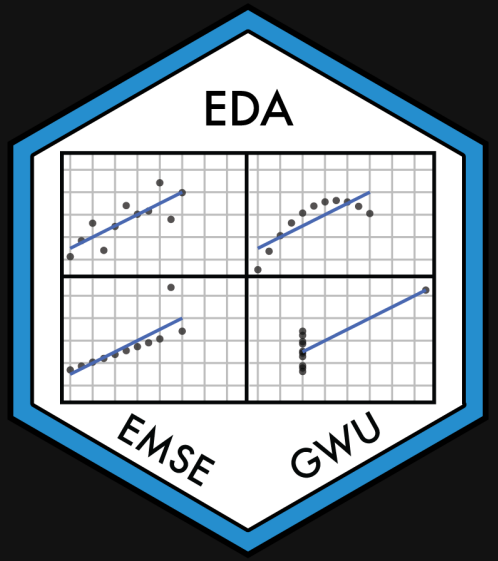


Week 7: *Comparisons*

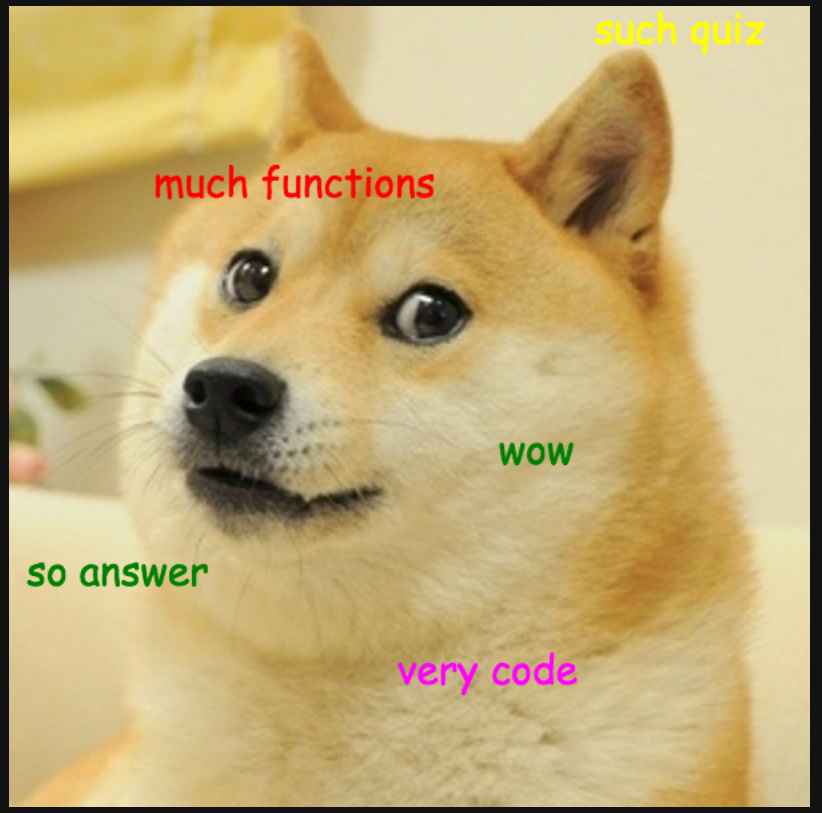
EMSE 4575: Exploratory Data Analysis

John Paul Helveston

February 24, 2021

Quiz 2

Link is on the schedule



10:00

Tip of the week

Shortcut keys

1) Quick shortcuts

Insert a `<-` operator:

- **Windows**: `ALT` + `-`
- **Mac**: `OPTION` + `-`

Insert a `%>%` operator:

- **Windows**: `CTRL` + `SHIFT` + `M`
- **Mac**: `COMMAND` + `SHIFT` + `M`

2) Edit multiple lines of code at once

1. Press and hold `ALT` (Windows) or `OPTION` (Mac)
2. Select multiple lines of code

https://twitter.com/i/status/995394452821721088

"At the heart of quantitative reasoning is a single question: Compared to what?"

-- Edward Tufte

Today's data

```
college_all_ages <- read_csv(here('data', 'college_all_ages.csv'))
gapminder        <- read_csv(here('data', 'gapminder.csv'))
marathon         <- read_csv(here('data', 'marathon.csv'))
milk_production  <- read_csv(here('data', 'milk_production.csv'))
internet_regions <- read_csv(here('data', 'internet_users_region.csv'))
```

New packages

```
install.packages("ggrepel")
install.packages("ggridges")
```

Week 7: *Comparisons*

1. Comparing to a reference
2. Comparing variables

BREAK

3. Comparing distributions

Week 7: *Comparisons*

1. Comparing to a reference
2. Comparing variables

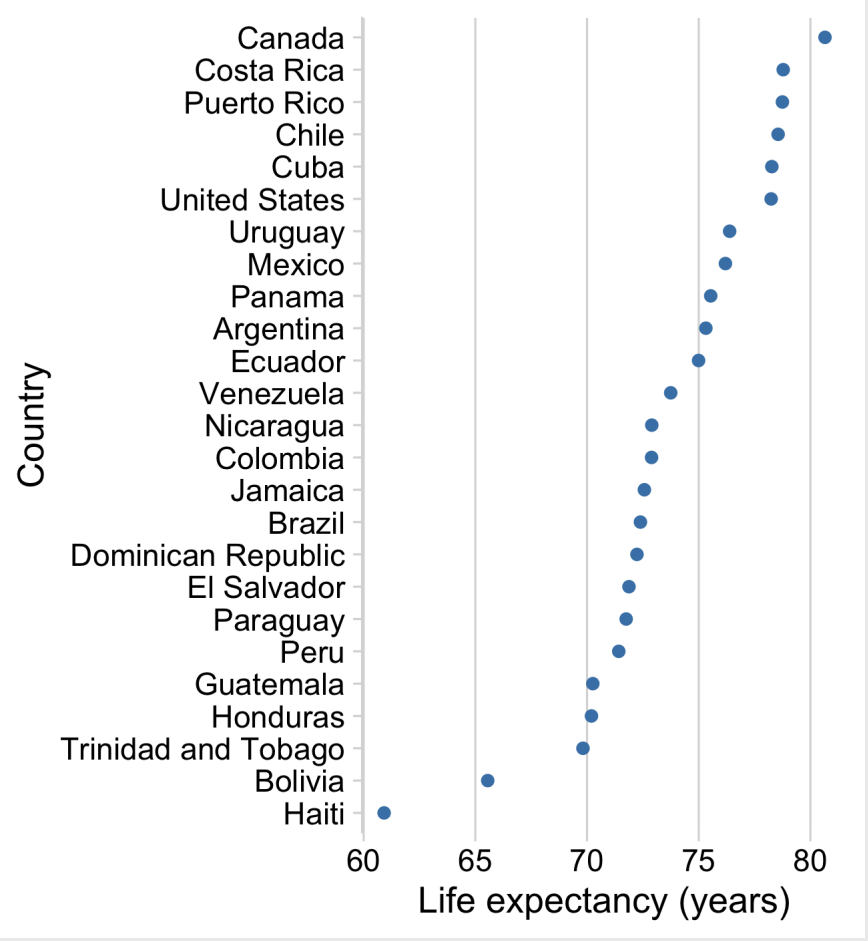
BREAK

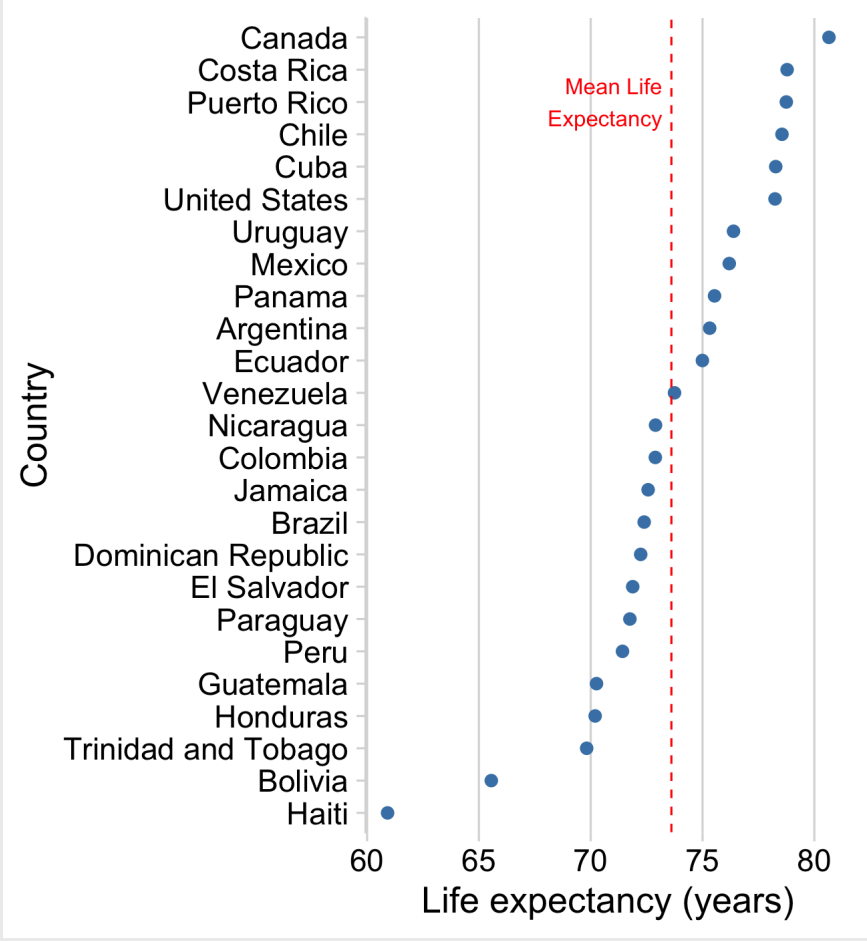
3. Comparing distributions

For this section, we'll be using this data frame:

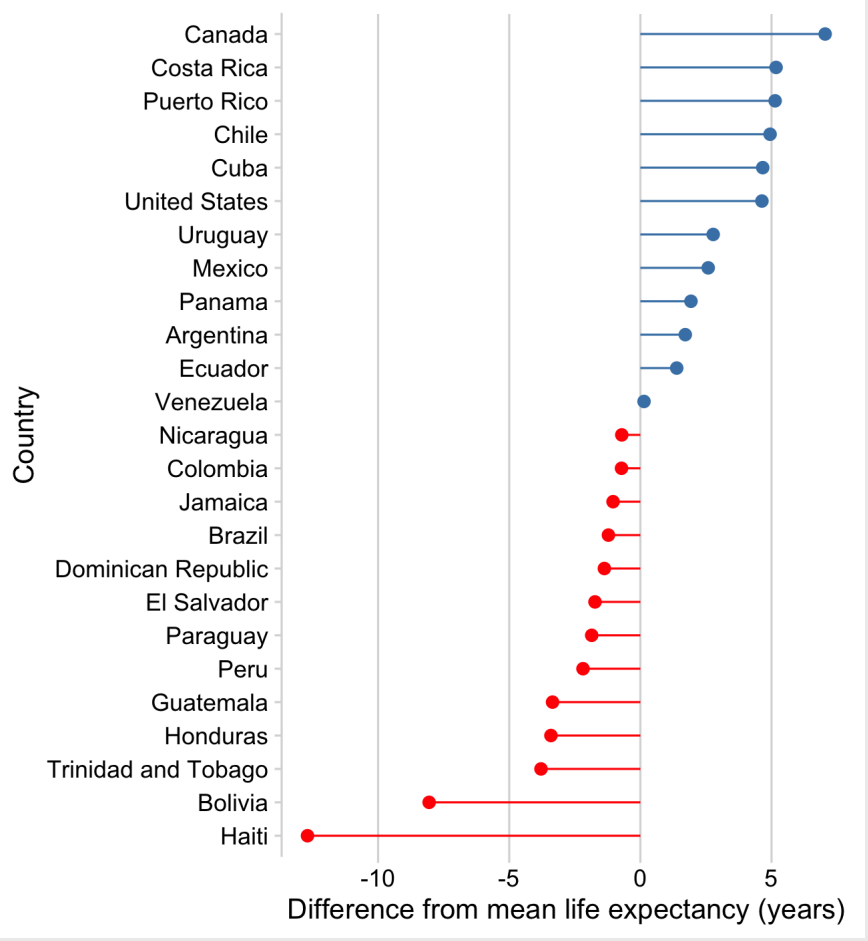
```
gapminder_americas <- gapminder %>%
  filter(continent == "Americas", year == 2007) %>%
  mutate(country = fct_reorder(country, lifeExp))
```

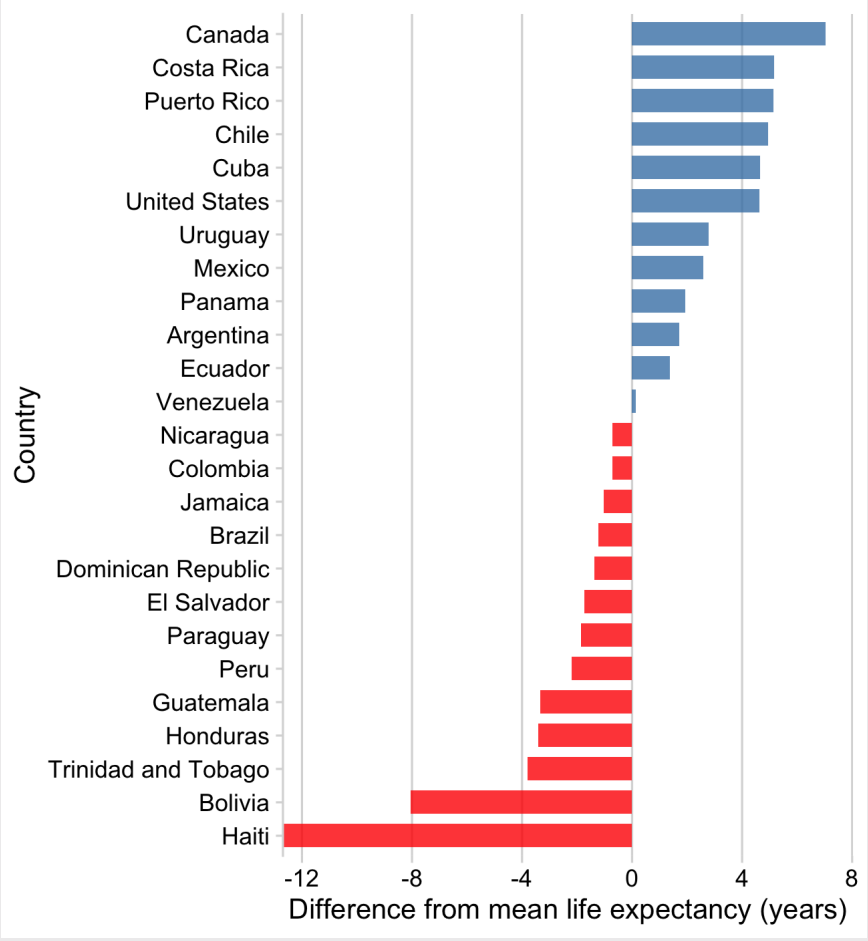
Use reference lines to add context to chart





Or make zero the reference line



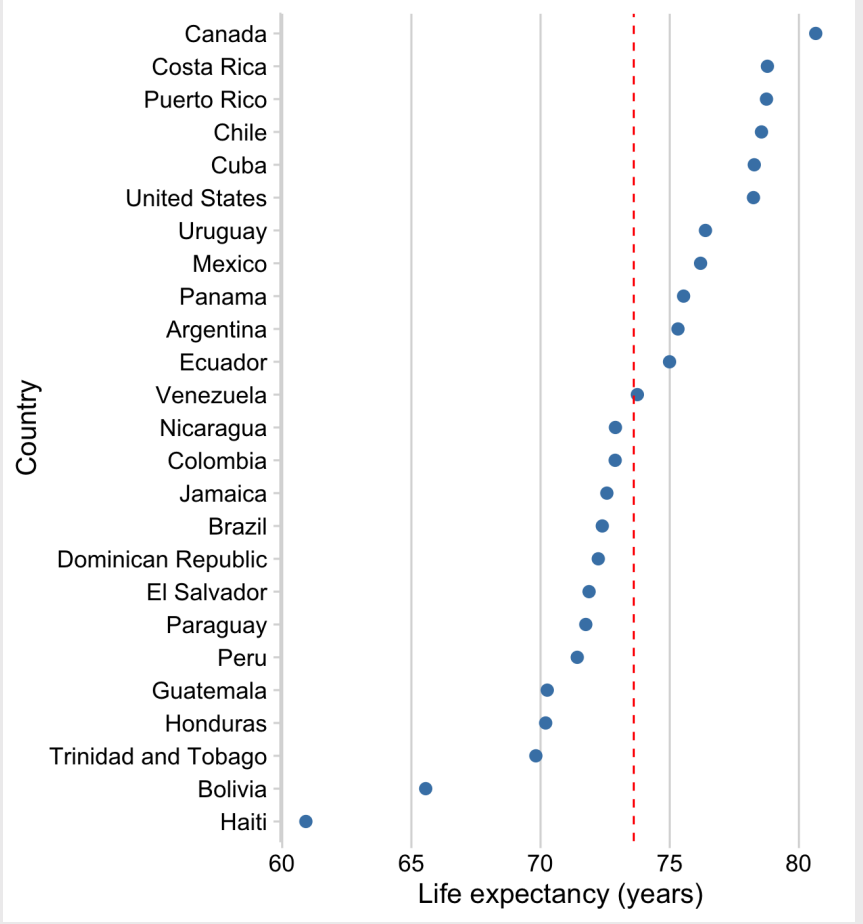


How to add a reference line

Add horizontal line with `geom_hline()`

Add vertical line with `geom_vline()`

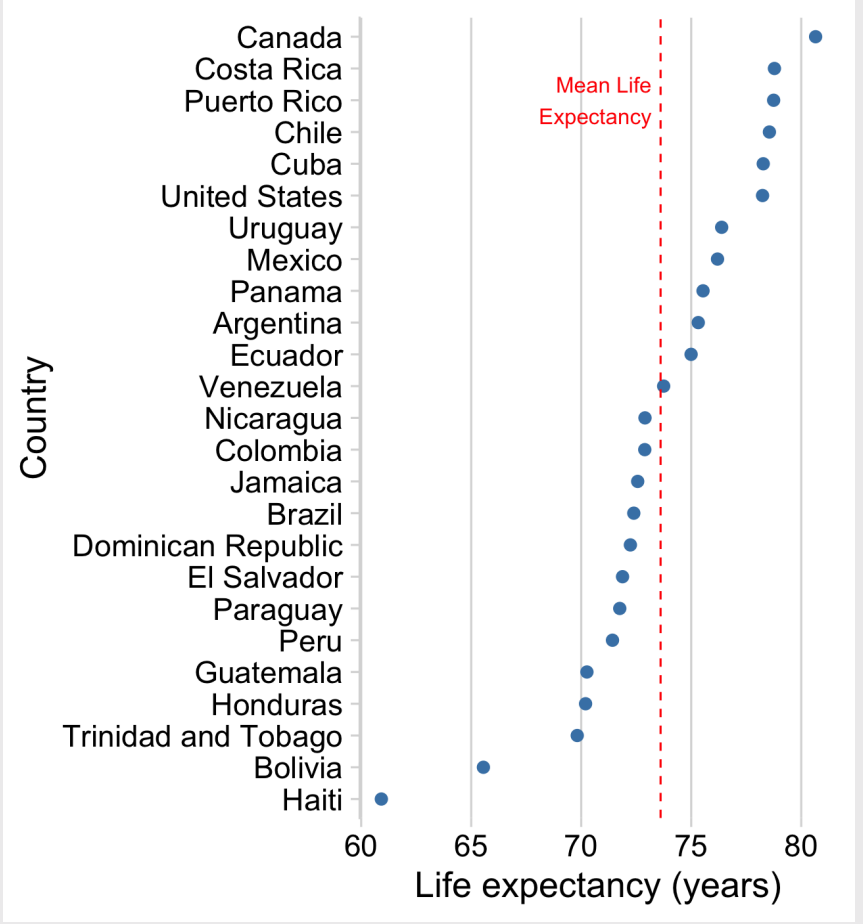
```
ggplot(gapminder_americas) +
  geom_point(
    aes(x = lifeExp, y = country),
    color = 'steelblue', size = 2.5) +
  geom_vline(
      xintercept = mean(gapminder_americas$lifeExp),
      color = 'red', linetype = 'dashed') +
  theme_minimal_vgrid() +
  labs(x = 'Life expectancy (years)',
       y = 'Country')
```



