Data Visualization

Recap

- `pivot_longer()` helps us take our data from wide to long format
  - `names_to =` gives a new name to the pivoted columns
  - `values_to =` gives a new name to the values that used to be in those columns
- `pivot_wider()` helps us take our data from long to wide format
  - `names_from` specifies the old column name that contains the new column names
  - `values_from` specifies the old column name that contains new cell values
- to merge/join data sets together need a variable in common - usually “id”

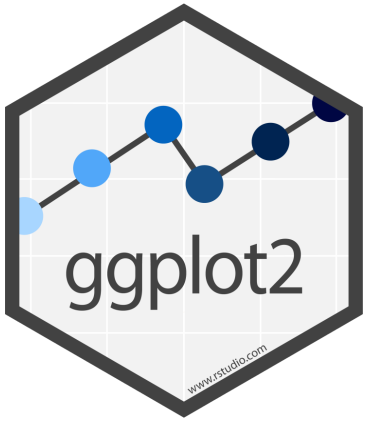
 Cheatsheet

Recap continued

- to merge/join data sets together need a variable in common - usually “id”
- `?join` - see different types of joining for `dplyr`
- `inner_join(x, y)` - only rows that match for `x` and `y` are kept
- `full_join(x, y)` - all rows of `x` and `y` are kept
- `left_join(x, y)` - all rows of `x` are kept even if not merged with `y`
- `right_join(x, y)` - all rows of `y` are kept even if not merged with `x`
- `anti_join(x, y)` - all rows from `x` not in `y` keeping just columns from `x`.
- `esquisser()` function of the `esquisse` package can help make plot sketches

 Cheatsheet

esquisse and ggplot2



Why learn ggplot2?

More customization:

- branding
- making plots interactive
- combining plots

Easier plot automation (creating plots in scripts)

Faster (eventually)

ggplot2

- A package for producing graphics - gg = *Grammar of Graphics*
- Created by Hadley Wickham in 2005
- Belongs to “Tidyverse” family of packages
- *“Make a ggplot”* = Make a plot with the use of ggplot2 package

Resources:

- https://ggplot2-book.org/
- https://www.opencasestudies.org/

ggplot2

Based on the idea of:

layering

plot objects are placed on top of each other with +

 +

ggplot2

- Pros: extremely powerful/flexible – allows combining multiple plot elements together, allows high customization of a look, many resources online
- Cons: ggplot2-specific “grammar of graphic” of constructing a plot
- ggplot2 gallery

Tidy data

To make graphics using `ggplot2`, our data needs to be in a **tidy** format

Tidy data:

1. Each variable forms a column.
2. Each observation forms a row.

Messy data:

- Column headers are values, not variable names.
- Multiple variables are stored in one column.
- Variables are stored in both rows and columns.

Tidy data: example

Ideally we want each variable as a column and we want each observation in a row.

Column headers are values, not variable names:

religion	<$10k	$10-20k	$20-30k	$30-40k	$40-50k	$50-75k
Agnostic	27	34	60	81	76	137
Atheist	12	27	37	52	35	70
Buddhist	27	21	30	34	33	58
Catholic	418	617	732	670	638	1116
Don't know/refused	15	14	15	11	10	35
Evangelical Prot	575	869	1064	982	881	1486
Hindu	1	9	7	9	11	34
Historically Black Prot	228	244	236	238	197	223
Jehovah's Witness	20	27	24	24	21	30
Jewish	19	19	25	25	30	95

Table 4: The first ten rows of data on income and religion from the Pew Forum. Three columns, `$75-100k`, `$100-150k` and `>150k`, have been omitted

Now the the data is "tidy" and in long format

religion	income	freq
Agnostic	<$10k	27
Agnostic	$10-20k	34
Agnostic	$20-30k	60
Agnostic	$30-40k	81
Agnostic	$40-50k	76
Agnostic	$50-75k	137
Agnostic	$75-100k	122
Agnostic	$100-150k	109
Agnostic	>150k	84
Agnostic	Don't know/refused	96

Read more about tidy data and see other examples: Tidy Data tutorial

Data to plot

Type `?Orange` for more information.

Is the data in tidy? Is it in long format?

```
head(Orange)
```

```
  Tree  age circumference
1    1  118            30
2    1  484            58
3    1  664            87
4    1 1004           115
5    1 1231           120
6    1 1372           142
```

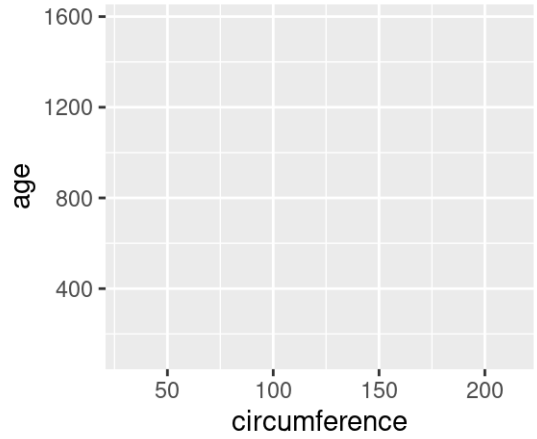
First plot with `ggplot2` package

First layer of code with **ggplot2** package

Will set up the plot - it will be empty!

- **Aesthetic mapping** (`mapping = aes(x= , y =)`) describes how variables in our data are mapped to elements of the plot

```
library(ggplot2) # don't forget to load ggplot2
# This is not code but shows the general format
ggplot({data_to plot},  mapping = aes(x = {var in data to plot},
                                      y = {var in data to plot}))

ggplot(Orange, mapping = aes(x = circumference, y = age))
```



Next layer code with `ggplot2` package

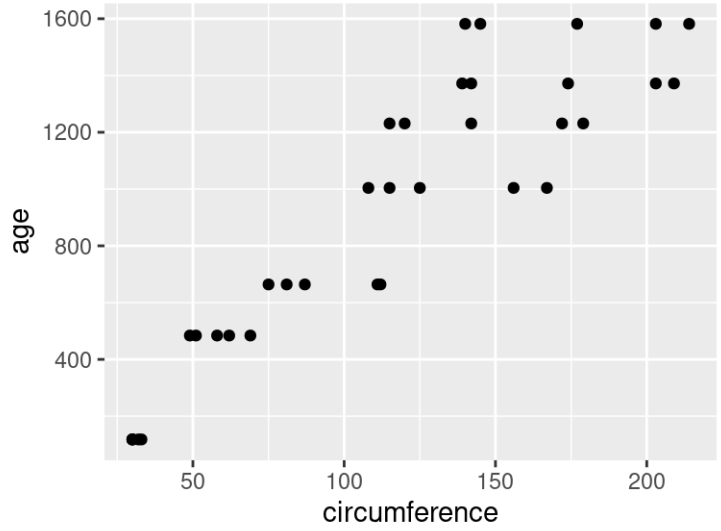
There are many to choose from, to list just a few:

- `geom_point()` – points (we have seen)
- `geom_line()` – lines to connect observations
- `geom_boxplot()`
- `geom_histogram()`
- `geom_bar()`
- `geom_col()`
- `geom_errorbar()`
- `geom_density()`
- `geom_tile()` – blocks filled with color

Next layer code with `ggplot2` package

Need the + sign to add the next layer to specify the type of plot

```
ggplot({data_to plot},  mapping = aes(x = {var in data to plot},
                                      y = {var in data to plot})) +
  geom_{type of plot}</div>

ggplot(Orange, mapping = aes(x = circumference, y = age)) +
  geom_point()
```



Read as: *using Orange data, and provided aesthetic mapping, add points to the plot*

Tip - plus sign + must come at end of line

Having the + sign at the beginning of a line will not work!

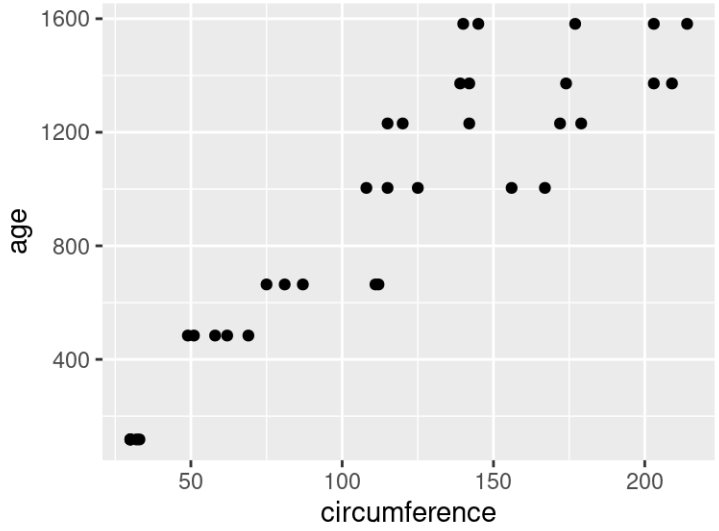
```
ggplot(food, mapping = aes(x = item_ID,
                           y = item_price_change,
                           fill = item_categ))
 + geom_boxplot()
```

Pipes will also not work in place of +!

```
ggplot(food, mapping = aes(x = item_ID,
                           y = item_price_change,
                           fill = item_categ))  %>%
geom_boxplot()
```

