Descriptive Statistics and Data Visualization

EPSY 630 - Statistics II

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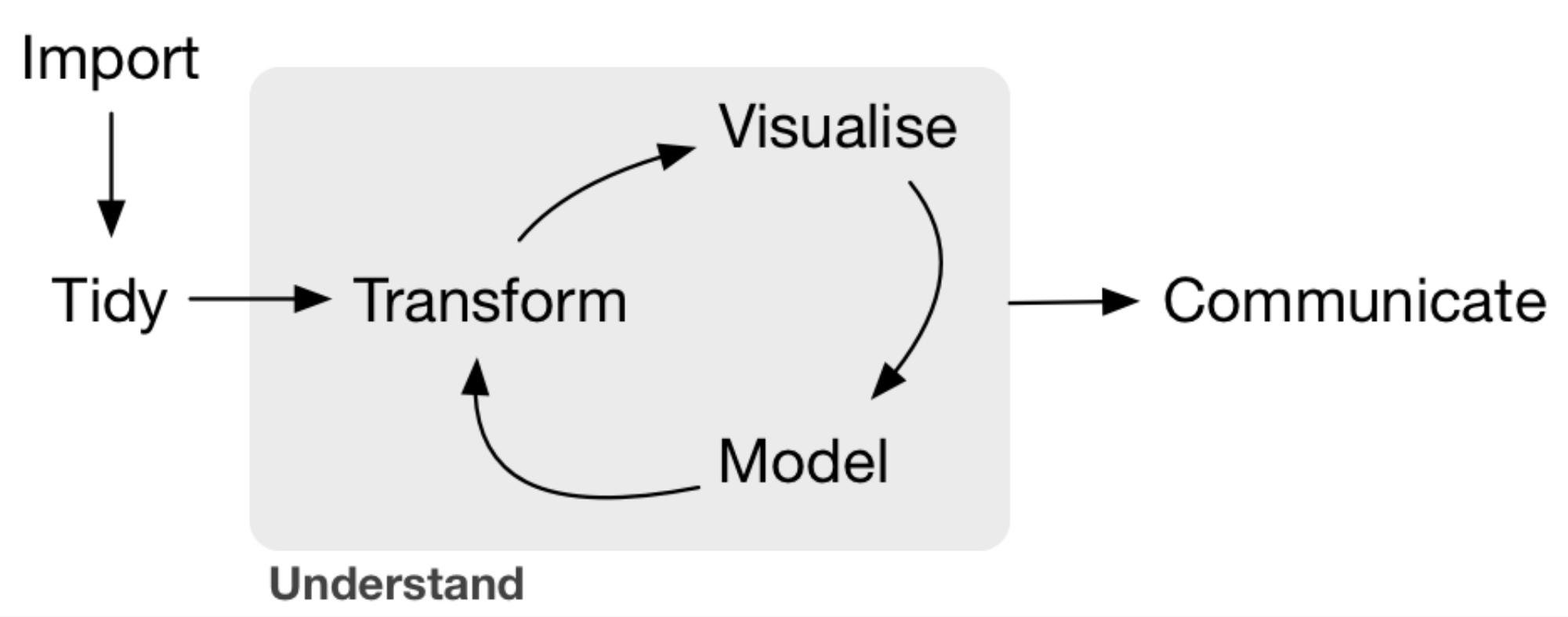
Agenda

- Data wrangling
  - Data types
  - Descriptive statistics
- Data visualization
  - Grammar of graphics
  - Types of graphics

Workflow



Source: Wickham & Grolemund, 2017

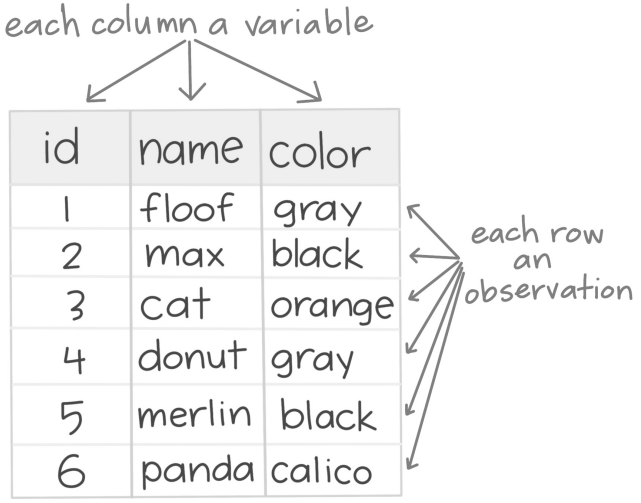
Tidy Data

"TIDY DATA is a standard way of mapping the meaning of a dataset to its structure."

—HADLEY WICKHAM

In tidy data:

- each variable forms a column
- each observation forms a row
- each cell is a single measurement



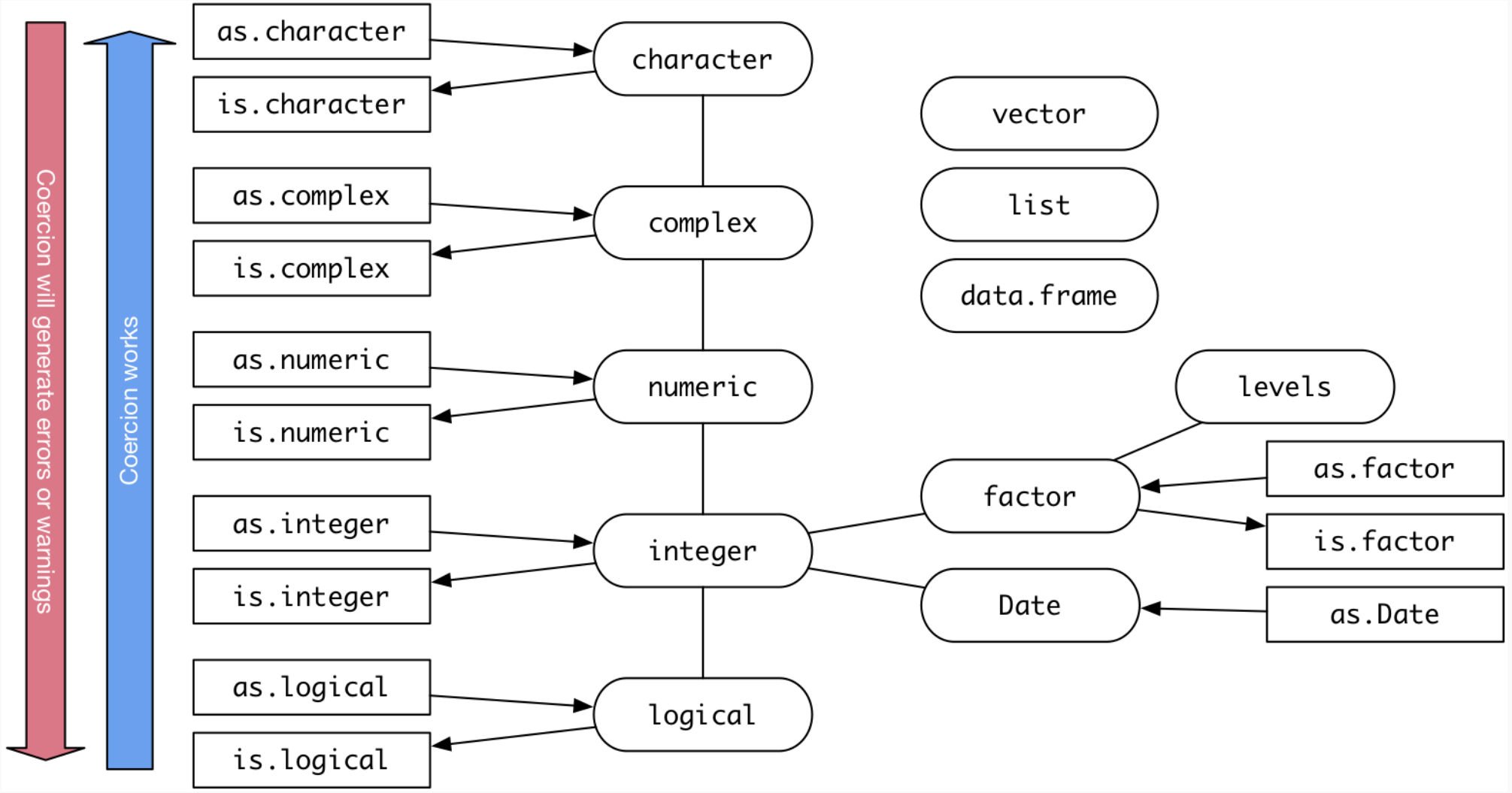
Wickham, H. (2014). Tidy Data. Journal of Statistical Software *59* (10). DOI: 10.18637/jss.v059.i10

See Wickham (2014) Tidy data.

