

# Colors/Themes + Inclusive Design Principles

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Week 4

# Agenda

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- Learn about C.R.A.P
- Color basics
  - 3 basic ways color is used
- Color blindness
- Some common problems with color use
- Quick discussion of palettes
- Quick discussion of themes
- Lab 4
- Q & A with Dr. Daniel Anderson, who pioneered this EDS specialization and class!

# Learning Objectives

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- Learn a bit more about good/inclusive design principles
- Understand different types of color palettes
  - ...and when you should use one versus another
- Understand and be able to effectively evaluate concerns related to color blindness
- Be able to fluently change colors/fills within ggplot

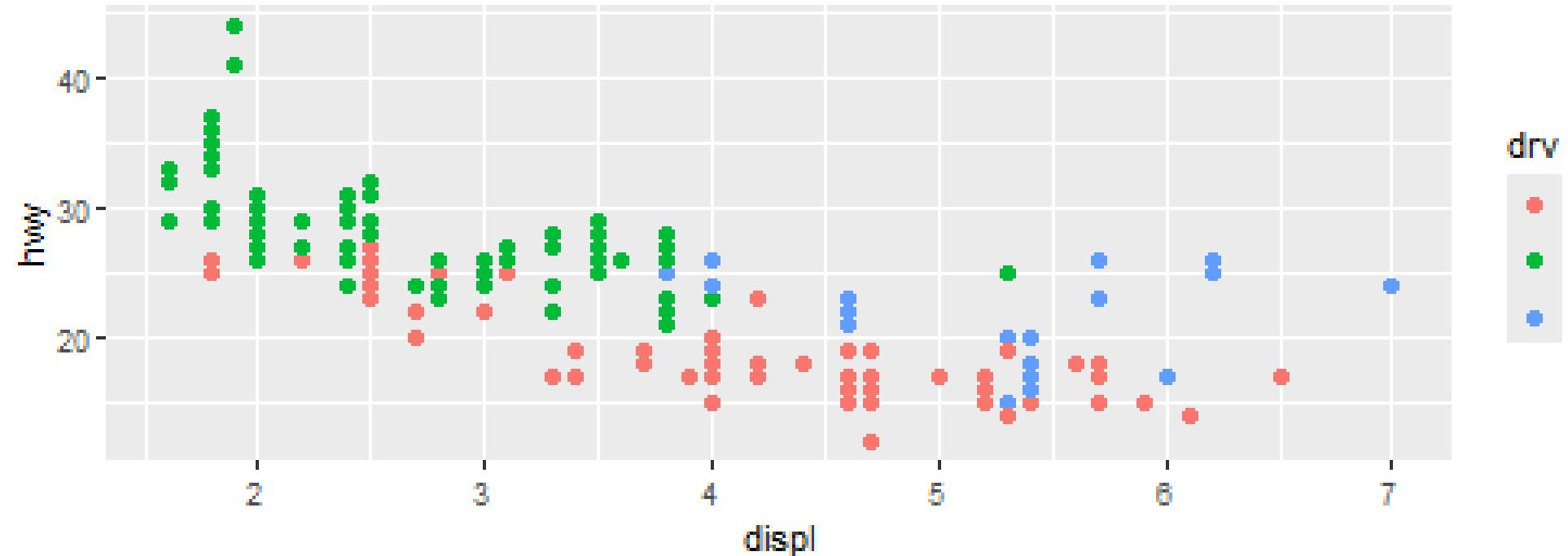
# Universal principles

- Contrast
- Repetition
- Alignment
- Proximity
  - Pioneered by Robin Patricia Williams

- These design principles apply everywhere!
- Graphic design, art, music, architecture... and graphs!

# Is that gray background okay?

```
theme_set(theme_gray())
ggplot(mpg, aes(x = displ, y = hwy, color = drv)) +
  geom_point(size = 2)
```



```
theme(gray)
```

# Applying CRAP to ggplot

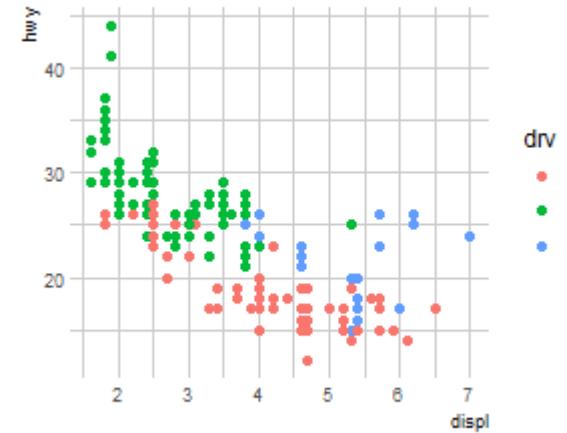
- We can follow CRAP principles to make big improvements to our plots
- Claus Wilke's chapter covers lots of these graph-specific principles
- We can apply these principles to ggplot plots

# Like this!

---

```
library(hrbrthemes)

ggplot(mpg, aes(x = displ, y = hwy,
                 color = drv)) +
  geom_point(size = 2) +
  theme_ipsum_ps()
```

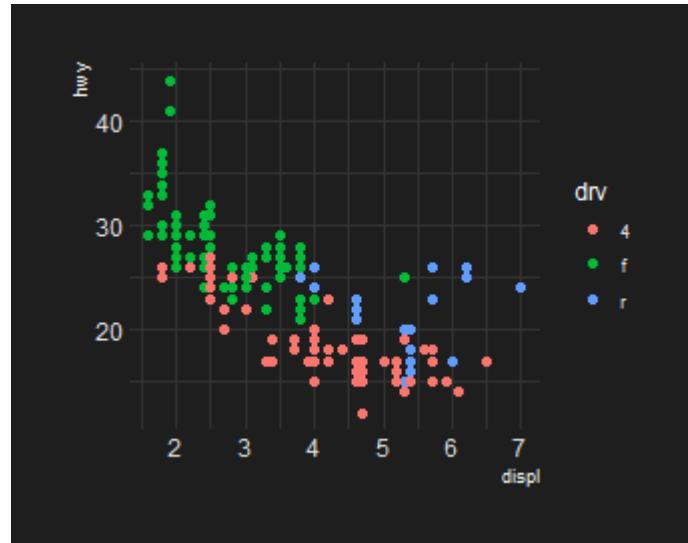


# And this!

---

```
library(hrbrthemes)

ggplot(mpg, aes(x = displ, y = hwy,
                 color = drv)) +
  geom_point(size = 2) +
  theme_modern_rc()
```

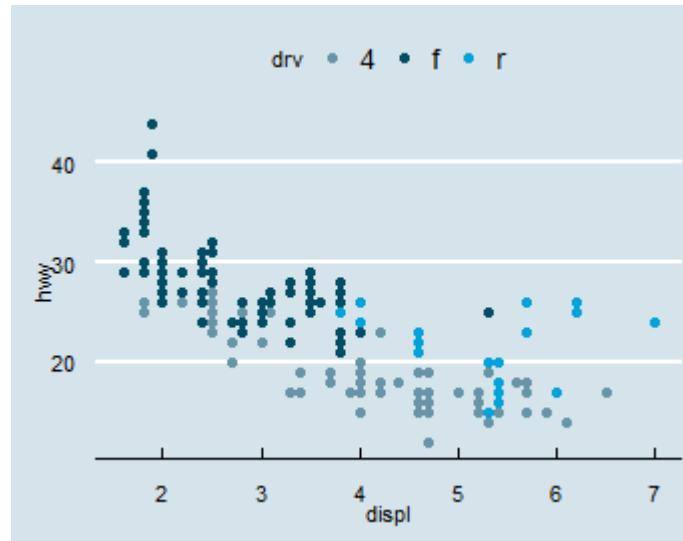


# Or this!

---

```
library(ggthemes)

ggplot(mpg, aes(x = displ, y = hwy,
                 color = drv)) +
  geom_point(size = 2) +
  scale_color_economist() +
  theme_economist()
```

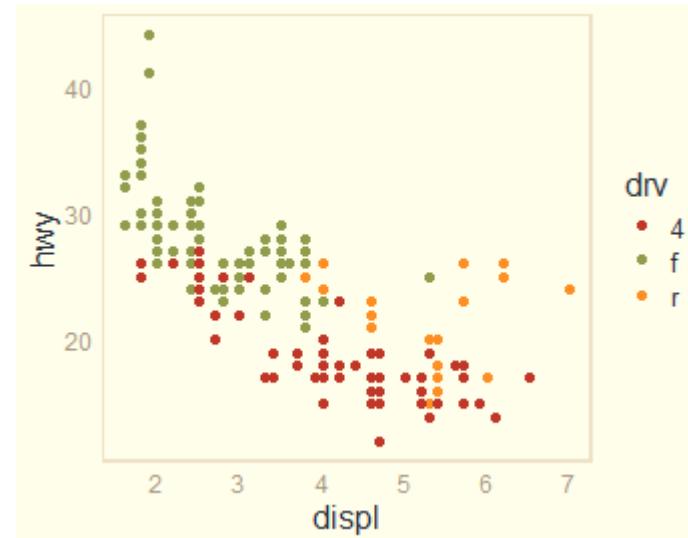


# And even this!

---

```
#remotes::install_github("gadenbuie/ggpomological")
library(ggpomological)

ggplot(mpg, aes(x = displ, y = hwy,
                 color = drv)) +
  geom_point(size = 2) +
  scale_color_pomological() +
  theme_pomological_fancy()
```



# One magic, powerful function

`theme()`

- Depending on time we come back to an anatomy of `theme` the end today or next week!

# Before we get too deep into themes of which colors is an essential element...

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## Some very practical advice about colors

- Keep straight when color is mapped to a variable through `aes` and when it's modifying an element overall
  - Former requires `scale_color_*` or `scale_fill_*` while the latter does not
- Keep straight colors and fills (see former bullet)
- Use advice of others to your advantage (e.g., <http://colorbrewer2.org/>)



Why color choice matters



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Why color choice matters

# Another quick example

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{rayshader}

# 3 fundamental uses of color

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1. Distinguish groups from each other
2. Represent data values
3. Highlight

# Color as a tool to distinguish

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# Discrete items

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- Often no intrinsic order

## Qualitative color scale

- Finite number of colors
  - Chosen to maximize distinctness, while also be equivalent
  - Equivalent
    - No color should stand out
    - No impression of order

# Some Examples

Okabe Ito



ColorBrewer Dark2



ggplot2 hue



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See more about the Okabe Ito palette origins [here](#)

# How do we use them?

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Imagine we have data like this

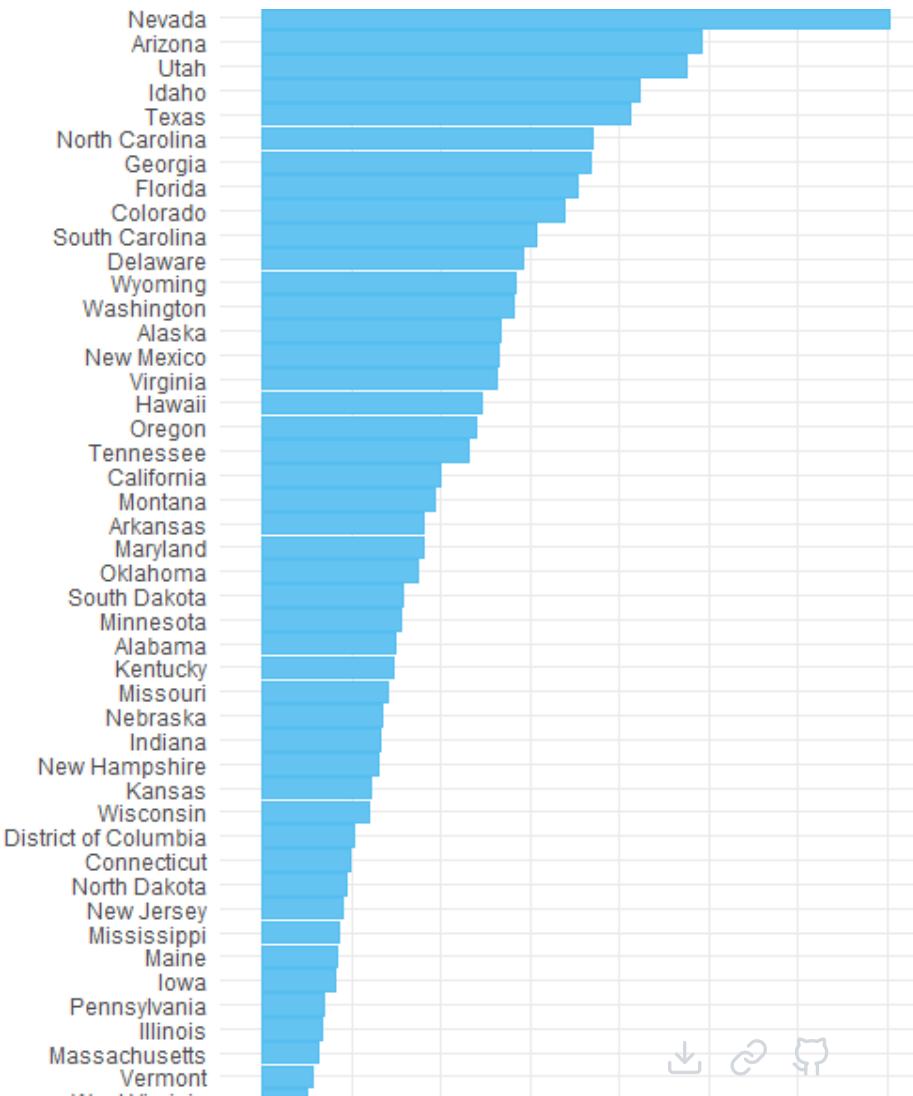
```
popgrowth_df

## # A tibble: 51 × 8
##   region division          state    pop2000    pop2010 popgrowth     area fill_color
##   <fct>  <chr>           <fct>      <dbl>      <dbl>      <dbl>      <dbl> <chr>
## 1 West    Mountain        Nevada    1998257  2700551  0.351 109781. West
## 2 West    Mountain        Arizona   5130632  6392017  0.246 113594. West
## 3 West    Mountain        Utah     2233169  2763885  0.238  82170. West
## 4 West    Mountain        Idaho    1293953  1567582  0.211  82643. West
## 5 South   West South Central Texas    20851820 25145561  0.206 261232. South
## 6 South   South Atlantic North Carolina 8049313  9535483  0.185  48618. South
## # i 45 more rows
```

# Maybe a plot like this

---

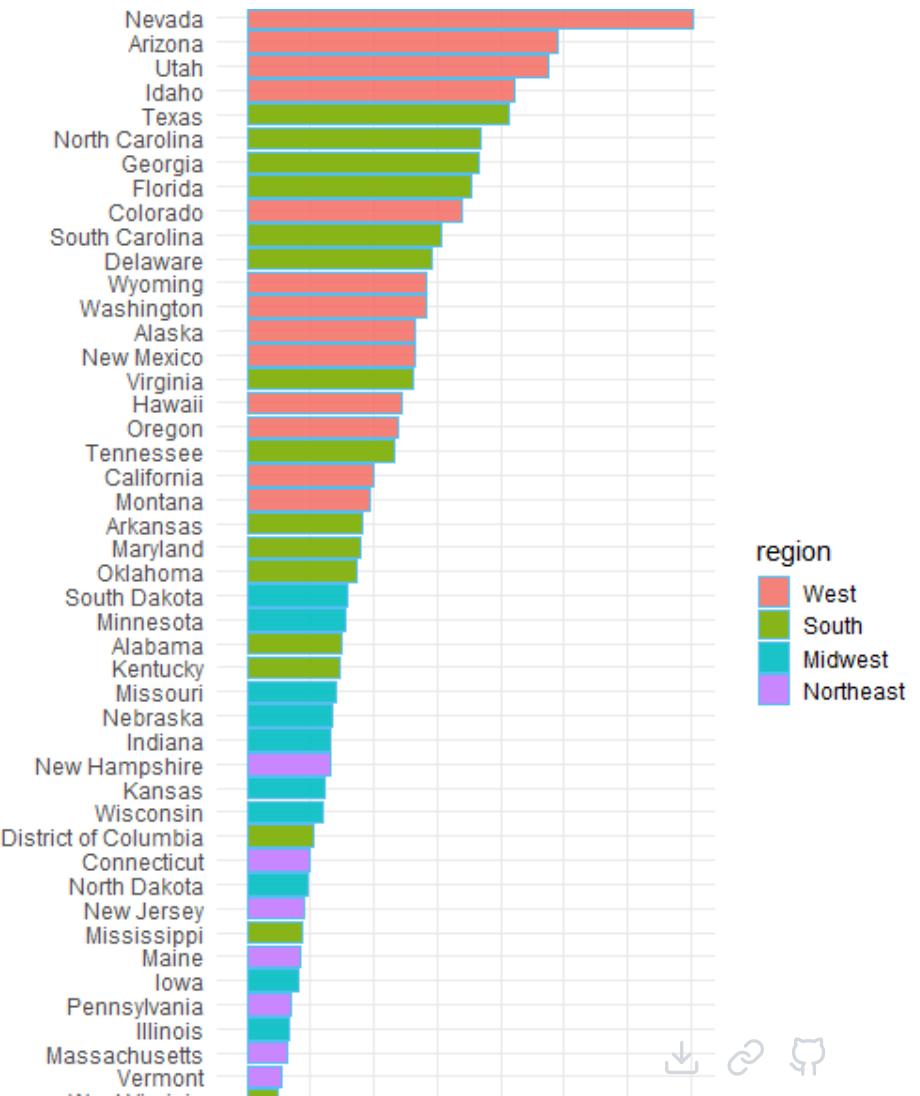
```
ggplot(popgrowth_df,  
       aes(x = popgrowth,  
            y = state)) +  
  geom_col(alpha = 0.9)
```



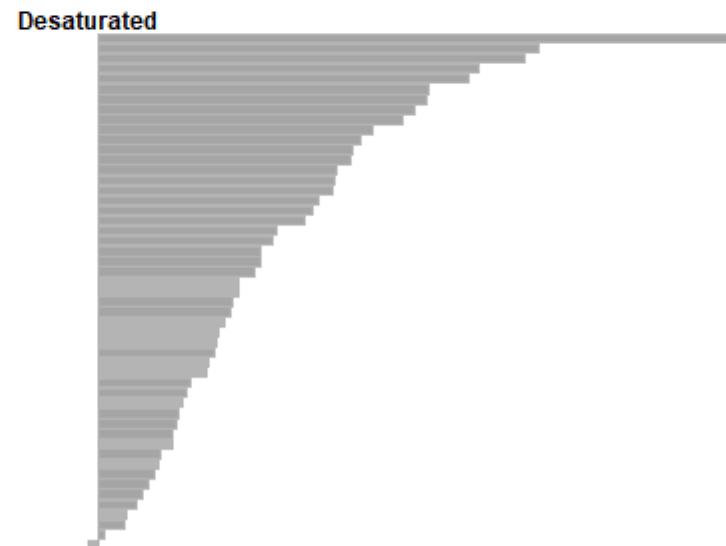
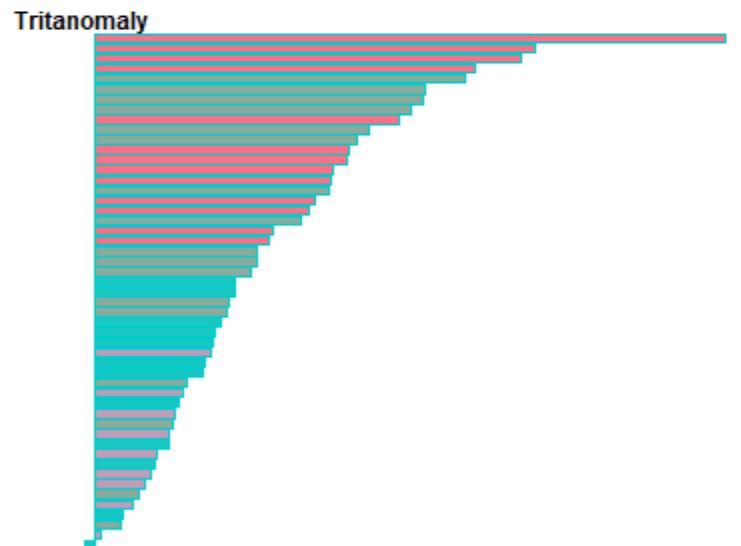
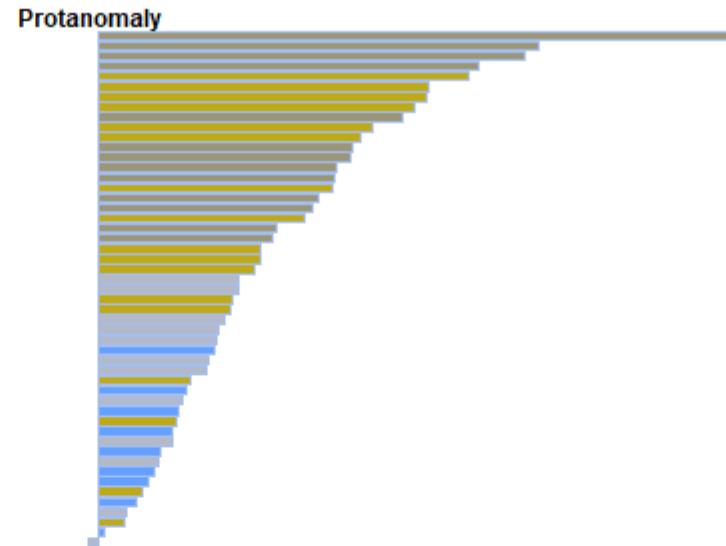
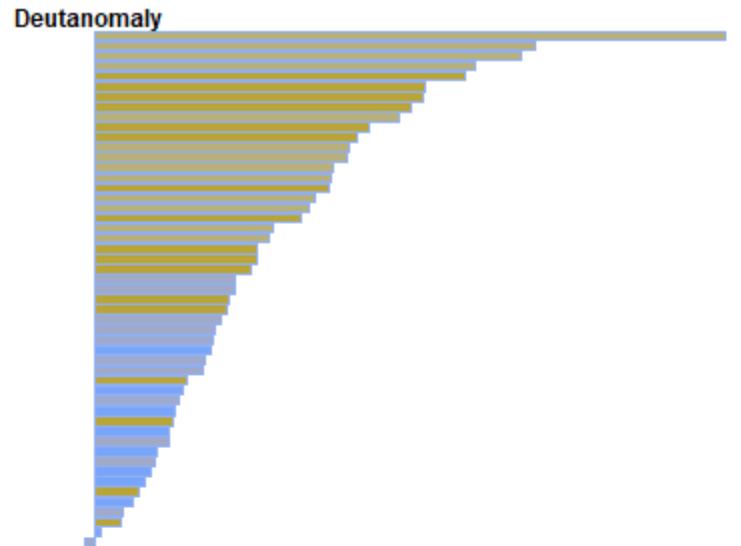
# Alternatively, fill by region

---

```
ggplot(popgrowth_df,  
       aes(x = popgrowth,  
            y = state)) +  
  geom_col(aes(fill = region),  
           alpha = 0.9)
```



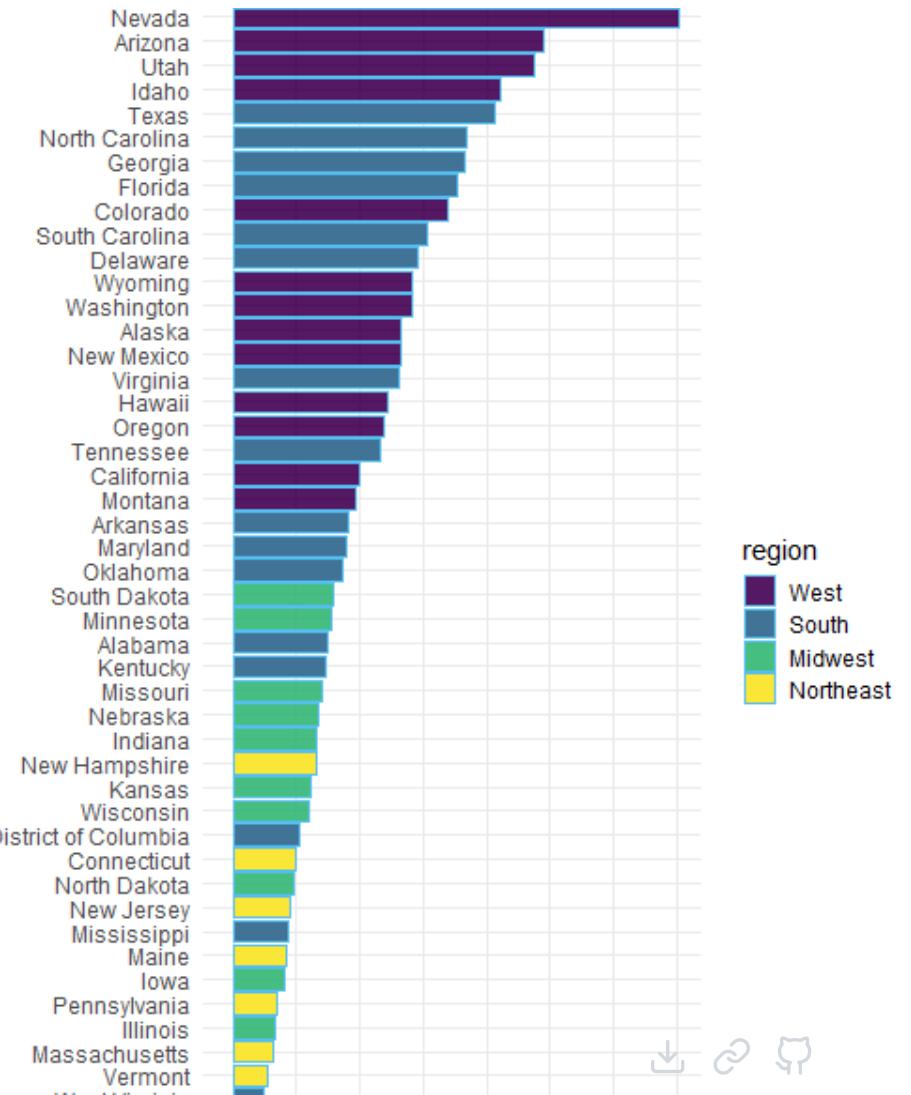
# Problem with default palette



# Alternative: viridis

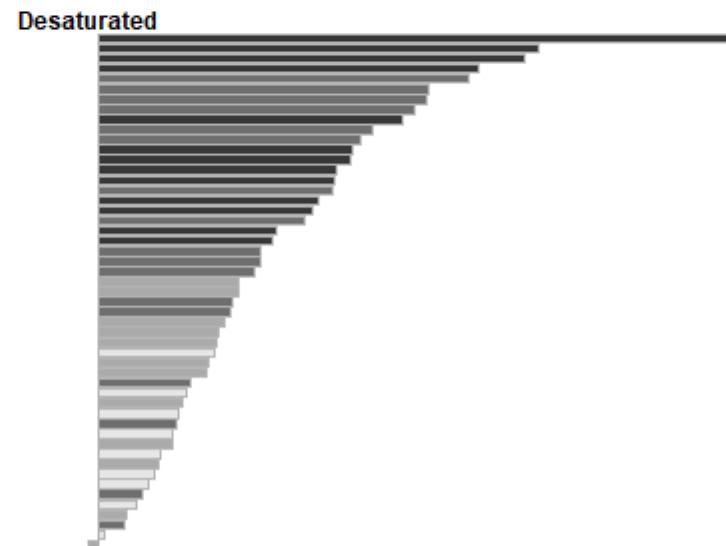
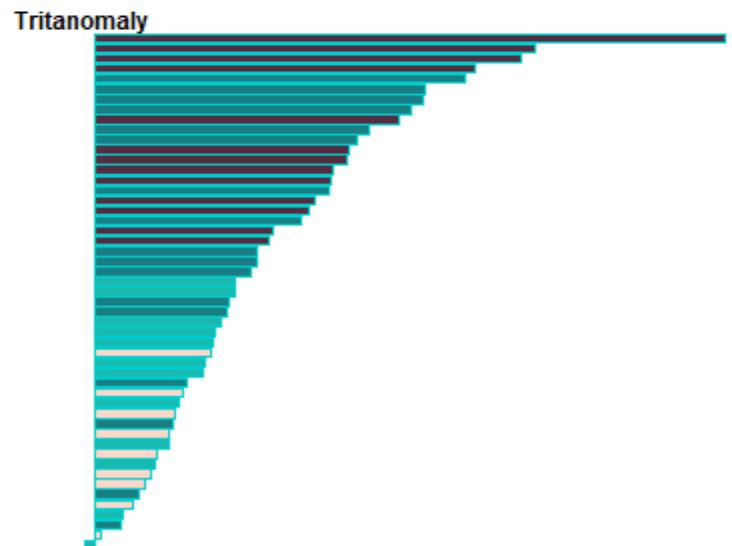
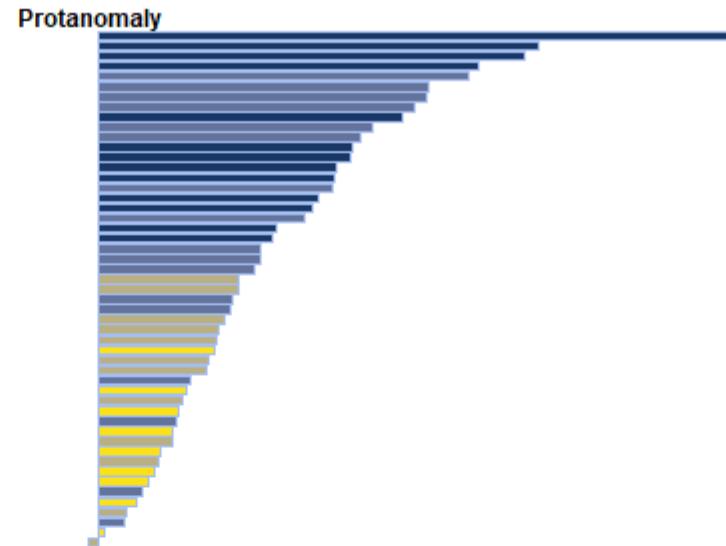
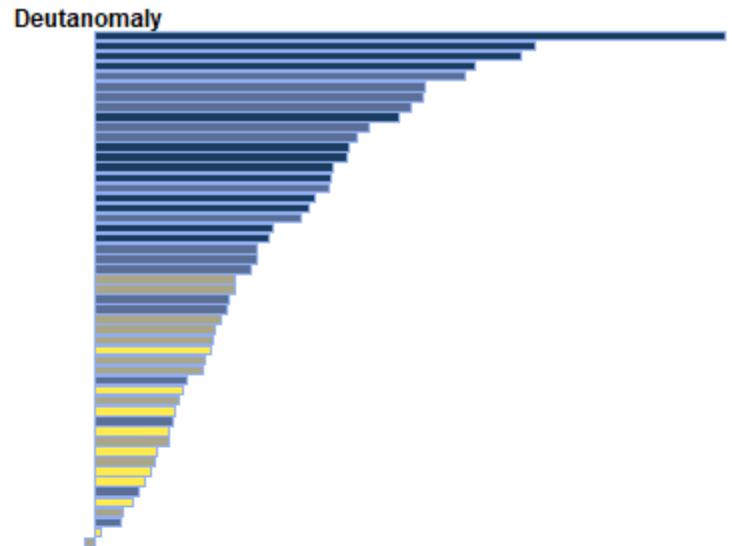
---

```
ggplot(popgrowth_df,  
       aes(x = popgrowth,  
            y = state)) +  
  geom_col(aes(fill = region),  
           alpha = 0.9) +  
  scale_fill_viridis_d()
```



