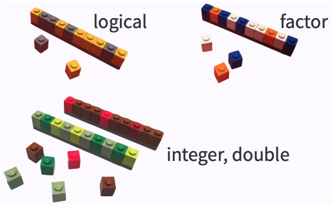
STATS 220

Data import⬇️/export⬆️

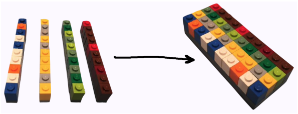
Atomic vector (1d)



```r
dept <- c("Physics", "Mathematics", "Statistics", "Computer Science")
nstaff <- c(12L, 8L, 20L, 23L)
```

image credit: Jenny Bryan

1d➡️2d



```r
library(tibble)
sci_tbl <- tibble(
  department = dept,
  count = nstaff,
  percentage = count / sum(count))
sci_tbl
```

```
#> # A tibble: 4 x 3
#>   department       count percentage
#>   <chr>            <int>      <dbl>
#> 1 Physics             12      0.190
#> 2 Mathematics          8      0.127
#> 3 Statistics          20      0.317
#> 4 Computer Science    23      0.365
```

image credit: Jenny Bryan

Beyond 1d vectors

1. Lists
2. Matrices and arrays
3. Data frames and tibbles

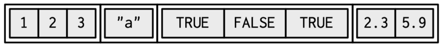
data strs
- lists

An object contains elements of **different data types**.

```
lst <- list( # list constructor/creator
  1:3,
  "a",
  c(TRUE, FALSE, TRUE),
  c(2.3, 5.9)
)
lst
```

```
#> [[1]]
#> [1] 1 2 3
#>
#> [[2]]
#> [1] "a"
#>
#> [[3]]
#> [1]  TRUE FALSE  TRUE
#>
#> [[4]]
#> [1] 2.3 5.9
```

data strs
- lists


1 2 3 "a" TRUE FALSE TRUE 2.3 5.9

data type

```
typeof(lst) # primitive type
```

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

data class

```
class(lst) # type + attributes
```

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

data structure

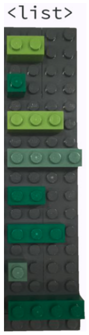
```
str(lst)
# el can be of diff lengths
```

```
#> List of 4
#>  $ : int [1:3] 1 2 3
#>  $ : chr "a"
#>  $ : logi [1:3] TRUE FALSE TRUE
#>  $ : num [1:2] 2.3 5.9
```

data strs
- lists

```
lst
```

```
#> [[1]]
#> [1] 1 2 3
#>
#> [[2]]
#> [1] "a"
#>
#> [[3]]
#> [1]  TRUE FALSE  TRUE
#>
#> [[4]]
#> [1] 2.3 5.9
```



data strs
- lists

A list can contain other lists, i.e. **recursive**

```
# a named list
str(list(first_el = lst, second_el = mtcars))
```

```
#> List of 2
#>  $ first_el :List of 4
#>   ..$ : int [1:3] 1 2 3
#>   ..$ : chr "a"
#>   ..$ : logi [1:3] TRUE FALSE TRUE
#>   ..$ : num [1:2] 2.3 5.9
#>  $ second_el:'data.frame':    32 obs. of  11 variables:
#>   ..$ mpg : num [1:32] 21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19
#>   ..$ cyl : num [1:32] 6 6 4 6 8 6 8 4 4 6 ...
#>   ..$ disp: num [1:32] 160 160 108 258 360 ...
#>   ..$ hp  : num [1:32] 110 110 93 110 175 105 245 62 95 123 ...
#>   ..$ drat: num [1:32] 3.9 3.9 3.85 3.08 3.15 2.76 3.21 3.69 3.92
#>   ..$ wt  : num [1:32] 2.62 2.88 2.32 3.21 3.44 ...
#>   ..$ qsec: num [1:32] 16.5 17 18.6 19.4 17 ...
#>   ..$ vs  : num [1:32] 0 0 1 1 0 1 0 1 1 1 ...
#>   ..$ am  : num [1:32] 1 1 1 0 0 0 0 0 0 0 ...
#>   ..$ gear: num [1:32] 4 4 4 3 3 3 3 4 4 4 ...
```

