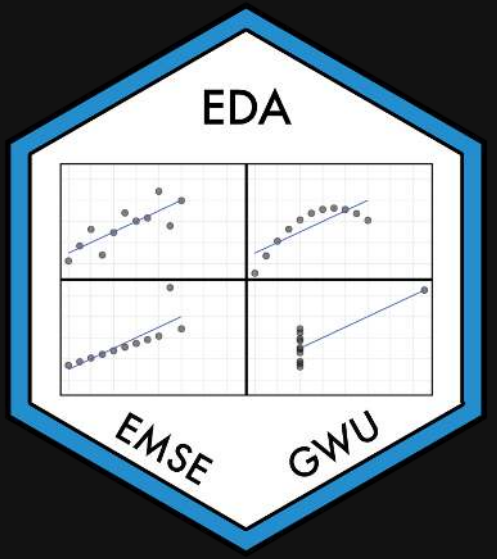



# Week 9: *Trends*

EMSE 4572: Exploratory Data Analysis

John Paul Helveston

October 25, 2023

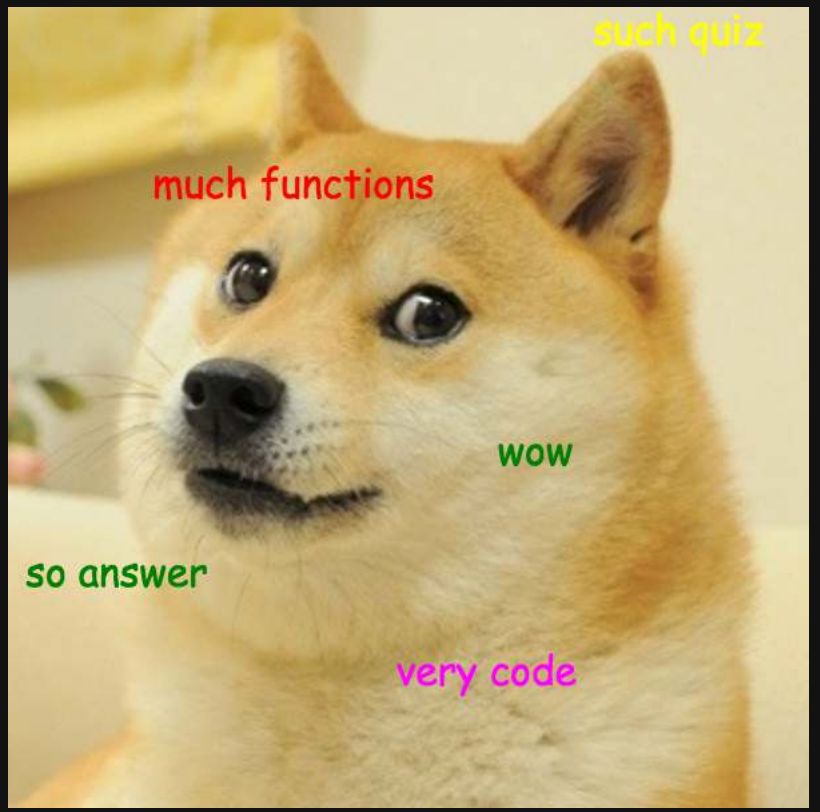
# Quiz 3

Download the template from the #class channel

Make sure you unzip it!

When done, submit your `quiz3.qmd` on Blackboard

10:00



# Today's data

Seen before:

```
gapminder         <- read_csv(here::here('data', 'gapminder.csv'))
milk_production   <- read_csv(here::here('data', 'milk_production.csv'))
global_temps      <- read_csv(here::here('data', 'nasa_global_temps.csv'))
internet_region   <- read_csv(here::here('data', 'internet_users_region.csv'))
hotdogs           <- read_csv(here::here('data', 'hot_dog_winners.csv'))
internet_country <- read_csv(here::here('data', 'internet_users_country.csv'))
```

New datasets:

```
us_covid          <- read_csv(here::here('data', 'us_covid.csv'))
us_diseases       <- read_csv(here::here('data', 'us_contagious_diseases.csv'))
```

# New packages:

```
install.packages('viridis')
install.packages('gganimate')
install.packages('magick')
```

# Week 9: *Trends*

1. Single Variables
2. Animations

BREAK

3. Multiple Variables

# Week 9: *Trends*

1. Single Variables
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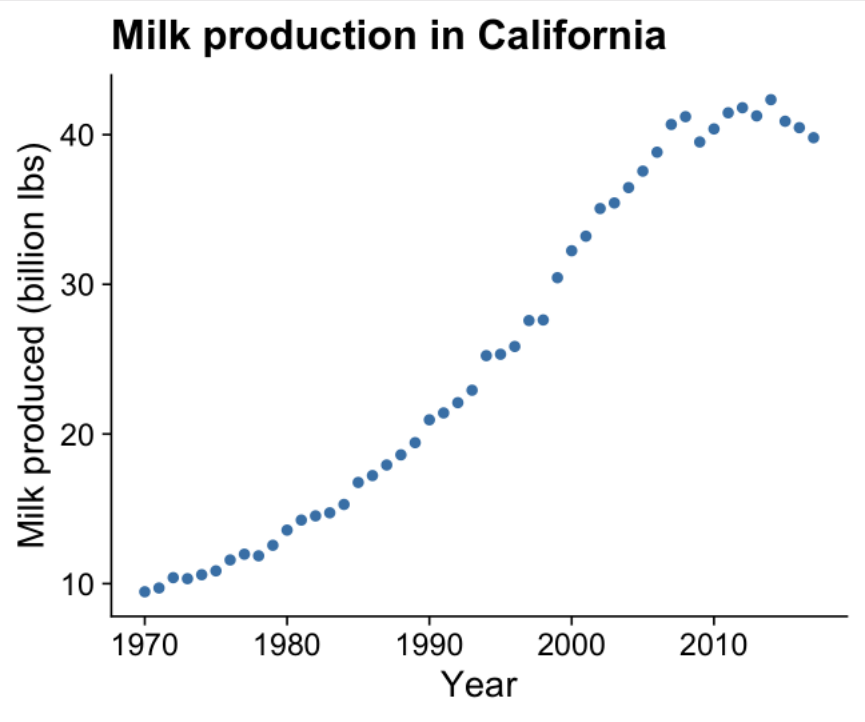
BREAK

3. Multiple Variables

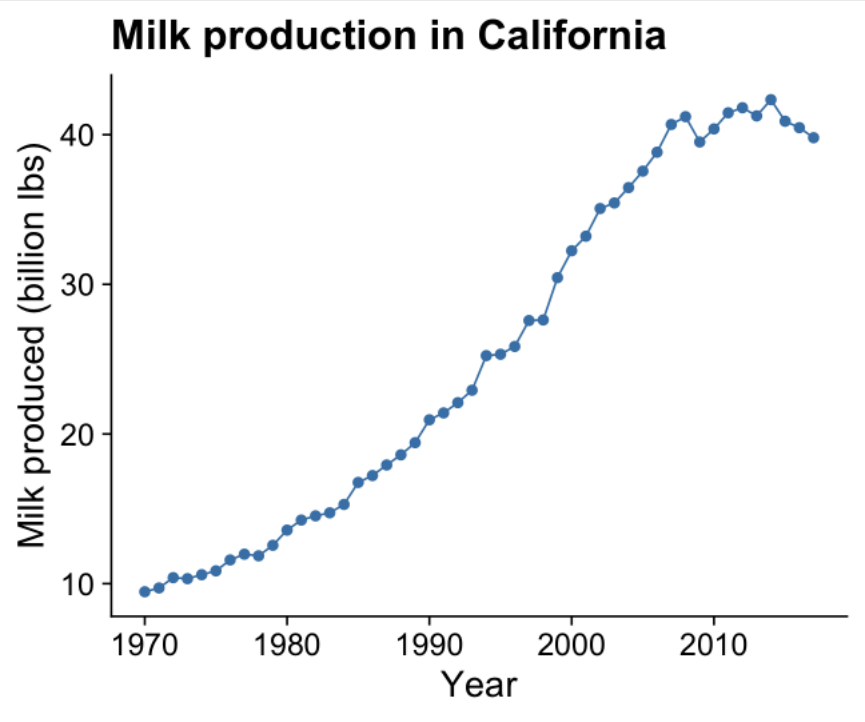
# Points

Plotting the data points is a good starting point for viewing trends



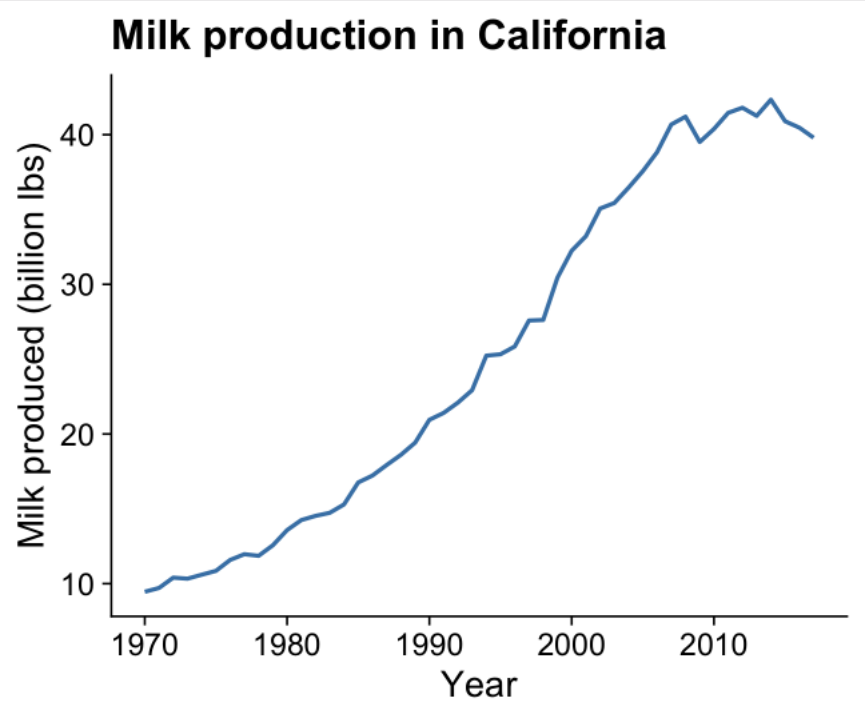

# Points + line

Adding lines between the points helps see the overall trend



# Line

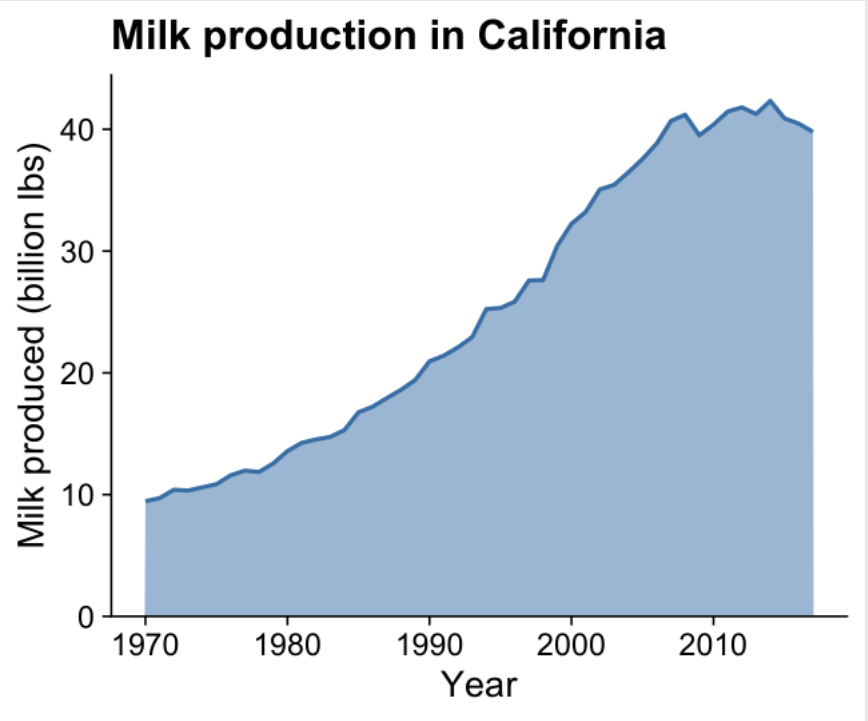
Omitting the points emphasizes the overall trend



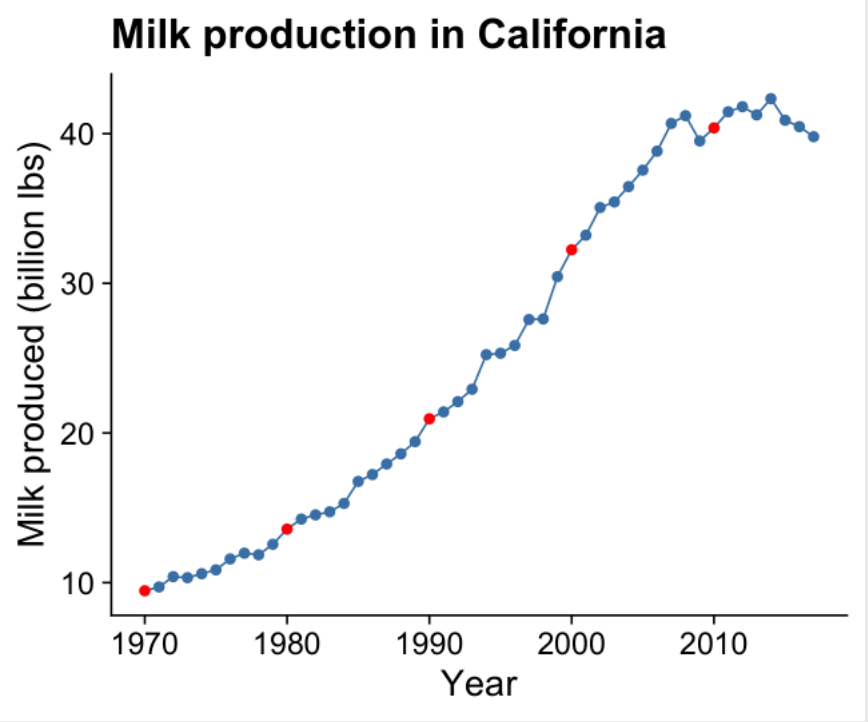

# Line + area

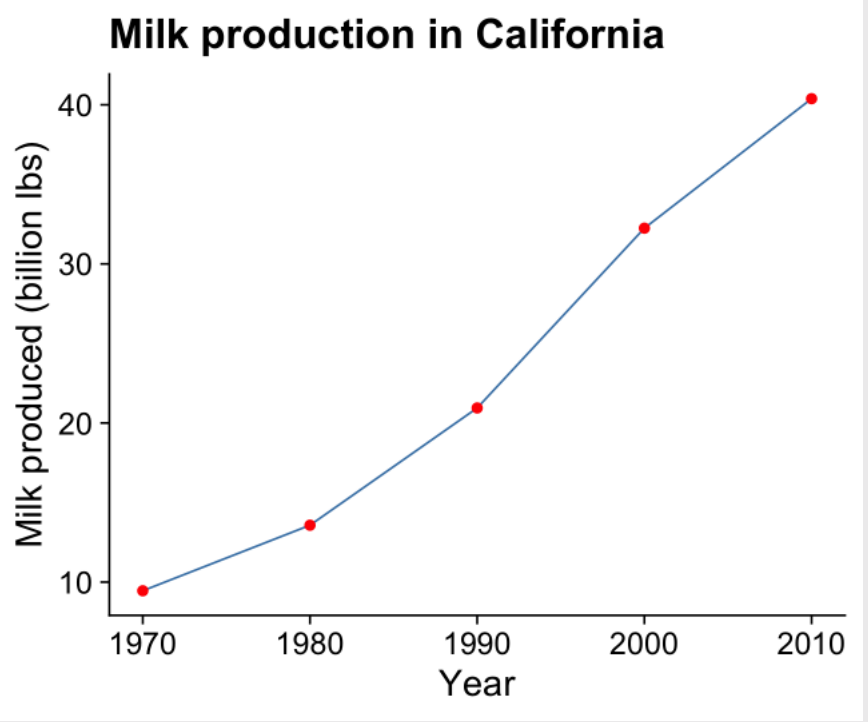
Filling area below line emphasizes cumulative over time

(y-axis should start at 0)