# Revised version

---

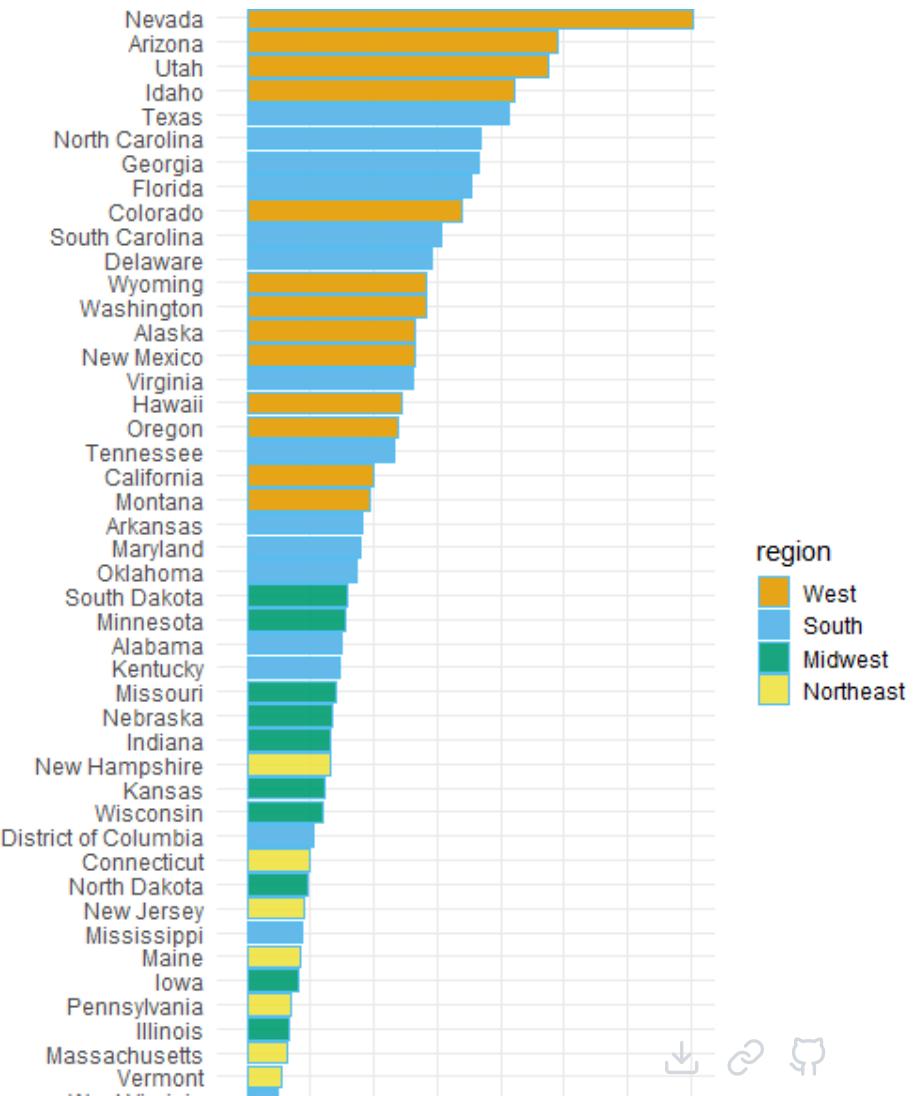


# The Okabe Ito palette

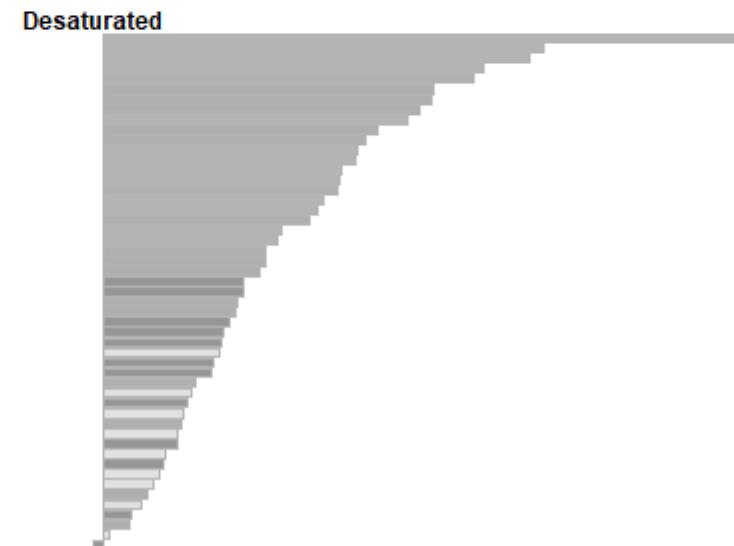
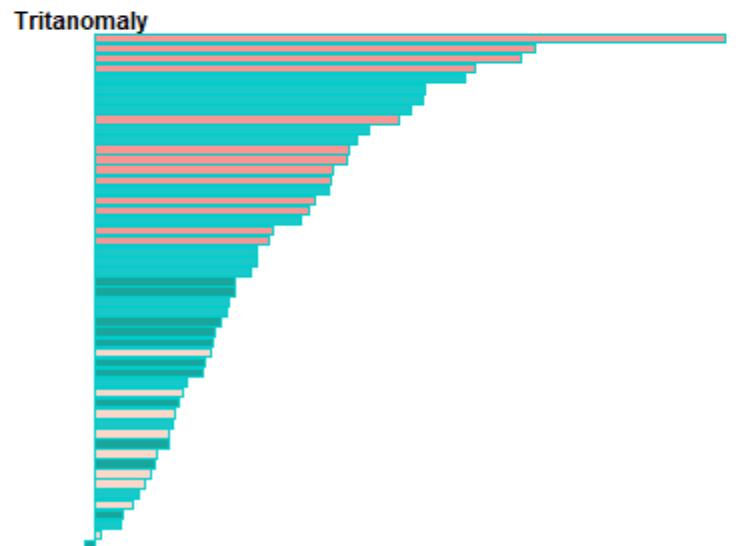
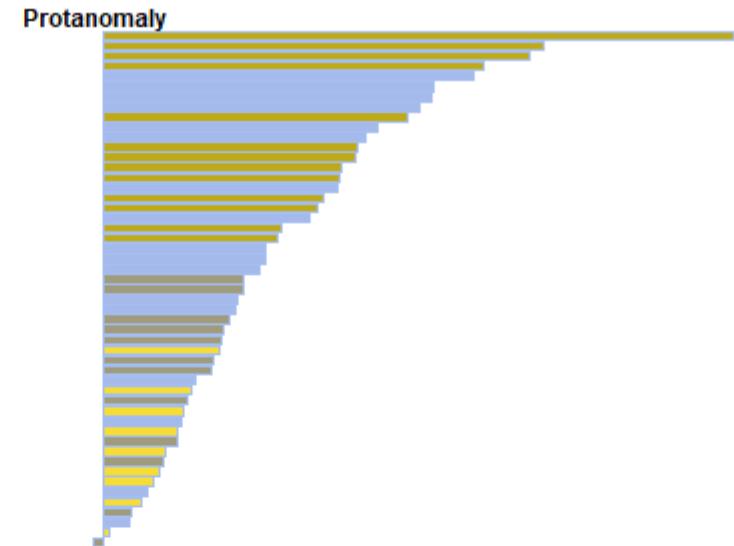
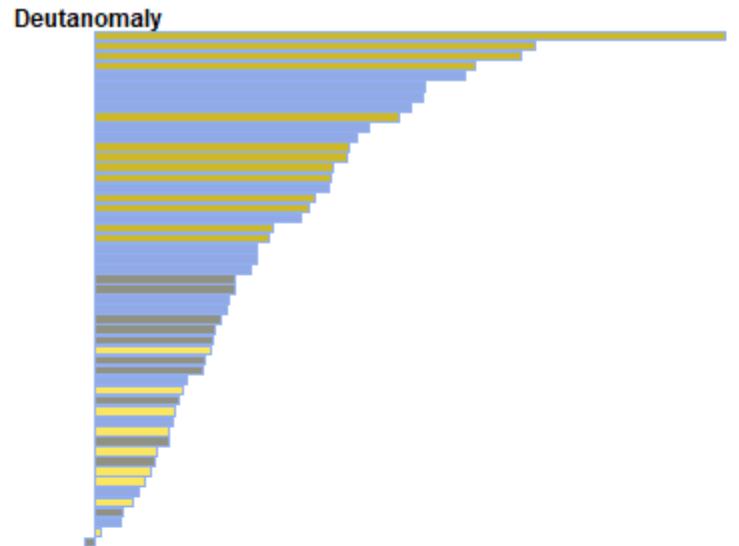
- From Color Universal Design

```
library(colorblindr)
```

```
ggplot(popgrowth_df,  
       aes(x = popgrowth,  
            y = state)) +  
  geom_col(aes(fill = region),  
           alpha = 0.9) +  
  scale_fill_OkabeIto()
```



# Okabe Ito for colorblindness



# How am I checking for colorblindness?

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- Also part of the **{colorblindr}** package ([here](#))
  - depends on the dev versions of **{colorspace}** and **{cowplot}**, which are useful packages in their own right

```
#devtools::install_github("wilkelab/cowplot")
#install.packages("colorspace", repos = "http://R-Forge.R-project.org")

#devtools::install_github("clauswilke/colorblindr")
```

# A note on installation

---

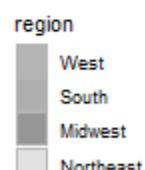
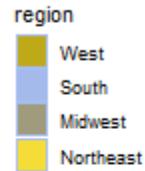
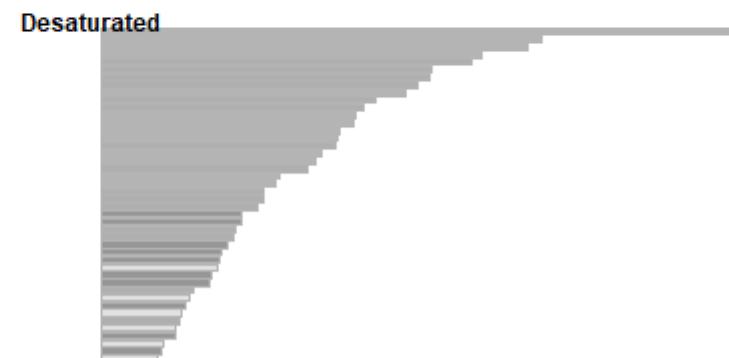
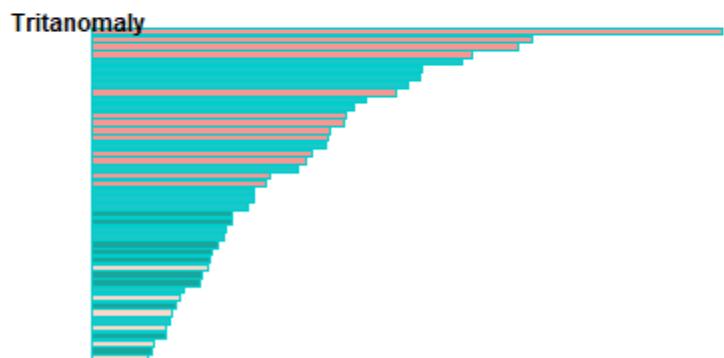
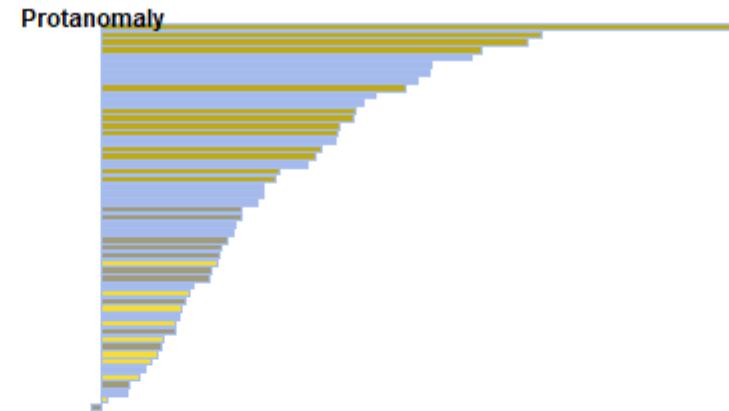
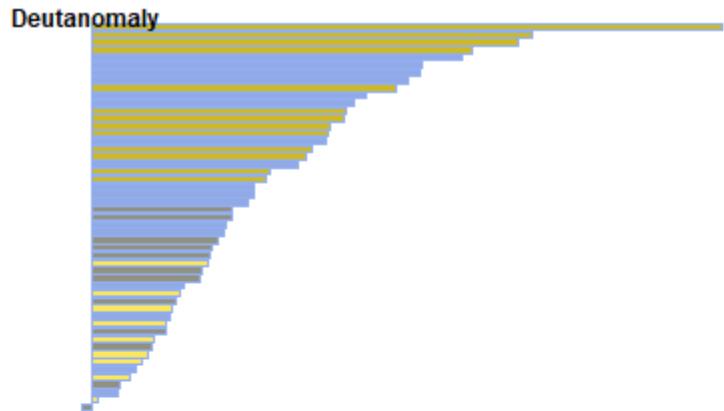
Occasionally people have run into issues with the install on the previous slide.

If that happens, try `install.packages("colorBlindness")` instead, and use the `cvdPlot` function.

(It's just a modified version of `cvd_grid` from *colorblindr*)

```
p <- ggplot(popgrowth_df,  
             aes(x = popgrowth,  
                  y = state)) +  
  geom_col(aes(fill = region),  
           alpha = 0.9) +  
  scale_fill_OkabeIto() +  
  theme_void() # not necessary but I like it
```

```
colorblindr::cvd_grid(p)
```



# Colors for continuous values

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# Sequential scale examples

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ColorBrewer Blues



Heat



Viridis



# Sequential scales

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- Which values are larger/smaller
- How distant two values are from each other
  - Scale must be perceptually uniform across its entire range
  - Similar to an interval scale, but for color
- Often based on a single hue
- Multi-hue sequential scales tend to follow gradients in the natural world

# Common uses of sequential palettes

---

# Heatmaps

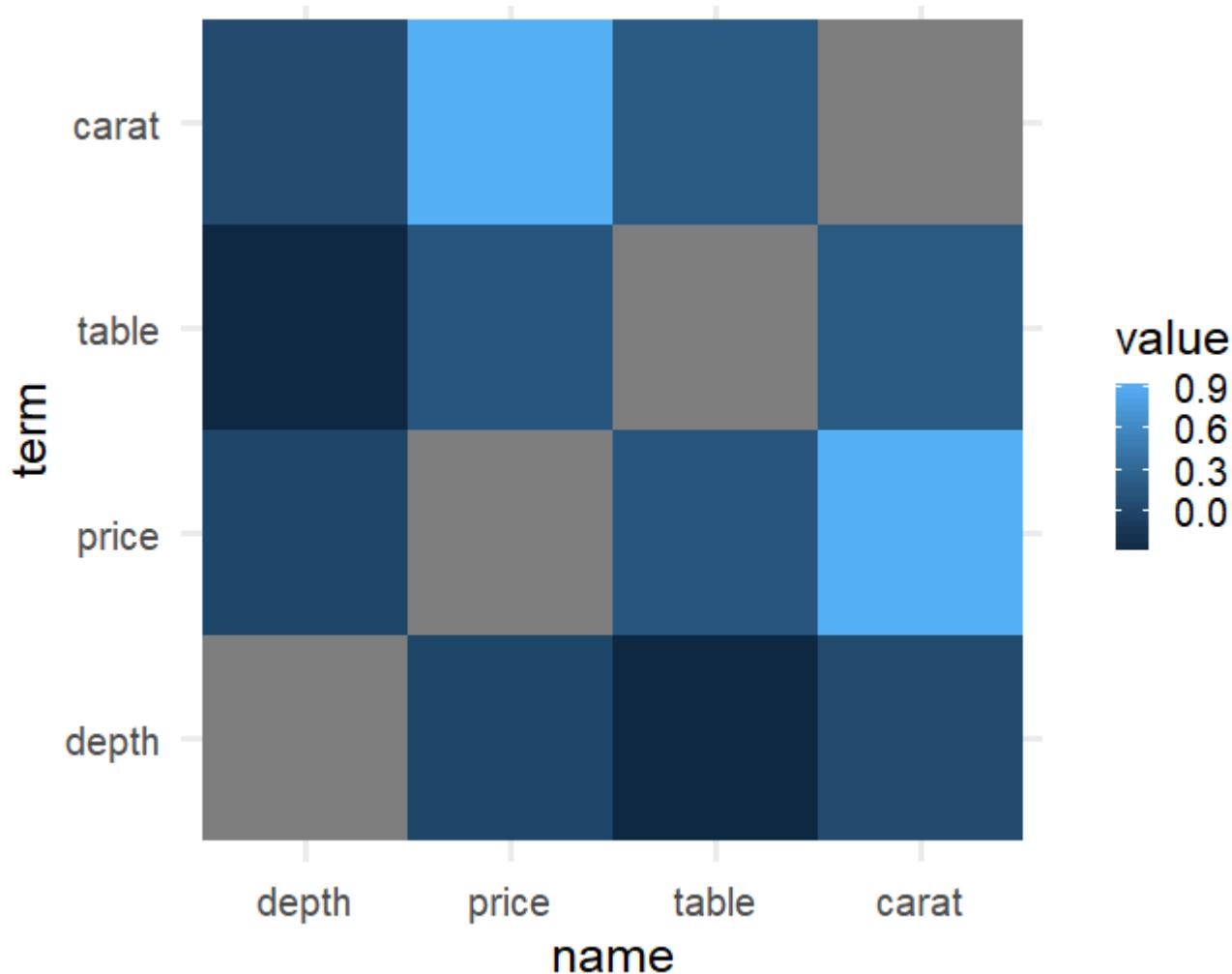
---

First the data:

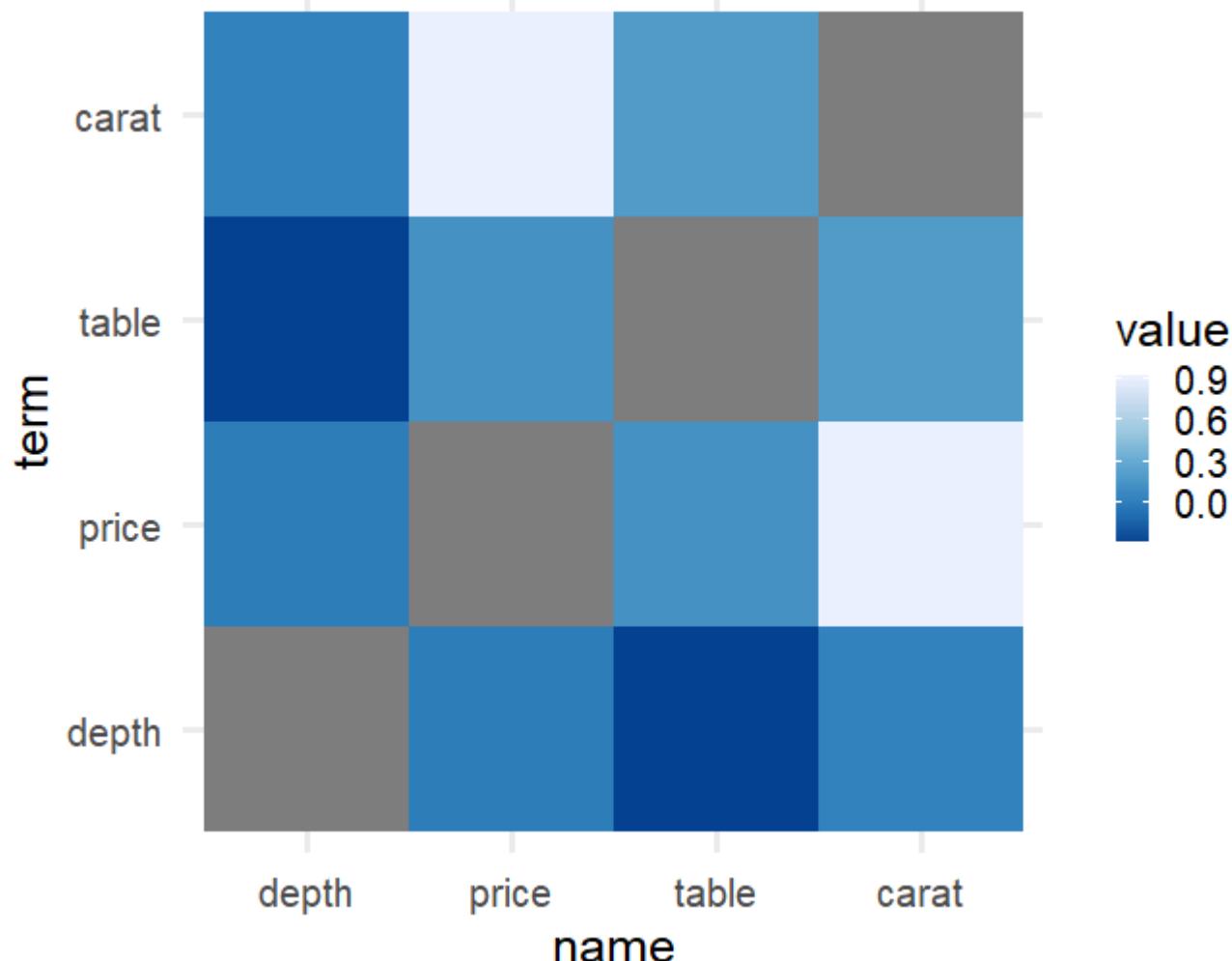
```
hm <- diamonds %>%
  select(table, price, depth, carat) %>%
  corrr::correlate() %>%
  pivot_longer(-term) %>%
  mutate(name = fct_reorder(name, value),
        term = fct_reorder(term, value))
hm

## # A tibble: 16 × 3
##   term    name   value
##   <fct> <fct>   <dbl>
## 1 table  table  NA
## 2 table  price   0.127
## 3 table  depth  -0.296
## 4 table  carat   0.182
## 5 price   table  0.127
## 6 price   price  NA
## # ... with 10 more rows
```

```
ggplot(hm, aes(name, term)) +  
  geom_tile(aes(fill = value)) +  
  coord_fixed()
```



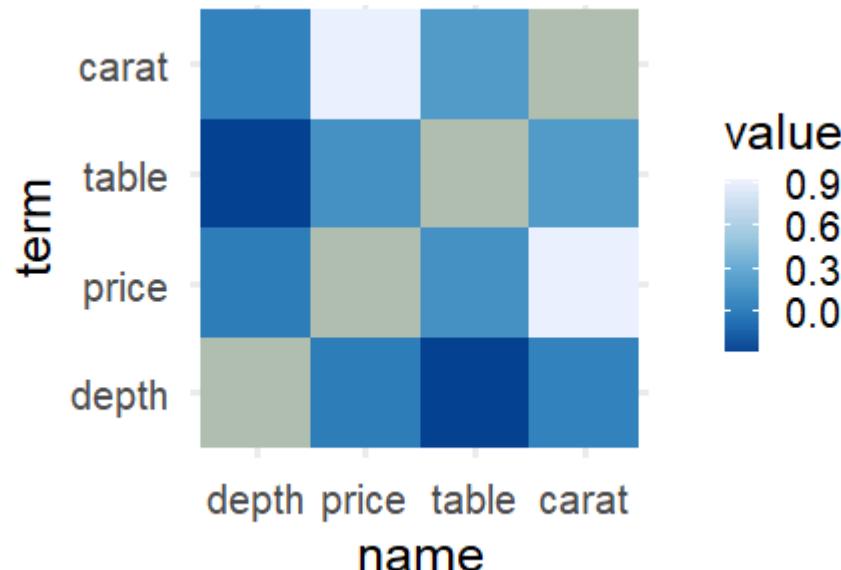
```
ggplot(hm, aes(name, term)) +  
  geom_tile(aes(fill = value)) +  
  coord_fixed() +  
  scale_fill_distiller(palette = "Blues")
```



# Change the NA value

In any `scale_*` you can change the `NA` value, including to "transparent".

```
ggplot(hm, aes(name, term)) +  
  geom_tile(aes(fill = value)) +  
  coord_fixed() +  
  scale_fill_distiller(palette = "Blues",  
                      na.value = "#b0bfb0")
```

