Investigating objects and data patterns using base R

EDUC 260A: Managing and Manipulating Data Using R

Lecture outline

1 Investigate objects, base R

Load .Rdata data frames we will use today

Data on off-campus recruiting events by public universities

- Data frame object `df_event`
  - One observation per university, recruiting event
- Data frame object `df_school`
  - One observation per high school (visited and non-visited)

```
rm(list = ls()) # remove all objects in current environment

getwd()
#> [1] "/Users/jaquette/Documents/rclass1/lectures/patterns_base_r"
#load dataset with one obs per recruiting event
load(url("https://github.com/ozanj/rclass/raw/master/data/recruiting/recruit_ev
#load("../../data/recruiting/recruit_event_somevars.Rdata")

#load dataset with one obs per high school
load(url("https://github.com/ozanj/rclass/raw/master/data/recruiting/recruit_sc
#load("../../data/recruiting/recruit_school_somevars.Rdata")
```

1.1 Functions to describe objects

Simple base R functions to describe objects

This section introduces some base R functions to describe objects (some of these you have seen before)

- list objects, `list.files()` and `ls()`
- remove objects, `rm()`
- object type, `typeof()`
- object length (number of elements), `length()`
- object structure, `str()`
- number of rows and columns, `ncol()` and `nrow()`

I use the functions `typeof()`, `length()`, `str()` anytime I encounter a new object

- Helps me understand the object before I start working with it

Listing objects

Files in your working directory

`list.files()` function lists files in your current working directory

- if you run this code from .Rmd file, working directory is location .Rmd file is stored

```
getwd() # what is your current working directory
#> [1] "/Users/jaquette/Documents/rclass1/lectures/patterns_base_r"
list.files()
#>  [1] "base_r_week1_video_lecture_script.R" "fp1.JPG"
#>  [3] "fp2.JPG"                             "one_carriage_train_vs_contents.pn
#>  [5] "patterns_base_r.pdf"                 "patterns_base_r.Rmd"
#>  [7] "patterns_base_r.tex"                 "smaller_trains.png"
#>  [9] "test.txt"                            "three_carriage_train.png"
#> [11] "transform-logical.png"
```

Objects currently open in your R session

Listing objects currently open in your R session

`ls()` function lists objects currently open in R

```
x <- "hello!"
ls() # Objects open in R
#> [1] "df_event"  "df_school" "x"
```

Removing objects currently open in your R session

`rm()` function removes specified objects open in R

```
rm(x)
ls()
#> [1] "df_event"  "df_school"
```

Command to remove all objects open in R (I don't run it)

```
#rm(list = ls())
```

Base R functions to describe objects, `typeof()`

`typeof()` function determines the the internal storage type of an object (e.g., logical vector, integer vector, list)

- syntax
  - `tyepof(x)`
- arguments
  - `x` : any R object
- help:

```
?typeof
```

Examples

- Recall that a data frame is an object where **type** is a list

```
typeof(c(TRUE,TRUE,FALSE,NA))
#> [1] "logical"
typeof(df_event)
#> [1] "list"
typeof(x = df_event)
#> [1] "list"
```

Base R functions to describe objects, `length()`

`length()` function determines the length of an R object

- for atomic vectors and lists, `length()` is the number of elements in the object
- syntax
  - `length(x)`
- arguments
  - `x` : any R object
- help:

```
?length
```

Example, length of an atomic vector is

```
length(c(TRUE,TRUE,FALSE,NA))
#> [1] 4
```

Example, length of a list or data frame

- length of a list is the number of elements
- data frame is a list
- length of a data frame = number of elements = number of variables

```
length(df_event) # = num elements = num columns
#> [1] 33
```

Base R functions to describe objects, `str()`

`str()` function compactly displays the structure of an R object

- "structure" includes type, length, and attribute of object and also nested objects
- syntax: `str(object)`
- arguments (partial)
  - `object` : any R object
  - `max.level` : max level of nesting to display nested structures; default `NA` = all levels
- help: `?str`

Example, atomic vectors

```
str(c(TRUE,TRUE,FALSE,NA))
#>  logi [1:4] TRUE TRUE FALSE NA
str(object = c(TRUE,TRUE,FALSE,NA))
#>  logi [1:4] TRUE TRUE FALSE NA
```

Example, lists/data frames (output omitted)

```
x <- list(c(1,2), list("apple", "orange"), list(2, 3)) # list
str(x)

str(df_event) # data frame
```

Base R functions to describe objects, `ncol()` and `nrow()`

`ncol()` `nrow()` and `dim()` functions

- Description
  - `ncol()` = number of columns; `nrow()` = number of rows
- syntax: `ncol(x)` `nrow(x)` `dim(x)`
- arguments
  - `x` : a vector, array, data frame, or NULL
- value/return:
  - if object `x` is an atomic vector: `ncol()` and `nrow()` returns `NULL`
  - if object `x` is a list but not a data frame: `ncol()` and `nrow()` returns `NULL`
  - if object `x` is a data frame: `ncol()` and `nrow()` returns integer of length 1

Example, object is a data frame

```
ncol(df_event) # num columns = num elements = num variables
#> [1] 33
nrow(df_event) # num rows = num observations
#> [1] 18680
# can wrap ncol() or nrow() within str() to see what functions return
#str(ncol(df_event))
```

Example, object is atomic vector or list that is not a data frame (output omitted)

```
ncol(c(TRUE,TRUE,FALSE,NA)) # atomic vector
x <- list(c(1,2), list("apple", "orange"), list(2, 3)) # list
nrow(x)
```

Base R functions to describe objects, `dim()`

`dim()` function returns the dimensions of an object (e.g., number of rows and columns)

- syntax: `dim(x)`
- arguments
  - `x` : a vector, array, data frame, or NULL
- value/return:
  - if object `x` is a data frame: `dim()` returns integer of length 2
    - first element = number of rows; second element = number of columns
  - if object `x` is an atomic vector: `dim()` returns `NULL`
  - if object `x` is a list but not a data frame: `dim()` returns `NULL`

Example, object is a data frame

```
dim(df_event) # shows number rows by columns
#> [1] 18680    33

str(dim(df_event)) # can wrap dim() within str() to see what functions return
#>  int [1:2] 18680 33
```

Example, object is atomic vector or list that is not a data frame (output omitted)

```
dim(c(TRUE,TRUE,FALSE,NA)) # atomic vector
x <- list(c(1,2), list("apple", "orange"), list(2, 3)) # list
dim(x)
```

1.2 Variables names

`names()` function

`names()` function gets or sets the names of elements of an object

- syntax:
  - get the names of an object: `names(x)`
  - set the names of an object: `names(x) <- value`
- arguments (partial)
  - `x` : an R object
  - `value` : a character vector with same length as object `x` or `NULL`
- value/return
  - `names(x)` returns a character vector of length = `length(x)` in which each element is the name of the element of `x`

Example, get names (of atomic vector)

```
a <- c(v1=1,v2=2,3,v4="hi!") # named atomic vector
a
#>    v1    v2          v4
#>   "1"   "2"   "3" "hi!"
length(a)
#> [1] 4
names(a)
#> [1] "v1" "v2" ""   "v4"
length(names(a)) # investigate length of object names(a)
#> [1] 4
str(names(a)) # investigate structure of object names(a)
#>  chr [1:4] "v1" "v2" "" "v4"
```

`names()` function

`names()` function gets or sets the names of elements of an object

- syntax:
  - get the names of an object: `names(x)`
  - set the names of an object: `names(x) <- value`
- arguments (partial)
  - `x` : an R object
  - `value` : a character vector with same length as object `x` or `NULL`
- value/return
  - `names(x)` returns a character vector of legnth = `length(x)` in which each element is the name of the element of `x`

Example, set names (of atomic vector)

```
names(a) <- NULL # set names of vector a to NULL
a
#> [1] "1"   "2"   "3"   "hi!"
names(a)
#> NULL

names(a) <- c("var1","var2","var3","var4") # set names of vector a
a
#>  var1  var2  var3  var4
#>   "1"   "2"   "3" "hi!"
names(a)
#> [1] "var1" "var2" "var3" "var4"
```

Applying `names()` function to a data frame

Recall that a data frame is an object where **type** is a **list** and each **element** is **named**

- each element is a variable
- each element name is a variable name

Example (output omitted)

```
names(df_event)
```

Investigate the object `names(df_event)`

```
typeof(names(df_event)) # type = character vector
#> [1] "character"
length(names(df_event)) # length = number of variables in data frame
#> [1] 33
str(names(df_event)) # structure of names(df_event)
#>  chr [1:33] "instnm" "univ_id" "instst" "pid" "event_date" "event_type" ...
```