data strs
- lists

Test for a list

```
is.list(lst)
```

```
#> [1] TRUE
```

Coerce to a list

```
as.list(1:3)
```

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

data strs
- lists

Subset by `[]`

```
lst[1]
```

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

Subset by `[[]]`

```
lst[[1]]
```

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

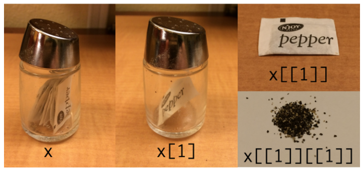


image credit: Hadley Wickham

data strs
- lists

- matrices

2D structure of homogeneous data types

- `matrix()` to construct a matrix

```
matrix(1:9, nrow = 3)
```

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

- `as.matrix()` to coerce to a matrix
- `is.matrix()` to test for a matrix

data strs
- lists

- matrices

array: more than 2D matrix

```
array(1:9, dim = c(1, 3, 3))
```

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

data strs

- lists
- matrices
- **tibbles**

A data frame is a **named list** of vectors of the **same length**.

```
sci_df <- data.frame(
  department = dept,
  count = nstaff)
sci_df
```

```
#>         department count
#> 1          Physics    12
#> 2      Mathematics     8
#> 3       Statistics    20
#> 4 Computer Science    23
```

data strs

- lists
- matrices
- **tibbles**

The underlying data type is a list.

```
typeof(sci_df)
```

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

data class

```
class(sci_df)
```

```
#> [1] "data.frame"
```

data attributes (meta info)

```
attributes(sci_df)
```

```
#> $names
#> [1] "department" "count"
#>
#> $class
#> [1] "data.frame"
#>
#> $row.names
#> [1] 1 2 3 4
```

data strs

- lists
- matrices
- **tibbles**

A tibble is a **modern reimagining** of the data frame.

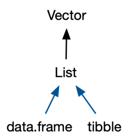
```
library(tibble)
sci_tbl <- tibble(
  department = dept,
  count = nstaff,
  percentage = count / sum(count))
sci_tbl
```

```
#> # A tibble: 4 x 3
#>   department       count percentage
#>   <chr>            <int>      <dbl>
#> 1 Physics             12      0.190
#> 2 Mathematics          8      0.127
#> 3 Statistics          20      0.317
#> 4 Computer Science    23      0.365
```

- `as_tibble()` to coerce to a tibble
- `is_tibble()` to test for a tibble

data strs

- lists
- matrices
- **tibbles**



```
typeof(sci_tbl) # list in essence
```

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

```
class(sci_tbl) # tibble is a special class of data.frame
```

```
#> [1] "tbl_df"     "tbl"        "data.frame"
```

Why tibble not data frame?

```r
sci_df <- data.frame(
  department = dept,
  count = nstaff)
sci_df
```

```
#>         department count
#> 1          Physics    12
#> 2      Mathematics     8
#> 3       Statistics    20
#> 4 Computer Science    23
```

```r
sci_tbl <- tibble(
  department = dept,
  count = nstaff,
  percentage = count / sum(count))
sci_tbl
```

```
#> # A tibble: 4 x 3
#>   department       count percentage
#>   <chr>            <int>      <dbl>
#> 1 Physics             12      0.190
#> 2 Mathematics          8      0.127
#> 3 Statistics          20      0.317
#> 4 Computer Science    23      0.365
```

Glimpse data

```r
glimpse(sci_tbl) # to replace str()
```

```
#> Rows: 4
#> Columns: 3
#> $ department <chr> "Physics", "Mathematics", "Statistics",…
#> $ count      <int> 12, 8, 20, 23
#> $ percentage <dbl> 0.1904762, 0.1269841, 0.3174603, 0.3650…
```

Data types and their abbreviations

- `chr`: character
- `dbl`: double
- `int`: integer
- `lgl`: logical
- `fct`: factor
- `date`: date
- `dttm`: date-time
- more column data types

Subsetting tibble

- to 1d

- with `[[]]` or `$`

```r
sci_tbl[["count"]] # col name
```

```
#> [1] 12  8 20 23
```

```r
sci_tbl[[2]] # col pos
```

```
#> [1] 12  8 20 23
```

```r
sci_tbl$count # col name
```

```
#> [1] 12  8 20 23
```

Subsetting tibble

- to 1d

- by columns

- with `[]` or `[, col]`

```r
sci_tbl["count"]
```

```
#> # A tibble: 4 x 1
#>   count
#>   <int>
#> 1    12
#> 2     8
#> 3    20
#> 4    23
```

```r
sci_tbl[2] # sci_tbl[, 2]
```

```
#> # A tibble: 4 x 1
#>   count
#>   <int>
#> 1    12
#> 2     8
#> 3    20
#> 4    23
```

