Strata+Hadoop WORLD

PRESENTED BY

O'REILLY cloudera

RStudio

Win-Vector LLC

strataconf.com

#StrataHadoop

Modeling big data with R, sparklyr, and Apache Spark

1:30pm–5:00pm Tuesday, March 14, 2017

Data science & advanced analytics

Location: LL21 C/D

Level: Intermediate

Secondary topics: R

John Mount (Win-Vector LLC)

Steve Nolen (RStudio)

Edgar Ruiz (RStudio)

url: https://github.com/WinVector/BigDataRStrata2017

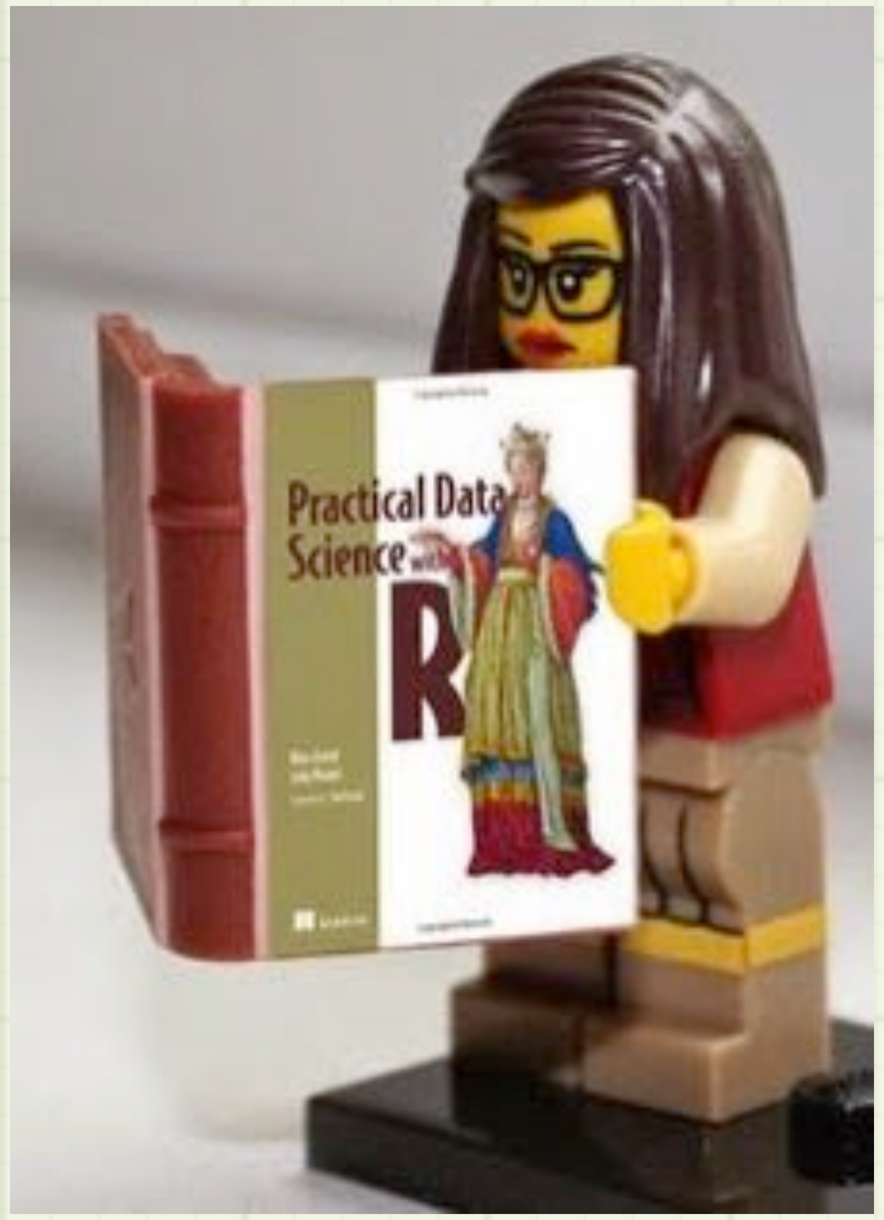
Part 1: lecture `R` and `dplyr`

HELLO
my name is

John

Win-Vector LLC
Data science consulting
http://www.win-vector.com/

John Mount
@Win-Vector LLC
http://win-vector.com/
jmount@win-vector.com



VTREAT
prepare data

Win-Vector LLC

Win-Vector LLC

- Data science and analytics training and consulting.
- We distribute a number of open source R packages
    - Most importantly the `vtreat` variable preparation package.
- Please reach out to us for partnerships
    - Myself or Dr. Lin Chase of Big Tech Strategy (who is working with us).


HELLO
my name is
Steve
RStudio

Steve Nolen


Shiny
stringr
tidyr
rmarkdown
dplyr
devtools
knitr
lubridate
ggplot2
packrat
%>%
Ceci n'est pas un pipe.
stringr
readr