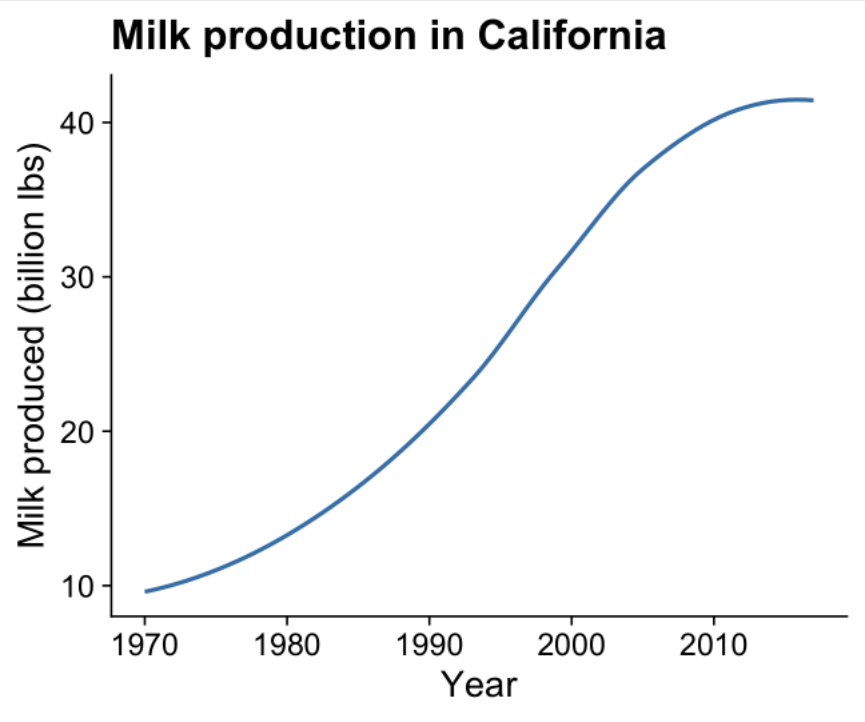
# If points are too sparse, a line can be misleading



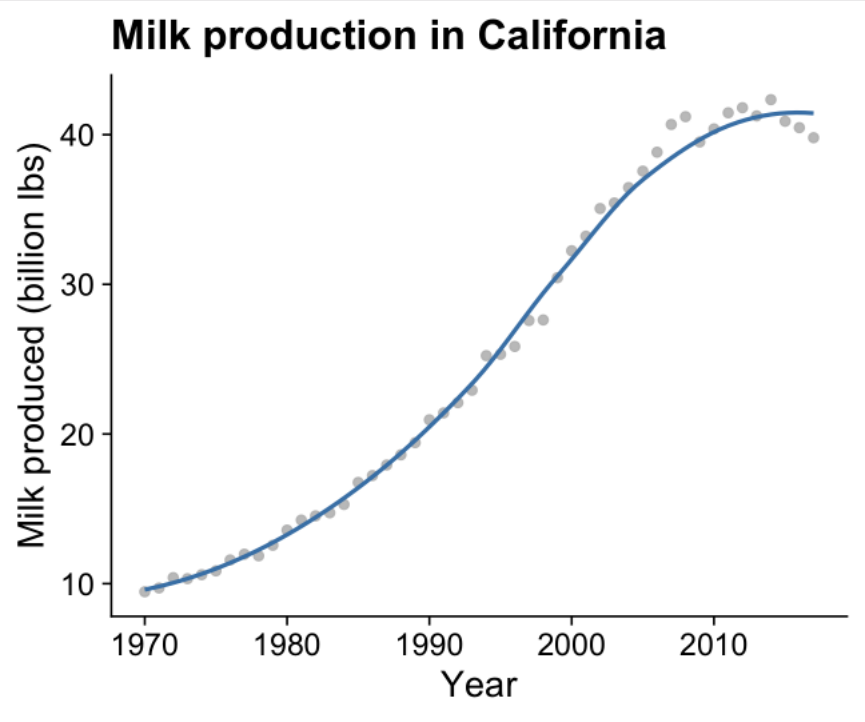
# Smoothed line

Adding a "smoothed" line shows a modeled representation of the overall trend

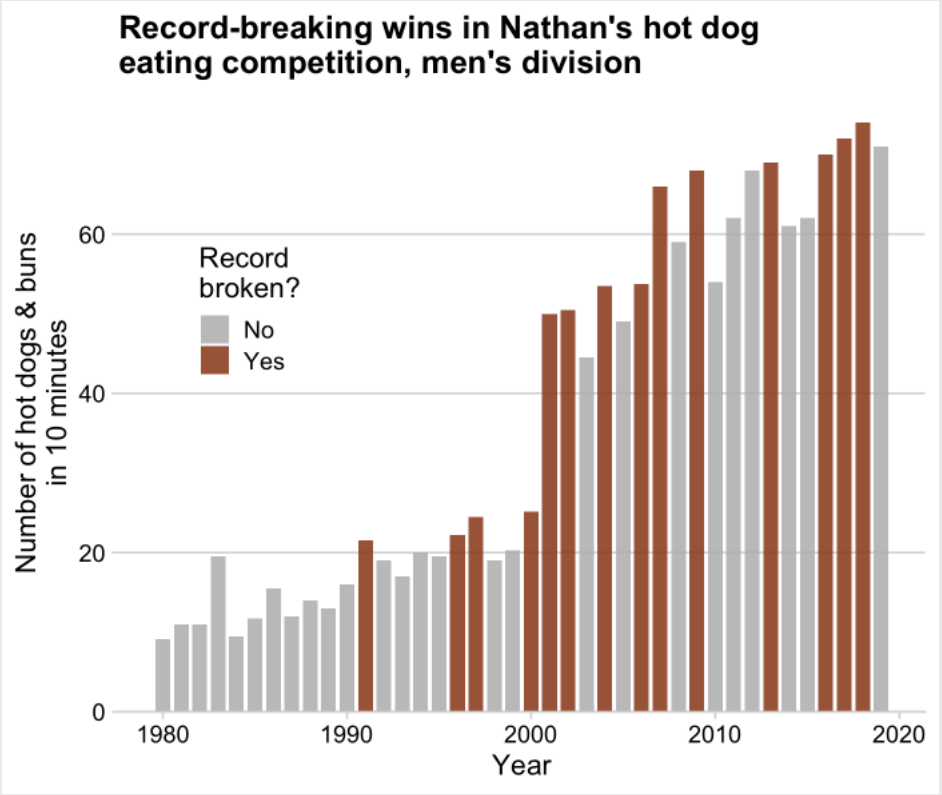


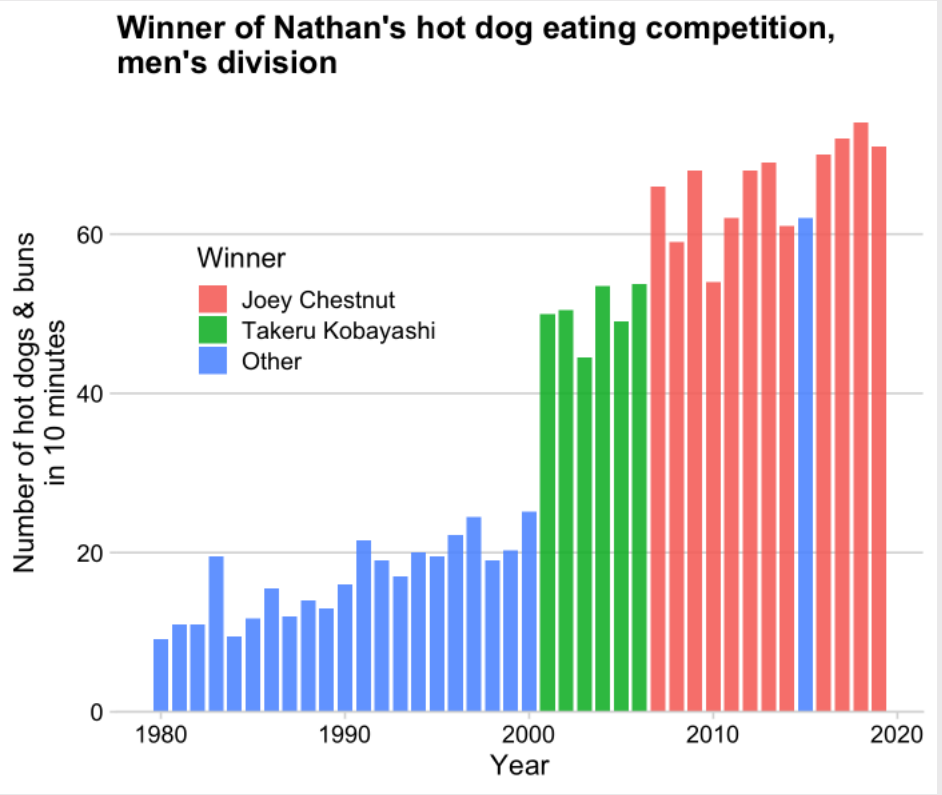

# Smoothed line + points

Putting the smoothed line over the data points helps show whether **outliers** are driving the trend line



Bars are useful when emphasizing the **data points** rather than the **slope between them**

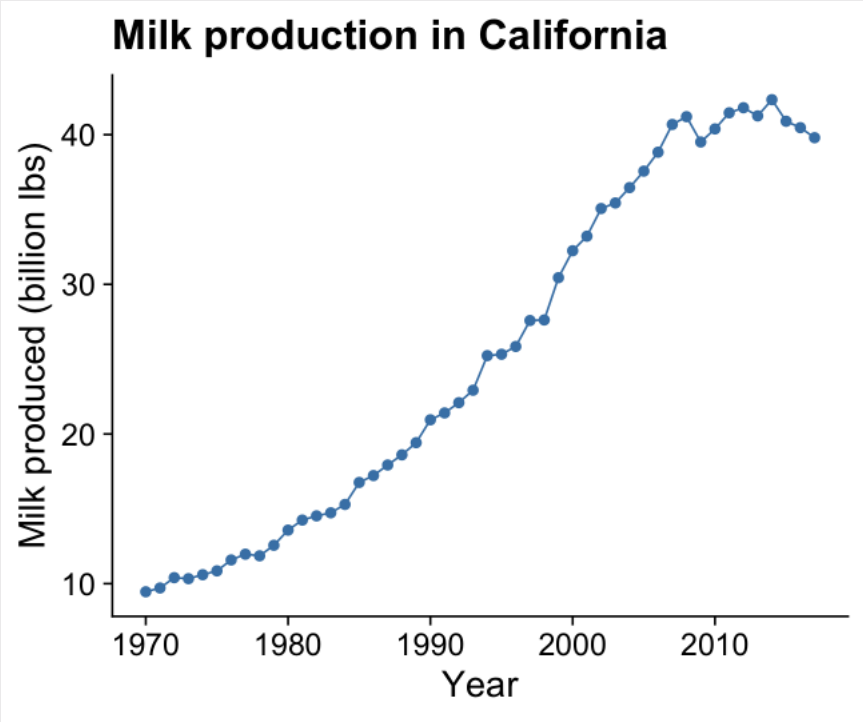


# How to: **Points + line**

Be sure to draw the line first,
then overlay the points

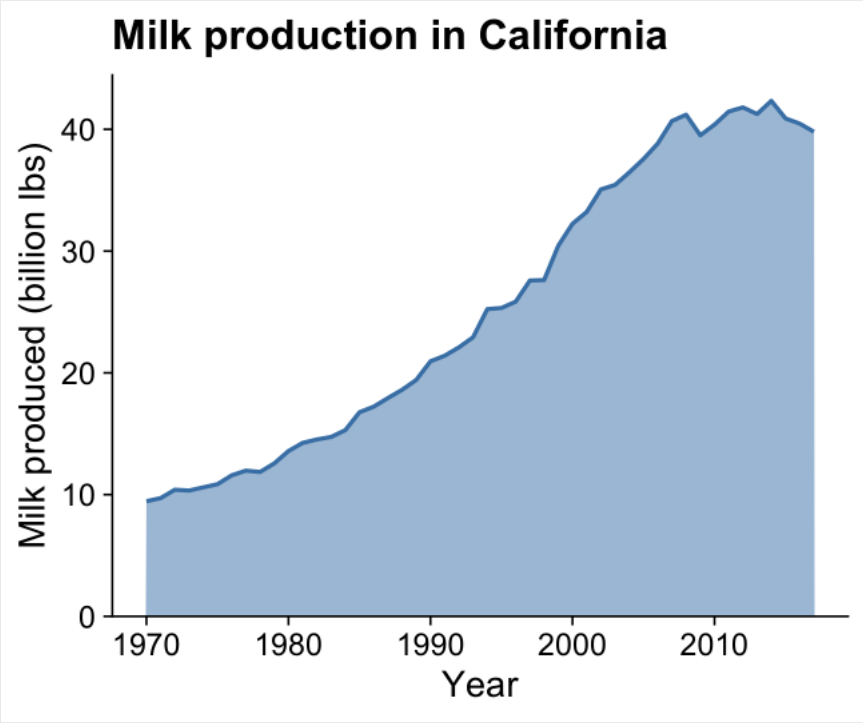
```
ggplot(milk_ca,
    aes(x = year, y = milk_produced)) +
    geom_line(color = 'steelblue', size = 0.5) +
    geom_point(color = 'steelblue', size = 2) +
    theme_half_open(font_size = 18) +
    labs(x = 'Year',
         y = 'Milk produced (billion lbs)',
         title = 'Milk production in California')
```



# How to: **Line + area**

Likewise, draw the area first then overlay the line

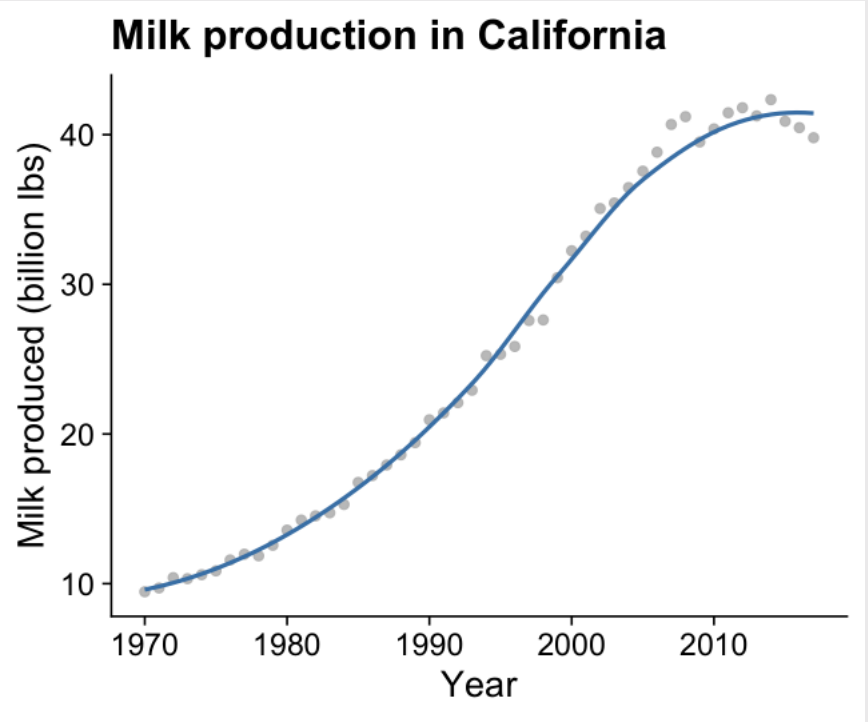
```
ggplot(milk_ca,
    aes(x = year, y = milk_produced)) +
    geom_area(fill = 'steelblue', alpha = 0.5) +
    geom_line(color = 'steelblue', size = 1) +
    scale_y_continuous(
        expand = expansion(mult = c(0, 0.05))) +
    theme_half_open(font_size = 18) +
    labs(x = 'Year',
         y = 'Milk produced (billion lbs)',
         title = 'Milk production in California')
```



# How to: **Smoothed line + points**

Use `alpha` to make points slightly transparent

```
ggplot(milk_ca,
    aes(x = year, y = milk_produced)) +
    geom_point(color = 'grey',
      size = 2, alpha = 0.9) +
    geom_smooth(color = 'steelblue',
      size = 1, se = FALSE) +
    theme_half_open(font_size = 18) +
    labs(
      x = 'Year',
      y = 'Milk produced (billion lbs)',
      title = 'Milk production in California')
```



# Your turn

15:00

Use the `global_temps` data frame to explore ways to visualize the change in average global temperatures.

