Data basics

ME 447/547 Visualizing Data

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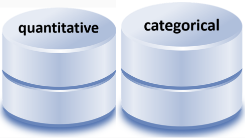
Preparing data for graphs starts with four basic skills

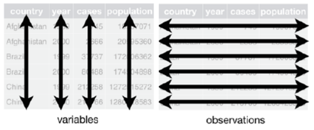
Obtain the raw data

Read raw data into R and examine it

Identify the structure of your data



Tidy the data and write to file



Big Data by Marcos Gasparutti is licensed under CC BY-SA 2.0

Data are everywhere

Data are provided in base R

Data are provided in R packages

Online sources are ubiquitous

- FiveThirtyEight `https://data.fivethirtyeight.com/`
- US government `https://www.data.gov/`
- NOAA climate data `https://www.ncdc.noaa.gov/cdo-web/`
- Publications for which code and/or data are available

  `https://reproducibleresearch.net/reproducible-material/`

You may even have data of your own from prior courses or research

For practice, use data in base R

`data()` to list data sets in base R

```
#> AirPassengers  Monthly Airline Passenger Numbers
#> BJsales        Sales Data with Leading Indicator
#> BOD            Biochemical Oxygen Demand
#> CO2            Carbon Dioxide Uptake in Grass Plants
#> Formaldehyde   Determination of Formaldehyde
etc.
```

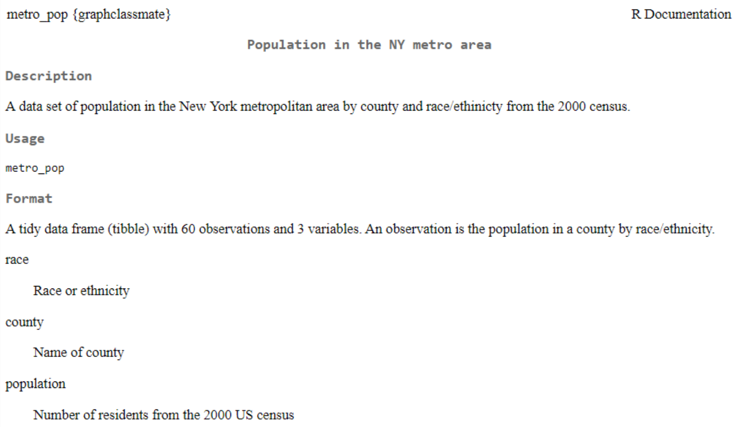
For practice, use data in R packages

`data(package = ”dplyr”)` to list data sets in package dplyr

```
#> band_instruments   Band membership
#> band_instruments2  Band membership
#> band_members       Band membership
#> nasa               NASA spatio-temporal data
#> starwars           Starwars characters
#> storms             Storm tracks data
```

? data_name shows the data set help page

```
library(”graphclassmate”)
data(package = ”graphclassmate”)
? metro_pop
```



metro_pop {graphclassmate} R Documentation

Population in the NY metro area

Description

A data set of population in the New York metropolitan area by county and race/ethinicty from the 2000 census.

Usage

```
metro_pop
```

Format

A tidy data frame (tibble) with 60 observations and 3 variables. An observation is the population in a county by race/ethnicity.

race

Race or ethnicity

county

Name of county

population

Number of residents from the 2000 US census

Data in base R and in R packages are automatically loaded

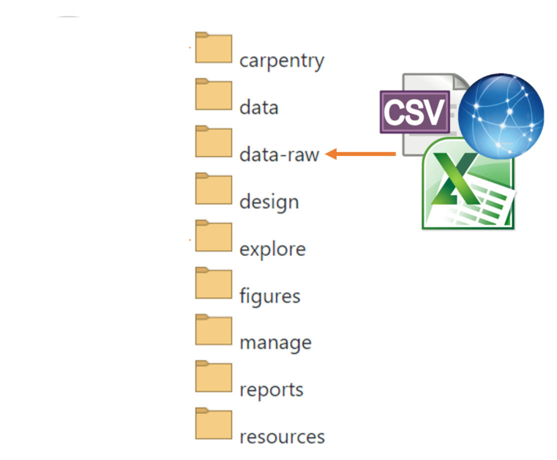
Launching R loads all data sets in base-R

Loading a package with `library()` loads all the data sets in the package

All other data files have to be read or web-scraped

Save original data files in the data-raw directory

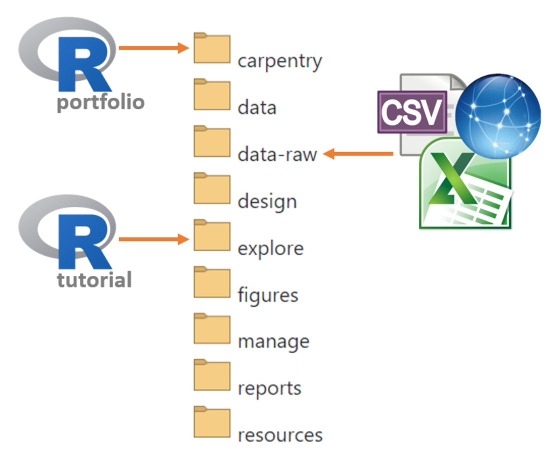
Data in their original form are never edited manually



We work with file manangement in detail during the data studio.

