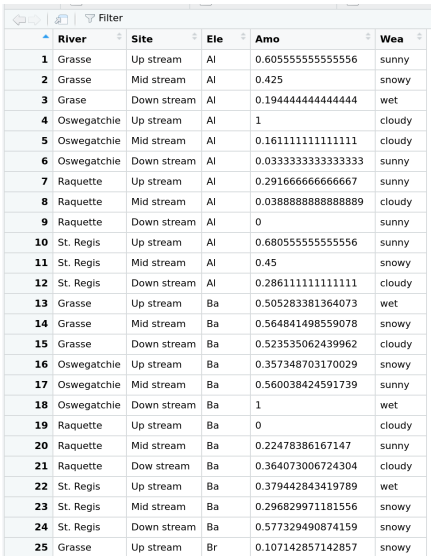
BU R Workshop 2021

Loading and Cleaning Data in R

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



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
11	St. Regis	Mid stream	Al	0.45	snowy
12	St. Regis	Down stream	Al	0.286111111111111	cloudy
13	Grasse	Up stream	Ba	0.505283381364073	wet
14	Grasse	Mid stream	Ba	0.564841498559078	snowy
15	Grasse	Down stream	Ba	0.523535062439962	cloudy
16	Oswegatchie	Up stream	Ba	0.357348703170029	snowy
17	Oswegatchie	Mid stream	Ba	0.560038424591739	sunny
18	Oswegatchie	Down stream	Ba	1	wet
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

Steffi LaZerte https://steffilazerte.ca

R base vs. `tidyverse`

R base

- R base is basic R
- Most packages used are installed and loaded by default

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- Most packages used are installed and loaded by default

`tidyverse`

- Collection of 'new' packages developed by a team closely affiliated with RStudio
- Packages designed to work well together
- Use a slightly different syntax
- Among others, includes packages used for data transformations and visualizations:
  - e.g., `ggplot2`, `dplyr`, `tidyr`, `readr`

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- Among others, includes packages used for data transformations and visualizations:
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> Can be helpful to understand whether functions are `tidyverse` or R base functions

Dealing with data

1. Loading data

- Get your data into R

2. Looking for problems

- Typos
- Incorrectly loaded data

3. Fixing problems

- Corrections
- Renaming

4. Setting formats

- Dates
- Numbers
- Factors

5. Saving your data

1. 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(sheet = 1)`
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()`

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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()`

Convenient but...

- Can be unreliable
- Can take longer

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

Data types: What kind of data do you have?

General text files

Type	R base	`readr` package (`tidyverse`)
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!), but have different arguments
- 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()`

Where is my data?

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

```
## Error: 'weather.csv' does not exist in current working directory ('/home/steffi/Projects/Teaching/R Workshop/Lessons').
```

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

Where is my data?

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my_data <- read_csv("weather.csv")
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## Error: 'weather.csv' does not exist in current working directory ('/home/steffi/Projects/Teaching/R
Workshop/Lessons').
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With no folder (just file name) R expects file to be in **Working directory**

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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my_data <- read_csv("weather.csv")
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> Using Projects in RStudio is a great idea, try to avoid **`setwd()`**

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Where is my data?

A note on file paths (file locations)

```
/home
```

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

Where is my data?

A note on file paths (file locations)

```
/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)

```
/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

Where is my data?

A note on file paths (file locations)

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

Full location, folders and filename

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A note on file paths (file locations)

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LINUX	/home/steffi/Documents/R Projects/mydata.csv
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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/)

Only include some folders, and filename.
Use relative symbols (`./` and `../`)

Where is my data?