We can even assign a new object based on `names(df_event)`

```
names_event <- names(df_event)
typeof(names_event) # type = character vector
#> [1] "character"
length(names_event) # length = number of variables in data frame
#> [1] 33
str(names_event) # structure of names(df_event)
#>  chr [1:33] "instnm" "univ_id" "instst" "pid" "event_date" "event_type" ...
```

Variable names

Refer to specific named elements of an object using this syntax:

- `object_name$element_name`

When object is data frame, refer to specific variables using this syntax:

- `data_frame_name$varname`
- **This approach to isolating variables is very useful for investigating data**

```
#df_event$instnm
typeof(df_event$instnm)
#> [1] "character"
typeof(df_event$med_inc)
#> [1] "double"
```

Variable names

Data frames are lists with the following criteria:

- each element of the list is (usually) a vector; each element of list is a variable
- length of data frame = number of variables

```
length(df_event)
#> [1] 33
nrow(df_event)
#> [1] 18680
#str(df_event)
```

- each element of the list (i.e., variable) has the same length
  - Length of each variable is equal to number of observations in data frame

```
typeof(df_event$event_state)
#> [1] "character"
length(df_event$event_state)
#> [1] 18680
str(df_event$event_state)
#>  chr [1:18680] "MA" "MA" "MA" "MA" "MA" "MA" "MA" "MA" "MA" "MA" "MA" "MA" ..

typeof(df_event$med_inc)
#> [1] "double"
length(df_event$med_inc)
#> [1] 18680
str(df_event$med_inc)
#>  num [1:18680] 71714 89122 70136 70136 71024 ...
```

Variable names

The object `df_school` has one obs per high school

- variable `visits_by_100751` shows number the of visits by University of Alabama to each high school
- like all variables in a data frame, the var `visits_by_100751` is just a vector

```
typeof(df_school$visits_by_100751)
#> [1] "integer"
length(df_school$visits_by_100751) # num elements in vector = num obs
#> [1] 21301
str(df_school$visits_by_100751)
#>  int [1:21301] 0 0 0 0 0 0 0 0 0 0 ...
sum(df_school$visits_by_100751) # sum of values of var across all obs
#> [1] 3338
```

We perform calculations on a variable like we would on any vector of same type

```
v <- c(2,4,6)
typeof(v)
#> [1] "double"
length(v)
#> [1] 3
sum(v)
#> [1] 12
```

1.3 View and print data

Viewing and printing, data frames

Many ways to view/print a data frame object. Here are three ways:

1. Simply type the object name (output omitted)
   - number of observations and rows printed depend on YAML header settings and on object "attributes" (attributes discussed in future week)

```
df_event
```

2. Use the `View()` function to view data in a browser

```
View(df_event)
```

3. `head()` to show the first *n* rows. The default is 6 rows.

```
#?head
#head(df_event)
head(df_event, n=5)
```

Viewing and printing, data frames

`obj_name[<rows>,<cols>]` to print specific rows and columns of data frame

- particularly powerful when combined with sequences (e.g., `1:10`)

Examples (output omitted):

- Print first five rows, all vars

```
df_event[1:5, ]
```

- Print first five rows and first three columns

```
df_event[1:5, 1:3]
```

- Print first three columns of the 100th observation

```
df_event[100, 1:3]
```

- Print the 50th observation, all variables

```
df_event[50,]
```

Viewing and printing, variables within data frames

Recall that:

- `obj_name$var_name` print specifics elements (i.e., variables) of a data frame

```
df_event$zip
```

- each element (i.e., variable) of data frame is an **atomic vector** with **length** = number of observations

```
typeof(df_event$zip)
#> [1] "character"
length(df_event$zip)
#> [1] 18680
```

- each element of a variable is the value of the variable for one observation

Print specific elements (i.e., observations) of variable based on element position

- syntax: `obj_name$var_name[<element position>]`
- vectors don't have "rows" or "columns"; they just have elements
- syntax combined with sequences (e.g., print first 10 observations)

```
df_event$event_state[1:10] # print obs 1-10 of variable "event_state"
#>  [1] "MA" "MA" "MA" "MA" "MA" "MA" "MA" "MA" "MA" "MA"
df_event$event_type[6:10] # print obs 6-10 of variable "event_type"
#> [1] "private hs" "private hs" "public hs"  "private hs" "public hs"
```

Viewing and printing, variables within data frames

Print specific elements (i.e., observations) of variable based on element position

- syntax: `obj_name$var_name[<element position>]`

Example, print individual elements

```
df_event$zip[1:5] # print obs 1-5 of variable for event zip code
#> [1] "01002" "01007" "01020" "01020" "01027"
df_event$zip[1] # print obs 1 of variable for event zip code
#> [1] "01002"
df_event$zip[5] # print obs 5 of variable for event zip code
#> [1] "01027"
df_event$zip[c(1,3,5)] # print obs 5 of variable for event zip code
#> [1] "01002" "01020" "01027"
```

Print specific elements of multiple variables using combine function `c()`

- syntax:
  `c(obj_name$var1_name[<element position>], obj_name$var2_name[<element posit`
- Example: print first five observations of variables `"event_state"` and `"event_type"`

```
c(df_event$event_state[1:5],df_event$event_type[1:5])
#>  [1] "MA"        "MA"        "MA"        "MA"        "MA"        "public hs"
#>  [7] "public hs" "public hs" "public hs" "public hs"
```

Exercise

Printing exercise using the df_school data frame

1. Use the `obj_name[<rows>,<cols>]` syntax to print the first 5 rows and 3 columns of the `df_school` data frame
2. Use the `head()` function to print the first 4 observations
3. Use the `obj_name$var_name[1:10]` syntax to print the first 10 observations of a variable in the `df_school` data frame
4. Use combine() to print the first 3 observations of variables “school_type” & “name”

Solution

1. Use the `obj_name[<rows>,<cols>]` syntax to print the first 5 rows and 3 columns of the `df_school` data frame

```
df_school[1:5,1:3]
#>   state_code school_type      ncessch
#> 1         AK      public 020000100208
#> 2         AK      public 020000100211
#> 3         AK      public 020000100212
#> 4         AK      public 020000100213
#> 5         AK      public 020000300216
```

Solution

2. Use the `head()` function to print the first 4 observations

```
head(df_school, n=4)
#>   state_code school_type      ncessch                          name
#> 1         AK      public 020000100208 Bethel Regional High School
#> 2         AK      public 020000100211      Ayagina'ar Elitnaurvik
#> 3         AK      public 020000100212         Kwigillingok School
#> 4         AK      public 020000100213   Nelson Island Area School
#>                       address         city zip_code pct_white pct_black
#> 1 1006 Ron Edwards Memorial Dr       Bethel    99559   11.7764    0.5988
#> 2             106 Village Road   Kongiganak    99559    0.0000    0.0000
#> 3             108 Village Road Kwigillingok    99622    0.0000    0.0000
#> 4             118 Village Road  Toksook Bay    99637    0.0000    0.0000
#>   pct_hispanic pct_asian pct_amerindian pct_other num_fr_lunch total_students
#> 1       1.5968     0.998        84.6307    0.3992          362            501
#> 2       0.0000     0.000        99.4505    0.5495          182            182
#> 3       0.0000     0.000       100.0000    0.0000          116            120
#> 4       0.0000     0.000       100.0000    0.0000          187            201
#>   num_took_math num_prof_math num_took_rla num_prof_rla avgmedian_inc_2564
#> 1           146         24.82          147        24.99            76160.0
#> 2            17          1.70           17         1.70            76160.0
#> 3            14          3.50           14         3.50                 NA
#> 4            30          3.00           30         3.00            57656.5
#>   visits_by_110635 visits_by_126614 visits_by_100751 inst_110635 inst_126614
#> 1                0                0                0          CA          CO
#> 2                0                0                0          CA          CO
#> 3                0                0                0          CA          CO
```

Solution

3. Use the `obj_name$var_name[1:10]` syntax to print the first 10 observations of a variable in the `df_school` data frame

```
df_school$name[1:10]
#>  [1] "Bethel Regional High School" "Ayagina'ar Elitnaurvik"
#>  [3] "Kwigillingok School"         "Nelson Island Area School"
#>  [5] "Alakanuk School"             "Emmonak School"
#>  [7] "Hooper Bay School"           "Ignatius Beans School"
#>  [9] "Pilot Station School"        "Kotlik School"
```

Solution

4. Use combine() to print the first 3 observations of variables “school_type” & “name”

```
c(df_school$school_type[1:3],df_school$name[1:3])
#> [1] "public"                          "public"
#> [3] "public"                          "Bethel Regional High School"
#> [5] "Ayagina'ar Elitnaurvik"          "Kwigillingok School"
```

1.4 Missing values

Missing values

Missing values have the value `NA`

- `NA` is a special keyword, not the same as the character string `"NA"`

use `is.na()` function to determine if a value is missing

- `is.na()` returns a logical vector

```
is.na(5)
#> [1] FALSE
is.na(NA)
#> [1] TRUE
is.na("NA")
#> [1] FALSE
typeof(is.na("NA")) # example of a logical vector
#> [1] "logical"

nvector <- c(10,5,NA)
is.na(nvector)
#> [1] FALSE FALSE  TRUE
typeof(is.na(nvector)) # example of a logical vector
#> [1] "logical"

svector <- c("e","f",NA,"NA")
is.na(svector)
#> [1] FALSE FALSE  TRUE FALSE
```

Missing values are “contagious”

What does “contagious” mean?