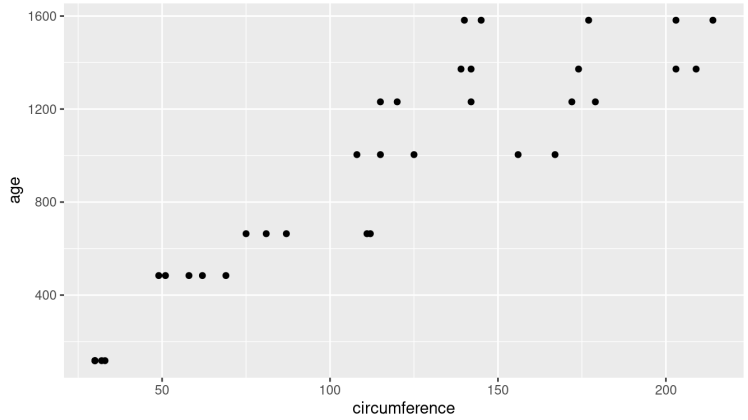
Plots can be assigned as an object

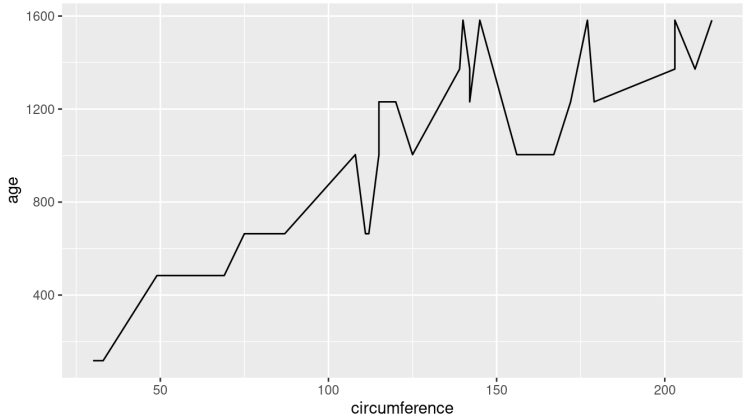
```
plt1 <- ggplot(Orange, aes(x = circumference, y = age)) +
          geom_point()

plt1
```



Examples of different geoms

```
plt1 <- ggplot(Orange, aes(x = circumference, y = age)) +
          geom_point()

plt2 <- ggplot(Orange, aes(x = circumference, y = age)) +
          geom_line()

plt1 # fig.show = "hold" makes plots appear
plt2 # next to one another in the chunk settings
```

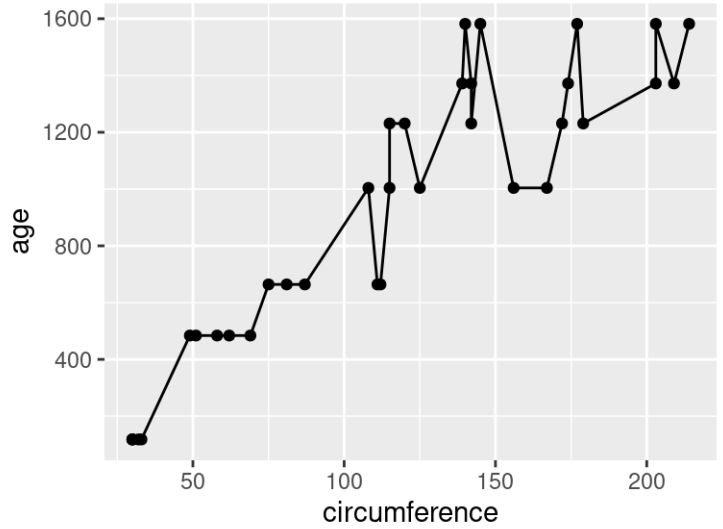




Specifying plot layers: combining multiple layers

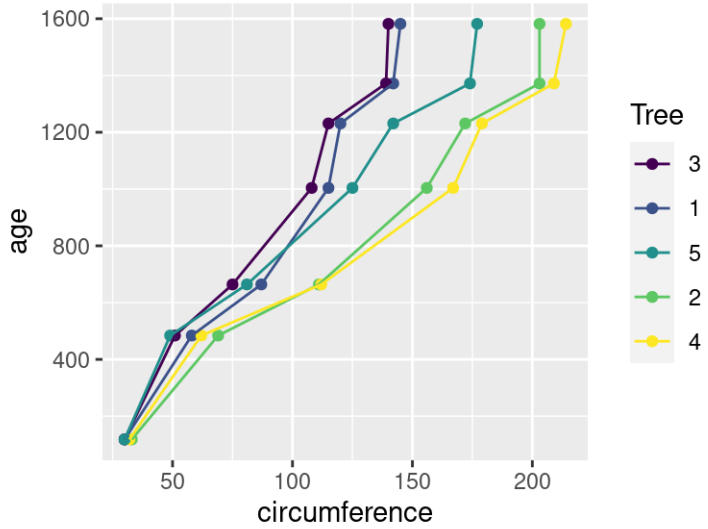
Layer a plot on top of another plot with **+**

```
ggplot(Orange, aes(x = circumference, y = age)) +
  geom_point() +
  geom_line()
```



Adding color - can map color to a variable

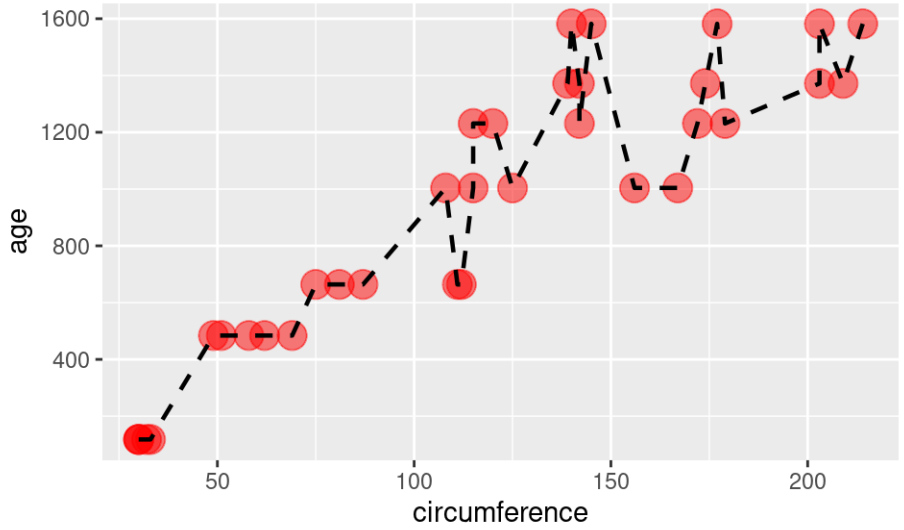
```
ggplot(Orange, mapping = aes(x = circumference, y = age, color = Tree)) +
  geom_point() +
  geom_line()
```



Adding color - or change the color of each plot layer

You can change look of each layer separately.

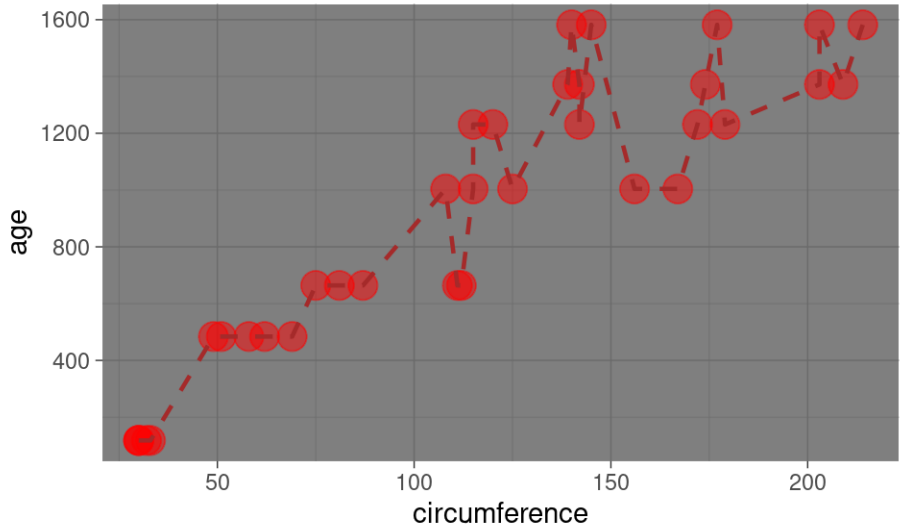
```
ggplot(Orange, mapping = aes(x = circumference, y = age)) +
  geom_point(size = 5, color = "red", alpha = 0.5) +
  geom_line(size = 0.8, color = "black", linetype = 2)
```



Customize the look of the plot

You can change the look of whole plot using `theme_*()` functions.

