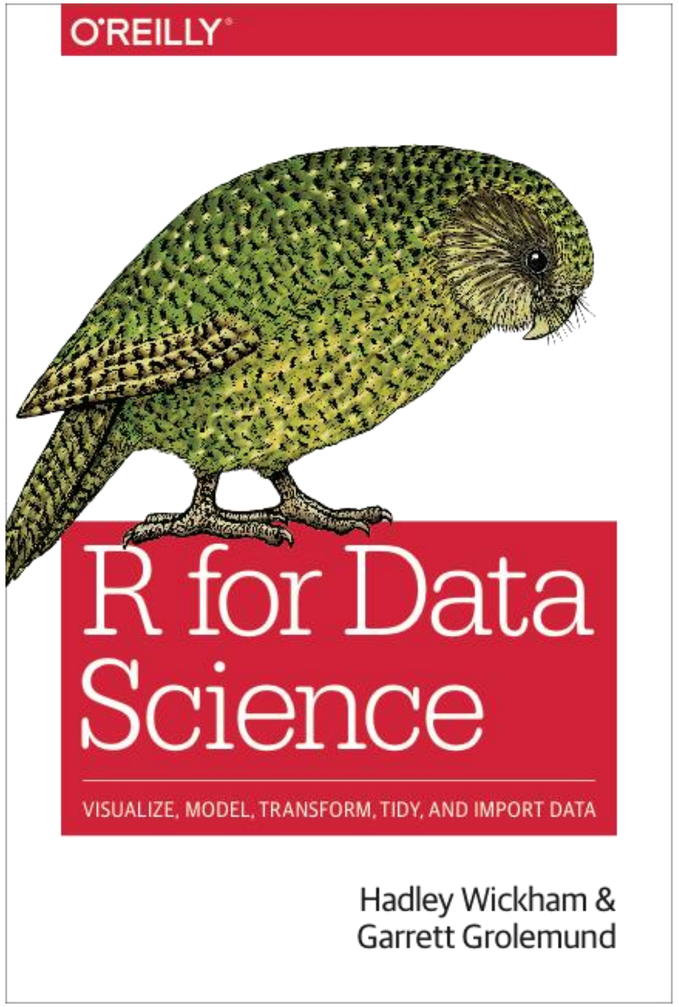
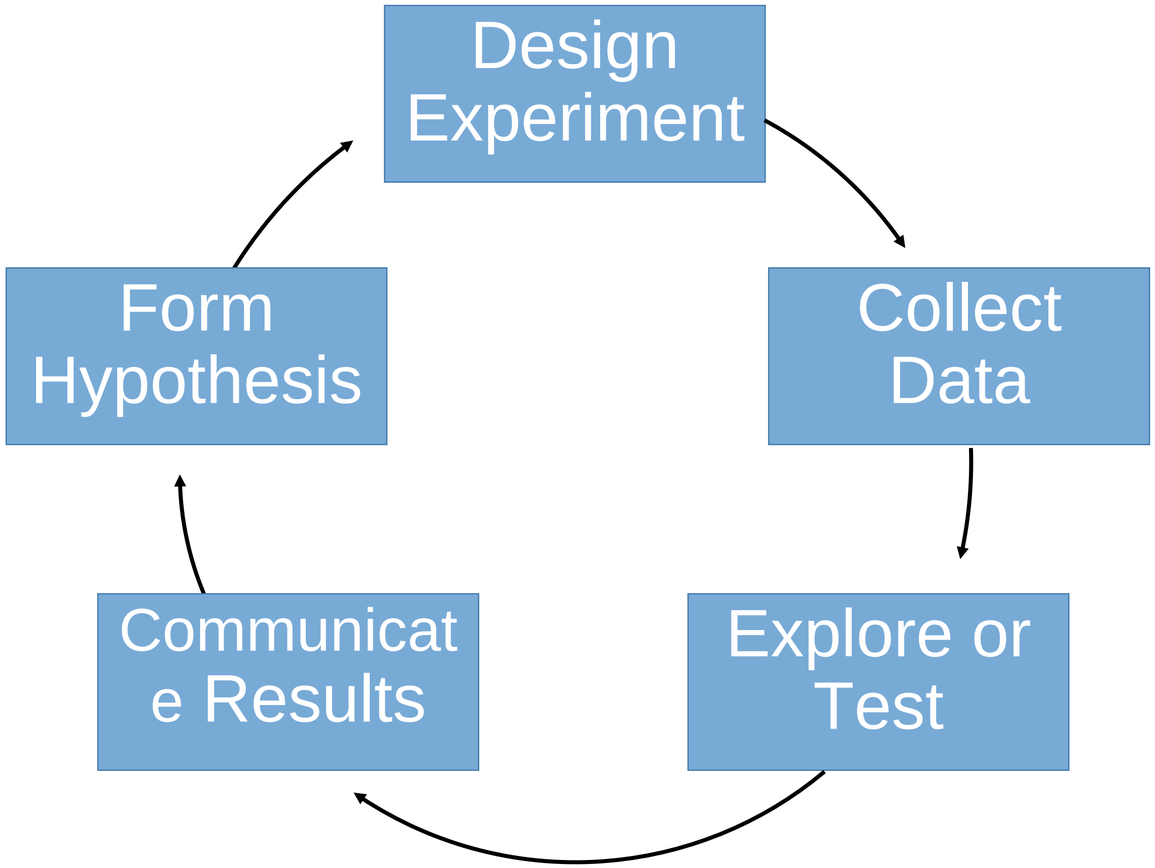
Transforming Data & Data Visualization

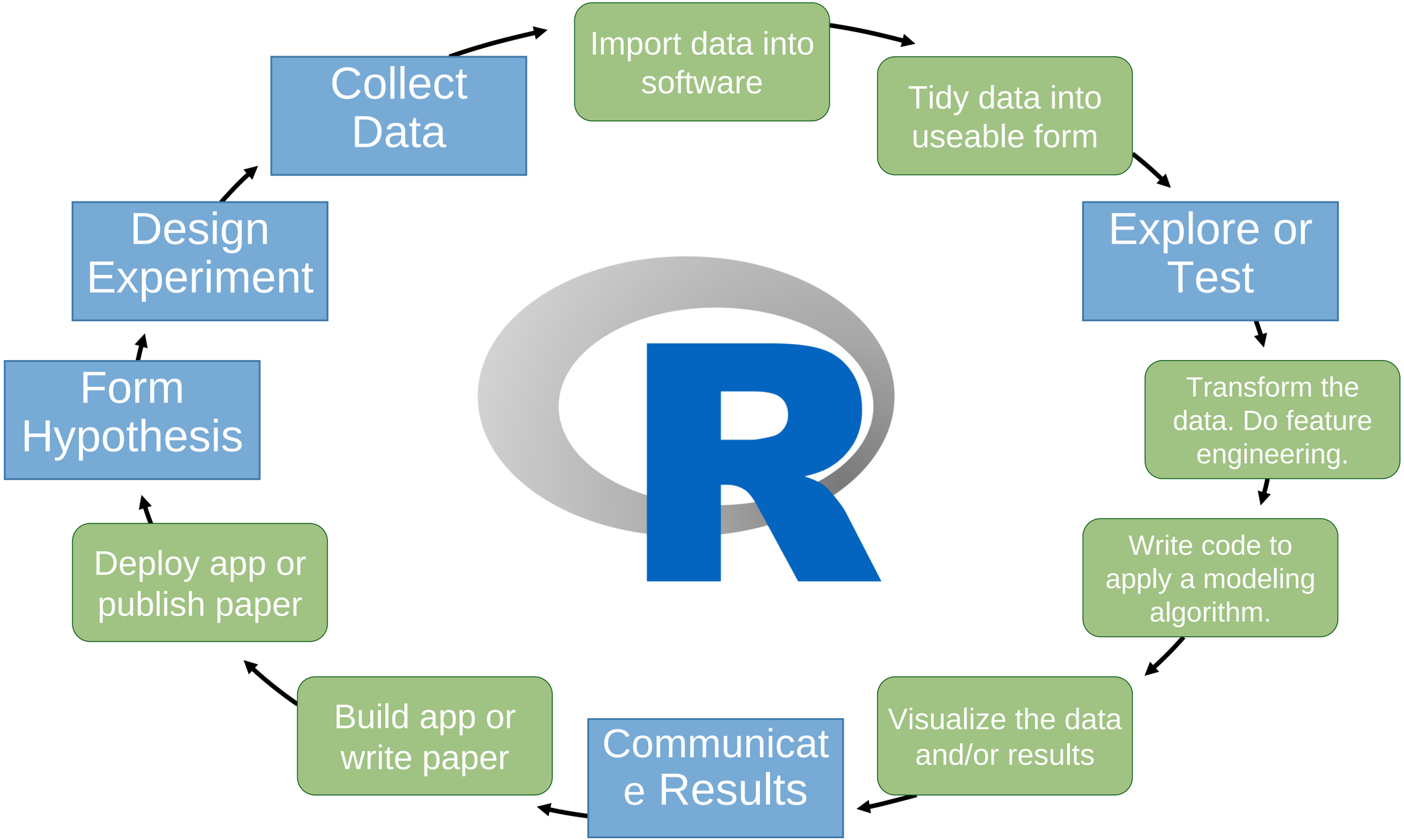
Art by Lou Pimentel



https://github.com/rstudio/RStartHere

"Data Science"



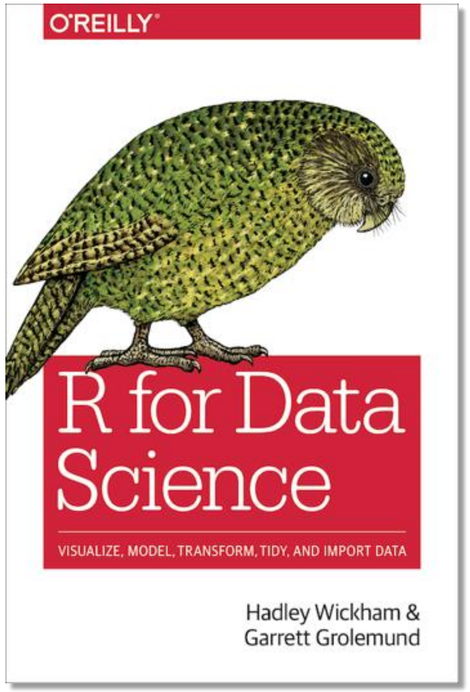


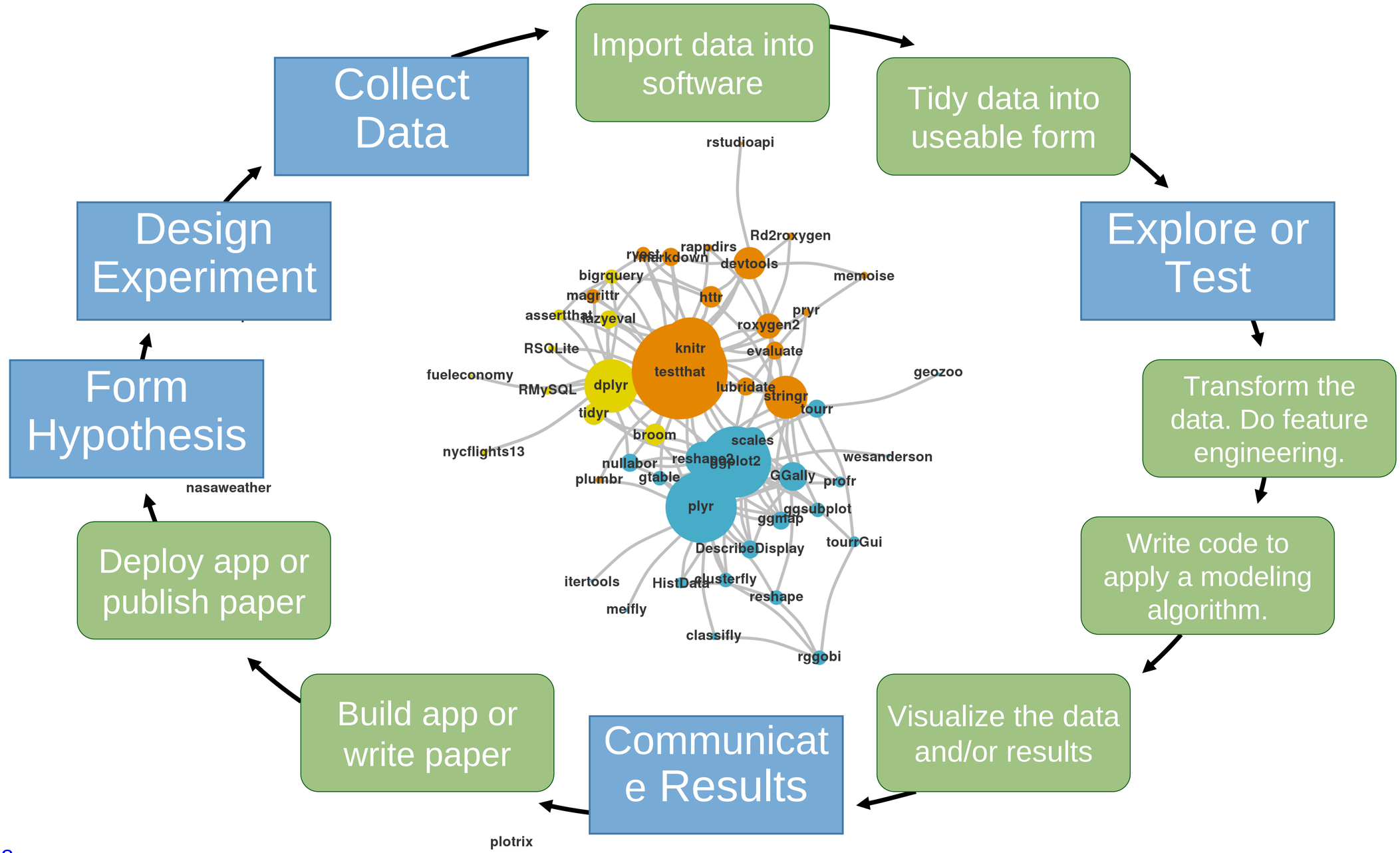
Tidyverse

A collection of R packages that share common philosophies and are designed to work together.