HELLO

my name is

Edgar

RStudio

2:40pm–3:20pm Wednesday, March 15, 2017

Sparklyr: An R interface for Apache Spark

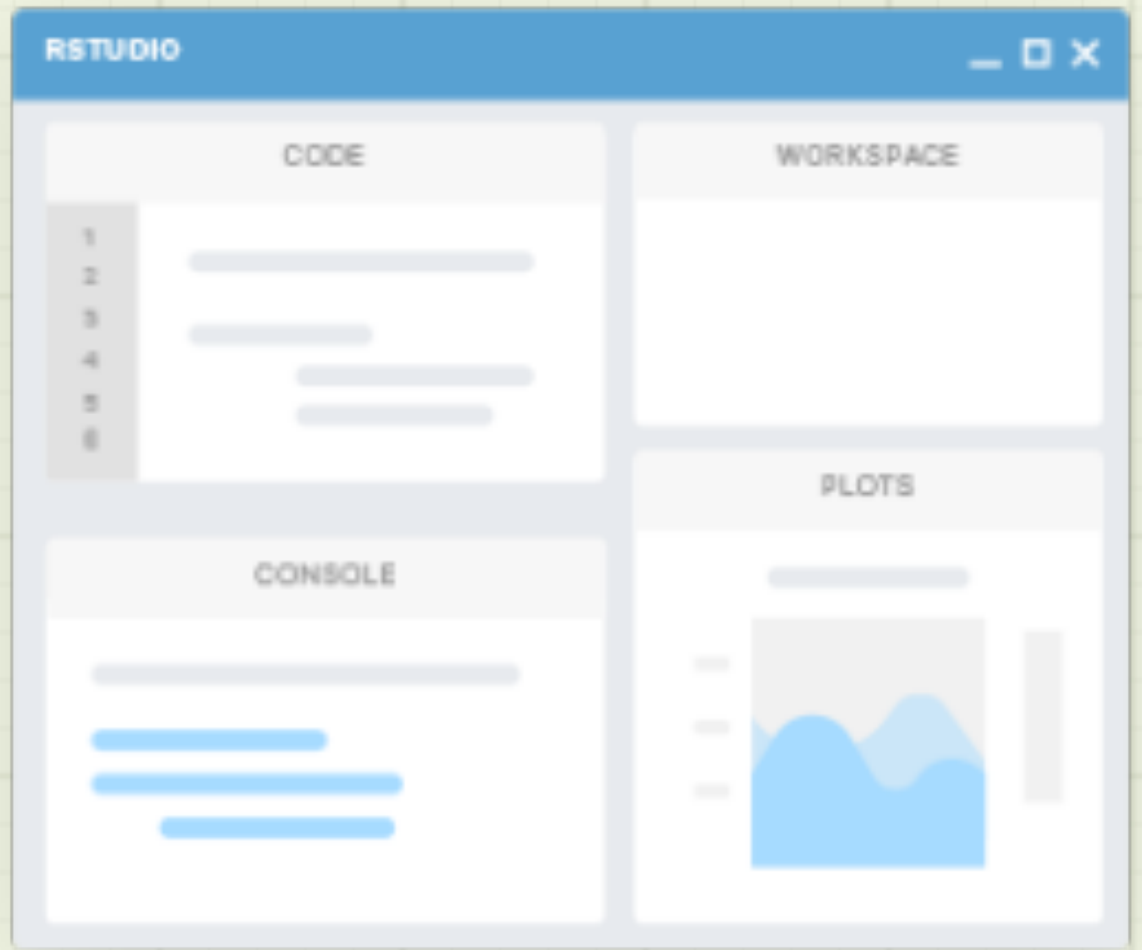
Edgar Ruiz (RStudio)

Primary topic: Spark & beyond

Location: LL21 C/D

Level: Beginner

RStudio



rmarkdown Shiny tidyr knitr ggplot2

RStudio asked us to produce and present this workshop, and is supplying the free accounts.

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Warm up

Introduce yourself to your table

Name

What do you do with data?

For how long have you been using R?

03:00

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The goal

- Help `R` users confidently work with data in `Spark` and `h2o`
    - Go over data manipulation
    - Try some basic supervised machine learning
    - Look at native commands and `Spark` extensions

The plan

- We will alternate
    - Lecture segments
        - All slides are being shared.
    - Hands-on exercises/ walk-throughs
- Using RStudio Server Pro accounts we are supplying.
    - All packages, code, and examples already loaded into each account.
    - We are practicing only with small data to learn the systems.
- All materials (slides, data, code, and solved exercise) are here at this public GitHub repository: https://github.com/WinVector/BigDataRStrata2017

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Workshop outline

1. Lecture: R and `dplyr`.

2. Exercises: manipulating data locally.

3. Lecture: `Spark` and `sparklyr`.

Break around here

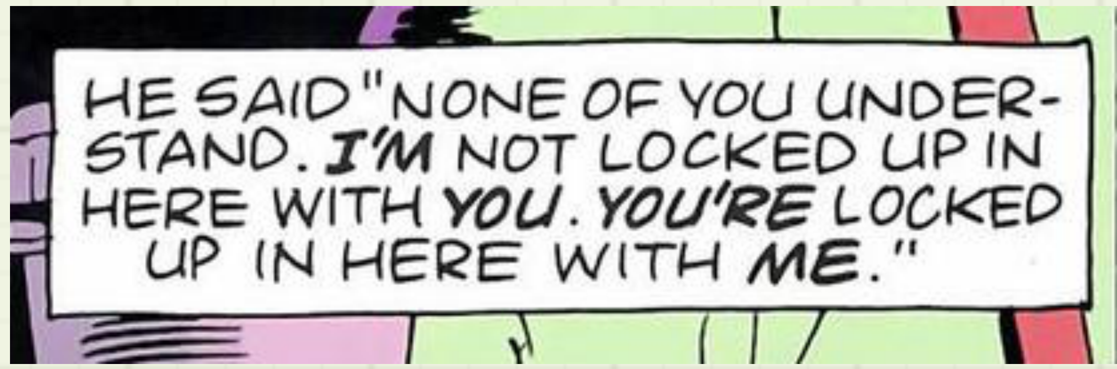
4. Exercises: Using `dplyr` to control `Spark` through `sparklyr`.

5. Lecture: Machine learning concepts review.

6. Exercises: Machine learning in `SparkML` and `h2o`.

7. Lecture: Advanced topics.

Possibly 5 pounds of sugar in the 3.5 pound bag.



Course developers

- Garrett Grolemund (RStudio)
- Nathan Stevens (RStudio)
- Nina Zumel (Win-Vector)
- John Mount (Win-Vector)

My strategy

- We will cover organizing data and performing supervised machine learning
    - `R`
    - `dplyr`
    - `Spark`
    - `SparkML` / `h2o` machine learning
- Going to (hopefully) avoid an installation debug fest by lending you ready to go RStudio Server Pro environments.
- We are going to go over everything
    - Guarantees I’ll hit that 20% you wanted to hear more about.
    - Great chance to see data manipulation tools as a coherent whole.

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We will use a warning symbol on some slides

- Doesn't mean "avoid."
- Just indicates: "be careful and you will get good results."