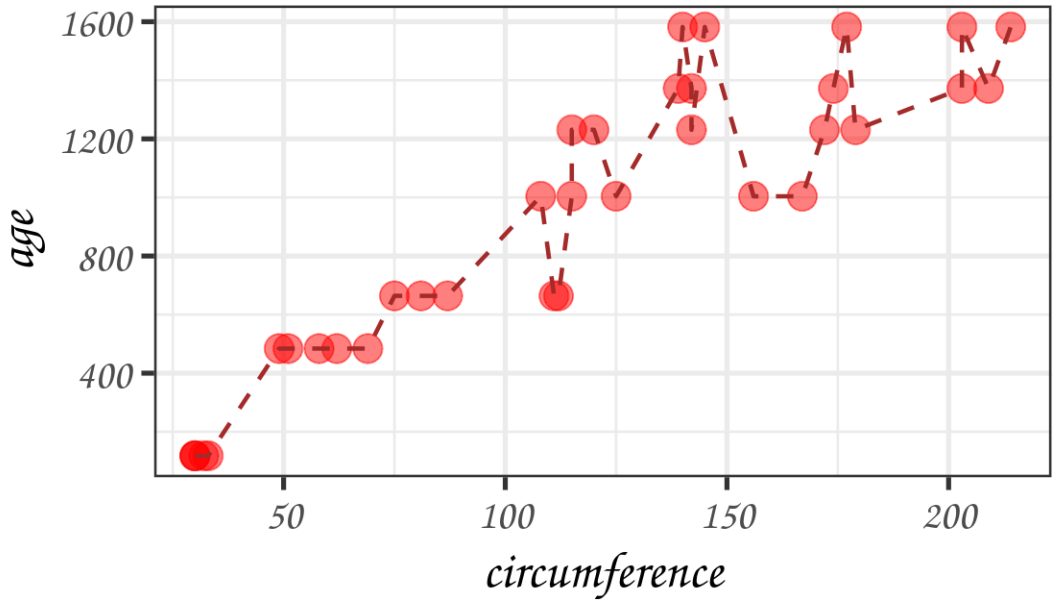
```
ggplot(Orange, mapping = aes(x = circumference, y = age)) +
  geom_point(size = 5, color = "red", alpha = 0.5) +
  geom_line(size = 0.8, color = "brown", linetype = 2) +
  theme_dark()
```



Customize the look of the plot

You can change the look of whole plot - **specific elements, too** - like changing font and font size - or even more fonts

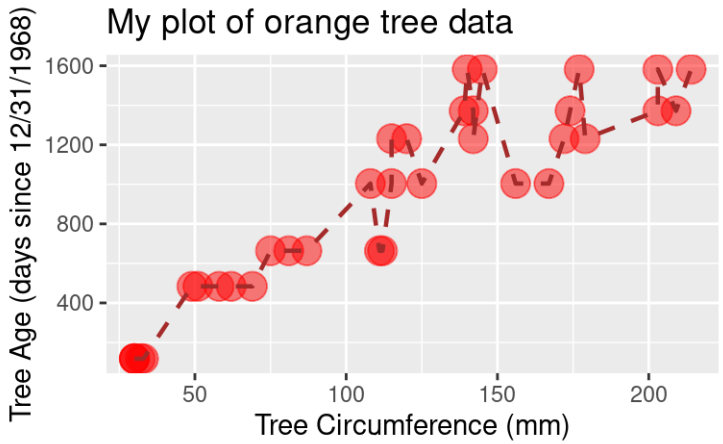
```
ggplot(Orange, mapping = aes(x = circumference, y = age)) +
  geom_point(size = 5, color = "red", alpha = 0.5) +
  geom_line(size = 0.8, color = "brown", linetype = 2) +
  theme_bw(base_size = 20, base_family = "Comic Sans MS")
```



Adding labels

The `labs()` function can help you add or modify titles on your plot. The `title` argument specifies the title. The `x` argument specifies the x axis label. The `y` argument specifies the x axis label.

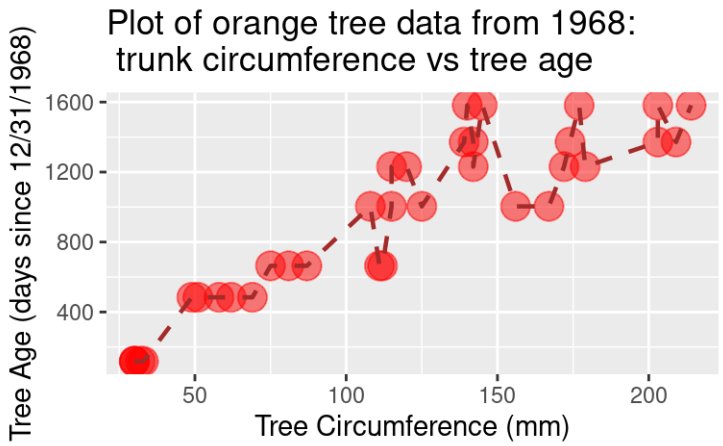
```
ggplot(Orange, mapping = aes(x = circumference, y = age)) +
            geom_point(size = 5, color = "red", alpha = 0.5) +
            geom_line(size = 0.8, color = "brown", linetype = 2) +
            labs(title = "My plot of orange tree data",
              x = "Tree Circumference (mm)",
              y = "Tree Age (days since 12/31/1968)")
```



Adding labels line break

Line breaks can be specified using `\n` within the `labs()` function to have a label with multiple lines.

```
ggplot(Orange, mapping = aes(x = circumference, y = age)) +
            geom_point(size = 5, color = "red", alpha = 0.5) +
            geom_line(size = 0.8, color = "brown", linetype = 2) +
            labs(title = "Plot of orange tree data from 1968: \n trunk circumference vs tree age",
              x = "Tree Circumference (mm)",
              y = "Tree Age (days since 12/31/1968)")
```



Changing axis: specifying axis scale

`scale_x_continuous()` and `scale_y_continuous()` can change how the axis is plotted. Can use the `breaks` argument to specify how you want the axis ticks to be.

```
range(pull(Orange, circumference))
```

```
[1]  30 214
```

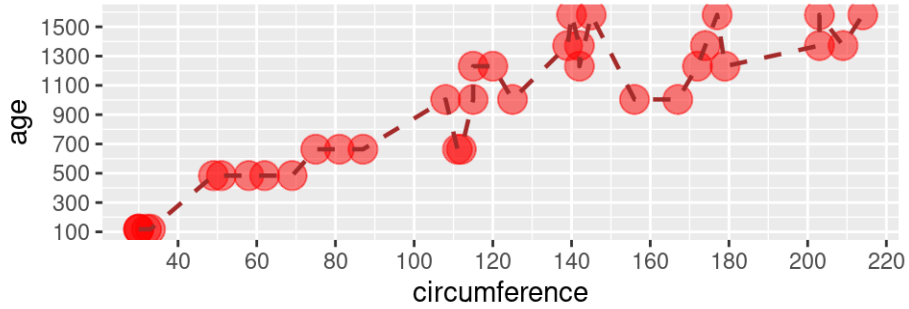
```
range(pull(Orange, age))
```

```
[1]  118 1582
```

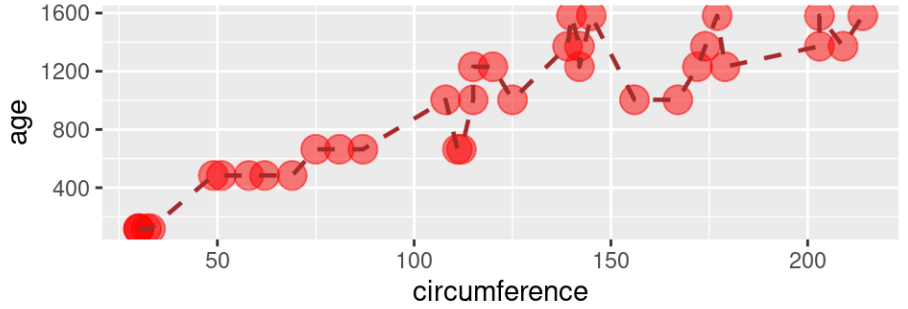
```
plot_scale <-ggplot(Orange, mapping = aes(x = circumference, y = age)) +
               geom_point(size = 5, color = "red", alpha = 0.5) +
               geom_line(size = 0.8, color = "brown", linetype = 2) +
               scale_x_continuous(breaks = seq(from = 20, to = 240, by = 20)) +
               scale_y_continuous(breaks = seq(from = 100, to = 1600, by = 200))
```

Changing axis: specifying axis scale

```
plot_scale
```



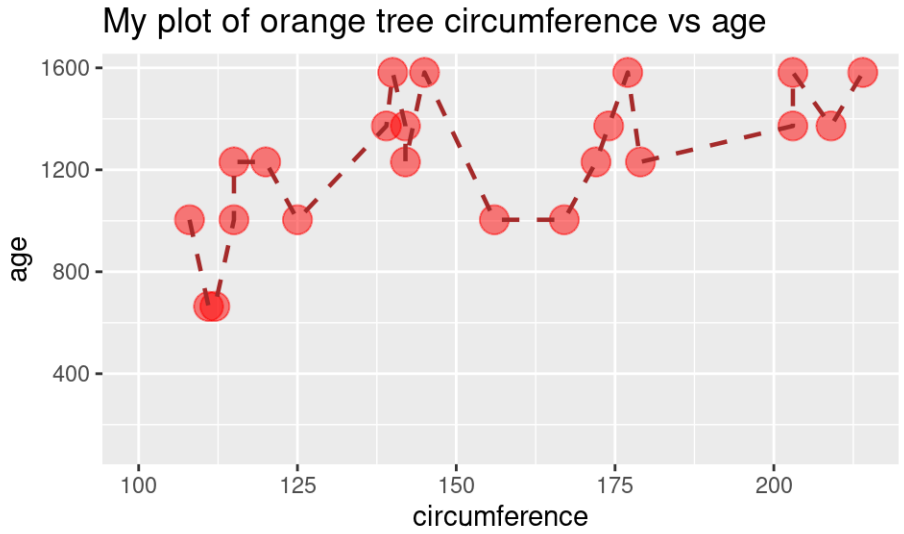

```
ggplot(Orange, mapping = aes(x = circumference, y = age)) +
                geom_point(size = 5, color = "red", alpha = 0.5) +
                geom_line(size = 0.8, color = "brown", linetype = 2)
```



Changing axis: specifying axis limits

`xlim()` and `ylim()` can specify the limits for each axis

```
ggplot(Orange, mapping = aes(x = circumference, y = age)) +
  geom_point(size = 5, color = "red", alpha = 0.5) +
  geom_line(size = 0.8, color = "brown", linetype = 2) +
  labs(title = "My plot of orange tree circumference vs age") +
  xlim(100, max(pull(Orange, circumference)))
```