Read the raw data with R scripts

R scripts are saved in the carpentry or explore directories

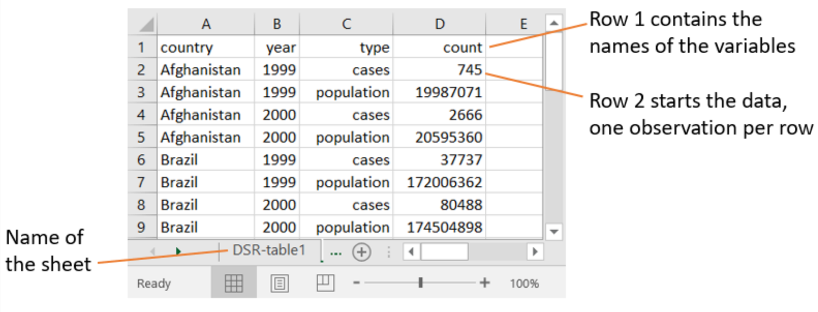


We work with file manangement in detail during the data studio.

Suppose `data-raw/` contains data in an Excel file

readxl is the package (you will have to install the package)

`read_excel()` is the function



	A	B	C	D	E
1	country	year	type	count	
2	Afghanistan	1999	cases	745	
3	Afghanistan	1999	population	19987071	
4	Afghanistan	2000	cases	2666	
5	Afghanistan	2000	population	20595360	
6	Brazil	1999	cases	37737	
7	Brazil	1999	population	172006362	
8	Brazil	2000	cases	80488	
9	Brazil	2000	population	174504898	

Row 1 contains the names of the variables

Row 2 starts the data, one observation per row

Name of the sheet

We work with data tidying in detail during the data studio.

`read_excel()` to read an Excel file

```r
library(”readxl”)
tidy_data <- read_excel(path  = ”data-raw/DSR-table1.xlsx”,
                        sheet = ”DSR-table1”)
```

We can pretty-print the data using `knitr::kable()`

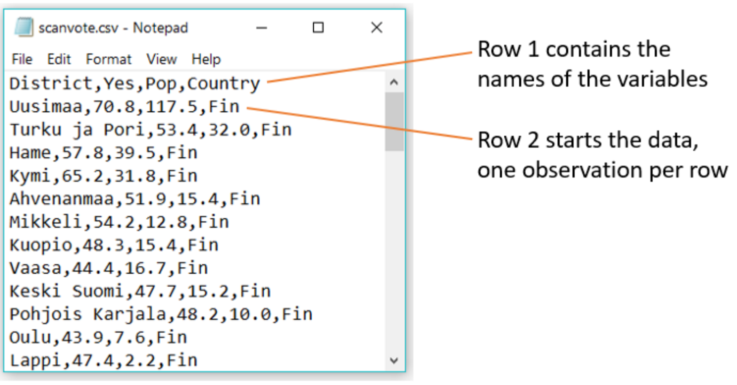
```
library("knitr")
kable(tidy_data)
```

country	year	cases	population
Afghanistan	1999	745	19987071
Afghanistan	2000	2666	20595360
Brazil	1999	37737	172006362
Brazil	2000	80488	174504898
China	1999	212258	1272915272
China	2000	213766	1280428583

Suppose `data-raw/` contains data in a CSV file

readr is the package (part of the tidyverse)

`read_csv()` is the function



```
District,Yes,Pop,Country
Uusimaa,70.8,117.5,Fin
Turku ja Pori,53.4,32.0,Fin
Hame,57.8,39.5,Fin
Kymi,65.2,31.8,Fin
Ahvenanmaa,51.9,15.4,Fin
Mikkeli,54.2,12.8,Fin
Kuopio,48.3,15.4,Fin
Vaasa,44.4,16.7,Fin
Keski Suomi,47.7,15.2,Fin
Pohjois Karjala,48.2,10.0,Fin
Oulu,43.9,7.6,Fin
Lappi,47.4,2.2,Fin
```

Row 1 contains the names of the variables

Row 2 starts the data, one observation per row

We work with data tidying in detail during the data studio.

read_csv() to read a CSV file

```
library(”tidyverse”) # loads the readr package
tidy_data_2 <- read_csv(file = ”data-raw/scanvote.csv”)
```

We can pretty-print the top n rows with head()

```
tidy_data_2 %>%
    head(., n = 5L) %>%
    kable()
```

