

# 2 Data Import and Wrangling

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# 1 Chapter 2: Data Import and Data Wrangling

## 1.1 Agenda

- **Part 1 (30 mins)** – Data Import and Data Wrangling (Reading Different Types of Data)
  - **Part 2 (40 mins)** – Data Cleaning and Manipulation using `dplyr`
  - **Part 3 (30 mins)** – Handling Missing Data
  - **Part 4 (20 mins)** – Practice and Q&A
- 

## 1.2 Part 1: Reading Different Types of Data (30 mins)

We can also check our working directory using the command `getwd()`.

### 1.2.1 CSV File Example: Iris Dataset

```
# We can import csv file using the base library using the command read.csv
iris_data <- read.csv("../data/Iris.csv")

# Or we can use readr library using the command read_csv to import csv
library(readr)
iris_data_r <- read_csv("../data/Iris.csv")
```

Rows: 150 Columns: 6

-- Column specification -----

Delimiter: ","

chr (1): Species

dbl (5): Id, SepalLengthCm, SepalWidthCm, PetalLengthCm, PetalWidthCm

i Use ``spec()`` to retrieve the full column specification for this data.

i Specify the column types or set ``show_col_types = FALSE`` to quiet this message.

```
# View column names
names(iris_data)
```

```
[1] "Id"          "SepalLengthCm" "SepalWidthCm"  "PetalLengthCm"
[5] "PetalWidthCm" "Species"
```

```
# View first few rows
head(iris_data)
```

|   | Id | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species     |
|---|----|---------------|--------------|---------------|--------------|-------------|
| 1 | 1  | 5.1           | 3.5          | 1.4           | 0.2          | Iris-setosa |
| 2 | 2  | 4.9           | 3.0          | 1.4           | 0.2          | Iris-setosa |
| 3 | 3  | 4.7           | 3.2          | 1.3           | 0.2          | Iris-setosa |
| 4 | 4  | 4.6           | 3.1          | 1.5           | 0.2          | Iris-setosa |
| 5 | 5  | 5.0           | 3.6          | 1.4           | 0.2          | Iris-setosa |
| 6 | 6  | 5.4           | 3.9          | 1.7           | 0.4          | Iris-setosa |

```
# Check structure
str(iris_data)
```

```
'data.frame': 150 obs. of 6 variables:
 $ Id      : int  1 2 3 4 5 6 7 8 9 10 ...
 $ SepalLengthCm: num  5.1 4.9 4.7 4.6 5 5.4 4.6 5 4.4 4.9 ...
 $ SepalWidthCm : num  3.5 3 3.2 3.1 3.6 3.9 3.4 3.4 2.9 3.1 ...
 $ PetalLengthCm: num  1.4 1.4 1.3 1.5 1.4 1.7 1.4 1.5 1.4 1.5 ...
 $ PetalWidthCm : num  0.2 0.2 0.2 0.2 0.2 0.4 0.3 0.2 0.2 0.1 ...
 $ Species      : chr  "Iris-setosa" "Iris-setosa" "Iris-setosa" "Iris-
setosa" ...
```

### 1.2.2 Understanding the Difference: read.csv() vs read\_csv()

```
# Base R: read.csv()
class(iris_data)      # Returns "data.frame"
```

```
[1] "data.frame"
```

```
# readr: read_csv()
class(iris_data_r)    # Returns "spec_tbl_df" "tbl_df" "tbl" "data.frame"
```

```
[1] "spec_tbl_df" "tbl_df"      "tbl"          "data.frame"
```

```
# Both work, but read_csv() is generally faster and has better defaults
```

### 1.2.3 Quick Data Exploration

```
# Dimensions  
dim(iris_data)
```

```
[1] 150  6
```

```
# Summary statistics  
summary(iris_data)
```

| Id             | SepalLengthCm | SepalWidthCm  | PetalLengthCm |
|----------------|---------------|---------------|---------------|
| Min. : 1.00    | Min. :4.300   | Min. :2.000   | Min. :1.000   |
| 1st Qu.: 38.25 | 1st Qu.:5.100 | 1st Qu.:2.800 | 1st Qu.:1.600 |
| Median : 75.50 | Median :5.800 | Median :3.000 | Median :4.350 |
| Mean : 75.50   | Mean :5.843   | Mean :3.054   | Mean :3.759   |
| 3rd Qu.:112.75 | 3rd Qu.:6.400 | 3rd Qu.:3.300 | 3rd Qu.:5.100 |
| Max. :150.00   | Max. :7.900   | Max. :4.400   | Max. :6.900   |

  

| PetalWidthCm  | Species          |
|---------------|------------------|
| Min. :0.100   | Length:150       |
| 1st Qu.:0.300 | Class :character |
| Median :1.300 | Mode :character  |
| Mean :1.199   |                  |
| 3rd Qu.:1.800 |                  |
| Max. :2.500   |                  |

```
# View in RStudio  
# View(iris_data)
```

---

## 1.3 Part 2: Data Cleaning and Manipulation using dplyr (40 mins)

### 1.3.1 Load Required Packages

```
library(dplyr)
```

```
Attaching package: 'dplyr'
```

The following objects are masked from 'package:stats':