Consider using:

- points
- lines
- areas
- smoothed lines

```
global_temps <- read_csv(here::here(
  'data', 'nasa_global_temps.csv'))

head(global_temps)
```

```
#> # A tibble: 6 × 3
#>    year meanTemp smoothTemp
#>   <dbl>    <dbl>      <dbl>
#> 1  1880    -0.15      -0.08
#> 2  1881    -0.07      -0.12
#> 3  1882    -0.1       -0.15
#> 4  1883    -0.16      -0.19
#> 5  1884    -0.27      -0.23
#> 6  1885    -0.32      -0.25
```

# Week 9: *Trends*

1. Single Variables
2. Animations

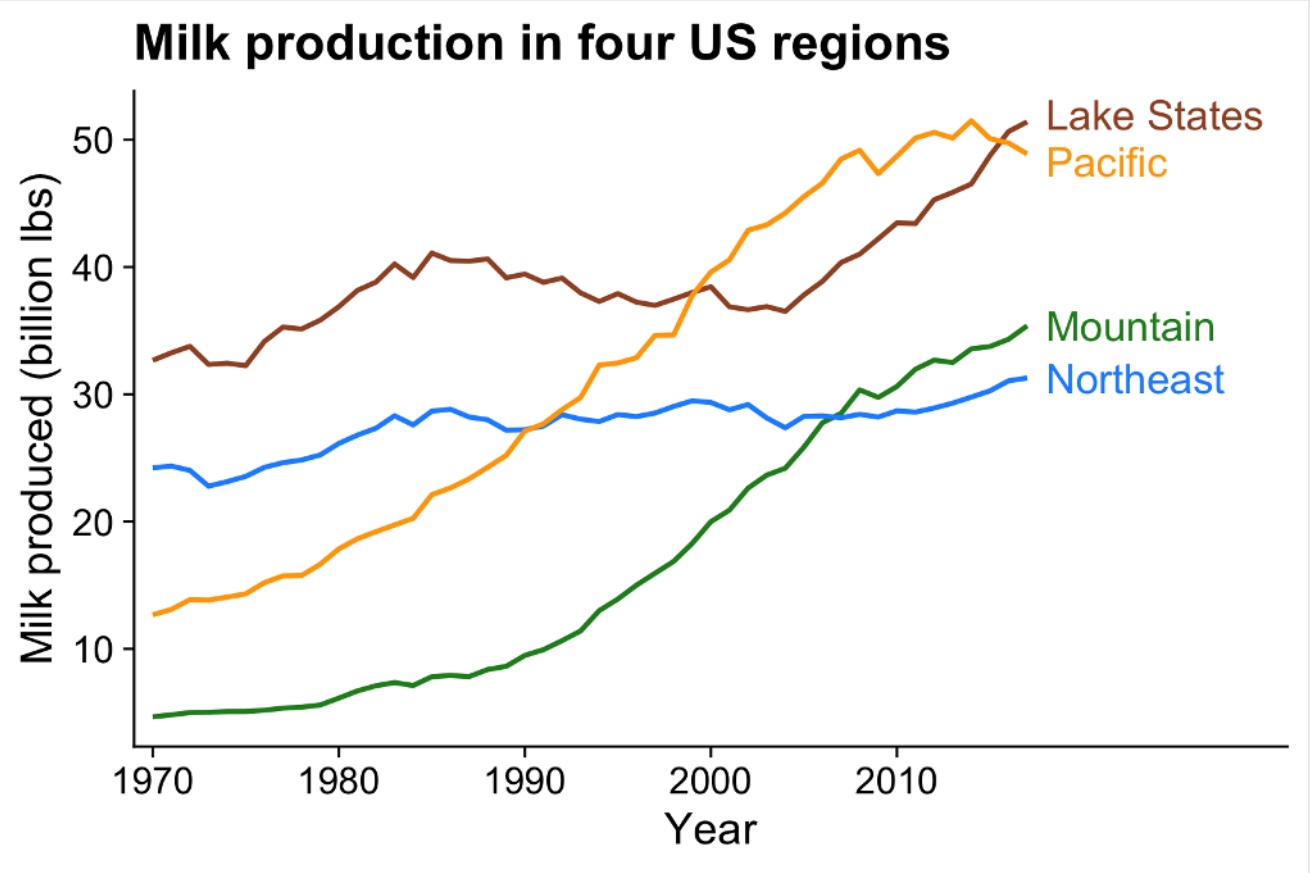
BREAK

3. Multiple Variables

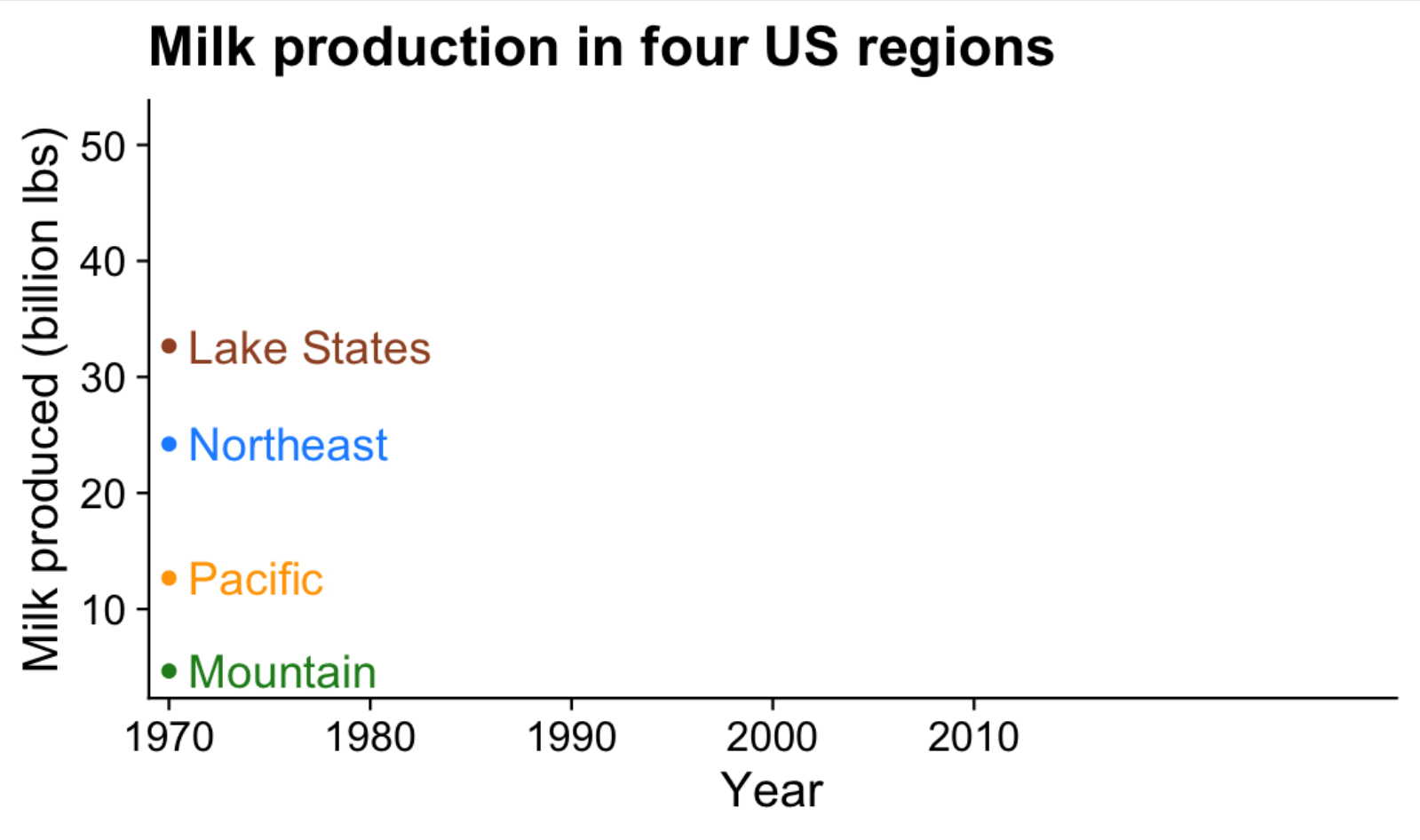
Animation adds emphasis to the **change over time**

...plus it's fun!

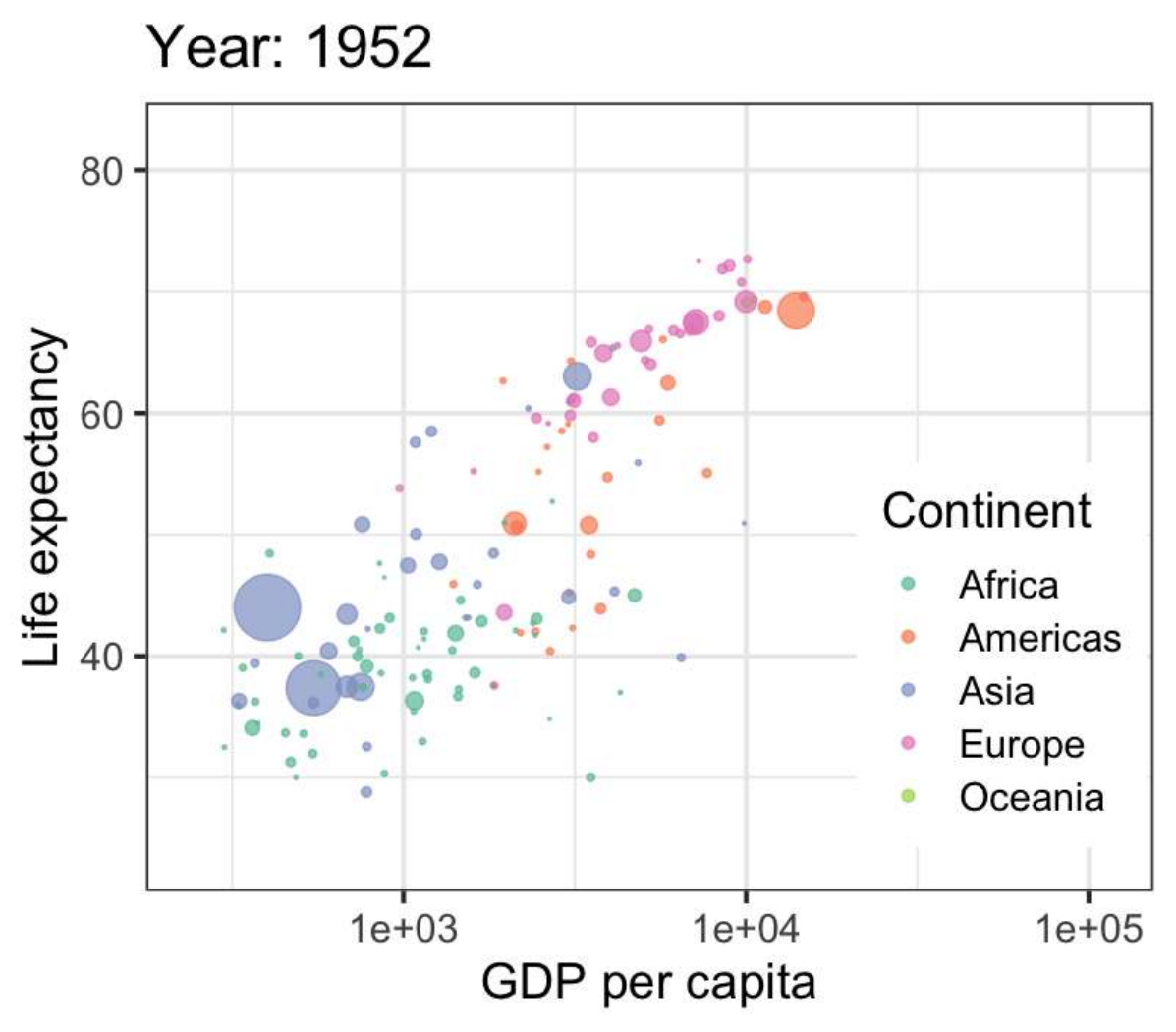
# Static chart



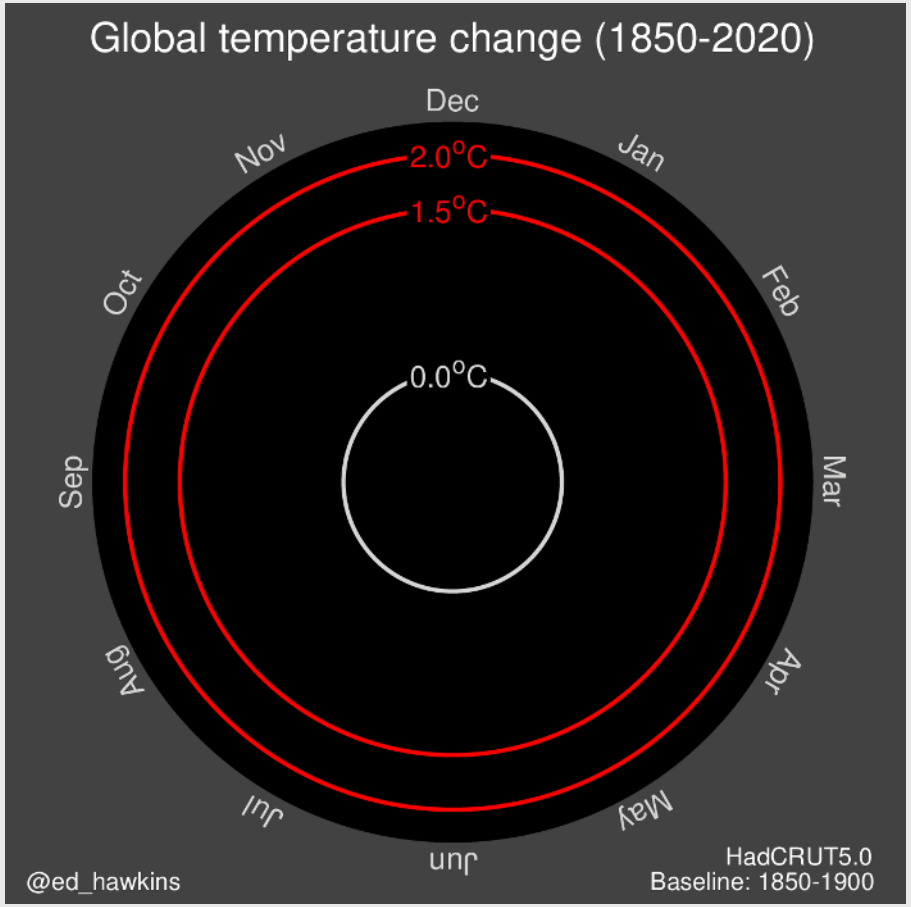
# Animated chart



Animation is particularly helpful for the **time dimension**



# Animation is particularly helpful for the **time dimension**

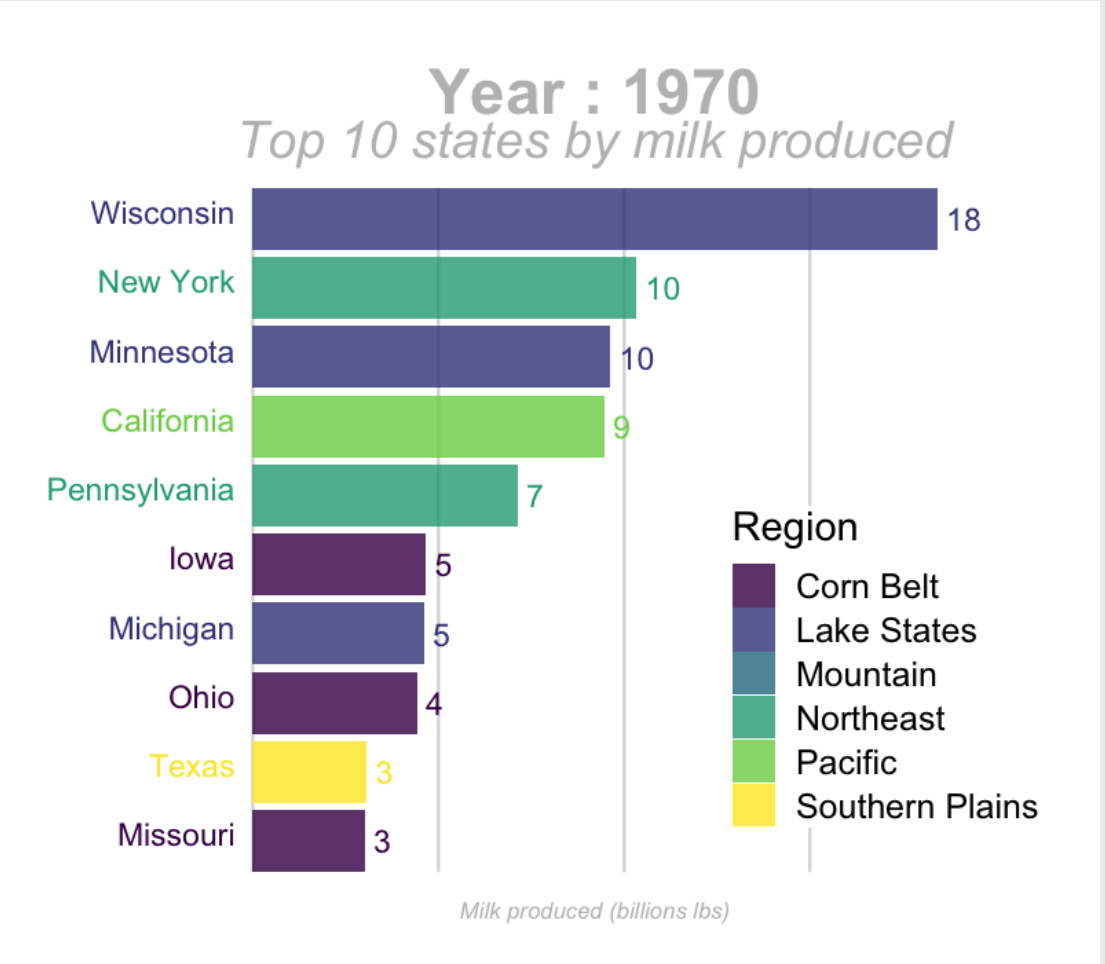



Source: https://www.climate-lab-book.ac.uk/spirals/

# Animation is particularly helpful for the **time dimension**


Financial Times comparison of Flu seasons to COVID-19

# Animation is particularly helpful for the **time dimension**

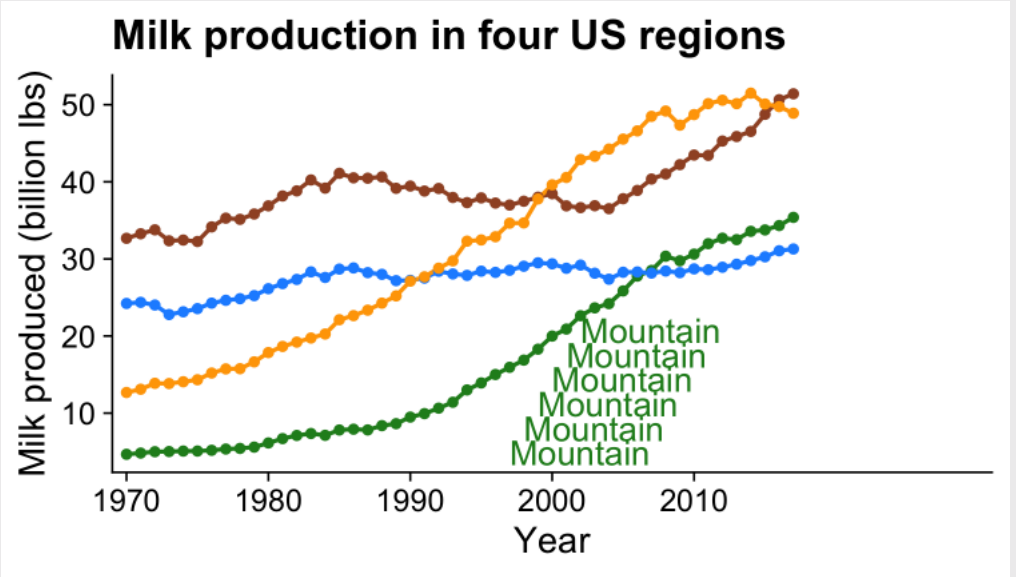



"Bar chart race" of top 10 milk producing states

# How to: **Animate a line plot**

Make a static plot w/labels for each year

```
milk_region_anim_plot <- milk_region %>%
  ggplot(
    aes(x = year, y = milk_produced,
        color = region)) +
  geom_line(size = 1) +
  geom_point(size = 2) +
  geom_text_repel(
    aes(label = region),
    hjust = 0, nudge_x = 1, direction = "y",
    size = 6, segment.color = NA) +
  scale_x_continuous(
    breaks = seq(1970, 2010, 10),
    expand = expansion(add = c(1, 13))) +
  scale_color_manual(values = c(
      'sienna', 'forestgreen', 'dodgerblue', 'orange')) +
  theme_half_open(font_size = 18) +
  theme(legend.position = 'none') +
  labs(x = 'Year',
       y = 'Milk produced (billion lbs)',
       title = 'Milk production in four US regions')

milk_region_anim_plot
```