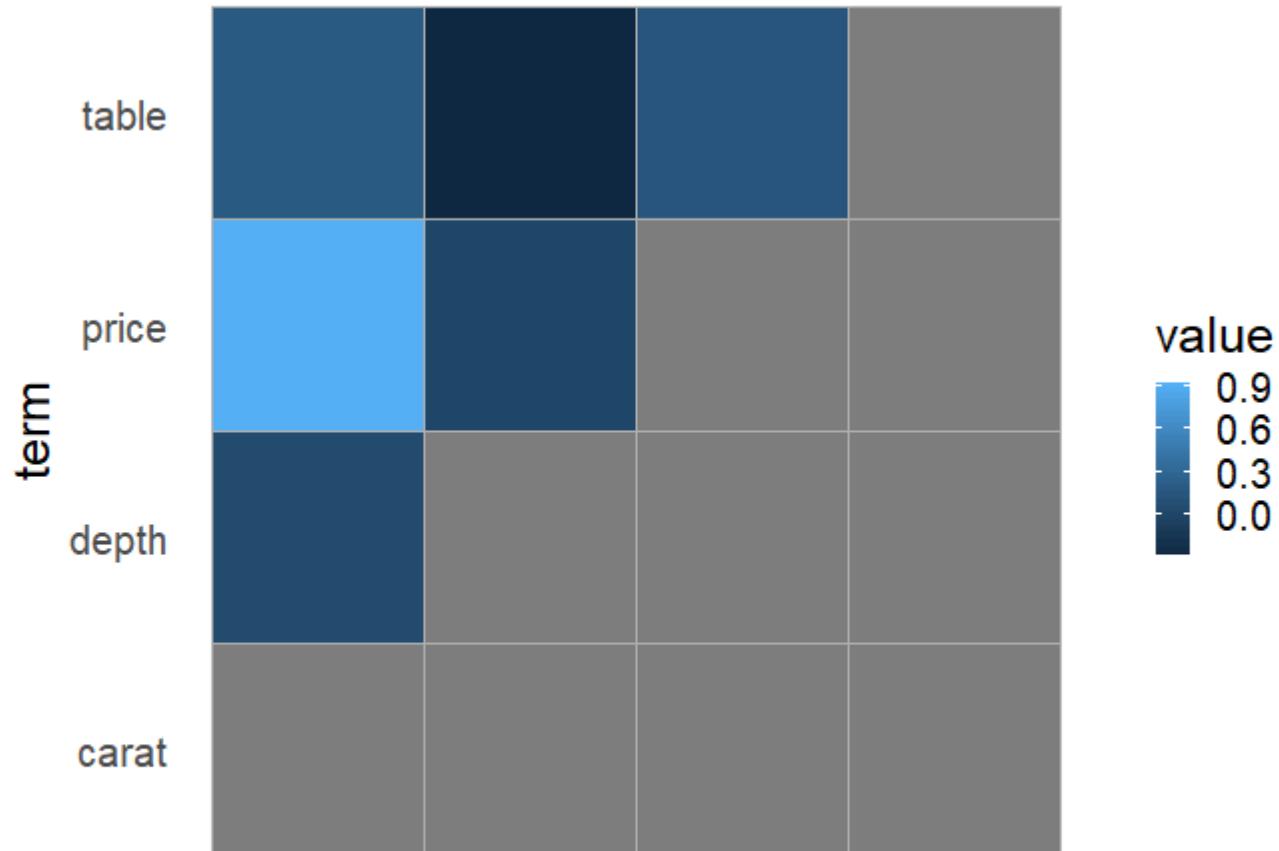


# Use this to our advantage

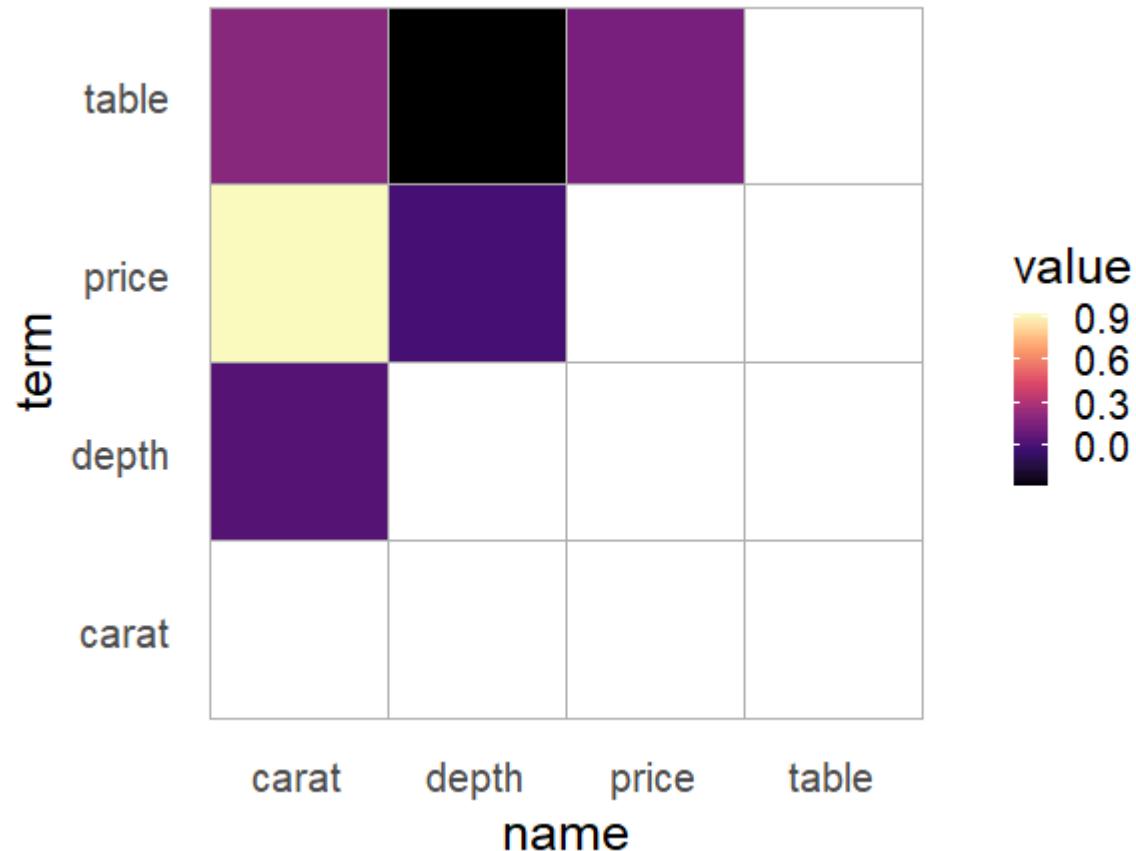
---

```
hm2 <- diamonds %>%
  select(table, price, depth, carat) %>%
  corrr::correlate() %>%
  corrr::shave(upper = FALSE) %>%
  pivot_longer(-term)
```

```
hm2_default <- ggplot(hm2, aes(name, term)) +  
  geom_tile(aes(fill = value), color = "gray70") +  
  coord_fixed() +  
  theme(panel.grid.major = element_blank(),  
        panel.grid.minor = element_blank())  
hm2_default
```



```
hm2_default +  
  scale_fill_viridis_c(  
    option = "magma",  
    na.value = "transparent"  
)
```



# Choropleths

---

```
library(tidycensus)
library(tigris)
options(tigris_use_cache = TRUE)
options(tigris_class="sf")

#census_api_key("Insert your key", install=TRUE)

vars_pl_2020 <- load_variables(2020, "p1")
#View(vars)
```

**Percentage of people identifying as White**  
Lane County

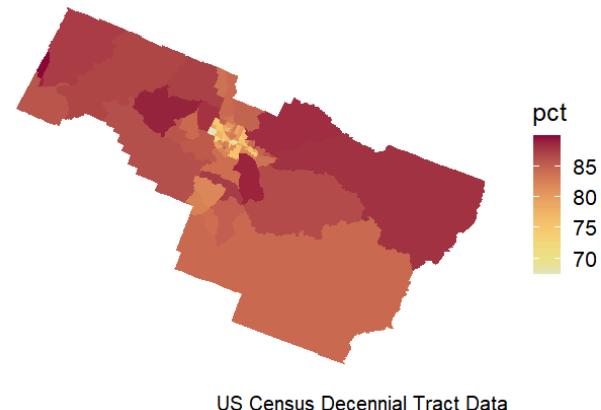


# Heat palette

```
lane %>%
  mutate(pct = 100 * (value / summary_value)) %
  ggplot(aes(fill = pct, color = pct)) +
  geom_sf() +
  coord_sf(crs = 26915) +
  theme_dviz_map(font_size = 25, font_family =
  scale_fill_continuous_sequential("Heat") +
  scale_color_continuous_sequential("Heat") +
  labs(title = "Percentage of people identifying as White",
       subtitle = "Lane County",
       caption = "US Census Decennial Tract Data")
```

Percentage of people identifying as White

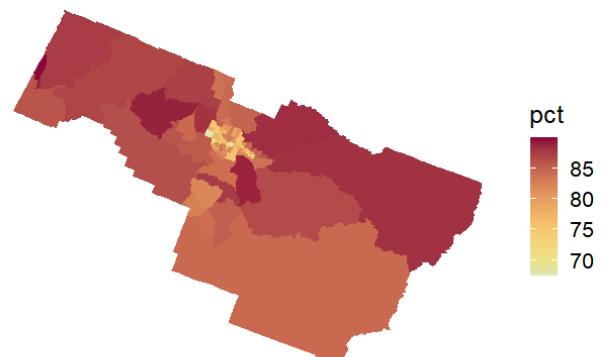
Lane County



US Census Decennial Tract Data

Percentage of people identifying as White

Lane County



US Census Decennial Tract Data

# Options

---

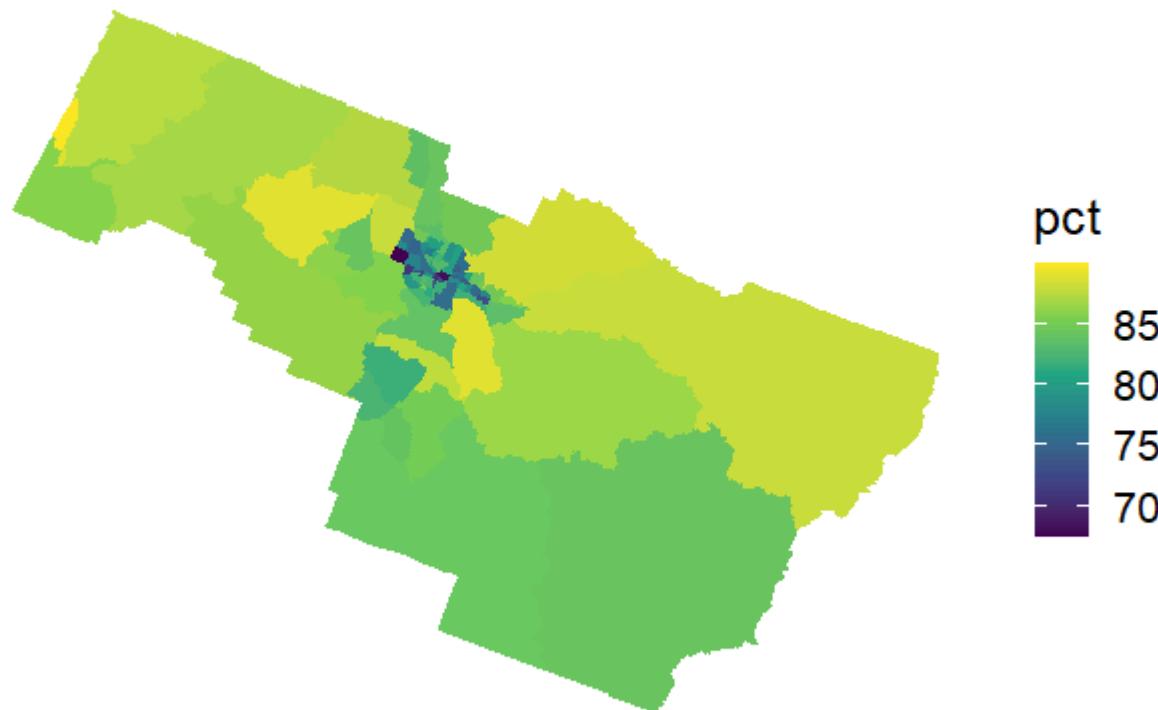
- `scale_fill_continuous_sequential("Heat")`
- `scale_color_continuous_sequential("Heat")`
- `scale_fill_discrete_sequential("Heat")`
- `scale_color_discrete_sequential("Heat")`

# viridis palette

---

**Percentage of people identifying as White**

Lane County



US Census Decennial Tract Data

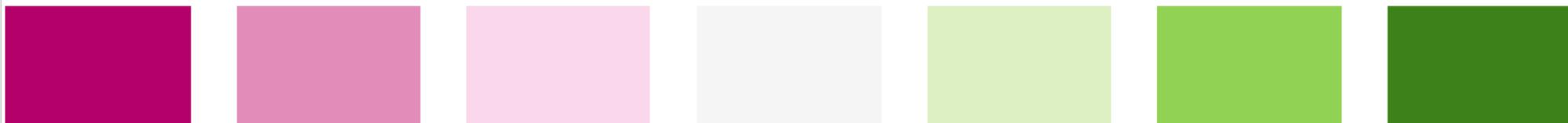
# Diverging palettes

---

CARTO Earth



ColorBrewer PiYG



Blue-Red

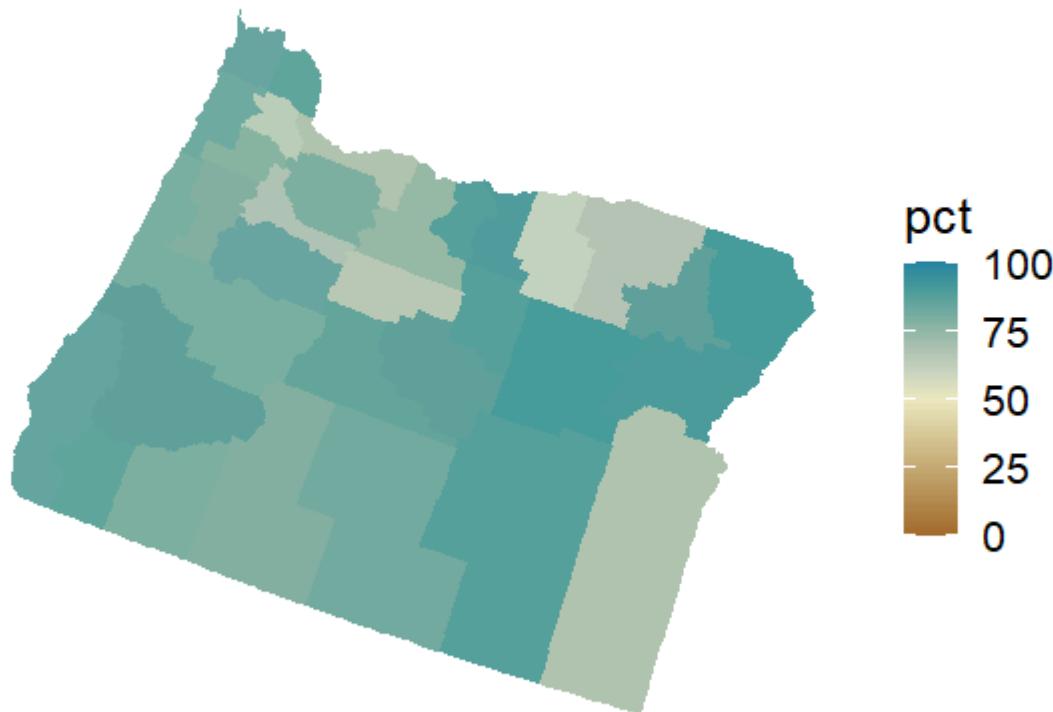


# Earth palette

---

**Percentage of people identifying as White**

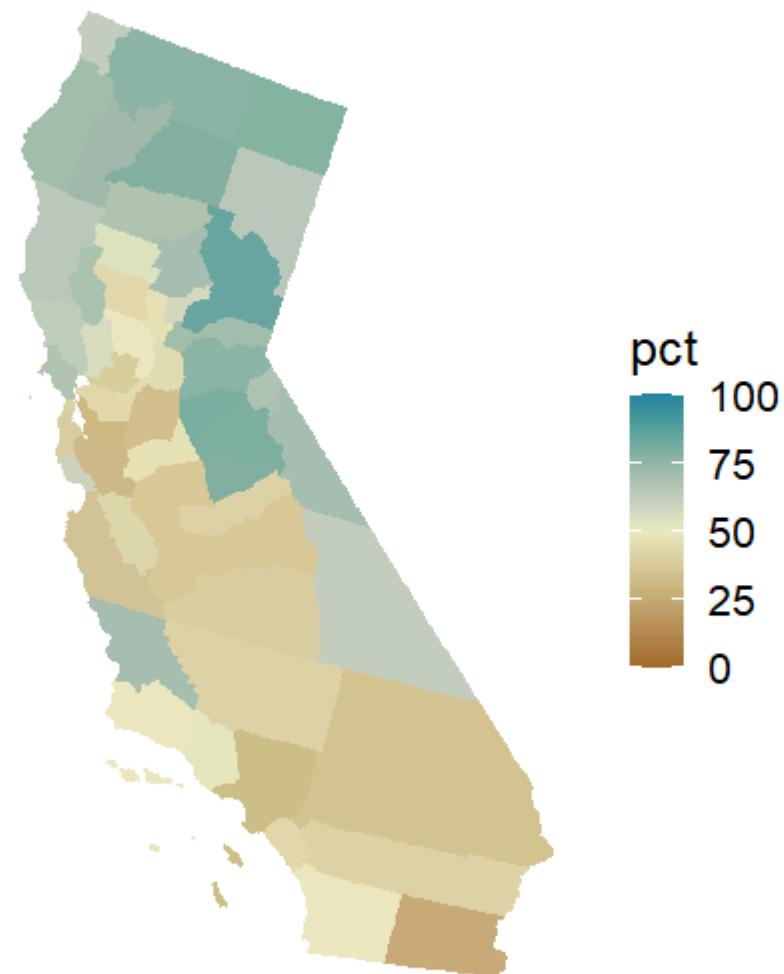
Oregon



US Census Decennial Tract Data

# Percentage of people identifying as White

California



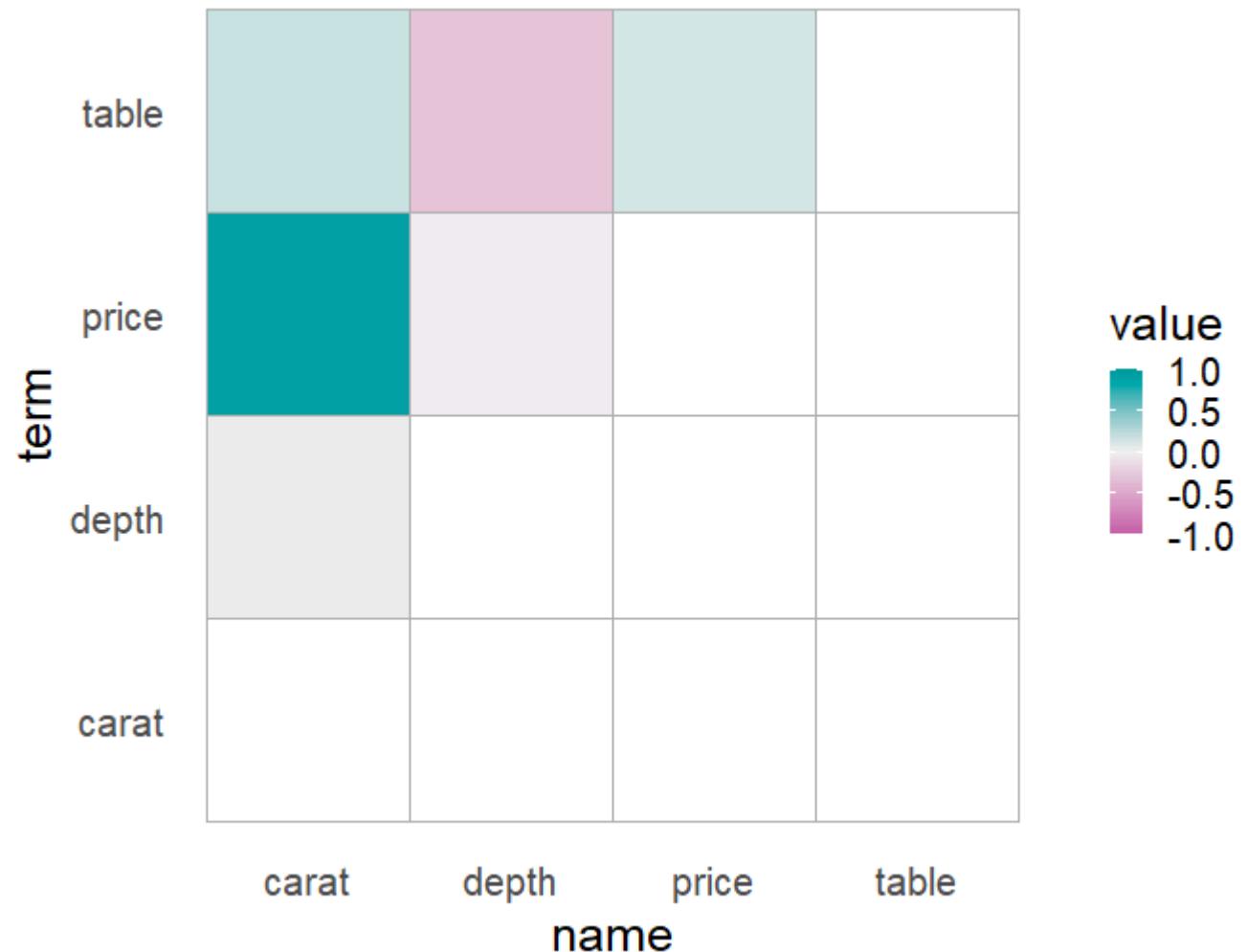
# Back to our heatmap

---

Use a diverging palette that balances at zero.

Notice the transparency is now a bit problematic...

```
library(colorspace)
hm2_default +
  scale_fill_continuous_divergingx(
    palette = "Tropic",
    mid = 0,
    limits = c(-1, 1),
    rev = TRUE,
    na.value = "transparent"
)
```

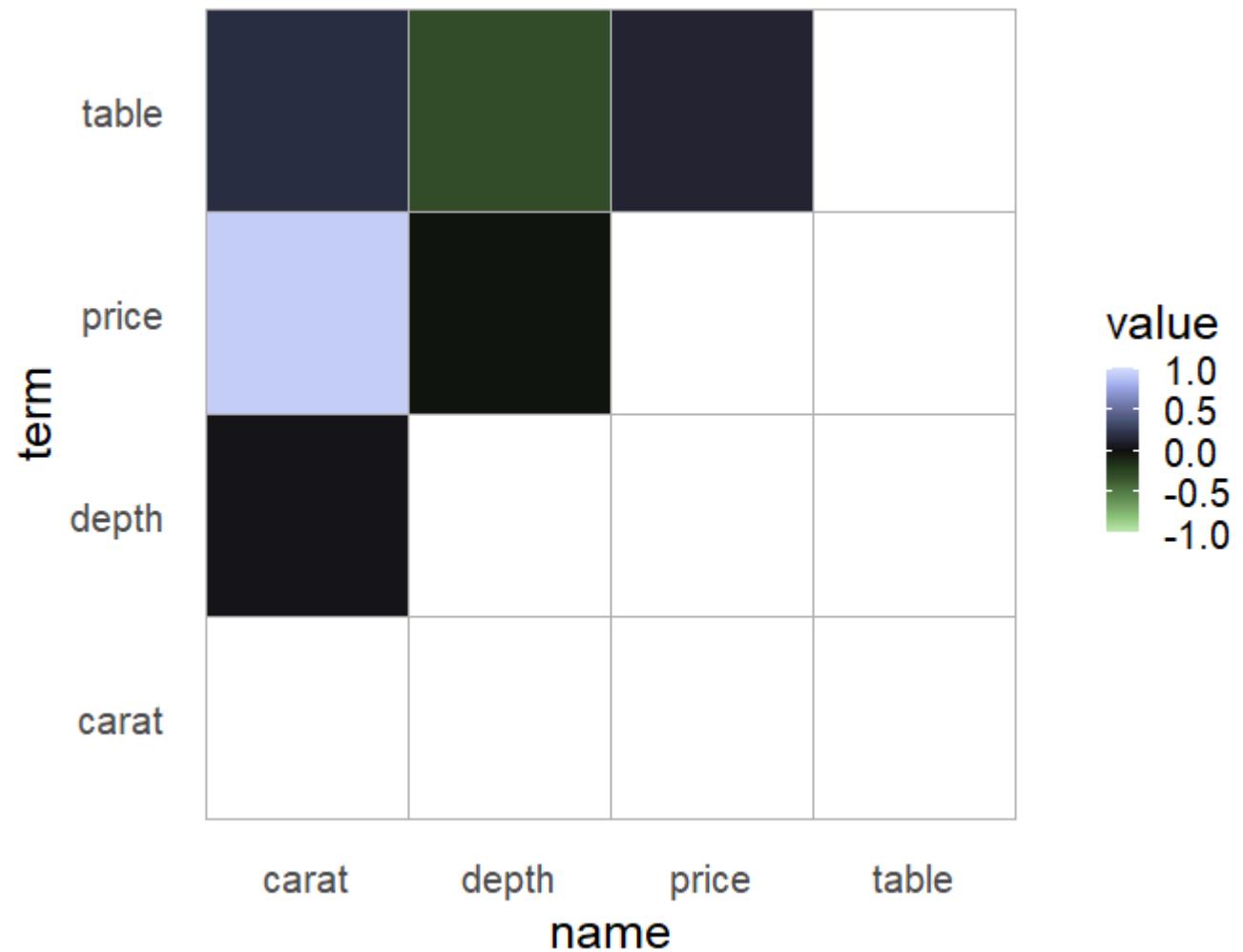


# Try a different palette

---

Most diverging palettes have a light gray or white center point. Some have black. Let's try one of those.

```
hm2_default +  
  scale_fill_continuous_diverging(  
    palette = "Tofino",  
    mid = 0,  
    limits = c(-1, 1),  
    rev = TRUE,  
    na.value = "transparent"  
)
```



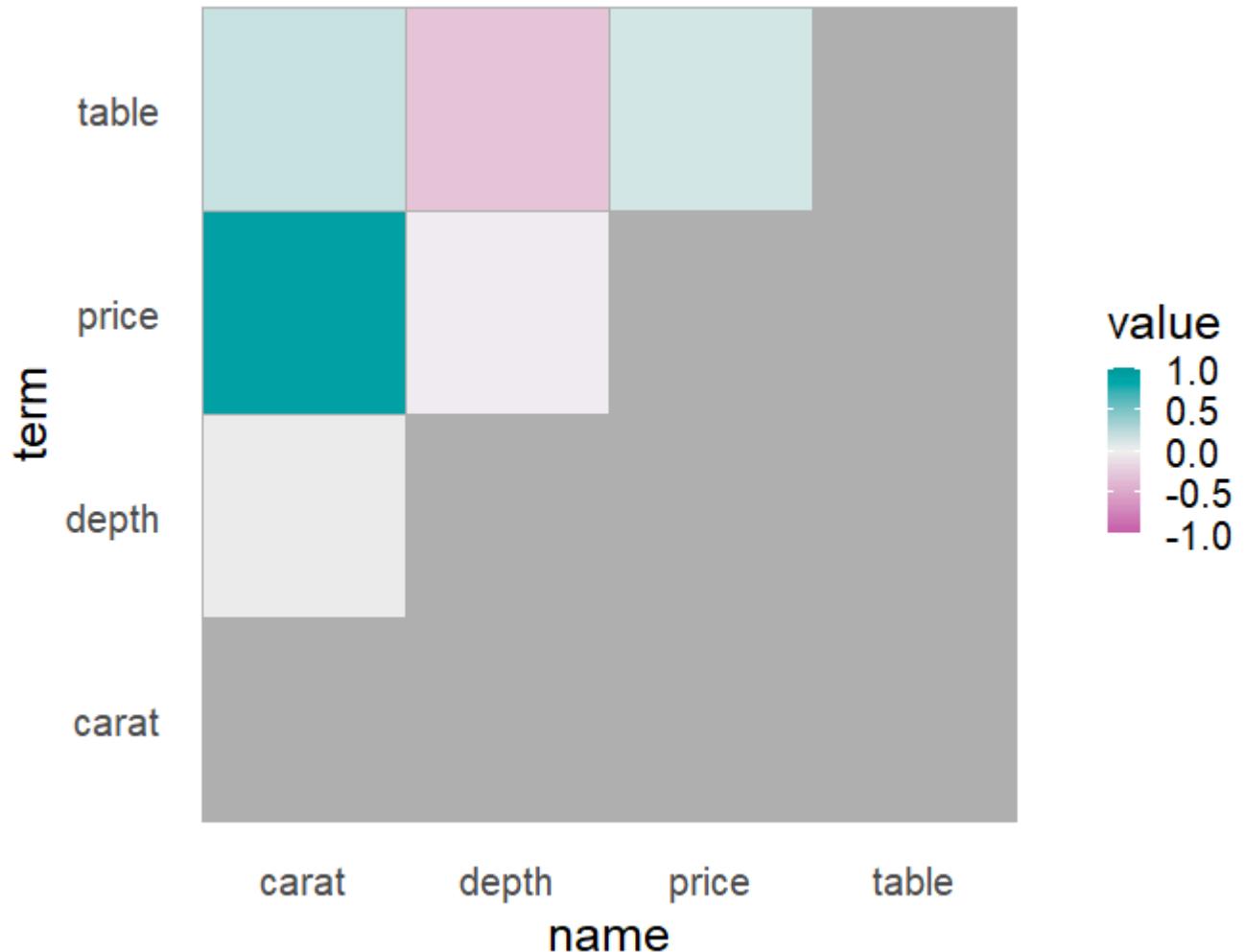
don't love it

# One more try!

---

Back to our last palette, but change the NA value to a light gray

```
hm2_default +  
  scale_fill_continuous_divergingx(  
    palette = "Tropic",  
    mid = 0,  
    limits = c(-1, 1),  
    rev = TRUE,  
    na.value = "gray70"  
)
```



Maybe better? I give up for now...