`filter, lag`

The following objects are masked from 'package:base':

`intersect, setdiff, setequal, union`

### 1.3.2 The Pipe Operator: %>%

The pipe operator %>% makes code more readable by chaining operations together.

```
# Without pipe (hard to read)
head(filter(iris_data, SepalLengthCm > 6))
```

|   | Id | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species         |
|---|----|---------------|--------------|---------------|--------------|-----------------|
| 1 | 51 | 7.0           | 3.2          | 4.7           | 1.4          | Iris-versicolor |
| 2 | 52 | 6.4           | 3.2          | 4.5           | 1.5          | Iris-versicolor |
| 3 | 53 | 6.9           | 3.1          | 4.9           | 1.5          | Iris-versicolor |
| 4 | 55 | 6.5           | 2.8          | 4.6           | 1.5          | Iris-versicolor |
| 5 | 57 | 6.3           | 3.3          | 4.7           | 1.6          | Iris-versicolor |
| 6 | 59 | 6.6           | 2.9          | 4.6           | 1.3          | Iris-versicolor |

```
# With pipe (easier to read)
iris_data %>%
  filter(SepalLengthCm > 6) %>%
  head()
```

|   | Id | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species         |
|---|----|---------------|--------------|---------------|--------------|-----------------|
| 1 | 51 | 7.0           | 3.2          | 4.7           | 1.4          | Iris-versicolor |
| 2 | 52 | 6.4           | 3.2          | 4.5           | 1.5          | Iris-versicolor |
| 3 | 53 | 6.9           | 3.1          | 4.9           | 1.5          | Iris-versicolor |
| 4 | 55 | 6.5           | 2.8          | 4.6           | 1.5          | Iris-versicolor |
| 5 | 57 | 6.3           | 3.3          | 4.7           | 1.6          | Iris-versicolor |
| 6 | 59 | 6.6           | 2.9          | 4.6           | 1.3          | Iris-versicolor |

**Keyboard shortcut:** Ctrl + Shift + M (Windows) or Cmd + Shift + M (Mac)

### 1.3.3 Basic Wrangling Examples

#### 1.3.3.1 Selecting Columns with `select()`

```
# Select specific columns
iris_data %>%
  select(Species, SepalLengthCm, PetalLengthCm) %>%
  head()
```

|   | Species     | SepalLengthCm | PetalLengthCm |
|---|-------------|---------------|---------------|
| 1 | Iris-setosa | 5.1           | 1.4           |
| 2 | Iris-setosa | 4.9           | 1.4           |
| 3 | Iris-setosa | 4.7           | 1.3           |
| 4 | Iris-setosa | 4.6           | 1.5           |
| 5 | Iris-setosa | 5.0           | 1.4           |
| 6 | Iris-setosa | 5.4           | 1.7           |

```
# Select columns using patterns
iris_data %>%
  select(starts_with("Petal")) %>%
  head()
```

|   | PetalLengthCm | PetalWidthCm |
|---|---------------|--------------|
| 1 | 1.4           | 0.2          |
| 2 | 1.4           | 0.2          |
| 3 | 1.3           | 0.2          |
| 4 | 1.5           | 0.2          |
| 5 | 1.4           | 0.2          |
| 6 | 1.7           | 0.4          |

```
iris_data %>%
  select(ends_with("Cm")) %>%
  head()
```

|   | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm |
|---|---------------|--------------|---------------|--------------|
| 1 | 5.1           | 3.5          | 1.4           | 0.2          |
| 2 | 4.9           | 3.0          | 1.4           | 0.2          |
| 3 | 4.7           | 3.2          | 1.3           | 0.2          |
| 4 | 4.6           | 3.1          | 1.5           | 0.2          |
| 5 | 5.0           | 3.6          | 1.4           | 0.2          |
| 6 | 5.4           | 3.9          | 1.7           | 0.4          |

```
# Exclude columns with minus sign
iris_data %>%
  select(-Id) %>%
  head()
```

|   | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species     |
|---|---------------|--------------|---------------|--------------|-------------|
| 1 | 5.1           | 3.5          | 1.4           | 0.2          | Iris-setosa |
| 2 | 4.9           | 3.0          | 1.4           | 0.2          | Iris-setosa |
| 3 | 4.7           | 3.2          | 1.3           | 0.2          | Iris-setosa |
| 4 | 4.6           | 3.1          | 1.5           | 0.2          | Iris-setosa |
| 5 | 5.0           | 3.6          | 1.4           | 0.2          | Iris-setosa |
| 6 | 5.4           | 3.9          | 1.7           | 0.4          | Iris-setosa |

