UNIVERSITY OF CAMBRIDGE
Bioinformatics Training

Introduction to 

for Data Science

Starting with Data

Starting with Data

- Critical to Understand Your Data!
- Download the data and Look at it
- Use R function download.file() to download the CSV file that contains the data

```
download.file(url="https://ndownloader.figshare.com/files/2292169",
              destfile = "data/portal_data_joined.csv")
```

View Data

- Go to **Files** section in **RStudio**,
- Click on the filename in **data** folder
- Click **View** File

Column	Description
record_id	Unique id for the observation
month	month of observation
day	day of observation
year	year of observation
plot_id	ID of a particular plot
species_id	2-letter code
sex	sex of animal (“M”, “F”)
hindfoot_length	length of the hindfoot in mm
weight	weight of the animal in grams
genus	genus of animal
species	species of animal
taxon	e.g. Rodent, Reptile, Bird, Rabbit
plot_type	type of plot

Reading in Data from a file

- We've **looked** at the **raw** format of the file (CSV format)
- Let us **Load** the data into R
- Use function read.csv() to load the data into an object of class data.frame

```
surveys <- read.csv("data/portal_data_joined.csv")
```

-
```
head(surveys)
```

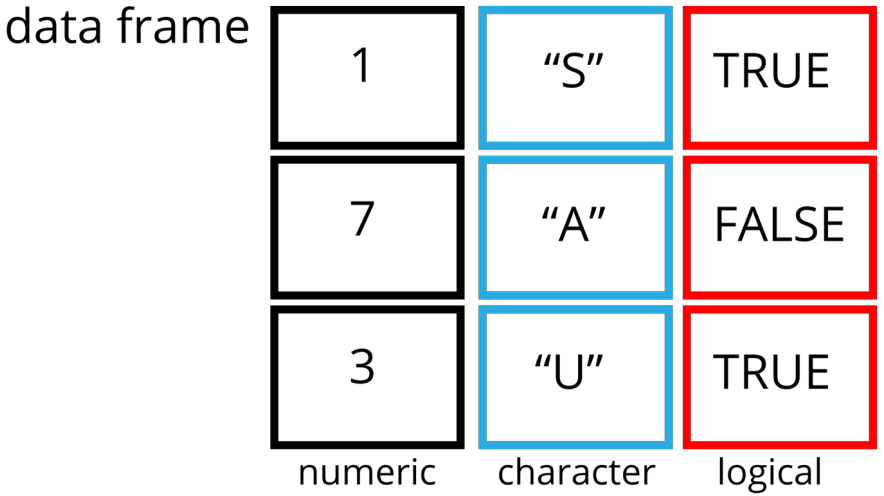
```
## Try also
View(surveys)
```

Reading in Data from a file

surveys

```
#>   record_id month day year plot_id species_id sex hindfoot_length weight   genus  sp
ecies   taxa plot_type
#> 1         1     7  16 1977       2          NL   M              32     NA Neotoma alb
igula Rodent   Control
#> 2        72     8  19 1977       2          NL   M              31     NA Neotoma alb
igula Rodent   Control
#> 3       224     9  13 1977       2          NL                  NA     NA Neotoma alb
igula Rodent   Control
#> 4       266    10  16 1977       2          NL                  NA     NA Neotoma alb
igula Rodent   Control
#> 5       349    11  12 1977       2          NL                  NA     NA Neotoma alb
igula Rodent   Control
#> 6       363    11  12 1977       2          NL                  NA     NA Neotoma alb
igula Rodent   Control
```

