Lecture 2.6 – Grammar of Graphics

Learning Objectives:

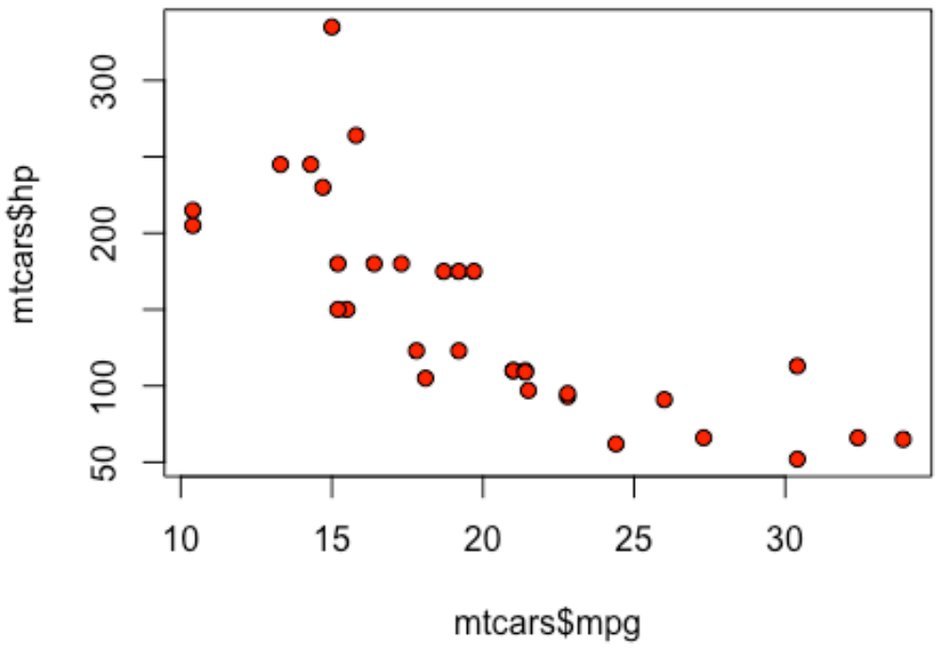
3.3 Learn the basics of `ggplot2`.

The Plotting Systems of R

- Base graphics and **grid**

```
plot(x = mtcars$mpg, y = mtcars$hp,
     col = "black", bg = "red",
     pch = 21)
```

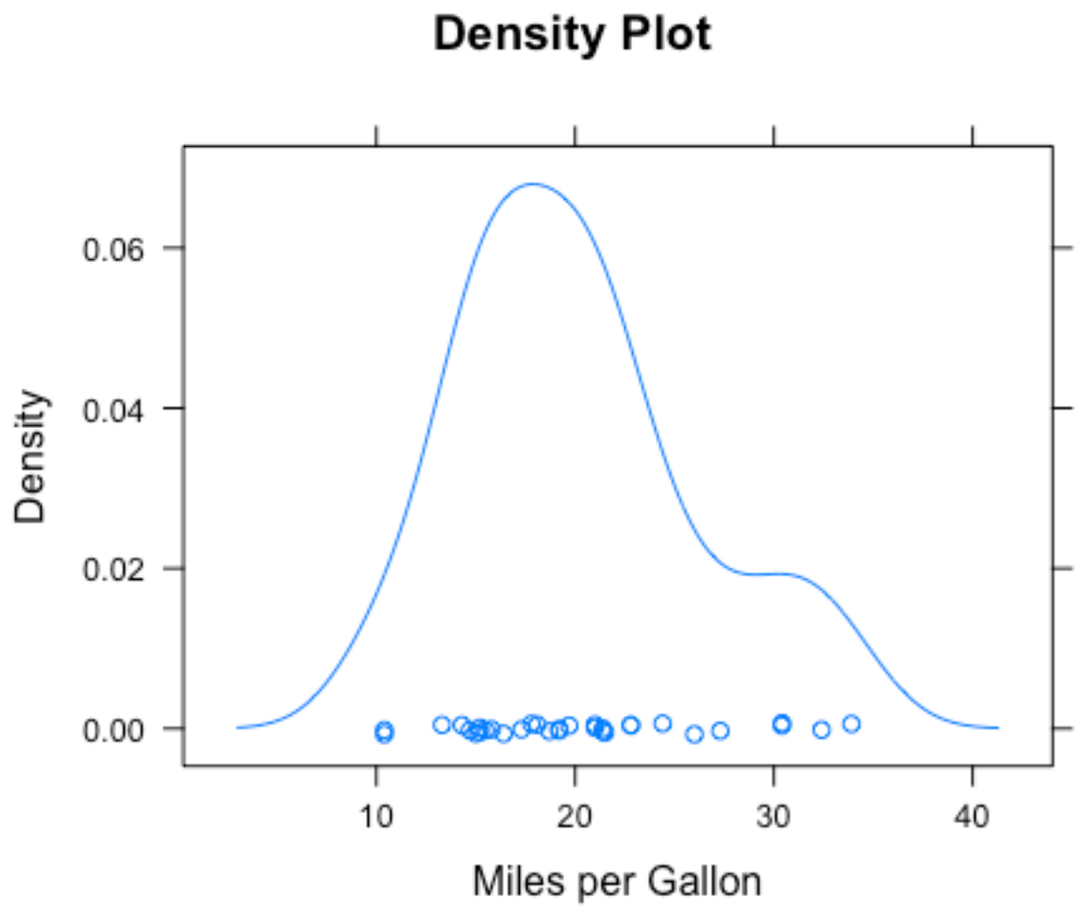
Benefits:
- simple and quick
- handles a variety of data types
- not many background calculations