How to add a reference line

Add text with `annotate()`

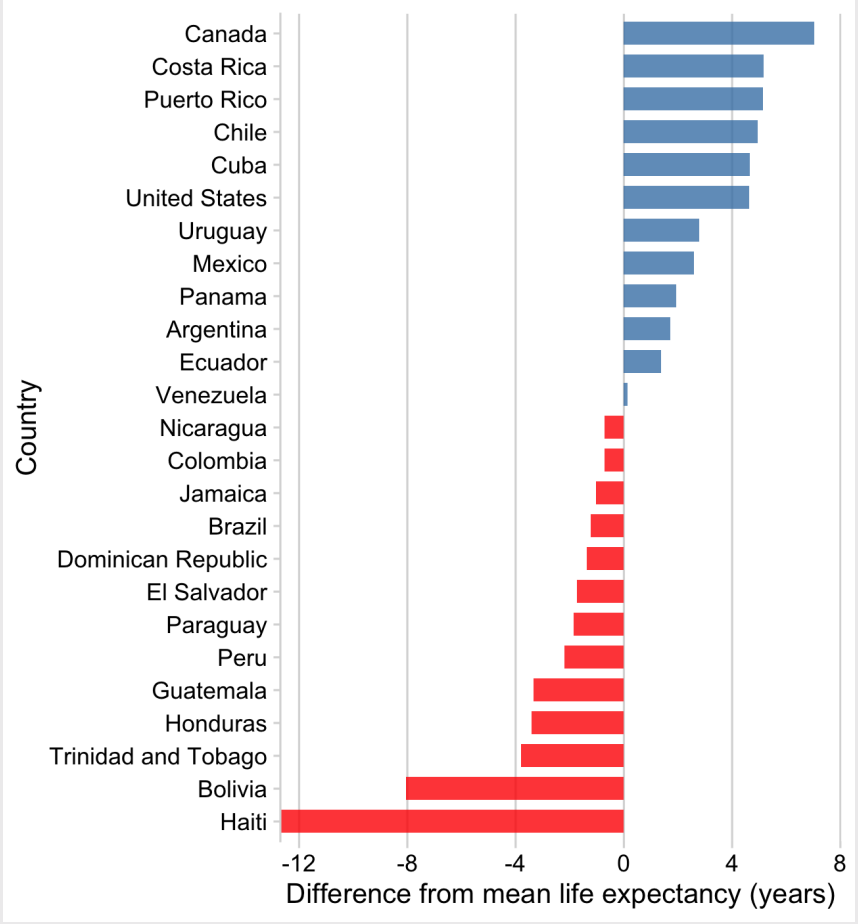
```
ggplot(gapminder_americas) +
  geom_point(
    aes(x = lifeExp, y = country),
    color = 'steelblue', size = 2.5) +
  geom_vline(
      xintercept = mean(gapminder_americas$lifeExp),
      color = 'red', linetype = 'dashed') +
  annotate(
    'text', x = 73.2, y = 'Puerto Rico',
    color = 'red', hjust = 1,
    label = 'Mean\nLife\nExpectancy') +
  theme_minimal_vgrid() +
  labs(x = 'Life expectancy (years)',
       y = 'Country')
```



How to make zero the reference point

```
gapminder_diverging <- gapminder_americas %>%
    mutate(
        # Subtract the mean
        lifeExp = lifeExp - mean(lifeExp),
        # Define the fill color
        color = ifelse(lifeExp > 0, 'Above', 'Below'))
```

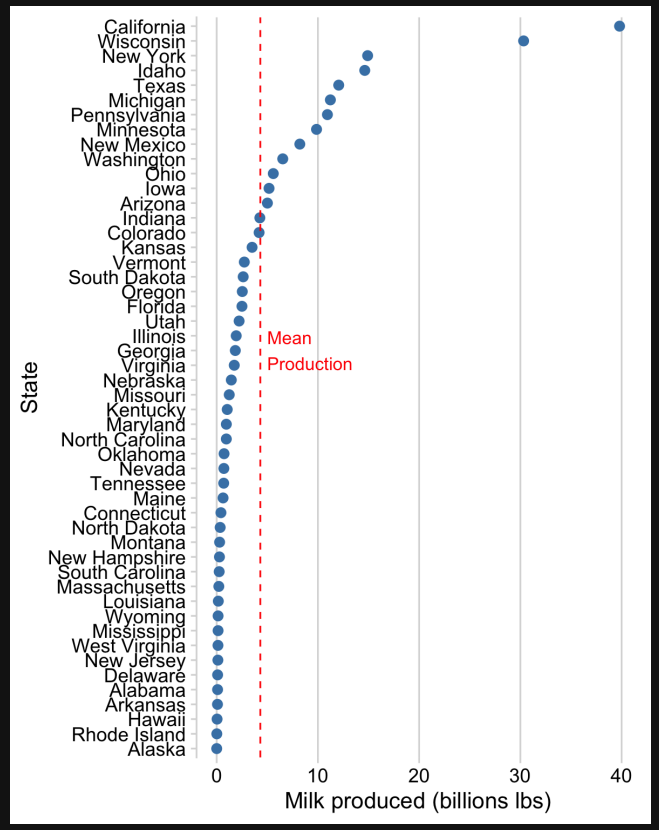
```
ggplot(gapminder_diverging) +
  geom_col(
    aes(x = lifeExp, y = country, fill = color),
    width = 0.7, alpha = 0.8) +
  scale_fill_manual(
    values = c('steelblue', 'red')) +
  theme_minimal_vgrid() +
  theme(legend.position = 'none') +
  labs(
    x = 'Country',
    y = 'Difference from mean life expectancy (years)')
```

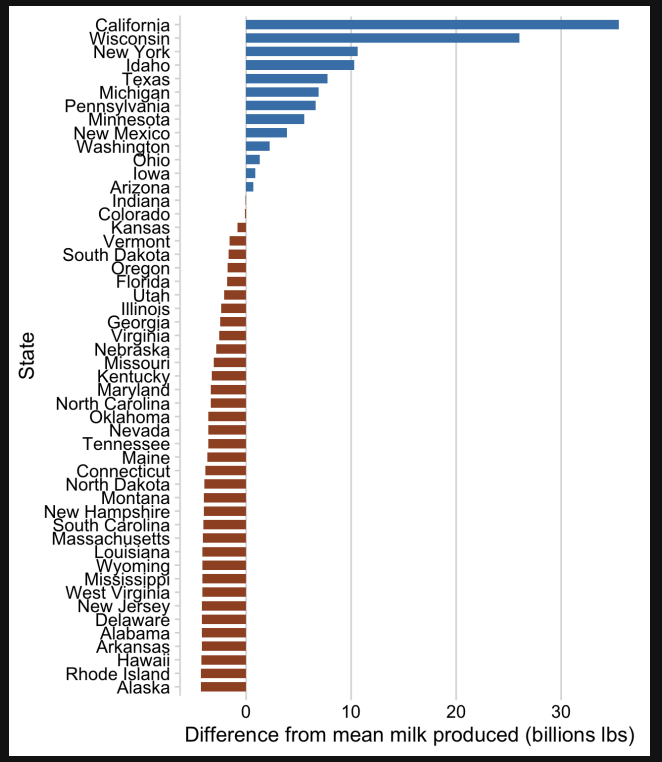


Your turn - comparing to a reference

20:00

Use the `milk_production.csv` data to create the following charts showing differences from the mean state milk production in 2017.





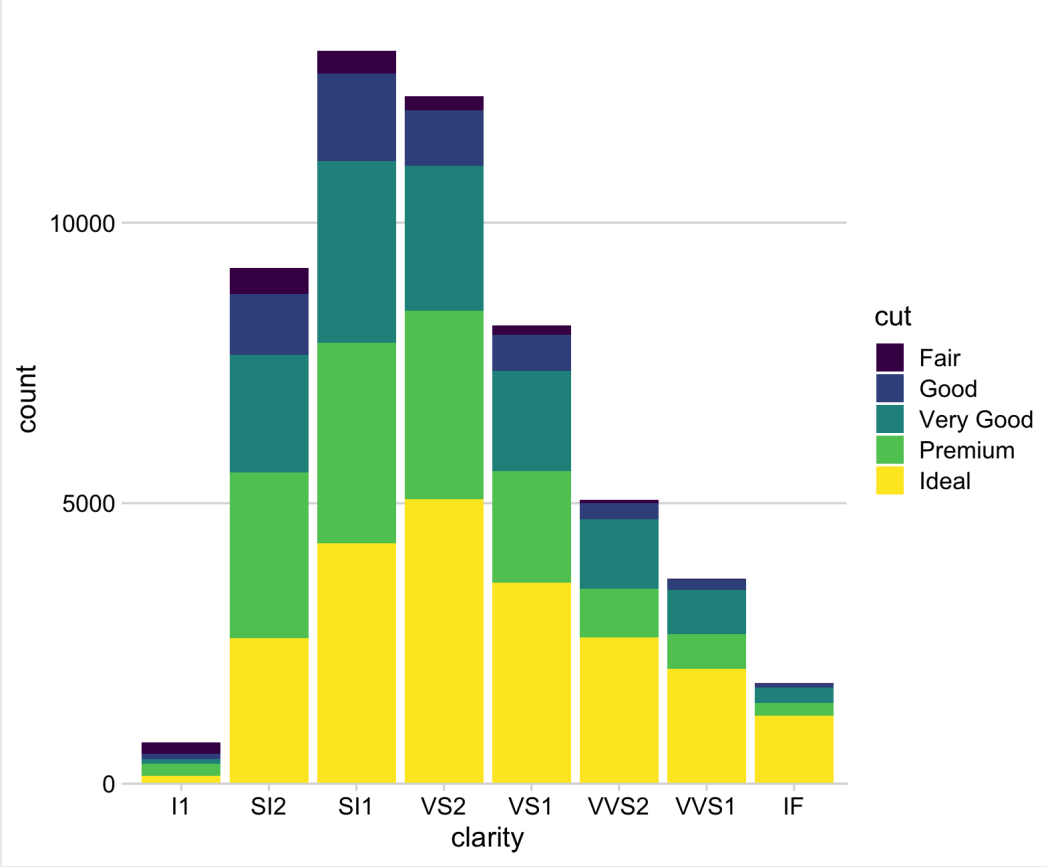
Week 7: *Comparisons*

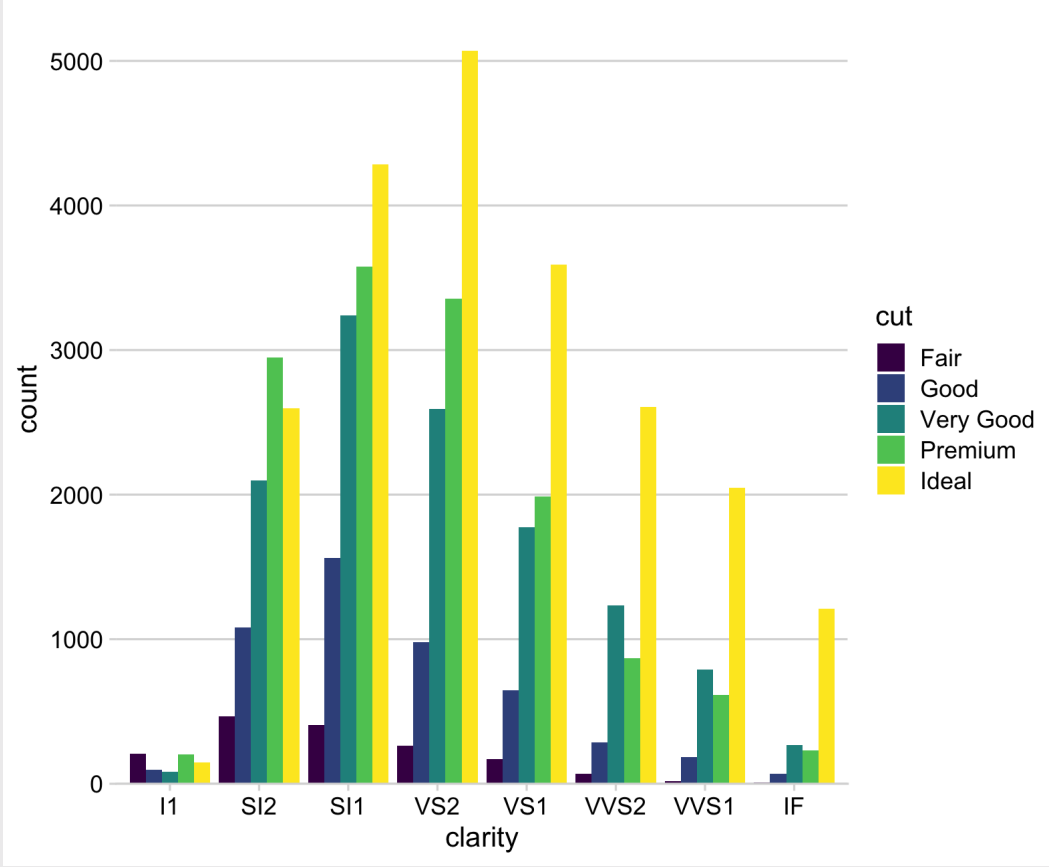
1. Comparing to a reference
2. Comparing variables

BREAK

3. Comparing distributions

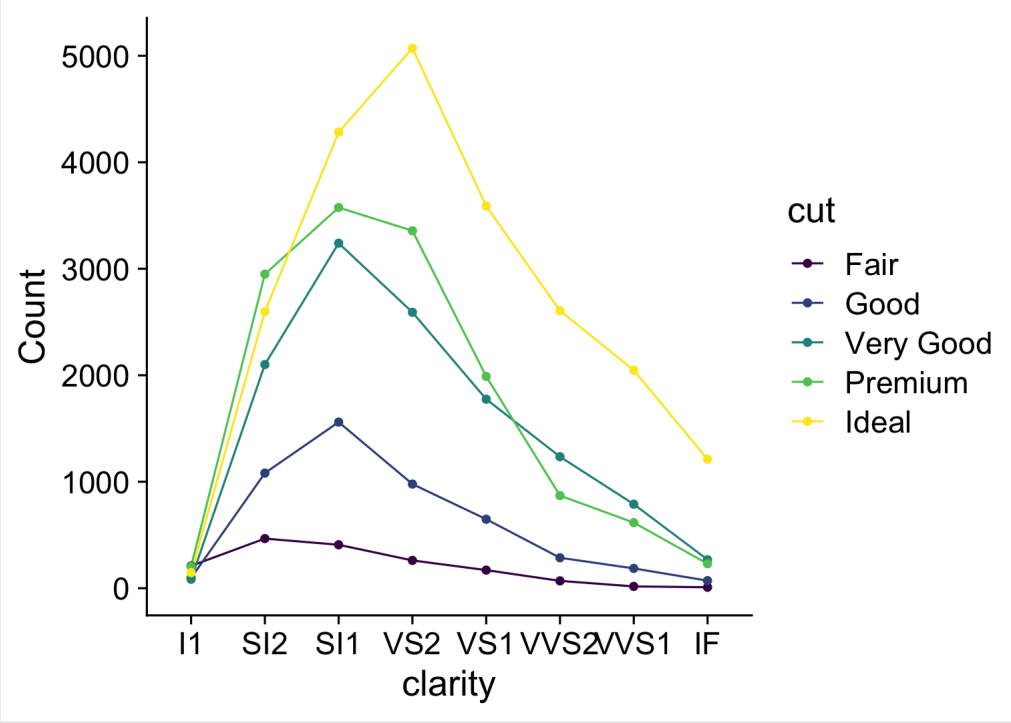
Neither of these charts are great





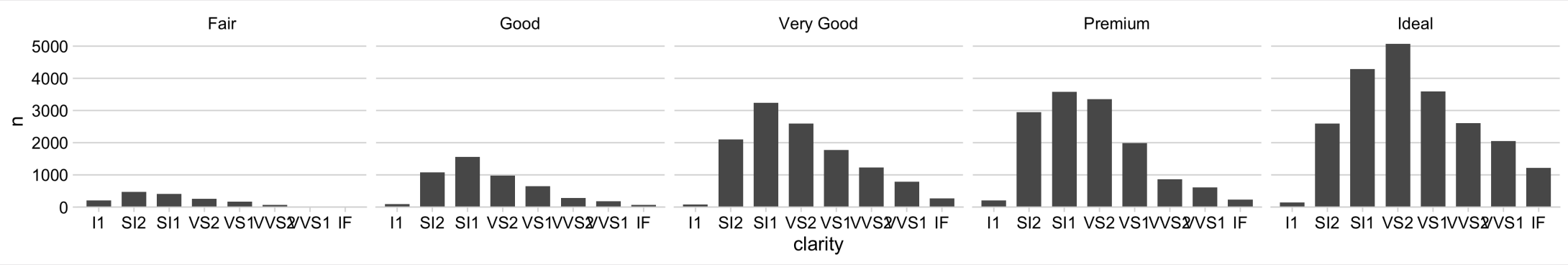
"Parallel Coordinates" plots work well

```
diamonds %>%
  count(clarity, cut) %>%
  ggplot(
    aes(x = clarity, y = n,
        color = cut, group = cut)) +
  geom_line() +
  geom_point() +
  scale_y_continuous(limits = c(0, 5100)) +
  theme_half_open(font_size = 18) +
  labs(y = "Count")
```



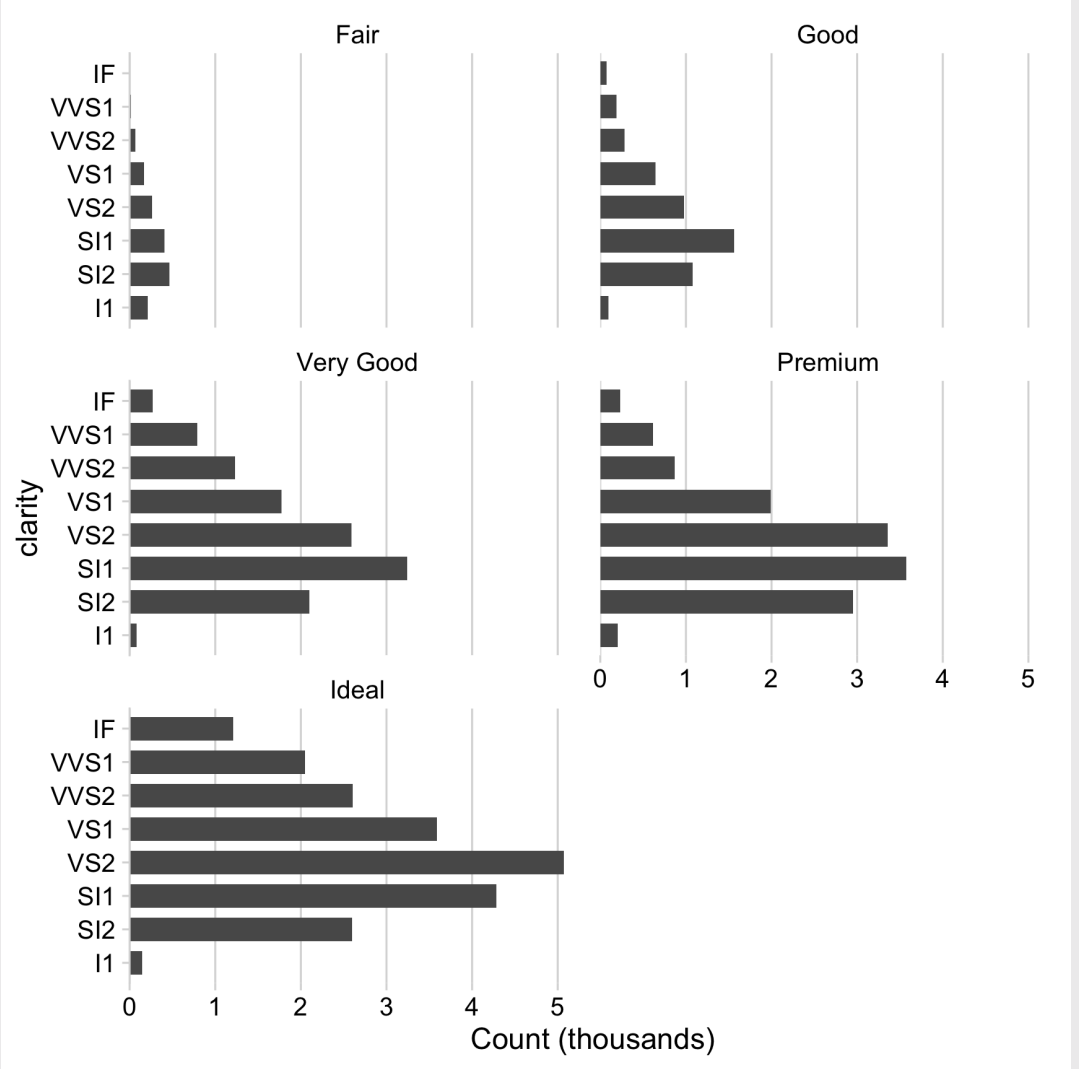
Consider facets for **comparing across categories**