Types of Data

- Numerical (quantitative)
  - Continuous
  - Discrete
- Categorical (qualitative)
  - Regular categorical
  - Ordinal

Data Types in R



Data Types / Descriptives / Visualizations

Data Type	Descriptive Stats	Visualization
Continuous	mean, median, mode, standard deviation, IQR	histogram, density, box plot
Discrete	contingency table, proportional table, median	bar plot
Categorical	contingency table, proportional table	bar plot
Ordinal	contingency table, proportional table, median	bar plot
Two quantitative	correlation	scatter plot
Two qualitative	contingency table, chi-squared	mosiac plot, bar plot
Quantitative & Qualitative	grouped summaries, ANOVA, t-test	box plot

About `legosets`

To install the **`brickset`** package:

```
remotes::install_github('jbryer/brickset')
```

To load the load the **`legosets`** dataset.

```
data('legosets', package = 'brickset')
```

The **`legosets`** data has 16355 observations of 34 variables.

```
names(legosets)
```

```
##  [1] "setID"                "name"                 "year"                 "theme"
##  [5] "themeGroup"           "subtheme"             "category"             "released"
##  [9] "pieces"               "minifigs"             "bricksetURL"          "rating"
## [13] "reviewCount"          "packagingType"        "availability"         "agerange_min"
## [17] "US_retailPrice"       "US_dateFirstAvailable" "US_dateLastAvailable" "UK_retailPrice"
## [21] "UK_dateFirstAvailable" "UK_dateLastAvailable" "CA_retailPrice"       "CA_dateFirstAvailable"
## [25] "CA_dateLastAvailable" "DE_retailPrice"       "DE_dateFirstAvailable" "DE_dateLastAvailable"
```

Structure

```
str(legosets)
```

```
## 'data.frame':    16355 obs. of  34 variables:
##  $ setID                : int  7693 7695 7697 7698 25534 7418 7419 6020 22704 7421 ...
##  $ name                 : chr  "Small house set" "Medium house set" "Medium house set" "Large house set" ...
##  $ year                 : int  1970 1970 1970 1970 1970 1970 1970 1970 1970 1970 ...
##  $ theme                : chr  "Minitalia" "Minitalia" "Minitalia" "Minitalia" ...
##  $ themeGroup           : chr  "Vintage" "Vintage" "Vintage" "Vintage" ...
##  $ subtheme             : chr  NA NA NA NA ...
##  $ category             : chr  "Normal" "Normal" "Normal" "Normal" ...
##  $ released             : logi  TRUE TRUE TRUE TRUE TRUE TRUE ...
##  $ pieces               : int  67 109 158 233 NA 1 1 60 65 NA ...
##  $ minifigs             : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ bricksetURL          : chr  "https://brickset.com/sets/1-8" "https://brickset.com/sets/2-8" "https://brickset.com/sets/3-6" "https://brickset.com/sets/4-4" ...
##  $ rating               : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ reviewCount          : int  0 0 1 0 0 0 0 1 0 0 ...
##  $ packagingType        : chr  "{Not specified}" "{Not specified}" "{Not specified}" "{Not specified}" ...
##  $ availability         : chr  "{Not specified}" "{Not specified}" "{Not specified}" "{Not specified}" ...
##  $ agerange_min         : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ US_retailPrice       : num  NA NA NA NA NA 1.99 NA NA 4.99 NA ...
##  $ US_dateFirstAvailable: Date, format: NA NA NA NA ...
##  $ US_dateLastAvailable : Date, format: NA NA NA NA ...
##  $ UK_retailPrice       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ UK_dateFirstAvailable: Date, format: NA NA NA NA ...
##  $ UK_dateLastAvailable : Date, format: NA NA NA NA ...
##  $ CA_retailPrice       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ CA_dateFirstAvailable: Date, format: NA NA NA NA ...
##  $ CA_dateLastAvailable : Date, format: NA NA NA NA ...
##  $ DE_retailPrice       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ DE_dateFirstAvailable: Date, format: NA NA NA NA ...
##  $ DE_dateLastAvailable : Date, format: NA NA NA NA ...
##  $ height               : num  NA NA NA NA NA ...
##  $ width                : num  NA NA NA NA NA ...
##  $ depth                : num  NA NA NA NA NA NA NA NA 5.08 NA ...
##  $ weight               : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ thumbnailURL         : chr  "https://images.brickset.com/sets/small/1-8.jpg" "https://images.brickset.com/sets/small/2-8.jpg" "https://images.brickset.com/sets/small/3-6.jpg" "https:
##  $ imageURL             : chr  "https://images.brickset.com/sets/images/1-8.jpg" "https://images.brickset.com/sets/images/2-8.jpg" "https://images.brickset.com/sets/images/3-6.jpg" "htt
```

RStudio Eenvironment tab can help

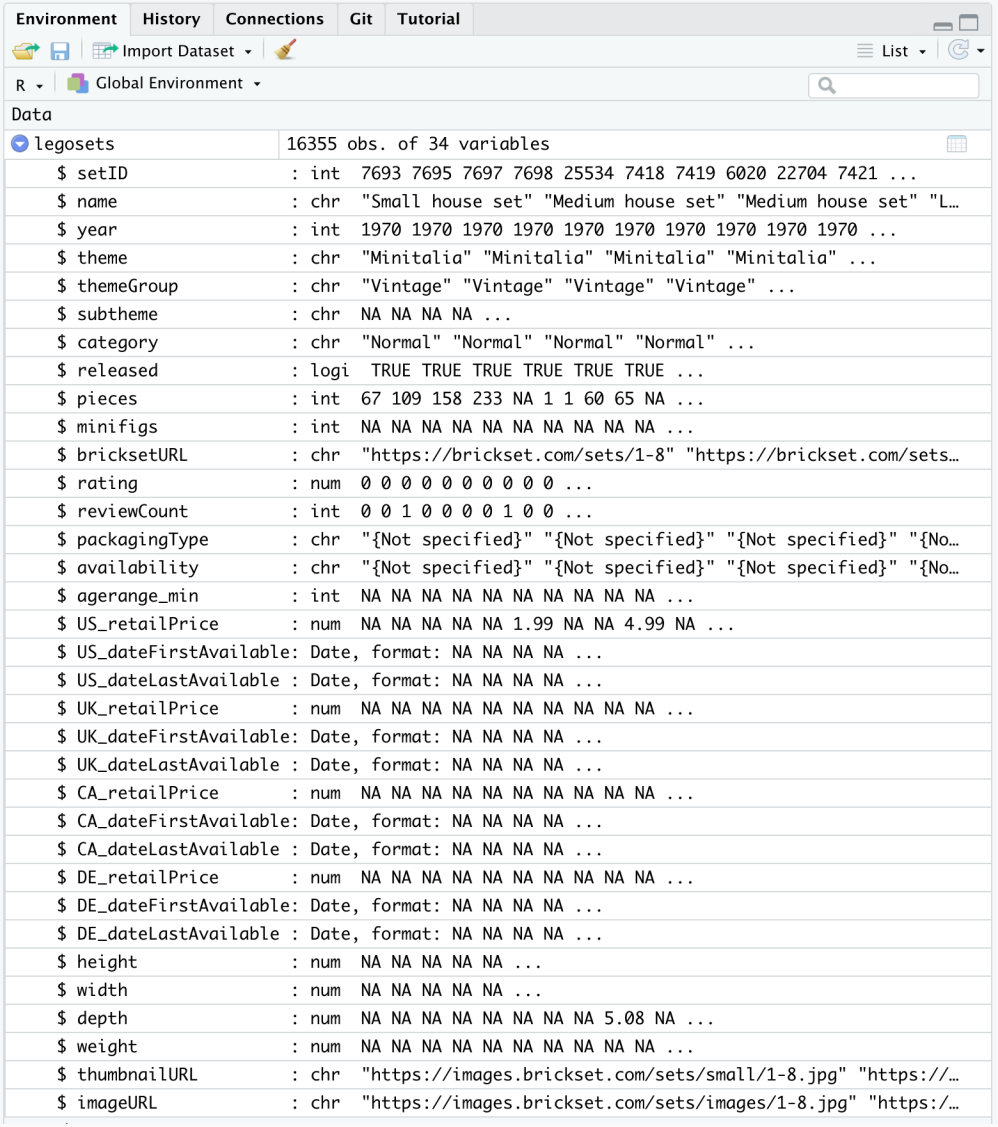


Table View

Show 10 entries

Search:

