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HAPPY R USERS PURRR: USING FUNCTIONAL PROGRAMMING TO SOLVE ITERATION PROBLEMS

GETTING SETUP

1. Download .zip of slides and code @ bit.ly/purrr-rstudioconf

2. Extract and open purrr_workshop.Rproj

3. Check you have packages:

```
library(purrr)
library(tidyverse)
```

SOLVE ITERATION PROBLEMS

FOR EACH ____ DO ____

You are already solving them:

copy & paste, for loops, `(l/s)apply()`

I'll show you an alternative `purrr::map()` & friends

Download .zip of slides and code @ bit.ly/purrr-rstudioconf

FUNCTIONAL PROGRAMMING

a programming paradigm

has some central concepts

you don't need to know them to use `purrr`, but I'll point them out

FP

Download .zip of slides and code @ bit.ly/purrr-rstudioconf

YOUR TURN

Star Wars API - http://swapi.co/
Data extracted using https://github.com/Ironholds/rwars/

```
# loads objects: films, people, vehicles, starships,
# planets & species

load("data/swapi.rda")
```

1. How many elements are in `people`?
2. Who is the first person listed in `people`? What information is given for this person?
3. What is the difference between `people[1]` and `people[[1]]`?

BEWARE!
ANSWERS ON FOLLOWING SLIDE

Download .zip of slides and code @ bit.ly/purrr-rstudioconf

```
length(people)
## [1] 87
```

```
people[[1]]
## $name
## [1] "Luke Skywalker"
##
## $height
## [1] "172"
##
## $mass
## [1] "77"
##
## $hair_color
## [1] "blond"
##
## $skin_color
## [1] "fair"
##
## $eye_color
## [1] "blue"
##
## $birth_year
## [1] "19BBY"
##
## $gender
## [1] "male"
##
## $homeworld
## [1] "http://swapi.co/api/planets/1/"
##
## $films
## [1] "http://swapi.co/api/films/6/"
## [2] "http://swapi.co/api/films/3/"
## [3] "http://swapi.co/api/films/2/"
## [4] "http://swapi.co/api/films/1/"
## [5] "http://swapi.co/api/films/7/"
##
## $species
## [1] "http://swapi.co/api/species/1/"
##
## $vehicles
## [1] "http://swapi.co/api/vehicles/14/"
## [2] "http://swapi.co/api/vehicles/30/"
##
## $starships
## [1] "http://swapi.co/api/starships/
12/"
## [2] "http://swapi.co/api/starships/
22/"
##
## $created
## [1] "2014-12-09T13:50:51.644000Z"
##
## $edited
## [1] "2014-12-20T21:17:56.891000Z"
##
## $url
## [1] "http://swapi.co/api/people/1/"
```

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map()

```
map( .x, .f, ...)
```

for each element of `.x` do `.f`

`.x`

- **a vector**
- a list
- a data frame (for each column)

`.f`

We'll get to that...

HOW MANY FILMS HAS EACH CHARACTER BEEN IN?

for each person in `people`, **count the number of films**

```
map(people, ____ )
```

STRATEGY

1. Do it for one element
2. Turn it into a recipe
3. Use `map()` to do it for all elements

```
luke <- people[[1]]
```

HOW MANY STARSHIPS HAS LUKE BEEN IN?

Write a line of code to find out.

Bored? Find the names of those starships...

DO IT FOR ONE

Solve the problem for one element

```
luke <- people[[1]]
```

```
length(luke$starships)
```

DO IT FOR ONE

Solve the problem for one element

```
luke <- people[[1]]
```

```
length(luke$starships)
```

DO IT FOR ONE

Solve the problem for one element

```
leia <- people[[5]]
```

```
length(leia$starships)
```

DO IT FOR ONE

Solve the problem for one element

```
____ <- people[[?]]
```

```
length(____$starships)
```

TURN IT INTO A RECIPE

Make it a formula

Use .x as a placeholder

```
~ length(___.x$starships)
```

A formula

purrr's placeholder for
one element of our vector

DO IT FOR ALL!