Summary

- `ggplot()` specifies what data use and what variables will be mapped to where
- inside `ggplot()`, `mapping = aes(x = , y = , color =)` specify what variables correspond to what aspects of the plot in general
- layers of plots can be combined using the `+` at the **end** of lines
- special `theme_*()` functions.functions can change the overall look
- individual layers can be customized using arguments like: `size`, `color` `alpha` (more transparent is closer to 0), and `linetype`
- labels can be added with the `labs()` function and `x`, `y`, `title` arguments - the `\n` can be used for line breaks -`xlim()` and `ylim()` can limit or expand the plot area
- `scale_x_continuous()` and `scale_y_continuous()` can modify the scale of the axes

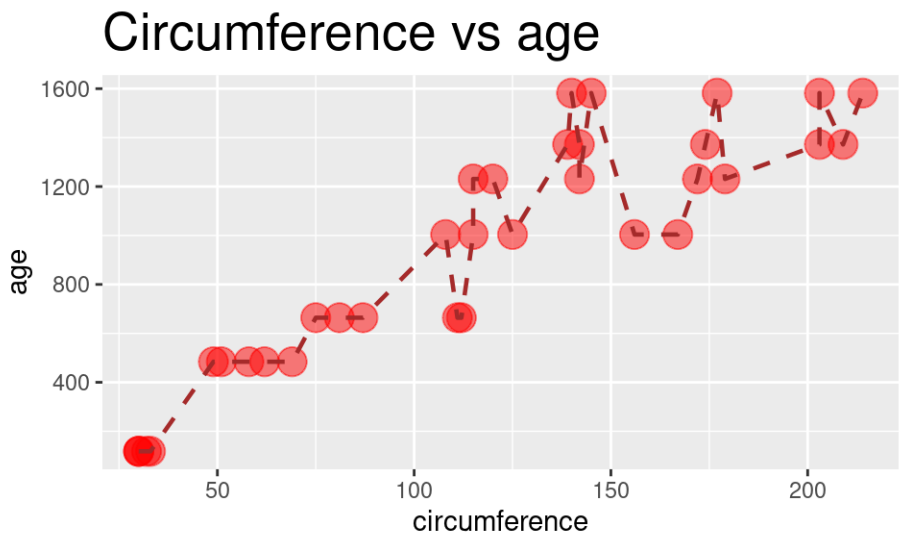
Lab 1

- Class Website
- Lab

theme() function:

The `theme()` function can help you modify various elements of your plot. Here we will adjust the font size of the plot title.

```
ggplot(Orange, mapping = aes(x = circumference, y = age)) +
  geom_point(size = 5, color = "red", alpha = 0.5) +
  geom_line(size = 0.8, color = "brown", linetype = 2) +
  labs(title = "Circumference vs age") +
  theme(plot.title = element_text(size = 20))
```



theme() function

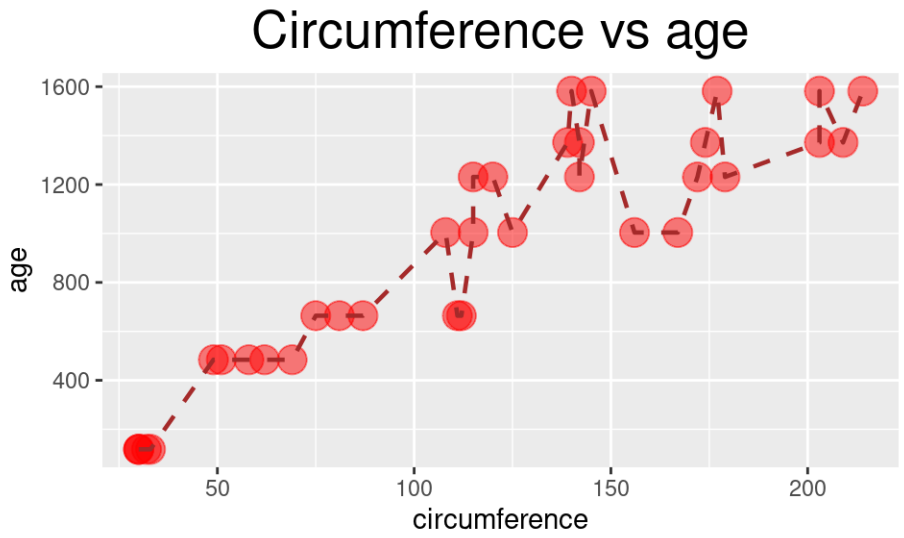
The `theme()` function always takes:

1. an object to change (use `?theme()` to see - `plot.title`, `axis.title`, `axis.ticks` etc.)
2. the aspect you are changing about this: `element_text()`, `element_line()`, `element_rect()`, `element_blank()`
3. what you are changing:
   - text: `size`, `color`, `fill`, `face`, `alpha`, `angle`
   - position: `"top"`, `"bottom"`, `"right"`, `"left"`, `"none"`
   - rectangle: `size`, `color`, `fill`, `linetype`
   - line: `size`, `color`, `linetype`

theme() function: center title and change size

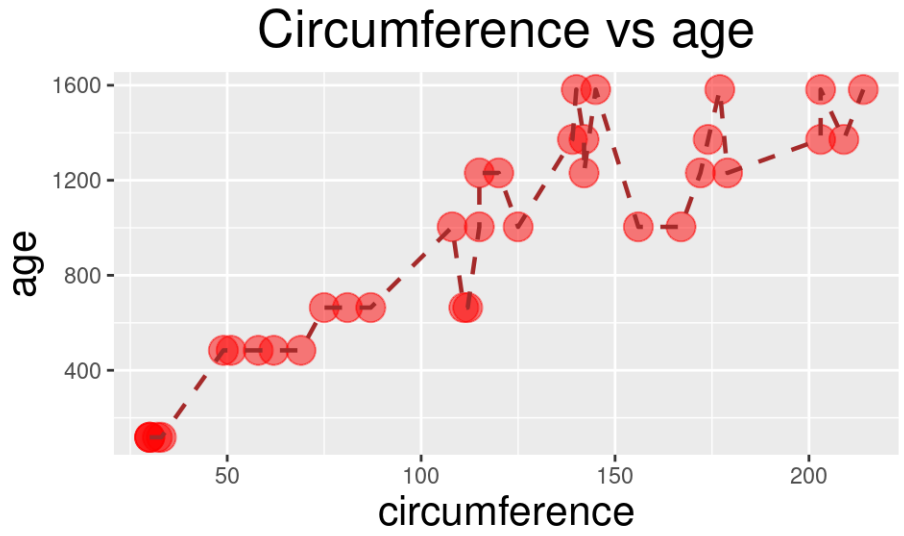
The `theme()` function can help you modify various elements of your plot. Here we will adjust the horizontal justification (`hjust`) of the plot title.

```
ggplot(Orange, mapping = aes(x = circumference, y = age)) +
  geom_point(size = 5, color = "red", alpha = 0.5) +
  geom_line(size = 0.8, color = "brown", linetype = 2) +
  labs(title = "Circumference vs age") +
  theme(plot.title = element_text(hjust = 0.5, size = 20))
```



theme() function: change title and axis format

```
ggplot(Orange, mapping = aes(x = circumference, y = age)) +
  geom_point(size = 5, color = "red", alpha = 0.5) +
  geom_line(size = 0.8, color = "brown", linetype = 2) +
  labs(title = "Circumference vs age") +
  theme(plot.title = element_text(hjust = 0.5, size = 20),
        axis.title = element_text(size = 16))
```

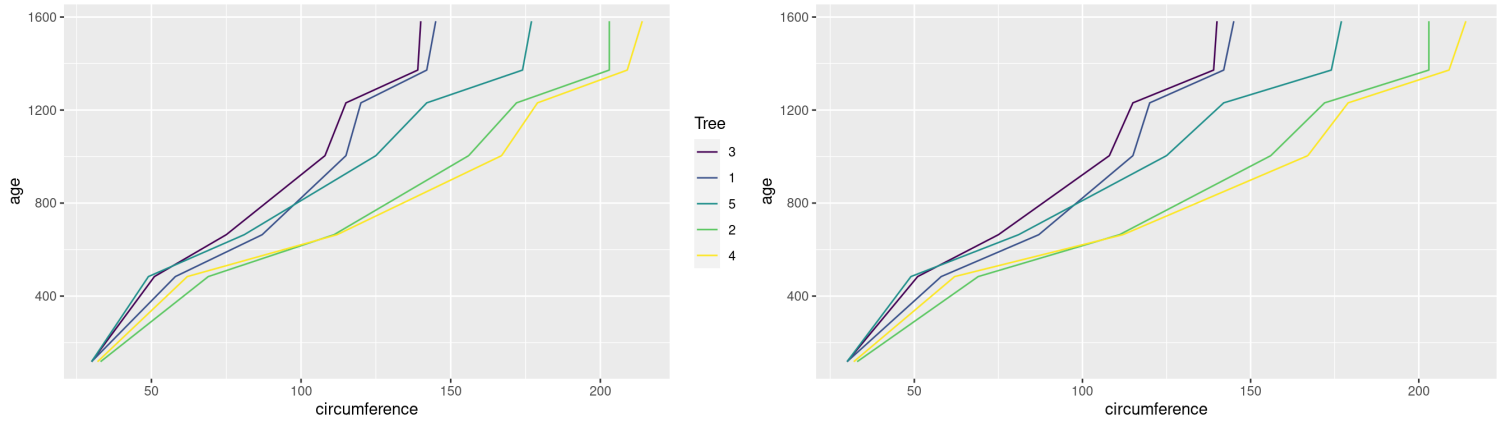


theme() function:moving (or removing) legend

If specifying position - use: “top”, “bottom”, “right”, “left”, “none”

```
ggplot(Orange, mapping = aes(x = circumference, y = age, color = Tree)) +
  geom_line()
```

```
ggplot(Orange, mapping = aes(x = circumference, y = age, color = Tree)) +
  geom_line() +
  theme(legend.position = "none")
```



Can make your own theme to use on plots!