	setID	name	year	theme	themeGroup	category	US_retailPrice	pieces	minifigs	rating
1	8472	Fountain of Youth	2011	Pirates of the Caribbean	Licensed	Normal	19.99	128	4	3.8
2	878	Kitty Cat's Building Set	1995	Duplo	Pre-school	Normal		36		0
3	6486	Volkswagen Beetle	2008	Creator Expert	Model making	Normal	119.99	1626		4.4
4	30726	Digi Kai	2020	Ninjago	Action/Adventure	Other		3	1	0
5	6265	Chameleon Hunter	2008	Exo-Force	Action/Adventure	Normal	14.99	188	1	3.8
6	7646	LEGO Minifigures Series 1 {Random bag}	2010	Collectable Minifigures	Miscellaneous	Random	1.99			4.7
7	13622	Bonus/Value Pack	2012	HERO Factory	Constraction	Collection		39		0
8	7672	Shoot 'n' Score (Zidane Edition)	2000	Sports	Modern day	Normal		22	2	0
9	26474	Battle Suit Lance	2017	Nexo Knights	Action/Adventure	Normal	9.99	83	1	3.8
10	28273	Brick Backpack Orange	2018	Gear	Miscellaneous	Gear	49.99			0

Showing 1 to 10 of 100 entries

Previous 1 2 3 4 5 ... 10 Next

Data Wrangling Cheat Sheet

Data Transformation with dplyr : : CHEAT SHEET

dplyr functions work with pipes and expect **tidy data**. In tidy data:

Each **variable** is in its own **column** & Each **observation**, or **case**, is in its own **row**

pipes
x %>% f(y) becomes **f(x, y)**

Summarise Cases

These apply **summary functions** to columns to create a new table of summary statistics. Summary functions take vectors as input and return one value (see back).

summary function

summarise(.data, …)
Compute table of summaries.
summarise(mtcars, avg = mean(mpg))

count(x, ..., wt = NULL, sort = FALSE)
Count number of rows in each group defined by the variables in … Also **tally**().
count(iris, Species)

VARIATIONS

summarise_all() - Apply funs to every column.
summarise_at() - Apply funs to specific columns.
summarise_if() - Apply funs to all cols of one type.

Group Cases

Use **group_by()** to create a "grouped" copy of a table. dplyr functions will manipulate each "group" separately and then combine the results.

```
mtcars %>%
group_by(cyl) %>%
summarise(avg = mean(mpg))
```

group_by(.data, ..., add = FALSE)
Returns copy of table grouped by …
g_iris <- group_by(iris, Species)

ungroup(x, …)
Returns ungrouped copy of table.
ungroup(g_iris)

Manipulate Cases

EXTRACT CASES

Row functions return a subset of rows as a new table.

filter(.data, …) Extract rows that meet logical criteria. *filter(iris, Sepal.Length > 7)*

distinct(.data, ..., .keep_all = FALSE) Remove rows with duplicate values.
distinct(iris, Species)

sample_frac(tbl, size = 1, replace = FALSE, weight = NULL, .env = parent.frame()) Randomly select fraction of rows.
sample_frac(iris, 0.5, replace = TRUE)

sample_n(tbl, size, replace = FALSE, weight = NULL, .env = parent.frame()) Randomly select size rows. *sample_n(iris, 10, replace = TRUE)*

slice(.data, …) Select rows by position.
slice(iris, 10:15)

top_n(x, n, wt) Select and order top n entries (by group if grouped data). *top_n(iris, 5, Sepal.Width)*

Logical and boolean operators to use with filter()

<	<=	is.na()	%in%	| xor()
>	>=	!is.na()	!	&

See **?base::logic** and **?Comparison** for help.

ARRANGE CASES

arrange(.data, …) Order rows by values of a column or columns (low to high), use with **desc()** to order from high to low.
arrange(mtcars, mpg)
arrange(mtcars, desc(mpg))

ADD CASES

add_row(.data, ..., .before = NULL, .after = NULL) Add one or more rows to a table.
add_row(faithful, eruptions = 1, waiting = 1)

Manipulate Variables

EXTRACT VARIABLES

Column functions return a set of columns as a new vector or table.

pull(.data, var = -1) Extract column values as a vector. Choose by name or index.
pull(iris, Sepal.Length)

select(.data, …)
Extract columns as a table. Also **select_if()**.
select(iris, Sepal.Length, Species)

Use these helpers with select (),
e.g. select(iris, starts_with("Sepal"))

contains(match)
ends_with(match)
matches(match)
num_range(prefix, range)
one_of(…)
starts_with(match)
:, e.g. mpg:cyl
-, e.g, -Species

MAKE NEW VARIABLES

These apply **vectorized functions** to columns. Vectorized funs take vectors as input and return vectors of the same length as output (see back).

vectorized function

mutate(.data, …)
Compute new column(s).
mutate(mtcars, gpm = 1/mpg)

transmute(.data, …)
Compute new column(s), drop others.
transmute(mtcars, gpm = 1/mpg)

mutate_all(.tbl, .funs, …) Apply funs to every column. Use with **funs()**. Also **mutate_if()**.
mutate_all(faithful, funs(log(.), log2(.)))
mutate_if(iris, is.numeric, funs(log(.)))

mutate_at(.tbl, .cols, .funs, …) Apply funs to specific columns. Use with **funs()**, **vars()** and the helper functions for select().
mutate_at(iris, vars(-Species), funs(log(.)))

add_column(.data, ..., .before = NULL, .after = NULL) Add new column(s). Also **add_count()**, **add_tally()**. *add_column(mtcars, new = 1:32)*

rename(.data, …) Rename columns.
rename(iris, Length = Sepal.Length)

RStudio

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Tidyverse vs Base R

R Syntax Comparison : : CHEAT SHEET

Dollar sign syntax

`goal(data$x, data$y)`

SUMMARY STATISTICS:

one continuous variable:
```
mean(mtcars$mpg)
```

one categorical variable:
```
table(mtcars$cyl)
```

two categorical variables:
```
table(mtcars$cyl, mtcars$am)
```

one continuous, one categorical:
```
mean(mtcars$mpg[mtcars$cyl==4])
mean(mtcars$mpg[mtcars$cyl==6])
mean(mtcars$mpg[mtcars$cyl==8])
```

PLOTTING:

one continuous variable:
```
hist(mtcars$disp)

boxplot(mtcars$disp)
```

one categorical variable:
```
barplot(table(mtcars$cyl))
```

two continuous variables:
```
plot(mtcars$disp, mtcars$mpg)
```

two categorical variables:
```
mosaicplot(table(mtcars$am, mtcars$cyl))
```

one continuous, one categorical:
```
histogram(mtcars$disp[mtcars$cyl==4])
histogram(mtcars$disp[mtcars$cyl==6])
histogram(mtcars$disp[mtcars$cyl==8])

boxplot(mtcars$disp[mtcars$cyl==4])
boxplot(mtcars$disp[mtcars$cyl==6])
boxplot(mtcars$disp[mtcars$cyl==8])
```

WRANGLING:

subsetting:
```
mtcars[mtcars$mpg>30, ]
```

making a new variable:
```
mtcars$efficient[mtcars$mpg>30] <- TRUE
mtcars$efficient[mtcars$mpg<30] <- FALSE
```

Formula syntax

`goal(y~x|z, data=data, group=w)`

SUMMARY STATISTICS:

one continuous variable:
```
mosaic::mean(~mpg, data=mtcars)
```

one categorical variable:
```
mosaic::tally(~cyl, data=mtcars)
```

two categorical variables:
```
mosaic::tally(cyl~am, data=mtcars)
```

one continuous, one categorical:
```
mosaic::mean(mpg~cyl, data=mtcars)
```

tilde

PLOTTING:

one continuous variable:
```
lattice::histogram(~disp, data=mtcars)

lattice::bwplot(~disp, data=mtcars)
```

one categorical variable:
```
mosaic::bargraph(~cyl, data=mtcars)
```

two continuous variables:
```
lattice::xyplot(mpg~disp, data=mtcars)
```

two categorical variables:
```
mosaic::bargraph(~am, data=mtcars, group=cyl)
```

one continuous, one categorical:
```
lattice::histogram(~disp|cyl, data=mtcars)

lattice::bwplot(cyl~disp, data=mtcars)
```