tidyverse.org

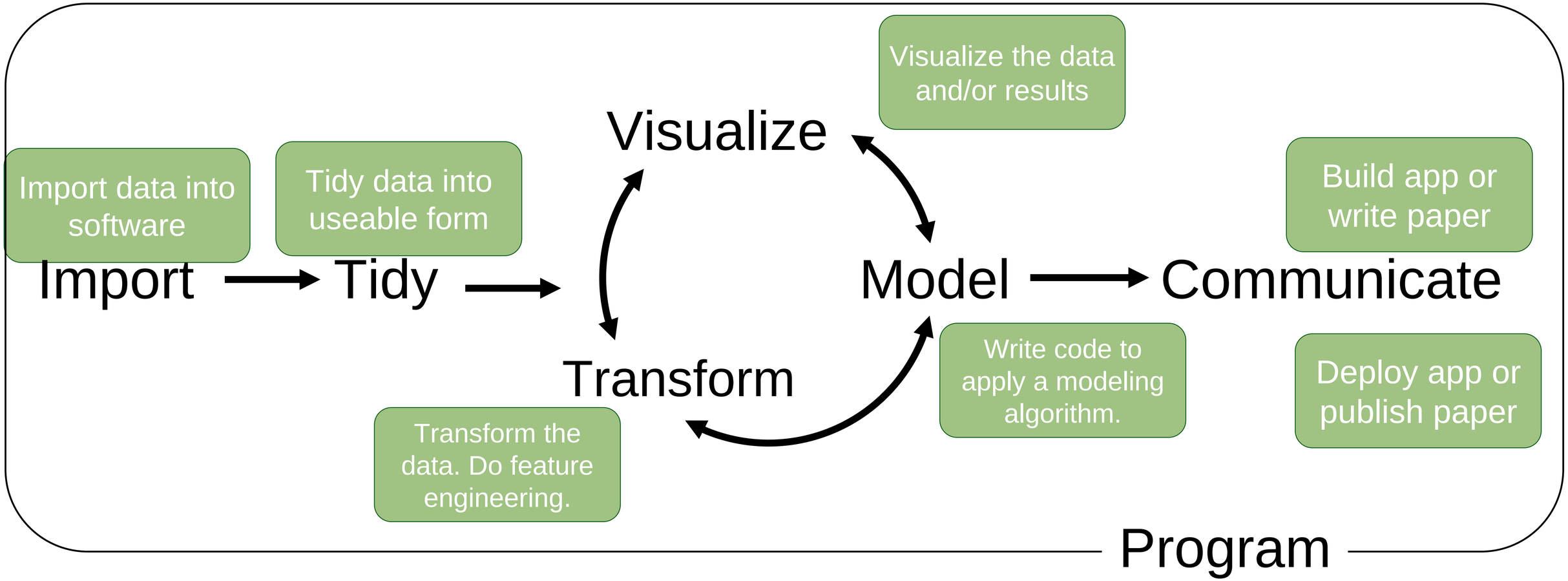
install.packages("tidyverse")
library(tidyverse)



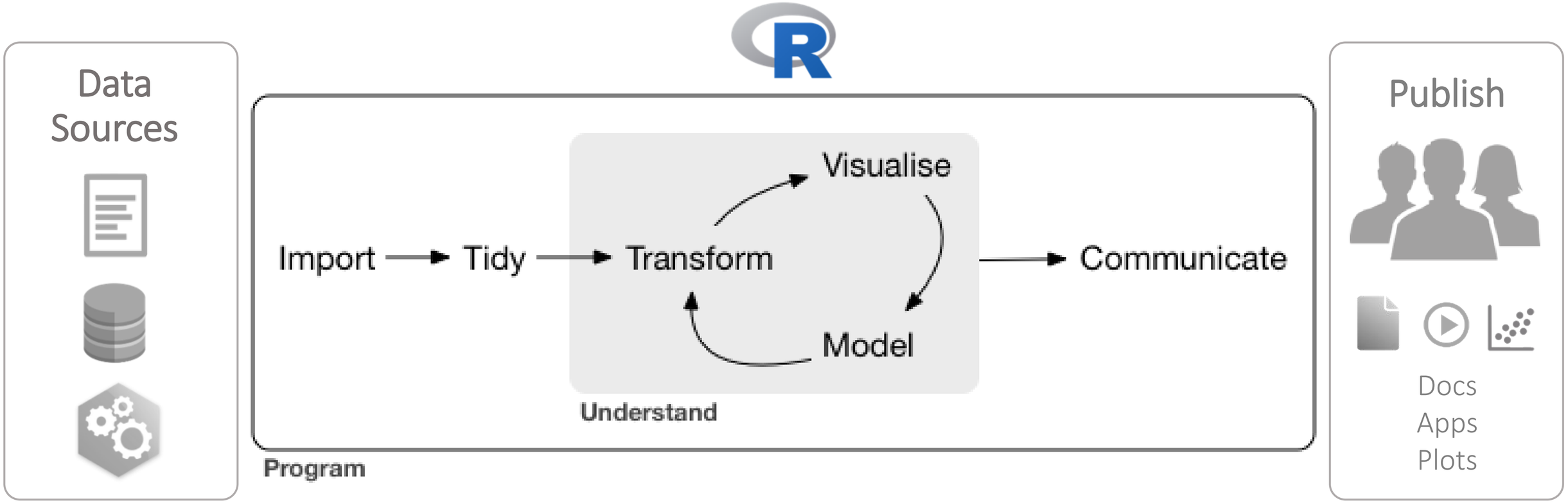


Display by Adolfo Álvarez

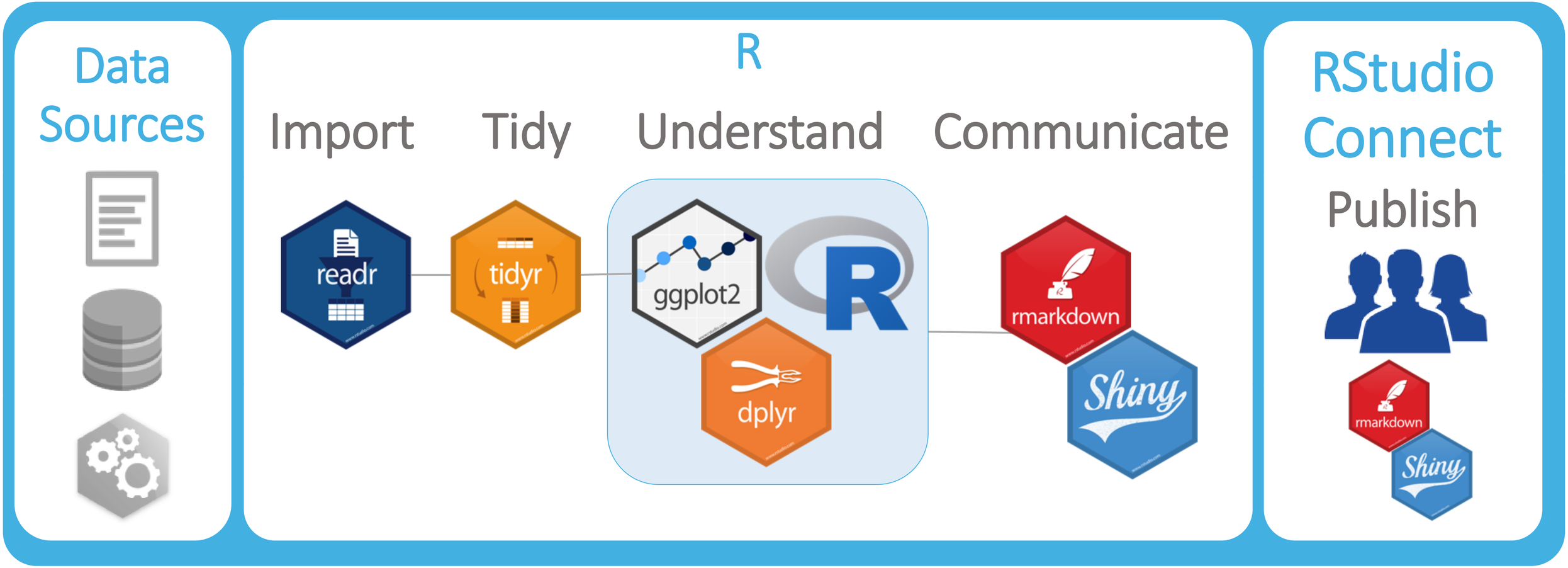
(Applied) Data Science



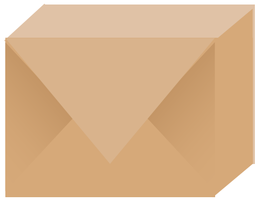
A Typical Data Science Project



R for Data Science Toolchain



tidyverse



An R package that serves as a short cut for installing and loading the components of the tidyverse.

```
install.packages("tidyverse")
```

does the equivalent of

```
install.packages("ggplot2")
install.packages("dplyr")
install.packages("tidyr")
install.packages("readr")
install.packages("purrr")
install.packages("tibble")
install.packages("hms")
install.packages("stringr")
install.packages("lubridate")
install.packages("forcats")
install.packages("DBI")
install.packages("haven")
install.packages("httr")
install.packages("jsonlite")
install.packages("readxl")
install.packages("rvest")
install.packages("xml2")
install.packages("modelr")
install.packages("broom")
```

```
install.packages("tidyverse")
```

does the equivalent of

```
install.packages("ggplot2")
install.packages("dplyr")
install.packages("tidyr")
install.packages("readr")
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install.packages("jsonlite")
install.packages("readxl")
install.packages("rvest")
install.packages("xml2")
install.packages("modelr")
install.packages("broom")
```
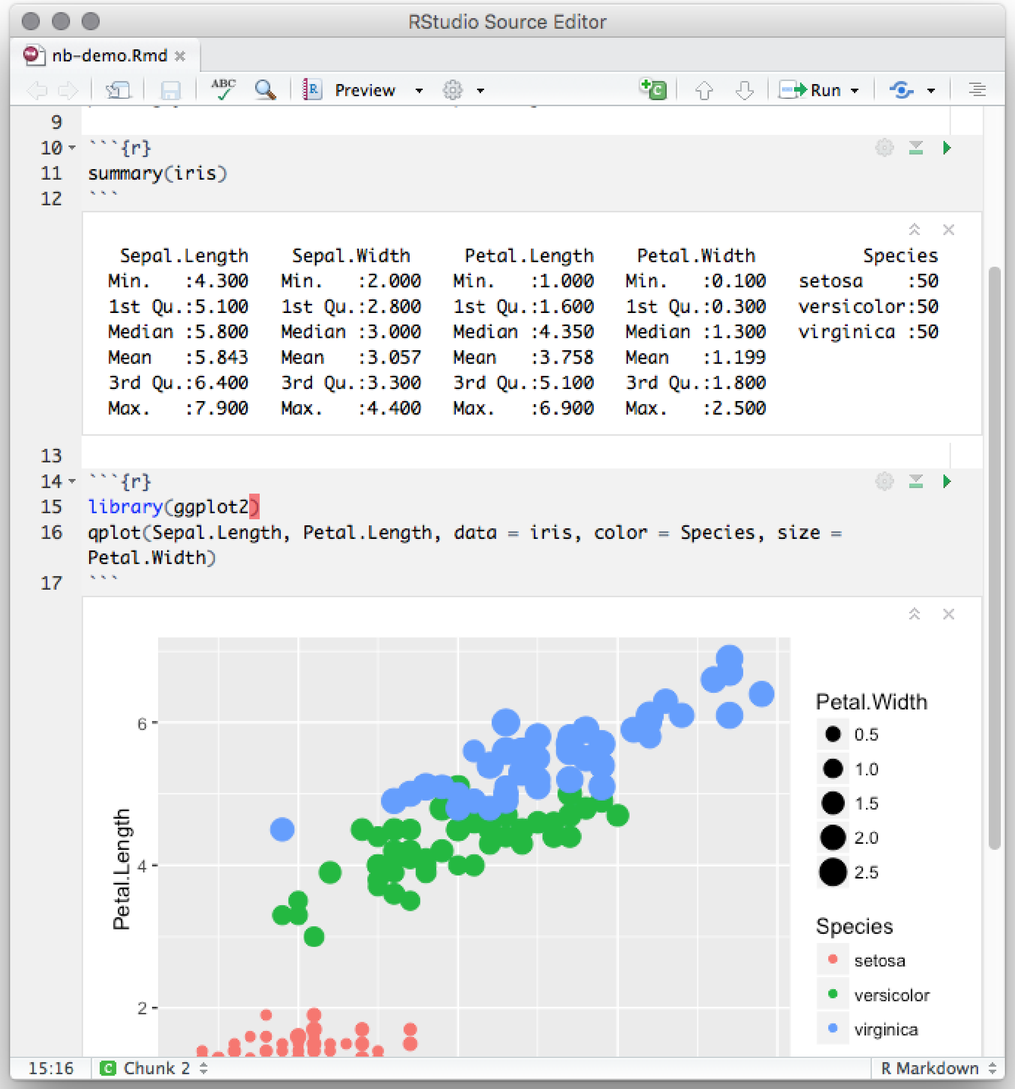

```
library("tidyverse")
```

does the equivalent of

```
library("ggplot2")
library("dplyr")
library("tidyr")
library("readr")
library("purrr")
library("tibble")
```

Notebooks



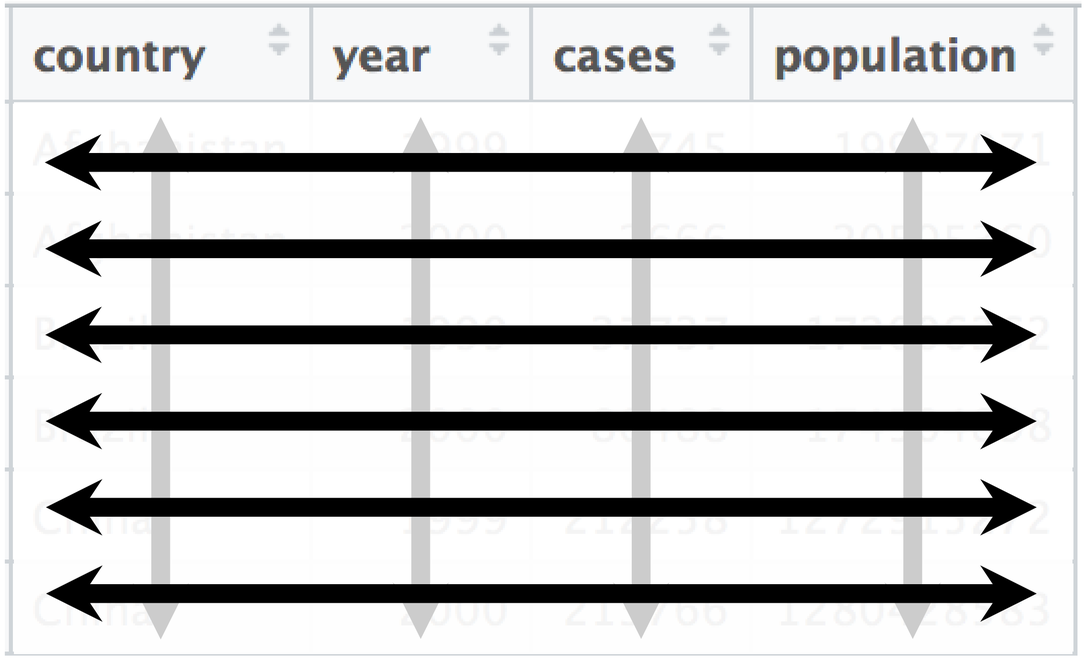
Combine in a single document:

- Narrative
- Code
- Output

Then Render to HTML

tibbles

Tidy data



A data set is tidy iff:

1. It is a data frame (e.g. tibble)
2. Each variable is in its own column
3. Each case is in its own row

Standardized framework allows your data to fit nicely into the APIs provided by base R and other key packages

Examining data frames in base R can be a challenge…

```
dim(iris)
str(iris)
iris
```