A note on file paths (file locations)

With RStudio 'Projects' only need to use **relative** paths

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

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/)

Only include some folders, and filename.
Use relative symbols (`./` and `../`)

Keep yourself organized

For simple projects

- Create an 'RStudio Project' for each Project (Chapter, Thesis, etc.)
- 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 (Chapter, Thesis, etc.)
- 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
```

- Use **relative** paths to refer to this folder ("./")

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

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Let's Load Some Data!

Your turn: Load some data

1. Save/move the **`rivers_correct.xlsx`** file to a "Data" folder in your project (download here)
2. Load the package

```
library(readxl)
```

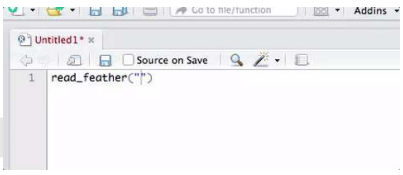
3. Read in the Excel file and assign to object **`rivers`**

```
rivers <- read_excel("./data/rivers_correct.xlsx")
```

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

```
head(rivers)
tail(rivers)
```

5. Click on the data 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

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Your turn: Load some data

```
rivers <- read_excel("./data/rivers_correct.xlsx")
```

```
head(rivers)
```

```
## # A tibble: 6 x 5
##   `River Name` Site        Ele   Amo                Wea
##   <chr>        <chr>       <chr> <chr>              <chr>
## 1 Grasse       Up stream   Al    0.605555555555556  wet
## 2 Grasse       Mid stream  Al    0.425              snowy
## 3 Grase        Down stream Al    0.194444444444444  wet
## 4 Oswegatchie  Up stream   Al    1                  snowy
## 5 Oswegatchie  Mid stream  Al    0.161111111111111  sunny
## 6 Oswegatchie  Down stream Al    0.0333333333333333 sunny
```

```
tail(rivers)
```

```
## # A tibble: 6 x 5
##   `River Name` Site        Ele   Amo               Wea
##   <chr>        <chr>       <chr> <chr>             <chr>
## 1 Raquette     Up stream   Zr    0.333333333333333 sunny
## 2 Raquette     Mid stream  Zr    0.111111111111111 snowy
## 3 Raquette     Down stream Zr    0                 sunny
## 4 St. Regis    Up stream   Zr    0.888888888888889 cloudy
```

Filter

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How do I know which function to use?

Look at the file extension:

- **`rivers_correct.csv`** (download here)
- **`.csv`** = Comma-separated-variables = **`read_csv()`**

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- **`rivers_correct.csv`** (download here)
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> But not always obvious...

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How do I know which function to use?

Look at the file:

- **`master_moch.txt`** (download here)
- In lower right-hand pane, click on **Files**
  - Click on **Data** folder
  - Click on **master_moch.txt**
  - Click "View File"

```
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.

How do I know which function to use?

Look at the file:

- **`master_moch.txt`** (download here)
- In lower right-hand pane, click on **Files**
  - Click on **Data** folder
  - Click on **master_moch.txt**
  - Click "View File"

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

```
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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How do I know what 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

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

```
## # A tibble: 3 x 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 x 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

1. `col_names`

- Geolocator data (download here)

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

```
## # A tibble: 20 x 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
## # … with 10 more rows
```

> Oops?

1. col_names

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my_data <- read_csv("./data/geolocators.csv")
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## # A tibble: 20 x 2
##    `02/05/11 22:29:59`  `64`
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##  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
## # … with 10 more rows
```

> Oops?

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

1. col_names

Declare no headings

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

```
## # A tibble: 21 x 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
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## # … with 11 more rows
```


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##  6 02/05/11 22:39:59    30
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##  8 02/05/11 22:43:59    40
##  9 02/05/11 22:45:59    46
## 10 02/05/11 22:47:59    48
## # … with 11 more rows
```

Name headings

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

```
## # A tibble: 21 x 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
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## 10 02/05/11 22:47:59    48
## # … with 11 more rows
```

2. **skip** info rows before data

- Grain size data (download here)

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

```
## Warning: Missing column names filled in: 'X2' [2], 'X3' [3], 'X4' [4], 'X5' [5], 'X6' [6], 'X7' [7]
```

```
my_data
```

```
## # A tibble: 36 x 7
##    `DATA DOWNLOAD: 2015-09-23` X2    X3          X4       X5    X6    X7
##    <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
```


2. **skip** info rows before data

- Grain size data (download here)

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

Look at the file:

- Go to **Files** tab (lower right-hand pane)
- Click on **Data** folder
- Click on **grain_size.txt** file
- Click **"View file"**

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```

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- Click **"View file"**

```
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

2. `skip` info rows before data

- Grain size data (download here)
- Add `skip = 3` to skip the first three rows

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