The variety of R syntaxes give you many ways to "say" the same thing

read **across** the cheatsheet to see how different syntaxes approach the same problem

Tidyverse syntax

`data %>% goal(x)`

SUMMARY STATISTICS:

one continuous variable:
```
mtcars %>% dplyr::summarize(mean(mpg))
```

one categorical variable:
```
mtcars %>% dplyr::group_by(cyl) %>%
  dplyr::summarize(n())
```

the pipe

two categorical variables:
```
mtcars %>% dplyr::group_by(cyl, am) %>%
  dplyr::summarize(n())
```

one continuous, one categorical:
```
mtcars %>%  dplyr::group_by(cyl) %>%
   dplyr::summarize(mean(mpg))
```

PLOTTING:

one continuous variable:
```
ggplot2::qplot(x=mpg, data=mtcars, geom = "histogram")

ggplot2::qplot(y=disp, x=1, data=mtcars, geom="boxplot")
```

one categorical variable:
```
ggplot2::qplot(x=cyl, data=mtcars, geom="bar")
```

two continuous variables:
```
ggplot2::qplot(x=disp, y=mpg, data=mtcars, geom="point")
```

two categorical variables:
```
ggplot2::qplot(x=factor(cyl), data=mtcars, geom="bar") +
        facet_grid(.~am)
```

one continuous, one categorical:
```
ggplot2::qplot(x=disp, data=mtcars, geom = "histogram") +
        facet_grid(.~cyl)

ggplot2::qplot(y=disp, x=factor(cyl), data=mtcars,
               geom="boxplot")
```

WRANGLING:

subsetting:
```
mtcars %>% dplyr::filter(mpg>30)
```

making a new variable:
```
mtcars <- mtcars %>%
dplyr::mutate(efficient = if_else(mpg>30,  TRUE, FALSE))
```

SMITH COLLEGE

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Pipes %>%

The pipe operator (`%>%`) introduced with the `magrittr` R package allows for the chaining of R operations. It takes the output from the left-hand side and passes it as the first parameter to the function on the right-hand side. In base R, to get the output of a proportional table, you need to first call `table` then `prop.table`.

You can do this in two steps:

```
tab_out <- table(legosets$category)
prop.table(tab_out)
```

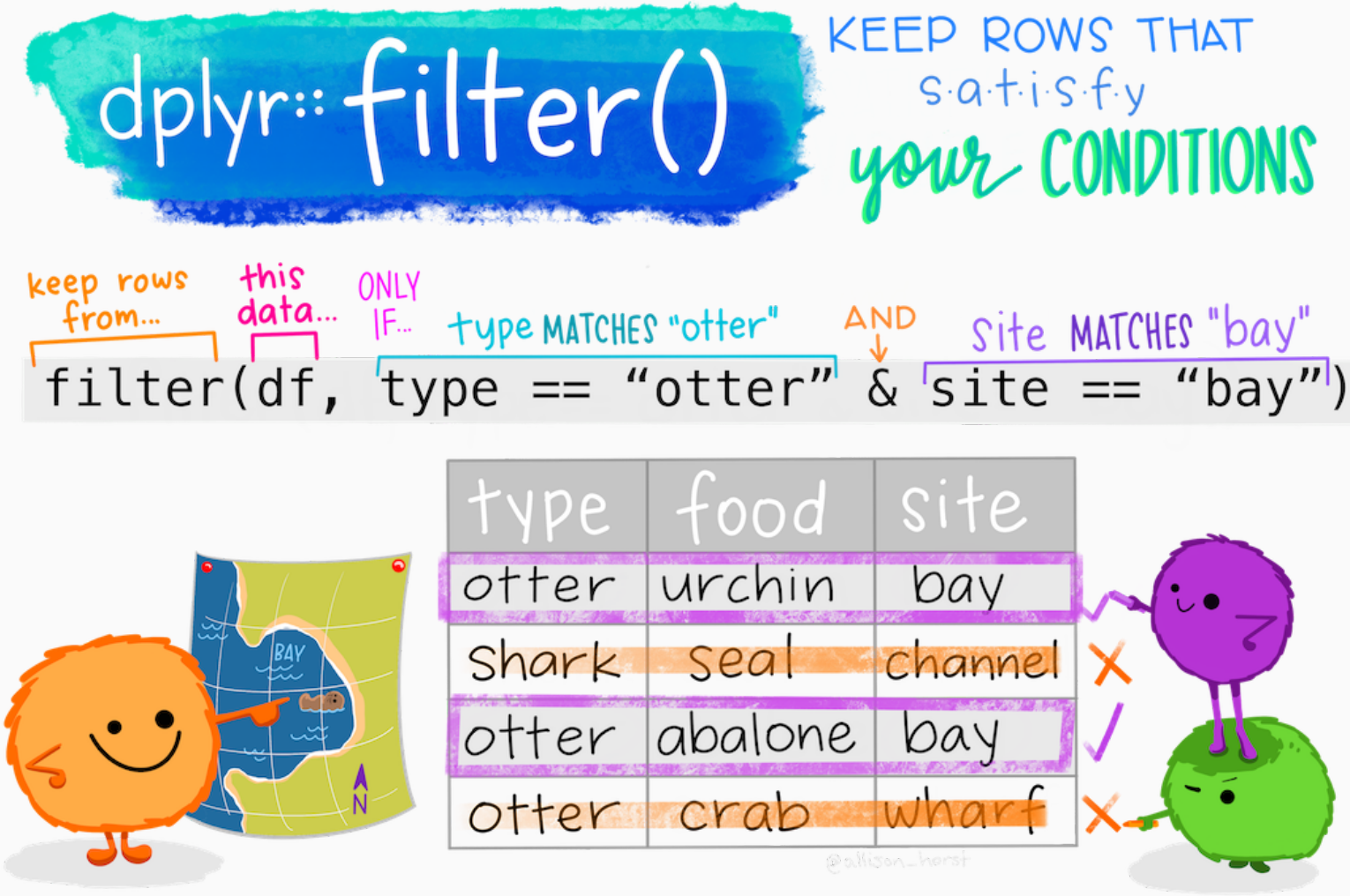
Or as nested function calls.

```
prop.table(table(legosets$category))
```

Using the pipe (`%>%`) operator we can chain these calls in a what is arguably a more readable format:

```
table(legosets$category) %>% prop.table()
```

Filter


dplyr::filter()
KEEP ROWS THAT satisfy your CONDITIONS
keep rows from...
this data...
ONLY IF...
type MATCHES "otter"
AND
site MATCHES "bay"
filter(df, type == "otter" & site == "bay")
BAY
N
type food site
otter urchin bay
shark seal channel
otter abalone bay
otter crab wharf
@allison_horst

Logical Operators

- `!a` - TRUE if a is FALSE
- `a == b` - TRUE if a and be are equal
- `a != b` - TRUE if a and b are not equal
- `a > b` - TRUE if a is larger than b, but not equal
- `a >= b` - TRUE if a is larger or equal to b
- `a < b` - TRUE if a is smaller than be, but not equal
- `a <= b` - TRUE if a is smaller or equal to b
- `a %in% b` - TRUE if a is in b where b is a vector

```
which( letters %in% c('a','e','i','o','u') )
```

```
## [1]  1  5  9 15 21
```

- `a | b` - TRUE if a *or* b are TRUE
- `a & b` - TRUE if a *and* b are TRUE
- `isTRUE(a)` - TRUE if a is TRUE

Filter

dplyr

```
mylego <- legosets %>% filter(themeGroup == 'Educational' & year > 2015)
```

Base R

```
mylego <- legosets[legosets$themeGroups == 'Educaitonal' & legosets$year > 2015,]
```

```
nrow(mylego)
```

```
## [1] 61
```

Select

dplyr

```
mylego <- mylego %>% select(setID, pieces, theme, availability, US_retailPrice, minifigs)
```