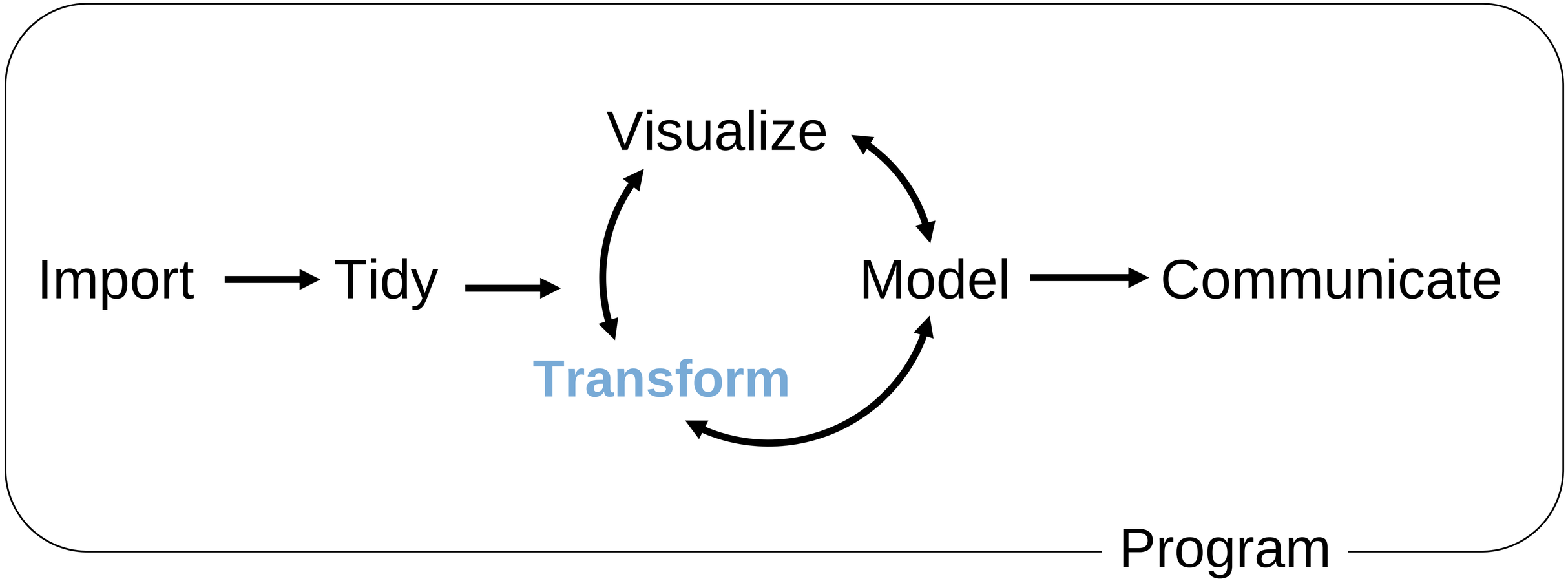
Coerce a data frame to a tibble, now it's pretty!...


```
tibble_iris <- tbl_df(iris)
tibble_iris
```

Or

```
tibble(treatment = sample(letters, 10),
       expression_value = rnorm(10, 100, 10))
```

(Applied) Data Science



tibbles

A type of data frame common throughout tidyverse packages.
Tibbles enhance data frames in three ways:

1. Subsetting - [always returns a new tibble, [[and $ always return a new vector
2. No partial matching - You must use full column names when subsetting
3. Display - When you print a tibble, R provides a concise view of the data that fits on one screen

tibble

A package with several helper functions for tibbles:

- as_tibble() - convert a data frame to a tibble
- as.data.frame() - convert a tibble to a data frame
- tribble() - make a tibble (transversed)

```
tribble(
   ~x,  ~y,
    1, "a",
    2, "b",
    3, "c")
```

x	y
1	a
2	b
3	c

babynames

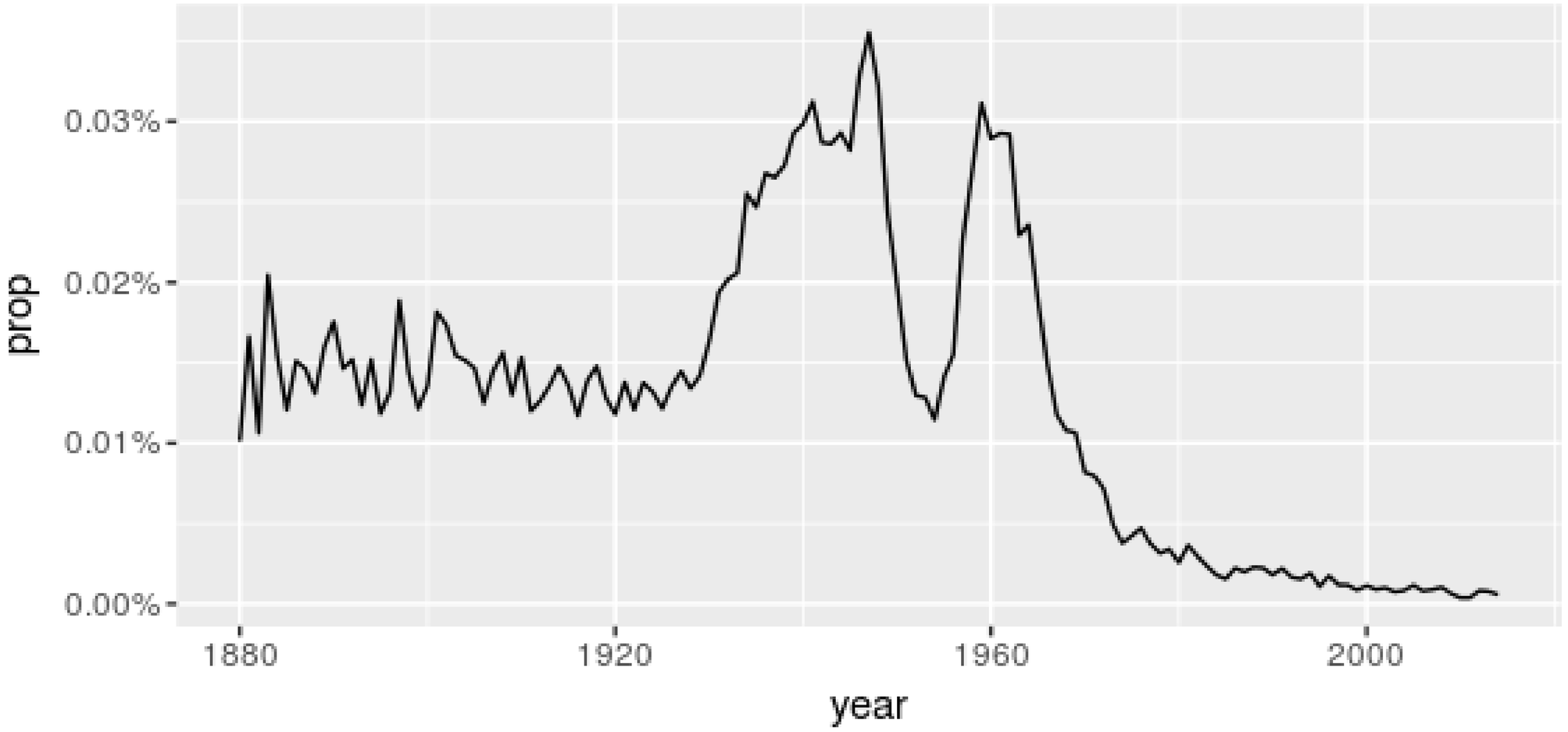
Names of male and female babies born in the US from 1880 to 2008. 1.8M rows.

```
# install.packages("babynames")
library(babynames)
```

View(babynames)

	year	sex	name	n	prop
1	1880	F	Mary	7065	0.0723835869
2	1880	F	Anna	2604	0.0266789611
3	1880	F	Emma	2003	0.0205214897
4	1880	F	Elizabeth	1939	0.0198657856
5	1880	F	Minnie	1746	0.0178884278
6	1880	F	Margaret	1578	0.0161672045
7	1880	F	Ida	1472	0.0150811946
8	1880	F	Alice	1414	0.0144869628
9	1880	F	Bertha	1320	0.0135238973
10	1880	F	Sarah	1288	0.0131960453
11	1880	F	Annie	1258	0.0128886840

Proportion of boys with the name Phil

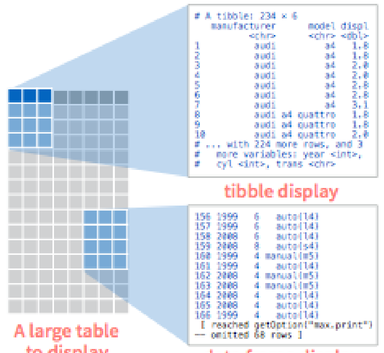


tibbles

Tibbles - an enhanced data frame

The **tibble** package provides a new S3 class for storing tabular data, the tibble. Tibbles inherit the data frame class, but improve two behaviors:

- **Display** - When you print a tibble, R provides a concise view of the data that fits on one screen.
- **Subsetting** - [always returns a new tibble, [[and $ always return a vector.
- **No partial matching** - You must use full column names when subsetting



- Control the default appearance with options:

  options(tibble.print_max = n, tibble.print_min = m, tibble.width = Inf)

- View entire data set with **View**(x, title) or **glimpse**(x, width = NULL, …)
- Revert to data frame with **as.data.frame()** (required for some older packages)

Construct a tibble in two ways

Both make this tibble

tibble(…)
Construct by columns.

```
tibble(x = 1:3,
       y = c("a", "b", "c"))
```

tribble(…)
Construct by rows.

```
tribble(
  ~x, ~y,
   1, "a",
   2, "b",
   3, "c")
```

```
A tibble: 3 × 2
      x     y
  <int> <dbl>
1     1     a
2     2     b
3     3     c
```

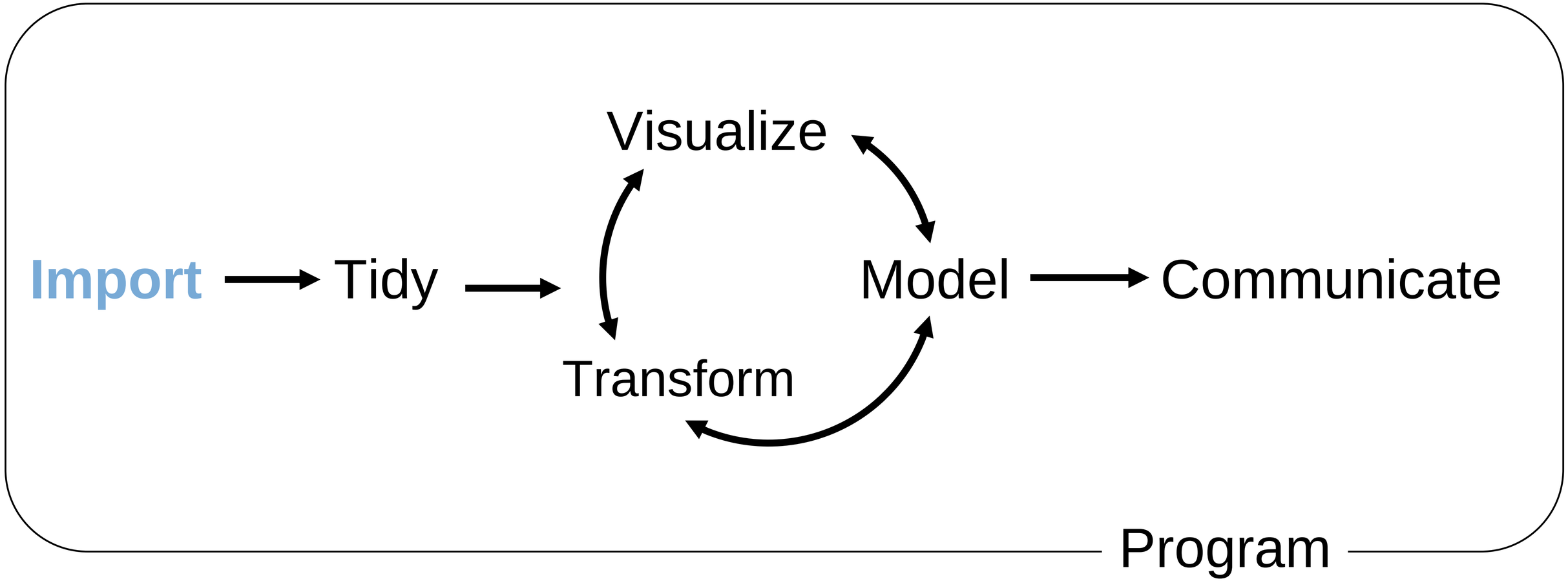
as_tibble(x, …) Convert data frame to tibble.

enframe(x, name = "name", value = "value")
Converts named vector to a tibble with a names column and a values column.

is_tibble(x) Test whether x is a tibble.

Import Data with

(Applied) Data Science



Importing Data

readr

Simple, consistent functions for working with strings.

```
# install.packages("tidyverse")
library(tidyverse)
```

Compared to read.table and its derivatives, readr functions are:

1. ~ 10 times faster
2. Return tibbles
3. Have more intuitive defaults. No row names, no strings as factors.

readr functions

function	reads
read_csv()	Comma separated values
read_csv2()	Semi-comma separated values
read_delim()	General delimited files
read_fwf()	Fixed width files
read_log()	Apache log files
read_table()	Space separated
read_tsv()	Tab delimited values

read_csv()

readr functions share a common syntax

```
df <- read_csv("path/to/file.csv", …)
```

object to save output into

path from working directory to file

dplyr

A package that transforms data.

dplyr implements a *grammar* for transforming tabular data.

Data transformation toolbox

Power of dplyr - sparklyr

http://spark.rstudio.com/dplyr.html

http://spark.rstudio.com/

http://spark.rstudio.com/examples-emr.html

It is often said that 80% of data analysis is spent on the process of cleaning and preparing the data. (Dasu and Johnson, 2003)

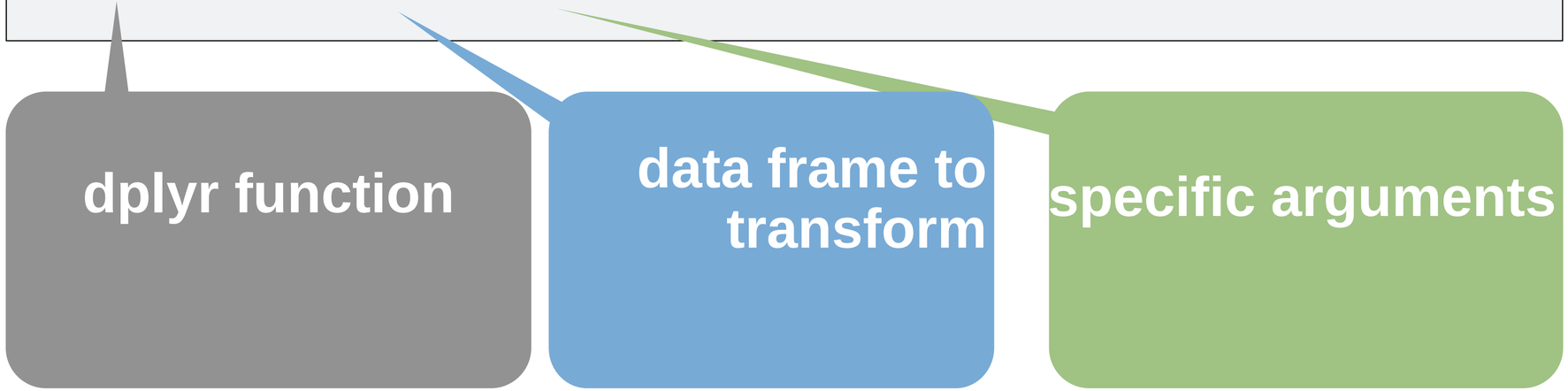
single table verbs

filter() - extract cases
arrange() - reorder cases
group_by() - group cases
select() - extract variables
mutate() - create new variables
summarise() - summarise variables / create cases

common syntax

Each function take a data frame / tibble as its first argument and returns a data frame / tibble.

```
filter(.data, … )
```



two table verbs

bind_rows() - adds one table to another as new cases

union(), intersect(), setdiff() - set operations for cases

semi_join(), anti_join() - filters cases in one table against another

bind_cols() - adds one table to another as new variables

left_join(), right_join(), full_join(), inner_join() - mutates one table by matching values from another as new variables

Toy data

```
storms <- tribble(
     ~storm, ~wind, ~pressure,        ~date,
  "Alberto",   110,      1007, "2000-08-12",
    "Alex",    45,       1009, "1998-07-30",
  "Allison",   65,       1005, "1995-06-04",
     "Ana",    40,       1013, "1997-07-01",
   "Arlene",    50,       1010, "1999-06-13",
   "Arthur",    45,       1010, "1996-06-21"
)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

filter()

filter()

Extract rows that meet logical criteria.

