink
  - Reduce redundant data ink
- Revise and redraw



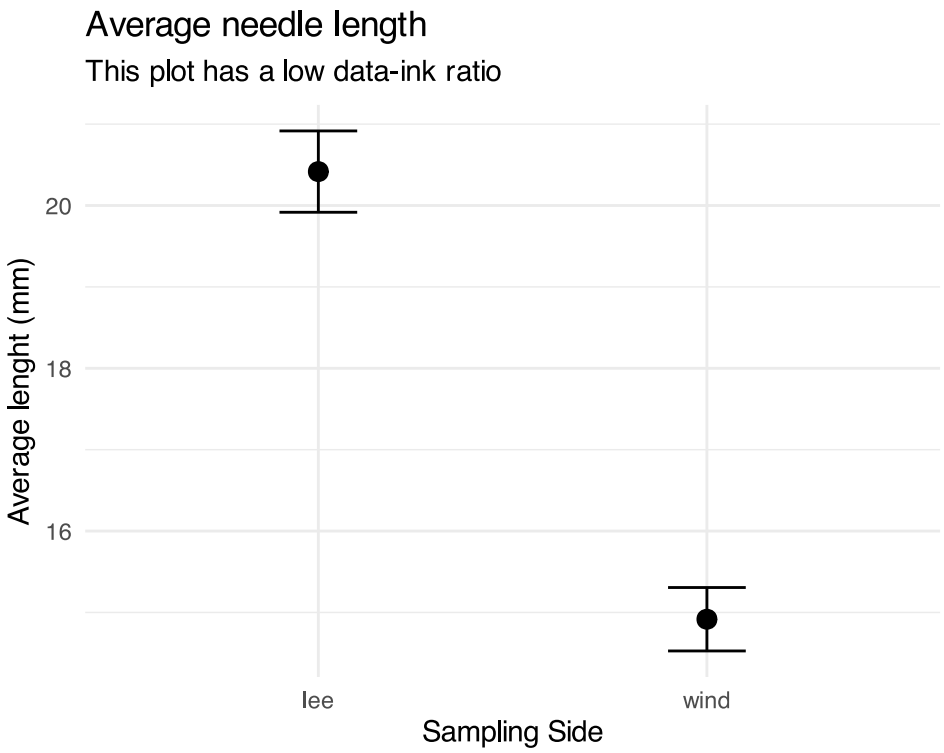

## Lecture 2: Displaying data - Better Example

What do you think?

Does this -

- Focus on data
- Distort data
- Is it directly proportional to numbers
- Is labeling clear
- Maximize data-ink ratio
  - Remove non-data ink
  - Reduce redundant data ink
- Revise and redraw

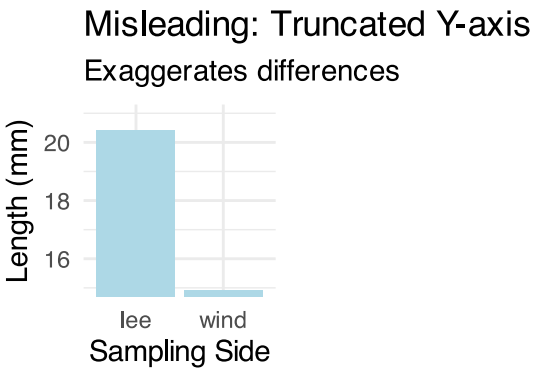
What is one of the most common plots you make all the time?

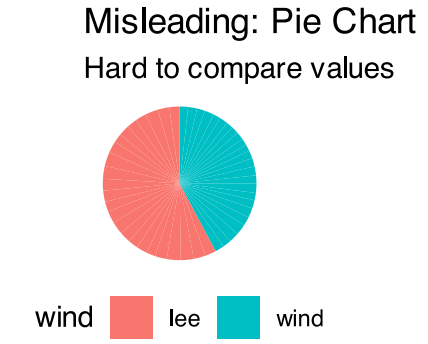


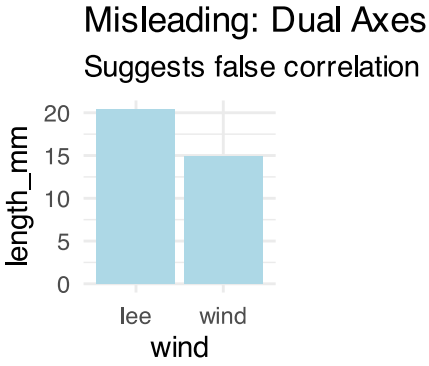

# Lecture 2: Displaying data - Common Problems

## Common Visualization Problems

1. **Data distortion**:
   - Non-zero baselines on bar charts
   - 3D effects that skew perspective
   - Inappropriate scales
2. **Excessive "chart junk"**:
   - Too many gridlines
   - Unnecessary decorative elements
   - Redundant information
3. **Poor color choices**:
   - Too many colors
   - Non-colorblind-friendly palettes
   - Colors that don't print well in grayscale
4. **Misleading representations**:
   - Pie charts with too many categories
   - Dual y-axes with different scales
   - Truncated axes without clear indication




## Practice Exercise 3: Basic Plots with Pine Data

Practice Exercise 3: Lets try some plots with pine data first

Lets try to make some basic plots

```
# Write your code here to make a dot plot or X y plot
# How do you examine the data - what are the ways you think and lets try it!
# what is missing - hwo do you tell the effect of wind?
```

## Practice Exercise 4: Colors, Shapes, and Fills

Practice Exercise 4: OK we are closer but what about colors or shape or fills

Lets try to make some more basic plots

This is free time - we will free code this....

