



# whoami

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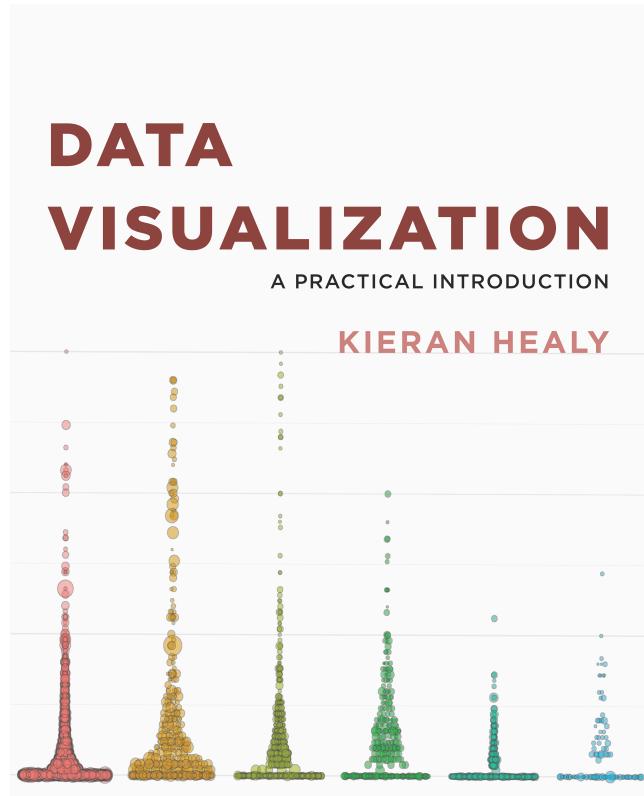
- Research Assistant Professor:  
Behavioral Research and  
Teaching
- Dad (two daughters: 8 and 6)
- Pronouns: he/him/his
- Primary areas of interest: ❤️❤️  
R❤️❤️, computational research,  
achievement gaps, systemic  
inequities, and variance  
between educational  
institutions



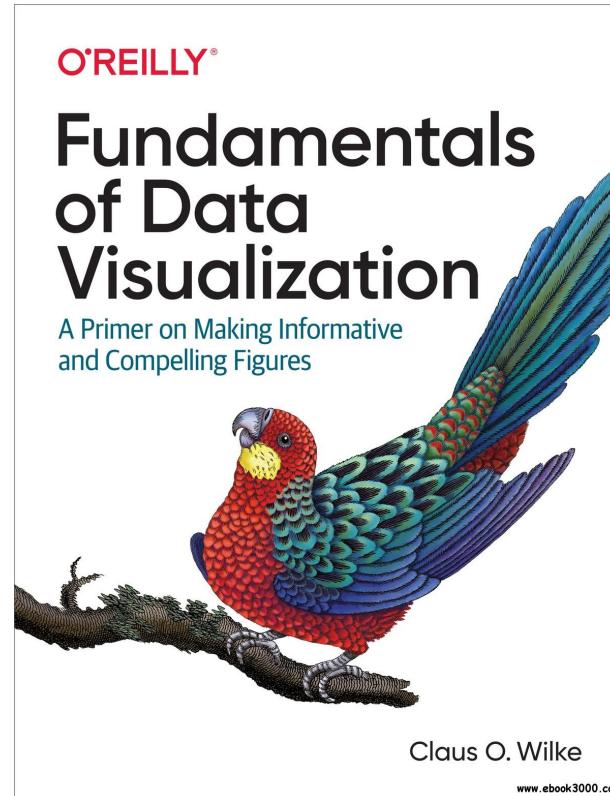
# Resources (free)

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Healy



Wilke



# Other Resources

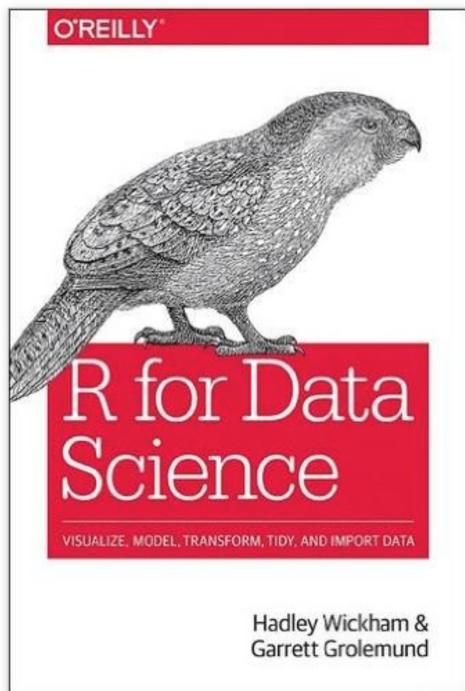
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- My classes!
- Sequence
  - EDLD 651: Introductory Educational Data Science (EDS)
  - EDLD 652: Data Visualization for EDS
  - EDLD 653: Functional Programming for EDS
  - EDLD 654: Machine Learning for EDS
  - Capstone

# Where to start?

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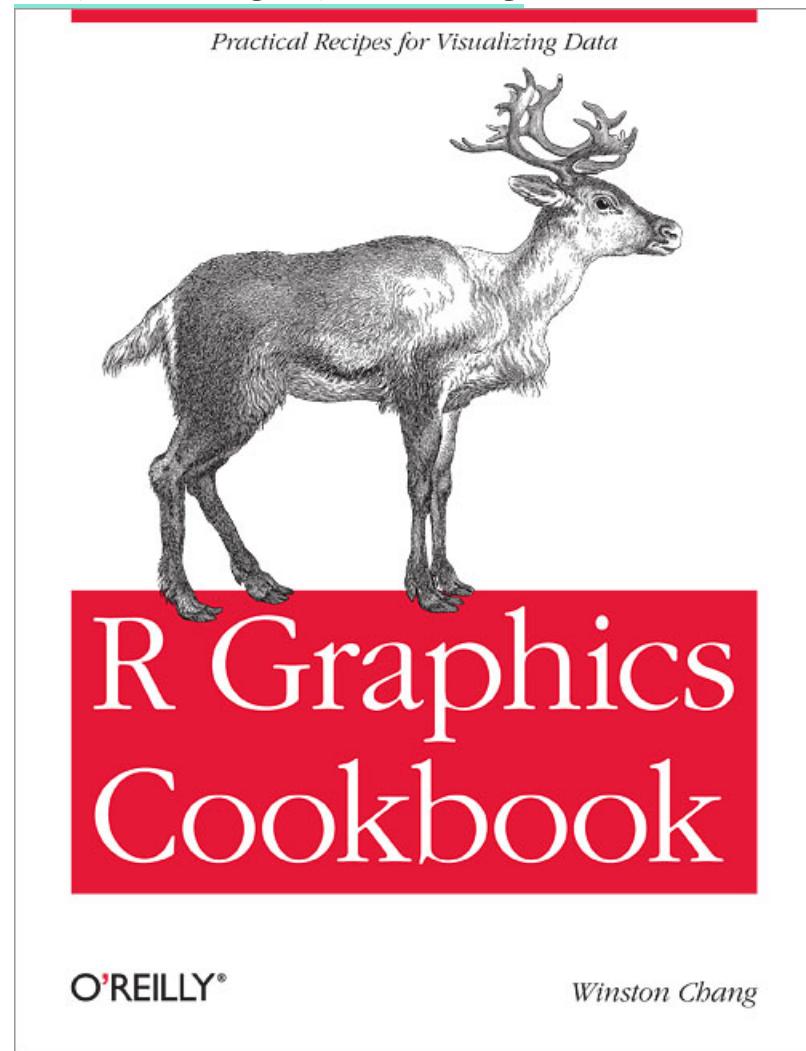
- I *really* recommend moving to R as quickly as possible



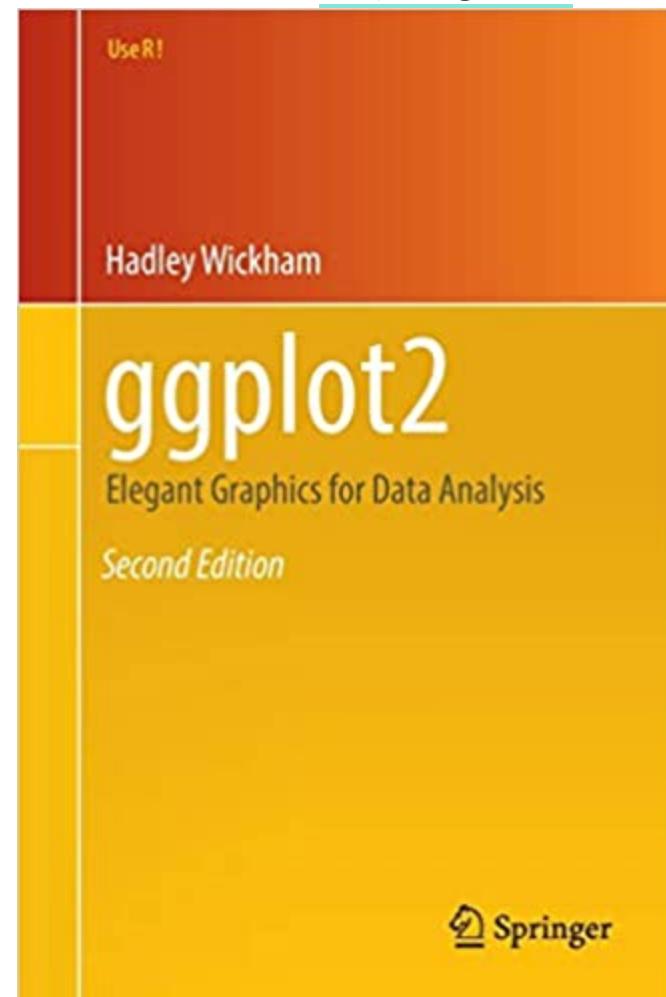
# ggplot2!

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<https://r-graphics.org>



Third edition in progress!



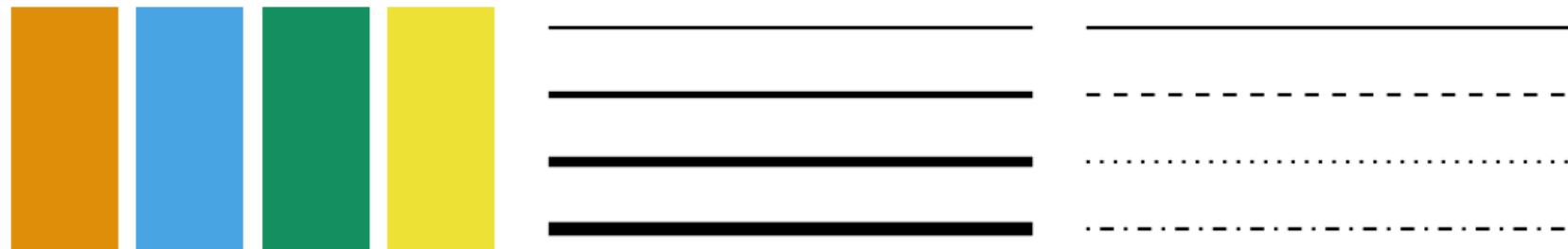
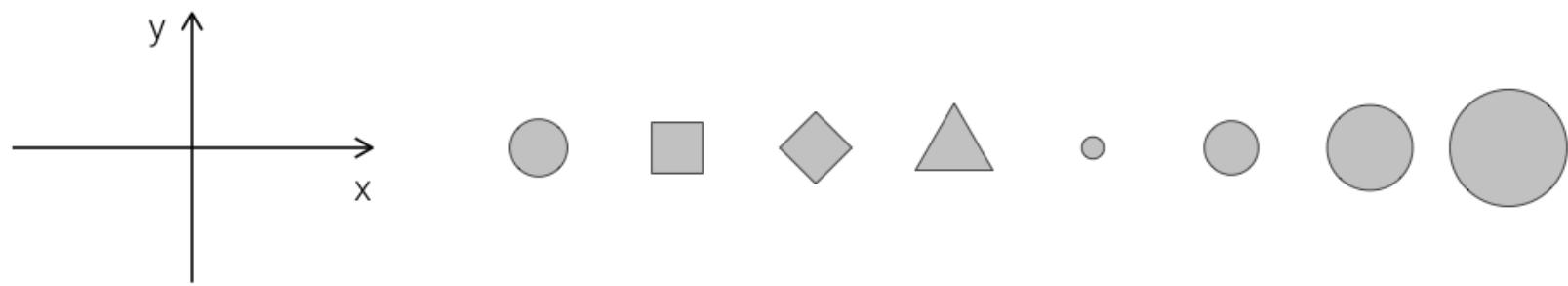
# Last note before we really start

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- These slides were produced with R
- See the source code [here](#)
- The focus of this particular talk is not on the code itself

# Different ways of encoding data

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# Other elements to consider

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- Text
  - How is the text displayed (e.g., font, face, location)?
  - What is the purpose of the text?
- Transparency
  - Are there overlapping pieces?
  - Can transparency help?

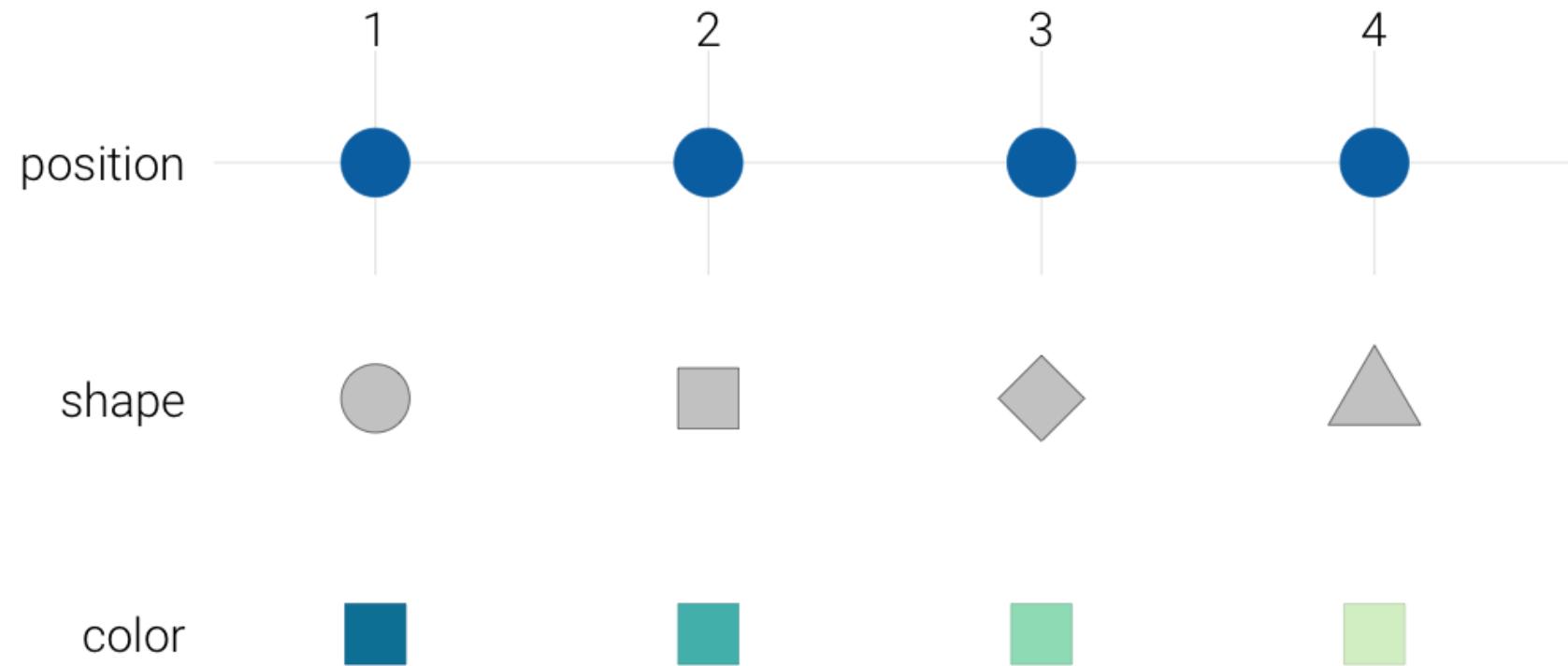
# Other elements to consider

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- Type of data
  - Continuous/categorical
  - Which can be mapped to each aesthetic?
  - e.g., shape and line type can only be mapped to categorical data, whereas color and size can be mapped to either.

# Basic Scales

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# Talk with a neighbor

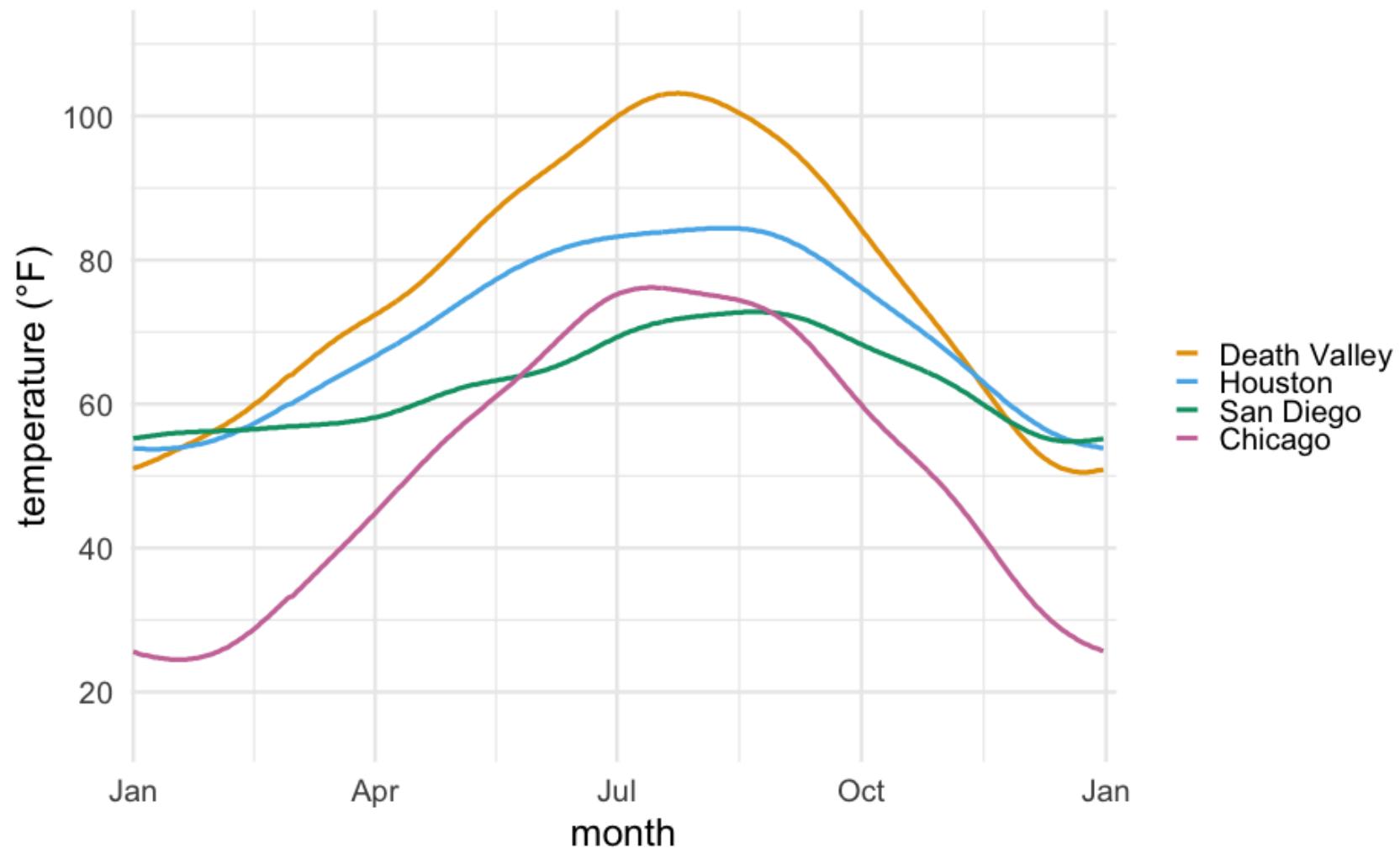
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How would you encode these data into a display?

Month	Day	Location	Temperature
Jan	1	Chicago	25.6
Jan	1	San Diego	55.2
Jan	1	Houston	53.9
Jan	1	Death Valley	51.0
Jan	2	Chicago	25.5
Jan	2	San Diego	55.3
Jan	2	Houston	53.8
Jan	2	Death Valley	51.2
Jan	3	Chicago	25.3

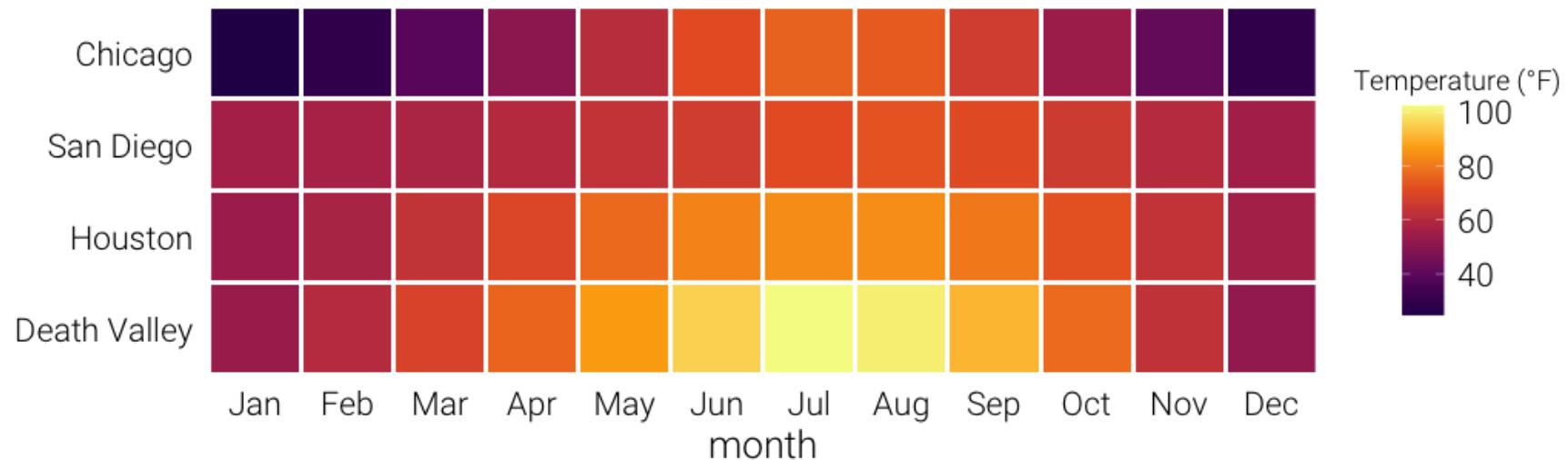
# Putting it to practice

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# Alternative representation

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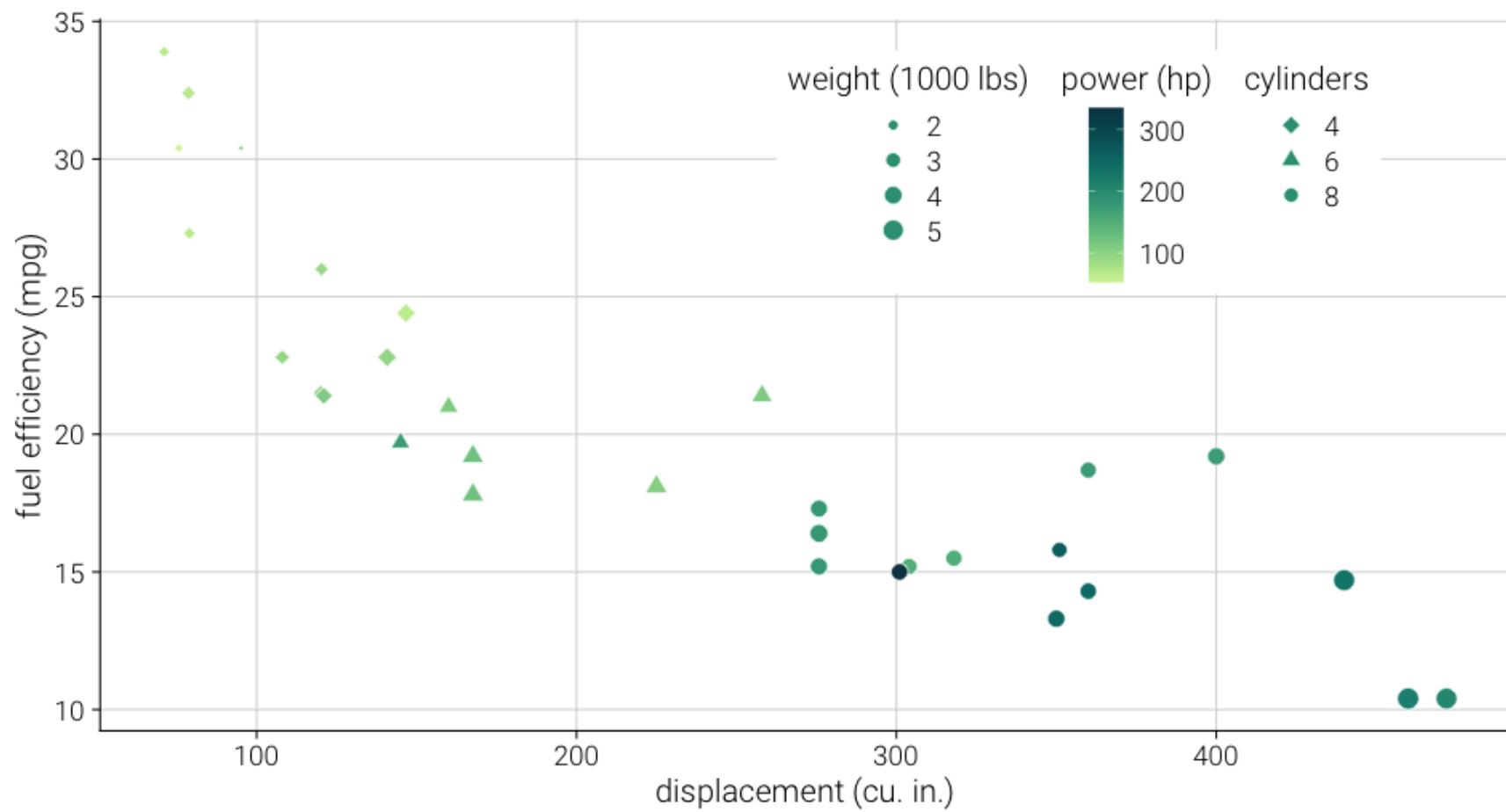
# Comparison

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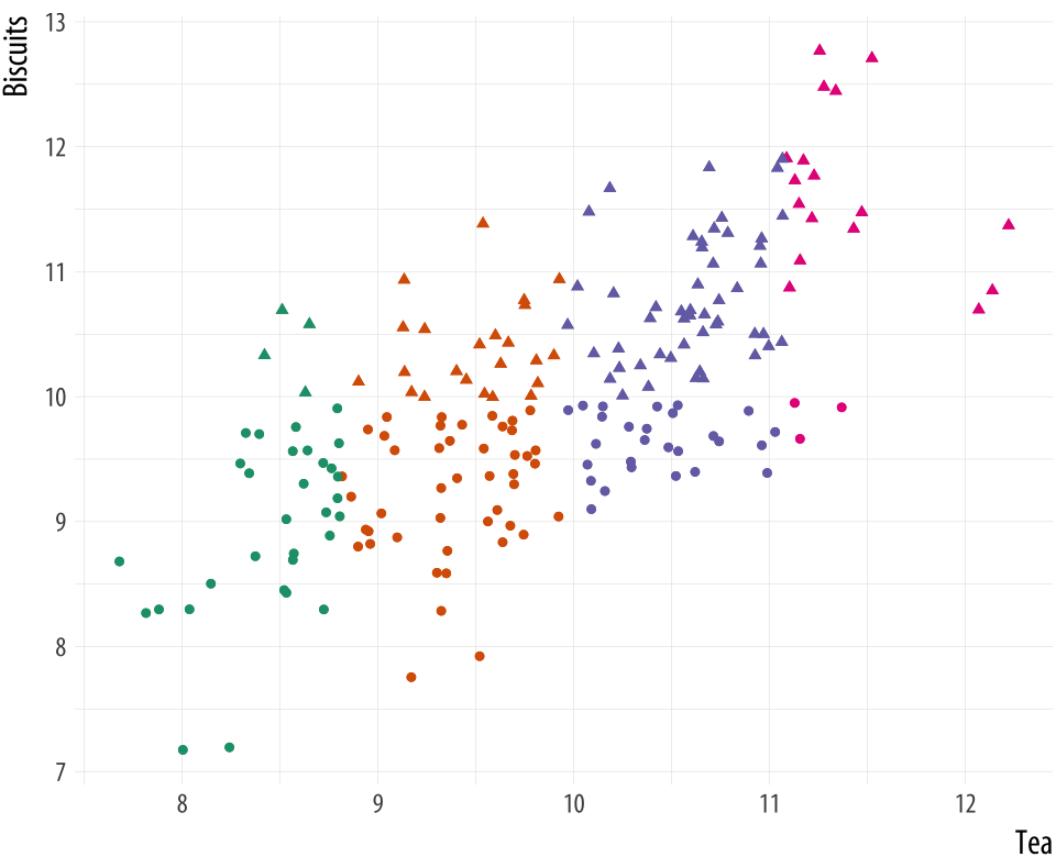
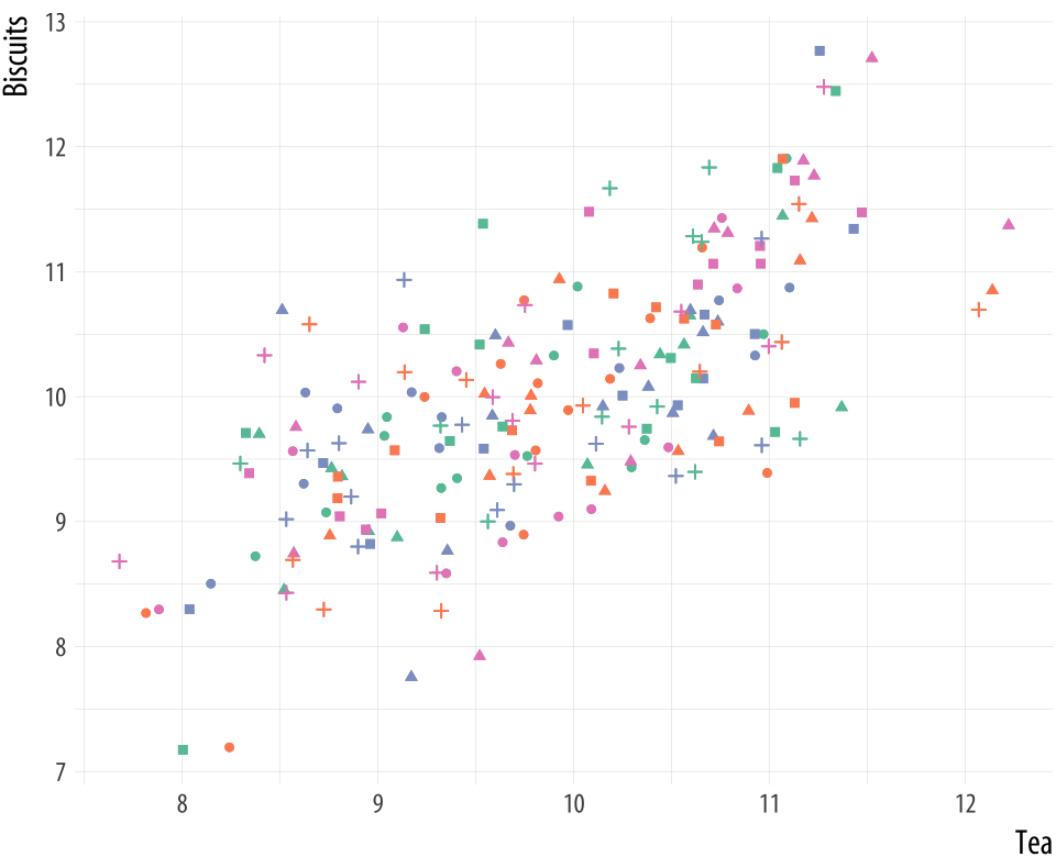
- Both represent three scales
  - Two position scales (x/y axis)
  - One color scale (categorical for the first, continuous for the second)

# More scales are possible

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Additional scales can become lost without high structure in the data