```
filter(.data, …)
```

data frame to transform

one or more logical tests (filter returns each row for which the test is TRUE)

filter()

Extract rows that meet logical criteria.

```
filter(storms, wind == 45)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

storm	wind	pressure	date
Alex	45	1009	1998-07-30
Arthur	45	1010	1996-06-21

= sets

(returns nothing)

== tests if equal

(returns TRUE or FALSE)

filter()

Extract rows that meet logical criteria.

```
filter(storms, wind == 45)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

storm	wind	pressure	date
Alex	45	1009	1998-07-30
Arthur	45	1010	1996-06-21

filter()

Extract rows that meet logical criteria.

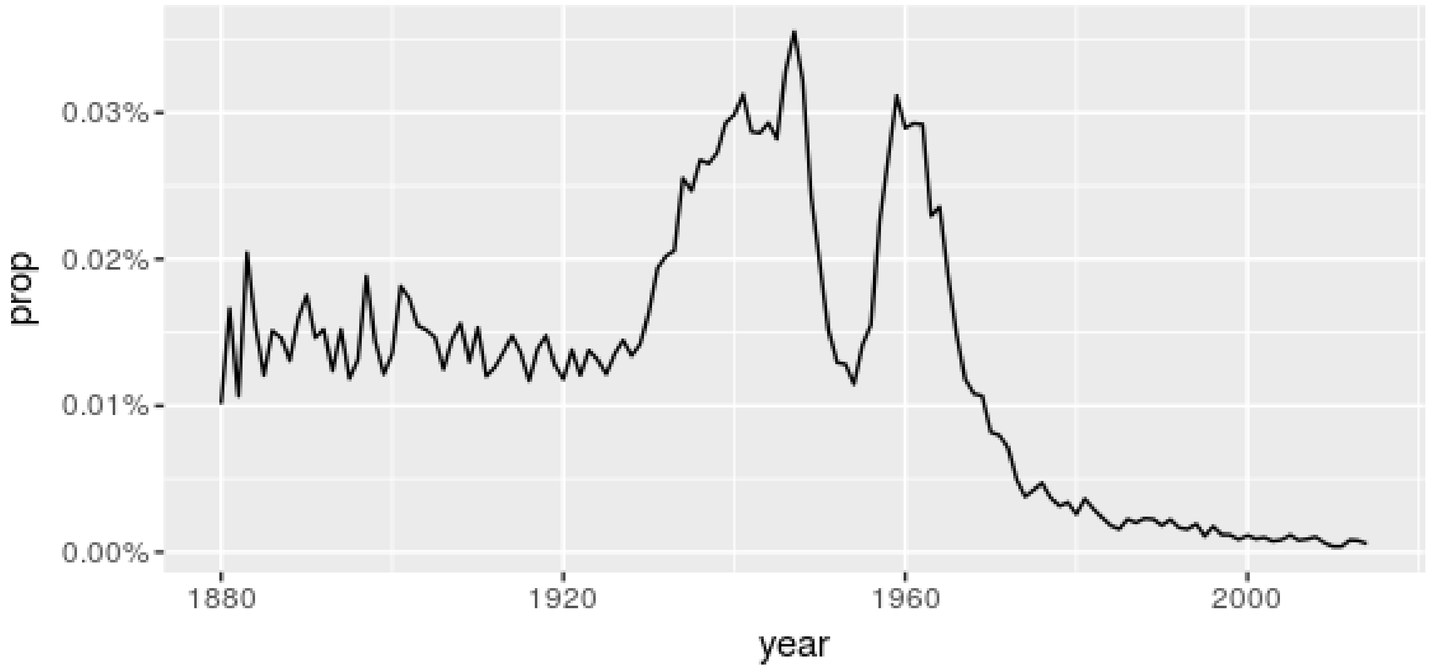
```
filter(storms, wind == 45, pressure == 1009)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

storm	wind	pressure	date
Alex	45	1009	1998-07-30

```
Phil <- filter(babynames, name == "Phil", sex == "M")
P <- ggplot(data = Phil, mapping = aes(year, prop)) +
  geom_line()
require(scales)
p + scale_y_continuous(labels = percent)
```



Logical tests

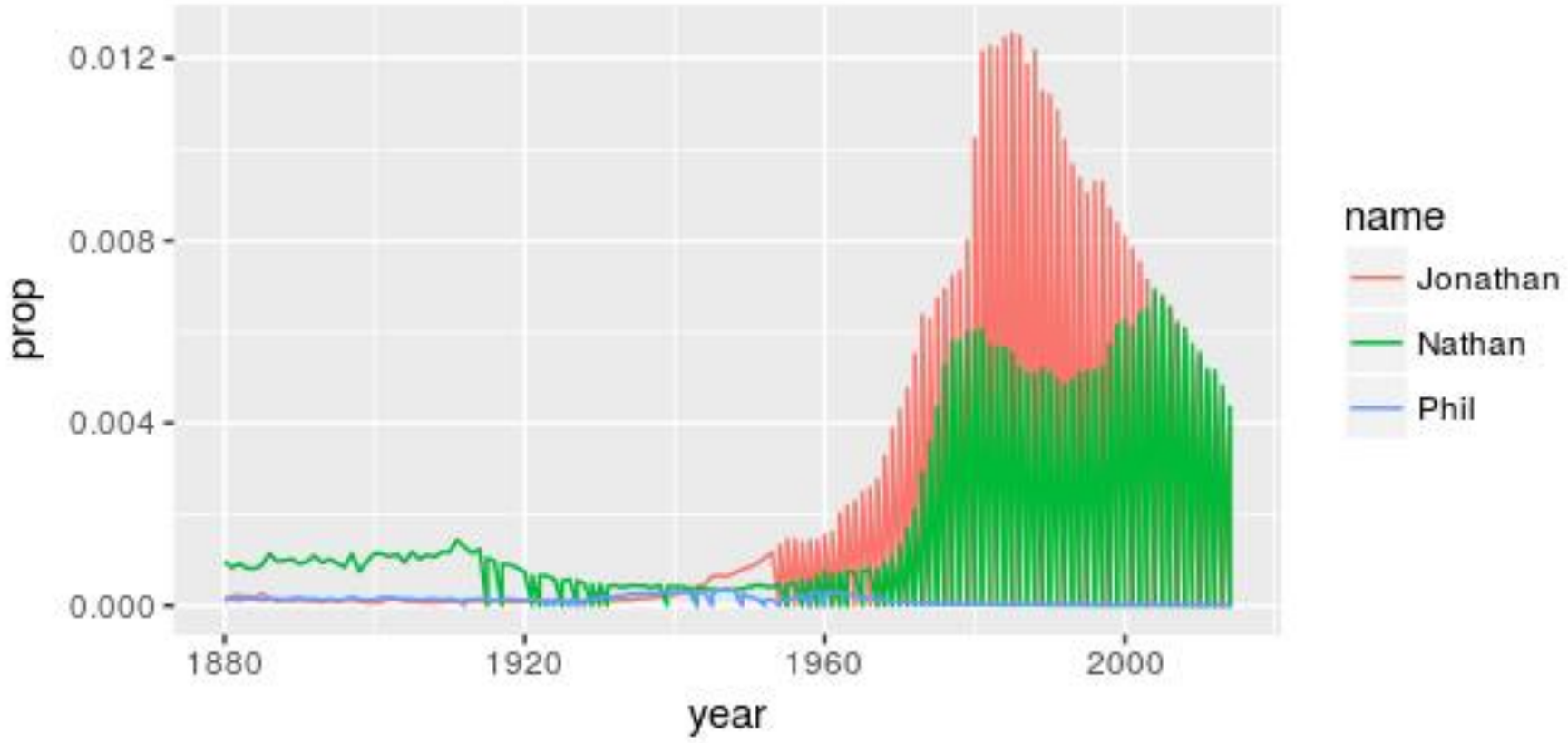
?Comparison

<	Less than
>	Greater than
==	Equal to
<=	Less than or equal to
>=	Greater than or equal to
!=	Not equal to
%in%	Group membership
is.na()	Is NA
!is.na()	Is not NA

?base::Logic

&	and
|	or
xor()	exactly or
!	not
any()	any true
all()	all true

```
gnames <- c("Nathan", "Jonathan", "Phil")
group_names <- filter(babynames, name %in% gnames)
ggplot(group_names, aes(year, prop, color = name)) +
  geom_line()
```



arrange()

arrange()

Order rows from smallest to largest values.

```
arrange(.data, …)
```

data frame to transform

one or more columns to order by (additional columns will be used as tie breakers)

arrange()

Order rows from smallest to largest values.

```
arrange(storms, wind)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

storm	wind	pressure	date
Ana	40	1013	1997-07-01
Alex	45	1009	1998-07-30
Arthur	45	1010	1996-06-21
Arlene	50	1010	1999-06-13
Allison	65	1005	1995-06-04
Alberto	110	1007	2000-08-12

desc()

Changes ordering to largest to smallest.

```
arrange(storms, desc(wind))
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Allison	65	1005	1995-06-04
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21
Alex	45	1009	1998-07-30
Ana	40	1013	1997-07-01

select()

select()

Extract columns by name.

```
select(.data, …)
```

data frame to transform

name(s) of columns to extract
(or a select helper function)

select()

Extract columns by name.

```
select(storms, storm, pressure)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

storm	pressure
Alberto	1007
Alex	1009
Allison	1005
Ana	1013
Arlene	1010
Arthur	1010

select() helpers

: - Select range of columns

```
select(storms, storm:pressure)
```

- - Select every column but

```
select(storms, -c(storm, pressure))
```

starts_with() - Select columns that start with…

```
select(storms, starts_with("w"))
```

ends_with() - Select columns that end with…

```
select(storms, ends_with("e"))
```

select() helpers

contains() - Select columns whose names contain…

```
select(storms, contains("d"))
```

matches() - Select columns whose names match regular expression

```
select(storms, matches("^.{4}$"))
```

one_of() - Select columns whose names are one of a set

```
select(storms, one_of(c("storm", "storms", "Storm")))
```

num_range() - Select columns named in prefix, number style

```
select(storms, num_range("x", 1:5))
```

mutate()

mutate()

Create new columns.

```
mutate(.data, …)
```

data frame to transform

named argument
(that consists of the name of column to create set equal to an expression that creates it)

mutate()

Create new columns.

```
mutate(storm, ratio = pressure / wind)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

storm	wind	pressure	date	ratio
Alberto	110	1007	2000-08-12	9.15
Alex	45	1009	1998-07-30	22.42
Allison	65	1005	1995-06-04	15.46
Ana	40	1013	1997-07-01	25.32
Arlene	50	1010	1999-06-13	20.20
Arthur	45	1010	1996-06-21	22.44

summarise()

summarise()

Compute table of summaries.

```
summarise(.data, …)
```

data frame to transform

named argument
(that consists of the name of column to create set equal to an expression that creates it)

summarise()

Compute table of summaries.

```
summarise(storms, avg_wind = mean(wind), n = n())
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	
Allison	65	1005	
Ana	40	1013	
Arlene	50	1010	
Arthur	45	1010	1996-06-21

avg_wind	n
59.17	6

Returns the number of cases (rows) Very useful!

n() and n_distinct()

Two helper functions for summarise.

```
summarise(storms,
  n = n(), # Number of cases / rows
  n_wind = n_distinct(wind) # number of unique values
)
```

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

→

n	n_wind
6	5

%>%

Little bunny Foo Foo
Went hopping through the forest
Scooping up the field mice
And bopping them on the head

```
# Every intermediate as a new object
foo_foo <- little_bunny()
foo_foo_1 <- hop(foo_foo, through = forest)
foo_foo_2 <- scoop(foo_foo_1, up = field_mice)
foo_foo_3 <- bop(foo_foo_2, on = head)

# Overwrite the original object
foo_foo <- hop(foo_foo, through = forest)
foo_foo <- scoop(foo_foo, up = field_mice)
foo_foo <- bop(foo_foo, on = head)

# Nested function calls
bop(
  scoop(
    hop(foo_foo, through = forest),
    up = field_mice
  ),
  on = head
)
```

```
foo_foo %>%
  hop(through = forest) %>%
  scoop(up = field_mouse) %>%
  bop(on = head)
```

```
head(filter(select(iris, Species, Petal.Length),
Species == "setosa"))
```

is clearer when written:

```
iris %>% select(Species, Petal.Length) %>%
filter(Species == "setosa") %>% head()
```

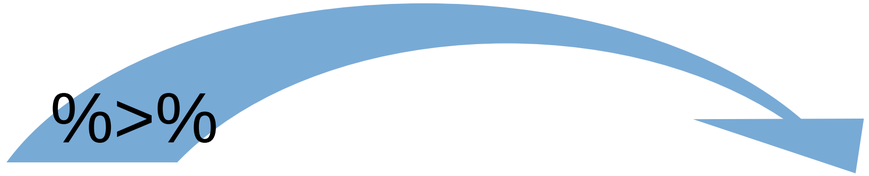
```
mutate(babynames, percent = prop * 100)
```

```
summarize(babynames, n = n_distinct(name))
```

```
garrett <- filter(babynames, name == "Garrett", sex == "M")
summarise(garrett, min = min(prop), mean = mean(prop),
  max = max(prop))
```

```
babynames2 <- mutate(babynames, percent = prop * 100)
babynames3 <- filter(babynames2, percent > 1)
summarise(babynames3, nn = n())
```

The pipe operator %>%



babynames mutate(___, percent = prop * 100)

Passes result on left into first argument of function on right.
So, for example, these do the same thing. Try it.