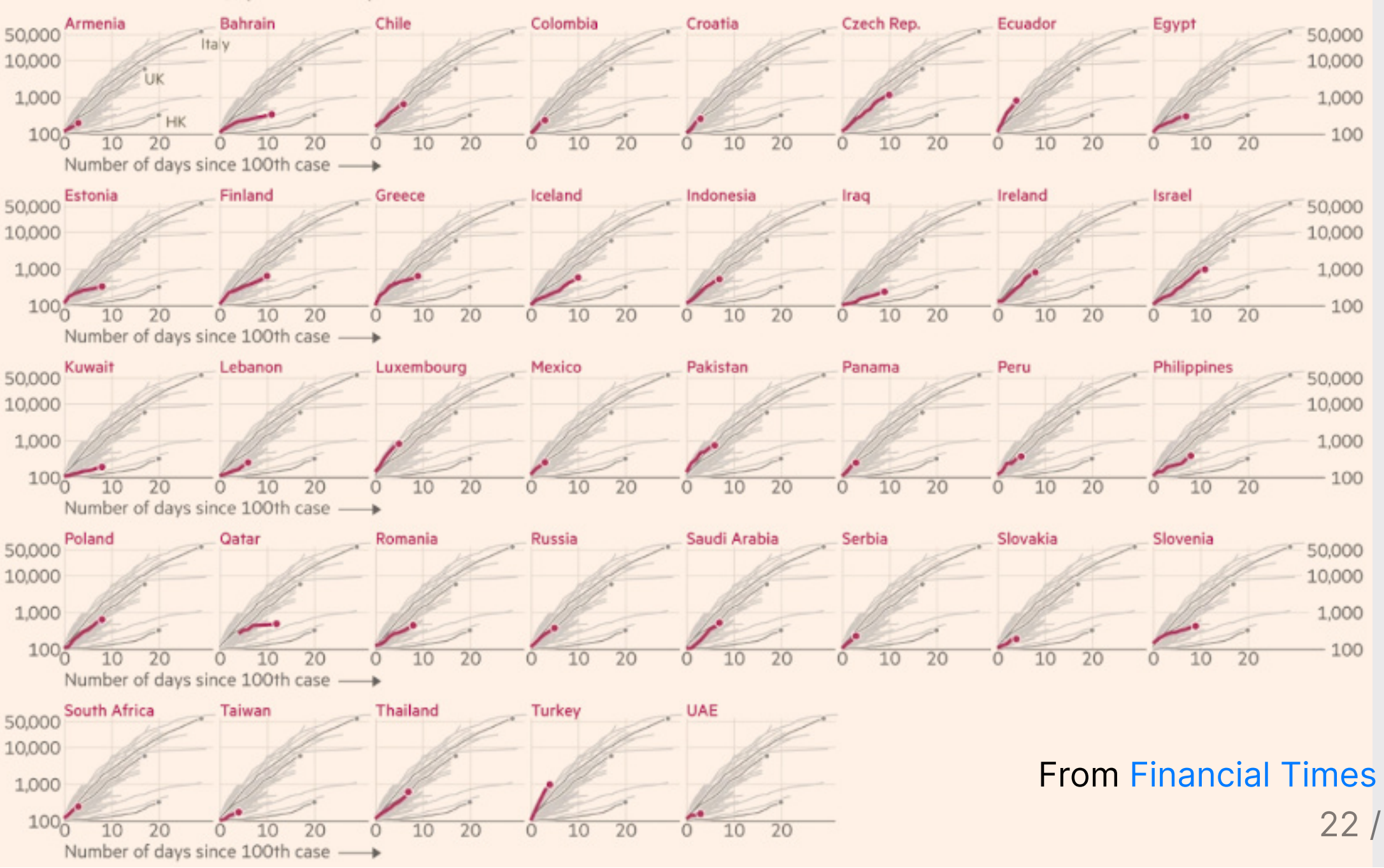
```
diamonds %>%
  count(clarity, cut) %>%
  ggplot() +
  geom_col(aes(x = clarity, y = n),
           width = 0.7) +
  facet_wrap(vars(cut), nrow = 1) +
  scale_y_continuous(
    expand = expansion(mult = c(0, 0.05))) +
  theme_minimal_hgrid(font_size = 16)
```



Consider facets for **comparing across categories**

```
diamonds %>%
  count(clarity, cut) %>%
  mutate(n = n / 1000) %>%
  ggplot() +
  geom_col(aes(x = clarity, y = n),
           width = 0.7) +
  facet_wrap(vars(cut), ncol = 2) +
  coord_flip() +
  scale_y_continuous(
    expand = expansion(mult = c(0, 0.05))) +
  theme_minimal_vgrid(font_size = 16) +
  labs(y = "Count (thousands)")
```

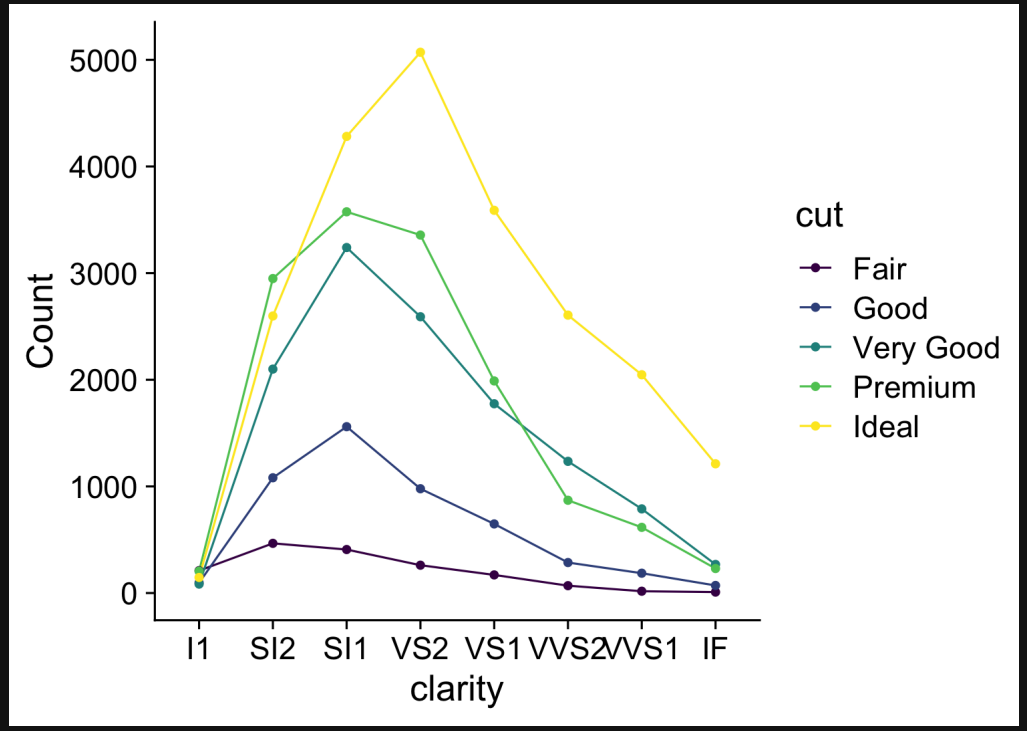




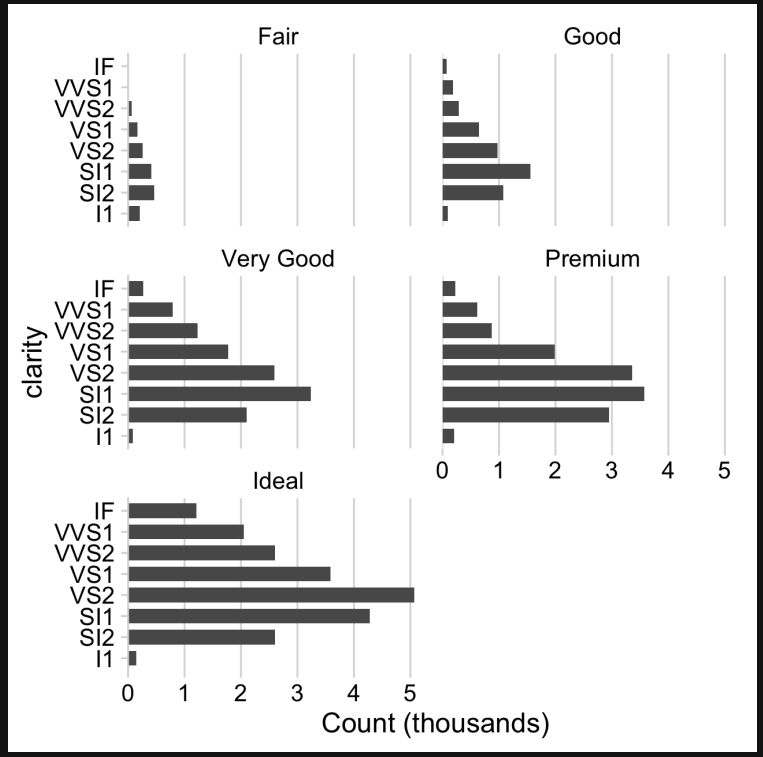
From Financial Times

When comparing across multiple categories, consider:

Parallel coordinates charts



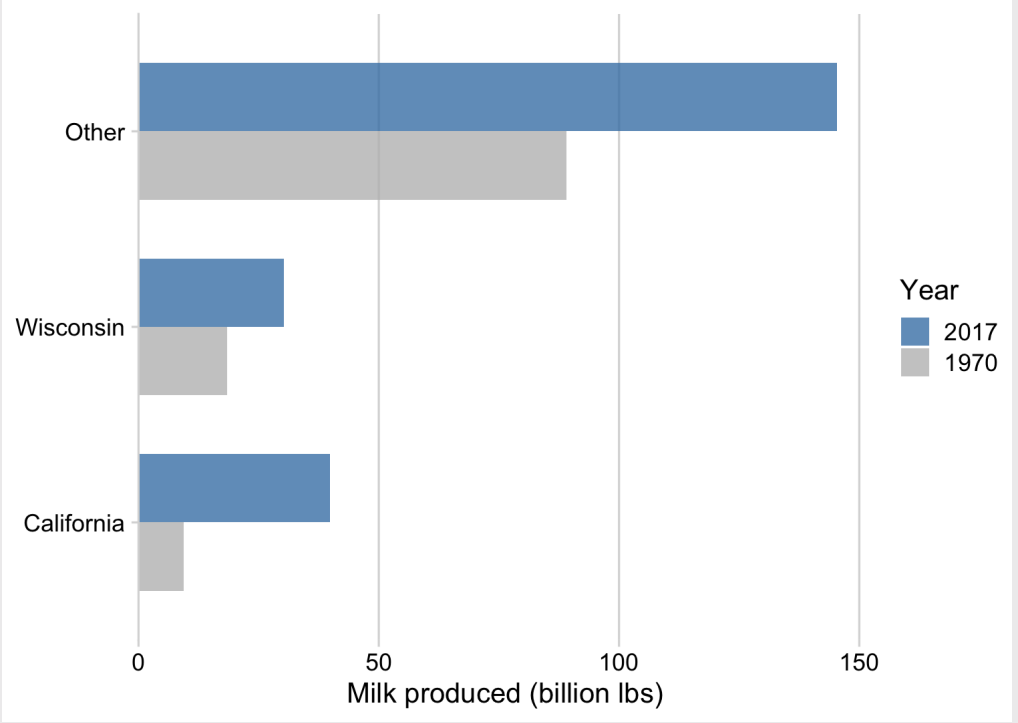
Faceting



When comparing **only 2** things, dodged bars are a good starting point

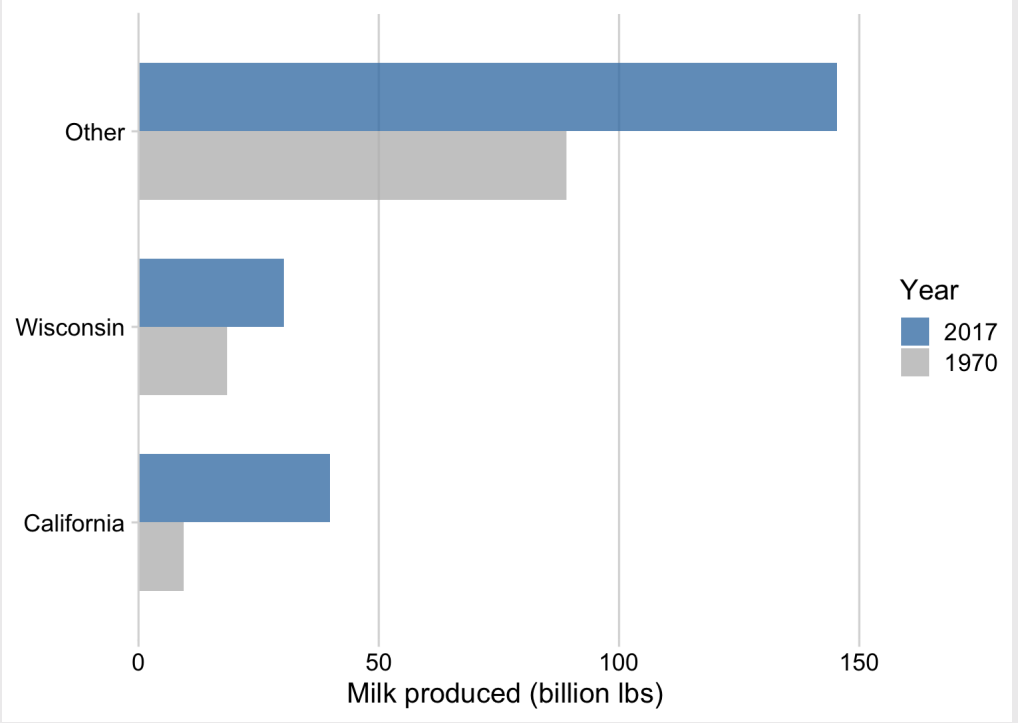
```
milk_compare <- milk_production %>%
  filter(year %in% c(1970, 2017)) %>%
  mutate(state = fct_other(state,
    keep = c('California', 'Wisconsin'))) %>%
  group_by(year, state) %>%
  summarise(
    milk_produced = sum(milk_produced) / 10^9)
```

```
#> # A tibble: 6 x 3
#> # Groups:   year [2]
#>    year state      milk_produced
#>   <dbl> <fct>              <dbl>
#> 1  1970 California          9.46
#> 2  1970 Wisconsin          18.4
#> 3  1970 Other              89.1
#> 4  2017 California         39.8
#> 5  2017 Wisconsin          30.3
#> 6  2017 Other             145.
```

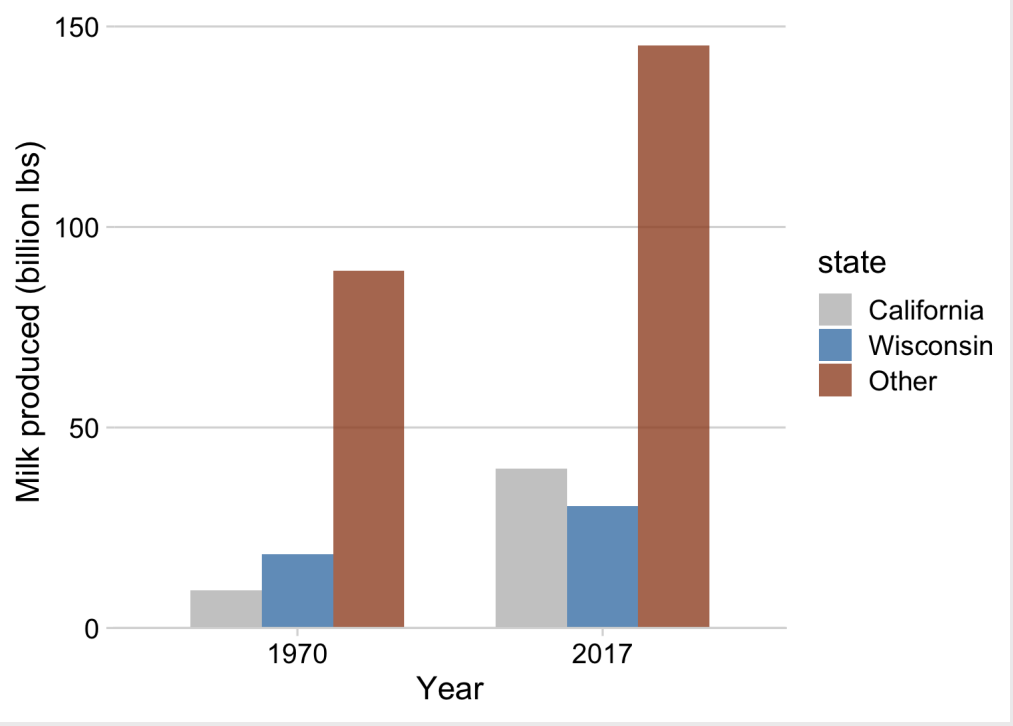


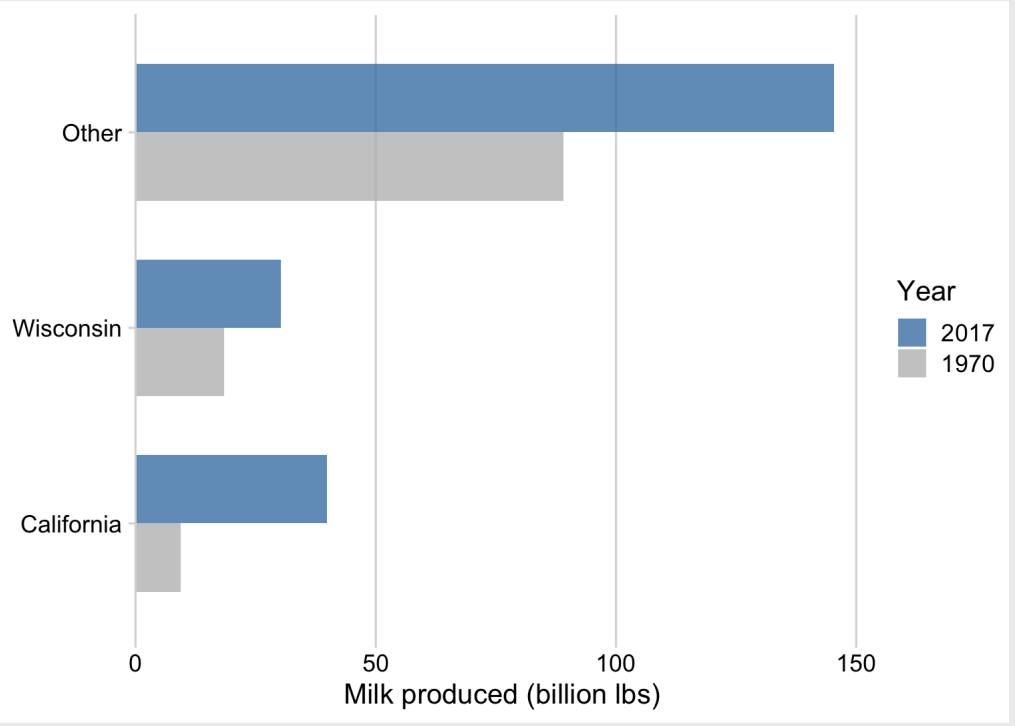
When comparing **only 2** things, dodged bars are a good starting point

```
ggplot(milk_compare) +
  geom_col(
    aes(x = milk_produced, y = state,
        fill = as.factor(year)),
    width = 0.7, alpha = 0.8,
    position = 'dodge') +
  scale_fill_manual(
      values = c('grey', 'steelblue'),
      guide  = guide_legend(reverse = TRUE)) +
  scale_x_continuous(
    expand = expansion(mult = c(0, 0.05))) +
  theme_minimal_vgrid() +
  labs(
    x = 'Milk produced (billion lbs)',
    y = NULL,
    fill = 'Year')
```

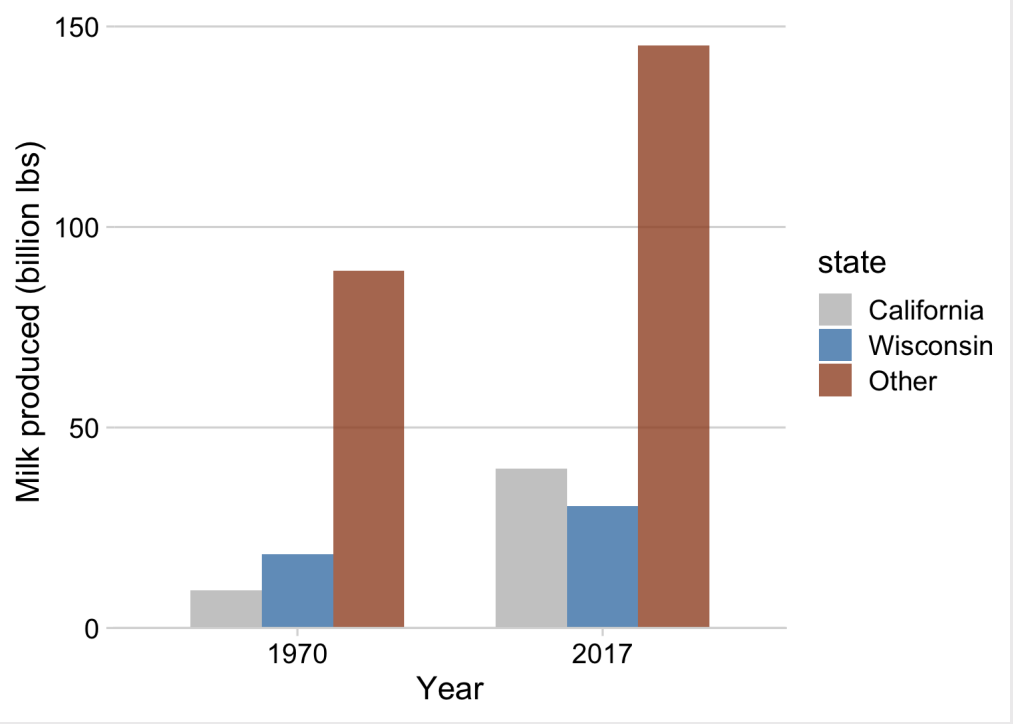


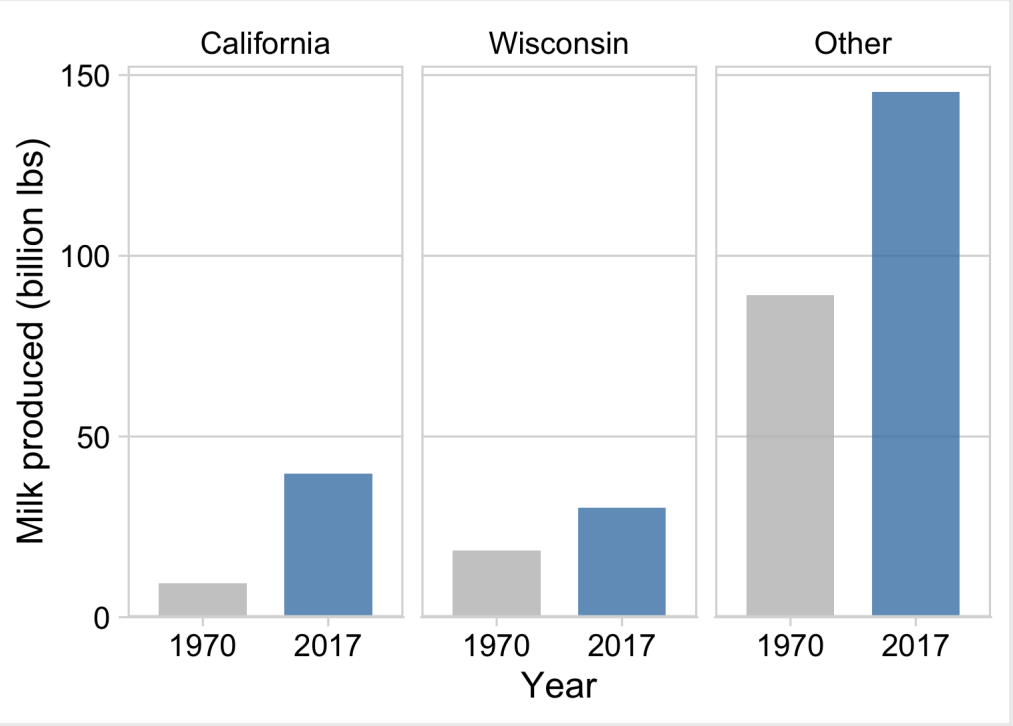
Avoid putting >2 categories in legend (if possible)