Let's define our terms

- `R`: The analysis language and platform we are using, descended from `S`.
- RStudio Server Pro: a remote `R` service and user interface.
- `Spark`: a fast and general engine for large-scale data processing.
- `h2o`: a large scale machine learning platform from h2o.ai

Apache Spark

- Prefers distributed in-memory operations.
- Can talk to Java, Scala, Python, R.
- Many data operations organized in terms of SQL.
- Runs in many configurations (standalone cluster mode, on EC2, on Hadoop YARN, or on Apache Mesos. Access data in HDFS, Cassandra, HBase, Hive, Tachyon).

Connecting using R

- Will use R as the control system.
  - Data scientist programs in R.
  - R issues commands to remote large data systems to work on remote data.
- For Spark
  - Use sparklyr and dplyr.
- For h2o
  - Use h2o R package and rsparkling.

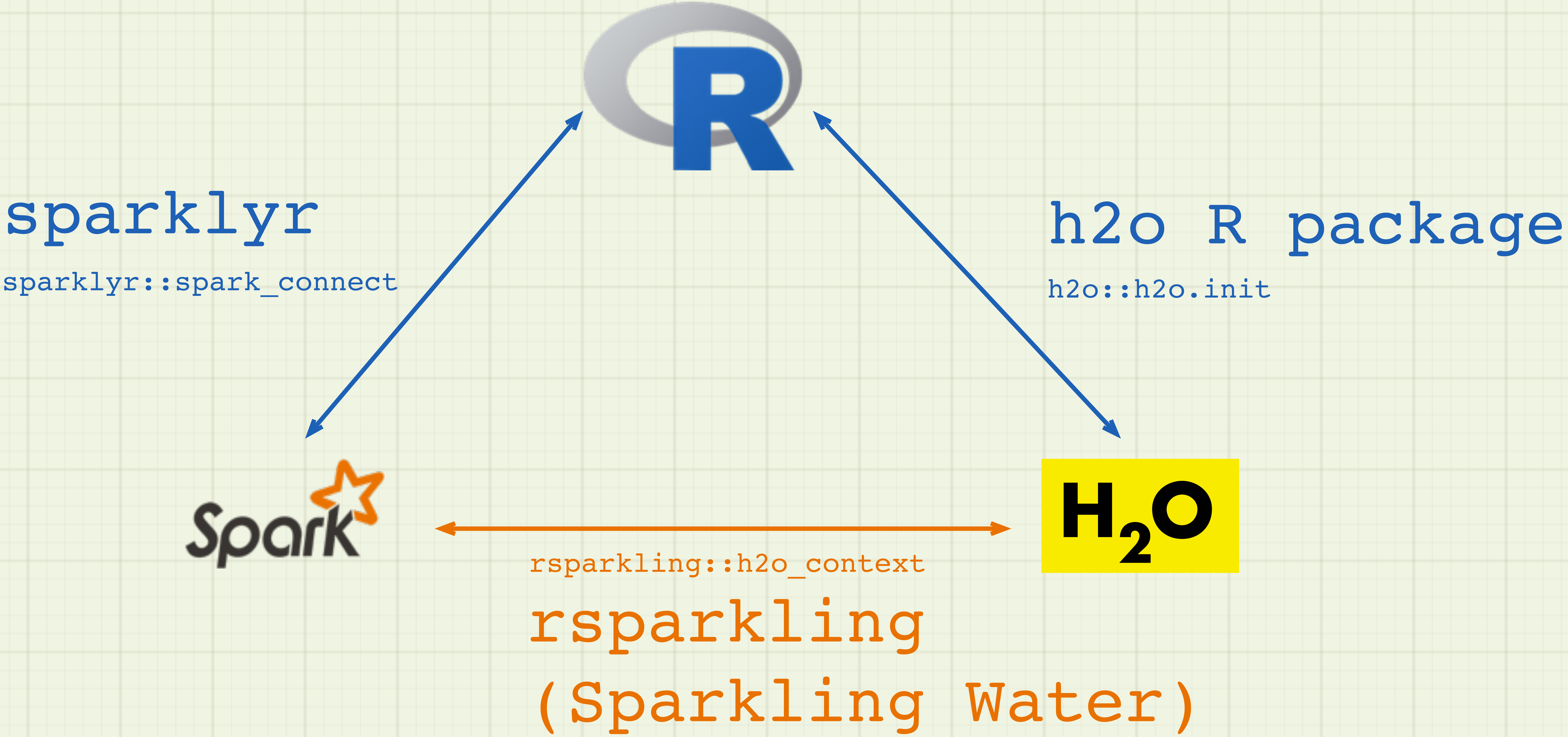
The three island view

```
ls()
<objectname>
```