- The Trellis system in **lattice**

```
densityplot(~mpg,
            main="Density Plot",
            xlab="Miles per Gallon")
```

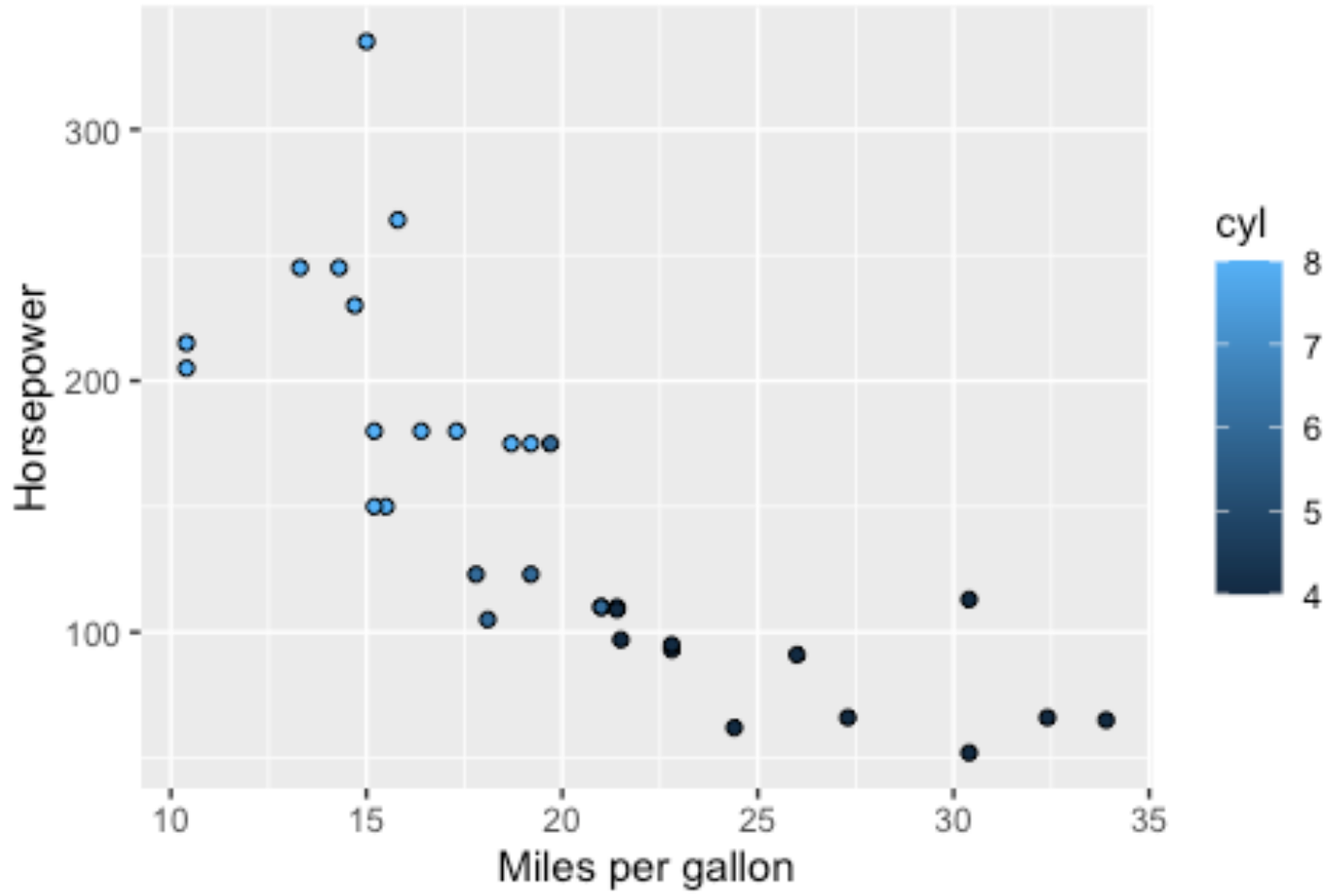
Benefits:
- quick
- many specialized stats plots
- not too many background calculations



The Plotting Systems of R

- Grammar of Graphics `ggplot2`

```
ggplot(mtcars, aes(x=mpg,y=hp,fill=cyl)) +
  geom_point(pch=21, size=2) +
  xlab("Miles per gallon") + ylab("Horsepower")
```



Benefits:
- beautiful visualizations
- many specialized plots
- consistent syntax
- have full control over aesthetics

Drawbacks:
- lots of background calculations
- slow
- only uses data frames in long format

Grammar of Graphics: terminology

Data

	mpg	cyl	disp	hp
Mazda RX4	21.0	6	160.0	110
Mazda RX4 Wag	21.0	6	160.0	110
Datsun 710	22.8	4	108.0	93
Hornet 4 Drive	21.4	6	258.0	110
Hornet Sportabout	18.7	8	360.0	175
Valiant	18.1	6	225.0	105
Duster 360	14.3	8	360.0	245
Merc 240D	24.4	4	146.7	62
Merc 230	22.8	4	140.8	95