District	Yes	Pop	Country
Uusimaa	70.8	117.5	Fin
Turku ja Pori	53.4	32.0	Fin
Hame	57.8	39.5	Fin
Kymi	65.2	31.8	Fin
Ahvenanmaa	51.9	15.4	Fin

read_excel() and read_csv() produce tibbles

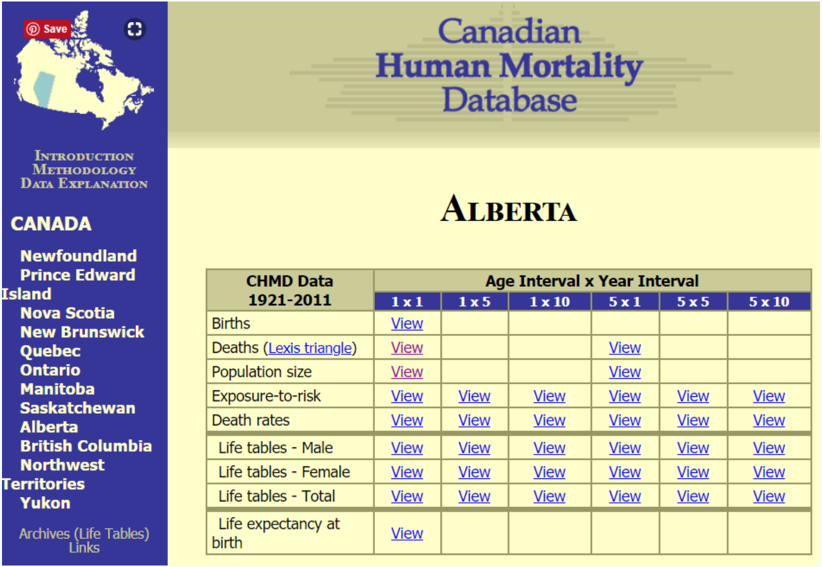
```
class(tidy_data)
```

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

```
class(tidy_data_2)
```

```
#> [1] ”spec_tbl_df” ”tbl_df”      ”tbl”         ”data.frame”
```

Confine your webscraping (for now) to data in ASCII format



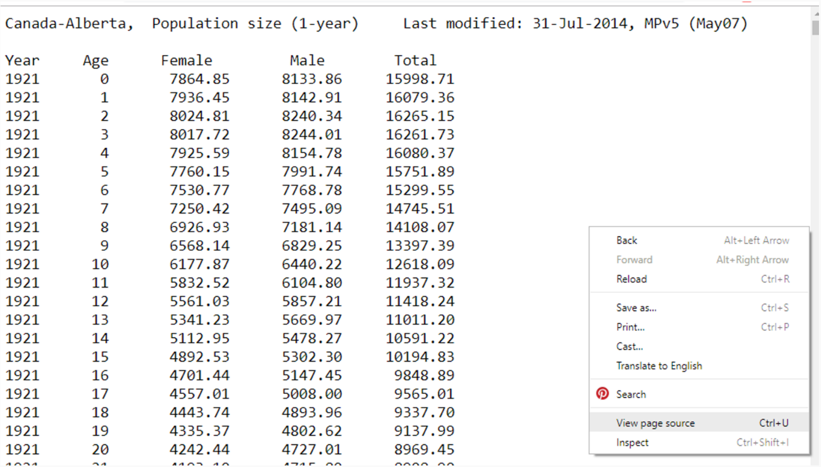
Canadian Human Mortality Database

Alberta

CHMD Data 1921-2011	Age Interval x Year Interval					
	1 x 1	1 x 5	1 x 10	5 x 1	5 x 5	5 x 10
Births	View					
Deaths (Lexis triangle)	View			View		
Population size	View			View		
Exposure-to-risk	View	View	View	View	View	View
Death rates	View	View	View	View	View	View
Life tables - Male	View	View	View	View	View	View
Life tables - Female	View	View	View	View	View	View
Life tables - Total	View	View	View	View	View	View
Life expectancy at birth	View					

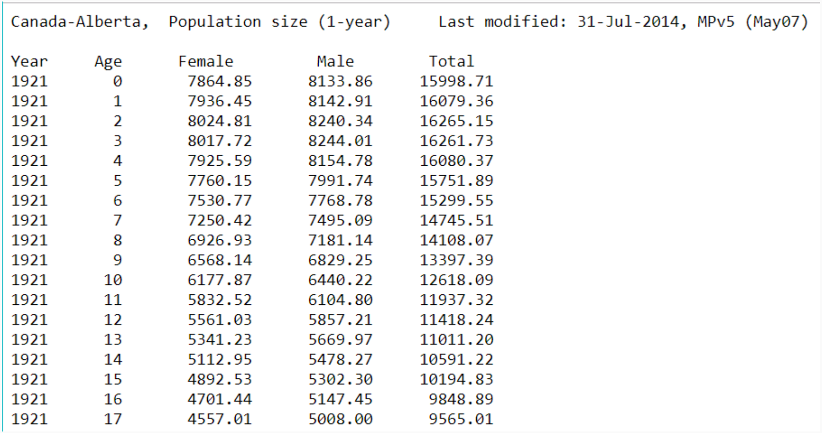
Source: Canadian Human Mortality Database