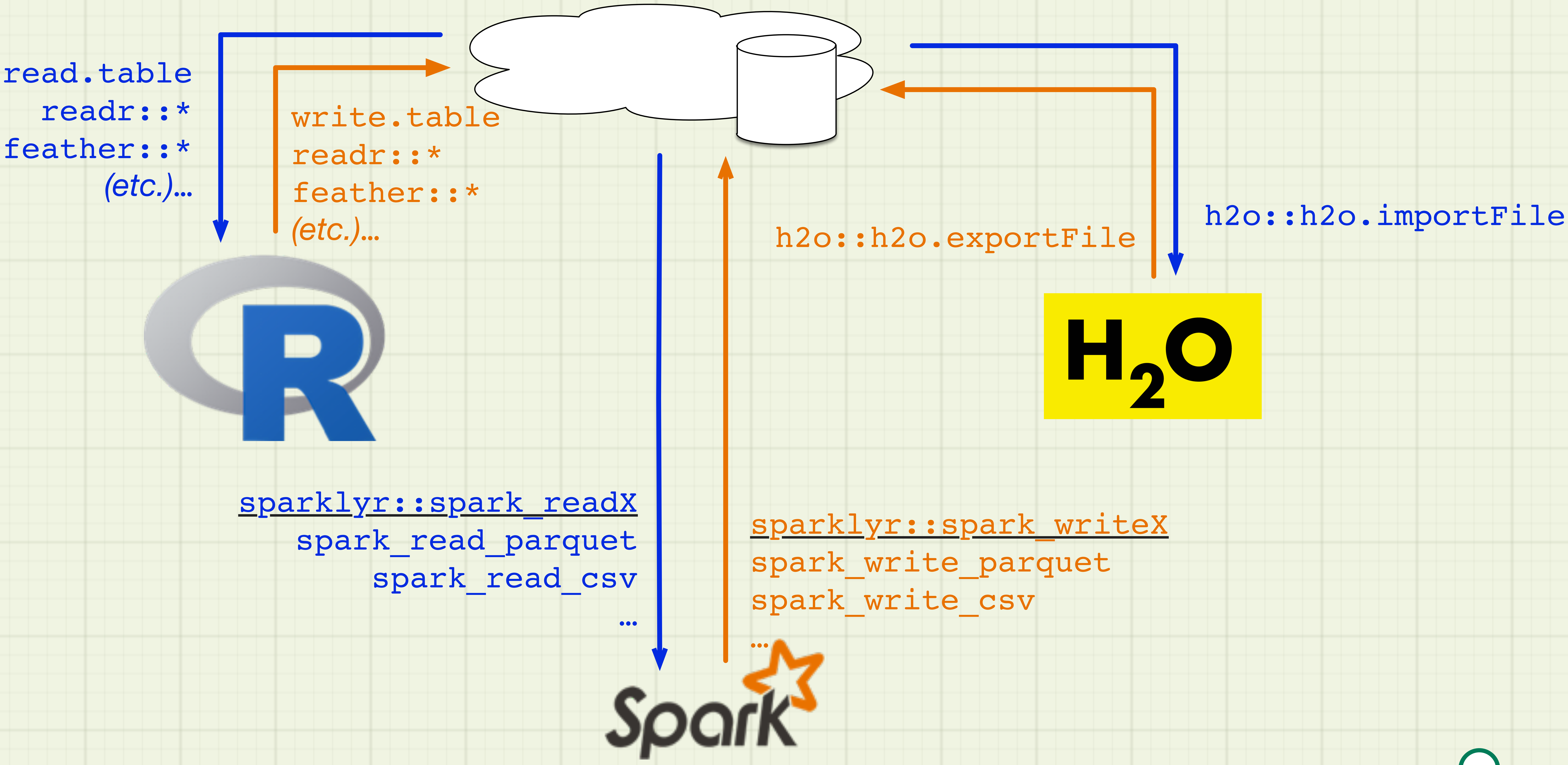
```
DBI::dbListTables(sc)
dplyr::tbl(sc, <objectname>)
```

```
h2o::h2o.ls()
h2o::h2o.getFrame(<keyid>)
```

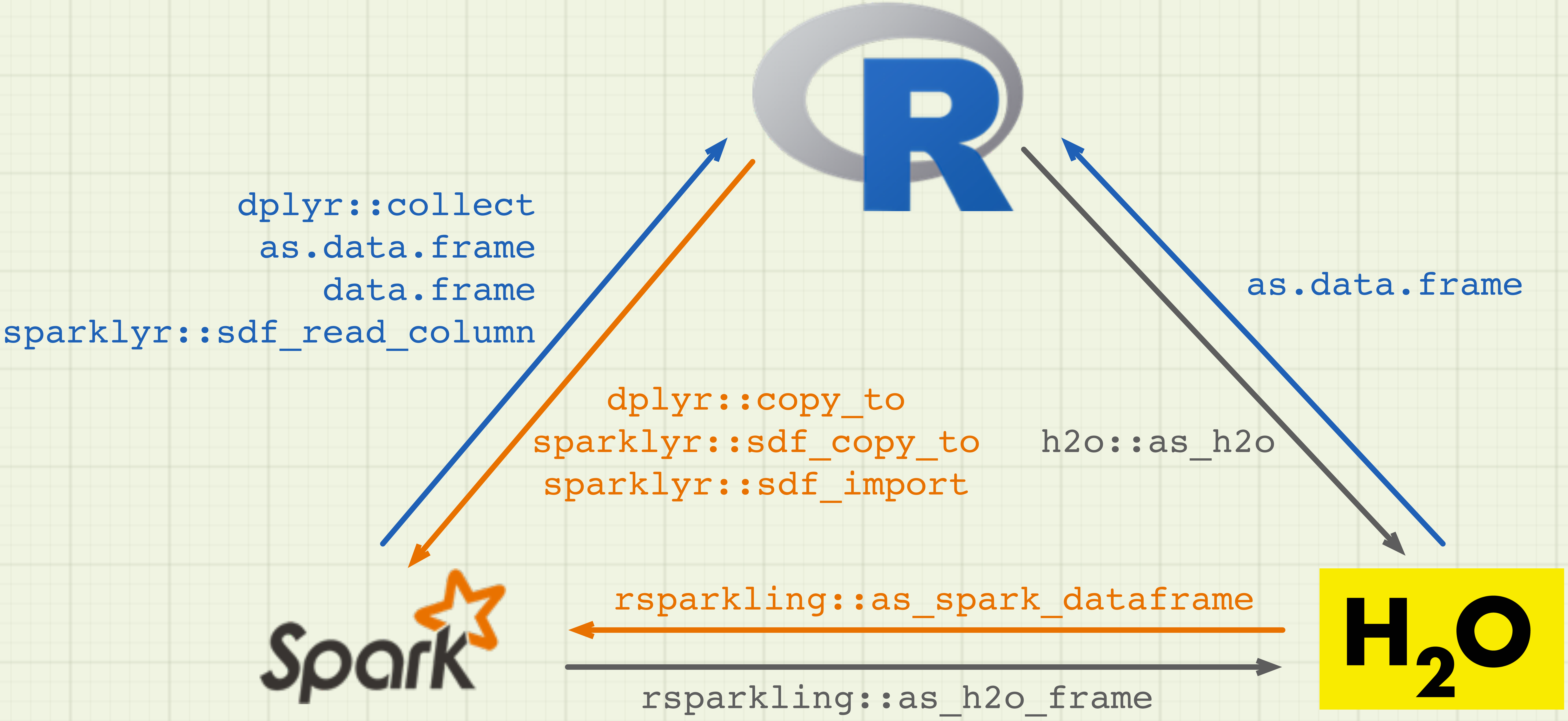
Bridging islands



Importing/Exporting data



Moving data between islands



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First: `R` and `dplyr`

Why data manipulation?

