

Data Visualization with ggplot2

Coffee, Cookie and Coding (C³)
Workshops are by the Public Health
Data Science and Data Equity team

Shelby Golden, M.S.

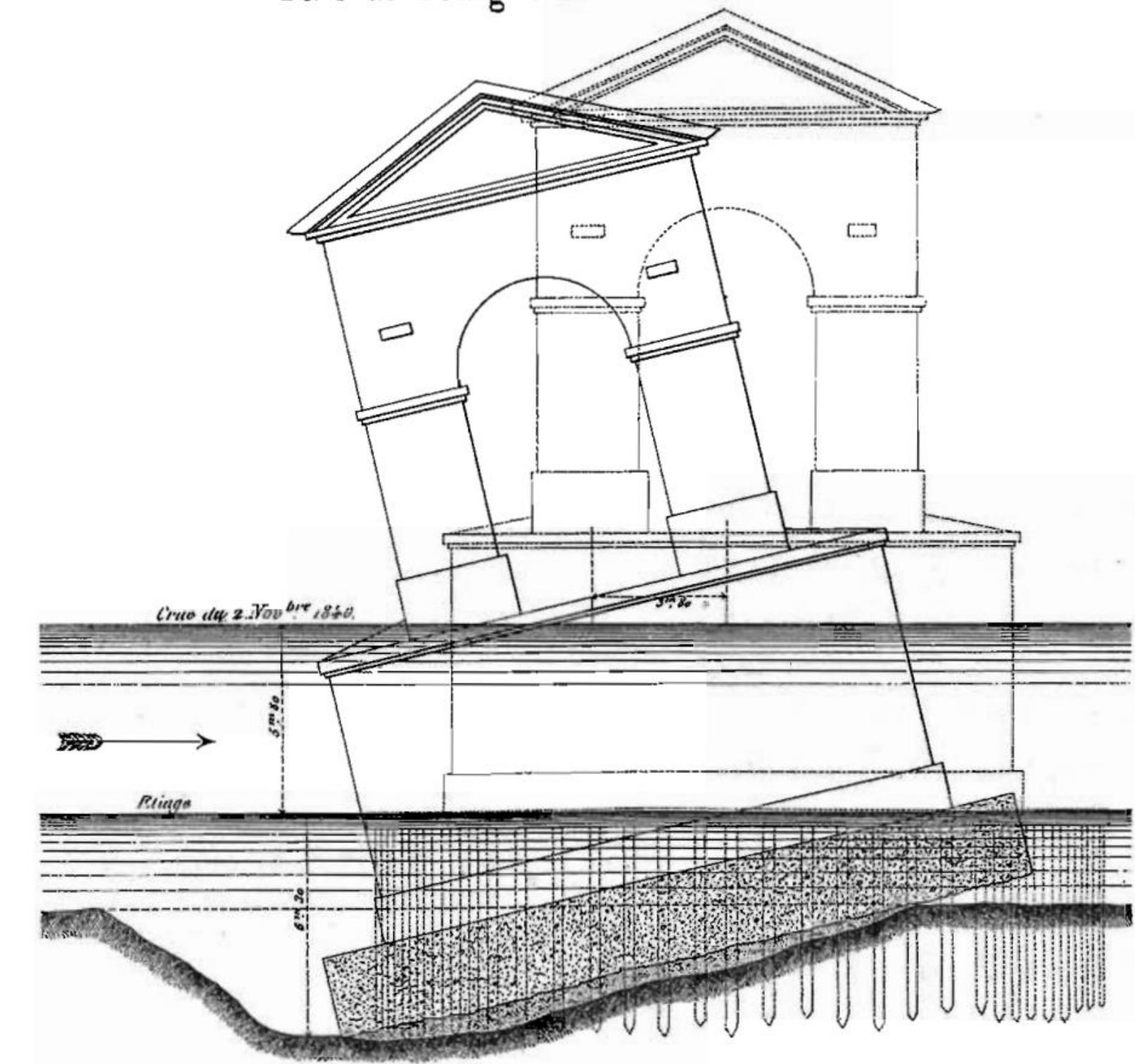
March 27th, 2025



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Data Science and Data Equity

Pont de Bourg-S^t Andéol sur le Rhône.



[The Visual Display of Quantitative Information 2nd Edition](#) by
Edward R. Tufte. Charles Minard's before/after bridge collapse on
the Rhône 1840 (pg. 39). Accessed March 14th, 2025.



Shelby Golden, M.S.

- Worked 7 years as a Molecular Biologist and Biochemist.
- Received a Masters in Applied Computational Mathematics from Johns Hopkins University in 2024.



Today's Learning Objectives

- 01 Classify the Grammar of Graphics layers used in ggplot syntax (~ 10 minutes)
- 02 Applications of different geometries, effective use of layering, and polishing the result. (~ 35 minutes)
- 03 Interactive plots, map projections, and leverage AI assisted coding (~ 10 minutes)



Our Choice Resources

- [R for Data Science](#) by Hadley Wickham, Mine Çetinkaya-Rundel, and Garrett Grolemund
- [ggplot2: Elegant Graphics for Data Analysis \(3e\)](#) by [Hadley Wickham](#), [Danielle Navarro](#), and [Thomas Lin Pedersen](#).
- [ggplot2](#) package documentation and [cheatsheets](#) by tidyverse. Specifically, the [function references](#) page.
- ggplot2 YouTube workshop [part 1](#) and [part 2](#) by [Thomas Lin Pedersen](#)



Please access the code:

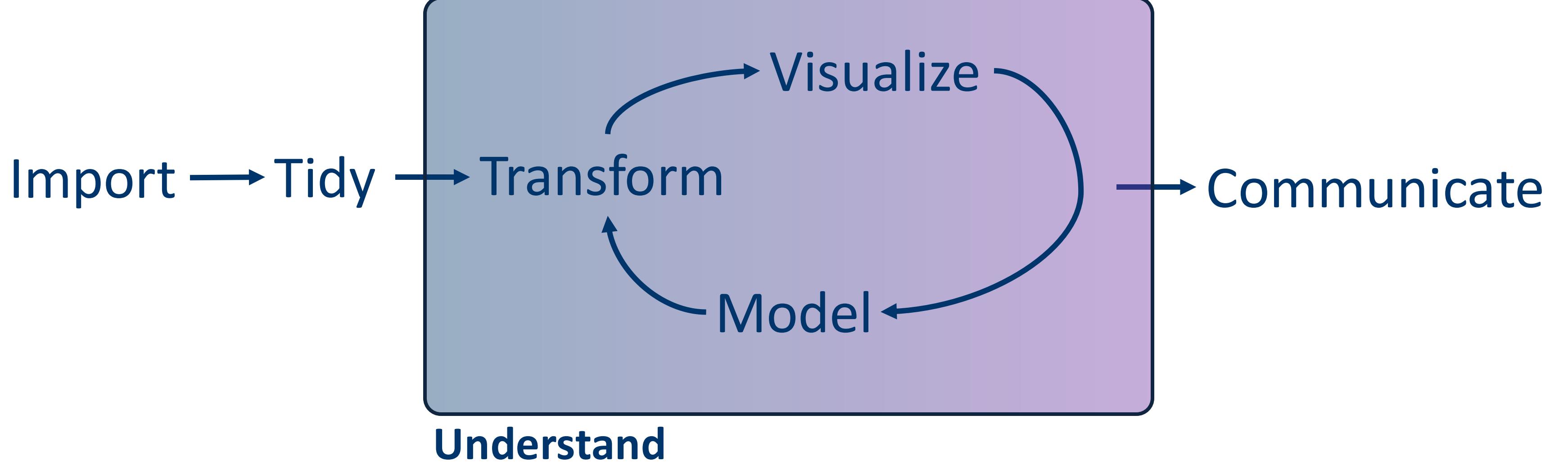
GitHub: github.com/ysph-dsde/Data-Visualization-with-ggplot2

PositCloud:

1. Open Data-Visualization-with-ggplot2.Rproj in RStudio.
2. Render the “Worked Through Example.qmd” and view the HTML version of that file.
3. Have the “Discussion and Challenge Questions.R” code ready.



Welcome (back) to the tidyverse



Program

[R for Data Science \(2e\) - Introduction Figure 1](#) by Hadley Wickham, Mine Çetinkaya-Rundel, and Garrett Grolemund. Accessed November 15th, 2024.



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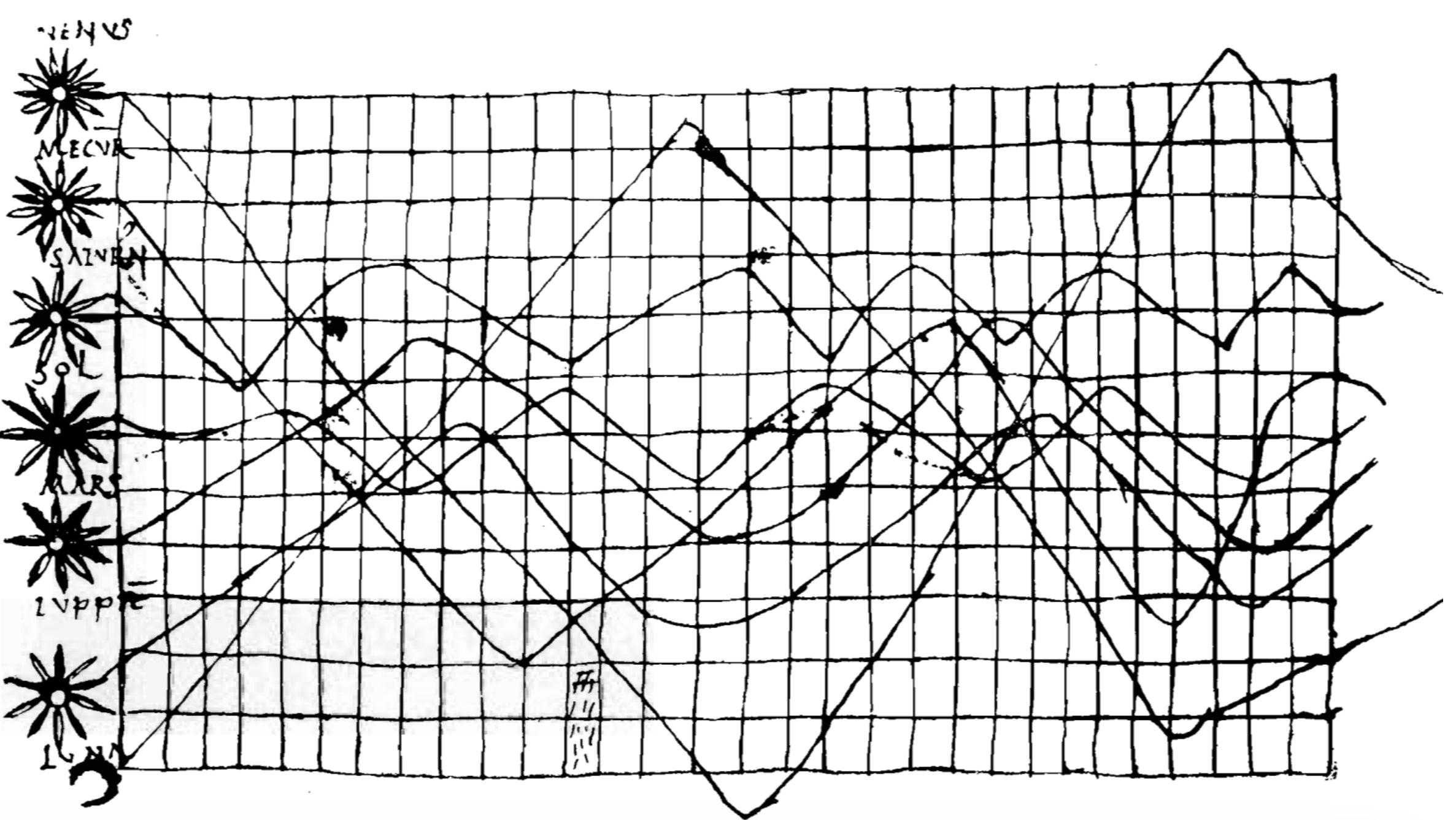
Part of the tidyverse

Core Packages

```
ggplot (data) +  
  geom_*(aes(x, y),  
        stat,  
        position) +  
  coordinates() +  
  scale_*() +  
  facet_*() +  
  theme()
```



The Layered Grammar of Graphics



[The Visual Display of Quantitative Information](#) 2nd Edition by
Edward R. Tufte. Accessed March 14th, 2025.