### 1.3.3.2 Filtering Rows with filter()

```
# Filter for setosa species only
iris_data %>%
  filter(Species == "Iris-setosa") %>%
  head()
```

|   | Id | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species     |
|---|----|---------------|--------------|---------------|--------------|-------------|
| 1 | 1  | 5.1           | 3.5          | 1.4           | 0.2          | Iris-setosa |
| 2 | 2  | 4.9           | 3.0          | 1.4           | 0.2          | Iris-setosa |
| 3 | 3  | 4.7           | 3.2          | 1.3           | 0.2          | Iris-setosa |
| 4 | 4  | 4.6           | 3.1          | 1.5           | 0.2          | Iris-setosa |
| 5 | 5  | 5.0           | 3.6          | 1.4           | 0.2          | Iris-setosa |
| 6 | 6  | 5.4           | 3.9          | 1.7           | 0.4          | Iris-setosa |

```
# Filter flowers with long petals
iris_data %>%
  filter(PetalLengthCm > 5) %>%
  head()
```

|   | Id  | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species         |
|---|-----|---------------|--------------|---------------|--------------|-----------------|
| 1 | 84  | 6.0           | 2.7          | 5.1           | 1.6          | Iris-versicolor |
| 2 | 101 | 6.3           | 3.3          | 6.0           | 2.5          | Iris-virginica  |
| 3 | 102 | 5.8           | 2.7          | 5.1           | 1.9          | Iris-virginica  |
| 4 | 103 | 7.1           | 3.0          | 5.9           | 2.1          | Iris-virginica  |
| 5 | 104 | 6.3           | 2.9          | 5.6           | 1.8          | Iris-virginica  |
| 6 | 105 | 6.5           | 3.0          | 5.8           | 2.2          | Iris-virginica  |

```
# Multiple conditions with AND (&)
iris_data %>%
  filter(Species == "Iris-virginica" & SepalLengthCm > 6.5) %>%
  head()
```

|   | Id  | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species        |
|---|-----|---------------|--------------|---------------|--------------|----------------|
| 1 | 103 | 7.1           | 3.0          | 5.9           | 2.1          | Iris-virginica |
| 2 | 106 | 7.6           | 3.0          | 6.6           | 2.1          | Iris-virginica |
| 3 | 108 | 7.3           | 2.9          | 6.3           | 1.8          | Iris-virginica |
| 4 | 109 | 6.7           | 2.5          | 5.8           | 1.8          | Iris-virginica |
| 5 | 110 | 7.2           | 3.6          | 6.1           | 2.5          | Iris-virginica |
| 6 | 113 | 6.8           | 3.0          | 5.5           | 2.1          | Iris-virginica |

```
# Multiple conditions with OR (|)
iris_data %>%
  filter(PetalLengthCm > 6 | PetalWidthCm > 2) %>%
  head()
```

|   | Id  | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species        |
|---|-----|---------------|--------------|---------------|--------------|----------------|
| 1 | 101 | 6.3           | 3.3          | 6.0           | 2.5          | Iris-virginica |
| 2 | 103 | 7.1           | 3.0          | 5.9           | 2.1          | Iris-virginica |
| 3 | 105 | 6.5           | 3.0          | 5.8           | 2.2          | Iris-virginica |
| 4 | 106 | 7.6           | 3.0          | 6.6           | 2.1          | Iris-virginica |
| 5 | 108 | 7.3           | 2.9          | 6.3           | 1.8          | Iris-virginica |
| 6 | 110 | 7.2           | 3.6          | 6.1           | 2.5          | Iris-virginica |

```
# Using %in% operator for multiple values
iris_data %>%
  filter(Species %in% c("Iris-setosa", "Iris-versicolor")) %>%
  head()
```

|   | Id | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species     |
|---|----|---------------|--------------|---------------|--------------|-------------|
| 1 | 1  | 5.1           | 3.5          | 1.4           | 0.2          | Iris-setosa |
| 2 | 2  | 4.9           | 3.0          | 1.4           | 0.2          | Iris-setosa |
| 3 | 3  | 4.7           | 3.2          | 1.3           | 0.2          | Iris-setosa |
| 4 | 4  | 4.6           | 3.1          | 1.5           | 0.2          | Iris-setosa |
| 5 | 5  | 5.0           | 3.6          | 1.4           | 0.2          | Iris-setosa |
| 6 | 6  | 5.4           | 3.9          | 1.7           | 0.4          | Iris-setosa |



### 1.3.3.3 Creating New Variables with mutate()

```
# Calculate areas
iris_data <- iris_data %>%
  mutate(
    SepalArea = SepalLengthCm * SepalWidthCm,
    PetalArea = PetalLengthCm * PetalWidthCm
  )

head(iris_data)
```

|   | Id | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species     |
|---|----|---------------|--------------|---------------|--------------|-------------|
| 1 | 1  | 5.1           | 3.5          | 1.4           | 0.2          | Iris-setosa |
| 2 | 2  | 4.9           | 3.0          | 1.4           | 0.2          | Iris-setosa |
| 3 | 3  | 4.7           | 3.2          | 1.3           | 0.2          | Iris-setosa |
| 4 | 4  | 4.6           | 3.1          | 1.5           | 0.2          | Iris-setosa |
| 5 | 5  | 5.0           | 3.6          | 1.4           | 0.2          | Iris-setosa |
| 6 | 6  | 5.4           | 3.9          | 1.7           | 0.4          | Iris-setosa |