- Supervised machine learning uses structured data in a very regular and explicit form called "denormalized":
    - Every row is an event or observation.
    - Each column is homogeneous facts or variables.
    - Every fact or variable is already landed in a column.
- We need good tools to get from wild recorded forms or efficient *normalized forms* into the above form.

Schematized

Denormalized

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R and dplyr

"No matter how complex and polished the individual operations are, it is often the quality of the glue that most directly determines the power of the system."

— Hal Abelson

dplyr

A grammar of data manipulation

select	left_join	bind_cols
filter	right_join	bind_rows
arrange	inner_join	union
mutate	full_join	intersect
summarise	semi_join	setdiff
group_by	anti_join	`%>%`

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dplyr formula components

Operators

+, -, *, /, %%, ^

Math functions

abs, acos, cosh, sin, asinh, atan, atan2, atanh, ceiling, cos, cosh, cot, coth, exp, floor, log, log10, round, sign, sin, sinh, sqrt, tan, tanh

Comparisons

<, <=, !=, >=, >, ==, %in%

Booleans

&, &&, |, ||, !, xor

Aggregations

mean, n(), rank, rank_min, sum, min, max, sd, var

example

```
> d <- data.frame(x= 1:4)
> d$y <- 2*d$x
> print(d)

  x y
1 1 2
2 2 4
3 3 6
4 4 8
```

```
> library("dplyr")
> d <- data_frame(x= 1:4)
> d <- mutate(d, y = 2*x)
> print(d)

# A tibble: 4 × 2
      x     y
  <int> <dbl>
1     1     2
2     2     4
3     3     6
4     4     8
```

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Why `dplyr`?

- `dplyr` is a collection of transforms you can decompose your task into.
- There are multiple `dplyr` “data service” implementations.
  - Tasks written as a sequence of `dplyr` operations can be moved from service to service.
    - Local `data.frame` / `tbl`
    - `Spark` / `Sparklyr`

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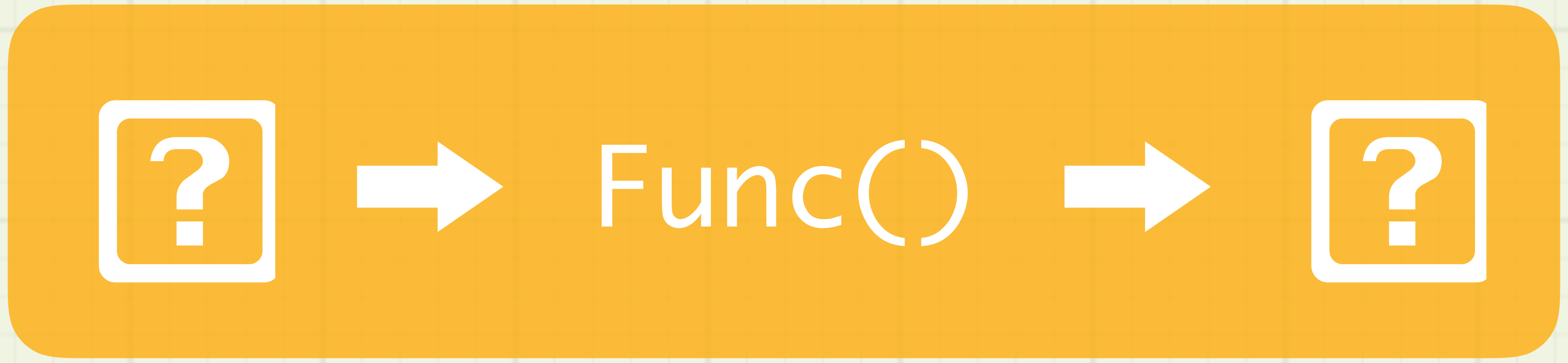
Why review `dplyr`?

To make sure we are all *really familiar* with `dplyr` operations before trying to use them on `Spark`.

Single Table Verbs

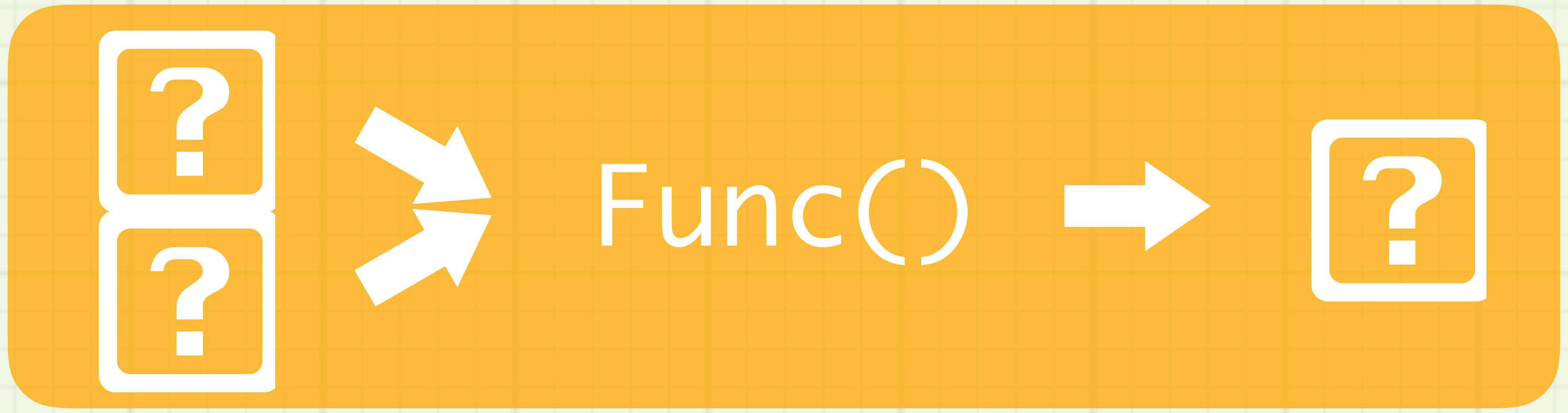
Manipulate tabular data



`select` `filter` `summarise`
`mutate` `arrange` `group_by`

Two Table Verbs

Join together relational data



`left_join` `full_join` `union` `bind_cols`
`right_join` `semi_join` `intersect` `bind_rows`
`inner_join` `anti_join` `setdiff`