Your recipe is the second argument to map

```
map( people ,
  ~ length(  .x$starships) )
```

A formula

purrr's placeholder for
one element of our vector

```
map(people, ~ length(.x$starships))
```

Copy and paste ME.

Load then look at `planet_lookup`:

```
load("data/planet_lookup.rda")

planet_lookup
```

FIND THE NAME OF EACH CHARACTERS HOME WORLD.

Bored? Find the body mass index (BMI) of all characters.

bmi = (mass in kg) / ((height in m)^2)

```
luke$homeworld
## [1] "http://swapi.co/api/planets/1/"

planet_lookup[luke$homeworld]
## http://swapi.co/api/planets/1/
##                     "Tatooine"

map(people, ~ planet_lookup[.x$homeworld])
## [[1]]
## http://swapi.co/api/planets/1/
##                     "Tatooine"

## [[2]]
## http://swapi.co/api/planets/1/
##                    "Tatooine"

## [[3]]
## http://swapi.co/api/planets/8/
##                       "Naboo"
...
```

ROAD map()

```
map_lgl( .x, .f, ...)
```

Other types of output

Other ways of specifying .f

Other iteration functions

ROAD `map()`

```
map( .x, length, ...)
```

Other types of output

Other ways of specifying .f

Other iteration functions

ROAD map()

```
map2( .x, .y, .f, ...)
```

Other types of output

Other ways of specifying .f

Other iteration functions

map() details

`map()` **always** returns a **list**

SIMPLER OUTPUT:

`map_lgl()` **logical** vector

`map_int()` **integer** vector

`map_dbl()` **double** vector

`map_chr()` **character** vector

`walk()` - when you want nothing at all, use a function for its side effects

Result: No surprises!

vector same length as `.x` or an `ERROR`

```
# names can be useful
people <- people %>% set_names(map_chr(people, "name"))
```

REPLACE map() WITH THE APPROPRIATELY TYPED FUNCTION

```
# How many starships has each character been in?
map(people, ~ length(.x[["starships"]]))

# What color is each character's hair?
map(people, ~ .x[["hair_color"]])

# Is the character male?
map(people, ~ .x[["gender"]] == "male")

# How heavy is each character?
map(people, ~ .x[["mass"]])
```

```r
# How many starships has each character been in?
map_int(people, ~ length(.x[["starships"]]))

##    Luke Skywalker  C-3PO   R2-D2   Darth Vader
##                 2      0       0             1  ...

# What color is each character's hair?
map_chr(people, ~ .x[["hair_color"]])

##    Luke Skywalker   C-3PO    R2-D2    Darth Vader
##           "blond"   "n/a"    "n/a"         "none" ...

# Is the character male?
map_lgl(people, ~ .x[["gender"]] == "male")

##    Luke Skywalker    C-3PO   R2-D2    Darth Vader
##              TRUE    FALSE   FALSE           TRUE ...
```

```r
# How heavy is each character?
map_dbl(people, ~ .x[["mass"]])
## Error: Can't coerce element 1 from a character to a double
# Doesn't work...because we get a string back
map(people, ~ .x[["mass"]])
## [[1]]
## [1] "77"
##
## [[2]]
## [1] "75"
...
```

```r
# A little risky

map_dbl(people, ~ as.numeric(.x[["mass"]]))

## [1]  77.0   75.0   32.0   136.0  49.0  120.0   75.0   32.0   84.0
## ...
## There were 29 warnings (use warnings() to see them)


# Probably want something like:

map_chr(people, ~ .x[["mass"]]) %>%

  readr::parse_number(na = "unknown")

## [1]   77.0   75.0   32.0  136.0   49.0  120.0   75.0   32.0   84.0
## ...
```

`.f` CAN BE A FORMULA

```
map(.x, .f =  ~ DO SOMETHING WITH .x)
```

```
map_int(people, ~ length(.x[["starships"]]))
map_chr(people, ~ .x[["hair_color"]])
map_chr(people, ~ .x[["mass"]])
```