1. Unknown author of Planetary Orbits. 10 or 11th century (pg. 28)
2. Petrus Apianus's Map of European Cities. 1546 (pg. 22)
3. John Snow's Map Showing Cholera Deaths. 1854 (pg. 24)
4. William Playfair's Prices, Labor, Monarch's in 1821 (pg. 34)

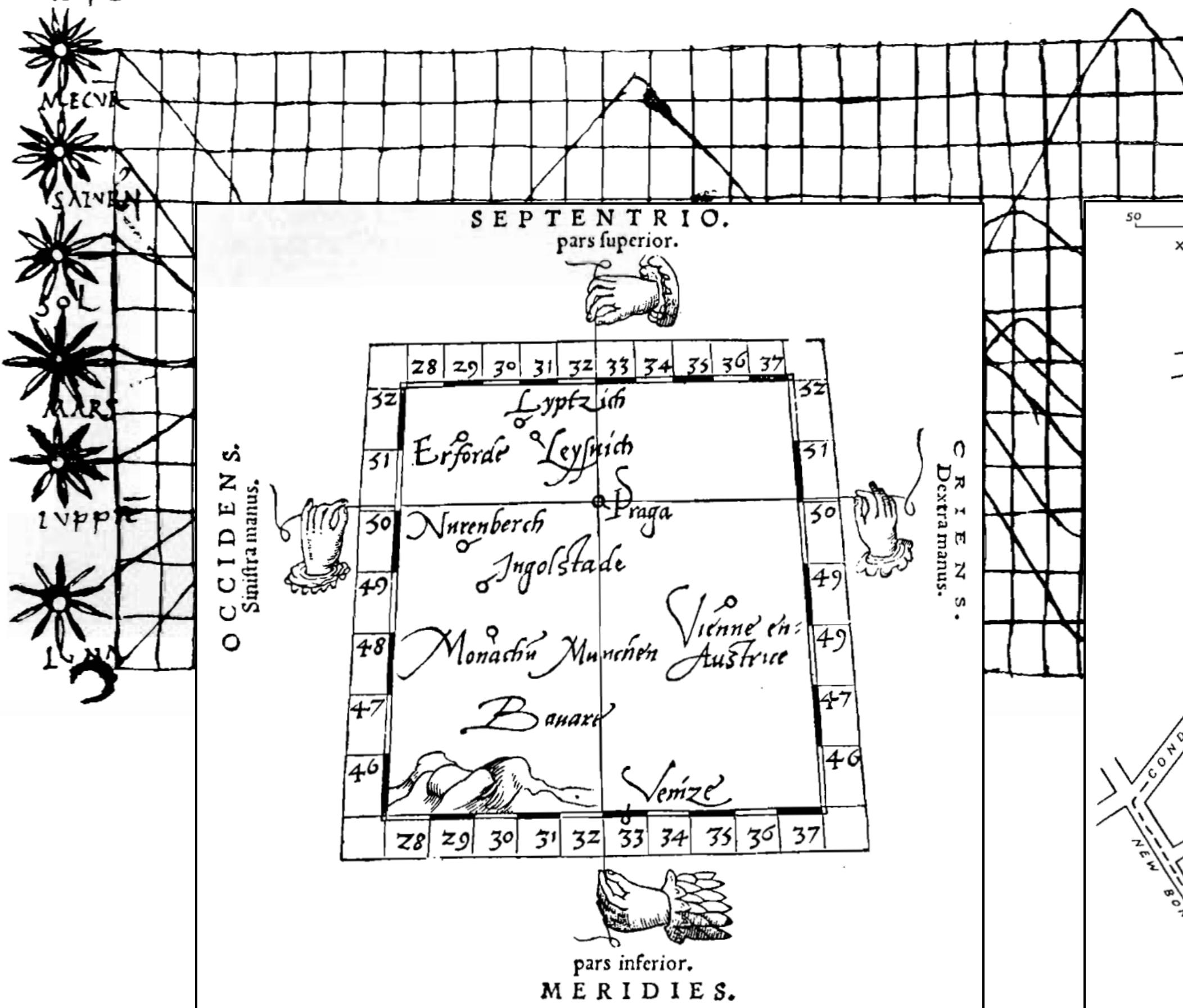


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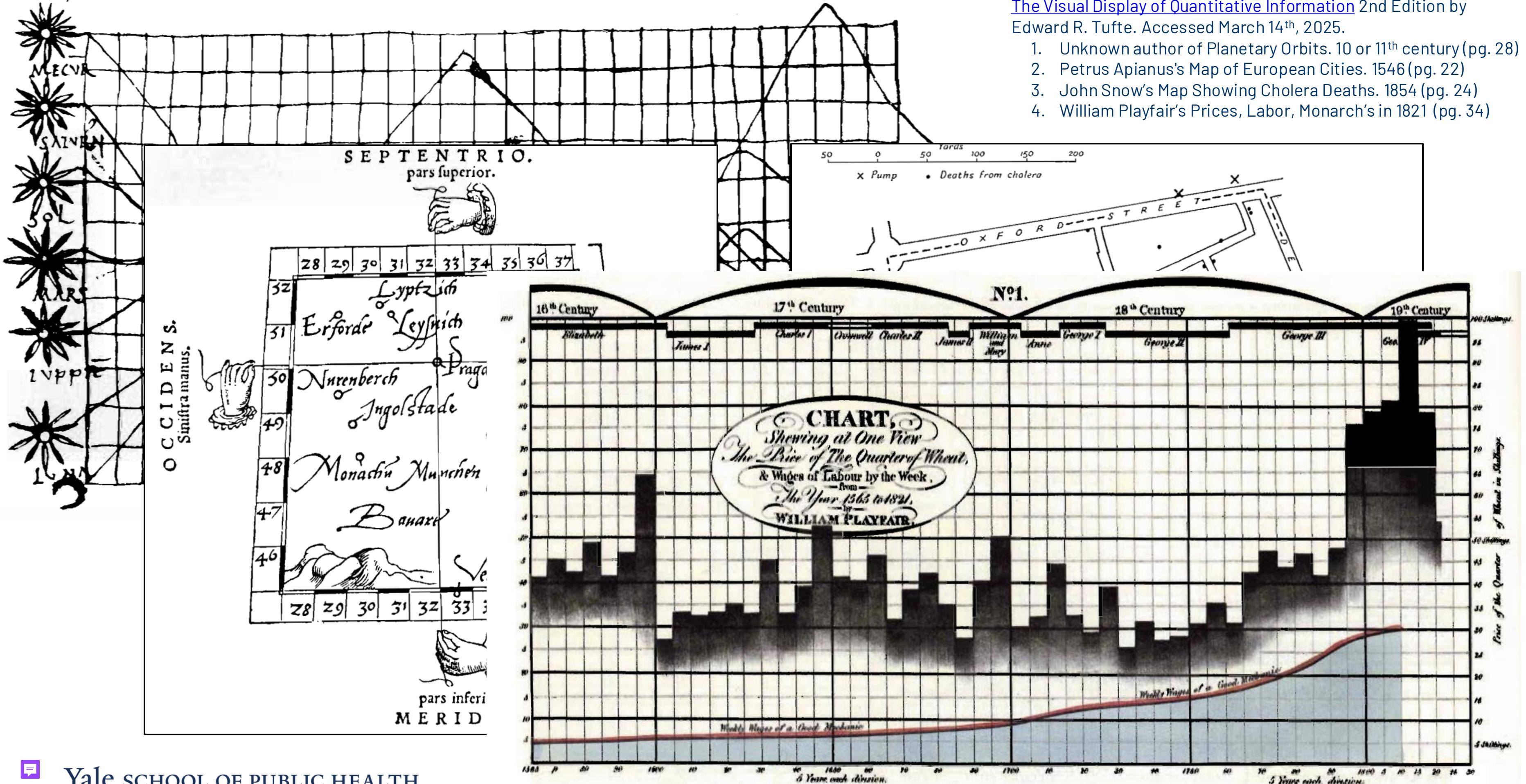
Data Science and Data Equity

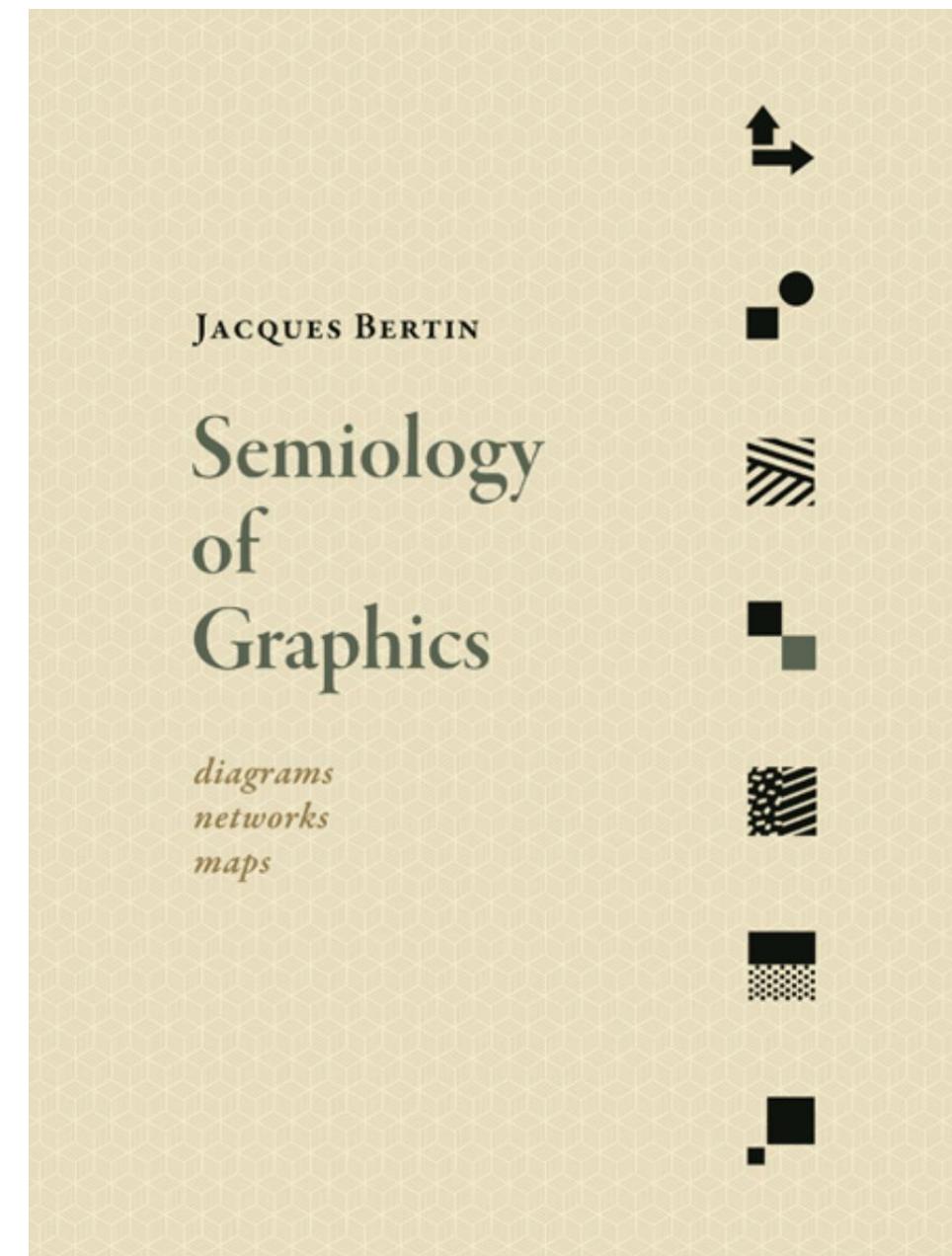
10a

1. Unknown author of Planetary Orbits. 10 or 11th century (pg. 28)
2. Petrus Apianus's Map of European Cities. 1546 (pg. 22)
3. John Snow's Map Showing Cholera Deaths. 1854 (pg. 24)
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3. John Snow's Map Showing Cholera Deaths. 1854 (pg. 24)
4. William Playfair's Prices, Labor, Monarch's in 1821 (pg. 34)





JACQUES BERTIN

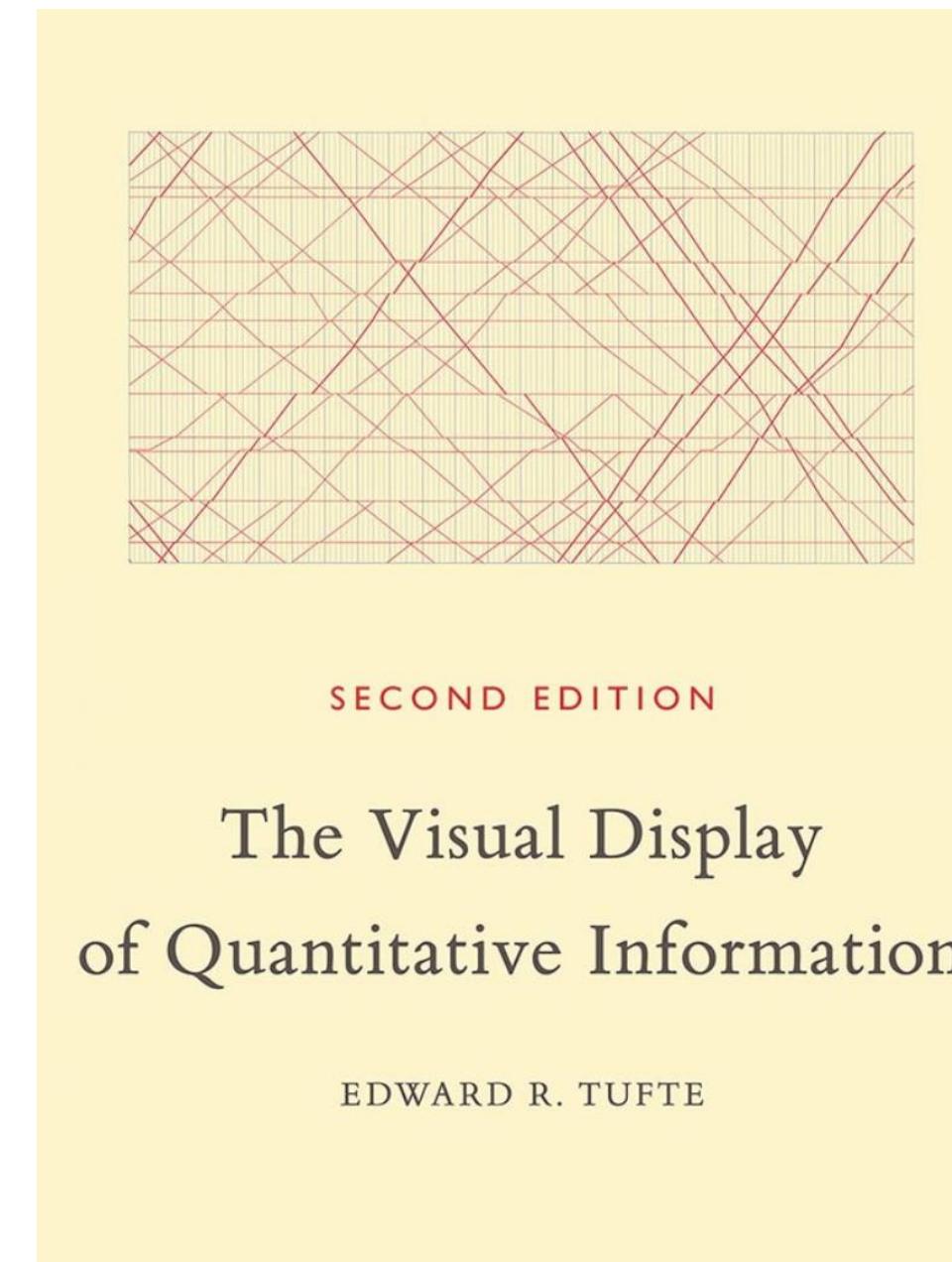
Semiology of Graphics

diagrams
networks
maps

1967
Principles



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Data Science and Data Equity



