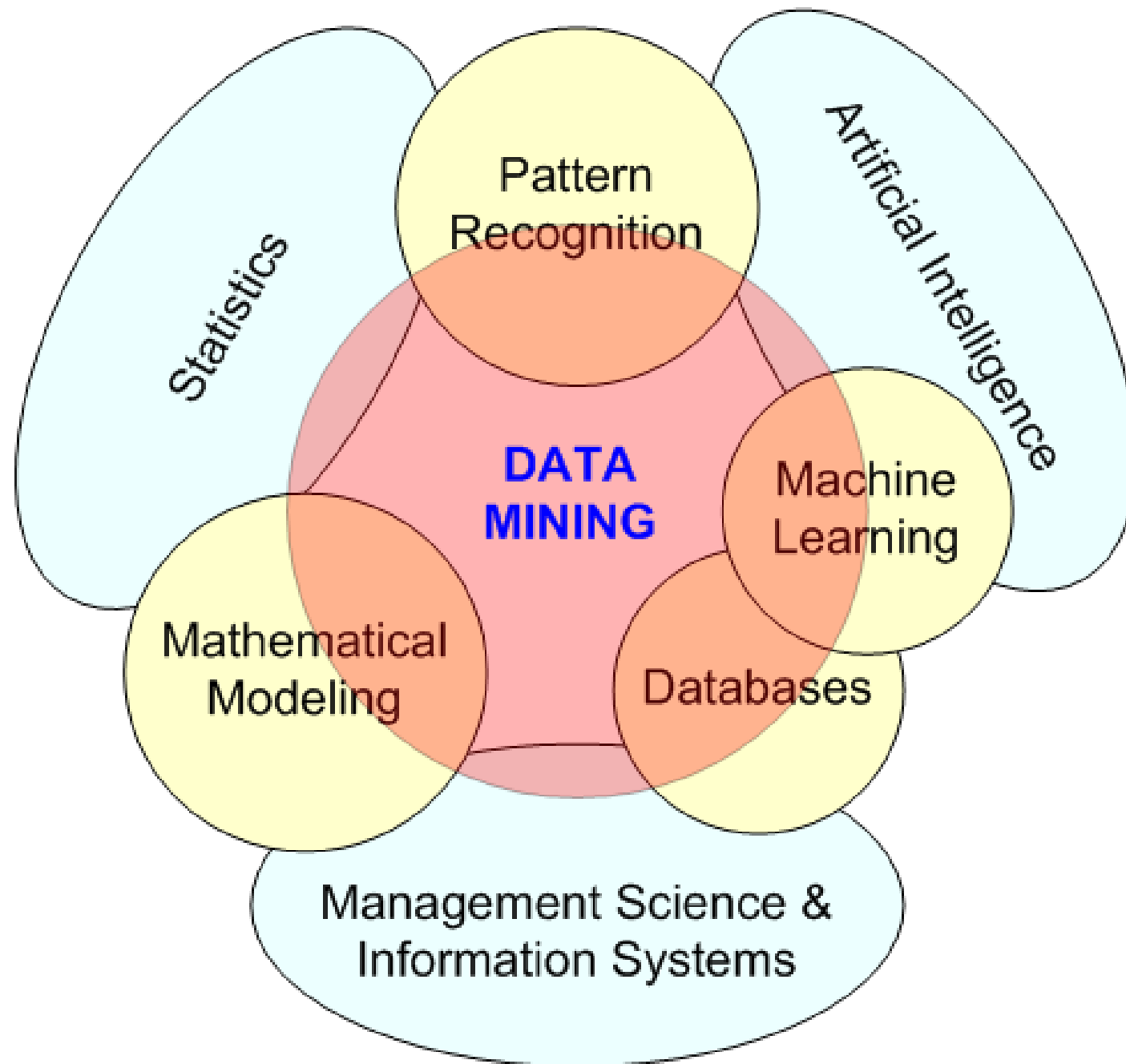


EDA II: Data Wrangling

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Bevera Solutions





Learning objectives of this module:

- Data Understanding
- Visit the tidyr package
- Introduction to data analysis
- Learn the basic vocabulary of dplyr
- Exercise commands

DATA WRANGLING: WHAT IT IS & WHY IT'S IMPORTANT

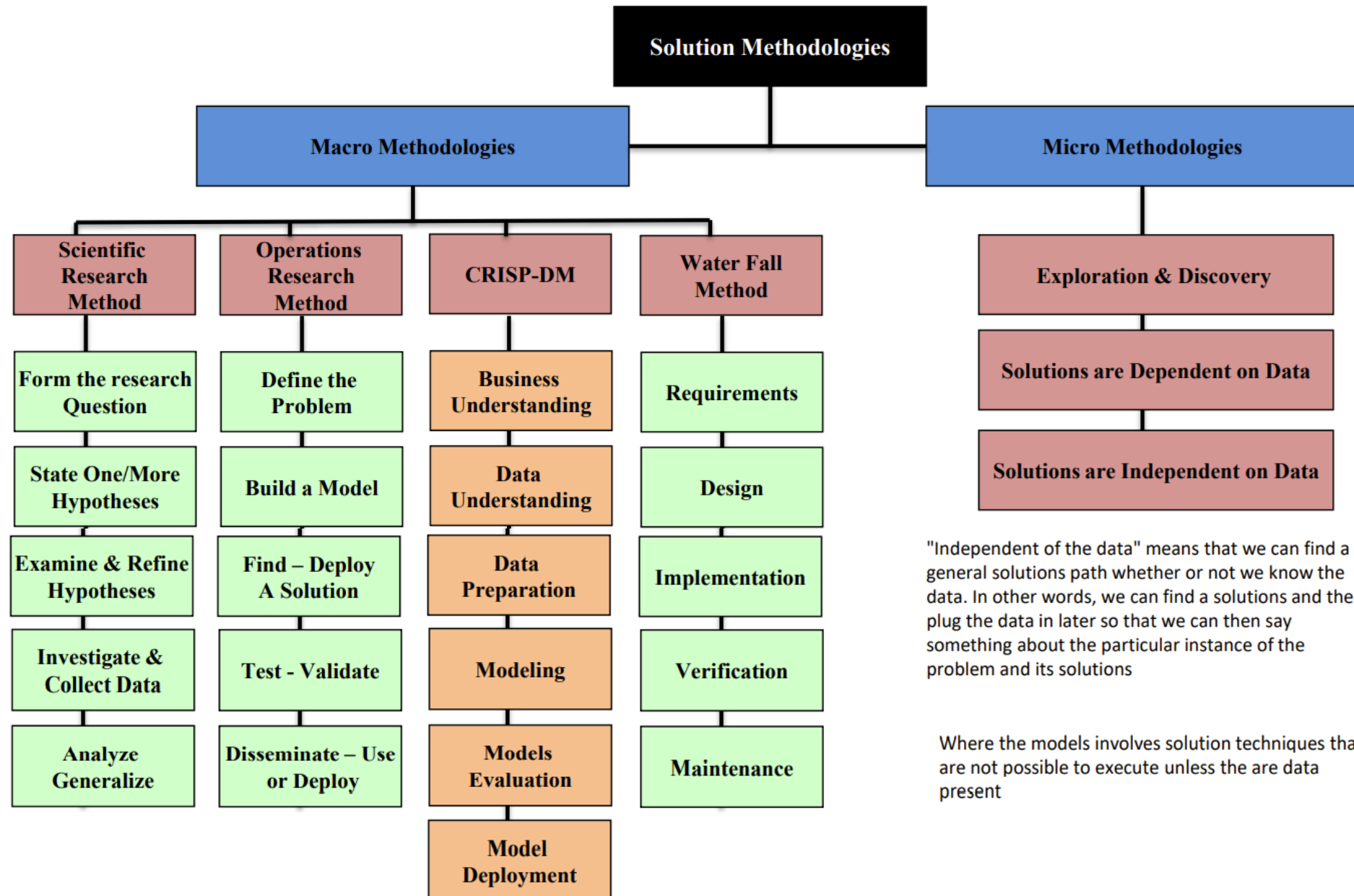


Article read

- <https://online.hbs.edu/blog/post/data-wrangling>

Hi there 🐼 Welcome to HBS Online! Can I help you find something?