Mapping

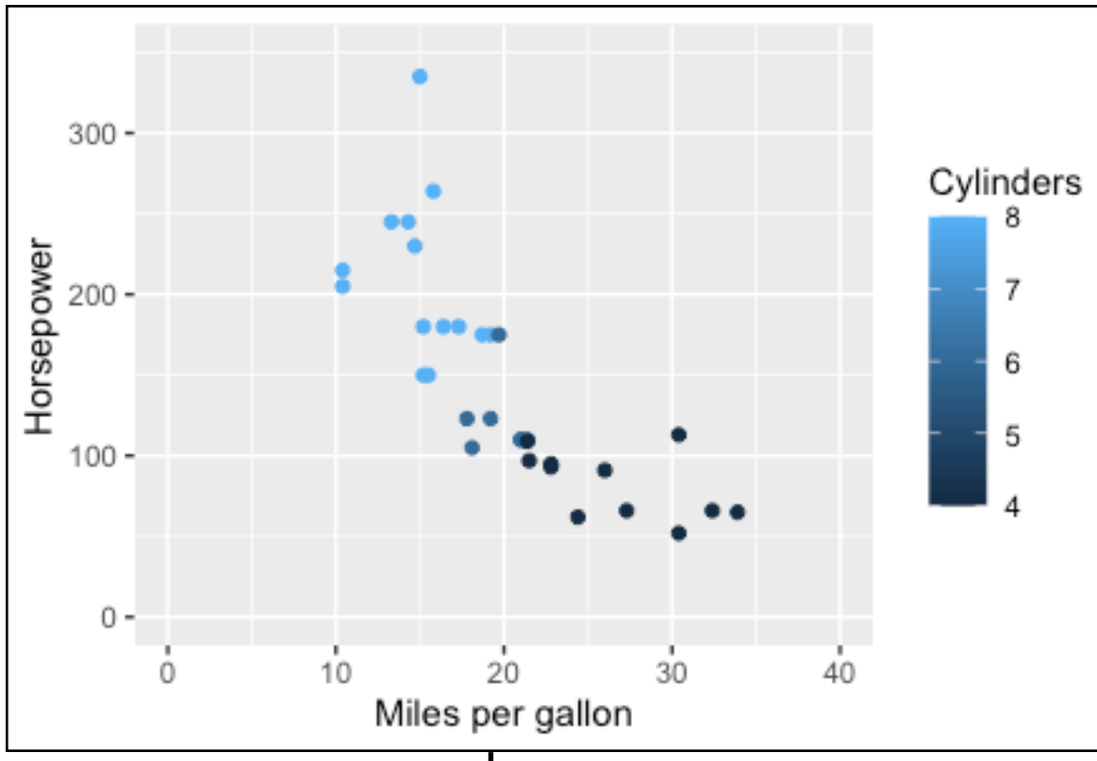
Aesthetic attributes

x

y

color/fill

Geometric object




```
ggplot( mtcars,        aes( x = mpg,     )      + geom_point()
                            y = hp,
                            fill = cyl)
```

Other stuff:

Scales

```
+ xlim(0, 40)
```

Guides

```
+ labs(color="Cylinders")
```

Check Your Understanding

Use the `Orange` data set to create a scatterplot with `ggplot2` of `circumference` versus tree `age`.

Data: wide versus long format

- To reap many of the benefits of the **`ggplot`** package, you may need to reshape your data set.

Wide: Columns represent different measurements

Seed	Year 3	Year 5	Year 10	Year 15	Year 20	Year 25
301	4.51	10.89	28.72	41.75	52.70	60.92
303	4.55	10.92	29.07	42.83	53.88	63.39
305	4.79	11.37	30.21	44.40	52.82	64.10
307	4.81	11.20	28.66	41.66	53.31	63.05

Long: Each row is a unique observation

Seed	Age	Height
301	3	4.51
301	5	10.89
301	10	28.72
301	15	41.74
301	20	52.70
301	25	60.92
303	3	4.55
303	5	10.92
303	10	29.07
303	15	42.38
303	20	53.88
303	25	63.39

Data: wide versus long format

Dataset: `Loblolly` **Package:** `tidyr`

Wide: Columns represent different measurements

Seed	Year 3	Year 5	Year 10	Year 15	Year 20	Year 25
301	4.51	10.89	28.72	41.75	52.70	60.92
303	4.55	10.92	29.07	42.83	53.88	63.39
305	4.79	11.37	30.21	44.40	52.82	64.10
307	4.81	11.20	28.66	41.66	53.31	63.05

```
Loblolly.wide <- pivot_wider(Loblolly,
                             names_from = age,
                             values_from = height)
```

```
Loblolly.long <-
  pivot_longer(Loblolly.wide, id.vars =
                 "Seed")
```

Long: Each row is a unique observation

Seed	Age	Height
301	3	4.51
301	5	10.89
301	10	28.72
301	15	41.74
301	20	52.70
301	25	60.92
303	3	4.55
303	5	10.92
303	10	29.07
303	15	42.38
303	20	53.88
303	25	63.39

Data: wide versus long format

- The **`pivot_wider()`** function: long to wide

data set in long format

where to get column names from

```
Loblolly.wide <- pivot_wider(Loblolly,
                             names_from = age,
                             values_from = height)
```

