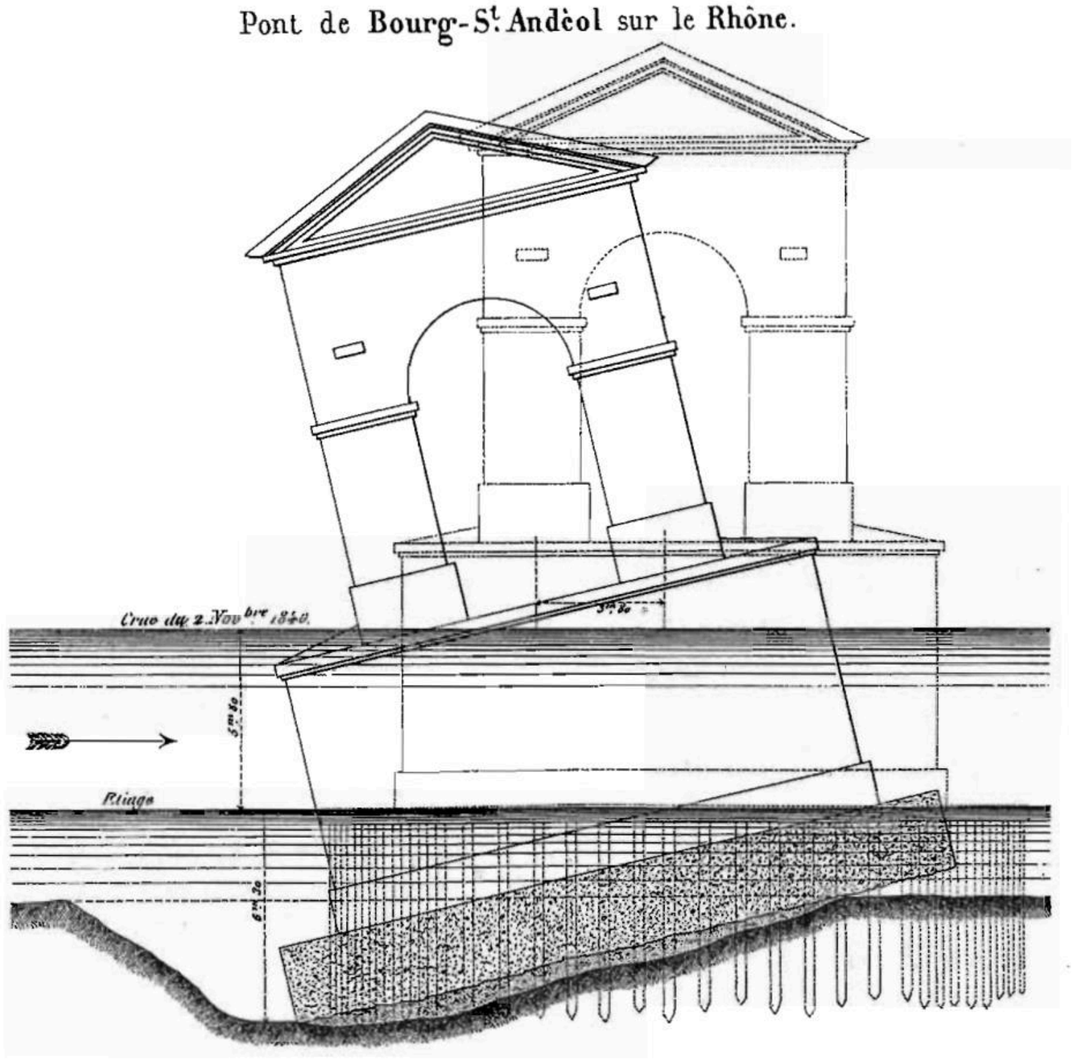
Data Visualization with ggplot2

Coffee, Cookie and Coding (C^3)

Workshops are by the Public Health Data Science and Data Equity team

Shelby Golden, M.S.

March 27th, 2025



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.