On any online data page, right-click > View page source



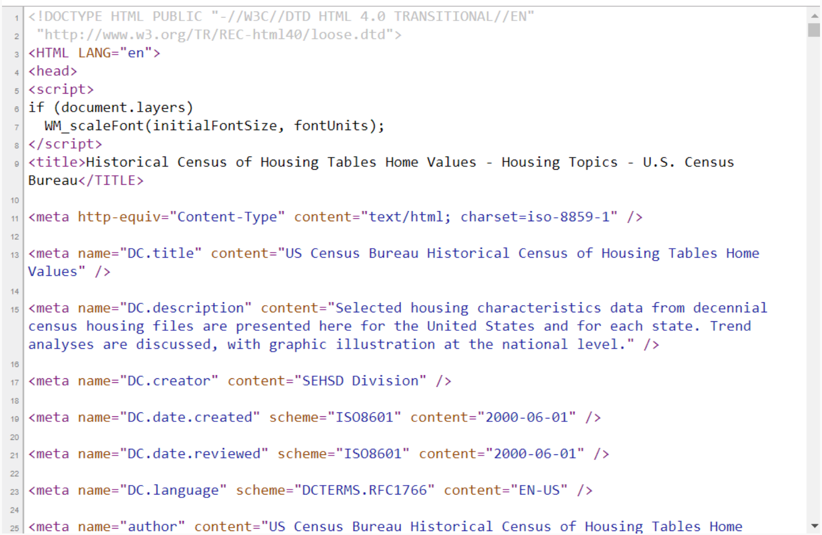
```
Canada-Alberta,  Population size (1-year)     Last modified: 31-Jul-2014, MPv5 (May07)

Year       Age       Female         Male        Total
1921         0      7864.85      8133.86     15998.71
1921         1      7936.45      8142.91     16079.36
1921         2      8024.81      8240.34     16265.15
1921         3      8017.72      8244.01     16261.73
1921         4      7925.59      8154.78     16080.37
1921         5      7760.15      7991.74     15751.89
1921         6      7530.77      7768.78     15299.55
1921         7      7250.42      7495.09     14745.51
1921         8      6926.93      7181.14     14108.07
1921         9      6568.14      6829.25     13397.39
1921        10      6177.87      6440.22     12618.09
1921        11      5832.52      6104.80     11937.32
1921        12      5561.03      5857.21     11418.24
1921        13      5341.23      5669.97     11011.20
1921        14      5112.95      5478.27     10591.22
1921        15      4892.53      5302.30     10194.83
1921        16      4701.44      5147.45      9848.89
1921        17      4557.01      5008.00      9565.01
1921        18      4443.74      4893.96      9337.70
1921        19      4335.37      4802.62      9137.99
1921        20      4242.44      4727.01      8969.45
```

Data formatted in ASCII (text) is easily recognized



```
Canada-Alberta,  Population size (1-year)    Last modified: 31-Jul-2014, MPv5 (May07)

Year       Age        Female          Male         Total
1921         0        7864.85        8133.86      15998.71
1921         1        7936.45        8142.91      16079.36
1921         2        8024.81        8240.34      16265.15
1921         3        8017.72        8244.01      16261.73
1921         4        7925.59        8154.78      16080.37
1921         5        7760.15        7991.74      15751.89
1921         6        7530.77        7768.78      15299.55
1921         7        7250.42        7495.09      14745.51
1921         8        6926.93        7181.14      14108.07
1921         9        6568.14        6829.25      13397.39
1921        10        6177.87        6440.22      12618.09
1921        11        5832.52        6104.80      11937.32
1921        12        5561.03        5857.21      11418.24
1921        13        5341.23        5669.97      11011.20
1921        14        5112.95        5478.27      10591.22
1921        15        4892.53        5302.30      10194.83
1921        16        4701.44        5147.45       9848.89
1921        17        4557.01        5008.00       9565.01
```

Data formatted in HTML is also easily recognized



```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.0 TRANSITIONAL//EN"
 "http://www.w3.org/TR/REC-html40/loose.dtd">
<HTML LANG="en">
<head>
<script>
if (document.layers)
  WM_scaleFont(initialFontSize, fontUnits);
</script>
<title>Historical Census of Housing Tables Home Values - Housing Topics - U.S. Census Bureau</TITLE>

<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1" />

<meta name="DC.title" content="US Census Bureau Historical Census of Housing Tables Home Values" />

<meta name="DC.description" content="Selected housing characteristics data from decennial census housing files are presented here for the United States and for each state. Trend analyses are discussed, with graphic illustration at the national level." />

<meta name="DC.creator" content="SEHSD Division" />

<meta name="DC.date.created" scheme="ISO8601" content="2000-06-01" />

<meta name="DC.date.reviewed" scheme="ISO8601" content="2000-06-01" />

<meta name="DC.language" scheme="DCTERMS.RFC1766" content="EN-US" />

<meta name="author" content="US Census Bureau Historical Census of Housing Tables Home
```

