

Data Classes

One dimensional vectors

Data classes/types

- * Character: strings or individual characters, quoted
- * Numeric: any real number(s)
- * Integer: any integer(s)/whole numbers (1,2,3)
- * Double: any number with fractional values (1.2, 4.01, 1.00004)
- * Factor: categorical/qualitative variables
- * Logical: variables composed of TRUE or FALSE
- * Date/POSIXct: represents calendar dates and times

Character and numeric

We have already covered character and numeric types.

```
class(c("tree", "cloud", "stars_&_sky"))
```

```
## [1] "character"
```

```
class(c(1, 4, 7))
```

```
## [1] "numeric"
```

Character and numeric

This can also be a bit tricky.

```
class(c(1, 2, "tree"))
```

```
## [1] "character"
```

```
class(c("1", "4", "7"))
```

```
## [1] "character"
```

Logical

`logical` is a type that only has two possible elements: `TRUE` and `FALSE`

```
x <- c(TRUE, FALSE, TRUE, TRUE, FALSE)
class(x)
```

```
## [1] "logical"
```

Note that `logical` elements are NOT in quotes.

```
z <- c("TRUE", "FALSE", "TRUE", "FALSE")
class(z)
```

```
## [1] "character"
```

General Class Information

There is one useful functions associated with practically all R classes:

`as.CLASS_NAME(x)` **coerces between classes**. It turns x into a certain class.

Examples:

- `as.numeric()`
- `as.character()`
- `as.logical()`
- `as.double()`
- `as.integer()`
- `as.Date()`
- `as.factor()` (More on this one later!)

Coercing: seamless transition

Sometimes coercing works great!

```
as.character(4)
```

```
## [1] "4"
```

```
as.numeric(c("1", "4", "7"))
```

```
## [1] 1 4 7
```

```
as.logical(c("TRUE", "FALSE", "FALSE"))
```

```
## [1] TRUE FALSE FALSE
```

```
as.logical(0)
```

```
## [1] FALSE
```


Coercing: not-so-seamless

When interpretation is ambiguous, R will return **NA** (an R constant representing “**N**ot **A**vailable” i.e. missing value)

```
as.numeric(c("1", "4", "7a"))
```

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

```
## [1] 1 4 NA
```

```
as.logical(c("TRUE", "FALSE", "UNKNOWN"))
```

```
## [1] TRUE FALSE NA
```

```
as.Date(c("2021-06-15", "2021-06-32"))
```

```
## [1] "2021-06-15" NA
```

Number Subclasses

There are two major number subclasses or types

1. Double (1.003)
2. Integer (1)

Double

Double is equivalent to `numeric`. It is a number that contains **fractional values**. Can be any amount of places after the decimal.

Double stands for [double-precision](#)

```
y <- c(1.1, 2.0, 3.21, 4.5, 5.62)
y
```

```
## [1] 1.10 2.00 3.21 4.50 5.62
```

```
class(y)
```

```
## [1] "numeric"
```

```
typeof(y)
```

```
## [1] "double"
```

Significant figures and other formats

The `num` function of the `tibble` package can be used to change format. See here for more: <https://tibble.tidyverse.org/articles/numbers.html>

Integer

Integer is a special number that contains only **whole numbers**.

```
y
```

```
## [1] 1.10 2.00 3.21 4.50 5.62
```

```
y_int <- as.integer(y)  
y_int
```

```
## [1] 1 2 3 4 5
```

```
class(y_int)
```

```
## [1] "integer"
```

```
typeof(y_int)
```

```
## [1] "integer"
```

Integer

Can use `as.integer()` function to create integers (unless they are read in as integers or created as such with `seq` and `sample`). Otherwise, will be double by default.

```
x <- c(1, 2, 3, 4, 5) # technically integers  
class(x)
```

```
## [1] "numeric"
```

```
typeof(x)
```

```
## [1] "double"
```

Checking double vs integer

A `tibble` will show the difference (as does `glimpse()`).

```
my_data <- tibble(double_var = y, int_var = y_int)
my_data
```

```
## # A tibble: 5 × 2
##   double_var int_var
##   <dbl>      <int>
## 1      1.1        1
## 2       2         2
## 3     3.21        3
## 4     4.5         4
## 5     5.62        5
```

```
glimpse(my_data)
```

```
## Rows: 5
## Columns: 2
## $ double_var <dbl> 1.10, 2.00, 3.21, 4.50, 5.62
## $ int_var    <int> 1, 2, 3, 4, 5
```

Factors

A **factor** is a special **character** vector where the elements have pre-defined groups or 'levels'. You can think of these as qualitative or categorical variables. Order is often important.

