Loading & Cleaning Data in R

I know the file exists, why doesn't R?

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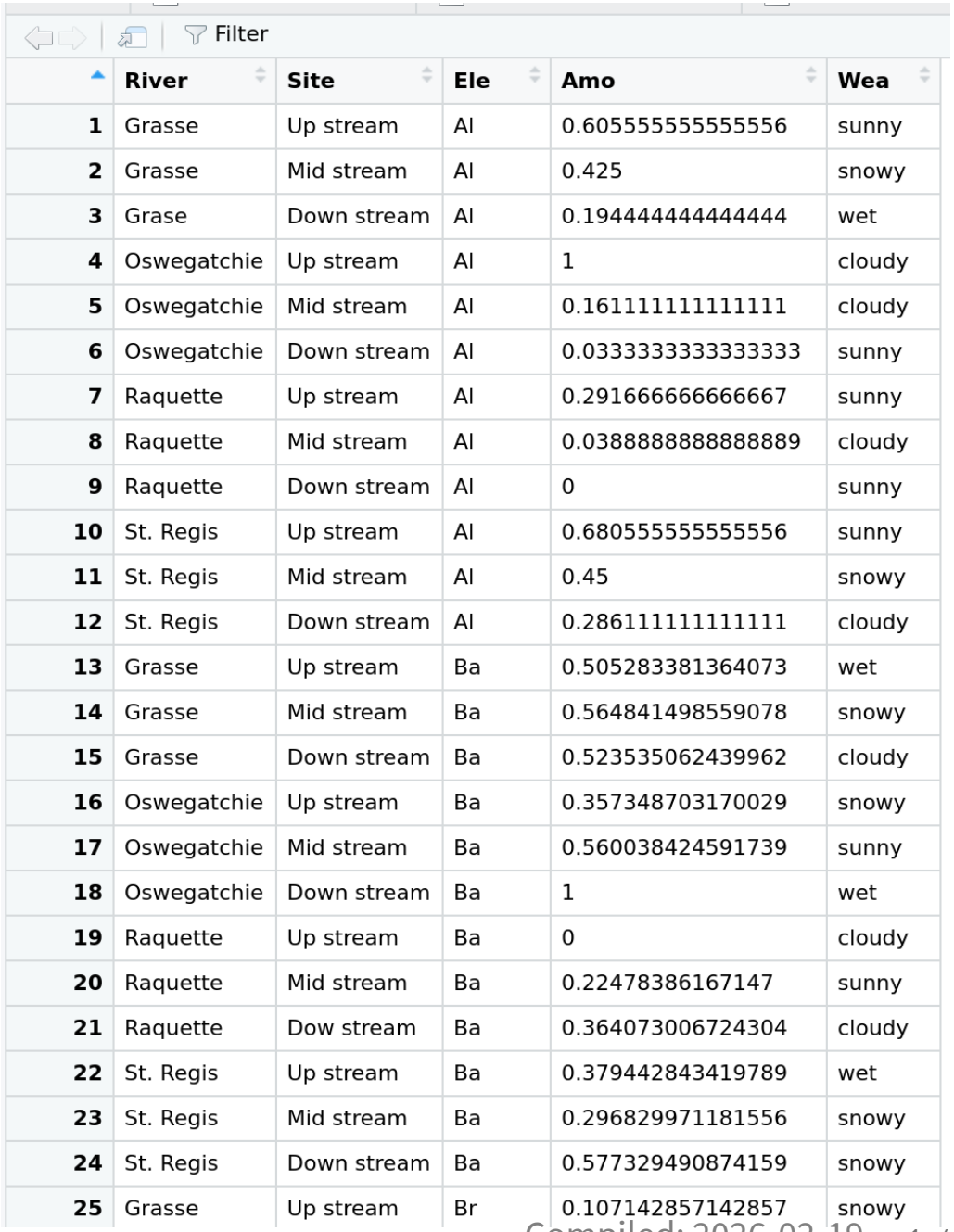
Analysis and Data Tools for Science



Filter

	River	Site	Ele	Amo	Wea
1	Grasse	Up stream	Al	0.605555555555556	sunny
2	Grasse	Mid stream	Al	0.425	snowy
3	Grase	Down stream	Al	0.194444444444444	wet
4	Oswegatchie	Up stream	Al	1	cloudy
5	Oswegatchie	Mid stream	Al	0.161111111111111	cloudy
6	Oswegatchie	Down stream	Al	0.0333333333333333	sunny
7	Raquette	Up stream	Al	0.291666666666667	sunny
8	Raquette	Mid stream	Al	0.0388888888888889	cloudy
9	Raquette	Down stream	Al	0	sunny
10	St. Regis	Up stream	Al	0.680555555555556	sunny
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19	Raquette	Up stream	Ba	0	cloudy
20	Raquette	Mid stream	Ba	0.22478386167147	sunny
21	Raquette	Dow stream	Ba	0.364073006724304	cloudy
22	St. Regis	Up stream	Ba	0.379442843419789	wet
23	St. Regis	Mid stream	Ba	0.296829971181556	snowy
24	St. Regis	Down stream	Ba	0.577329490874159	snowy
25	Grasse	Up stream	Br	0.107142857142857	snowy

First things first

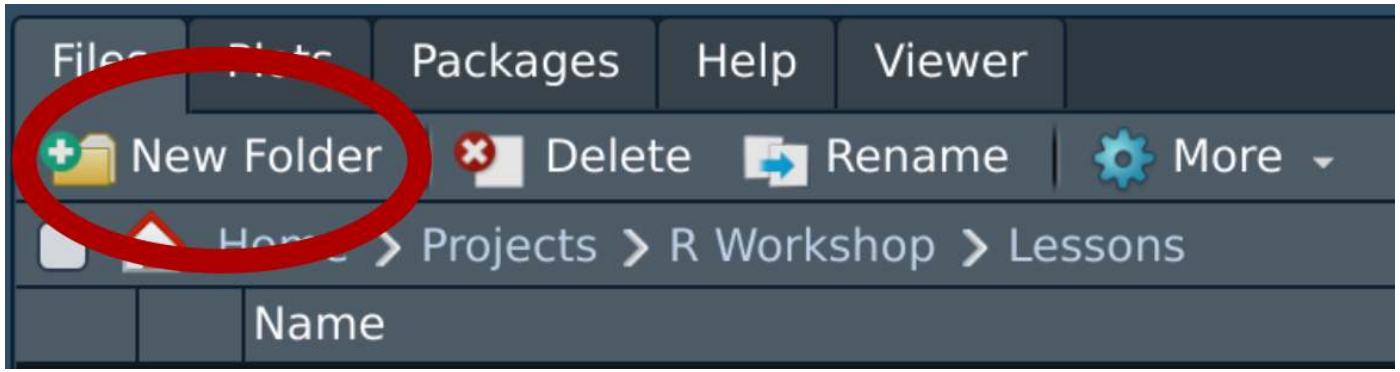
- Save previous script
- Open New File

  (make sure you're in the RStudio Project)
- Write `library(tidyverse)` at the top
- Save this new script

  (consider names like `cleaning.R` or `3_loading_and_cleaning.R`)

Download the data we'll use in this workshop

1. Create a '**data**' folder in your RStudio project
    - In the "Files" pane click on the folder icon **OR**
    - Navigate to your project folder via your computer's file browser



Click on "New Folder"

2. Right-click "Save Link As.." and download these files to your **data** folder

- 🔗`water_cleaned.xlsx`
- 🔗`water_raw.csv`
- 🔗`master_moch.txt`
- 🔗`geolocators.csv`
- 🔗`grain_size.txt`
- 🔗`grain_size2.csv`
- 🔗`grain_meta.csv`
- 🔗`Sta A Data 2006-11-07.dmp`

Side Note

R base vs. `tidyverse`

R base vs. `tidyverse`

R base

- Basic R
- Packages are installed and loaded by default
- Base pipe `|>` *

*We'll cover pipes soon 😁

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`tidyverse`

- Collection of 'new' packages developed by a team closely affiliated with RStudio
  - e.g., `ggplot2`, `dplyr`, `tidyr`, `readr`
  - Packages designed to work well together
- Use a slightly different syntax
- tidyverse pipe `%>%` or base pipe `|>` *

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Useful to know if functions are `tidyverse` or **R base**

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Dealing with data

1. Loading data

- Get your data into R

2. Looking for problems

- Typos
- Incorrectly loaded data

3. Fixing problems

- Corrections
- Renaming
- Dealing with NA’s

4. Setting formats

- Text,
- Numbers
- Factors
- Dates

5. Saving your data

Loading Data

Data types: What kind of data do you have?

Specific program files

Type	Extension	R Package	R function
Excel	.xls, .xlsx	`readxl`*	`read_excel()`
Open Document	.ods	`readODS`	`read_ods()`
SPSS	.sav, .zsav, .por	`haven`	`read_spss()`
SAS	.sas7bdat	`haven`	`read_sas()`
Stata	.dta	`haven`	`read_dta()`
Database Files	.dbf	`foreign`	`read.dbf()`

* part of the `tidyverse`

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SAS	.sas7bdat	`haven`	`read_sas()`
Stata	.dta	`haven`	`read_dta()`
Database Files	.dbf	`foreign`	`read.dbf()`

Convenient but…

- Can be unreliable
- Can take longer

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SAS	.sas7bdat	`haven`	`read_sas()`
Stata	.dta	`haven`	`read_dta()`
Database Files	.dbf	`foreign`	`read.dbf()`

Convenient but…

- Can be unreliable
- Can take longer

For files that don't change, better to save as a `*.csv` (Comma-separated-variables file)

* part of the `tidyverse`

Data types: What kind of data do you have?

General text files

Type	R base	`readr` package *
Comma separated	`read.csv()`	`read_csv()`, `read_csv2()`
Tab separated	`read.delim()`	`read_tsv()`
Space separated	`read.table()`	`read_table()`
Fixed-width	`read.fwf()`	`read_fwf()`

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- **`readr` package** especially useful for big data sets (fast!)
- Error/warnings from `readr` are a bit more helpful

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We'll focus on

- `readxl` package → `read_excel()`
- `readr` package → `read_csv()`, `read_tsv()`

* part of the `tidyverse`

Where is my data?

Common error

```
1 my_data <- read_csv("weather.csv")
```

```
Error: 'weather.csv' does not exist in current working directory ('/home/steffi/Projects/Workshops/workshop-dealing-with-data').
```

With no folder (just file name) R expects file to be in **Working directory**

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Working directory is:

- Where your RStudio project is
- Your home directory (My Documents, etc.) [If not using RStudio Projects]
- Where you've set it (using `setwd()` or RStudio's Session > Set Working Directory)

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Don't use `setwd()`
Do use Projects in RStudio

Where is my data?

A note on file paths (file locations)

```
1  /home
```

- folders separated by `/`
- `home` is a folder

Where is my data?

A note on file paths (file locations)

```
1  /home/steffi/
```

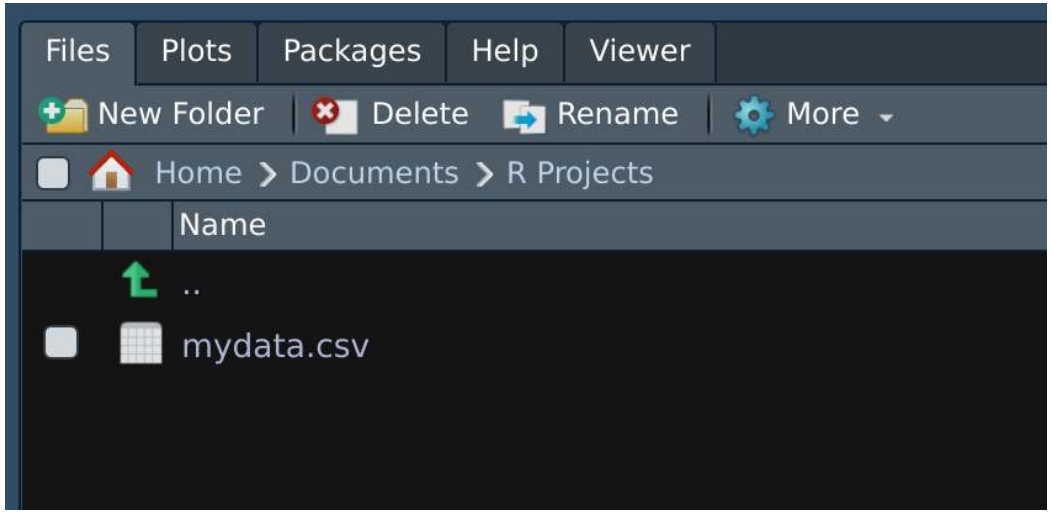
- folders separated by `/`
- `home` and `steffi` are folders
- `steffi` is a folder inside of `home`

Where is my data?