`.f` CAN BE A STRING OR INTEGER

For each element, extract the named/numbered element

```
map(.x, .f = "some_name")
```

equivalent to

```
map(.x, ~ .x[[some_name]])
```

`.f` CAN BE A STRING OR INTEGER

For each element, extract the named/numbered element

```
map(.x, .f =  some_number )
```

equivalent to

```
map(.x, ~ .x[[some_number]])
```

```
map_chr(people, ~ .x[["hair_color"]])
# becomes
map_chr(people, "hair_color")
```

.f CAN BE A FUNCTION

```
map(.x, .f = some_function, ...)
```

equivalent to

```
map(.x, ~ some_function(.x, ...))
```

gets passed on to .f

```
char_starships <- map(people, "starships")
map_int(char_starships, length)

# In one go
map(people, "starships") %>% map_int(length)

# equivalent to
map_int(people, ~ length(.x[["starships"]]))
```

don't be afraid to do things in little steps and pipe them together

WHAT ABOUT `sapply()` & `lapply()`?

What type of object does `sapply()` return? It depends.

Motivation for `purrr`:

- consistent return type,
- useful shortcuts,
- consistent syntax for more complicated iteration

STAR WARS CHALLENGES

Which film (see `films`) has the most characters?

Create the `planet_lookup` vector from earlier.

Which `species` has the most possible eye colors?

```r
# Which film (see films) has the most characters?
map(films, "characters") %>%
  map_int(length) %>%
  set_names(map_chr(films, "title")) %>%
  sort()


# Create the planet_lookup vector from earlier.
planet_lookup <- map_chr(planets, "name") %>%
  set_names(map(planets, "url"))
```

```
# Which species has the most possible eye colors?
species[[1]]$eye_colors


map_chr(species, "eye_colors") %>%
  strsplit(", ") %>%
  map_int(length)
# this is lazy, what about n/a and unknown?
```

FP

FUNCTIONS CAN BE ARGUMENTS

Functions are **first class** citizens in R, they can occur anywhere a number could:

- as arguments,
- as return values,
- assigning them to variables,
- storing in data structures.

Higher order function: a function that takes a function as input or returns a function

`map()` is a higher order function.

purrr and list columns

PURRR AND LIST COLUMNS

Data should be in a data frame as soon as it makes sense!

Data frame: **cases** in rows, **variables** in columns

YOUR TURN:

What are the **cases** and **variables** in the `people` data?

```
# A tibble: 87 × 4
             name      films height                          species
            <chr>     <list>  <dbl>                            <chr>
1 Luke Skywalker <chr [5]>    172 http://swapi.co/api/species/1/
2          C-3PO <chr [6]>    167 http://swapi.co/api/species/2/
3          R2-D2 <chr [7]>     96 http://swapi.co/api/species/2/
4    Darth Vader <chr [4]>    202 http://swapi.co/api/species/1/
5    Leia Organa <chr [5]>    150 http://swapi.co/api/species/1/
# ... with 82 more rows
```

PURRR CAN HELP TURN LISTS INTO TIBBLES

```
people_tbl <- tibble(
  name    =                                  ,
  films   =                              ,
  height  =

                                                  ,
  species =
)
```

Full code in `code/star_wars-tbl.R`

PURRR CAN HELP TURN LISTS INTO TIBBLES

```
people_tbl <- tibble(
  name    = people %>% map_chr("name"),
  films   = people %>% map("films"),
  height  = people %>% map_chr("height") %>%
              readr::parse_number(na = "unknown"),
  species = people %>% map_chr("species", .null = NA_character_)
)
```

will result in list column

needs some parsing

isn't in every element

Full code in `code/star_wars-tbl.R`

COMBINE PURRR WITH DPLYR TO WORK WITH LIST COLUMNS

```
people_tbl$films


people_tbl %>%
  mutate(
    film_numbers = map(films, ~ film_number_lookup[.x]),
    n_films = map_int(films, length)
)
```