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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:

1. Open the workshop webpage:

   https://ysph-dsde.github.io/Data-Visualization-with-ggplot2/Worked-Through-Example

2. Follow the steps under “Download Materials” at the top.

3. Use this webpage to follow along during the worked through example presentation.

Welcome (back) to the tidyverse

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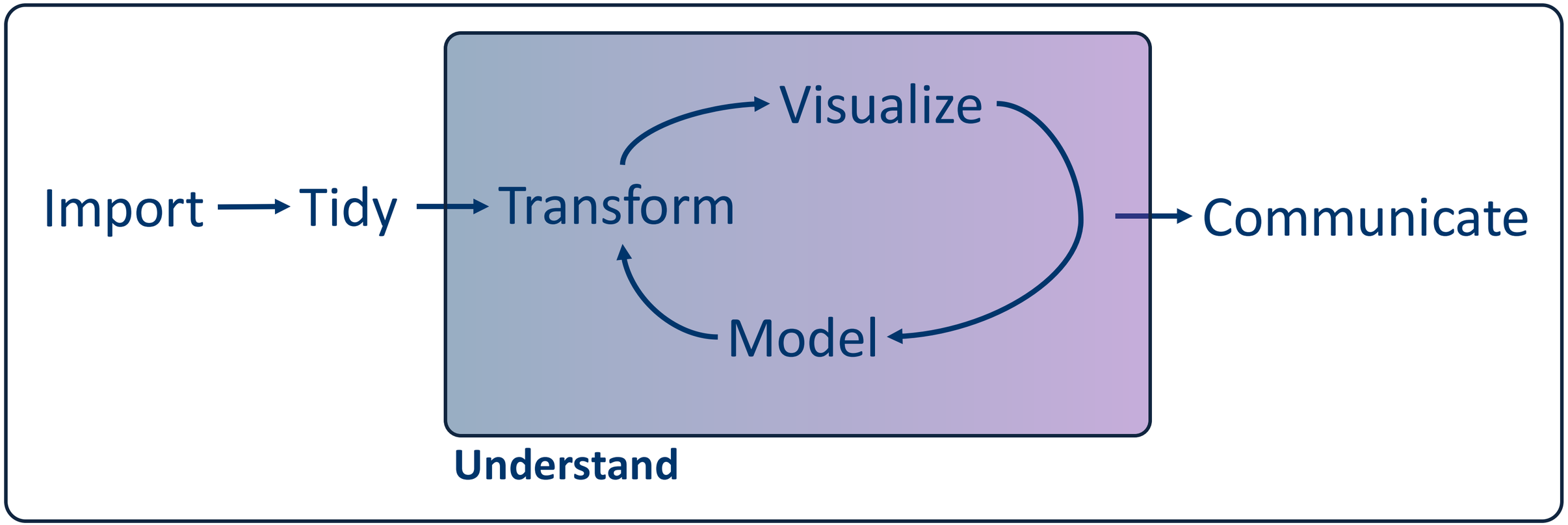