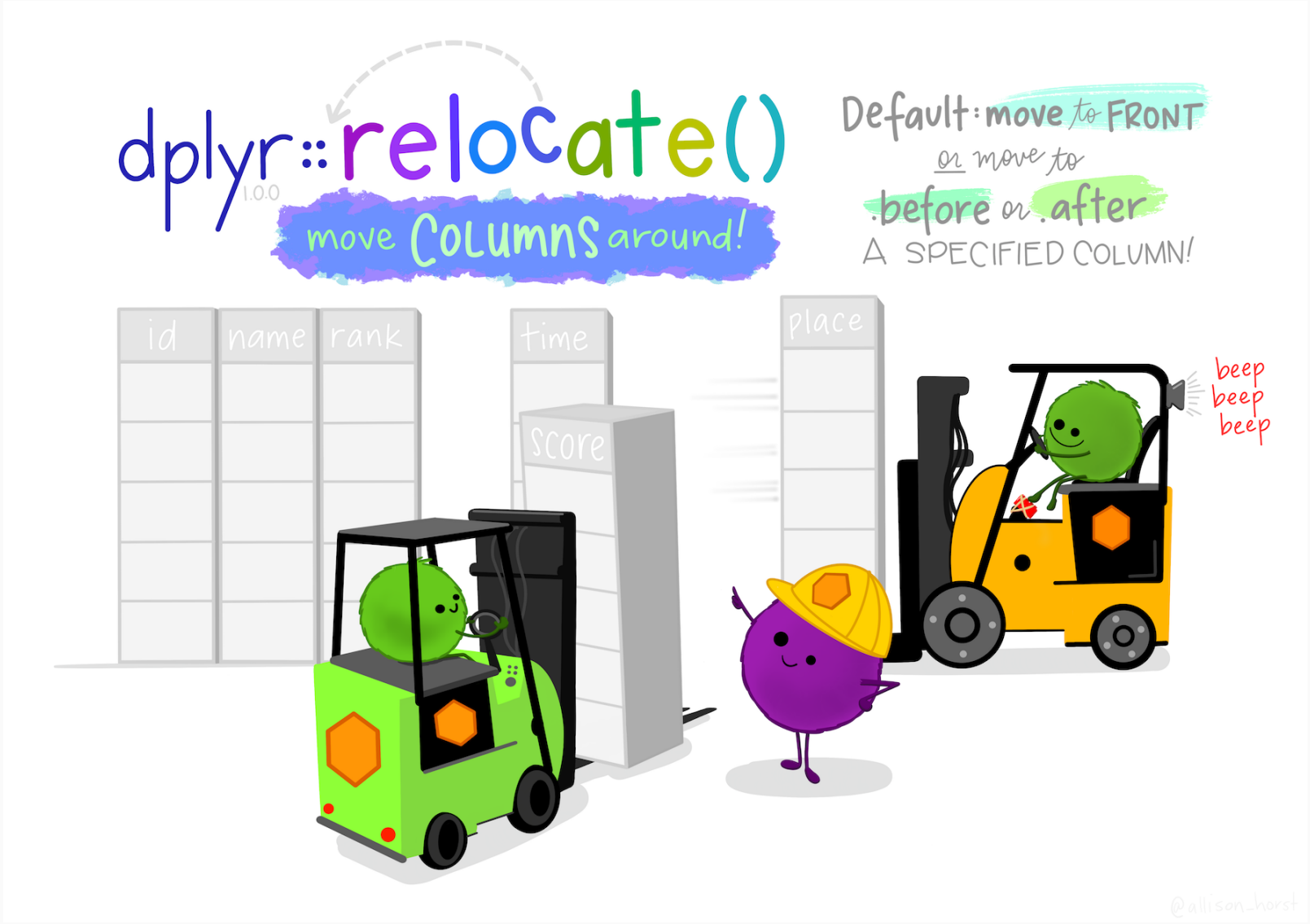
Base R

```
mylego <- mylego[,c('setID', 'pieces', 'theme', 'availability', 'US_retailPrice', 'minifigs')]
```

```
head(mylego, n = 4)
```

```
##   setID pieces     theme    availability US_retailPrice minifigs
## 1 26803    103 Education {Not specified}             NA        6
## 2 26689    142 Education {Not specified}             NA        4
## 3 26804     98 Education {Not specified}             NA        6
## 4 26277    188 Education     Educational          78.95       NA
```

Relocate


dplyr::relocate()
1.0.0
move columns around!
Default: move to FRONT
or move to
.before or .after
A SPECIFIED COLUMN!
id
name
rank
time
score
place
beep
beep
beep
@allison_horst

Relocate

dplyr

```
mylego %>% relocate(where(is.numeric), .after = where(is.character)) %>% head(n = 3)
```

```
##       theme    availability setID pieces US_retailPrice minifigs
## 1 Education {Not specified} 26803    103             NA        6
## 2 Education {Not specified} 26689    142             NA        4
## 3 Education {Not specified} 26804     98             NA        6
```

Base R

```
mylego2 <- mylego[,c('theme', 'availability', 'setID', 'pieces', 'US_retailPrice', 'minifigs')]
head(mylego2, n = 3)
```

```
##       theme    availability setID pieces US_retailPrice minifigs
```

Rename

dplyr::rename()

RENAME COLUMNS*

```
df %>% rename(lair = site)
```

~~species~~ nemesis	status	~~site~~ lair
narwhal	unknown	ocean
chicken	active	coop
pika	active	mountain

*See **rename_with()** to rename using a function.

Rename

dplyr

```
mylego %>% dplyr::rename(USD = US_retailPrice) %>% head(n = 3)
```

```
##   setID pieces     theme    availability USD minifigs
## 1 26803    103 Education {Not specified}  NA        6
## 2 26689    142 Education {Not specified}  NA        4
## 3 26804     98 Education {Not specified}  NA        6
```

Base R

```
names(mylego2)[5] <- 'USD'
head(mylego2, n = 3)
```

```
##       theme    availability setID pieces USD minifigs
```

Mutate

Mutate

dplyr

```
mylego %>% filter(!is.na(pieces) & !is.na(US_retailPrice)) %>%
    mutate(Price_per_piece = US_retailPrice / pieces) %>% head(n = 3)
```

```
##   setID pieces     theme availability US_retailPrice minifigs Price_per_piece
## 1 26277    188 Education  Educational          78.95       NA       0.4199468
## 2 25949    280 Education  Educational         224.95       NA       0.8033929
## 3 25954      1 Education  Educational          14.95       NA      14.9500000
```

Base R

```
mylego2 <- mylego[!is.na(mylego$US_retailPrice) & !is.na(mylego$Price_per_piece),]
mylego2$Price_per_piece <- mylego2$Price_per_piece / mylego2$US_retailPrice
head(mylego2, n = 3)
```

Group By and Summarize

```
legosets %>% group_by(themeGroup) %>% summarize(mean_price = mean(US_retailPrice, na.rm = TRUE),
                                                sd_price = sd(US_retailPrice, na.rm = TRUE),
                                                median_price = median(US_retailPrice, na.rm = TRUE),
                                                n = n(),
                                                missing = sum(is.na(US_retailPrice)))
```

```
## # A tibble: 15 x 6
##    themeGroup       mean_price sd_price median_price     n missing
##  * <chr>                 <dbl>    <dbl>        <dbl> <int>   <int>
##  1 Action/Adventure      31.3     29.9         20.0   1280     462
##  2 Basic                 13.1     12.8          7.99   843     473
##  3 Constraction          15.1     14.0          9.99   501     125
##  4 Educational           89.0    107.          59.7    452     294
##  5 Girls                 23.4     22.6         15.0    677     225
##  6 Historical            25.5     27.7         15.0    473     125
##  7 Junior                18.6     13.2         17.8    228      93
##  8 Licensed              42.9     58.3         25.0   2060     467
##  9 Miscellaneous         14.3     20.8          6.99  4925    2117
## 10 Model making          52.8     65.1         30.0    582     166
## 11 Modern day            31.2     33.7         20.0   1723     763
## 12 Pre-school            23.8     19.4         20.0   1487     699
## 13 Racing                24.8     30.2         10      270      59
## 14 Technical             60.8     68.1         40.0    550     137
```

Describe and Describe By

```
library(psych)
describe(legosets$US_retailPrice)
```

```
##    vars    n  mean sd median trimmed   mad min    max  range skew kurtosis   se
## X1    1 9886 28.52 42  14.99   20.14 14.83   0 799.99 799.99 5.62    58.91 0.42
```

```
describe.by(legosets$US_retailPrice, group = legosets$availability, mat = TRUE, skew = FALSE)
```

```
##      item                group1 vars    n      mean        sd   min    max  range         s
## X11     1       {Not specified}    1 3197  24.24484 36.282072  0.60 789.99 789.39  0.641683
## X12     2           Educational    1    9 140.95000 86.358265 14.95 244.95 230.00 28.786088
## X13     3         LEGO exclusive    1 1066  28.79797 70.954538  0.00 799.99 799.99  2.173209
## X14     4  LEGOLAND exclusive    1    7  12.70429  6.447591  4.99  19.99  15.00  2.436960
## X15     5             Not sold    1    1  12.99000        NA 12.99  12.99   0.00         N
## X16     6           Promotional    1  167   9.19485 23.667555  0.00 249.99 249.99  1.831456
## X17     7 Promotional (Airline)    1   11  15.79455  6.614819  5.00  28.00  23.00  1.994
## X18     8               Retail    1 4824  29.82030 33.270049  1.95 399.99 398.04  0.479015
```


EPSY 630
Spring 2021

Data Visualizations with ggplot2

- `ggplot2` is an R package that provides an alternative framework based upon Wilkinson's (2005) Grammar of Graphics.
- `ggplot2` is, in general, more flexible for creating "prettier" and complex plots.
- Works by creating layers of different types of objects/geometries (i.e. bars, points, lines, polygons, etc.) `ggplot2` has at least three ways of creating plots:
  1. `qplot`
  2. `ggplot(...) + geom_XXX(...) + ...`
  3. `ggplot(...) + layer(...)`
- We will focus only on the second.