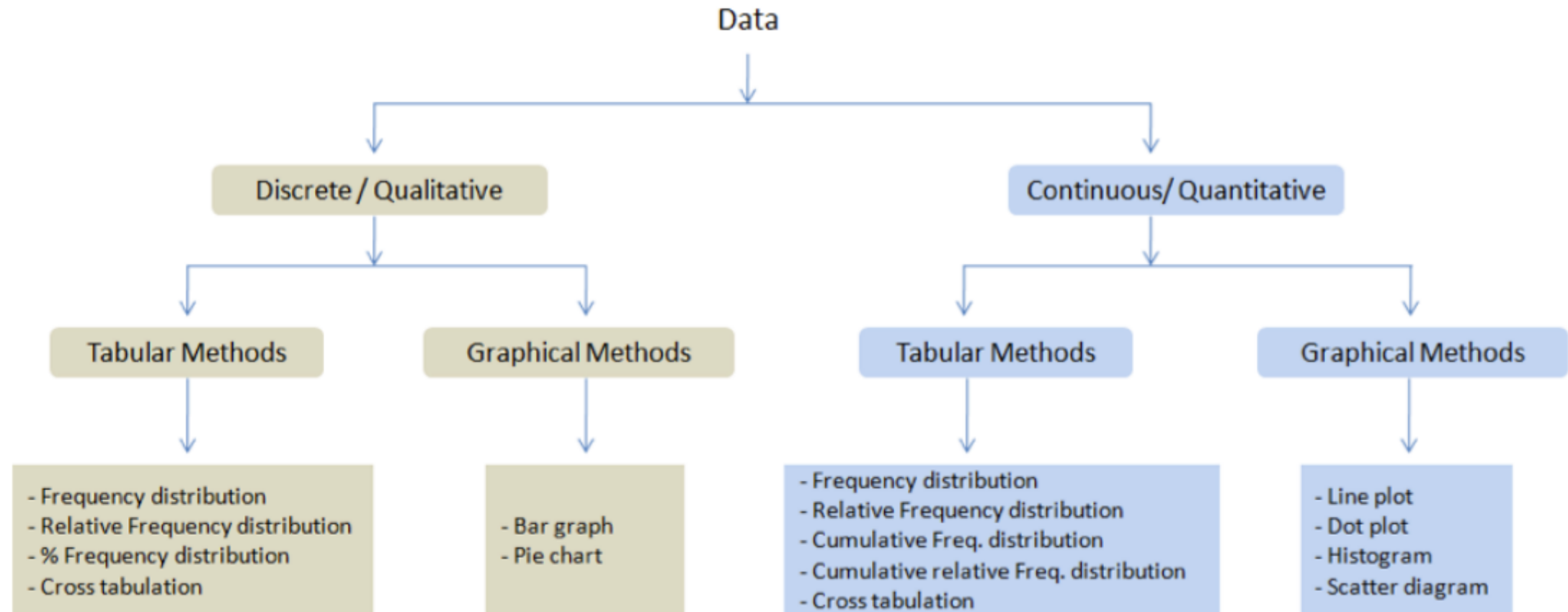
Technical Solution Methodologies



Data Scientist Day to Day Activities (CRISP-DM)

Business Understanding	Data Understanding	Data Preparation		Modeling	Optimization	Deployment
Determine Business Objectives	Design Features	Transform/Fix Target Variable	Data Normalization	Select The Model	Model Selection	Planning Deployment
Frame the Problem Assess Feasibility	Collect Initial Data	Redundant & Duplicates	Data Factorization	Split Data	Model Optimization	Monitoring & Maintenance
Define Success Measurements	Install & Import Packages	Data Quality Audit (Missing Values)	Data Binarization	Data Scaling	Parameters Tuning	Final Report
Identify Target Variables (Y)	Read the Data	Data Quality Audit (Outliers)	Data Standardizing	Dummy Model		Lessons Learned
Identify Analytical Approach	Data Manipulation & Wrangling	Data Quality Audit (Cardinality Check)	Data Correlations	Build Model		
Identify Deployment Plan	Exploratory Data Analysis (EDA)	Data Conversion	Data Aggregation Binning	Fit Model (Train)		
Produce Project Plan	Data Visualization	Data Transformation	Data Decomposition	Predict (Test)		
Identify the team & Stakeholders	Statistical Analysis	Feature Engineering <small>(Importance, Low variance, PCA)</small>	Feature Selections	Assess & Evaluate		
Analytics Base Table (ABT)	Code Book Quality Report	Data Version 2/3/4		Best Model	Best Parameters	ROI

A Simple Taxonomy of Data



Designing and Implementing Features

-
- Design and implement concrete feature based on the concepts
 - A feature is any measure derived from a domain concept that can be directly included in an ABT for use by a machine learning algorithm
 - Often it will take multiple features to express a domain concept
 - We may have to use some proxy features to capture something that is closely related to a domain concept when direct measurement is not possible
 - In some extreme cases we may have to abandon a domain concept completely if the data required to express it isn't available

Now that data has been collected for a modeling project, it needs to be examined so the analyst knows what is there. In many situations, the analyst is the first person to even look at the data as compiled into the modeling table in-depth. The analyst, therefore, will see all the **imperfections and problems** in the data that were previously unknown or ignored. [Without Data Understanding, you don't know what problems may arise in modeling.](#)

Data Understanding, as the first analytical step in predictive modeling, has the following purposes:

- **Examine** key summary characteristics about the data to be used for modeling, including how many records are available, how many variables are available, and how many target variables are included in the data.
- Begin to **enumerate** problems with the data, including inaccurate or invalid values, missing values, unexpected distributions, and outliers.
- **Visualize** data to gain further insights into the characteristics of the data, especially those masked by summary statistics.

Different Types of Features

Sample descriptive feature data illustrating numeric, binary, ordinal, interval, categorical, and textual types.

ID	NAME	DATE OF BIRTH	GENDER	CREDIT RATING	COUNTRY	SALARY
0034	Brian	22/05/78	male	aa	ireland	67,000
0175	Mary	04/06/45	female	c	france	65,000
0456	Sinead	29/02/82	female	b	ireland	112,000
0687	Paul	11/11/67	male	a	usa	34,000
0982	Donald	01/12/75	male	b	australia	88,000
1103	Agnes	17/09/76	female	aa	sweden	154,000

The features in an ABT can be of two types: Raw features or Derived features.

- **Raw features:** are features that come directly from raw data sources. For example, patient age, patient gender, drug treatment amount, or blood type are all descriptive features that we would most likely be able to transfer directly from a raw data source to an ABT.
- **Derived descriptive features:** do not exist in any raw data source, so they must be constructed from data in one or more raw data sources.