- operations involving a missing value will yield a missing value

```
7>5
#> [1] TRUE
7>NA
#> [1] NA
sum(1,2,NA)
#> [1] NA
0==NA
#> [1] NA
2*c(0,1,2,NA)
#> [1]  0  2  4 NA
NA*c(0,1,2,NA)
#> [1] NA NA NA NA
```

Functions and missing values example, `table()`

`table()` function is useful for investigating categorical variables

```
str(df_event$event_type)
#>  chr [1:18680] "public hs" "public hs" "public hs" "public hs" "public hs" ..
table(df_event$event_type)
#>
#> 2yr college 4yr college       other  private hs   public hs
#>         951         531        2001        3774       11423
```

Functions and missing values example, `table()`

By default `table()` ignores `NA` values

```
#?table
str(df_event$school_type_pri)
#>  int [1:18680] NA NA NA NA NA 1 1 NA 1 NA ...
table(df_event$school_type_pri)
#>
#>    1    2    5
#> 3765    8    1
```

`useNA` argument controls if table includes counts of `NA`s. Allowed values:

- never ("no") [DEFAULT VALUE]
- only if count is positive ("ifany");
- even for zero counts ("always")"

```
nrow(df_event)
#> [1] 18680
table(df_event$school_type_pri, useNA="always")
#>
#>    1    2    5 <NA>
#> 3765    8    1 14906
```

Broader point: Most functions that create descriptive statistics have options about how to treat missing values'

- When investigating data, good practice to *always* show missing values

2 Subsetting using subset operators

Subsetting to Extract Elements

"Subsetting" refers to isolating particular elements of an object

Subsetting operators can be used to select/exclude elements (e.g., variables, observations)

- there are three subsetting operators: `[]` , `$` , `[[]]`
- these operators function differently based on vector types (e.g, atomic vectors, lists, data frames)

Wichham refers to number of "dimensions" in R objects

An atomic vector is a 1-dimensional object that contains n elements

```
x <- c(1.1, 2.2, 3.3, 4.4, 5.5)
str(x)
#>  num [1:5] 1.1 2.2 3.3 4.4 5.5
```

Lists are multi-dimensional objects

- Contains n elements; each element may contain a 1-dimensional atomic vector or a multi-dimensional list. Below list contains 3 dimensions

```
list <- list(c(1,2), list("apple", "orange"))
str(list)
#> List of 2
#>  $ : num [1:2] 1 2
#>  $ :List of 2
#>   ..$ : chr "apple"
#>   ..$ : chr "orange"
```

Data frames are 2-dimensional lists

- each element is a variable (dimension=columns)
- within each variable, each element is an observation (dimension=rows)

```
ncol(df_school)
#> [1] 26
nrow(df_school)
#> [1] 21301
```

2.1 Subset atomic vectors using []

Subsetting elements of atomic vectors

"Subsetting" a vector refers to isolating particular elements of a vector

- I sometimes refer to this as "accessing elements of a vector"
- subsetting elements of a vector is similar to "filtering" rows of a data-frame
- `[]` is the subsetting function for vectors

Six ways to subset an atomic vector using `[]`

1. Using positive integers to return elements at specified positions
2. Using negative integers to exclude elements at specified positions
3. Using logicals to return elements where corresponding logical is `TRUE`
4. Empty `[]` returns original vector (useful for dataframes)
5. Zero vector [0], useful for testing data
6. If vector is "named," use character vectors to return elements with matching names

1. Using positive integers to return elements at specified positions (subset atomic vectors using [])

Create atomic vector `x`

```
(x <- c(1.1, 2.2, 3.3, 4.4, 5.5))
#> [1] 1.1 2.2 3.3 4.4 5.5
str(x)
#>  num [1:5] 1.1 2.2 3.3 4.4 5.5
```

`[]` is the subsetting function for vectors

- contents inside `[]` can refer to element number (also called "position").
  - e.g., `[3]` refers to contents of 3rd element (or position 3)

```
x[5] #return 5th element
#> [1] 5.5

x[c(3, 1)] #return 3rd and 1st element
#> [1] 3.3 1.1

x[c(4,4,4)] #return 4th element, 4th element, and 4th element
#> [1] 4.4 4.4 4.4

#Return 3rd through 5th element
x[3:5]
#> [1] 3.3 4.4 5.5
```

2. Using negative integers to exclude elements at specified positions (subset atomic vectors using [])

Before excluding elements based on position, investigate object

```
x
#> [1] 1.1 2.2 3.3 4.4 5.5

length(x)
#> [1] 5
str(x)
#>  num [1:5] 1.1 2.2 3.3 4.4 5.5
```

Use negative integers to exclude elements based on element position

```
x[-1] # exclude 1st element
#> [1] 2.2 3.3 4.4 5.5

x[c(3,1)] # 3rd and 1st element
#> [1] 3.3 1.1
x[-c(3,1)] # exclude 3rd and 1st element
#> [1] 2.2 4.4 5.5
```

3. Using logicals to return elements where corresponding logical is `TRUE` (subset atomic vectors using [])

```
x
#> [1] 1.1 2.2 3.3 4.4 5.5
```

When using `x[y]` to subset `x`, good practice to have `length(x)==length(y)`

```
length(x) # length of vector x
#> [1] 5
length(c(TRUE,FALSE,TRUE,FALSE,TRUE)) # length of y
#> [1] 5
length(x) == length(c(TRUE,FALSE,TRUE,FALSE,TRUE)) # condition true
#> [1] TRUE
x[c(TRUE,TRUE,FALSE,FALSE,TRUE)]
#> [1] 1.1 2.2 5.5
```

Recycling rules:

- in `x[y]`, if `x` is different length than `y`, R "recycles" length of shorter to match length of longer

```
length(c(TRUE,FALSE))
#> [1] 2
x
#> [1] 1.1 2.2 3.3 4.4 5.5
x[c(TRUE,FALSE)]
#> [1] 1.1 3.3 5.5
```

3. Using logicals to return elements where corresponding logical is `TRUE` (subset atomic vectors using [])

```
x
#> [1] 1.1 2.2 3.3 4.4 5.5
```

Note that a missing value (`NA`) in the index always yields a missing value in the output:

```
x[c(TRUE, FALSE, NA, TRUE, NA)]
#> [1] 1.1  NA 4.4  NA
```

Return all elements of object `x` where element is greater than 3:

```
x # print object X
#> [1] 1.1 2.2 3.3 4.4 5.5
x>3 # for each element of X, print T/F whether element value > 3
#> [1] FALSE FALSE  TRUE  TRUE  TRUE
str(x>3)
#>  logi [1:5] FALSE FALSE TRUE TRUE TRUE
x[x>3] # prints only the values that had TRUE at that position
#> [1] 3.3 4.4 5.5
```

3. Using logicals to return elements where corresponding logical is `TRUE` (subset atomic vectors using []) [cont.]

The `visits_by_100751` column shows how many visits the University of Alabama made to each school. Let's subset this to only include 2 or more visits:

```
df_school$visits_by_100751[1:100]
#>   [1] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
#>  [38] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
#>  [75] 0 0 0 0 0 0 0 0 0 0 5 2 4 4 3 3 3 3 3 3 2 3 3 3 3 1
df_school$visits_by_100751[1:100]>2
#>   [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
#>  [13] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
#>  [25] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
#>  [37] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
#>  [49] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
#>  [61] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
#>  [73] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
#>  [85]  TRUE FALSE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE FALSE  TRUE
#>  [97]  TRUE  TRUE  TRUE FALSE
df_school$visits_by_100751[df_school$visits_by_100751>2]
#>   [1] 5 4 4 3 3 3 3 3 3 3 3 3 3 4 4 3 3 3 3 3 4 4 3 3 3 4 3 3 3 3 3 3 3 4 3 3
#>  [38] 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 3 3 3 3 4 5 3 3 3 4 3 3 4 3 3 3
#>  [75] 3 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 5 4 6 5 3 5 5 5
#> [112] 4 4 3 3 3 5 3 4 4 3 3 3 3 4 4 3 3 4 3 3 3 3 3 3 3 3 3 3 3 4 3 3 3 3 3 3
#> [149] 3 3 3 3 4 3 3 3 3 3 3 3 3
```

4. Empty `[]` returns original vector (subset atomic vectors using [])

```
x
#> [1] 1.1 2.2 3.3 4.4 5.5

x[]
#> [1] 1.1 2.2 3.3 4.4 5.5
```

This is useful for sub-setting data frames, as we will show below

5. Zero vector [0] (subset atomic vectors using [])

Zero vector, `x[0]`

- R interprets this as returning element 0

```
x[0]
#> numeric(0)
```

Wickham states:

- "This is not something you usually do on purpose, but it can be helpful for generating test data."