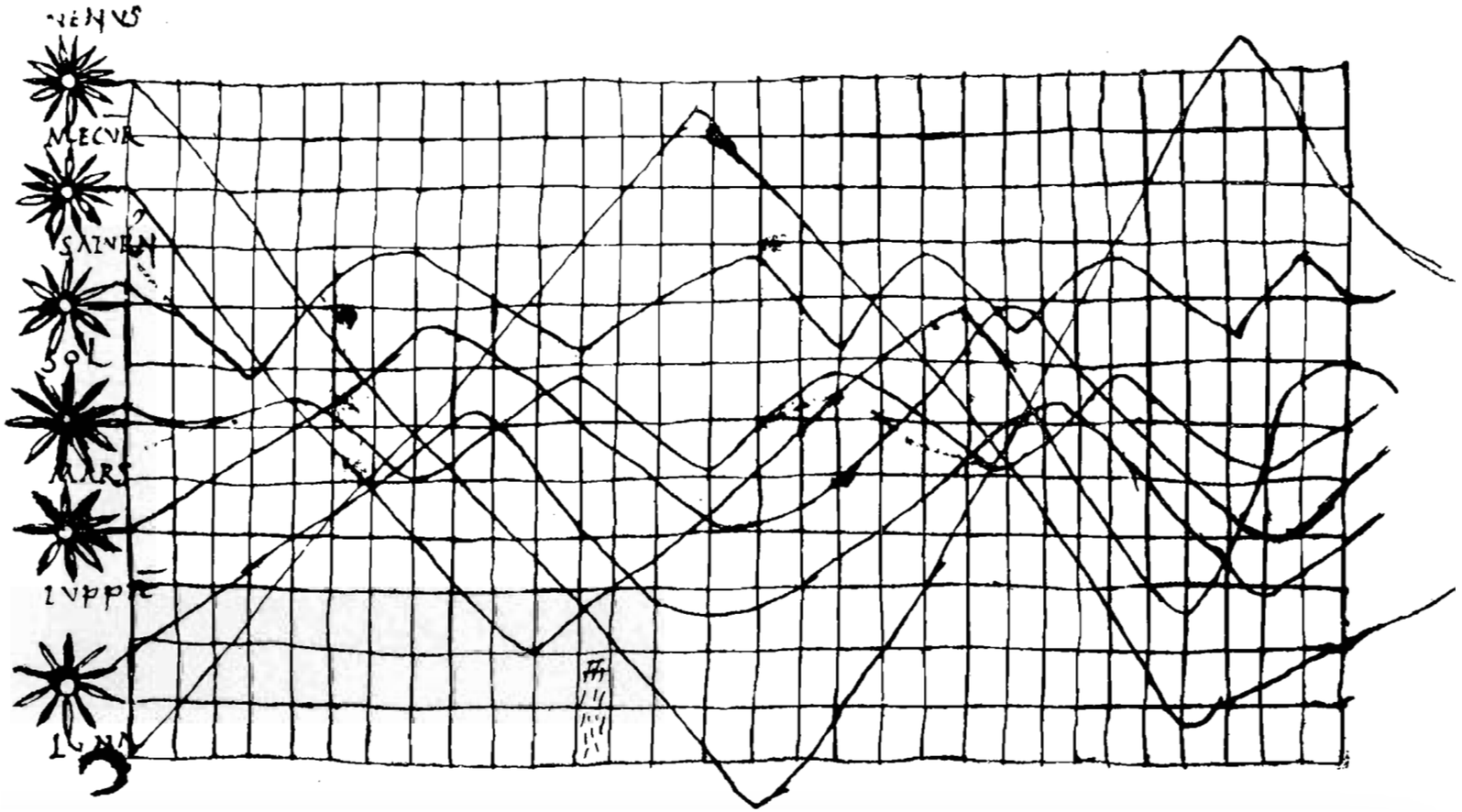
R for Data Science (2e) - Introduction Figure 1 by Hadley Wickham, Mine Çetinkaya-Rundel, and Garrett Grolemund. Accessed November 15th, 2024.