A note on file paths (file locations)

```
1  /home/steffi/Documents/R Projects/mydata.csv
```

- folders separated by `/`
- `home`, `steffi`, `Documents`, `R Projects` are folders
- `steffi` is inside of `home`, `Documents` is inside of `steffi`, etc.
- `mydata.csv` is a data file inside `R Projects` folder



RStudio Files Pane

Where is my data?

Absolute Paths

OS	Path
LINUX	/home/steffi/Documents/R Projects/mydata.csv
WINDOWS	C:/Users/steffi/My Documents/R Projects/mydata.csv
MAC	/users/steffi/Documents/R Projects/mydata.csv

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Full location, folders and filename

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Full location, folders and filename

Relative Paths

Path	Where to look
mydata.csv	Here (current directory)
../mydata.csv	Go up one directory (../)
data/mydata.csv	Stay here, go into “data” folder (data/)
../data/mydata.csv	Go up one directory (../), then into “data” folder (data/)

Where is my data?

Absolute Paths

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Only *relative* info
Use relative symbols
(e.g., `../`)

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Only *relative* info
Use relative symbols (e.g., `../`)

With RStudio ‘Projects’ only need to use **relative** paths

Keep yourself organized

For simple projects

- Create an ‘RStudio Project’ for each Project
- Create a specific “data” folder within each project (one per project)

```
- Prospect Lake Quality                  # Project Folder
    - prospect_analysis.R
    - data                               # Data Folder
        - prospect_data_2017-01-01.csv
        - prospect_data_2017-02-01.csv
```

Keep yourself organized

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- Create an ‘RStudio Project’ for each Project
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- Prospect Lake Quality                    # Project Folder
    - prospect_analysis.R
    - data                                 # Data Folder
        - prospect_data_2017-01-01.csv
        - prospect_data_2017-02-01.csv
```

- Use **relative** paths to refer to this folder

```
d <- read_csv("data/prospect_data_2017-01-01.csv")
```

Let’s load some data!

A reminder about Assignments!

- `<-`
- “Assign” an object to a handle/name

```
my_figure <- ggplot(data = penguins, aes(x = body_mass_g, y = bill_length_mm)) +
    geom_point()

my_data <- read_csv("my_data_spreadsheet.csv")
```

- `my_figure` is an R object, specifically a ggplot2 figure
- `my_data` is an R object, specifically a data.frame

To *use* your data, you need to load it *and* assign it to a handle/name

Your turn: Load some data

Working with 🔗`water_cleaned.xlsx`

1. Load the package

```
1  library(readxl)
```

2. Read in the Excel file and assign to object `water`

```
1  water <- read_excel("data/water_cleaned.xlsx")
```

3. Use `head()` and `tail()` functions to look at the data

   e.g., `head(water)` and `tail(water)`

4. Click on the `water` object in your "Environment" pane to look at the whole data set

Use the *'tab'* key in RStudio when typing in the file name for auto-complete

Your turn: Load some data

```r
library(readxl)
water <- read_excel("data/water_cleaned.xlsx")
```

```r
head(water)
```

```
# A tibble: 6 × 6
  river       site        element amount temperature  year
  <chr>       <chr>       <chr>    <dbl>       <dbl> <dbl>
1 Grasse      Up stream   Al       0.606        10.9  2019
2 Grasse      Mid stream  Al       0.425         8.68 2020
3 Grasse      Down stream Al       0.194         8.75 2021
4 Oswegatchie Up stream   Al       1             0.791 2022
5 Oswegatchie Mid stream  Al       0.161         9.32 2023
6 Oswegatchie Down stream Al       0.0333       10.6  2019
```

```r
tail(water)
```

```
# A tibble: 6 × 6
  river     site        element amount temperature  year
  <chr>     <chr>       <chr>    <dbl>       <dbl> <dbl>
1 Raquette  Up stream   Zr       0.333        14.0  2023
2 Raquette  Mid stream  Zr       0.111         7.61 2019
3 Raquette  Down stream Zr      NA             7.36 2020
4 St. Regis Up stream   Zr       0.889         7.94 2021
5 St. Regis Mid stream  Zr       0.778         9.28 2022
6 St. Regis Down stream Zr       0.667        10.1  2023
```

Filter

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How do I know which function to use?

Program-specific files

- Files which only normally open in a particular program (e.g., Excel)
- **Load with function from specific package (e.g. `read_excel` from readxl package)**

Text files

- Files which open in notepad
- Files which open in RStudio when you click on them in the Files Pane
- **Load with function from readr package (e.g. `read_csv()`, `read_tsv()`, etc.)**

Look at the file extension:

- 🔗`water_cleaned.xlsx` → Excel file → `read_excel()`
- 🔗`water_raw.csv` → Comma-separated-variables → `read_csv()`

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Look at the file extension:

- 🔗`water_cleaned.xlsx` → Excel file → `read_excel()`
- 🔗`water_raw.csv` → Comma-separated-variables → `read_csv()`

But sometimes not clear…

How do I know which function to use?

Working with: 🔗 `master_moch.txt`

- In lower right-hand pane, click on **Files**
- Click on **data** folder
- Click on **master_moch.txt**
- Click “View File” (if asked)

```
ID  region  hab freq    freq.sd p.notes
MCB02   kam 0.5266879074    3.9806600009    3.9806600009    0.4592592593
MCB03   kam -0.9707703735   4.1090031783    4.1090031783    0.5
MCB04   kam -0.9707703735   4.2463067674    4.2463067674    0.5151515152
```

This **does not** read the file into R, but only shows you the contents as text.

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MCB04   kam -0.9707703735   4.2463067674    4.2463067674    0.5151515152
```

This **does not** read the file into R, but only shows you the contents as text.

Hmm, not comma-separated, maybe tab-separated?

How do I know which function to use?

Peak:

- Pick a read function with your best guess (`read_csv()` is a good start)
- Use `n_max` to read only first few rows

```
  1  read_csv("data/master_moch.txt", n_max = 3)
```

```
# A tibble: 3 × 1
  `ID\tregion\thab\tfreq\tfreq.sd\tp.notes`
  <chr>
1 "MCB02\tkam\t0.5266879074\t3.9806600009\t3.9806600009\t0.4592592593"
2 "MCB03\tkam\t-0.9707703735\t4.1090031783\t4.1090031783\t0.5"
3 "MCB04\tkam\t-0.9707703735\t4.2463067674\t4.2463067674\t0.5151515152"
```

`\t` means tab, so this is tab-separated data

How do I know what to use?

Peak:

- Try again with `read_tsv()`

```
read_tsv("data/master_moch.txt", n_max = 3)   # note change in function!
```

```
# A tibble: 3 × 6
  ID    region    hab  freq freq.sd p.notes
  <chr> <chr>   <dbl> <dbl>   <dbl>   <dbl>
1 MCB02 kam     0.527  3.98    3.98   0.459
2 MCB03 kam    -0.971  4.11    4.11   0.5
3 MCB04 kam    -0.971  4.25    4.25   0.515
```

Excellent!

Specifics of loading functions

col_names

Working with 🔗geolocators.csv

```
1 my_data <- read_csv("data/geolocators.csv")
2 my_data
```

```
# A tibble: 20 × 2
   `02/05/11 22:29:59`  `64`
   <chr>               <dbl>
 1 02/05/11 22:31:59      64
 2 02/05/11 22:33:59      38
 3 02/05/11 22:35:59      38
 4 02/05/11 22:37:59      34
 5 02/05/11 22:39:59      30
 6 02/05/11 22:41:59      34
 7 02/05/11 22:43:59      40
 8 02/05/11 22:45:59      46
 9 02/05/11 22:47:59      48
10 02/05/11 22:49:59      46
# i 10 more rows
```

Oops?

col_names

Working with 🔗 geolocators.csv

```
1 my_data <- read_csv("data/geolocators.csv")
2 my_data
```

```
# A tibble: 20 × 2
   `02/05/11 22:29:59`  `64`
   <chr>               <dbl>
 1 02/05/11 22:31:59      64
 2 02/05/11 22:33:59      38
 3 02/05/11 22:35:59      38
 4 02/05/11 22:37:59      34
 5 02/05/11 22:39:59      30
 6 02/05/11 22:41:59      34
 7 02/05/11 22:43:59      40
 8 02/05/11 22:45:59      46
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10 02/05/11 22:49:59      46
# i 10 more rows
```

Oops?

- `read_csv`, `read_tsv`, etc. assume that the first row contains the column names
- This file doesn't have headers

col_names

Working with 🔗 `geolocators.csv`

Declare no headings

```
1 my_data <- read_csv("data/geolocators.csv",
2                     col_names = FALSE)
3 my_data
```

```
# A tibble: 21 × 2
   X1                   X2
   <chr>             <dbl>
 1 02/05/11 22:29:59    64
 2 02/05/11 22:31:59    64
 3 02/05/11 22:33:59    38
 4 02/05/11 22:35:59    38
 5 02/05/11 22:37:59    34
 6 02/05/11 22:39:59    30
 7 02/05/11 22:41:59    34
 8 02/05/11 22:43:59    40
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# i 11 more rows
```

col_names

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 3 02/05/11 22:33:59    38
 4 02/05/11 22:35:59    38
 5 02/05/11 22:37:59    34
 6 02/05/11 22:39:59    30
 7 02/05/11 22:41:59    34
 8 02/05/11 22:43:59    40
 9 02/05/11 22:45:59    46
10 02/05/11 22:47:59    48
# i 11 more rows
```

Name headings

```
1 my_data <- read_csv("data/geolocators.csv",
2                     col_names = c("date", "light"))
3 my_data
```

```
# A tibble: 21 × 2
   date                light
   <chr>               <dbl>
 1 02/05/11 22:29:59    64
 2 02/05/11 22:31:59    64
 3 02/05/11 22:33:59    38
 4 02/05/11 22:35:59    38
 5 02/05/11 22:37:59    34
 6 02/05/11 22:39:59    30
 7 02/05/11 22:41:59    34
 8 02/05/11 22:43:59    40
 9 02/05/11 22:45:59    46
10 02/05/11 22:47:59    48
# i 11 more rows
```

`skip` info rows before data

Working with 🔗 `grain_size.txt`

```
1 my_data <- read_tsv("data/grain_size.txt")
2 my_data
```

```
# A tibble: 36 × 7
  `DATA DOWNLOAD: 2015-09-23` ...2  ...3        ...4      ...5  ...6  ...7
  <chr>                       <chr> <chr>       <chr>     <chr> <chr> <chr>
 1 SYSTEM 001                 <NA>  <NA>        <NA>      <NA>  <NA>  <NA>
 2 LOGGER X                   <NA>  <NA>        <NA>      <NA>  <NA>  <NA>
 3 lab_num                    CSP   sample_num  depth_lb  csa   msa   fsa
 4 3177                       CSP01 CSP01-P-1-1 4         13.04 17.37 8.19
 5 3178                       CSP01 CSP01-P-1-2 12        10.74 16.9  7.92
 6 3179                       CSP01 CSP01-P-1-3 35        12.11 17.75 6.99
 7 3180                       CSP01 CSP01-P-1-4 53        17.61 18.16 6.29
 8 3181                       CSP01 CSP01-P-1-5 83        21.05 18.38 6.26
 9 3182                       CSP01 CSP01-P-1-6 105       19.02 18.43 6.28
10 3183                       CSP08 CSP08-P-1-1 10        11.6  17.14 8.18
# i 26 more rows
```

`skip` info rows before data

Working with 🔗`grain_size.txt`

```
1 my_data <- read_tsv("data/grain_size.txt")
2 my_data
```

Look at the file:

- Click on **Files** tab
- Click on **data** folder
- Click on **grain_size.txt**
- Click **“View file”** (if asked)

`skip` info rows before data

Working with 🔗`grain_size.txt`

```
my_data <- read_tsv("data/grain_size.txt")
my_data
```

Look at the file:

- Click on **Files** tab
- Click on **data** folder
- Click on **grain_size.txt**
- Click **“View file”** (if asked)