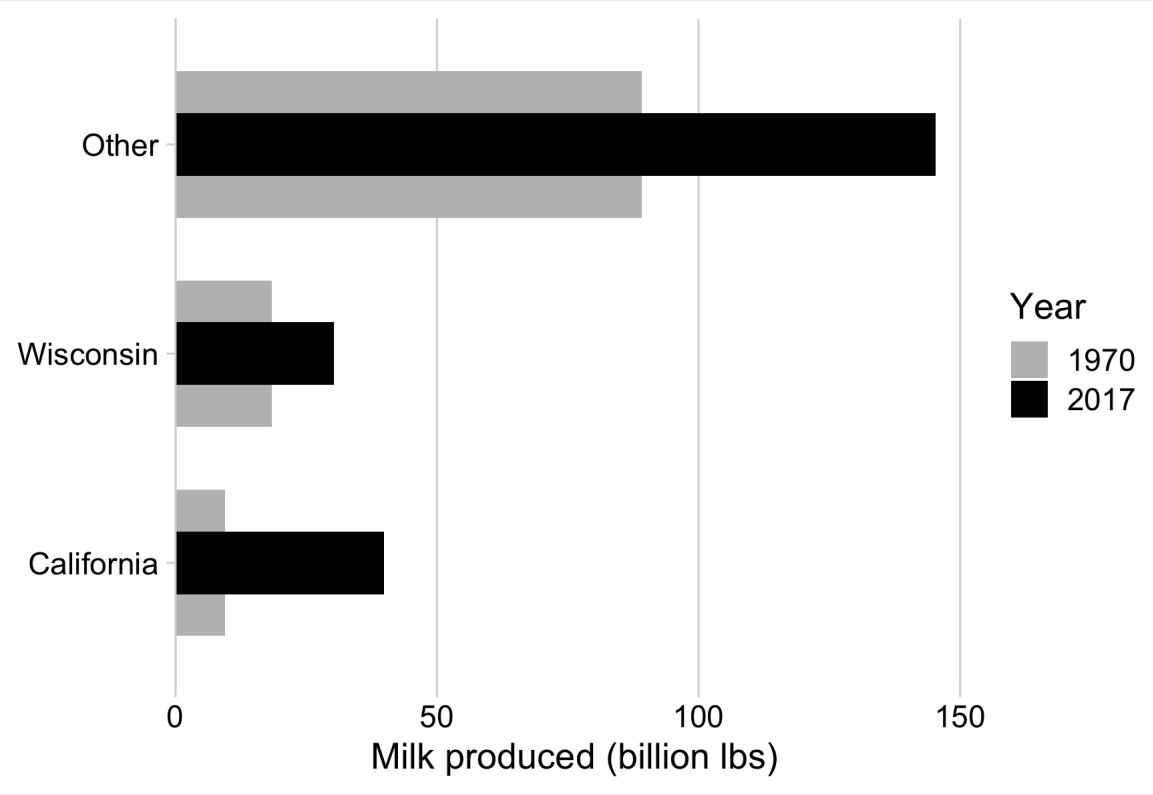


Or use facets to get rid of the legend!



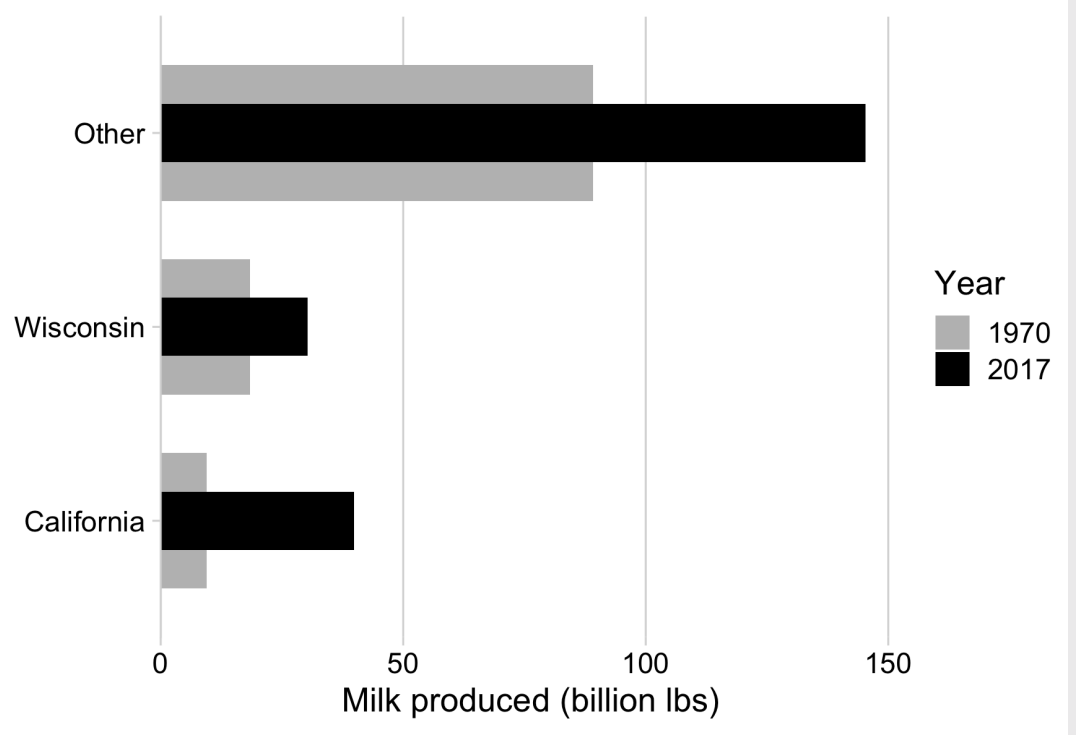


"Bullet" charts are also effective for comparing **2** things



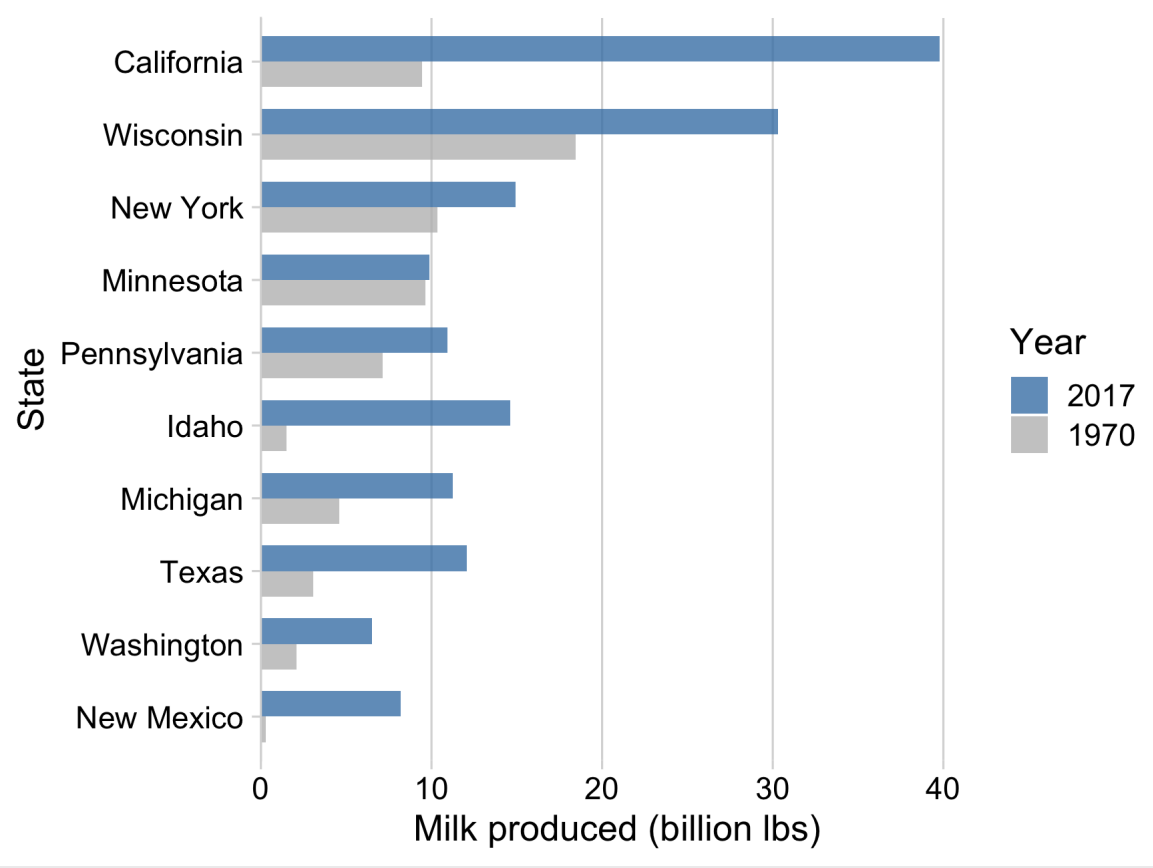
How to make a "bullet" chart

```
milk_compare %>%
  spread(year, milk_produced) %>%
  ggplot() +
  geom_col(
    aes(x = `1970`, y = state, fill = '1970'),
        width = 0.7) +
  geom_col(
    aes(x = `2017`, y = state, fill = '2017'),
        width = 0.3) +
  scale_fill_manual(
    values = c('grey', 'black')) +
  scale_x_continuous(
      expand = expansion(mult = c(0, 0.05))) +
  theme_minimal_vgrid(font_size = 18) +
  labs(
    x = 'Milk produced (billion lbs)',
    y = NULL,
    fill = "Year")
```



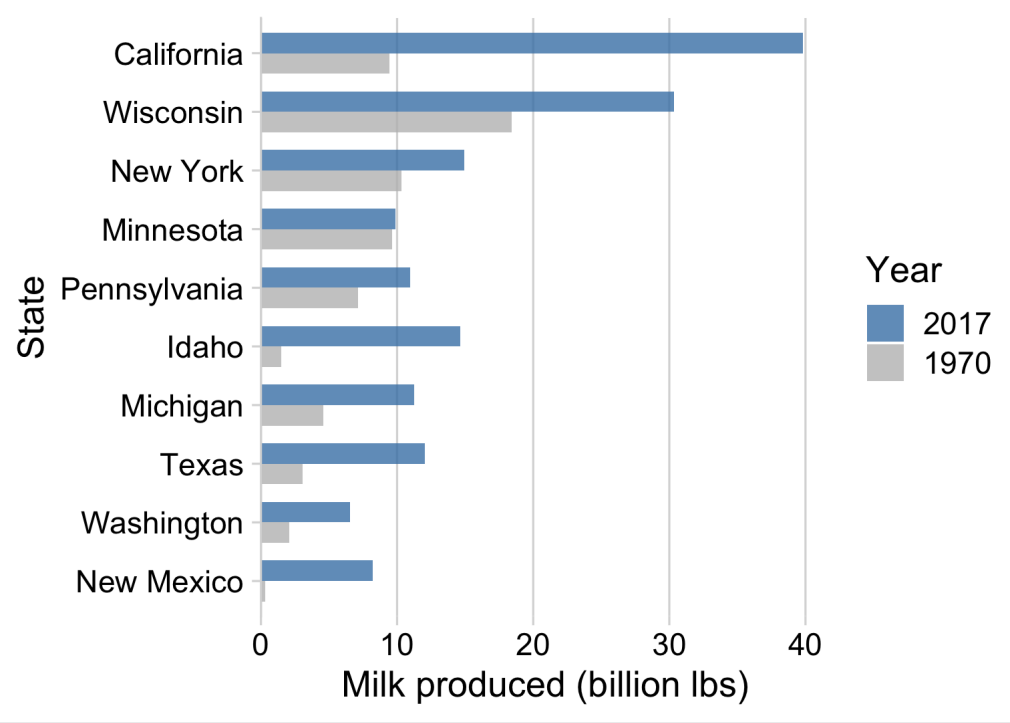
With **more than 2** things, dodged bars can get confusing