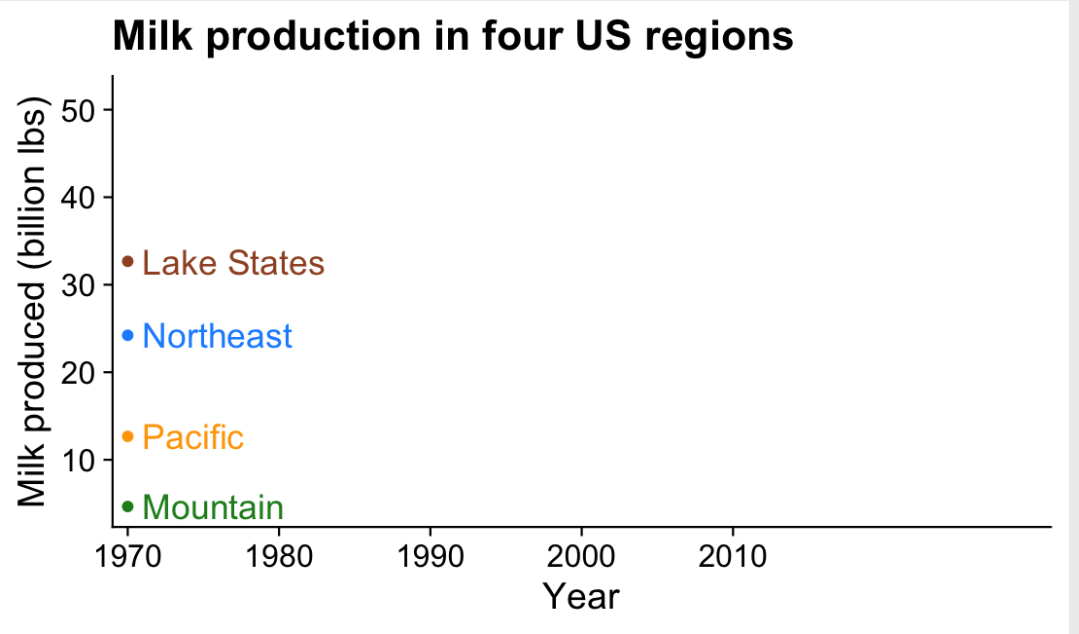


# How to: **Animate a line plot**

Now animate it

**Note the pause at the end!**

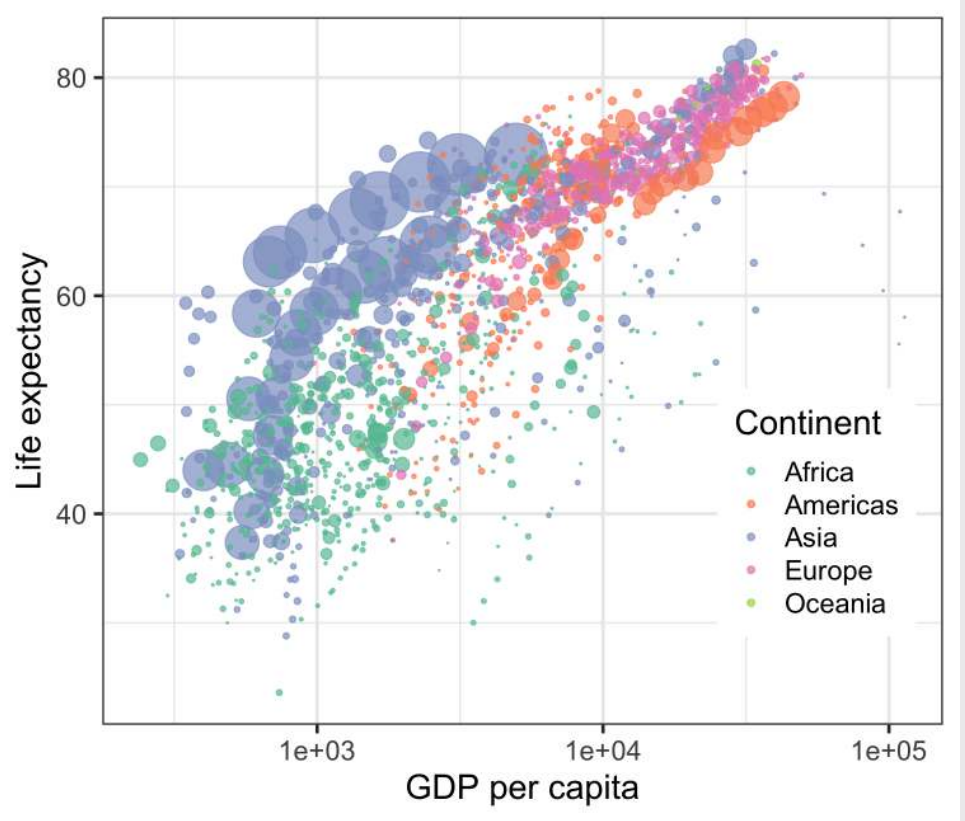
```
library(gganimate)

milk_region_anim <- milk_region_anim_plot +
    transition_reveal(year)

# Render the animation
animate(milk_region_anim,
        end_pause = 15,
        duration = 10,
        width = 1100, height = 650, res = 150,
        renderer = magick_renderer())

# Save last animation
anim_save(here::here(
  'figs', 'milk_region_animation.gif'))
```



# How to: **Change label based on year**

First make a static plot

```
gapminder_anim_plot <- ggplot(gapminder,
  aes(x = gdpPercap, y = lifeExp,
      size = pop, color = continent)) +
  geom_point(alpha = 0.7) +
  scale_size_area(
    guide = FALSE, max_size = 15) +
  scale_color_brewer(palette = 'Set2') +
  scale_x_log10() +
  theme_bw(base_size = 18) +
  theme(legend.position = c(0.85, 0.3)) +
  labs(x = 'GDP per capita',
       y = 'Life expectancy',
       color = 'Continent')

gapminder_anim_plot
```

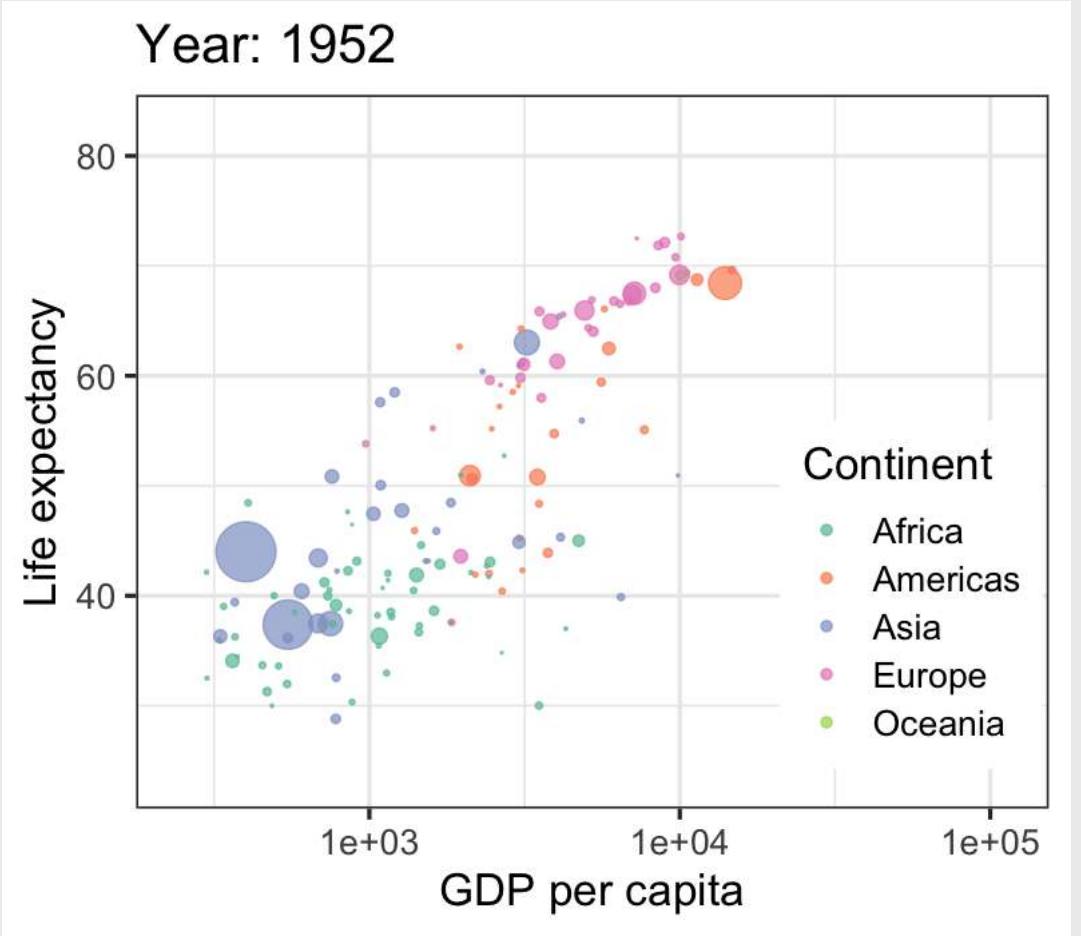


# How to: **Change label based on year**

Now animate it

**Note**: Year must be an integer!

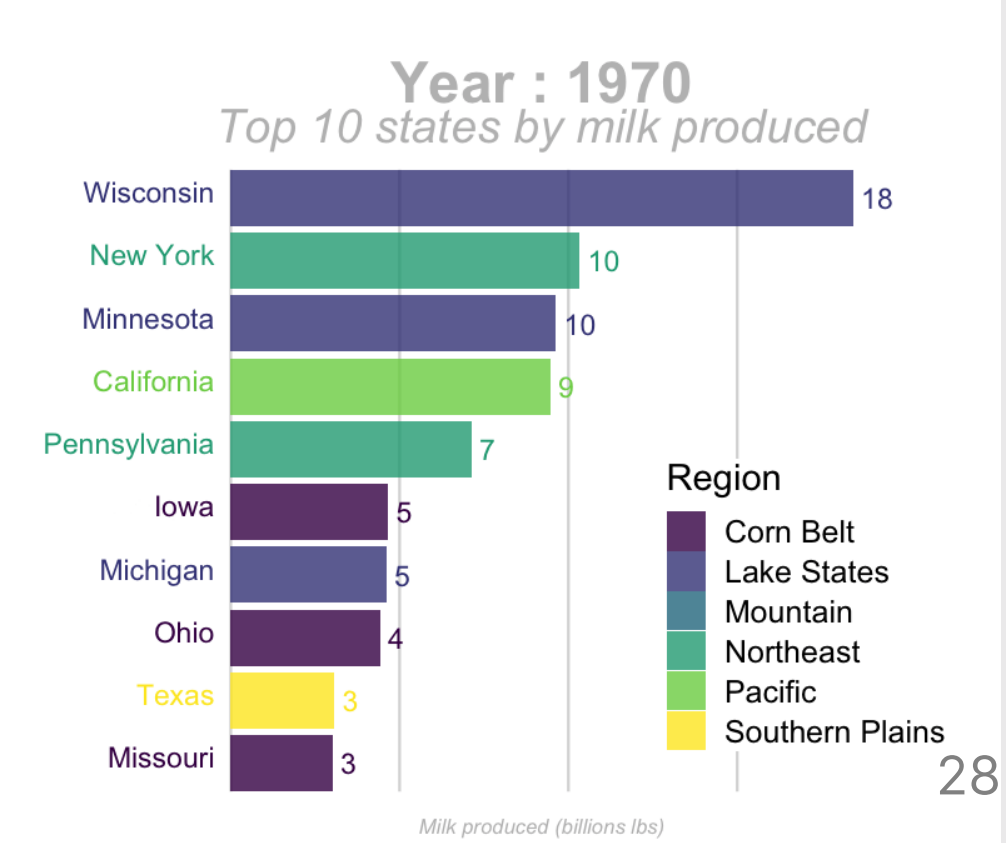
```
gapminder_anim <- gapminder_anim_plot +
  transition_time(year) +
  labs(title = "Year: {frame_time}")

# Render the animation
animate(gapminder_anim, end_pause = 10,
        width = 800, height = 600,
        res = 150,
        renderer = magick_renderer())
```



```
milk_race_anim <- milk_production %>%
    group_by(year) %>%
    mutate(
        rank = rank(-milk_produced),
        Value_rel = milk_produced / milk_produced[rank==1],
        Value_lbl = paste0(' ', round(milk_produced))) %>%
    group_by(state) %>%
    filter(rank <= 10) %>%
    ungroup() %>%
    mutate(year = as.integer(year)) %>%
    ggplot(aes(x = rank, group = state,
               fill = region, color = region)) +
    geom_tile(aes(y = milk_produced / 2,
                  height = milk_produced),
              width = 0.9, alpha = 0.8, color = NA) +
    geom_text(aes(y = 0, label = paste(state, " ")),
              vjust = 0.2, hjust = 1) +
    geom_text(aes(y = milk_produced, label = Value_lbl),
              hjust = 0) +
    coord_flip(clip = 'off', expand = FALSE) +
    scale_y_continuous(labels = scales::comma) +
    scale_fill_viridis(discrete = TRUE) +
    scale_color_viridis(discrete = TRUE) +
    scale_x_reverse() +
    guides(color = FALSE) +
    theme_minimal_vgrid() +
    theme(
        axis.line = element_blank(),
        axis.text = element_blank(),
        axis.ticks = element_blank(),
        axis.title = element_blank(),
        legend.position = c(0.7, 0.3),
        legend.background = element_rect(fill = 'white'),
        plot.title = element_text(
          size = 22, hjust = 0.5, face = 'bold',
          colour = 'grey', vjust = -1),
        plot.subtitle = element_text(
          size = 18, hjust = 0.5,
          face = 'italic', color = 'grey'),
        plot.caption = element_text(
          size = 8, hjust = 0.5,
          face = 'italic', color = 'grey'),
          plot.margin = margin(0.5, 2, 0.5, 3, 'cm')) +
    transition_time(year) +
    view_follow(fixed_x = TRUE) +
    labs(title    = 'Year : {frame_time}',
         subtitle = 'Top 10 states by milk produced',
         fill     = 'Region',
         caption  = 'Milk produced (billions lbs)')
```

# Making a bar chart race (tutorial here)

```
animate(milk_race_anim, duration = 17, end_pause = 15,
        width = 800, height = 700, res = 150,
        renderer = magick_renderer())
```



# Resources

More animation options:

- More on gapminder + line charts
- Customizing the animation

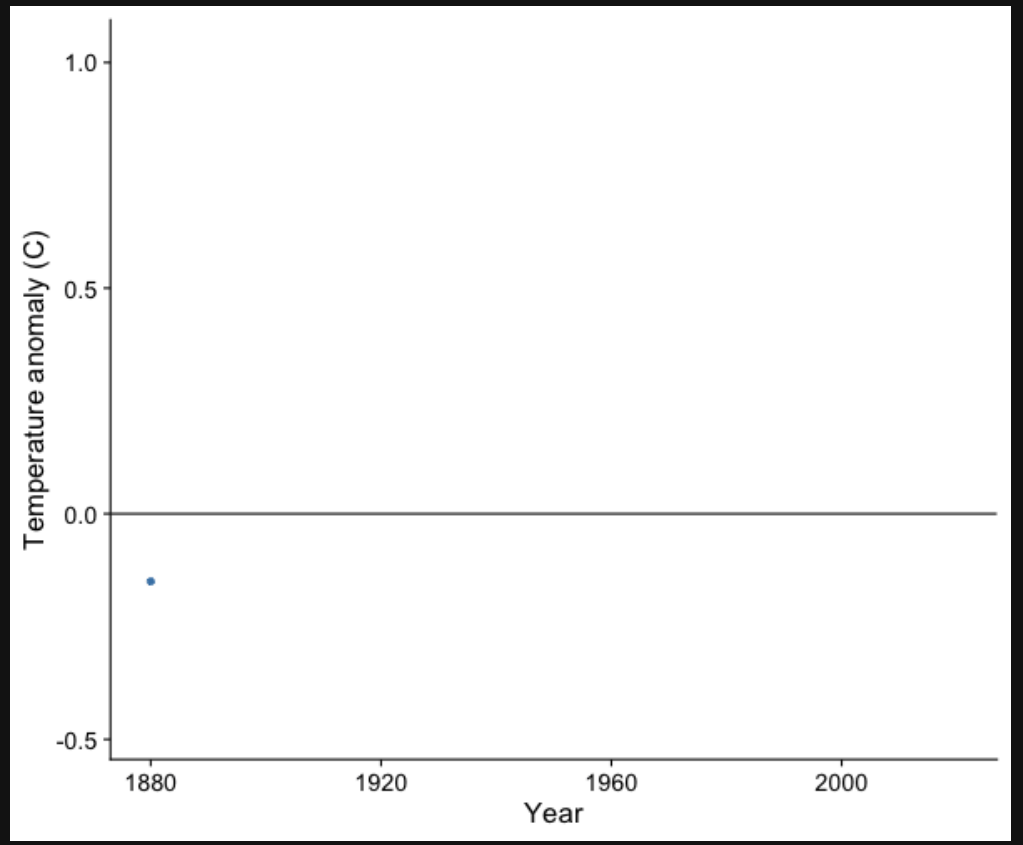
# Your turn

15:00

Use the `global_temps` data frame to explore ways to *animate* the change in average global temperatures.