6. If vector is named, character vectors to return elements with matching names (subset atomic vectors using [])

Create vector `y` that has values of vector `x` but each element is named

```
x
#> [1] 1.1 2.2 3.3 4.4 5.5

(y <- c(a=1.1, b=2.2, c=3.3, d=4.4, e=5.5))
#>   a   b   c   d   e
#> 1.1 2.2 3.3 4.4 5.5
```

Return elements of vector based on name of element

- enclose element names in single `''` or double `""` quotes

```
#show element named "a"
y["a"]
#>   a
#> 1.1

#show elements "a", "b", and "d"
y[c("a", "b", "d" )]
#>   a   b   d
#> 1.1 2.2 4.4
```

2.2 Subsetting lists/data frames using []

Subsetting lists using []

Using `[]` operator to subset lists works the same as subsetting atomic vector

- Using `[]` with a list always returns a list

```
list_a <- list(list(1,2),3,"apple")
str(list_a)
#> List of 3
#>  $ :List of 2
#>   ..$ : num 1
#>   ..$ : num 2
#>  $ : num 3
#>  $ : chr "apple"

#create new list that consists of elements 3 and 1 of list_a
list_b <- list_a[c(3, 1)]
str(list_b)
#> List of 2
#>  $ : chr "apple"
#>  $ :List of 2
#>   ..$ : num 1
#>   ..$ : num 2

#show elements 3 and 1 of object list_a
#str(list_a[c(3, 1)])
```

Subsetting data frames using []

Recall that a data frame is just a particular kind of list

- each element = a column = a variable

Using `[]` with a list always returns a list

- Using `[]` with a data frame always returns a data frame

Two ways to use `[]` to extract elements of a data frame

1. use "single index" `df_name[<columns>]` to extract columns (variables) based on element position number (i.e., column number)
2. use "double index" `df_name[<rows>, <columns>]` to extact particular rows and columns of a data frame

Subsetting data frames using [] to extract columns (variables) based on element position

Use "single index" `df_name[<columns>]` to extract columns (variables) based on element number (i.e., column number)

Examples [output omitted]

```
names(df_event)

#extract elements 1 through 4 (elements=columns=variables)
df_event[1:4]
df_event[c(1,2,3,4)]

str(df_event[1:4])
#extract columns 13 and 7
df_event[c(13,7)]
```

Subsetting Data Frames to extract columns (variables) and rows (observations) based on positionality

use "double index" syntax `df_name[<rows>, <columns>]` to extact particular rows and columns of a data frame

- often combined with sequences (e.g., `1:10`)

```
#Return rows 1-3 and columns 1-4
df_event[1:3, 1:4]
#>       instnm univ_id instst   pid
#> 1 UM Amherst  166629     MA 57570
#> 2 UM Amherst  166629     MA 56984
#> 3 UM Amherst  166629     MA 57105

#Return rows 50-52 and columns 10 and 20
df_event[50:52, c(10,20)]
#>    event_state pct_tworaces_zip
#> 50          MA           1.9831
#> 51          MA           1.9831
#> 52          MA           1.9831
```

Subsetting Data Frames to extract columns (variables) and rows (observations) based on positionality

use "double index" syntax `df_name[<rows>, <columns>]` to extact particular rows and columns of a data frame

recall that empty `[]` returns original object (output omitted)

```
#return original data frame
df_event[]

#return specific rows and all columns (variables)
df_event[1:5, ]

#return all rows and specific columns (variables)
df_event[, c(1,2,3)]
```

Use [] to extract data frame columns based on variable names

Selecting columns from a data frame by subsetting with `[]` and list of element names (i.e., variable names) enclose in quotes

"single index" approach extracts specific variables, all rows (output omitted)

```
df_event[c("instnm", "univ_id", "event_state")]
```

"Double index" approach extracts specific variables and specific rows

- syntax `df_name[<rows>, <columns>]`

```
df_event[1:5, c("instnm", "event_state", "event_type")]
#>        instnm event_state event_type
#> 1  UM Amherst          MA  public hs
#> 2  UM Amherst          MA  public hs
#> 3  UM Amherst          MA  public hs
#> 4  UM Amherst          MA  public hs
#> 5 Stony Brook          MA  public hs
```

Student exercises

Use subsetting operators from base R in extracting columns (variables), observations:

1. Use both "single index" and "double index" in subsetting to create a new dataframe by extracting the columns `instnm`, `event_date`, `event_type` from the `df_event` data frame. And show what columns (variables) are in the newly created dataframe.
2. Use subsetting to return rows 1-5 of columns `state_code`, `name`, `address` from the `df_school` data frame.

Solution to Student Exercises

Solution to 1

base R using subsetting operators

```
# single index
df_event_br <- df_event[c("instnm", "event_date", "event_type")]
#double index
df_event_br <- df_event[, c("instnm", "event_date", "event_type")]
names(df_event_br)
#> [1] "instnm"     "event_date" "event_type"
```

Solution to 2

base R using subsetting operators

```
df_school[1:5, c("state_code", "name", "address")]
#>   state_code                          name                       address
#> 1         AK Bethel Regional High School 1006 Ron Edwards Memorial Dr
#> 2         AK      Ayagina'ar Elitnaurvik              106 Village Road
#> 3         AK         Kwigillingok School              108 Village Road
#> 4         AK   Nelson Island Area School              118 Village Road
#> 5         AK              Alakanuk School                 9 School Road
```

2.3 Subsetting lists/data frames using [[]] and $

Subset single element from object using [[]] operator, atomic vectors

So far we have used `[]` to extract elements from an object

- Apply `[]` to atomic vector: returns atomic vector with elements you requested
- Apply `[]` to list: returns list with elements you requested

`[[]]` also extract elements from an object

- Applying `[[]]` to atomic vector gives same result as `[]`; that is, an atomic vector with element you request

```
(x <- c(1.1, 2.2, 3.3, 4.4, 5.5))
#> [1] 1.1 2.2 3.3 4.4 5.5

str(x[3])
#>  num 3.3

str(x[[3]])
#>  num 3.3
```

- Caveat: when applying `[[]]` to atomic vector, you can only subset a single element

```
x[c(3,4)] # single bracket; this works
#> [1] 3.3 4.4

#x[[c(3,4)]] # double bracket; this won't work
```

Subsetting lists using `[]` vs. `[[]]`, introduce "train metaphor"

Applying `[[]]` to a list

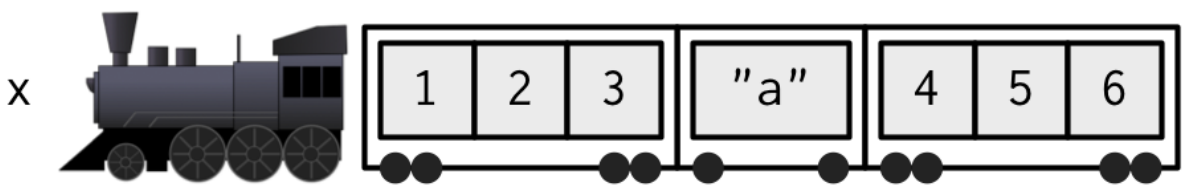
- Understanding what `[]` vs. `[[]]` does to a list is very important but requires some explanation!