```
DATA DOWNLOAD: 2015-09-23
SYSTEM 001
LOGGER X
lab_num CSP sample_num  depth_lb    csa msa fsa
3177    CSP01   CSP01-P-1-1 4   13.04   17.37   8.19
3178    CSP01   CSP01-P-1-2 12  10.74   16.9    7.92
3179    CSP01   CSP01-P-1-3 35  12.11   17.75   6.99
3180    CSP01   CSP01-P-1-4 53  17.61   18.16   6.29
3181    CSP01   CSP01-P-1-5 83  21.05   18.38   6.26
```

`skip` info rows before data

Working with 🔗`grain_size.txt`

```
1 my_data <- read_tsv("data/grain_size.txt")
2 my_data
```

Look at the file:

- Click on **Files** tab
- Click on **data** folder
- Click on **grain_size.txt**
- Click **"View file"** (if asked)

```
DATA DOWNLOAD: 2015-09-23
SYSTEM 001
LOGGER X
lab_num CSP sample_num  depth_lb    csa msa fsa
3177    CSP01   CSP01-P-1-1 4   13.04   17.37   8.19
3178    CSP01   CSP01-P-1-2 12  10.74   16.9    7.92
3179    CSP01   CSP01-P-1-3 35  12.11   17.75   6.99
3180    CSP01   CSP01-P-1-4 53  17.61   18.16   6.29
3181    CSP01   CSP01-P-1-5 83  21.05   18.38   6.26
```

Ah ha!
Metadata was stored at the top of the file

`skip` info rows before data

Working with 🔗`grain_size.txt`

- Add `skip = 3` to skip the first three rows

```
1 my_data <- read_tsv("data/grain_size.txt", skip = 3)
2 my_data
```

```
# A tibble: 33 × 7
   lab_num CSP   sample_num  depth_lb   csa   msa   fsa
     <dbl> <chr> <chr>          <dbl> <dbl> <dbl> <dbl>
 1    3177 CSP01 CSP01-P-1-1        4 13.0  17.4   8.19
 2    3178 CSP01 CSP01-P-1-2       12 10.7  16.9   7.92
 3    3179 CSP01 CSP01-P-1-3       35 12.1  17.8   6.99
 4    3180 CSP01 CSP01-P-1-4       53 17.6  18.2   6.29
 5    3181 CSP01 CSP01-P-1-5       83 21.0  18.4   6.26
 6    3182 CSP01 CSP01-P-1-6      105 19.0  18.4   6.28
 7    3183 CSP08 CSP08-P-1-1       10 11.6  17.1   8.18
 8    3184 CSP08 CSP08-P-1-2       27 15.4  16.2   6.76
 9    3185 CSP08 CSP08-P-1-3       90 14.9  15.8   7.12
10    3186 CSP02 CSP02-P-1-1        5  8.75  8.64  3.41
# i 23 more rows
```

Much better!

Your turn: Load this data set

Load Data: 🔗`Sta A Data 2006-11-07.dmp`

1. Look at the file
2. Decide which R function to use based on delimiter (comma, space, or tab?)
3. Any other options need to be specified?

It should look like this:

```
# A tibble: 19 × 7
  StartDate Time     Frequency `Rate/Temp`   Pwr Ant       SD
      <dbl> <time>       <dbl>       <dbl> <dbl> <chr> <dbl>
1     39022 17:15:36      150.        34.8   175 M0        0
2     39022 17:19:14      148.        19.2    72 M0        0
3     39022 17:19:25      148.        19.7   194 M1        0
4     39022 17:20:04      149.        33.8   104 M0        0
5     39022 17:20:17      149.        33.7   152 M1        0
6     39022 17:20:57      150.        34.2   188 M0        0
7     39022 17:22:50      148.         9.8
# i 12 more rows
```

Too Easy?
Load some of your own tricky data

OR
Try to load the second sheet of `water_cleaned.xlsx`

Your turn: Load this data set

Load Data: 🔗`Sta A Data 2006-11-07.dmp`

```
telemetry <- read_csv("data/Sta A Data 2006-11-07.dmp", skip = 2)
telemetry
```

```
# A tibble: 19 × 7
  StartDate Time     Frequency `Rate/Temp`   Pwr Ant       SD
      <dbl> <time>       <dbl>       <dbl> <dbl> <chr> <dbl>
1     39022 17:15:36      150.        34.8   175 M0        0
2     39022 17:19:14      148.        19.2    72 M0        0
3     39022 17:19:25      148.        19.7   194 M1        0
4     39022 17:20:04      149.        33.8   104 M0        0
5     39022 17:20:17      149.        33.7   152 M1        0
6     39022 17:20:57      150.        34.2   188 M0        0
7     39022 17:22:50      148.         9.8   188 M0        0
# i 12 more rows
```

Your turn: Load this data set

Too Easy?

- Use `sheet` argument to access specific sheet (`excel_sheets()` lists them all)
- skip the first *two* rows (including the headers)

```
excel_sheets("data/water_cleaned.xlsx")  # Or look yourself ;)
```

```
[1] "Sheet1"      "Oswegatchie"
```

```
water2 <- read_excel("data/water_cleaned.xlsx", sheet = "Oswegatchie", skip = 2)
water2
```

```
# A tibble: 75 × 6
   river       site        element  amount temperature  year
   <chr>       <chr>       <chr>     <dbl>       <dbl> <dbl>
 1 Oswegatchie Up stream   Al        1            0.791  2022
 2 Oswegatchie Mid stream  Al        0.161        9.32   2023
 3 Oswegatchie Down stream Al        0.0333      10.6    2019
 4 Oswegatchie Up stream   Ba        0.357        3.73   2019
 5 Oswegatchie Mid stream  Ba        0.560        9.66   2020
 6 Oswegatchie Down stream Ba        1            8.56   2021
 7 Oswegatchie Up stream   Br        0.107       20.9    2021
 8 Oswegatchie Mid stream  Br        0.857       10.8    2022
 9 Oswegatchie Down stream Br        1            4.79   2023
10 Oswegatchie Up stream   Ca       NA            4.76   2023
# i 65 more rows
```

Looking for problems

Look at the data

- Make sure columns as expected (correctly assigned file format)
- Make sure no extra lines above the data (should we have used a skip?)
- Make sure column names look appropriate

```
1 library(palmerpenguins)
2 penguins
```

```
# A tibble: 344 × 8
   species island    bill_length_mm bill_depth_mm flipper_length_mm body_mass_g sex     year
   <fct>   <fct>              <dbl>         <dbl>             <int>       <int> <fct>  <int>
 1 Adelie  Torgersen           39.1          18.7               181        3750 male    2007
 2 Adelie  Torgersen           39.5          17.4               186        3800 female  2007
 3 Adelie  Torgersen           40.3          18                 195        3250 female  2007
 4 Adelie  Torgersen           NA            NA                  NA          NA <NA>    2007
 5 Adelie  Torgersen           36.7          19.3               193        3450 female  2007
 6 Adelie  Torgersen           39.3          20.6               190        3650 male    2007
 7 Adelie  Torgersen           38.9          17.8               181        3625 female  2007
 8 Adelie  Torgersen           39.2          19.6               195        4675 male    2007
 9 Adelie  Torgersen           34.1          18.1               193        3475 <NA>    2007
10 Adelie  Torgersen           42            20.2               190        4250 <NA>    2007
# i 334 more rows
```

Look at the data

- Did the whole data set load?
- Are there extra blank lines at the end of the data?

```
1 tail(penguins)
```

```
# A tibble: 6 × 8
  species   island bill_length_mm bill_depth_mm flipper_length_mm body_mass_g sex     year
  <fct>     <fct>           <dbl>         <dbl>             <int>       <int> <fct>  <int>
1 Chinstrap Dream            45.7          17                 195        3650 female  2009
2 Chinstrap Dream            55.8          19.8               207        4000 male    2009
3 Chinstrap Dream            43.5          18.1               202        3400 female  2009
4 Chinstrap Dream            49.6          18.2               193        3775 male    2009
5 Chinstrap Dream            50.8          19                 210        4100 male    2009
6 Chinstrap Dream            50.2          18.7               198        3775 female  2009
```

`skim()` the data

`skim()` is from `skimr`

- Are the formats correct?
  - numbers (`numeric`),
  - text (`character`)
  - date (`date`, `POSIXct`, `datetime`)
  - categories (`factor`)
- Are values appropriate?
  - Should there be `NA`s?
- Are there any typos?
- Number of rows expected?

```
  1  library(skimr)
  2  skim(penguins)
```

```
── Data Summary ────────────────────────
                           Values
Name                       penguins
Number of rows             344
Number of columns          8
_______________________
Column type frequency:
  factor                   3
  numeric                  5
_______________________
Group variables            None

── Variable type: factor ─────────────────────────────────────────────────────────────────────────
  skim_variable n_missing complete_rate ordered n_unique top_counts
1 species               0             1 FALSE          3 Ade: 152, Gen: 124, Chi: 68
2 island                0             1 FALSE          3 Bis: 168, Dre: 124, Tor: 52
3 sex                  11             0.968 FALSE      2 mal: 168, fem: 165

── Variable type: numeric ────────────────────────────────────────────────────────────────────────
  skim_variable     n_missing complete_rate   mean      sd     p0    p25    p50    p75   p100 hist
1 bill_length_mm            2         0.994   43.9    5.46   32.1   39.2   44.4   48.5   59.6 ▃▇▇▆▁
2 bill_depth_mm             2         0.994   17.2    1.97   13.1   15.6   17.3   18.7   21.5 ▅▇▇▆▂
3 flipper_length_mm         2         0.994  201.    14.1    172    190    197    213    231  ▂▇▃▅▂
4 body_mass_g               2         0.994 4202.   802.    2700   3550   4050   4750   6300 ▃▇▆▅▂
5 year                      0         1     2008.    0.818 2007   2007   2008   2009   2009 ▇▁▇▁▇
```

`count()` categories

`count()` is from `dplyr`*

- Check for sample sizes and potential typos in categorical columns
- Assess missing values

```
  1  count(penguins, species)
```

```
# A tibble: 3 × 2
  species       n
  <fct>     <int>
1 Adelie      152
2 Chinstrap    68
3 Gentoo      124
```

```
  1  count(penguins, island)
```

```
# A tibble: 3 × 2
  island        n
  <fct>     <int>
1 Biscoe      168
2 Dream       124
3 Torgersen    52
```

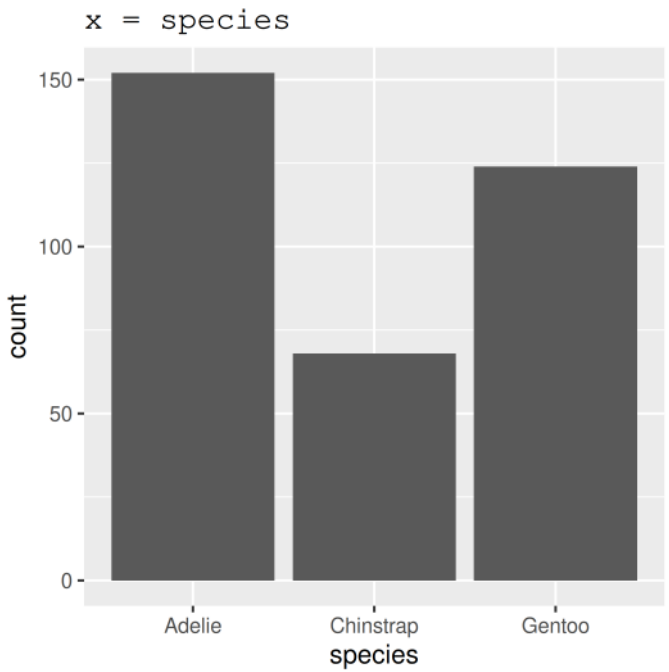
```
  1  count(penguins, sex)
```

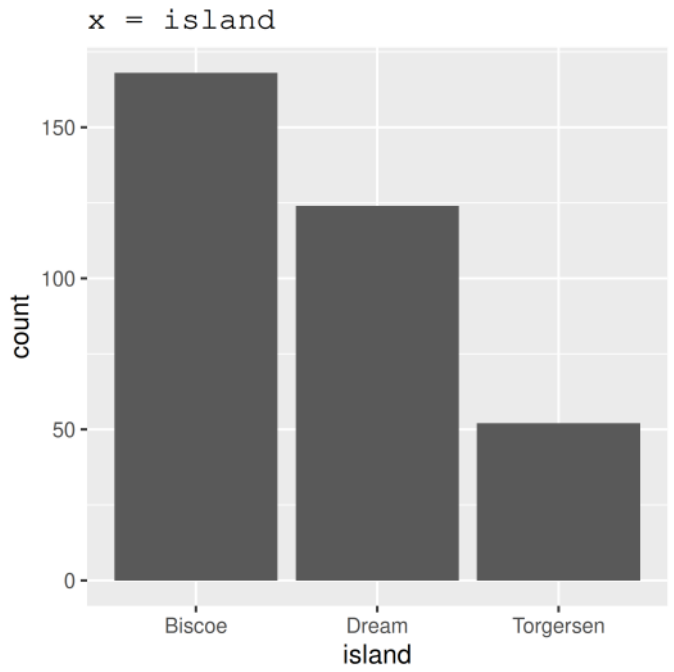
```
# A tibble: 3 × 2
  sex         n
  <fct>   <int>
1 female    165
2 male      168
3 <NA>       11
```

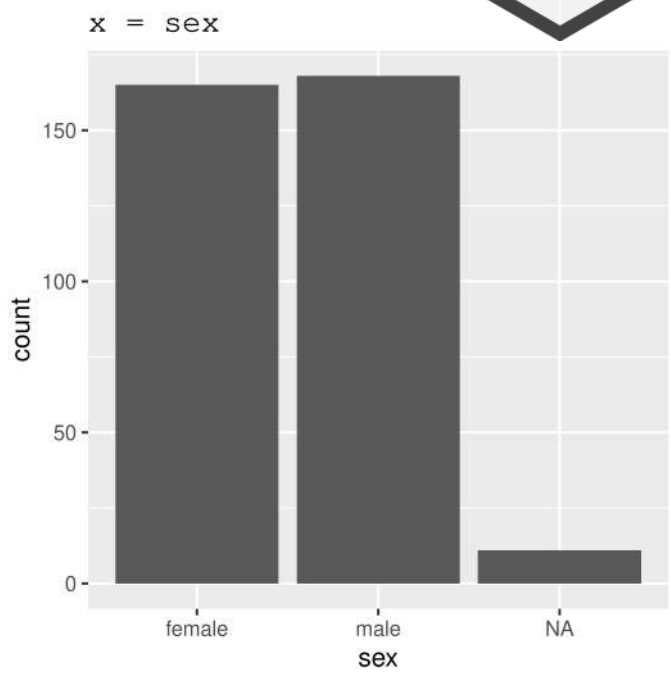
* part of the `tidyverse`

Plot categories