YOUR TURN

Code to create tibble in `04-purrr-list-columns.R`

Create a new character column that collapses the film numbers into a single string,

e.g. for Luke: " 6, 3, 2, 1, 7"

```
people_tbl <- people_tbl %>%
  mutate(
    films_squashed = map_chr(film_numbers, paste,
                             collapse = ", "))


people_tbl %>% select(name, n_films, films_squashed)
```

More iteration functions

to each element of **.x** apply **.f**

```
map(  .x , .f                )
```

to each `cat` apply `give_fish`

```
map(
```

```
, give_fish)
```

to each element of **.x** apply **.f**

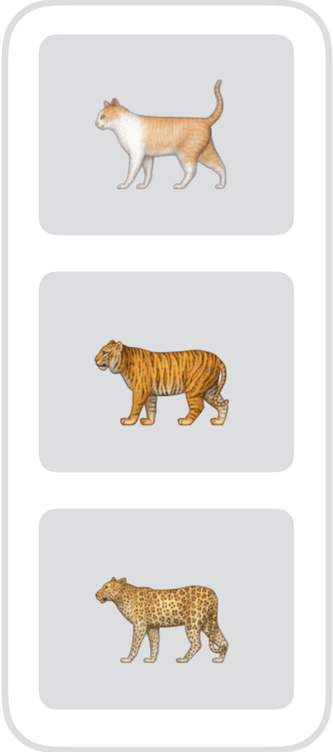
```
walk(.x  ,.f    )
```

Expect nothing in return

You actually get .x invisibly back,
good for piping

to each `cat` apply `love`

`walk(`



`, love )`

Expect nothing in return

You actually get .x invisibly back, good for piping

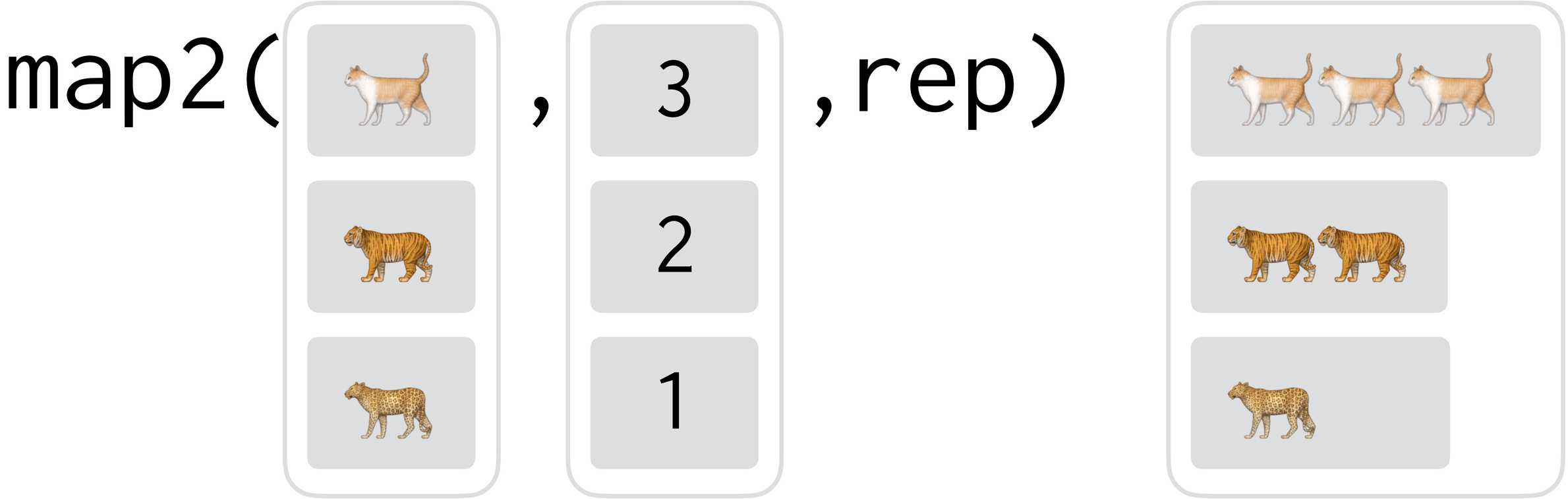
For functions called for their side effects:

- printing to screen
- plotting to graphics device
- file manipulation (saving, writing, moving etc.)
- system calls

to each element of **.x** and corresponding element of **.y** apply **.f**

```
map2(  .x ,  .y , .f)
```

to each `cat` and corresponding `times` apply `rep`



Always get a list back, or use:

`walk2()`, `map2_lgl()`, `map2_int()`, `map2_dbl()`, `map2_chr()`

DISCUSS WITH YOUR NEIGHBOR

1. For each function, which two arguments might be useful to iterate over?

   `download.file()`

   `rnorm()`

   `lm()`

   `predict.lm()`

   `write.csv()`

2. Which functions should we use `walk2()` or a typed version of `map2()`?

`download.file()` for each `url` download to `destfile` `walk2(), map2_int()`

`rnorm()` for each `n` generate a Normal sample with mean `mean` (or `sd`)
(See `purrr::rerun()` for repeating a function many times)

`lm()` for each `data` fit a model (`formula`)

`predict.lm()` for each model (`object`) , generate predictions at data (`newdata`)

`readr::write_csv()` for each data frame (`x`) save to `path` `walk2()`
Similar for `ggplot::ggsave()` for each `plot` save to `filename`

NATIONAL ELECTRONIC INJURY SURVEILLANCE SYSTEM (NEISS)

From https://github.com/hadley/neiss

`load("data/neiss_by_day.rda")`

`common_prods`: 11 product codes with at least 50,000 injuries 2009-2014

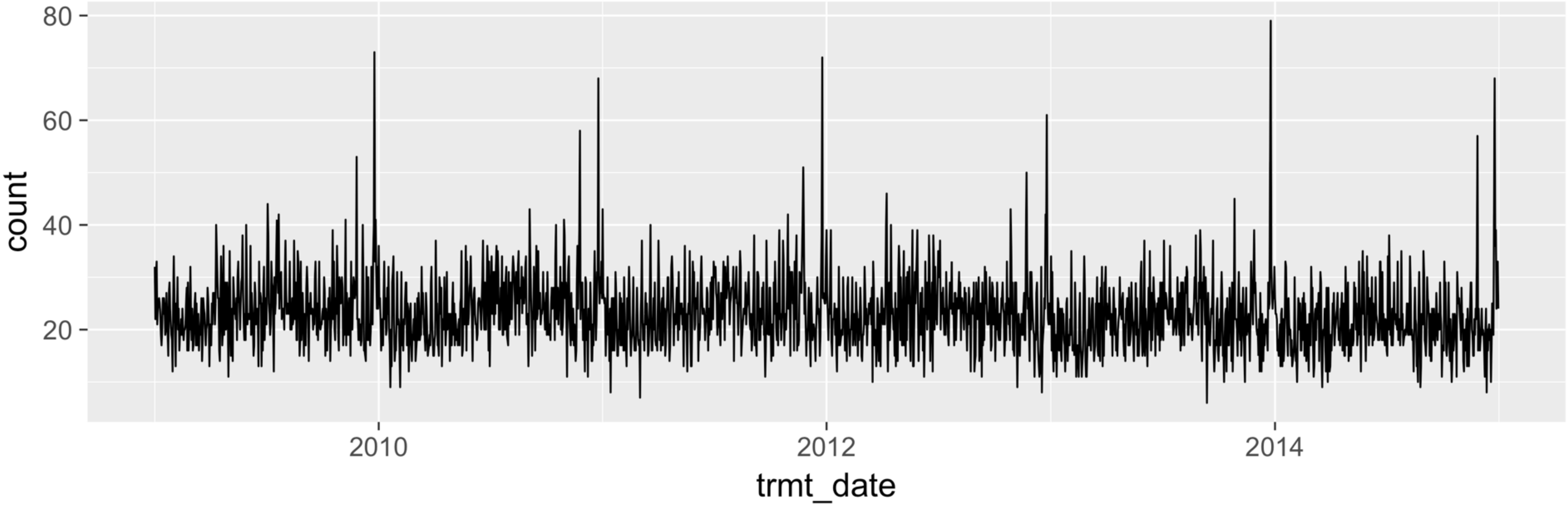
`common_names`: corresponding product description