Source: US Census of Housing

With online data in ASCII format, webscraping is easy

`utils` is the package

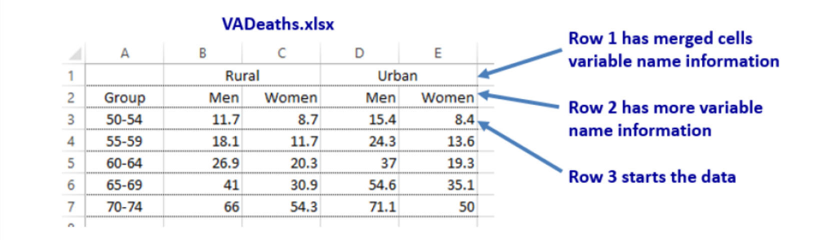
`read./table()` is the function

```
library(”utils”)
url <-
  ”http://www.prdh.umontreal.ca/BDLC/data/alb/Population.txt”

df  <- read.table(url,
                  skip = 2,
                  header = TRUE,
                  stringsAsFactors = FALSE)

df <- as_tibble(df)
```

Examine it and write it to the `data-raw` directory

```
glimpse(df)
#> Observations: 10,212
#> Variables: 5
#> $ Year   <int> 1921, 1921, 1921, 1921, 1921, 1921, 192
#> $ Age    <chr> ”0”, ”1”, ”2”, ”3”, ”4”, ”5”, ”6”, ”7”,
#> $ Female <dbl> 7864.85, 7936.45, 8024.81, 8017.72, 792
#> $ Male   <dbl> 8133.86, 8142.91, 8240.34, 8244.01, 815
#> $ Total  <dbl> 15998.71, 16079.36, 16265.15, 16261.73,

write_csv(df, ”data-raw/alberta_mortality.csv”)
```

When the data are not tidy, ...



VADeaths.xlsx

	A	B	C	D	E
1		Rural		Urban	
2	Group	Men	Women	Men	Women
3	50-54	11.7	8.7	15.4	8.4
4	55-59	18.1	11.7	24.3	13.6
5	60-64	26.9	20.3	37	19.3
6	65-69	41	30.9	54.6	35.1
7	70-74	66	54.3	71.1	50

Row 1 has merged cells variable name information

Row 2 has more variable name information

Row 3 starts the data

… the read results can be weird.

```
untidy_data <- read_excel(path = ”data-raw/VADeaths.xlsx”,
                          sheet = ”VADeaths”) %>%
                glimpse()
```

```
#> Observations: 6
#> Variables: 5
#> $ `..1` <chr> ”Group”, ”50-54”, ”55-59”, ”60-64”, ”65-69”, ”
#> $ Rural <chr> ”Men”, ”11.7”, ”18.100000000000001”, ”26.9”, ”
#> $ `..3` <chr> ”Women”, ”8.6999999999999993”, ”11.7”, ”20.3”,
#> $ Urban <chr> ”Men”, ”15.4”, ”24.3”, ”37”, ”54.6”, ”71.09999
#> $ `..5` <chr> ”Women”, ”8.4”, ”13.6”, ”19.3”, ”35.1”, ”50”
```

All the cells have been converted to character data

The result is more easily seen using `knitr::kable()`

```r
kable(untidy_data)
```

..1	Rural	..3	Urban	..5
Group	Men	Women	Men	Wome
50-54	11.7	8.6999999999999993	15.4	8.4
55-59	18.100000000000001	11.7	24.3	13.6
60-64	26.9	20.3	37	19.3
65-69	41	30.9	54.6	35.1
70-74	66	54.3	71.099999999999994	50

The first row is not an observation—that's the problem

When reading the file, we need to skip the first row

The data are at least readable but we have lost information

```
untidy_data <- read_excel(path = ”data-raw/VADeaths.xlsx”,
                          sheet = ”VADeaths”,
                          skip = 1)
```

Group	Men..2	Women..3	Men..4	Women..5
50-54	11.7	8.7	15.4	8.4
55-59	18.1	11.7	24.3	13.6
60-64	26.9	20.3	37.0	19.3
65-69	41.0	30.9	54.6	35.1
70-74	66.0	54.3	71.1	50.0

Carpentry on untidy data is a large fraction of your effort

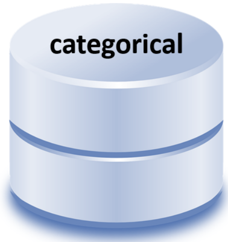
> *It is often said that 80% of data analysis is spent on the process of cleaning and preparing the data.*
>
> *Data preparation is not just a first step, but must be repeated many times over the course of analysis as new problems come to light or new data is collected.*

—Hadley Wickham, Tidy Data

Understanding data structure is necessary for tidying

Number of variables?