```
mutate(babynames, percent = prop * 100)
babynames %>% mutate(percent = prop * 100)
```

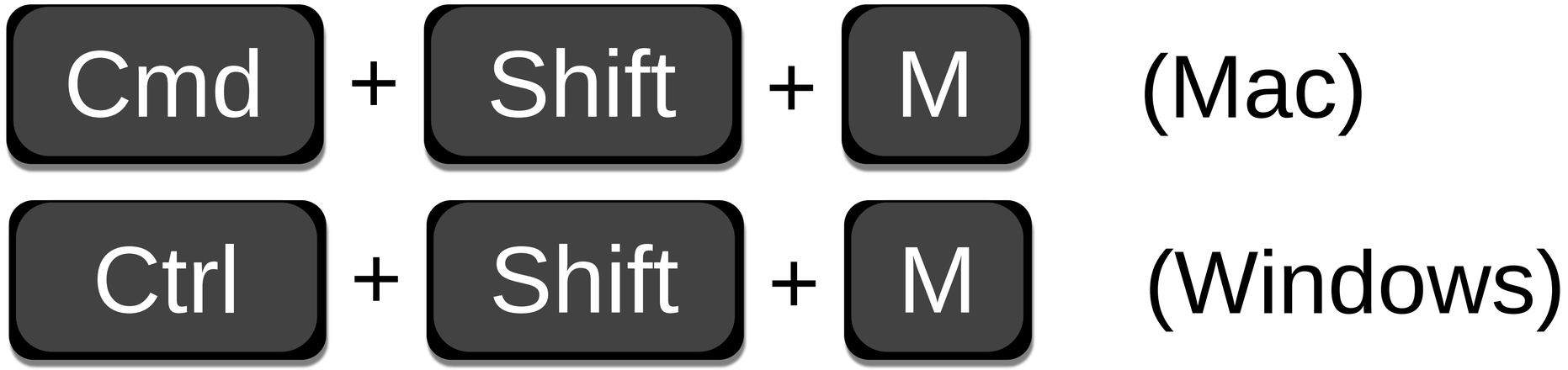
```
Phil <- filter(babynames, name == "Phil", sex == "M")
summarise(Phil, min = min(prop), mean = mean(prop),
  max = max(prop))
```

```
filter(babynames, name == "Phil", sex == "M") %>%
  summarise(min = min(prop), mean = mean(prop),
    max = max(prop))
```

```
garrett <- filter(babynames, name == "Garrett", sex == "M")
summarise(garrett, min = min(prop), mean = mean(prop),
  max = max(prop))
```

```
babynames %>%
  filter(name == "Garrett", sex == "M") %>%
  summarise(min = min(prop), mean = mean(prop),
    max = max(prop))
```

Shortcut to type %>%



Grouping cases

group_by()

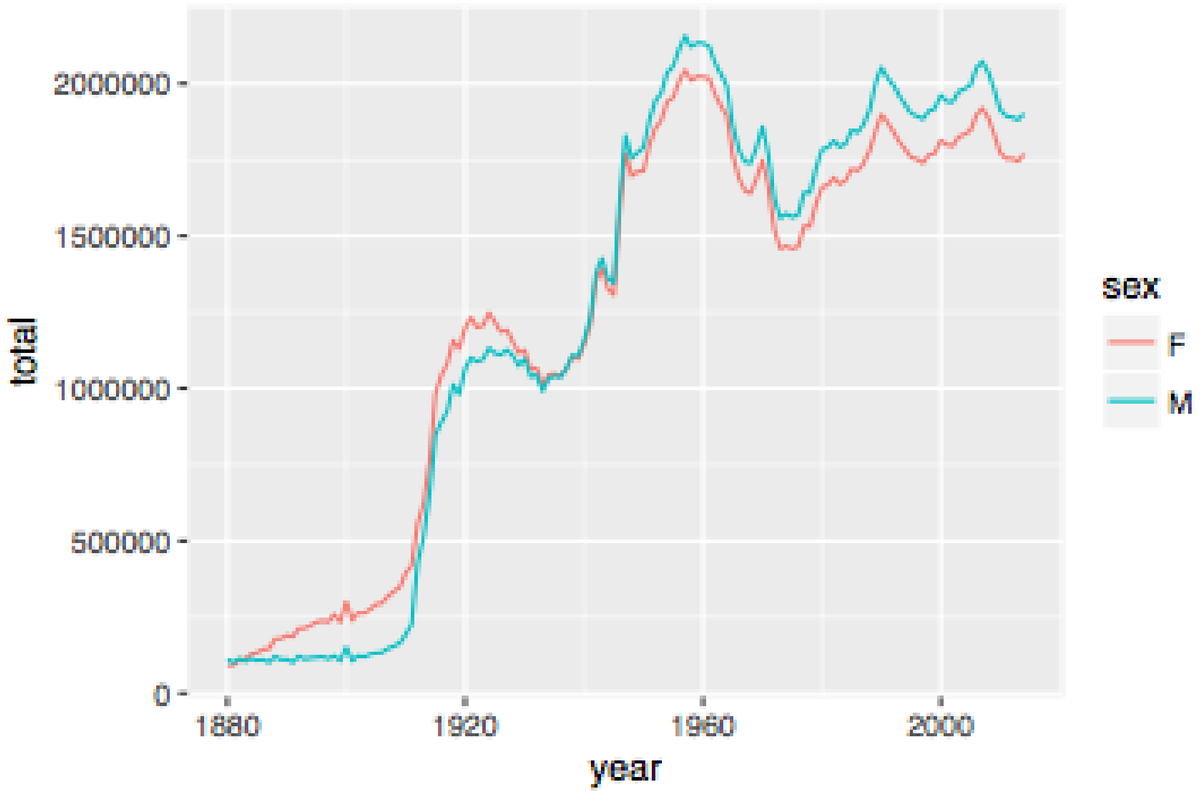
Groups cases by common values.

```
group_by(.data, …)
```

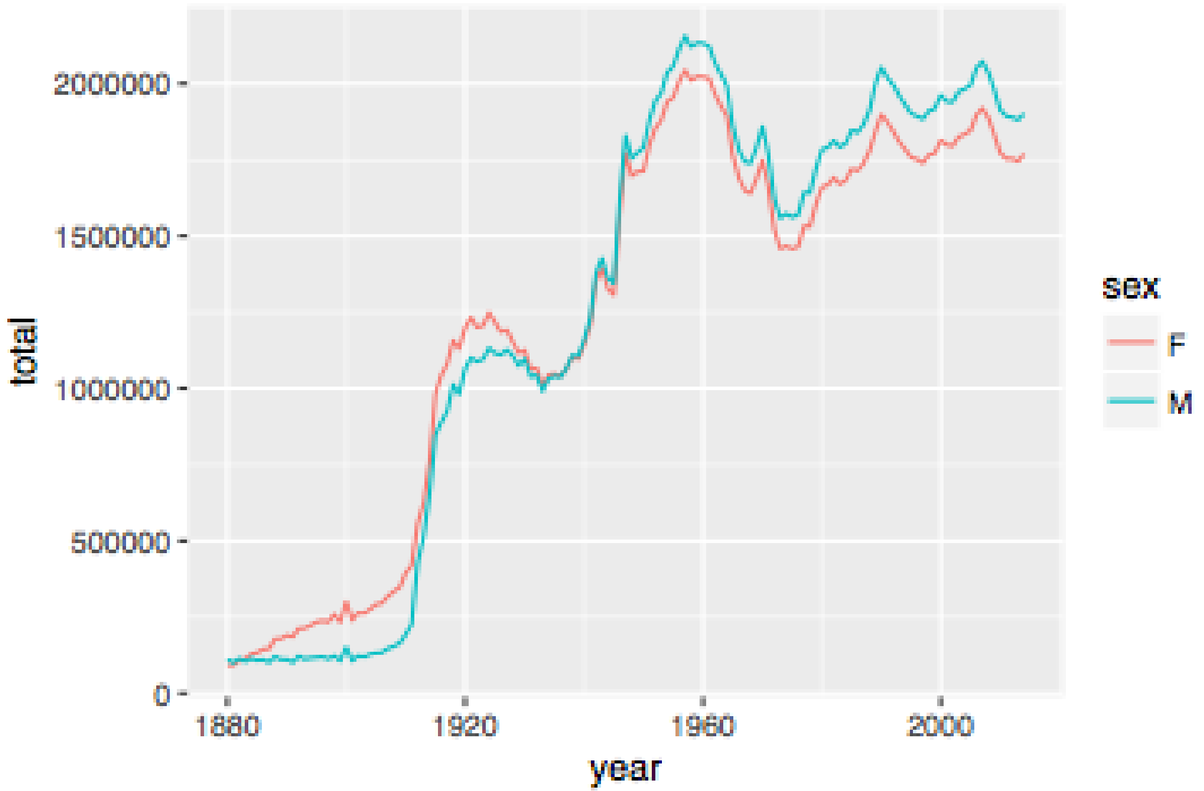
data frame to transform

column(s) to group by
(will group by combinations of values if more than one column is specified)

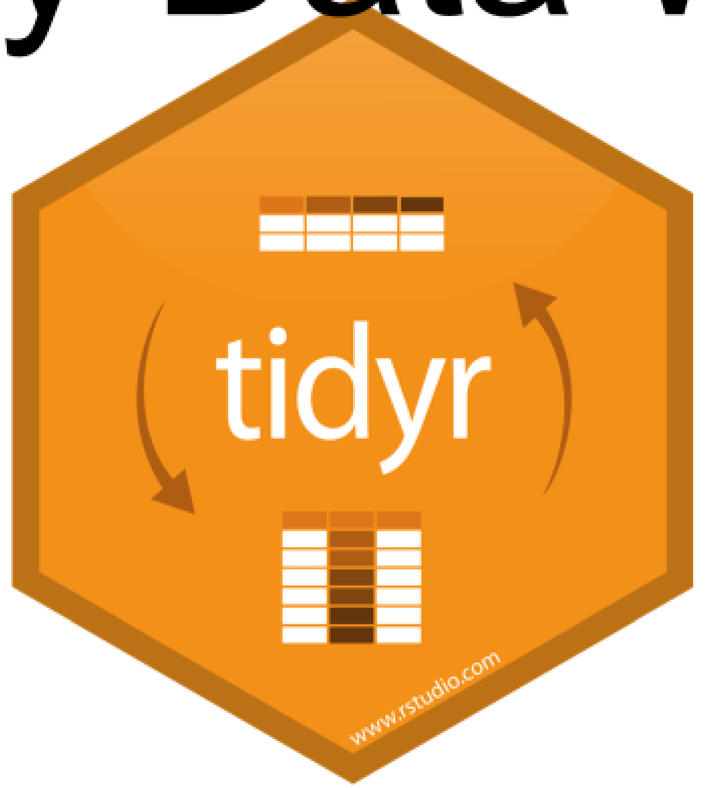
```
babynames %>%
  group_by(year, sex) %>%
  summarise(total = sum(n)) %>%
  ggplot(aes(x = year, y = total, color = sex)) +
    geom_line()
```



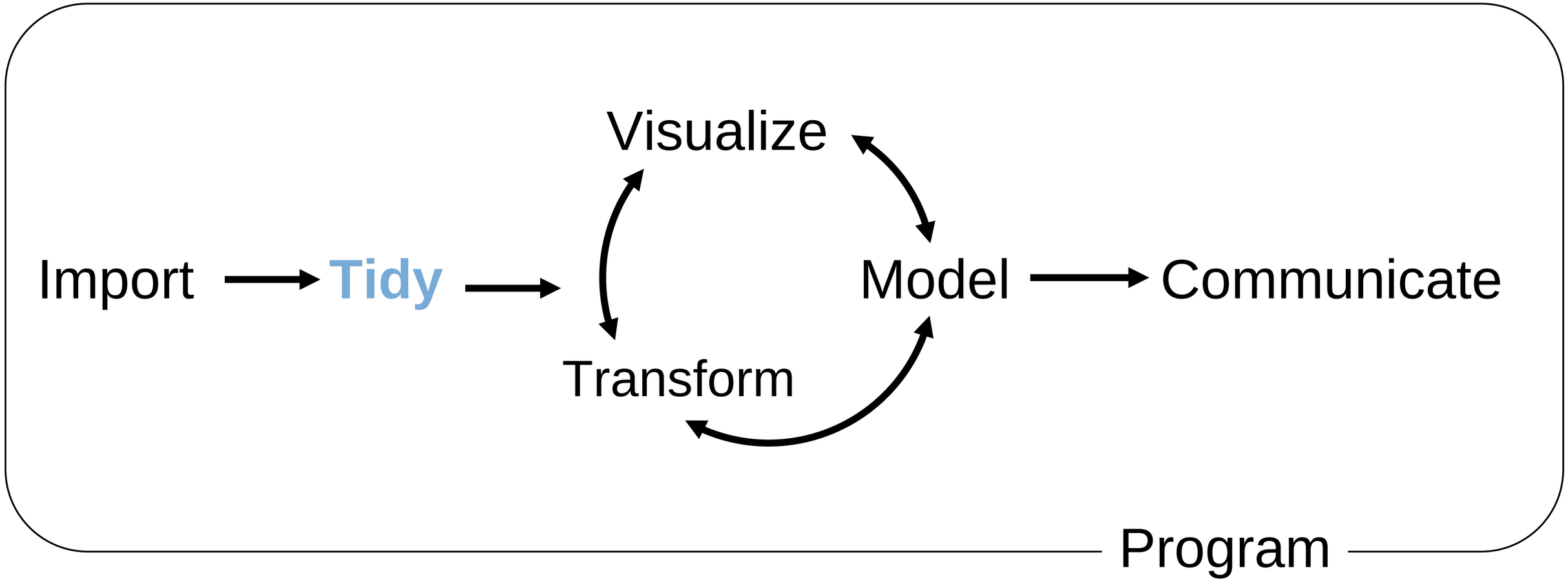
```
babynames %>%
  group_by(year, sex) %>%
  summarise(total = sum(n)) %>%
  ggplot(aes(x = year, y = total, color = sex)) +
    geom_line()
```



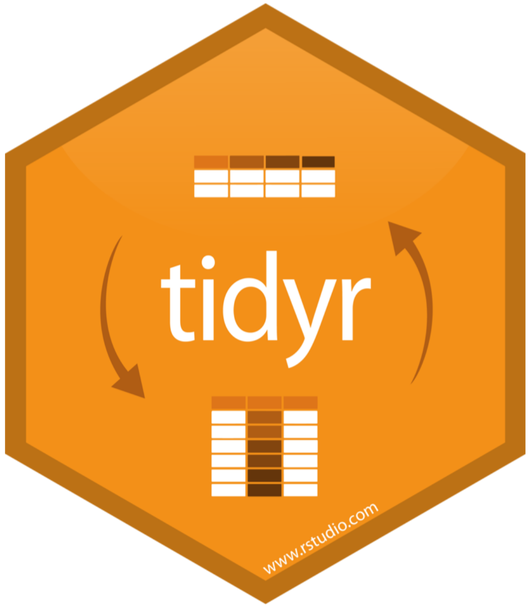
Tidy Data with



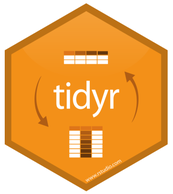
(Applied) Data Science



tidyr



A package that reshapes the layout of tabular data.



Reshaping tables

spread() is one of a family of functions for reshaping tables.

- spread() - move values into column names
- gather() - move column names into values
- separate() - separate variables that share a column
- unite() - unite a variable that is split across several columns

Most data comes to you untidy

spread()
and gather()

You can represent any group of values as **key:value pairs**

key		value
2011	:	7000
2011	:	5800
2011	:	15000
2012	:	6900
2012	:	6000
2012	:	14000
2013	:	7000
2013	:	6200
2013	:	13000

You can represent any group of values as **key:value pairs** or a **group of columns** with column names.

key	value
2011	7000
2011	5800
2011	15000
2012	6900
2012	6000
2012	14000
2013	7000
2013	6200
2013	13000

2011	2012	2013
7000	6900	7000
5800	6000	6200
15000	14000	13000

spread()

```
pollution %>% spread(key = size, value = amount)
```

data frame to reshape

column to use for keys (becomes new column names)

column to use for values (becomes new column cells)

gather()

```
cases %>% gather(key = "year", value = "n", 2:4)
```

data frame to reshape

name of the new key column (a character string)

name of the new value column (a character string)

numeric indexes of columns to collapse (or names)

separate()

separate()

Splits a column by dividing values at a specific character.