Thinking more  
about color

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# Three fundamental uses

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

# Discrete items

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Often no intrinsic order

Qualitative color scale

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

# Some examples

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Okabe Ito



ColorBrewer Dark2



ggplot2 hue



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

# Sequential scale examples

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ColorBrewer Blues



Heat



Viridis



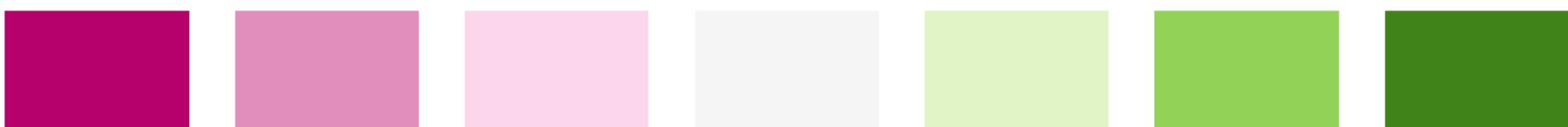
# Diverging palettes

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CARTO Earth



ColorBrewer PiYG



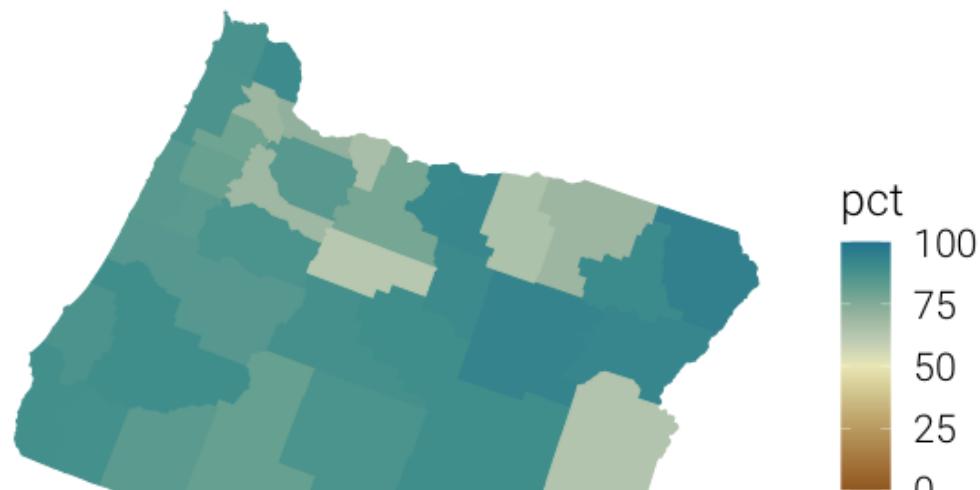
Blue-Red



# Earth palette

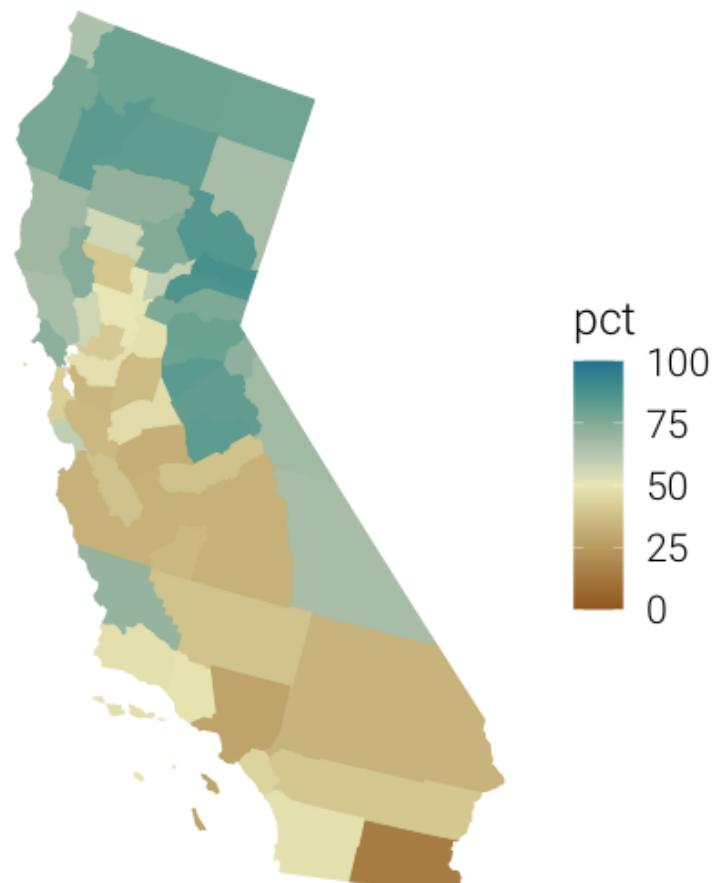
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Percentage of people identifying as White  
Oregon



US Census Decennial Tract Data

# Percentage of people identifying as White California

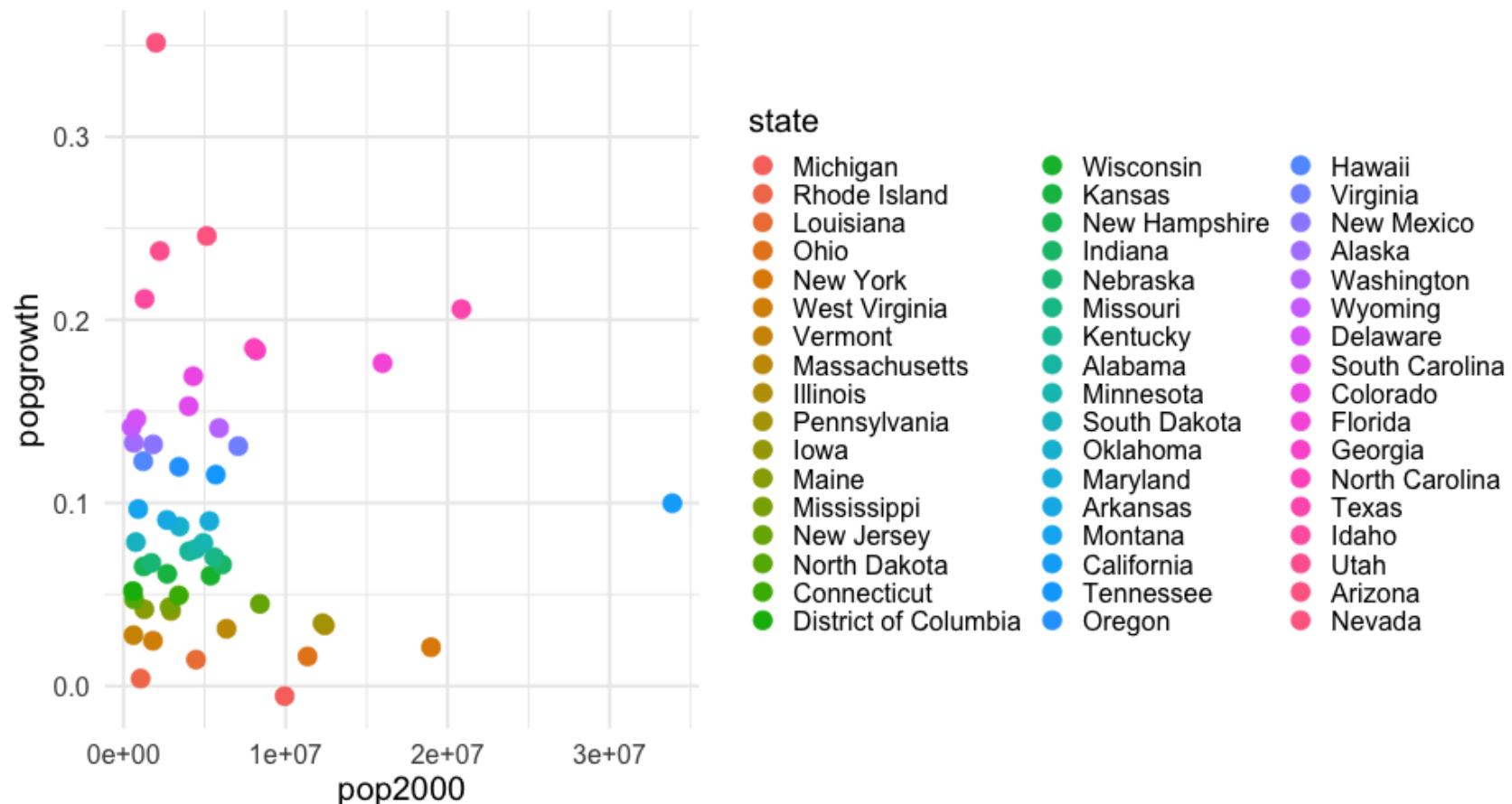


US Census Decennial County Data

# Common problems

Too many colors

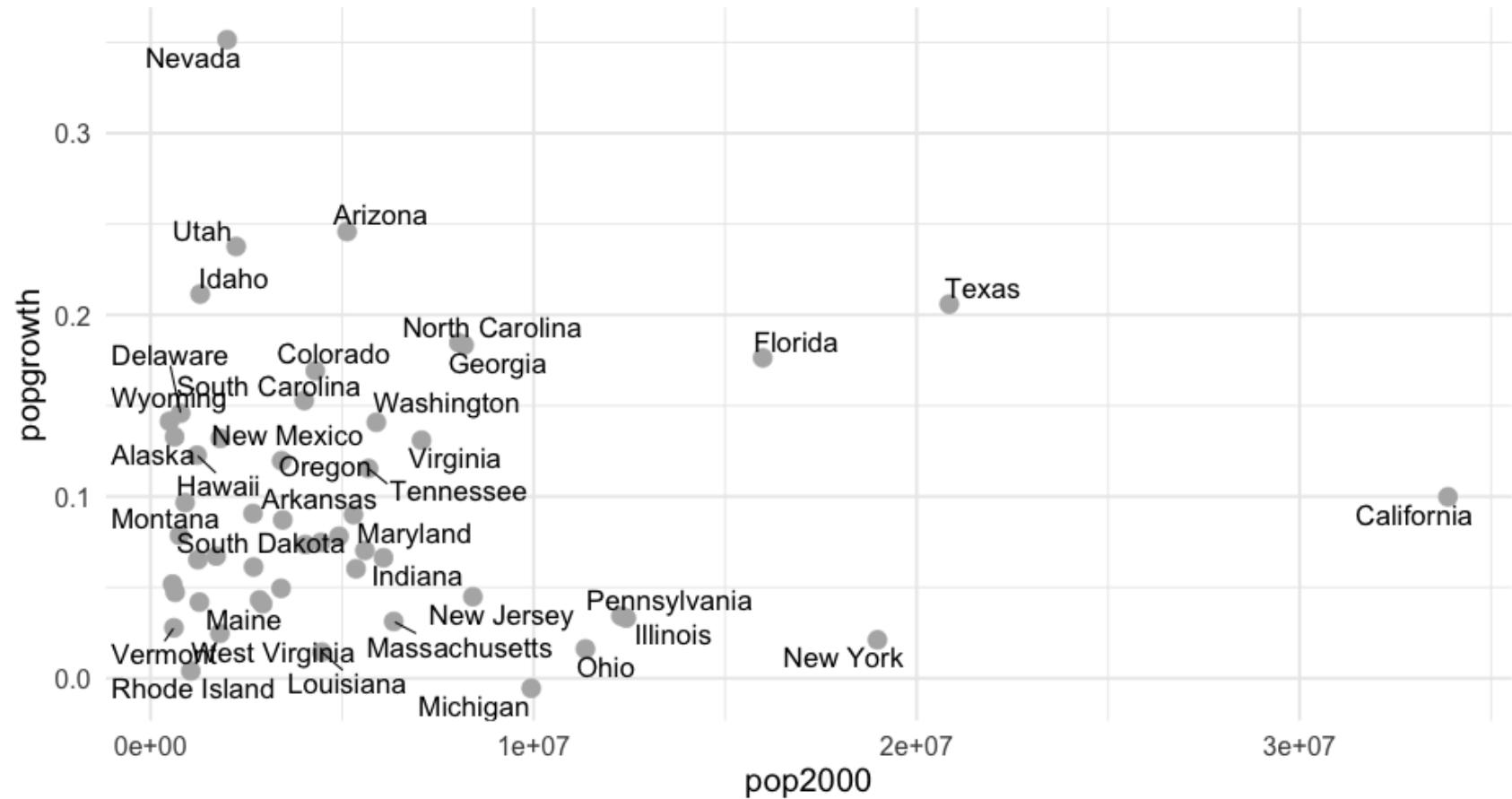
More than 5-ish generally becomes difficult to track



# Use labels

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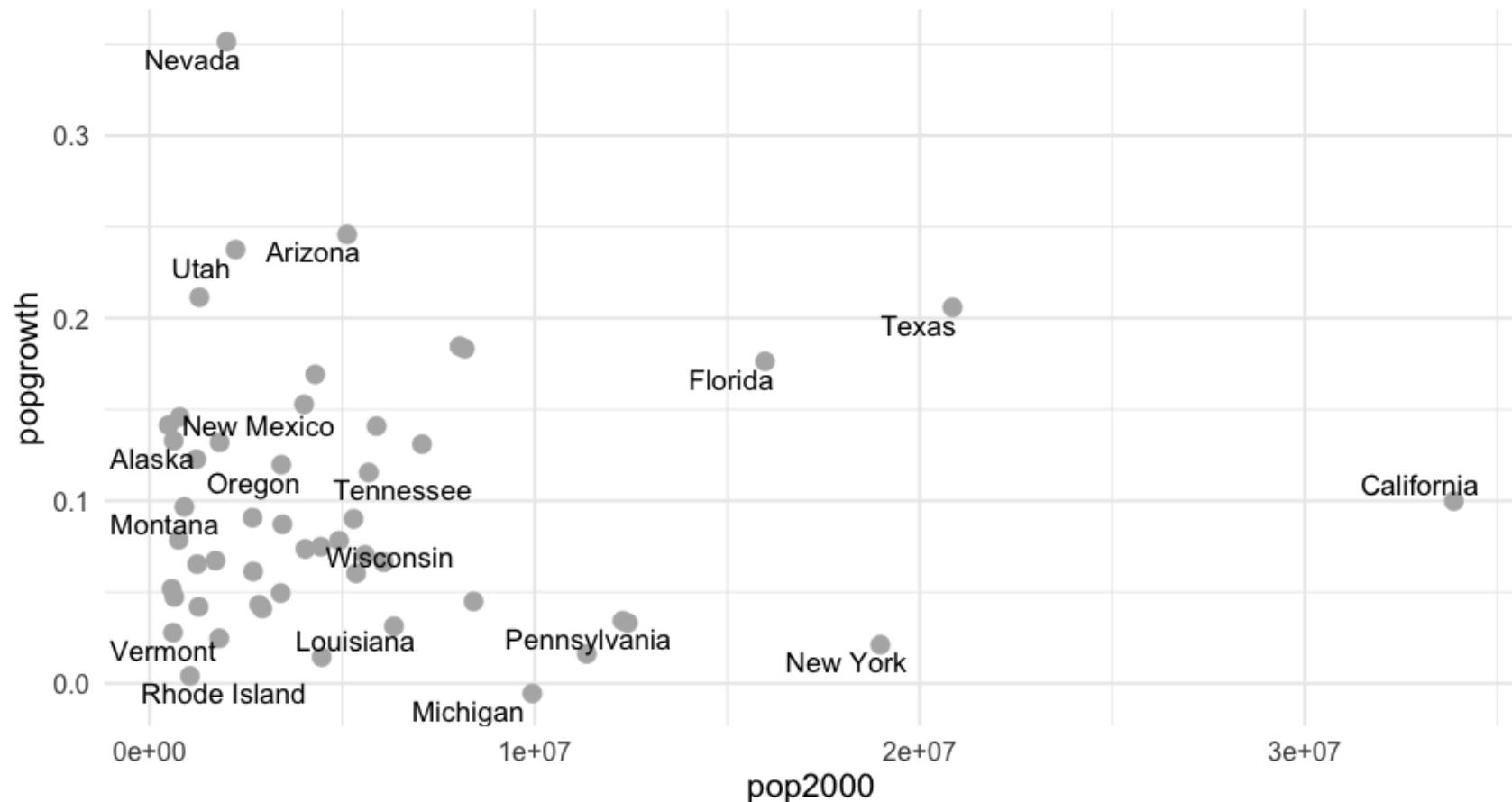
still too many...



# Better

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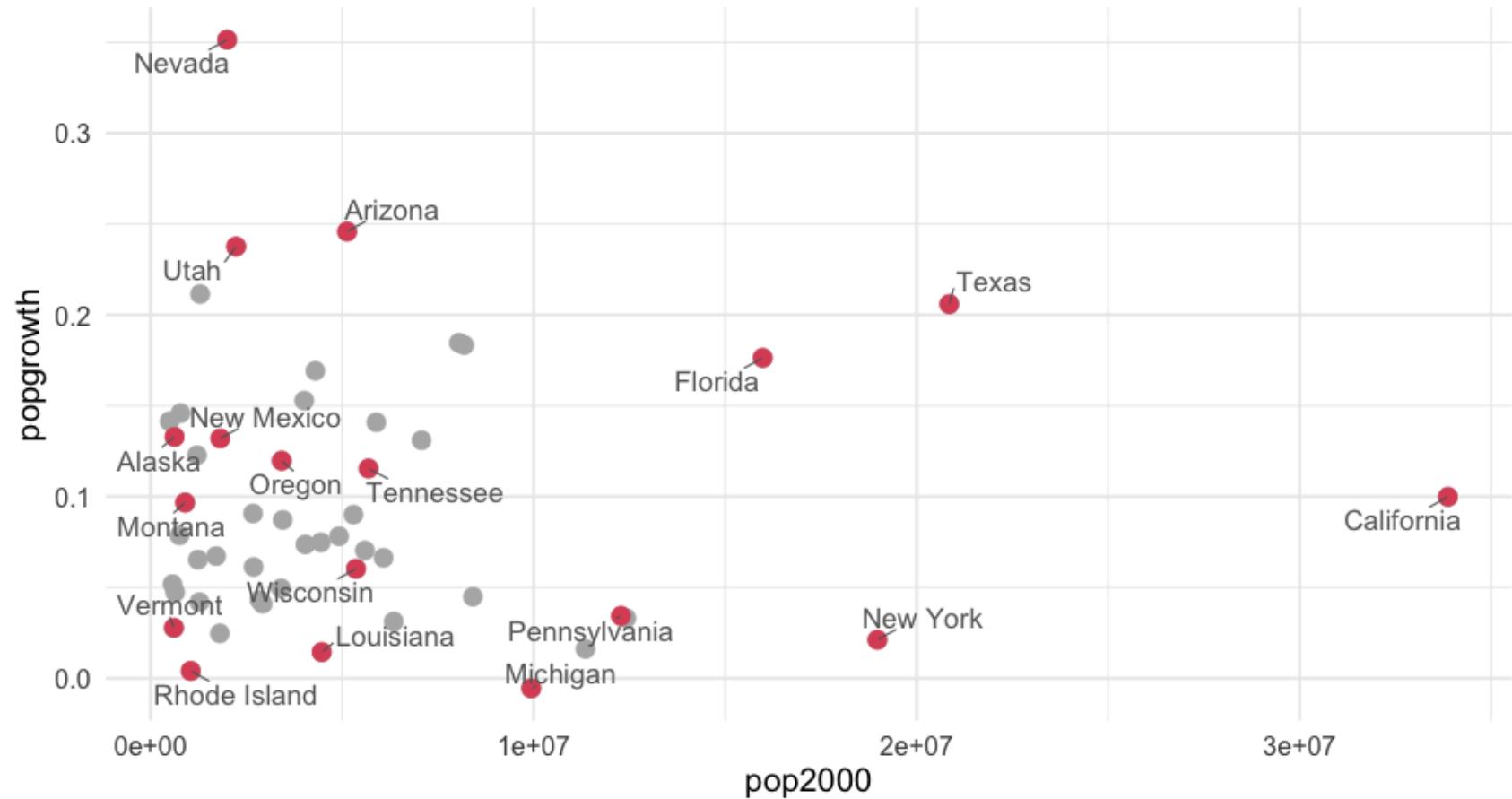
Get a subset



# Best

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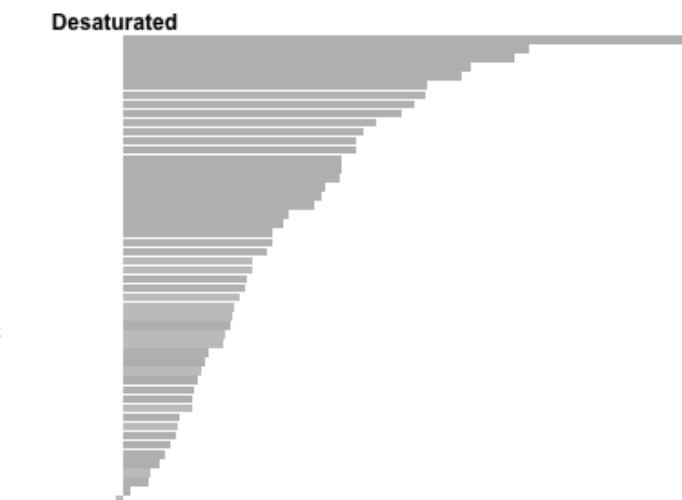
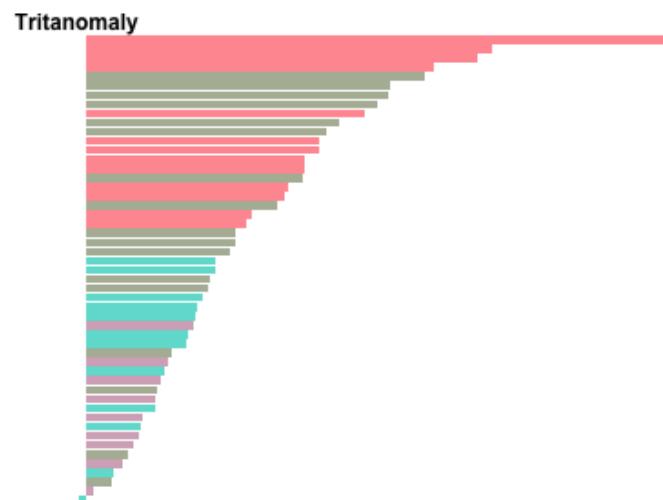
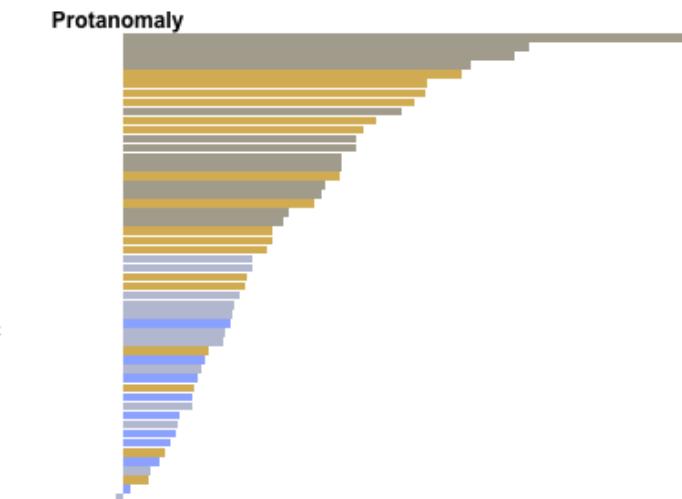
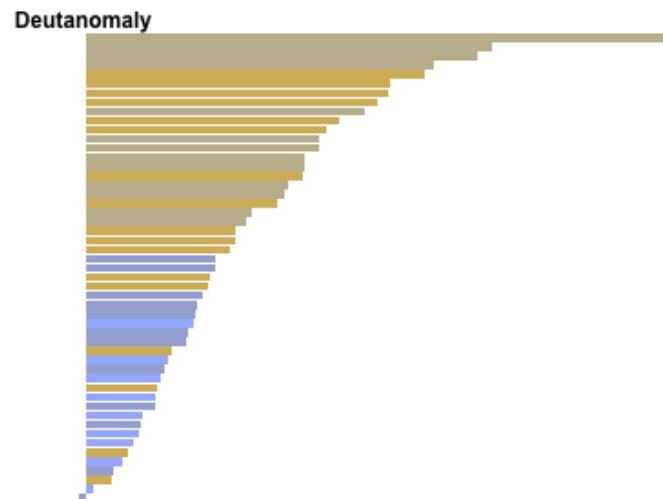
(but could still be improved)



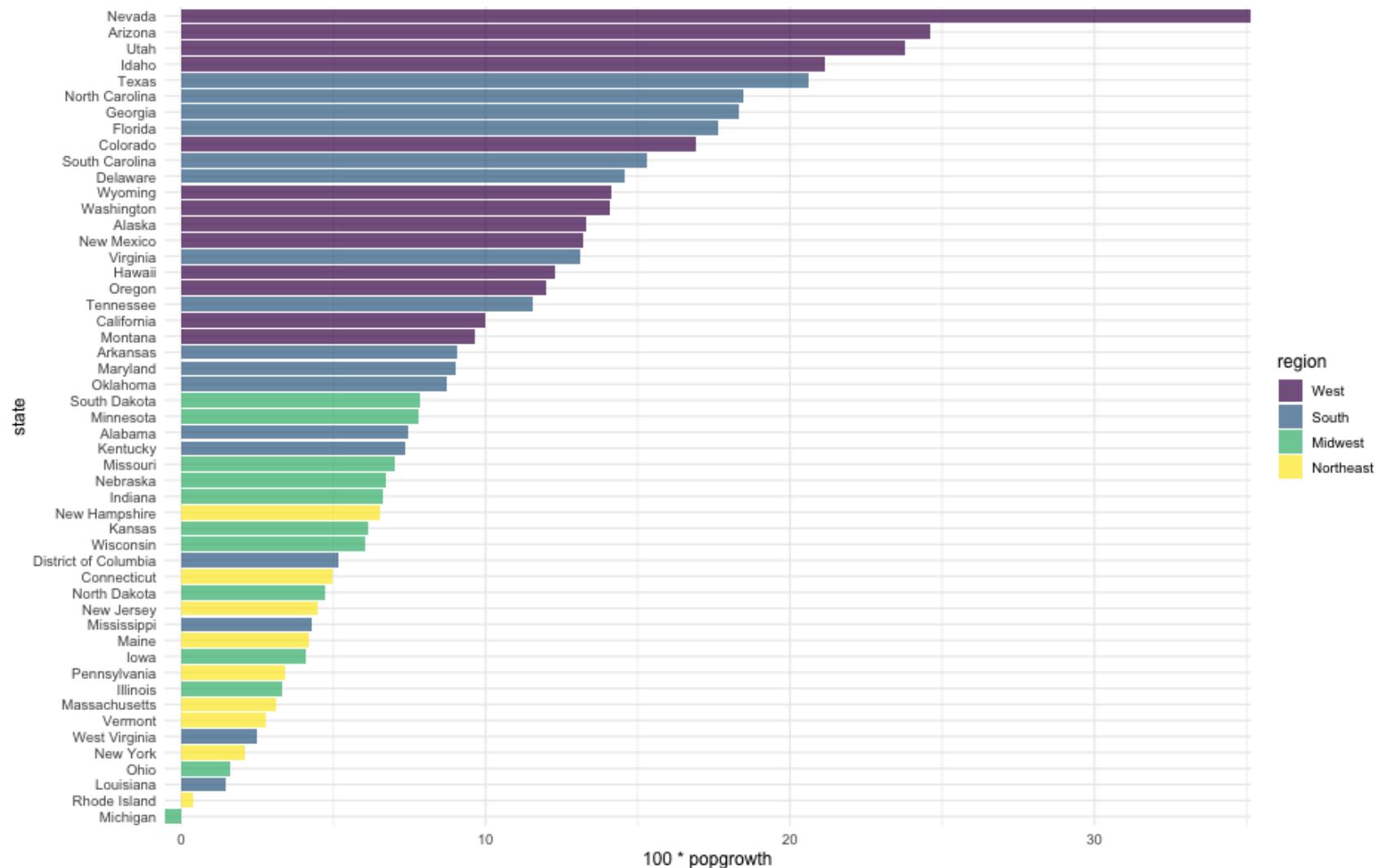
# Problem w/ default palette

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For {ggplot2}

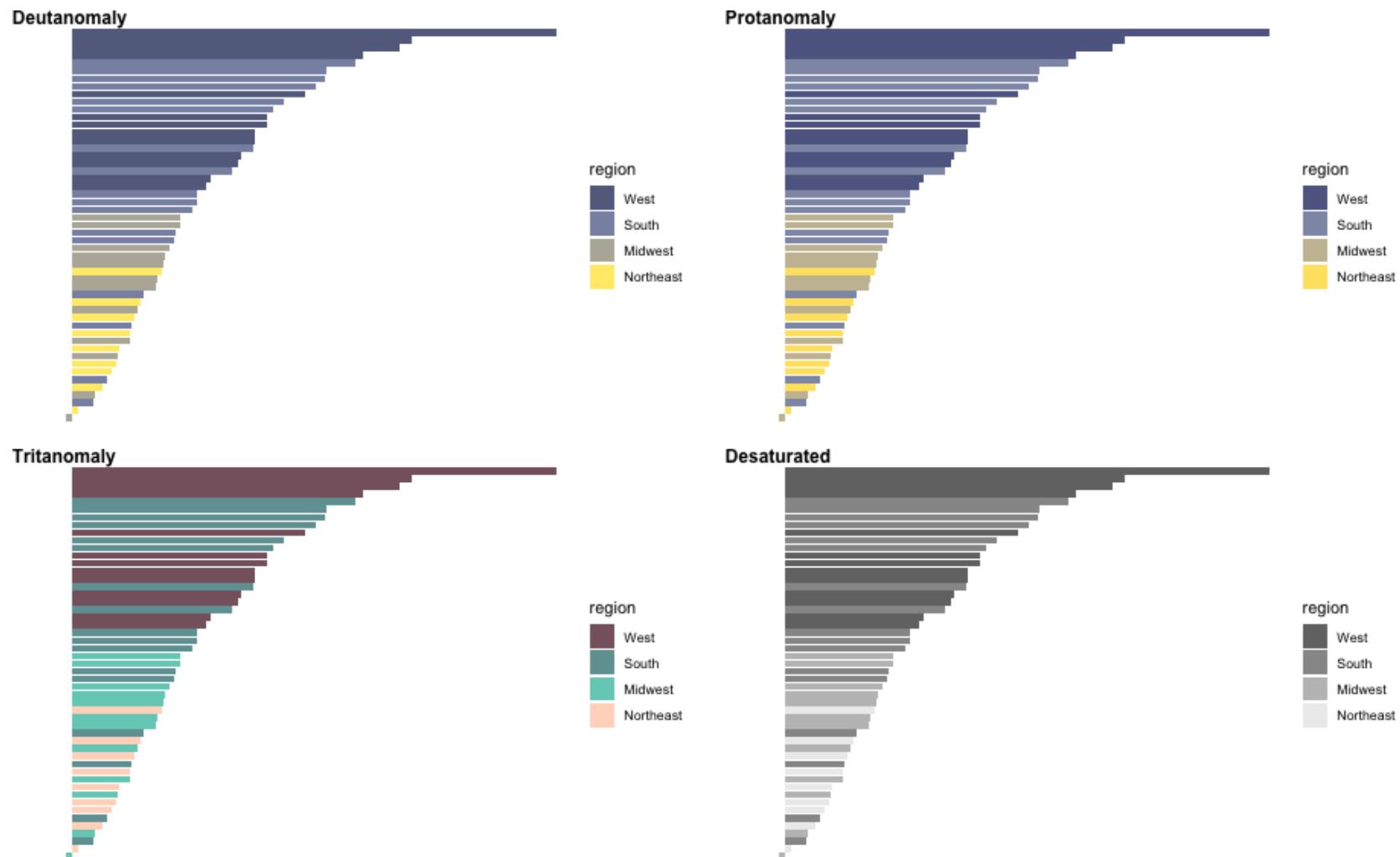


# Alternative: viridis



# Revised version

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# Last few note on palettes

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- Do some research, find what you like and what tends to work well
- Check for colorblindness
- Look into <http://colorbrewer2.org/>

# Data ink ratio

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# What is it?