Consider using:

- points
- lines
- areas



# Break!

Stand up, Move around, Stretch!

05:00

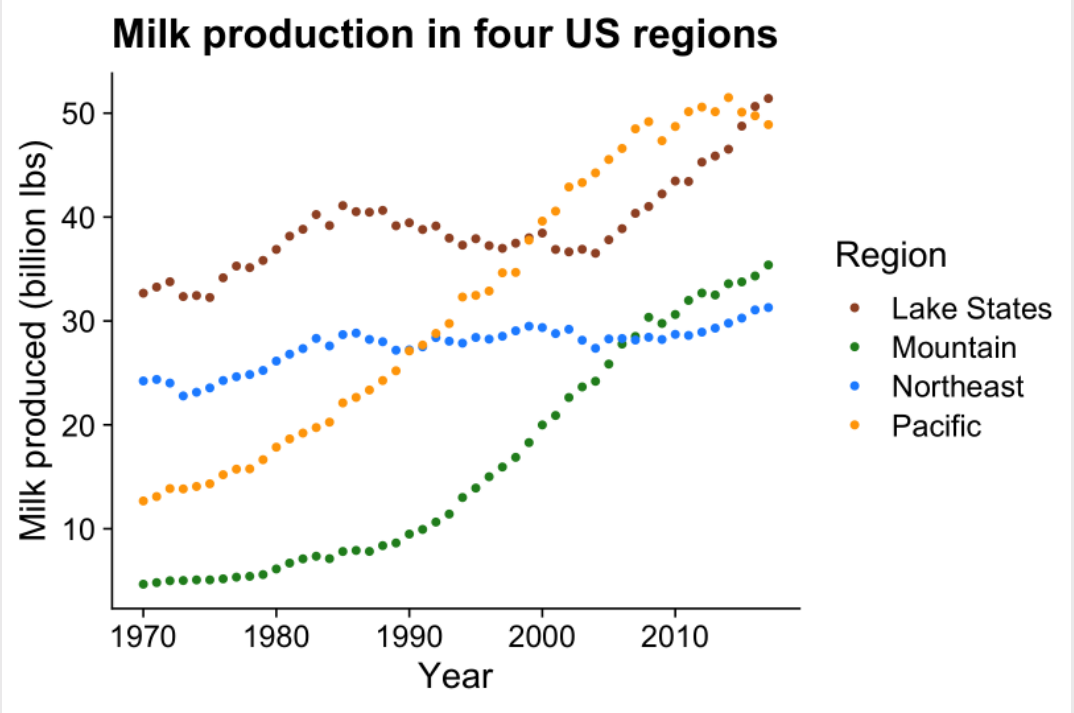
# Week 9: *Trends*

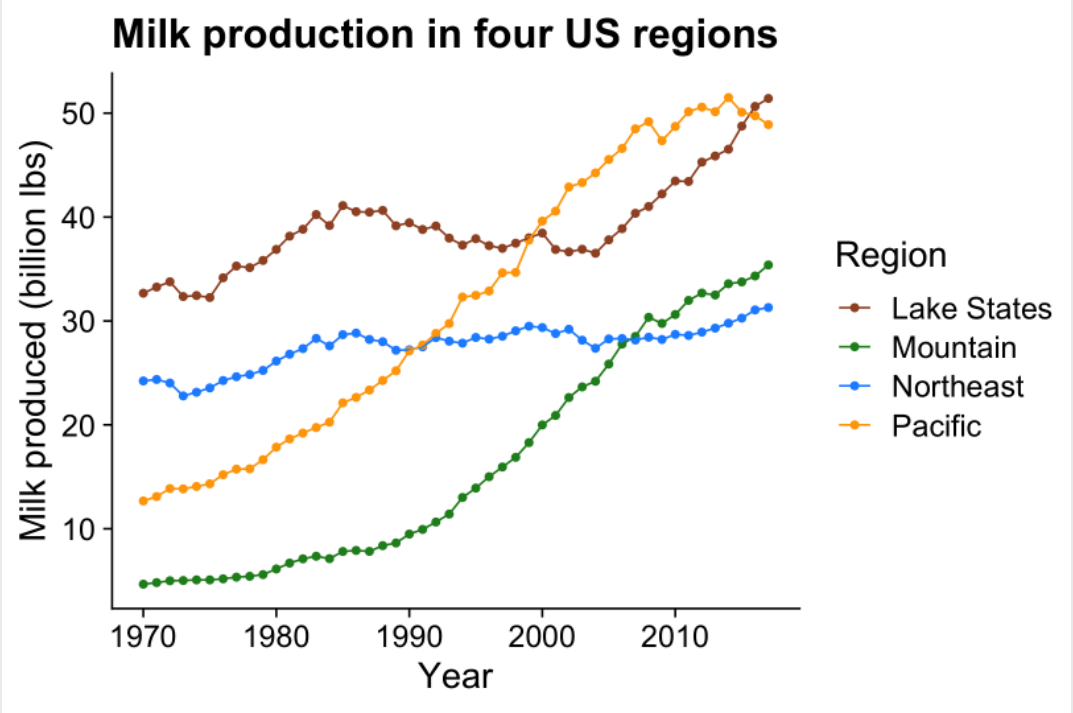
1. Single Variables
2. Animations

BREAK

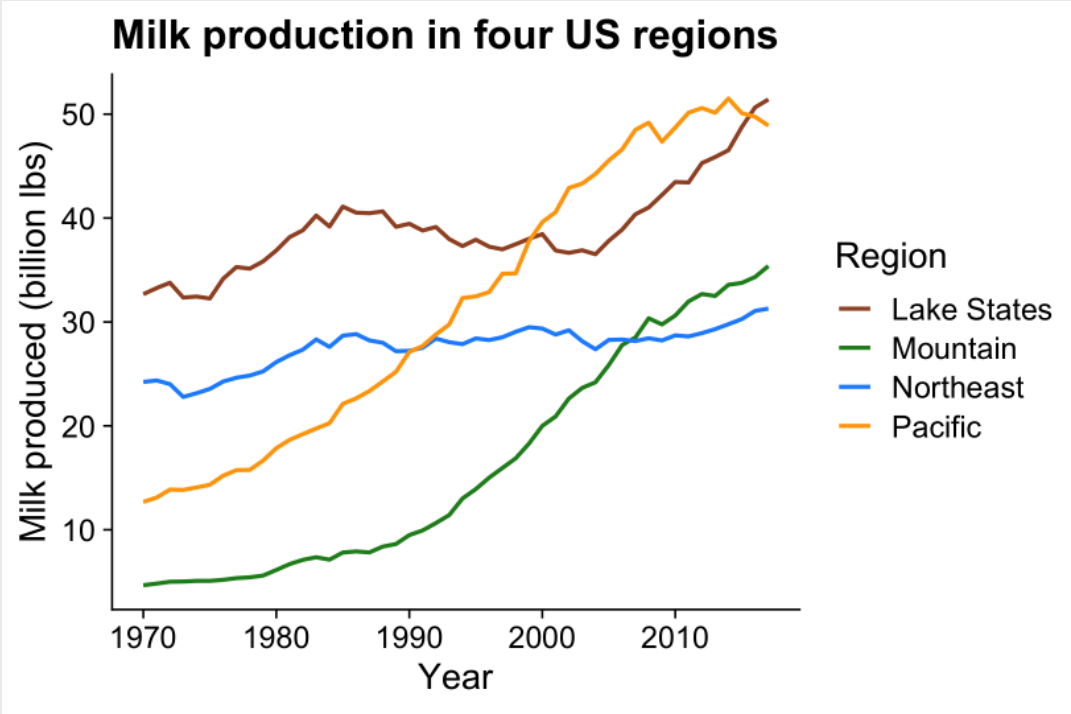
3. Multiple Variables

# With multiple categories, points & lines can get messy

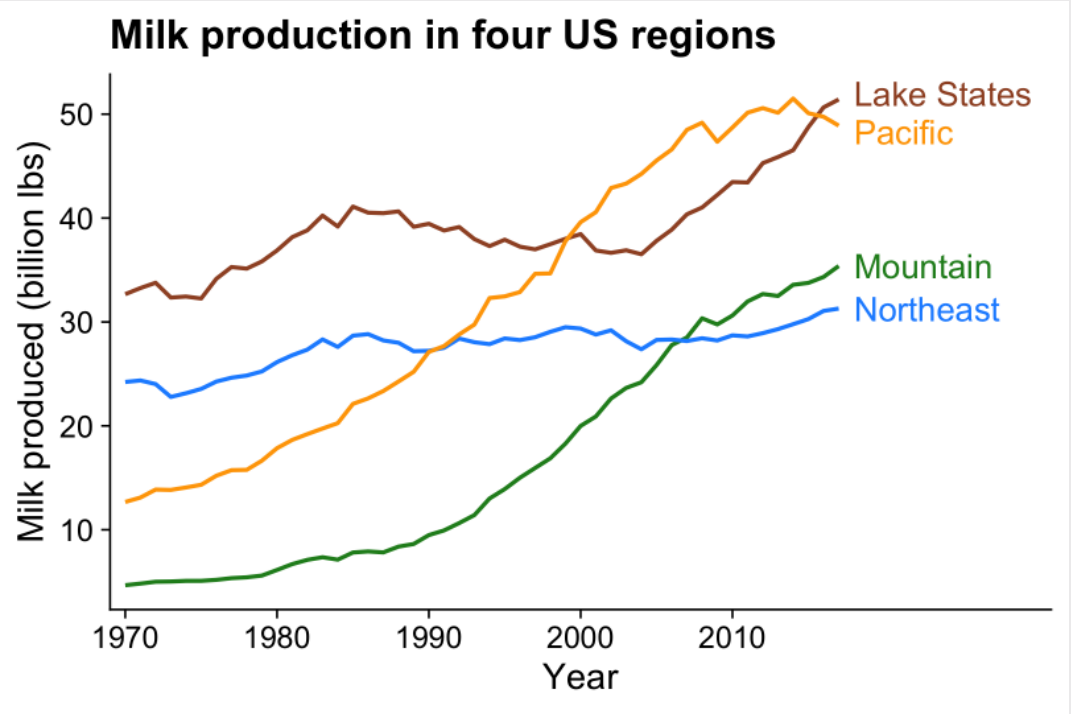


**Better**: Lines alone makes distinguishing trends easier

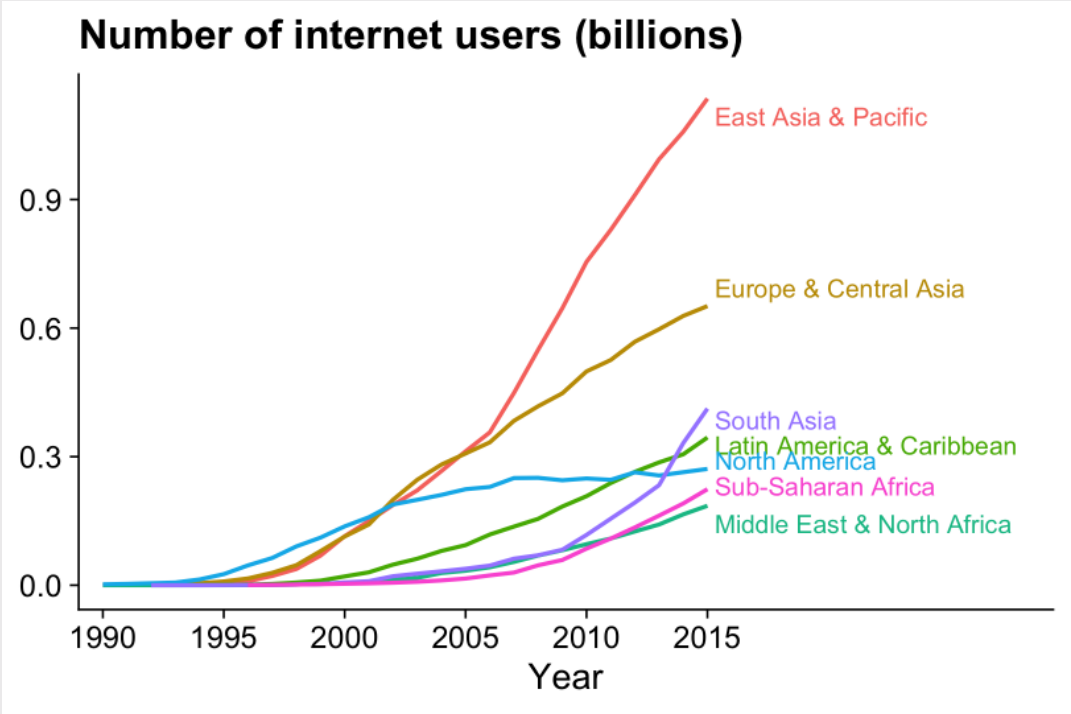



**Even better**: Directly label lines to remove legend

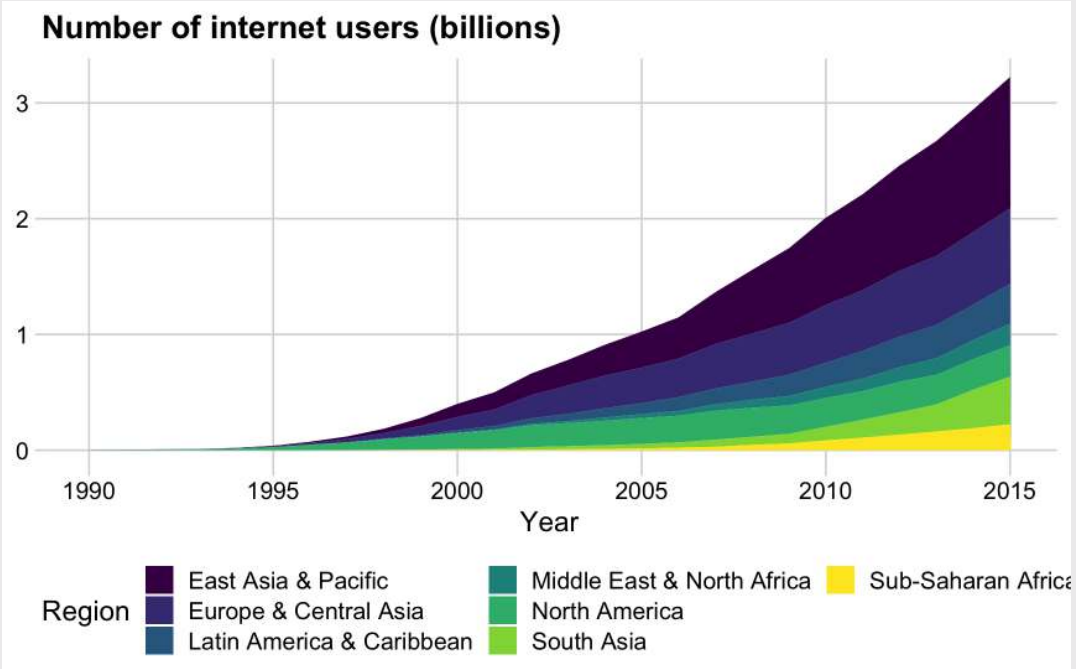


If goal is to communicate the **overall / total** trend, consider a stacked area chart