Subsetting tibble

- to 1d
- by columns
- **by rows**

> with `[row, ]`

```
sci_tbl[c(1, 3), ]
```

```
#> # A tibble: 2 x 3
#>   department count percentage
#>   <chr>      <int>      <dbl>
#> 1 Physics       12      0.190
#> 2 Statistics    20      0.317
```

```
sci_tbl[-c(2, 4), ]
```

```
#> # A tibble: 2 x 3
#>   department count percentage
#>   <chr>      <int>      <dbl>
#> 1 Physics       12      0.190
#> 2 Statistics    20      0.317
```

Subsetting tibble

- to 1d
- by columns
- by rows
- **by cols & rows**

> with `[row, col]`

```
sci_tbl[1:3, 2]
## sci_tbl[-4, 2]
## sci_tbl[1:3, "count"]
## sci_tbl[c(rep(TRUE, 3), FALSE), 2]
```

```
#> # A tibble: 3 x 1
#>   count
#>   <int>
#> 1    12
#> 2     8
#> 3    20
```

Subsetting tibble

> Use `[[` to extract 1d vectors from 2d tibbles
> Use `[` to subset tibbles to a new tibble
>> numbers (positive/negative) as indices
>> characters (column names) as indices
>> logicals as indices

```
sci_tbl[1:3, 2]
sci_tbl[-4, 2]
sci_tbl[1:3, "count"]
sci_tbl[c(rep(TRUE, 3), FALSE), 2]
```

The tidyverse is an opinionated collection of R packages designed for data science. *All packages share an underlying design philosophy, grammar, and data structures.*

Use {tidyverse}

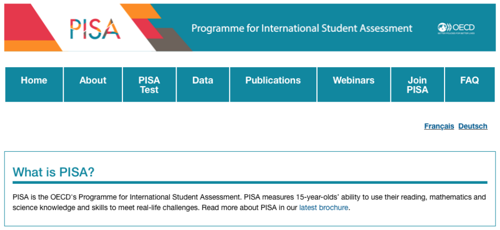
```
library(tidyverse)
```

```
#> ── Attaching packages ─────────────────────────────────────── tidyverse 1.3.0 ──

#> ✔ ggplot2 3.3.3     ✔ purrr   0.3.4
#> ✔ tibble  3.1.0     ✔ dplyr   1.0.5
#> ✔ tidyr   1.1.3     ✔ stringr 1.4.0
#> ✔ readr   1.4.0     ✔ forcats 0.5.1

#> ── Conflicts ────────────────────────────────────────── tidyverse_conflicts() ──
#> ✖ dplyr::filter() masks stats::filter()
#> ✖ dplyr::lag()    masks stats::lag()
```

Data import ⬇️



What is PISA?

PISA is the OECD's Programme for International Student Assessment. PISA measures 15-year-olds' ability to use their reading, mathematics and science knowledge and skills to meet real-life challenges. Read more about PISA in our latest brochure.

https://www.oecd.org/pisa/

Reading plain-text rectangular files

(a.k.a. flat or spreadsheet-like files)

- delimited text files with `read_delim()`
  - `.csv`: comma separated values with `read_csv()`
  - `.tsv`: tab separated values `read_tsv()`
- `.fwf`: fixed width files with `read_fwf()`

```
head -4 data/pisa/pisa-student.csv # shell command, not R
```

```
#> year,country,school_id,student_id,mother_educ,father_educ,gender,c
#> 2000,ALB,1001,1,NA,NA,female,NA,no,324.35,397.87,345.66,2.16,yes,n
#> 2000,ALB,1001,3,NA,NA,female,NA,no,NA,368.41,385.83,2.16,yes,yes,n
#> 2000,ALB,1001,6,NA,NA,male,NA,no,NA,294.17,327.94,2.16,yes,yes,no,
```

Reading comma delimited files

```r
library(readr) # library(tidyverse)
pisa <- read_csv("data/pisa/pisa-student.csv", n_max = 2929621)
pisa
```

```
#> # A tibble: 2,929,621 x 22
#>    year country school_id student_id mother_educ father_educ
#>   <dbl> <chr>       <dbl>      <dbl> <lgl>       <lgl>
#> 1  2000 ALB          1001          1 NA          NA
#> 2  2000 ALB          1001          3 NA          NA
#> 3  2000 ALB          1001          6 NA          NA
#> 4  2000 ALB          1001          8 NA          NA
#> 5  2000 ALB          1001         11 NA          NA
#> 6  2000 ALB          1001         12 NA          NA
#> # … with 2,929,615 more rows, and 16 more variables:
#> #   gender <chr>, computer <lgl>, internet <chr>,
#> #   math <dbl>, read <dbl>, science <dbl>, stu_wgt <dbl>,
#> #   desk <chr>, room <chr>, dishwasher <chr>,
#> #   television <chr>, computer_n <chr>, car <chr>,
#> #   book <chr>, wealth <dbl>, escs <dbl>
```

Let's talk about the file path again!

```r
pisa <- read_csv("data/pisa/pisa-student.csv", n_max = 2929621)
```

`data/pisa/pisa-student.csv` relative to the top-level (or root) directory:

- `stats220.Rproj`
- `data/`
  - `pisa/pisa-student.csv`

If you don't like `/`, you can use `here::here()` instead.

```r
read_csv(here::here("data", "pisa", "pisa-student.csv"))
```

NOTE: I use the `here()` function from the {here} package using `pkg::fun()`, without calling `library(here)` the ususal way.