Still comparing 2 time periods, but across **10** categories

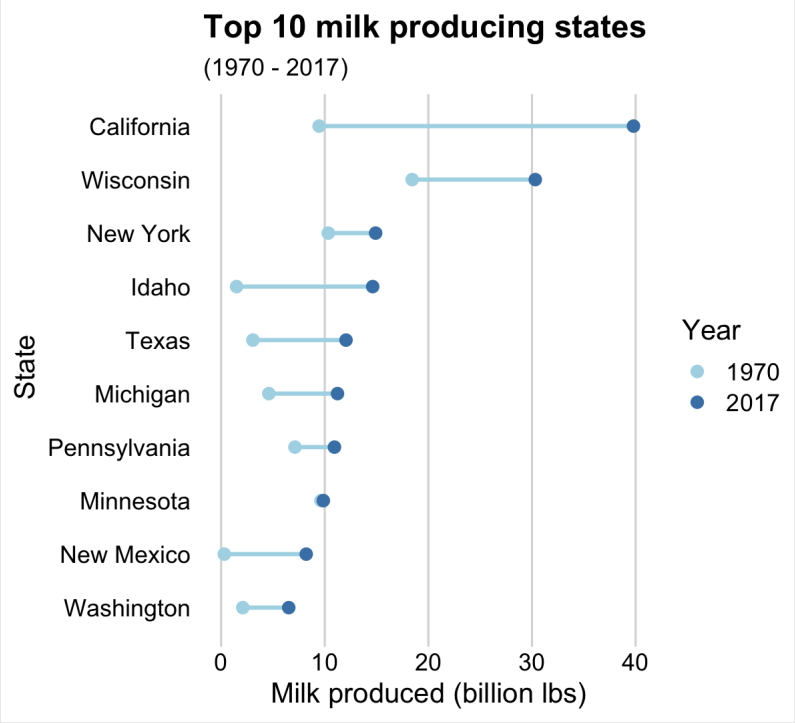


Strategies for comparing 2 things across **more than 2 categories**

Dodged bars 👨‍🦲

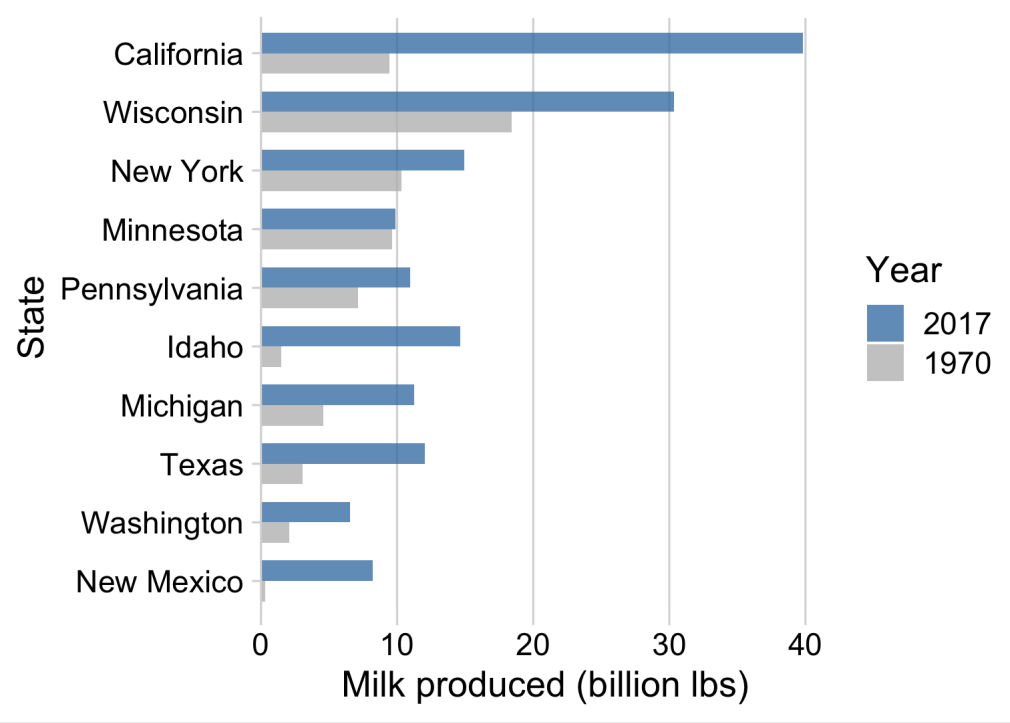


Dumbbell chart

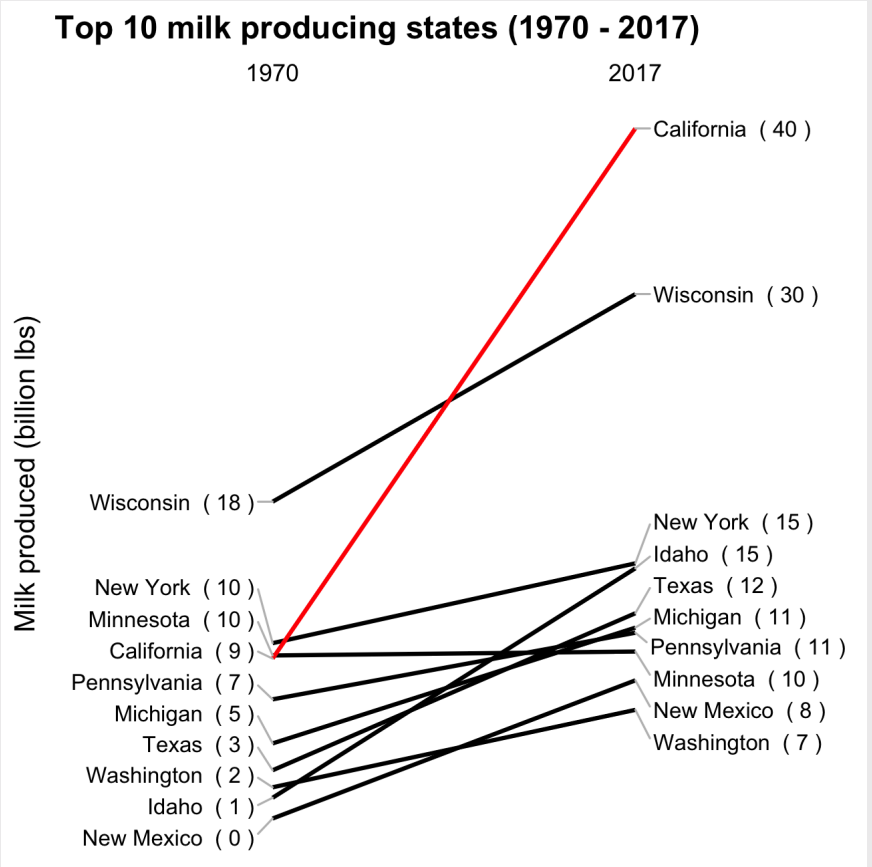


Strategies for comparing 2 things across **more than 2 categories**

Dodged bars 😦

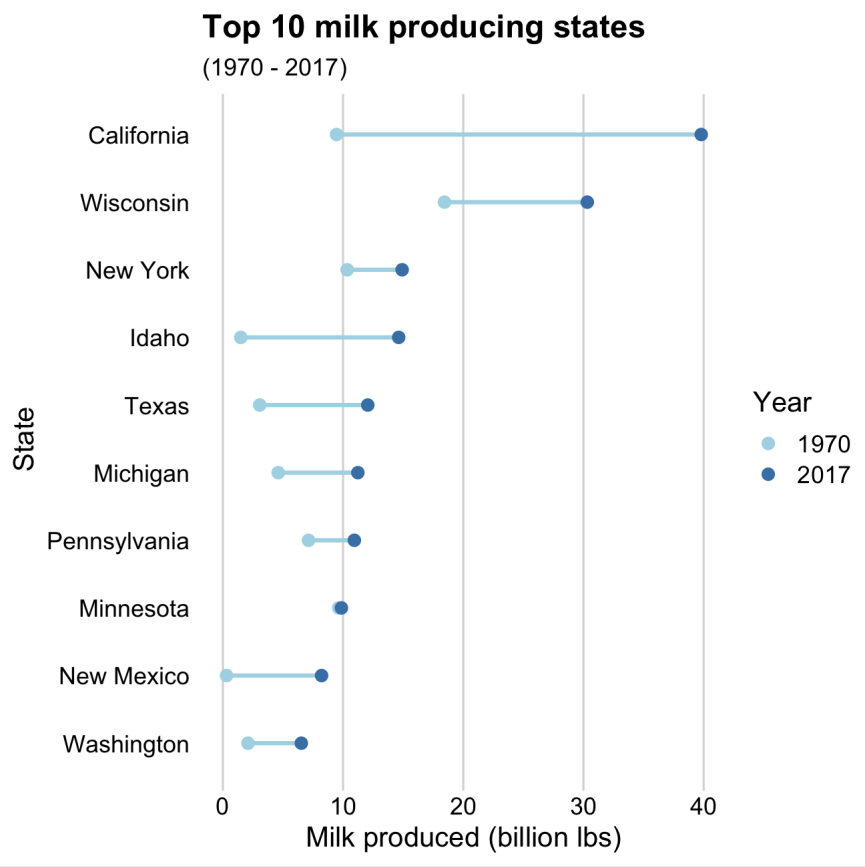


Slope chart



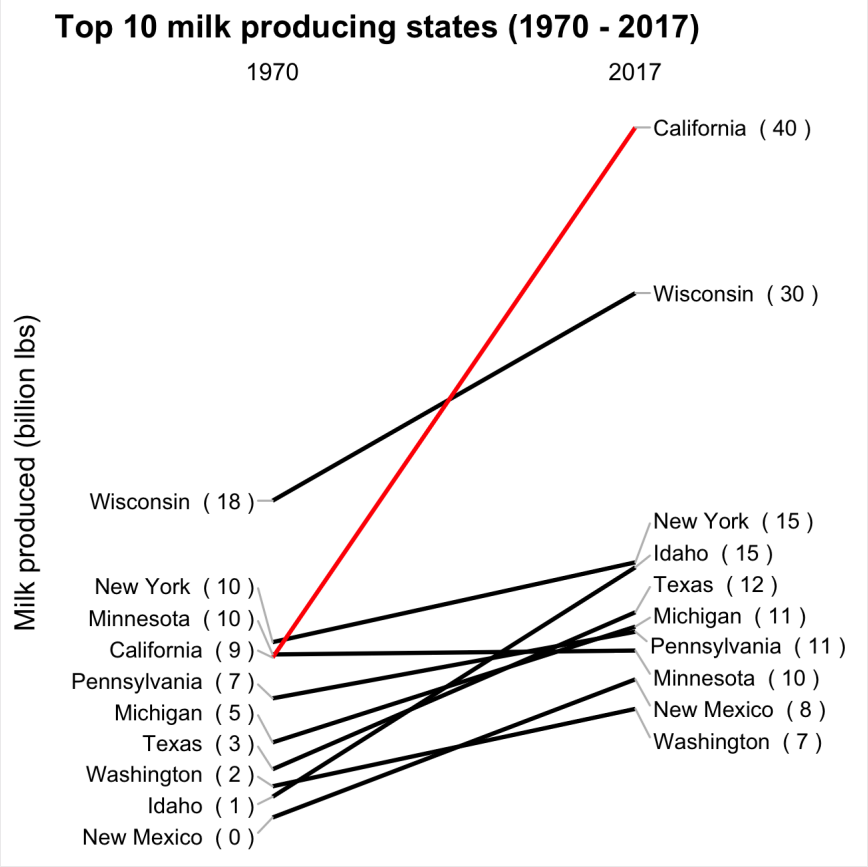
Dumbbell charts highlight:

- Compare **magnitudes** across two periods / groups



Slope charts highlight:

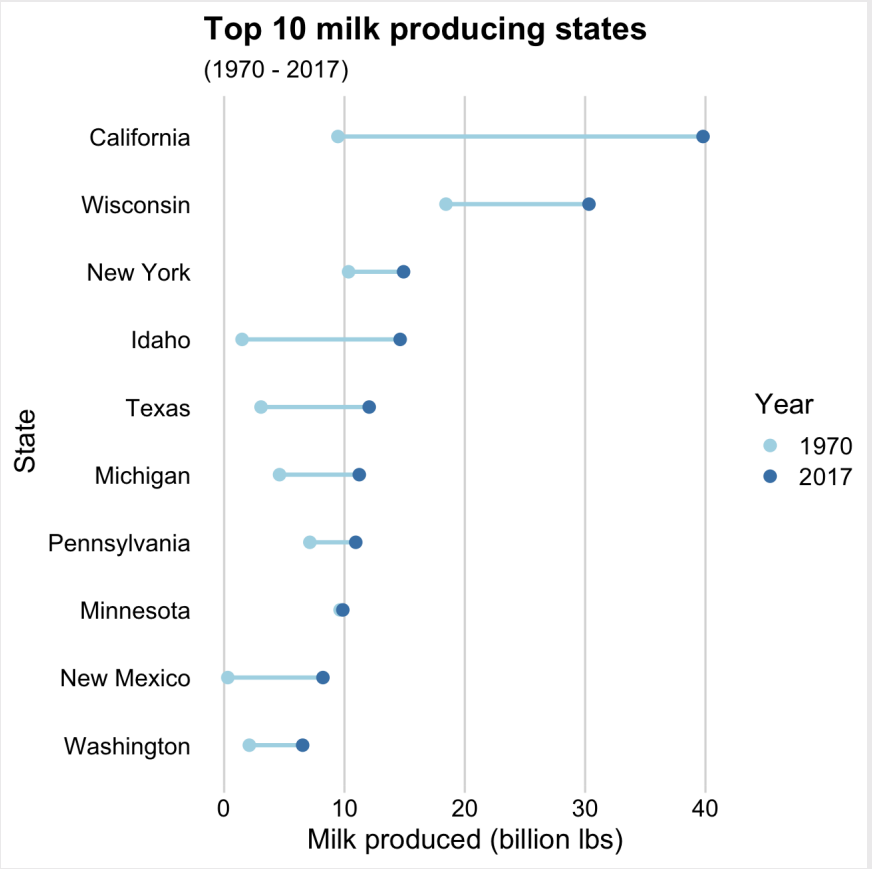
- *Change* in **rankings**
- Highlight individual categories



How to make a **Dumbbell chart**

Create data frame for plotting

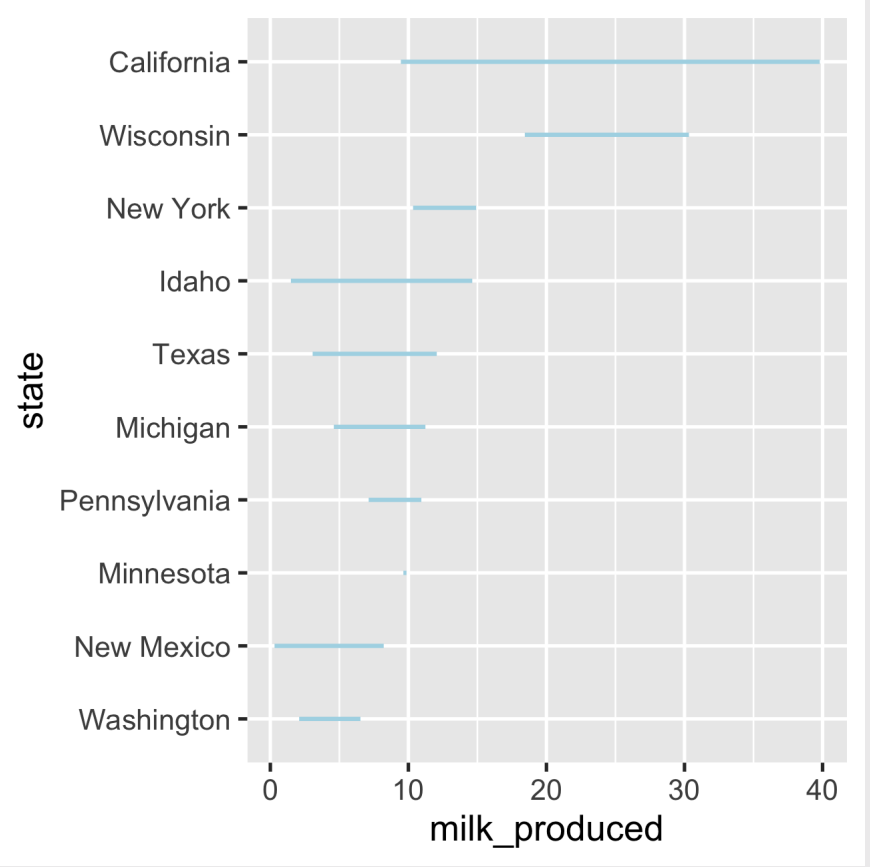
```
top10states <- milk_production %>%
    filter(year == 2017) %>%
    arrange(desc(milk_produced)) %>%
    slice(1:10)

milk_summary_dumbbell <- milk_production %>%
  filter(
    year %in% c(1970, 2017),
    state %in% top10states$state) %>%
  mutate(
    # Reorder state variables
    state = fct_reorder2(state,
      year, desc(milk_produced)),
    # Convert year to discrete variable
    year = as.factor(year),
    # Modify units
    milk_produced = milk_produced / 10^9)
```



How to make a **Dumbbell chart**

Make lines (note the `group` variable)

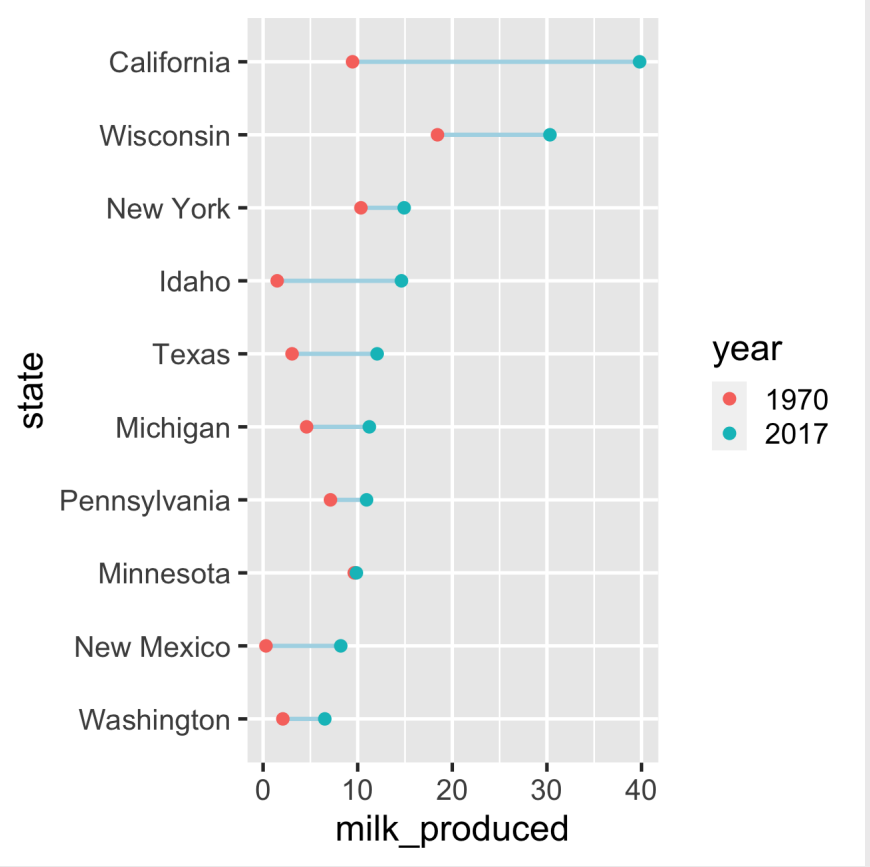
```
ggplot(milk_summary_dumbbell,
       aes(x = milk_produced, y = state)) +
  geom_line(aes(group = state),
            color = 'lightblue', size = 1)
```



How to make a **Dumbbell chart**

Add points (note the `color` variable)

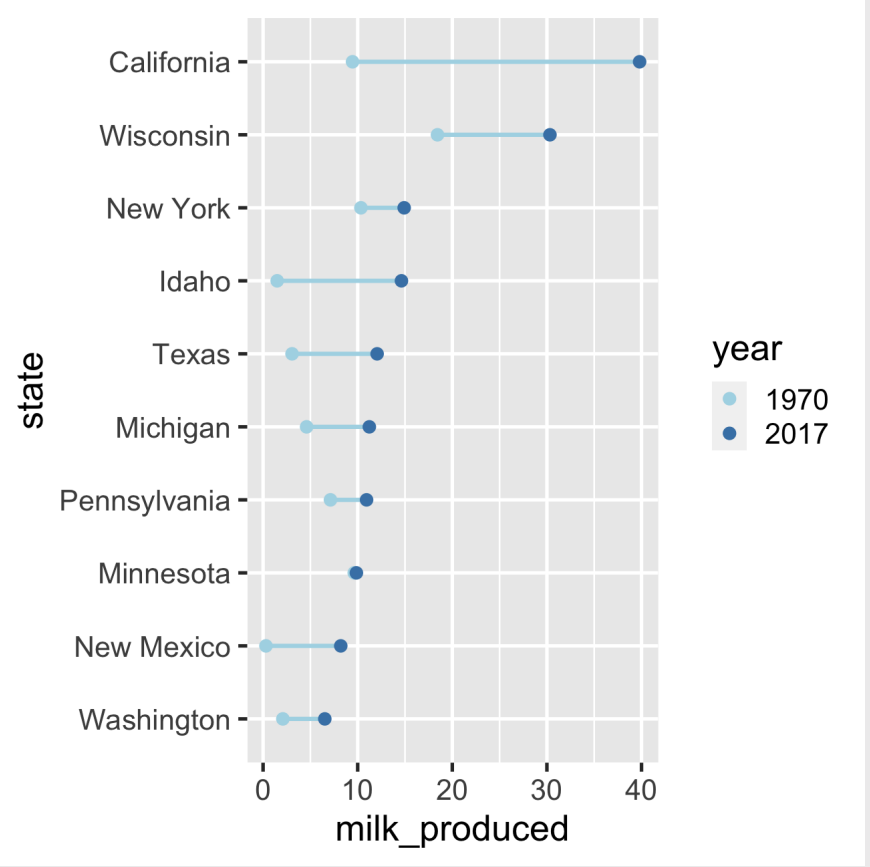
```
ggplot(milk_summary_dumbbell,
       aes(x = milk_produced, y = state)) +
  geom_line(aes(group = state),
            color = 'lightblue', size = 1) +
  geom_point(aes(color = year), size = 2.5)
```



How to make a **Dumbbell chart**

Change the colors:

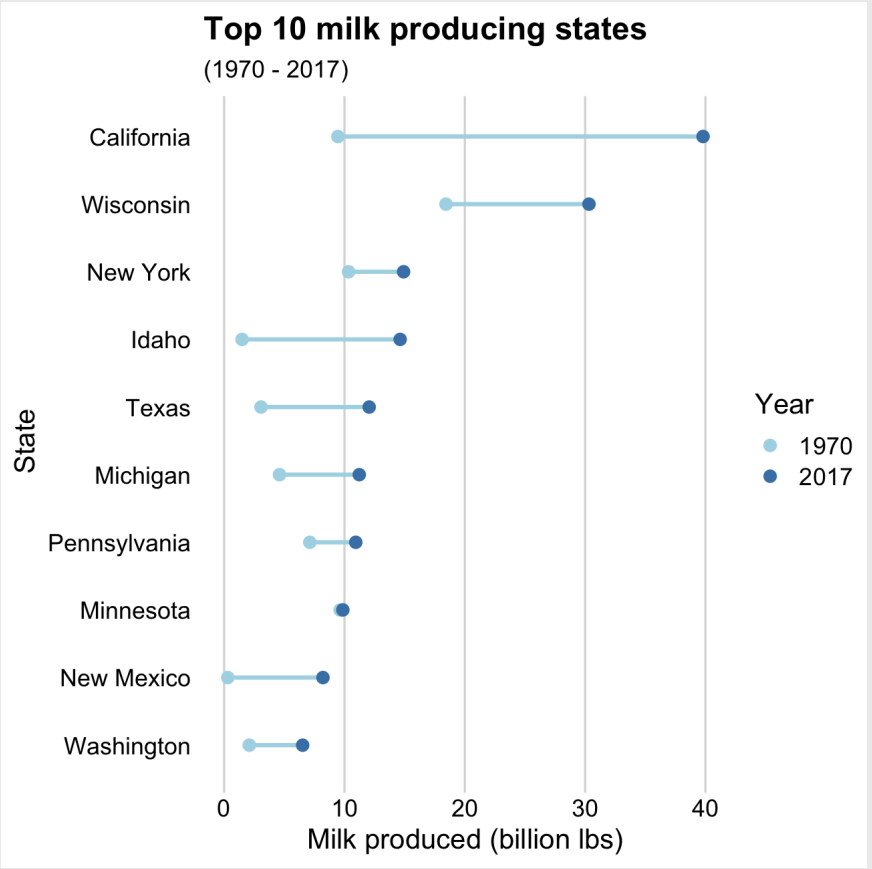
```
ggplot(milk_summary_dumbbell,
       aes(x = milk_produced, y = state)) +
  geom_line(aes(group = state),
            color = 'lightblue', size = 1) +
  geom_point(aes(color = year), size = 2.5) +
  scale_color_manual(
      values = c('lightblue', 'steelblue'))
```



How to make a **Dumbbell chart**

Adjust the theme and annotate

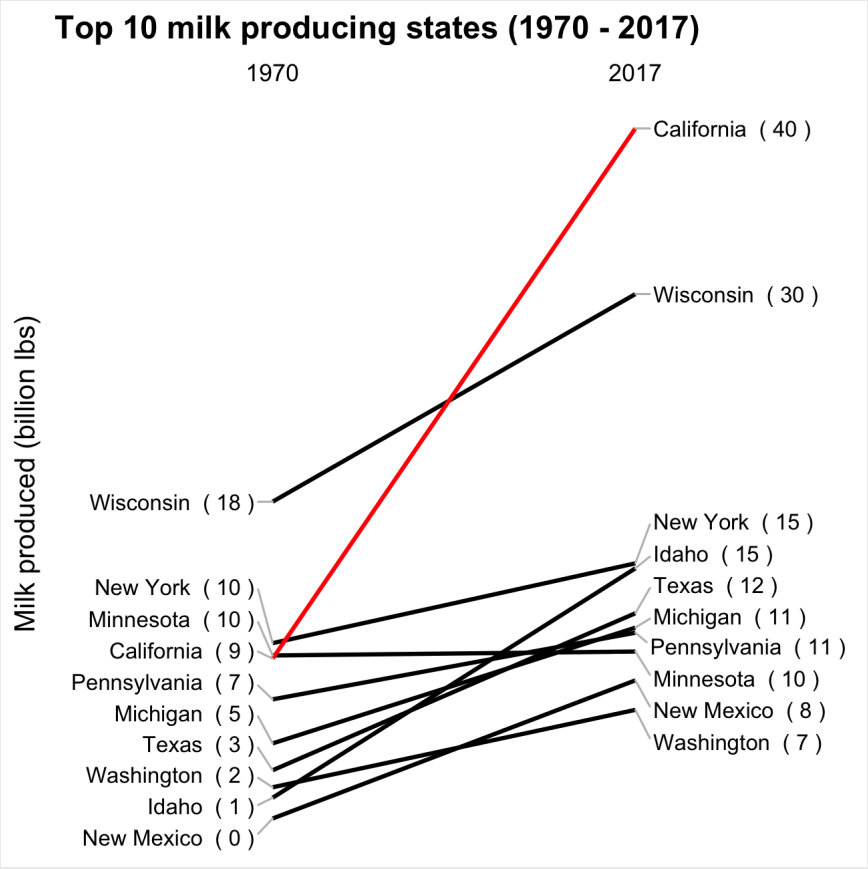
```
ggplot(milk_summary_dumbbell,
       aes(x = milk_produced, y = state)) +
  geom_line(aes(group = state),
            color = 'lightblue', size = 1) +
  geom_point(aes(color = year), size = 2.5) +
  scale_color_manual(
      values = c('lightblue', 'steelblue')) +
  theme_minimal_vgrid() +
  # Remove y axis line and tick marks
  theme(
    axis.line.y = element_blank(),
    axis.ticks.y = element_blank()) +
  labs(x = 'Milk produced (billion lbs)',
       y = 'State',
       color = 'Year',
       title = 'Top 10 milk producing states',
       subtitle = '(1970 - 2017)')
```