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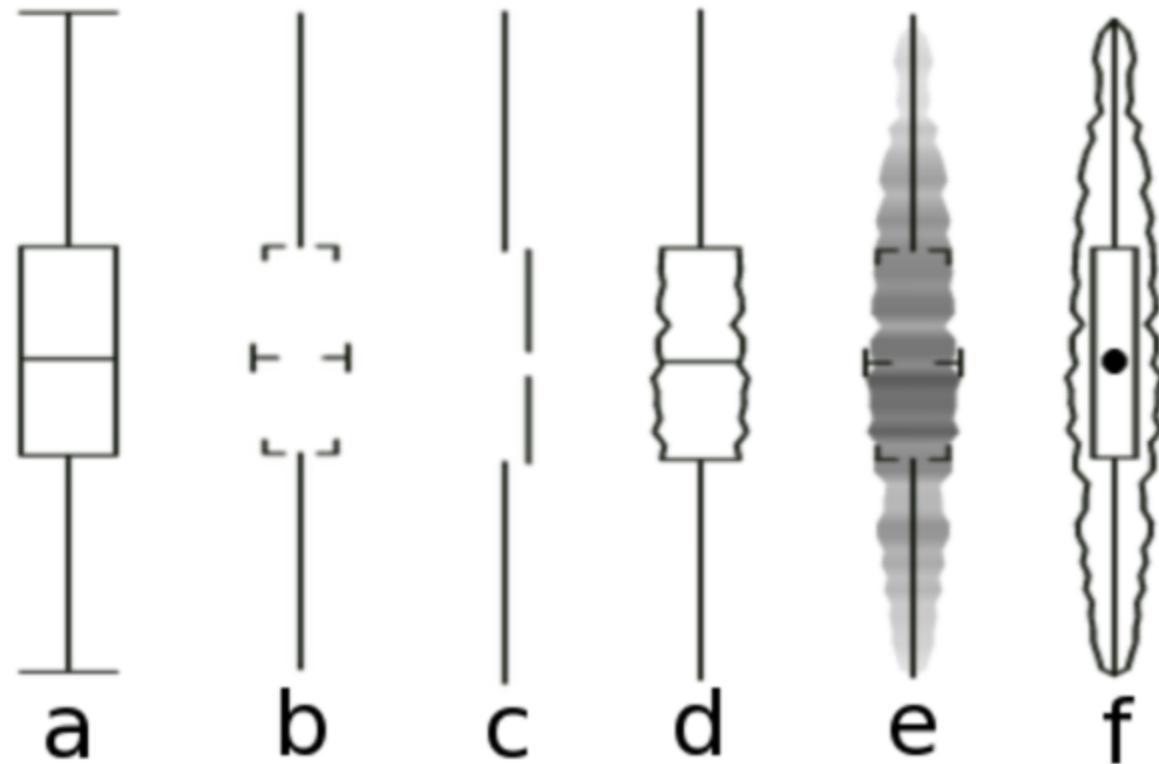
Above all else, show the data

—Edward Tufte

- Data–Ink Ratio = Ink devoted to the data / total ink used to produce the figure
- Common goal: Maximize the data–ink ratio

# Example

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- First thought might be... Cool!

A color photograph of an elderly man with white hair, wearing a dark suit jacket, a white shirt, and a red patterned tie. He is smiling broadly and looking slightly to his right. A large, thin-lined circular speech bubble originates from his mouth and extends upwards and to the right. Inside the bubble, the text "NOT SO FAST, MY FRIEND!" is written in a bold, black, sans-serif font.

**NOT SO  
FAST, MY  
FRIEND!**

# Minimize cognitive load

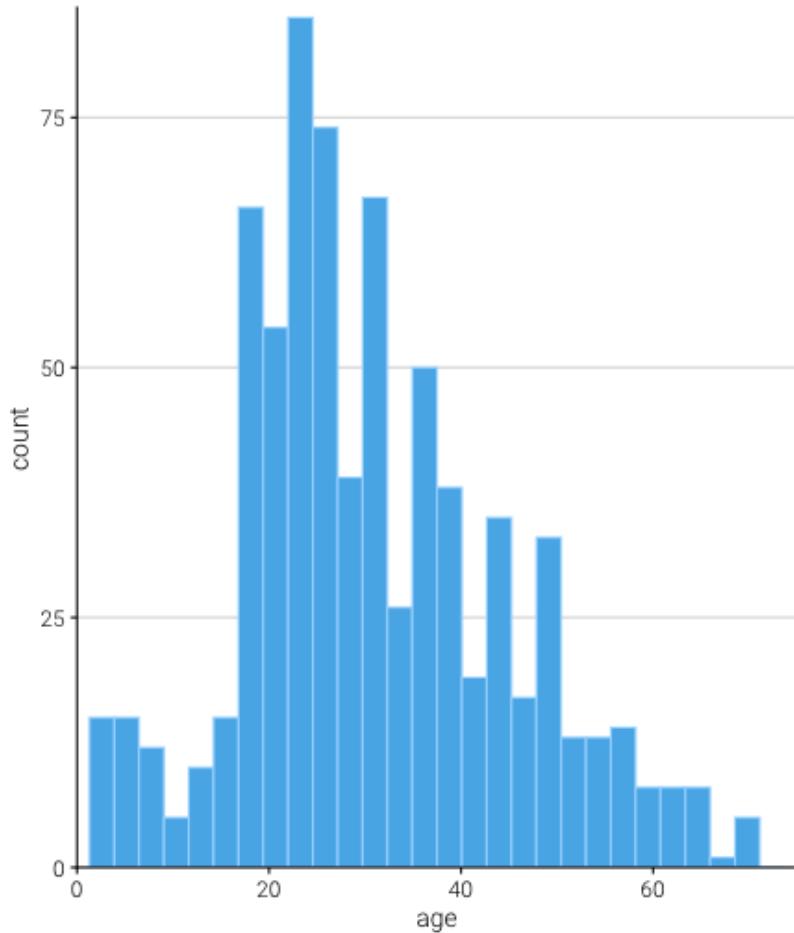
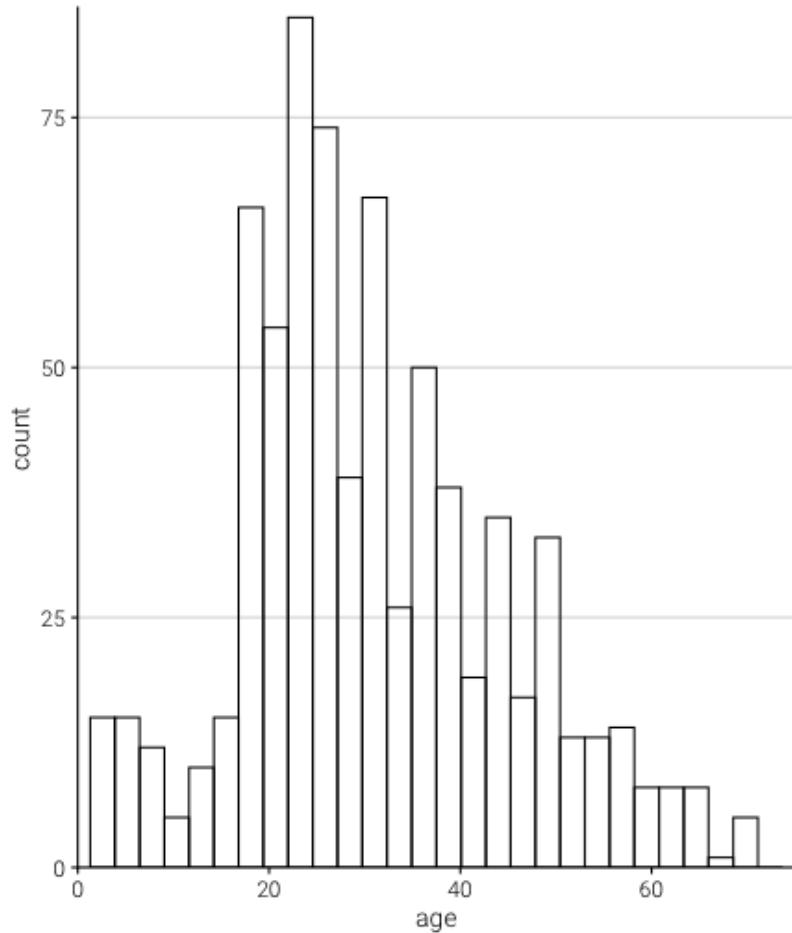
---

- Empirically, Tufte's plot was the most difficult for viewers to interpret.
- Visual cues (labels, gridlines) reduce the data–ink ratio, but can also reduce cognitive load.

# An example

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Which do you prefer?



# Advice from Wilke

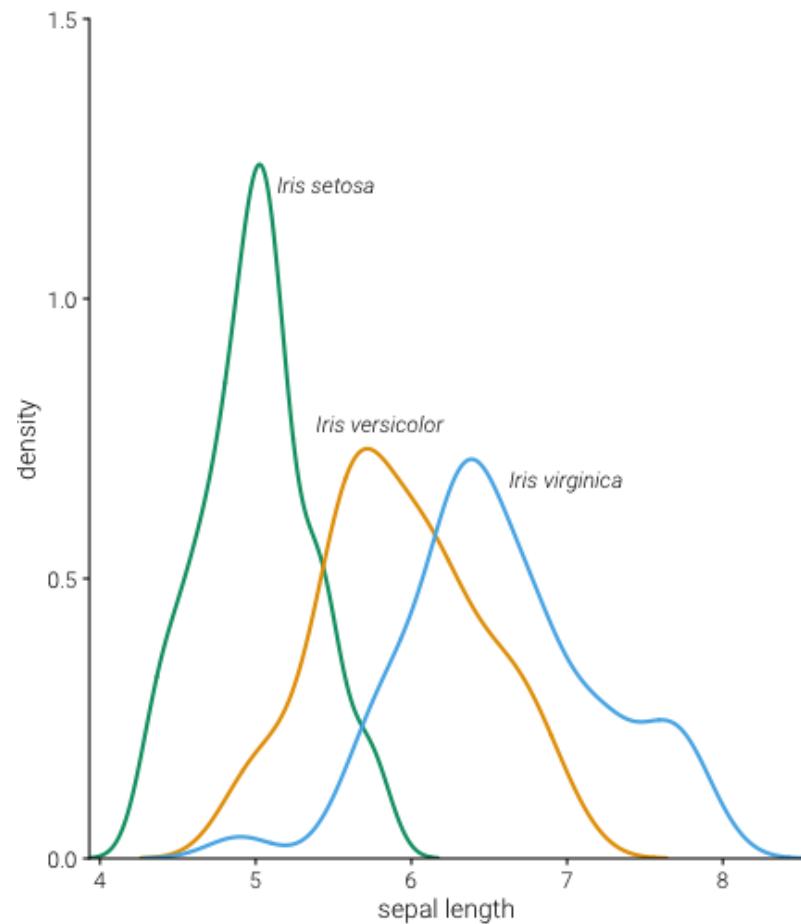
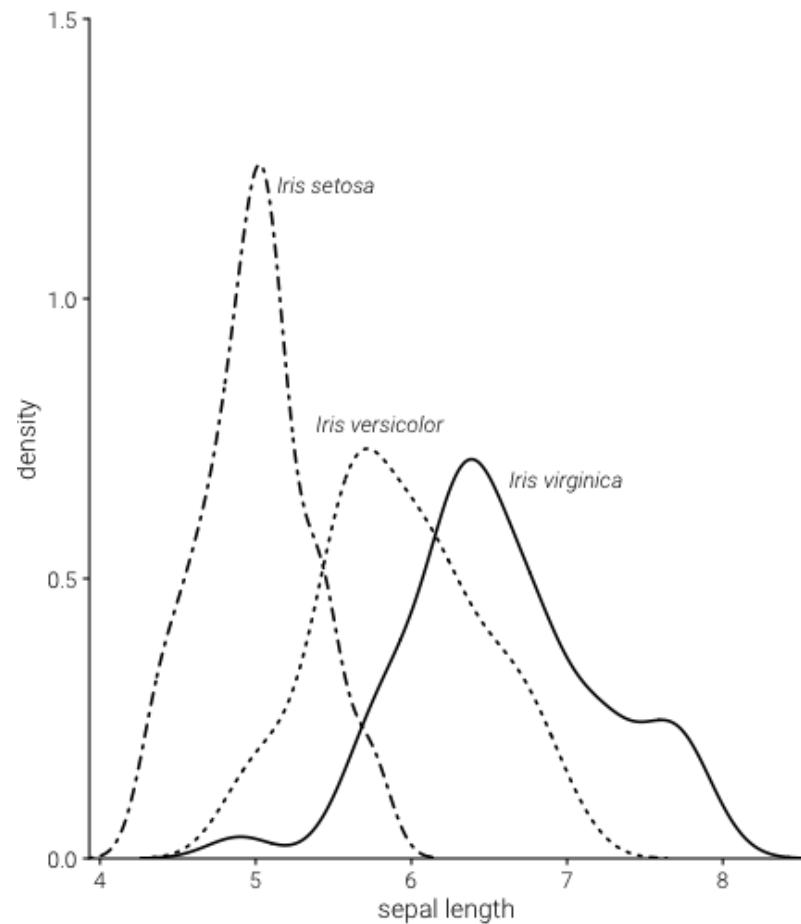
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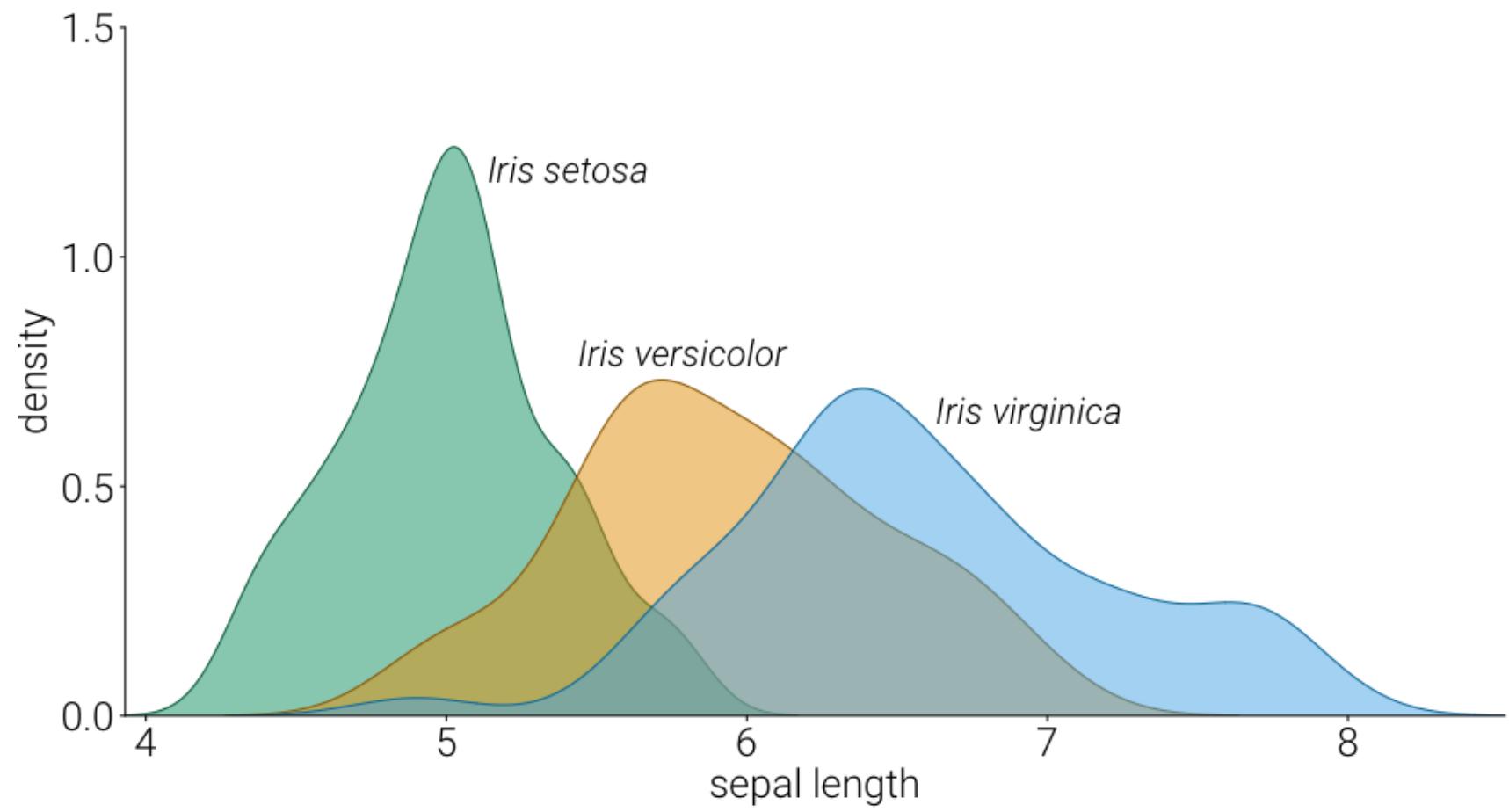
Whenever possible, **visualize your data with solid, colored shapes** rather than with lines that outline those shapes. Solid shapes are more easily perceived, are less likely to create visual artifacts or optical illusions, and do more immediately convey amounts than do outlines.

emphasis added

# Another example

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# Labels in place of legends

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Prior slide is a great example of when annotations can be used in place of a legend to

- reduce cognitive load
- increase clarity
- increase beauty
- maximize the figure size

Practical advice  
so far

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Avoid line drawings

Maximize the data–ink ratio within reason  
(but preference reduction of cognitive  
load)

Use color to your advantage (and think critically about the palettes you choose)

Consider plot annotations over legends

# Grouped data

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# Distributions

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How do we display more than one distribution at a time?

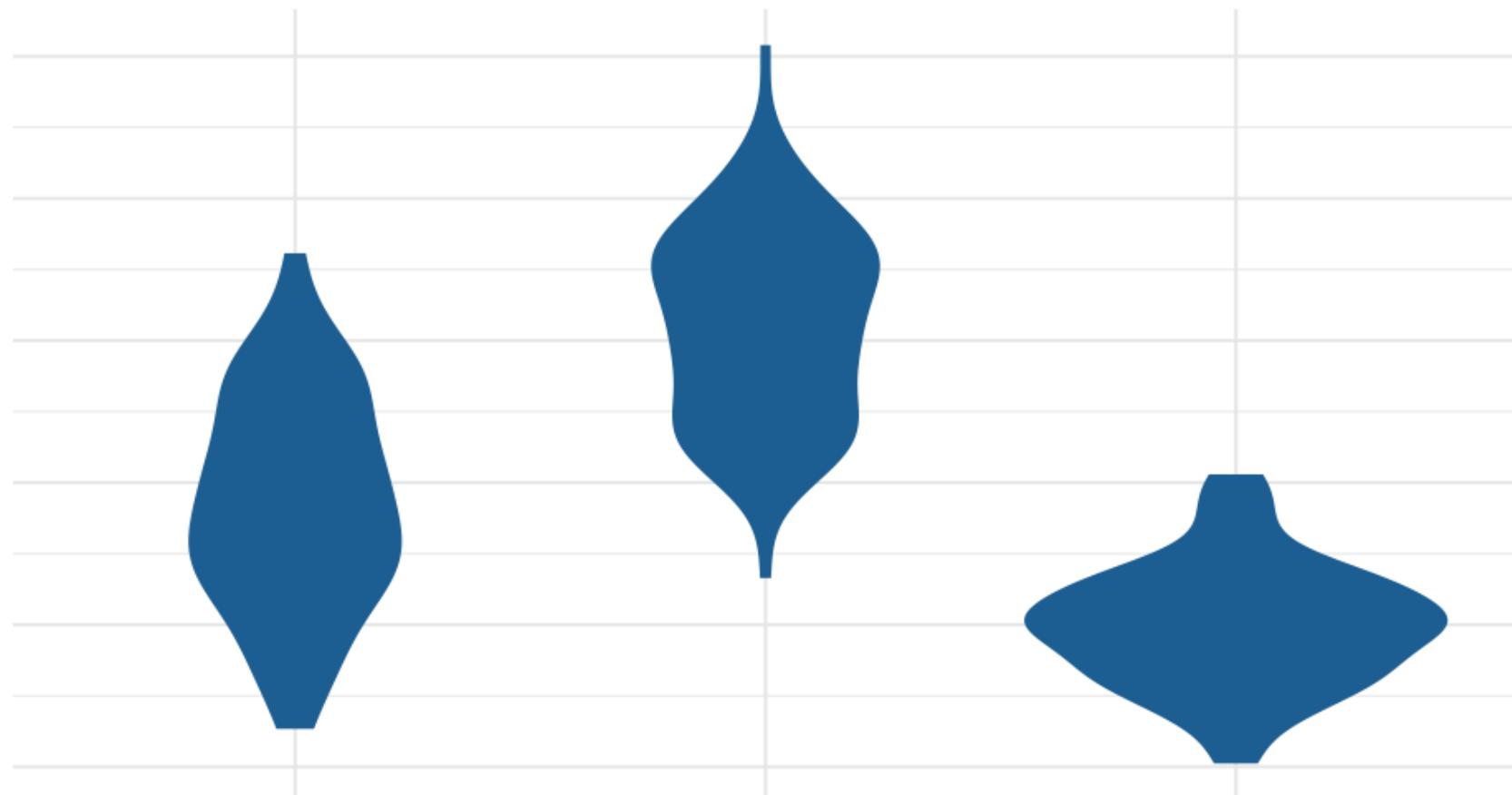
# Boxplots

---



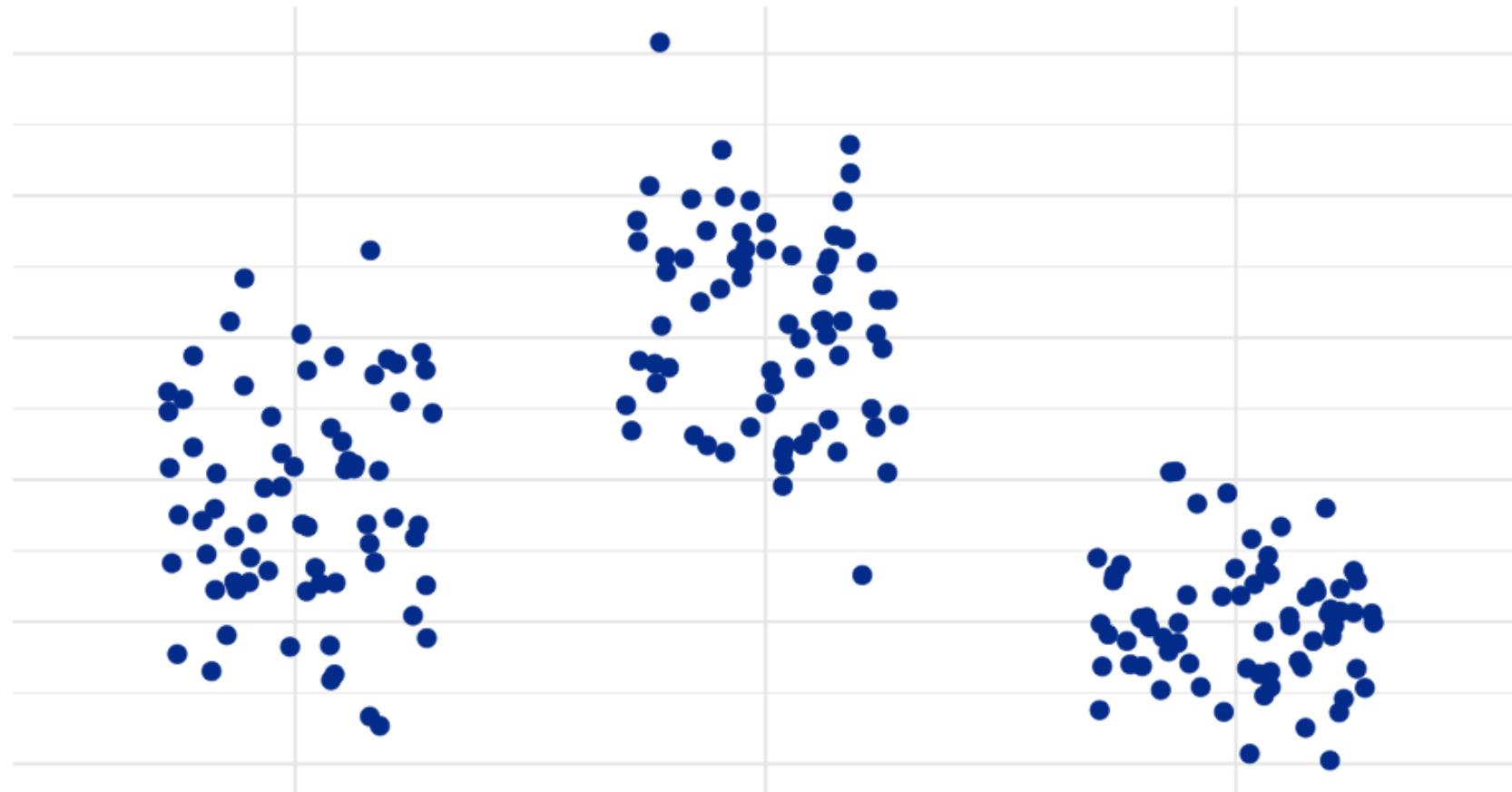
# Violin plots

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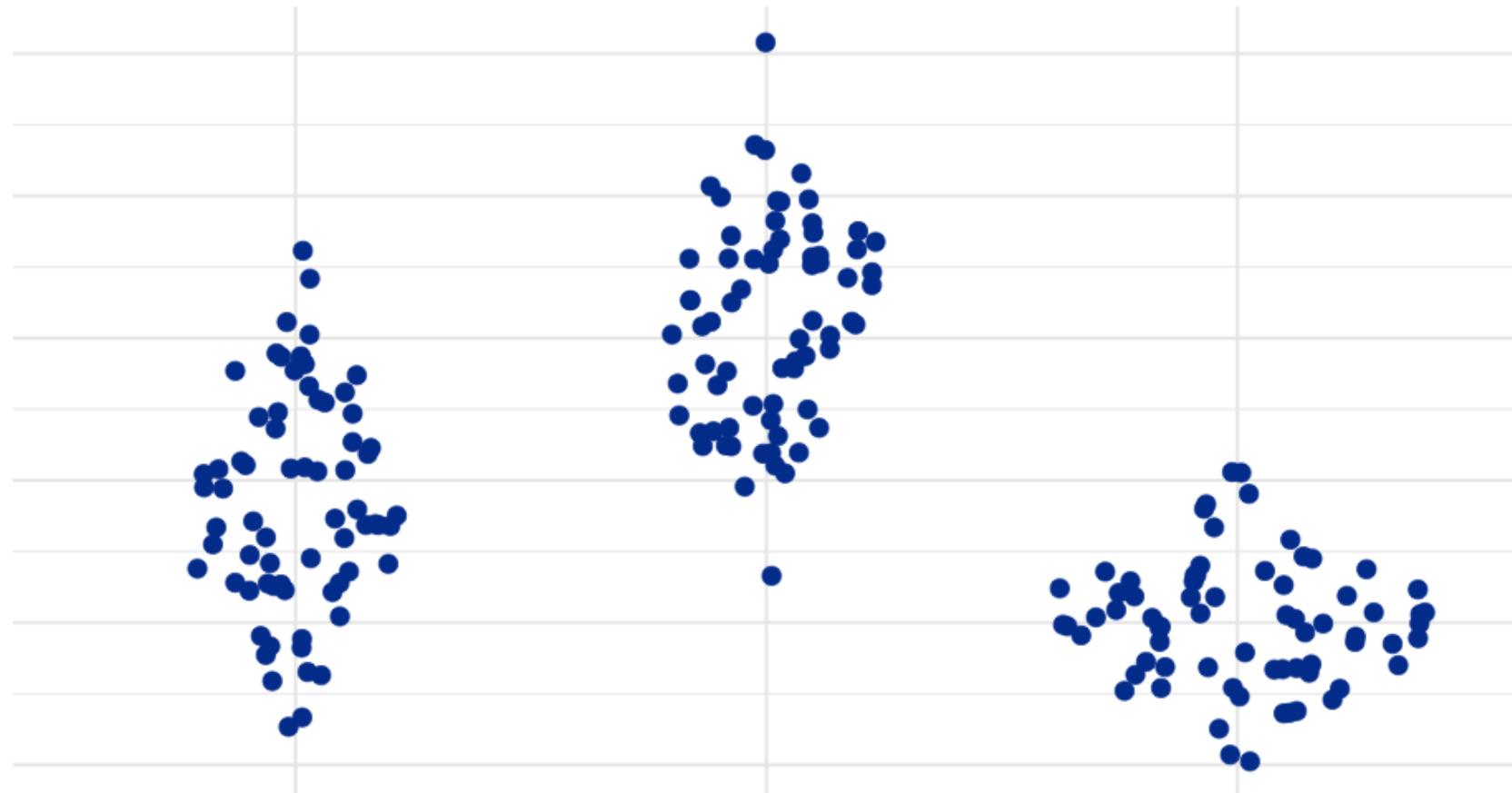
# Jittered points

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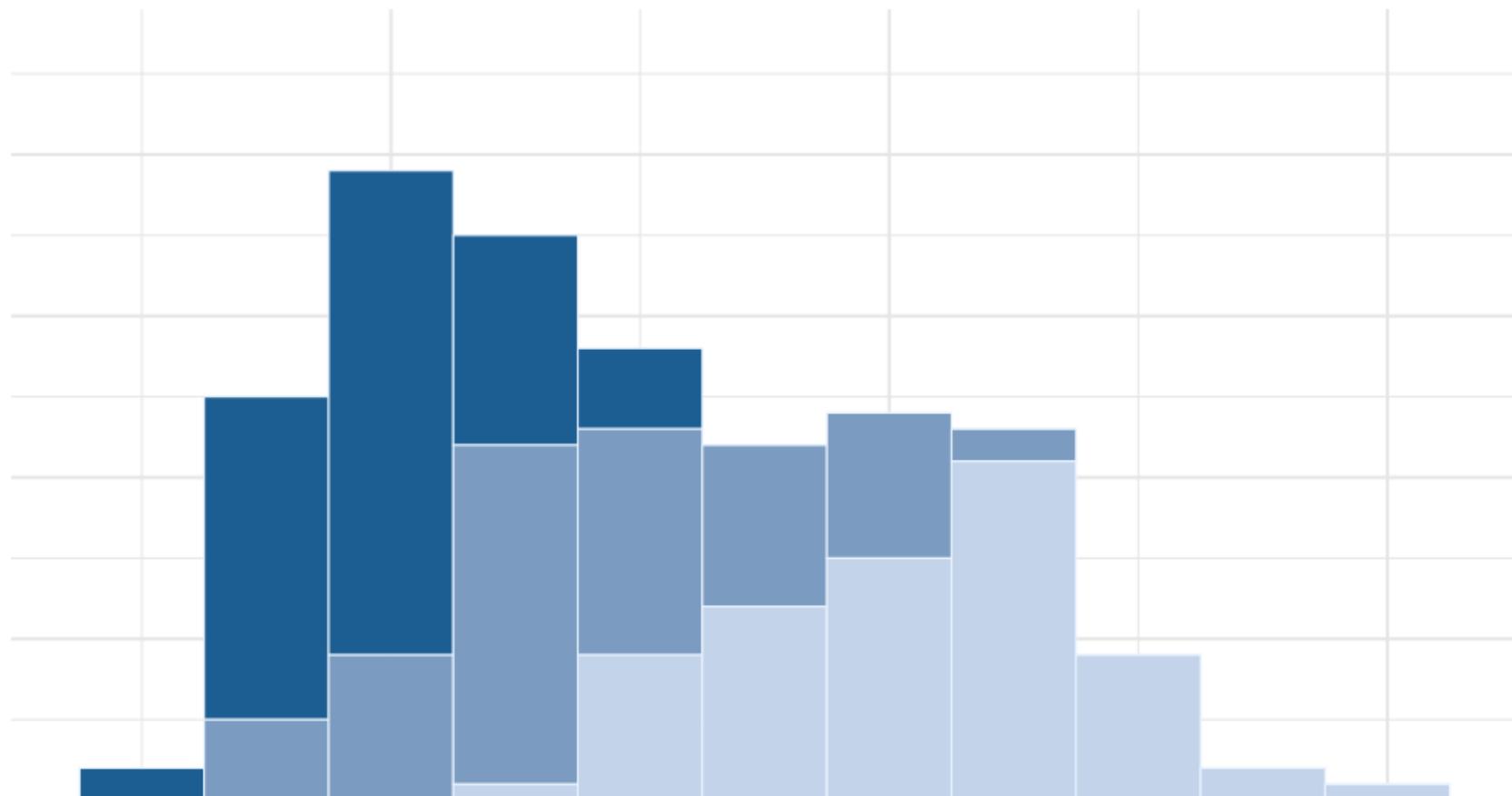
# Sina plots