```
## # A tibble: 33 x 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
## # … with 23 more rows
```


Your turn: Load this data set

Try loading the telemetry data set: **`Sta A Data 2006-11-07.dmp`** (download it here)

1. Look at the file (click on the file in your File window in RStudio)
2. Decide function based on the delimiter (comma, space, or tab?)
3. Any other options need to be specified?

Extra Challenge
Load some of your own tricky data

It should look like this:

```
## # A tibble: 19 x 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
## # … with 12 more rows
```


Your turn: Load this data set

Try loading the data set: **`Sta A Data 2006-11-07.dmp`** (download it here)

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

```
## # A tibble: 19 x 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
## # … with 12 more rows
```

2. 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

```
library(palmerpenguins)
penguins
```

```
## # A tibble: 344 x 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
## # … with 334 more rows
```


Look at the data

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

```
tail(penguins)
```

```
## # A tibble: 6 x 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()

- Are the columns appropriate?
- Are numeric values appropriate? Should there be NAs?
- Are there any typos in the factors?
- Are the columns in the appropriate format (i.e., numeric, character, factor, date)
- Are there as many observations as you expected?

```
library(skimr)
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
```


skim()

```
##
## ── 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()

- Check for typos in categorical columns

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

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

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

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

Example of problematic data

```
rivers <- read_csv("./data/rivers_correct.csv")
rivers
```

```
## # A tibble: 300 x 5
##    `River Name` Site        Ele   Amo               Wea
##    <chr>        <chr>       <chr> <chr>             <chr>
##  1 Grasse       Up stream   Al    0.605555555555556 wet
##  2 Grasse       Mid stream  Al    0.425             snowy
##  3 Grase        Down stream Al    0.194444444444444 wet
##  4 Oswegatchie  Up stream   Al    1                 snowy
##  5 Oswegatchie  Mid stream  Al    0.161111111111111 sunny
##  6 Oswegatchie  Down stream Al    0.0333333333333333 sunny
##  7 Raquette     Up stream   Al    0.291666666666667 cloudy
##  8 Raquette     Mid stream  Al    0.0388888888888889 cloudy
##  9 Raquette     Down stream Al    0                 wet
## 10 St. Regis    Up stream   Al    0.680555555555556 snowy
## # … with 290 more rows
```

- Column names are not all clean (**`River Name`** or obvious (what is **`Ele`**?)
- **`Amo`** - should be numeric but isn't
- At least one typo in River (**`Grase`** should be **`Grasse`**)

Example of problematic data

```
skim(rivers)
```

```
##
## ── Variable type: character
```

skim_variable	n_missing	complete_rate	min	max	empty	n_unique	whitespace
River Name	0	1	5	11	0	8	0
Site	0	1	8	11	0	5	0
Ele	0	1	1	2	0	25	0
Amo	12	0.96	1	19	0	198	0
Wea	0	1	3	6	0	4	0

- Not much additional info here

Example of problematic data

```
count(rivers, `River Name`)
```

```
## # A tibble: 8 x 2
##   `River Name`     n
##   <chr>        <int>
## 1 Grase            1
## 2 Grass            1
## 3 grasse           1
## 4 Grasse          72
## 5 Oswegatchie     75
## 6 raquette         1
## 7 Raquette        74
## 8 St. Regis       75
```

```
count(rivers, Site)
```

```
## # A tibble: 5 x 2
##   Site            n
##   <chr>       <int>
## 1 Dow stream      1
## 2 Down stream    99
## 3 Mid stream    100
## 4 Up stream      99
## 5 Upstream        1
```

> Typos in both categorical columns

3. Fixing problems

Cleaning column names

`clean_names()`

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