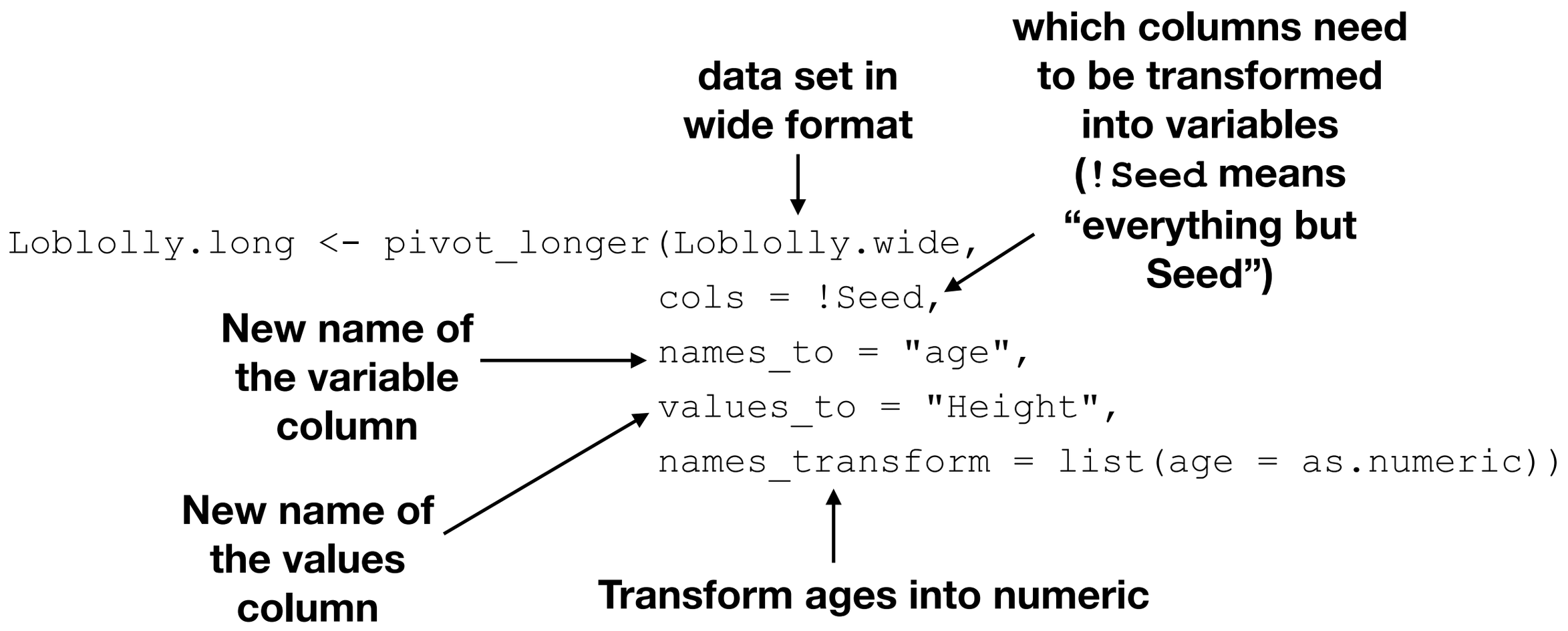
where to get values from

- The new columns are named based on **`names_from`**

- The cell values are filled from **`values_from`**

Data: wide versus long format

- The **`pivot_longer()`** function: wide to long



- Pick the columns that should be data values (**`cols`**). The column names will become variables in long format. The variable column will be named by **`names_to`**.

- Pick the name of that new column where the values will be stored (**`values_to`**).