# More on colorspace

---

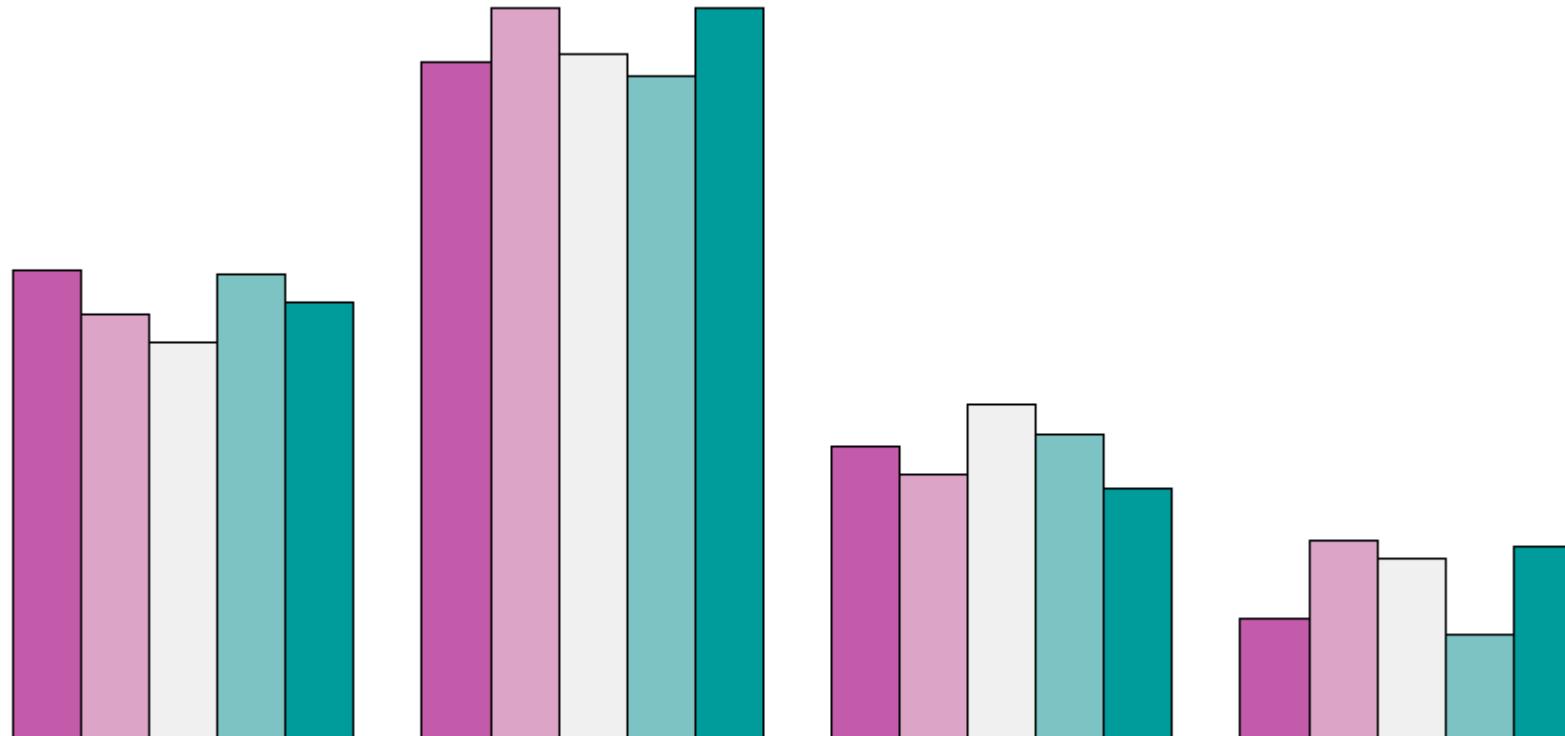
Great package with great documentation. Let's go look!

colorspace

# More diagnostics

---

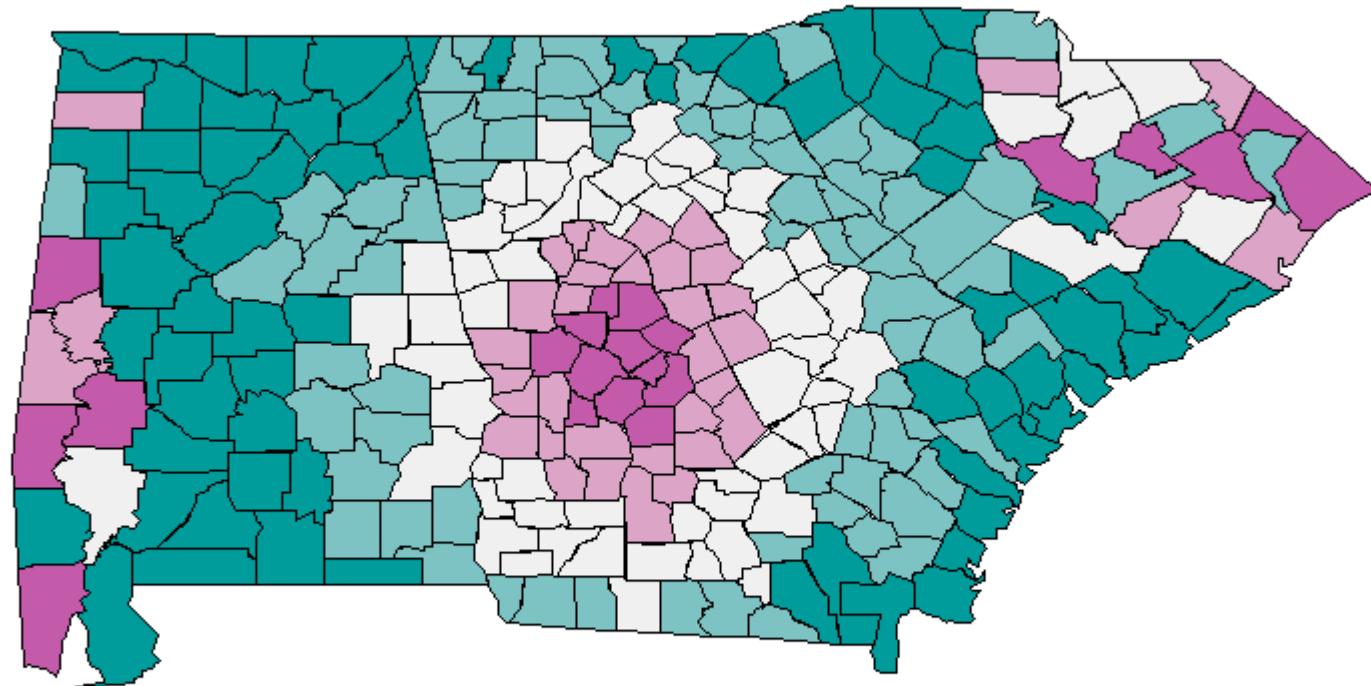
```
our_scale <- diverge_hcl(5, palette = "Tropic", rev = TRUE)
demoplot(our_scale, "bar")
```



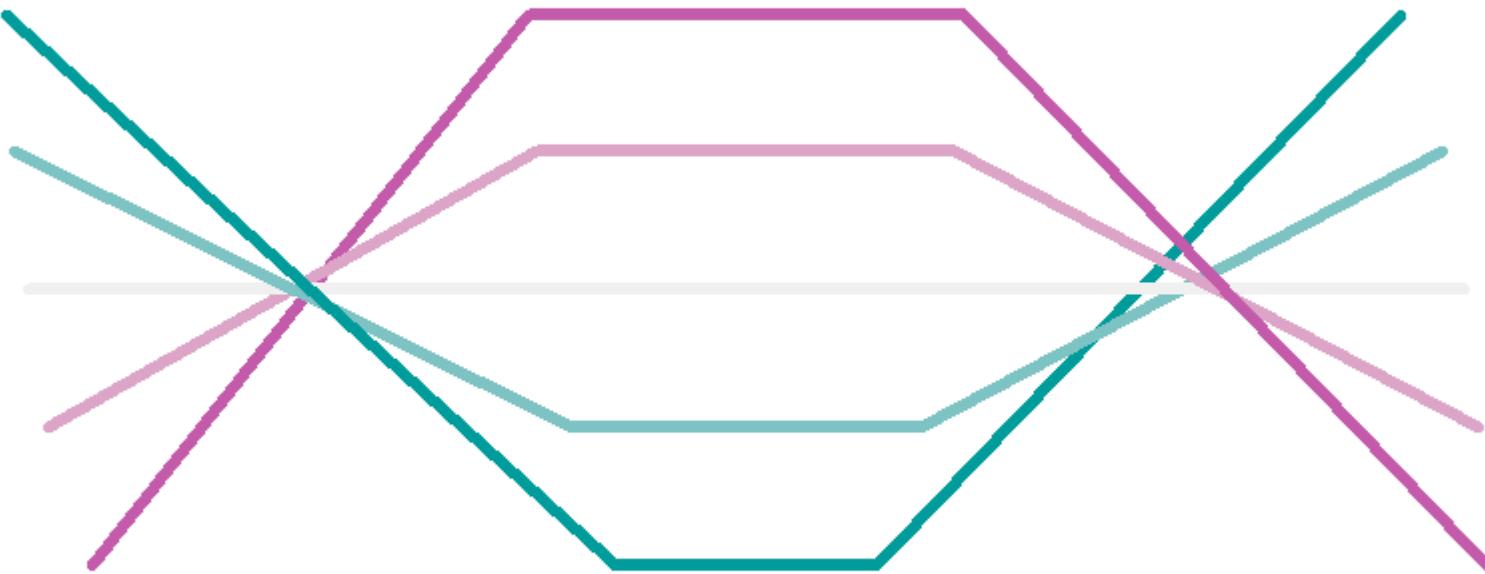
```
demoplot(our_scale, "heatmap")
```



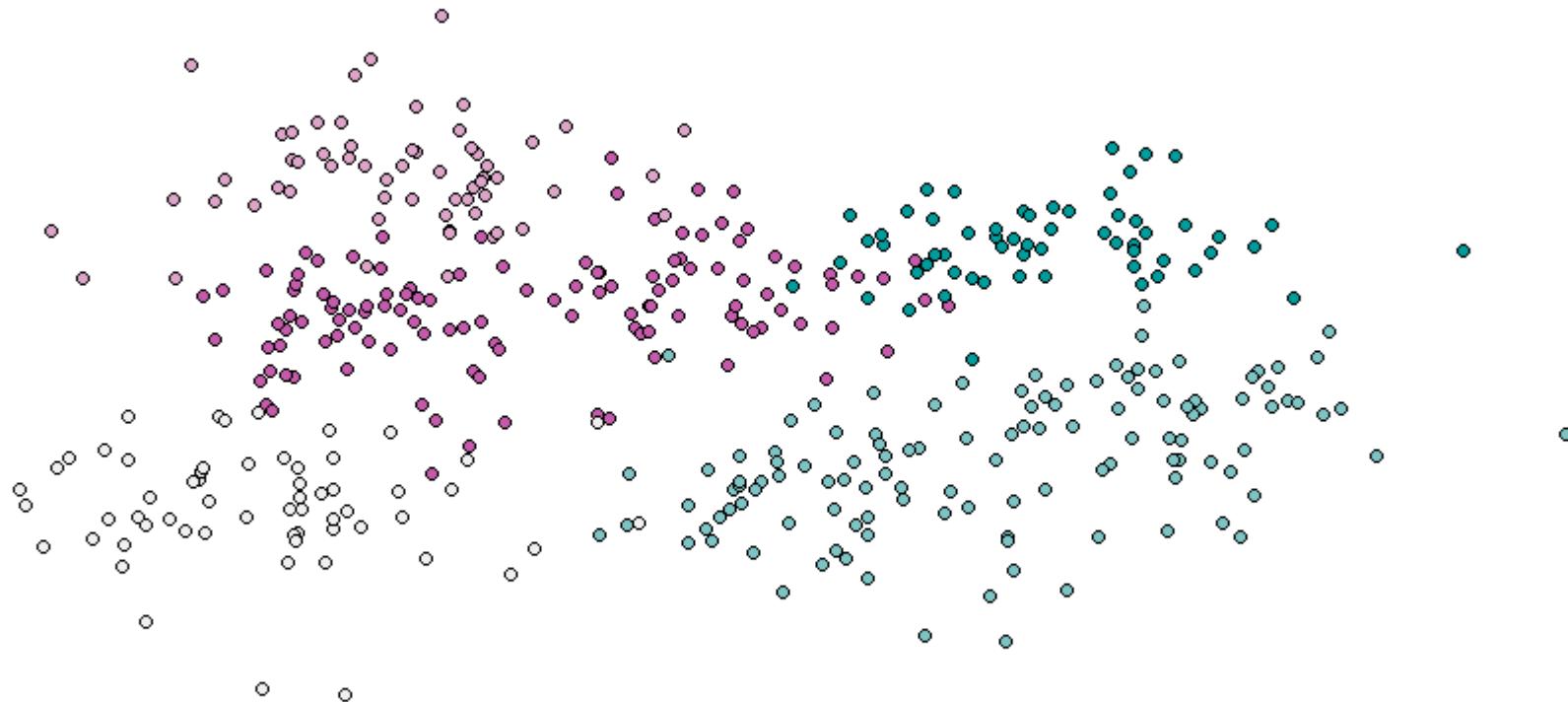
```
demoplot(our_scale, "map")
```



```
demoplot(our_scale, "lines")
```



```
demoplot(our_scale, "scatter")
```

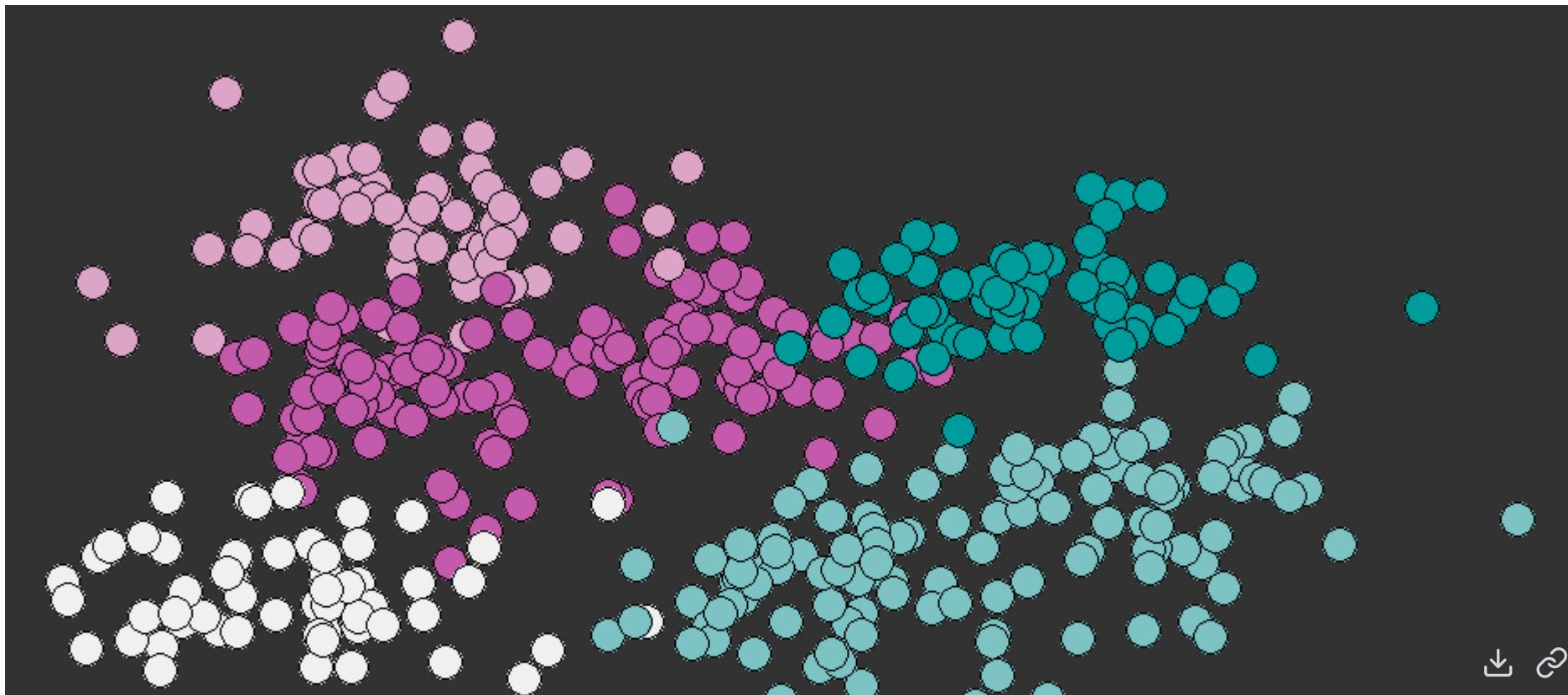


# Diferent background

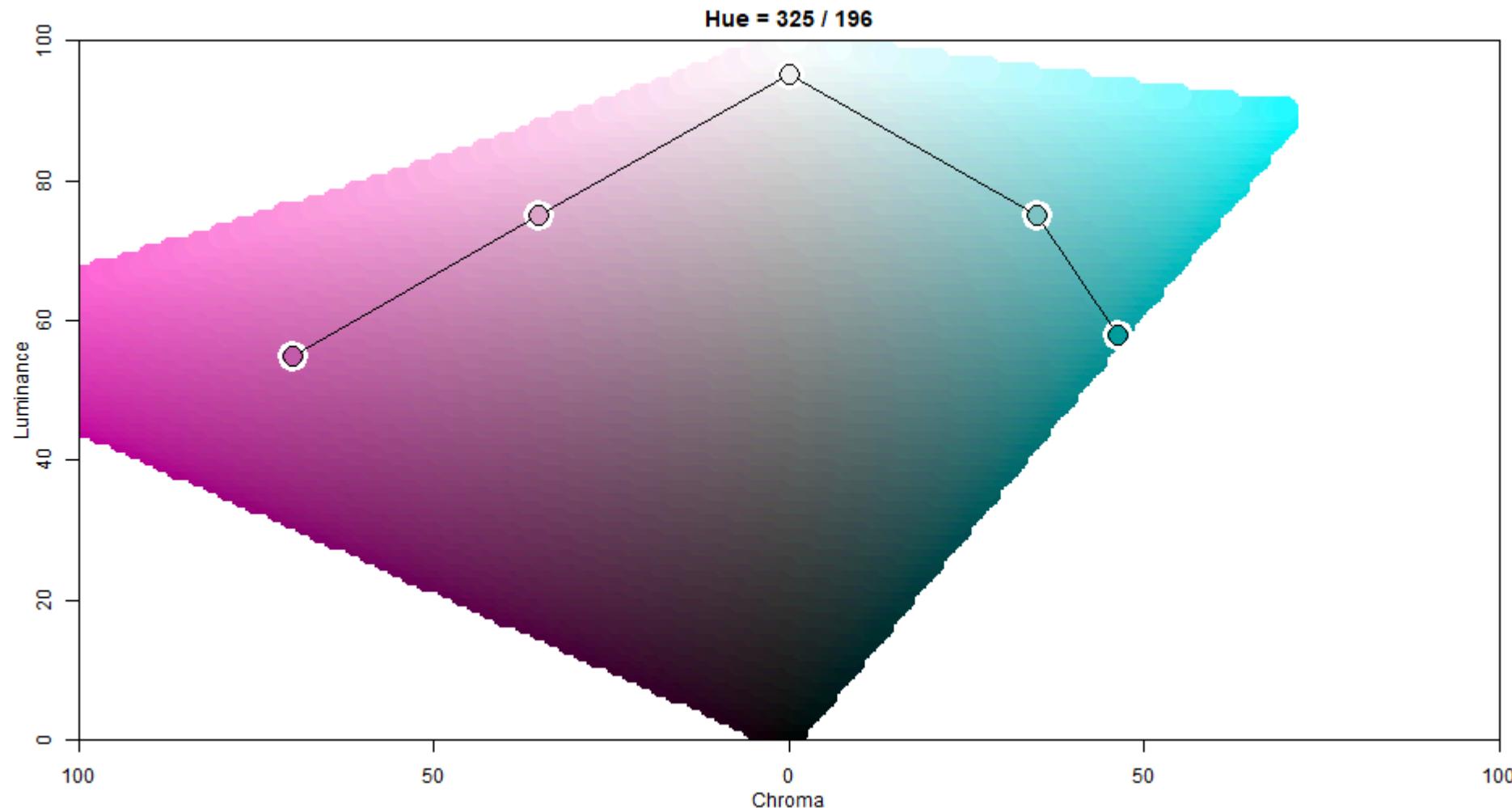
---

Note - this is base graphics

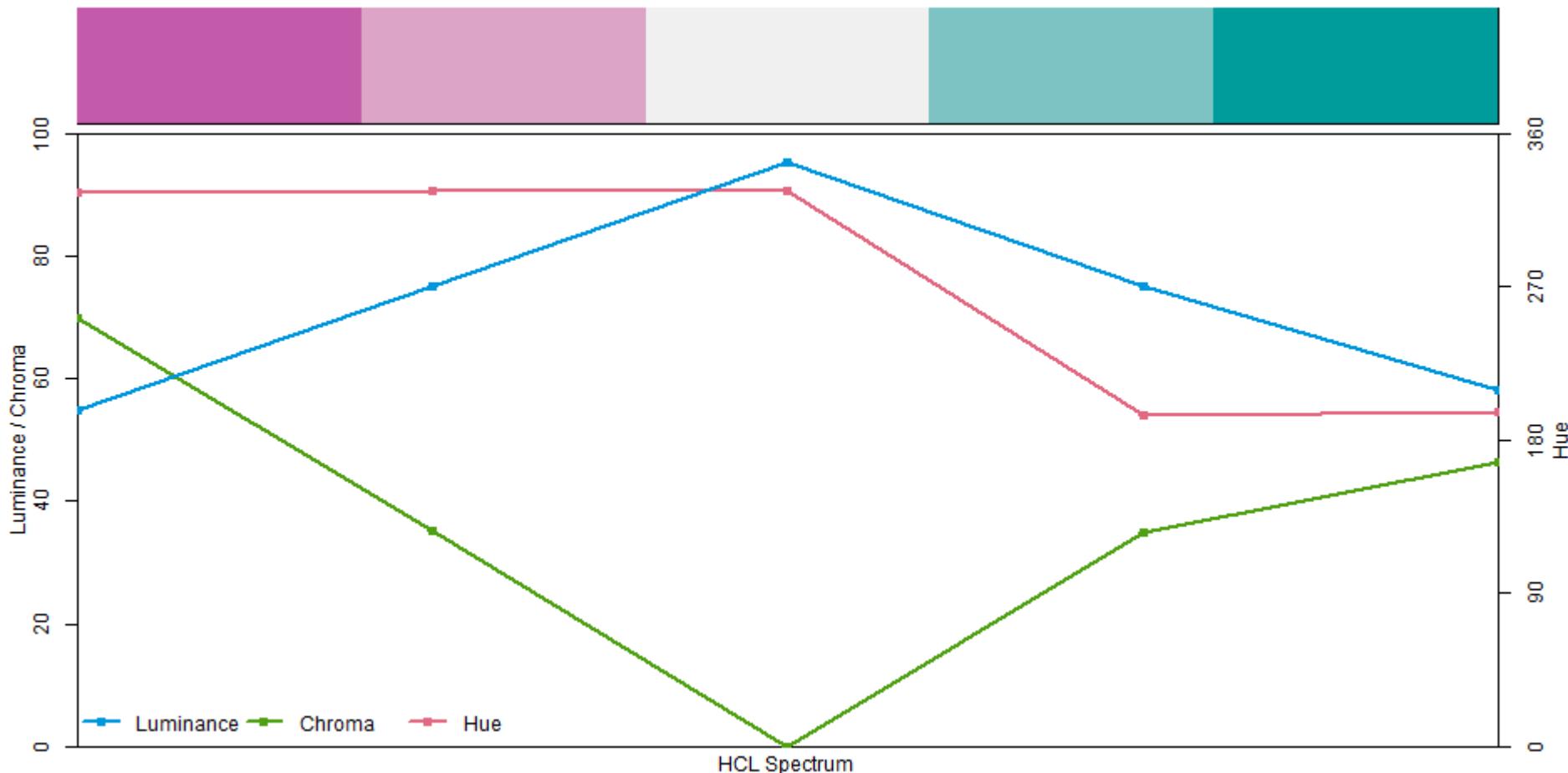
```
par(bg = "gray20", cex = 3, mar = rep(0, 4))
demoplot(our_scale, "scatter")
```



```
hclplot(our_scale)
```



```
specplot(our_scale, type = "o")
```

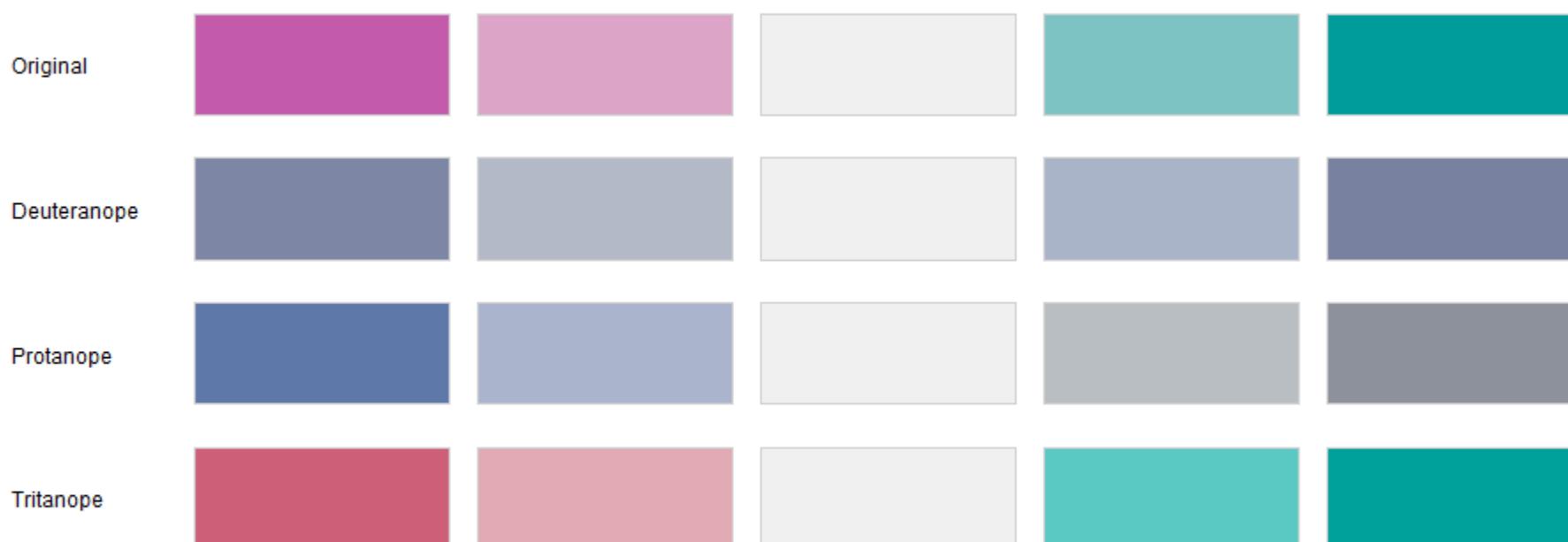


# Check colorblindness

We can check for our palette, in addition to our figure overall

```
swatchplot("Our palette" = our_scale, cvd = TRUE)
```