Different Types of Features

- **Aggregates:** are measures defined over a group or period and are usually defined as the count, sum, average, minimum, or maximum of the values within a group.
- **Flags:** are binary features that indicate presence or absence of some characteristic within a dataset. For example, a flag indicating whether a bank account has ever been overdrawn might be a useful descriptive feature.
- **Ratios:** are continuous features that capture the relationship between two or more raw data values.
- **Mappings:** are used to convert continuous features into categorical features and are often used to reduce the number of unique values that a model will have to deal with.
- **Other:** There are no restrictions to the ways in which we can combine data to make derived features.

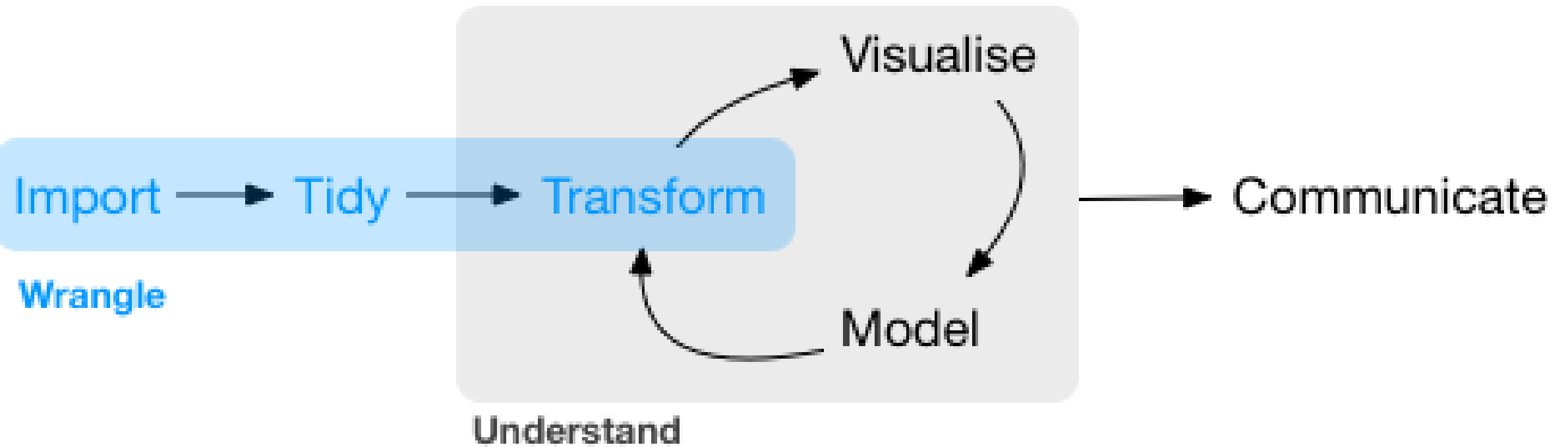
Two goals

- 1** Make data suitable to use with a particular piece of software
- 2** Reveal information

Exploratory Data Analysis (EDA) and Visualization are very important steps in any analysis task.

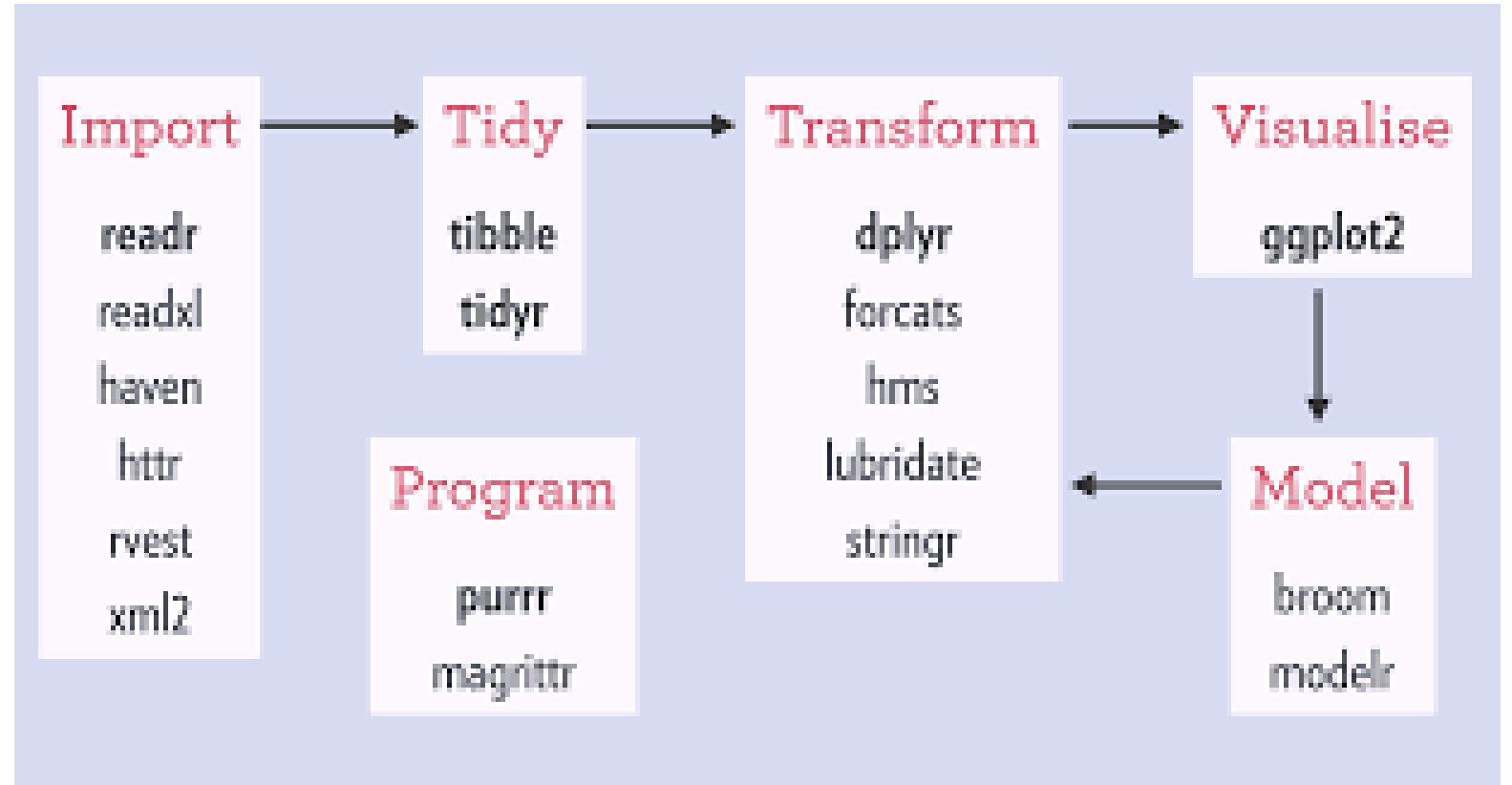
- Get to know your data!
- ✓ Distributions (symmetric, normal, skewed)
- ✓ Data quality problems
- ✓ Outliers
- ✓ Correlations and inter-relationships
- ✓ Subsets of interest
- ✓ Suggest functional relationships