  

|   | SepalArea | PetalArea |
|---|-----------|-----------|
| 1 | 17.85     | 0.28      |
| 2 | 14.70     | 0.28      |
| 3 | 15.04     | 0.26      |
| 4 | 14.26     | 0.30      |
| 5 | 18.00     | 0.28      |
| 6 | 21.06     | 0.68      |

```
# Create categorical variables
iris_data <- iris_data %>%
  mutate(
    SizeCategory = ifelse(PetalLengthCm > 4, "Large", "Small"),
    SepalRatio = SepalLengthCm / SepalWidthCm
  )

head(iris_data)
```

|   | Id | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species     |
|---|----|---------------|--------------|---------------|--------------|-------------|
| 1 | 1  | 5.1           | 3.5          | 1.4           | 0.2          | Iris-setosa |
| 2 | 2  | 4.9           | 3.0          | 1.4           | 0.2          | Iris-setosa |
| 3 | 3  | 4.7           | 3.2          | 1.3           | 0.2          | Iris-setosa |
| 4 | 4  | 4.6           | 3.1          | 1.5           | 0.2          | Iris-setosa |
| 5 | 5  | 5.0           | 3.6          | 1.4           | 0.2          | Iris-setosa |

| 6 | 6         | 5.4       | 3.9          | 1.7        | 0.4 | Iris-setosa |
|---|-----------|-----------|--------------|------------|-----|-------------|
|   | SepalArea | PetalArea | SizeCategory | SepalRatio |     |             |
| 1 | 17.85     | 0.28      | Small        | 1.457143   |     |             |
| 2 | 14.70     | 0.28      | Small        | 1.633333   |     |             |
| 3 | 15.04     | 0.26      | Small        | 1.468750   |     |             |
| 4 | 14.26     | 0.30      | Small        | 1.483871   |     |             |
| 5 | 18.00     | 0.28      | Small        | 1.388889   |     |             |
| 6 | 21.06     | 0.68      | Small        | 1.384615   |     |             |

```
# Using case_when() for multiple conditions
iris_data <- iris_data %>%
  mutate(
    PetalSize = case_when(
      PetalLengthCm < 2 ~ "Small",
      PetalLengthCm < 5 ~ "Medium",
      TRUE ~ "Large"
    )
  )
head(iris_data)
```

|   | Id | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species     |
|---|----|---------------|--------------|---------------|--------------|-------------|
| 1 | 1  | 5.1           | 3.5          | 1.4           | 0.2          | Iris-setosa |
| 2 | 2  | 4.9           | 3.0          | 1.4           | 0.2          | Iris-setosa |
| 3 | 3  | 4.7           | 3.2          | 1.3           | 0.2          | Iris-setosa |
| 4 | 4  | 4.6           | 3.1          | 1.5           | 0.2          | Iris-setosa |
| 5 | 5  | 5.0           | 3.6          | 1.4           | 0.2          | Iris-setosa |
| 6 | 6  | 5.4           | 3.9          | 1.7           | 0.4          | Iris-setosa |

  

|   | SepalArea | PetalArea | SizeCategory | SepalRatio | PetalSize |
|---|-----------|-----------|--------------|------------|-----------|
| 1 | 17.85     | 0.28      | Small        | 1.457143   | Small     |
| 2 | 14.70     | 0.28      | Small        | 1.633333   | Small     |
| 3 | 15.04     | 0.26      | Small        | 1.468750   | Small     |
| 4 | 14.26     | 0.30      | Small        | 1.483871   | Small     |
| 5 | 18.00     | 0.28      | Small        | 1.388889   | Small     |
| 6 | 21.06     | 0.68      | Small        | 1.384615   | Small     |

#### 1.3.3.4 Sorting Rows with arrange()

```
# Sort by Petal Length (ascending)
iris_data %>%
  arrange(PetalLengthCm) %>%
  head()
```

|   | Id | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species     |
|---|----|---------------|--------------|---------------|--------------|-------------|
| 1 | 23 | 4.6           | 3.6          | 1.0           | 0.2          | Iris-setosa |
| 2 | 14 | 4.3           | 3.0          | 1.1           | 0.1          | Iris-setosa |
| 3 | 15 | 5.8           | 4.0          | 1.2           | 0.2          | Iris-setosa |
| 4 | 36 | 5.0           | 3.2          | 1.2           | 0.2          | Iris-setosa |
| 5 | 3  | 4.7           | 3.2          | 1.3           | 0.2          | Iris-setosa |
| 6 | 17 | 5.4           | 3.9          | 1.3           | 0.4          | Iris-setosa |

|   | SepalArea | PetalArea | SizeCategory | SepalRatio | PetalSize |
|---|-----------|-----------|--------------|------------|-----------|
| 1 | 16.56     | 0.20      | Small        | 1.277778   | Small     |
| 2 | 12.90     | 0.11      | Small        | 1.433333   | Small     |
| 3 | 23.20     | 0.24      | Small        | 1.450000   | Small     |
| 4 | 16.00     | 0.24      | Small        | 1.562500   | Small     |
| 5 | 15.04     | 0.26      | Small        | 1.468750   | Small     |
| 6 | 21.06     | 0.52      | Small        | 1.384615   | Small     |

```
# Sort by Petal Length (descending)
iris_data %>%
  arrange(desc(PetalLengthCm)) %>%
  head()
```