Advanced R chapter 4.3 by Wickham uses the "train metaphor" to explain a list vs. **contents** of a list and how this relates to `[]` vs. `[[]]`

Below code chunk makes a list named `list_x` that contains 3 elements

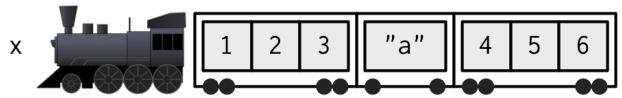
```
list_x <- list(1:3, "a", 4:6) # create list object list_x
```

In our train metaphor, object `list_x` is a train that contains 3 carriages

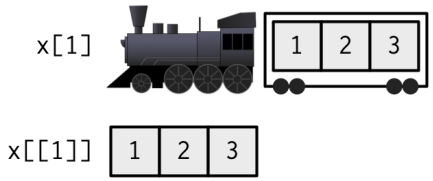


Subsetting lists using `[]` vs. `[[]]`, introduce "train metaphor"

list object `list_x` is a train that contains 3 carriages



When we "subset a list" – that is, extract one or more elements from the list – we have two broad choices (image below)



1. Extracting elements using `[]` always returns a list, usually one with fewer elements
   - you can think of this as a train with fewer carriages

```
#str(list_x)
str(list_x[1]) # returns a list
#> List of 1
#>  $ : int [1:3] 1 2 3
```

2. Extracting element using `[[]]` returns ***contents*** of particular carriage
   - I say applying `[[]]` to a list or data frame returns a simpler object that moves up one level of hierarchy

```
str(list_x[[1]]) # returns an atomic vector
#>  int [1:3] 1 2 3
```

Subset lists using `[]` vs. `[[]]`, deepen understanding of `[]`

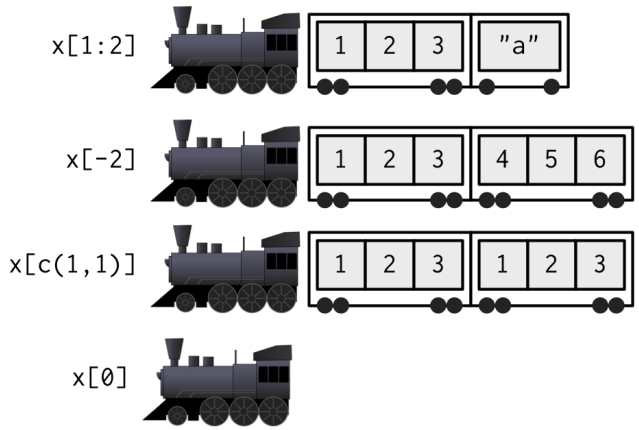
Rules about applying subset operator `[]` to a list

- Applying `[]` to a list always returns a list
- Resulting list contains 1 or more elements depending on what typed inside `[]`

Here is a list object named `list_x`

```
list_x <- list(1:3, "a", 4:6)
```

Here is an image of a few "trains" that can be created by applying `[]` to `list_x`



And here is code to create the "trains" shown in above image (output omitted)

```
list_x[1:2]
list_x[-2]
list_x[c(1,1)]
list_x[0]
list_x[] # returns the original list; not shown in above train picture
```

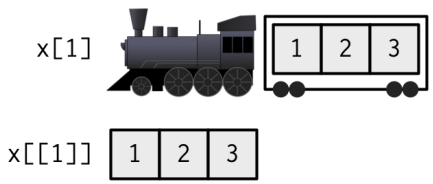
Subset lists using `[]` vs. `[[]]`, deepen understanding of `[[]]`

Rules about applying subset operator `[[]]` to a list

- Can apply `[[]]` to return the **contents** of a **single element** of a list

Create list `list_x` and show "train" Image of applying `list_x[1]` vs. `list_x[[1]]`

```
list_x <- list(1:3, "a", 4:6)
```



Object created by `list_x[1]` is a list with one element (output omitted)

```
list_x[1]
str(list_x[1])
```

Object created by `list_x[[1]]` is a vector with 3 elements (output omitted)

- `list_x[[1]]` gives us "contents" of element 1
- Since element 1 contains a numeric vector, object created by `list_x[[1]]` is a numeric vector

```
list_x[[1]]
str(list_x[[1]])
```

Subset lists using `[]` vs. `[[]]`, deepen understanding of `[[]]`

Rules about applying subset operator `[[]]` to a list

- Can apply `[[]]` to return the **contents** of a **single element** of a list

```
list_x <- list(1:3, "a", 4:6) # create list list_x
```

We cannot use `[[]]` to subset multiple elements of a list (output omitted)

- e.g., we could write `list_x[[2]]` but not `list_x[[2:3]]`

```
list_x[[c(2)]] # this works, subset element 2 using [[]]
list_x[[c(2,3)]] # this doesn't work; subset element 2 and 3 using [[]]
list_x[c(2,3)] # this works; subset element 2 and 3 using []
```

Subset lists using `[]` vs. `[[]]`, deepen understanding of `[[]]`

Like `[]`, can use `[[]]` to return contents of **named** elements specified using quotes

- syntax: `obj_name[["element_name"]]`

```
list_x <- list(var1=1:3, var2="a", var3=4:6) # create list with named elements
```

Subset list `list_x` using `[[]]` element names

```
list_x[["var1"]] # subset by element position: list_x[[1]]
#> [1] 1 2 3
str(list_x[["var1"]])
#>  int [1:3] 1 2 3
str(list_x["var1"]) # note: suggests var name is attribute of list, not atomic v
#> List of 1
#>  $ var1: int [1:3] 1 2 3
```

Can do same thing with data frames because data frames are lists (output omitted)

- e.g., `df_event[["zip"]]` returns contents of element named `"zip"`
- object created by `df_event[["zip"]]` is character vector of length = 18,680

```
# df_event[["zip"]] # this works but long output
str(df_event[["zip"]]) # character vector of length 18,860
typeof(df_event[["zip"]])
length(df_event[["zip"]])
str(df_event["zip"]) # by contrast, this is a dataframe w/ one variable
```

General rules of applying `[]` vs `[[]]` to (nested) objects

What we just learned about applying `[]` vs `[[]]` to lists applies more generally to "nested objects"

- "nested objects" are objects with a hierarchical structure such that an element of an object contains another object

General rules of applying `[]` vs. `[[]]` to nested objects

- subset any object `x` using `[]` will return object with same data structure as `x`
- subset any object `x` using `[[]]` will return an object thay may or may not have same data structure of `x`
  - if object `x` is not a nested object, then applying `[[]]` to a single element of `x` will return object with same data structure as `x`
  - if object `x` has a nested data structure, then then applying `[[]]` to a single element of `x` will "move up one level of hierarchy" to extract the **contents** of an element within the object `x`

When working w/ data frames, functions that calculate things expect to be working with atomic vectors (think `[[]]`) not lists (think `[]`)

```
mean(df_event[['med_inc']], na.rm = TRUE)
#> [1] 89089.28
# mean(df_event['med_inc'], na.rm = TRUE) # by contrast, this doesn't work
```

Subset lists/data frames using $

```
list_x <- list(var1=1:3, var2="a", var3=4:6)
```

`obj_name$element_name` is shorthand operator for `obj_name[["element_name"]]`

These three lines of code all give the same result

```
list_x[[1]]
#> [1] 1 2 3
list_x[["var1"]]
#> [1] 1 2 3
list_x$var1
#> [1] 1 2 3
```

`df_name$var_name` : easiest way in base R to refer to variable in a data frame

- these two lines of code are equivalent

```
str(df_event[["zip"]])
#>  chr [1:18680] "01002" "01007" "01020" "01020" "01027" "01027" "01027" ...
str(df_event$zip)
#>  chr [1:18680] "01002" "01007" "01020" "01020" "01027" "01027" "01027" ...
```

2.4 Subset Data frames by combining [] and $

Subset Data Frames by combining `[]` and `$`, Motivation

Motivation

- When working with data frames we often want to isolate those observations that satisfy certain conditions
- This is often referred to as "filtering"
  - We filter observations based on the values of one or more variables
- Perhaps you have seen "filtering" in Microsoft Excel
  - open some spreadsheet that contains variables (columns) and observations (rows)
  - click on `Data` » `Filter` and then filter observations based on values of variable(s)

Filtering example using data frame `df_school`

- Observations:
  - One observation per high school (public and private)
- Variables:
  - high school characteristics; number of off-campus recruiting visits from particular universities
  - NCES ID for UC Berkeley is `110635`
  - variable `visits_by_110635` shows number of visits a high school received from UC Berkeley
- **Task**:
  - Isolate observations where the high school received at least 1 visit from UC Berkeley

Subset Data Frames by combining `[]` and `$`

Task:

- Isolate obs where school received at least 1 visit from UC Berkeley

General syntax: `df_name[df_name$var_name <condition>, ]`

- where `<condition>` is something that evaluates to `TRUE` or `FALSE` for each element of the atomic vector (i.e., variable)
- Note that syntax uses "double index" `df_name[<rows>, <columns>]` syntax
  - Therefore, the `<condition>` in above syntax is isolating `<rows>`
- **Cannot** use "single index" syntax `df_name[<columns>]`