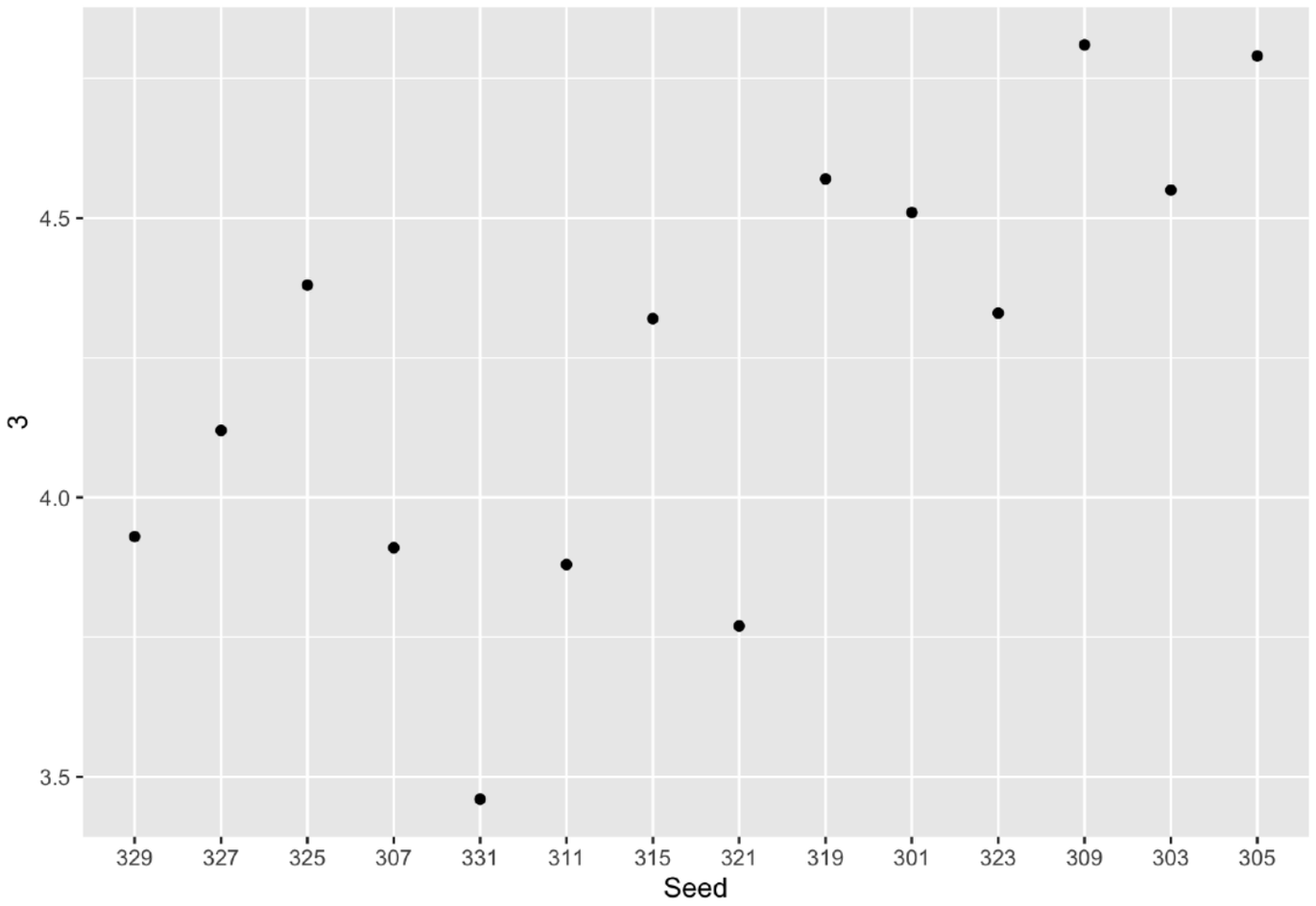
Plotting: wide format

- Plotting in the wide format limits your options. You are forced to choose which columns to map, which limits you to the ways in which you can plot!

column options for `Loblolly.wide`:

	Seed	3	5	10	15	20	25
1	329	3.93	9.34	26.08	37.79	48.31	56.43
2	327	4.12	9.92	26.54	37.82	48.43	56.81

```
ggplot(Loblolly.wide,
          aes(x = Seed,
              y = `3`))+
    geom_point()
```



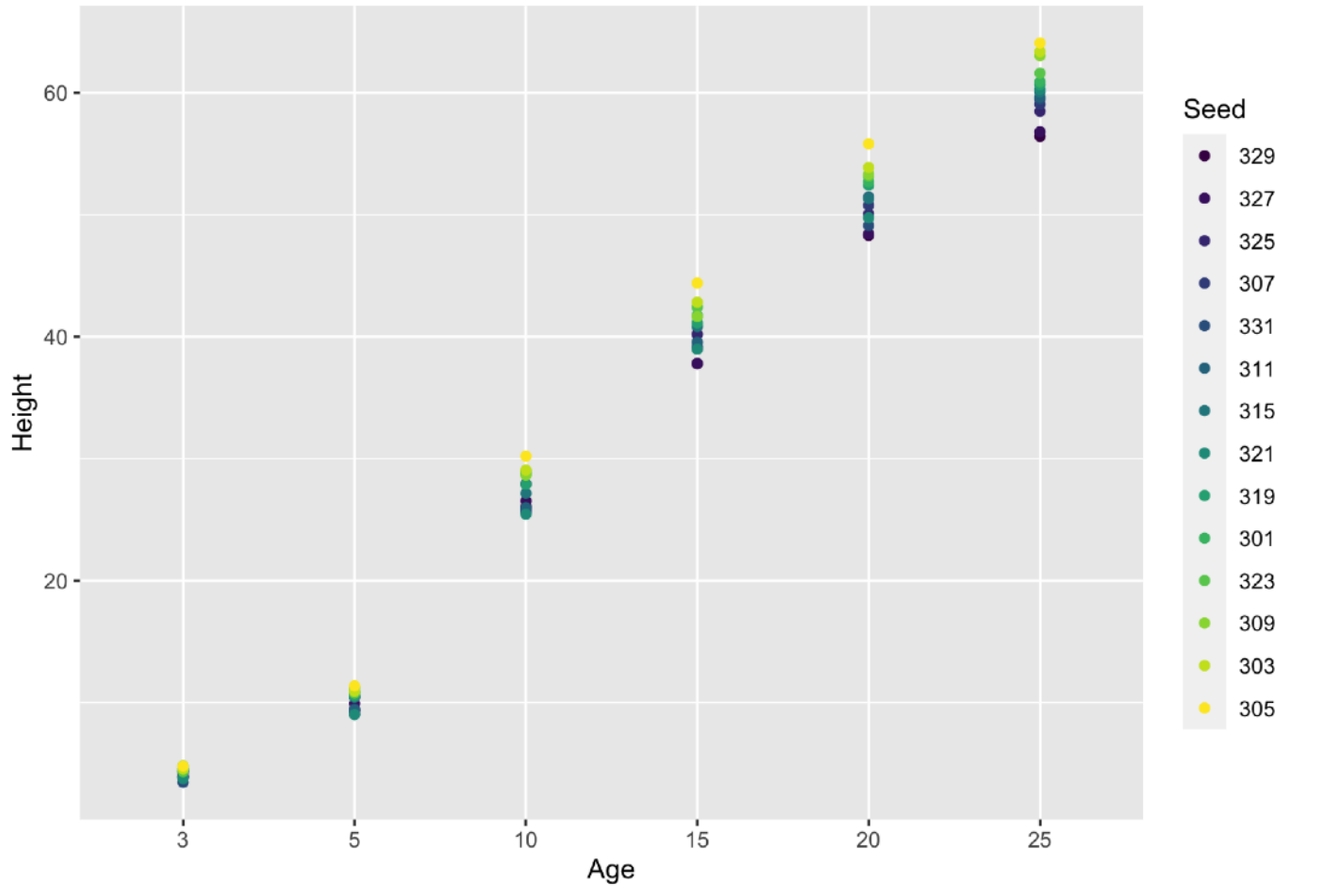
Plotting: long format

- The long format doesn't suffer from this same issue. You have appropriate options for plotting and mapping aesthetics.

column options for `Loblolly.long`:

	Seed	Age	Height
1	329	3	3.93
2	327	3	4.12

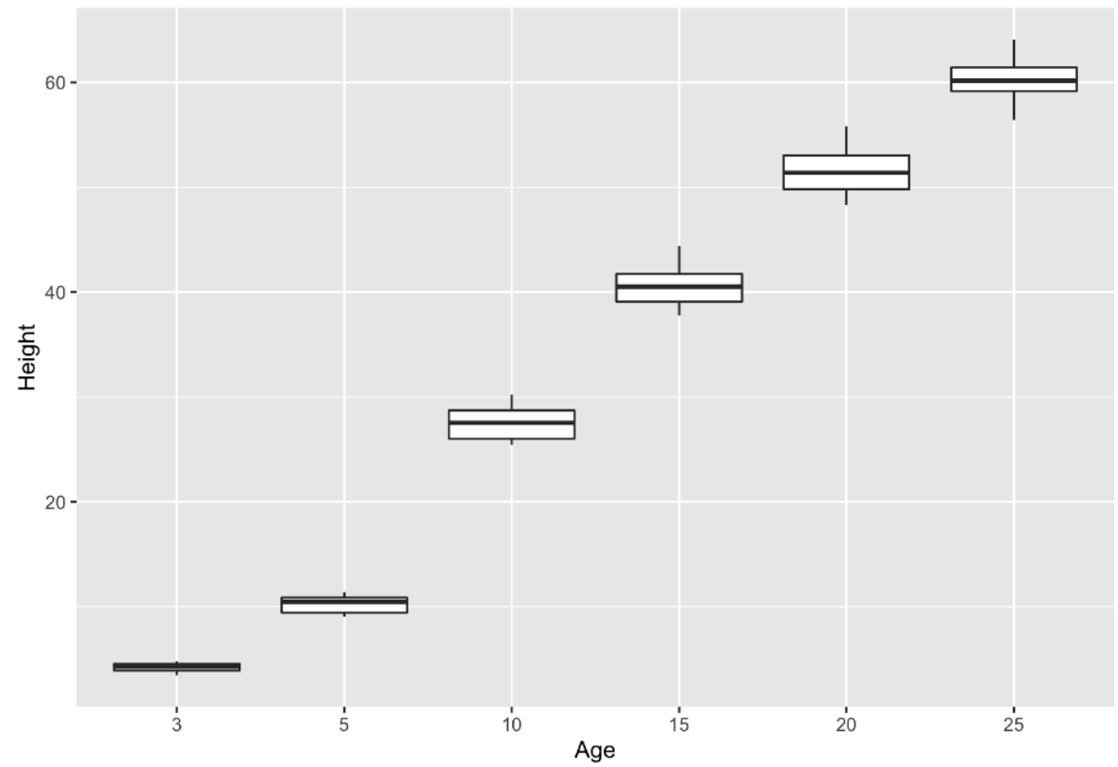
```
ggplot(Loblolly.long,
       aes(x = age,
           y = Height,
           color = Seed)) +
  geom_point(pch = 19)
```



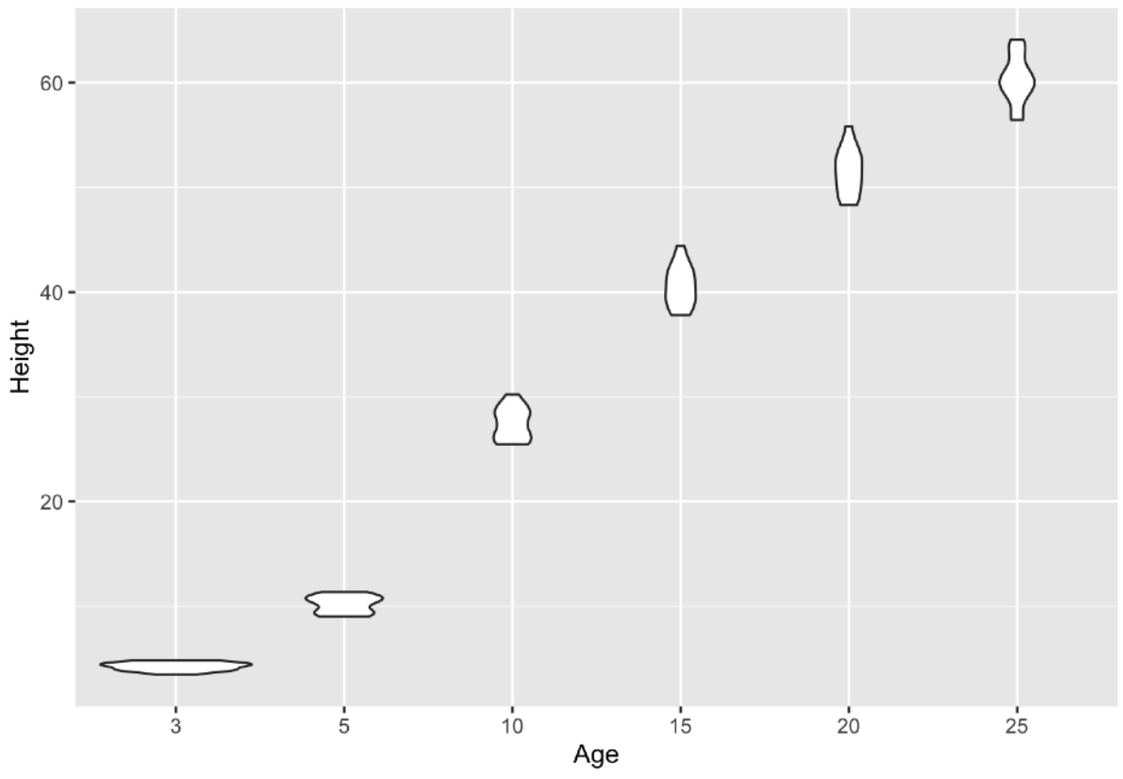
Plotting: long format

- You can push many calculations for plot types into **`ggplot`** so as not to worry about doing them yourself!

```
ggplot(Loblolly.long,
       aes(x = factor(age),
           y = Height)) +
    geom_boxplot()
```




```
ggplot(Loblolly.long,
       aes(x = factor(age),
           y = Height)) +
    geom_violin()
```