```
# Replace COLUMN with the column name to explore
ggplot(data = penguins, aes(x = COLUMN)) +
  geom_bar()
```



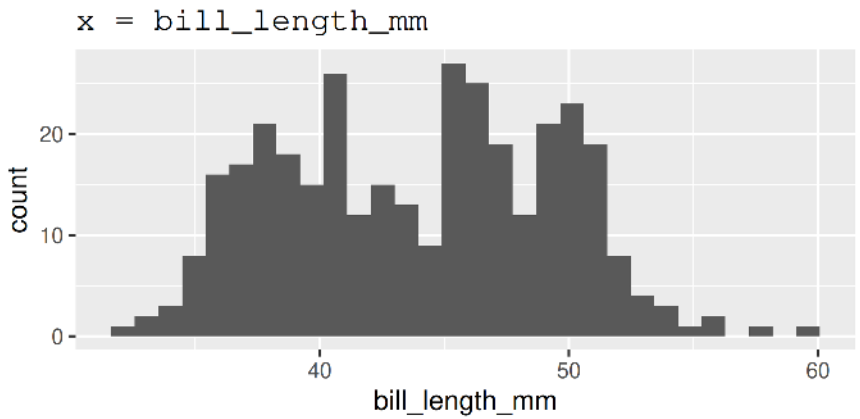


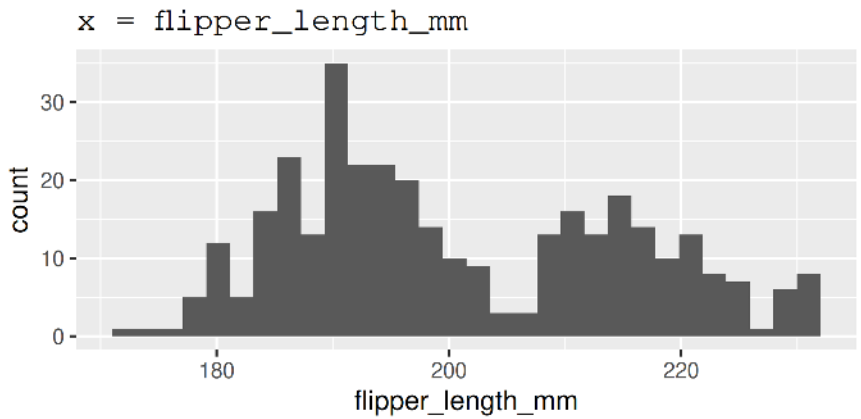


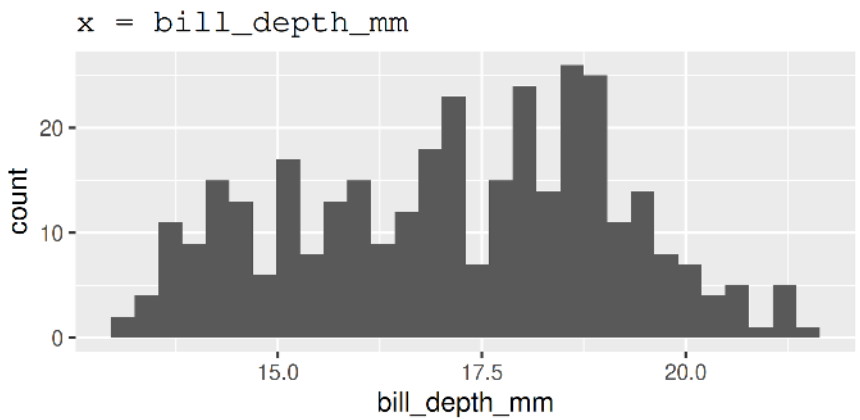
* part of the `tidyverse`

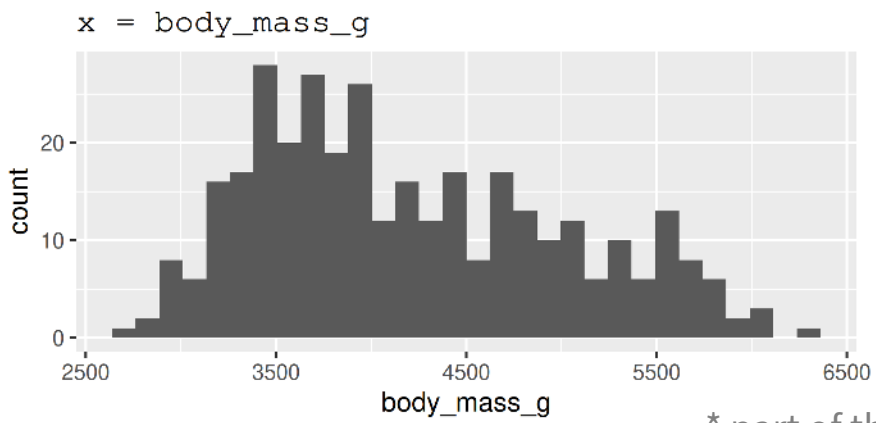
Plot numbers

```
# Replace COLUMN with the column name to explore
ggplot(data = penguins, aes(x = COLUMN)) +
  geom_histogram()
```









* part of the `tidyverse`

Example of problematic data

Look at the data

Working with: 🔗 `water_raw.csv`

```
1 water <- read_csv("data/water_raw.csv")
2 water
```

```
# A tibble: 300 × 7
  `River Name` Site        Ele       Amo `Temperature C°`  Year Wea
  <chr>        <chr>       <chr>   <dbl>            <dbl> <dbl> <chr>
 1 Grasse       Up stream   Al     0.606             10.9   2019 snowy
 2 Grasse       Mid stream  Al     0.425              8.68  2020 cloudy
 3 Grase        Down stream Al     0.194              8.75  2021 cloudy
 4 Oswegatchie  Up stream   Al     1                  0.791 2022 sunny
 5 Oswegatchie  Mid stream  Al     0.161              9.32  2023 snowy
 6 Oswegatchie  Down stream Al     0.0333            10.6   2019 wet
 7 Raquette     Up stream   Al     0.292              4.01  2020 snowy
 8 Raquette     Mid stream  Al     0.0389             5.96  2021 sunny
 9 Raquette     Down stream Al    NA                  6.21  2022 cloudy
10 St. Regis    Up stream   Al     0.681              8.02  2023 wet
# i 290 more rows
```

- Column names are not R-friendly (`River Name` and `Temperature C°`) or obvious (what is `Ele`?)
- At least one typo in River (`Grase` should be `Grasse`)

Looking for problems

Your Turn!

```
1 water <- read_csv("data/water_raw.csv")
2 water
```

```
# A tibble: 300 × 7
   `River Name` Site        Ele       Amo `Temperature C°`  Year Wea
   <chr>        <chr>       <chr>   <dbl>            <dbl> <dbl> <chr>
 1 Grasse       Up stream   Al     0.606             10.9    2019 snowy
 2 Grasse       Mid stream  Al     0.425              8.68   2020 cloudy
 3 Grase        Down stream Al     0.194              8.75   2021 cloudy
 4 Oswegatchie  Up stream   Al     1                  0.791  2022 sunny
 5 Oswegatchie  Mid stream  Al     0.161              9.32   2023 snowy
 6 Oswegatchie  Down stream Al     0.0333            10.6    2019 wet
 7 Raquette     Up stream   Al     0.292              4.01   2020 snowy
 8 Raquette     Mid stream  Al     0.0389             5.96   2021 sunny
 9 Raquette     Down stream Al    NA                  6.21   2022 cloudy
10 St. Regis    Up stream   Al     0.681              8.02   2023 wet
# i 290 more rows
```

- `skim()` the data
- `count()` some columns
- Perhaps make some `ggplot()`s

Find any problems?

`skim()` the data

```
1 library(skimr)
2 skim(water)
```

```
── Data Summary ────────────────────────
                           Values
Name                       water
Number of rows             300
Number of columns          7
_________________________
Column type frequency:
  character                4
  numeric                  3
_________________________
Group variables            None

── Variable type: character ──────────────────────────────────────────────────────────────────────────────────────────
  skim_variable n_missing complete_rate min max empty n_unique whitespace
1 River Name            0             1   5  11     0        7          0
2 Site                  0             1   9  11     0        3          0
3 Ele                   0             1   1   2     0       25          0
4 Wea                   0             1   3   6     0        4          0

── Variable type: numeric ────────────────────────────────────────────────────────────────────────────────────────────
  skim_variable  n_missing complete_rate     mean     sd         p0      p25      p50      p75   p100 hist
1 Amo                   39          0.87    0.429  0.299    0.00656    0.169    0.379    0.643    1   ▆▆▃▂
2 Temperature C°         0          1       9.17  11.5     -99          7.54    10.3     12.7     20.9 ▁▁▁▁▇
3 Year                   0          1    2021      1.42  2019       2020     2021     2022     2023   ▇▇▇▇
```

count() categories

```
1 count(water, `River Name`)
```

```
# A tibble: 7 × 2
  `River Name`      n
  <chr>         <int>
1 Grase             1
2 Grasse           73
3 Oswegatchie      75
4 Raquette         74
5 St. Regis        75
6 grasse            1
7 raquette          1
```

```
1 count(water, Wea)
```

```
# A tibble: 4 × 2
  Wea         n
  <chr>   <int>
1 cloudy     84
2 snowy      61
3 sunny      85
4 wet        70
```