Parts of a ggplot2 Statement

- Data

  `ggplot(myDataFrame, aes(x=x, y=y))`
- Layers

  `geom_point()`, `geom_histogram()`
- Facets

  `facet_wrap(~ cut)`, `facet_grid(~ cut)`
- Scales

  `scale_y_log10()`
- Other options

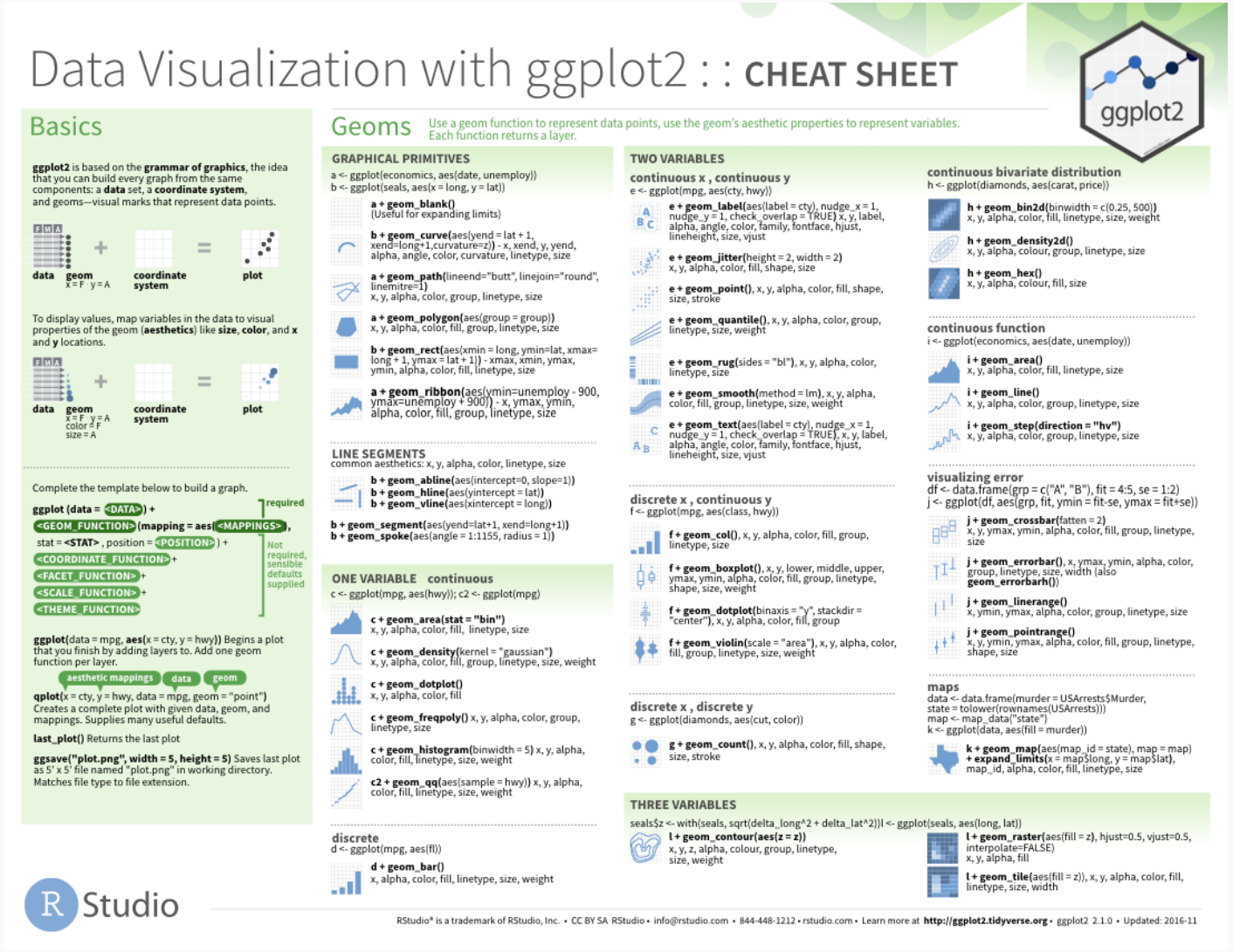
  `ggtitle('my title')`, `ylim(c(0, 10000))`, `xlab('x-axis label')`

Lots of geoms

```
ls('package:ggplot2')[grep('^geom_', ls('package:ggplot2'))]
```

```
##  [1] "geom_abline"           "geom_area"           "geom_bar"                "geom_bin2d
##  [5] "geom_blank"            "geom_boxplot"        "geom_col"                "geom_contc
##  [9] "geom_contour_filled"   "geom_count"          "geom_crossbar"           "geom_curve
## [13] "geom_density"          "geom_density_2d"     "geom_density_2d_filled"  "geom_dens
## [17] "geom_density2d_filled" "geom_dotplot"        "geom_errorbar"           "geom_erro
## [21] "geom_freqpoly"         "geom_function"       "geom_hex"                "geom_histc
## [25] "geom_hline"            "geom_jitter"         "geom_label"              "geom_line"
## [29] "geom_linerange"        "geom_map"            "geom_path"               "geom_poin
## [33] "geom_pointrange"       "geom_polygon"        "geom_qq"                 "geom_qq_l
## [37] "geom_quantile"         "geom_raster"         "geom_rect"               "geom_ribbc
## [41] "geom_rug"              "geom_segment"        "geom_sf"                 "geom_sf_la
## [45] "geom_sf_text"          "geom_smooth"         "geom_spoke"              "geom_step"
## [49] "geom_text"             "geom_tile"           "geom_violin"             "geom_vline
```

Data Visualization Cheat Sheet



Data Visualization with ggplot2 : : CHEAT SHEET

Basics

ggplot2 is based on the **grammar of graphics**, the idea that you can build every graph from the same components: a **data** set, a **coordinate system**, and geoms—visual marks that represent data points.

data | geom (x = F, y = A) | coordinate system | plot

To display values, map variables in the data to visual properties of the geom (**aesthetics**) like **size**, **color**, and **x** and **y** locations.

data | geom (x = F, y = A, color = F, size = A) | coordinate system | plot

Complete the template below to build a graph.

```
ggplot (data = <DATA>) +                                  required
<GEOM_FUNCTION> (mapping = aes(<MAPPINGS>),
 stat = <STAT> , position = <POSITION> ) +                Not required, sensible defaults supplied
<COORDINATE_FUNCTION> +
<FACET_FUNCTION> +
<SCALE_FUNCTION> +
<THEME_FUNCTION>
```

ggplot(data = mpg, **aes**(x = cty, y = hwy)) Begins a plot that you finish by adding layers to. Add one geom function per layer.

aesthetic mappings | data | geom

qplot(x = cty, y = hwy, data = mpg, geom = "point") Creates a complete plot with given data, geom, and mappings. Supplies many useful defaults.

last_plot() Returns the last plot

ggsave("plot.png", width = 5, height = 5) Saves last plot as 5' x 5' file named "plot.png" in working directory. Matches file type to file extension.

Geoms

Use a geom function to represent data points, use the geom's aesthetic properties to represent variables. Each function returns a layer.