Guide on how to: https://rpubs.com/mclaire19/ggplot2-custom-themes

Group and/or color by variable's values

First, we will generate some data frame for the purpose of demonstration.

- 2 different categories (e.g. pasta, rice)
- 4 different items (e.g. 2 of each category)
- 10 price values changes collected over time for each item

```
# create 4 vectors: 2x character class and 2x numeric class
item_categ <- rep(c("pasta", "rice"),each = 20)
item_ID  <- rep(seq(from = 1, to = 4), each = 10)
item_ID <- paste0("ID_", item_ID)
observation_time  <- rep(seq(from = 1, to = 10), times = 4)
item_price_change <- c(sample(0.5:2.5, size = 10, replace = TRUE),
                       sample(0:1, size = 10, replace = TRUE),
                       sample(2:5, size = 10, replace = TRUE),
                       sample(6:9, size = 10, replace = TRUE))
# use 4 vectors to create data frame with 4 columns
food  <- tibble(item_ID, item_categ, observation_time, item_price_change)
```

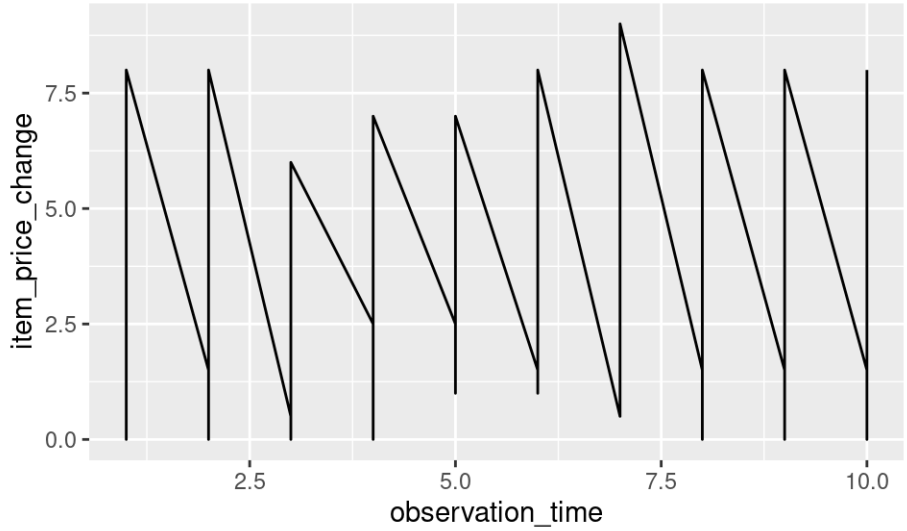
Group and/or color by variable's values

```
food
```

```
# A tibble: 40 × 4
   item_ID item_categ observation_time item_price_change
   <chr>   <chr>                 <int>              <dbl>
 1 ID_1    pasta                     1                1.5
 2 ID_1    pasta                     2                1.5
 3 ID_1    pasta                     3                0.5
 4 ID_1    pasta                     4                2.5
 5 ID_1    pasta                     5                2.5
 6 ID_1    pasta                     6                1.5
 7 ID_1    pasta                     7                0.5
 8 ID_1    pasta                     8                1.5
 9 ID_1    pasta                     9                1.5
10 ID_1    pasta                    10                1.5
# … with 30 more rows
```

Starting a plot

```
ggplot(food, mapping = aes(x = observation_time,
                           y = item_price_change)) +
  geom_line()
```

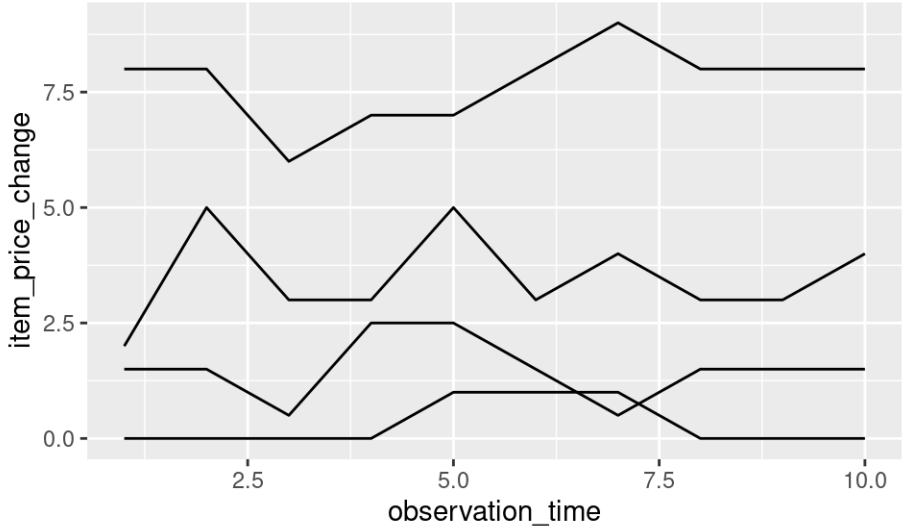


If it looks confusing to you, try again

Using **group** in plots

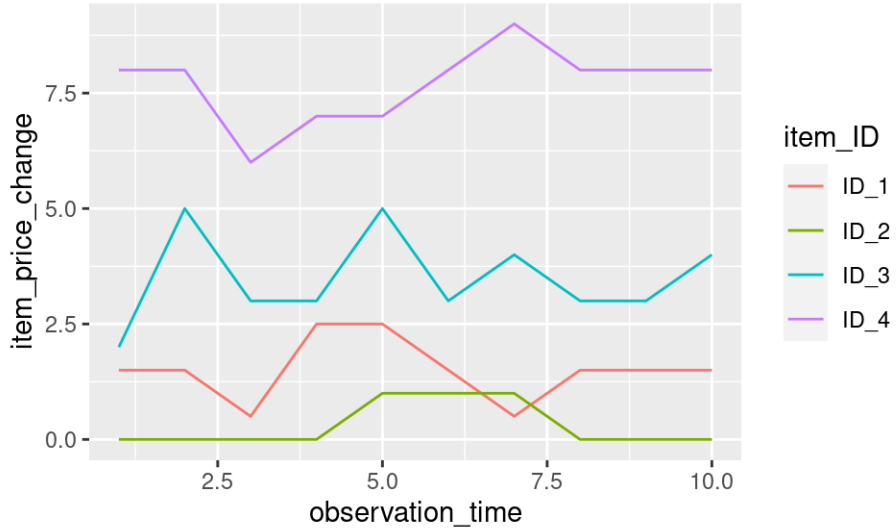
You can use `group` element in a mapping to indicate that each `item_ID` will have a separate price line.

```
ggplot(food, mapping = aes(x = observation_time,
                           y = item_price_change,
                           group = item_ID)) +
  geom_line()
```



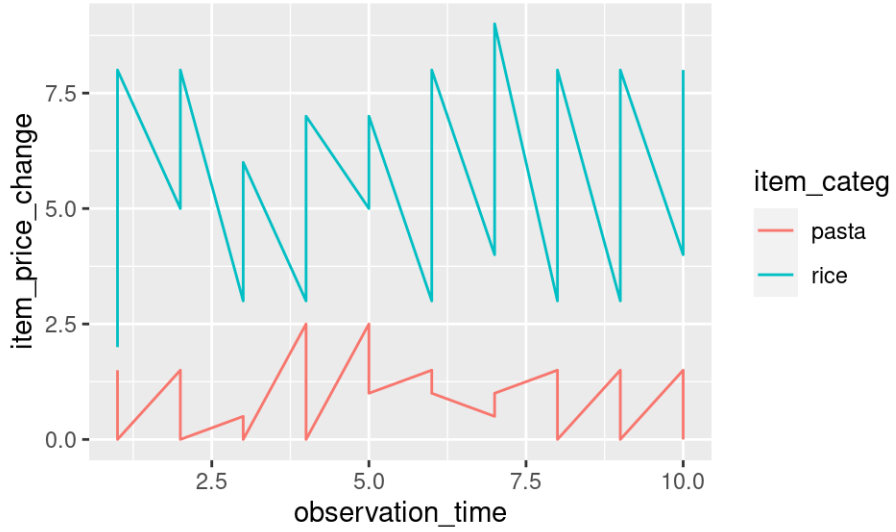
Adding color will automatically group the data

```
ggplot(food, aes(x = observation_time,
                 y = item_price_change,
                color = item_ID)) +
  geom_line()
```