Data frame


data frame
1
"S"
TRUE
7
"A"
FALSE
3
"U"
TRUE
numeric
character
logical

Data frame

```
str(surveys)
```

```
#> 'data.frame':    34786 obs. of  13 variables:
#>  $ record_id      : int  1 72 224 266 349 363 435 506 588 661 ...
#>  $ month          : int  7 8 9 10 11 11 12 1 2 3 ...
#>  $ day            : int  16 19 13 16 12 12 10 8 18 11 ...
#>  $ year           : int  1977 1977 1977 1977 1977 1977 1977 1978 1978 1978 ...
#>  $ plot_id        : int  2 2 2 2 2 2 2 2 2 2 ...
#>  $ species_id     : chr  "NL" "NL" "NL" "NL" ...
#>  $ sex            : chr  "M" "M" "" "" ...
#>  $ hindfoot_length: int  32 31 NA NA NA NA NA NA NA NA ...
#>  $ weight         : int  NA NA NA NA NA NA NA NA 218 NA ...
#>  $ genus          : chr  "Neotoma" "Neotoma" "Neotoma" "Neotoma" ...
#>  $ species        : chr  "albigula" "albigula" "albigula" "albigula" ...
#>  $ taxa           : chr  "Rodent" "Rodent" "Rodent" "Rodent" ...
#>  $ plot_type      : chr  "Control" "Control" "Control" "Control" ...
```

Inspecting a data.frame object

- Size:
  - `dim(surveys)` - returns a vector with the number of rows in the first element, and the number of columns as the second element (the **dim**ensions of the object)
  - `nrow(surveys)` - returns the number of rows
  - `ncol(surveys)` - returns the number of columns
- Content:
  - `head(surveys)` - shows the first 6 rows
  - `tail(surveys)` - shows the last 6 rows
- Names:
  - `names(surveys)` - returns the column names (synonym of `colnames()` for `data.frame` objects)
  - `rownames(surveys)` - returns the row names
- Summary:
  - `str(surveys)` - structure of the object and information about the class, length and c content of each column
  - `summary(surveys)` - summary statistics for each column

Challenge!

- **Based on the output of str(surveys), can you answer the following questions?**
- **What is the class of the object surveys?**
- **How many rows and how many columns are in this object?**
- **How many taxa have been recorded during these surveys?**

Indexing and sub-setting data frames

```
> head(surveys)
  record_id month day year plot_id species_id sex hindfoot_length weight   genus  species   taxa plot_type
1         1     7  16 1977       2         NL   M              32     NA Neotoma albigula Rodent   Control
2        72     8  19 1977       2         NL   M              31     NA Neotoma albigula Rodent   Control
3       224     9  13 1977       2         NL                  NA     NA Neotoma albigula Rodent   Control
4                  [illegible]    2         NL                  NA     NA Neotoma albigula Rodent   Control
5                  [illegible]    2         NL                  NA     NA Neotoma albigula Rodent   Control
6       363        [illegible]    2         NL                  NA     NA Neotoma albigula Rodent   Control
>
```

	record_id	month	day
	[1,1]	[1,2]	[1,3]
1	1	7	16
	[2,1]	[2,2]	[2,3]
2	72	8	19
	[3,1]	[3,2]	[3,3]
3	224	9	13

colnames(surveys)

index [R,C]

rownames(surveys)

Numeric Indexing

Numeric Indexing

```r
# get first element in the first column of the data frame
surveys[1, 1]
# get first element in the 6th column
surveys[1, 6]
# get first column of the data frame (as a vector)
surveys[, 1]
# get first three elements in the 7th column (as a vector)
surveys[1:3, 7]
# get the 3rd row of the data frame (as a data.frame)
surveys[3, ]
# equivalent to head_surveys <- head(surveys)
head_surveys <- surveys[1:6, ]
```

Numeric Indexing (cont.)

- : is an R operator to create a sequence of numeric vectors

(Integers in increasing or decreasing order)

- Try 1:10 and 10:1
- It is equivalent to the function seq(from, to)

- You can also exclude certain indices of a data frame using the “-” sign:

```
surveys[, -1]          # get the whole data frame, except the first column
surveys[-c(7:34786), ] # equivalent to head(surveys)
```

Name Indexing

- Data frames can **also** be subset by calling row names and column names directly!
- This is known as **name indexing**
- Examples:

```
# get species_id column as a vector
surveys[, "species_id"]
# same as above
surveys$species_id
# get the record_id and species columns for the first three rows
# Note: we are mixing numeric and name indexing here
surveys[1:3, c("record_id", "species")]
```

Logical Indexing

- Another way to retrieve data from a data frame is by logical indexing
- Let's perform a logical operation on **surveys**

```
# get all the records that have species as "albigula"
surveys[surveys$species == "albigula",]
# save all the records that have species as "albigula" into a variable
albigula_data <- surveys[surveys$species == "albigula",]
# how many records have species as "albigula" in the surveys data frame?
nrow(albigula_data)
```

- Who's this fellow By the way!