---



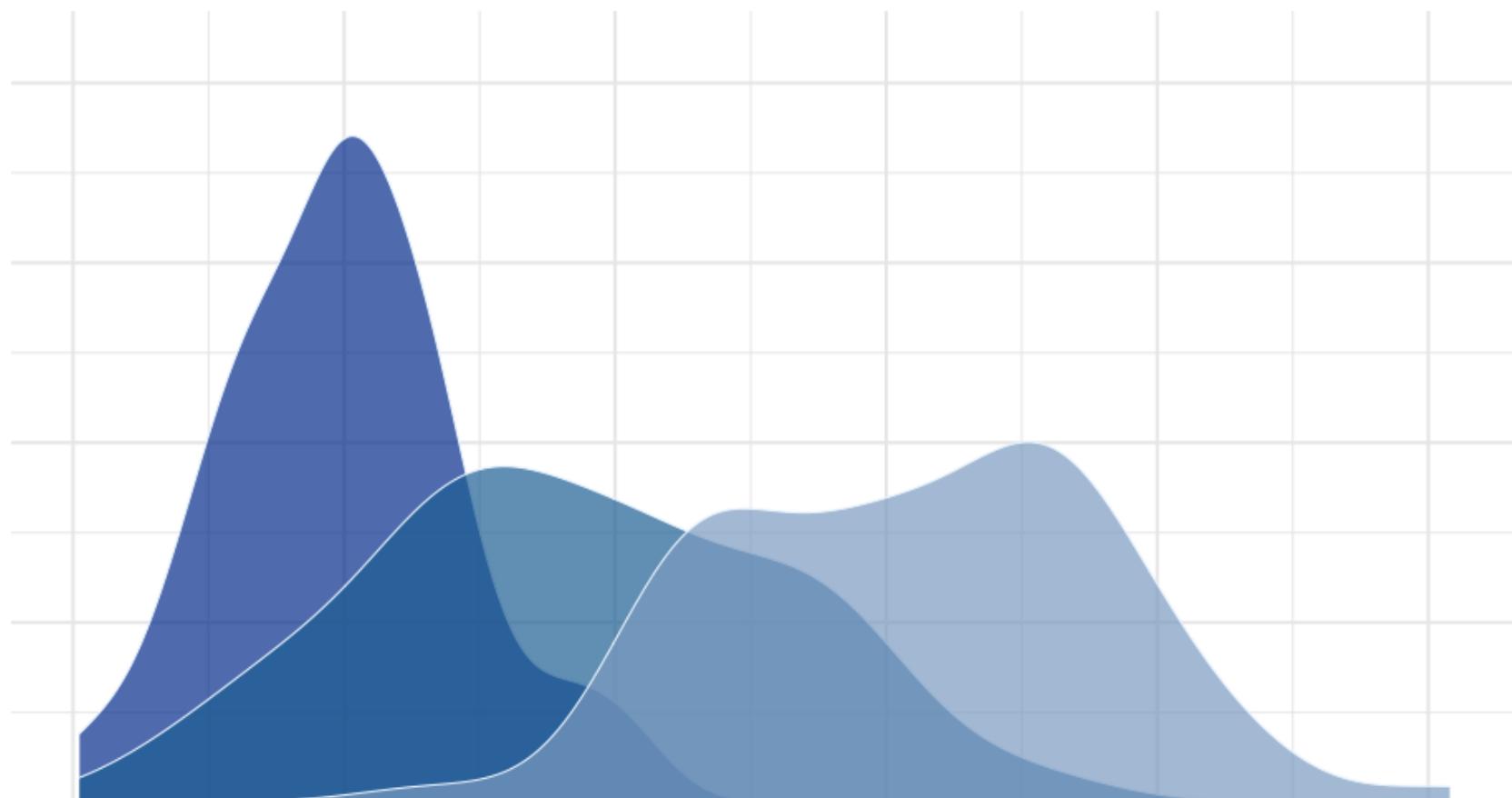
# Stacked histograms

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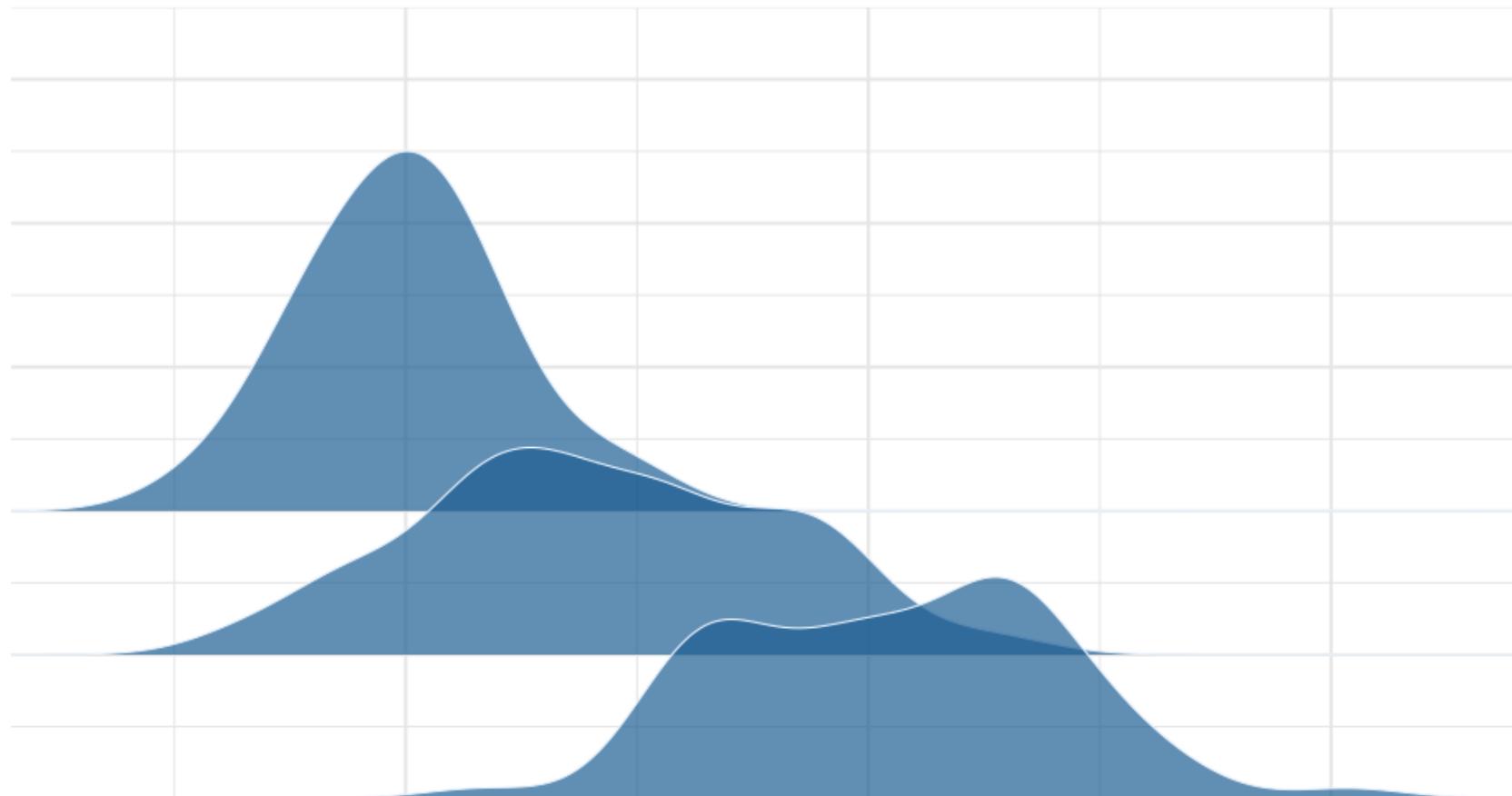
# Overlapping densities

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# Ridgeline densities

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# Quick empirical examples

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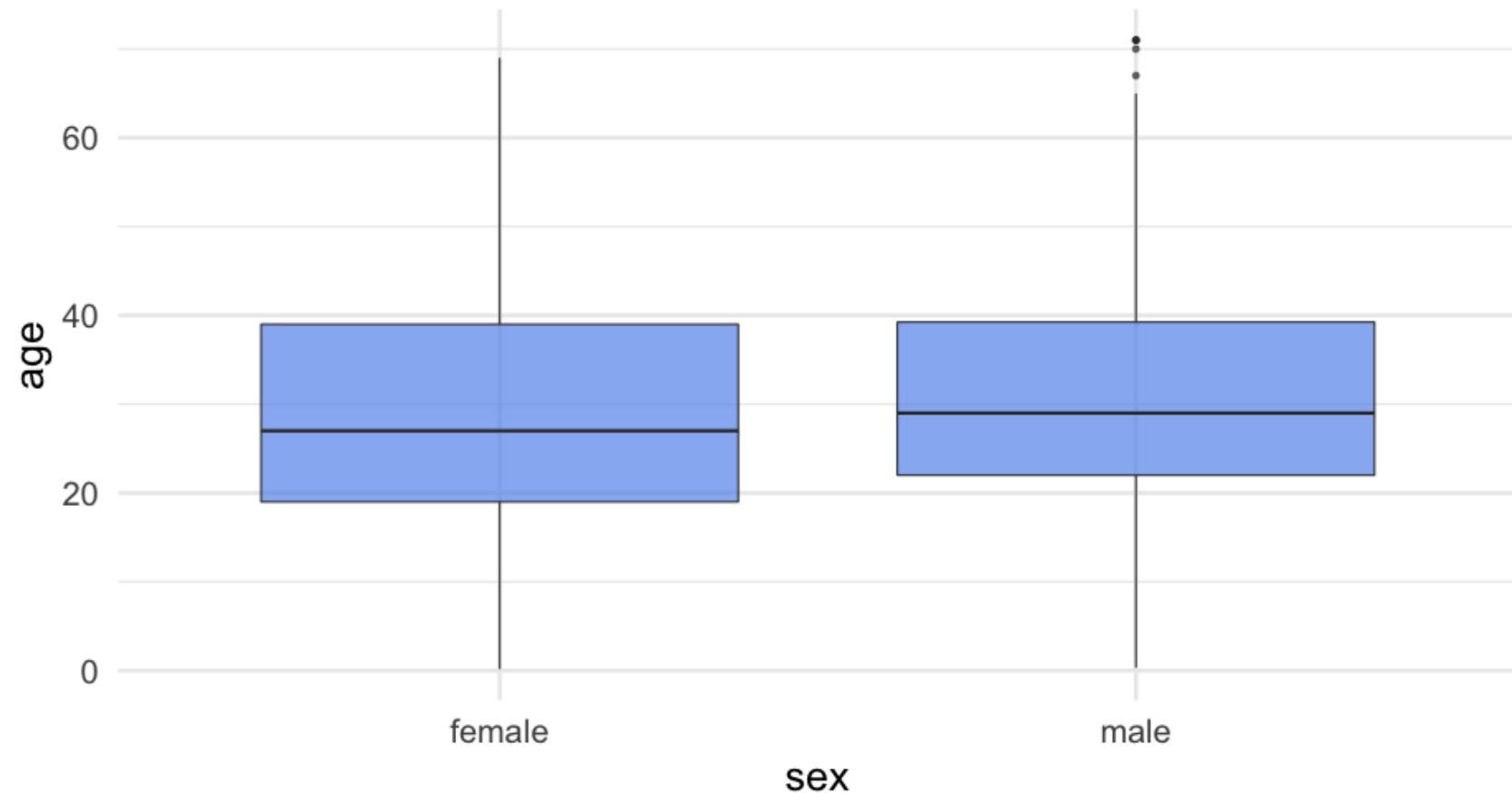
# Titanic data

---

```
## # A tibble: 1,313 x 5
##   name           class    age sex  survived
##   <chr>          <chr>  <dbl> <chr>     <int>
## 1 Allen, Miss Elisabeth Walton  1st      29  female      1
## 2 Allison, Miss Helen Loraine  1st       2  female      0
## 3 Allison, Mr Hudson Joshua Creighton 1st      30  male       0
## 4 Allison, Mrs Hudson JC (Bessie Waldo Daniels) 1st      25  female      0
## 5 Allison, Master Hudson Trevor  1st      0.92 male      1
## 6 Anderson, Mr Harry            1st      47  male       1
## # ... with 1,307 more rows
```

# Boxplots

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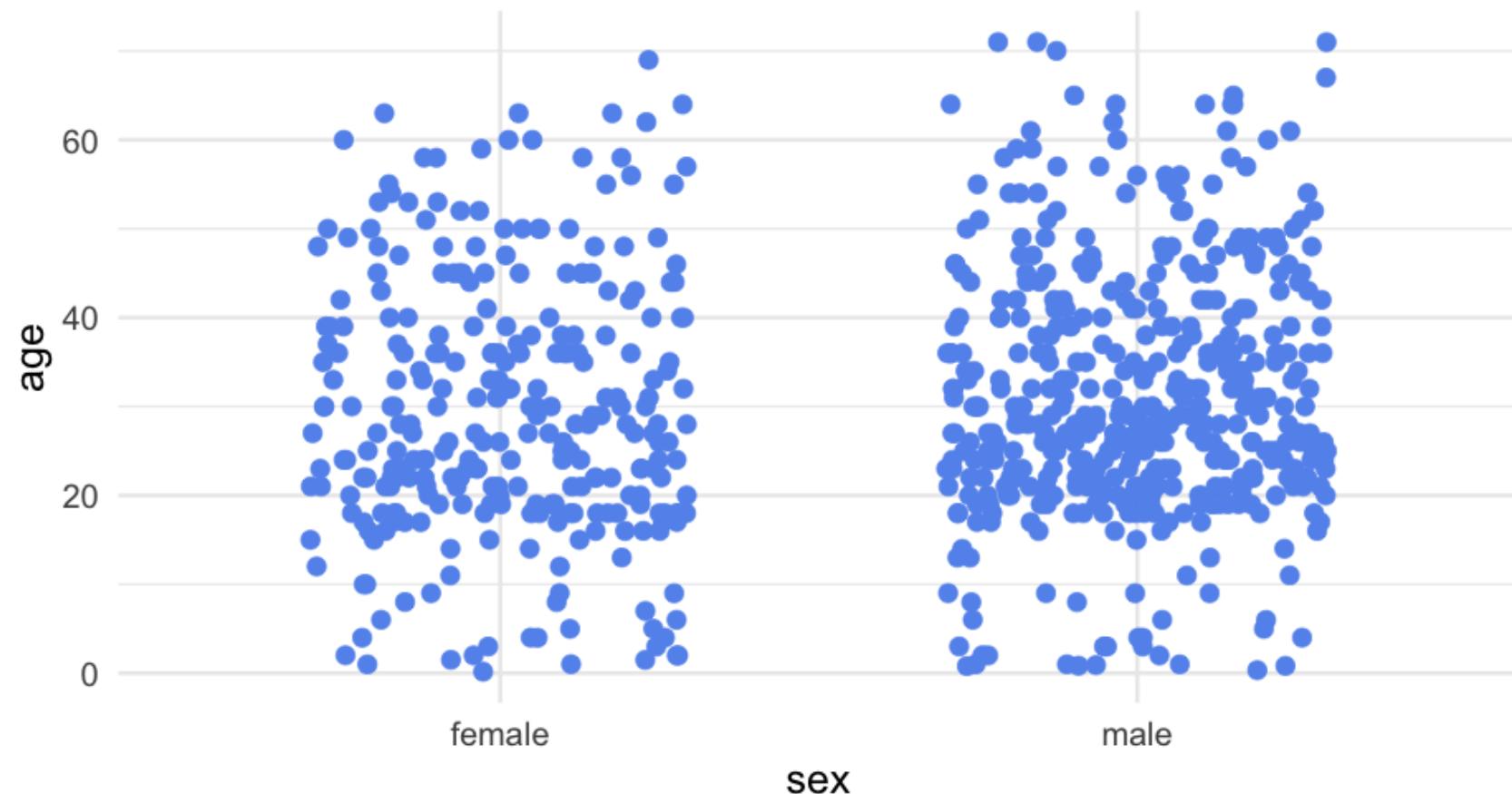
# Violin plots

---



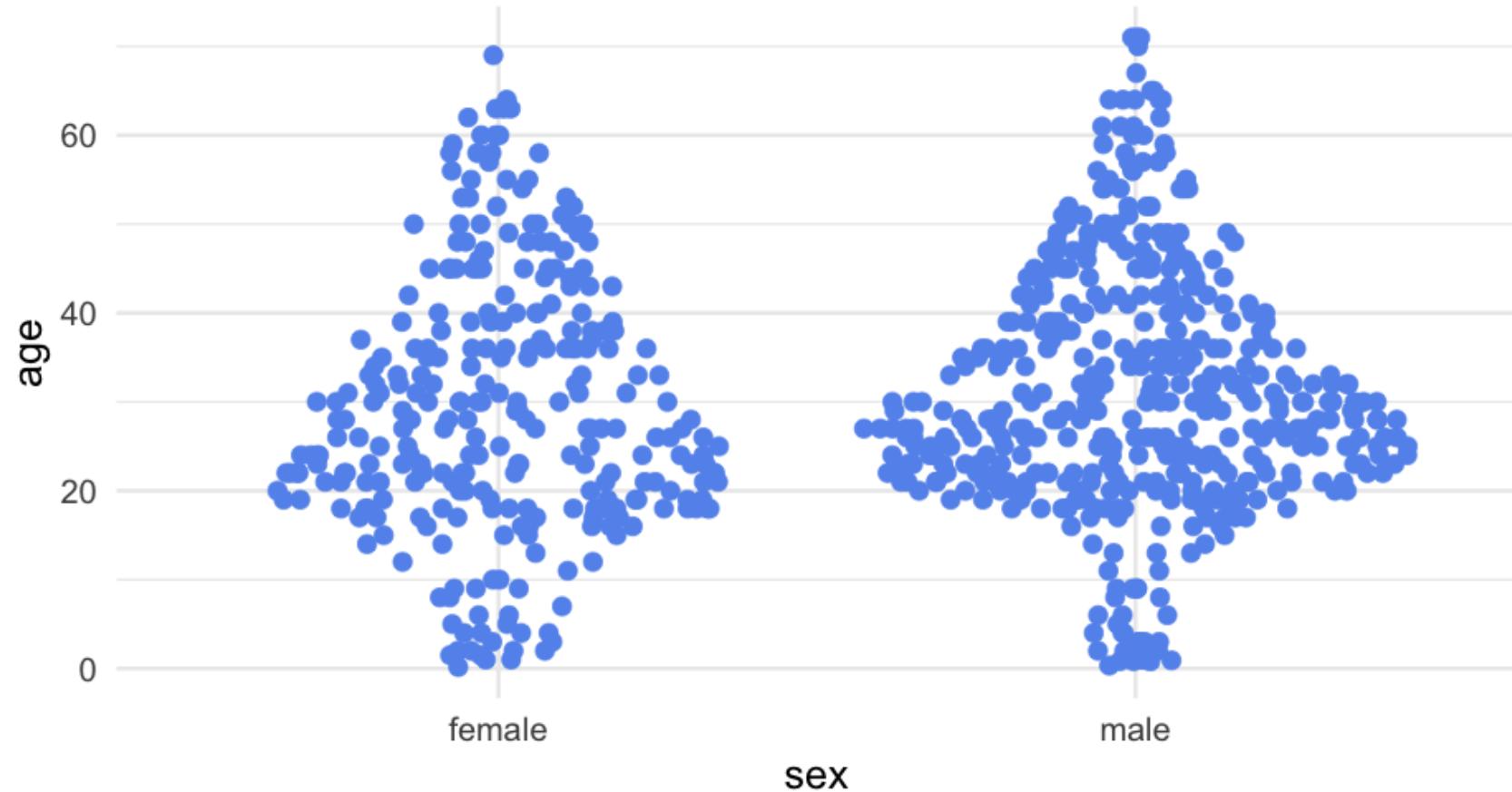
# Jittered point plots

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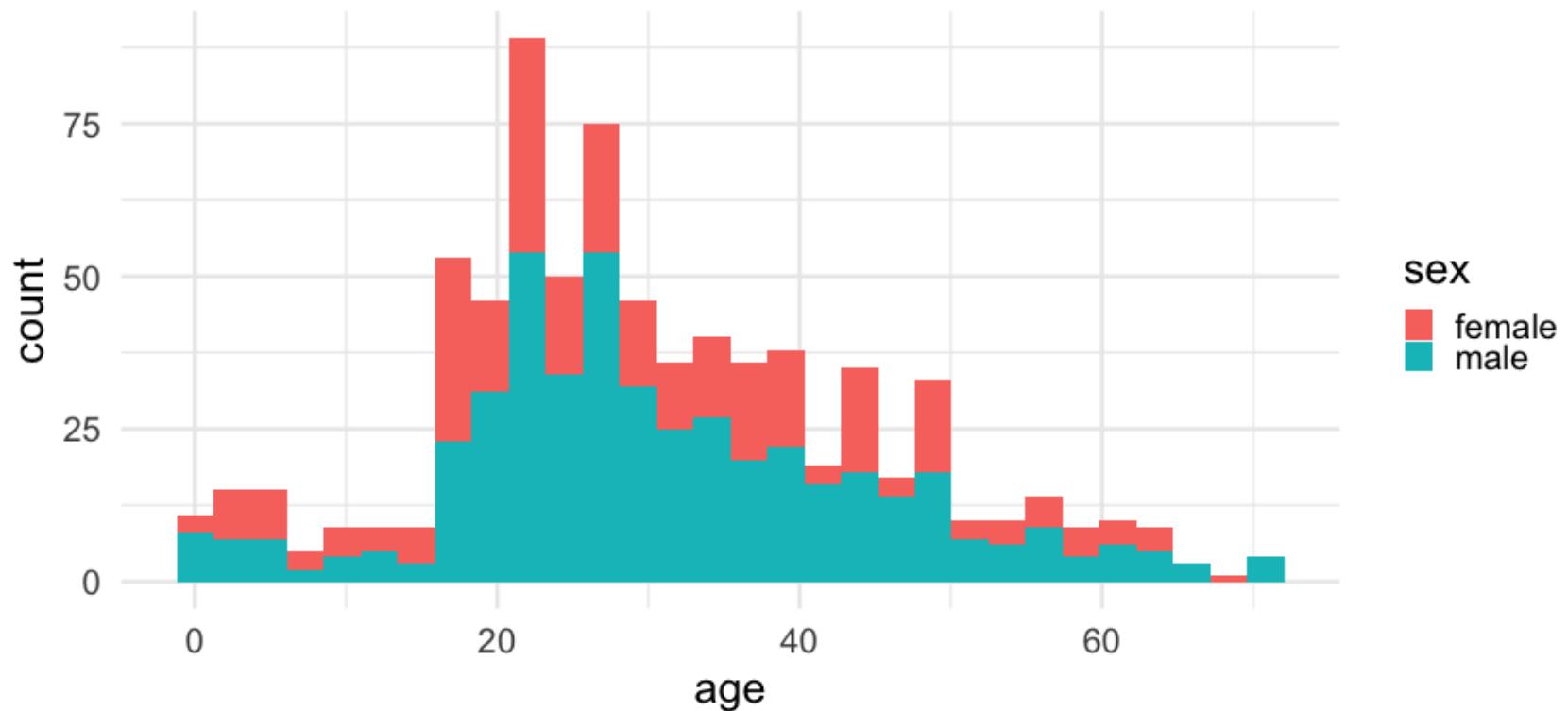
# Sina plot

---



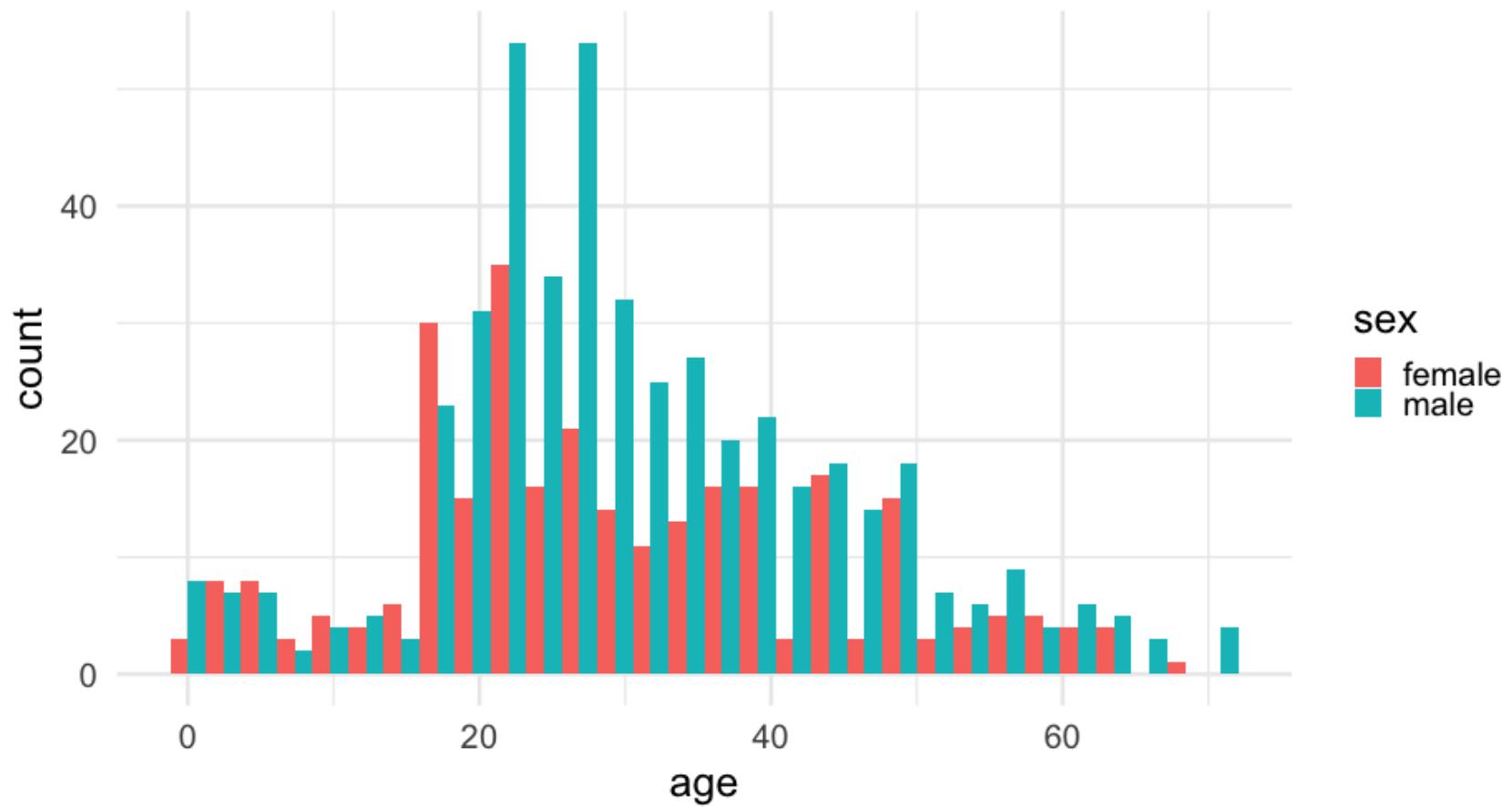
# Stacked histogram

---



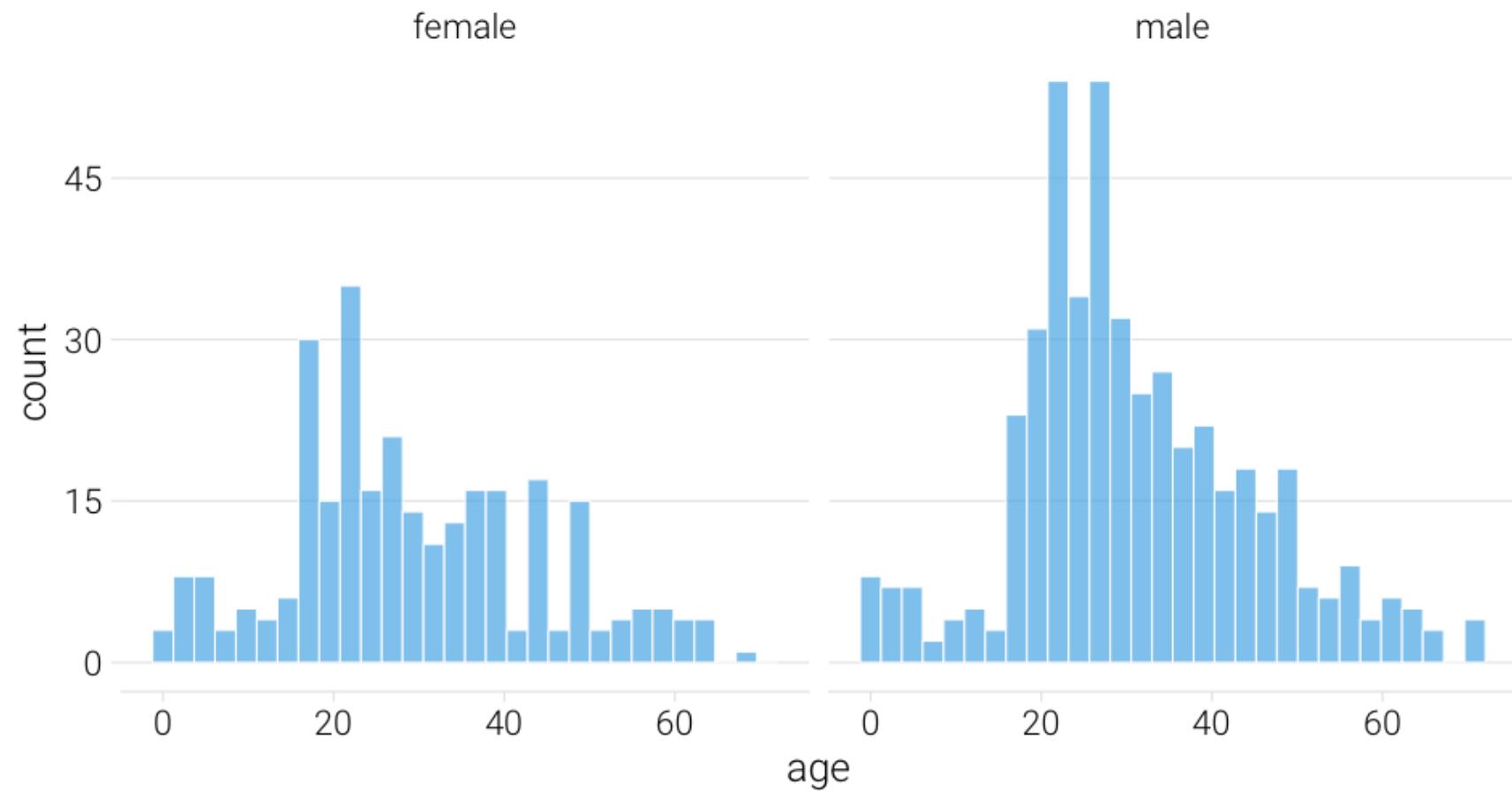
# Dodged

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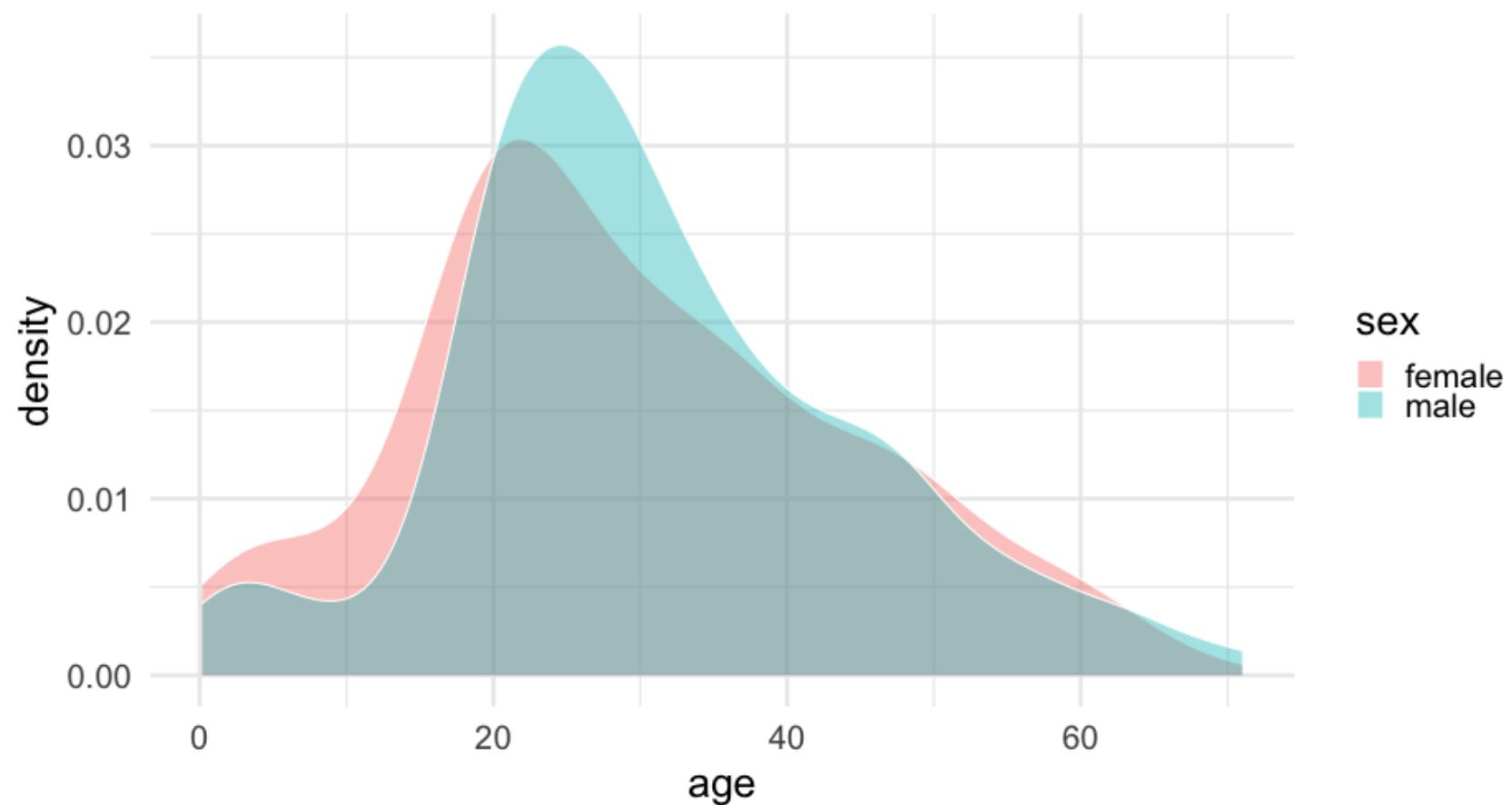
# Better