Highlights **regional** trends



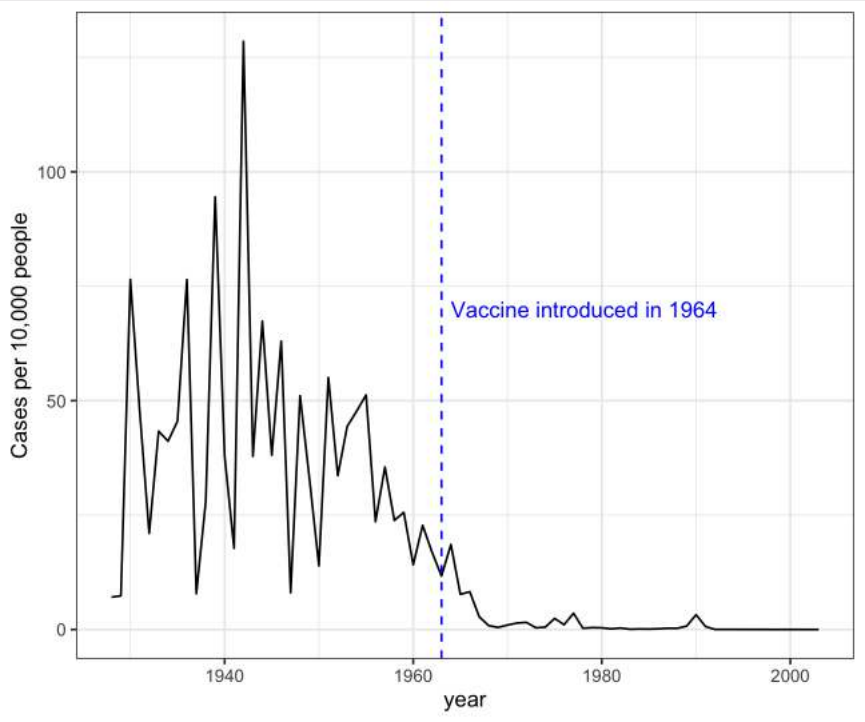

Highlights **overall / total** trend



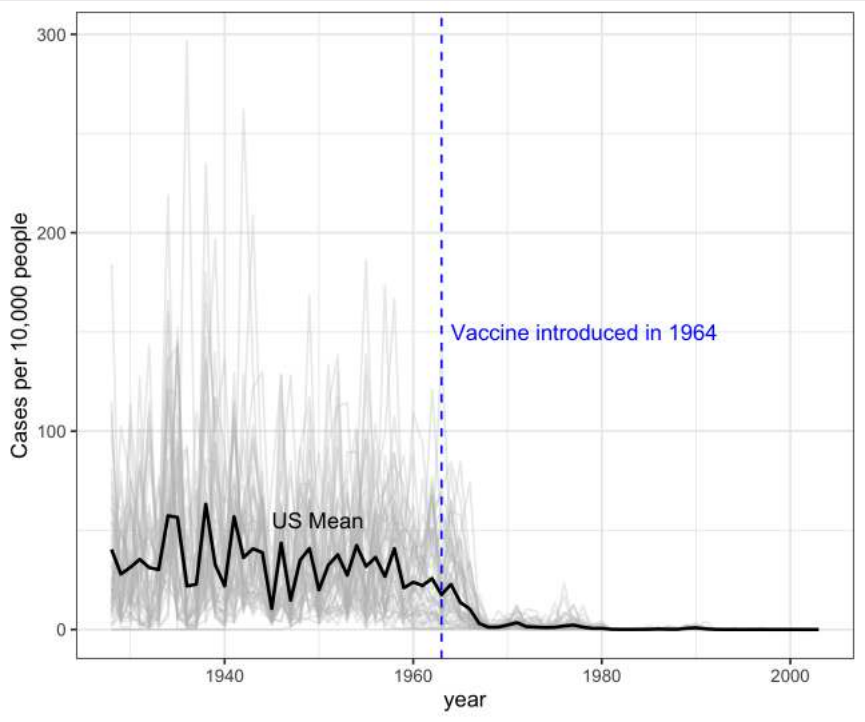
If you have **lots** of categories:

# 1) Plot all the data with the average highlighted

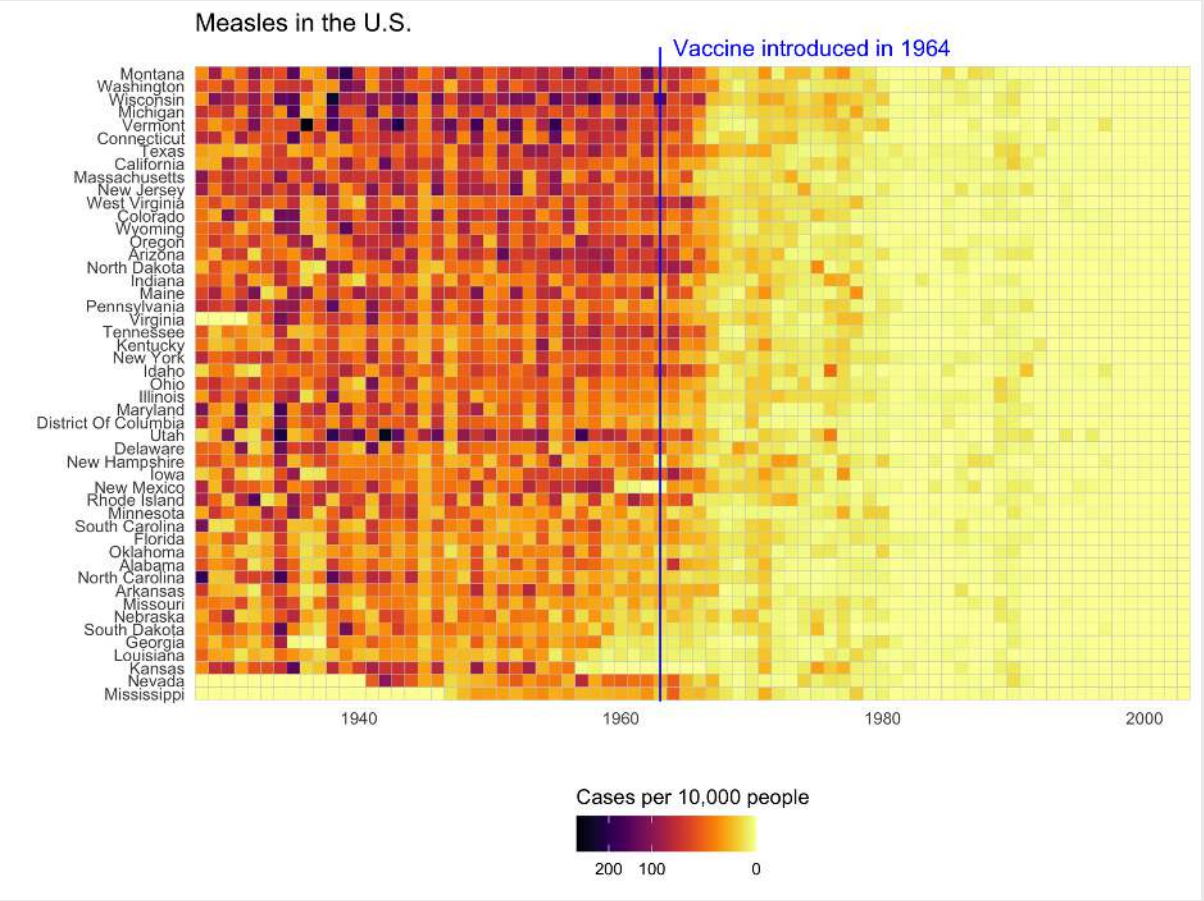
Measles in **California**




Measles in **all 50 states**

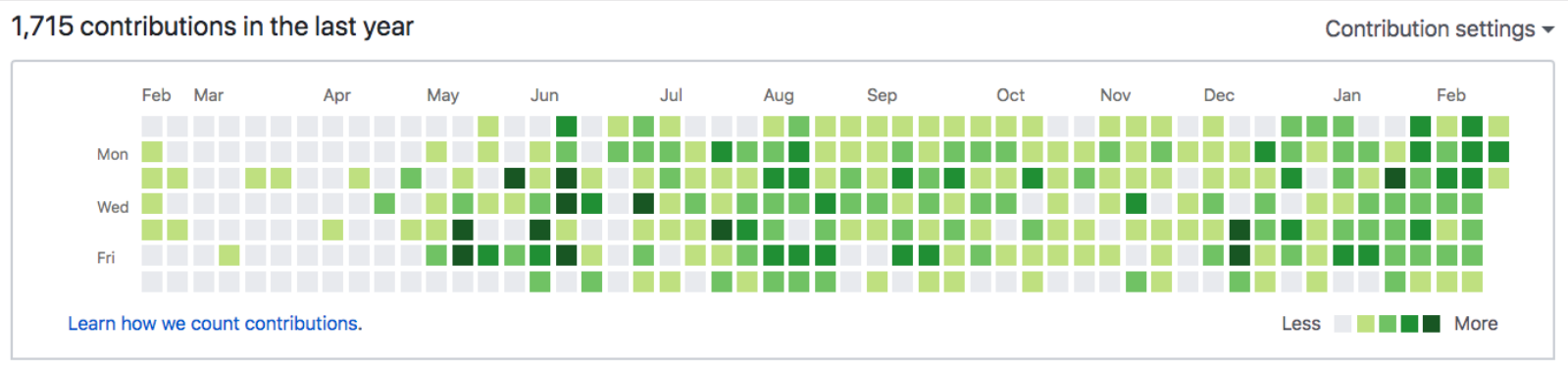


If you have **lots** of categories:
1) Plot all the data with the average highlighted
**2) Plot all the data with a heat map**



# Heatmaps are great for multiple divisions of time

My activity on Github:

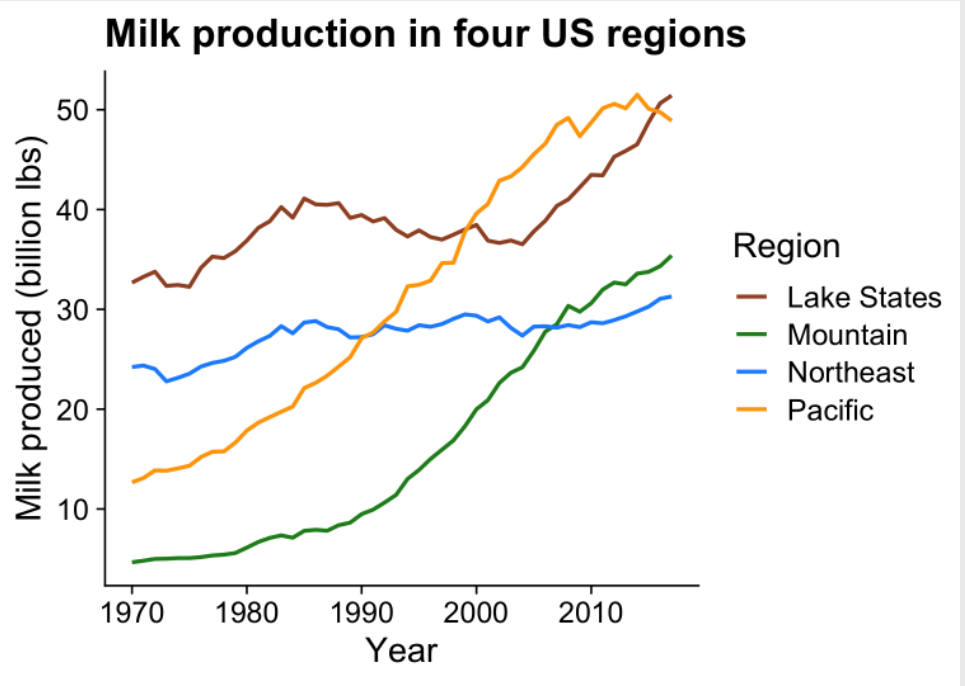



Check out this heat map on Traffic fatalities

Make the basic line chart first

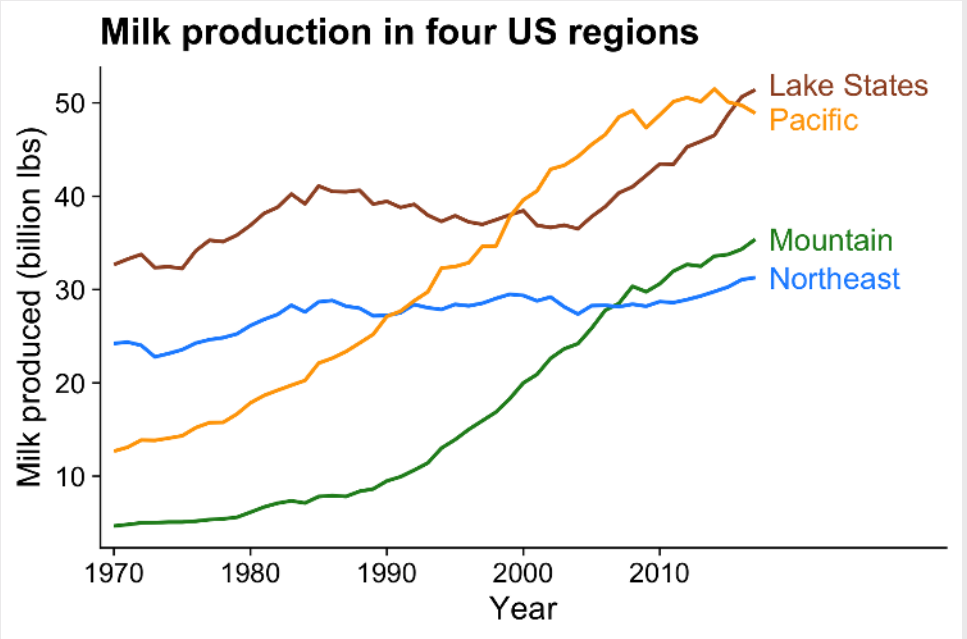
```
# Format the data
milk_region <- milk_production %>%
  filter(region %in% c(
    'Pacific', 'Northeast', 'Lake States', 'Mountain')) %>%
  group_by(year, region) %>%
  summarise(milk_produced = sum(milk_produced)) %>%
  ungroup()

# Make the line chart
ggplot(milk_region,
  aes(x = year, y = milk_produced,
      color = region)) +
  geom_line(size = 1) +
  scale_color_manual(values = c(
    'sienna', 'forestgreen', 'dodgerblue', 'orange')) +
  theme_half_open(font_size = 18) +
  labs(
    x     = 'Year',
    y     = 'Milk produced (billion lbs)',
    color = 'Region',
    title = 'Milk production in four US regions')
```

# How to:
# **Directly label lines**



```r
# Format the data
milk_region <- milk_production %>%
  filter(region %in% c(
    'Pacific', 'Northeast', 'Lake States', 'Mountain')) %>%
  group_by(year, region) %>%
  summarise(milk_produced = sum(milk_produced)) %>%
  ungroup()

# Make the line plot
ggplot(milk_region,
  aes(x = year, y = milk_produced,
      color = region)) +
  geom_line(size = 1) +
  # Add labels
  geom_text_repel(
    data = milk_region %>%
      filter(year == max(year)),
    aes(label = region),
      hjust = 0, nudge_x = 1, direction = "y",
      size = 6, segment.color = NA) +
  # Create space for labels on right side
  scale_x_continuous(
    breaks = seq(1970, 2010, 10),
    expand = expansion(add = c(1, 13))) +
  scale_color_manual(values = c(
    'sienna', 'forestgreen', 'dodgerblue', 'orange')) +
  theme_half_open(font_size = 18) +
  # Remove legend
  theme(legend.position = 'none') +
  labs(x = 'Year',
       y = 'Milk produced (billion lbs)',
       title = 'Milk production in four US regions')
```

# How to:
# **Directly label lines**

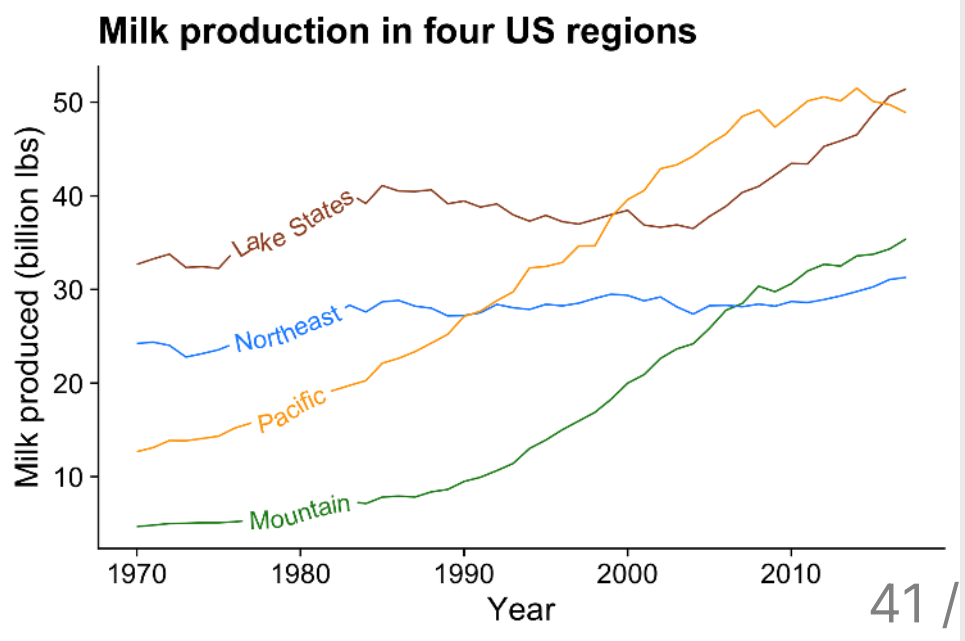


```r
library(geomtextpath)

# Format the data
milk_production %>%
  filter(region %in% c(
    'Pacific', 'Northeast', 'Lake States', 'Mountain')) %>%
  group_by(year, region) %>%
  summarise(milk_produced = sum(milk_produced)) %>%
  ungroup() %>%

# Make the line plot
  ggplot() +
  geom_textline(
    aes(
      x = year, y = milk_produced,
      color = region, label = region, group = region),
    size = 5, hjust = 0.15
  ) +
  scale_color_manual(values = c(
    'sienna', 'forestgreen', 'dodgerblue', 'orange')) +
  theme_half_open(font_size = 18) +
  # Remove legend
  theme(legend.position = 'none') +
  labs(x = 'Year',
       y = 'Milk produced (billion lbs)',
       title = 'Milk production in four US regions')
```