```
1 count(water, Site)
```

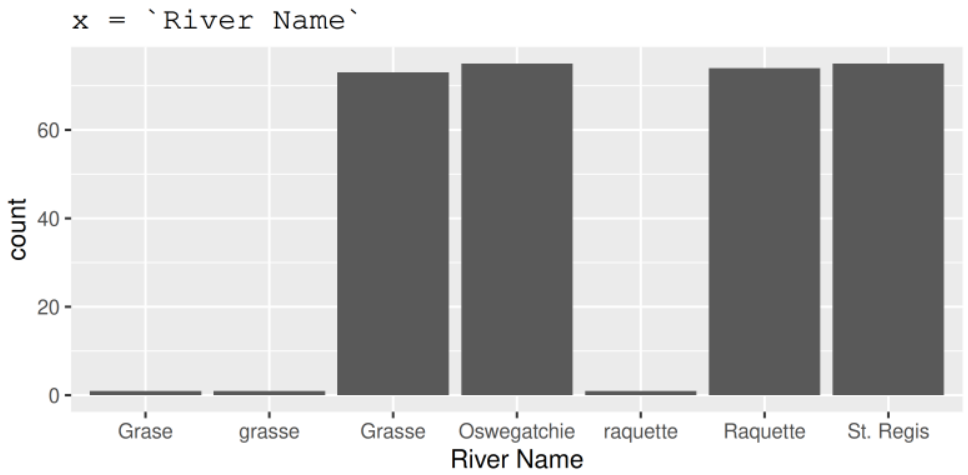
```
# A tibble: 3 × 2
  Site             n
  <chr>        <int>
1 Down stream    100
2 Mid stream     100
3 Up stream      100
```

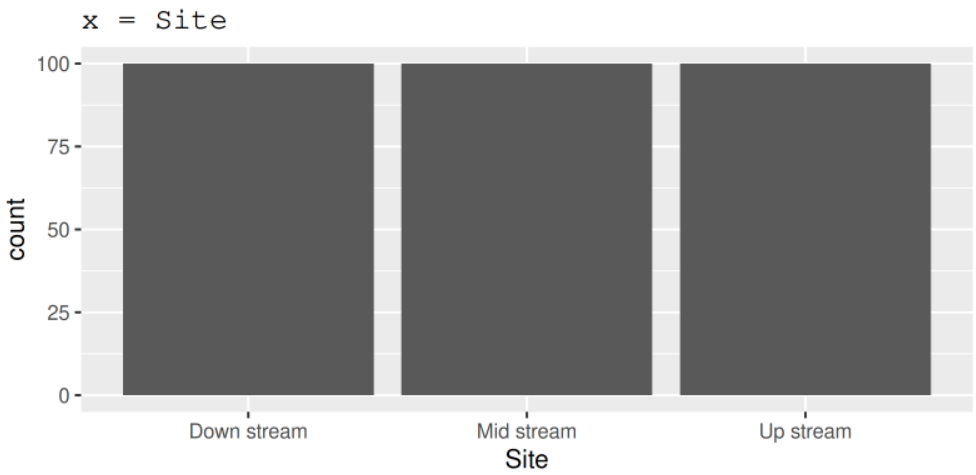
```
1 count(water, Ele)
```

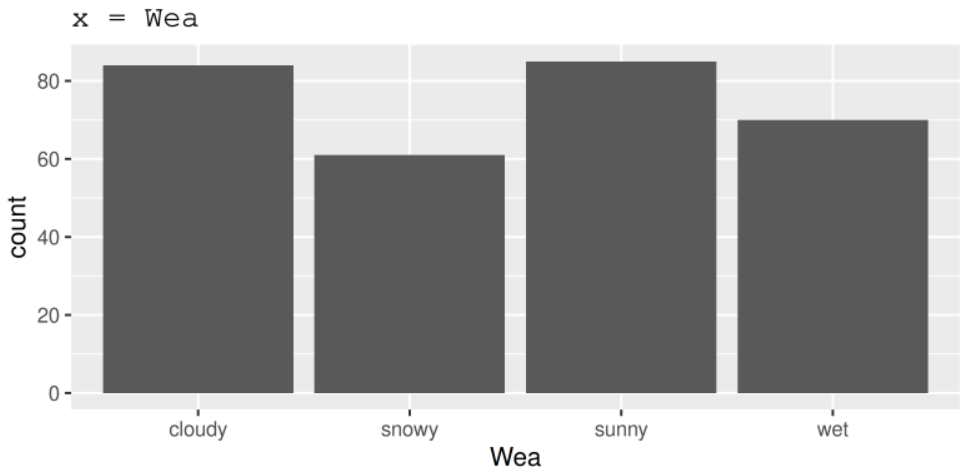
```
# A tibble: 25 × 2
   Ele       n
   <chr> <int>
 1 Al       12
 2 Ba       12
 3 Br       12
 4 Ca       12
 5 Ce       12
 6 Cu       12
 7 Dy       12
 8 Er       12
 9 Fe       12
10 Gd       12
# i 15 more rows
```

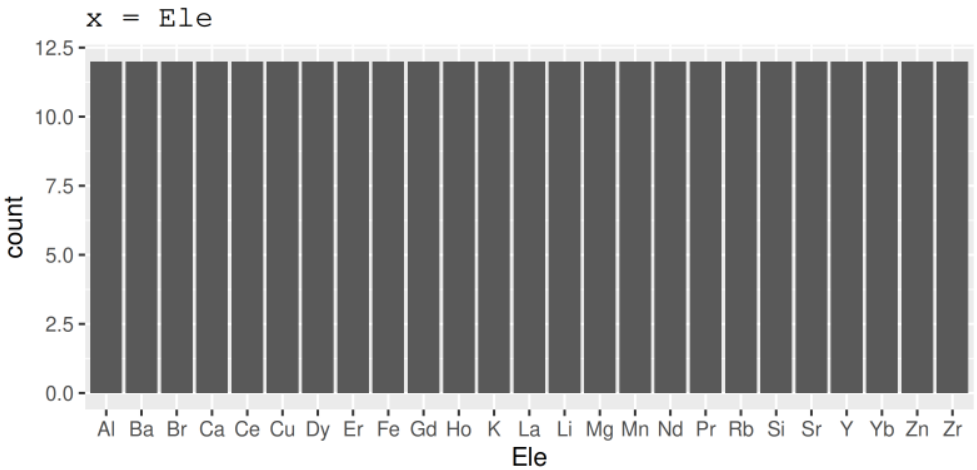
Plot categories

```
# Replace COLUMN with the column name to explore
ggplot(data = water, aes(x = COLUMN)) +
  geom_bar()
```



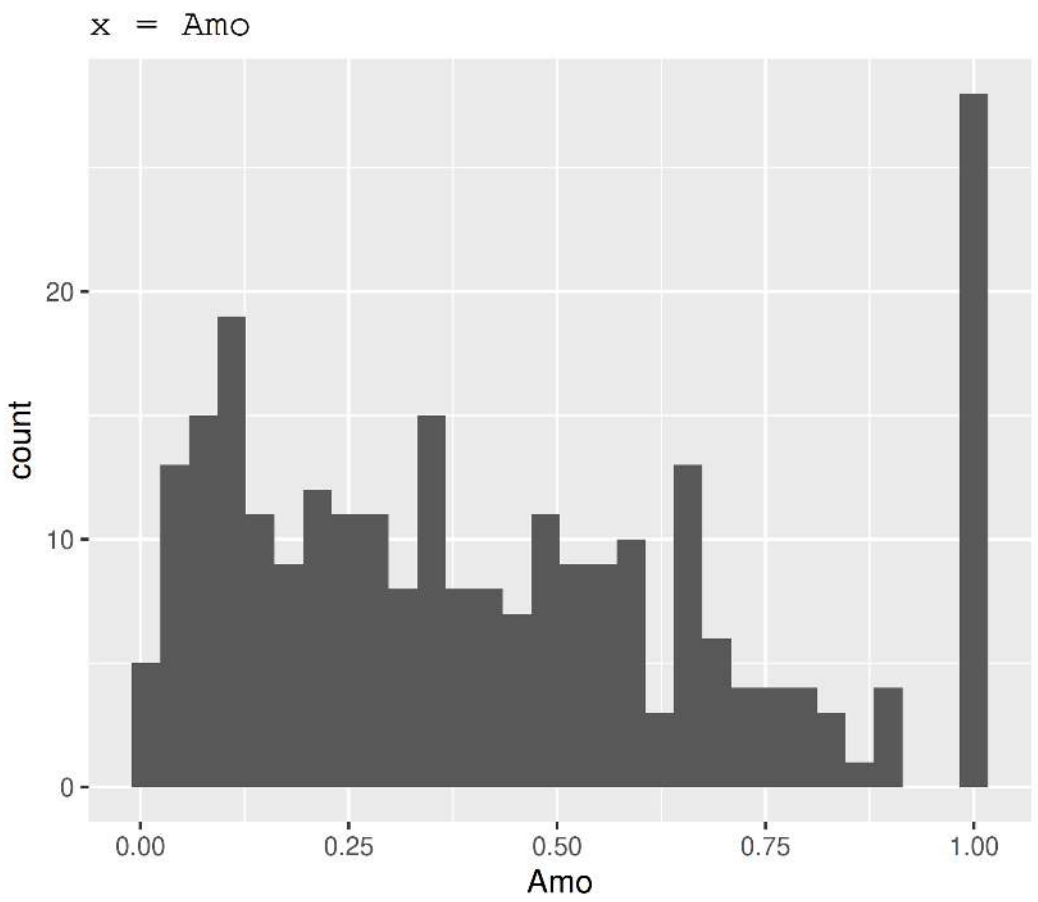


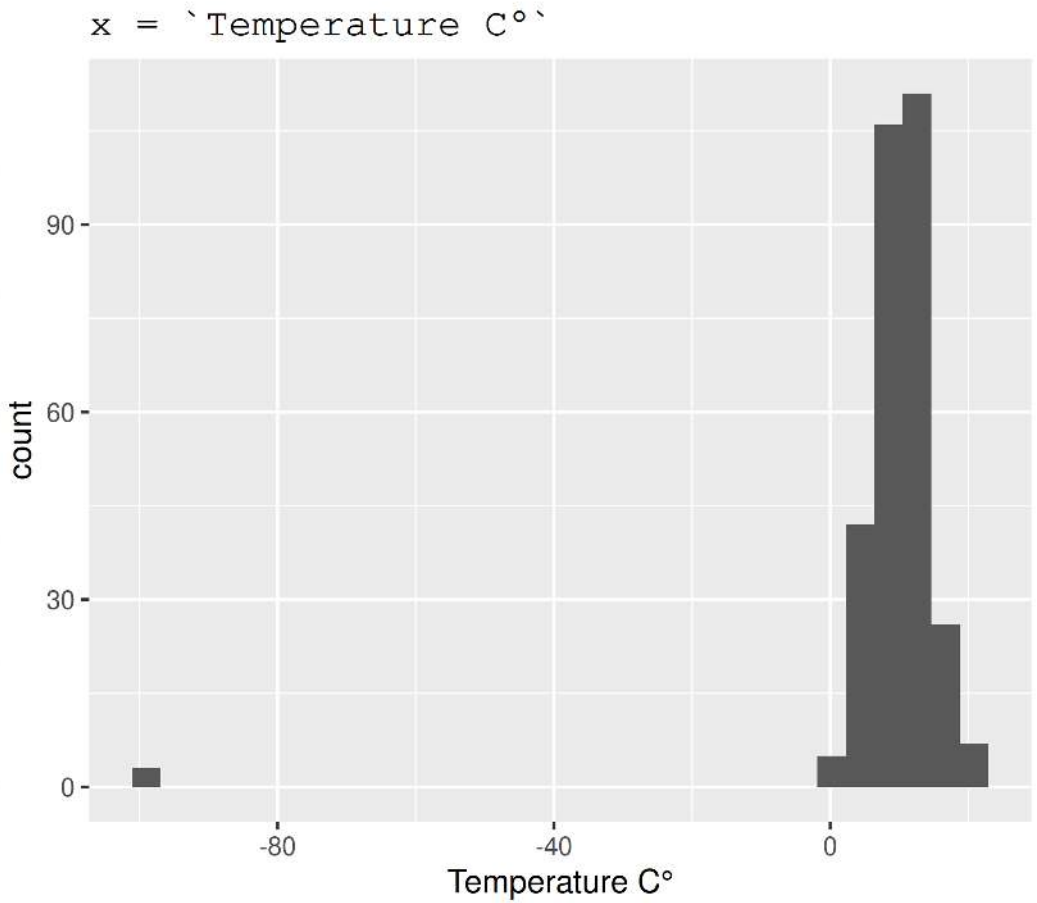




Plot numbers