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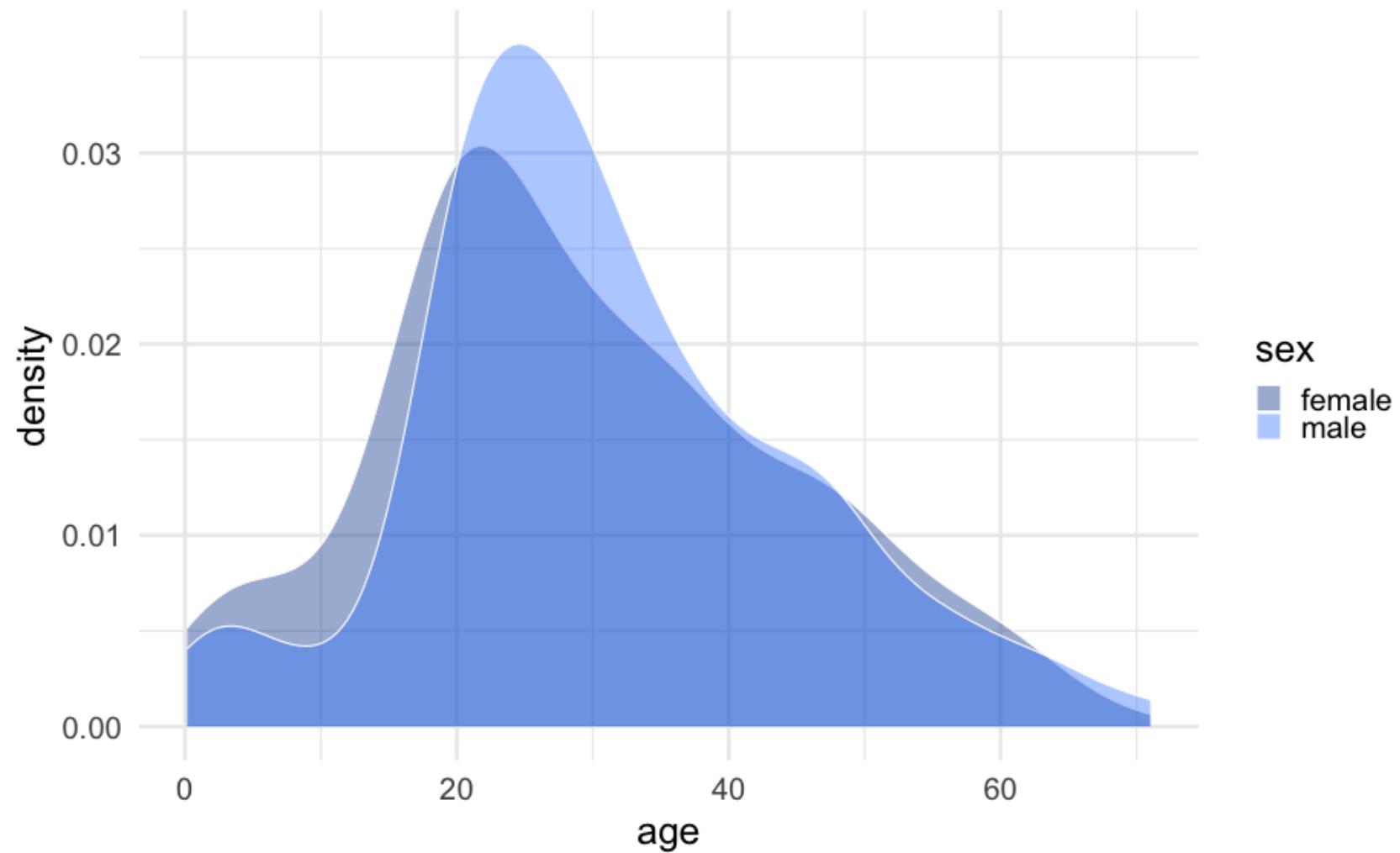


# Overlapping densities

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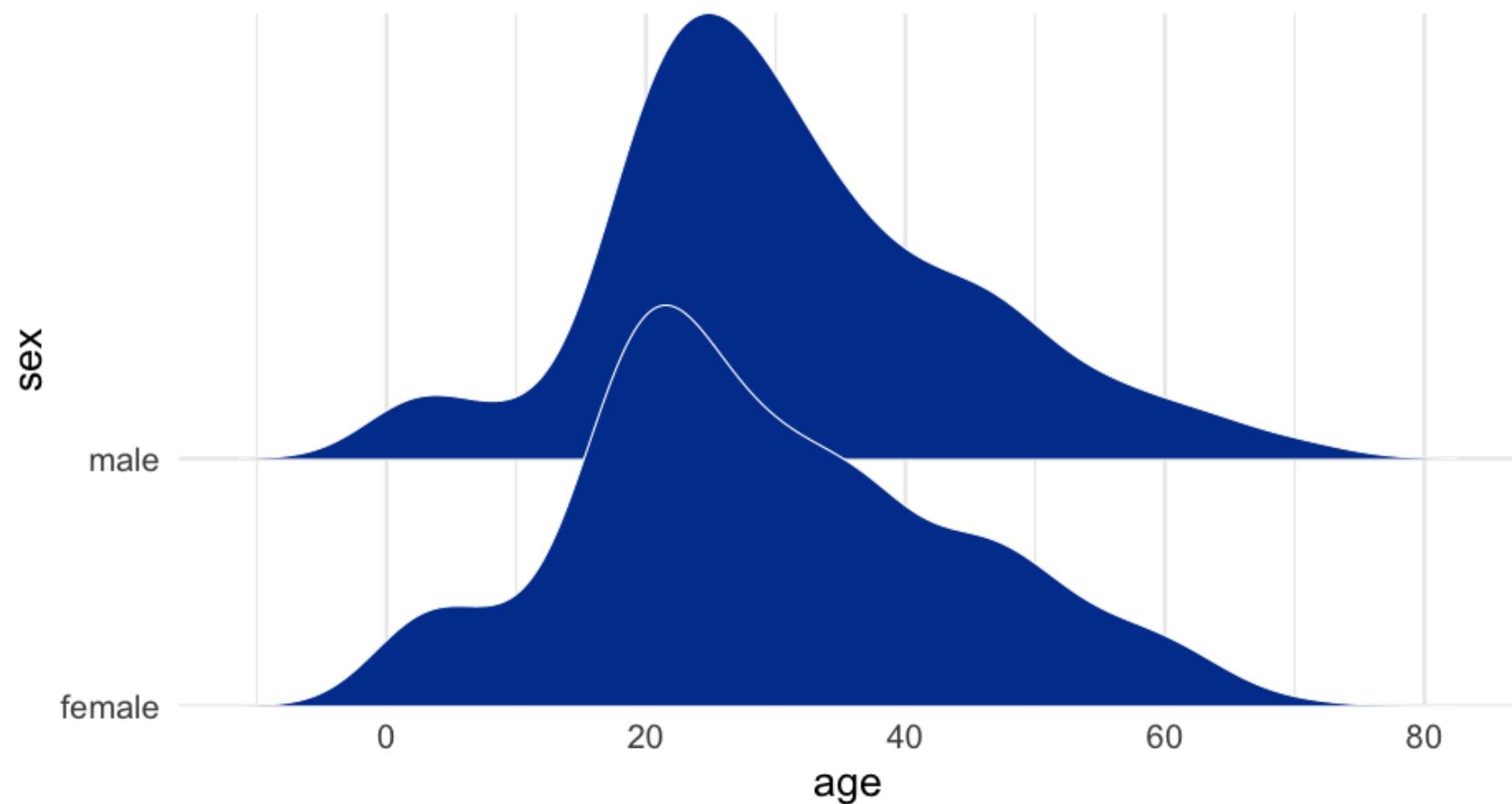


Note the default colors really don't work well in most of these



# Ridgeline densities

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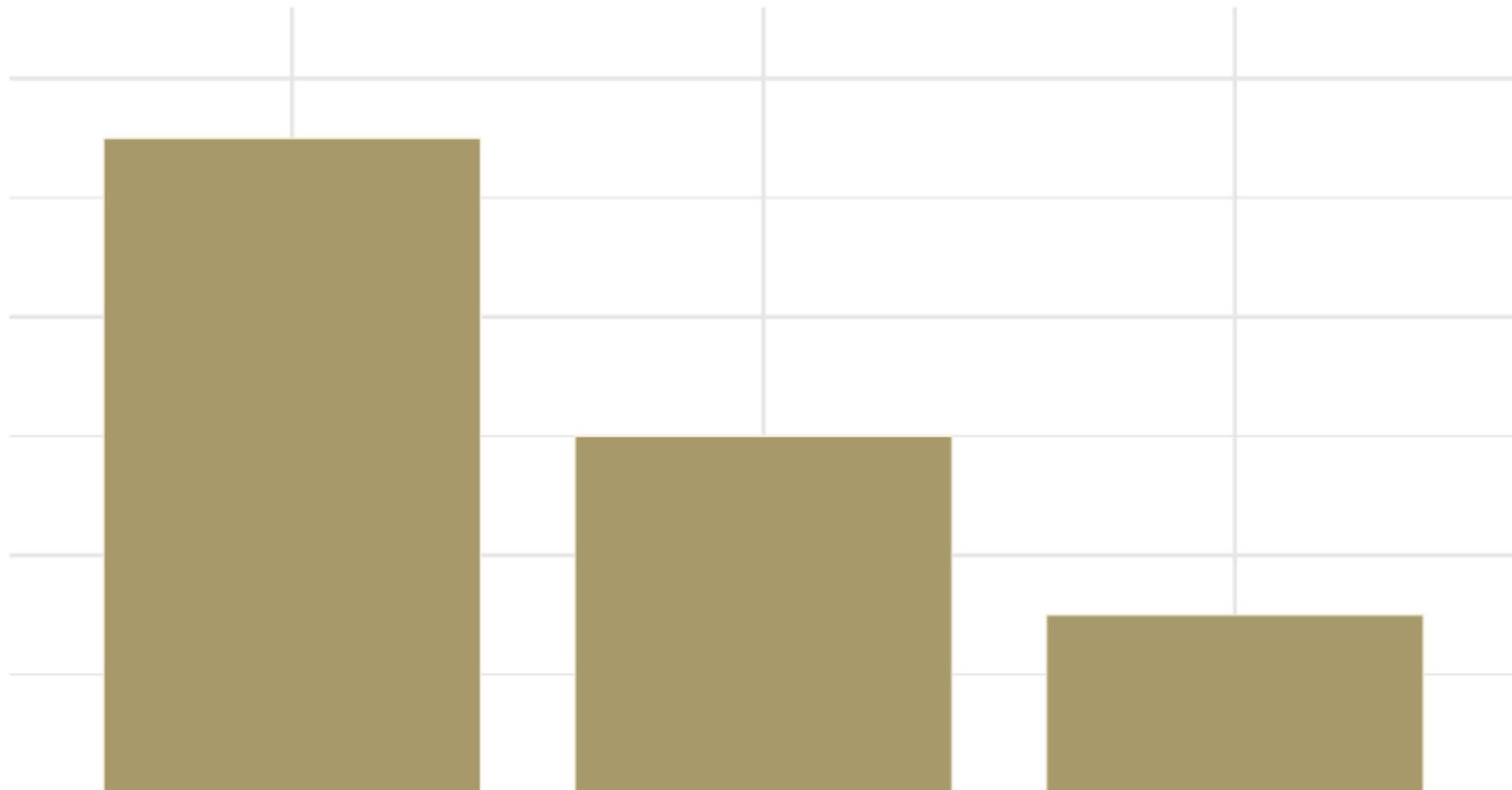


# Visualizing amounts

---

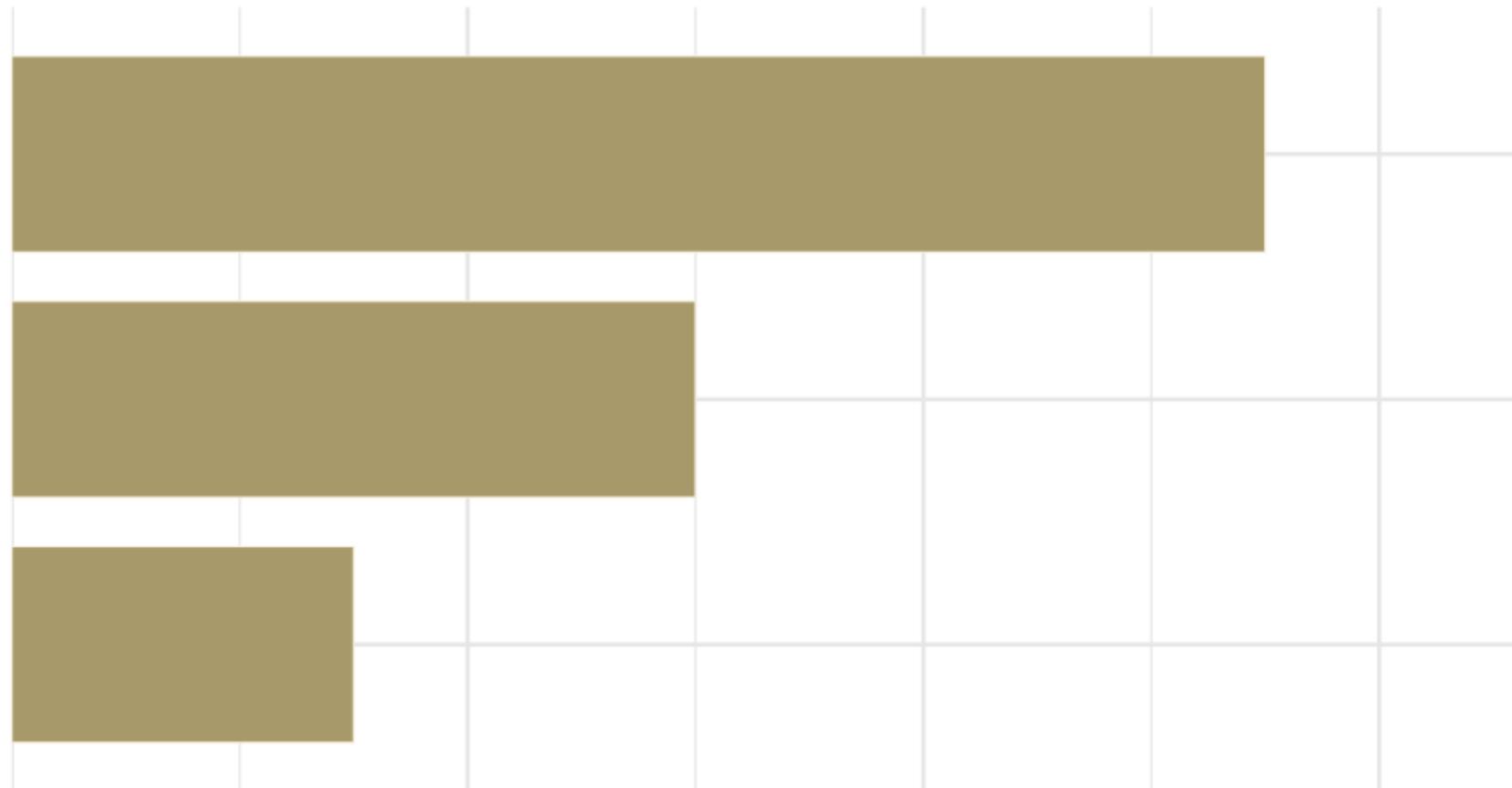
# Bar plots

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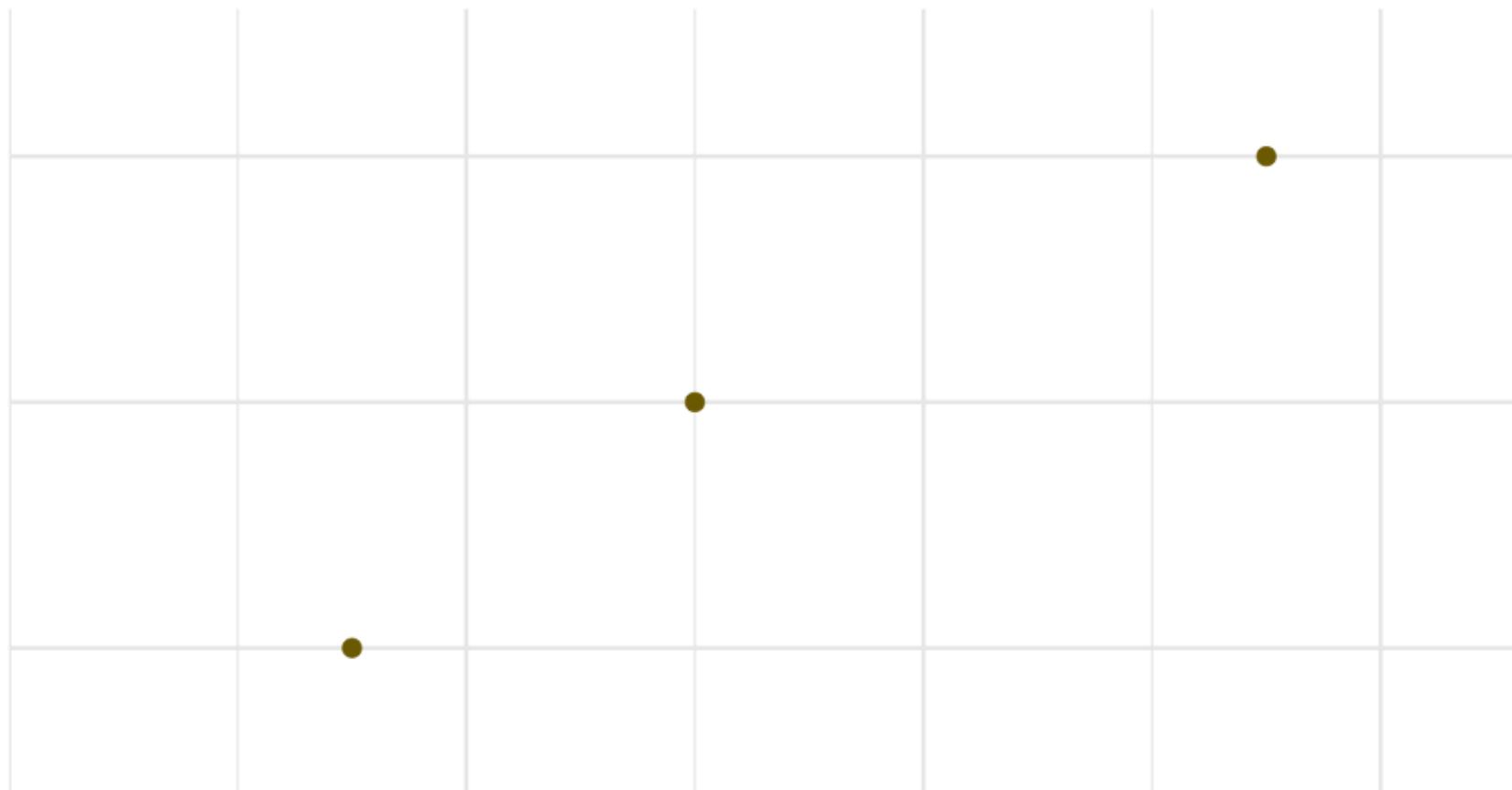
# Flipped bars

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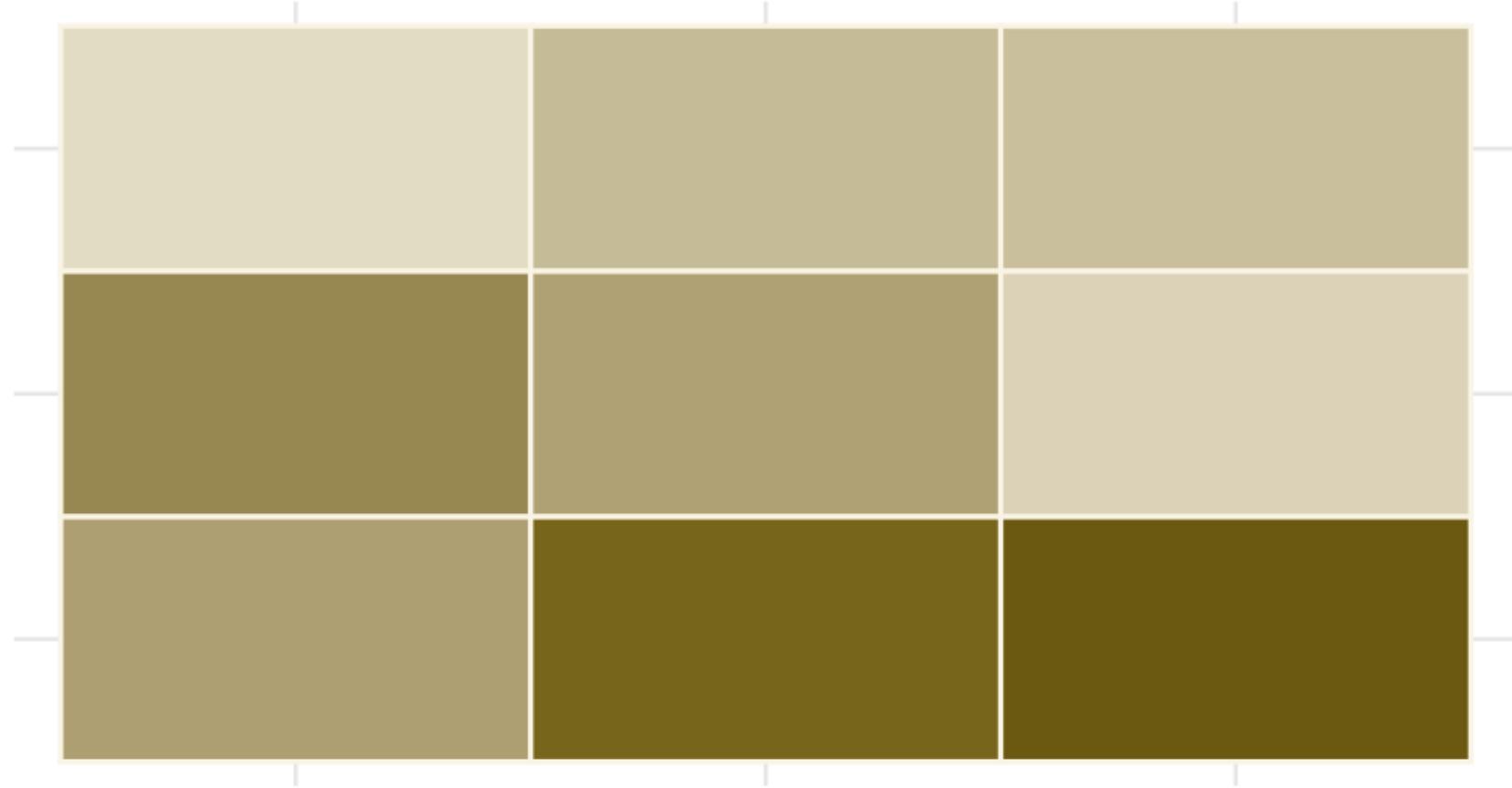
# Dotplot

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# Heatmap

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# A short journey

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How much does college cost?

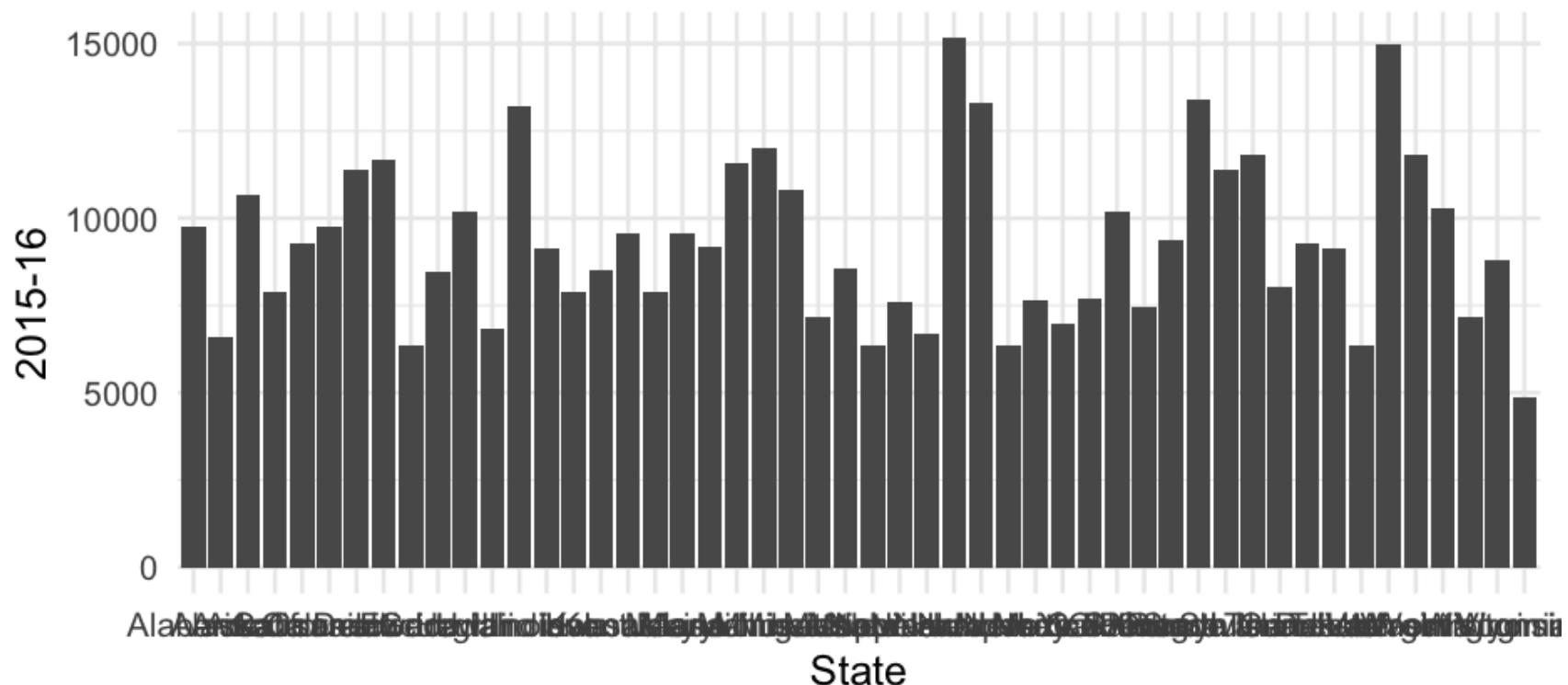
# Tuition data

---

```
## # A tibble: 6 x 13
##   State    `2004-05` `2005-06` `2006-07` `2007-08` `2008-09` `2009-10` 
##   <chr>     <dbl>     <dbl>     <dbl>     <dbl>     <dbl>     <dbl>    
## 1 Alabama  5682.838  5840.550  5753.496  6008.169  6475.092  7188.954
## 2 Alaska   4328.281  4632.623  4918.501  5069.822  5075.482  5454.607
## 3 Arizona  5138.495  5415.516  5481.419  5681.638  6058.464  7263.204
## 4 Arkansas 5772.302  6082.379  6231.977  6414.900  6416.503  6627.092
## 5 California 5285.921  5527.881  5334.826  5672.472  5897.888  7258.771
## 6 Colorado  4703.777  5406.967  5596.348  6227.002  6284.137  6948.473
## # ... with 6 more variables: 2010-11 <dbl>, 2011-12 <dbl>, 2012-13 <dbl>,
## #   2013-14 <dbl>, 2014-15 <dbl>, 2015-16 <dbl>
```

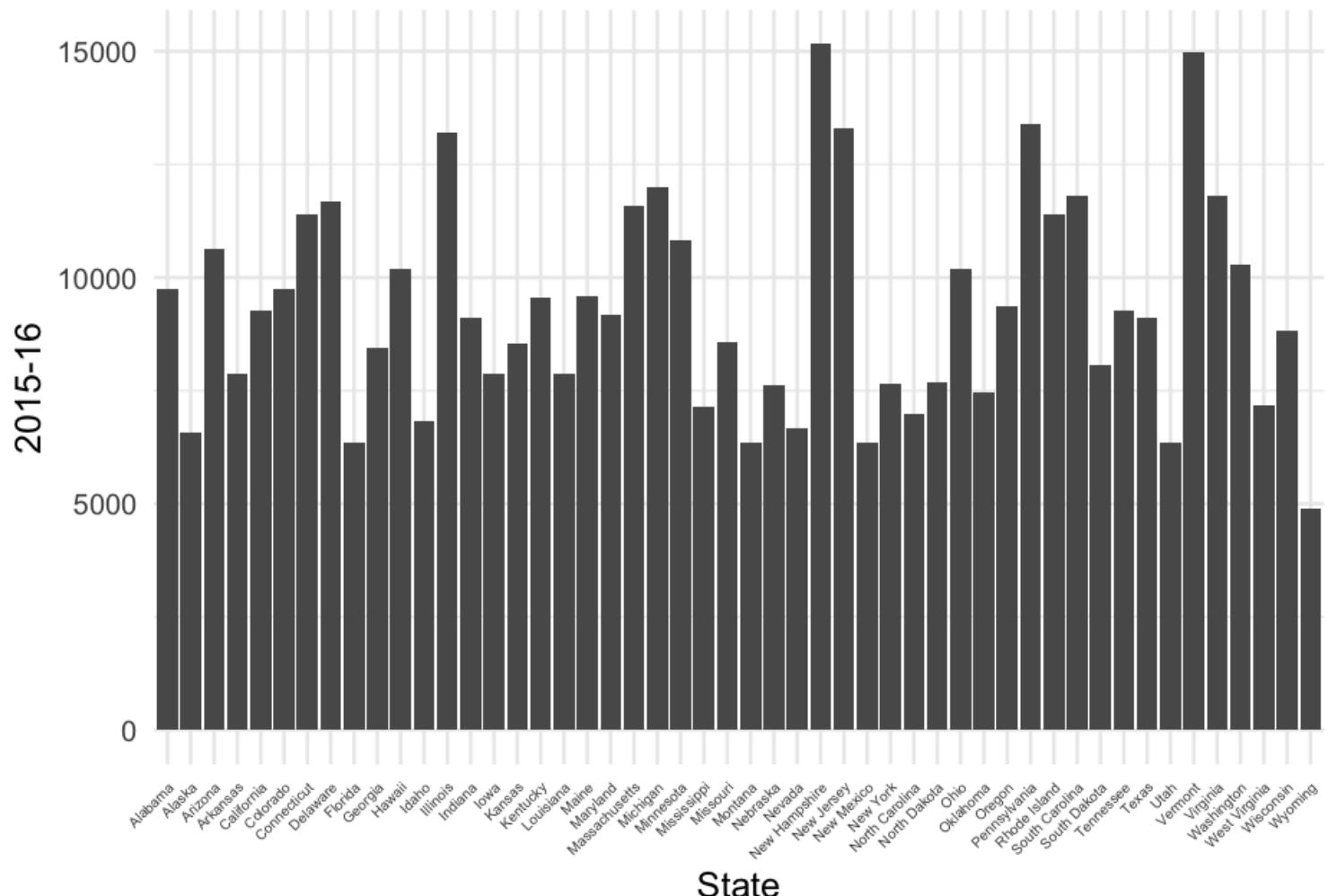
# By state: 2015–16

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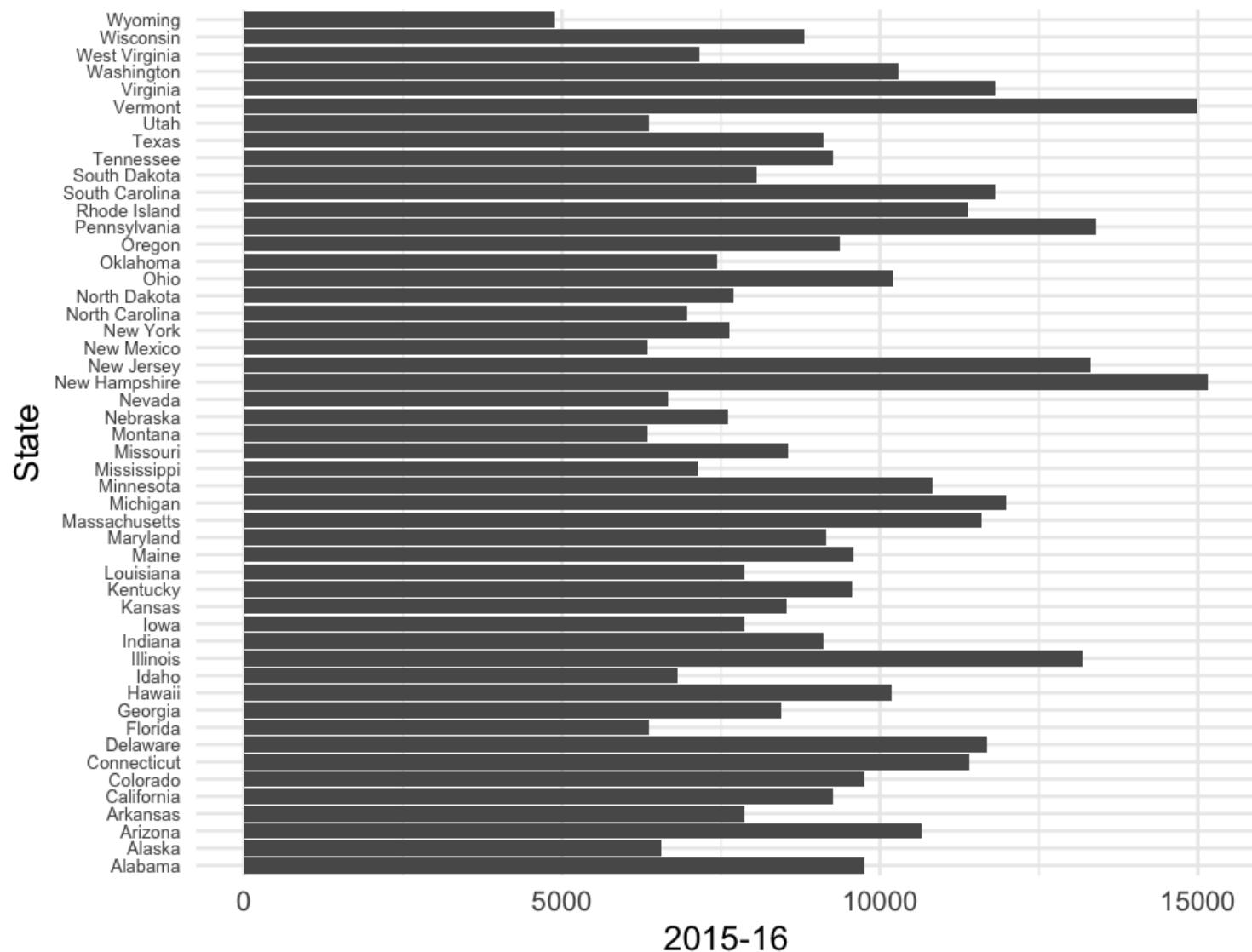
# Two puke emoji version