Check Your Understanding

1. **Reshape the `fish_encounters` data set (in the `tidyr` package) into a wide format.**

2. **Reshape the `relig_income` data set (in the `tidyr` package) into a long format.**

Changing Basic Plot Attributes

- Changing basic attributes:

Base plot: `p <- ggplot(mtcars, aes(x = mpg, y = hp)) + geom_point()`

- Plot labels and titles:

X-axis label: `p + xlab("Miles per Gallon")`
Y-axis label: `p + ylab("Horsepower")`
Plot title: `p + ggtitle("Horsepower vs MPG from MtCARS")`

- Axis scales:

Change x limits: `p + xlims(min, max)`
Change y limits: `p + ylims(min, max)`
Change color limits: `p + lims(color = c(newlimits))`

- Formatting of plot area and text:

There are lots of arguments here!

Most items: `p + theme()`
Minimal theme: `p + theme_minimal()`

Changing Aesthetic Attributes

If independent of mapping, you will change them in the geom!

- Changing aesthetic attributes:

```
ggplot(mtcars, aes(x = mpg, y = hp)) + geom_point()
```

- Point size, shape, color, and fill:

(2 is 2x size of default points)

Point size: `... + geom point(size = 2)`

Point shape: `... + geom_point(shape = 19)`

or

`... + geom_point(pch = 19)`

Point color: `... + geom_point(color = “red”)`

Point fill:
```
... + geom_point(pch = 21,
                 color = “black”, fill = “red”)
```

Check Your Understanding

Add to the plot in your last check your understanding by:

1. **Adding axis labels and a title.**
2. **Changing the color, shape, or size of the points.**
3. **Rotating the x-axis labels by 45 degrees.**

Grouping and Aesthetic Values

- It's easy to change group characteristics using **`aes()`**, include the specific characteristic you want (**`color`**, **`fill`**, **`shape`**) or use **`group`** and define those later.

Assign colors based on `cyl`:

```
ggplot(mtcars, aes(x = mpg, y = hp,
                   color = factor(cyl)) +
       geom_point()
```

Assign fill based on `cyl`:

```
ggplot(mtcars, aes(x = mpg, y = hp,
                   fill = factor(cyl)) +
       geom_point(pch = 21)
```

Assign shape based on `cyl`:

```
ggplot(mtcars, aes(x = mpg, y = hp,
                   shape = factor(cyl)) +
       geom_point()
```

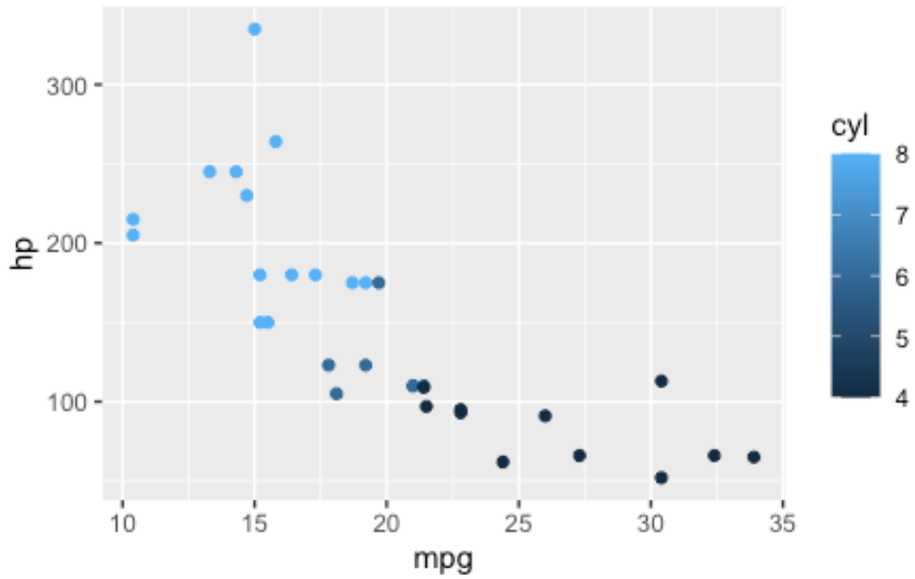
Note: using `factor(cyl)` will help out these plots!

Mapping aesthetics based on data

- Mapping aesthetics that change with data must be done with **`aes()`**

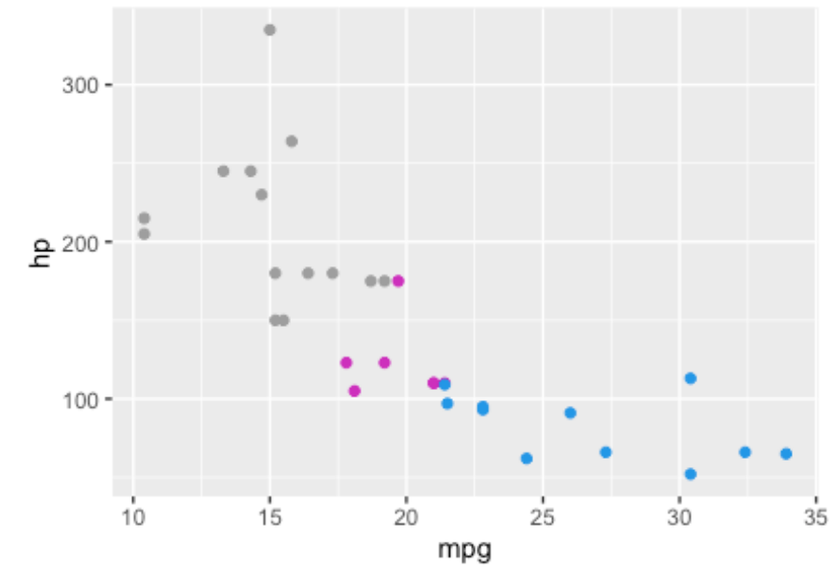
```
ggplot(mtcars,
       aes(x = mpg, y = hp,
           color = cyl)) +
  geom_point()
```