|   | Id  | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species        |
|---|-----|---------------|--------------|---------------|--------------|----------------|
| 1 | 119 | 7.7           | 2.6          | 6.9           | 2.3          | Iris-virginica |
| 2 | 118 | 7.7           | 3.8          | 6.7           | 2.2          | Iris-virginica |
| 3 | 123 | 7.7           | 2.8          | 6.7           | 2.0          | Iris-virginica |
| 4 | 106 | 7.6           | 3.0          | 6.6           | 2.1          | Iris-virginica |
| 5 | 132 | 7.9           | 3.8          | 6.4           | 2.0          | Iris-virginica |
| 6 | 108 | 7.3           | 2.9          | 6.3           | 1.8          | Iris-virginica |

|   | SepalArea | PetalArea | SizeCategory | SepalRatio | PetalSize |
|---|-----------|-----------|--------------|------------|-----------|
| 1 | 20.02     | 15.87     | Large        | 2.961538   | Large     |
| 2 | 29.26     | 14.74     | Large        | 2.026316   | Large     |
| 3 | 21.56     | 13.40     | Large        | 2.750000   | Large     |
| 4 | 22.80     | 13.86     | Large        | 2.533333   | Large     |
| 5 | 30.02     | 12.80     | Large        | 2.078947   | Large     |
| 6 | 21.17     | 11.34     | Large        | 2.517241   | Large     |

```
# Sort by multiple columns
iris_data %>%
  arrange(Species, desc(SepalLengthCm)) %>%
  head()
```

|  | Id | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species |
|--|----|---------------|--------------|---------------|--------------|---------|
|--|----|---------------|--------------|---------------|--------------|---------|

|   |    |     |     |     |     |             |
|---|----|-----|-----|-----|-----|-------------|
| 1 | 15 | 5.8 | 4.0 | 1.2 | 0.2 | Iris-setosa |
| 2 | 16 | 5.7 | 4.4 | 1.5 | 0.4 | Iris-setosa |
| 3 | 19 | 5.7 | 3.8 | 1.7 | 0.3 | Iris-setosa |
| 4 | 34 | 5.5 | 4.2 | 1.4 | 0.2 | Iris-setosa |
| 5 | 37 | 5.5 | 3.5 | 1.3 | 0.2 | Iris-setosa |
| 6 | 6  | 5.4 | 3.9 | 1.7 | 0.4 | Iris-setosa |

  

|   | SepalArea | PetalArea | SizeCategory | SepalRatio | PetalSize |
|---|-----------|-----------|--------------|------------|-----------|
| 1 | 23.20     | 0.24      | Small        | 1.450000   | Small     |
| 2 | 25.08     | 0.60      | Small        | 1.295455   | Small     |
| 3 | 21.66     | 0.51      | Small        | 1.500000   | Small     |
| 4 | 23.10     | 0.28      | Small        | 1.309524   | Small     |
| 5 | 19.25     | 0.26      | Small        | 1.571429   | Small     |
| 6 | 21.06     | 0.68      | Small        | 1.384615   | Small     |

### 1.3.3.5 Summarizing with group\_by() and summarize()

```
# Overall summary
iris_data %>%
  summarize(
    avg_sepal_length = mean(SepalLengthCm, na.rm = TRUE),
    avg_petal_length = mean(PetalLengthCm, na.rm = TRUE),
    total_flowers = n()
  )
```

|   | avg_sepal_length | avg_petal_length | total_flowers |
|---|------------------|------------------|---------------|
| 1 | 5.843333         | 3.758667         | 150           |

```
# Summary by species
iris_data %>%
  group_by(Species) %>%
  summarize(
    avg_sepal_length = mean(SepalLengthCm, na.rm = TRUE),
    avg_sepal_width = mean(SepalWidthCm, na.rm = TRUE),
    avg_petal_length = mean(PetalLengthCm, na.rm = TRUE),
    avg_petal_width = mean(PetalWidthCm, na.rm = TRUE),
    count = n()
  )
```

```
# A tibble: 3 x 6
  Species      avg_sepal_length avg_sepal_width avg_petal_length avg_petal_width
  <chr>          <dbl>          <dbl>          <dbl>          <dbl>
```

|   |              |      |      |      |       |
|---|--------------|------|------|------|-------|
| 1 | Iris-setosa  | 5.01 | 3.42 | 1.46 | 0.244 |
| 2 | Iris-versic~ | 5.94 | 2.77 | 4.26 | 1.33  |
| 3 | Iris-virgin~ | 6.59 | 2.97 | 5.55 | 2.03  |