```
separate(storms, date, c("year","month","day"), sep = "-")
```

data frame to reshape

a column to split

names of new columns to make

string to split on
(Defaults to any non_alpha-numeric character)

```
separate(storms, date, c("year","month","day"), sep = "-",
  convert = TRUE)
```

	storm	wind	pressure	date
1	Alberto	110	1007	2000-08-03
2	Alex	45	1009	1998-07-27
3	Allison	65	1005	1995-06-03
4	Ana	40	1013	1997-06-30
5	Arlene	50	1010	1999-06-11
6	Arthur	45	1010	1996-06-17

	storm	wind	pressure	year	month	day
1	Alberto	110	1007	2000	08	03
2	Alex	45	1009	1998	07	27
3	Allison	65	1005	1995	06	03
4	Ana	40	1013	1997	06	30
5	Arlene	50	1010	1999	06	11
6	Arthur	45	1010	1996	06	17

unite()

unite()

Unites columns into single column by combining cells.

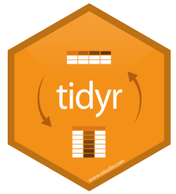
```
unite(data, col, …, sep = "")
```

name of new column to make (in quotes)

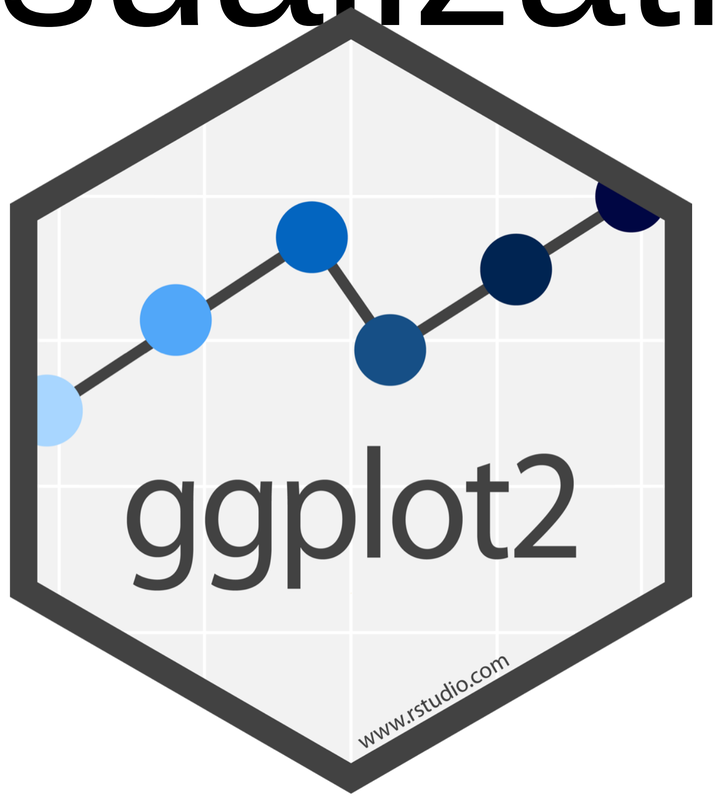
two or more columns to combine

separator to place between elements in new column (Defaults to an underscore)

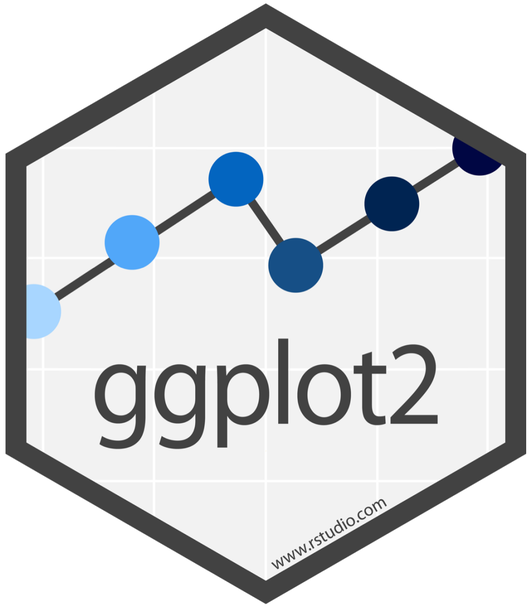
```