Continuous or discrete?



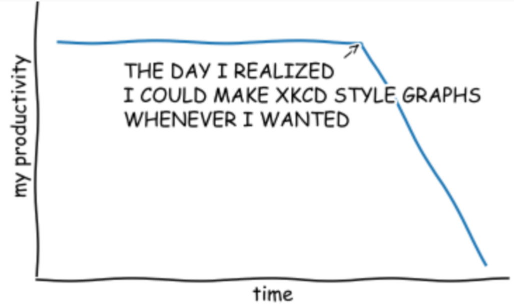
Number of variables?

Nominal or ordinal?

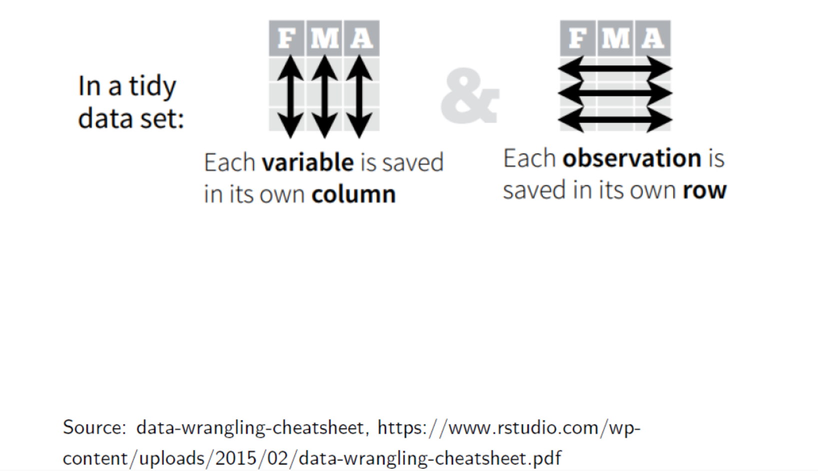
Number of levels each?

Transforming data to tidy form is necesaary for productivity

- how you tidy the data set before graphing
- the graph types that are suitable
- how easy it is to get ggplot to do your bidding
- how productively you spend your time



For graphical productivity, data has to be tidy



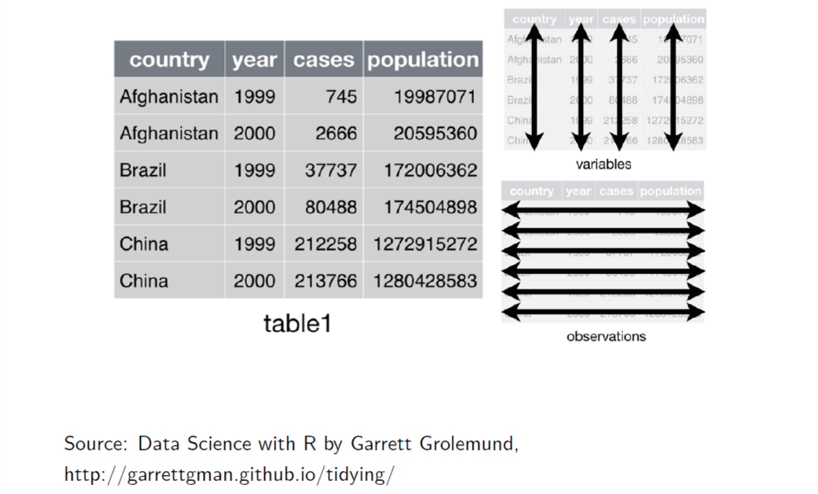
In a tidy data set:

Each **variable** is saved in its own **column**

Each **observation** is saved in its own **row**

Source: data-wrangling-cheatsheet, https://www.rstudio.com/wp-content/uploads/2015/02/data-wrangling-cheatsheet.pdf