<https://www.tidyverse.org/>



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

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

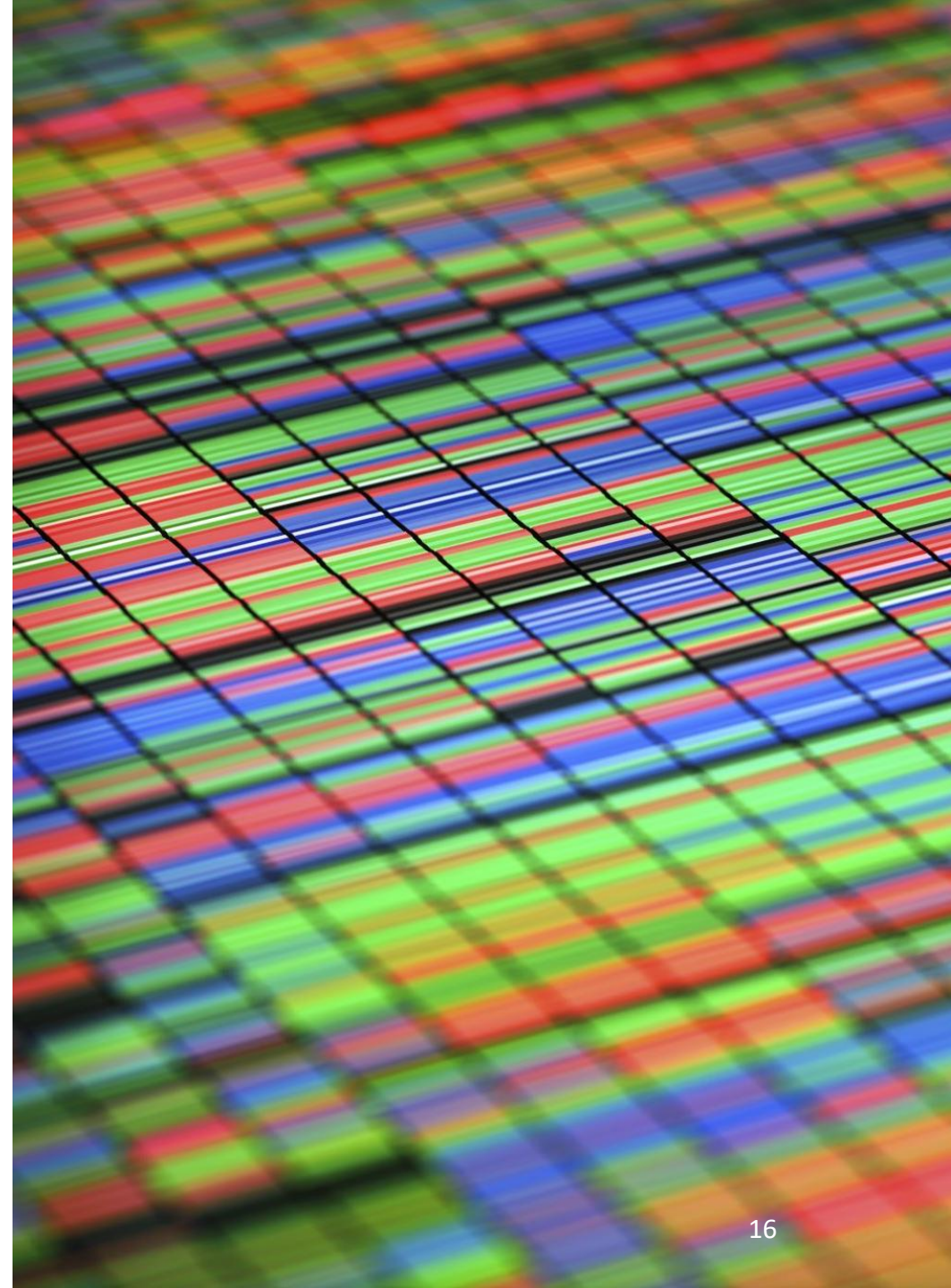
<https://github.com/rstudio/master-the-tidyverse/archive/master.zip>

Untidy Data

There are various features of messy data that one can observe in practice.

Here are some of the more commonly observed patterns.

- Column headers are values, not variable names
- Multiple variables are stored in one column
- Variables are stored in both rows and columns
- Multiple types of experimental unit stored in the same table
- One type of experimental unit stored in multiple tables



Data Wrangling with dplyr and tidyr
Cheatsheet
RStudio

Syntax - Helpful conventions for wrangling

- tbl_df()**
Converts data to tbl class. It's an easier to examine than data frames. It displays only the data that fits on screen.
- summary()**
Summarize data from tbl class. It's an easier to examine than data frames. It displays only the data that fits on screen.
- glimpse()**
Informational summary of tbl data.
- View()**
View data set in spreadsheet like display (like a copy of).
- %>%**
Pipes objects are left-hand side as first argument (or argument of function on right-hand side).
- %>%**
Pipes objects are left-hand side as first argument (or argument of function on right-hand side).
- %>%**
Pipes objects are left-hand side as first argument (or argument of function on right-hand side).

Tidy Data - A foundation for wrangling in R

- In a tidy data set:
 - Each variable is stored in its own column.
 - Each observation is recorded in its own row.
- Tidy data complements R's **vectorized operations**. It will automatically generate observations as you manipulate variables. No other format works as intuitively with R.

Reshaping Data - Change the layout of a data set

- gather()**
Gather columns into rows.
- spread()**
Spread rows into columns.
- separate()**
Separate one column into several.
- unite()**
Unite several columns into one.

Subset Observations (Rows)

- filter()**
Filter rows that meet logical criteria.
- distinct()**
Remove duplicate rows.
- sample_n()**
Randomly select fraction of rows.
- sample_frac()**
Randomly select n rows.
- slice()**
Select rows by position.
- top_n()**
Select and order top n rows by group if grouped data.

Subset Variables (Columns)

- select()**
Select columns by name or helper function.
- rename()**
Rename columns.
- extract()**
Extract data from a column into a vector.
- pull()**
Extract data from a column into a vector.
- select_at()**
Select columns by name or helper function.
- rename_at()**
Rename columns.
- extract_at()**
Extract data from a column into a vector.
- pull_at()**
Extract data from a column into a vector.

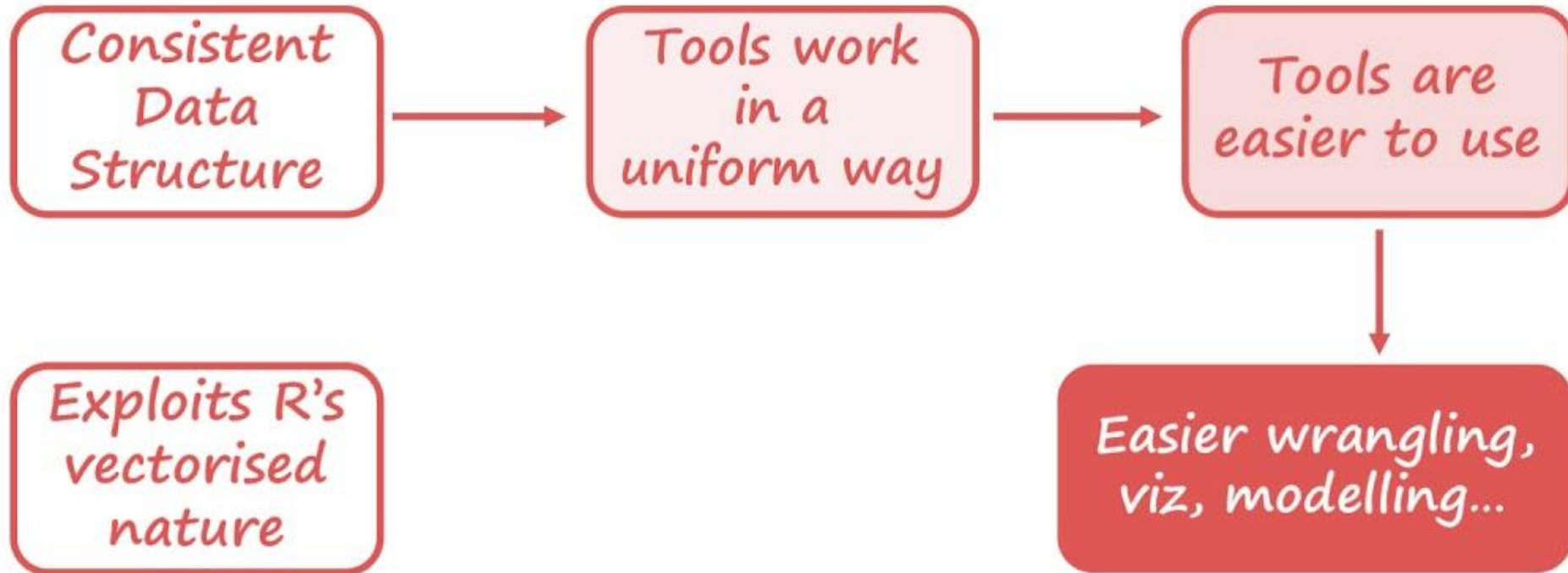
Helper Functions for select()