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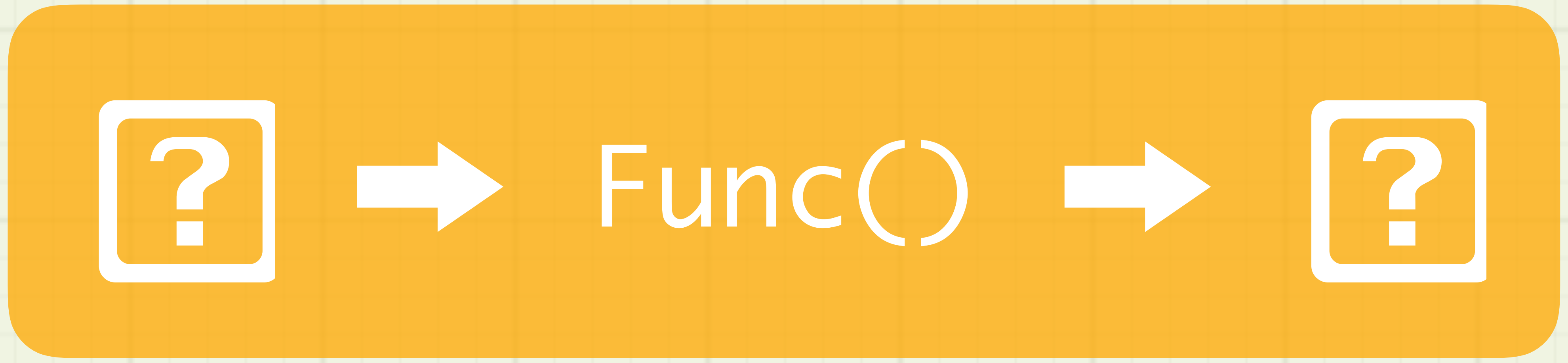
Single Table Verbs

Manipulate tabular data



`select` `filter` `summarise`

`mutate` `arrange` `group_by`

Two Table Verbs

Join together relational data

`left_join` `full_join` `union` `bind_cols`

`right_join` `semi_join` `intersect` `bind_rows`

`inner_join` `anti_join` `setdiff`

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select()

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(storms, storm, pressure)
```

* These data sets are in the EDAWR package

mutate()

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

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

* These data sets are in the EDAWR package

logical tests in R

?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

<table>
<tr><td>&</td><td>boolean and</td></tr>
<tr><td>|</td><td>boolean or</td></tr>
<tr><td>xor</td><td>exactly or</td></tr>
<tr><td>!</td><td>not</td></tr>
<tr><td>any</td><td>any true</td></tr>
<tr><td>all</td><td>all true</td></tr>
</table>

filter()

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

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

* These data sets are in the EDAWR package

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filter()

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

```
filter(storms, wind >= 50)
```

* These data sets are in the EDAWR package

filter()

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
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

```
filter(storms, wind < 60, wind >= 40)
```

* These data sets are in the EDAWR package

arrange()

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

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

* These data sets are in the EDAWR package

arrange()

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

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

* These data sets are in the EDAWR package

arrange()

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

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

* These data sets are in the EDAWR package

summarise()

city	particle size	amount ($\mu g/m^3$)
New York	large	23
New York	small	14
London	large	22
London	small	16
Beijing	large	121
Beijing	small	56

median
22.5

```
summarise(pollution, median = median(amount))
```

* These data sets are in the EDAWR package

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summarise()

city	particle size	amount ($\mu g/m^3$)
New York	large	23
New York	small	14
London	large	22
London	small	16
Beijing	large	121
Beijing	small	56

mean	sum	n
42	252	6

```
summarise(pollution, mean = mean(amount), sum = sum(amount), n = n())
```

* These data sets are in the EDAWR package

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city	particle size	amount ($\mu g/m^3$)
New York	large	23
New York	small	14
London	large	22
London	small	16
Beijing	large	121
Beijing	small	56

mean	sum	n
42	252	6

* These data sets are in the EDAWR package

city	particle size	amount (μg/m^3)
New York	large	23
New York	small	14
London	large	22
London	small	16
Beijing	large	121
Beijing	small	56

mean	sum	n
42	252	6

* These data sets are in the EDAWR package

city	particle size	amount (μg/m^3)
New York	large	23
New York	small	14
London	large	22
London	small	16
Beijing	large	121
Beijing	small	56

mean	sum	n
18.5	37	2
19.0	38	2
88.5	177	2

group_by() + summarise()

* These data sets are in the EDAWR package

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group_by()

city	particle size	amount (μg/m³)
New York	large	23
New York	small	14
London	large	22
London	small	16
Beijing	large	121
Beijing	small	56

city	particle size	amount (μg/m³)
New York	large	23
New York	small	14

London	large	22
London	small	16

Beijing	large	121
Beijing	small	56

mean	sum	n
18.5	37	2
19.0	38	2
88.5	177	2