```
## # A tibble: 300 x 5
##    river_name  site        ele   amo               wea
##    <chr>       <chr>       <chr> <chr>             <chr>
##  1 Grasse      Up stream   Al    0.605555555555556 wet
##  2 Grasse      Mid stream  Al    0.425             snowy
##  3 Grase       Down stream Al    0.194444444444444 wet
##  4 Oswegatchie Up stream   Al    1                 snowy
##  5 Oswegatchie Mid stream  Al    0.161111111111111 sunny
##  6 Oswegatchie Down stream Al    0.0333333333333333 sunny
##  7 Raquette    Up stream   Al    0.291666666666667 cloudy
##  8 Raquette    Mid stream  Al    0.0388888888888889 cloudy
##  9 Raquette    Down stream Al    0                 wet
## 10 St. Regis   Up stream   Al    0.680555555555556 snowy
## # … with 290 more rows
```


Cleaning column names

`rename()` columns

```
rivers <- rename(rivers, element = ele, amount = amo)
rivers
```

```
## # A tibble: 300 x 5
##    river_name  site        element amount            wea
##    <chr>       <chr>       <chr>   <chr>             <chr>
##  1 Grasse      Up stream   Al      0.605555555555556 wet
##  2 Grasse      Mid stream  Al      0.425             snowy
##  3 Grase       Down stream Al      0.194444444444444 wet
##  4 Oswegatchie Up stream   Al      1                 snowy
##  5 Oswegatchie Mid stream  Al      0.161111111111111 sunny
##  6 Oswegatchie Down stream Al      0.0333333333333333 sunny
##  7 Raquette    Up stream   Al      0.291666666666667 cloudy
##  8 Raquette    Mid stream  Al      0.0388888888888889 cloudy
##  9 Raquette    Down stream Al      0                 wet
## 10 St. Regis   Up stream   Al      0.680555555555556 snowy
## # … with 290 more rows
```

Subsetting columns

`select()` columns you do want

```
rivers <- select(rivers, river_name, site, element, amount)
```


Subsetting columns

`select()` columns you do want

```
rivers <- select(rivers, river_name, site, element, amount)
```

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

```
rivers <- select(rivers, -wea)
rivers
```

```
## # A tibble: 300 x 4
##    river_name  site        element amount
##    <chr>       <chr>       <chr>   <chr>
##  1 Grasse      Up stream   Al      0.605555555555556
##  2 Grasse      Mid stream  Al      0.425
##  3 Grase       Down stream Al      0.194444444444444
##  4 Oswegatchie Up stream   Al      1
##  5 Oswegatchie Mid stream  Al      0.161111111111111
##  6 Oswegatchie Down stream Al      0.0333333333333333
##  7 Raquette    Up stream   Al      0.291666666666667
##  8 Raquette    Mid stream  Al      0.0388888888888889
```


Cleaning columns

Put it all together

```
rivers <- read_csv("./data/rivers_correct.csv")
rivers <- clean_names(rivers)
rivers <- rename(rivers, element = ele, amount = amo)
rivers <- select(rivers, -wea)
rivers
```

```
## # A tibble: 300 x 4
##    river_name  site        element amount
##    <chr>       <chr>       <chr>   <chr>
##  1 Grasse      Up stream   Al      0.605555555555556
##  2 Grasse      Mid stream  Al      0.425
##  3 Grase       Down stream Al      0.194444444444444
##  4 Oswegatchie Up stream   Al      1
##  5 Oswegatchie Mid stream  Al      0.161111111111111
##  6 Oswegatchie Down stream Al      0.0333333333333333
##  7 Raquette    Up stream   Al      0.291666666666667
##  8 Raquette    Mid stream  Al      0.0388888888888889
##  9 Raquette    Down stream Al      0
```

Cleaning columns

Put it all together