# i 1 more variable: count <int>

```
# Summary by multiple groups
iris_data %>%
  group_by(Species, SizeCategory) %>%
  summarize(
    avg_sepal_length = mean(SepalLengthCm, na.rm = TRUE),
    count = n(),
    .groups = 'drop'
  )
```

```
# A tibble: 4 x 4
  Species      SizeCategory avg_sepal_length count
  <chr>      <chr>          <dbl>   <int>
1 Iris-setosa Small            5.01     50
2 Iris-versicolor Large          6.15     34
3 Iris-versicolor Small          5.49     16
4 Iris-virginica Large          6.59     50
```

### 1.3.4 Combining Multiple Operations

```
# Complex pipeline: Find large virginica flowers and their stats
iris_data %>%
  filter(Species == "Iris-virginica", PetalLengthCm > 6) %>%
  select(Species, SepalLengthCm, PetalLengthCm, SepalArea, PetalArea) %>%
  arrange(desc(PetalArea)) %>%
  head(10)
```

|   | Species        | SepalLengthCm | PetalLengthCm | SepalArea | PetalArea |
|---|----------------|---------------|---------------|-----------|-----------|
| 1 | Iris-virginica | 7.7           | 6.9           | 20.02     | 15.87     |
| 2 | Iris-virginica | 7.2           | 6.1           | 25.92     | 15.25     |
| 3 | Iris-virginica | 7.7           | 6.7           | 29.26     | 14.74     |
| 4 | Iris-virginica | 7.7           | 6.1           | 23.10     | 14.03     |
| 5 | Iris-virginica | 7.6           | 6.6           | 22.80     | 13.86     |
| 6 | Iris-virginica | 7.7           | 6.7           | 21.56     | 13.40     |
| 7 | Iris-virginica | 7.9           | 6.4           | 30.02     | 12.80     |
| 8 | Iris-virginica | 7.4           | 6.1           | 20.72     | 11.59     |
| 9 | Iris-virginica | 7.3           | 6.3           | 21.17     | 11.34     |

### 1.3.5 Additional Useful Functions

#### 1.3.5.1 Count rows with count()

```
# Count flowers by species
iris_data %>%
  count(Species)
```

```
      Species  n
1  Iris-setosa 50
2 Iris-versicolor 50
3  Iris-virginica 50
```

```
# Count with sorting
iris_data %>%
  count(Species, sort = TRUE)
```

```
      Species  n
1  Iris-setosa 50
2 Iris-versicolor 50
3  Iris-virginica 50
```

```
# Count by multiple variables
iris_data %>%
  count(Species, SizeCategory)
```

```
      Species SizeCategory  n
1  Iris-setosa      Small  50
2 Iris-versicolor      Large 34
3 Iris-versicolor      Small 16
4  Iris-virginica      Large 50
```

#### 1.3.5.2 Get unique values with distinct()

```
# Get unique species
iris_data %>%
  distinct(Species)
```

```

      Species
1    Iris-setosa
2 Iris-versicolor
3  Iris-virginica

```

```

# Get unique combinations
iris_data %>%
  distinct(Species, PetalSize)

```

```

      Species PetalSize
1    Iris-setosa    Small
2 Iris-versicolor  Medium
3 Iris-versicolor   Large
4  Iris-virginica   Large
5  Iris-virginica  Medium

```

## 1.4 Part 3: Handling Missing Data (30 mins)

### 1.4.1 Checking Missing Values

```

# Load nanian for missing data visualization
library(nanian)

# Check for missing values
miss_var_summary(iris_data)

```

```

# A tibble: 11 x 3
  variable      n_miss pct_miss
  <chr>         <int>   <num>
1 Id             0         0
2 SepalLengthCm  0         0
3 SepalWidthCm   0         0
4 PetalLengthCm  0         0
5 PetalWidthCm   0         0
6 Species        0         0
7 SepalArea      0         0
8 PetalArea      0         0

```

```

 9 SizeCategory      0      0
10 SepalRatio        0      0
11 PetalSize         0      0

```

```

# Check if any values are missing
any(is.na(iris_data))

```

```
[1] FALSE
```

```

# Count NAs in each column
colSums(is.na(iris_data))

```

```

      Id SepalLengthCm SepalWidthCm PetalLengthCm PetalWidthCm
      0              0              0              0              0
Species      SepalArea      PetalArea SizeCategory      SepalRatio
      0              0              0              0              0
PetalSize
      0

```

## 1.4.2 Creating Sample Data with Missing Values

For demonstration, let's introduce some missing values:

```

# Create a copy with missing values
iris_missing <- iris_data
set.seed(123) # For reproducibility

# Randomly introduce NAs
iris_missing$SepalLengthCm[sample(1:nrow(iris_missing), 10)] <- NA
iris_missing$PetalWidthCm[sample(1:nrow(iris_missing), 15)] <- NA

# Check missing data
miss_var_summary(iris_missing)

```

```

# A tibble: 11 x 3
  variable      n_miss pct_miss
  <chr>         <int>   <num>
1 PetalWidthCm     15     10
2 SepalLengthCm    10     6.67
3 Id               0      0

```



|    |               |   |   |
|----|---------------|---|---|
| 4  | SepalWidthCm  | 0 | 0 |
| 5  | PetalLengthCm | 0 | 0 |
| 6  | Species       | 0 | 0 |
| 7  | SepalArea     | 0 | 0 |
| 8  | PetalArea     | 0 | 0 |
| 9  | SizeCategory  | 0 | 0 |
| 10 | SepalRatio    | 0 | 0 |
| 11 | PetalSize     | 0 | 0 |