```
# Replace COLUMN with the column name to explore
ggplot(data = water, aes(x = COLUMN)) +
  geom_histogram()()
```





Fixing problems

Cleaning column names

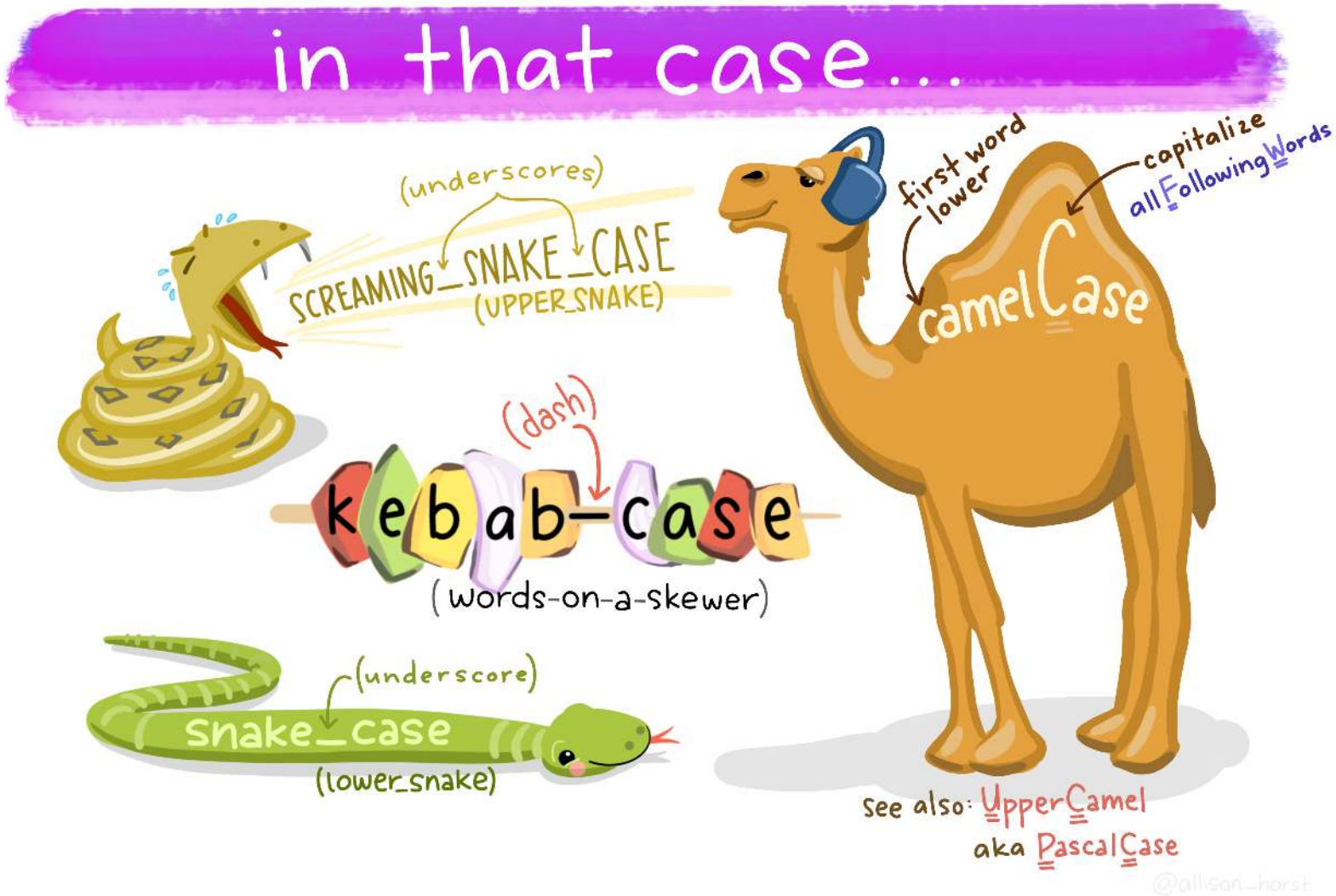
`clean_names()` is from `janitor`*

```
library(janitor)
water <- clean_names(water)
water
```

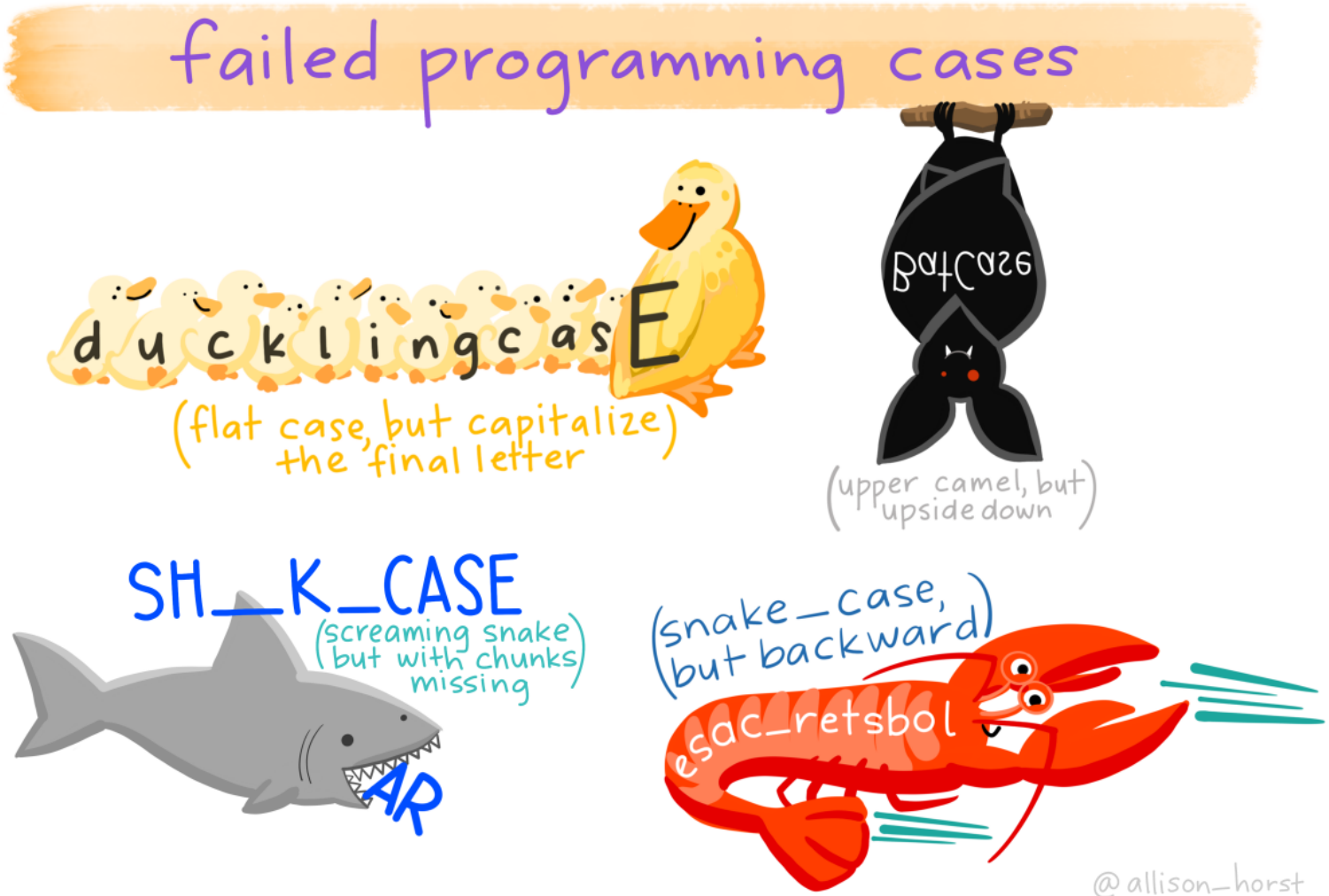
```
# A tibble: 300 × 7
   river_name  site        ele       amo temperature_c  year wea
   <chr>       <chr>       <chr>   <dbl>         <dbl> <dbl> <chr>
 1 Grasse      Up stream   Al     0.606          10.9    2019 snowy
 2 Grasse      Mid stream  Al     0.425           8.68   2020 cloudy
 3 Grase       Down stream Al     0.194           8.75   2021 cloudy
 4 Oswegatchie Up stream   Al     1               0.791  2022 sunny
 5 Oswegatchie Mid stream  Al     0.161           9.32   2023 snowy
 6 Oswegatchie Down stream Al     0.0333         10.6    2019 wet
 7 Raquette    Up stream   Al     0.292           4.01   2020 snowy
 8 Raquette    Mid stream  Al     0.0389          5.96   2021 sunny
 9 Raquette    Down stream Al    NA               6.21   2022 cloudy
10 St. Regis   Up stream   Al     0.681           8.02   2023 wet
# i 290 more rows
```

* *not* part of the `tidyverse` but `tidyverse`-orientated

Side Note: Naming conventions



Side Note: Naming conventions



Cleaning column names

`rename()` is from `dplyr`*

`rename()` columns

```
1 water <- rename(water, element = ele, amount = amo, temperature = temperature_c)
2 water
```

```
# A tibble: 300 × 7
   river_name  site        element  amount temperature  year wea
   <chr>       <chr>       <chr>     <dbl>       <dbl> <dbl> <chr>
 1 Grasse      Up stream   Al       0.606        10.9    2019 snowy
 2 Grasse      Mid stream  Al       0.425         8.68   2020 cloudy
 3 Grase       Down stream Al       0.194         8.75   2021 cloudy
 4 Oswegatchie Up stream   Al       1             0.791  2022 sunny
 5 Oswegatchie Mid stream  Al       0.161         9.32   2023 snowy
 6 Oswegatchie Down stream Al       0.0333       10.6    2019 wet
 7 Raquette    Up stream   Al       0.292         4.01   2020 snowy
 8 Raquette    Mid stream  Al       0.0389        5.96   2021 sunny
 9 Raquette    Down stream Al      NA             6.21   2022 cloudy
10 St. Regis   Up stream   Al       0.681         8.02   2023 wet
# i 290 more rows
```

* part of the `tidyverse`

Subsetting columns

`select()` is from `dplyr`*

`select()` columns you want

```
1  water <- select(water, river_name, site, element, amount)
```

* part of the `tidyverse`

Subsetting columns

`select()` is from `dplyr`*

`select()` columns you want

```
1 water <- select(water, river_name, site, element, amount)
```

OR, un`select()` columns you don't want

```
1 water <- select(water, -wea)
2 water
```

```
# A tibble: 300 × 6
   river_name  site        element  amount temperature  year
   <chr>       <chr>       <chr>     <dbl>       <dbl> <dbl>
 1 Grasse      Up stream   Al       0.606        10.9    2019
 2 Grasse      Mid stream  Al       0.425         8.68   2020
 3 Grase       Down stream Al       0.194         8.75   2021
 4 Oswegatchie Up stream   Al       1             0.791  2022
 5 Oswegatchie Mid stream  Al       0.161         9.32   2023
 6 Oswegatchie Down stream Al       0.0333       10.6    2019
 7 Raquette    Up stream   Al       0.292         4.01   2020
 8 Raquette    Mid stream  Al       0.0389        5.96   2021
 9 Raquette    Down stream Al      NA             6.21   2022
10 St. Regis   Up stream   Al       0.681         8.02   2023
# i 290 more rows
```

Cleaning columns

Put it all together

```
water <- read_csv("data/water_raw.csv")
water <- clean_names(water)
water <- rename(water, element = ele, amount = amo, temperature = temperature_c)
water <- select(water, -wea)
water
```

```
# A tibble: 300 × 6
   river_name  site        element  amount temperature  year
   <chr>       <chr>       <chr>     <dbl>       <dbl> <dbl>
 1 Grasse      Up stream   Al       0.606       10.9    2019
 2 Grasse      Mid stream  Al       0.425        8.68   2020
 3 Grase       Down stream Al       0.194        8.75   2021
 4 Oswegatchie Up stream   Al       1            0.791  2022
 5 Oswegatchie Mid stream  Al       0.161        9.32   2023
 6 Oswegatchie Down stream Al       0.0333      10.6    2019
 7 Raquette    Up stream   Al       0.292        4.01   2020
 8 Raquette    Mid stream  Al       0.0389       5.96   2021
 9 Raquette    Down stream Al      NA            6.21   2022
10 St. Regis   Up stream   Al       0.681        8.02   2023
# i 290 more rows
```

Cleaning columns

Put it all together

```r
water <- read_csv("data/water_raw.csv")
water <- clean_names(water)
water <- rename(water, element = ele, amount = amo, temperature = temperature_c)
water <- select(water, -wea)
water
```

```
# A tibble: 300 × 6
   river_name  site        element  amount temperature  year
   <chr>       <chr>       <chr>     <dbl>       <dbl> <dbl>
 1 Grasse      Up stream   Al       0.606       10.9    2019
 2 Grasse      Mid stream  Al       0.425        8.68   2020
 3 Grase       Down stream Al       0.194        8.75   2021
 4 Oswegatchie Up stream   Al       1            0.791  2022
 5 Oswegatchie Mid stream  Al       0.161        9.32   2023
 6 Oswegatchie Down stream Al       0.0333      10.6    2019
 7 Raquette    Up stream   Al       0.292        4.01   2020
 8 Raquette    Mid stream  Al       0.0389       5.96   2021
 9 Raquette    Down stream Al      NA            6.21   2022
10 St. Regis   Up stream   Al       0.681        8.02   2023
# i 290 more rows
```

Note how code repeats data frame `water`...

Fixing typos

Remember the typos…