```
rivers <- read_csv("./data/rivers_correct.csv")
rivers <- clean_names(rivers)
rivers <- rename(rivers, element = ele, amount = amo)
rivers <- select(rivers, -wea)
rivers
```

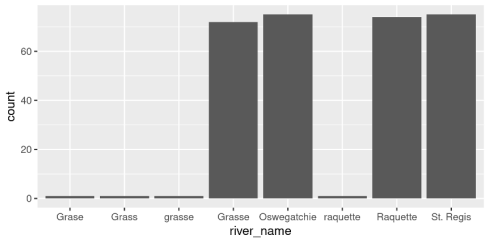
Note repeated data frame **`rivers`**

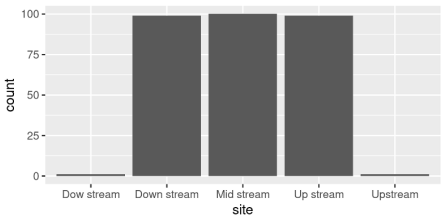
```
## # A tibble: 300 x 4
##    river_name  site        element amount
##    <chr>       <chr>       <chr>   <chr>
##  1 Grasse      Up stream   Al      0.605555555555556
##  2 Grasse      Mid stream  Al      0.425
##  3 Grase       Down stream Al      0.194444444444444
##  4 Oswegatchie Up stream   Al      1
##  5 Oswegatchie Mid stream  Al      0.161111111111111
##  6 Oswegatchie Down stream Al      0.0333333333333333
##  7 Raquette    Up stream   Al      0.291666666666667
##  8 Raquette    Mid stream  Al      0.0388888888888889
##  9 Raquette    Down stream Al      0
```

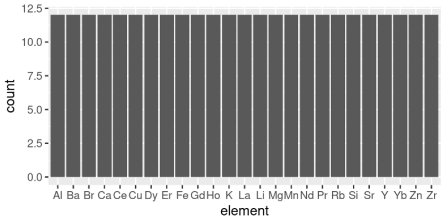

Fixing typos

Look for typos (Visually)

```
ggplot(data = rivers, aes(x = river_name)) + geom_bar()
ggplot(data = rivers, aes(x = site)) + geom_bar()
ggplot(data = rivers, aes(x = element)) + geom_bar()
```







Fixing typos

Look for typos with `count()`

```
count(rivers, river_name)
```

```
## # A tibble: 8 x 2
##   river_name      n
##   <chr>       <int>
## 1 Grase           1
## 2 Grass           1
## 3 grasse          1
## 4 Grasse         72
## 5 Oswegatchie    75
## 6 raquette        1
## 7 Raquette       74
## 8 St. Regis      75
```

`filter()` the data to highlight them

```
filter(rivers, river_name == "Grase")
```

```
## # A tibble: 1 x 4
##   river_name site        element amount
##   <chr>      <chr>       <chr>   <chr>
## 1 Grase      Down stream Al      0.194444444444444
```

Fixing typos

Replace typos

Combine the **`if_else()`** / **`case_when()`** functions with **`mutate()`** function

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

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

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

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

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

```
case_when(condition1 ~ value_if_true,
          condition2 ~ value_if_true,
          condition3 ~ value_if_true,
          TRUE ~ default_value)
```


Fixing typos

Replace typos

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

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

Check that it's gone:

```
filter(rivers, river_name == "Grase")
```

```
## # A tibble: 0 x 4
## # … with 4 variables: river_name <chr>, site <chr>, element <chr>, amount <chr>
```


Iterative process

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

Your Turn: Fix another one of the "Grasse" typos

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

Extra Challenge
Examine and fix problems in your own data

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

rivers <- mutate(???, ??? = ???)
```


Your Turn: Fix another one of the "Grasse" typos

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

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

rivers <- mutate(rivers, river_name = if_else(river_name == "Grass", "Grasse", river_name))
```


Fixing typos

To be more efficient, fix all typos at once

```
rivers <- read_csv("./data/rivers_correct.csv")
rivers <- clean_names(rivers)
rivers <- rename(rivers, element = ele, amount = amo)
rivers <- select(rivers, -wea)
rivers <- mutate(rivers, river_name = if_else(river_name %in% c("Grase", "Grass", "grasse"),
                                              "Grasse",
                                              river_name))
```

`==` compares one item to one other

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

Tangent: Why use tidyverse packages?

Pipes! %>% Allow you to string commands together

Instead of:

```
rivers <- read_csv("./data/rivers_correct.csv")
rivers <- clean_names(rivers)
rivers <- rename(rivers, element = ele, amount = amo)
rivers <- select(rivers, -wea)
rivers <- mutate(rivers,
                 river_name = if_else(river_name == "Grase", "Grasse", river_name),
                 site = if_else(site == "Dow stream", "Down stream", site))
```


Tangent: Why use tidyverse packages?

Pipes! %>% Allow you to string commands together

Instead of:

```
rivers <- read_csv("./data/rivers_correct.csv")
rivers <- clean_names(rivers)
rivers <- rename(rivers, element = ele, amount = amo)
rivers <- select(rivers, -wea)
rivers <- mutate(rivers,
                 river_name = if_else(river_name == "Grase", "Grasse", river_name),
                 site = if_else(site == "Dow stream", "Down stream", site))
```

We have:

```
rivers <- read_csv("./data/rivers_correct.csv") %>%
  clean_names() %>%
  rename(element = ele, amount = amo) %>%
  select(-wea) %>%
  mutate(river_name = if_else(river_name == "Grase", "Grasse", river_name),
         site = if_else(site == "Dow stream", "Down stream", site))
```


Play around

Take a moment to play with this code in your console

Convert this:

```
rivers <- read_csv("./data/rivers_correct.csv")
rivers <- clean_names(rivers)
rivers <- rename(rivers, element = ele, amount = amo)
rivers <- select(rivers, -wea)
rivers <- mutate(rivers,
                 river_name = if_else(river_name %in% c("Grase", "Grass", "grasse"), "Grasse", river_name),
                 site = if_else(site == "Dow stream", "Down stream", river_name))
```

To this:

```
rivers <- read_csv("./data/rivers_correct.csv") %>%
  clean_names() %>%
  rename(element = ele, amount = amo) %>%
  select(-wea) %>%
  mutate(river_name = if_else(river_name %in% c("Grase", "Grass", "grasse"), "Grasse", river_name),
         site = if_else(site == "Dow stream", "Down stream", site))
```

Your turn: Fix the remaining typos

- Remember this is an iterative process (you may find your self reloading the data often)
- Don't worry about numerical problems for now

Add to this code

Extra Challenge
Examine and fix problems in your own data

```
rivers <- read_csv("./data/rivers_correct.csv") %>%
  clean_names() %>%
  rename(element = ele, amount = amo) %>%
  select(-wea) %>%
  mutate(river_name = if_else(river_name %in% c("Grase", "Grass", "grasse"), "Grasse", river_name),
         site = if_else(site == "Dow stream", "Down stream", site))
```

Expect `river_name`: **Grasse**, **Oswegatchie**, **Raquette**, **St.Regis**
Expect `site`: **Down stream**, **Up stream**

Comparing single items

```
A == "hello"
A %in% "hello"
```

Comparing multiple items

```
A %in% c("hello", "bye"))
# NOT A == c("hello", "bye")
```


Your turn: Fix the remaining typos

- Remember this is an iterative process (you may find your self reloading the data often)
- Don't worry about numerical problems for now

All typos fixed

```
rivers <- read_csv("./data/rivers_correct.csv") %>%
  clean_names() %>%
  rename(element = ele, amount = amo) %>%
  select(-wea) %>%
  mutate(river_name = if_else(river_name %in% c("Grase", "Grass", "grasse"),
                              "Grasse", river_name),
         river_name = if_else(river_name == "raquette", "Raquette", river_name),
         site = if_else(site == "Dow stream", "Down stream", site),
         site = if_else(site == "Upstream", "Up stream", site))
```


Your turn: Fix the remaining typos

- Remember this is an iterative process (you may find your self reloading the data often)
- Don't worry about numerical problems for now

All typos fixed

```
rivers <- read_csv("./data/rivers_correct.csv") %>%
  clean_names() %>%
  rename(element = ele, amount = amo) %>%
  select(-wea) %>%
  mutate(river_name = if_else(river_name %in% c("Grase", "Grass", "grasse"),
                              "Grasse", river_name),
         river_name = if_else(river_name == "raquette", "Raquette", river_name),
         site = if_else(site == "Dow stream", "Down stream", site),
         site = if_else(site == "Upstream", "Up stream", site))
```

Let's combine these with `case_when()`...

Your turn: Fix the remaining typos

- Remember this is an iterative process (you may find your self reloading the data often)
- Don't worry about numerical problems for now

All typos fixed