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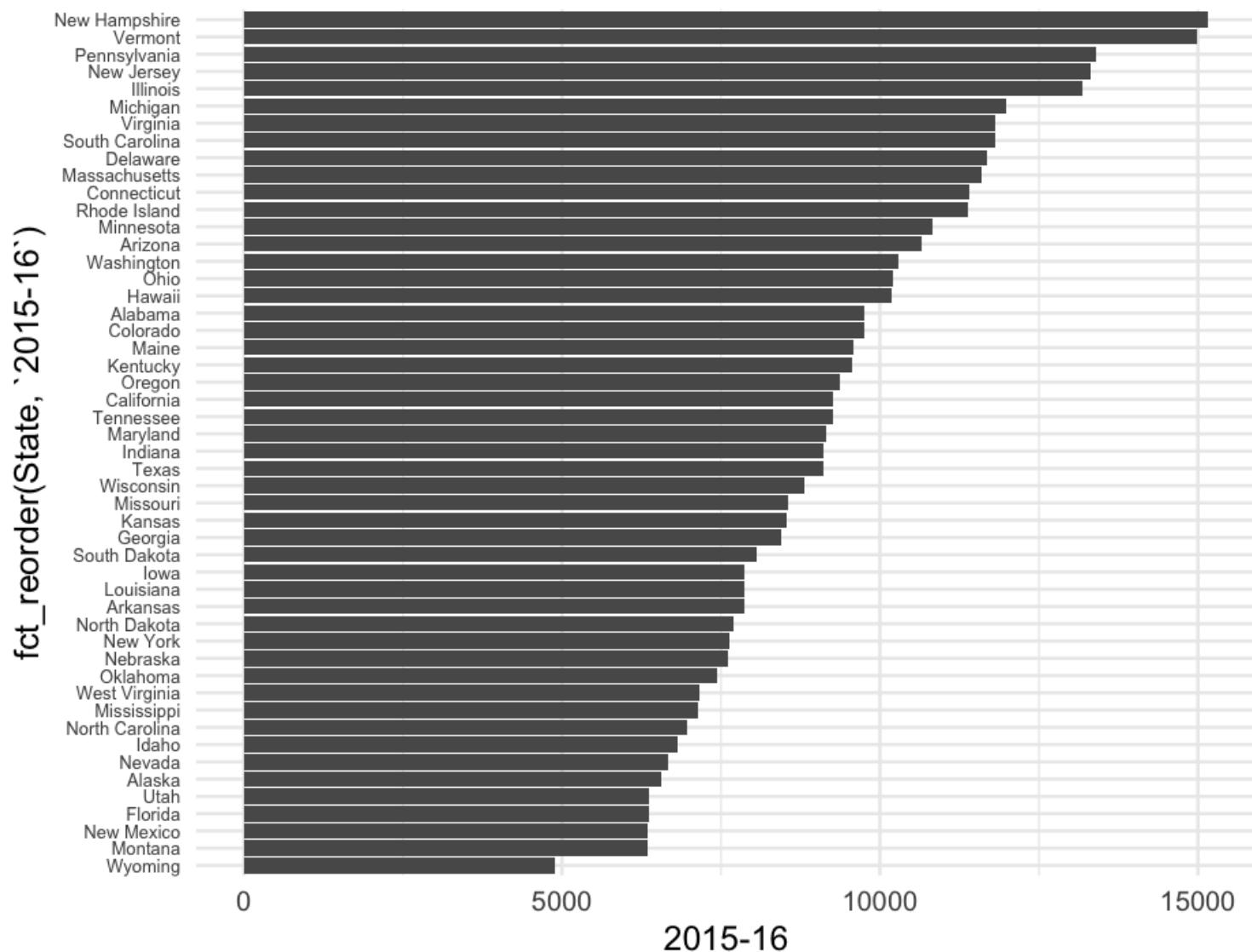
# One puke emoji version

---



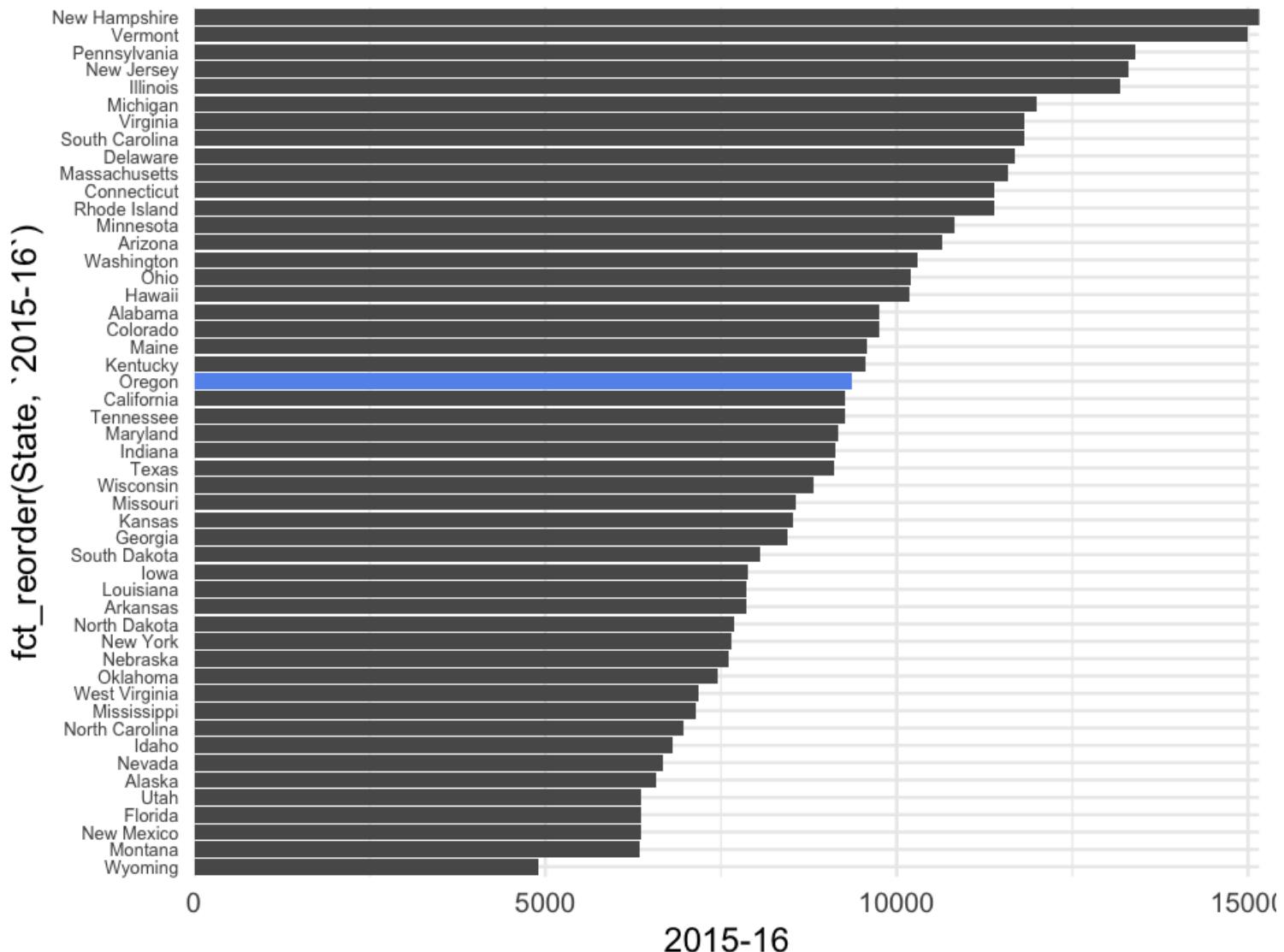
# Kinda smiley version

---



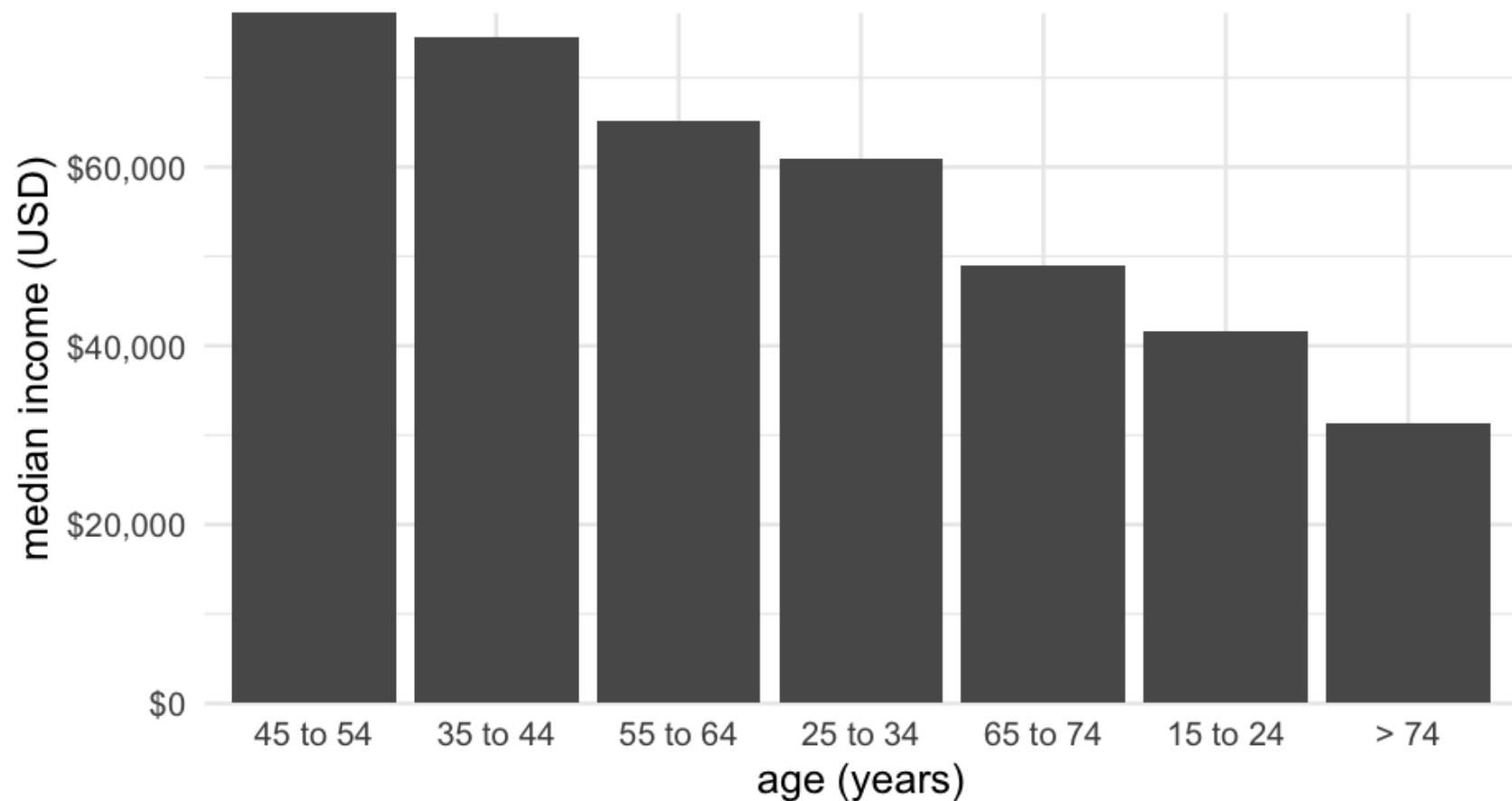
# Highlight Oregon

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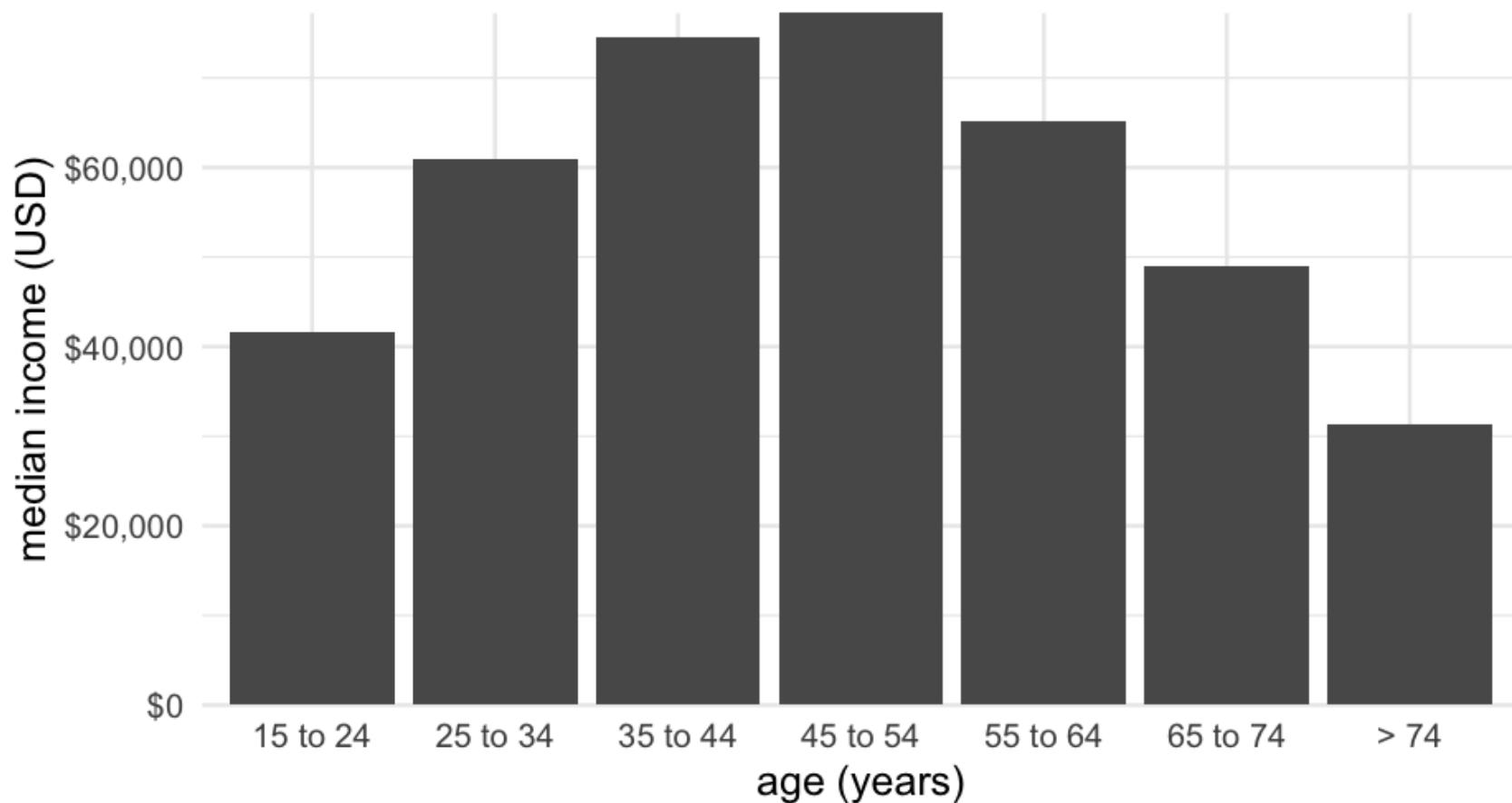
# Not always good to sort

---



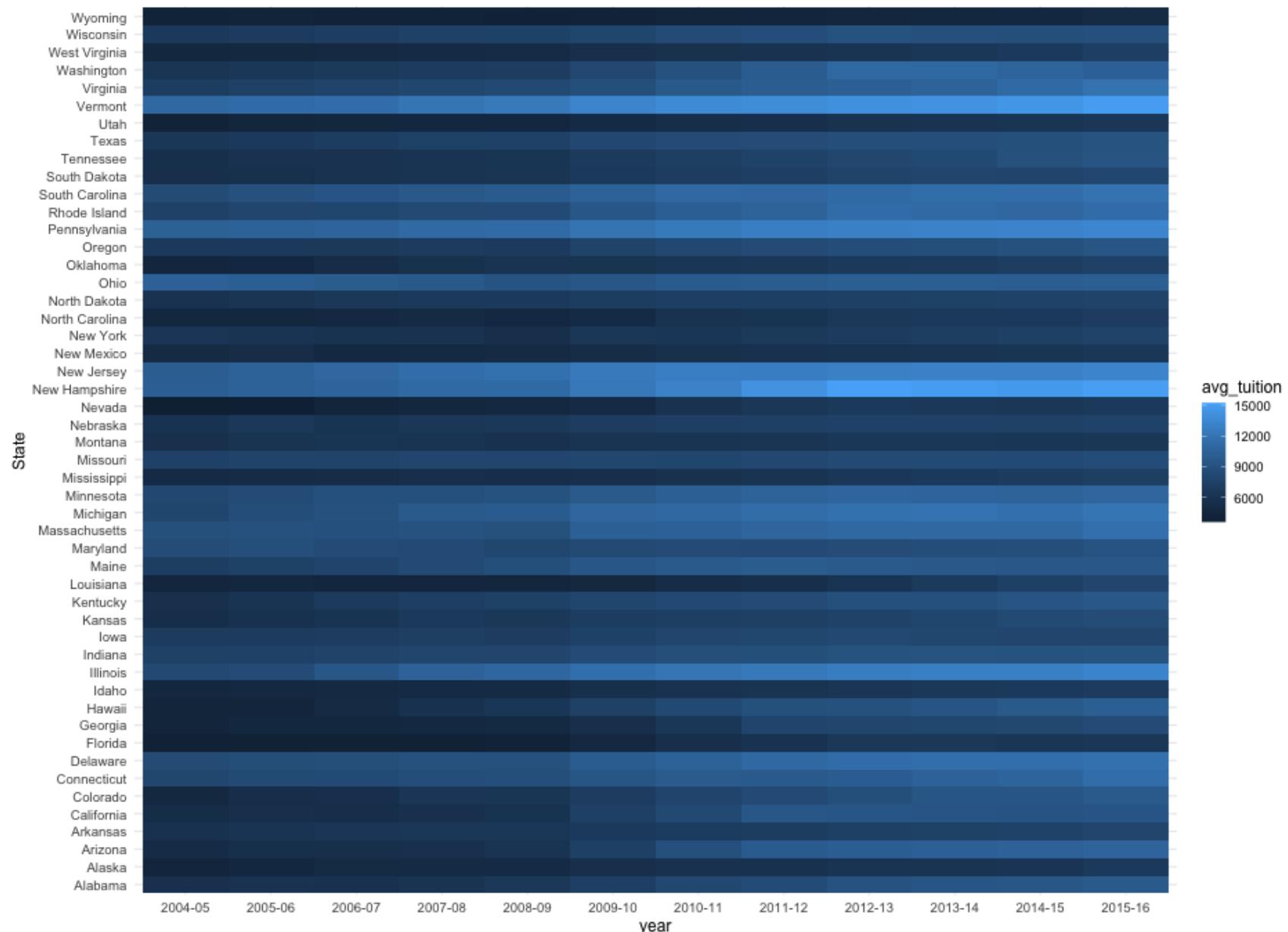
# Much better

---



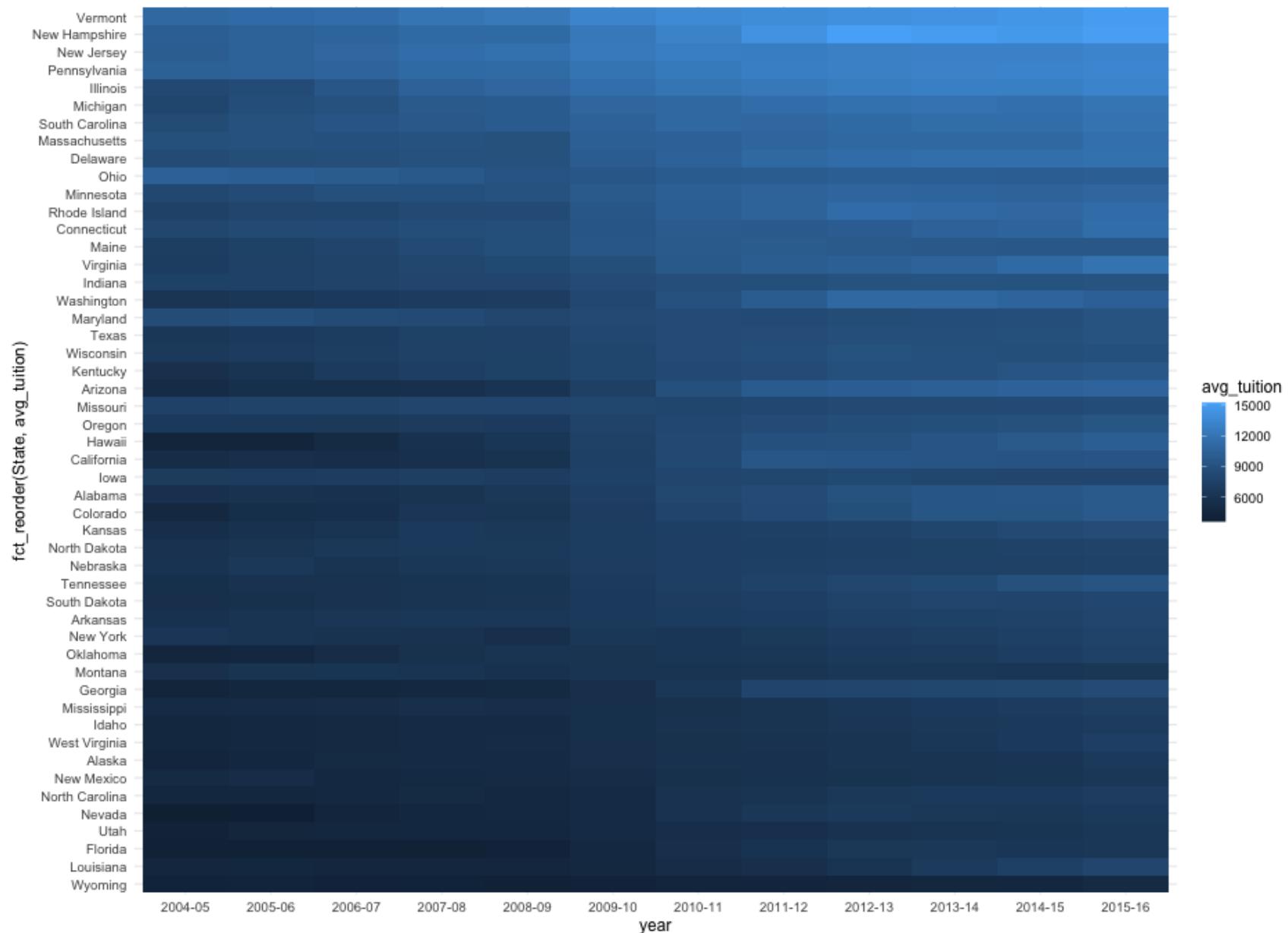
# Heatmap

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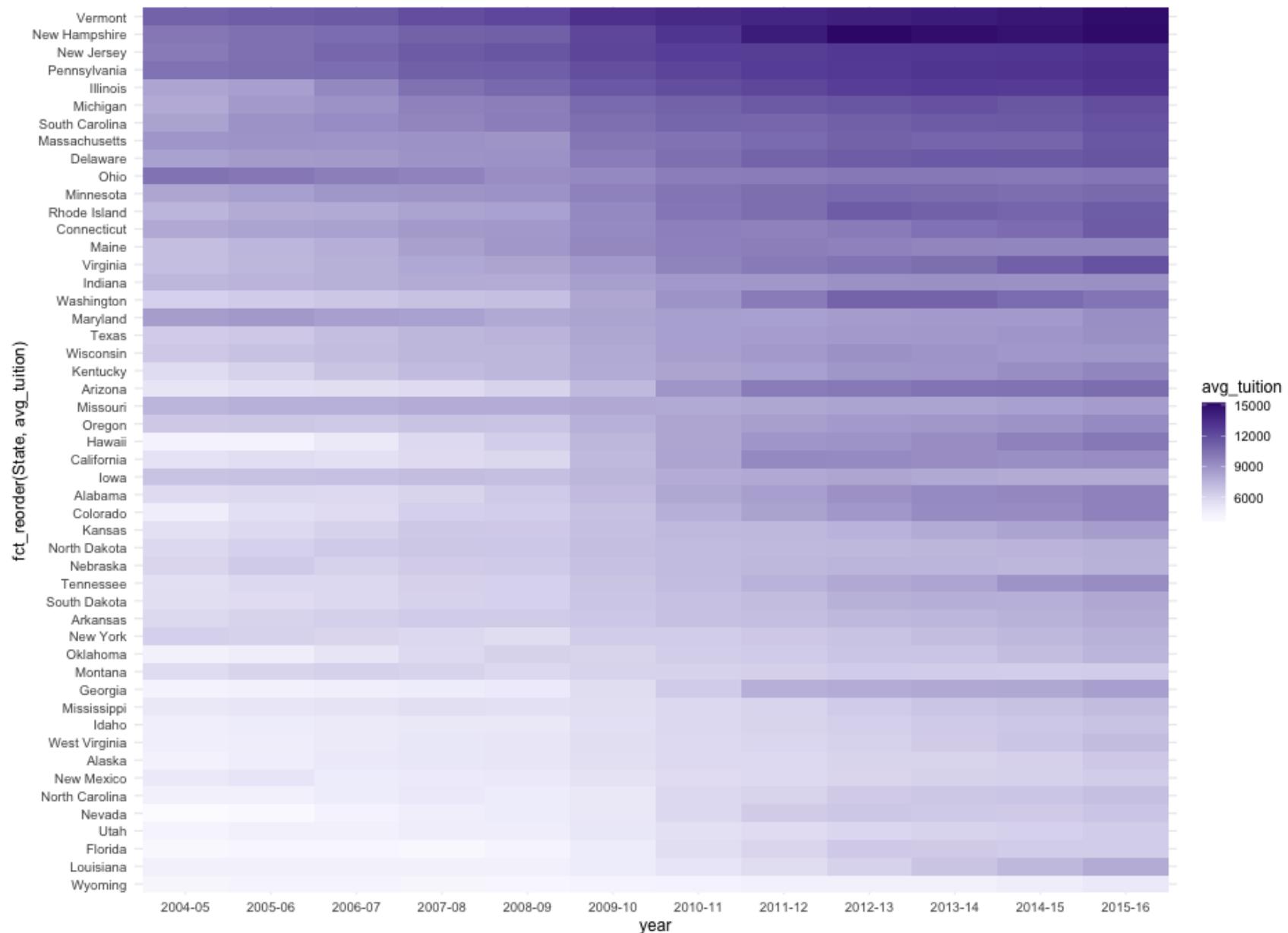
# Better heatmap

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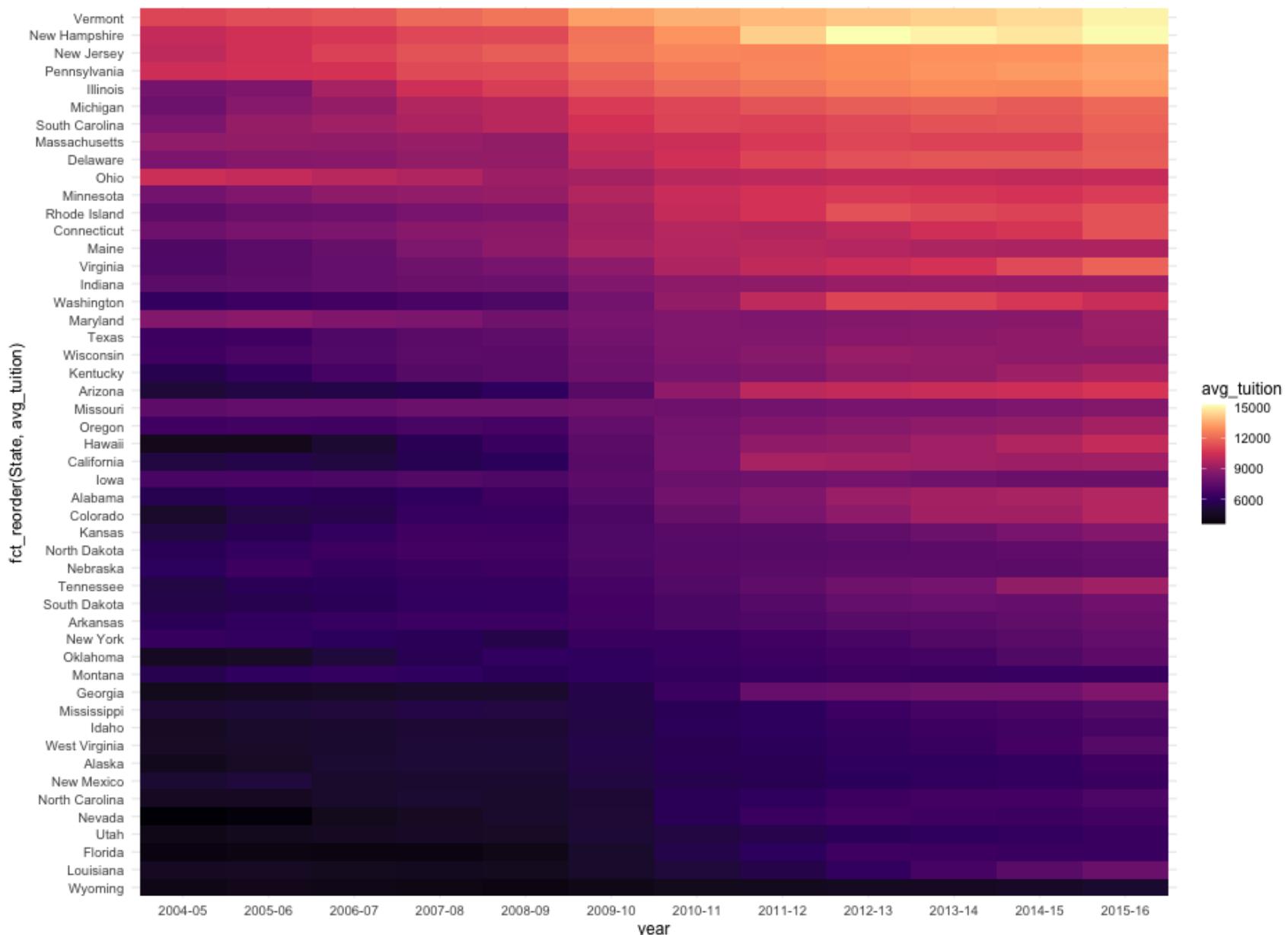
# Even better?