Every column is a variable, every row is an observation

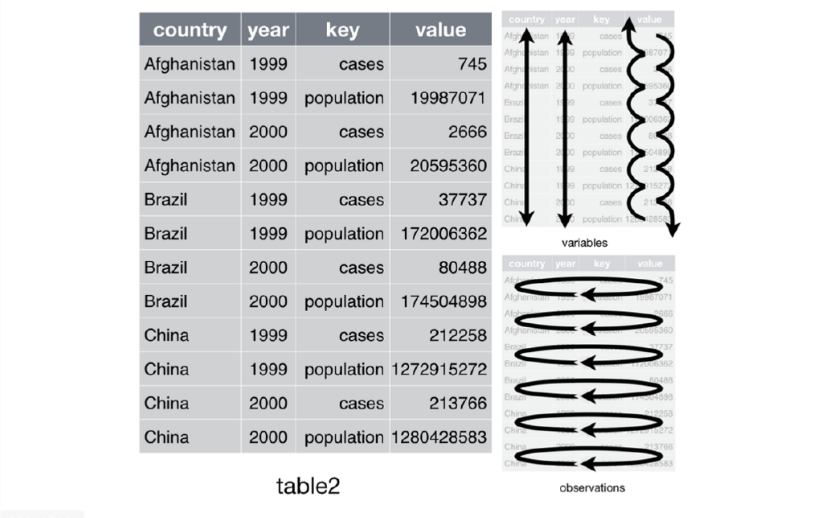


country	year	cases	population
Afghanistan	1999	745	19987071
Afghanistan	2000	2666	20595360
Brazil	1999	37737	172006362
Brazil	2000	80488	174504898
China	1999	212258	1272915272
China	2000	213766	1280428583

table1

Source: Data Science with R by Garrett Grolemund,
http://garrettgman.github.io/tidying/

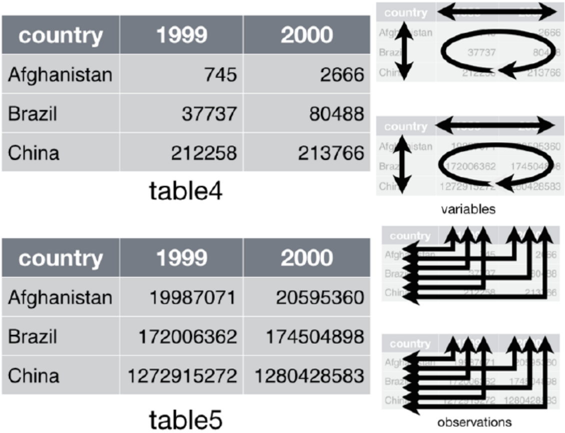
Sadly, untidy data is common



country	year	key	value
Afghanistan	1999	cases	745
Afghanistan	1999	population	19987071
Afghanistan	2000	cases	2666
Afghanistan	2000	population	20595360
Brazil	1999	cases	37737
Brazil	1999	population	172006362
Brazil	2000	cases	80488
Brazil	2000	population	174504898
China	1999	cases	212258
China	1999	population	1272915272
China	2000	cases	213766
China	2000	population	1280428583

table2

Sadly, untidy data is common



country	1999	2000
Afghanistan	745	2666
Brazil	37737	80488
China	212258	213766

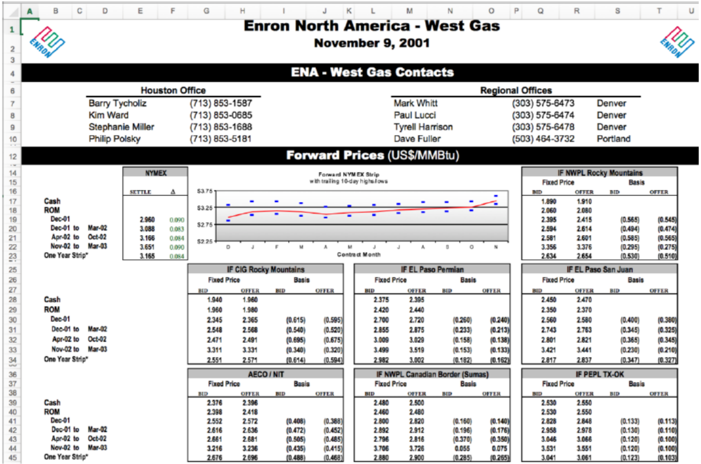
table4

country	1999	2000
Afghanistan	19987071	20595360
Brazil	172006362	174504898
China	1272915272	1280428583

table5

Source: Data Science with R by Garrett Grolemund, http://garrettgman.github.io/tidying/

Some industry or government spreadsheets are horribly untidy



Enron North America - West Gas

November 9, 2001

ENA - West Gas Contacts

Houston Office		Regional Offices		
Barry Tycholiz	(713) 853-1587	Mark Whitt	(303) 575-6473	Denver
Kim Ward	(713) 853-0685	Paul Lucci	(303) 575-6474	Denver
Stephanie Miller	(713) 853-1688	Tyrell Harrison	(303) 575-6478	Denver
Philip Polsky	(713) 853-5181	Dave Fuller	(503) 464-3732	Portland

Forward Prices (US$/MMBtu)

	NYMEX		IF NWPL Rocky Mountains			
			Fixed Price		Basis	
	SETTLE	Δ	BID	OFFER	BID	OFFER
Cash			1.890	1.910		
ROM			2.060	2.080		
Dec-01	2.960	0.090	2.395	2.415	(0.565)	(0.545)
Dec-01 to Mar-02	3.088	0.083	2.594	2.614	(0.494)	(0.474)
Apr-02 to Oct-02	3.166	0.084	2.581	2.601	(0.585)	(0.565)
Nov-02 to Mar-03	3.651	0.090	3.356	3.376	(0.295)	(0.275)
One Year Strip*	3.165	0.084	2.634	2.654	(0.530)	(0.510)