**Our palette**



# Interactivity

---

You can do this all online interactively with the demo plots

<http://hclwizard.org:3000/hclwizard/>

## CVD Emulator online

<http://hclwizard.org:3000/cvdemulator/>

# Color as a tool to highlight

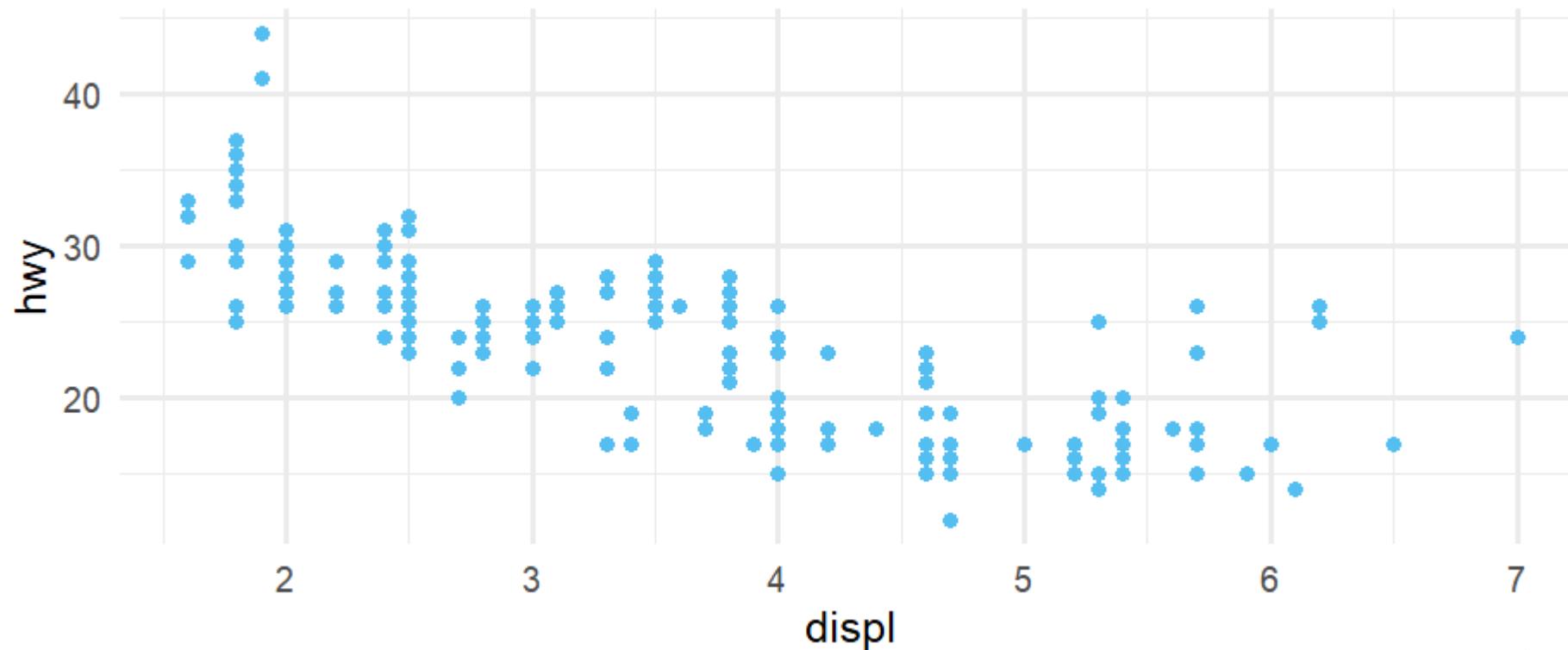
---

# MPG data

---

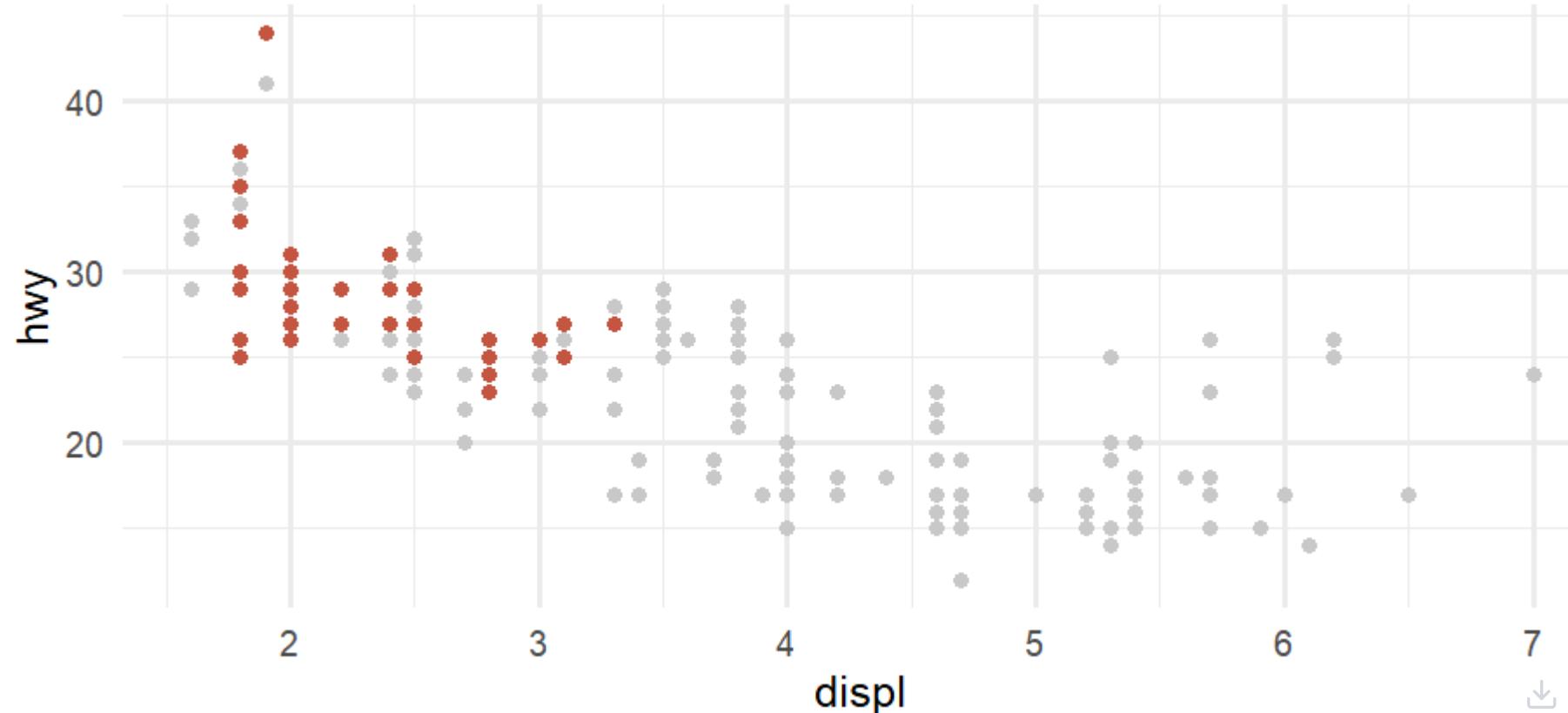
Basic scatterplot of weight to highway mpg

```
ggplot(mpg, aes(displ, hwy)) +  
  geom_point()
```



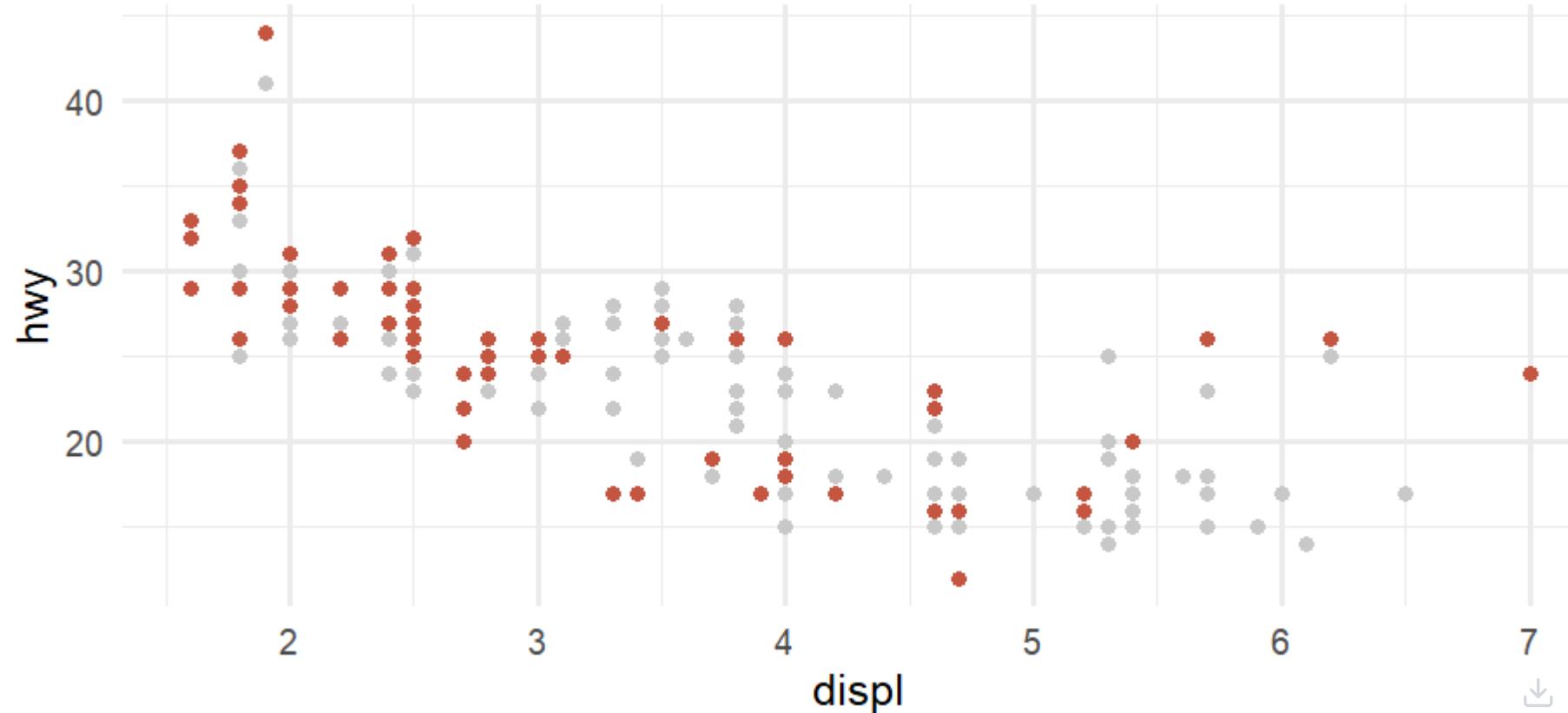
# Highlight compact cars

```
ggplot(mpg, aes(displ, hwy)) +  
  geom_point(color = "gray80") +  
  geom_point(data = filter(mpg, class == "compact"),  
             color = "#C55644")
```



# Highlight manual cars

```
ggplot(mpg, aes(displ, hwy)) +  
  geom_point(color = "gray80") +  
  geom_point(data = filter(mpg, str_detect(trans, "manual")),  
             color = "#C55644")
```



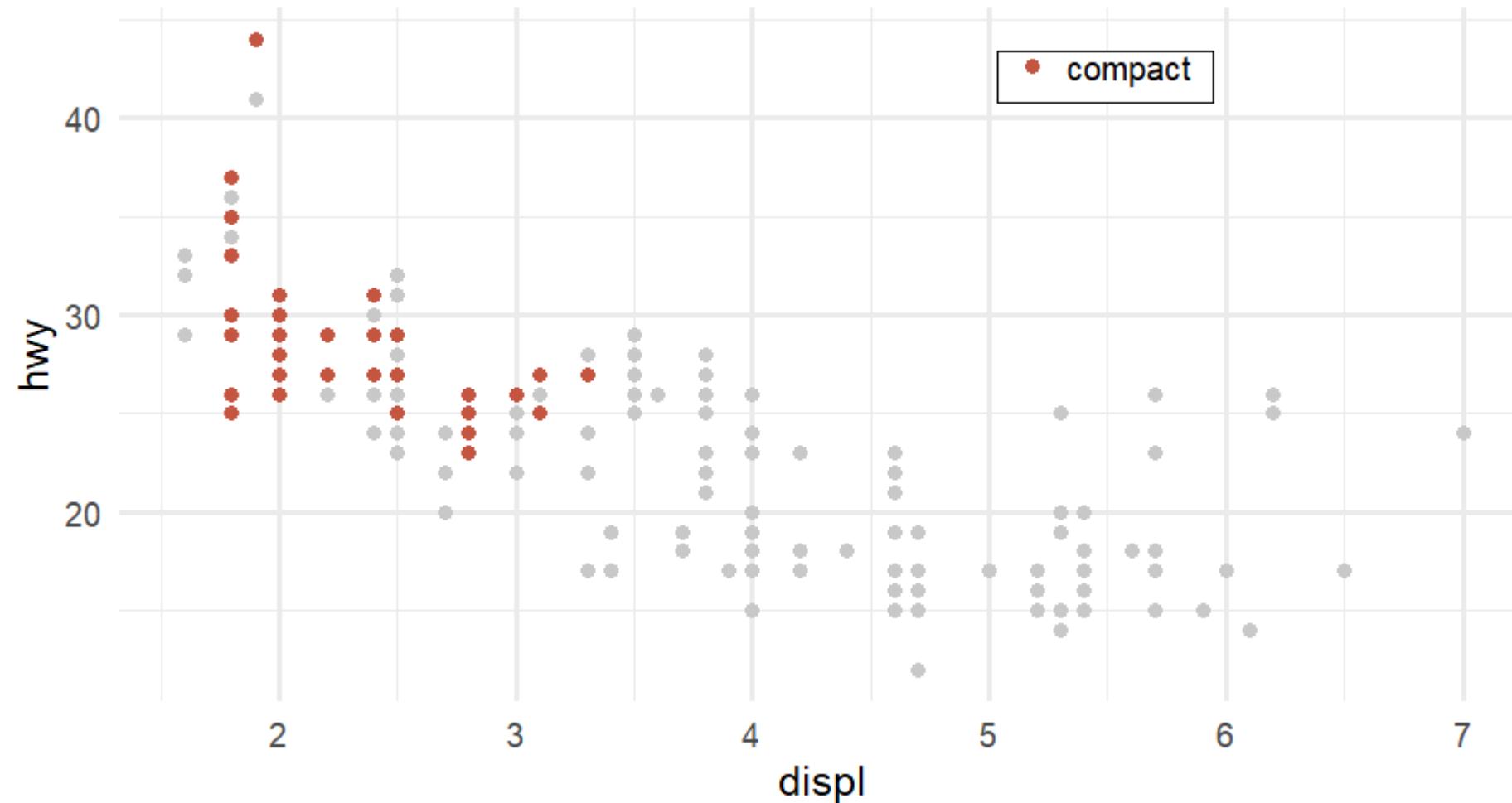
# Add a legend

---

Couple of different ways - mostly hacky

- Pretend you have a column called "compact"

```
ggplot(mpg, aes(displ, hwy)) +  
  geom_point(color = "gray80") +  
  geom_point(data = filter(mpg, class == "compact"),  
             aes(color = "compact")) +  
  scale_color_manual(values = "#C55644") +  
  theme(  
    legend.title = element_blank(),  
    legend.position = c(0.7, 0.9),  
    legend.box.background = element_rect(colour = "black"),  
    legend.box.margin = margin(t = -0.5, unit = "cm"))  
)
```



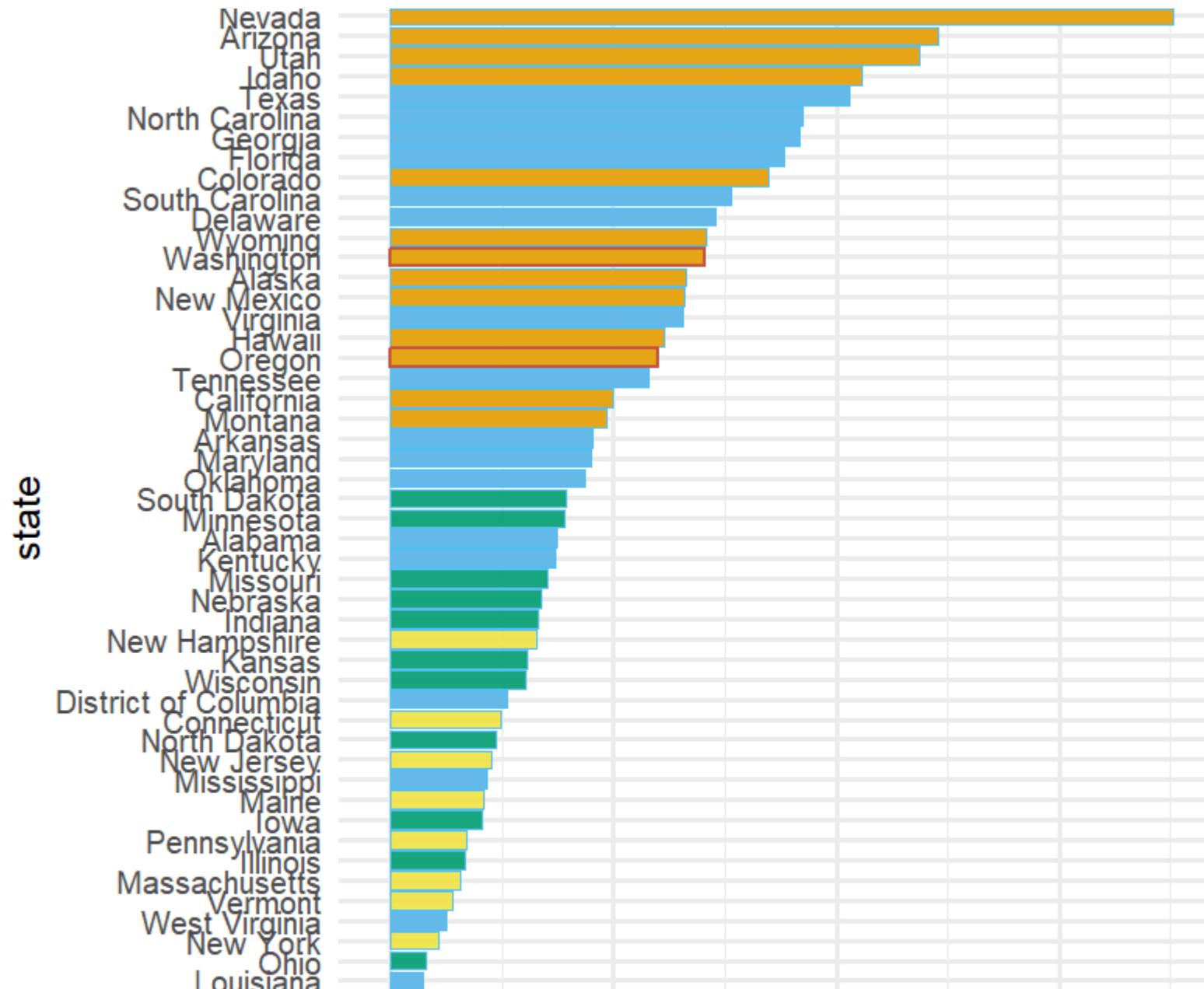
# Back to our states plot

---

## Highlight Oregon and Washington

```
popgrowth_df <- popgrowth_df %>%
  arrange(desc(popgrowth)) %>%
  mutate(state = factor(state, levels = state))

ggplot(popgrowth_df, aes(x=popgrowth, y=state)) +
  geom_col(aes(fill = region), alpha = 0.9) +
  geom_col(data=filter(popgrowth_df, state == 'Oregon' | state == 'Washington'),
           fill = NA,
           color = '#C55644',
           linewidth = 1,
           width = 0.9) + # Added width parameter to make it slightly narrower
  scale_fill_OkabeIto()
```



region

- West
- South
- Midwest
- Northeast

# Color labels

---

```
states <- unique(popgrowth_df$state)

label_color <- ifelse(states == "Oregon" | states == "Washington",
                      "#C55644",
                      "gray30")

label_color
```

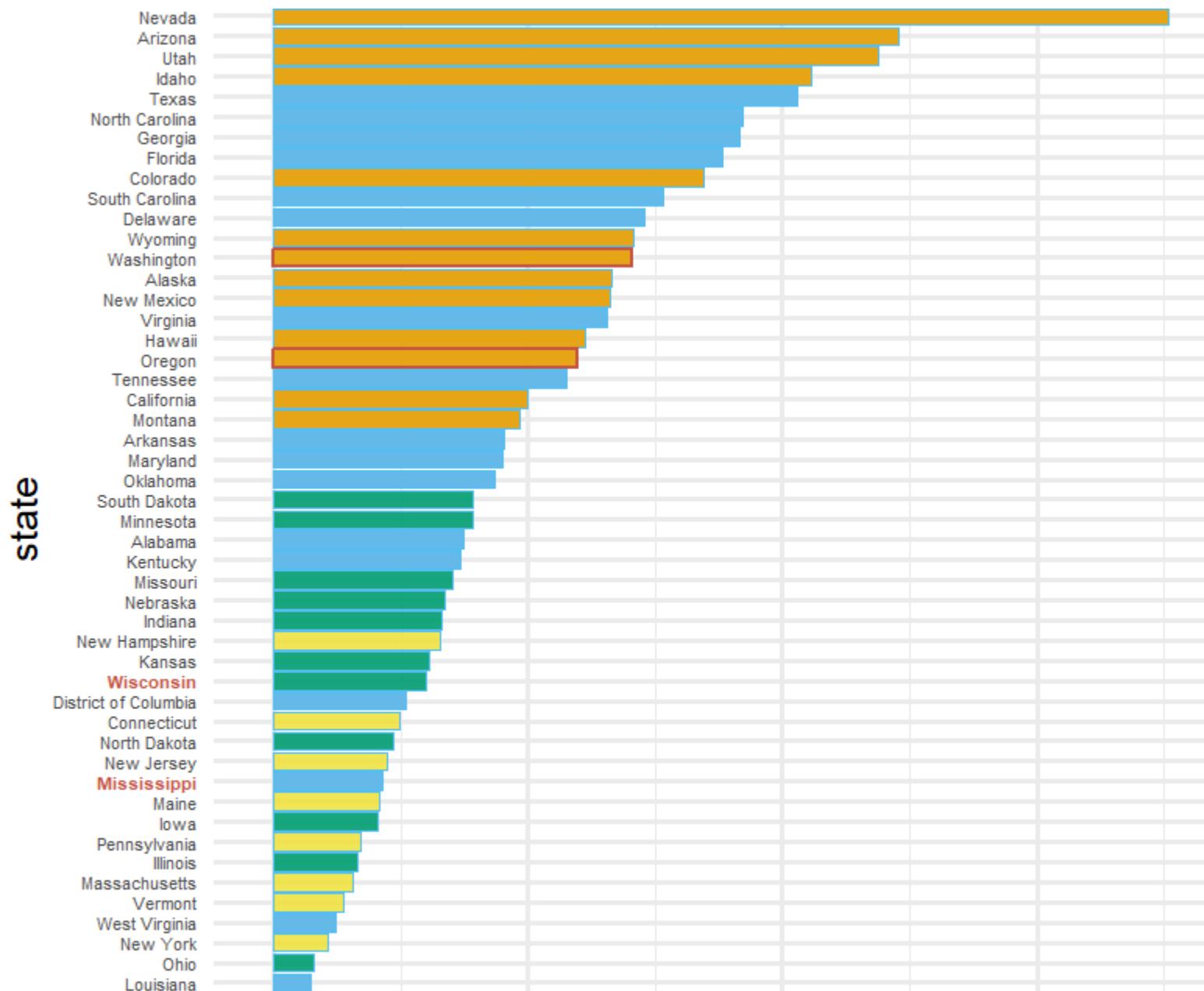
```
## [1] "gray30"  "gray30"
## [19] "gray30"  "gray30"
## [37] "gray30"  "gray30"
```

```
label_face <- ifelse(states == "Oregon" | states == "Washington",
                      "bold",
                      "plain")

label_face
```

```
## [1] "plain"  "bold"
## [23] "plain"  "plain"
## [45] "plain"  "plain"  "plain"  "plain"  "plain"  "plain"  "plain"
```

```
ggplot(popgrowth_df, aes(x=popgrowth, y=state)) +  
  geom_col(aes(fill = region), alpha = 0.9) +  
  geom_col(data=filter(popgrowth_df, state == 'Oregon' | state == 'Washington'),  
           fill = NA,  
           color = '#C55644',  
           linewidth = 1,  
           width = 0.9) + # Added width parameter to make it slightly narrower  
  scale_fill_OkabeIto() +  
  theme(  
    axis.text.y = element_text(  
      color = label_color,  
      face = label_face  
    )  
  )
```