# Alternative: **Embed the labels!**

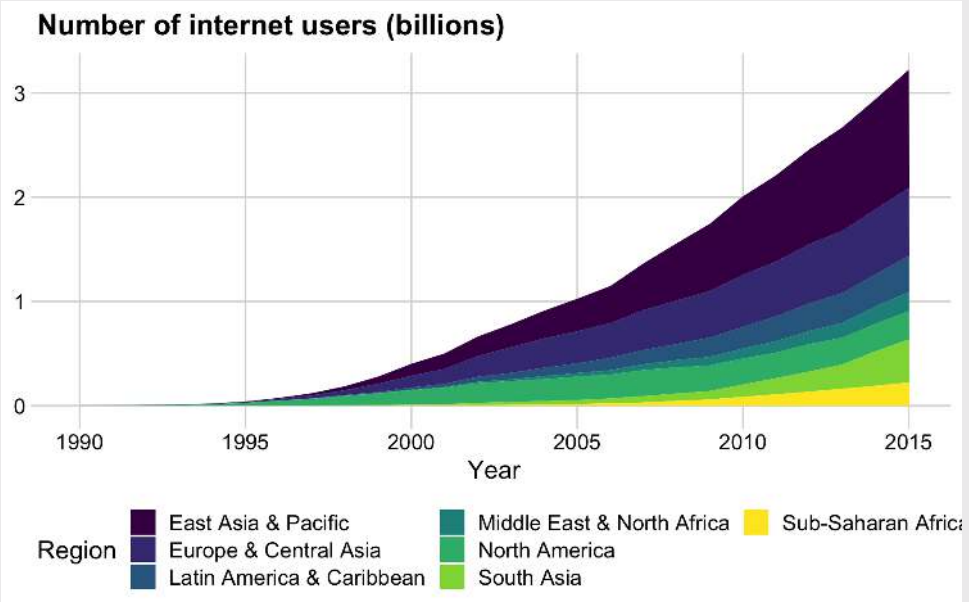
Use `{geomtextpath}` package

(see this SO issue for other strategies)



# How to: **Stacked area**

```
internet_region %>%
  mutate(numUsers = numUsers / 10^9) %>%
  ggplot() +
  geom_area(aes(x = year, y = numUsers,
        fill = region)) +
  # Nice colors from "viridis" library:
  scale_fill_viridis(discrete = TRUE) +
  # Sort the legend into 3 rows
  guides(fill = guide_legend(
    nrow = 3, byrow = FALSE)) +
  theme_minimal_grid(font_size = 15) +
  theme(legend.position = 'bottom') +
  labs(
    x = 'Year',
    y = NULL,
    fill = 'Region',
    title = 'Number of internet users (billions)')
```



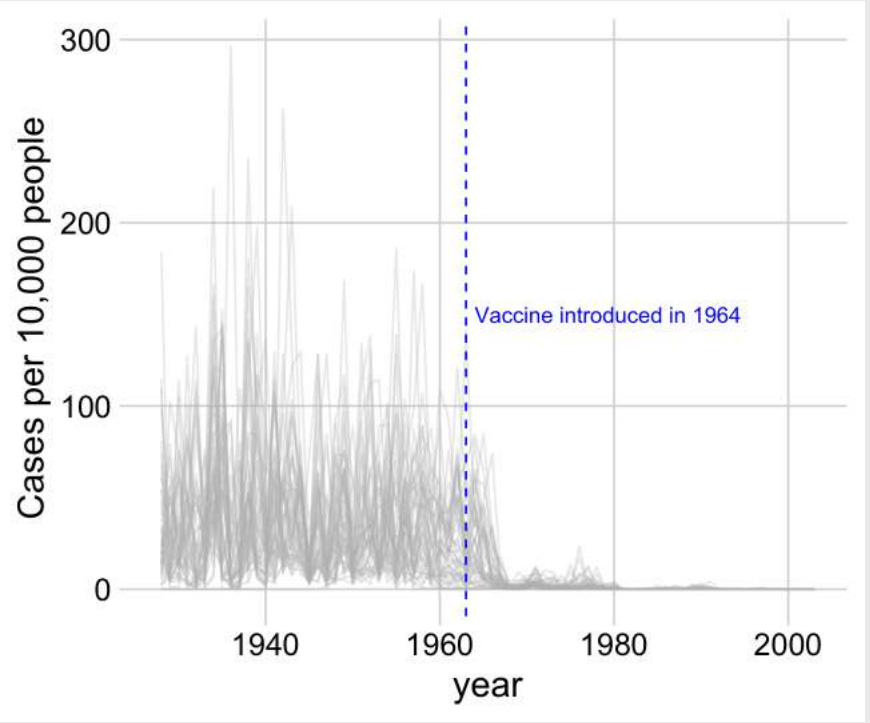
# How to:
# **Average line overlay**

## Format the data

```
# Format the data
measles <- us_diseases %>%
  filter(
    disease == 'Measles',
    !state %in% c("Hawaii", "Alaska")) %>%
  mutate(
    rate = (count / population) * 10000,
    state = fct_reorder(state, rate)) %>%
  # Compute annual mean rate across all states
  group_by(year) %>%
  mutate(
    mean_rate = sum(count) / sum(population) * 10000)
```

## Make all the state lines in light grey color

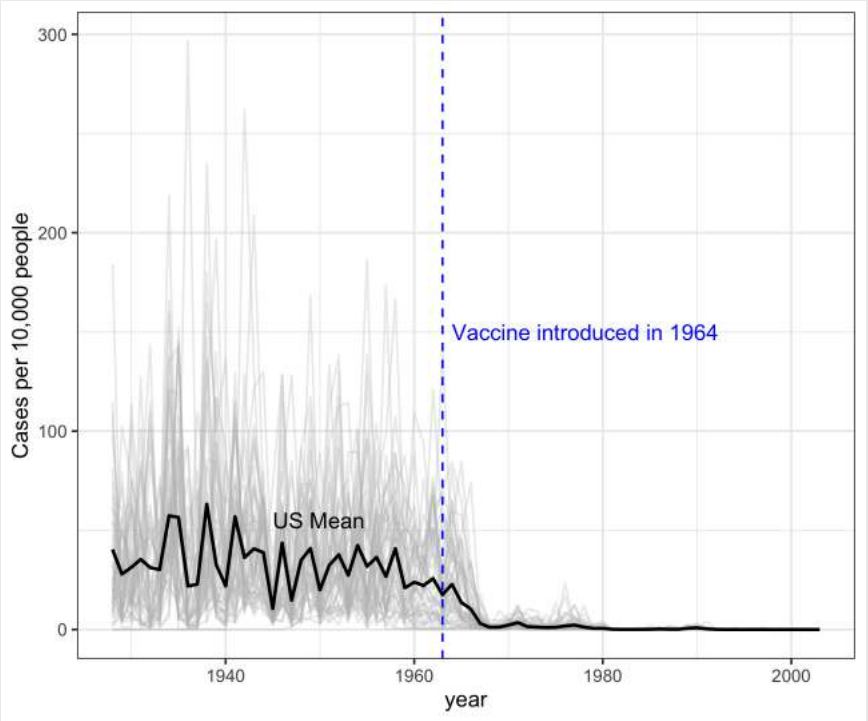
```
ggplot(measles) +
    geom_line(aes(x = year, y = rate, group = state),
              color = 'grey', alpha = 0.3) +
    # Add reference line & label:
    geom_vline(xintercept = 1963, col = 'blue',
               linetype = 'dashed') +
    annotate('text', x = 1964, y = 150, hjust = 0,
             label = 'Vaccine introduced in 1964',
             color = 'blue') +
    theme_minimal_grid(font_size = 18) +
    labs(y = 'Cases per 10,000 people')
```



Now overlay the annual mean line

```
ggplot(measles) +
  geom_line(
    aes(x = year, y = rate, group = state),
    color = 'grey', alpha = 0.3) +
  geom_line(
    aes(x = year, y = mean_rate), size = 0.8) +
  # Add US mean label
  annotate(
    'text', x = 1945, y = 55, hjust = 0,
    label = 'US Mean') +
  # Add reference line & label
  geom_vline(xintercept = 1963, col = 'blue',
             linetype = 'dashed') +
  annotate('text', x = 1964, y = 150, hjust = 0,
           label = 'Vaccine introduced in 1964',
           color = 'blue') +
  theme_minimal_grid(font_size = 18) +
  labs(y = 'Cases per 10,000 people')
```

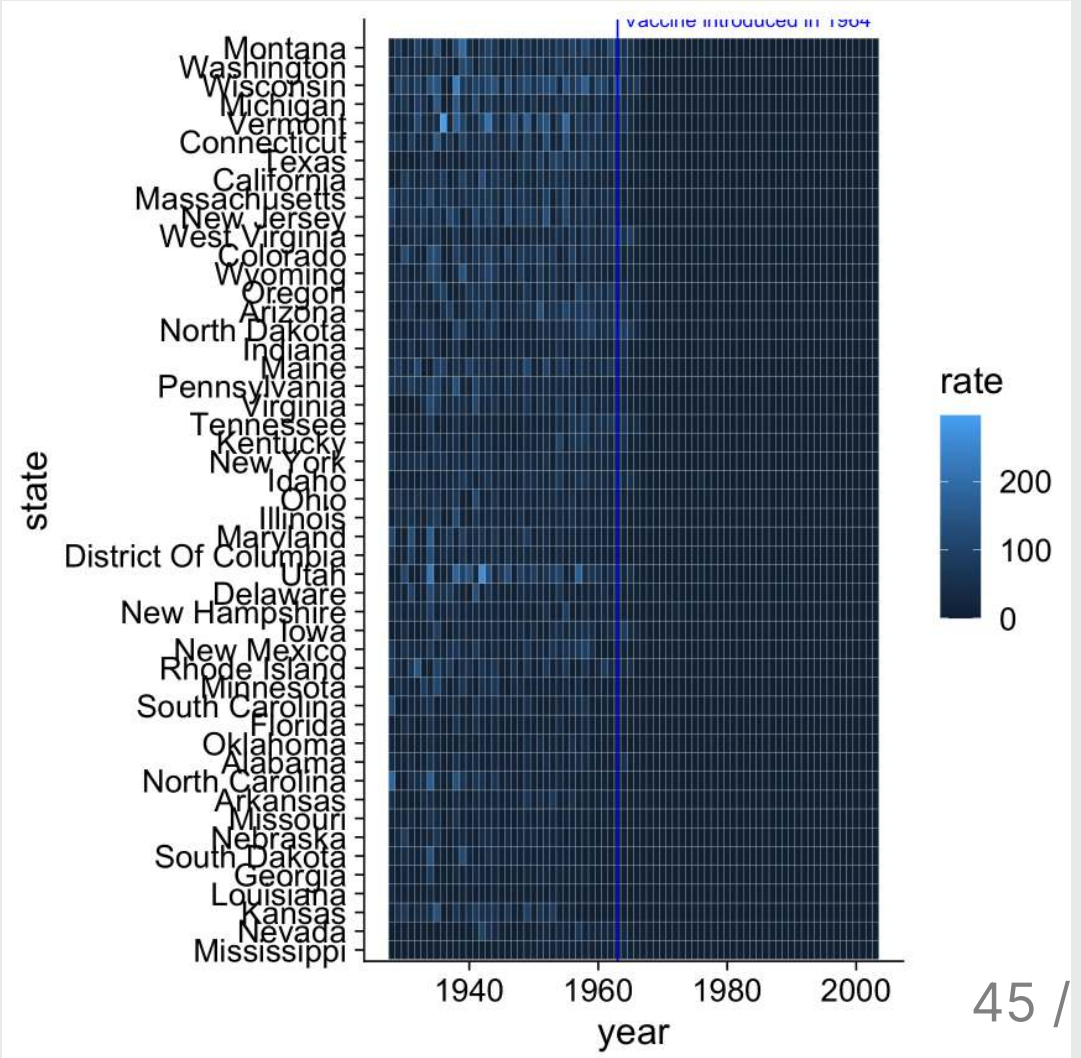
# How to:
# **Average line overlay**



# How to: **Heat map**

Create main grid with `geom_tile()`

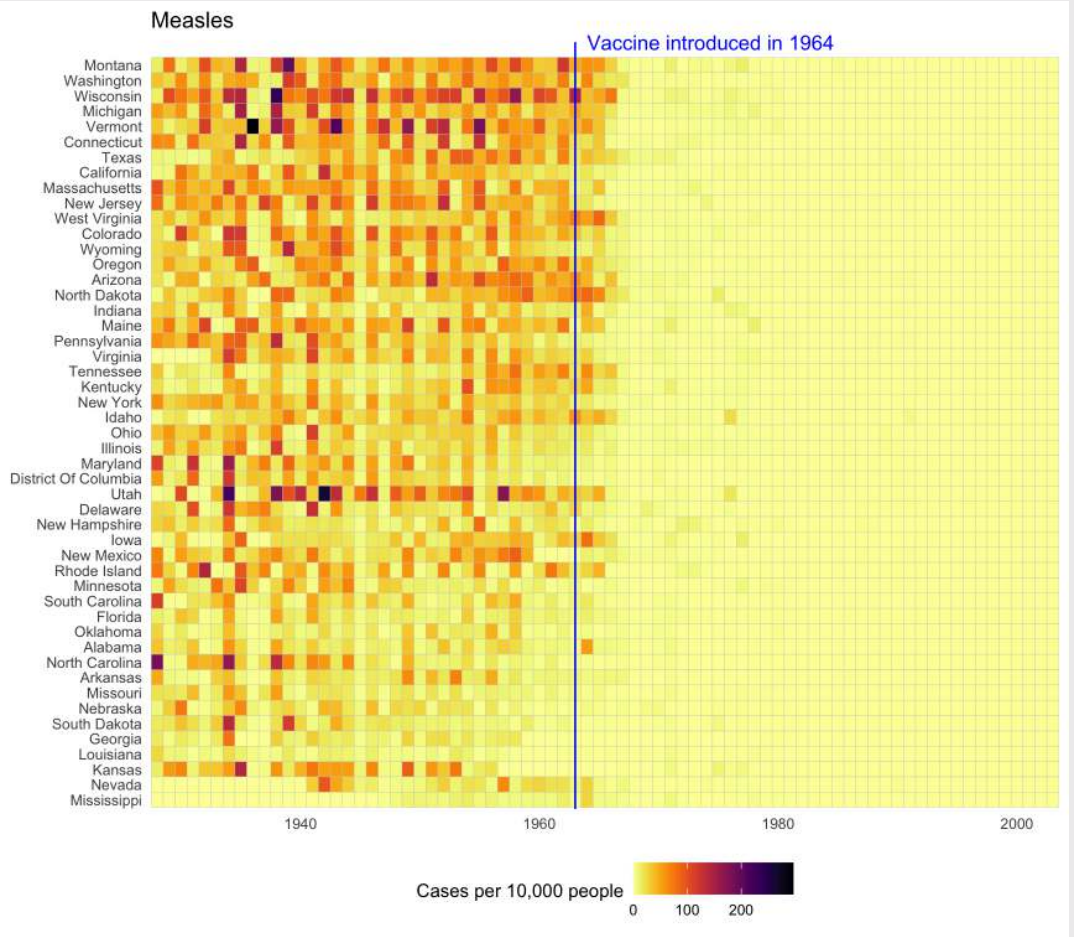
```
ggplot(measles) +
  geom_tile(
    aes(x = year, y = state, fill = rate),
    color = 'grey80') +
  # Add reference line & label
  geom_vline(
    xintercept = 1963, col = 'blue') +
  annotate(
    'text', x = 1964, y = 50.5, hjust = 0,
    label = 'Vaccine introduced in 1964',
    color = 'blue')
```



# Adjust scales and adjust theme

```
ggplot(measles) +
  geom_tile(aes(x = year, y = state, fill = rate),
    color = 'grey80') +
  # Add reference line & label
  geom_vline(xintercept = 1963, col = 'blue') +
  annotate(
    'text', x = 1964, y = 50.5, hjust = 0,
    label = 'Vaccine introduced in 1964',
    color = 'blue') +
  # Adjust scales
  scale_x_continuous(expand = c(0, 0)) +
  scale_fill_viridis(
    option = 'inferno', direction = -1) +
  # Adjust theme
  theme_minimal() +
  theme(
    panel.grid = element_blank(),
    legend.position = 'bottom',
    text = element_text(size = 10)) +
  coord_cartesian(clip = 'off') +
  labs(
    x = NULL, y = NULL,
    fill = 'Cases per 10,000 people',
    title = 'Measles')
```