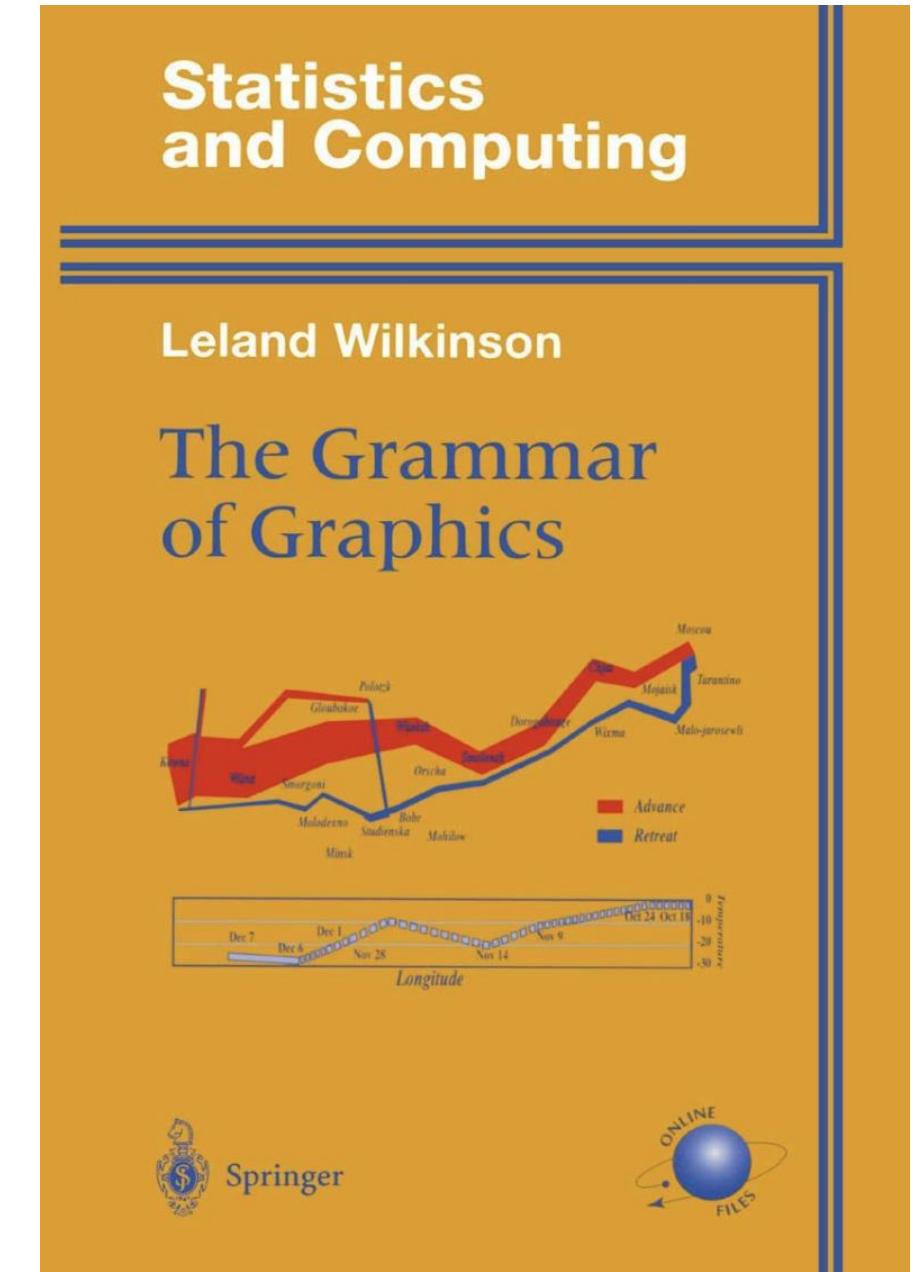
SECOND EDITION

The Visual Display of Quantitative Information

EDWARD R. TUFTE

1983
Clarity

[Semiology of Graphics: Diagrams, Networks, Maps](#) by Jacques Bertin. Accessed March 2nd, 2025.
[The Visual Display of Quantitative Information](#) 2nd Edition by Edward R. Tufte. Accessed March 2nd, 2025.



Statistics
and Computing

Leland Wilkinson

The Grammar of Graphics

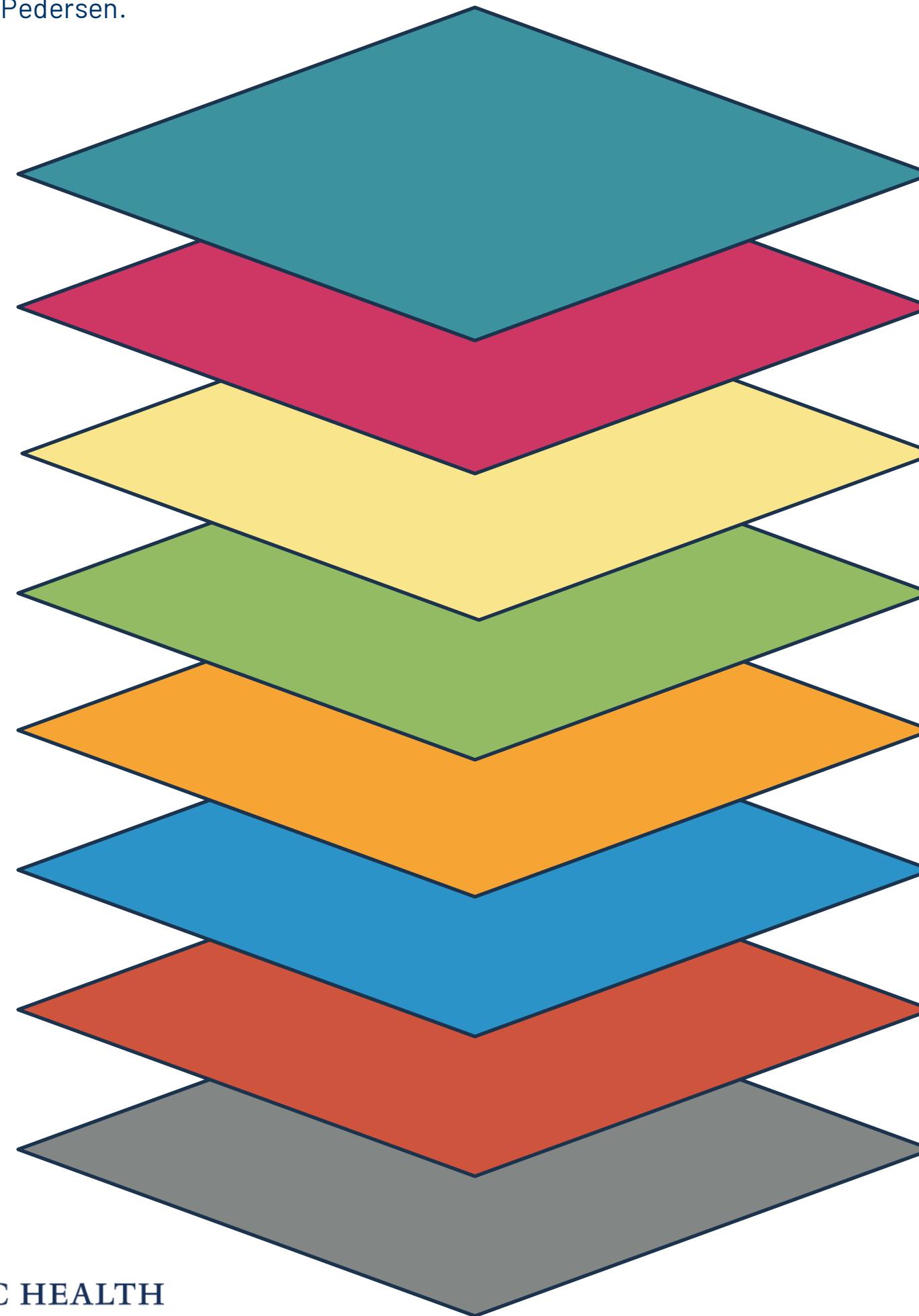


Springer



1999
Formalize

[The Grammar of Graphics](#) 1st Edition by Leland Wilkinson. Accessed March 13th, 2025.



Theme
Coordinates
Facets
Scales
Statistics
Geometries
Mapping
Data



“... good grammar is just the first step to creating a good sentence.” - Hadley Wickham

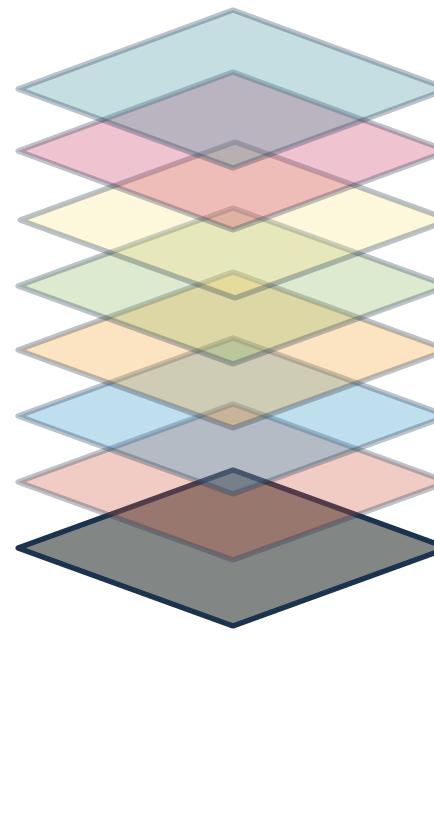
- [The Visual Display of Quantitative Information](#) by Professor Edward Tufte
- [Ten guidelines for effective data visualization in scientific publications](#) by Christa Kelleher and Thorsten Wagener, 2011
- Recommendations from Professor Wilkinson's Grammar of Graphics: Cleveland, [1985](#), [1995](#) and Tufte, [1990](#), [1997](#)

Common uses of ggplot2



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Variables

Country	Year	Cases	Pop
AFG	1999	745	20 M
AFG	2000	2667	20.5 M
Brazil	1999	37737	172 M
Brazil	2000	80488	174.5 M
China	1999	212258	1,272 M
China	2000	216766	1,280 M

Observations

Country	Year	Cases	Pop
AFG	1999	745	20 M
AFG	2000	2667	20.5 M
Brazil	1999	37737	172 M
Brazil	2000	80488	174.5 M
China	1999	212258	1,272 M
China	2000	216766	1,280 M

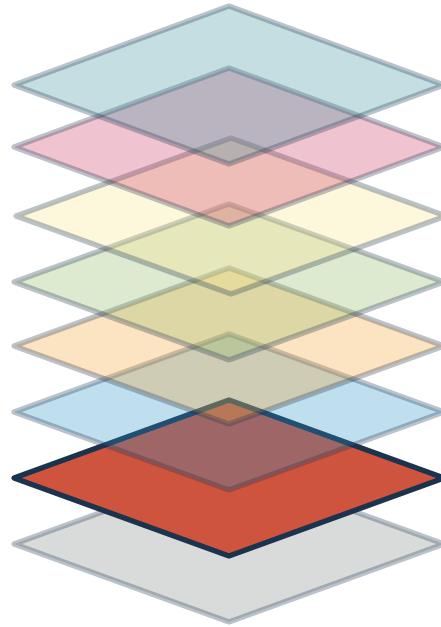
Values

Country	Year	Cases	Pop
AFG	1999	745	20 M
AFG	2000	2667	20.5 M
Brazil	1999	37737	172 M
Brazil	2000	80488	174.5 M
China	1999	212258	1,272 M
China	2000	216766	1,280 M