	IF CIG Rocky Mountains				IF EL Paso Permian				IF EL Paso San Juan			
	Fixed Price		Basis		Fixed Price		Basis		Fixed Price		Basis	
	BID	OFFER	BID	OFFER	BID	OFFER	BID	OFFER	BID	OFFER	BID	OFFER
Cash	1.940	1.960			2.375	2.395			2.450	2.470		
ROM	1.960	1.980			2.420	2.440			2.350	2.370		
Dec-01	2.345	2.365	(0.615)	(0.595)	2.700	2.720	(0.260)	(0.240)	2.560	2.580	(0.400)	(0.380)
Dec-01 to Mar-02	2.548	2.568	(0.540)	(0.520)	2.855	2.875	(0.233)	(0.213)	2.743	2.763	(0.345)	(0.325)
Apr-02 to Oct-02	2.471	2.491	(0.695)	(0.675)	3.009	3.029	(0.158)	(0.138)	2.801	2.821	(0.365)	(0.345)
Nov-02 to Mar-03	3.311	3.331	(0.340)	(0.320)	3.499	3.519	(0.153)	(0.133)	3.421	3.441	(0.230)	(0.210)
One Year Strip*	2.551	2.571	(0.614)	(0.594)	2.982	3.002	(0.182)	(0.162)	2.817	2.837	(0.347)	(0.327)

	AECO / NIT				IF NWPL Canadian Border (Sumas)				IF PEPL TX-OK			
	Fixed Price		Basis		Fixed Price		Basis		Fixed Price		Basis	
	BID	OFFER	BID	OFFER	BID	OFFER	BID	OFFER	BID	OFFER	BID	OFFER
Cash	2.376	2.396			2.480	2.500			2.530	2.550		
ROM	2.398	2.418			2.460	2.480			2.530	2.550		
Dec-01	2.552	2.572	(0.408)	(0.388)	2.800	2.820	(0.160)	(0.140)	2.828	2.848	(0.133)	(0.113)
Dec-01 to Mar-02	2.616	2.636	(0.472)	(0.452)	2.892	2.912	(0.196)	(0.176)	2.958	2.978	(0.130)	(0.110)
Apr-02 to Oct-02	2.661	2.681	(0.505)	(0.485)	2.796	2.816	(0.370)	(0.350)	3.046	3.066	(0.120)	(0.100)
Nov-02 to Mar-03	3.216	3.236	(0.435)	(0.415)	3.706	3.726	0.055	0.075	3.531	3.551	(0.120)	(0.100)
One Year Strip*	2.676	2.696	(0.488)	(0.468)	2.880	2.900	(0.285)	(0.265)	3.041	3.061	(0.123)	(0.103)

Source: Extract tables from messy spreadsheets with jailbreakr, http://blog.revolutionanalytics.com/2016/08/jailbreakr.html

Data beyond the “raw” stage are written to file

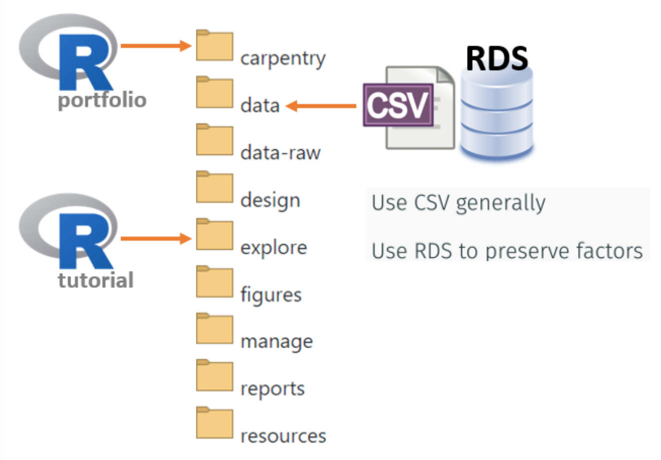
Write functions

```
write_csv()  # use CSV generally
saveRDS()    # use RDS to preserve factors
```

Read functions for further data carpentry

```
read_csv()
readRDS()
```

Data beyond the "raw" stage reside in the `data` directory



Use CSV generally

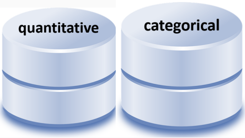
Use RDS to preserve factors

In the data studio, you’ll start practicing the skills we’ve outlined

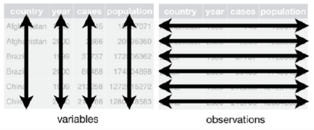
Obtain the raw data

Read raw data into R and examine it

Identify the structure of your data



Tidy the data and write to file


country
year
cases
population
variables
country
year
cases
population
observations