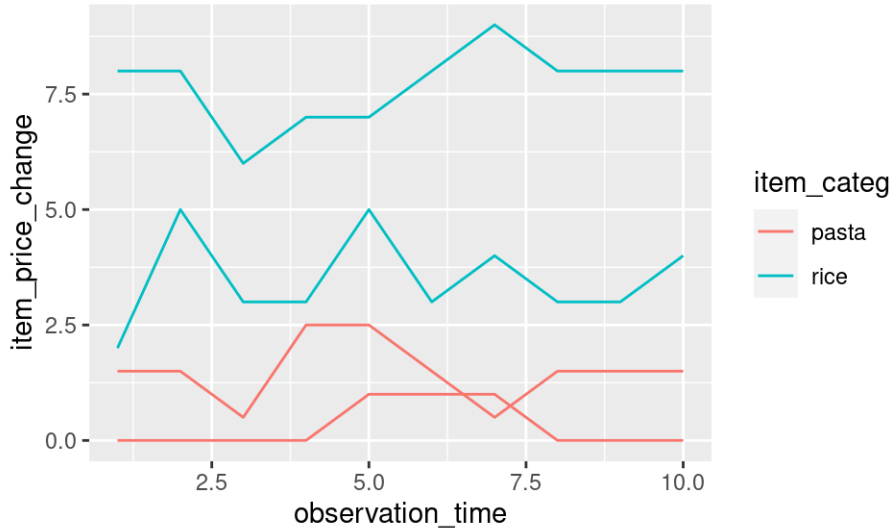
Adding color will automatically group the data

```
ggplot(food, mapping = aes(x = observation_time,
                           y = item_price_change,
                           color = item_categ)) +
  geom_line()
```



Sometimes you need group and color

```
ggplot(food, aes(x = observation_time,
                 y = item_price_change,
                 group = item_ID,
                color = item_categ)) +
           geom_line()
```

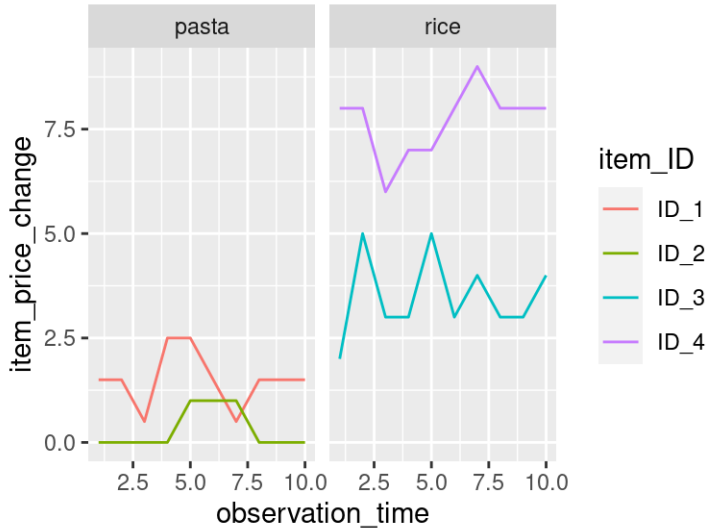


Adding a facet can help make it easier to see what is happening

Two options: `facet_grid()`- creates a grid shape `facet_wrap()` -more flexible

Need to specify how you are faceting with the `~` sign.

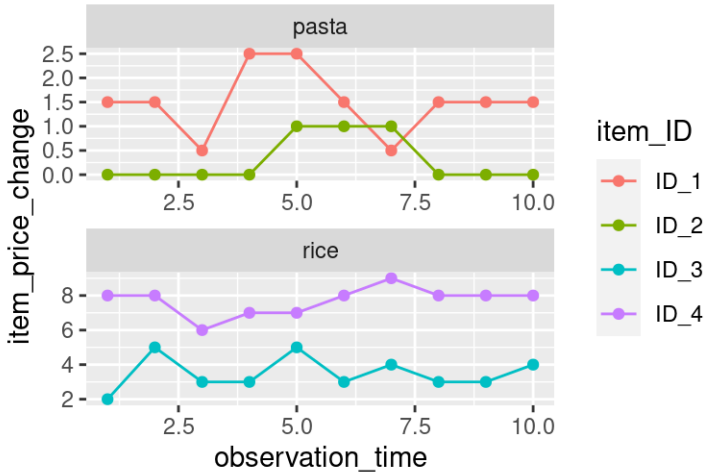
```
ggplot(food, mapping = aes(x = observation_time,
                           y = item_price_change,
                           color = item_ID)) +
  geom_line() +
  facet_grid( ~ item_categ)
```



facet_wrap()

- more flexible - arguments `ncol` and `nrow` can specify layout
- can have different scales for axes using `scales = "free_x"`, `scales = "free_y"`, or `scales = "free"`

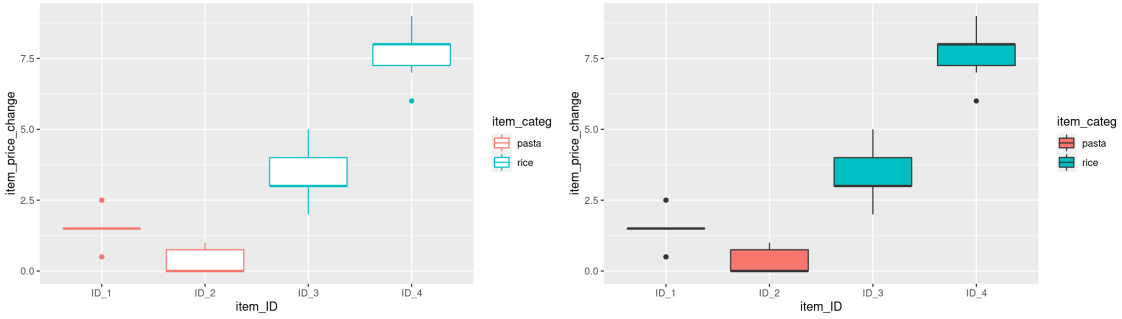
```
rp_fac_plot <- ggplot(food, mapping = aes(x = observation_time, y = item_price_change,color = item_ID)) +
                  geom_line()  +
                  geom_point() +
                  facet_wrap( ~ item_categ, ncol = 1, scales = "free")
rp_fac_plot
```



Tips - Color vs Fill

- `color` is needed for points and lines
- `fill` is generally needed for boxes and bars

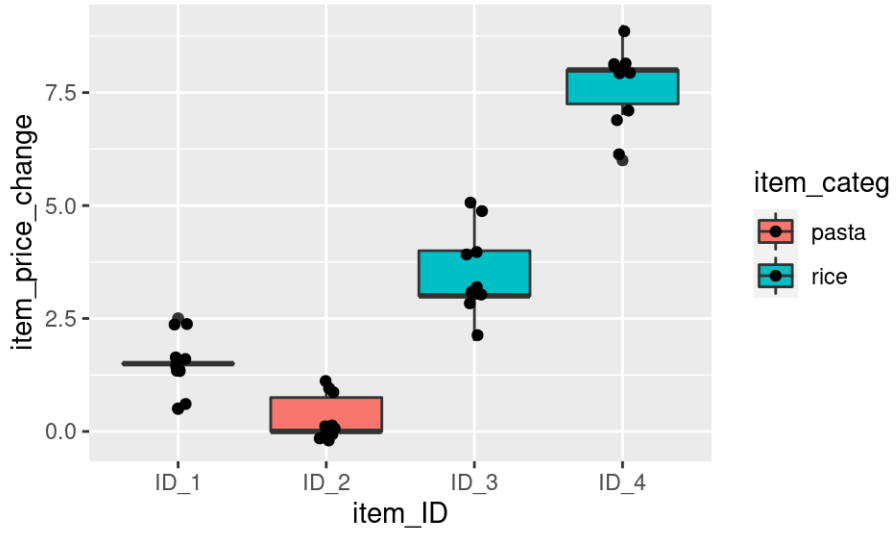
```
ggplot(food, mapping = aes(x = item_ID,
                           y = item_price_change,
                           color = item_categ)) + #color creates an outline
  geom_boxplot()

ggplot(food, mapping = aes(x = item_ID,
                           y = item_price_change,
                           fill = item_categ)) + # fills the boxplot
  geom_boxplot()
```



Tip - Good idea to add jitter layer to top of box plots

Can add `width` argument to make the jitter more narrow.

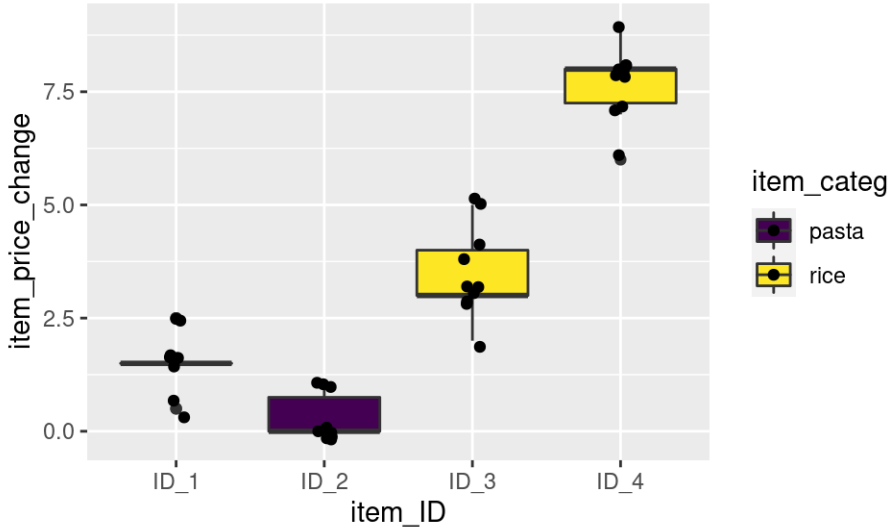
```
ggplot(food, mapping = aes(x = item_ID,
                           y = item_price_change,
                           fill = item_categ)) +
  geom_boxplot() +
  geom_jitter(width = .06)
```