Rows: 92,519

Columns: 14

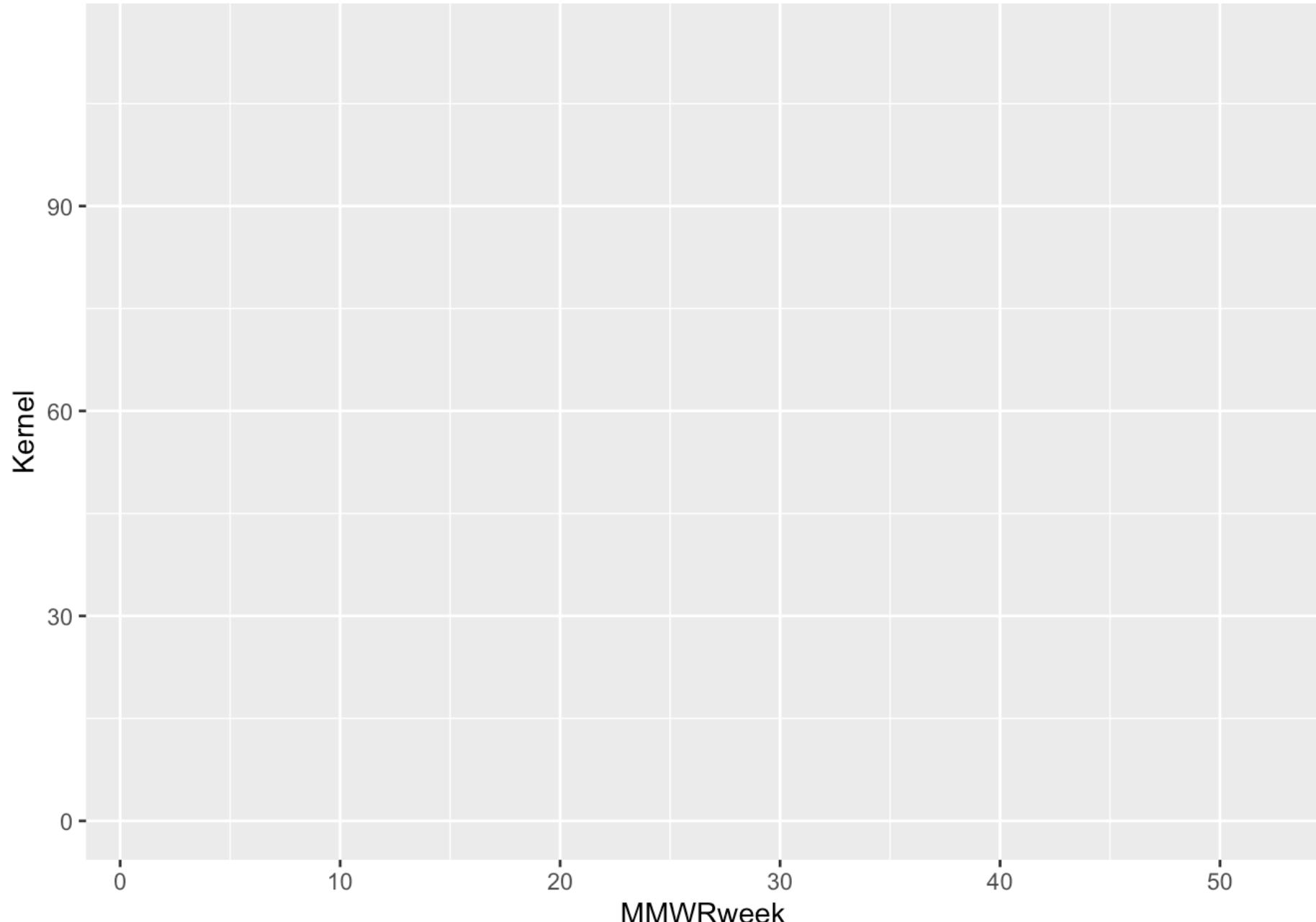
```
$ Region           <chr> "California", "California", "California", "Cal...
$ Season          <chr> "2018-19", "2018-19", "2018-19", "2018-19", "2...
$ `Week Observed` <date> 2018-10-06, 2018-10-13, 2018-10-20, 2018-10-2...
$ MMWRyear        <dbl> 2018, 2018, 2018, 2018, 2018, 2018, 2018, 2018...
$ MMWRweek        <dbl> 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25...
$ MMWRday         <dbl> 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7...
$ Characteristic   <chr> "Age", "Age", "Age", "Age", "Age", "Age", "Age...
$ Level            <chr> "1-4 Years", "1-4 Years", "1-4 Years", "1-4 Ye...
$ `Positives Detected` <dbl> 0, 0, 3, 10, 8, 8, 3, 6, 8, 15, 15, 25, 23, 22...
$ `Scaled Positives` <dbl> 0.000000, 0.000000, 3.896104, 12.987013, 10.38...
$ Spline           <dbl> 0.000000, 2.184079, 5.738394, 8.770741, 9.5923...
$ Kernel           <dbl> 0.000000, 2.897880, 6.721988, 9.740228, 10.945...
$ `Crude Rate`     <dbl> 0.0, 0.0, 0.6, 2.5, 1.9, 1.9, 0.6, 1.3, 1.9, 3...
$ `Cumulative Crude Rate` <dbl> 0.0, 0.0, 0.6, 3.1, 5.0, 6.9, 7.6, 8.8, 10.7, ...
```

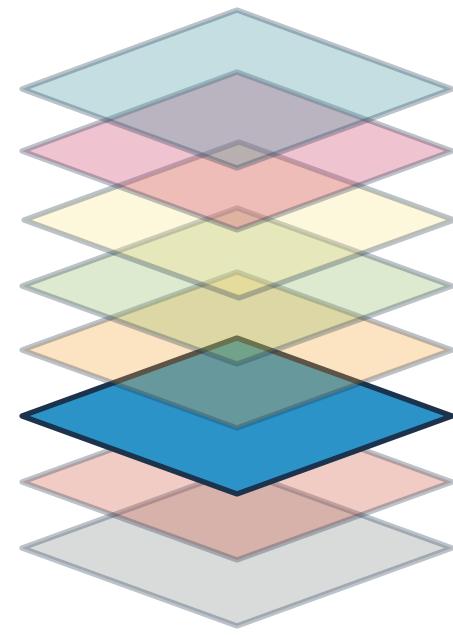


Mapping tells the function which variables get used for which aesthetic feature.

```
ggplot(data, aes(x, y, group)) +  
  geom_*/stat_*(aes(color, fill, size/linewidth,  
                     shape/linetype))
```

```
ggplot(data = df,  
       aes(x = MMWRweek, y = Kernel))
```

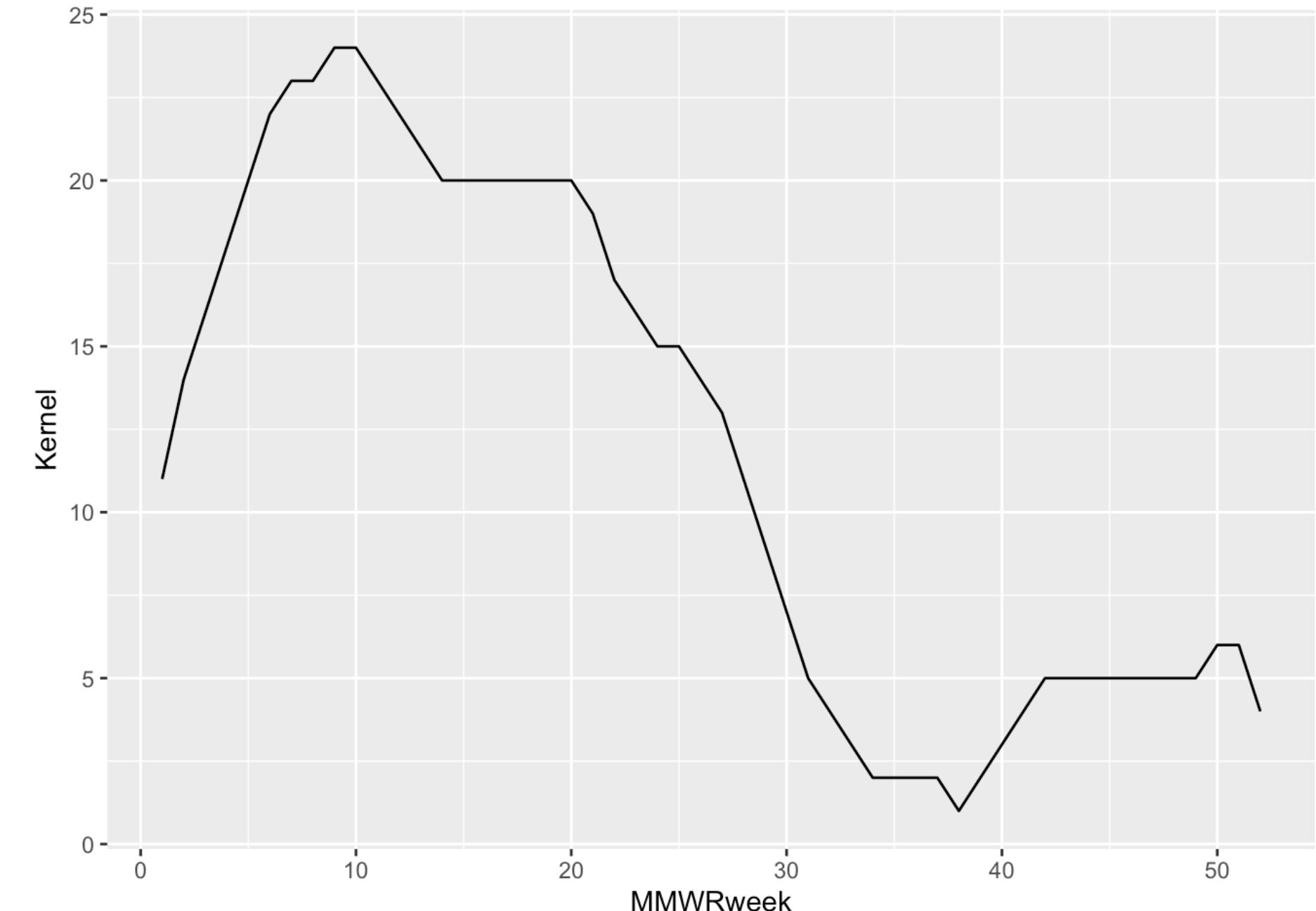




Geometry functions are engines that process data mappings into the defined plot type.

```
ggplot() + geom_*(data, aes(), position, statistics)
```

```
df |>  
  ggplot() +  
    geom_line(aes(x = MMWRweek,  
                  y = Kernel))
```



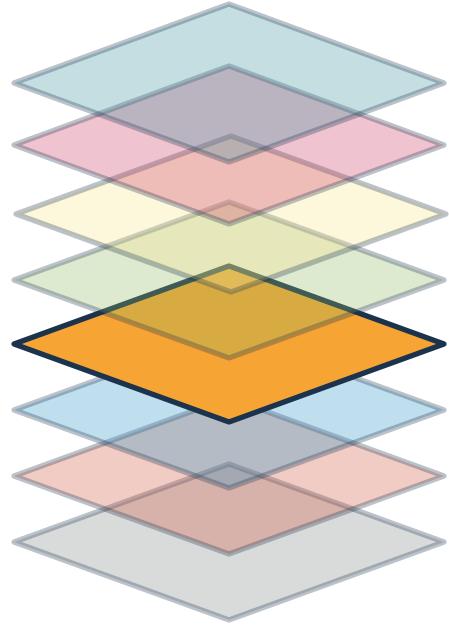
Discussion:

Can you think of reasons why you would choose one over the other?



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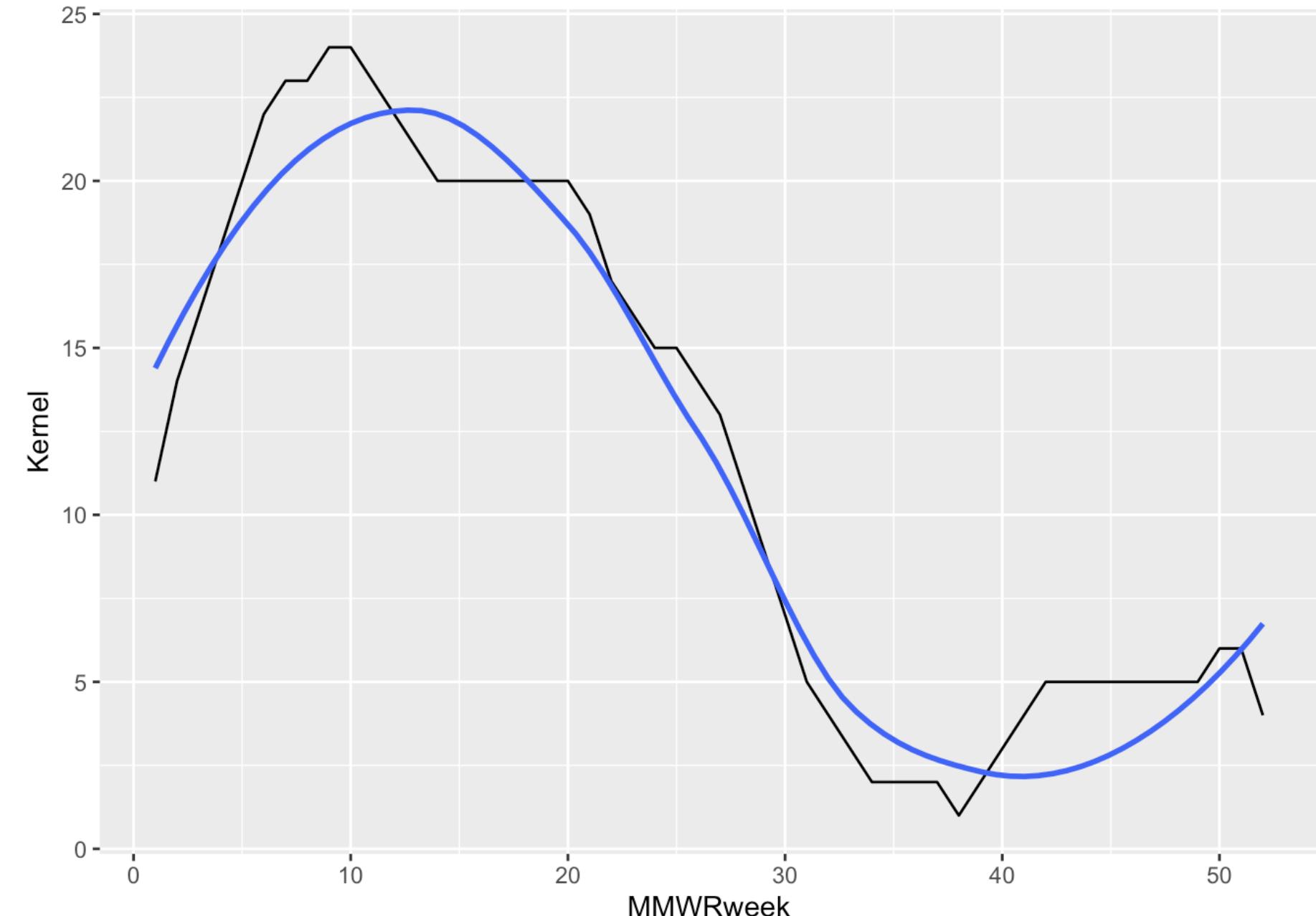
Data Science and Data Equity