Maps correctly




```
ggplot(mtcars,
       aes(x = mpg, y = hp)) +
  geom_point(color = cyl)
```

Maps incorrectly



- Changing non-mapped aesthetics can be done anywhere

```
ggplot(mtcars,
       aes(x = mpg, y = hp)) +
  geom_point(aes(color = cyl))
```

Maps correctly

Adding data from other sets to existing plots

- Adding data manually from other sets is very clunky and should be avoided whenever possible.

```
p2 <- ggplot(Loblolly.wide, aes(x = Seed, y = `3`)) +
         geom_point()
```

Add another column from `Loblolly.wide` to the graph as red dots:

```
p2 + geom_point(data = Loblolly.wide,
                mapping = aes(x = Seed, y = `5`),
                color = "red")
```

- the data set must be specified in the geom using **`data=`**
- mapping must be specified in the geom using **`mapping=`** and **`aes()`**
- other attributes have to be set independently in the geom
- it is ugly and won't give you a correct legend

Check Your Understanding

Add to the plot in your last check your understanding by:

1. **Coloring the plot points by Tree**
2. **Adding lines in the link data from the individual trees together**

Geometric objects

Scatter plot – `geom_point()`

Line plot – `geom_line()`

Box plot – `geom_boxplot()`

Violin plot – `geom_violin()`

Bar plot – `geom_bar()`

Contour plot – `geom_contour()`

Density plot – `geom_density()`

Plot a map – `geom_sf()`

Rectangles – `geom_raster()`
`geom_tile()`

Quantile-quantile plot – `geom_qq_line()`

Stacked dot plot – `geom_dotplot()`

Histogram – `geom_histogram()`

Choose the correct plot for your data!

Skill Check 2.1 – Present Graph Types

Group 1: Continuous x and y data

`geom_point()`, `geom_line()`, `geom_qq_line()`

Group 2: Continuous y and Categorical x data

`geom_bar()`, `geom_boxplot()`, `geom_violin()`

Group 3: Data that form distributions

`geom_histogram()`, `geom_density()`, `geom_dotplot()`

Group 4: Data on maps

`map_data()`, `geom_polygon()`, `coord_map()`

Group 5: Data in matrices

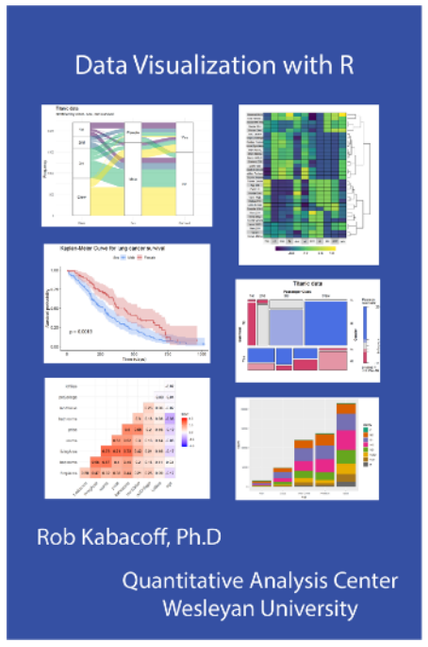
`geom_raster()`, `geom_tile()`, `geom_contour()`

Group 6: “Other”

Pick one from https://exts.ggplot2.tidyverse.org/gallery/

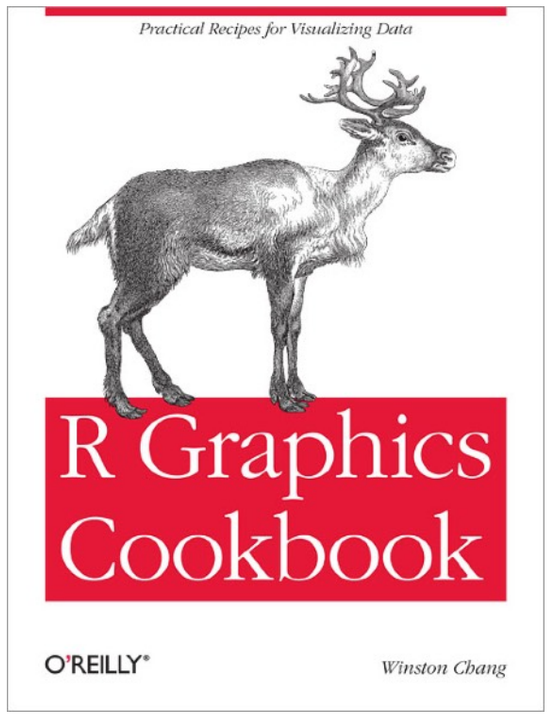
Excellent Resources for ggplot2

Tidyverse Reference Guide – https://ggplot2.tidyverse.org/reference/



Data Visualization with R – https://rkabacoff.github.io/datavis/

The R Graphics Cookbook – https://r-graphics.org/



Additional Resources

https://www.stat.auckland.ac.nz/~ihaka/787/lectures-trellis.pdf –
The Trellis system in lattice (PDF lecture slides)

http://www.cookbook-r.com/Manipulating_data/Converting_data_between_wide_and_long_format/ –
Converting between long and wide format with reshape2, tidyr, and base R

Action Items

1. **Read Assigned Chang Chapter for next time**

2. **Prepare SK 2.1 in your group**