Part of the tidyverse Core Packages

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

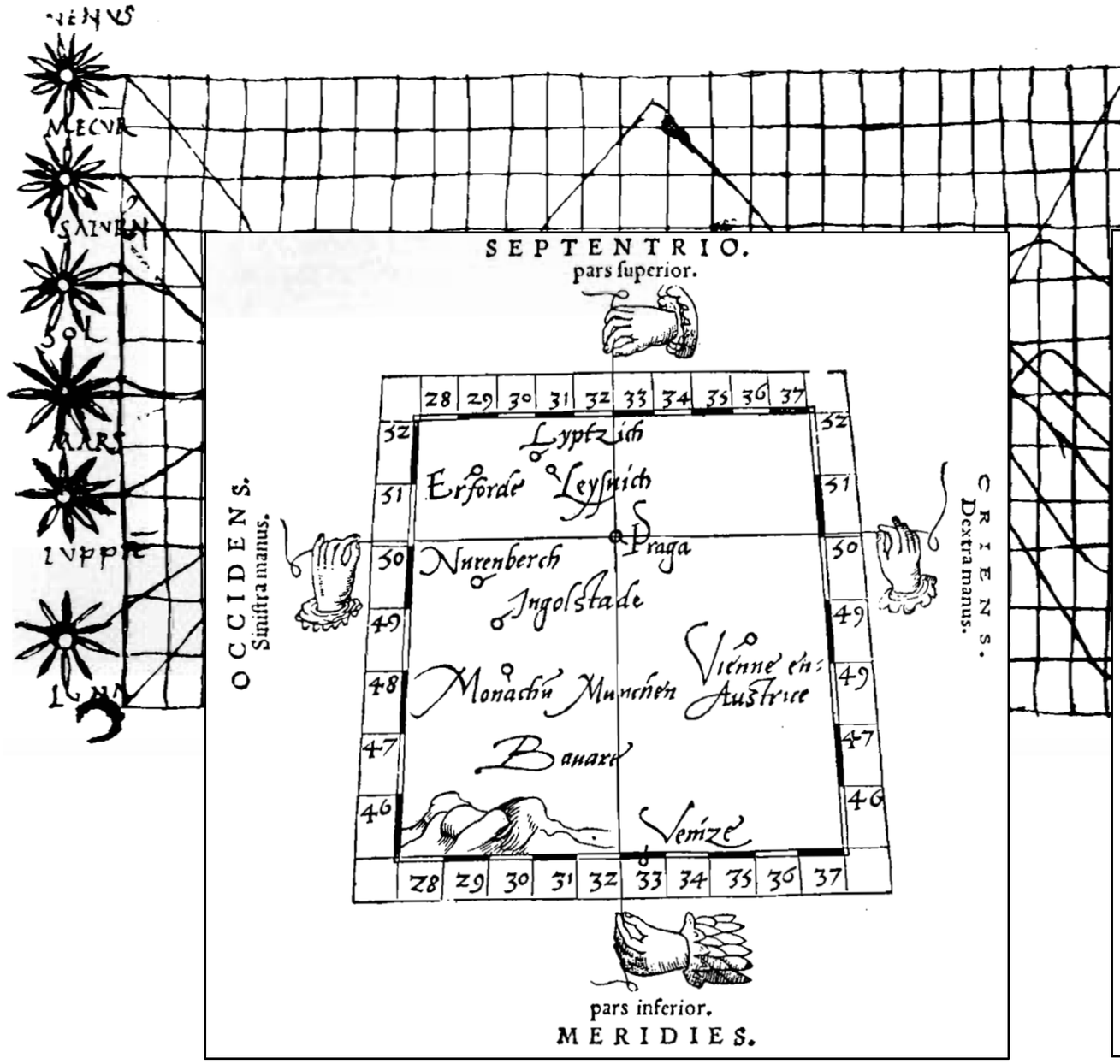
Tidyverse Package Graphic. Accessed November 15th, 2024.