Examples:

- red, orange, yellow, green, blue, purple
- breakfast, lunch, dinner
- baby, toddler, child, teen, adult
- Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
- beginner, novice, intermediate, expert

Factors

Use the `factor()` function to create factors.

```
x <- c("small", "medium", "large", "medium", "large")  
class(x)
```

```
## [1] "character"
```

```
x_fact <- factor(x)  
class(x_fact)
```

```
## [1] "factor"
```

```
x_fact
```

```
## [1] small medium large medium large  
## Levels: large medium small
```

Note that levels are, by default, in **alphanumerical** order!

Factors

Q: Why not use `as.factor()` ?

A: You can coerce with `as.factor()`. But you can't specify levels! More on this soon.

Factors

You can learn what are the unique levels of a `factor` vector

```
levels(x_fact)
```

```
## [1] "large" "medium" "small"
```

More on how to change the levels ordering in a lecture coming up!

Factors

Factors can be converted to `numeric` or `character` very easily.

```
x_fact
```

```
## [1] small medium large medium large  
## Levels: large medium small
```

```
as.character(x_fact)
```

```
## [1] "small" "medium" "large" "medium" "large"
```

```
as.numeric(x_fact)
```

```
## [1] 3 2 1 2 1
```

Class conversion in with a dataset

```
library(dasehr)
covidww <- covid_wastewater
```

```
head(covidww)
```

```
## # A tibble: 6 × 12
##   reporting_jurisdiction sample_location key_plot_id county_na
##   <chr>                 <chr>         <chr>         <chr>
## 1 Missouri             Treatment plant NWSS_mo_259_Treatment pla.. Barry, Law
## 2 Missouri             Treatment plant NWSS_mo_259_Treatment pla.. Barry, Law
## 3 Missouri             Treatment plant NWSS_mo_259_Treatment pla.. Barry, Law
## 4 Missouri             Treatment plant NWSS_mo_259_Treatment pla.. Barry, Law
## 5 Missouri             Treatment plant NWSS_mo_259_Treatment pla.. Barry, Law
## 6 Missouri             Treatment plant NWSS_mo_259_Treatment pla.. Barry, Law
## #   8 more variables: population_served <dbl>, date_start <chr>,
## #   date_end <chr>, rna_pct_change_15d <dbl>, pos_PCR_prop_15d <dbl>,
## #   percentile <dbl>, sampling_prior <chr>, first_sample_date <chr>
```

Class conversion in with a dataset

Say we want to change `daily` to be an integer. We would need to use `mutate` to help us modify that column or create a new column. Let's create a new one so it is easier to see what is happening.

```
covidww_updated <- mutate(covidww, pop_int= as.integer(population_served))  
covidww_updated %>% select(population_served, pop_int)
```

```
## # A tibble: 776,059 × 2  
##   population_served pop_int  
##           <dbl>    <int>  
## 1             9100     9100  
## 2             9100     9100  
## 3             9100     9100  
## 4             9100     9100  
## 5             9100     9100  
## 6             9100     9100  
## 7             9100     9100  
## 8             9100     9100  
## 9             9100     9100  
## 10            9100     9100  
## #   776,049 more rows
```

Classes Overview

Example	Class	Type	Notes
1.1	Numeric	double	default for numbers
1	integer	integer	Need to coerce to integer with <code>as.integer()</code> or use <code>sample()</code> or <code>seq()</code> with whole numbers
"FALSE", "Ball"	Character	Character	Need quotes
FALSE, TRUE	logical	logical	No quotes
"Small", "Large"	Factor	Factor	Need to coerce to factor with <code>factor()</code>

Summary

- There are two types of number class objects: integer and double
- Logic class objects only have **TRUE** or **FALSE** (without quotes)
- `class()` can be used to test the class of an object `x`
- `as.CLASS_NAME(x)` can be used to change the class of an object `x`
- Factors are a special character class that has levels - more on that soon!
- tibbles show column classes!