- everything()**
Select all columns.
- starts_with()**
Select columns that start with a string.
- ends_with()**
Select columns that end with a string.
- contains()**
Select columns that contain a string.
- matches()**
Select columns that match a regular expression.
- num_range()**
Select columns that are numeric.
- str_detect()**
Select columns that contain a string.
- str_extract()**
Extract data from a column into a vector.
- str_remove()**
Remove data from a column.
- str_replace()**
Replace data in a column.
- str_remove_all()**
Remove all data from a column.
- str_replace_all()**
Replace all data in a column.

<http://www.rstudio.com/resources/cheatsheets/>

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Why tidy data?

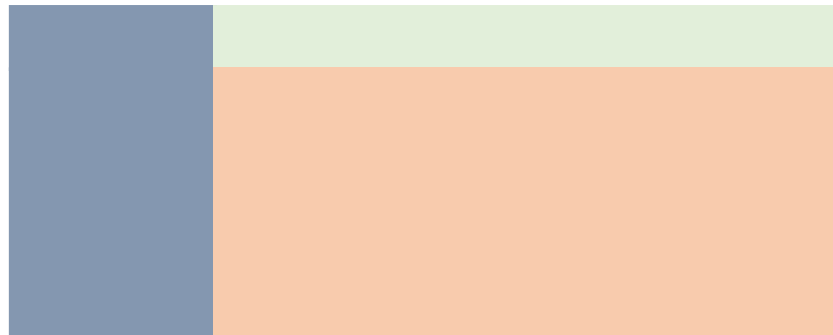


The tidy package is used to manipulate the structure of your data while preserving all original information, using the following functions:

`gather()` our data (wide \rightarrow long)

`spread()` our data (long \rightarrow wide)

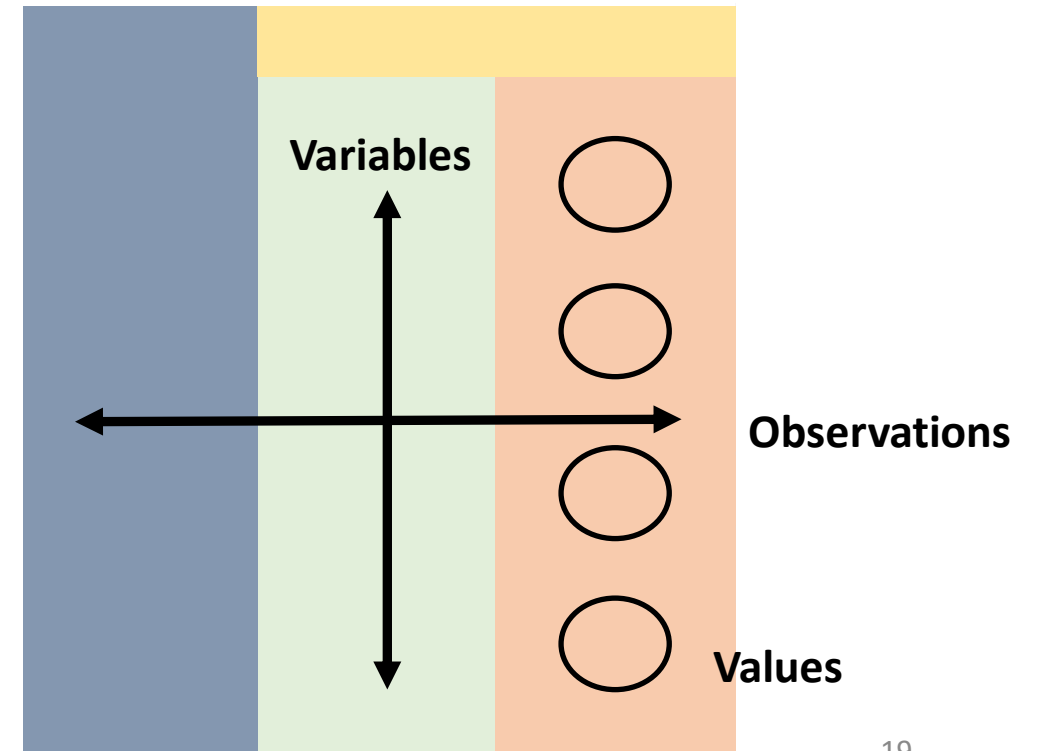
Tame Data



Gather()

Spread()

Tidy Data



There are four main verbs which are essentially pairs of opposites:

turn columns into rows (`gather()`),

turn rows into columns (`spread()`),

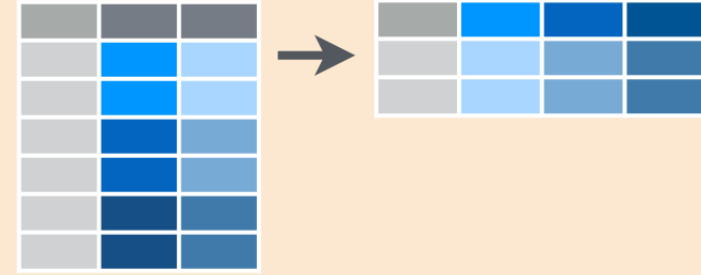
turn a character column into multiple columns (`separate()`),

turn multiple character columns into a single column (`unite()`)



`tidyr::gather(cases, "year", "n", 2:4)`

Gather columns into rows.



`tidyr::spread(pollution, size, amount)`

Spread rows into columns.



`tidyr::separate(storms, date, c("y", "m", "d"))`

Separate one column into several.



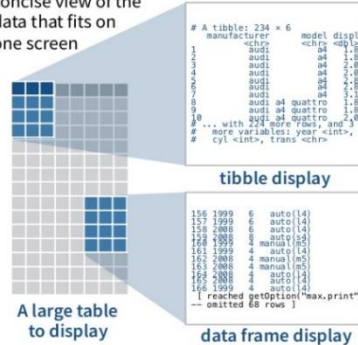
`tidyr::unite(data, col, ..., sep)`

Unite several columns into one.