### 1.4.3 Removing Missing Values

```
# Remove rows with any missing values
iris_complete <- na.omit(iris_missing)

cat("Original rows:", nrow(iris_missing), "\n")
```

Original rows: 150

```
cat("After removing NAs:", nrow(iris_complete), "\n")
```

After removing NAs: 127

```
# Remove only if specific column has NA
iris_filtered <- iris_missing %>%
  filter(!is.na(SepalLengthCm))

cat("After filtering SepalLengthCm:", nrow(iris_filtered), "\n")
```

After filtering SepalLengthCm: 140

### 1.4.4 Replacing Missing Values

```
# Replace NAs with mean
iris_mean <- iris_missing %>%
  mutate(
    SepalLengthCm = ifelse(is.na(SepalLengthCm),
                          mean(SepalLengthCm, na.rm = TRUE),
```

```

        SepalLengthCm),
    PetalWidthCm = ifelse(is.na(PetalWidthCm),
                          mean(PetalWidthCm, na.rm = TRUE),
                          PetalWidthCm)
  )

# Verify
miss_var_summary(iris_mean)

# A tibble: 11 x 3
  variable      n_miss pct_miss
  <chr>         <int>    <num>
1 Id             0         0
2 SepalLengthCm  0         0
3 SepalWidthCm   0         0
4 PetalLengthCm  0         0
5 PetalWidthCm   0         0
6 Species        0         0
7 SepalArea      0         0
8 PetalArea      0         0
9 SizeCategory   0         0
10 SepalRatio    0         0
11 PetalSize     0         0

# Replace with median (more robust to outliers)
iris_median <- iris_missing %>%
  mutate(
    SepalLengthCm = ifelse(is.na(SepalLengthCm),
                          median(SepalLengthCm, na.rm = TRUE),
                          SepalLengthCm),
    PetalWidthCm = ifelse(is.na(PetalWidthCm),
                          median(PetalWidthCm, na.rm = TRUE),
                          PetalWidthCm)
  )

# Replace with species-specific mean (group imputation)
iris_group_mean <- iris_missing %>%
  group_by(Species) %>%
  mutate(
    SepalLengthCm = ifelse(is.na(SepalLengthCm),
                          mean(SepalLengthCm, na.rm = TRUE),

```

```

        SepalLengthCm),
  PetalWidthCm = ifelse(is.na(PetalWidthCm),
                        mean(PetalWidthCm, na.rm = TRUE),
                        PetalWidthCm)
) %>%
ungroup()

miss_var_summary(iris_group_mean)

```

```

# A tibble: 11 x 3
  variable      n_miss pct_miss
  <chr>         <int>   <num>
1 Id             0       0
2 SepalLengthCm  0       0
3 SepalWidthCm   0       0
4 PetalLengthCm  0       0
5 PetalWidthCm   0       0
6 Species        0       0
7 SepalArea      0       0
8 PetalArea      0       0
9 SizeCategory   0       0
10 SepalRatio    0       0
11 PetalSize     0       0

```

### 1.4.5 Handling NAs During Analysis

```

# Without na.rm - returns NA
mean(iris_missing$SepalLengthCm)

```

```
[1] NA
```

```

# With na.rm = TRUE - ignores NAs
mean(iris_missing$SepalLengthCm, na.rm = TRUE)

```

```
[1] 5.855714
```

```
# Summary with NA handling
iris_missing %>%
  summarize(
    mean_sepal = mean(SepalLengthCm, na.rm = TRUE),
    median_sepal = median(SepalLengthCm, na.rm = TRUE),
    count_non_na = sum(!is.na(SepalLengthCm)),
    count_na = sum(is.na(SepalLengthCm))
  )
```

```
mean_sepal median_sepal count_non_na count_na
1 5.855714 5.8 140 10
```

---

## 1.5 Part 4: Practice and Q&A (20 mins)

### 1.5.1 Practice Tasks (based on iris data)

#### 1.5.1.1 Task 1: Import and Explore

- Import the iris dataset
- Display the first 10 rows
- Check the number of rows and columns

```
# Solution
iris_practice <- read.csv("../data/Iris.csv")
head(iris_practice, 10)
```

|    | Id | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species     |
|----|----|---------------|--------------|---------------|--------------|-------------|
| 1  | 1  | 5.1           | 3.5          | 1.4           | 0.2          | Iris-setosa |
| 2  | 2  | 4.9           | 3.0          | 1.4           | 0.2          | Iris-setosa |
| 3  | 3  | 4.7           | 3.2          | 1.3           | 0.2          | Iris-setosa |
| 4  | 4  | 4.6           | 3.1          | 1.5           | 0.2          | Iris-setosa |
| 5  | 5  | 5.0           | 3.6          | 1.4           | 0.2          | Iris-setosa |
| 6  | 6  | 5.4           | 3.9          | 1.7           | 0.4          | Iris-setosa |
| 7  | 7  | 4.6           | 3.4          | 1.4           | 0.3          | Iris-setosa |
| 8  | 8  | 5.0           | 3.4          | 1.5           | 0.2          | Iris-setosa |
| 9  | 9  | 4.4           | 2.9          | 1.4           | 0.2          | Iris-setosa |
| 10 | 10 | 4.9           | 3.1          | 1.5           | 0.1          | Iris-setosa |

```
dim(iris_practice)
```

```
[1] 150   6
```