Solution to task (output omitted)

- Note: below code filters observations but keeps all variables

```
df_school[df_school$visits_by_110635 >= 1, ]
```

Subset Data Frames by combining `[]` and `$`, decompose syntax

Task: Isolate obs where school received at least 1 visit from UC Berkeley

- general syntax: `df_name[df_name$var_name <condition>, ]`
- solution: `df_school[df_school$visits_by_110635 >= 1, ]`

Decomposing syntax `df_school[df_school$visits_by_110635 >= 1, ]`

- `df_school$visits_by_110635 >= 1`: returns a logical (`TRUE` / `FALSE`) atomic vector with length equal to number of obs in `df_school`

```
typeof(df_school$visits_by_110635 >= 1)
length(df_school$visits_by_110635 >= 1)
str(df_school$visits_by_110635 >= 1)
```

- `df_school[df_school$visits_by_110635 >= 1, ]`
  - uses "double index" `df_name[<rows>, <columns>]` syntax to extract rows, columns
  - rows: extract rows where `df_school$visits_by_110635 >= 1` is `TRUE`
  - columns: since `<columns>` is empty, extracts all columns
- **key point**: `df_name[df_name$var_name <condition>, ]` is "subset a vector approach #3": "Using logicals to return elements where condition `TRUE`"
- example using atomic vectors (output omitted)

```
x <- c(1.1, 2.2, 3.3, 4.4, 5.5)
x[x>3]
```

Subset Data Frames by combining `[]` and `$`, keep desired columns

- General syntax to filter desired observations (rows) and variables (columns) of data frame:
- `df_name[df_name$var_name <condition>, <desired columns>]`

Tasks (output omitted)

- Extract observations where the high school received at least 1 visit from UC Berkeley and the first three columns

```
df_school[df_school$visits_by_110635 >= 1, 1:3]
```

- Extract observations where the high school received at least 1 visit from UC Berkeley and variables "state_code" "school_type" "name"

```
df_school[df_school$visits_by_110635 >= 1, c("state_code","school_type","name")]
```

Subset Data Frames by combining `[]` and `$`, more examples

Syntax:

- filter based on one variable:
  - `df_name[df_name$var_name <condition>, <columns>]`
- Example syntax to filter based on two conditions being true
  - `df_name[df_name$var_name <condition> & df_name$var_name <condition>, <columns>]`

Pro tip:

- wrap above syntax within `nrow()` function to count how many observations (rows) satisfy the condition (as opposed to printing all rows that satisfy condition)

Tasks

- Count obs where high schools received at least 1 visit by Bama (100751) **and** at least one visit by Berkeley (110635)

```
nrow(df_school[df_school$visits_by_110635 >= 1 &
                 df_school$visits_by_100751 >= 1, ])
#> [1] 247
# Equivalently:
# nrow(df_school[df_school[["visits_by_110635"]] >= 1 &
#                  df_school[["visits_by_100751"]] >= 1, ])
```

- Count obs where schools received 1+ visit by Bama **or** 1+ visit by Berkeley

```
nrow(df_school[df_school$visits_by_110635 >= 1
  | df_school$visits_by_100751 >= 1, ])
```

Logical operators for comparisons

- Logical operators to isolate/filter observations of data frame

Symbol	Meaning
`==`	Equal to
`!=`	Not equal to
`>`	greater than
`>=`	greater than or equal to
`<`	less than
`<=`	less than or equal to
`&`	AND
`|`	OR
`%in%`	includes

- Visualization of "Boolean" operators (e.g., AND, OR, AND NOT)

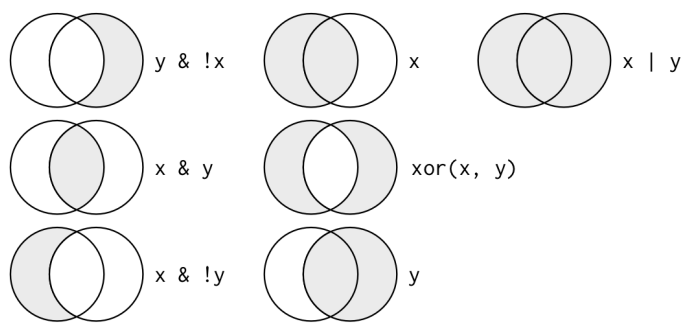


Figure 1: "Boolean" operations, x=left circle, y=right circle, from Wichkam (2018)

Subset Data Frames by combining `[]` and `$`, more examples

Example: Count the number of out-of-state high schools that UC Berkeley visited.

```
# The `inst_110635` variable contains the home state of UC Berkeley
unique(df_school$inst_110635)
#> [1] "CA"

# Filter for schools visited by UC Berkeley AND whose state is not "CA"
nrow(df_school[df_school$visits_by_110635 >= 1 &
                 df_school$state_code != df_school$inst_110635, ])
#> [1] 302
```

Example: Count the number of schools in the Northeast that received a visit from either UC Berkeley, U of Alabama, or CU Boulder.

```
# Vector containing states located in the Northeast region
northeast_states <- c('CT', 'ME', 'MA', 'NH', 'RI', 'VT', 'NJ', 'NY', 'PA')

# Filter for schools in the Northeast AND visited by any of the 3 univs
nrow(df_school[df_school$state_code %in% northeast_states &
                 (df_school$visits_by_110635 >= 1 |
                    df_school$visits_by_100751 >= 1 |
                    df_school$visits_by_126614 >= 1), ])
#> [1] 544
```

Subset Data Frames by combining `[]` and `$`, `NA` Observations

Filtering observations of data frame using `[]` combined with `$` is more complicated in the presence of missing values (`NA` values)

The next few slides will explain

- why it is more complicated
- how to filter correctly when `NA`s are present

Subset Data Frames by combining `[]` and `$`, `NA` Observations

When sub-setting via `[]` combined with `$`, result will include:

- rows where condition is `TRUE`
- **as well as** rows with `NA` (missing) values for `<condition>`.

Task (using `df_event`, which has one obs per university, recruiting event)

- How many events at public HS with at least $50k median household income?

```
sum(is.na(df_event$med_inc)) # number of observations (all events) with missing
#> [1] 470

#num obs event_type=="public hs" and med_inc is missing
nrow(df_event[df_event$event_type == "public hs"
  & is.na(df_event$med_inc)==1 , ]) # note TRUE evaluates to 1
#> [1] 75

#num obs event_type=="public hs" & med_inc is not NA & med_inc >= $50,000
nrow(df_event[df_event$event_type == "public hs"
  & is.na(df_event$med_inc)==0 & df_event$med_inc>=50000 , ])  # note FALSE eva
#> [1] 9941

#num obs event_type=="public hs" and med_inc >= $50,000
nrow(df_event[df_event$event_type == "public hs"
  & df_event$med_inc>=50000 , ])
#> [1] 10016
```

Subset Data Frames by combining `[]` and `$`, `NA` Observations

To exclude rows where condition is `NA` if subset using `[]` combined w/ `$`

- use `which()` to ask only for values where condition evaluates to `TRUE`
- `which()` returns position numbers for elements where condition is `TRUE`

```
#?which
c(TRUE,FALSE,NA,TRUE)
#> [1]  TRUE FALSE    NA  TRUE
str(c(TRUE,FALSE,NA,TRUE))
#>  logi [1:4] TRUE FALSE NA TRUE
which(c(TRUE,FALSE,NA,TRUE))
#> [1] 1 4
```

Task: Count events at public HS with at least $50k median household income?

```
#Base R, `[]` combined with `$`; without which()
nrow(df_event[df_event$event_type == "public hs" & df_event$med_inc>=50000, ])
#> [1] 10016

#Base R, `[]` combined with `$`; with which()
nrow(df_event[which(df_event$event_type == "public hs"
  & df_event$med_inc>=50000), ])
#> [1] 9941
```

Student Exercises

Subsetting Data Frames with `[]` and `$`:

1. Show how many public high schools in California with at least 50% Latinx (hispanic in data) student enrollment from df_school.
2. Show how many out-state events at public high schools with more than $30K median from df_event (do not forget to exclude missing values).