`read_csv()` arguments with `?read_csv()`

```r
read_csv(
  file,
  col_names = TRUE,
  col_types = NULL,
  locale = default_locale(),
  na = c("", "NA"),
  quoted_na = TRUE,
  quote = "\"",
  comment = "",
  trim_ws = TRUE,
  skip = 0,
  n_max = Inf,
  guess_max = min(1000, n_max),
  progress = show_progress(),
  skip_empty_rows = TRUE
)
```

Faster delimited reader at 1.4GB/sec

```r
library(vroom)
pisa <- vroom("data/pisa/pisa-student.csv", n_max = 2929621)
```

Reading proprietary binary files

- Microsoft Excel
  - `.xls`: MSFT Excel 2003 and earlier
  - `.xlsx`: MSFT Excel 2007 and later

```
library(readxl)
time_use <- read_xlsx("data/time-use-oecd.xlsx")
time_use
```

```
#> # A tibble: 461 x 3
#>   Country   Category  `Time (minutes)`
#>   <chr>     <chr>                <dbl>
#> 1 Australia Paid work             211.
#> 2 Austria   Paid work             280.
#> 3 Belgium   Paid work             194.
#> 4 Canada    Paid work             269.
#> 5 Denmark   Paid work             200.
#> 6 Estonia   Paid work             231.
#> # … with 455 more rows
```

Reading proprietary binary files

- SAS
  - `.sas7bdat` with `read_sas()`
- Stata
  - `.dta` with `read_dta()`
- SPSS
  - `.sav` with `read_sav()`

```
library(haven)
pisa2018 <- read_spss("data/pisa/CY07_MSU_STU_QQQ.sav")
```

Raw PISA data is made available in SAS and SPSS data formats.

data source: https://www.oecd.org/pisa/data/2018database/

Your turn

> *What is the R data format for a single object? What is its file extension?*

Well, SQL!

- **Structured Query Language** for accessing and manipulating databases.
- Relational database management systems
  - SQLite
  - MySQL
  - PostgresSQL
  - BigQuery
  - Spark SQL

However, 220 is all about R!

{DBI}

Connecting R to database*

```
library(RSQLite)
con <- dbConnect(SQLite(), dbname = "data/pisa/pisa-student.db")
dbListTables(con)
```

```
#> [1] "pisa"
```

```
dbListFields(con, "pisa")
```

```
#>  [1] "year"        "country"     "school_id"   "student_id"  "moth
#>  [6] "father_educ" "gender"      "computer"    "internet"    "math
#> [11] "read"        "science"     "stu_wgt"     "desk"        "room
#> [16] "dishwasher"  "television"  "computer_n"  "car"         "book
#> [21] "wealth"      "escs"
```

NOTE: slides marked with * *are not examinable.*

{DBI}

Connecting R to database*

- reading data from database

```
pisa <- dbReadTable(con, "pisa")
```

- writing SQL queries to read chunks

```
res <- dbSendQuery(con, "SELECT * FROM pisa WHERE year = 2018")
pisa2018 <- dbFetch(res)
```

- closing connection

```
dbDisconnect(con)
```

Reading chunks for larger than memory data*

```
chunked <- function(x, pos) {
  dplyr::filter(x, year == 2018)
}
pisa2018 <- read_csv_chunked("data/pisa/pisa-student.csv",
  callback = DataFrameCallback$new(chunked))
```

{jsonlite}

JSON: JavaScript Object Notation

- object: `{}`
- array: `[]`
- value: string/character, number, object, array, logical, `null`

JSON

```
{
  "firstName": "Earo",
  "lastName": "Wang",
  "address": {
    "city": "Auckland",
    "postalCode": 1010
  }
  "logical": [true, false]
}
```

R list

```
list(
  firstName = "Earo",
  lastName = "Wang",
  address = list(
    city = "Auckland",
    postalCode = 1010
  ),
  logical = c(TRUE, FALSE)
)
```