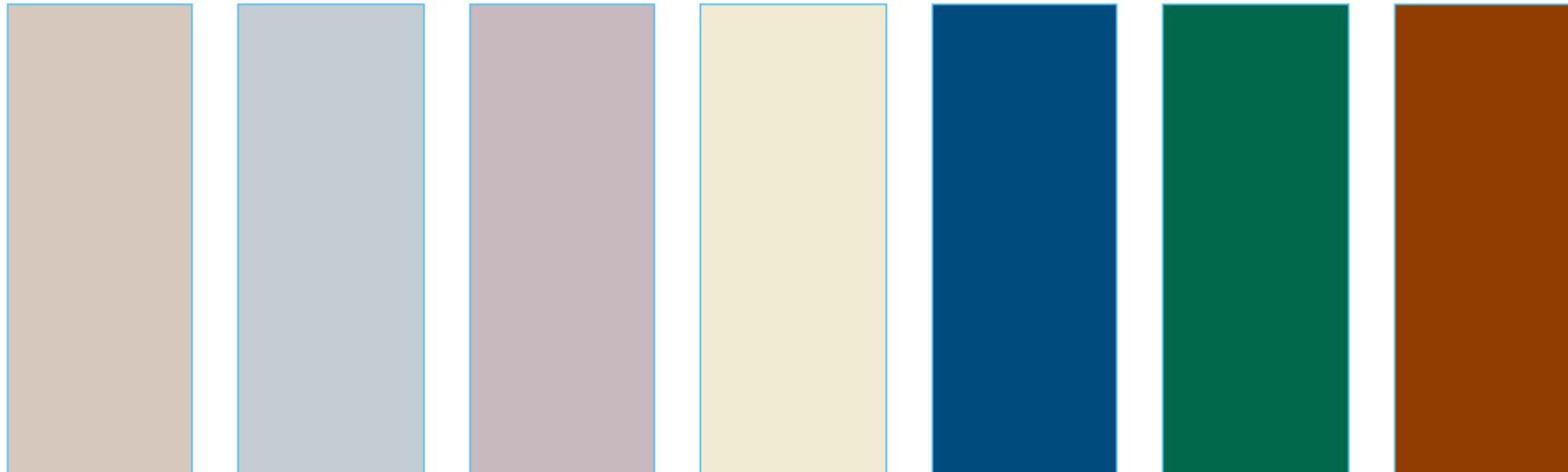
region

- West
- South
- Midwest
- Northeast

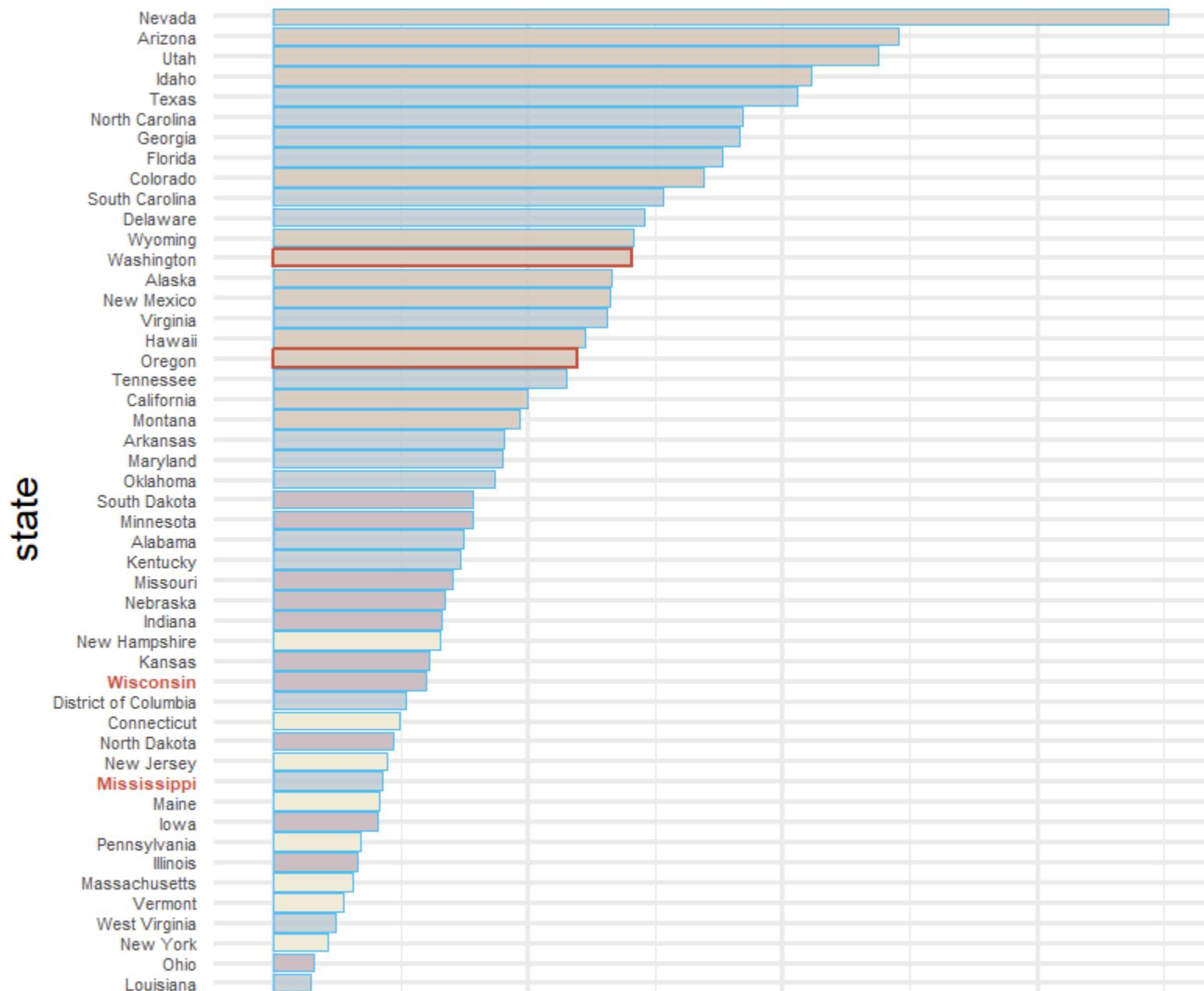
# Even better

---

```
accent_OkabeIto <- palette_OkabeIto[c(1, 2, 7, 4, 5, 3, 6)]
accent_OkabeIto[1:4] <- desaturate(lighten(accent_OkabeIto[1:4], .4), .8)
accent_OkabeIto[5:7] <- darken(accent_OkabeIto[5:7], .3)
gg_color_swatches(7) +
  scale_fill_manual(values = accent_OkabeIto)
```



```
ggplot(popgrowth_df, aes(x=popgrowth, y=state)) +  
  geom_col(aes(fill = region), alpha = 0.9) +  
  geom_col(data=filter(popgrowth_df, state == 'Oregon' | state == 'Washington'),  
            fill = NA,  
            color = '#C55644',  
            linewidth = 1,  
            width = 0.9) +  
  scale_fill_manual(values = accent_OkabeIto) +  
  theme(axis.text.y = element_text(color = label_color,  
                                    face = label_face))
```



region

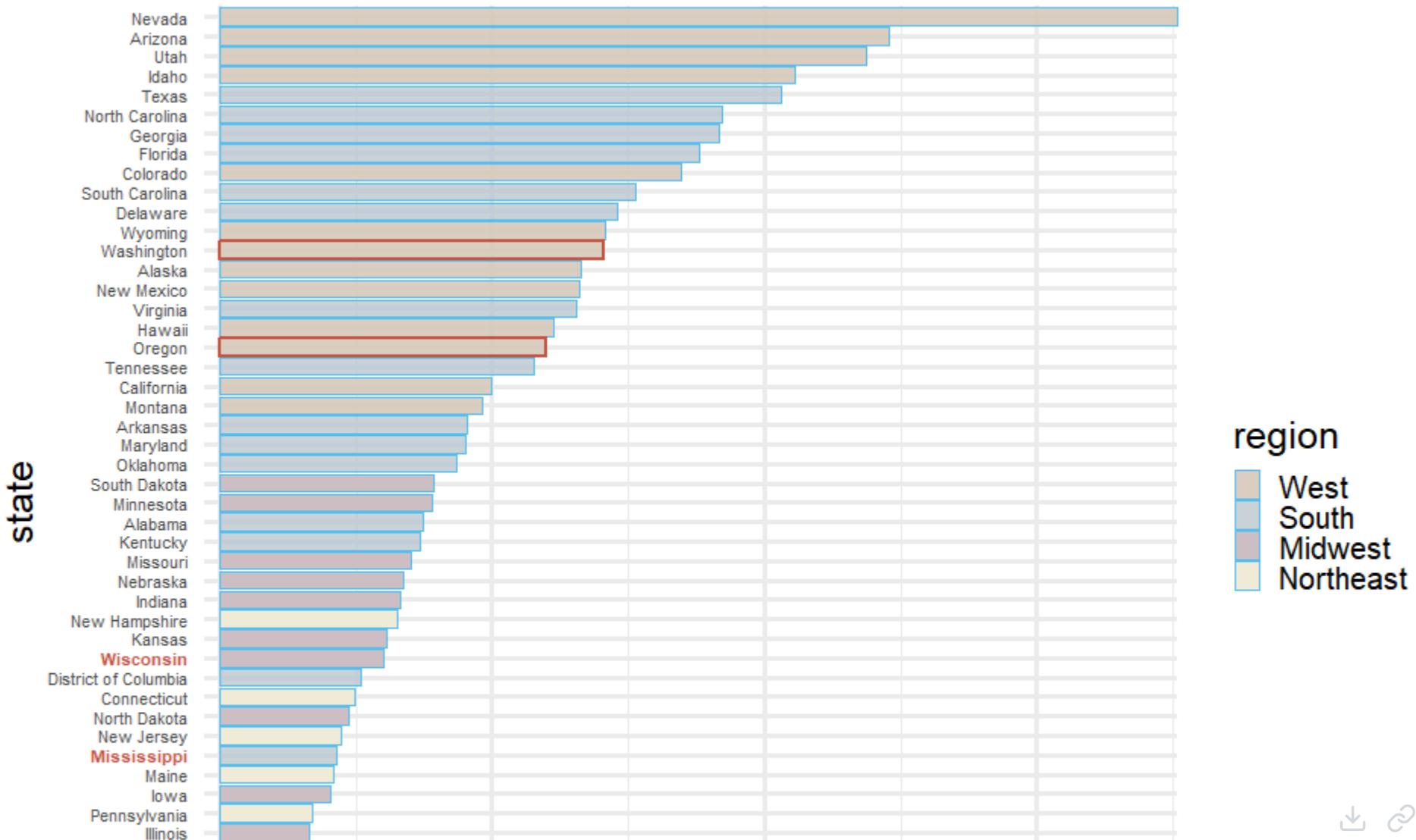
- West
- South
- Midwest
- Northeast

# Or even better (imo)

```
library(ggtext)
ggplot(popgrowth_df, aes(x=popgrowth, y=state)) +
  geom_col(aes(fill = region), alpha = 0.9) +
  geom_col(data=filter(popgrowth_df, state == 'Oregon' | state == 'Washington'),
            fill = NA,
            color = '#C55644',
            linewidth = 1,
            width = 0.9) + # Added width parameter to make it slightly narrower
  scale_fill_manual(values = accent_OkabeIto) +
  scale_x_continuous(expand = c(0, 0)) +
  labs(title = "Population growth by region",
       subtitle = "The <span style = 'color: #C55644'>**northwest**</span> is where it's at") +
  theme(axis.text.y = element_text(color = label_color,
                                    face = label_face),
        plot.subtitle = element_markdown())
```

# Population growth by region

The **northwest** is where it's at

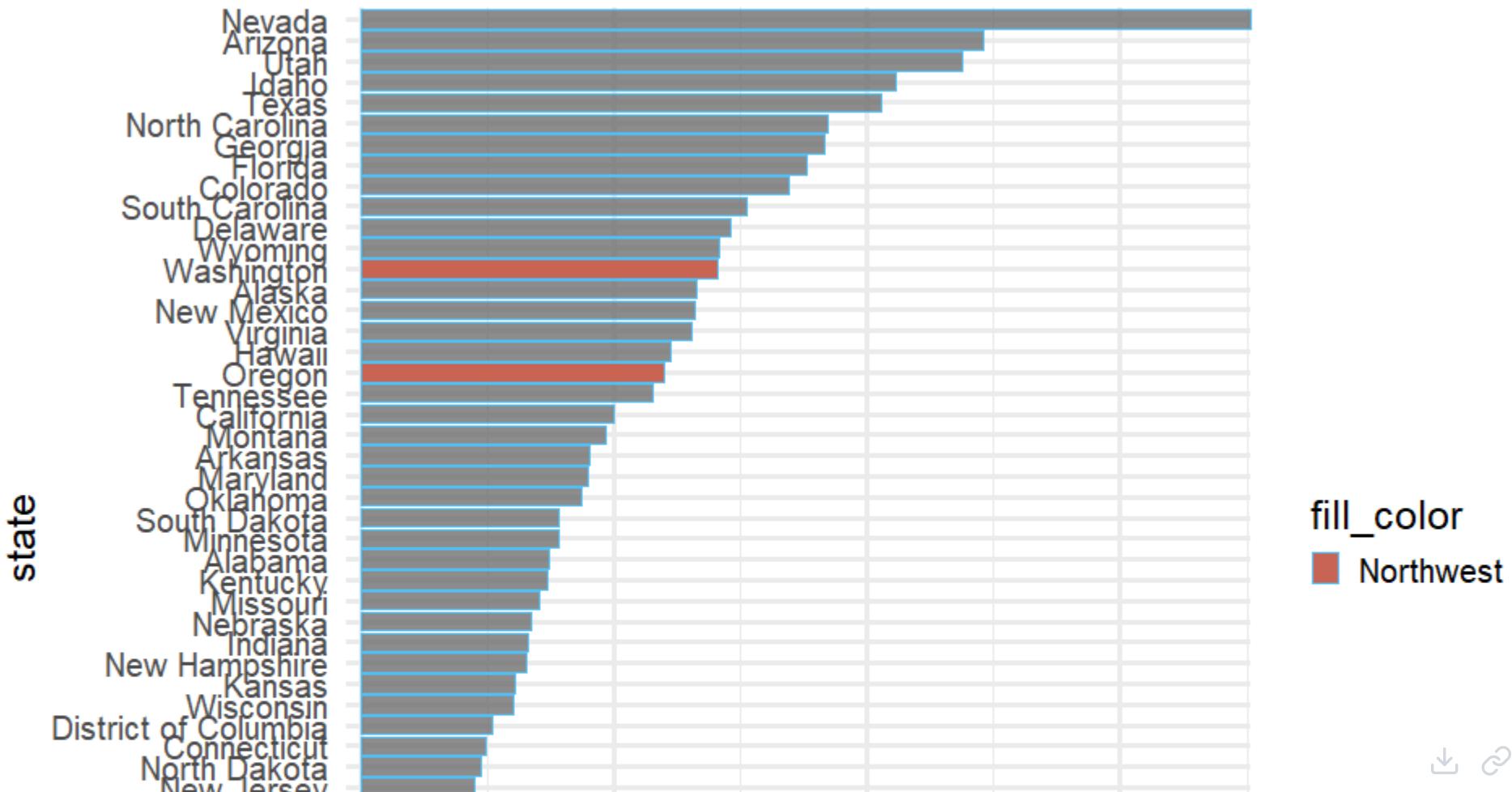


# One last attempt

---

Population growth by region

The **northwest** is where it's at



# Back to cars plot

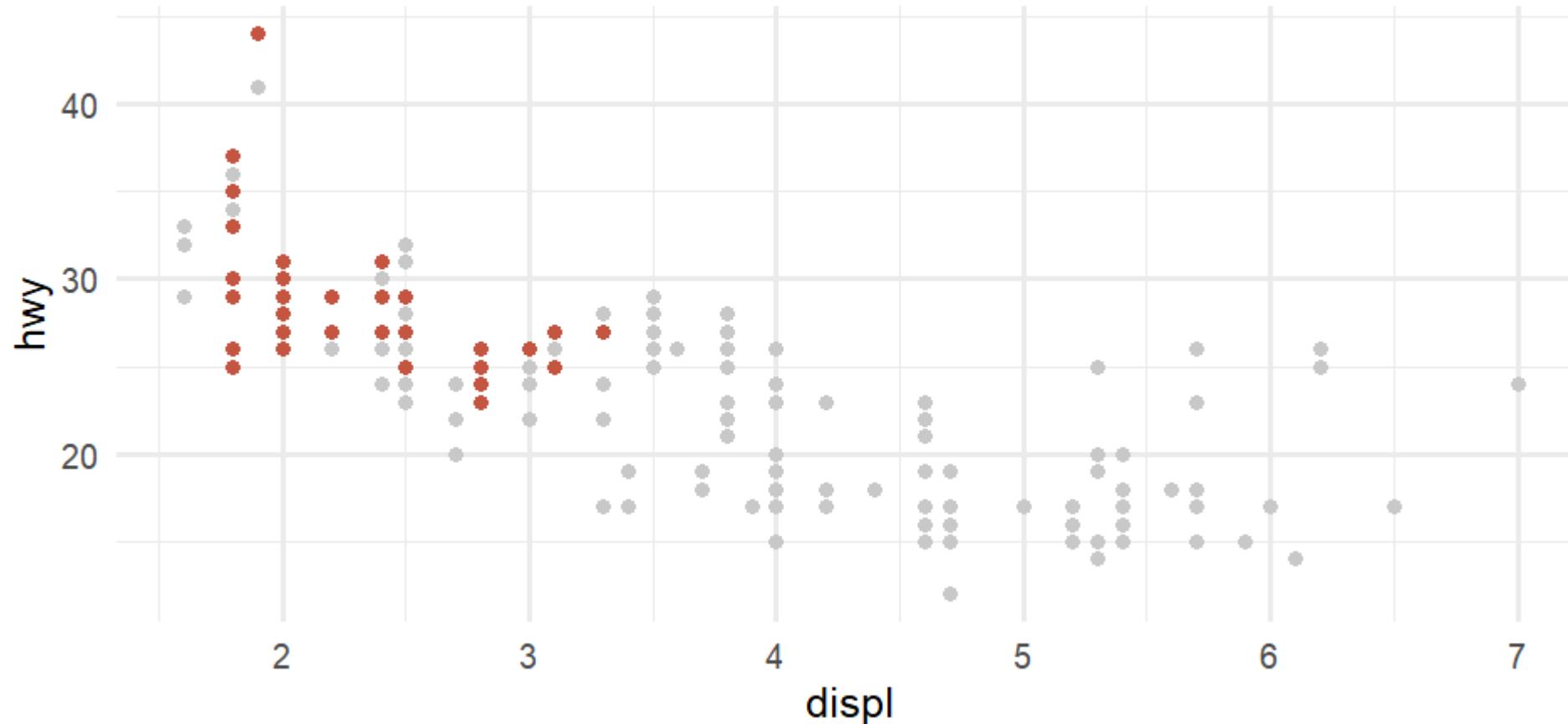
---

We can do this same thing and avoid the legend altogether.

```
ggplot(mpg, aes(displ, hwy)) +  
  geom_point(color = "gray80") +  
  geom_point(data = filter(mpg, class == "compact"),  
             color = "#C55644") +  
  labs(  
    title = "Cars with bigger engines get lower miles per gallon",  
    subtitle = "<span style = 'color: #C55644'>**Compact**</span> cars typically have small engines"  
) +  
  theme(plot.subtitle = element_markdown())
```

Cars with bigger engines get lower miles per gallon

**Compact** cars typically have small engines



# Data viz in Wild

---

Erick

Emily

Saratessa and Sophia on deck

# Last example

---

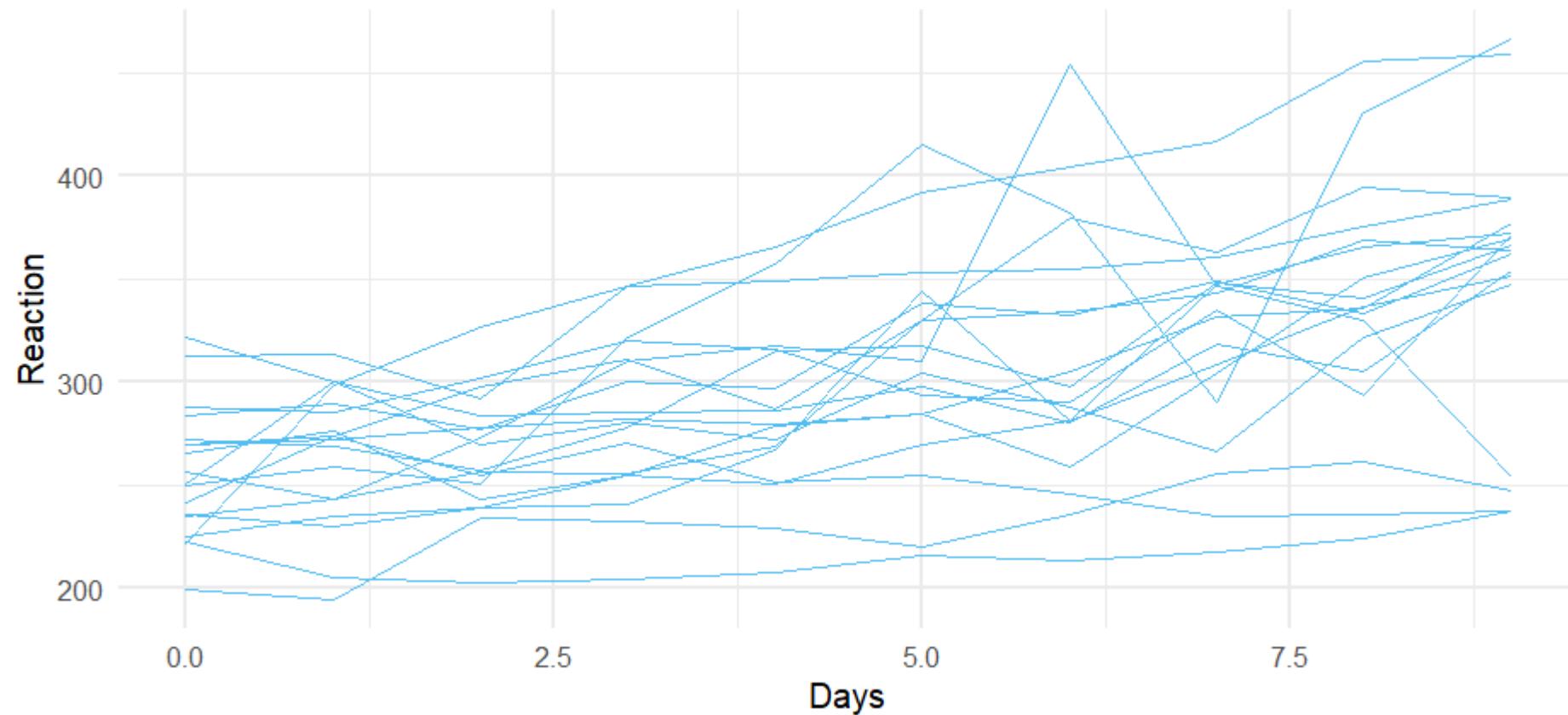
```
data(sleepstudy, package = "lme4")
head(sleepstudy)
```

```
##   Reaction Days Subject
## 1      250     0    308
## 2      259     1    308
## 3      251     2    308
## 4      321     3    308
## 5      357     4    308
## 6      415     5    308
```

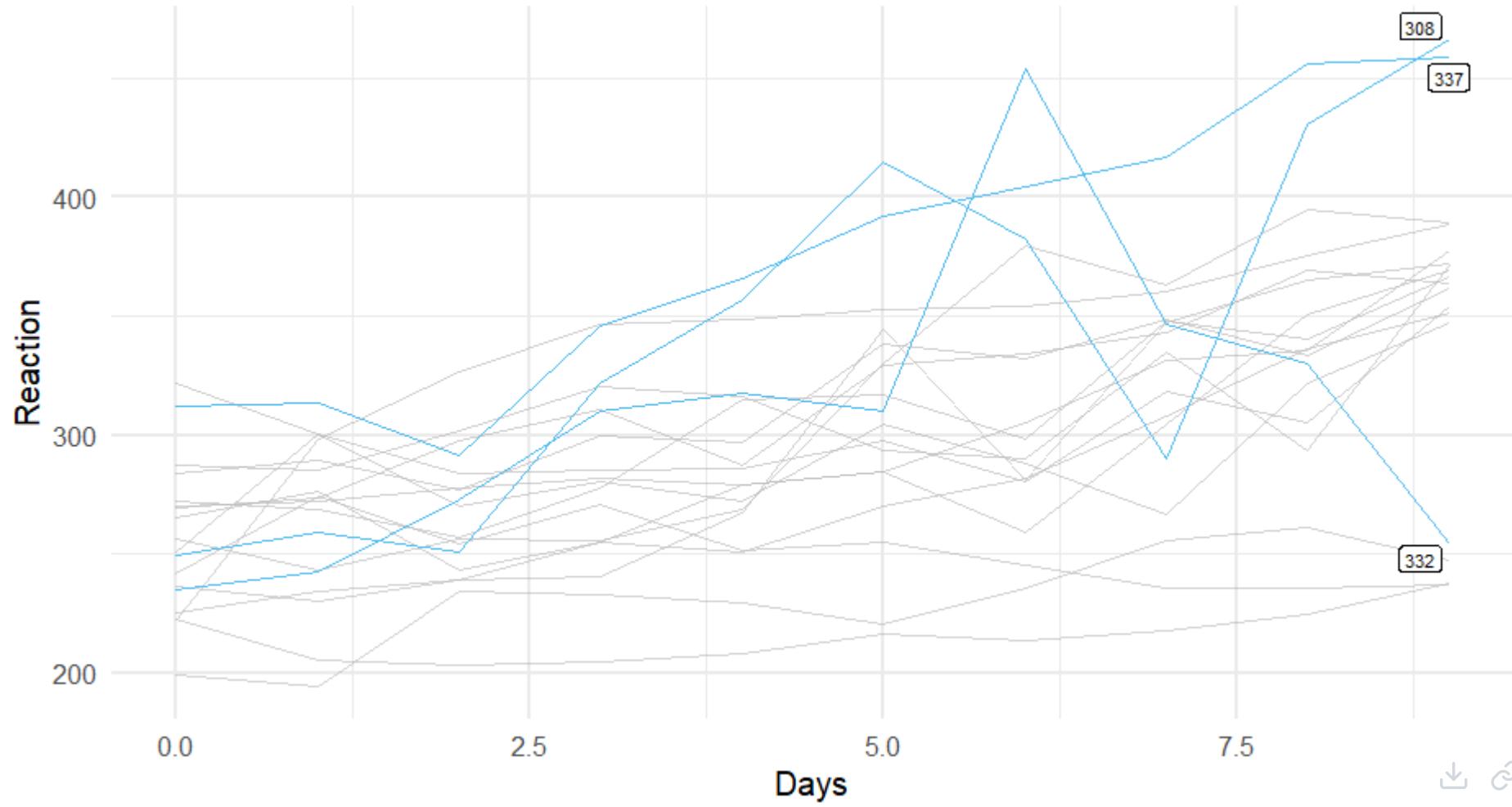
# Plot by subject

---

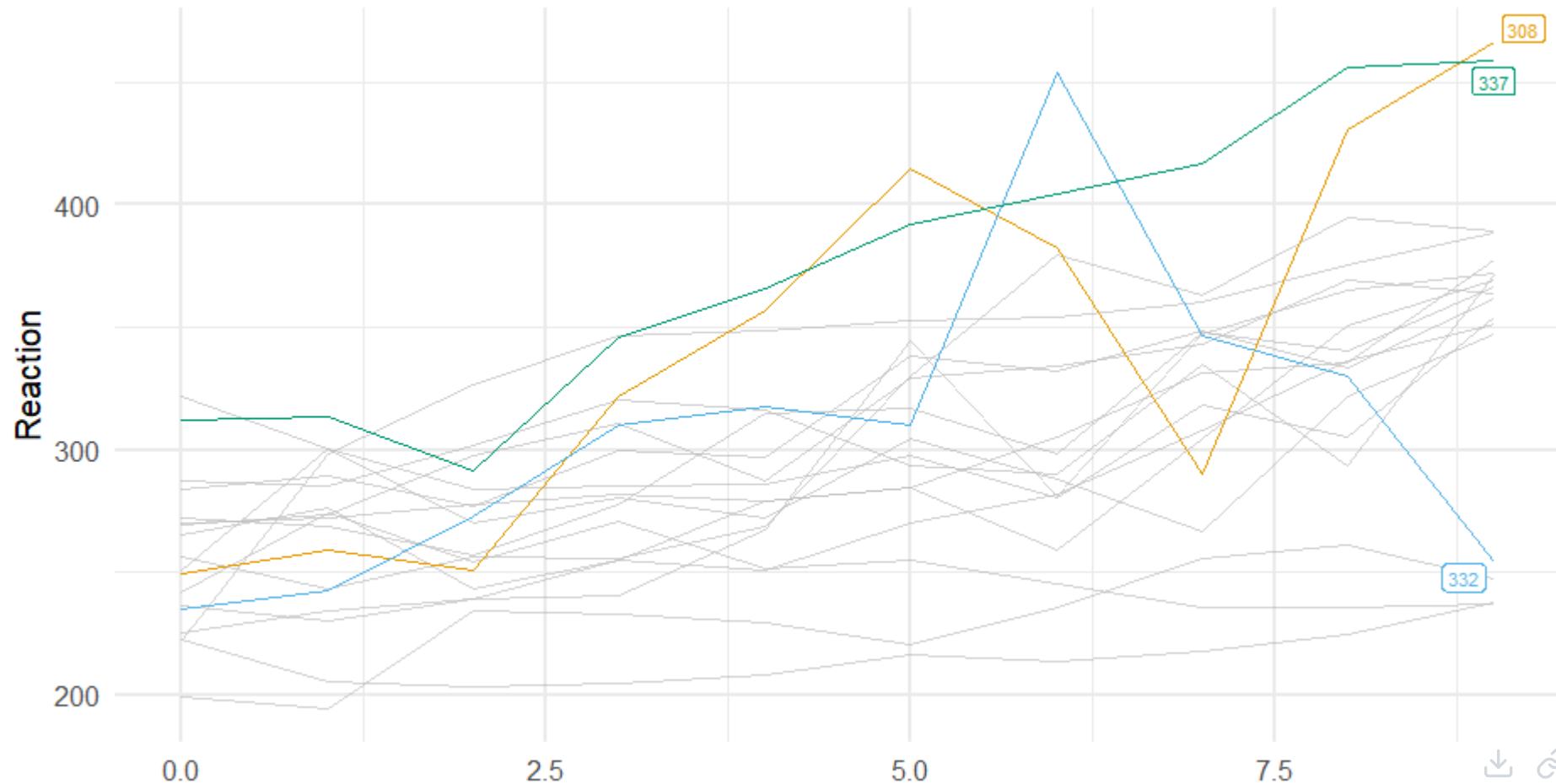
```
ggplot(sleepstudy, aes(Days, Reaction, group = Subject)) +  
  geom_line()
```