`per_day`: a list with 11 elements, one for each product, injuries summarized to daily counts

ARE THERE PRODUCTS WITH PERIODIC PATTERNS IN INCIDENCE?

TAKING A LOOK

```
plots <- map(per_day, ~ ggplot(.x, aes(trmt_date, count)) + geom_line())

plots[[1]]   # try: walk(plots, print)
```



CAN WE SAVE THIS PLOT FOR ALL PRODUCTS?

DO IT FOR ONE

Solve the problem for one pair of elements

```
one_plot <- plots[[1]]
one_code <- common_codes[[1]]

    ggsave(paste0(one_code, ".png"), one_plot)
```

TURN IT INTO A RECIPE

Make it a formula

Use .x and .y as placeholders

```
~ ggsave(paste0(   .x    , ".png"),   .y    )
```

code

plot

DO IT FOR ALL!

Your recipe is the .f argument to map2

```
walk2( common_codes, plots,
    ~ ggsave(paste0(   .x     , ".png"),    .y     ))
```

code

plot

WHEN THE SHORTCUT, ISN'T A SHORTCUT

```
walk2(paste0(common_codes, ".png"),
      plots, ggsave)
```

WHEN THE SHORTCUT, ISN'T A SHORTCUT

```
walk2(paste0(common_codes, ".png"),
      plots, ggsave,
      width = 10, height = 3)
```

YOUR TURN

This fits a **naive** model with effects for month and day of the week to the first product:

```
lm(count ~ month + wday, data = per_day[[1]])
```

1. Fit the model to all products

2. Use `modelr::rsquare` to find the R-squared for each model (you'll probably want to look at `?modelr::rsquare`)

3. Bored? Repeat the plots but title them with the product names in `common_names`

```
models <- map(per_day, ~ lm(count ~ month + wday, data = .x))

map2_dbl(models, per_day, modelr::rsquare)


plots[[3]]

common_names[[3]]
```

SHOULD REALLY BE USING LIST COLUMNS...

```
accidents <- tibble(
  name = common_names,
  code = common_codes,
  data = per_day)

accidents %>%
  mutate(
    model = map(data, ~ lm(count ~ month + wday, data = .x)),
    rsquare = map2_dbl(model, data, modelr::rsquare)) %>%
  arrange(rsquare) %>%
  select(name, rsquare)
```

CHALLENGES:

`challenges/01-mtcars.R` - Fit and summarise many regression models

`challenges/02-word_count.R` - Count the number of words of all files in a directory

`challenges/03-starwars.R` - Print who used which vehicles in the films

`challenges/04-weather.R` - Download, tidy, plot and save daily temperatures

`challenges/05-swapi.R` - Download all Star Wars data using `rwars` package

Next up: a few remaining iteration functions, a comment about other functions in purrr, wrap up.