GRAPHICAL PRIMITIVES

a <- ggplot(economics, aes(date, unemploy))
b <- ggplot(seals, aes(x = long, y = lat))

a + geom_blank() (Useful for expanding limits)

b + geom_curve(aes(yend = lat + 1, xend=long+1,curvature=z)) - x, xend, y, yend, alpha, angle, color, curvature, linetype, size

a + geom_path(lineend="butt", linejoin="round", linemitre=1) x, y, alpha, color, group, linetype, size

a + geom_polygon(aes(group = group)) x, y, alpha, color, fill, group, linetype, size

b + geom_rect(aes(xmin = long, ymin=lat, xmax= long + 1, ymax = lat + 1)) - xmax, xmin, ymax, ymin, alpha, color, fill, linetype, size

a + geom_ribbon(aes(ymin=unemploy - 900, ymax=unemploy + 900)) - x, ymax, ymin, alpha, color, fill, group, linetype, size

LINE SEGMENTS

common aesthetics: x, y, alpha, color, linetype, size

b + geom_abline(aes(intercept=0, slope=1))
b + geom_hline(aes(yintercept = lat))
b + geom_vline(aes(xintercept = long))

b + geom_segment(aes(yend=lat+1, xend=long+1))
b + geom_spoke(aes(angle = 1:1155, radius = 1))

ONE VARIABLE continuous

c <- ggplot(mpg, aes(hwy)); c2 <- ggplot(mpg)

c + geom_area(stat = "bin") x, y, alpha, color, fill, linetype, size

c + geom_density(kernel = "gaussian") x, y, alpha, color, fill, group, linetype, size, weight

c + geom_dotplot() x, y, alpha, color, fill

c + geom_freqpoly() x, y, alpha, color, group, linetype, size

c + geom_histogram(binwidth = 5) x, y, alpha, color, fill, linetype, size, weight

c2 + geom_qq(aes(sample = hwy)) x, y, alpha, color, fill, linetype, size, weight

discrete

d <- ggplot(mpg, aes(fl))

d + geom_bar() x, alpha, color, fill, linetype, size, weight

TWO VARIABLES

continuous x , continuous y

e <- ggplot(mpg, aes(cty, hwy))

e + geom_label(aes(label = cty), nudge_x = 1, nudge_y = 1, check_overlap = TRUE) x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

e + geom_jitter(height = 2, width = 2) x, y, alpha, color, fill, shape, size

e + geom_point(), x, y, alpha, color, fill, shape, size, stroke

e + geom_quantile(), x, y, alpha, color, group, linetype, size, weight

e + geom_rug(sides = "bl"), x, y, alpha, color, linetype, size

e + geom_smooth(method = lm), x, y, alpha, color, fill, group, linetype, size, weight

e + geom_text(aes(label = cty), nudge_x = 1, nudge_y = 1, check_overlap = TRUE), x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

discrete x , continuous y

f <- ggplot(mpg, aes(class, hwy))

f + geom_col(), x, y, alpha, color, fill, group, linetype, size

f + geom_boxplot(), x, y, lower, middle, upper, ymax, ymin, alpha, color, fill, group, linetype, shape, size, weight

f + geom_dotplot(binaxis = "y", stackdir = "center"), x, y, alpha, color, fill, group

f + geom_violin(scale = "area"), x, y, alpha, color, fill, group, linetype, size, weight

discrete x , discrete y

g <- ggplot(diamonds, aes(cut, color))

g + geom_count(), x, y, alpha, color, fill, shape, size, stroke

continuous bivariate distribution

h <- ggplot(diamonds, aes(carat, price))

h + geom_bin2d(binwidth = c(0.25, 500)) x, y, alpha, color, fill, linetype, size, weight

h + geom_density2d() x, y, alpha, colour, group, linetype, size

h + geom_hex() x, y, alpha, colour, fill, size

continuous function

i <- ggplot(economics, aes(date, unemploy))

i + geom_area() x, y, alpha, color, fill, linetype, size

i + geom_line() x, y, alpha, color, group, linetype, size

i + geom_step(direction = "hv") x, y, alpha, color, group, linetype, size

visualizing error

df <- data.frame(grp = c("A", "B"), fit = 4:5, se = 1:2)
j <- ggplot(df, aes(grp, fit, ymin = fit-se, ymax = fit+se))

j + geom_crossbar(fatten = 2) x, y, ymax, ymin, alpha, color, fill, group, linetype, size

j + geom_errorbar(), x, ymax, ymin, alpha, color, group, linetype, size, width (also **geom_errorbarh()**)

j + geom_linerange() x, ymin, ymax, alpha, color, group, linetype, size

j + geom_pointrange() x, y, ymin, ymax, alpha, color, fill, group, linetype, shape, size

maps

data <- data.frame(murder = USArrests$Murder, state = tolower(rownames(USArrests)))
map <- map_data("state")
k <- ggplot(data, aes(fill = murder))

k + geom_map(aes(map_id = state), map = map) **+ expand_limits**(x = map$long, y = map$lat), map_id, alpha, color, fill, linetype, size

THREE VARIABLES

seals$z <- with(seals, sqrt(delta_long^2 + delta_lat^2))l <- ggplot(seals, aes(long, lat))

l + geom_contour(aes(z = z)) x, y, z, alpha, colour, group, linetype, size, weight

l + geom_raster(aes(fill = z), hjust=0.5, vjust=0.5, interpolate=FALSE) x, y, alpha, fill

l + geom_tile(aes(fill = z)), x, y, alpha, color, fill, linetype, size, width

Scatterplot

```
ggplot(legosets, aes(x=pieces, y=US_retailPrice)) + geom_point()
```

Scatterplot (cont.)

```
ggplot(legosets, aes(x=pieces, y=US_retailPrice, color=availability)) + geom_point()
```

Scatterplot (cont.)

```
ggplot(legosets, aes(x=pieces, y=US_retailPrice, size=minifigs, color=availability)) + geom_pc
```

Scatterplot (cont.)

```
ggplot(legosets, aes(x=pieces, y=US_retailPrice, size=minifigs)) + geom_point() + facet_wrap(~
```

Boxplots

```
ggplot(legosets, aes(x='Lego', y=US_retailPrice)) + geom_boxplot()
```

Boxplots (cont.)

```
ggplot(legosets, aes(x=availability, y=US_retailPrice)) + geom_boxplot()
```

Boxplot (cont.)

```
ggplot(legosets, aes(x=availability, y=US_retailPrice)) + geom_boxplot() + coord_flip()
```

Histograms

```
ggplot(legosets, aes(x = US_retailPrice)) + geom_histogram()
```

Histograms (cont.)

```
ggplot(legosets, aes(x = US_retailPrice)) + geom_histogram() + scale_x_log10()
```

Histograms (cont.)

```
ggplot(legosets, aes(x = US_retailPrice)) + geom_histogram() + facet_wrap(~ availability)
```

Density Plots

```
ggplot(legosets, aes(x = US_retailPrice, color = availability)) + geom_density()
```

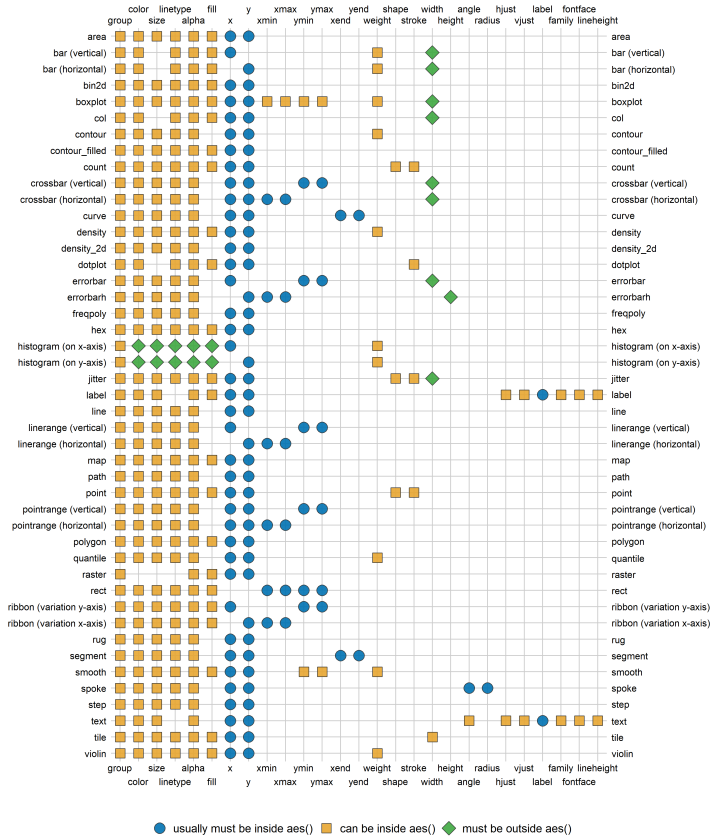
ggplot2 aesthetics

ggplot2 aesthetics cheat sheet

Use this table to find the right aesthetics for your geoms:

Aesthetics that usually must be mapped to the data: use inside aes()
Aesthetics that can be mapped to the data: use in or outside aes()
Aesthetics that cannot be mapped to the data: use outside aes()

e.g., ggplot(mpg, aes(x = class, y = displ)) + geom_col(aes(fill = class), width = .9)



idea and design: Christian Burkhart
design advice: Ida Aarnio

Likert Scales

Likert scales are a type of questionaire where respondents are asked to rate items on scales usually ranging from four to seven levels (e.g. strongly disagree to strongly agree).

```
library(likert)
library(reshape)
data(pisaitems)
items24 <- pisaitems[,substr(names(pisaitems), 1,5) == 'ST24Q']
items24 <- rename(items24, c(
            ST24Q01="I read only if I have to.",
            ST24Q02="Reading is one of my favorite hobbies.",
            ST24Q03="I like talking about books with other people.",
            ST24Q04="I find it hard to finish books.",
            ST24Q05="I feel happy if I receive a book as a present.",
            ST24Q06="For me, reading is a waste of time.",
            ST24Q07="I enjoy going to a bookstore or a library.",
            ST24Q08="I read only to get information that I need.",
            ST24Q09="I cannot sit still and read for more than a few minutes.",
            ST24Q10="I like to express my opinions about books I have read.",
```

likert R Package

```
l24 <- likert(items24)
summary(l24)
```

```
##                                                        Item      low neutral     high     n
## 10   I like to express my opinions about books I have read. 41.07516       0 58.92484 2.604
## 5            I feel happy if I receive a book as a present. 46.93475       0 53.06525 2.466
## 8               I read only to get information that I need. 50.39874       0 49.60126 2.484
## 7                I enjoy going to a bookstore or a library. 51.21231       0 48.78769 2.428
## 3             I like talking about books with other people. 54.99129       0 45.00871 2.328
## 11               I like to exchange books with my friends. 55.54115       0 44.45885 2.343
## 2                   Reading is one of my favorite hobbies. 56.64470       0 43.35530 2.344
## 1                                I read only if I have to. 58.72868       0 41.27132 2.291
## 4                           I find it hard to finish books. 65.35125       0 34.64875 2.178
## 9  I cannot sit still and read for more than a few minutes. 76.24524       0 23.75476 1.974
## 6                       For me, reading is a waste of time. 82.88729       0 17.11271 1.810
```

likert Plots

```
plot(l24)
```

likert Plots

```
plot(l24, type='heat')
```

likert Plots

```
plot(l24, type='density')
```

Dual Scales

Some problems[1]:

- The designer has to make choices about scales and this can have a big impact on the viewer
- "Cross-over points" where one series cross another are results of the design choices, not intrinsic to the data, and viewers (particularly unsophisticated viewers)
- They make it easier to lazily associate correlation with causation, not taking into account autocorrelation and other time-series issues
- Because of the issues above, in malicious hands they make it possible to deliberately mislead

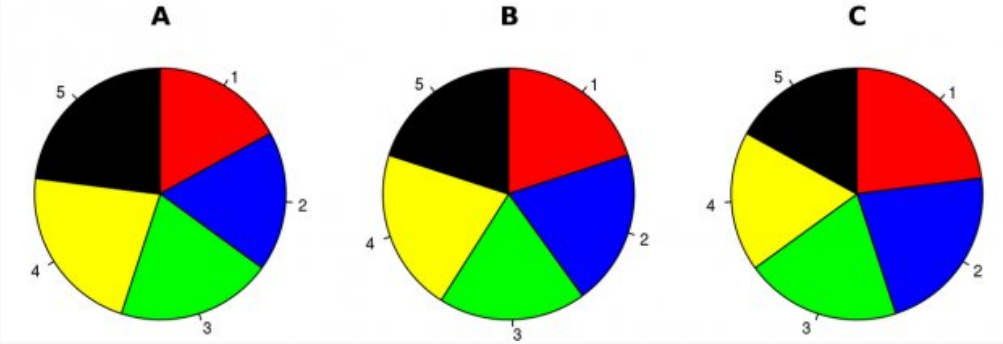
This example looks at the relationship between NZ dollar exchange rate and trade weighted index.

```
DATA606::shiny_demo('DualScales', package='DATA606')
```

My advise:

Pie Charts

There is only one pie chart in *OpenIntro Statistics* (Diez, Barr, & Çetinkaya-Rundel, 2015, p. 48). Consider the following three pie charts that represent the preference of five different colors. Is there a difference between the three pie charts? This is probably a difficult to answer.



Pie Charts

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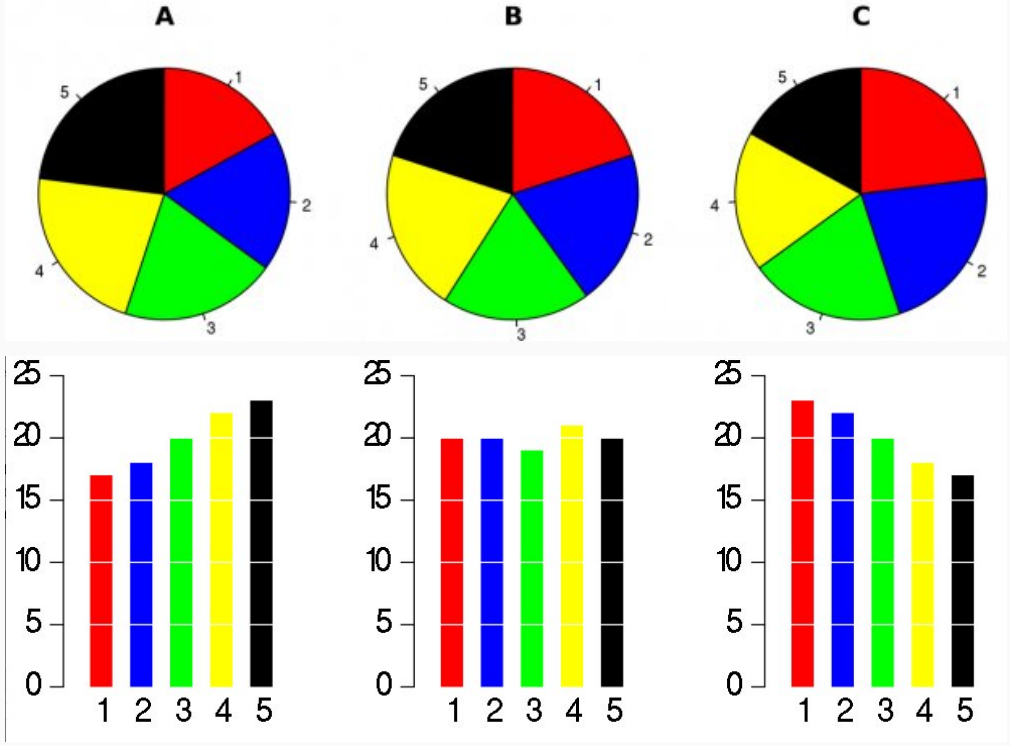

"There is no data that can be displayed in a pie chart that cannot better be displayed in some other type of chart"

John Tukey

Additional Resources

For data wrangling:

- `dplyr` website: https://dplyr.tidyverse.org
- R for Data Science book: https://r4ds.had.co.nz/wrangle-intro.html
- Wrangling penguins tutorial: https://allisonhorst.shinyapps.io/dplyr-learnr/#section-welcome
- Data transformation cheat sheet: https://github.com/rstudio/cheatsheets/raw/master/data-transformation.pdf

For data visualization:

- `ggplot2` website: https://ggplot2.tidyverse.org
- R for Data Science book: https://r4ds.had.co.nz/data-visualisation.html
- R Graphics Cookbook: https://r-graphics.org
- Data visualization cheat sheet: https://github.com/rstudio/cheatsheets/raw/master/data-visualization-2.1.pdf

One Minute Paper

Complete the one minute paper:

https://forms.gle/yB3ds6MYE89Z1pURA

1. What was the most important thing you learned during this class?
2. What important question remains unanswered for you?