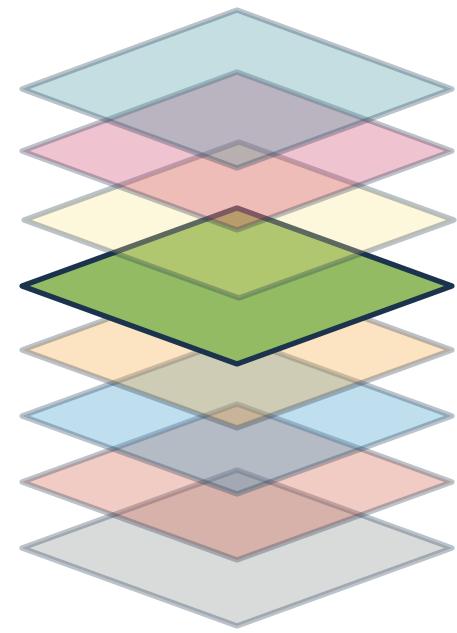


Statistics layers do the statistical calculations used in geometric engines. Many are interchangeable with a comparable geometry.

```
ggplot(data) + stat_*(aes(), geometry, parameters)
```

```
df |>  
  ggplot() +  
    geom_line(aes(x = MMWRweek,  
                  y = Kernel)) +  
    stat_smooth(aes(x = MMWRweek,  
                     y = `Scaled Positives`),  
                geom = "smooth",  
                method = "loess",  
                se = FALSE)
```

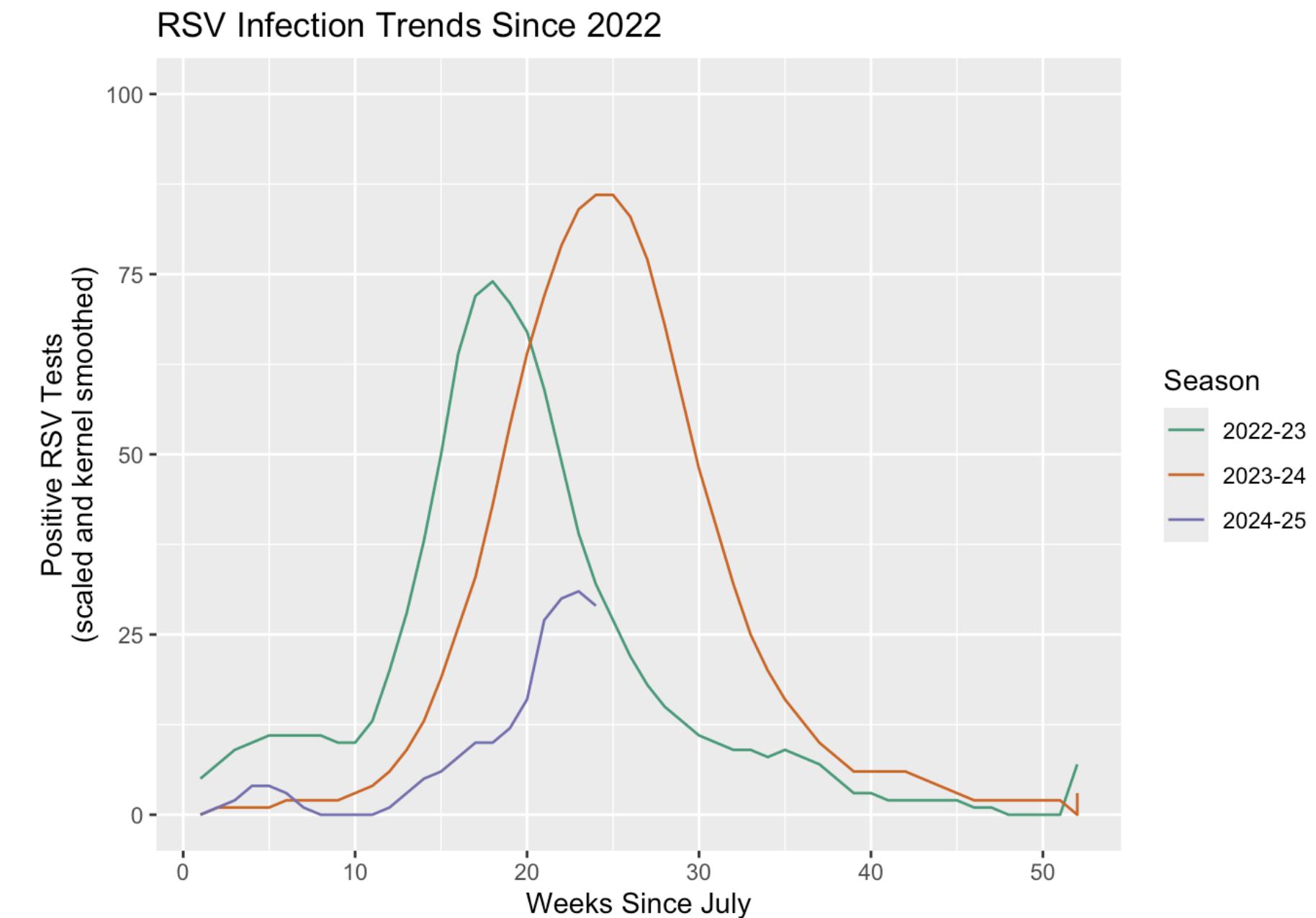




Scales interpret an aesthetic mapping into plottable values. This layer offers the most opportunity for plot customization.

```
ggplot(data, aes()) + geom_*/stat_*() +  
scale_*(parameters)
```

```
df |>  
  ggplot(aes(x = MMWRweek, y = Kernel,  
             color = Season)) +  
  geom_line() +  
  labs(title, x, y) +  
  ylim(0, 100) +  
  scale_color_brewer(type = "qual",  
                      palette = "Dark2")
```

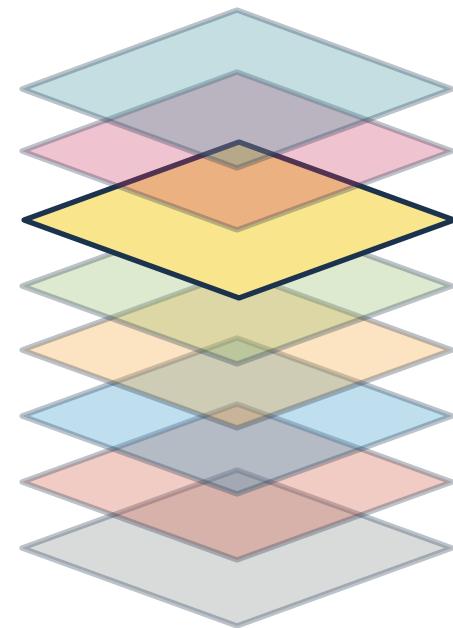


Discussion:

We see that associating a variable with an aes (color) will also group by that same variable.

- a) What happens if we only group the outcome?
- b) Does adding a `scale_color_*` help?
- c) Why do we get the result we do?

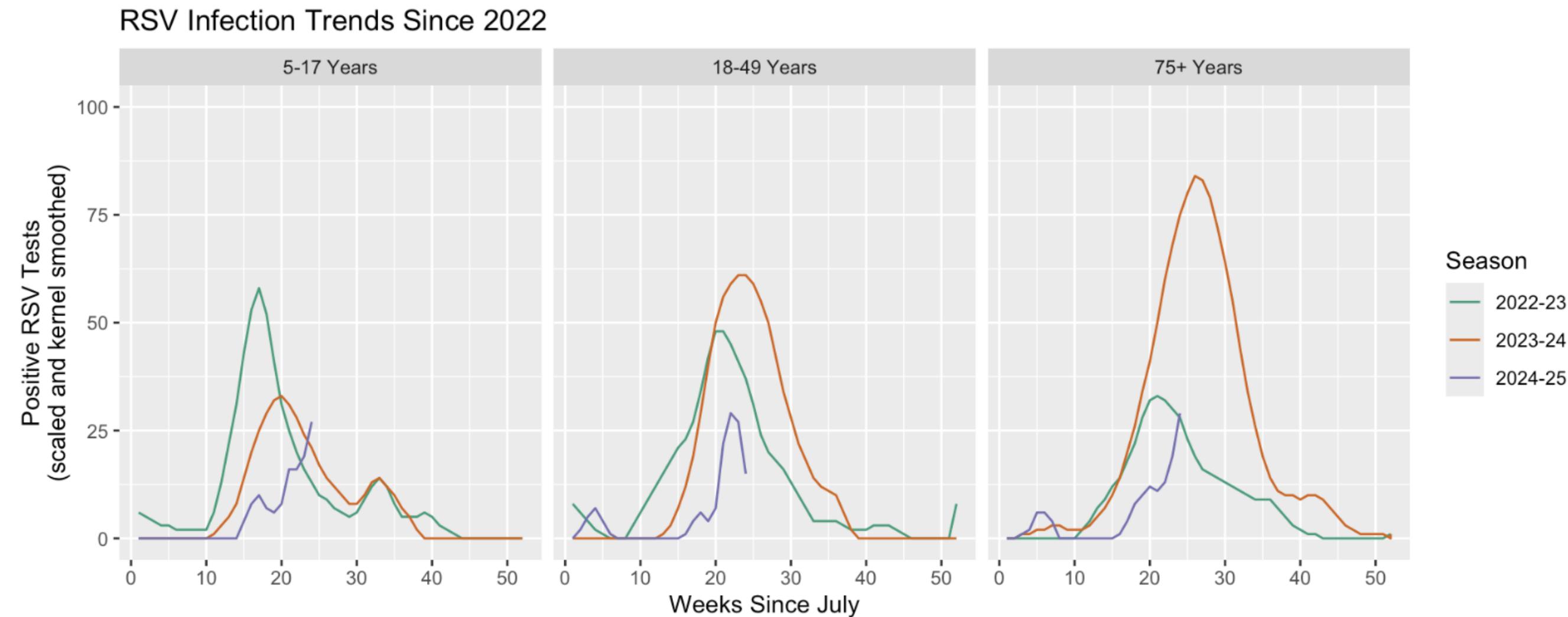


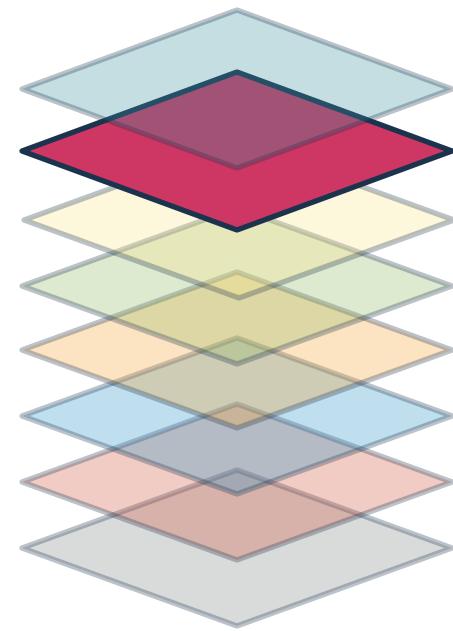


Facets spread out the same plot over subgroups in a discrete variable.

```
ggplot(data, aes()) + geom_*(/) / stat_*(/) +  
facet_*(discrete variable)
```

```
df |>  
  ggplot(aes(...)) +  
  geom_line() +  
  ...  
  facet_grid(~Level)
```