Solution to Student Exercises

Solution to 1

base R using [] and $

```
df_school_br1<- df_school[df_school$school_type == "public"
                  & df_school$pct_hispanic >= 50
                  & df_school$state_code == "CA", ]
nrow(df_school_br1)
#> [1] 713
```

Solution to Student Exercises

Solution to 2:

base R using [] and $

```
# use is.na to exclude NA
nrow(df_event[df_event$event_type == "public hs" & df_event$event_inst =="Out-S
               & df_event$med_inc > 30000 & is.na(df_event$med_inc) ==0, ])
#> [1] 7784

# use which to exclude NA
nrow(df_event[which(df_event$event_type == "public hs" & df_event$event_inst ==
               & df_event$med_inc > 30000 ), ])
#> [1] 7784
```

3 Subset using subset() function

Subset function

The `subset()` is a base R function to "filter" observations from some object `x`

- object `x` can be a matrix, data frame, list
- `subset()` automatically excludes elements/rows with `NA` for condition
- Can also use `subset()` to select variables
- what `subset()` function returns:
  - "An object similar to x contain just the selected ...rows and columns (for a matrix or data frame)"
- `subset()` can be combined with:
  - assignment (`<-`) to create new objects
  - `nrow()` to count number of observations that satisfy criteria

```
?subset
```

Syntax [when object is data frame]: **subset(x, subset, select, drop = FALSE)**

- `x` is object to be subset
- `subset` is the logical expression(s) (evaluates to `TRUE/FALSE`) indicating elements (rows) to keep
- `select` indicates columns to select from data frame (if argument is not used default will keep all columns)
- `drop` to preserve original **dimensions** [SKIP]

Subset function, examples

Recall the previous example where we count events at public HS with at least $50k median household income.

- *Note.* `subset()` automatically excludes rows where condition is `NA`:

```
#Base R, `[]` combined with `$`, without which(); includes `NA`
nrow(df_event[df_event$event_type == "public hs"
              & df_event$med_inc>=50000, ])
#> [1] 10016

#Base R, `[]` combined with `$`, with which(); excludes `NA`
nrow(df_event[which(df_event$event_type == "public hs"
                    & df_event$med_inc>=50000), ])
#> [1] 9941

#Base R, `subset()`; excludes `NA`
nrow(subset(df_event, event_type == "public hs"
            & med_inc>=50000))
#> [1] 9941

#Base R, `subset()`; excludes `NA`; explicitly name arguments of subset()
nrow(subset(x = df_event, subset = event_type == "public hs"
            & med_inc>=50000))
#> [1] 9941
```

Subset function, examples

Using `df_school`, show all public high schools that are at least 50% Latinx (var=`pct_hispanic`) student enrollment in California

- Using base R, `subset()` [output omitted]

```
#public high schools with at least 50% Latinx student enrollment
subset(x= df_school, subset = school_type == "public" & pct_hispanic >= 50
     & state_code == "CA")
```

- Can wrap `subset()` within `nrow()` to count number of observations that satisfy criteria

```
nrow(subset(df_school, school_type == "public" & pct_hispanic >= 50
     & state_code == "CA"))
#> [1] 713
```

Subset function, examples

Note that `subset()` identify the number of observations for which the condition is `TRUE`

```
nrow(subset(x = df_school, subset = TRUE))
#> [1] 21301
nrow(subset(x = df_school, subset = FALSE))
#> [1] 0
```

Subset function, examples

Count all CA public high schools that are at least 50% Latinx and received at least 1 visit from UC Berkeley (var= `visits_by_110635`)

```
nrow(subset(df_school, school_type == "public" & pct_hispanic >= 50
  & state_code == "CA" & visits_by_110635 >= 1))
#> [1] 100
```

Subset function, examples

`subset()` can also use `%in%` operator, which is more efficient version of **OR** operator `|`

- Count number of schools from MA, ME, or VT that received at least one visit from University of Alabama (var= `visits_by_100751`)

```
nrow(subset(df_school, state_code %in% c("MA","ME","VT")
  & visits_by_100751 >= 1))
#> [1] 108
```

Subset function, examples

Use the `select` argument within `subset()` to keep selected variables

- syntax: `select = c(var_name1,var_name2,...,var_name_n)`

Subset all CA public high schools that are at least 50% Latinx **AND** only keep variables `name` and `address`

```
subset(x = df_school, subset = school_type == "public" & pct_hispanic >= 50
             & state_code == "CA", select = c(name, address))
#>                                                                  name
#> 1254                                                     Tustin High
#> 1301                                                Bell Gardens High
#> 1309                                                   Santa Ana High
#> 1332                                                      Warren High
#> 1336                                           Hollywood Senior High
#> 1337                                              Venice Senior High
#> 1345                                                    Sequoia High
#> 1360                                         Santa Barbara Senior High
#> 1361                                                 Santa Paula High
#> 1362                                                     Azusa High
#> 1363                                                  Alta Loma High
#> 1373                                                Garden Grove High
#> 1374                                                   Mt. Eden High
#> 1375                                                  Ocean View High
#> 1376                                                  Inglewood High
#> 1378                                                 Bell Senior High
#> 1379                                                    El Camino High
```

Subset function, examples

Combine `subset()` with assignment (`<-`) to create a new data frame

Create a new date frame of all CA public high schools that are at least 50% Latinx **AND** only keep variables `name` and `address`

```
df_school_v2 <- subset(df_school, school_type == "public" & pct_hispanic >= 50
  & state_code == "CA", select = c(name, address))

head(df_school_v2, n=5)
#>                          name                address
#> 1254            Tustin High   1171 El Camino Real
#> 1301     Bell Gardens High          6119 Agra St.
#> 1309        Santa Ana High          520 W. Walnut
#> 1332            Warren High      8141 De Palma St.
#> 1336 Hollywood Senior High 1521 N. Highland Ave.

nrow(df_school_v2)
#> [1] 713
```

Student Exercises

Using `subset()` from base R:

1. Create a new dataframe by extracting the columns `instnm`, `event_date`, `event_type` from `df_event` data frame. And show what columns (variables) are in the newly created dataframe.
2. Create a new dataframe from the `df_school` data frame that includes out-of-state public high schools with 50%+ Latinx student enrollment that received at least one visit by the University of California Berkeley (var= visits_by_110635). And count the number of observations.
3. Count the number of public schools from CA, FL or MA that received one or two visits from UC Berkeley from the `df_school` data frame.
4. Subset all public out-of-state high schools visited by University of California Berkeley that enroll at least 50% Black students, and only keep variables `state_code`, `name` and `zip_code`.

Solution to Student Exercises

Solution to 1

```
df_event_br <- subset(df_event, select=c(instnm, event_date, event_type))
names(df_event_br)
#> [1] "instnm"     "event_date" "event_type"
```

Solution to 2

```
df_school_br <- subset(df_school, state_code != "CA" & school_type == "public"
                          & pct_hispanic >= 50 & visits_by_110635 >=1 )
nrow(df_school_br)
#> [1] 10
```

Solution to 3

```
nrow(subset(df_school, state_code %in% c("CA", "FL", "MA")
              & school_type == "public" & visits_by_110635 %in% c(1,2) ))
#> [1] 246
```

Solution to Student Exercises

Solution to 4

```
subset(df_school, school_type == "public" & state_code != "CA"
       & visits_by_110635 >= 1 & pct_black >= 50,
       select = c(state_code, name, zip_code))
#>       state_code                                  name zip_code
#> 4523          GA                  Grady High School    30309
#> 8519          MD             Frederick Douglass High    20772
#> 9666          MN                   DOWNTOWN CAMPUS    55403
#> 10681         MS                MURRAH HIGH SCHOOL    39202
#> 14569         OH              Shaker Hts High School    44120
#> 14632         OH    Cleveland Heights High School     44118
#> 17142         SC                  Spring Valley High    29229
#> 17143         SC             Richland Northeast High    29223
#> 17623         TN          Soulsville Charter School     38106
#> 17624         TN KIPP Memphis Collegiate High School    38108
```

4 Creating variables

Create new data frame based on `df_school_all`

Data frame `df_school_all` has one obs per US high school and then variables identifying number of visits by particular universities

```
load(url("https://github.com/ozanj/rclass/raw/master/data/recruiting/recruit_sc
names(df_school_all)
#>  [1] "state_code"          "school_type"         "ncessch"
#>  [4] "name"                "address"             "city"
#>  [7] "zip_code"            "pct_white"           "pct_black"
#> [10] "pct_hispanic"        "pct_asian"           "pct_amerindian"
#> [13] "pct_other"           "num_fr_lunch"        "total_students"
#> [16] "num_took_math"       "num_prof_math"       "num_took_rla"
#> [19] "num_prof_rla"        "avgmedian_inc_2564"  "latitude"
#> [22] "longitude"           "visits_by_196097"    "visits_by_186380"
#> [25] "visits_by_215293"    "visits_by_201885"    "visits_by_181464"
#> [28] "visits_by_139959"    "visits_by_218663"    "visits_by_100751"
#> [31] "visits_by_199193"    "visits_by_110635"    "visits_by_110653"
#> [34] "visits_by_126614"    "visits_by_155317"    "visits_by_106397"
#> [37] "visits_by_149222"    "visits_by_166629"    "total_visits"
#> [40] "inst_196097"         "inst_186380"         "inst_215293"
#> [43] "inst_201885"         "inst_181464"         "inst_139959"
#> [46] "inst_218663"         "inst_100751"         "inst_199193"
#> [49] "inst_110635"         "inst_110653"         "inst_126614"
#> [52] "inst_155317"         "inst_106397"         "inst_149222"
#> [55] "inst_166629"
```