Two-dimensional data classes

Two-dimensional data classes

Two-dimensional classes are those we would often use to store data read from a file

- a data frame (`data.frame` or `tibble` class)
- a matrix (`matrix` class)
 - also composed of rows and columns
 - unlike `data.frame` or `tibble`, the entire matrix is composed of one R class
 - for example: all entries are `numeric`, or all entries are `character`

Lists

- One other data type that is the most generic are `lists`.
- Can hold vectors, strings, matrices, models, list of other list!
- Lists are used when you need to do something repeatedly across lots of data - for example wrangling several similar files at once
- Lists are a bit more advanced but you may encounter them when you work with others or look up solutions

Making Lists

- Can be created using `list()`

```
mylist <- list(c("A", "b", "c"), c(1, 2, 3))  
mylist
```

```
## [[1]]  
## [1] "A" "b" "c"  
##  
## [[2]]  
## [1] 1 2 3
```

```
class(mylist)
```

```
## [1] "list"
```

Special data classes

Dates

There are two most popular R classes used when working with dates and times:

- `Date` class representing a calendar date
- `POSIXct` class representing a calendar date with hours, minutes, seconds

We convert data from character to `Date`/`POSIXct` to use functions to manipulate date/date and time

`lubridate` is a powerful, widely used R package from “tidyverse” family to work with `Date` / `POSIXct` class objects

Creating **Date** class object

```
class("2021-06-15")
```

```
## [1] "character"
```

```
library(lubridate)
```

```
ymd("2021-06-15") # lubridate package Year Month Day
```

```
## [1] "2021-06-15"
```

```
class(ymd("2021-06-15")) # lubridate package
```

```
## [1] "Date"
```

```
class(date("2021-06-15")) # lubridate package
```

```
## [1] "Date"
```

Note for function ymd: **y**ear **m**onth **d**ay

Dates are useful!

```
a <- ymd("2021-06-15")  
b <- ymd("2021-06-18")  
a - b
```

```
## Time difference of -3 days
```


Creating **Date** class object

`date()` is picky...

```
date("06/15/2021") # This doesn't work, needs to be year month day
```

```
## Error in as.POSIXlt.character(x, tz = tz(x)): character string is not in a st
```

But we can use the month day year function **mdy**

```
mdy("06/15/2021") # This works
```

```
## [1] "2021-06-15"
```

```
mdy("06/15/21") # This works
```

```
## [1] "2021-06-15"
```

Note for function **mdy**: **m**onth **d**ay **y**ear

They right lubridate function needs to be used

Must match the data format!

```
ymd("06/15/2021") # This doesn't work - gives NA
```

```
## Warning: All formats failed to parse. No formats found.
```

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

```
mdy("06/15/2021") # This works
```

```
## [1] "2021-06-15"
```

Creating **POSIXct** class object

```
class("2013-01-24 19:39:07")
```

```
## [1] "character"
```

```
ymd_hms("2013-01-24 19:39:07") # lubridate package
```

```
## [1] "2013-01-24 19:39:07 UTC"
```

```
class(ymd_hms("2013-01-24 19:39:07")) # lubridate package
```

```
## [1] "POSIXct" "POSIXt"
```

UTC represents time zone, by default: Coordinated Universal Time

Note for function `ymd_hms`: year month day hour minute second.

There are functions in case your data have only date, hour and minute (`ymd_hm()`) or only date and hour (`ymd_h()`).