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 three behaviors:

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



- Control the default appearance with options:
`options(tibble.print_max = n,
tibble.print_min = m, tibble.width = Inf)`
- View full data set with **View()** or **glimpse()**
- Revert to data frame with **as.data.frame()**

CONSTRUCT A TIBBLE IN TWO WAYS

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")`

Both make this tibble

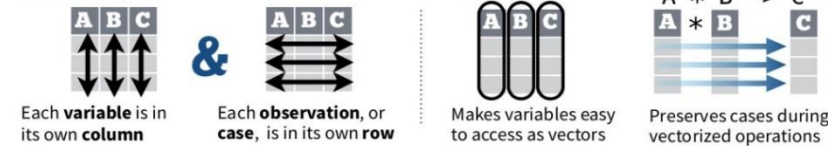
as_tibble(x, ...) Convert data frame to tibble.
enframe(x, name = "name", value = "value")
Convert named vector to a tibble
is_tibble(x) Test whether x is a tibble.



Tidy Data with tidyr

Tidy data is a way to organize tabular data. It provides a consistent data structure across packages.

A table is tidy if:



Reshape Data - change the layout of values in a table

Use **gather()** and **spread()** to reorganize the values of a table into a new layout.

gather(data, key, value, ..., na.rm = FALSE, convert = FALSE, factor_key = FALSE)

gather() moves column names into a **key** column, gathering the column values into a single **value** column.

table4a

country	1999	2000
A	0.7K	2K
B	37K	80K
C	212K	213K

key value

`gather(table4a, `1999`, `2000`,
key = "year", value = "cases")`

spread(data, key, value, fill = NA, convert = FALSE, drop = TRUE, sep = NULL)

spread() moves the unique values of a **key** column into the column names, spreading the values of a **value** column across the new columns.

table2

country	year	type	count
A	1999	cases	0.7K
A	1999	pop	19M
A	2000	cases	2K
A	2000	pop	20M
B	1999	cases	37K
B	1999	pop	172M
B	2000	cases	80K
B	2000	pop	174M
C	1999	cases	212K
C	1999	pop	1T
C	2000	cases	213K
C	2000	pop	1T

key value

`spread(table2, type, count)`

Handle Missing Values

drop_na(data, ...)

Drop rows containing NA's in ... columns.

x

x1	x2
A	1
B	NA
C	NA
D	3
E	NA

drop_na(x, x2)

fill(data, ..., direction = c("down", "up"))

Fill in NA's in ... columns with most recent non-NA values.

x

x1	x2
A	1
B	1
C	1
D	3
E	3

fill(x, x2)

replace_na(data, replace = list(), ...)

Replace NA's by column.

x

x1	x2
A	1
B	2
C	2
D	3
E	2

replace_na(x, list(x2 = 2))

Expand Tables - quickly create tables with combinations of values

complete(data, ..., fill = list())

Adds to the data missing combinations of the values of the variables listed in ...
`complete(mtcars, cyl, gear, carb)`

expand(data, ...)

Create new tibble with all possible combinations of the values of the variables listed in ...
`expand(mtcars, cyl, gear, carb)`

Split Cells

Use these functions to split or combine cells into individual, isolated values.



separate(data, col, into, sep = "[^:alnum:]", "+", remove = TRUE, convert = FALSE, extra = "warn", fill = "warn", ...)

Separate each cell in a column to make several columns.

table3

country	year	rate
A	1999	0.7K/19M
A	2000	2K/20M
B	1999	37K/172M
B	2000	80K/174M
C	1999	212K/1T
C	2000	213K/1T

country year cases pop

`separate(table3, rate,
into = c("cases", "pop"))`

separate_rows(data, ..., sep = "[^:alnum:]", "+", convert = FALSE)

Separate each cell in a column to make several rows. Also **separate_rows()**.

table3

country	year	rate
A	1999	0.7K
A	2000	2K
B	1999	37K
B	2000	80K
C	1999	212K
C	2000	213K

country year rate

`separate_rows(table3, rate)`

unite(data, col, ..., sep = "_", remove = TRUE)

Collapse cells across several columns to make a single column.

table5

country	century	year
Afghan	19	99
Afghan	20	0
Brazil	19	99
Brazil	20	0
China	19	99
China	20	0