Neotoma albigula

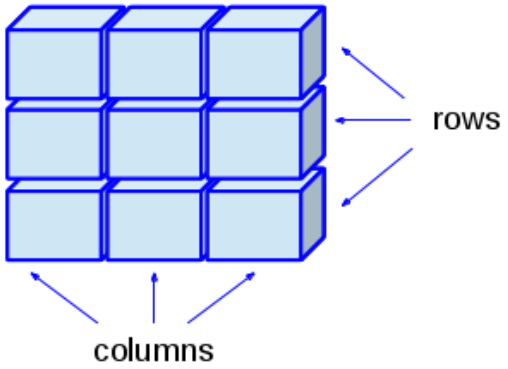
Challenge!

1. Create a data.frame (surveys_200) containing only the data in row 200 of the surveys dataset.
2. Notice how nrow() gave you the number of rows in a data.frame?
    1. Use that number to pull out just that last row in the surveys data frame.
    2. Compare that with what you see as the last row using tail() to make sure it's meeting expectations.
    3. Pull out that last row using nrow() instead of the row number.
    4. Create a new data frame (surveys_last) from that last row.
3. Use nrow() to extract the row that is in the middle of the data frame. Store the content of this row in an object named surveys_middle.
4. Combine nrow() with the - notation above to reproduce the behavior of head(surveys), keeping just the first through 6th rows of the surveys dataset.

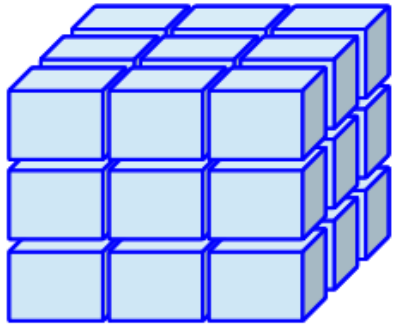
Data Structures (Recap)

Vector

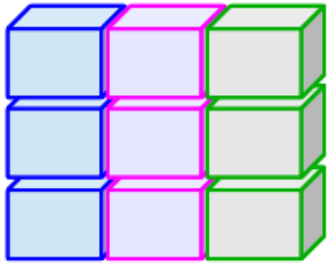
Matrix



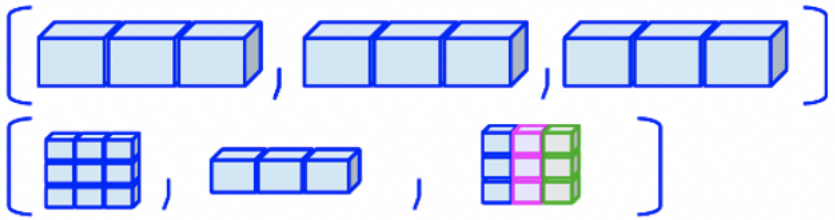
Array



Data Frame (Table)