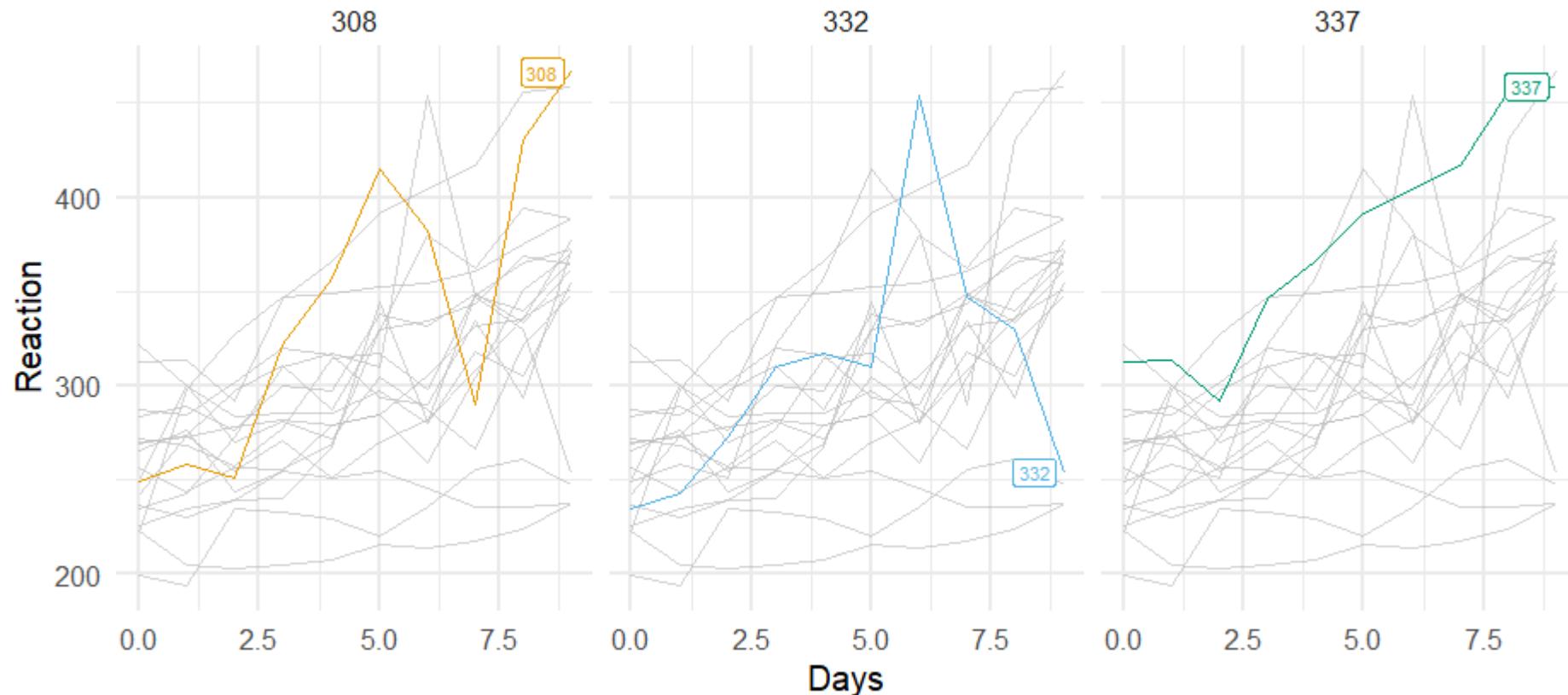
```
library(gghighlight)
ggplot(sleepstudy, aes(Days, Reaction, group = Subject)) +
  geom_line() +
  gghighlight(max(Reaction) > 400)
```



```
library(gghighlight)
ggplot(sleepstudy, aes(Days, Reaction, color = Subject)) +
  geom_line() +
  gghighlight(max(Reaction) > 400) +
  scale_color_OkabeIto()
```



```
library(gghighlight)
ggplot(sleepstudy, aes(Days, Reaction, color = Subject)) +
  geom_line() +
  facet_wrap(~Subject) +
  gghighlight(max(Reaction) > 400) +
  scale_color_OkabeIto()
```



# Highlighting

The `gghighlight` package is really neat, but I have had issues with it in the past.

If you have troubles, you can always create them more manually has we did previously

# Example

---

This is a little tricky. First, create a subset of the data that only has the cases you want to highlight

```
# filter
high <- sleepstudy %>%
  filter(Reaction > 400) %>%
  select(Subject)

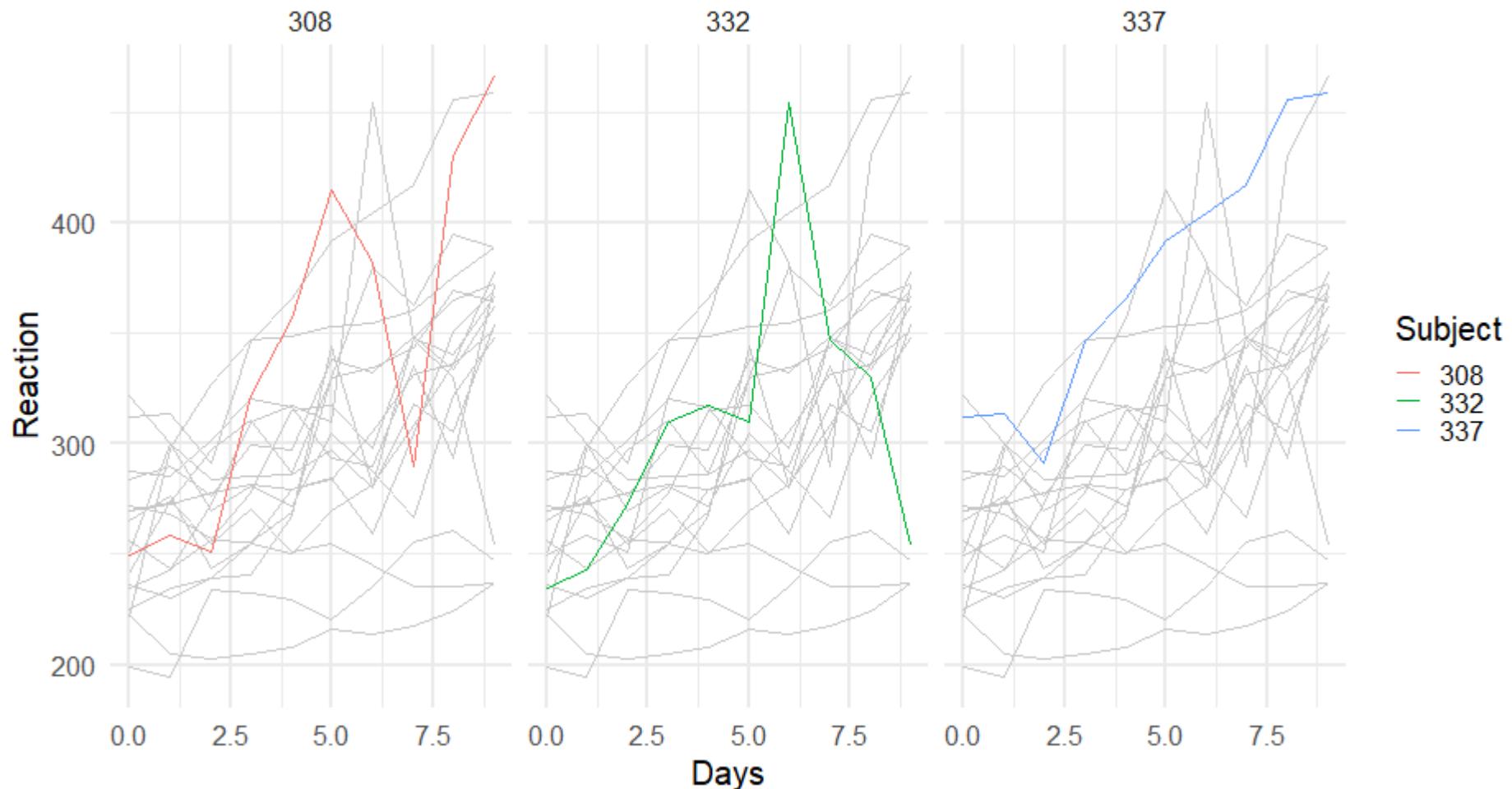
# highlight dataframe
hl <- semi_join(sleepstudy, high)
```

Next, create the background data. We usually just *drop* the faceting column, but in this case we still need the id, so we'll rename it.

```
# rename facet column; use for grouping
bg_data <- sleepstudy %>%
  rename(id = Subject)
```

Finally, plot the highlight data, adding a layer with the background data

```
ggplot(hl, aes(Days, Reaction)) +  
  geom_line(  
    aes(group = id),  
    color = "gray80",  
    data = bg_data  
) +  
  geom_line(  
    aes(color = Subject)  
) +  
  facet_wrap(~Subject)
```



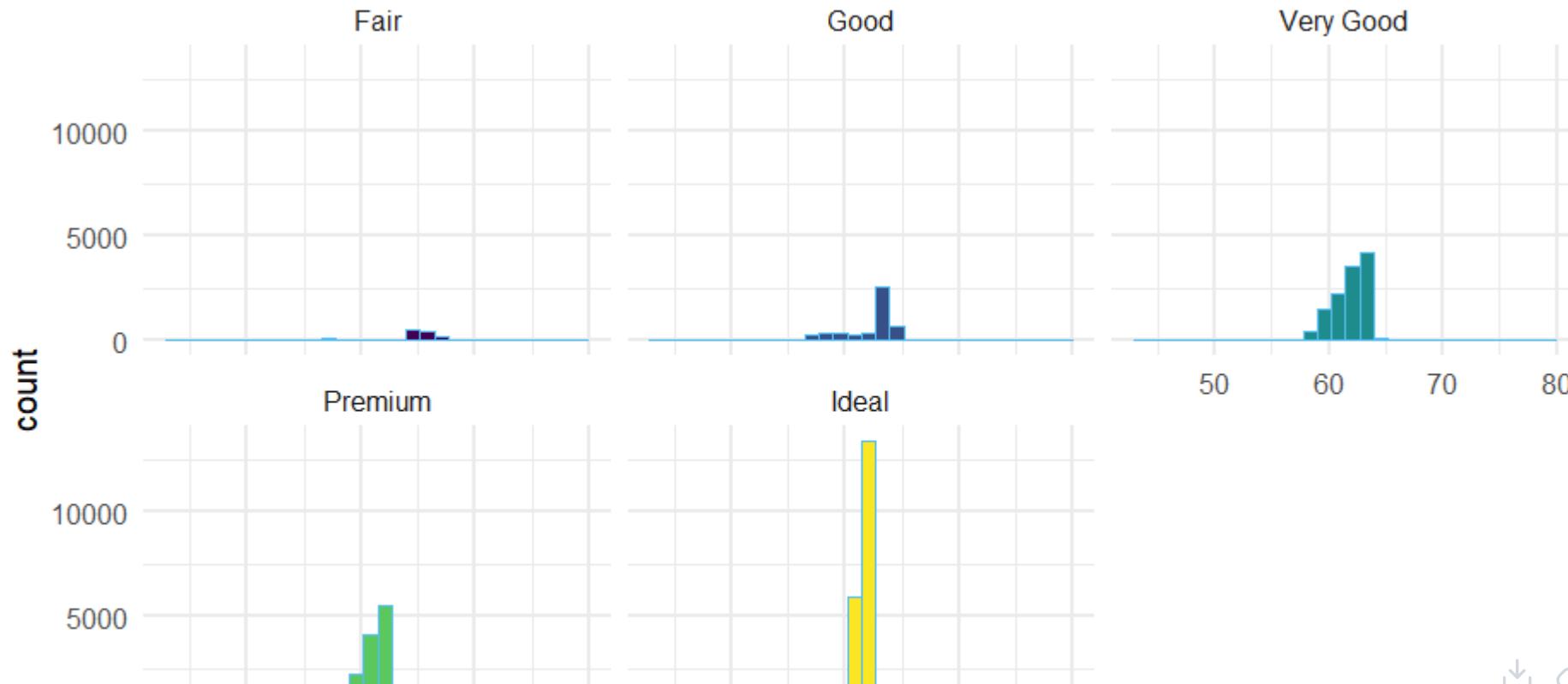
# Very quick aside

---

You can do this with any data - a great alternative to stacked histograms.

# Standard faceted histogram

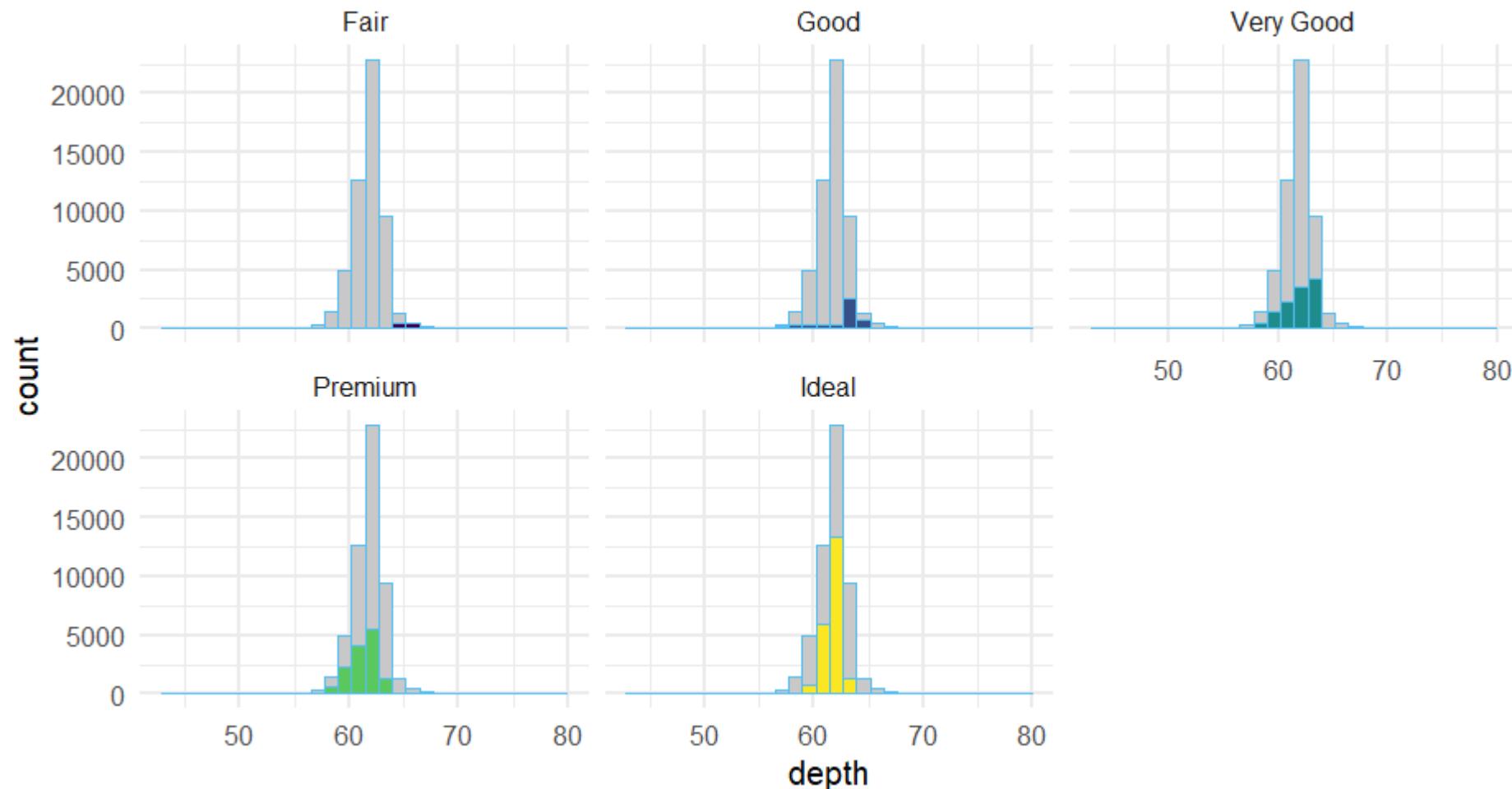
```
ggplot(diamonds, aes(depth)) +  
  geom_histogram(aes(fill = cut)) +  
  facet_wrap(~cut) +  
  guides(fill = "none") # drop Legend
```



# Add a background layer

---

```
ggplot(diamonds, aes(depth)) +  
  geom_histogram(  
    data = select(diamonds, -cut),  
    fill = "gray80"  
  ) +  
  geom_histogram(aes(fill = cut)) +  
  facet_wrap(~cut) +  
  guides(fill = "none") # drop Legend
```

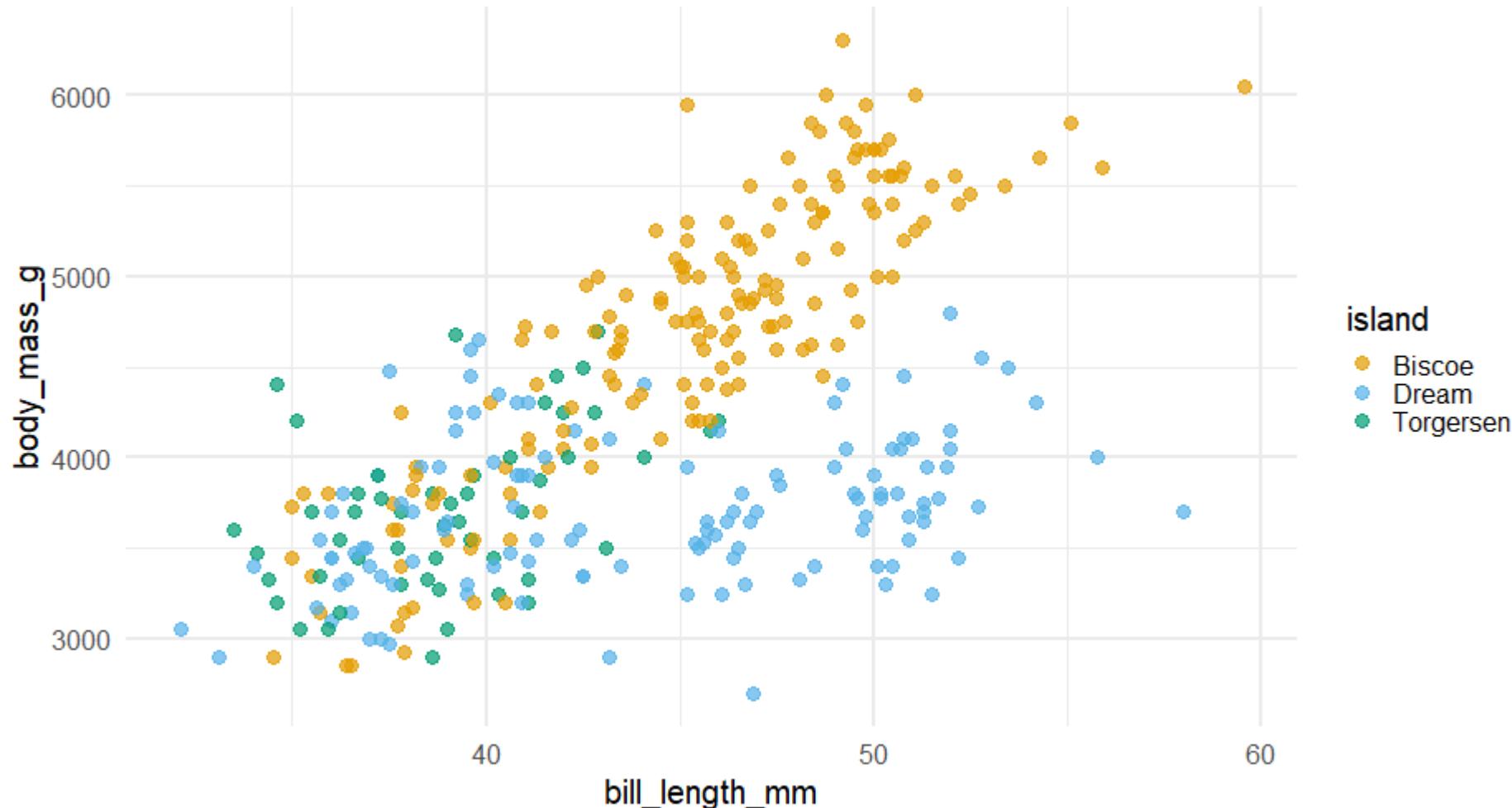


A few other  
things to  
consider

---

# Double encodings

---

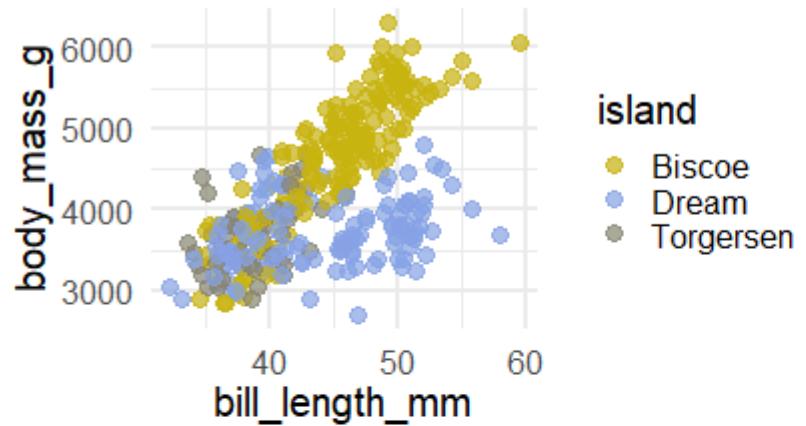


plot is less than ideal. Why?