to each element of each vector in .l, apply **.f**

`pmap( .l , .f , ...)`

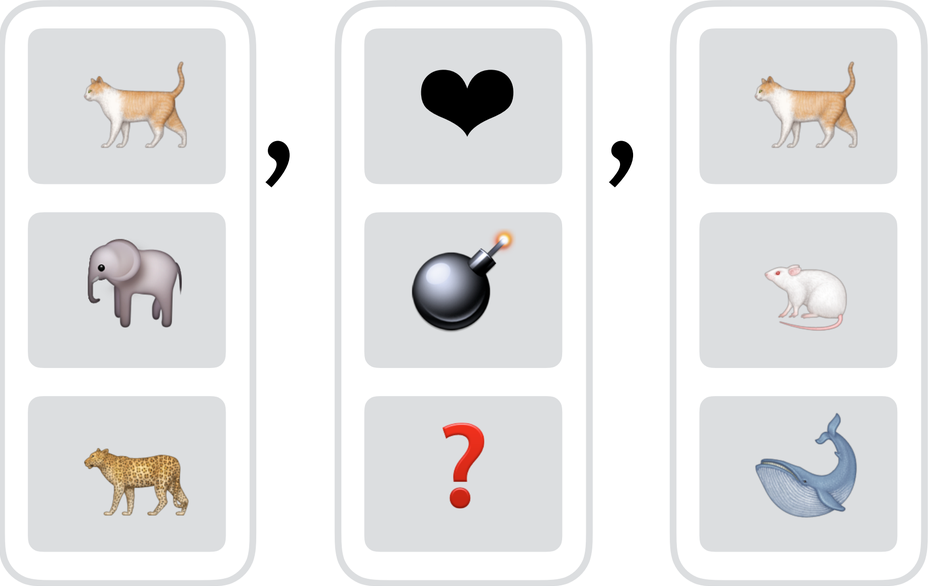
```
.f(.l[[1]][[1]], .l[[2]][[1]], .l[[3]][[1]], ...)

.f(.l[[1]][[2]], .l[[2]][[2]], .l[[3]][[1]], ...)

.f(.l[[1]][[3]], .l[[2]][[3]], .l[[3]][[1]], ...)
```

and so on

or by name if supplied

to each element `in animal, reaction, and animal2`, apply `c`

```
pmap(data.frame(🐈, ❤️, 🐈), c)
```



no more formula shortcut

for each function in **.f**, apply it to **.x**

`invoke_map(.f, .x, ...)`

```
.f[[1]](.x, ...)

.f[[2]](.x, ...)

.f[[3]](.x, ...)
```

and so on

for each function in **.f**, apply it to **.x**

```
invoke_map(give_fish, 🐈)
```

```
double
count_legs
```

🐟🐈

🐈🐈

4

OTHER FEATURES OF PURRR

06-other-features.R

LISTS AND FUNCTIONS

Key objects in `purrr`

`purrr` provides a pile of functions to make working with them easier

WITH YOUR NEIGHBOUR

Look at the help for `safely()` and `transpose()`

What kind of objects do they expect as input?

What kind of objects are returned as output?

SAFELY() TO HANDLE ERRORS

```
urls <- list(
  example = "http://example.org",
  asdf = "http://asdfasdasdkfjlda"
)

map(urls, read_lines)

safe_readLines <- safely(readLines)
safe_readlines

# Use the safe_readLines() function with map(): html
html <- map(urls, safe_readLines)
```

TRANSPOSE() TO HANDLE RESULTS

```
# Easier to handle transposed
str(html)
str(transpose(html))

# Extract the results: res
res <- transpose(html)[["result"]]

# Extract the errors: errs
errs <- transpose(html)[["error"]]
```

WRAP UP

purrr provides:

- functions that write for loops for you
- with consistent syntax, and
- convenient shortcuts for specifying functions to iterate

Choosing the right function depends on:

- type of iteration
- type of output

Check out "Bonus" cheatsheet
in your conference packet

LEARNING MORE

R for Data Science:

- http://r4ds.had.co.nz/iteration.html
- http://r4ds.had.co.nz/many-models.html

DataCamp Writing functions in R
https://www.datacamp.com/courses/writing-functions-in-r

Jenny Bryan's purrr tutorial
https://github.com/jennybc/purrr-tutorial

THANK YOU

Slides and code @ bit.ly/purrr-rstudioconf

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