Create data frame for plotting

```
top10states <- milk_production %>%
    filter(year == 2017) %>%
    arrange(desc(milk_produced)) %>%
    slice(1:10)

milk_summary_slope <- milk_production %>%
  filter(
    year %in% c(1970, 2017),
    state %in% top10states$state) %>%
  mutate(
    # Reorder state variables
    state = fct_reorder2(state,
      year, desc(milk_produced)),
    # Convert year to discrete variable
    year = as.factor(year),
    # Modify units
    milk_produced = milk_produced / 10^9,
    # Define line color
    lineColor = if_else(
      state == 'California', 'CA', 'other'),
    # Make labels
    label = paste(state, ' (',
                  round(milk_produced), ')'),
    label_left = ifelse(year == 1970, label, NA),
    label_right = ifelse(year == 2017, label, NA))
```

How to make a **Slope chart**



Create data frame for plotting

```
top10states <- milk_production %>%
    filter(year == 2017) %>%
    arrange(desc(milk_produced)) %>%
    slice(1:10)

milk_summary_slope <- milk_production %>%
  filter(
    year %in% c(1970, 2017),
    state %in% top10states$state) %>%
  mutate(
    # Reorder state variables
    state = fct_reorder2(state,
      year, desc(milk_produced)),
    # Convert year to discrete variable
    year = as.factor(year),
    # Modify units
    milk_produced = milk_produced / 10^9,
    # Define line color
    lineColor = if_else(
      state == 'California', 'CA', 'other'),
    # Make labels
    label = paste(state, ' (',
                  round(milk_produced), ')'),
    label_left = ifelse(year == 1970, label, NA),
    label_right = ifelse(year == 2017, label, NA))
```

How to make a **Slope chart**

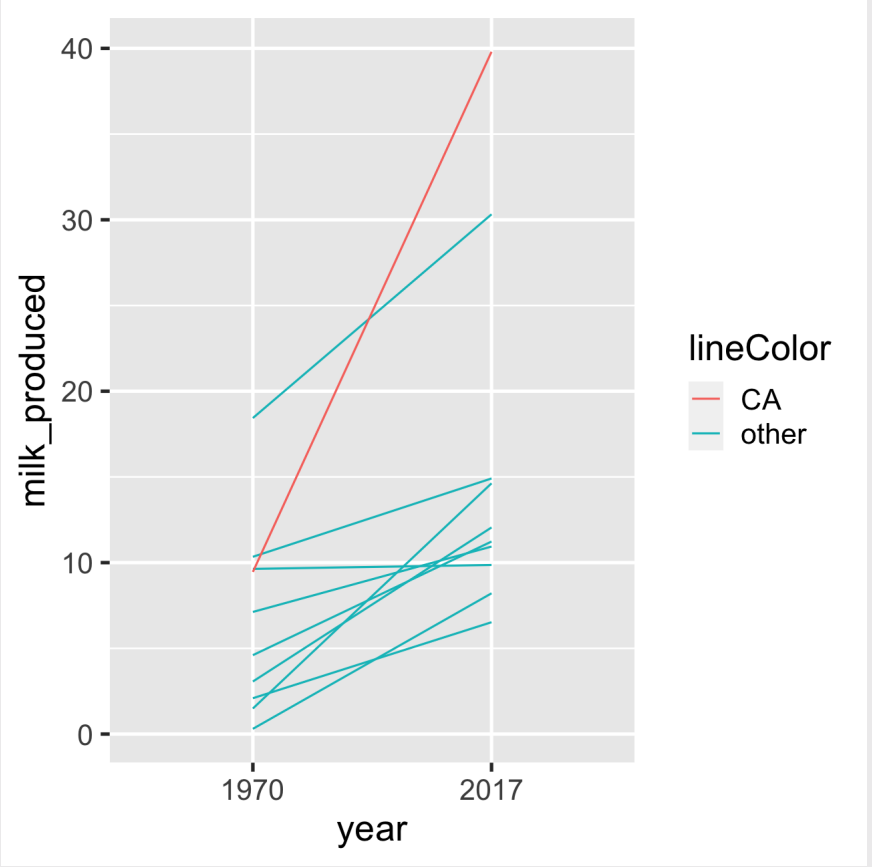
```
milk_summary_slope %>%
    select(state, year, milk_produced, label, lineColor)
```

```
#> # A tibble: 20 x 5
#>    state        year  milk_produced label               lineCo
#>    <fct>        <fct>         <dbl> <chr>               <chr>
#>  1 New York     1970          10.3   New York  ( 10 )    other
#>  2 Pennsylvania 1970           7.12  Pennsylvania  ( 7 ) other
#>  3 Michigan     1970           4.60  Michigan  ( 5 )     other
#>  4 Wisconsin    1970          18.4   Wisconsin  ( 18 )   other
#>  5 Minnesota    1970           9.64  Minnesota  ( 10 )   other
#>  6 Texas        1970           3.06  Texas  ( 3 )        other
#>  7 Idaho        1970           1.49  Idaho  ( 1 )        other
#>  8 New Mexico   1970           0.304 New Mexico  ( 0 )   other
#>  9 Washington   1970           2.09  Washington  ( 2 )   other
#> 10 California   1970           9.46  California  ( 9 )   CA
#> 11 New York     2017          14.9   New York  ( 15 )    other
#> 12 Pennsylvania 2017          10.9   Pennsylvania  ( 11 ) other
#> 13 Michigan     2017          11.2   Michigan  ( 11 )    other
#> 14 Wisconsin    2017          30.3   Wisconsin  ( 30 )   other
#> 15 Minnesota    2017           9.86  Minnesota  ( 10 )   other
#> 16 Texas        2017          12.1   Texas  ( 12 )       other
#> 17 Idaho        2017          14.6   Idaho  ( 15 )       other
#> 18 New Mexico   2017           8.21  New Mexico  ( 8 )   other
#> 19 Washington   2017           6.53  Washington  ( 7 )   other
#> 20 California   2017          39.8   California  ( 40 )  CA
```

How to make a **Slope chart**

Start with a line plot - note the `group` variable:

```
ggplot(milk_summary_slope,
       aes(x = year, y = milk_produced,
           group = state)) +
    geom_line(aes(color = lineColor))
```

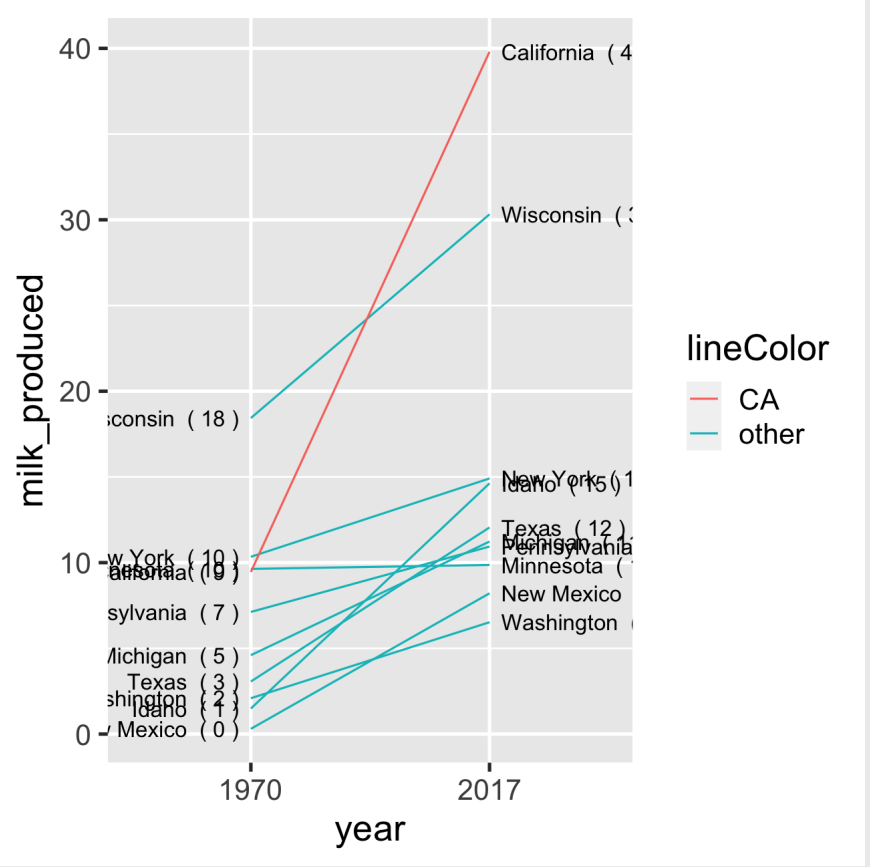


How to make a **Slope chart**

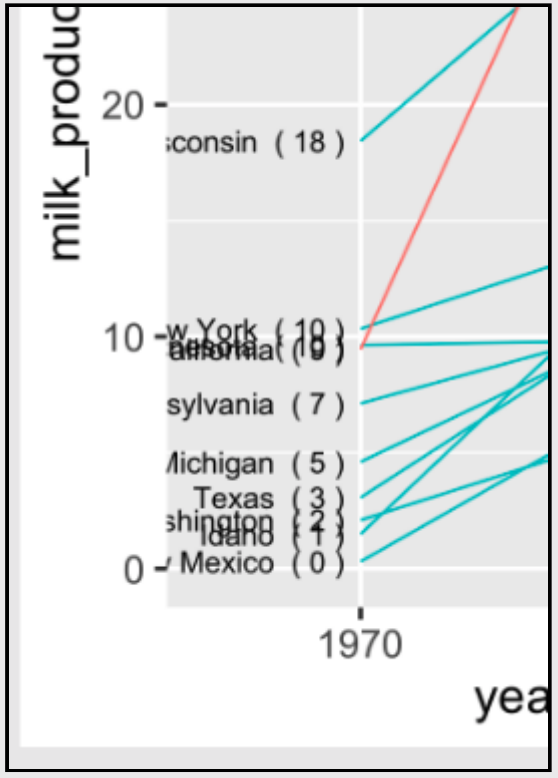
Add labels:

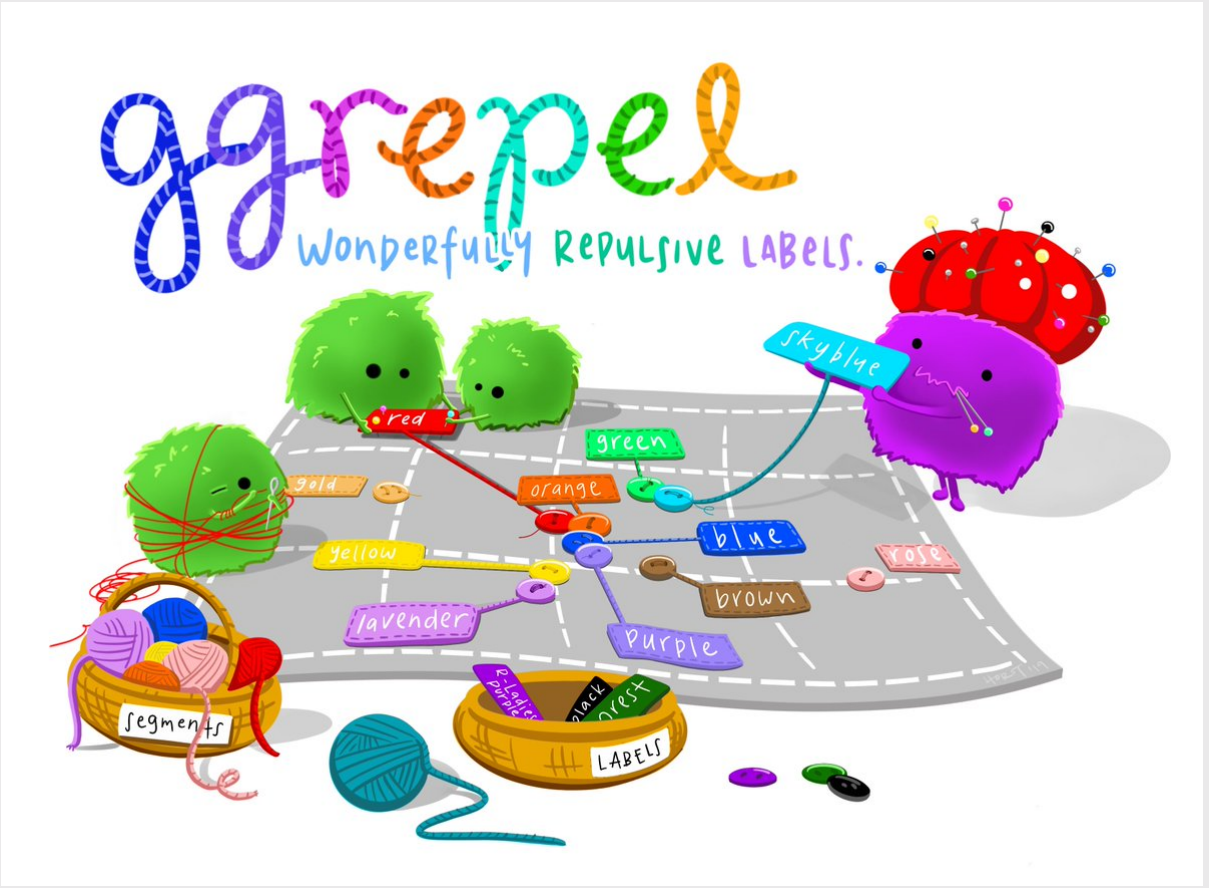
```
ggplot(milk_summary_slope,
       aes(x = year, y = milk_produced,
           group = state)) +
    geom_line(aes(color = lineColor)) +
    # Add 1970 labels (left side)
    geom_text(aes(label = label_left),
              hjust = 1, nudge_x = -0.05) +
    # Add 2017 labels (right side)
    geom_text(aes(label = label_right),
              hjust = 0, nudge_x = 0.05)
```

Justification	`hjust`
Left	0
Center	0.5
Right	1



Overlapping labels?
ggrepel library to the rescue!

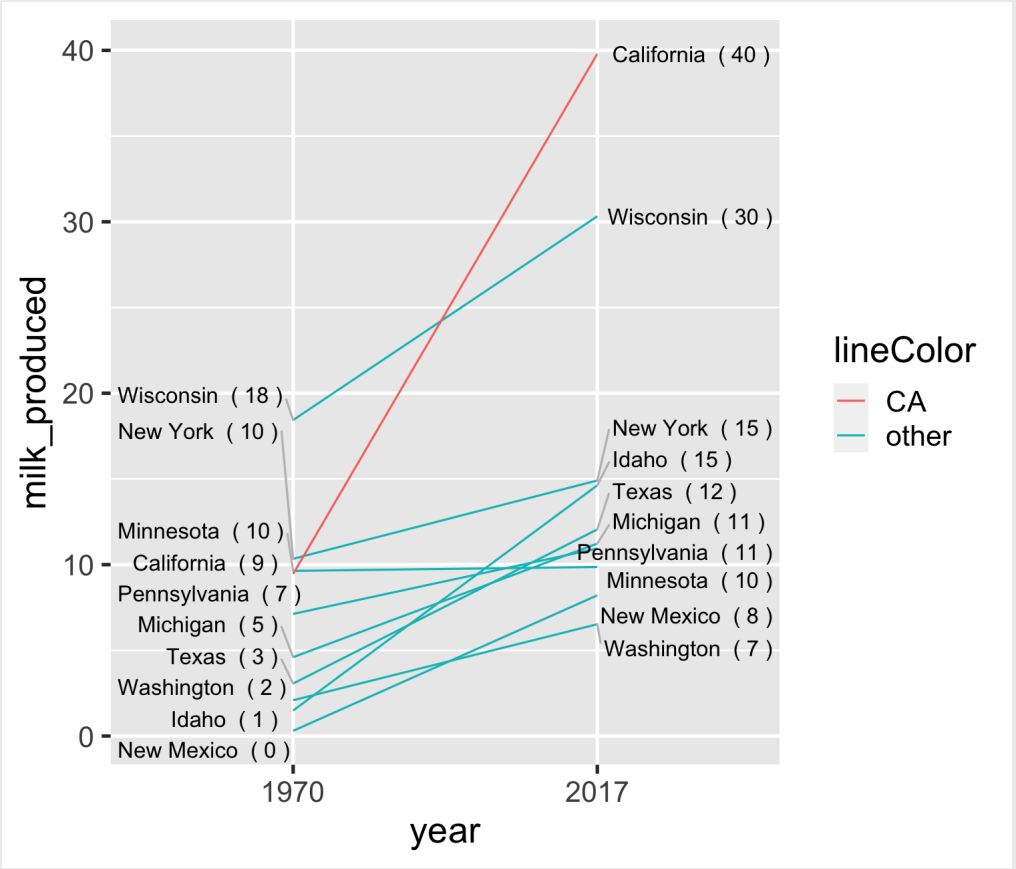




How to make a **Slope chart**

Align labels so they don't overlap:

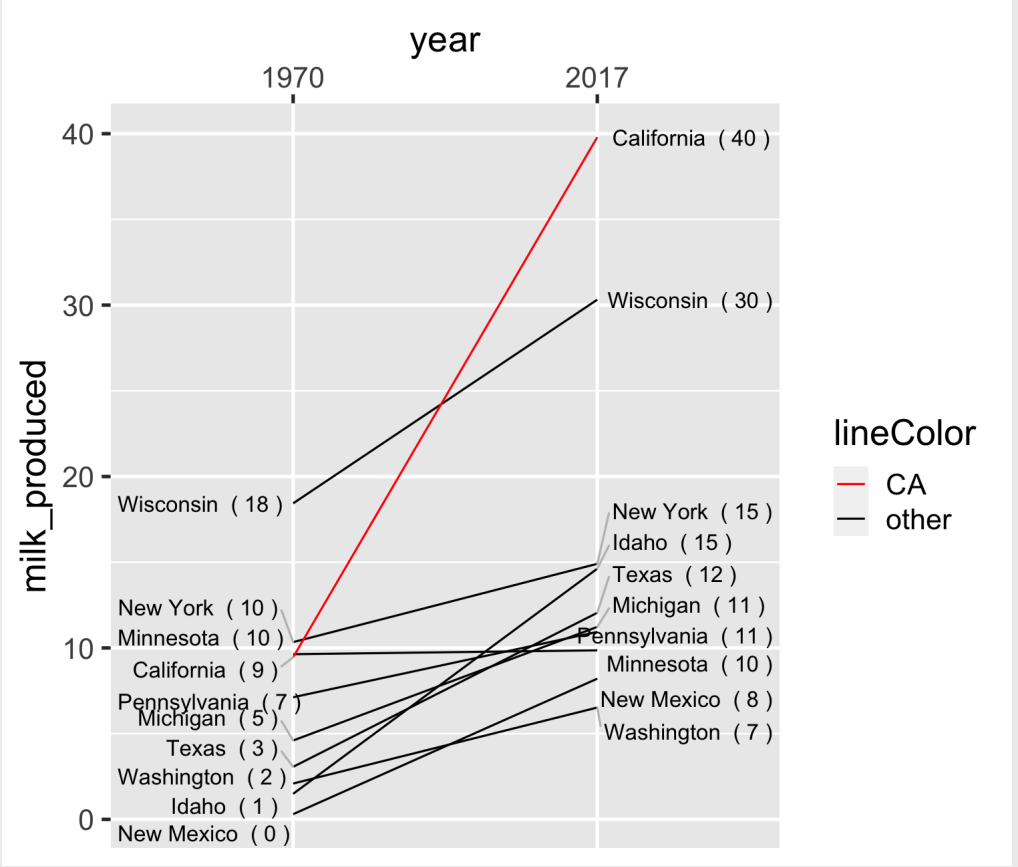
```
library(ggrepel)

ggplot(milk_summary_slope,
       aes(x = year, y = milk_produced,
           group = state)) +
    geom_line(aes(color = lineColor)) +
    # Add 1970 labels (left side)
    geom_text_repel(
      aes(label = label_left),
      hjust = 1, nudge_x = -0.05,
      direction = 'y', segment.color = 'grey') +
    # Add 2017 labels (right side)
    geom_text_repel(
      aes(label = label_right),
      hjust = 0, nudge_x = 0.05,
      direction = 'y', segment.color = 'grey')
```



How to make a **Slope chart**

Adjust colors:

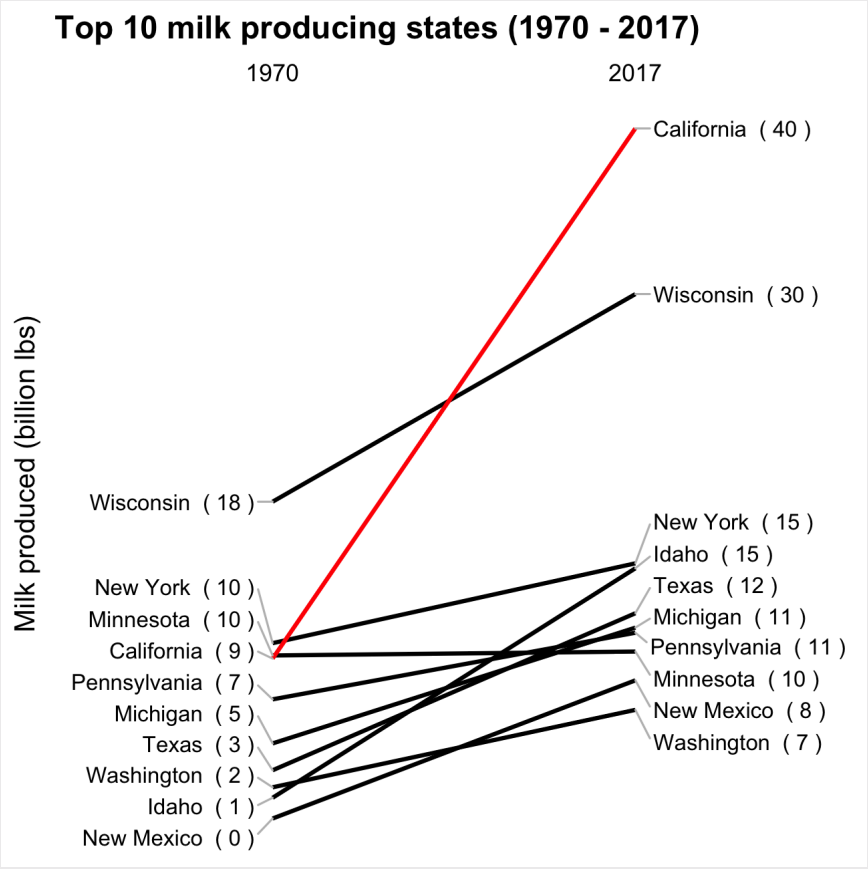
```
ggplot(milk_summary_slope,
       aes(x = year, y = milk_produced,
           group = state)) +
    geom_line(aes(color = lineColor)) +
    geom_text_repel(
      aes(label = label_left),
      hjust = 1, nudge_x = -0.05,
      direction = 'y', segment.color = 'grey') +
    geom_text_repel(
      aes(label = label_right),
      hjust = 0, nudge_x = 0.05,
      direction = 'y', segment.color = 'grey') +
    # Move year labels to top, modify line colo
    scale_x_discrete(position = 'top') +
    scale_color_manual(values = c('red', 'black
```



Adjust the theme and annotate

```
ggplot(milk_summary_slope,
       aes(x = year, y = milk_produced,
           group = state)) +
    geom_line(aes(color = lineColor)) +
    # Add 1970 labels (left side)
    geom_text_repel(
      aes(label = label_left),
      hjust = 1, nudge_x = -0.05,
      direction = 'y', segment.color = 'grey') +
    # Add 2017 labels (right side)
    geom_text_repel(aes(label = label_right),
      hjust = 0, nudge_x = 0.05,
      direction = 'y', segment.color = 'grey') +
    # Move year labels to top, modify line colors
    scale_x_discrete(position = 'top') +
    scale_color_manual(values = c('red', 'black')) +
    # Annotate & adjust theme
    labs(x = NULL,
         y = 'Milk produced (billion lbs)',
         title = 'Top 10 milk producing states (1970 -
    theme_minimal_grid() +
    theme(panel.grid  = element_blank(),
          axis.text.y = element_blank(),
          axis.ticks = element_blank(),
          legend.position = 'none')
```

How to make a **Slope chart**



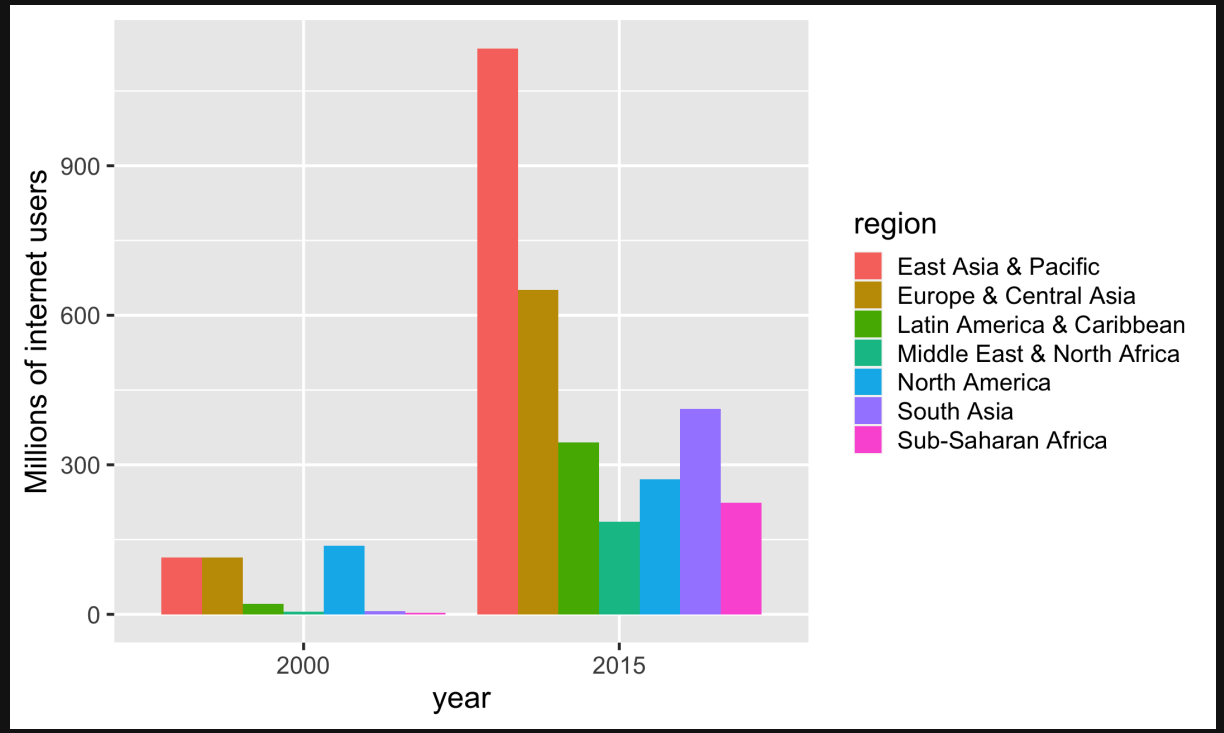
Your turn - comparing multiple categories

20:00

Using the `internet_regions` data frame, pick a strategy and create an improved version of this chart.

Strategies:

- Dodged bars
- Facets
- Bullet chart
- Dumbell chart
- Slope chart



Break!

Stand up, Move around, Stretch!

05:00

Week 7: *Comparisons*

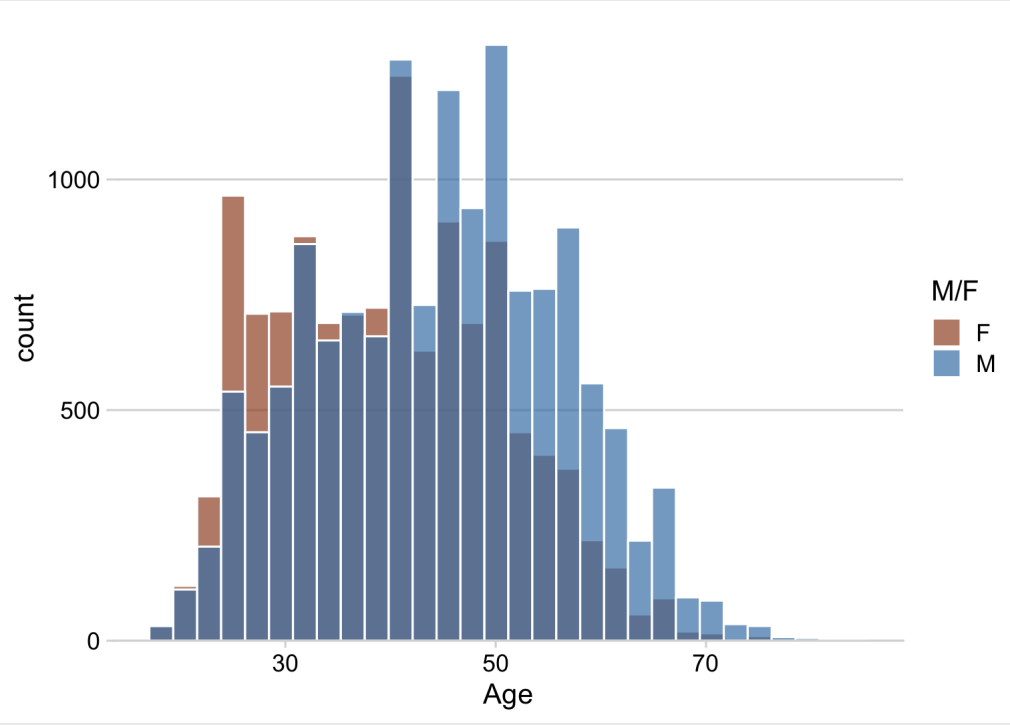
1. Comparing to a reference
2. Comparing variables

BREAK

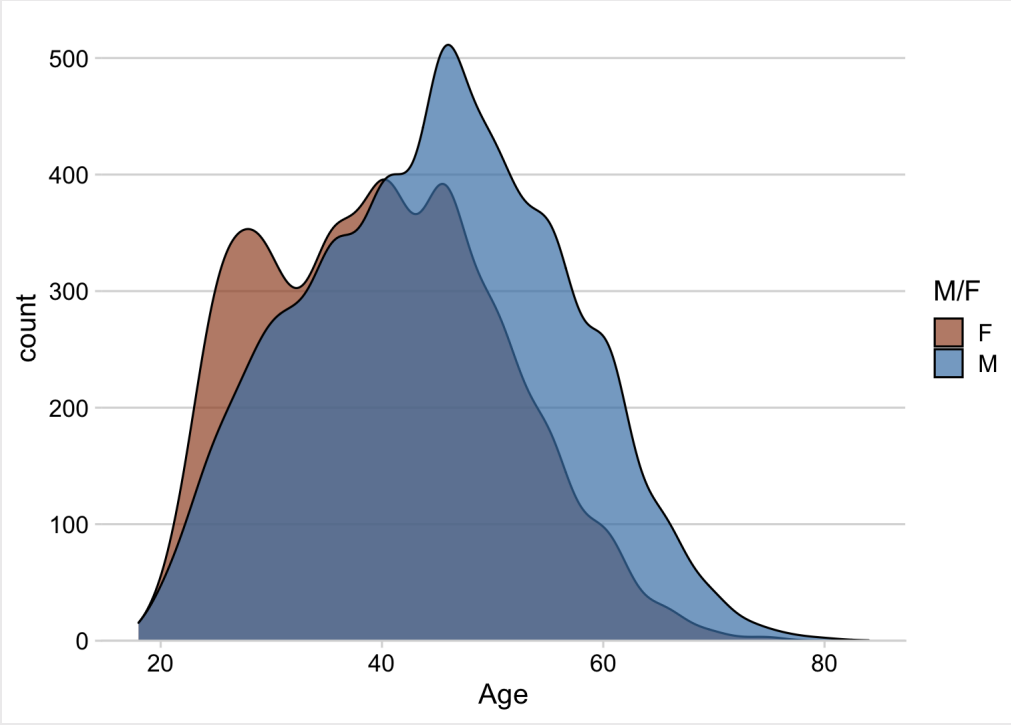
3. Comparing distributions

Overlapping histograms have issues

Bad

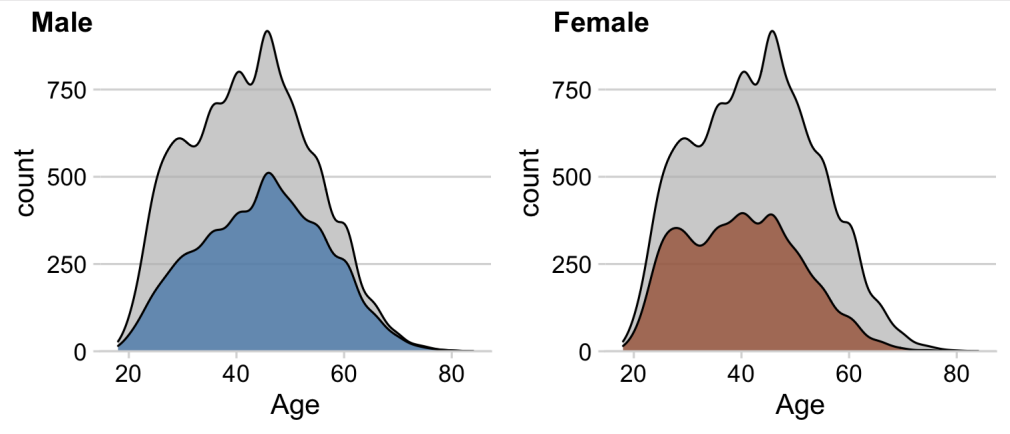


Slightly better

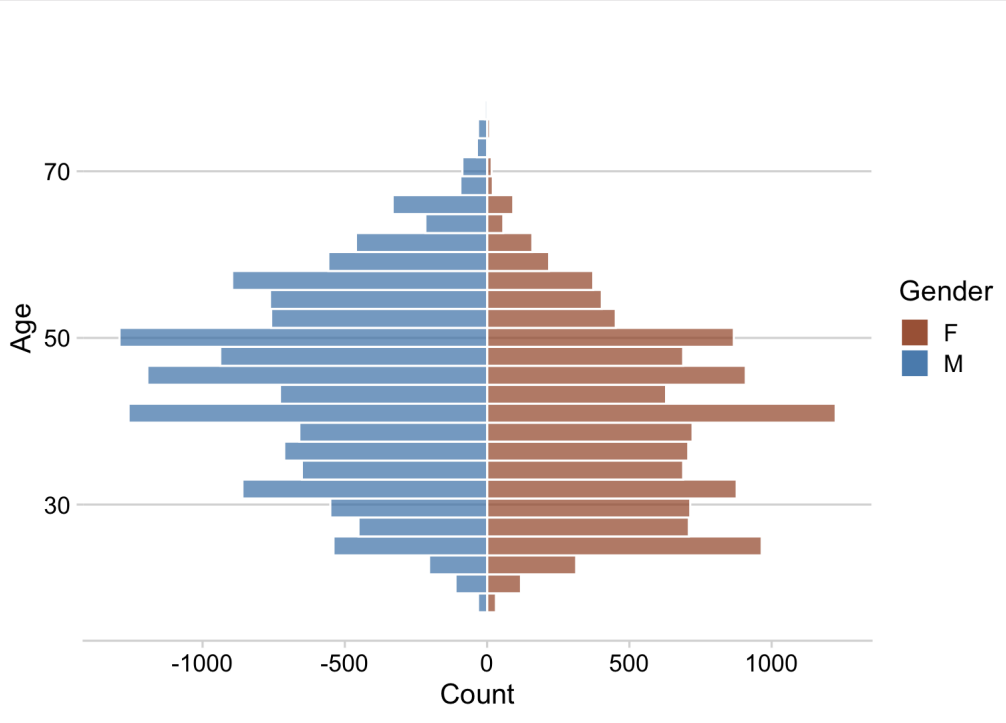


Good when number of categories is **small**

Density facets

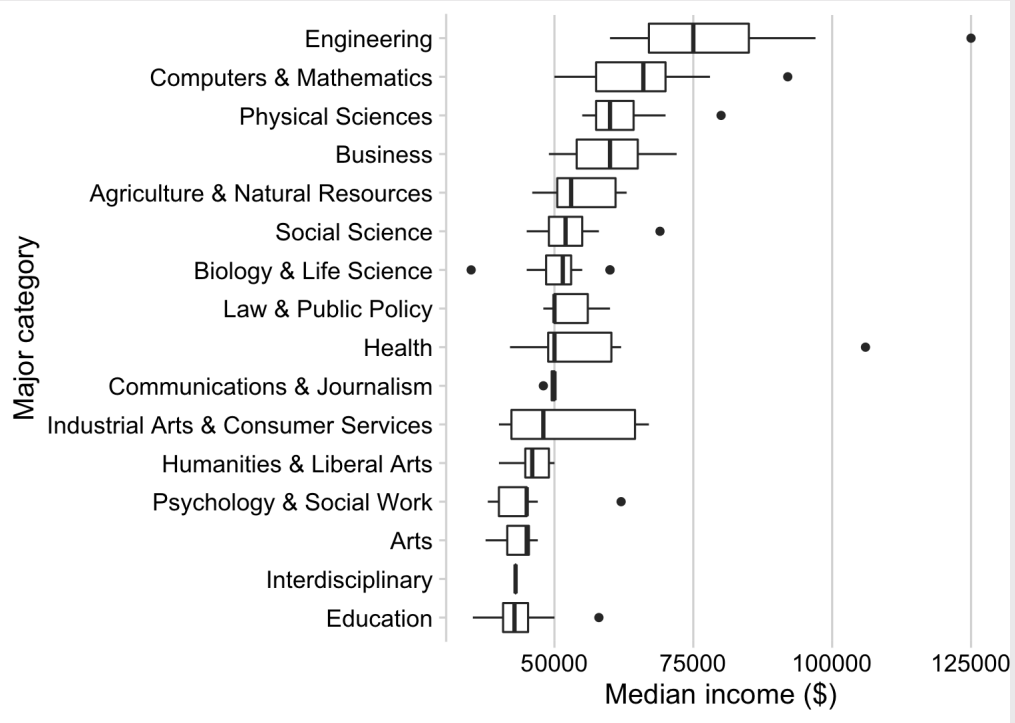


Diverging histograms

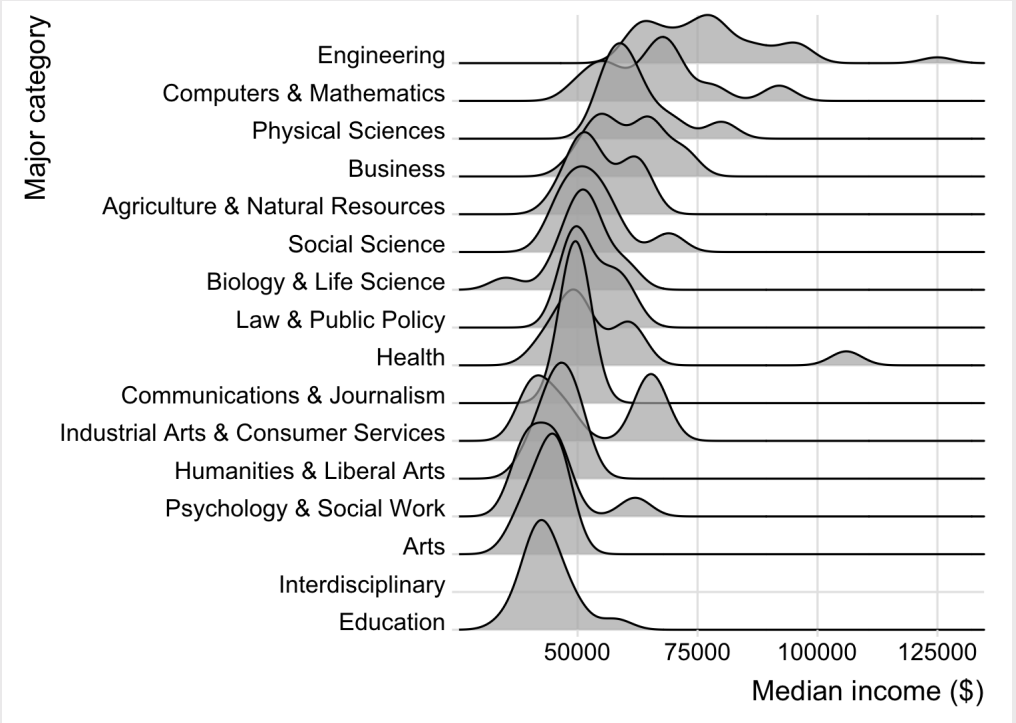


Good when number of categories is **large**

Boxplot



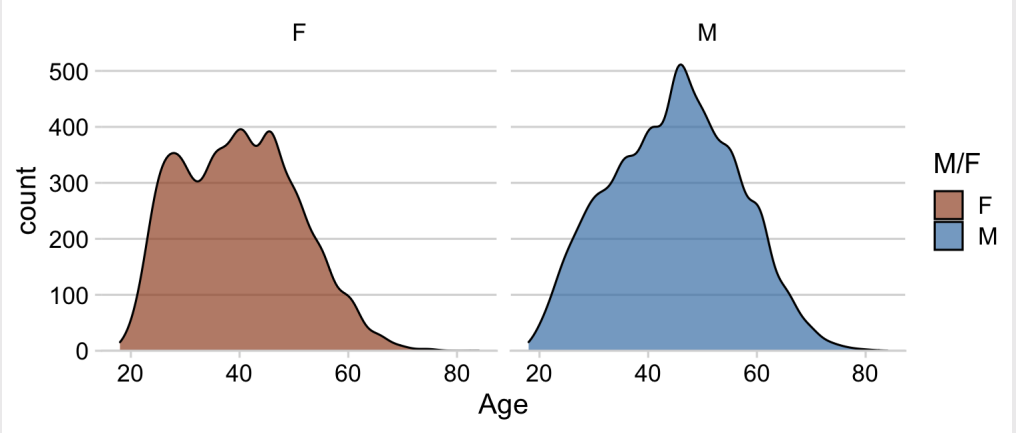
Ridgeplot



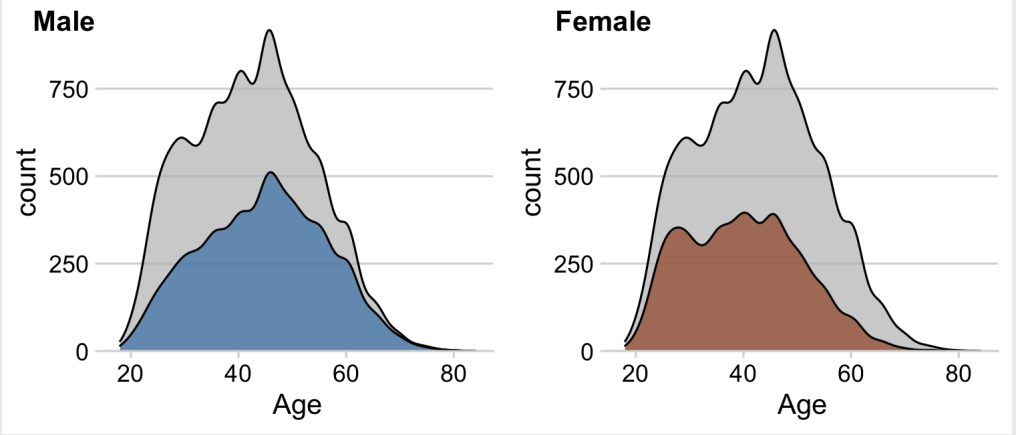
How to make density facets

You can use `facet_wrap()`, but
you won't get the full density overlay

```
ggplot(marathon,
       aes(x = Age, y = ..count..,
           fill = `M/F`)) +
    geom_density(alpha = 0.7) +
    facet_wrap(vars(`M/F`)) +
    scale_fill_manual(
        values = c('sienna', 'steelblue')) +
    scale_y_continuous(
        expand = expansion(mult = c(0, 0.05))) +
    theme_minimal_hgrid()
```