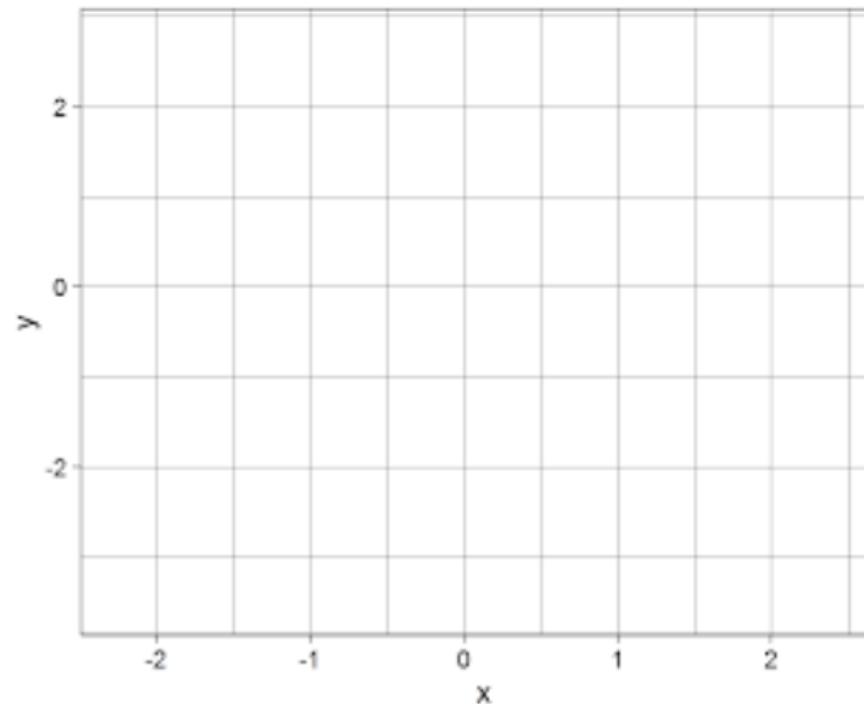




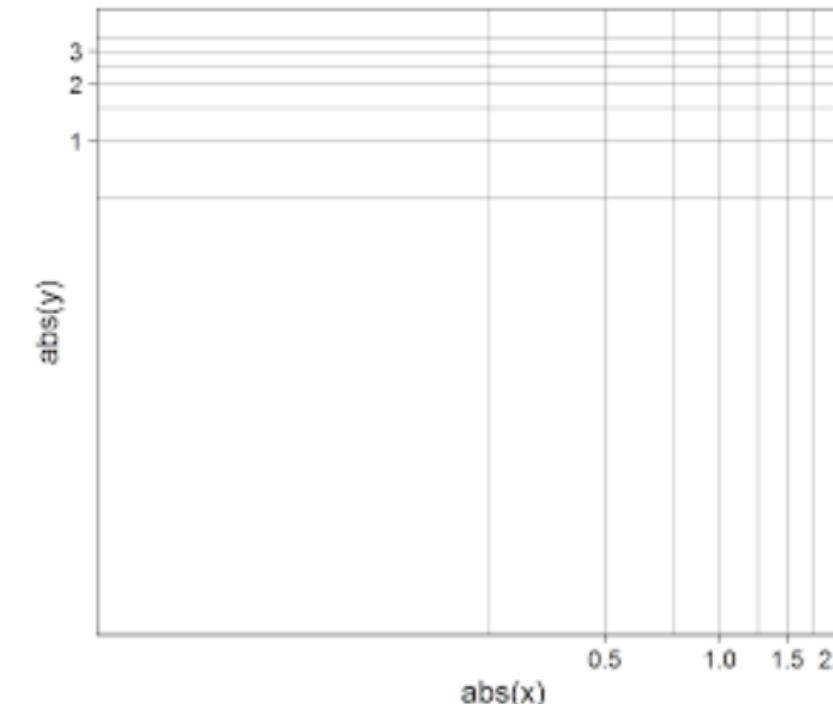
Coordinates plots the values prepared by preceding layers in a specified coordinate system.

```
ggplot(data, aes()) + geom_*( ) / stat_*( ) +  
  coord_*( )
```

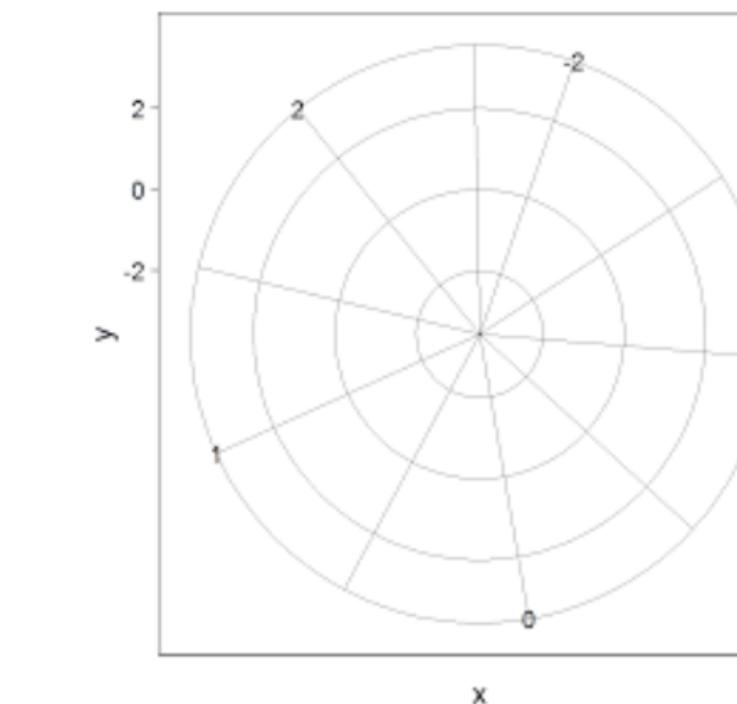
Cartesian



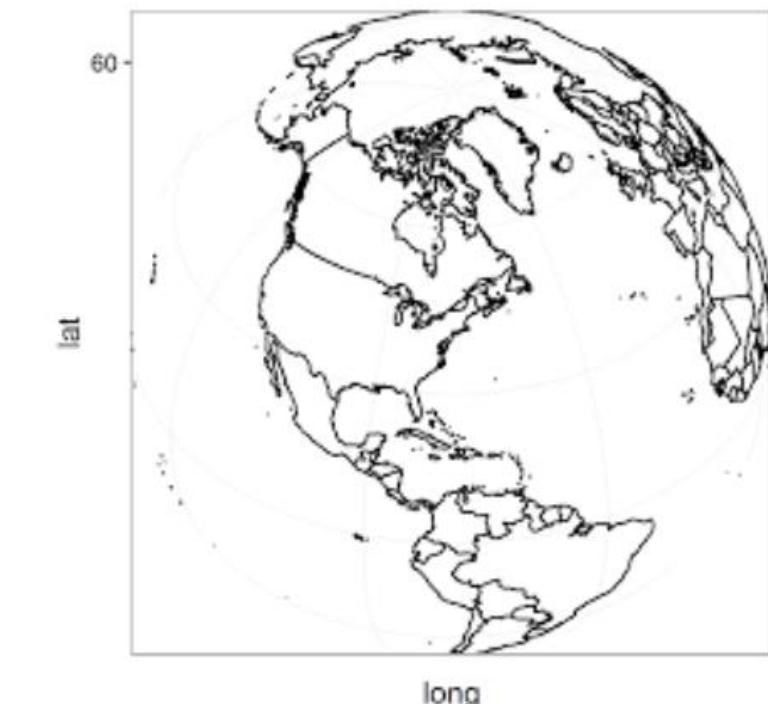
Transformed (log10)



Polar



Map



[Data Visualisation: From Theory to Practice Figure 5.5](#)
by James Baglin. Accessed March 22nd, 2025.



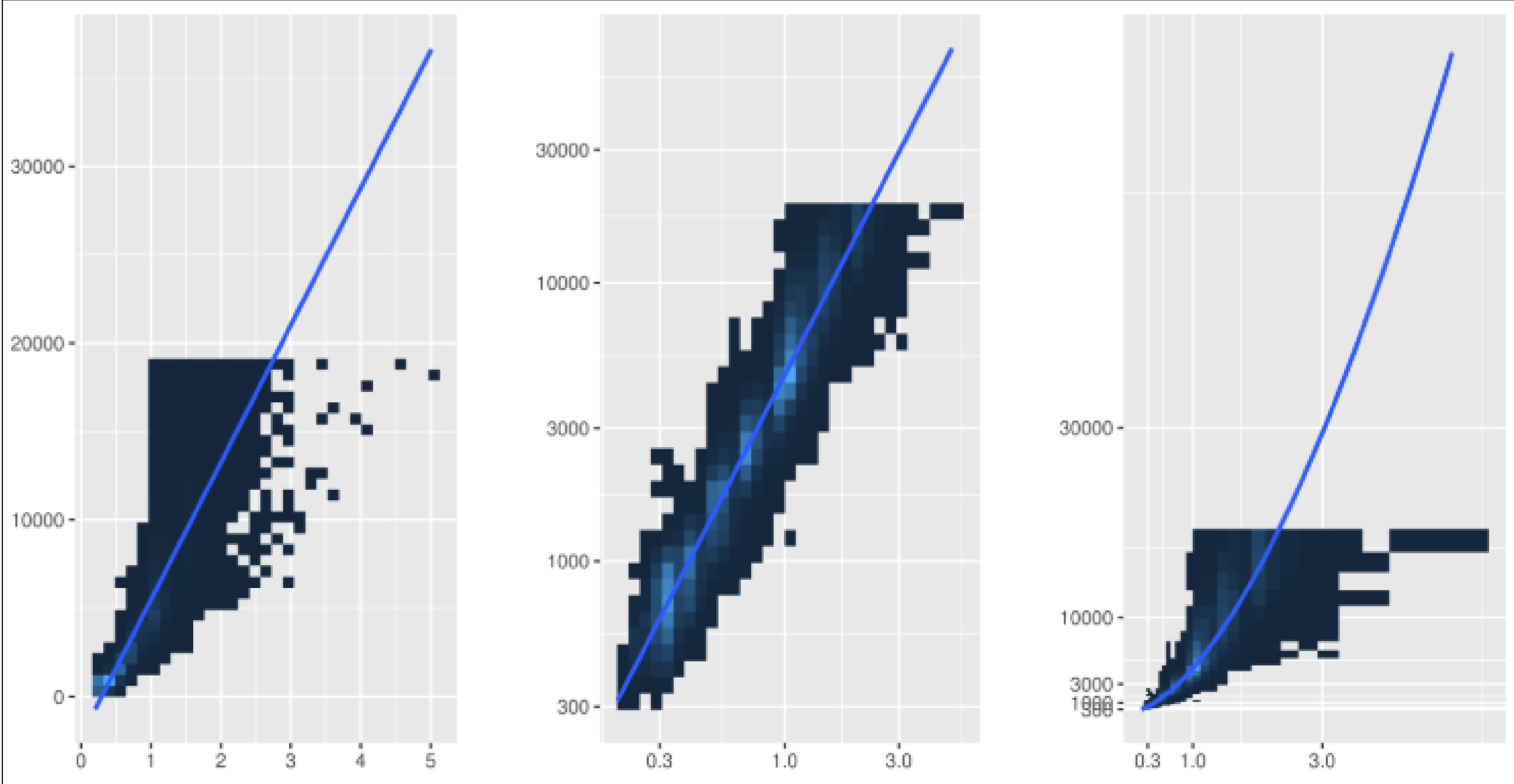
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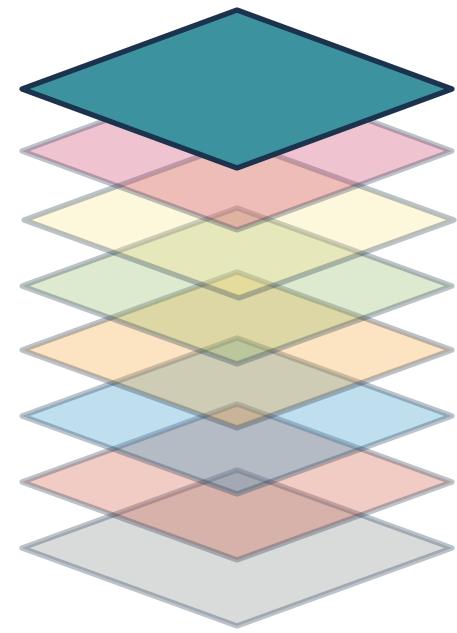
Data Science and Data Equity

Discussion:

If we apply each option individually, do they all plot the same way? If not, what do you think is happening and how would you fix the code?



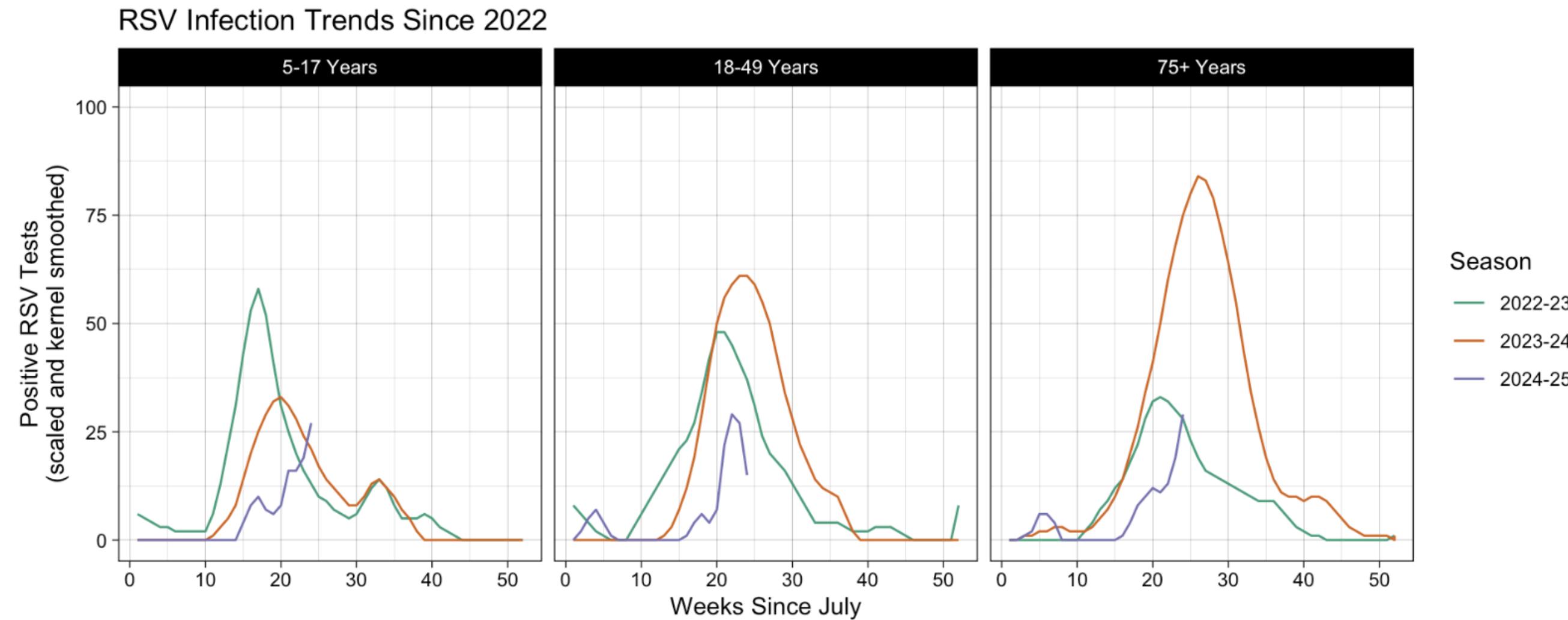


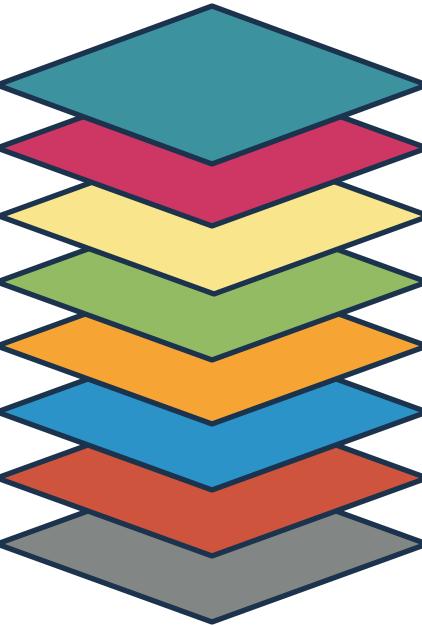


Theme is the only layer where users can change non-data aspects of their plot to improved its visual appeal and styling.

```
ggplot(data, aes()) + geom_() / stat_() +  
theme_()
```

```
df |>  
  ggplot(aes(...)) +  
  geom_line() +  
  ...  
  theme_linedraw()
```