Tip - be careful about colors for color vision deficiency

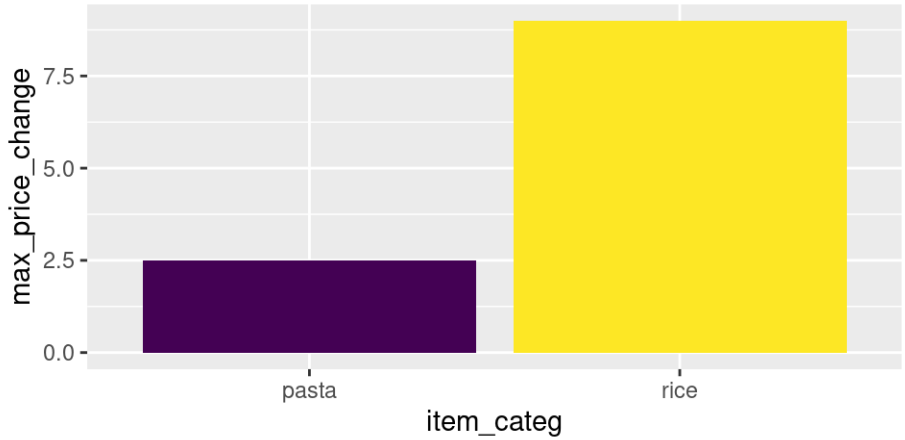
`scale_fill_viridis_d()` for discrete /categorical data
`scale_fill_viridis_c()` for continuous data

```
ggplot(food, mapping = aes(x = item_ID,
                           y = item_price_change,
                           fill = item_categ)) +
  geom_boxplot() +
  geom_jitter(width = .06) +
  scale_fill_viridis_d()
```



Tip - can pipe data after wrangling into ggplot()

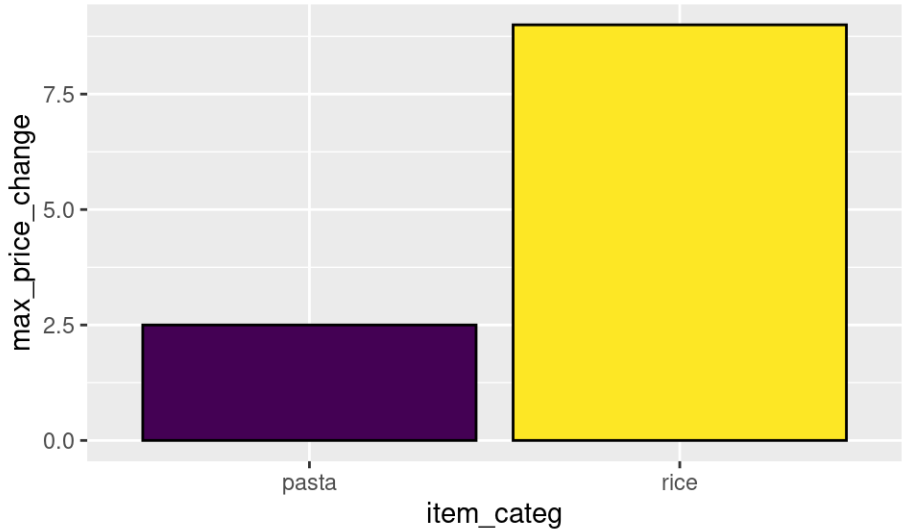
```
food_bar <-food %>%
  group_by(item_categ) %>%
  summarize("max_price_change" = max(item_price_change)) %>%
  ggplot(mapping = aes(x = item_categ,
                       y = max_price_change,
                       fill = item_categ)) +
  scale_fill_viridis_d()+
  geom_col() +
  theme(legend.position = "none")

food_bar
```



Tip - color outside of **aes( )**

Can be used to add an outline around column/bar plots.

```
food_bar +
   geom_col(color = "black")
```



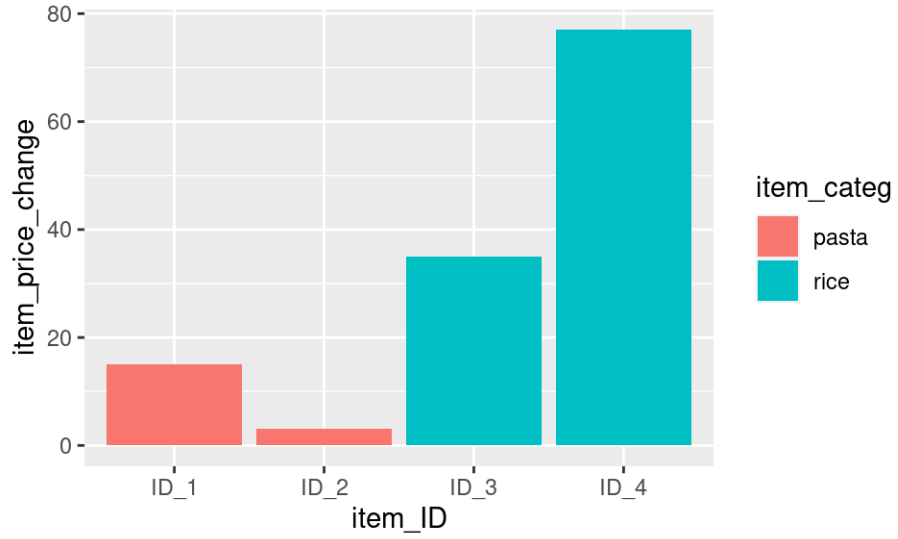
Tip - col vs bar

`geom_bar(x =)` can only use one `aes` mapping `geom_col(x = , y = )` can have two

Tip - Check what you plot

- May not be plotting what you think you are!

```
ggplot(food, mapping = aes(x = item_ID,
                           y = item_price_change,
                           fill = item_categ)) +
  geom_col()
```



What did we plot? Always good to check it is correct!

```
head(food, n = 3)
```

```
# A tibble: 3 × 4
  item_ID item_categ observation_time item_price_change
  <chr>   <chr>                 <int>             <dbl>
1 ID_1    pasta                     1               1.5
2 ID_1    pasta                     2               1.5
3 ID_1    pasta                     3               0.5
```

```
food %>% group_by(item_ID) %>%
  summarize(sum = sum(item_price_change))
```

```
# A tibble: 4 × 2
  item_ID   sum
  <chr>   <dbl>
1 ID_1       15
2 ID_2        3
3 ID_3       35
4 ID_4       77
```

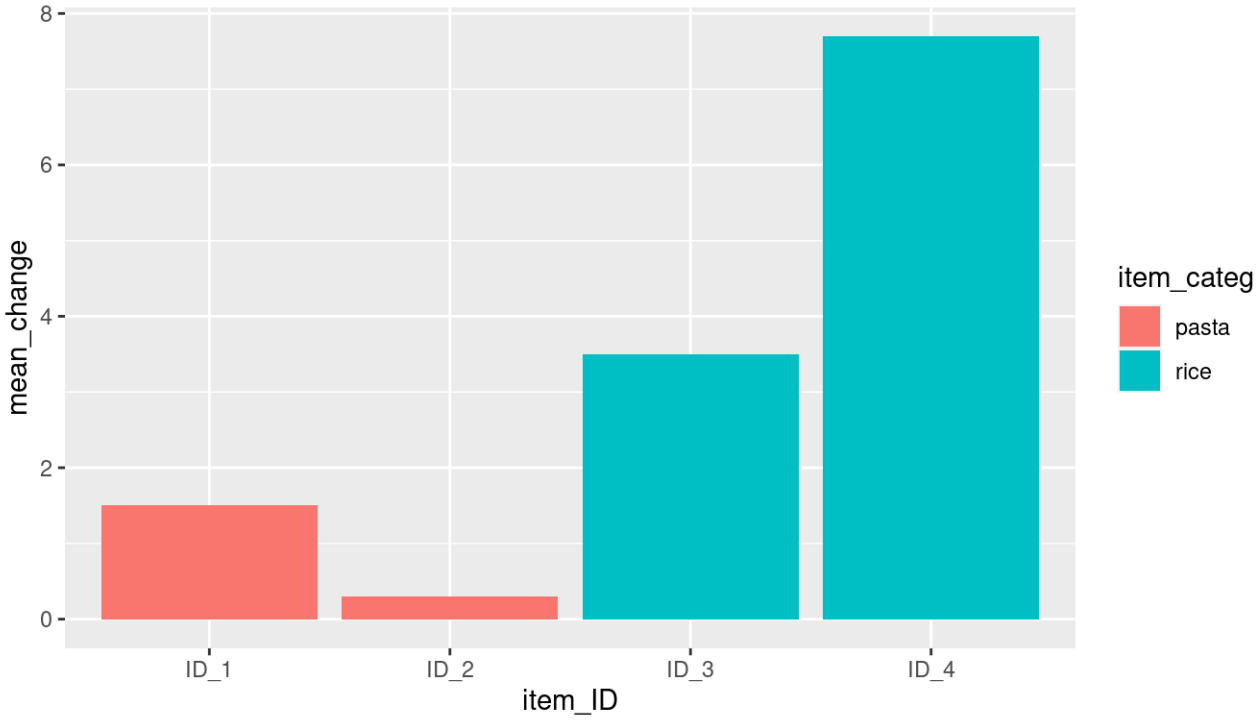
Try that again

```
food %>% group_by(item_categ, item_ID) %>%
  summarize(mean_change = mean(item_price_change))
```

```
# A tibble: 4 × 3
# Groups:   item_categ [2]
  item_categ item_ID mean_change
  <chr>      <chr>         <dbl>
1 pasta      ID_1            1.5
2 pasta      ID_2            0.3
3 rice       ID_3            3.5
4 rice       ID_4            7.7
```