```
rivers <- read_csv("./data/rivers_correct.csv") %>%
  clean_names() %>%
  rename(element = ele, amount = amo) %>%
  select(-wea) %>%
  mutate(river_name = case_when(river_name %in% c("Grase", "Grass", "grasse") ~ "Grasse",
                                river_name == "raquette" ~ "Raquette",
                                TRUE ~ river_name),
         site = case_when(site == "Dow stream" ~ "Down stream",
                          site == "Upstream" ~ "Up stream",
                          TRUE ~ site))
```


Your turn: Fix the remaining typos

- Remember this is an iterative process (you may find your self reloading the data often)
- Don't worry about numerical problems for now

All typos fixed

```
rivers <- read_csv("./data/rivers_correct.csv") %>%
  clean_names() %>%
  rename(element = ele, amount = amo) %>%
  select(-wea) %>%
  mutate(river_name = case_when(river_name %in% c("Grase", "Grass", "grasse") ~ "Grasse",
                                river_name == "raquette" ~ "Raquette",
                                TRUE ~ river_name),
         site = case_when(site == "Dow stream" ~ "Down stream",
                          site == "Upstream" ~ "Up stream",
                          TRUE ~ site))
```


4. Fixing formats

Typos that affect classes (formats)

Look for problems

```
rivers
```

```
## # A tibble: 300 x 4
##    river_name  site        element amount
##    <chr>       <chr>       <chr>   <chr>
##  1 Grasse      Up stream   Al      0.605555555555556
##  2 Grasse      Mid stream  Al      0.425
##  3 Grasse      Down stream Al      0.194444444444444
##  4 Oswegatchie Up stream   Al      1
##  5 Oswegatchie Mid stream  Al      0.161111111111111
##  6 Oswegatchie Down stream Al      0.0333333333333333
##  7 Raquette    Up stream   Al      0.291666666666667
##  8 Raquette    Mid stream  Al      0.0388888888888889
##  9 Raquette    Down stream Al      0
## 10 St. Regis   Up stream   Al      0.680555555555556
## # … with 290 more rows
```

Why all character (chr)?

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, 0 (FALSE), any other number (all TRUE)	TRUE or FALSE
`as.factor()`	Any vector	Categories

Changing classes

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`as.character()`	Any vector	Text (Characters)
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`as.logical()`	TRUE, FALSE, T, F, 0 (FALSE), any other number (all TRUE)	TRUE or FALSE
`as.factor()`	Any vector	Categories

For example...

```
a <- c(1, 2, 10)

as.character(a)
```

```
## [1] "1"  "2"  "10"
```

```
as.numeric(a)
```

```
## [1]  1  2 10
```

```
b <- c("hello", "bye", 1)
as.character(b)
```

```
## [1] "hello" "bye"   "1"
```

```
as.numeric(b)
```

```
## Warning: NAs introduced by coercion
```

```
## [1] NA NA  1
```

We'll deal with dates and times later...

Fixing numerical typos

Find the problem (when we don't know what they are)

- Make a new column and convert **`amount`** to numbers

```
rivers <- mutate(rivers, amount2 = as.numeric(amount))
```

```
## Warning: Problem with `mutate()` input `amount2`.
## ℹ NAs introduced by coercion
## ℹ Input `amount2` is `as.numeric(amount)`.
```

```
## Warning in mask$eval_all_mutate(dots[[i]]): NAs introduced by coercion
```

> This warning tells us that some values didn't convert to numbers

Fixing numerical typos

Find the problem (when we don't know what it is)

- Make a new column and convert **`amount`** to numbers
- Find out where the conversion didn't work

```
filter(rivers, !is.na(amount), is.na(amount2))
```

```
## # A tibble: 1 x 5
##   river_name site       element amount amount2
##   <chr>      <chr>      <chr>   <chr>    <dbl>
## 1 Raquette   Mid stream Ca      <0.1        NA
```

> - **`is.na()`** is **`TRUE`** when the value is missing (**`NA`**)
> - **`!`** turns a **`TRUE`** into a **`FALSE`** (and vice versa)
> - This asks, which values are not missing to begin with (**`!is.na(amount)`**) but *are* missing after the conversion (**`is.na(amount2)`**)

Fixing numerical typos

Find the problem (when we know what it is):