In a dataframe

Note dates are always displayed year month day, even if made with `mdy`!

```
covidww <- mutate(covidww, date_start_formatted = mdy(date_start)) %>%  
  relocate(date_start_formatted, .before = date_end)  
glimpse(covidww)
```

```
## Rows: 776,059  
## Columns: 13  
## $ reporting_jurisdiction <chr> "Missouri", "Missouri", "Missouri", "Missouri"  
## $ sample_location        <chr> "Treatment plant", "Treatment plant", "Treatme  
## $ key_plot_id            <chr> "NWSS_mo_259_Treatment plant_raw wastewater",  
## $ county_names           <chr> "Barry, Lawrence", "Barry, Lawrence", "Barry, Law  
## $ population_served      <dbl> 9100, 9100, 9100, 9100, 9100, 9100, 9100, 9100  
## $ date_start             <chr> "6/21/2020", "6/22/2020", "6/23/2020", "6/24/2  
## $ date_start_formatted   <date> 2020-06-21, 2020-06-22, 2020-06-23, 2020-06-2  
## $ date_end              <chr> "7/5/2020", "7/6/2020", "7/7/2020", "7/8/2020"  
## $ rna_pct_change_15d     <dbl> NA, NA, NA, NA, NA, NA, NA, 3683, 3683, 3683,  
## $ pos_PCR_prop_15d       <dbl> 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 1  
## $ percentile            <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA  
## $ sampling_prior         <chr> "yes", "yes", "yes", "yes", "yes", "yes", "yes", "yes"  
## $ first_sample_date      <chr> "7/5/2020", "7/5/2020", "7/5/2020", "7/5/2020"
```

Once a variable is a date type we can convert to other types

```
covidww %>% mutate(year = year(date_start_formatted)) %>%  
  mutate(month = month(date_start_formatted)) %>%  
  relocate(c(year, month), .before = date_end) %>%  
  glimpse()
```

```
## Rows: 776,059  
## Columns: 15  
## $ reporting_jurisdiction <chr> "Missouri", "Missouri", "Missouri", "Missouri"  
## $ sample_location        <chr> "Treatment plant", "Treatment plant", "Treatme  
## $ key_plot_id            <chr> "NWSS_mo_259_Treatment plant_raw wastewater",  
## $ county_names           <chr> "Barry, Lawrence", "Barry, Lawrence", "Barry, Law  
## $ population_served      <dbl> 9100, 9100, 9100, 9100, 9100, 9100, 9100, 9100  
## $ date_start             <chr> "6/21/2020", "6/22/2020", "6/23/2020", "6/24/2  
## $ date_start_formatted   <date> 2020-06-21, 2020-06-22, 2020-06-23, 2020-06-2  
## $ year                   <dbl> 2020, 2020, 2020, 2020, 2020, 2020, 2020, 2020  
## $ month                  <dbl> 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 7, 7, 7, 7, 7  
## $ date_end               <chr> "7/5/2020", "7/6/2020", "7/7/2020", "7/8/2020"  
## $ rna_pct_change_15d     <dbl> NA, NA, NA, NA, NA, NA, NA, NA, 3683, 3683, 3683,  
## $ pos_PCR_prop_15d       <dbl> 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 1  
## $ percentile             <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA  
## $ sampling_prior         <chr> "yes", "yes", "yes", "yes", "yes", "yes", "yes", "yes  
## $ first_sample_date      <chr> "7/5/2020", "7/5/2020", "7/5/2020", "7/5/2020"
```

Summary

- two dimensional object classes include: data frames, tibbles, matrices, and lists
- matrix has columns and rows but is all one data class
- lists can contain multiples of any other class of data including lists!
- calendar dates can be represented with the **Date** class using `ymd()`, `mdy()` functions from `lubridate` package
- Make sure you choose the right function for the way the date is formatted!
- **POSIXct** class representing a calendar date with hours, minutes, seconds. Can use `ymd_hms()` or `ymd_hm()` or `ymd_h()` functions from the [lubridate package](#)
- can then easily subtract **Date** or **POSIXct** class variables or pull out aspects like year

Lab Part 1

▮ [Class Website](#)

▮ [Lab](#)



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Extra Slides

Matrices

`as.matrix()` creates a matrix from a data frame or tibble (where all values are the same class).

```
covidww_mat <- select(covidww, contains("Missouri")) %>%  
  head(n = 3)  
covidww_mat
```

```
## # A tibble: 3 × 0
```

```
as.matrix(covidww_mat)
```

```
##  
## [1, ]  
## [2, ]  
## [3, ]
```

Matrices

`matrix()` creates a matrix from scratch.

```
matrix(1:6, ncol = 2)
```

```
##      [,1] [,2]  
## [1,]    1    4  
## [2,]    2    5  
## [3,]    3    6
```