{jsonlite}

Reading json files

```r
library(jsonlite)
url <- "https://vega.github.io/vega-editor/app/data/movies.json"
movies <- read_json(url)
length(movies)
```

```
#> [1] 3201
```

```r
movies[[1]]
```

```
#> $Title
#> [1] "The Land Girls"
#>
#> $US_Gross
#> [1] 146083
#>
#> $Worldwide_Gross
#> [1] 146083
#>
#> $US_DVD_Sales
```

{jsonlite}

Reading json files as tibbles

```r
movies_tbl <- as_tibble(read_json(url, simplifyVector = TRUE))
movies_tbl
```

```
#> # A tibble: 3,201 x 16
#>   Title                 US_Gross Worldwide_Gross US_DVD_Sales
#>   <chr>                    <int>           <dbl>        <int>
#> 1 The Land Girls          146083          146083           NA
#> 2 First Love, Last Ri…     10876           10876           NA
#> 3 I Married a Strange…    203134          203134           NA
#> 4 Let's Talk About Sex    373615          373615           NA
#> 5 Slam                   1009819         1087521           NA
#> 6 Mississippi Mermaid      24551         2624551           NA
#> # … with 3,195 more rows, and 12 more variables:
#> #   Production_Budget <int>, Release_Date <chr>,
#> #   MPAA_Rating <chr>, Running_Time_min <int>,
#> #   Distributor <chr>, Source <chr>, Major_Genre <chr>,
#> #   Creative_Type <chr>, Director <chr>,
#> #   Rotten_Tomatoes_Rating <int>, IMDB_Rating <dbl>,
#> #   IMDB_Votes <int>
```

Reading spatial data*

```r
library(sf)
akl_bus <- st_read("data/BusService/BusService.shp")
```

```
#> Reading layer `BusService' from data source `/Users/wany568/Teachi
#> Simple feature collection with 509 features and 7 fields
#> geometry type:  MULTILINESTRING
#> dimension:      XY
#> bbox:           xmin: 1727652 ymin: 5859539 xmax: 1787138 ymax: 59
#> projected CRS:  NZGD2000_New_Zealand_Transverse_Mercator_2000
```

data source: Auckland Transport Open GIS Data

Reading spatial data*

```r
library(sf)
akl_bus <- st_read("data/BusService/BusService.shp")
```

```
#> Reading layer `BusService' from data source `/Users/wany568/Teachi
#> Simple feature collection with 509 features and 7 fields
#> geometry type:  MULTILINESTRING
#> dimension:      XY
#> bbox:           xmin: 1727652 ymin: 5859539 xmax: 1787138 ymax: 59
#> projected CRS:  NZGD2000_New_Zealand_Transverse_Mercator_2000
```

data source: Auckland Transport Open GIS Data

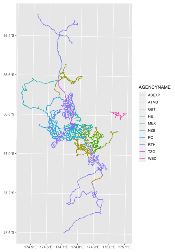
Reading spatial data*

```
akl_bus[1:4, ]
```

```
#> Simple feature collection with 4 features and 7 fields
#> geometry type:  MULTILINESTRING
#> dimension:      XY
#> bbox:           xmin: 1751253 ymin: 5915245 xmax: 1758019 ymax: 59
#> projected CRS:  NZGD2000_New_Zealand_Transverse_Mercator_2000
#>   OBJECTID ROUTEPATTE AGENCYNAME                                  R
#> 1   343077      02005        NZB St Lukes To Wynyard Quarter Via K
#> 2   343078      02006        NZB Wynyard Quarter To St Lukes Via K
#> 3   343079      02209        NZB  Avondale To City Centre Via New 
#> 4   343080      02208        NZB  City Centre To Avondale Via New 
#>   ROUTENUMBE MODE Shape__Len                       geometry
#> 1         20  Bus   7948.418 MULTILINESTRING ((1755487 5...
#> 2         20  Bus   7919.198 MULTILINESTRING ((1756321 5...
#> 3        22A  Bus  11419.588 MULTILINESTRING ((1757613 5...
#> 4        22A  Bus  11607.711 MULTILINESTRING ((1757346 5...
```

Spatial visualisation*

› Map   › R Code

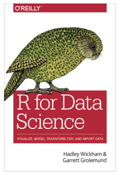


Data export ⬆️

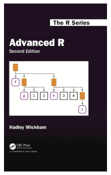
From `read_*()` to `write_*()`

```
write_csv(movies_tbl, file = "data/movies.csv")
write_sas(movies_tbl, path = "data/movies.sas7bdat")
write_json(movies_tbl, path = "data/movies.json")
```

Reading



- Tibbles
- Data import



- Subsetting