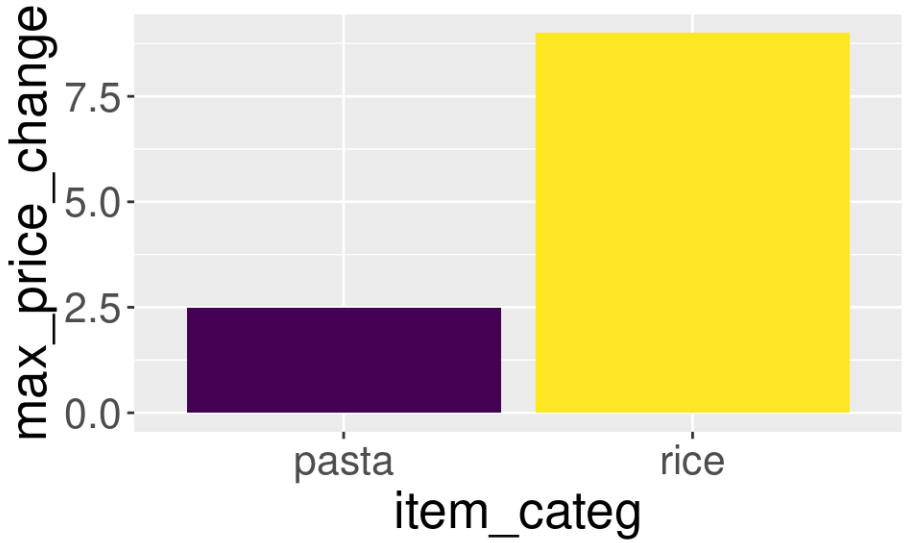
Try that again

```
food %>% group_by(item_categ, item_ID) %>%
  summarize(mean_change = mean(item_price_change)) %>%
    ggplot(mapping = aes(x = item_ID,
                         y = mean_change,
                         fill = item_categ)) +
  geom_col()
```



Tip - make sure labels aren't too small

```
food_bar +
  theme(text = element_text(size = 20))
```



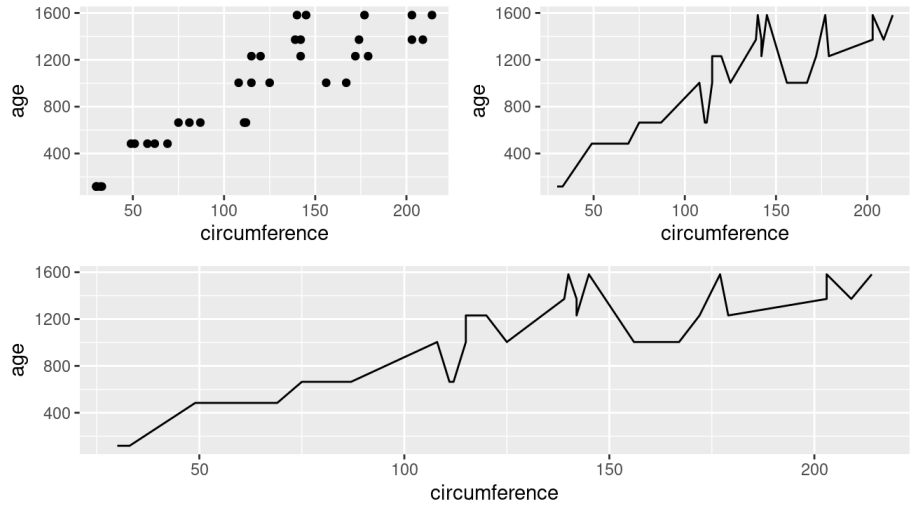
Extensions

`patchwork` package

Great for combining plots together

Also check out the `patchwork` package

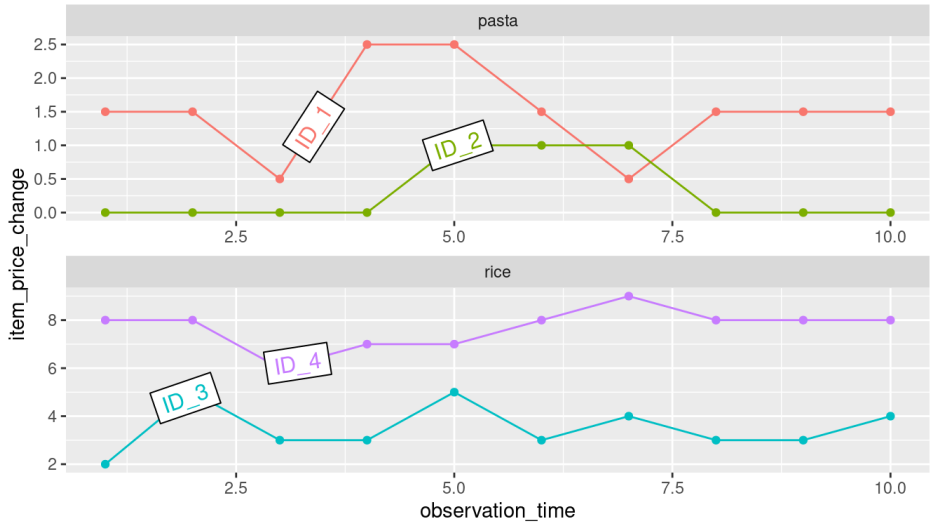
```
#install.packages("patchwork")
library(patchwork)
(plt1 + plt2)/plt2
```



`directlabels` package

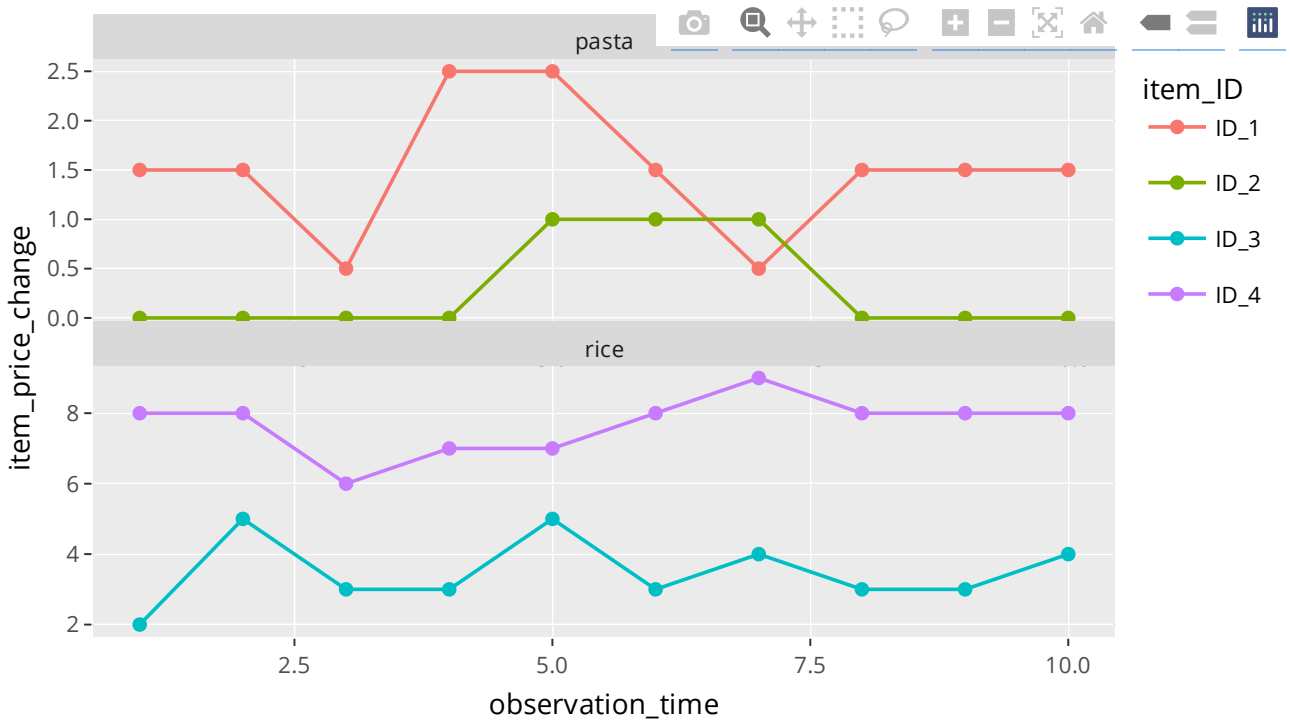
Great for adding labels directly onto plots https://www.opencasestudies.org/ocs-bp-co2-emissions/

```
#install.packages("directlabels")
library(directlabels)
direct.label(rp_fac_plot, method = list("angled.boxes"))
```



plotly

```
#install.packages("plotly")
library("plotly") # creates interactive plots!
ggplotly(rp_fac_plot)
```



Also check out the `ggiraph` package

Saving plots

Saving a ggplot to file

A few options:

- RStudio > Plots > Export > Save as image / Save as PDF
- RStudio > Plots > Zoom > [right mouse click on the plot] > Save image as
- In the code

```
ggsave(filename = "saved_plot.png",  # will save in working directory
       plot = rp_fac_plot,
       width = 6, height = 3.5)                # by default in inches
```

Summary

- The `theme()` function helps you specify aspects about your plot
  - move or remove a legend with `theme(legend.position = "none")`
  - change font aspects of individual text elements `theme(plot.title = element_text(size = 20))`
  - center a title: `theme(plot.title = element_text(hjust = 0.5))`
- sometimes you need to add a `group` element to `mapping = aes()` if your plot looks strange
- make sure you are plotting what you think you are by checking the numbers!
- `facet_grid(~ variable)` and `facet_wrap(~variable)` can be helpful to quickly split up your plot
  - `facet_wrap()` allows for a `scales = "free"` argument so that you can have a different axis scale for different plots
- use `fill` to fill in boxplots

Good practices for plots

Check out this guide for more information!

Lab 2

- Class Website
- Lab

The End