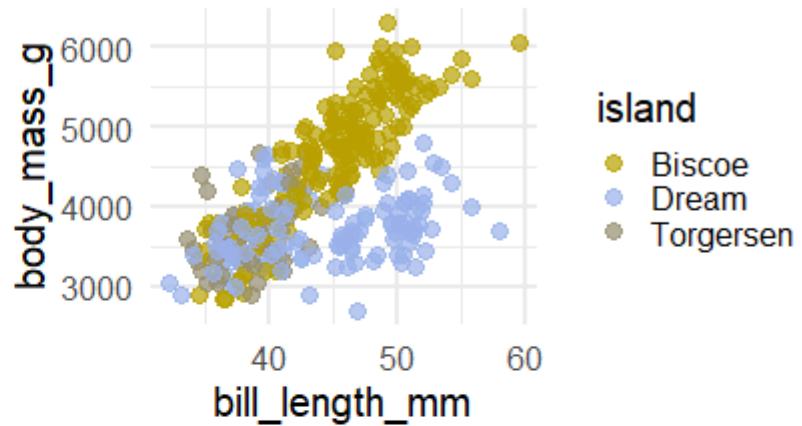
This

# Color blindness

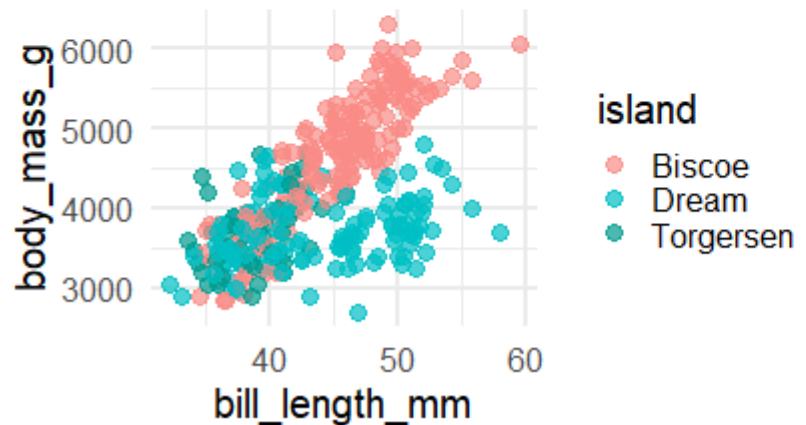
Deutanomaly



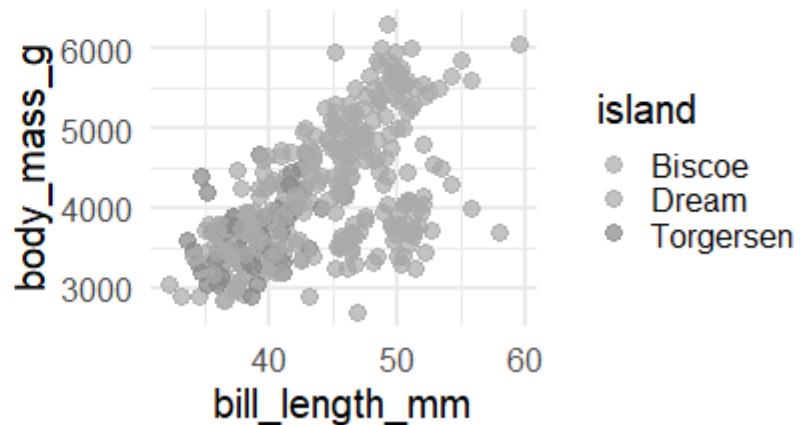
Protanomaly



Tritanomaly

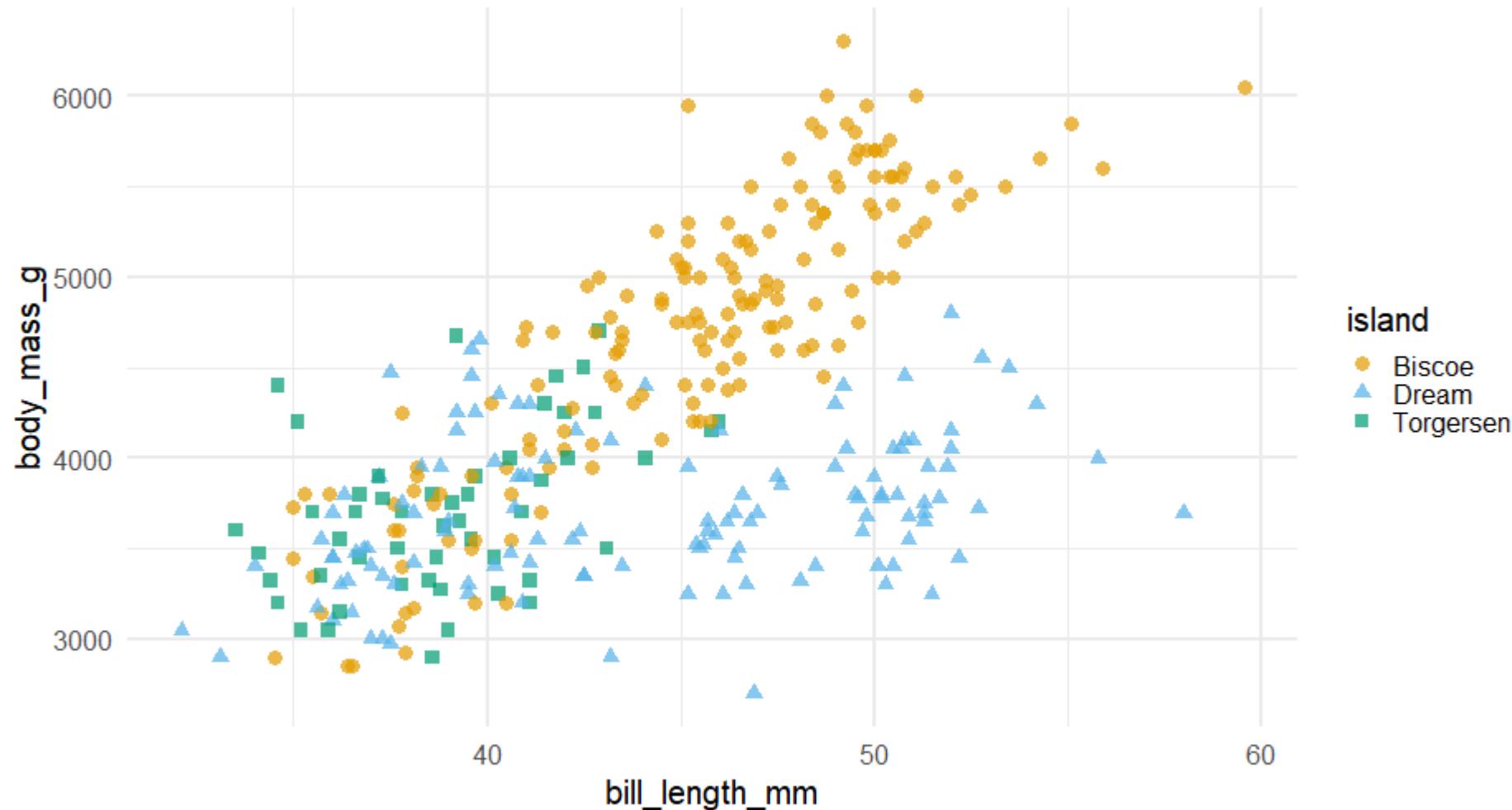


Desaturated

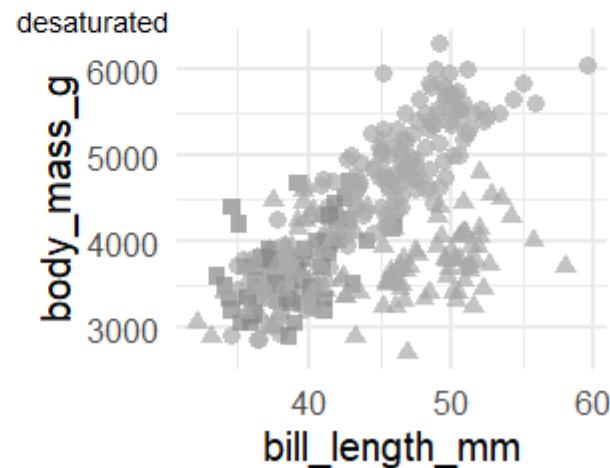
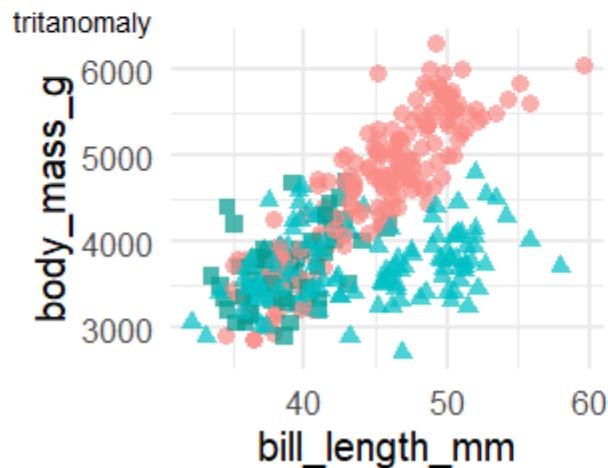
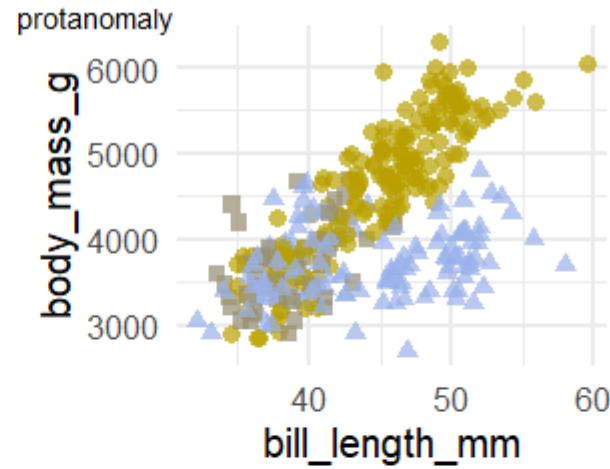
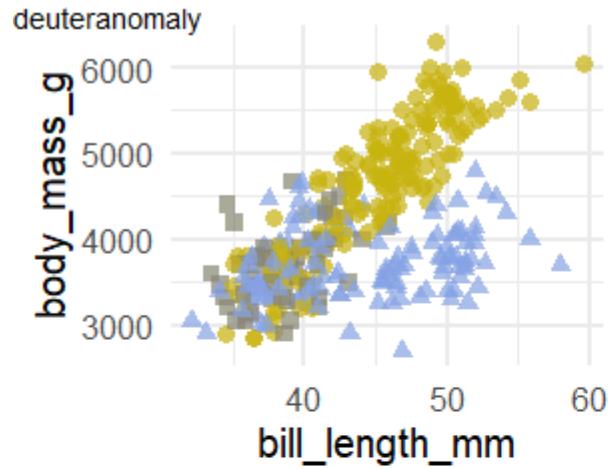


# Better version

---



# Color blindness check



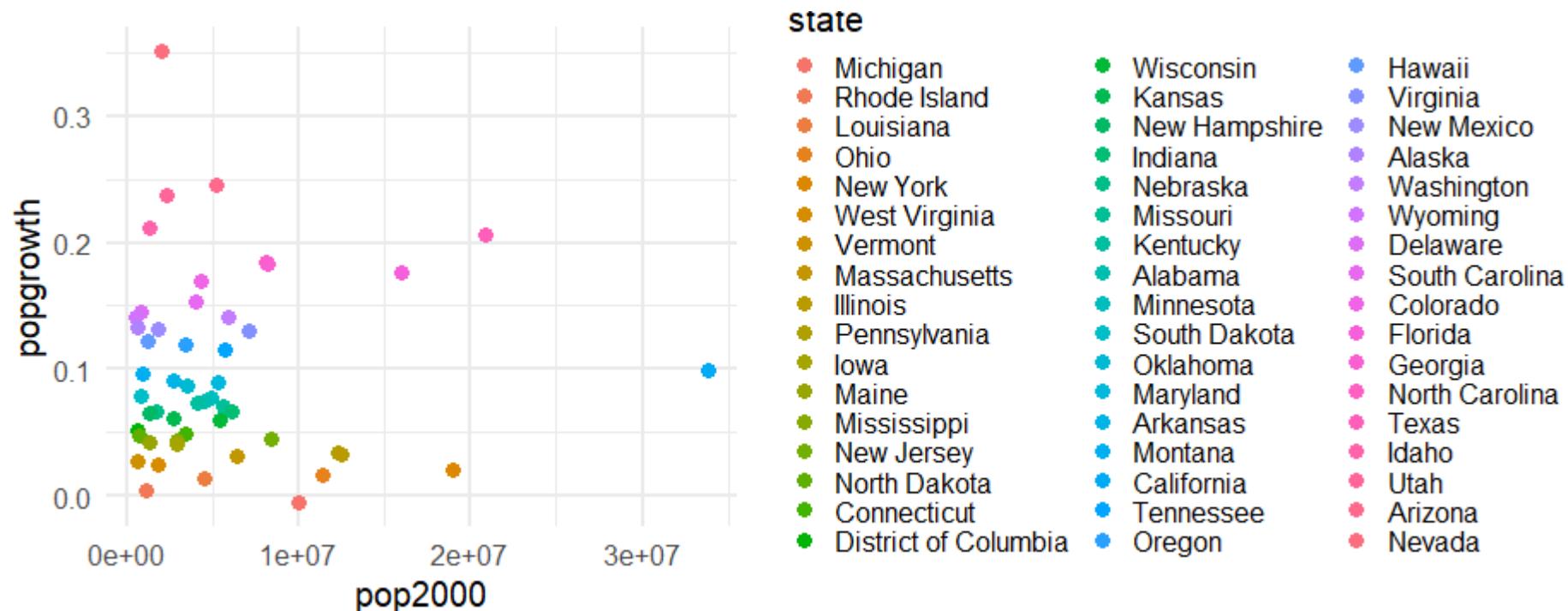
# Common problems with color

---

# Too many colors

More than 5-ish categories generally becomes too difficult to track

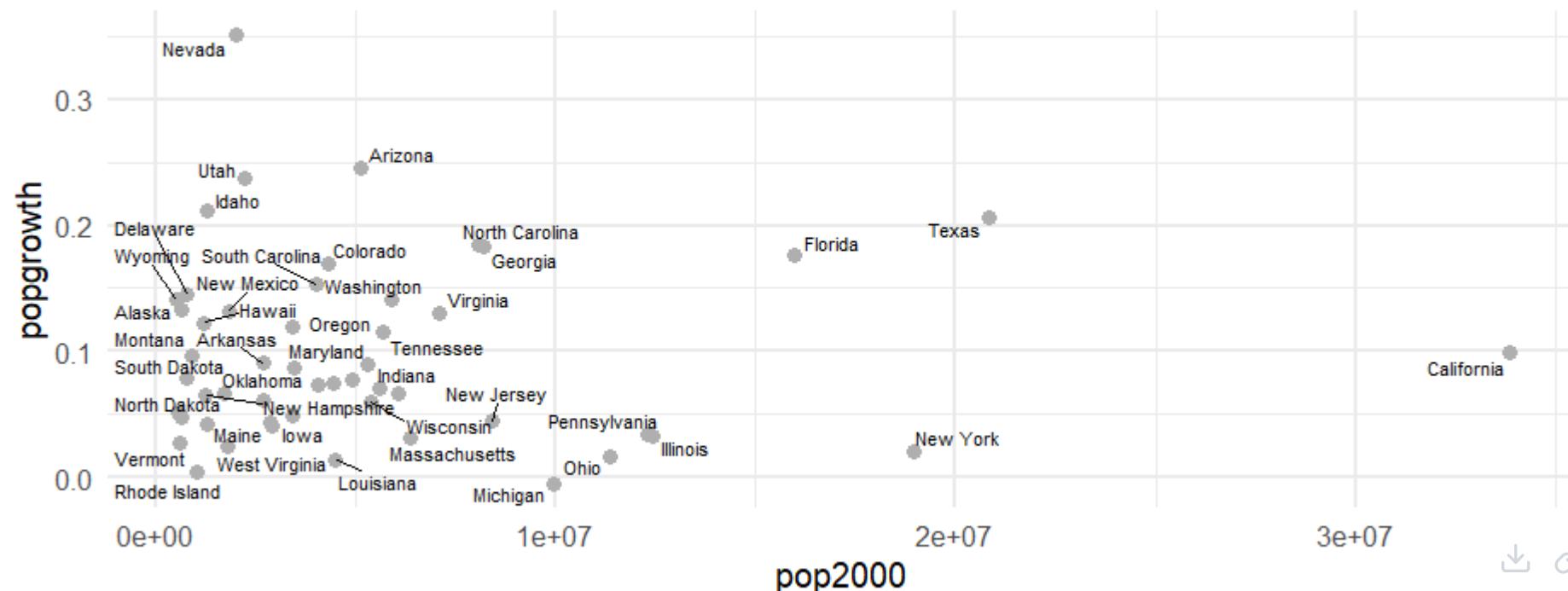
```
ggplot(popgrowth_df, aes(pop2000, popgrowth, color = state)) +  
  geom_point()
```



# Use labels

More than 5-ish categories generally becomes too difficult to track

```
library(ggrepel)  
  
ggplot(popgrowth_df, aes(pop2000, popgrowth)) +  
  geom_point(color = "gray70") +  
  geom_text_repel(aes(label = state))
```



# Better

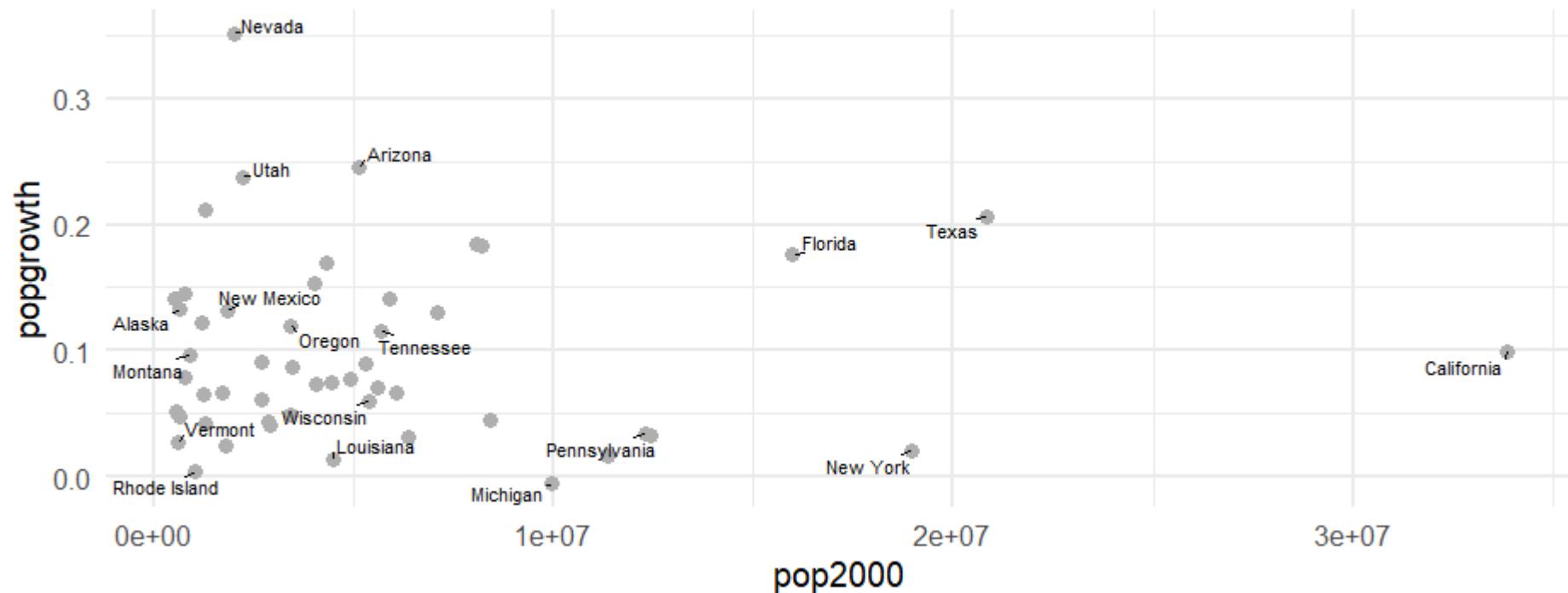
---

Get a subset

```
to_label <- c("Alaska", "Arizona", "California", "Florida", "Wisconsin",
            "Louisiana", "Nevada", "Michigan", "Montana", "New Mexico",
            "Pennsylvania", "New York", "Oregon", "Rhode Island",
            "Tennessee", "Texas", "Utah", "Vermont")
subset_states <- popgrowth_df %>%
  filter(state %in% to_label)
```

```
library(ggrepel)
```

```
ggplot(popgrowth_df, aes(pop2000, popgrowth)) +  
  geom_point(color = "gray70") +  
  geom_text_repel(aes(label = state),  
                 data = subset_states,  
                 min.segment.length = 0)
```



(still lots more cleaning up we could do here...)

# Rainbow palette

---

```
rainbow(3)
```

```
## [1] "#FF0000" "#00FF00" "#0000FF"
```

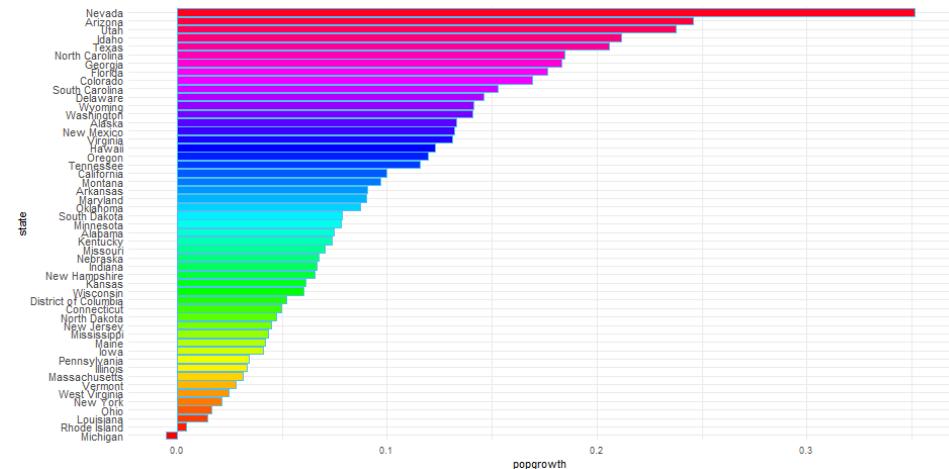
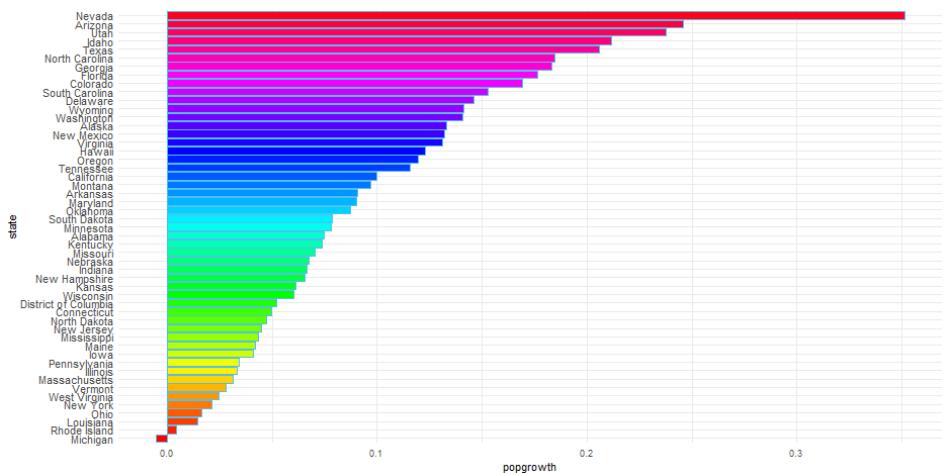
```
rainbow(7)
```

```
## [1] "#FF0000" "#FFDB00" "#49FF00" "#00FF92" "#0092FF" "#4900FF" "#FF00DB"
```

# Pretty! Doesn't work well

See [here](#) for one (of many) articles on why this is the case

```
ggplot(popgrowth_df, aes(x = popgrowth, y = state)) +  
  geom_col(aes(fill = state)) +  
  scale_fill_manual(values = rainbow(51)) +  
  guides(fill = "none")
```



# Last few notes on palettes

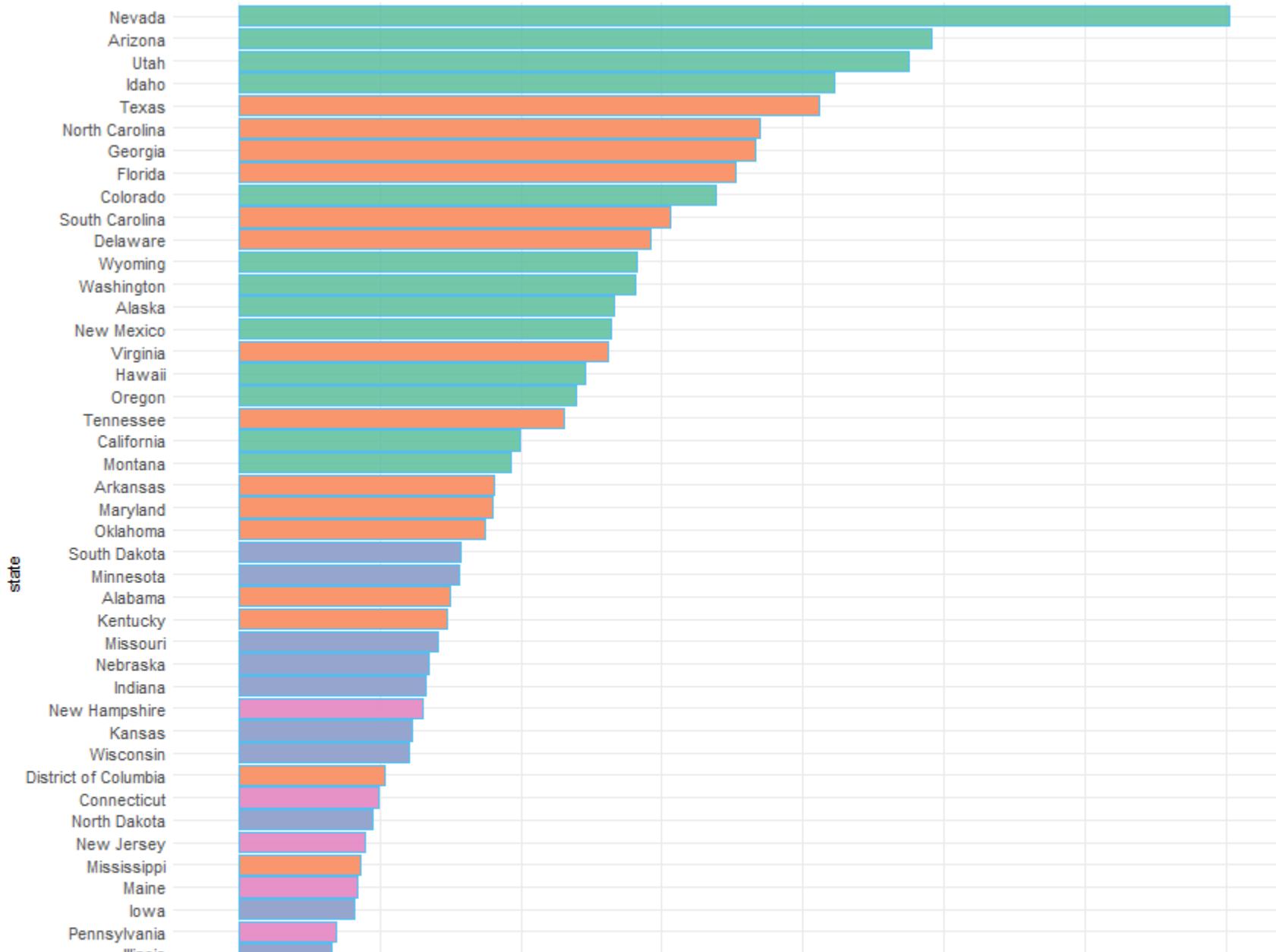
---

- Do some research, find what you like **and** what tends to work well
- Check for colorblindness
- Look into <http://colorbrewer2.org/>
  - `scale_color_brewer()` and `scale_fill_brewer()` ship with ggplot2

# For example

---

```
ggplot(popgrowth_df, aes(x = popgrowth, y = state)) +  
  geom_col(aes(fill = region),  
           alpha = 0.9) +  
  scale_fill_brewer(palette = "Set2")
```



# Paleteer package

---



# The anatomy of a ggplot() theme

---

# Theme system

## ggplot2 Theme Elements

```
theme(element_name = element_function())
- element_text()
- element_line()
- element_rect()
- element_blank()
```

## Axis elements:

axis.ticks  
element\_line()

axis.title  
element\_text()

axis.text  
element\_text()

axis.line  
element\_line()

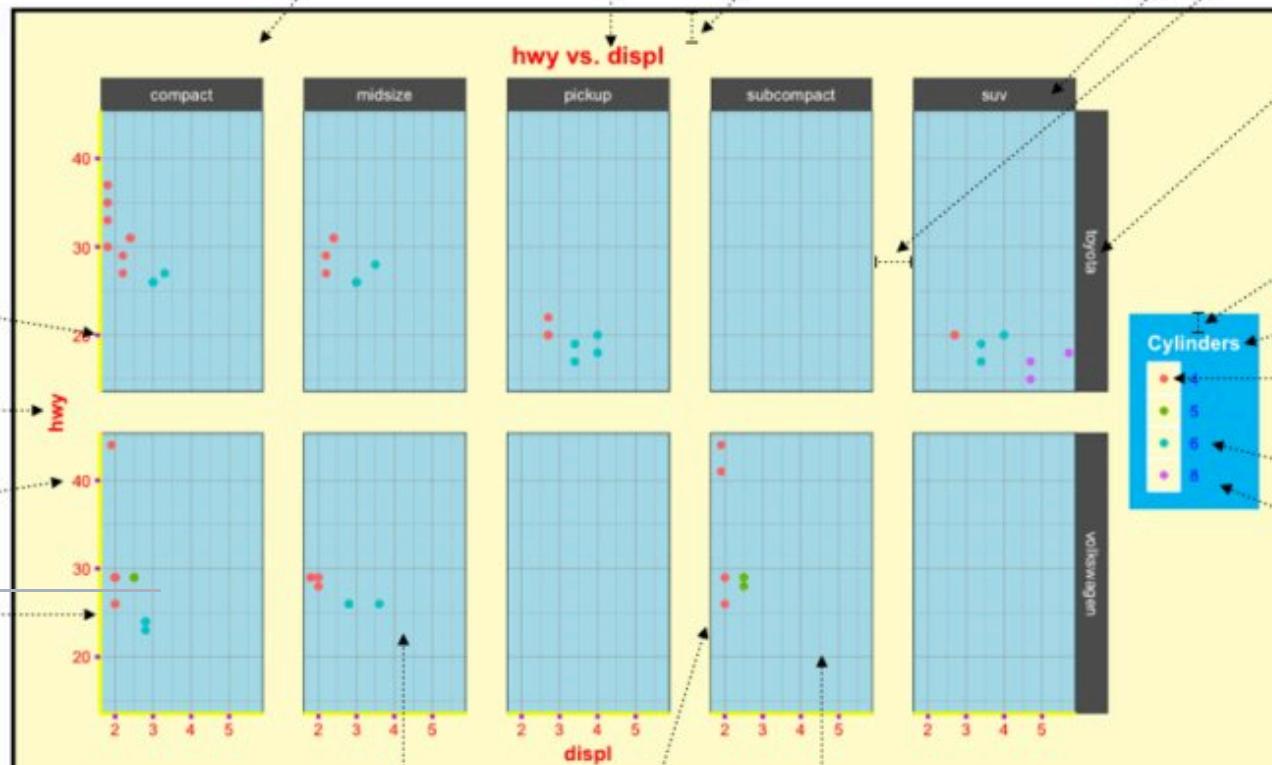
By Henry Wang

## Plot elements:

plot.background  
element\_rect()  
  
plot.title  
element\_text()

plot.margin  
margin()

hwy vs. displ



## Facetting elements:

strip.background  
element\_rect()  
  
panel.spacing  
unit()

strip.text  
element\_text()

## Legend elements:

legend.margin  
margin()

legend.title  
element\_text()

legend.key  
element\_rect()

legend.text  
element\_text()

legend.background  
element\_rect()

# Theme elements

---

- Each element in the plot can be targeted
- Plot title = `plot.title`
- Grid lines = `panel.grid`
- Legend background = `legend.background`

# Theme functions

---

- Use special functions to manipulate specific elements
- Text-based things = `element_text()`
- Rectangular things (backgrounds) = `element_rect()`
- Line-based things (axis lines, grid lines) = `element_line()`
- Disable element completely = `element_blank()`

# How to learn `theme()`

---

- The `theme()` function has **94** possible arguments(!!!)
- You can get hyper-specific with things like `axis.ticks.length.x.bottom`
- The only way to learn how to use `theme()` is to use it and tinker with it

# Review Lab 3

---

# Lab 4

---

# Q & A with Dr. Daniel Anderson

---

# Next time

---

More colors, themes, refinement of plots