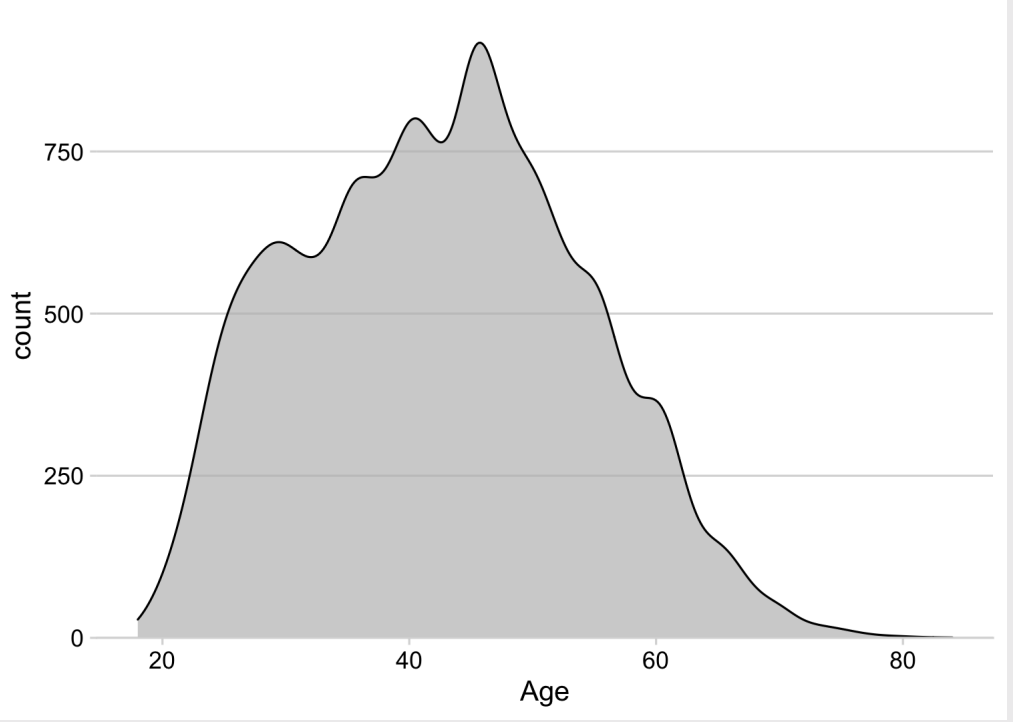
If you want the full density overlay,
you have to hand-make the facets



How to make density facets

Make the full density plot first

```
base <- ggplot(marathon,
                aes(x = Age, y = ..count..)) +
    geom_density(fill = 'grey', alpha = 0.7) +
    scale_y_continuous(
        expand = expansion(mult = c(0, 0.05))) +
    theme_minimal_hgrid()
```

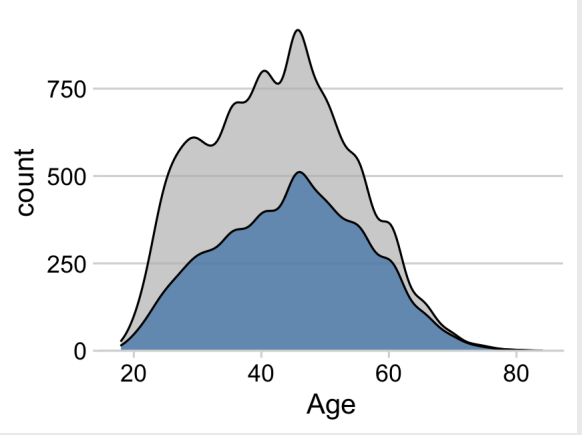


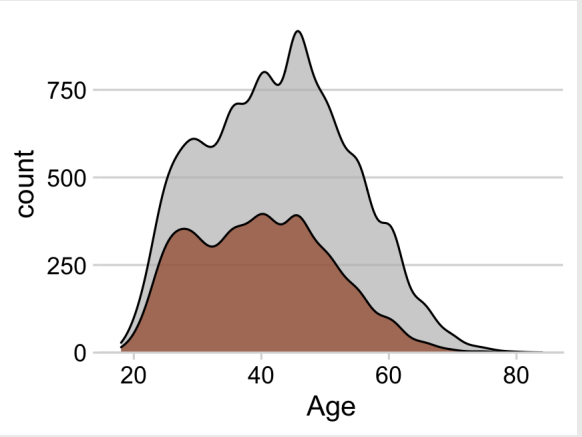
How to make density facets

Separately create each sub-plot

```
male <- base +
  geom_density(
    data = marathon %>%
      filter(`M/F` == 'M'),
    fill = 'steelblue', alpha = 0.7) +
  theme(legend.position = 'none')
```

```
female <- base +
  geom_density(
    data = marathon %>%
      filter(`M/F` == 'F'),
    fill = 'sienna', alpha = 0.7) +
  theme(legend.position = 'none')
```

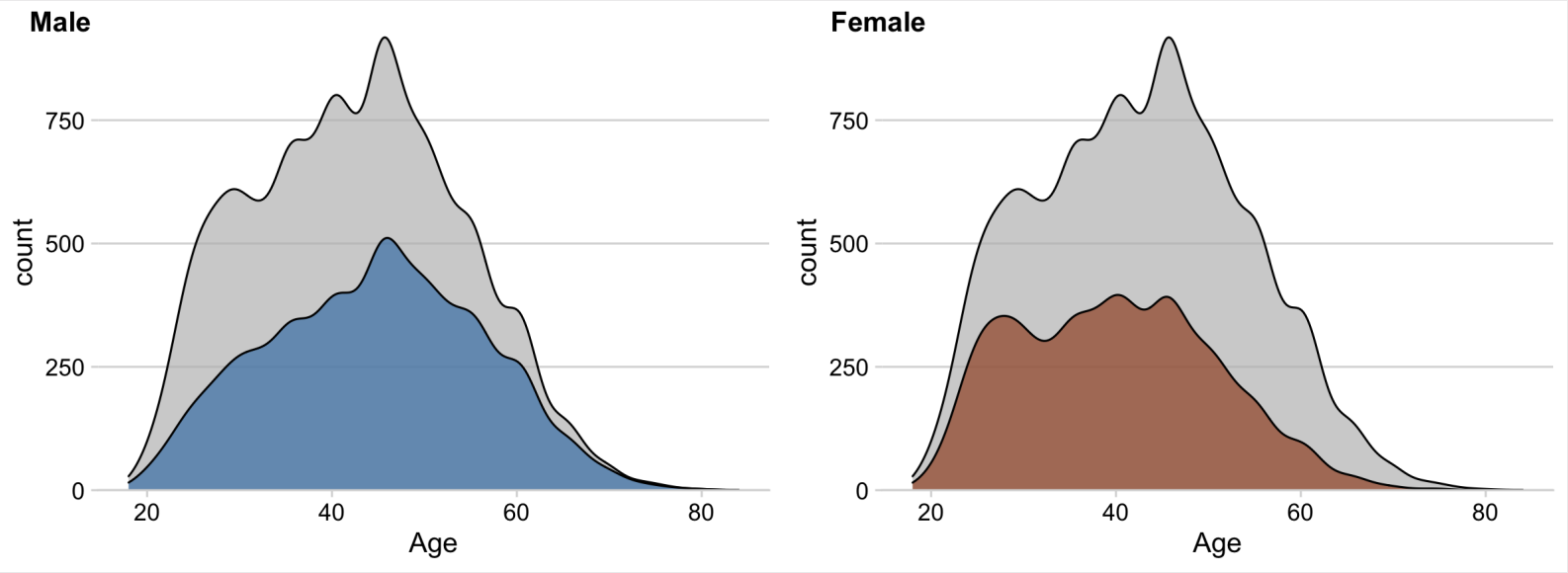




How to make density facets

Combine into single plot

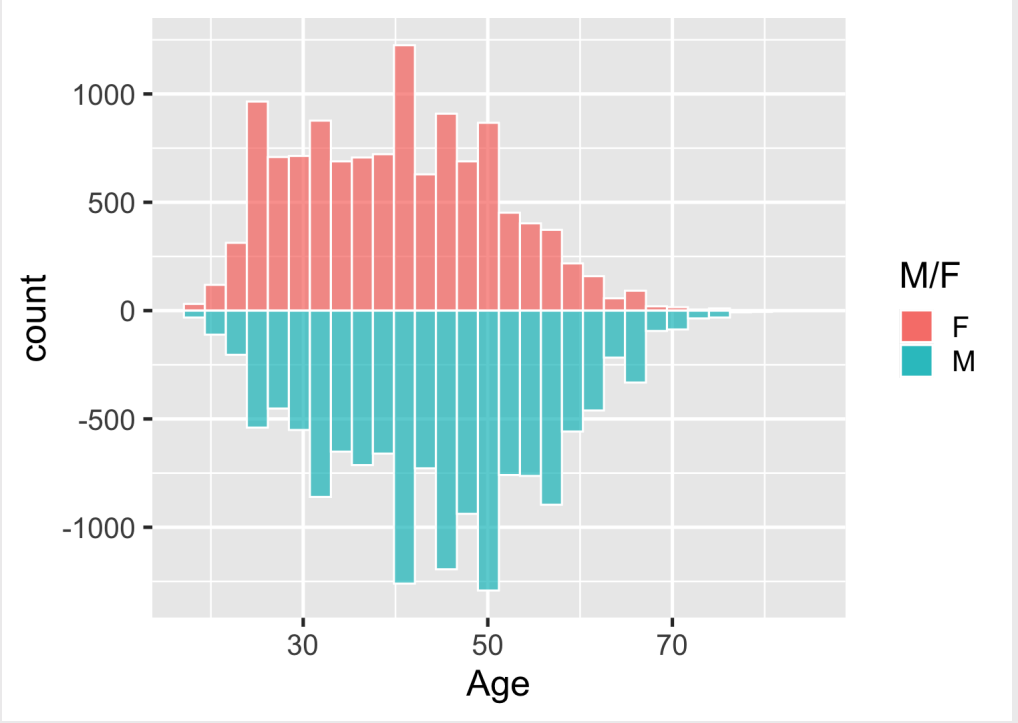
```
plot_grid(male, female,
          labels = c('Male', 'Female'))
```



How to make diverging histograms

Make the histograms by filtering the data

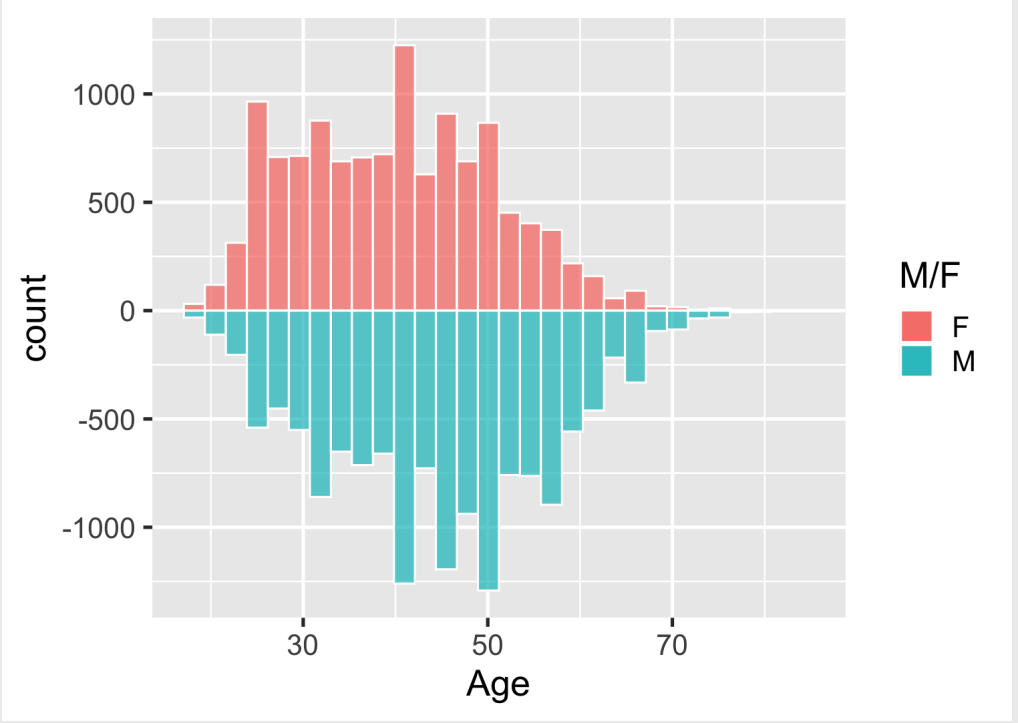
```
ggplot(marathon, aes(x = Age)) +
    # Add histogram for Female runners:
    geom_histogram(
      data = marathon %>%
        filter(`M/F` == 'F'),
      aes(fill = `M/F`, y=..count..),
      alpha = 0.7, color = 'white') +
    # Add negative histogram for Male runners:
    geom_histogram(
      data = marathon %>%
        filter(`M/F` == 'M'),
      aes(fill = `M/F`, y=..count..*(-1)),
      alpha = 0.7, color = 'white')
```



How to make diverging histograms

Make the histograms by filtering the data

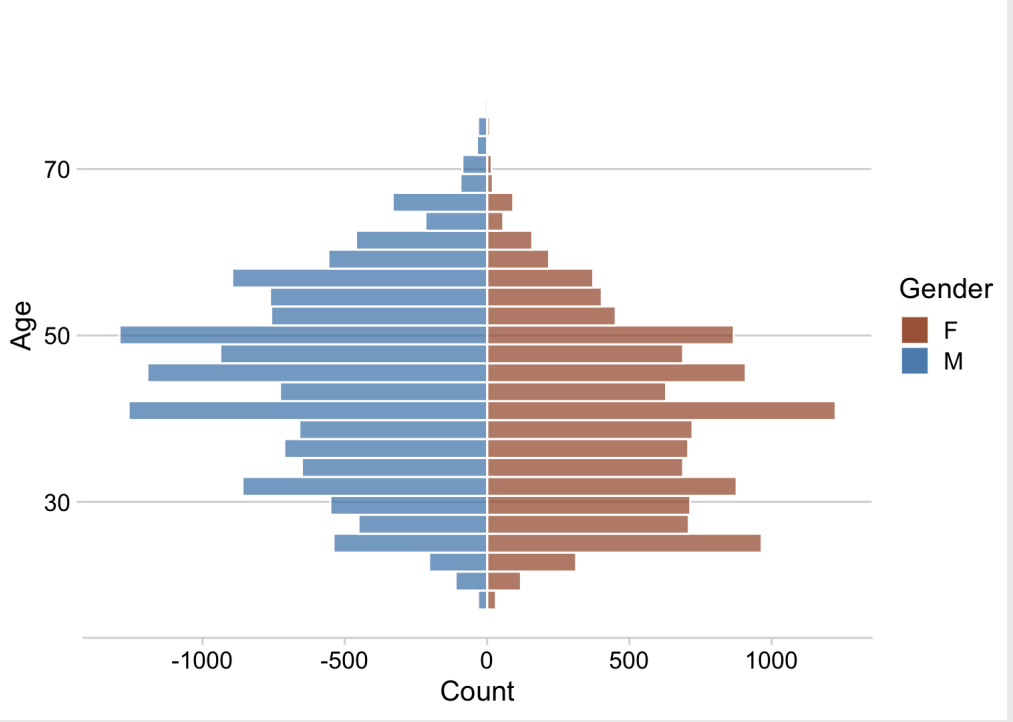
```
ggplot(marathon, aes(x = Age)) +
    # Add histogram for Female runners:
    geom_histogram(
      data = marathon %>%
        filter(`M/F` == 'F'),
      aes(fill = `M/F`, y=..count..),
      alpha = 0.7, color = 'white') +
    # Add negative histogram for Male runners:
    geom_histogram(
      data = marathon %>%
        filter(`M/F` == 'M'),
      aes(fill = `M/F`, y=..count..*(-1)),
      alpha = 0.7, color = 'white')
```



How to make diverging histograms

Rotate, adjust colors, theme, annotate

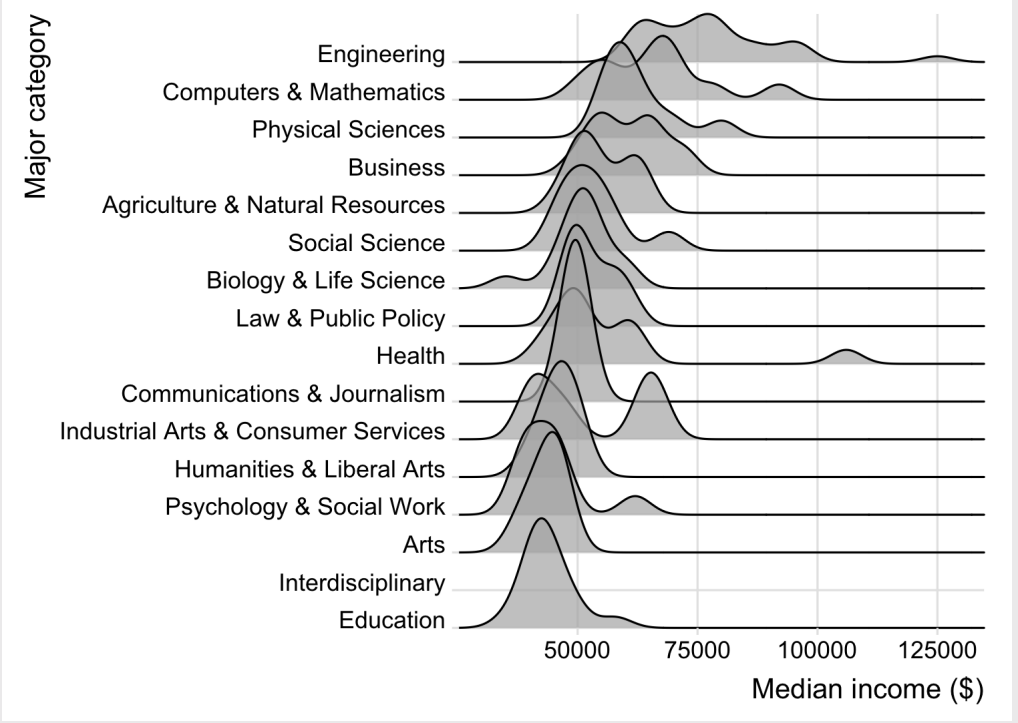
```
ggplot(marathon, aes(x = Age)) +
    # Add histogram for Female runners:
    geom_histogram(
      data = marathon %>%
        filter(`M/F` == 'F'),
      aes(fill = `M/F`, y=..count..),
      alpha = 0.7, color = 'white') +
    # Add negative histogram for Male runners:
    geom_histogram(
      data = marathon %>%
        filter(`M/F` == 'M'),
      aes(fill = `M/F`, y=..count..*(-1)),
      alpha = 0.7, color = 'white')
    scale_fill_manual(
        values = c('sienna', 'steelblue')) +
    coord_flip() +
    theme_minimal_hgrid() +
    labs(fill = 'Gender',
         y    = 'Count')
```



How to make ridgeplots

Make a ridgeplot with **ggridges** library

```
library(ggridges)

college_all_ages %>%
  mutate(
    major_category = fct_reorder(
      major_category, median)) %>%
  ggplot() +
  geom_density_ridges(
    aes(x = median, y = major_category),
    scale = 4, alpha = 0.7) +
  scale_y_discrete(expand = c(0, 0)) +
  scale_x_continuous(expand = c(0, 0)) +
  coord_cartesian(clip = "off") +
  theme_ridges() +
  labs(x = 'Median income ($)',
       y = 'Major category')
```



Your turn - comparing distributions

15:00

Use the `gapminder.csv` data to create the following charts comparing the distribution of life expectancy across countries in continents in 2007.