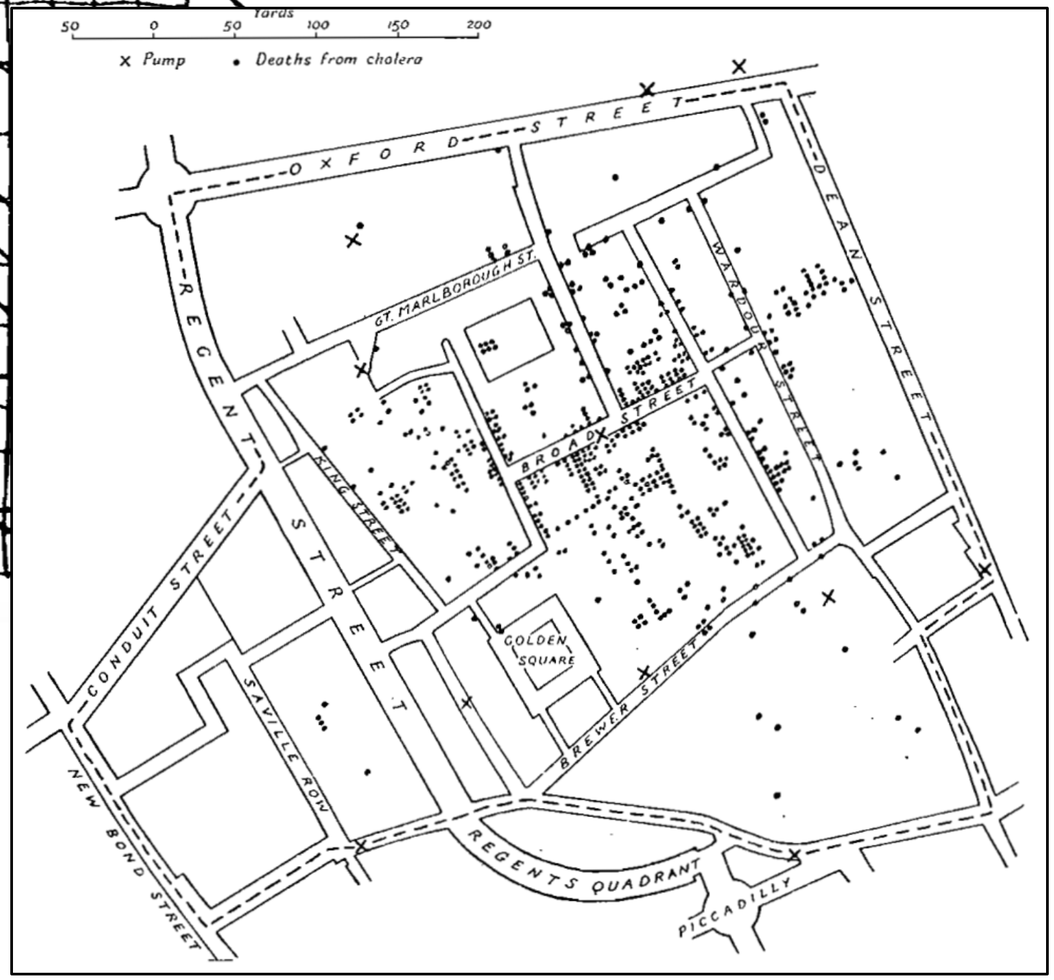
The Layered Grammar of Graphics



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