country year

`unite(table5, century, year,
col = "year", sep = "")`



Practice



Practice



Practice

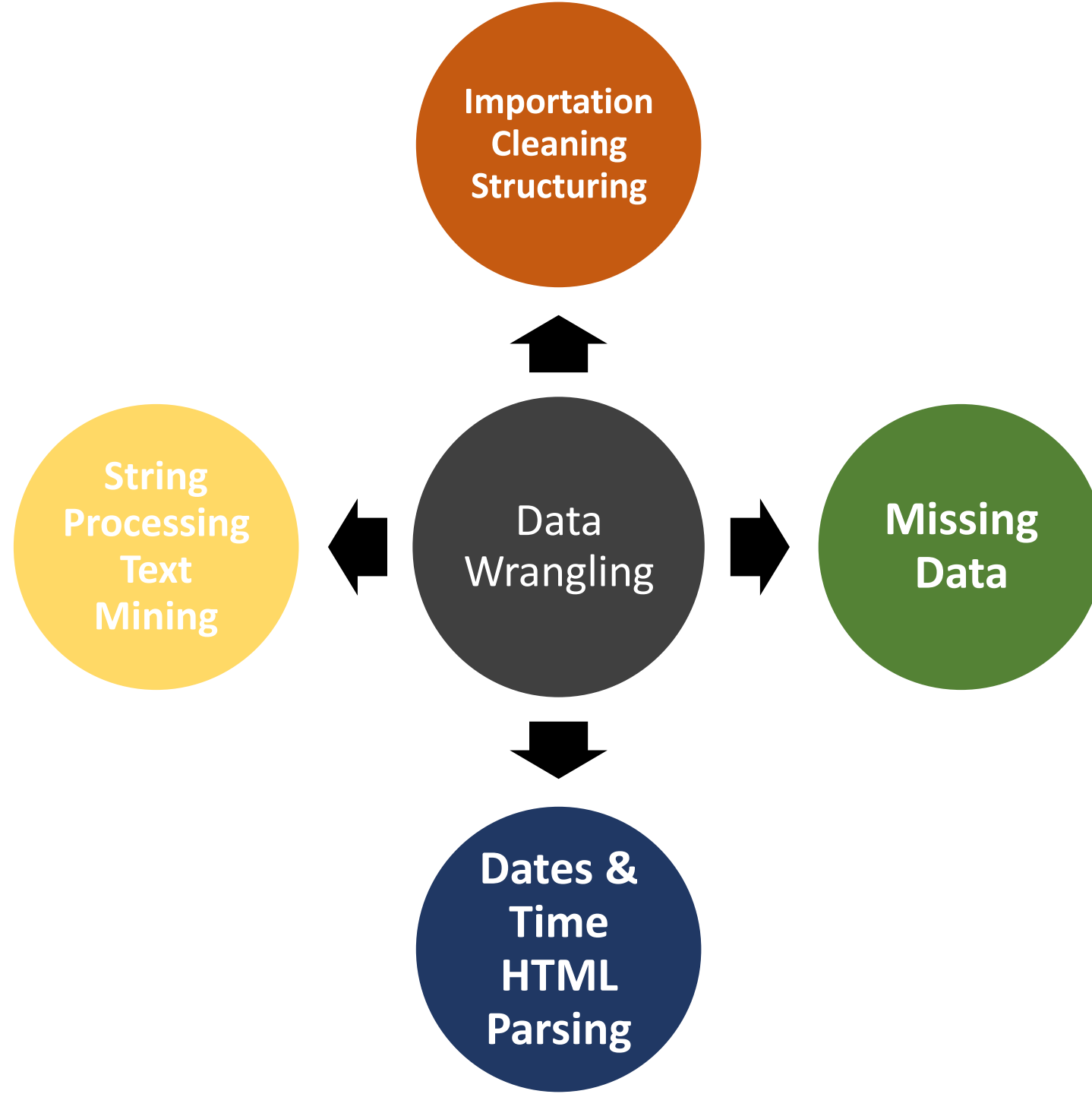
Tidy Data



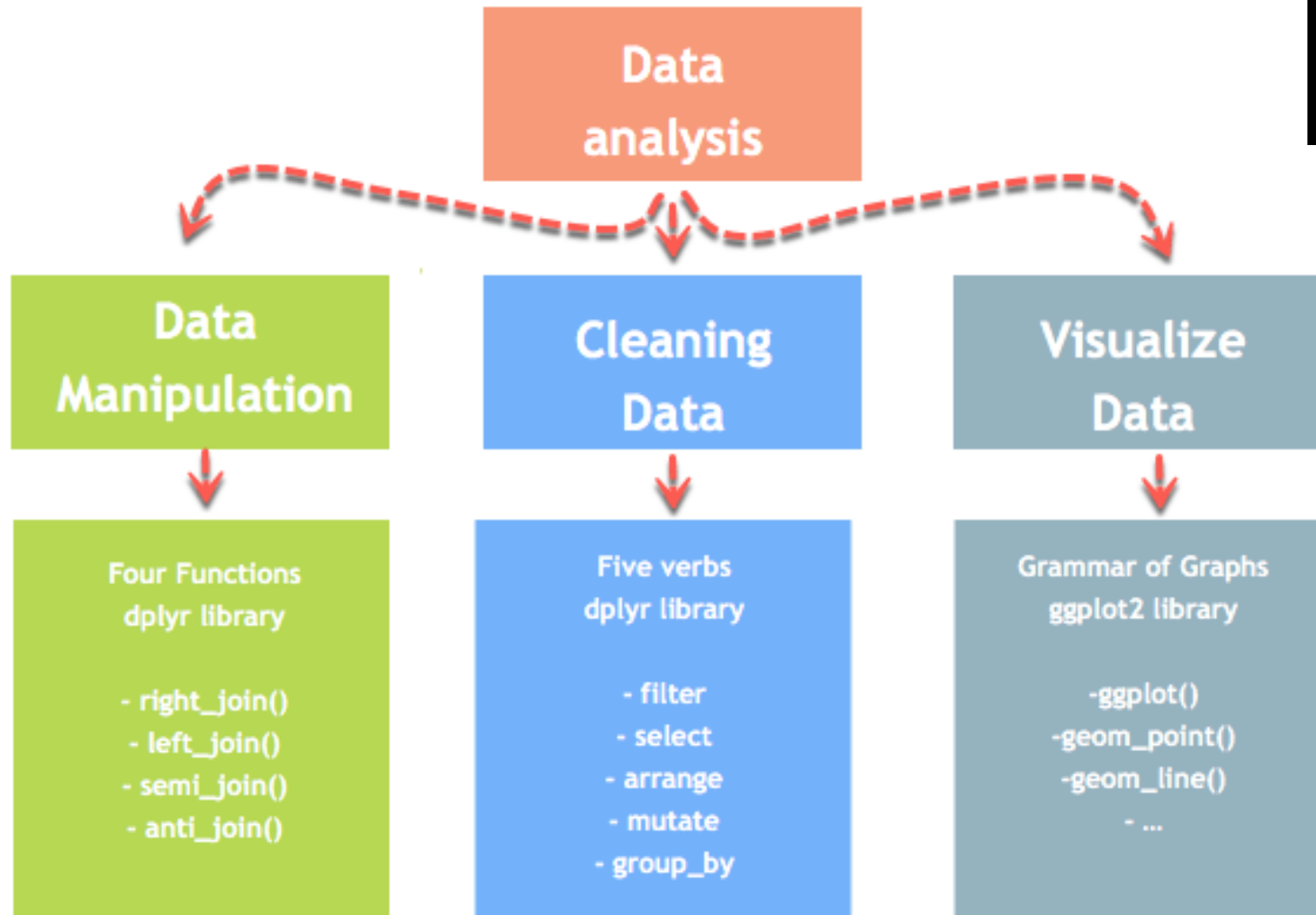
See the paper Tidy Data by Hadley Wickham in Journal of Statistical Software (2014)

<https://github.com/rstudio/master-the-tidyverse/archive/master.zip>

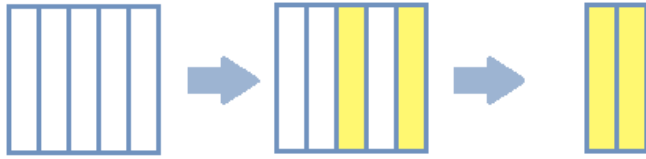
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Data Wrangling – Dplyr Package



select



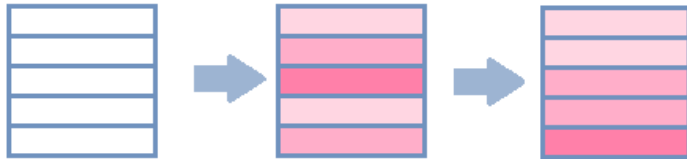
- Inspect your tibble (`glimpse()`)
- Select specific columns (`select()`)

filter



- Filter out a subset of rows (`filter()`)
- Reorders rows by one or multiple columns (`arrange()`)

arrange



- Change or add columns (`mutate()`)

mutate



- Group observations by a grouping variable (`group_by()`)

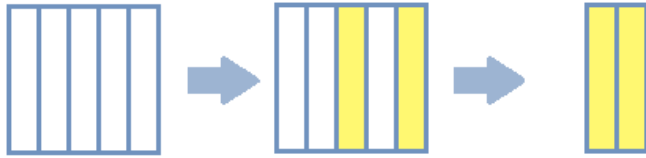
summarise



- Get a summary (in particular per group) (`summarise()`)
- Join two distinct tibbles by a common column (`left_join()`, `right_join()` and `full_join()`)

Source: <http://perso.ens-lyon.fr/lise.vaudor/dplyr/>

select



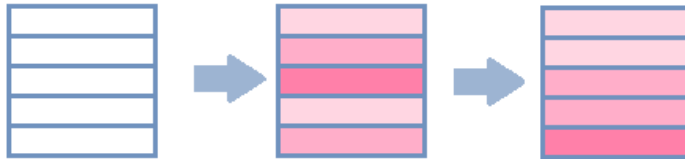
- `select(dataframe, column1, column2, ...)`

filter



- `filter(dataframe, logical statement 1, logical statement 2, ...)`

arrange



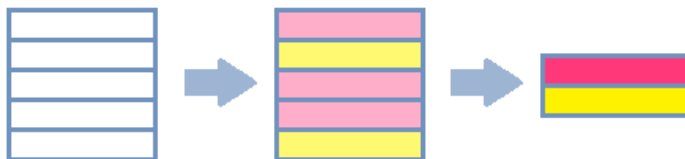
- `arrange(data, variable1, desc(variable2), ...)`