Below are some examples of code you will need for the future

```
# Write your code here to make a dot plot or X y plot
# How do you examine the data - what are the ways you think and lets try it!
# what is missing - hwo do you tell the effect of wind?
```

## Lecture 2: Introduction to the Grammar of Graphics - ggPLOT

We will learn the anatomy of a GGplot is layers

- ggplot2 uses a **layered grammar of graphics** approach:
  1. **Data**: The dataset you're visualizing
  2. **Aesthetics**: Mapping variables to visual properties
  3. **Geometries**: The visual elements representing data
  4. **Facets**: Splitting visualization into subplots
  5. **Statistics**: Statistical transformations of the data
  6. **Coordinates**: The space in which data is plotted
  7. **Themes**: Overall visual style of the plotWe have aesthetics

## Lecture 2: Building a ggplot Visualization

**Key Components:**

1. **Aesthetics (aes)** map variables to visual properties:
   - x and y positions
   - color, fill, shape, size, alpha
   - group, linetype
2. **Geometries (geom_*)** determine how data is displayed:
   - `geom_point()`: Scatter plots
   - `geom_line()`: Line graphs
   - `geom_boxplot()`: Box-and-whisker plots
   - `geom_violin()`: Violin plots
   - `geom_histogram()`: Histograms
   - `geom_bar()`: Bar charts
3. **Position adjustments** control how elements are arranged:
   - `position_dodge()`: Side-by-side elements
   - `position_jitter()`: Add random noise to points
   - `position_stack()`: Stack elements on top of each other
4. **Labels and annotations** provide context:
   - `labs()`: Title, subtitle, caption, axis labels
   - `annotate()`: Add text, shapes, etc.

## Lecture 2: Fine-tuning your visualizations

1. **Colors, fills, and shapes**:

```
scale_color_manual(
  values = c("wind" = "darkblue", "lee" = "darkred"),
  labels = c("wind" = "Windward", "lee" = "Leeward")
)
```

2. **Coordinate systems**:

```
coord_cartesian(ylim = c(10, 30))  # Zoom in without dropping data
```

3. **Themes**:

```
theme_minimal() +
theme(
  axis.title = element_text(size = 14),
  legend.position = "bottom"
)
```

4. **Combining plots with patchwork**:

```
plot1 + plot2 + plot_layout(ncol = 2)
```

## Practice Exercise 5: Publication-Quality Plot

Practice Exercise 4: Creating a Publication-Quality Plot

Create a fully customized plot that would be suitable for publication:

```
# Create a publication-quality plot
pine_df %>%
  ggplot(aes(x = wind, y = length_mm, fill = wind)) +
  geom_violin(alpha = 0.4) +
  geom_boxplot(width = 0.2, alpha = 0.7, outlier.shape = NA) +
  geom_jitter(width = 0.1, alpha = 0.5, color = "gray30", size = 2) +
  stat_summary(fun = mean, geom = "point", shape = 23, size = 3, fill = "white") +
  labs(
    title = "Pine Needle Length Varies with Wind Exposure",
    subtitle = "Needles on the leeward side tend to be longer",
    x = "Tree Side",
    y = "Needle Length (mm)",
    caption = "Data collected Spring 2023") +
  scale_fill_manual(
    values = c("wind" = "#1b9e77", "lee" = "#d95f02"),
    labels = c("wind" = "Windward", "lee" = "Leeward")) +
  theme_minimal() +
  theme(
    plot.title = element_text(face = "bold", size = 16),
    plot.subtitle = element_text(size = 12, color = "gray30"),
    axis.title = element_text(face = "bold"),
    legend.title = element_blank(),
    legend.position = "bottom")
```

## Key Takeaways

1. **Plan your data management** from the beginning
   - Consistent naming conventions
   - Good organization
   - Regular backups
2. **Make your data tidy** from the start
   - One observation per row
   - One variable per column
   - One value per cell
3. **Create effective visualizations** by:
   - Focusing on data, not decoration
   - Using appropriate plot types
   - Following good design principles
   - Customizing for clear communication
4. **Master the grammar of graphics** to:
   - Build plots layer by layer
   - Communicate patterns clearly
   - Tell compelling stories with data

## Next Steps

- Practice creating different types of plots
- Learn to combine multiple plots effectively
- Explore statistical transformations in ggplot2
- Develop a consistent visualization style