```
filter(rivers, amount == "<0.1")
```

```
## # A tibble: 1 x 5
##   river_name site       element amount amount2
##   <chr>      <chr>      <chr>   <chr>    <dbl>
## 1 Raquette   Mid stream Ca      <0.1        NA
```

Fixing numerical typos

Find the problem (when we know what it is):

```
filter(rivers, amount == "<0.1")
```

```
## # A tibble: 1 x 5
##   river_name site       element amount amount2
##   <chr>      <chr>      <chr>   <chr>    <dbl>
## 1 Raquette   Mid stream Ca      <0.1        NA
```

Fix problem

```
rivers <- mutate(rivers, amount = if_else(amount == "<0.1", "0", amount))
```


Fixing numerical typos

Find the problem (when we know what it is):

```
filter(rivers, amount == "<0.1")
```

```
## # A tibble: 1 x 5
##   river_name site       element amount amount2
##   <chr>      <chr>      <chr>   <chr>    <dbl>
## 1 Raquette   Mid stream Ca      <0.1        NA
```

Fix problem

```
rivers <- mutate(rivers, amount = if_else(amount == "<0.1", "0", amount))
```

Correct the class

```
rivers <- mutate(rivers, amount = as.numeric(amount))
```


Put it together...

```
rivers <- read_csv("./data/rivers_correct.csv") %>%
  clean_names() %>%
  rename(element = ele, amount = amo) %>%
  select(-wea) %>%
  mutate(river_name = case_when(river_name %in% c("Grase", "Grass", "grasse") ~ "Grasse",
                                river_name == "raquette" ~ "Raquette",
                                TRUE ~ river_name),
         site = case_when(site == "Dow stream" ~ "Down stream",
                          site == "Upstream" ~ "Up stream",
                          TRUE ~ site),
         amount = if_else(amount == "<0.1", "0", amount),
         amount = as.numeric(amount))
```

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

- You have not changed the original data
- You have a record of all corrections
- You can alter these corrections at any time
- You have formatted your data for use in R

Dates and Times

(Or why does R hate me?)

Dates and Times

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

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

```
## # A tibble: 21 x 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
## # … with 15 more rows
```

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

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Artwork by @allison_horst

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`lubridate` package

- Part of **`tidyverse`**, but needs to be loaded
- Great for converting date/time formats

```
library(lubridate)
geolocators <- mutate(geolocators, time = dmy_hms(time))
geolocators
```

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

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`lubridate` package

date/time	function	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

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5. Saving data

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 data sets produced:
  - `1_cleaned.csv`
  - `2_summarized.csv`
  - `3_graphing.csv`

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 data sets produced:
  - `1_cleaned.csv`
  - `2_summarized.csv`
  - `3_graphing.csv`

Save your data to file:

```
write_csv(rivers, "./Datasets/rivers_cleaned.csv")
```


Dealing with data

1. Loading data

- Get your data into R

2. Looking for problems

- Typos
- Incorrectly loaded data

3. Fixing problems

- Corrections
- Renaming

4. Setting formats

- Dates
- Numbers
- Factors

5. Saving your data

Wrapping up: Common mistakes

Forgetting to use `as.character()` when switching from factor to numeric

- Applies especially if you use `read.csv()` (R base function which often creates factors)
- To convert factor to numeric use: `as.numeric(as.character(my_factor))`

Wrapping up: Common mistakes

Forgetting to use `as.character()` when switching from factor to numeric

- Applies especially if you use `read.csv()` (R base function which often creates factors)
- To convert factor to numeric use: `as.numeric(as.character(my_factor))`

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 (`%>%`) pass the *output* from one function as *input* 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 = replace(...),   # No passing (no pipes!)
         my_column2 = replace(...),   # Instead, give 3 arguments to mutate:
         my_column3 = replace(...))   # Arguments separated by ",", and surrounded by ( )
```

Wrapping up: Further reading

- R for Data Science
  - Chapter 5: Transforming data
  - Chapter 8: RStudio Projects
  - Chapter 14: Strings
  - Chapter 15: Factors
  - Chapter 18: Pipes