More about Lists

List elements can be named

```
mylist_named <- list(  
  letters = c("A", "b", "c"),  
  numbers = c(1, 2, 3),  
  one_matrix = matrix(1:4, ncol = 2)  
)  
mylist_named
```

```
## $letters  
## [1] "A" "b" "c"  
##  
## $numbers  
## [1] 1 2 3  
##  
## $one_matrix  
##      [,1] [,2]  
## [1,]    1    3  
## [2,]    2    4
```

Some useful functions from **lubridate** to manipulate **Date** objects

```
x <- ymd(c("2021-06-15", "2021-07-15"))
```

```
x
```

```
## [1] "2021-06-15" "2021-07-15"
```

```
day(x) # see also: month(x) , year(x)
```

```
## [1] 15 15
```

```
x + days(10)
```

```
## [1] "2021-06-25" "2021-07-25"
```

```
x + months(1) + days(10)
```

```
## [1] "2021-07-25" "2021-08-25"
```

```
wday(x, label = TRUE)
```

```
## [1] Tue Thu
```

```
## Levels: Sun < Mon < Tue < Wed < Thu < Fri < Sat
```

Some useful functions from **lubridate** to manipulate **POSIXct** objects

```
x <- ymd_hms("2013-01-24 19:39:07")
```

```
x
```

```
## [1] "2013-01-24 19:39:07 UTC"
```

```
date(x)
```

```
## [1] "2013-01-24"
```

```
x + hours(3)
```

```
## [1] "2013-01-24 22:39:07 UTC"
```

```
floor_date(x, "1 hour") # see also: ceiling_date()
```

```
## [1] "2013-01-24 19:00:00 UTC"
```

Differences in dates

```
x1 <- ymd(c("2021-06-15"))  
x2 <- ymd(c("2021-07-15"))
```

```
difftime(x2, x1, units = "weeks")
```

```
## Time difference of 4.285714 weeks
```

```
as.numeric(difftime(x2, x1, units = "weeks"))
```

```
## [1] 4.285714
```

Similar can be done with time (e.g. difference in hours).

Data Selection

Matrices

```
n <- 1:9  
n
```

```
## [1] 1 2 3 4 5 6 7 8 9
```

```
mat <- matrix(n, nrow = 3)  
mat
```

```
##      [,1] [,2] [,3]  
## [1,]    1    4    7  
## [2,]    2    5    8  
## [3,]    3    6    9
```

Vectors: data selection

To get element(s) of a vector (one-dimensional object):

- Type the name of the variable and open the rectangular brackets []
- In the rectangular brackets, type index (/vector of indexes) of element (/elements) you want to pull. **In R, indexes start from 1** (not: 0)

```
x <- c("a", "b", "c", "d", "e", "f", "g", "h")  
x
```

```
## [1] "a" "b" "c" "d" "e" "f" "g" "h"
```

```
x[2]
```

```
## [1] "b"
```

```
x[c(1, 2, 100)]
```

```
## [1] "a" "b" NA
```

Matrices: data selection

Note you cannot use `dplyr` functions (like `select`) on matrices. To subset matrix rows and/or columns, use `matrix[row_index, column_index]`.

```
mat
```

```
##      [,1] [,2] [,3]
## [1,]    1    4    7
## [2,]    2    5    8
## [3,]    3    6    9
```

```
mat[1, 1] # individual entry: row 1, column 1
```

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

```
mat[1, 2] # individual entry: row 1, column 2
```

```
## [1] 4
```

```
mat[1, ] # first row
```

```
## [1] 1 4 7
```

```
mat[, 1] # first column
```

```
## [1] 1 2 3
```

```
mat[c(1, 2), c(2, 3)] # subset of original matrix: two rows and two columns
```

Lists: data selection

You can reference data from list using `$` (if elements are named) or using `[[]]`

```
mylist_named[[1]]
```

```
## [1] "A" "b" "c"
```

```
mylist_named[["letters"]] # works only for a list with elements' names
```

```
## [1] "A" "b" "c"
```

```
mylist_named$letters # works only for a list with elements' names
```

```
## [1] "A" "b" "c"
```