```
p <- group_by(pollution, city)
summarise(p, mean = mean(amount), sum = sum(amount), n = n())
```

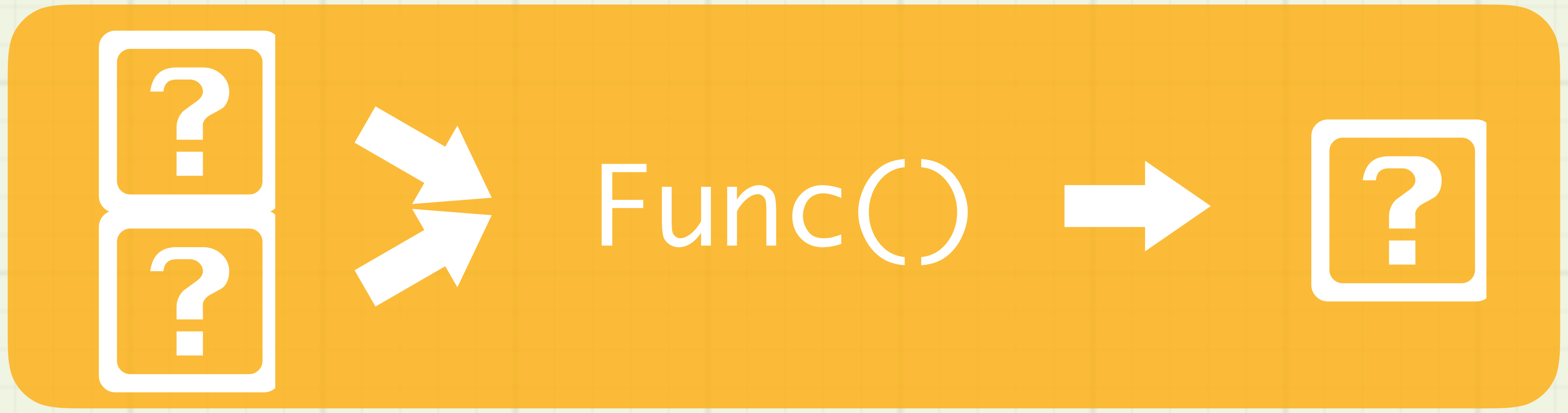
Single Table Verbs

Manipulate tabular data

select	filter	summarise
mutate	arrange	group_by

Two Table Verbs

Join together relational data



left_join	full_join	union	bind_cols
right_join	semi_join	intersect	bind_rows
inner_join	anti_join	setdiff	

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Joins

- The core of relational data processing.
- Most important data transforms can be written in terms of a sequence of joins:
    - intersection
    - cross-product
    - lookup
    - lapply / list comprehensions
- Master these and you have mastered class data manipulation

Joins: the math

- Joins are implemented *as if:*
  - Each row in each table is paired with every other row in the other table and once more with an extra "no match" row.
    - Two tables with `m` rows and `n` rows respectively could generate as many as (m+1)*(n+1) notional rows.
    - Rows contain columns from both tables. Duplicate column names are disambiguated by appending extra names to the columns.
  - The result is winnowed down to only rows matching the join conditions, and only columns named in the statement.
- Join implementations are *much* more efficient than the above specification.
  - The database implementation examines to join conditions to only generate rows the user wants. Filtering is implicit, unwanted rows and duplicate columns are not generated.

joins: first example

- Task: For each band member look up what, if any instrument they play.
- The right tool:
    - “left join by name” (also called “left join on name”).
        - “left” means keep records from left table
        - “by name” means names must match
- This join can be implemented in time proportional to the smallest of the two tables!
    - *Very* fast.

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

left_join(): result

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

+

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

=

name	band	plays
Mick	Stones	<NA>
John	Beatles	guitar
Paul	Beatles	bass

```
left_join(band, instrument, by = "name")
```

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left_join(): theory

band

name	band
Paul	Beatles

+

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

Smaller example, so we can illustrate all the notional steps.

```
left_join(band, instrument, by = "name")
```

left_join(): theory

band

name	band
Paul	Beatles

+

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

Augment each table with a no-match or empty row.

```
left_join(band, instrument, by = "name")
```

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left_join(): theory

band

name	band
Paul	Beatles

+

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

=

name	band	name	plays
Paul	Beatles	John	guitar
Paul	Beatles	Paul	bass
Paul	Beatles	Keith	guitar
Paul	Beatles		
		John	guitar
		Paul	bass
		Keith	guitar

Form the cross product.

```
left_join(band, instrument, by = "name")
```

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left_join(): theory

band

name	band
Paul	Beatles

\+

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

=

name	band	name	plays
~~Paul~~	~~Beatles~~	~~John~~	~~guitar~~
Paul	Beatles	Paul	bass
~~Paul~~	~~Beatles~~	~~Keith~~	~~guitar~~
~~Paul~~	~~Beatles~~		
		~~John~~	~~guitar~~
		~~Paul~~	~~bass~~
		~~Keith~~	~~guitar~~

Cross out rows that don't match specified conditions.

killed by "left" specification

killed by "by = "name"" specification

```
left_join(band, instrument, by = "name")
```

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ProTip

- *Always* inspect your intermediate results after joins.
- In particular ***count rows*** and groups of rows to make sure you haven't missed a join condition.
    - Missing a join condition can cause some rows to be duplicated.

right_join()

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

+

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

=

name	band	plays
John	Beatles	guitar
Paul	Beatles	bass
Keith	<NA>	guitar

```
right_join(band, instrument, by = "name")
```

inner_join()

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

+

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

=

name	band	plays
John	Beatles	guitar
Paul	Beatles	bass