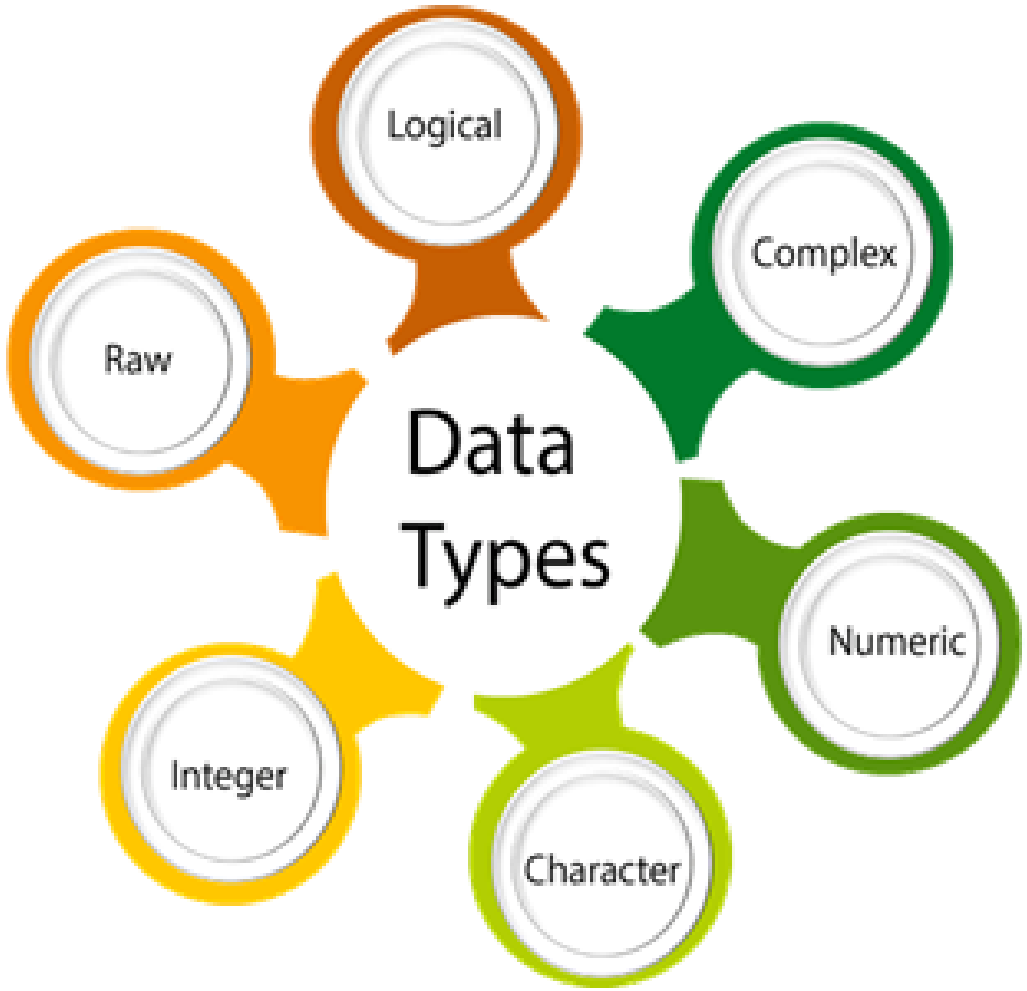


Lists



List

Data Type (Recap)