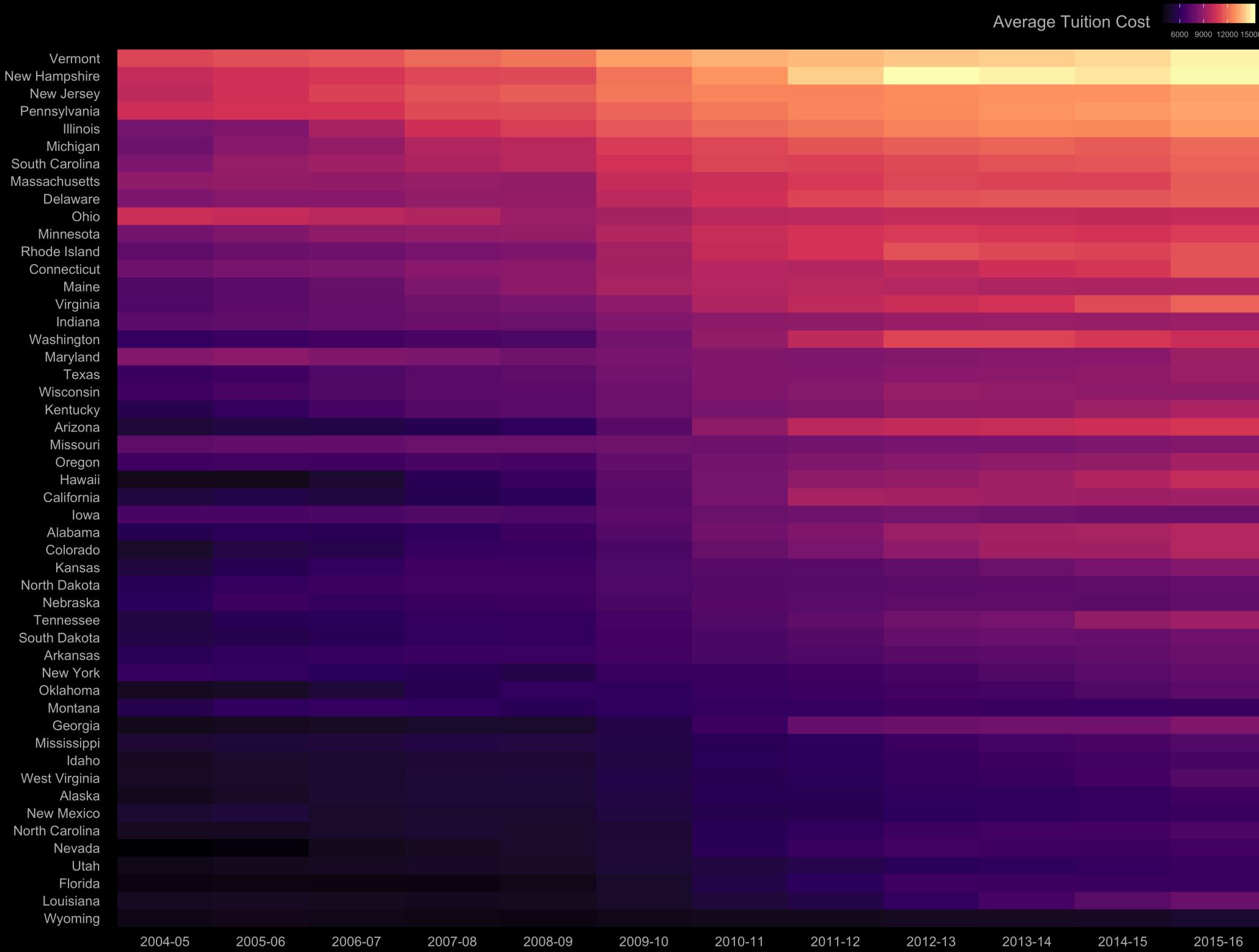
---



# Or maybe this one?

---



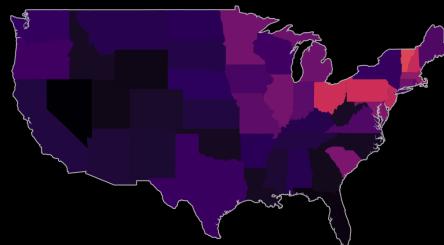


# Quick aside

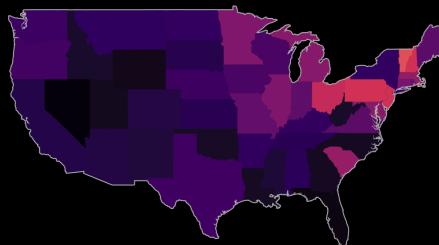
---

- Think about the data you have
- Given that these are state–level data, they have a geographic component

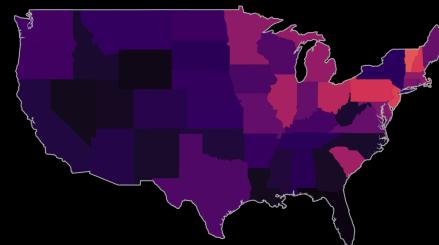
2004-05



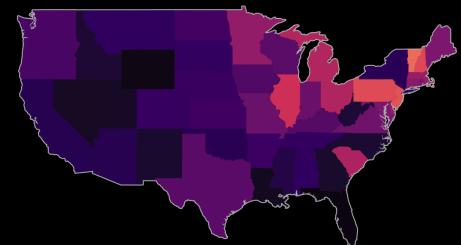
2005-06



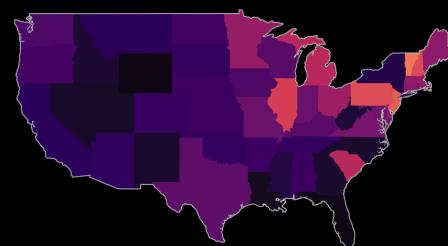
2006-07



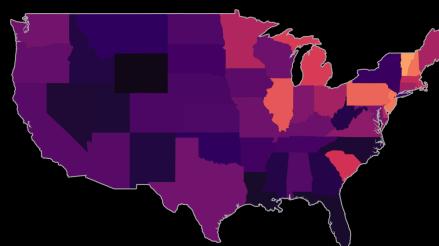
2007-08



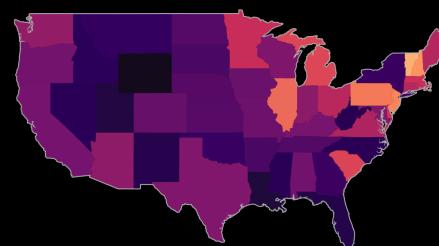
2008-09



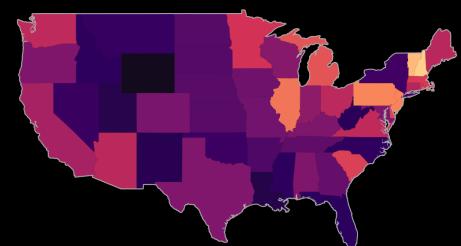
2009-10



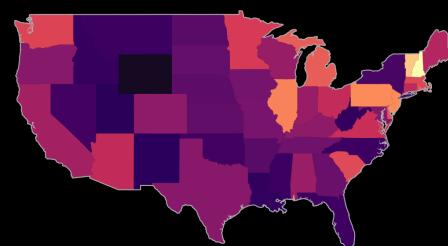
2010-11



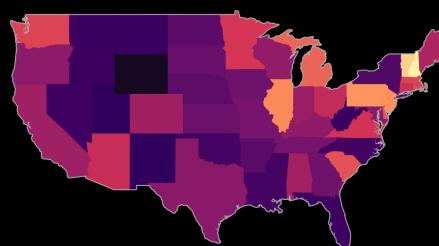
2011-12



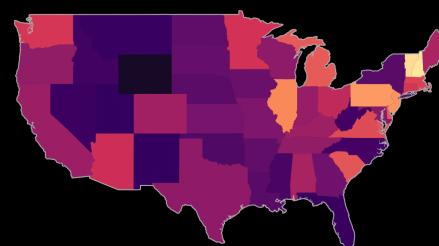
2012-13



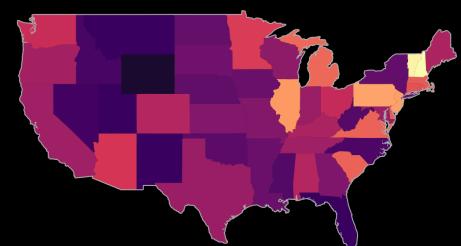
2013-14



2014-15



2015-16



Some things to  
avoid

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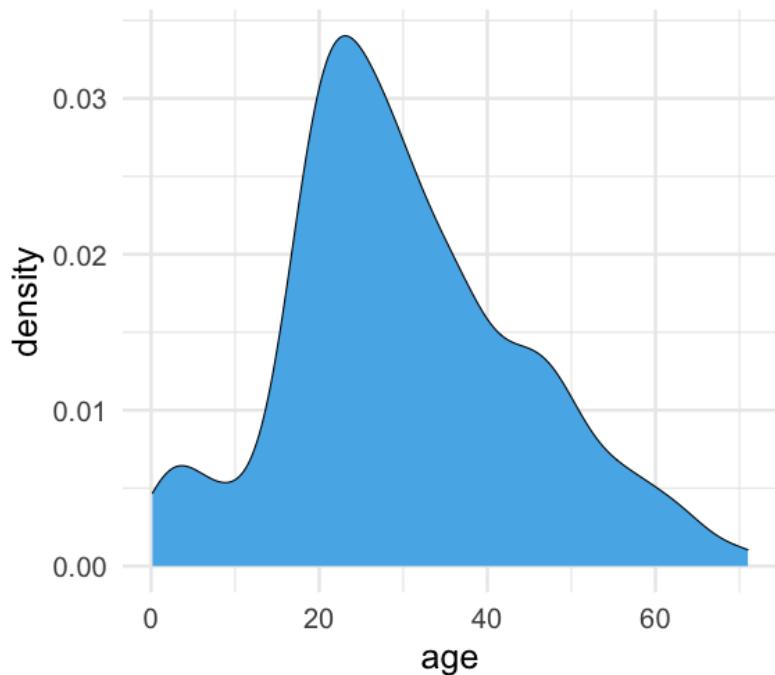
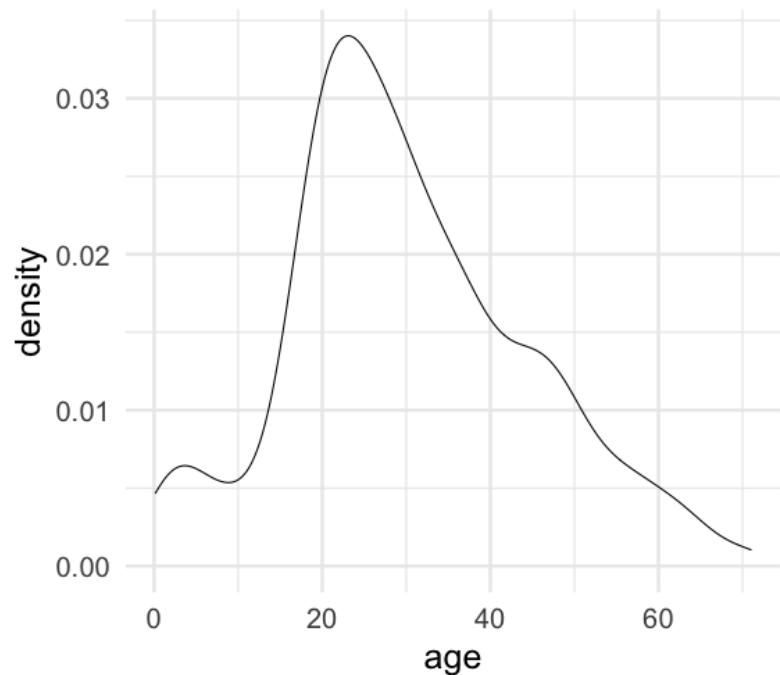
# Line drawings

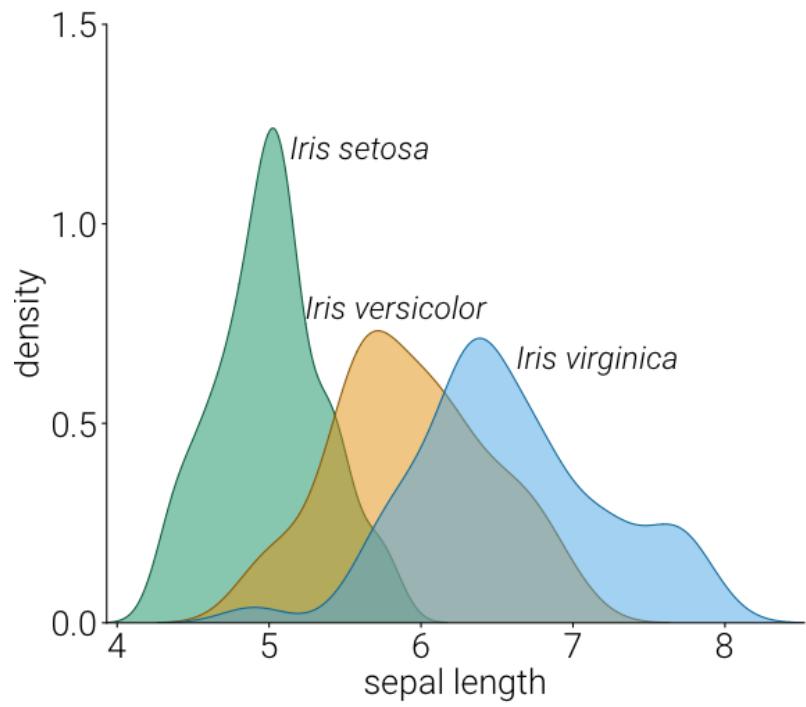
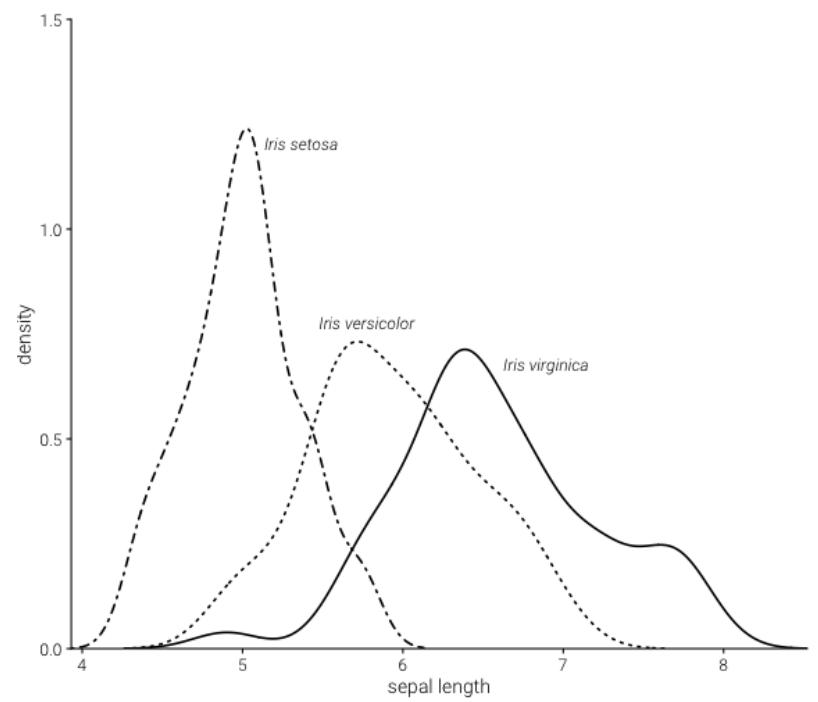
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As discussed earlier



Change the fill

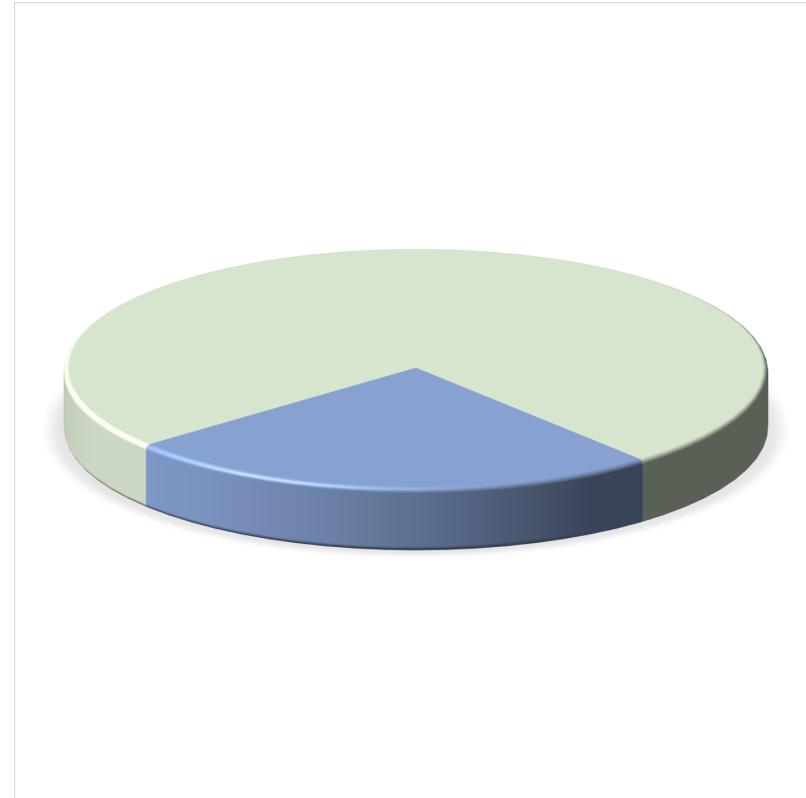
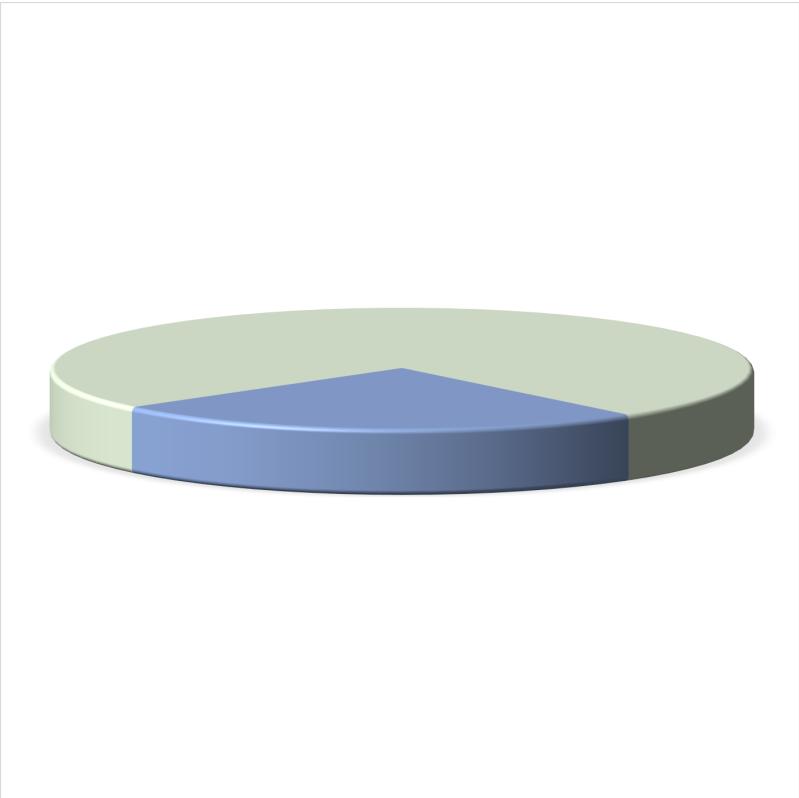




# Much worse

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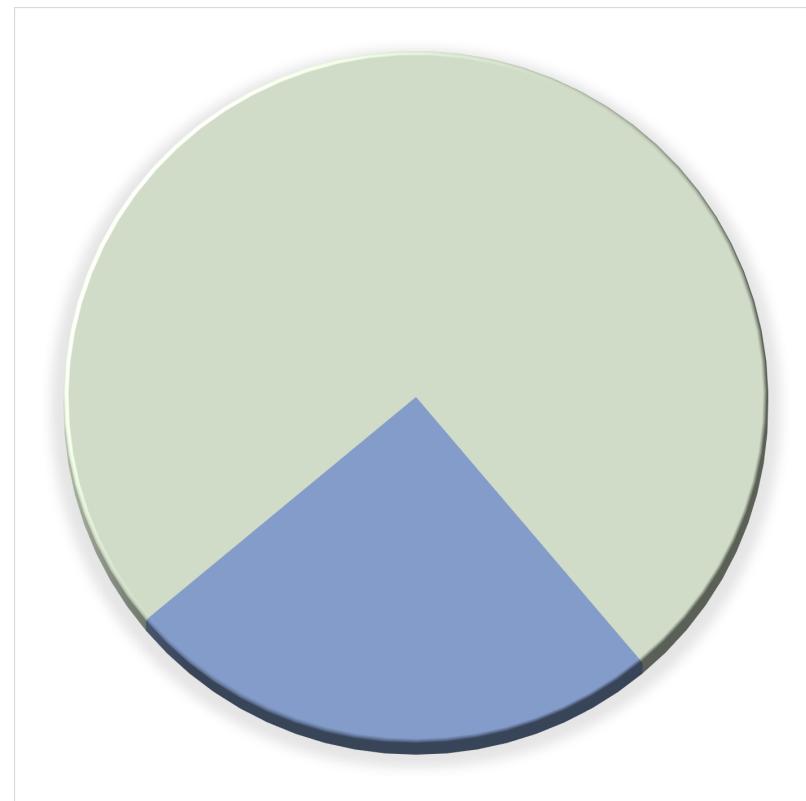
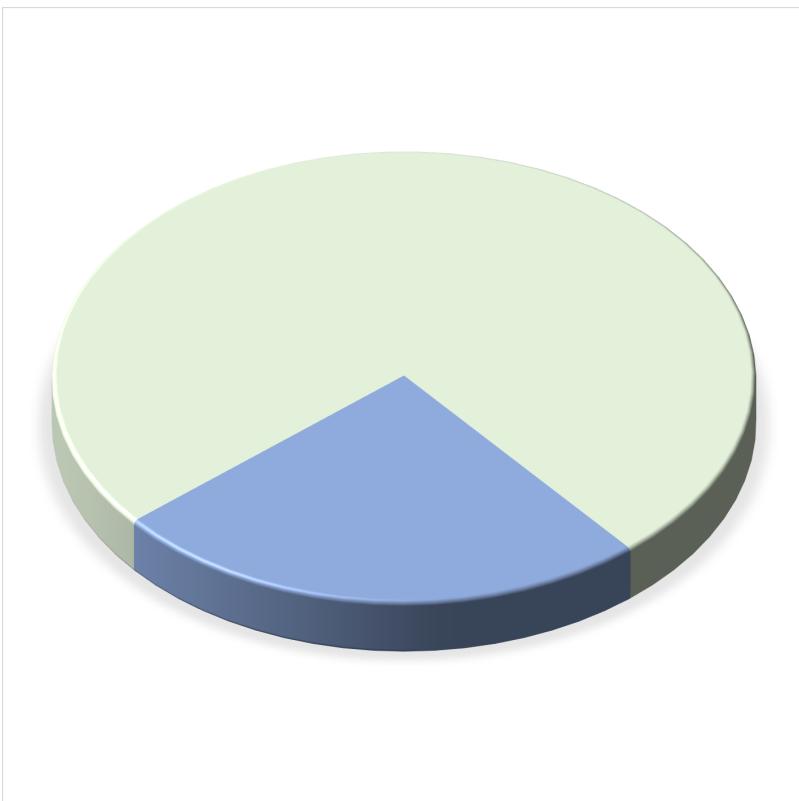
Unnecessary 3D



# Much worse

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Unnecessary 3D

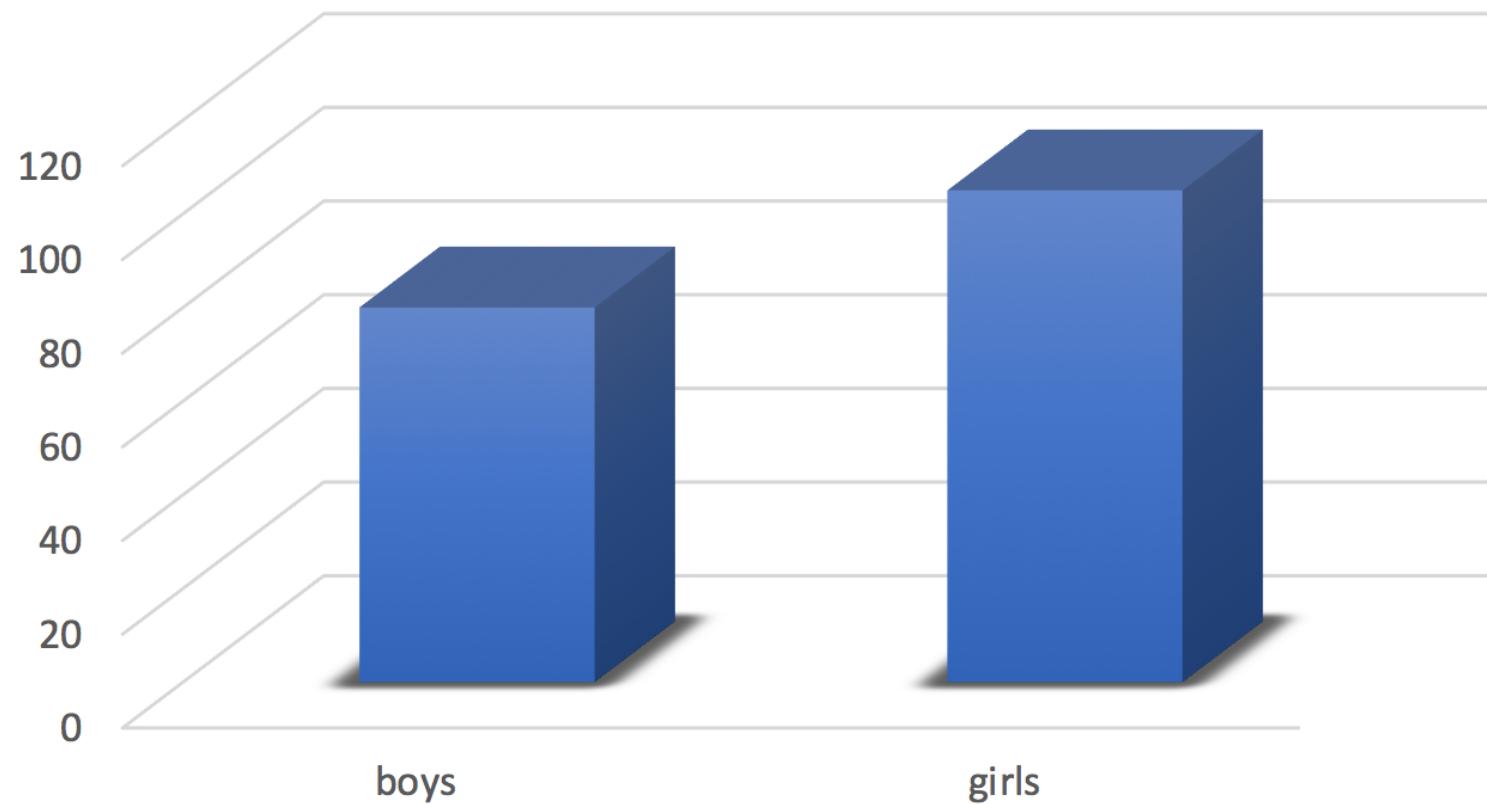


# Horrid example

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Used relatively regularly

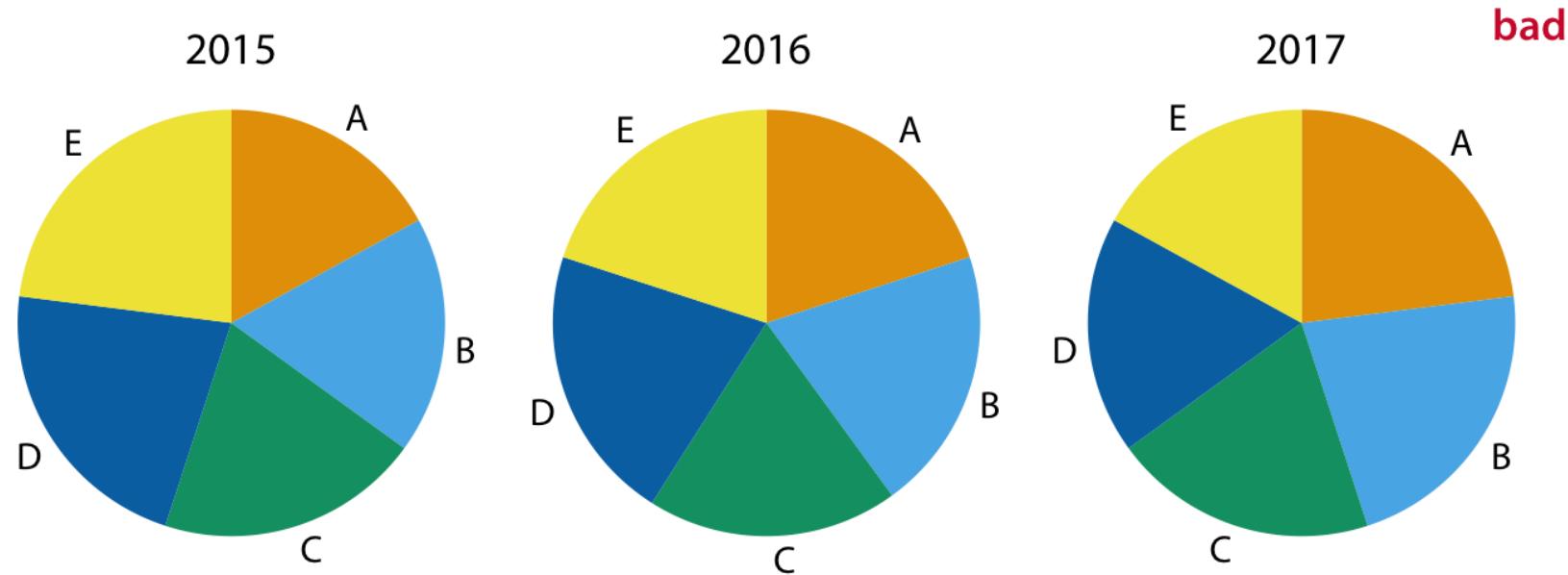
**The left bar is 80; the right is 105**