Create new data frame based on `df_school_all`

Create new version of data frame, called `school_v2`, which we'll use to introduce how to create new variables

```
library(tidyverse) # below code use tidyverse functions and pipe operator
#> -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0
#> v dplyr     1.1.3     v readr     2.1.4
#> v forcats   1.0.0     v stringr   1.5.0
#> v ggplot2   3.4.3     v tibble    3.2.1
#> v lubridate 1.9.3     v tidyr     1.3.0
#> v purrr     1.0.2
#> -- Conflicts ------------------------------------------ tidyverse_conflicts()
#> x dplyr::filter() masks stats::filter()
#> x dplyr::lag()    masks stats::lag()
#> i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all co
school_v2 <- df_school_all %>%
  select(-contains("inst_")) %>% # remove vars that start with "inst_"
  rename( # rename selected variables
    visits_by_berkeley = visits_by_110635,
    visits_by_boulder = visits_by_126614,
    visits_by_bama = visits_by_100751,
    visits_by_stonybrook = visits_by_196097,
    visits_by_rutgers = visits_by_186380,
    visits_by_pitt = visits_by_215293,
    visits_by_cinci = visits_by_201885,
    visits_by_nebraska = visits_by_181464,
    visits_by_georgia = visits_by_139959,
    visits_by_scarolina = visits_by_218663,
```

Base R approach to creating new variables

Create new variables using assignment operator `<-` and subsetting operators `[]` and `$` to create new variables and set conditions of the input variables

Pseudo syntax: `df$newvar <- ...`

- where `...` argument is expression(s)/calculation(s) used to create new variables
  - expressions can include subsetting operators and/or other base R functions

Task: Create measure of percent of students on free-reduced lunch

base R approach

```
school_v2_temp<- school_v2 #create copy of dataset; not necessary
school_v2_temp$pct_fr_lunch <-
   school_v2_temp$num_fr_lunch/school_v2_temp$total_students

#investigate variable you created
str(school_v2_temp$pct_fr_lunch)
#>  num [1:21301] 0.723 1 0.967 0.93 1 ...
school_v2_temp$pct_fr_lunch[1:5] # print first 5 obs
#> [1] 0.7225549 1.0000000 0.9666667 0.9303483 1.0000000
```

tidyverse approach (with pipes)

```
school_v2_temp <- school_v2 %>%
  mutate(pct_fr_lunch = num_fr_lunch/total_students)
```

Base R approach to creating new variables

If creating new variable based on the condition/values of input variables, basically the tidyverse equivalent of `mutate()` **with** `if_else()` or `recode()`

- Pseudo syntax: `df$newvar[logical condition]<- new value`
- `logical condition`: a condition that evaluates to `TRUE` or `FALSE`

Base R approach to creating new variables

Task: Create 0/1 indicator if school has median income greater than $100k

tidyverse approach (using pipes)

```
school_v2_temp %>% select(med_inc) %>%
  mutate(inc_gt_100k= if_else(med_inc>100000,1,0)) %>%
  count(inc_gt_100k) # note how NA values of med_inc treated
#> # A tibble: 3 x 2
#>   inc_gt_100k     n
#>         <dbl> <int>
#> 1           0 18632
#> 2           1  2045
#> 3          NA   624
```

Base R approach

```
school_v2_temp$inc_gt_100k<-NA #initialize an empty column with NAs
                               # otherwise you'll get warning
school_v2_temp$inc_gt_100k[school_v2_temp$med_inc>100000] <- 1
school_v2_temp$inc_gt_100k[school_v2_temp$med_inc<=100000] <- 0
count(school_v2_temp, inc_gt_100k)
#> # A tibble: 3 x 2
#>   inc_gt_100k     n
#>         <dbl> <int>
#> 1           0 18632
#> 2           1  2045
#> 3          NA   624
```

Creating variables

Task: Using data frame `wwlist` and input vars `state` and `firstgen`, create a 4-category var with following categories:

- "instate_firstgen"; "instate_nonfirstgen"; "outstate_firstgen"; "outstate_nonfirstgen"

tidyverse approach (using pipes)

```
load(url("https://github.com/ozanj/rclass/raw/master/data/prospect_list/wwlist_
wwlist_temp <- wwlist %>%
  mutate(state_gen = case_when(
    state == "WA" & firstgen =="Y" ~ "instate_firstgen",
    state == "WA" & firstgen =="N" ~ "instate_nonfirstgen",
    state != "WA" & firstgen =="Y" ~ "outstate_firstgen",
    state != "WA" & firstgen =="N" ~ "outstate_nonfirstgen")
  )
str(wwlist_temp$state_gen)
#>  chr [1:268396] NA "instate_nonfirstgen" "instate_nonfirstgen" ...
wwlist_temp %>% count(state_gen)
#> # A tibble: 5 x 2
#>   state_gen                n
#>   <chr>                <int>
#> 1 instate_firstgen     32428
#> 2 instate_nonfirstgen  58646
#> 3 outstate_firstgen    32606
#> 4 outstate_nonfirstgen 134616
#> 5 <NA>                 10100
```

Base R approach to creating new variables

Task: Using `wwlist` and input vars `state` and `firstgen`, create a 4-category var

base R approach

```
wwlist_temp <- wwlist

wwlist_temp$state_gen <- NA
wwlist_temp$state_gen[wwlist_temp$state == "WA"
  & wwlist_temp$firstgen =="Y"] <- "instate_firstgen"
wwlist_temp$state_gen[wwlist_temp$state == "WA"
  & wwlist_temp$firstgen =="N"] <- "instate_nonfirstgen"
wwlist_temp$state_gen[wwlist_temp$state != "WA"
  & wwlist_temp$firstgen =="Y"] <- "outstate_firstgen"
wwlist_temp$state_gen[wwlist_temp$state != "WA"
  & wwlist_temp$firstgen =="N"] <- "outstate_nonfirstgen"

str(wwlist_temp$state_gen)
#>  chr [1:268396] NA "instate_nonfirstgen" "instate_nonfirstgen" ...
count(wwlist_temp, state_gen)
#> # A tibble: 5 x 2
#>   state_gen                n
#>   <chr>                <int>
#> 1 instate_firstgen     32428
#> 2 instate_nonfirstgen  58646
#> 3 outstate_firstgen    32606
#> 4 outstate_nonfirstgen 134616
#> 5 <NA>                 10100
```

5 Appendix

5.1 Sorting data

Base R `sort()` for vectors

`sort()` is a base R function that sorts vectors

Syntax: `sort(x, decreasing=FALSE, ...)`

- where x is object being sorted
- By default it sorts in ascending order (low to high)
- Need to set decreasing argument to `TRUE` to sort from high to low

```
#?sort()
x<- c(31, 5, 8, 2, 25)
sort(x)
#> [1]  2  5  8 25 31
sort(x, decreasing = TRUE)
#> [1] 31 25  8  5  2
```

Base R `order()` for dataframes

`order()` is a base R function that sorts vectors

- Syntax: `order(..., na.last = TRUE, decreasing = FALSE)`
- where `...` are variable(s) to sort by
- By default it sorts in ascending order (low to high)
- Need to set decreasing argument to `TRUE` to sort from high to low

Descending argument only works when we want either one (and only) variable descending or all variables descending (when sorting by multiple vars)

- use `-` when you want to indicate which variables are descending while using the default ascending sorting

```
df_event[order(df_event$event_date), ]
df_event[order(df_event$event_date, df_event$total_12), ]

#sort descending via argument
df_event[order(df_event$event_date, decreasing = TRUE), ]
df_event[order(df_event$event_date, df_event$total_12, decreasing = TRUE), ]

#sorting by both ascending and descending variables
df_event[order(df_event$event_date, -df_event$total_12), ]
```

Example, sorting

- Create a new dataframe from df_events that sorts by ascending by `event_date`, ascending `event_state`, and descending `pop_total`.

base R using `order()` function:

```
df_event_br1 <- df_event[order(df_event$event_date, df_event$event_state,
                               -df_event$pop_total), ]
```