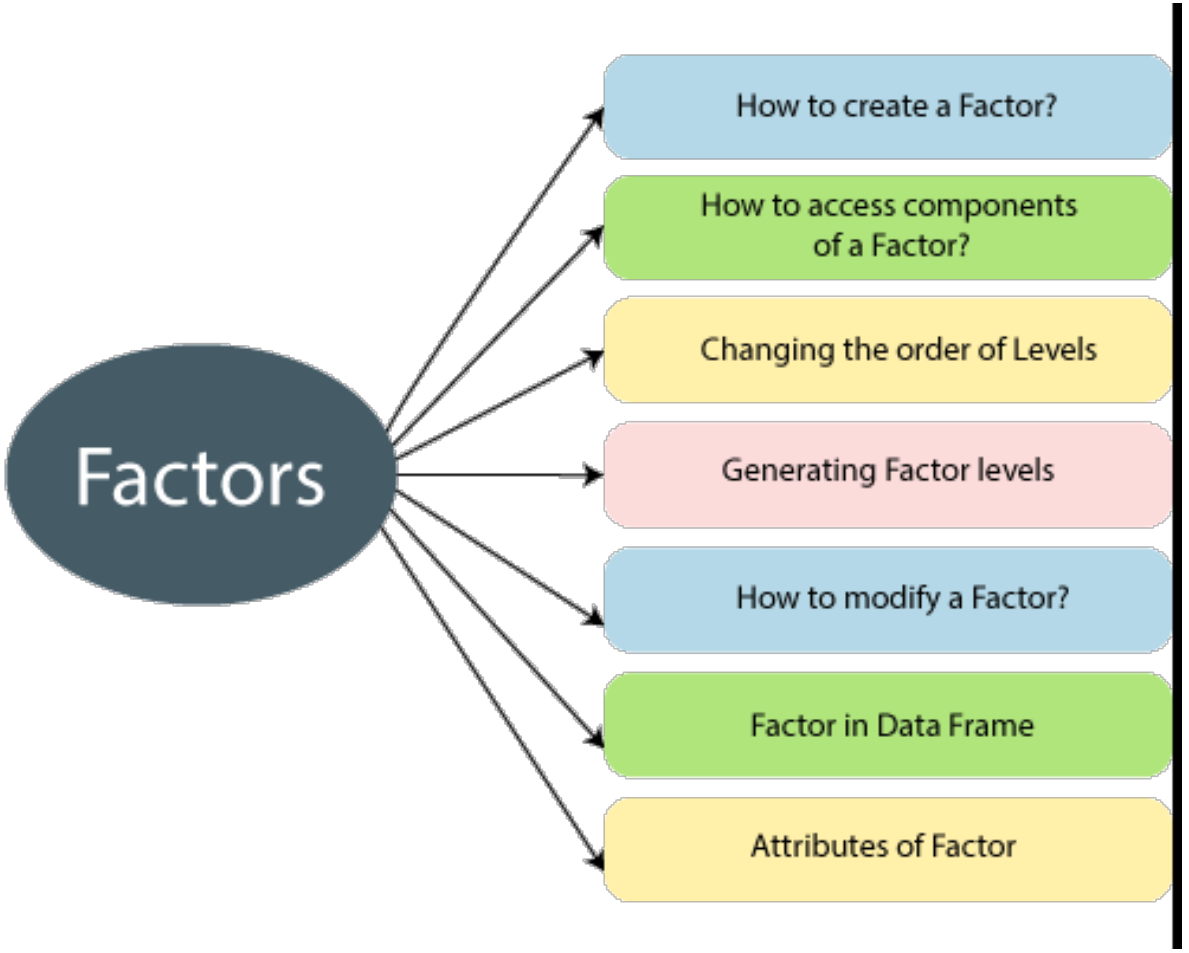
Factors

- **Categorical** Variables in Statistics
- Can take Limited set of Values (levels)
  - Example:

"Gender" = {Male, Female}

"Meal" = {Breakfast, Lunch, Dinner}

- No Intrinsic Ordering (alphabetical)
- Order can be changed
  - Why/When would you wish this!?



Factors

- Let's convert survey columns that contain categorical data to type factor with the factor() function:

```
surveys$sex <- factor(surveys$sex)
```

- We can see that the conversion has worked by using the summary() function

```
summary(surveys$sex)
```

- By default, R always sorts levels in alphabetical order

- R will assign 1 to the level "female" and 2 to the level "male" (because **f** comes before **m**, even though the first element in this vector is "male")

```
sex <- factor(c("male", "female", "female", "male"))
```

Factors

- Use function levels() to check this! [You can find the number of levels using nlevels()]

```
levels(sex)
nlevels(sex)
```

- **Order** of factors does not usually matter. But It might! Eg. It's meaningful (e.g., "low", "medium", "high"), or improves your visualization, or it is required by the analysis
- Here,

```
sex # current order
```

```
#> [1] male   female female male
#> Levels: female male
```

be:

```
sex <- factor(sex, levels = c("male", "female"))
sex # after re-ordering
```

```
#> [1] male   female female male
#> Levels: male female
```

Challenge!