# Pie charts

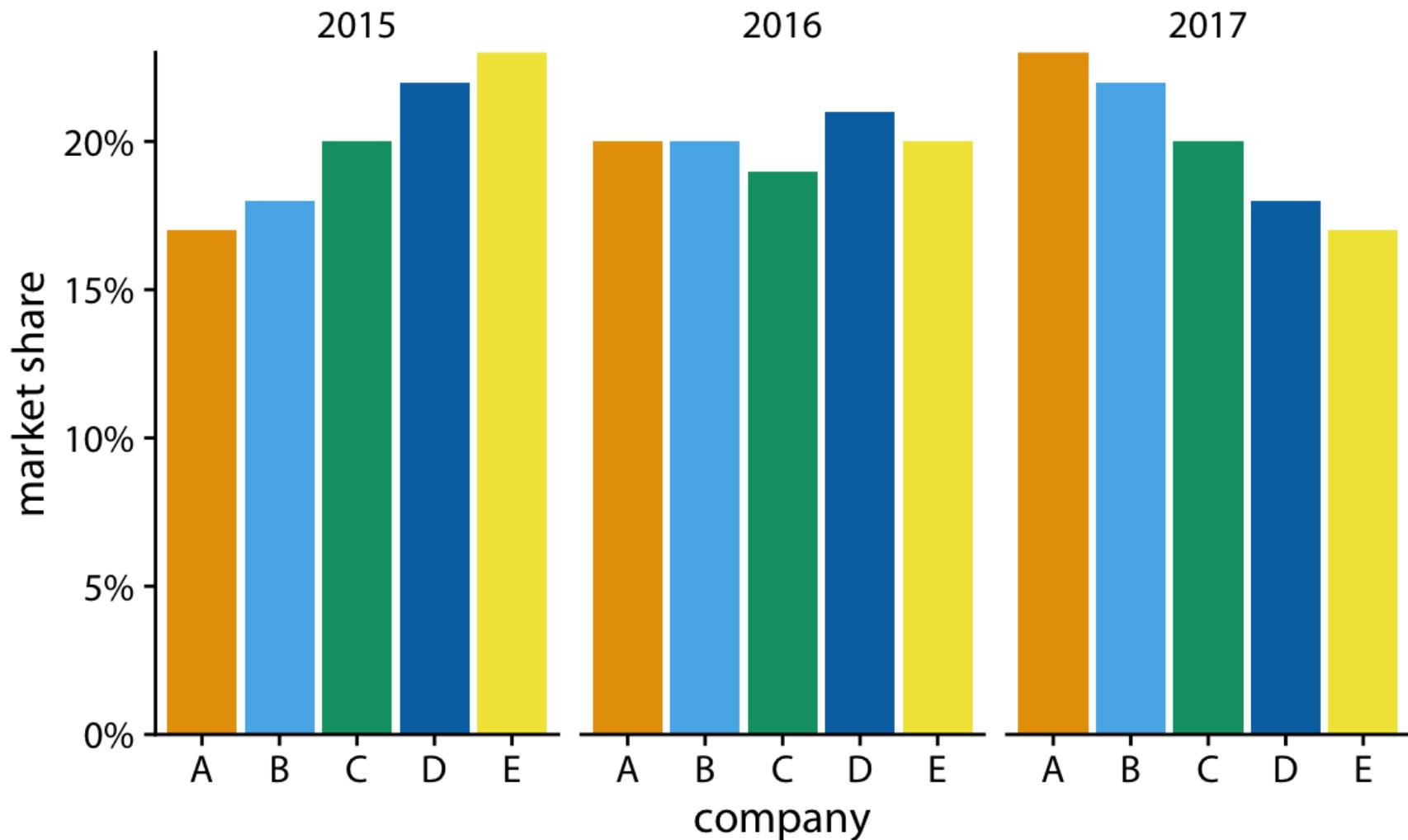
---

Especially w/lots of categories



# Alternative representation

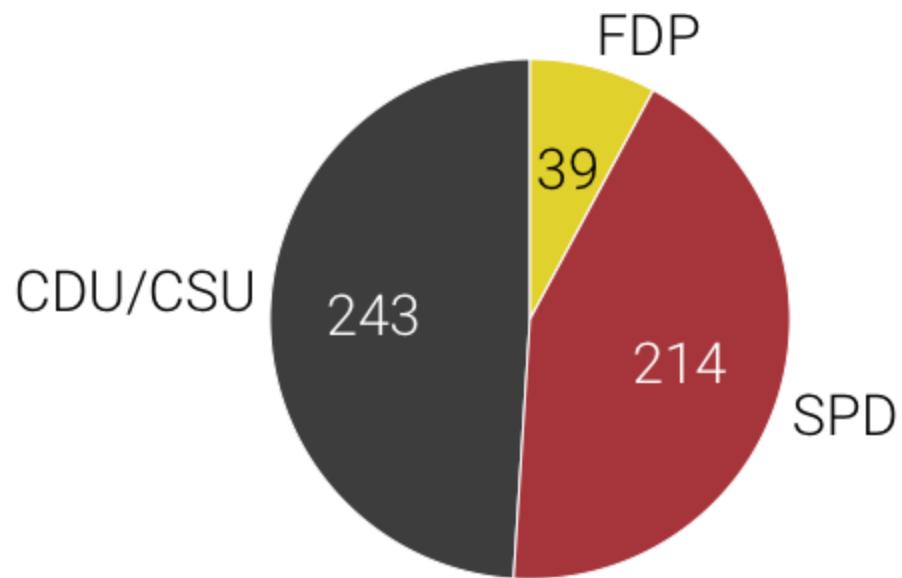
---



# A case for pie charts

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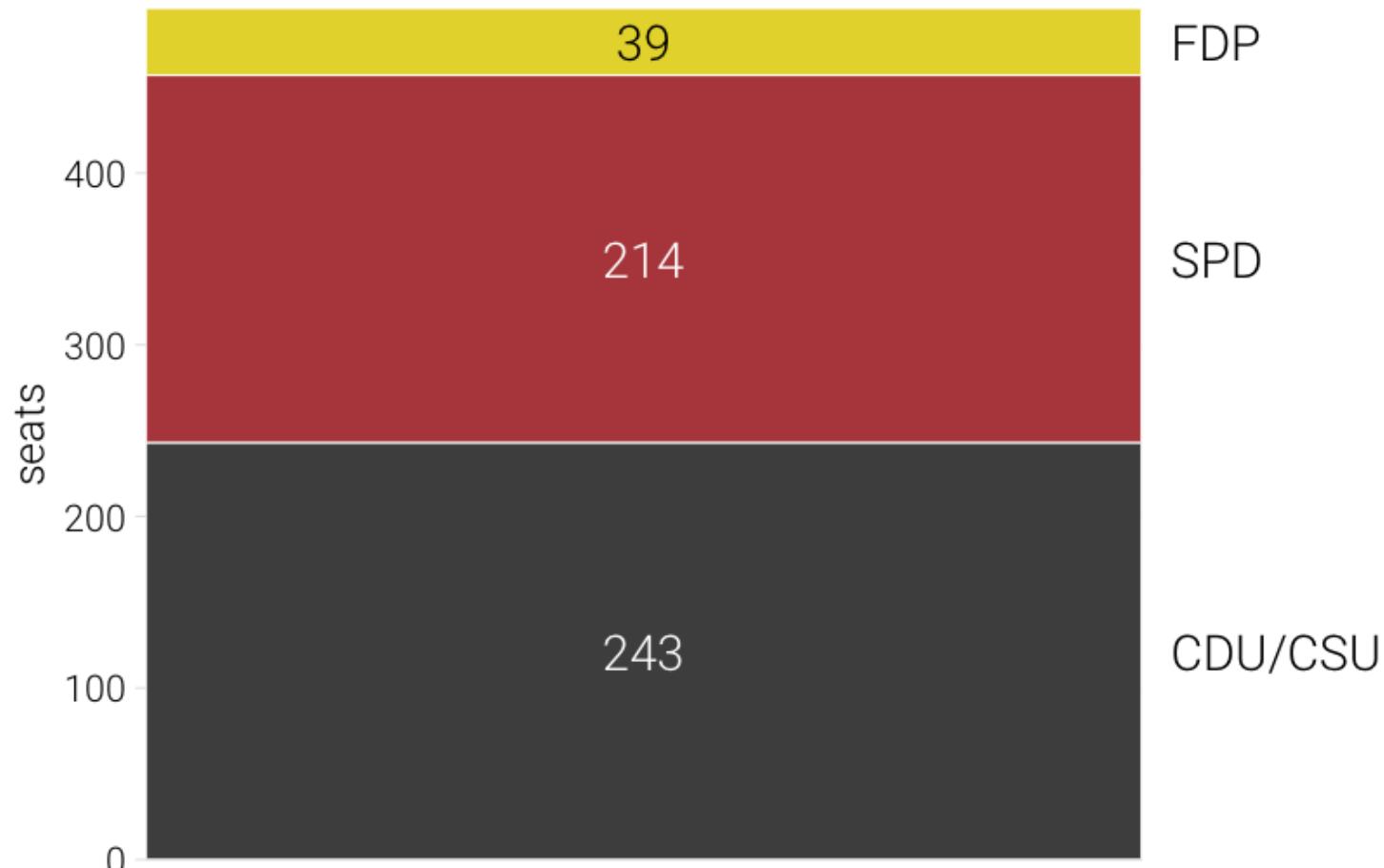
- $n$  categories low,
- differences are relatively large
- familiar for some audiences



# The anatomy of a pie chart

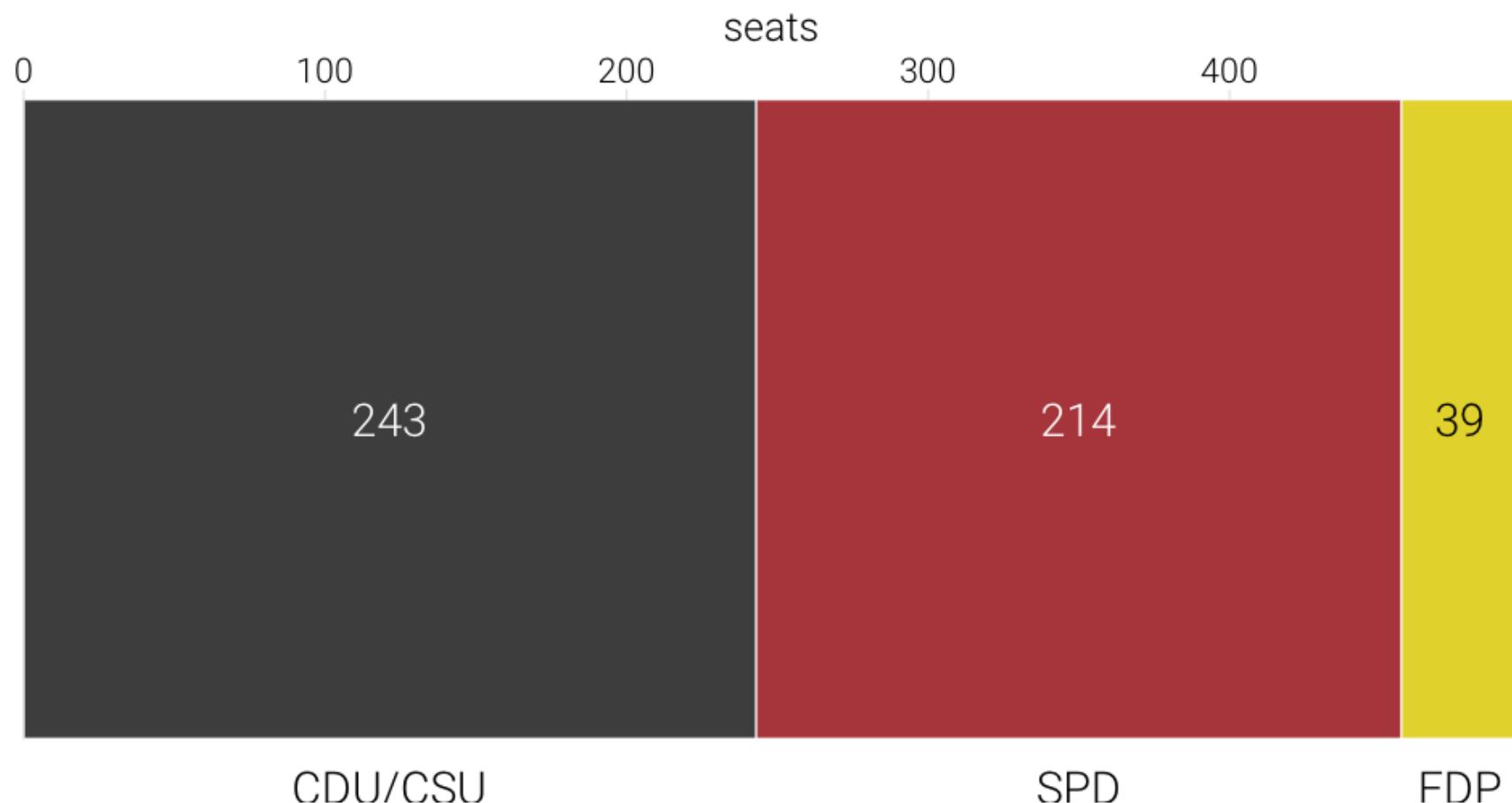
---

Pie charts are just stacked bar charts with a radial coordinate system



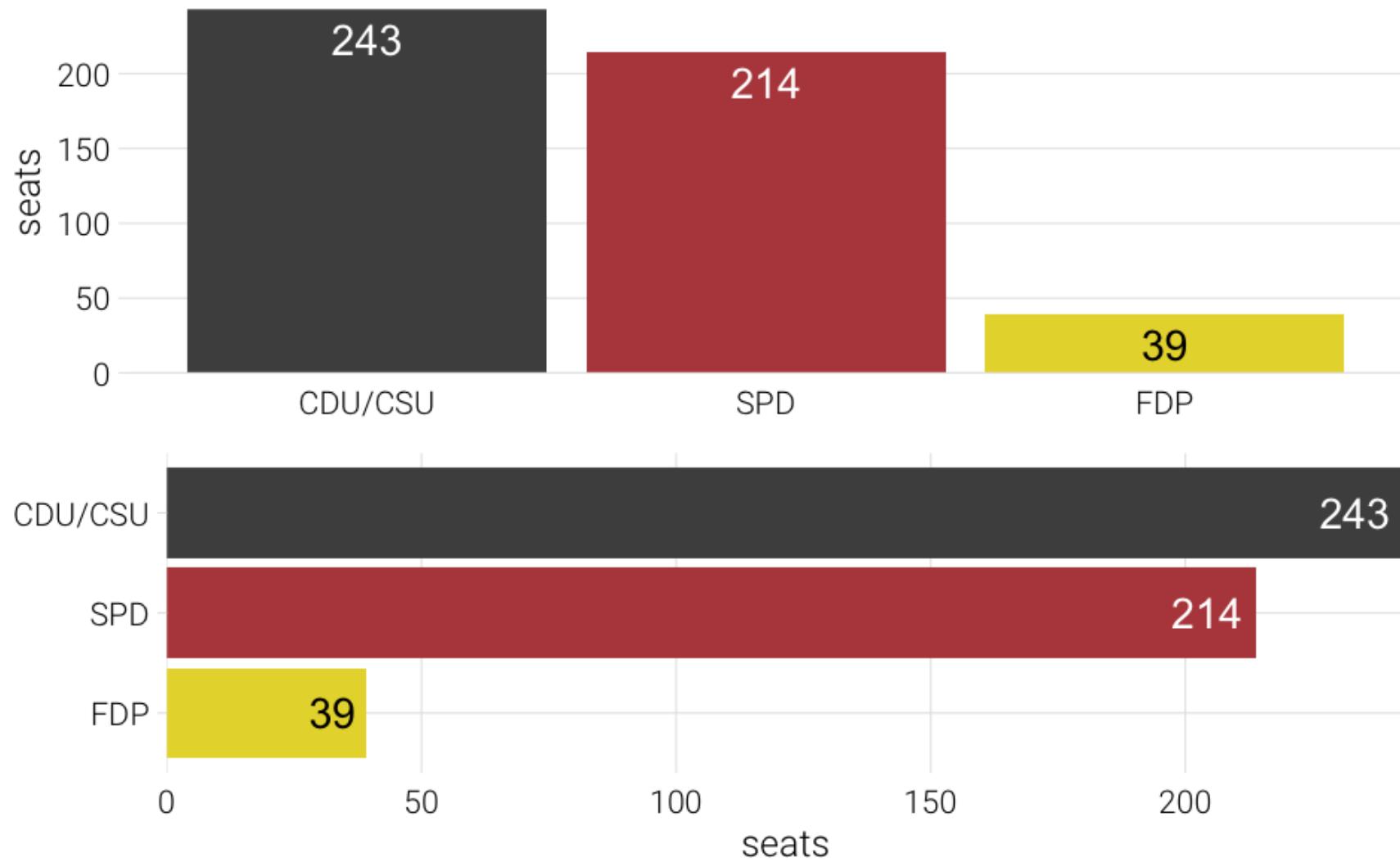
# Horizontal

---



# My preference

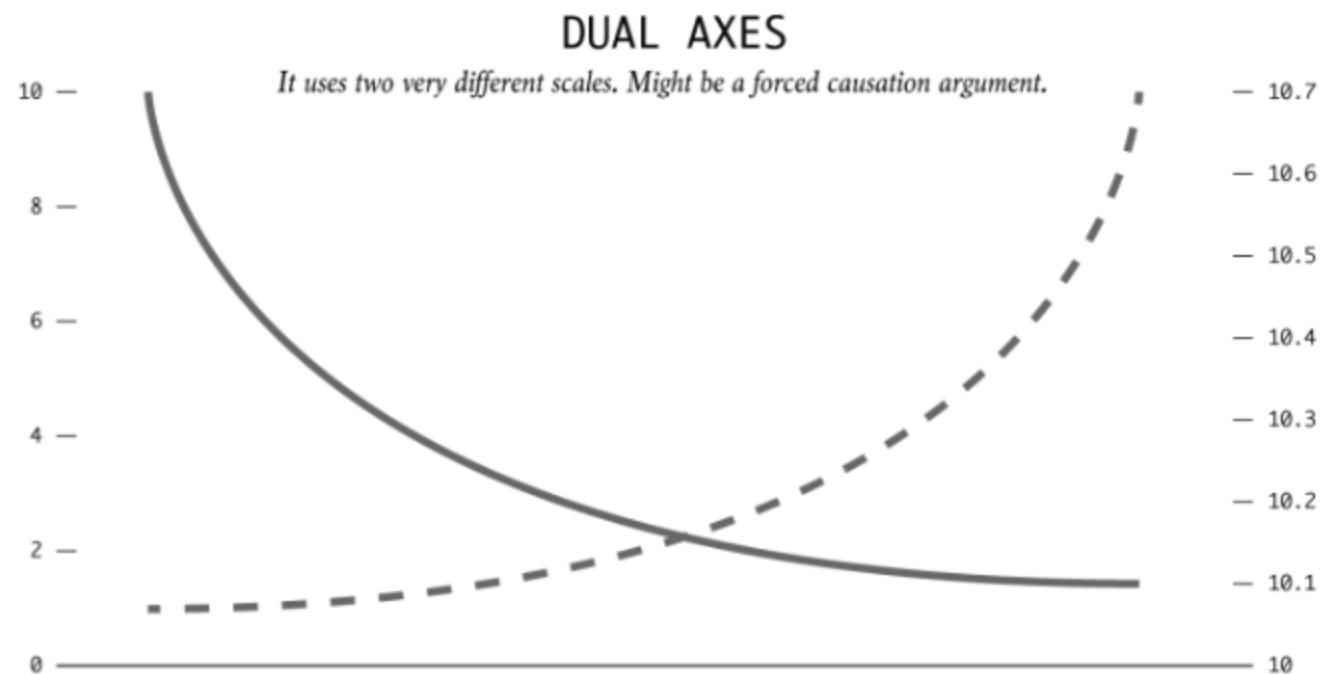
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# Dual axes

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- Exception: if second axis is a direct transformation of the first



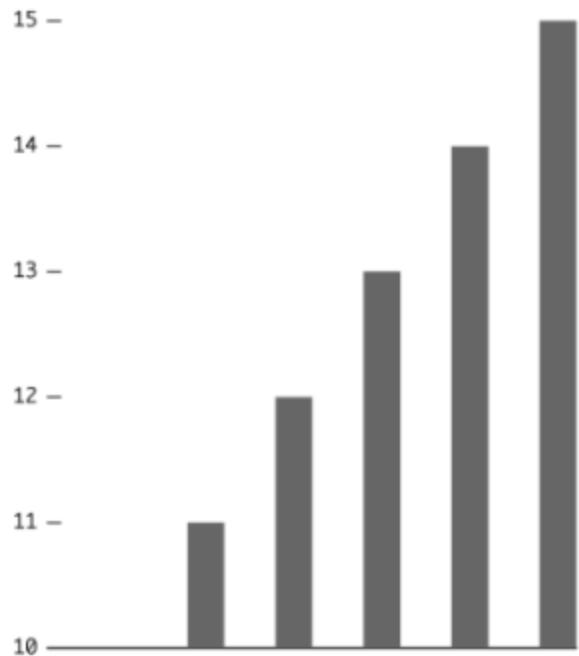
.footnote[See many examples here [here](#)]

# Truncated axes

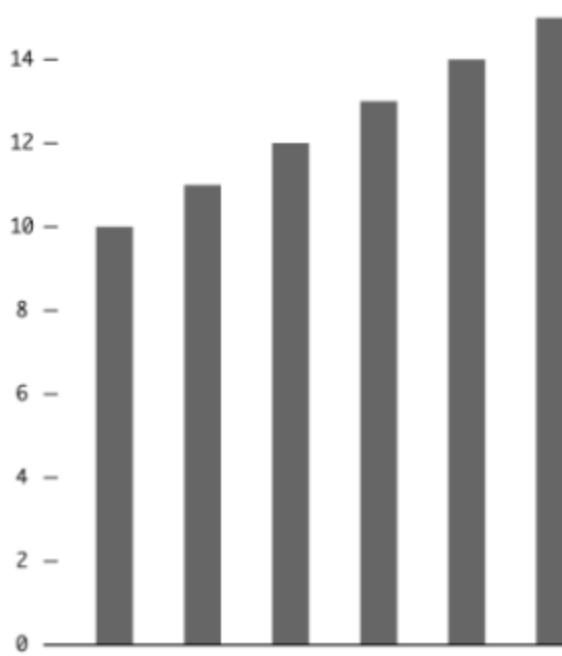
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## TRUNCATED AXIS

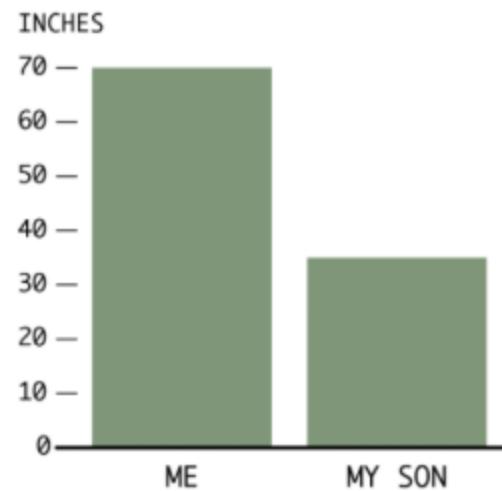
*The value axis starts at ten. Liar, liar, pants on fire.*



*The value axis starts at zero. Good.*

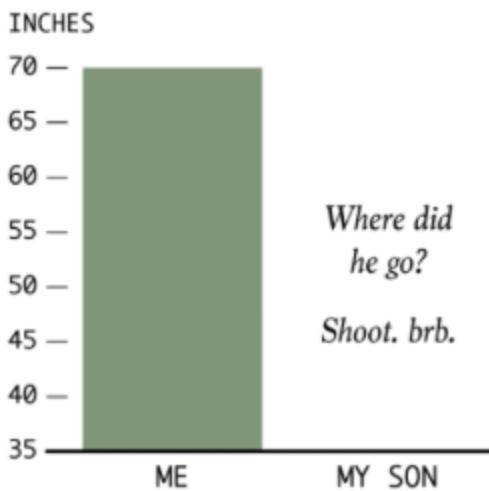


**Height**



**VS.**

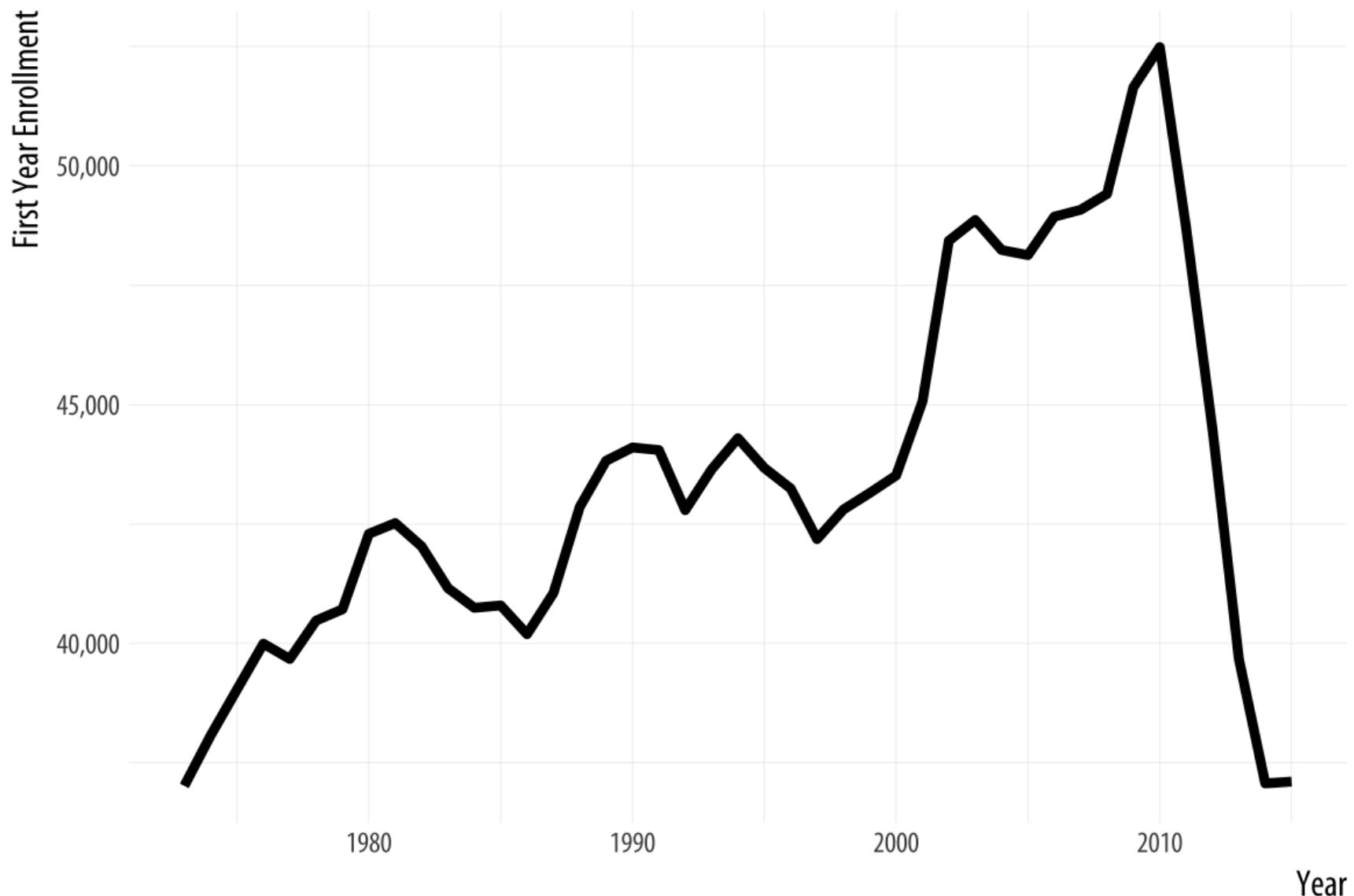
**Height**

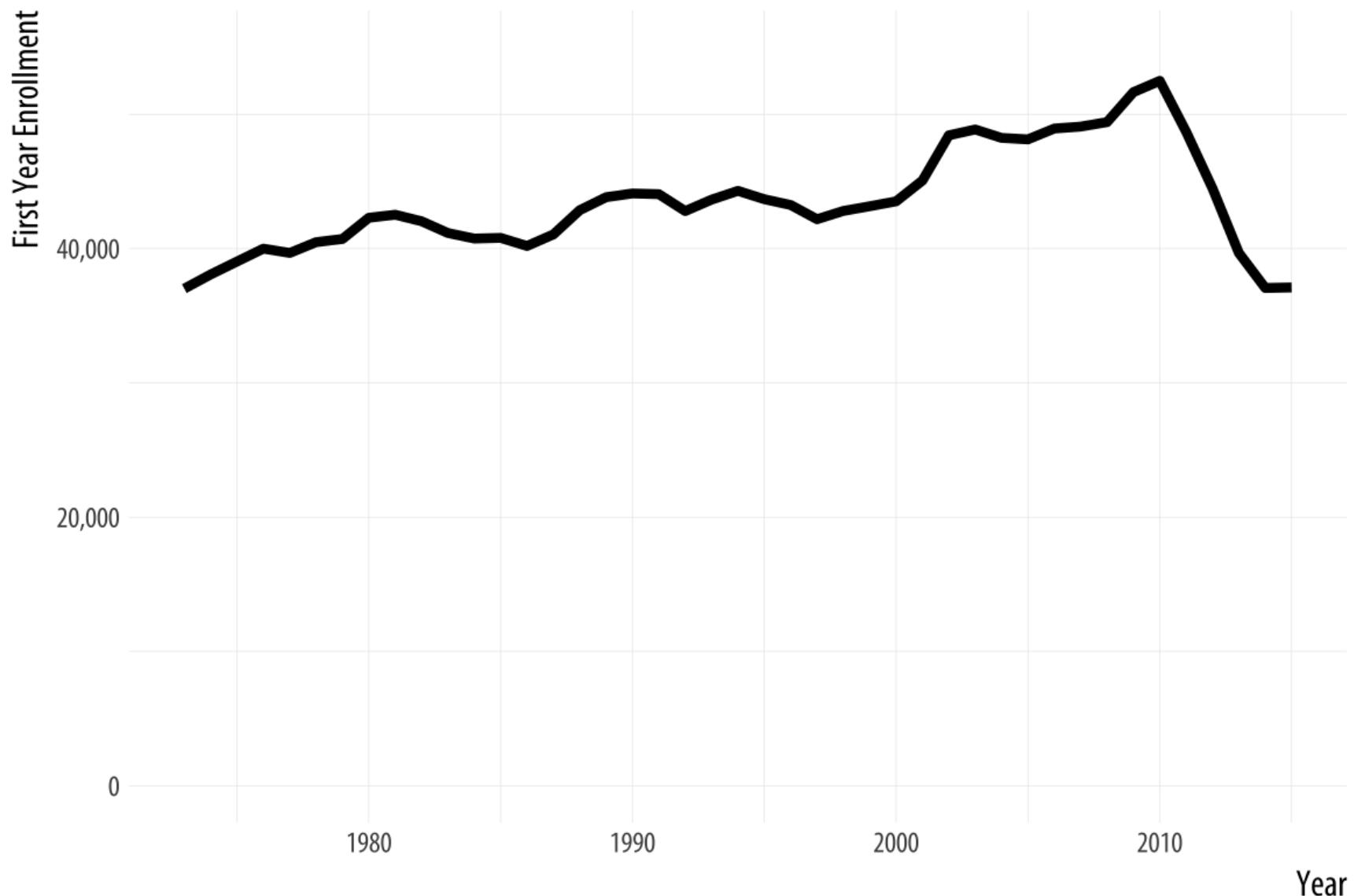


# Not always a bad thing

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It is tempting to lay down inflexible rules about what to do in terms of producing your graphs, and to dismiss people who don't follow them as producing junk charts or lying with statistics. But being honest with your data is a bigger problem than can be solved by rules of thumb about making graphs. In this case there is a moderate level of agreement that bar charts should generally include a zero baseline (or equivalent) given that bars encode their variables as lengths. But it would be a mistake to think that a dot plot was by the same token deliberately misleading, just because it kept itself to the range of the data instead.





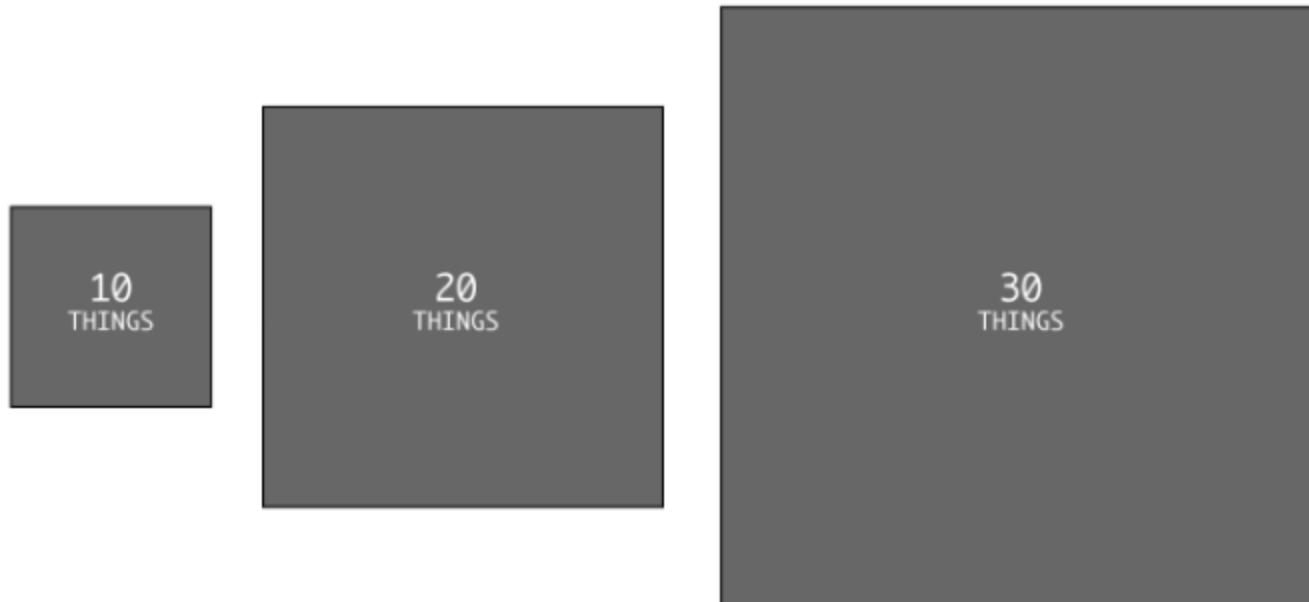
# Scaling issues

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## AREA SIZED BY SINGLE DIMENSION

*Thirty is three times ten, but that third rectangle looks a lot bigger than the first.*

*Might be trying to inflate significance.*



# Poor binning choices

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## ODD CHOICE OF BINNING

*Two bins. What's really in the 1+ category?  
Might be hiding something.*



*That's better. It can show more variation.*



# Conclusions

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Practical takeaways to make better visualizations

1. Avoid line drawings
2. Sort bar charts in ascending/descending order as long as the other axis does not have implicit meaning
3. Consider dropping legends and using annotations, when possible
4. Use color to your advantage, but be sensitive to color-blindness, and use the right kind of palette
5. Consider double-encoding data (shapes and color)
6. Make your labels bigger! Didn't talk about this one much but it's super common and really important

# Some things to avoid

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- Essentially never
  - Use dual axes (produce separate plots instead)
  - Use 3D unnecessarily
- Be wary of
  - Truncated axes
  - Pie charts (particularly with lots of categories)

# Thanks!

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Questions?

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 [website](#)

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