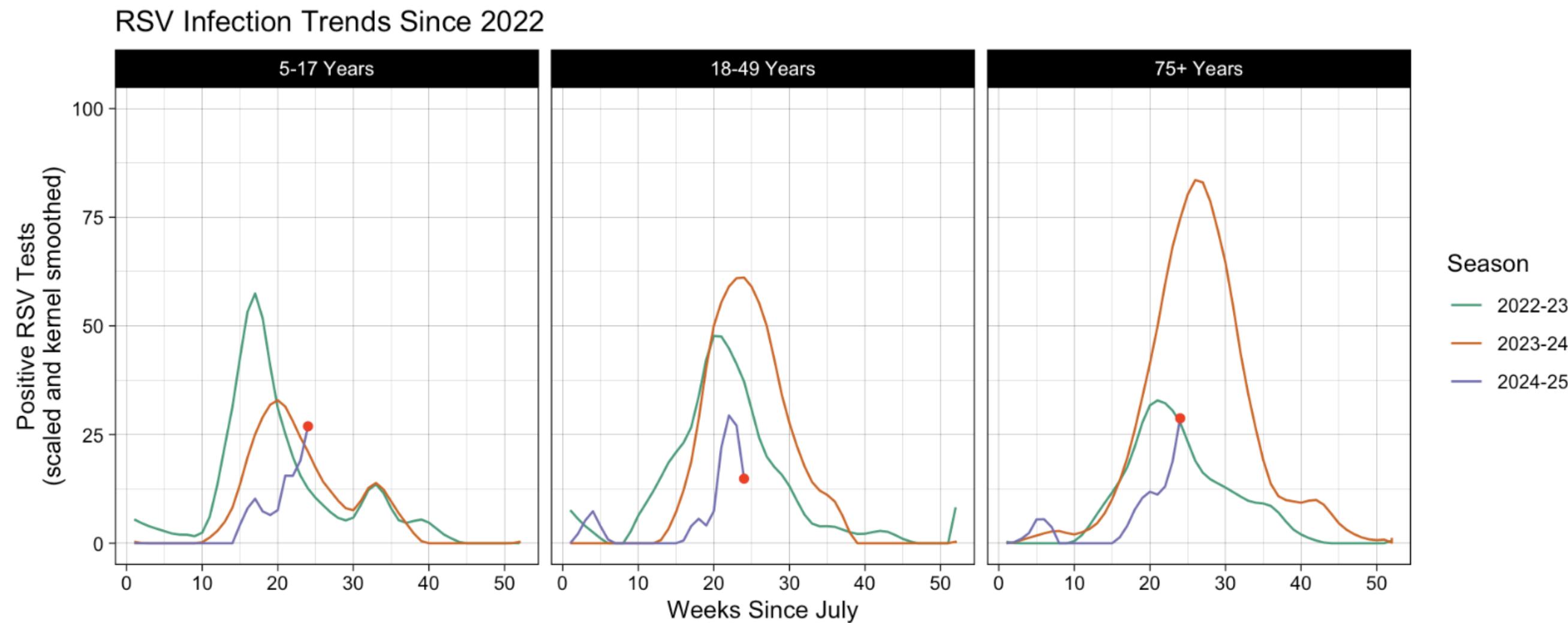




Overlay new layers to a base plot to create more advanced visualization.

- Each layer is an independent object, allowing for adaptive and functional programming.
- Data and aesthetics Mapping can be inherited from `ggplot()`.

```
df |>  
  ggplot(aes(...)) +  
    geom_line() +  
    geom_point(df2) +  
    ...
```



Advanced use of ggplot2

Going beyond the basics

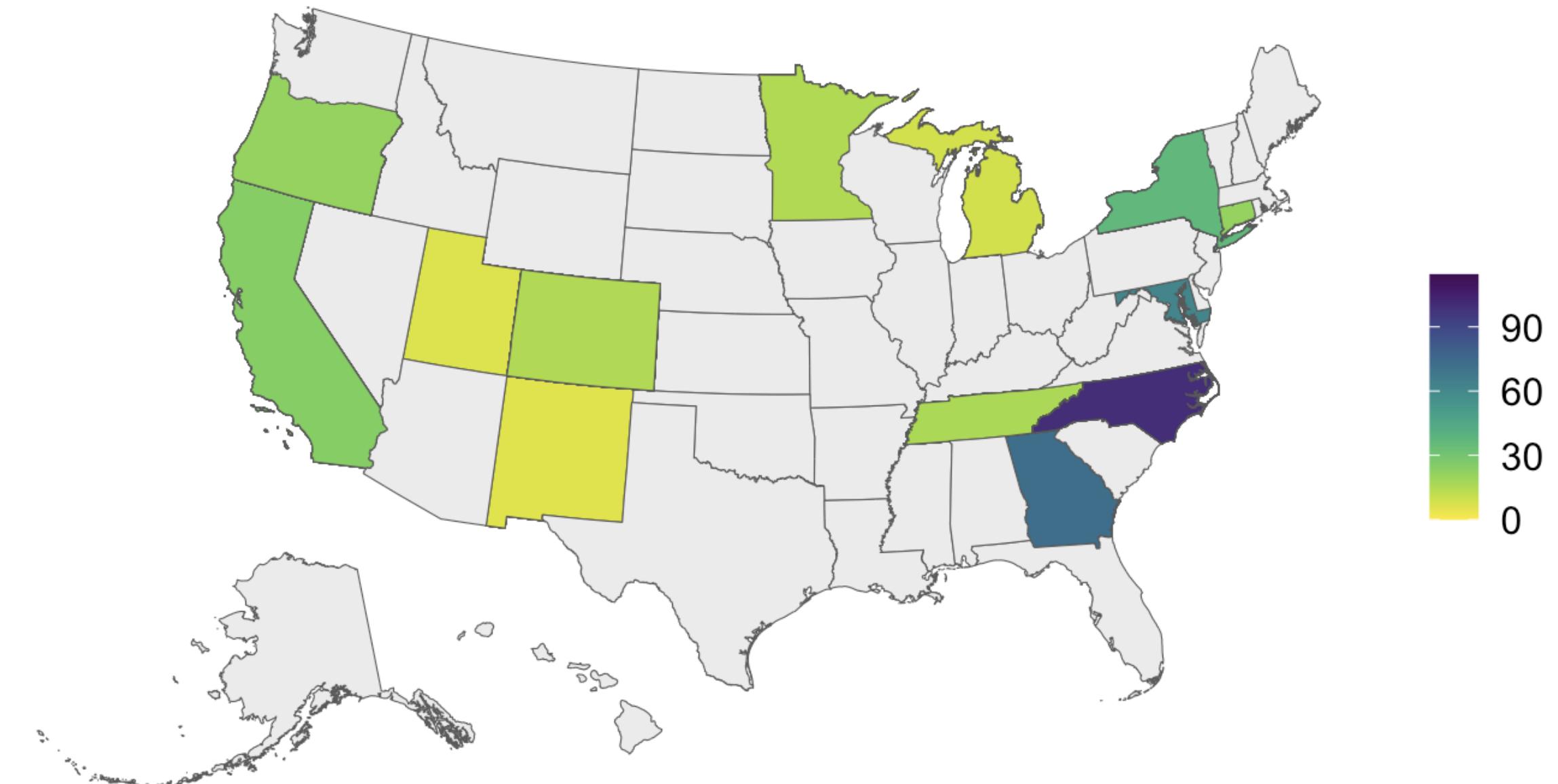
- Community managed [ggplot2 extensions](#) list
- [R Graph Gallery](#) – focuses on applications with ggplot2
- Additional topics from ggplot2: Elegant Graphics for Data Analysis: [annotations](#), [statistical summaries](#), [spacial networks](#), and [programming with ggplot2](#), and writing your own [extensions to ggplot2](#)
- [Extending ggplot2](#) vignette
- [Using ggplot2 in packages](#) vignette



Use vector data, sf, to tell `geom_sf()` where on a map the data gets filled.

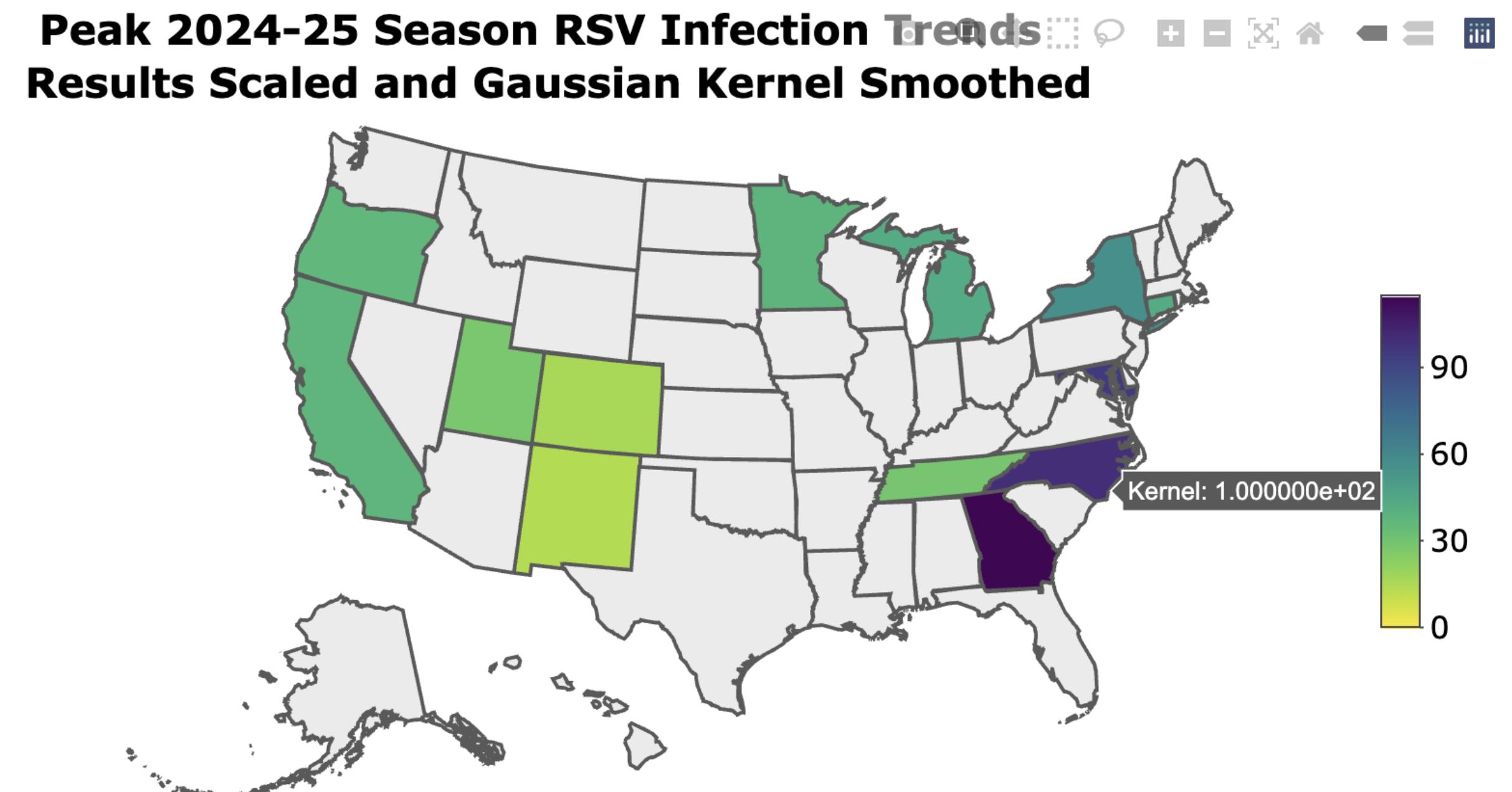
**Peak 2024-25 Season RSV Infection Trends
Results Scaled and Gaussian Kernel Smoothed**

```
df |>  
  ggplot(aes(fill)) +  
  geom_sf() +  
  coord_sf()
```