- **Change the columns taxa and genus in the surveys data frame into a factor.**
- **Using the functions you learned before, can you find out…**
  - **How many rabbits were observed?**
  - **How many different genera are in the genus column?**

Converting Factors

- One way to convert a **factor** to a **character** vector, you use as.character(x)

```
as.character(sex)
```

- The as.numeric() function returns the **index values** of the factor, not its levels, so it will result in an entirely new (and unwanted in this case) set of numbers.
- One method to avoid this is to convert factors to characters, and then to numbers.
- **Another method** is to use the levels() function

```
year_fct <- factor(c(1990, 1983, 1977, 1998, 1990))
as.numeric(year_fct)               # Wrong! And there is no warning...
as.numeric(as.character(year_fct)) # Works...
as.numeric(levels(year_fct))[year_fct]    # The recommended way.
```

Renaming Factors

- Quick glance at the number of observations represented by each factor level. Use plot() function:

```
## bar plot of the number of females and males captured during the experiment:
plot(surveys$sex)
```

Renaming Factors

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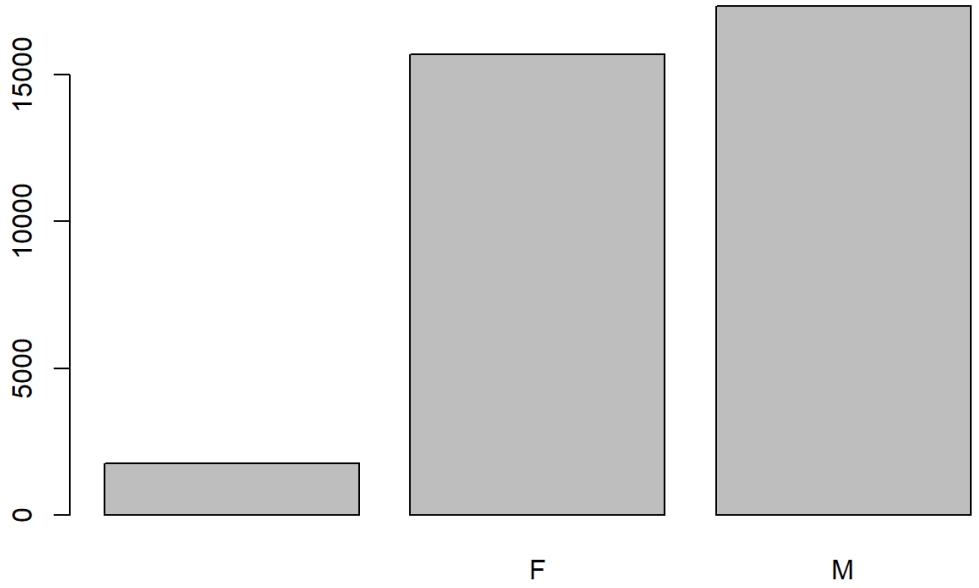


- **Note**: For 1700 individuals - sex information hasn't been recorded. **How to show them in the plot**?!

Renaming Factors

- To show them in the plot, we can turn the **missing values** into a **factor** level.
- **New label** to the new factor level. [Copy **sex** column to avoid modifying the working copy of the **data frame!**]

```
sex <- as.factor(surveys$sex)
head(sex)
```

```
#> [1] M M
#> Levels:  F M
```

```
levels(sex)
```

```
#> [1] ""  "F" "M"
```