mutate

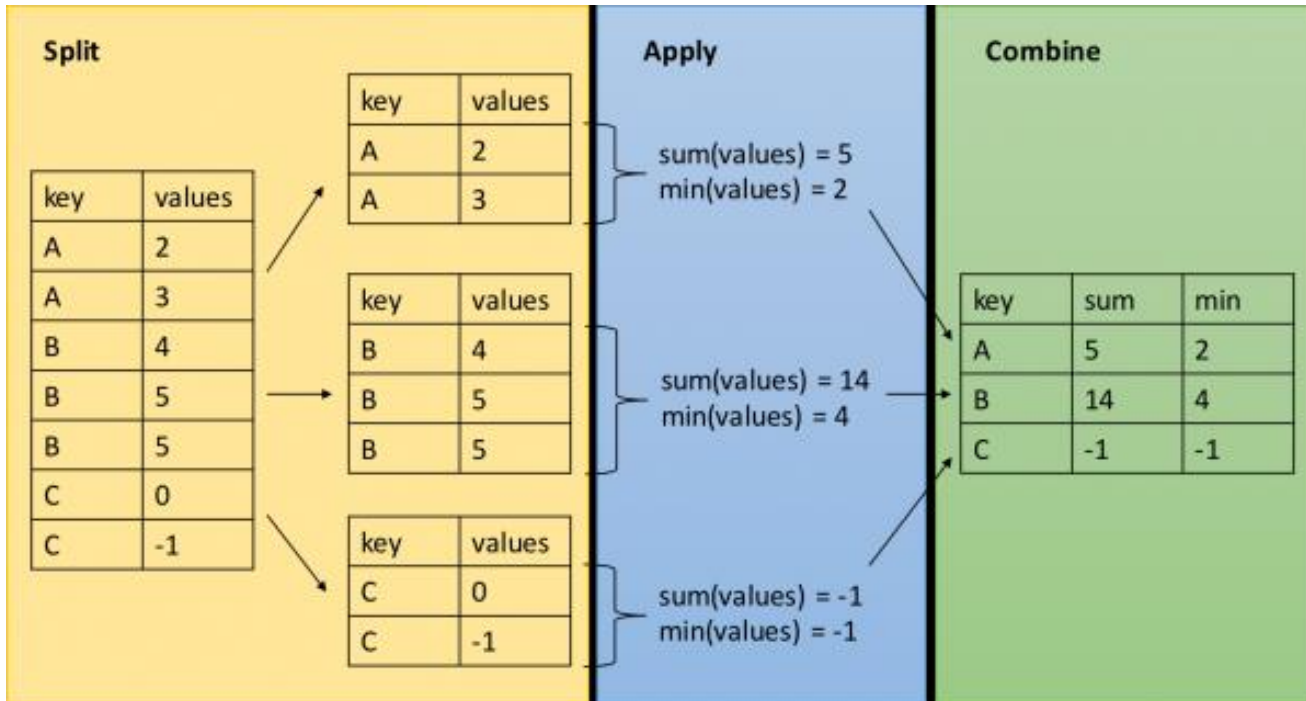


- `mutate(data, newVar1 = expression1, newVar2 = expression2, ...)`

summarise



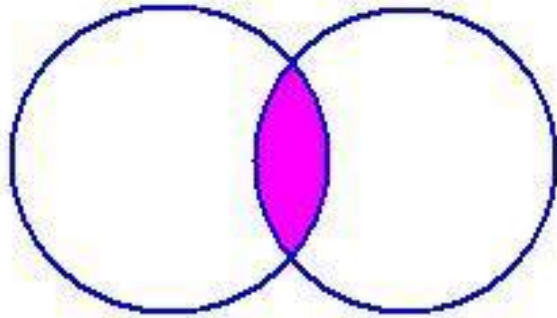
Source: <http://perso.ens-lyon.fr/lise.vaudor/dplyr/>



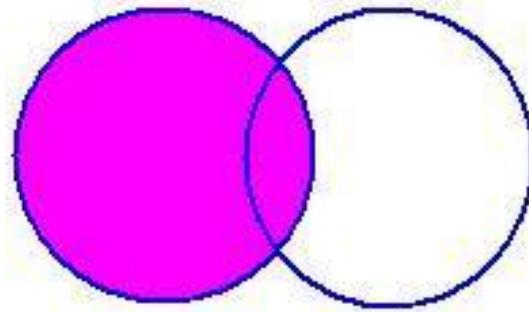
`group_by()`: group data frame by a factor for downstream commands (usually summarise)

`summarise()`: summarise values in a data frame or in groups within the data frame with aggregation functions (e.g. `min()`, `max()`, `mean()`, etc...)

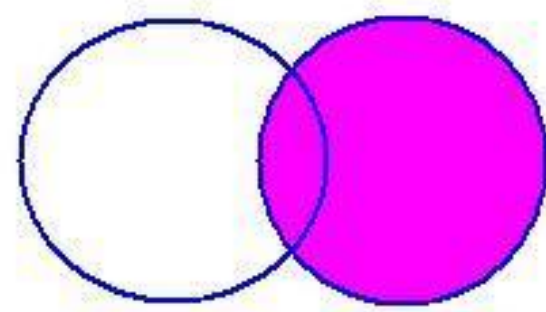
JOINS AND SET OPERATIONS IN RELATIONAL DATABASES



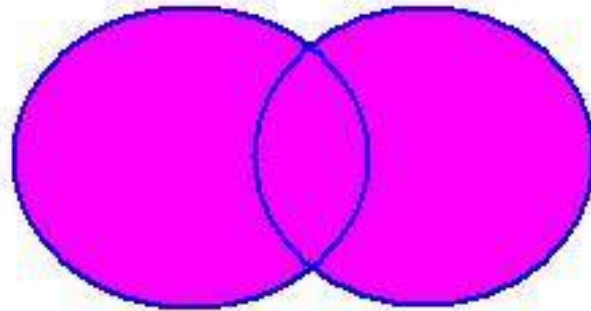
Inner join (result similar to Intersect)



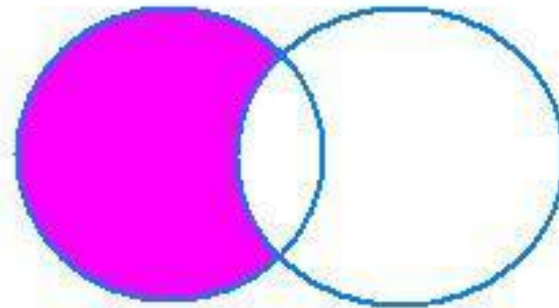
Left outer join



Right outer join



Full outer join



Minus

Functions that allow you to join two data frames together.

a		b		
x1	x2	x1	x3	
A	1	A	T	+
B	2	B	F	
C	3	D	T	
				=

Mutating Joins

x1	x2	x3
A	1	T
B	2	F
C	3	NA

dplyr::left_join(a, b, by = "x1")
Join matching rows from b to a.

x1	x3	x2
A	T	1
B	F	2
D	T	NA

dplyr::right_join(a, b, by = "x1")
Join matching rows from a to b.

x1	x2	x3
A	1	T
B	2	F

dplyr::inner_join(a, b, by = "x1")
Join data. Retain only rows in both sets.

x1	x2	x3
A	1	T
B	2	F
C	3	NA
D	NA	T

dplyr::full_join(a, b, by = "x1")
Join data. Retain all values, all rows.

Magrittr package: using the pipe operator



- Pipe operators provide ways of linking functions together so that the output of a function flows into the input of next function in the chain.
- Specify the dataset first, then “pipe” into the next function in the chain.
 - `dlpyr::select (Tb, child:elderly)`
 - `Tb %>% dlpyr::select(child:elderly)`



Practice

Practice

Practice