storms %>%
  separate(date, c("year", "month", "day"), sep = "-") %>%
  unite("date", month, day, year, sep = "/")
```



Data Visualization with



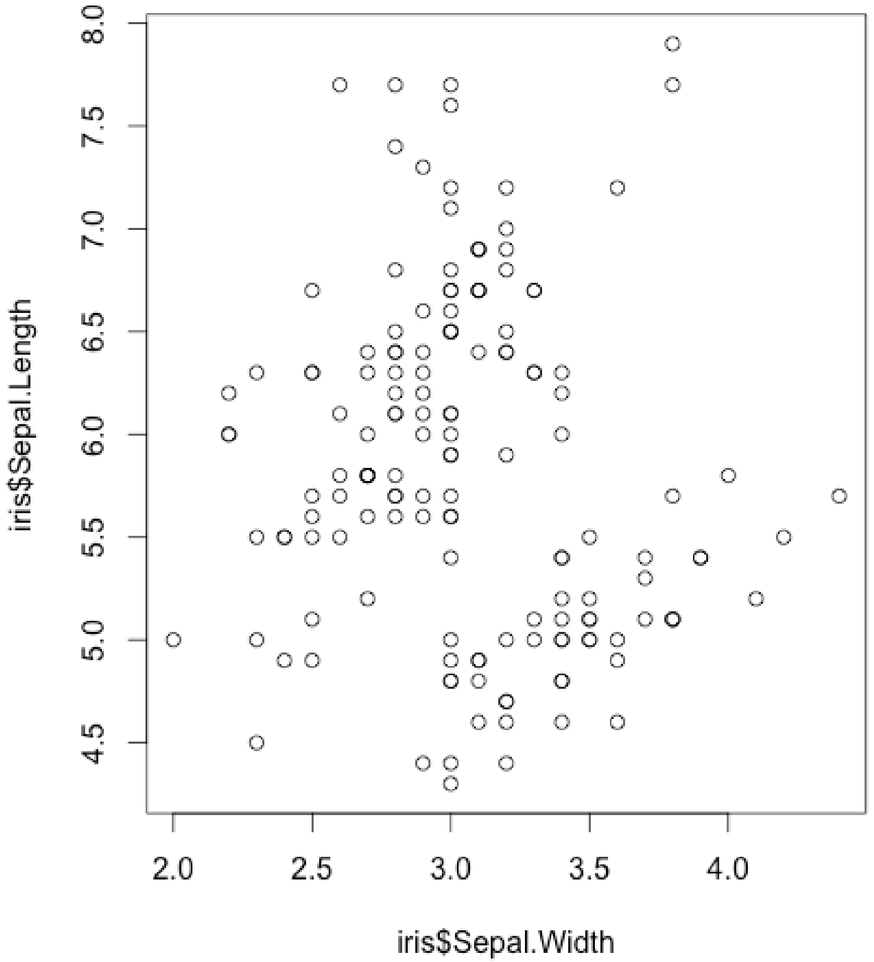
ggplot2

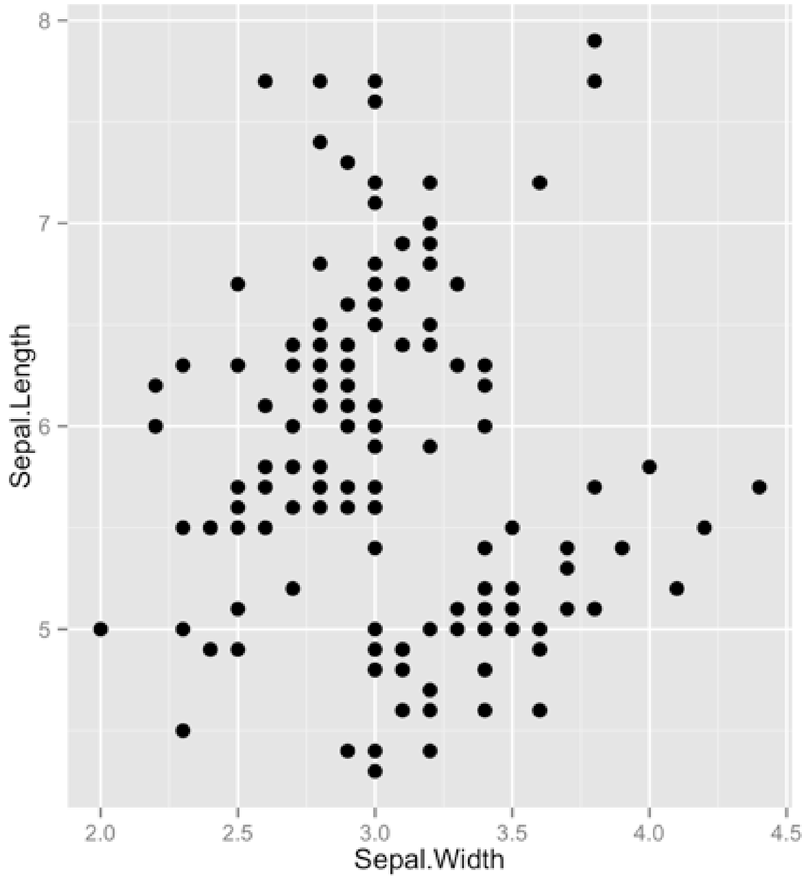


A package that visualizes data.

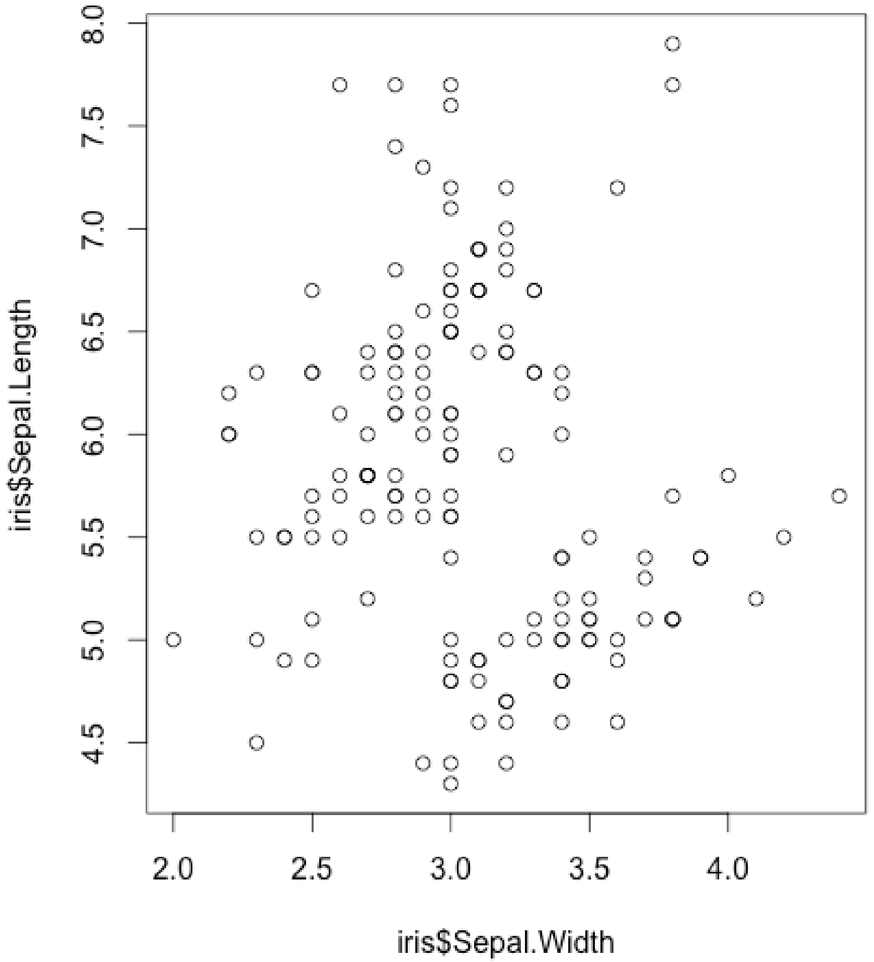
ggplot2 implements the *grammar of graphics*, a system for building visualizations that is built around cases and variables.

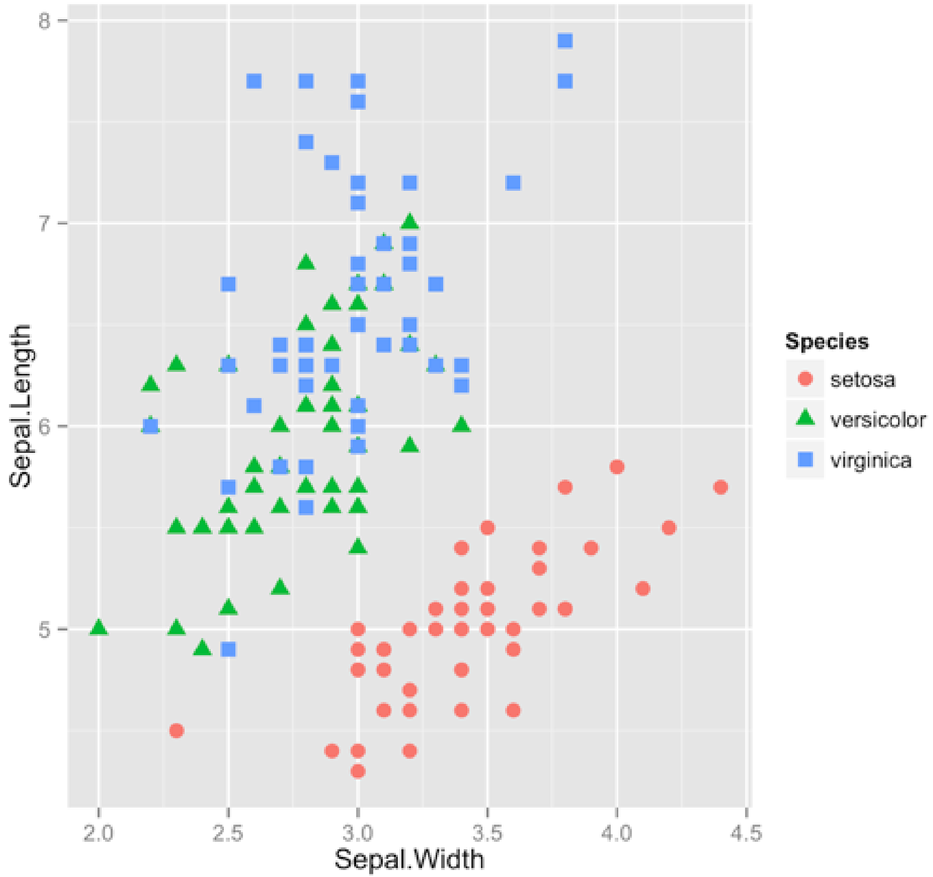
ggplot2



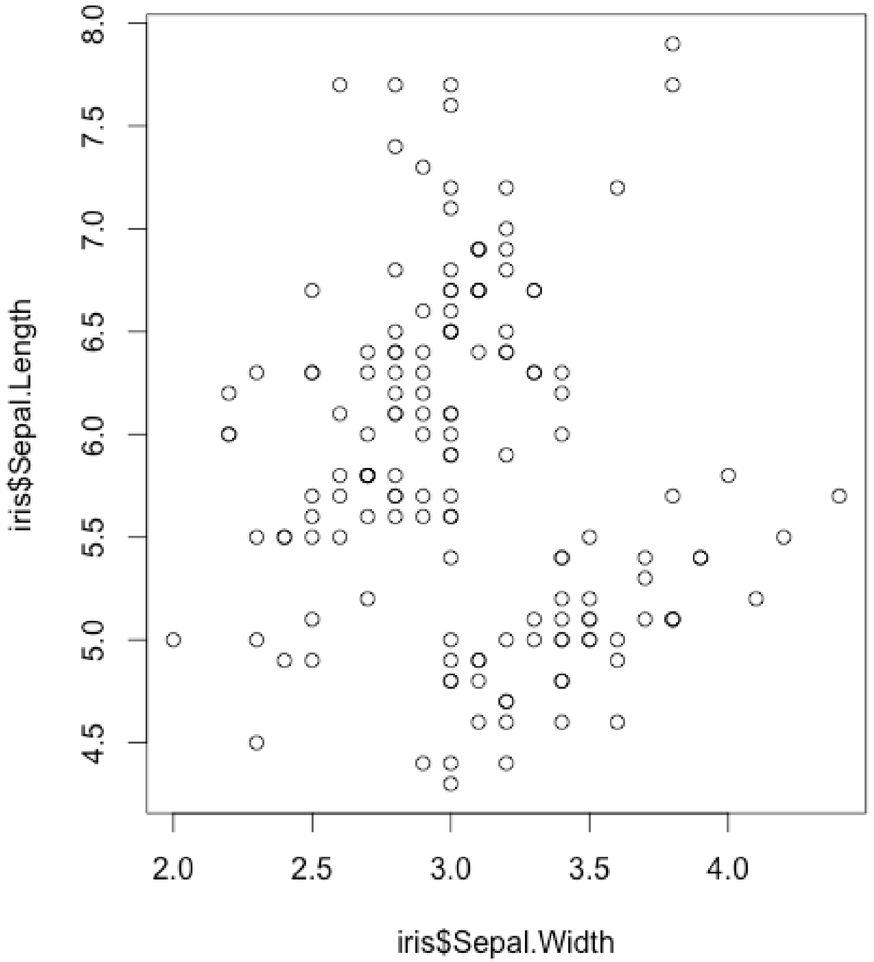


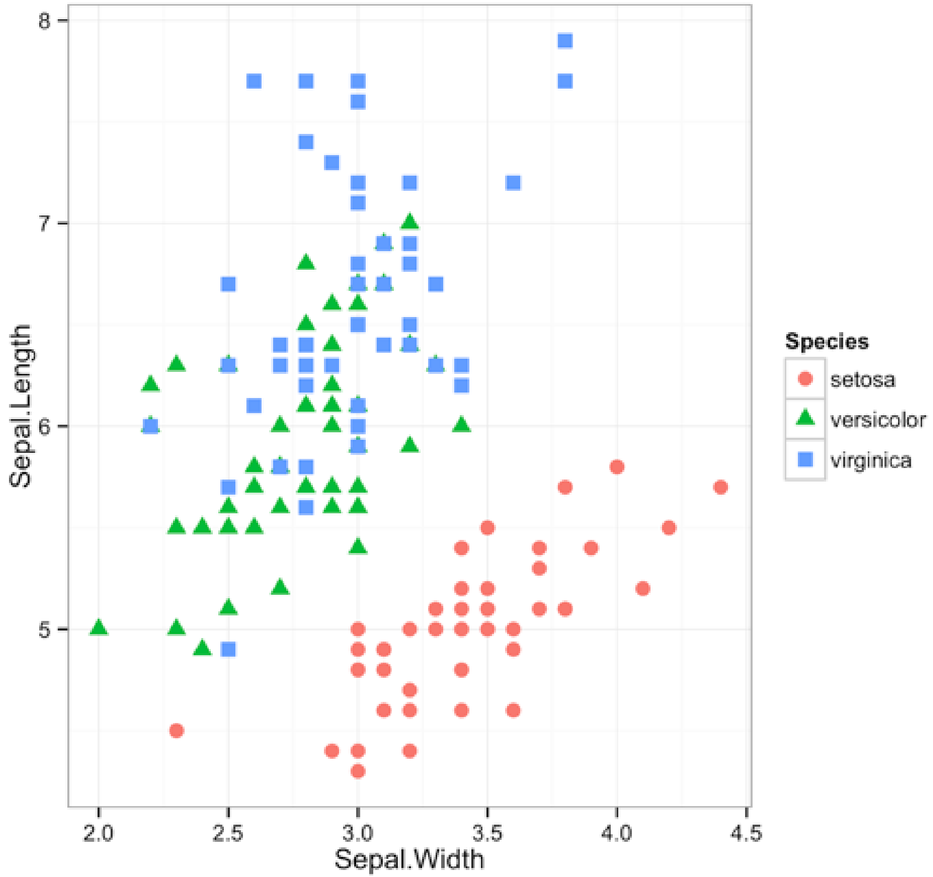
ggplot2



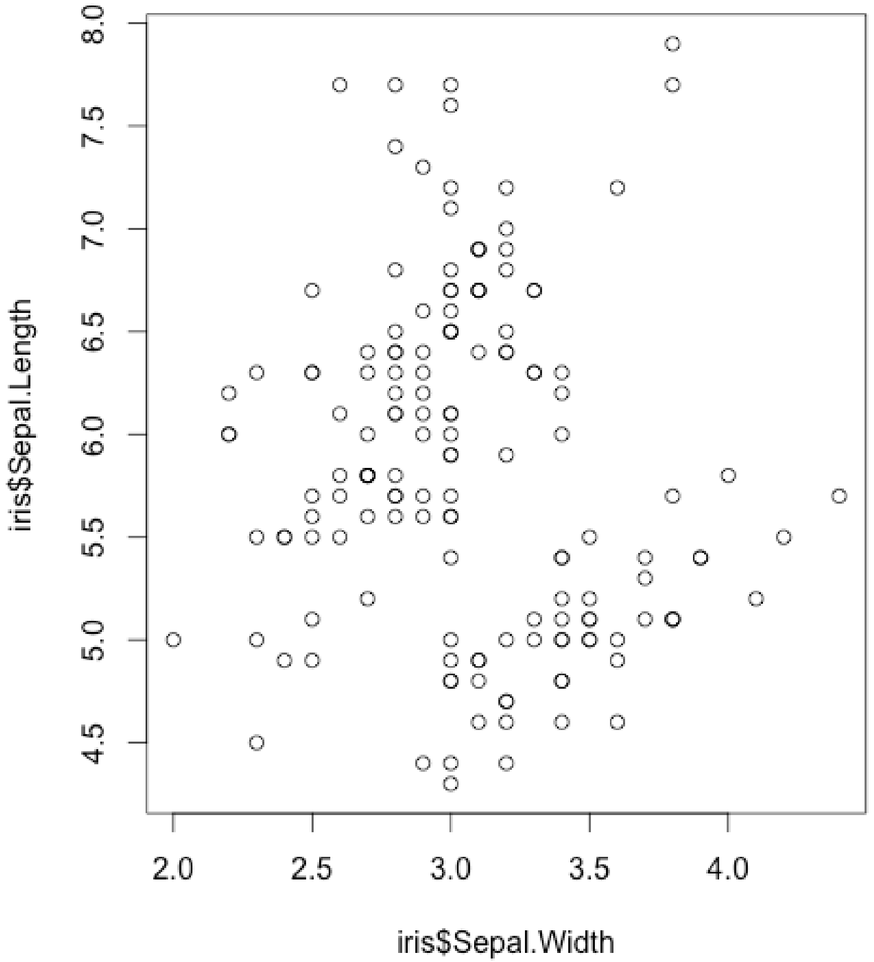


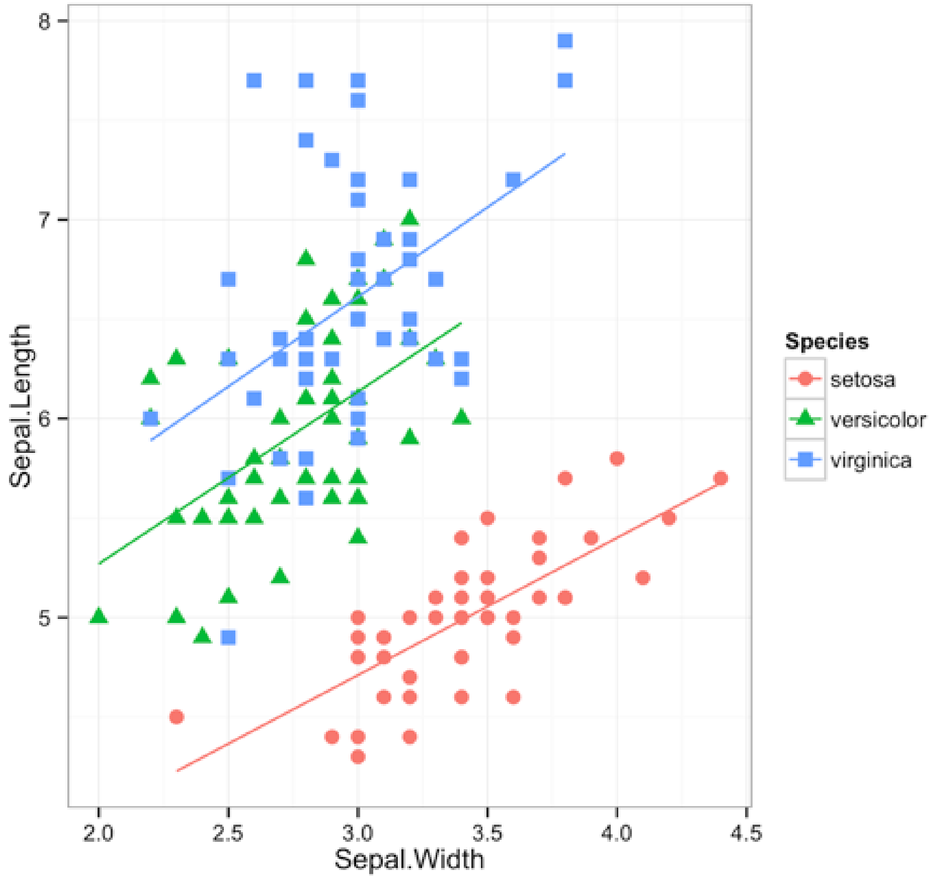
ggplot2



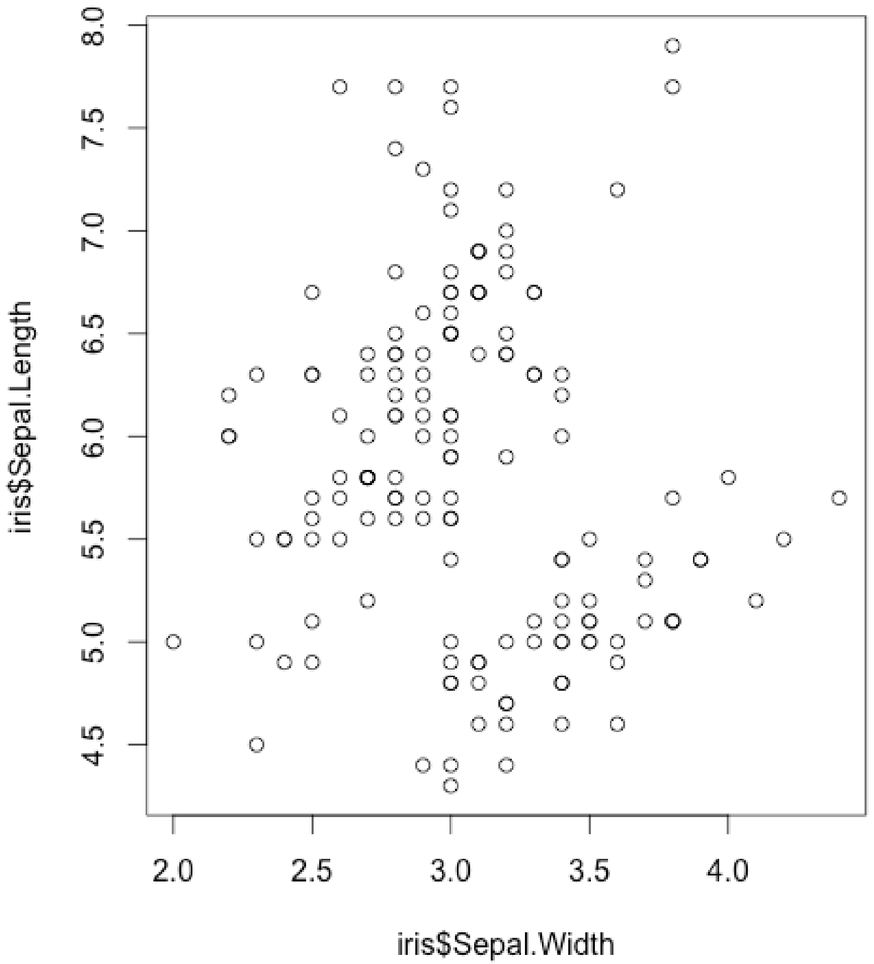


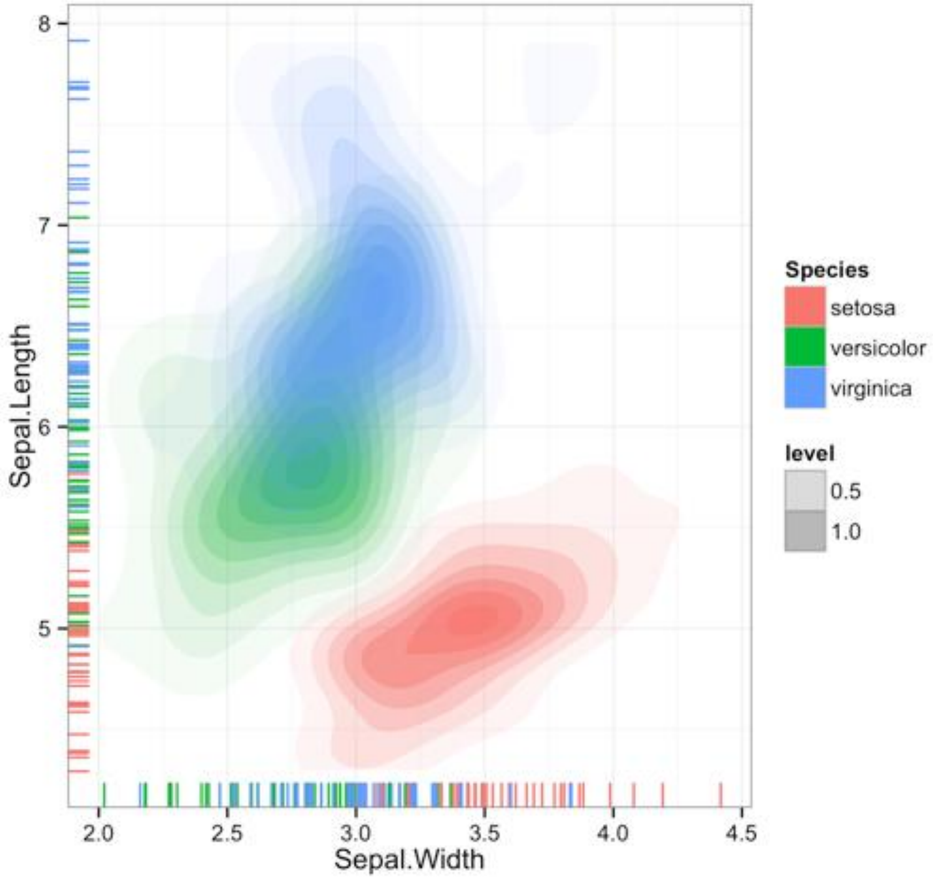
ggplot2



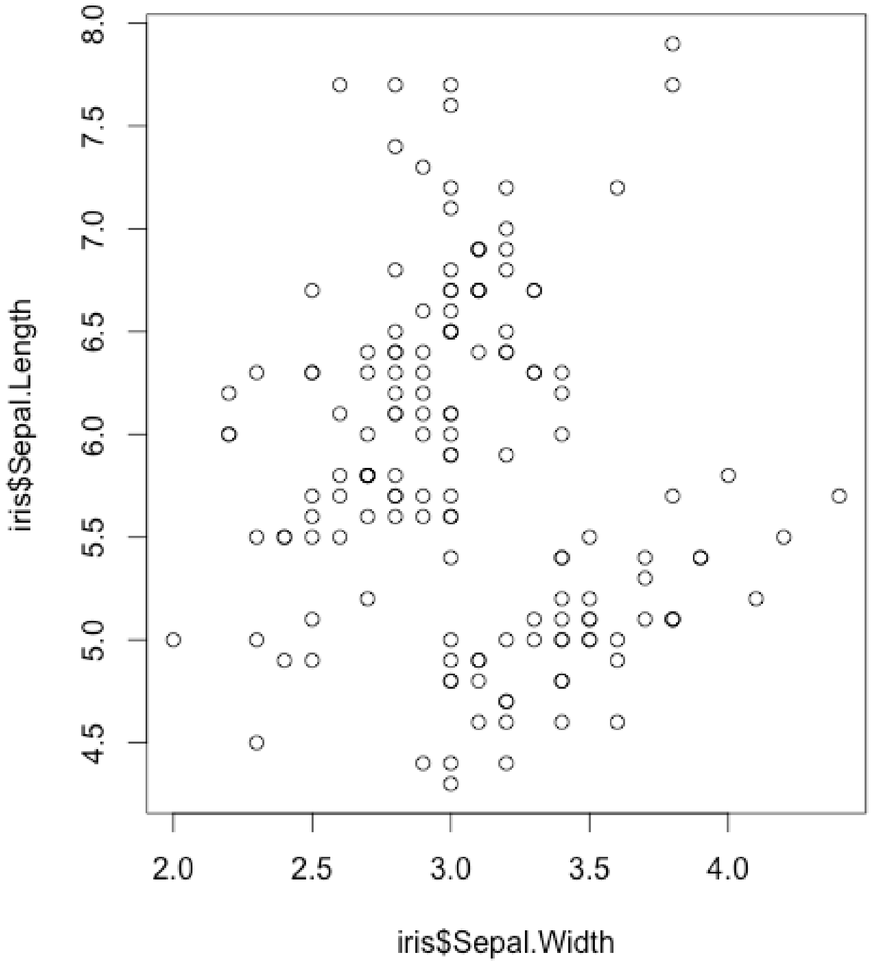


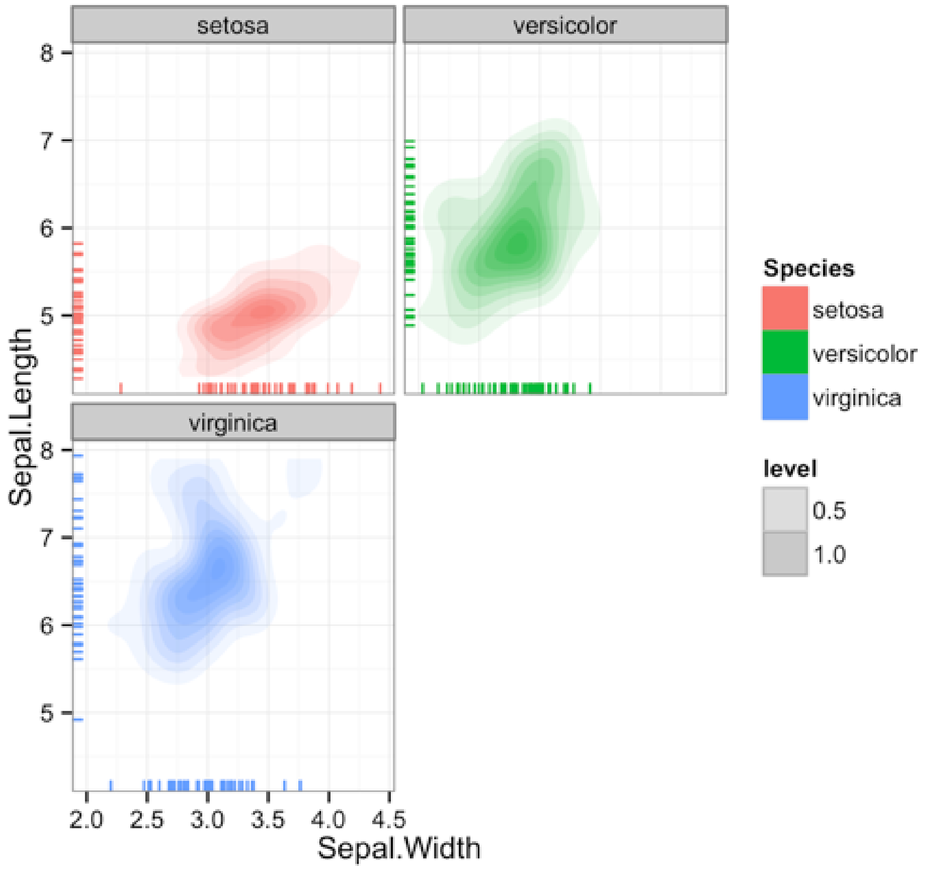
ggplot2





ggplot2





To plot

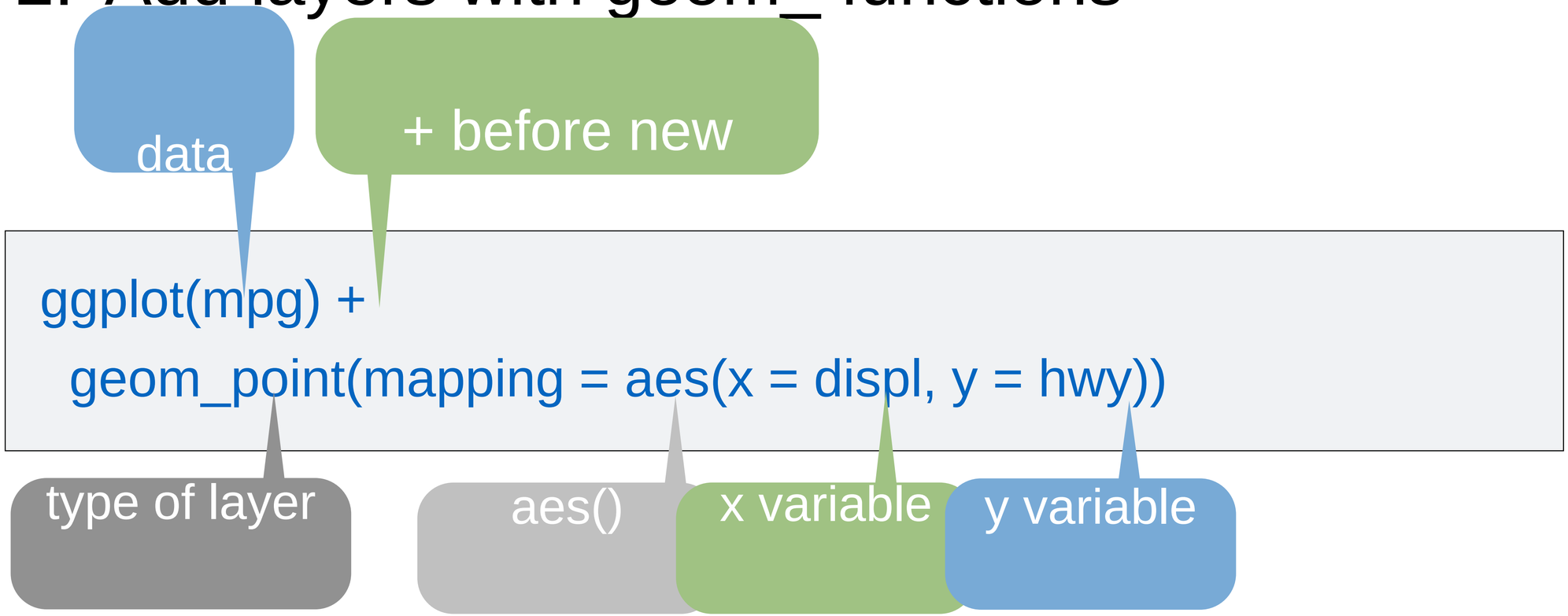
1. "Initialize" a plot with ggplot()
2. Add layers with geom_ functions

Pro tip: Always put the + at the end of a line, Never at the beginning