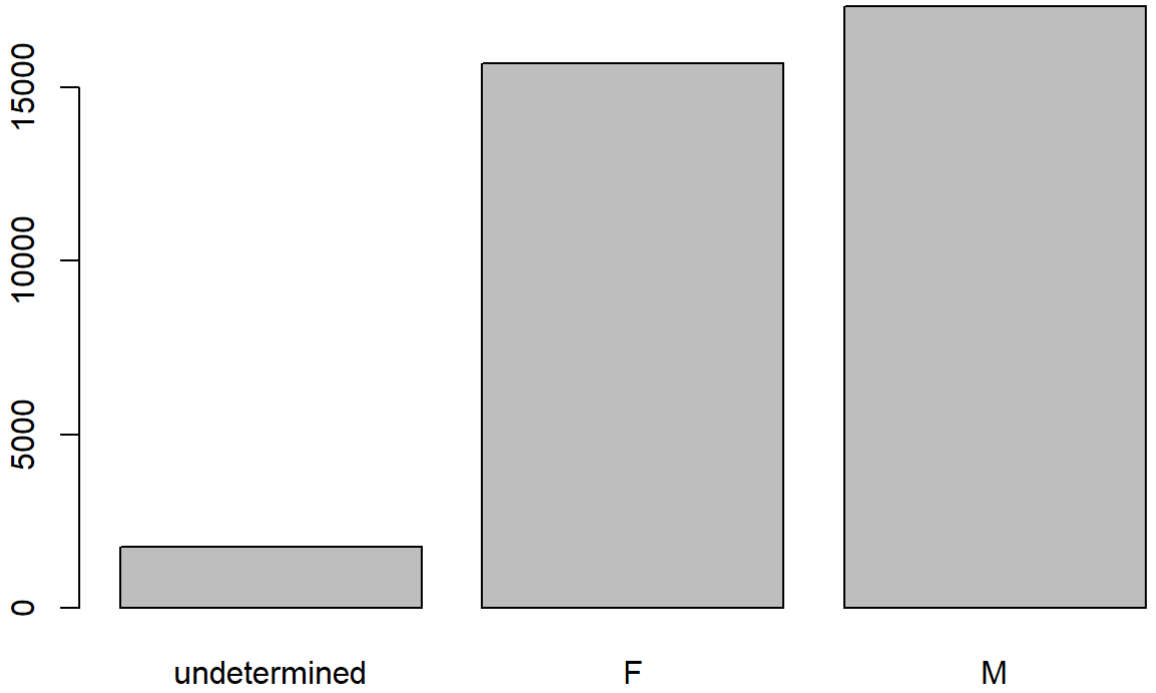
```
levels(sex)[1] <- "undetermined"
levels(sex)
```

```
#> [1] "undetermined" "F"            "M"
```

```
head(sex)
```

Renaming Factors

- Now let's plot the data again!
- plot (sex)



Challenge!

- **Rename “F” and “M” to “female” and “male” respectively.**

- **Now that we have renamed the factor level to “undetermined”, can you recreate the barplot such that “undetermined” is last (after “male”)?**

Using STRINGS as Factors

- Depending on what you want to do with the data, when you have a column with categorical data you may want to keep these columns as character or else you may want to change them to factor.

- To do so, read.csv() and read.table() have an argument called stringsAsFactors which can be set to TRUE.

```
## Compare the difference between our data read as `factor` vs `character`.
surveys <- read.csv("data/portal_data_joined.csv", stringsAsFactors = TRUE)
str(surveys)
surveys <- read.csv("data/portal_data_joined.csv", stringsAsFactors = FALSE)
str(surveys)
## Convert the column "plot_type" into a factor
surveys$plot_type <- factor(surveys$plot_type)
```

Challenge!

1. **We have seen how data frames are created when using read.csv(), but they can also be created by hand with the data.frame() function. There are a few mistakes in this hand-crafted data.frame. Can you spot and fix them? Don't hesitate to experiment!**

```
animal_data <- data.frame(
          animal = c(dog, cat, sea cucumber, sea urchin),
          feel = c("furry", "squishy", "spiny"),
          weight = c(45, 8 1.1, 0.8)
          )
```

2. **Can you predict the class for each of the columns in the following example? Check your guesses using str(country_climate):**
   - **Are they what you expected? Why? Why not?**
   - **What would have been different if we had added stringsAsFactors = FALSE when creating the data frame?**
   - **What would you need to change to ensure that each column had the accurate data type?**

```
country_climate <- data.frame(
       country = c("Canada", "Panama", "South Africa", "Australia"),
       climate = c("cold", "hot", "temperate", "hot/temperate"),
       temperature = c(10, 30, 18, "15"),
       northern_hemisphere = c(TRUE, TRUE, FALSE, "FALSE"),
       has_kangaroo = c(FALSE, FALSE, FALSE, 1)
       )
```

NEXT

DATA VISUALISATION