```
inner_join(band, instrument, by = "name")
```

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full_join()

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

+

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

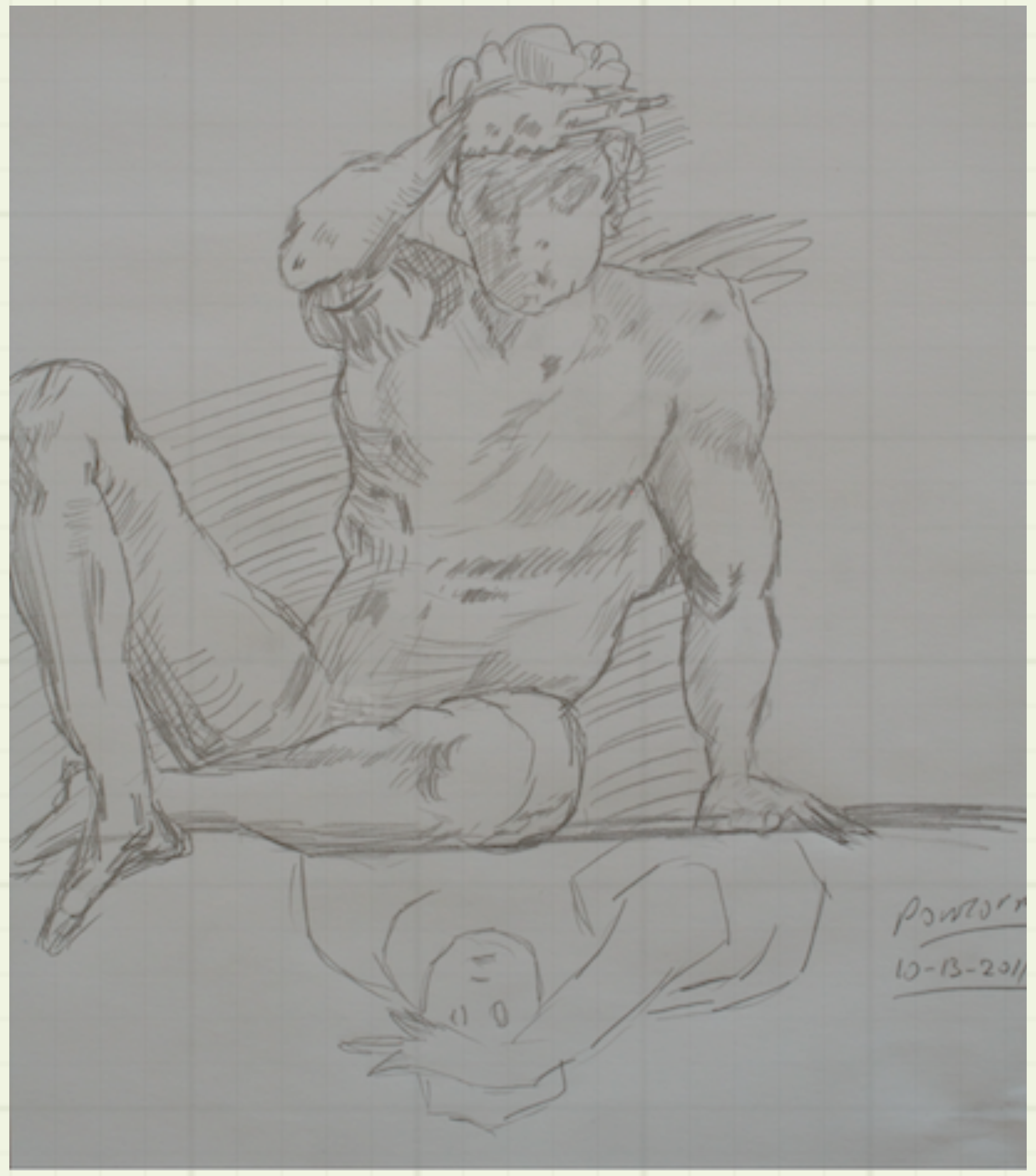
=

name	band	plays
Mick	Stones	<NA>
John	Beatles	guitar
Paul	Beatles	bass
Keith	<NA>	guitar

```
full_join(band, instrument, by = "name")
```

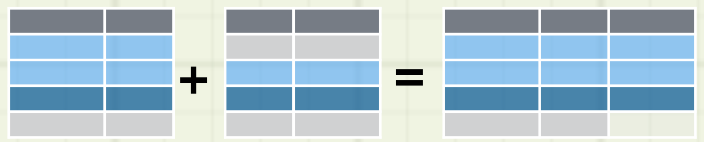
Relational Thinking

- To think relationally (in terms of joins) you must simultaneously hold three conflicting ideas in your head:
    - join sequences can be made comprehensible
    - joins are powerful
    - joins can be fast.

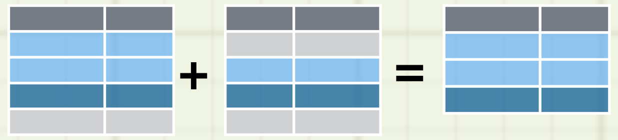


“Theory versus practice” (after Pontromo).

Recap: Two table verbs

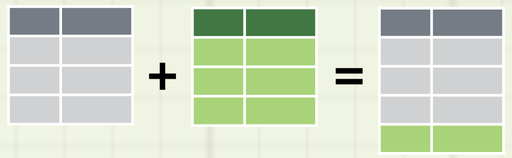


Join together observations with **left_join()**, **right_join()**, **inner_join()**, and **full_join()**



Filter one data set based on another with **semi_join()** and **anti_join()**

Bind data sets together with **bind_rows()** and **bind_cols()**



Do set operations on rows with dplyr's **union()**, **intersect()**, and **setdiff()**

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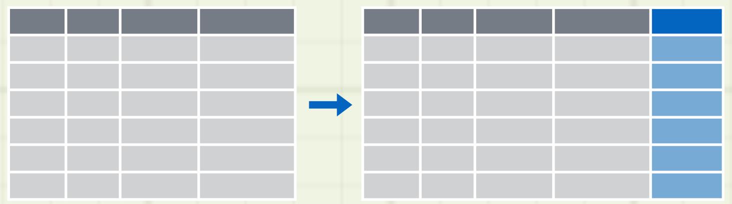
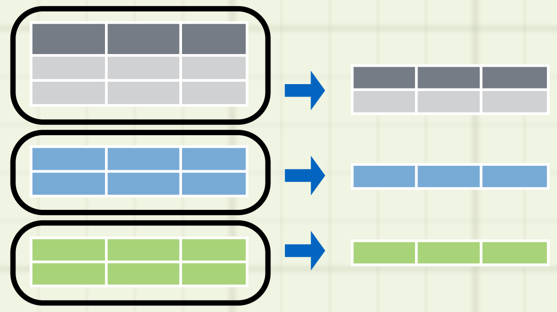
Recap: dplyr one table verbs

Extract columns and rows with **select()** and **filter()**

Arrange rows with **arrange()**.



Make new columns with **mutate()**.



Make groupwise summaries with **group_by()** and **summarise()**.

Next:

`dplyr` exercises

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