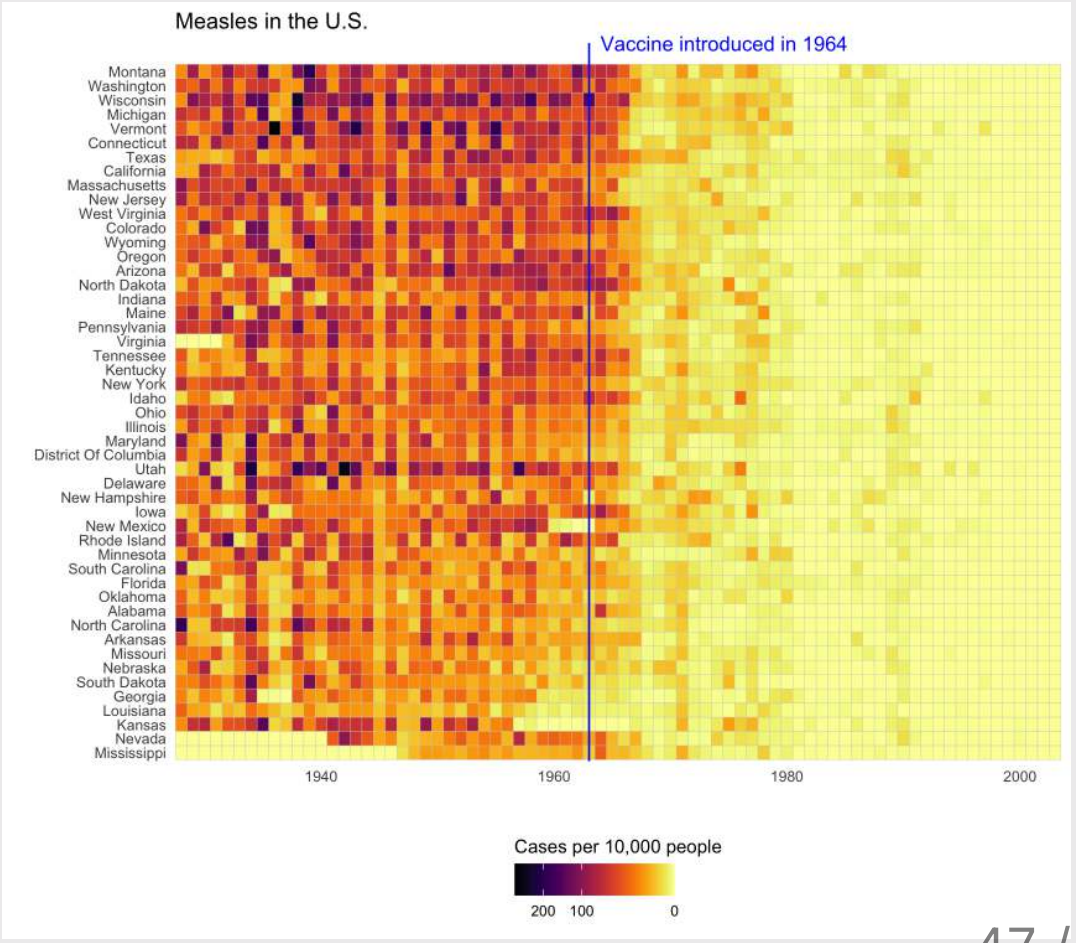
## Color scale is linear in this chart



# Adjust scales and adjust theme

```
ggplot(measles) +
  geom_tile(aes(x = year, y = state, fill = rate),
    color = 'grey80') +
  # Add reference line & label
  geom_vline(xintercept = 1963, col = 'blue') +
  annotate(
    'text', x = 1964, y = 50.5, hjust = 0,
    label = 'Vaccine introduced in 1964',
    color = 'blue') +
  # Adjust scales
  scale_x_continuous(expand = c(0, 0)) +
  scale_fill_viridis(
    option = 'inferno', direction = -1,
    trans = 'sqrt') +
  # Modify legend color bar
  guides(fill = guide_colorbar(
      title.position = 'top', reverse = TRUE)) +
  # Adjust theme
  theme_minimal() +
  theme(
    panel.grid = element_blank(),
    legend.position = 'bottom',
    text = element_text(size = 10)) +
  coord_cartesian(clip = 'off') +
  labs(
    x = NULL, y = NULL,
    fill = 'Cases per 10,000 people',
    title = 'Measles')
```

## Non-linear color scale helps with large variations



# Your turn

20:00

Use the `us_covid` data frame to explore ways to visualize the number of daily cases using:

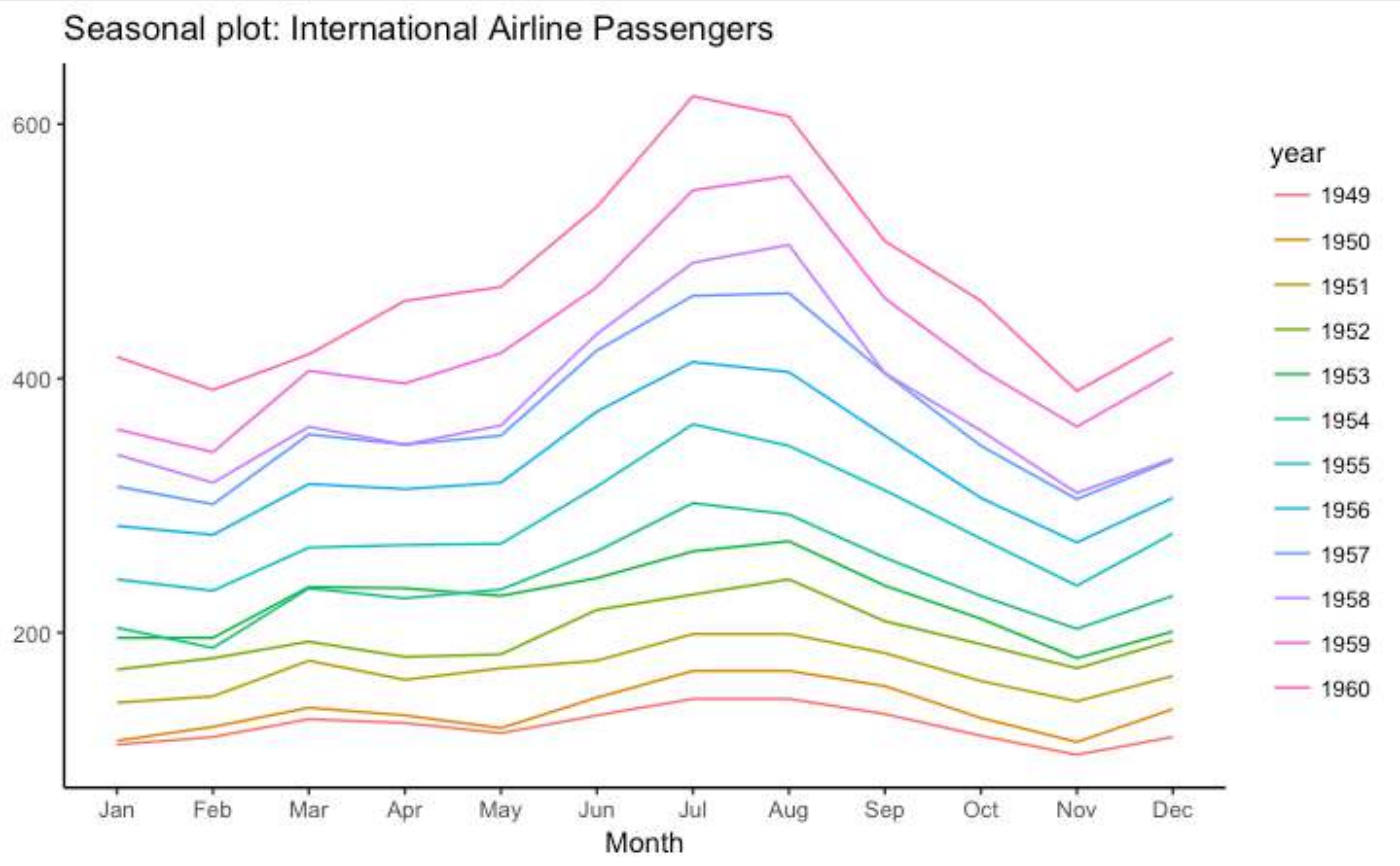
1. A labeled line chart
2. A stacked area chart
3. A heat map

```
us_covid <- read_csv(here::here(
  'data', 'us_covid.csv'))

head(us_covid)
```

```
#> # A tibble: 6 × 7
#>   date         day state   cases_daily de
#>   <date>     <dbl> <chr>         <dbl>
#> 1 2020-01-23     1 Alabama           0
#> 2 2020-01-24     2 Alabama           0
#> 3 2020-01-25     3 Alabama           0
#> 4 2020-01-26     4 Alabama           0
#> 5 2020-01-27     5 Alabama           0
#> 6 2020-01-28     6 Alabama           0
```

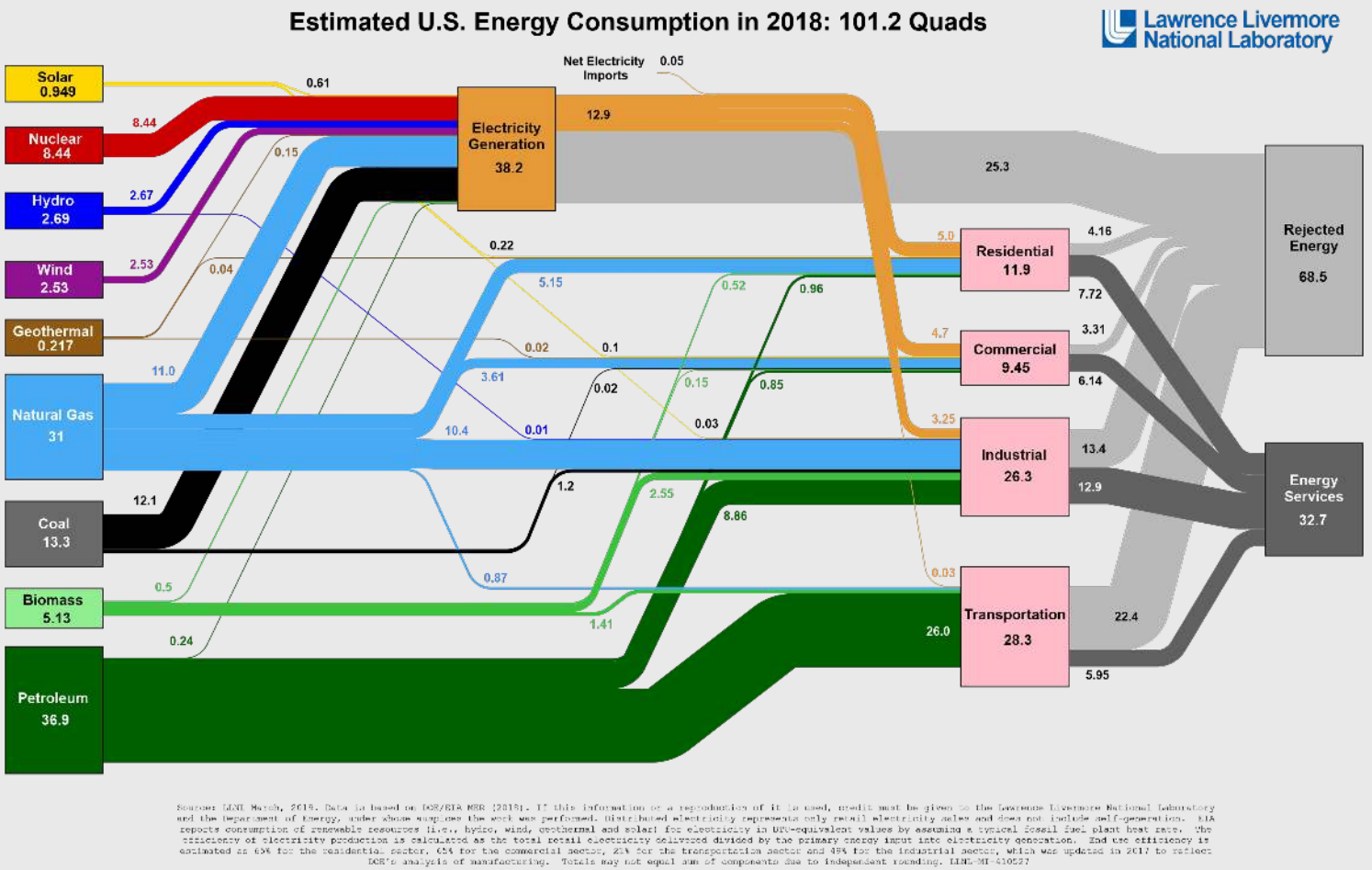
Two other examples for showing change across mutliple categories

# Seasonal chart



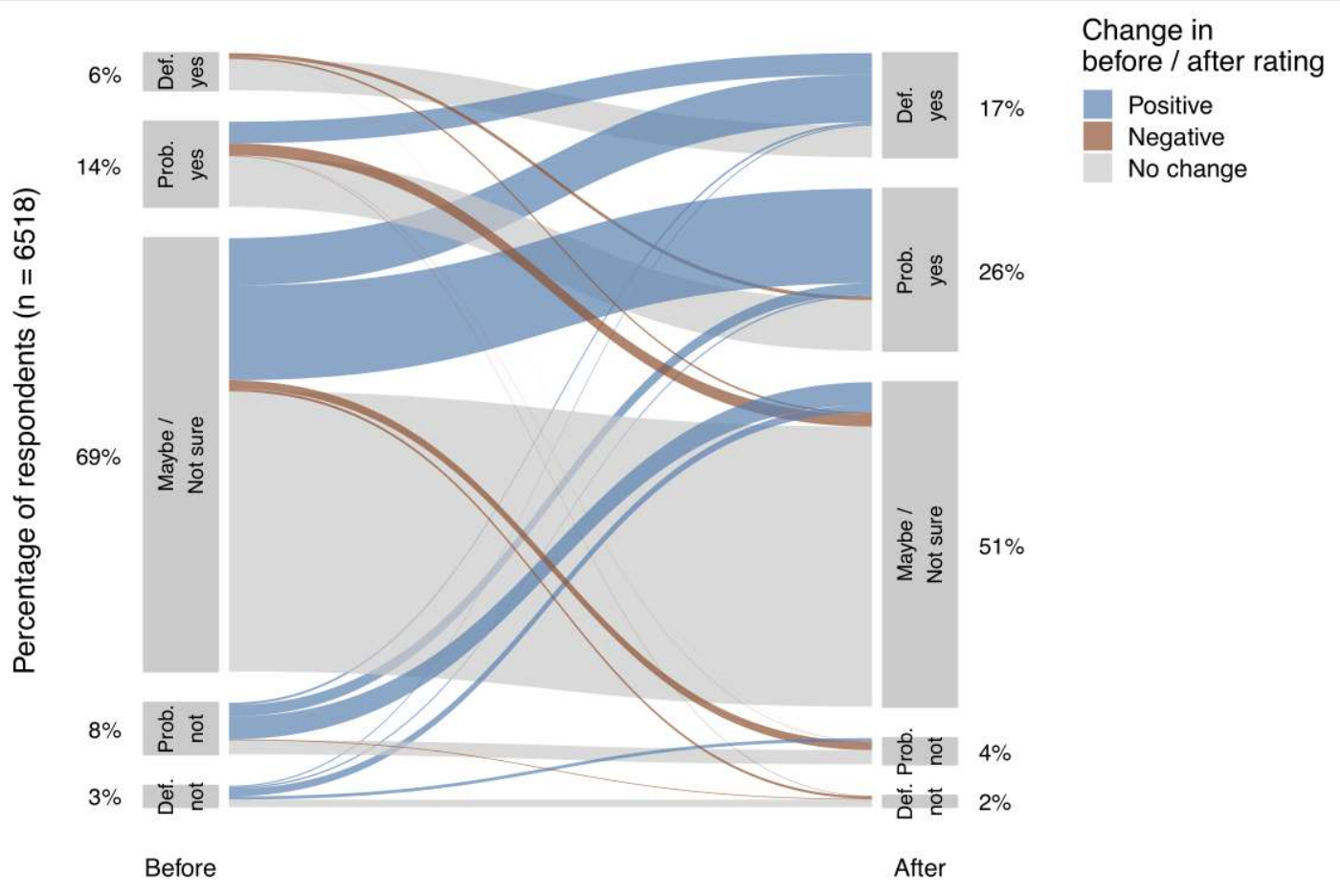

Source: http://r-statistics.co/Top50-Ggplot2-Visualizations-MasterList-R-Code.html#Seasonal%20Plot

# Sankey chart




Source: https://flowcharts.llnl.gov/

# Would you consider purchasing an electric car?




Roberson, Laura A. & Helveston, J.P. (2020) "Electric vehicle adoption: can short experiences lead to big change?," Environmental Research Letters. 15(0940c3).
Made using the ggforce package