```
  1  count(water, river_name)
```

```
# A tibble: 7 × 2
  river_name      n
  <chr>       <int>
1 Grase           1
2 Grasse         73
3 Oswegatchie    75
4 Raquette       74
5 St. Regis      75
6 grasse          1
7 raquette        1
```

Fixing typos

Replace typos

Combine the `if_else` function with the `mutate()` function

```
water <- mutate(water, river_name = if_else(river_name == "Grase", "Grasse", river_name))
```

Check that it's gone:

```
count(water, river_name)
```

```
# A tibble: 6 × 2
  river_name      n
  <chr>       <int>
1 Grasse         74
2 Oswegatchie    75
3 Raquette       74
4 St. Regis      75
5 grasse          1
6 raquette        1
```

Fixing typos

`if_else()` and `mutate()` from `dplyr` package*

`mutate()` creates or changes columns in a data frame:

```
1 mutate(dataframe, column = new_values)
```

`if_else()` tests for a condition, and returns one value if `FALSE` and another if `TRUE`

```
1 if_else(condition, value_if_true, value_if_false)
```

* part of the `tidyverse`

Iterative process

- Make some corrections
- Check the data
- Make some more corrections (either add to or modify existing code)

Iterative process

- Make some corrections
- Check the data
- Make some more corrections (either add to or modify existing code)

Many corrections?

Try `case_when()` from `dplyr` package*

`case_when()` tests for multiple conditions, and returns different values depending

```
case_when(condition1 ~ value_if_true1,
          condition2 ~ value_if_true2,
          condition3 ~ value_if_true3,
          TRUE ~ default_value)
```

* part of the `tidyverse`

Your Turn: Fix another “Grasse” typo

1. Check the data with `count()`
2. Use `mutate()` and `if_else()` to fix the typo

```
1  water <- read_csv("data/water_raw.csv")
2  water <- clean_names(water)
3  water <- rename(water, element = ele, amount = amo, temperature = temperature_c)
4  water <- select(water, -wea)
5  water <- mutate(water, river_name = if_else(river_name == "Grase", "Grasse", river_name))
6
7  water <- mutate(???, ??? = ???)
```

Too Easy?
Examine and fix problems in your own data

OR
Use `case_when()` to fix all the river name typos at once…

Your Turn: Fix another “Grasse” typo

1. Check the data with `count()`
2. Use `mutate()` and `if_else()` to fix the typo

```
water <- read_csv("data/water_raw.csv")
water <- clean_names(water)
water <- rename(water, element = ele, amount = amo, temperature = temperature_c)
water <- select(water, -wea)
water <- mutate(water, river_name = if_else(river_name == "Grase", "Grasse", river_name))

water <- mutate(water, river_name = if_else(river_name == "grasse", "Grasse", river_name))
```

Fixing typos

To be more efficient, fix all typos at once

```
1 water <- read_csv("data/water_raw.csv")
2 water <- clean_names(water)
3 water <- rename(water, element = ele, amount = amo, temperature = temperature_c)
4 water <- select(water, -wea)
5 water <- mutate(water,
6                 river_name = if_else(river_name %in% c("Grase", "grasse"), "Grasse", river_name))
```

`==` compares one item to one other

`%in%` compares one item to many different ones

Fixing typos

One last typo to fix

```
water <- read_csv("data/water_raw.csv")
water <- clean_names(water)
water <- rename(water, element = ele, amount = amo, temperature = temperature_c)
water <- select(water, -wea)
water <- mutate(water,
                river_name = if_else(river_name %in% c("Grase","grasse"), "Grasse", river_name),
                river_name = if_else(river_name == "raquette", "Raquette", river_name))
```

Fixing typos

One last typo to fix

```
water <- read_csv("data/water_raw.csv")
water <- clean_names(water)
water <- rename(water, element = ele, amount = amo, temperature = temperature_c)
water <- select(water, -wea)
water <- mutate(water,
                river_name = if_else(river_name %in% c("Grase","grasse"), "Grasse", river_name),
                river_name = if_else(river_name == "raquette", "Raquette", river_name))
```

Combine with `case_when()`

```
water <- read_csv("data/water_raw.csv")
water <- clean_names(water)
water <- rename(water, element = ele, amount = amo, temperature = temperature_c)
water <- select(water, -wea)
water <- mutate(water,
                river_name = case_when(river_name %in% c("Grase", "grasse") ~ "Grasse",
                                       river_name == "raquette" ~ "Raquette",
                                       TRUE ~ river_name))
```

Tangent: `tidyverse` functions

`tidyverse` functions

`rename()`, `select()`, `mutate()`

- `tidyverse` functions always start with the **data**, followed by other arguments
- you can reference any **column** from '**data**'

```
1 water <- read_csv("data/water_raw.csv")
2 water <- clean_names(water)
3 water <- rename(water, element = ele, amount = amo, temperature = temperature_c)
4 water <- select(water, -wea)
5 water <- mutate(water, river_name = if_else(river_name %in% c("Grase", "grasse"), "Grasse",  river_name))
```

- `rename()` changes column names
- `select()` chooses columns to keep or to remove (with `-`)
- `mutate()` changes column contents

Why use `tidyverse` functions?

Pipes! `|>`* Allow you to string commands together

Instead of:

```
water <- read_csv("data/water_raw.csv")
water <- clean_names(water)
water <- rename(water, element = ele, amount = amo, temperature = temperature_c)
water <- select(water, -wea)
water <- mutate(water,
                river_name = case_when(river_name %in% c("Grase", "grasse") ~ "Grasse",
                                       river_name == "raquette" ~ "Raquette",
                                       TRUE ~ river_name))
```

* `|>` is the base pipe, `%>%` is the tidyverse pipe, you can use either

Why use `tidyverse` functions?

Pipes! `|>`* Allow you to string commands together

Instead of:

```
water <- read_csv("data/water_raw.csv")
water <- clean_names(water)
water <- rename(water, element = ele, amount = amo, temperature = temperature_c)
water <- select(water, -wea)
water <- mutate(water,
                river_name = case_when(river_name %in% c("Grase", "grasse") ~ "Grasse",
                                       river_name == "raquette" ~ "Raquette",
                                       TRUE ~ river_name))
```

We have:

```
water <- read_csv("data/water_raw.csv") |>
  clean_names() |>
  rename(element = ele, amount = amo, temperature = temperature_c) |>
  select(-wea) |>
  mutate(river_name = case_when(river_name %in% c("Grase", "grasse") ~ "Grasse",
                                river_name == "raquette" ~ "Raquette",
                                TRUE ~ river_name))
```

* `|>` is the base pipe, `%>%` is the tidyverse pipe, you can use either

Play around

Take a moment to play with this code in your console

Convert this:

```
water <- read_csv("data/water_raw.csv")
water <- clean_names(water)
water <- rename(water, element = ele, amount = amo, temperature = temperature_c)
water <- select(water, -wea)
water <- mutate(water,
                river_name = case_when(river_name %in% c("Grase", "grasse") ~ "Grasse",
                                       river_name == "raquette" ~ "Raquette",
                                       TRUE ~ river_name))
```

To this:

```
water <- read_csv("data/water_raw.csv") |>
  clean_names() |>
  rename(element = ele, amount = amo, temperature = temperature_c) |>
  select(-wea) |>
  mutate(river_name = case_when(river_name %in% c("Grase", "grasse") ~ "Grasse",
                                river_name == "raquette" ~ "Raquette",
                                TRUE ~ river_name))
```

Dealing with NAs

Data that *is* missing

Data that *should* be missing

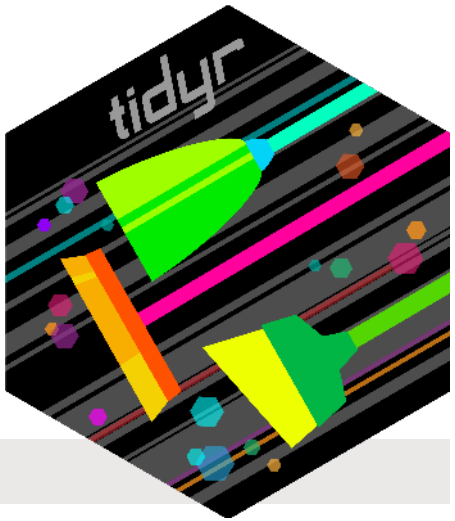
Exploring NAs

- We saw missing values in `amount`
- Use `filter()` to take a closer look

```
1 filter(water, is.na(amount))
```

```
# A tibble: 39 × 6
   river_name  site        element amount temperature  year
   <chr>       <chr>       <chr>    <dbl>       <dbl> <dbl>
 1 Raquette    Down stream Al          NA        6.21  2022
 2 Raquette    Up stream   Ba          NA        5.23  2022
 3 Raquette    Up stream   Br          NA      -99     2019
 4 Oswegatchie Up stream   Ca          NA        4.76  2023
 5 Raquette    Down stream Ce          NA       13.9   2020
 6 Grasse      Up stream   Cu          NA        9.13  2019
 7 Raquette    Down stream Dy          NA        4.98  2019
 8 Raquette    Down stream Er          NA        3.07  2021
 9 Raquette    Down stream Fe          NA        7.20  2023
10 Raquette    Down stream Gd          NA        4.73  2020
# i 29 more rows
```

Omitting NAs



`drop_na()` is from `tidyr`*

Omit `NA`s from the `amount` column only (drop those rows)

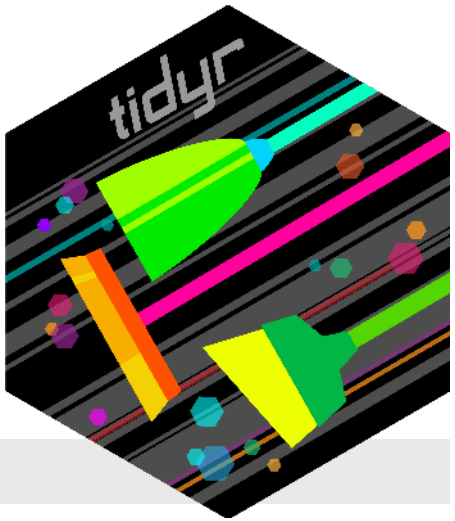
```
1 water_no_na <- drop_na(water, amount)
```

Omit **all** `NA`s from **all** columns (drop those rows)

```
1 water_no_na <- drop_na(water)
```

* part of the `tidyverse`

Omitting NAs



`drop_na()` is from `tidyr`*

Omit `NA`s from the `amount` column only (drop those rows)

```
1 water_no_na <- drop_na(water, amount)
```

Omit **all** `NA`s from **all** columns (drop those rows)

```
1 water_no_na <- drop_na(water)
```

Check…

```
1 filter(water_no_na, is.na(amount))
```

```
# A tibble: 0 × 6
# i 6 variables: river_name <chr>, site <chr>, element <chr>, amount <dbl>, temperature <dbl>, year <dbl>
```

```
1 nrow(water_no_na)
```

```
[1] 261
```

No more `NA`s!
Fewer rows

* part of the `tidyverse`

Side Note: `filter()` also omits `NAS` 😱

If we filter by the column with `NA`s, they are silently dropped

```
1 filter(water, amount < 0.05)
```

```
# A tibble: 15 × 6
   river_name  site        element  amount temperature  year
   <chr>       <chr>       <chr>     <dbl>       <dbl> <dbl>
 1 Oswegatchie Down stream Al      0.0333       10.6    2019
 2 Raquette    Mid stream  Al      0.0389        5.96   2021
 3 Grasse      Mid stream  Br      0.0357       12.4    2019
 4 St. Regis   Up stream   Br      0.0357        3.52   2022
 5 St. Regis   Mid stream  Br      0.0357        0.936  2023
 6 Raquette    Mid stream  Ce      0.0116        6.61   2019
 7 Raquette    Mid stream  Fe      0.00656      10.8    2022
 8 Grasse      Up stream   K       0.0313        3.61   2021
 9 Raquette    Mid stream  La      0.0275        2.50   2020
10 Oswegatchie Down stream Mn      0.00672       8.89   2019
# i 5 more rows
```

We need to be explicit if we want to keep them

```
1 filter(water, amount < 0.05 | is.na(amount))
```

```
# A tibble: 54 × 6
   river_name  site        element  amount temperature  year
   <chr>       <chr>       <chr>     <dbl>       <dbl> <dbl>
 1 Oswegatchie Down stream Al       0.0333      10.6    2019
 2 Raquette    Mid stream  Al       0.0389       5.96   2021
 3 Raquette    Down stream Al      NA            6.21   2022
 4 Raquette    Up stream   Ba      NA            5.23   2022
 5 Grasse      Mid stream  Br       0.0357      12.4    2019
 6 Raquette    Up stream   Br      NA           -99      2019
 7 St. Regis   Up stream   Br       0.0357       3.52   2022
 8 St. Regis   Mid stream  Br       0.0357       0.936  2023
 9 Oswegatchie Up stream   Ca      NA            4.76   2023
```

Replacing NAs

`replace_na()` is from `tidyr`*

```
1  water_no_na <- mutate(water, amount = replace_na(amount, 0))
```

* part of the `tidyverse`

Replacing NAs

`replace_na()` is from `tidyr`*

```
1  water_no_na <- mutate(water, amount = replace_na(amount, 0))
```

Check...