### 1.5.1.2 Task 2: Filter and Select

- Select only Iris-virginica flowers with PetalLengthCm > 6
- Show only Species, SepalLengthCm, and PetalLengthCm columns

```
# Solution
iris_practice %>%
  filter(Species == "Iris-virginica", PetalLengthCm > 6) %>%
  select(Species, SepalLengthCm, PetalLengthCm)
```

|   | Species        | SepalLengthCm | PetalLengthCm |
|---|----------------|---------------|---------------|
| 1 | Iris-virginica | 7.6           | 6.6           |
| 2 | Iris-virginica | 7.3           | 6.3           |
| 3 | Iris-virginica | 7.2           | 6.1           |
| 4 | Iris-virginica | 7.7           | 6.7           |
| 5 | Iris-virginica | 7.7           | 6.9           |
| 6 | Iris-virginica | 7.7           | 6.7           |
| 7 | Iris-virginica | 7.4           | 6.1           |
| 8 | Iris-virginica | 7.9           | 6.4           |
| 9 | Iris-virginica | 7.7           | 6.1           |

### 1.5.1.3 Task 3: Create New Variables

- Create a variable for PetalRatio = PetalLengthCm / PetalWidthCm
- Create a variable for SepalRatio = SepalLengthCm / SepalWidthCm

```
# Solution
iris_practice <- iris_practice %>%
  mutate(
    PetalRatio = PetalLengthCm / PetalWidthCm,
    SepalRatio = SepalLengthCm / SepalWidthCm
  )

head(iris_practice)
```

|   | Id | SepalLengthCm | SepalWidthCm | PetalLengthCm | PetalWidthCm | Species     |
|---|----|---------------|--------------|---------------|--------------|-------------|
| 1 | 1  | 5.1           | 3.5          | 1.4           | 0.2          | Iris-setosa |
| 2 | 2  | 4.9           | 3.0          | 1.4           | 0.2          | Iris-setosa |
| 3 | 3  | 4.7           | 3.2          | 1.3           | 0.2          | Iris-setosa |
| 4 | 4  | 4.6           | 3.1          | 1.5           | 0.2          | Iris-setosa |
| 5 | 5  | 5.0           | 3.6          | 1.4           | 0.2          | Iris-setosa |
| 6 | 6  | 5.4           | 3.9          | 1.7           | 0.4          | Iris-setosa |

  

|   | PetalRatio | SepalRatio |
|---|------------|------------|
| 1 | 7.00       | 1.457143   |
| 2 | 7.00       | 1.633333   |
| 3 | 6.50       | 1.468750   |
| 4 | 7.50       | 1.483871   |
| 5 | 7.00       | 1.388889   |
| 6 | 4.25       | 1.384615   |

#### 1.5.1.4 Task 4: Group and Summarize

- Group by Species
- Calculate average SepalLengthCm, PetalLengthCm, and count per species

```
# Solution
iris_practice %>%
  group_by(Species) %>%
  summarize(
    avg_sepal_length = mean(SepalLengthCm, na.rm = TRUE),
    avg_petal_length = mean(PetalLengthCm, na.rm = TRUE),
    count = n()
  )
```

```
# A tibble: 3 x 4
  Species      avg_sepal_length avg_petal_length count
  <chr>          <dbl>          <dbl> <int>
1 Iris-setosa      5.01            1.46     50
2 Iris-versicolor  5.94            4.26     50
3 Iris-virginica   6.59            5.55     50
```

#### 1.5.1.5 Task 5: Complex Pipeline

- Filter for flowers with SepalLengthCm > 6
- Create a new variable TotalLength = SepalLengthCm + PetalLengthCm
- Group by Species

- Calculate average TotalLength
- Sort by average TotalLength descending

```
# Solution
iris_practice %>%
  filter(SepalLengthCm > 6) %>%
  mutate(TotalLength = SepalLengthCm + PetalLengthCm) %>%
  group_by(Species) %>%
  summarize(
    avg_total_length = mean(TotalLength, na.rm = TRUE),
    count = n()
  ) %>%
  arrange(desc(avg_total_length))
```

```
# A tibble: 2 x 3
  Species      avg_total_length count
  <chr>          <dbl>   <int>
1 Iris-virginica      12.5     41
2 Iris-versicolor     11.0     20
```

---

## 1.6 Further Resources (for Data Import & Wrangling)

- Tidyverse Documentation: <https://www.tidyverse.org/packages/>
- Importing Data in R: <https://r4ds.hadley.nz/data-import.html>
- Data Transformation Cheatsheet: <https://posit.co/resources/cheatsheets/>