Plotly allows you to quickly render an html based, user interactive ggplot.

```
ggplotly(plot_name)
```

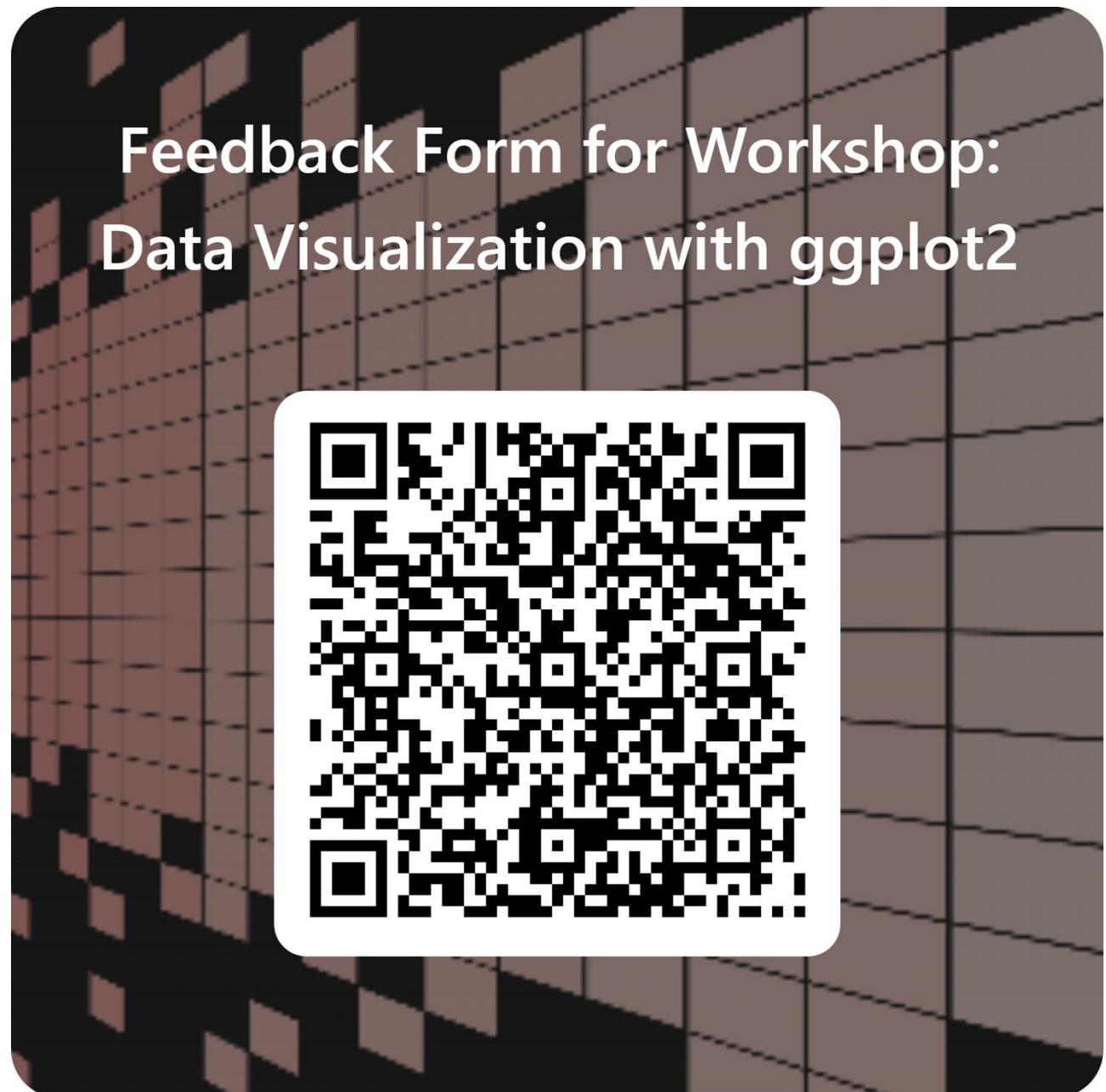


Yale's Clarity

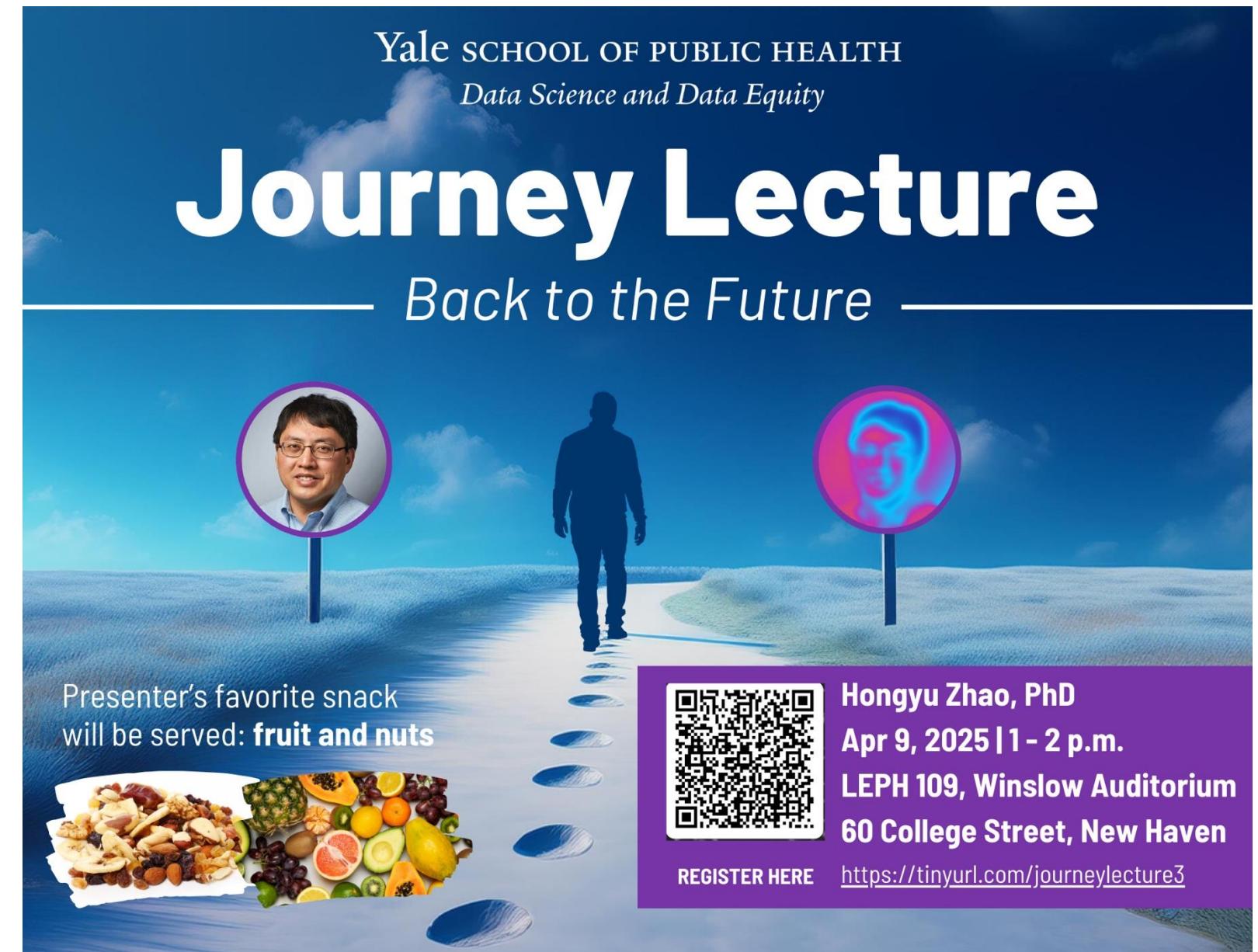
1. Take a screenshot of one of the plots from the workshop or one of your own.
2. Navigate to <https://ai-chat.yale.edu/signin-oidc>
3. Upload the screenshot into the chat and ask "Suggest R code that could make this plot in ggplot2."

Discuss – how did the AI chatbot do?

Evaluation



Next DSDE Event





ysph.yale.edu
sph.yale.edu/dsde

@YaleSPH

Public Health Data Science and Data Equity
Yale School of Public Health
60 College Street, New Haven, CT 06510

Appendix

Glossary

Grammar of Graphics Definition for the distinct elements that make up all graphical representations of relational data in tabular form. First created by Professor Leland Wilkinson in 1999.

Layered Grammar of Graphics The modified version of Grammar of Graphics that stores each element as an independent object. These objects get added together to generate a comprehensive plot.

Layer: Data A “tidy” data frame with the necessary columns of information to generate the plot you intend.

Layer: Mapping Assigns variables in the data frame to aesthetic features on the plot (i.e. shape, color, etc.).

Glossary

- Layer: Geometry** Engines (composite of operations) that process the data into a defined plot type (i.e. boxplot, histogram, line, etc.).
- Layer: Statistics** Statistical transformations that generate a geometry. Sometimes interchangeable with geom_() objects.
- Layer: Scales** Interpret aesthetic Mappings into plottable values (i.e. axis scaling, color scaling, etc.).
- Layer: Facets** Spreads out the same plot into new subplots, each showing distinct instantiations of a variable.

Glossary

- Layer: Coordinates** Defines the coordinate plane of the plot: i.e. Cartesian, polar, transformed, or a map projection.
- Layer: Theme** Controls for the non-data elements of the plot.
- Map Projection** Interpreting the curved surface of the earth into a flat plane for 2D plotting.
- Simple Feature (SF)** Standard vector data produced by the Open Geospatial Consortium (OGC) that's translates projection data into plottable polygons.

References

Slide 1

1. E. Tufte, *The Visual Display of Quantitative Information*, Second Edition. Cheshire, CT: Graphics Press, LLC, 2001. Accessed: Mar. 13, 2025. [Online]. Available: <https://www.edwardtufte.com/book/the-visual-display-of-quantitative-information/>

Slide 4

1. Hadley Wickham et al., *ggplot2: Elegant Graphics for Data Analysis*. New York: Springer-Verlag, 2016. Accessed: Mar. 12, 2025. [Online]. Available: <https://ggplot2.tidyverse.org/>
2. Hadley Wickham et al., “Function references,” *ggplot2 Documentation*. Accessed: Mar. 09, 2025. [Online]. Available: <https://ggplot2.tidyverse.org/reference/index.html>
3. D. Navarro, “Personal Website.” Accessed: Mar. 20, 2025. [Online]. Available: <https://djnavarro.net/>
4. T. L. Pedersen, “*ggplot2 workshop part 1*,” YouTube. Accessed: Mar. 12, 2025. [Online]. Available: <https://www.youtube.com/watch?v=h29g21z0a68>

References

Slide 4 continued

5. T. L. Pedersen, "ggplot2 workshop part 2," YouTube. Accessed: Mar. 12, 2025. [Online]. Available: <https://www.youtube.com/watch?v=0m4yywqNPVY>
6. T. L. Pedersen, "Personal Website." Accessed: Mar. 20, 2025. [Online]. Available: <https://thomaslinpedersen.art/>
7. Posit Contributors, Data visualization with ggplot2 :: Cheat Sheet. Springer-Verlag, 2024. Accessed: Mar. 20, 2025. [Online]. Available: <https://rstudio.github.io/cheatsheets/html/data-visualization.html>
8. H. Wickham, "Personal Website." Accessed: Nov. 17, 2024. [Online]. Available: <https://hadley.nz/>
9. H. Wickham, M. Çetinkaya-Rundel, and G. Grolemund, R for Data Science, Second. O'Reilly Media, 2023. Accessed: Mar. 12, 2025. [Online]. Available: <https://r4ds.hadley.nz/>
10. H. Wickham, D. Navarro, and T. L. Pedersen, ggplot2: Elegant Graphics for Data Analysis, Second. Springer, 2010. Accessed: Mar. 20, 2025. [Online]. Available: <https://ggplot2-book.org/>

References

Slide 4 continued

11. T. L. Pedersen, "ggplot2 workshop part 2," YouTube. Accessed: Mar. 12, 2025. [Online]. Available: <https://www.youtube.com/watch?v=0m4yywqNPVY>

Slide 7

1. "ggplot2," Wikipedia. Accessed: Mar. 13, 2025. [Online]. Available: <https://en.wikipedia.org/wiki/Ggplot2>
2. H. Wickham, M. Çetinkaya-Rundel, and G. Grolemund, R for Data Science, Second. O'Reilly Media, 2023. Accessed: Mar. 12, 2025. [Online]. Available: <https://r4ds.hadley.nz/>

Slide 8

1. Hadley Wickham et al., ggplot2: Elegant Graphics for Data Analysis. New York: Springer-Verlag, 2016. Accessed: Mar. 12, 2025. [Online]. Available: <https://ggplot2.tidyverse.org/>
2. H. Wickham, "Personal Website." Accessed: Nov. 17, 2024. [Online]. Available: <https://hadley.nz/>

References

Slide 8

3. H. Wickham, "Tidyverse." Accessed: Nov. 14, 2024. [Online]. Available: <https://www.tidyverse.org/>

Slide 10

1. E. Tufte, *The Visual Display of Quantitative Information*, Second Edition. Cheshire, CT: Graphics Press, LLC, 2001. Accessed: Mar. 13, 2025. [Online]. Available: <https://www.edwardtufte.com/book/the-visual-display-of-quantitative-information/>

Slide 11

1. "Edward Tufte," Wikipedia. Accessed: Mar. 13, 2025. [Online]. Available: https://en.wikipedia.org/wiki/Edward_Tufte
2. "Leland Wilkinson," Wikipedia. Accessed: Mar. 14, 2025. [Online]. Available: https://en.wikipedia.org/wiki/Leland_Wilkinson

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