```
ggplot(data = mpg) +
  geom_point(mapping = aes(x = displ, y = hwy))
```

To plot

1. "Initialize" a plot with ggplot()
2. Add layers with geom_ functions



A ggplot2 template

Make any plot by filling in the parameters of this template

```
ggplot(data = <DATA>) +
  <GEOM_FUNCTION>(mapping = aes(<MAPPINGS>))
```

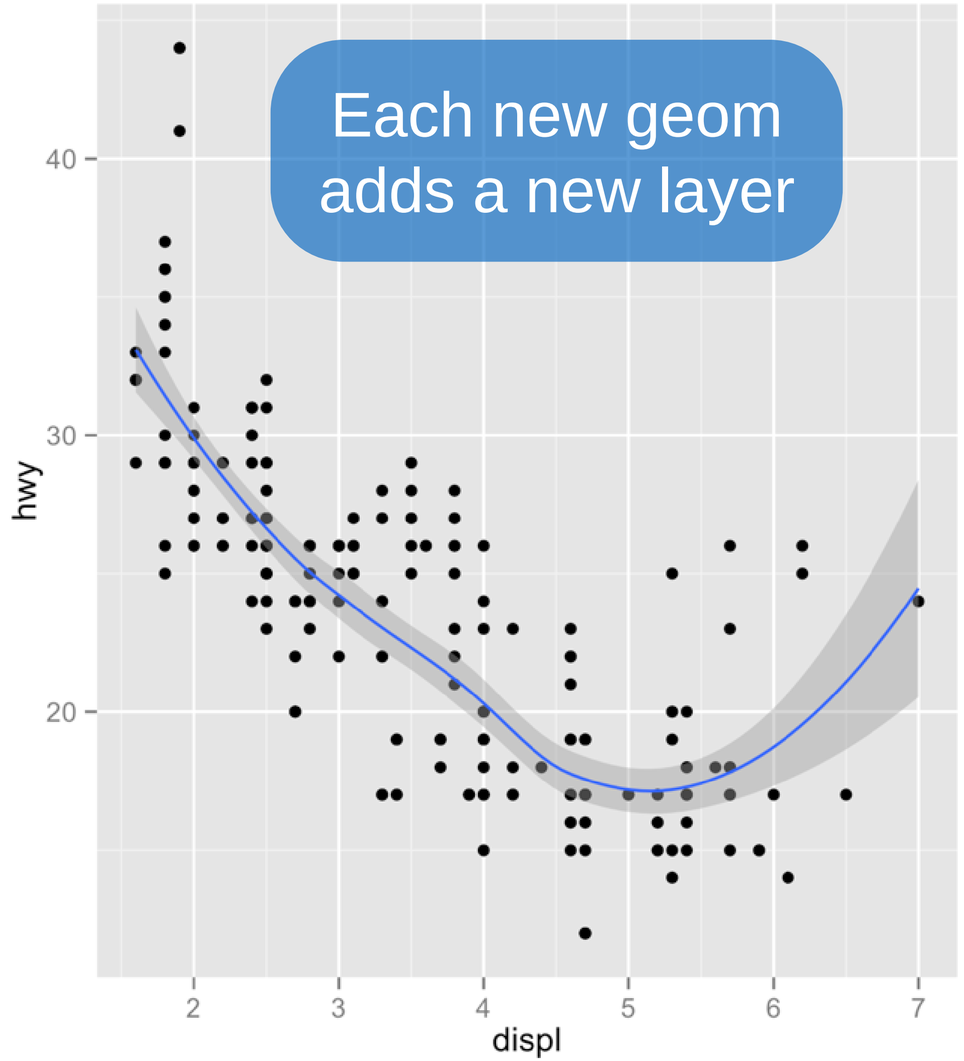
```
ggplot(data = mpg) +
  geom_point(mapping = aes(x = displ, y = hwy))
```

geom

The visual objects that represents the cases. geom functions add layers to the graph.

```
ggplot(data = <DATA>) +
  <GEOM_FUNCTION>(mapping = aes(<MAPPINGS>))
```

The geom




```
ggplot(mpg) +
  geom_point(mapping = aes(x = displ, y = hwy)) +
  geom_smooth(mapping = aes(x = displ, y = hwy))
```

A ggplot2 template

Make any plot by filling in the parameters of this template

```
ggplot(data = <DATA>) +
  <GEOM_FUNCTION>(mapping = aes(<MAPPINGS>),
                  stat = <STAT>) +
  <FACET_FUNCTION>
```

```
ggplot(data = diamonds) +
  geom_bar(mapping = aes(x = cut), stat = "count")
```

Data types with

Iteration with

Modeling with