```
1  filter(water_no_na, is.na(amount))
```

```
# A tibble: 0 × 6
# i 6 variables: river_name <chr>, site <chr>, element <chr>, amount <dbl>, temperature <dbl>, year <dbl>
```

```
1  nrow(water_no_na)
```

```
[1] 300
```

No more `NA`s!
Same number of rows

* part of the `tidyverse`

Replacing NAs

`replace_na()` is from `tidyr`*


```
1 water_no_na <- mutate(water, amount = replace_na(amount, 0))
```

Check...

```
1 filter(water_no_na, is.na(amount))
```

```
# A tibble: 0 × 6
# i 6 variables: river_name <chr>, site <chr>, element <chr>, amount <dbl>, temperature <dbl>, year <dbl>
```

```
1 nrow(water_no_na)
```

```
[1] 300
```

No more `NA`s!
Same number of rows

(If you want to do a more complex replacement, you'll have to use `if_else()` or `case_when()` like we did for typos.)

* part of the `tidyverse`

Converting *to* NA

Remember the problem with `temperature`?

```
  1  filter(water, temperature < -10)
```

```
# A tibble: 3 × 6
  river_name  site       element amount temperature  year
  <chr>       <chr>      <chr>    <dbl>       <dbl> <dbl>
1 Raquette    Up stream  Br      NA             -99  2019
2 Oswegatchie Mid stream K        0.426         -99  2020
3 St. Regis   Mid stream La       0.367         -99  2023
```

Converting *to* NA

Remember the problem with `temperature`?

```
filter(water, temperature < -10)
```

```
# A tibble: 3 × 6
  river_name  site        element amount temperature  year
  <chr>       <chr>       <chr>    <dbl>       <dbl> <dbl>
1 Raquette    Up stream   Br          NA         -99  2019
2 Oswegatchie Mid stream K            0.426      -99  2020
3 St. Regis   Mid stream La           0.367      -99  2023
```

`na_if()` is from `dplyr`*

```
water <- mutate(water, temperature = na_if(temperature, -99))
```

* part of the `tidyverse`

Converting *to* NA

Remember the problem with `temperature`?

```
filter(water, temperature < -10)
```

```
# A tibble: 3 × 6
  river_name  site        element amount temperature  year
  <chr>       <chr>       <chr>    <dbl>       <dbl> <dbl>
1 Raquette    Up stream   Br          NA         -99  2019
2 Oswegatchie Mid stream K            0.426      -99  2020
3 St. Regis   Mid stream La           0.367      -99  2023
```

`na_if()` is from `dplyr`*

```
water <- mutate(water, temperature = na_if(temperature, -99))
```

Check...

```
filter(water, is.na(temperature))
```

```
# A tibble: 3 × 6
  river_name  site        element amount temperature  year
  <chr>       <chr>       <chr>    <dbl>       <dbl> <dbl>
1 Raquette    Up stream   Br          NA          NA  2019
2 Oswegatchie Mid stream K            0.426       NA  2020
3 St. Regis   Mid stream La           0.367       NA  2023
```

part of the tidyverse

Fixing formats

Fixing formats

Basic data types

- Text (Characters or Strings)
- Numbers (Doubles, Integers)
- Logical (TRUE or FALSE)
- Factor (Categories)
- Dates
- Date/Times

Fixing formats

Basic data types

- Text (Characters or Strings)
- Numbers (Doubles, Integers)
- Logical (TRUE or FALSE)
- Factor (Categories)
- Dates
- Date/Times

Look for problems

```
  1  water
```

```
# A tibble: 300 × 6
   river_name  site        element  amount temperature  year
   <chr>       <chr>       <chr>     <dbl>       <dbl> <dbl>
 1 Grasse      Up stream   Al       0.606       10.9    2019
 2 Grasse      Mid stream  Al       0.425        8.68   2020
 3 Grasse      Down stream Al       0.194        8.75   2021
 4 Oswegatchie Up stream   Al       1            0.791  2022
 5 Oswegatchie Mid stream  Al       0.161        9.32   2023
 6 Oswegatchie Down stream Al       0.0333      10.6    2019
 7 Raquette    Up stream   Al       0.292        4.01   2020
 8 Raquette    Mid stream  Al       0.0389       5.96   2021
 9 Raquette    Down stream Al      NA            6.21   2022
10 St. Regis   Up stream   Al       0.681        8.02   2023
# i 290 more rows
```

Year could be categorical (factor)
Better for plotting!
(although it really depends)

Convert to categorical

```r
water <- mutate(water, year = as.factor(year))
water
```

```
# A tibble: 300 × 6
   river_name  site        element  amount temperature year
   <chr>       <chr>       <chr>     <dbl>       <dbl> <fct>
 1 Grasse      Up stream   Al       0.606       10.9   2019
 2 Grasse      Mid stream  Al       0.425        8.68  2020
 3 Grasse      Down stream Al       0.194        8.75  2021
 4 Oswegatchie Up stream   Al       1            0.791 2022
 5 Oswegatchie Mid stream  Al       0.161        9.32  2023
 6 Oswegatchie Down stream Al       0.0333      10.6   2019
 7 Raquette    Up stream   Al       0.292        4.01  2020
 8 Raquette    Mid stream  Al       0.0389       5.96  2021
 9 Raquette    Down stream Al      NA            6.21  2022
10 St. Regis   Up stream   Al       0.681        8.02  2023
# i 290 more rows
```

Changing classes

Function	Input	Output
`as.character()`	Any vector	Text (Characters)
`as.numeric()`	Any vector (but returns NAs if not numbers)	Numbers
`as.logical()`	TRUE, FALSE, T, F, 1, 0 (FALSE), any other number (all TRUE)	TRUE or FALSE
`as.factor()`	Any vector	Categories

We'll deal with dates and times later…

Put it all together...

```
water <- read_csv("data/water_raw.csv") |>
  clean_names() |>
  rename(element = ele, amount = amo, temperature = temperature_c) |>
  select(-wea) |>
  mutate(river_name = case_when(river_name %in% c("Grase", "grasse") ~ "Grasse",
                                river_name == "raquette" ~ "Raquette",
                                TRUE ~ river_name),
         amount = replace_na(amount, 0),
         temperature = na_if(temperature, -99),
         year = as.factor(year))
```

And you have a clean, corrected data frame ready to use

- You have not changed the original data
- You have a **reproducible** record of all corrections
- You can alter these corrections at any time
- You have formatted your data for use in R
- Read these steps line by line to remind yourself what you did

Put it all together...

Feel free to annotate within a pipe

```
water <- read_csv("data/water_raw.csv") |>
  # Fix column names
  clean_names() |>
  rename(element = ele, amount = amo, temperature = temperature_c) |>
  select(-wea) |>
  mutate(
    # Correct typos
    river_name = case_when(river_name %in% c("Grase", "grasse") ~ "Grasse",
                           river_name == "raquette" ~ "Raquette",
                           TRUE ~ river_name),
    # Missing amounts should be 0
    amount = replace_na(amount, 0),
    # Problems with temperature logger, -99 is a mistake
    temperature = na_if(temperature, -99),
    # Convert for plotting
    year = as.factor(year))
```

Dates and Times

(Or why does R hate me?)

Dates and Times

Working with 🔗`geolocators.csv`

- Date/times aren't always recognized as date/times

```
1 geolocators <- read_csv("data/geolocators.csv", col_names = c("time", "light"))
2 geolocators
```

```
# A tibble: 21 × 2
  time                light
  <chr>               <dbl>
1 02/05/11 22:29:59      64
2 02/05/11 22:31:59      64
3 02/05/11 22:33:59      38
4 02/05/11 22:35:59      38
5 02/05/11 22:37:59      34
6 02/05/11 22:39:59      30
# i 15 more rows
```

Here `time` column is considered `chr` (character/text)

You may know it's a date, but R does not

Artwork by @allison_horst

`lubridate` package*

- Part of `tidyverse`, but needs to be loaded separately
- Great for converting date/times (i.e. telling R this is a date/time)

```
1 library(lubridate)
2 geolocators <- mutate(geolocators, time_fixed = dmy_hms(time))
3 geolocators
```

```
# A tibble: 21 × 3
  time                light time_fixed
  <chr>               <dbl> <dttm>
1 02/05/11 22:29:59      64 2011-05-02 22:29:59
2 02/05/11 22:31:59      64 2011-05-02 22:31:59
3 02/05/11 22:33:59      38 2011-05-02 22:33:59
4 02/05/11 22:35:59      38 2011-05-02 22:35:59
5 02/05/11 22:37:59      34 2011-05-02 22:37:59
6 02/05/11 22:39:59      30 2011-05-02 22:39:59
# i 15 more rows
```

Now `time_fixed` column is considered `dttm` (Date/Time)

So **You** know it's a Date/Time and now **R** knows too

* part of the `tidyverse`

`lubridate` package*

Generally, only the order of the **y**ear, **m**onth, **d**ay, **h**our, **m**inute, or **s**econd matters.

For example

date/time format	function	output class
2018-01-01 13:09:11	`ymd_hms()`	dttm (POSIXct/POSIXt)
12/20/2019 10:00 PM	`mdy_hm()`	dttm (POSIXct/POSIXt)
31/01/2000 10 AM	`dmy_h()`	dttm (POSIXct/POSIXt)
31-01/2000	`dmy()`	Date

`lubridate` is smart enough to detect AMs and PMs

Note: R *generally* requires that times have dates (`datetime`/`POSIXct`), but dates don't have to have times (`Date`)

* part of the `tidyverse`

Saving data

For the love of all that is good don’t *lose* that data!!!*

* but if you’ve been paying attention, you know that you only need the script 😉

Saving data

Keep yourself organized

- Keep your R-created data in a **different** folder from your 'raw' data*
- If you have a lot going on, split your work into several scripts, and number the both the scripts AND the data sets produced:
- `1_cleaned.csv`
- `2_summarized.csv`
- `3_graphing.csv`

* I usually have a `data` folder and then both `raw` and `datasets` folders inside of that

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Save your data to file:

- First create the *datasets* folder

```
1  write_csv(water, "datasets/water_cleaned.csv")
```

* I usually have a `data` folder and then both `raw` and `datasets` folders inside of that

Dealing with data

1. Loading data

- Get your data into R

2. Looking for problems

- Typos
- Incorrectly loaded data

3. Fixing problems

- Corrections
- Renaming
- Dealing with NA's

4. Setting formats

- Text
- Numbers
- Factors
- Dates

5. Saving your data

Wrapping up: Common mistakes

Assuming your data is in one format when it's not

- Print your data to the console and use `skim()` to explore the format of your data
- Use `skim()`, `count()`, `filter()`, `select()`, `ggplot()` to explore the content of your data

Wrapping up: Common mistakes

Confusing pipes with function arguments

- Pipes (`|>` or `%>%`) pass the *output* from one function as *input* (first argument) to the next function

```
my_data <- my_data |>                  # Pass my_data
  filter(my_column > 5) |>             # Pass my_data, filtered
  select(my_column, my_second_column)
```

- Arguments may be on different lines, but all part of *one* function

```
my_data <- my_data |>                   # Pass my_data
  mutate(my_column1 = if_else(...),     # No passing (no pipes!)
         my_column2 = if_else(...),     # Instead, give 3 arguments to mutate:
         my_column3 = if_else(...))     # Arguments separated by ",", and surrounded by ( )
```

Wrapping up: Further reading

- R for Data Science
  - Chapter 3: Data transformation
  - Chapter 6: Workflow: scripts and projects
  - Chapter 14: Strings
  - Chapter 16: Factors
  - Chapter 4.3: Workflow: code style > Pipes