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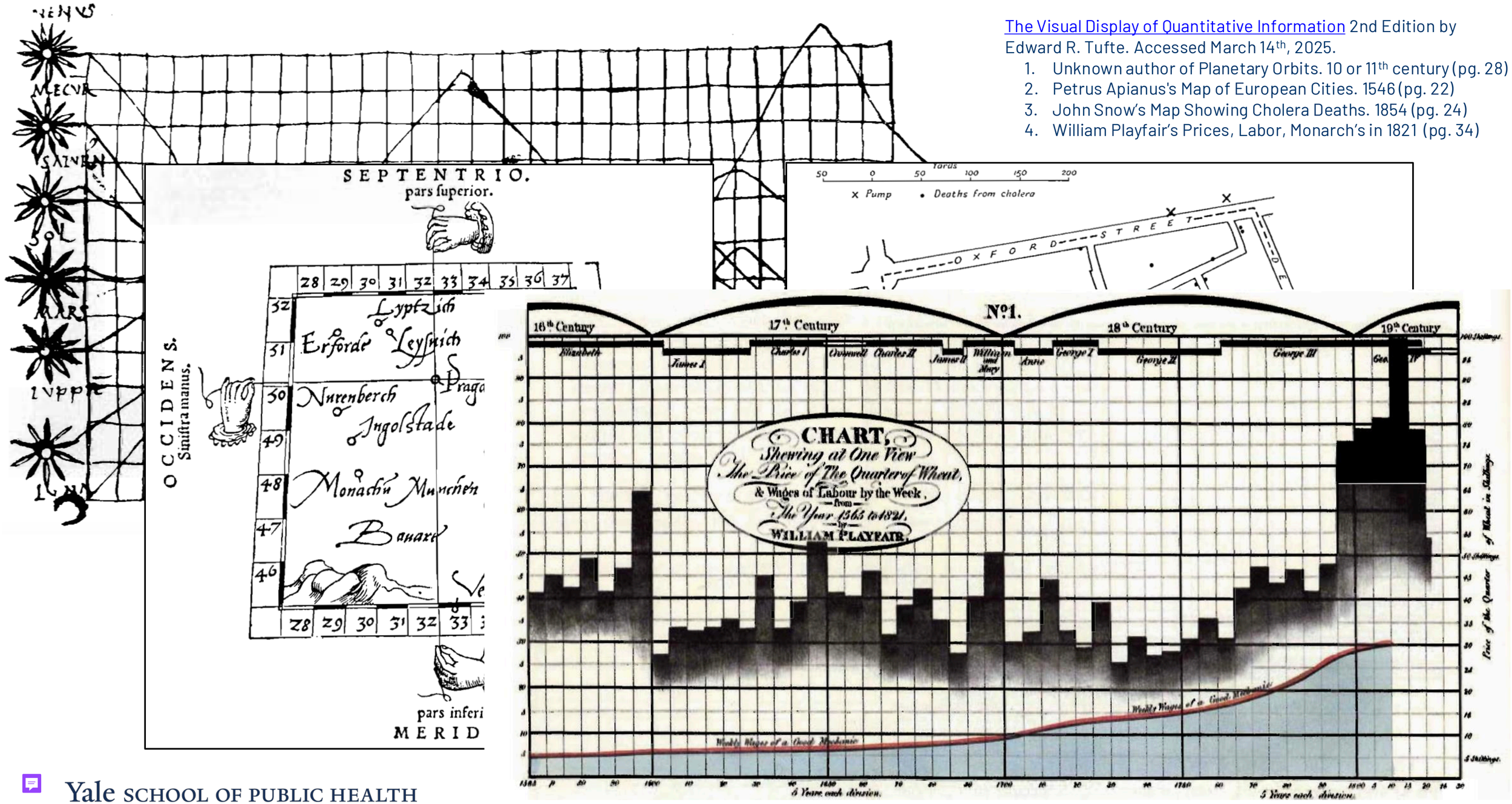

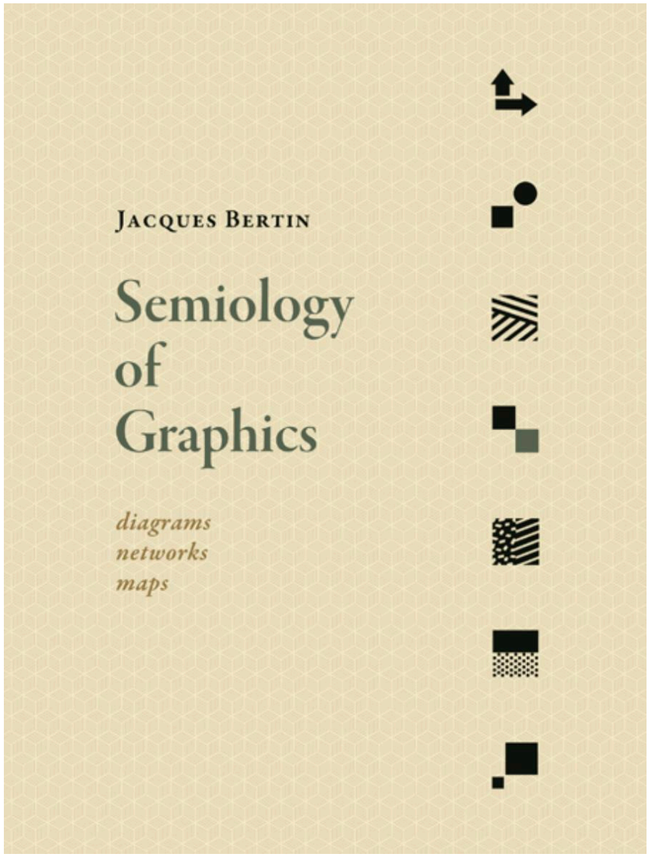

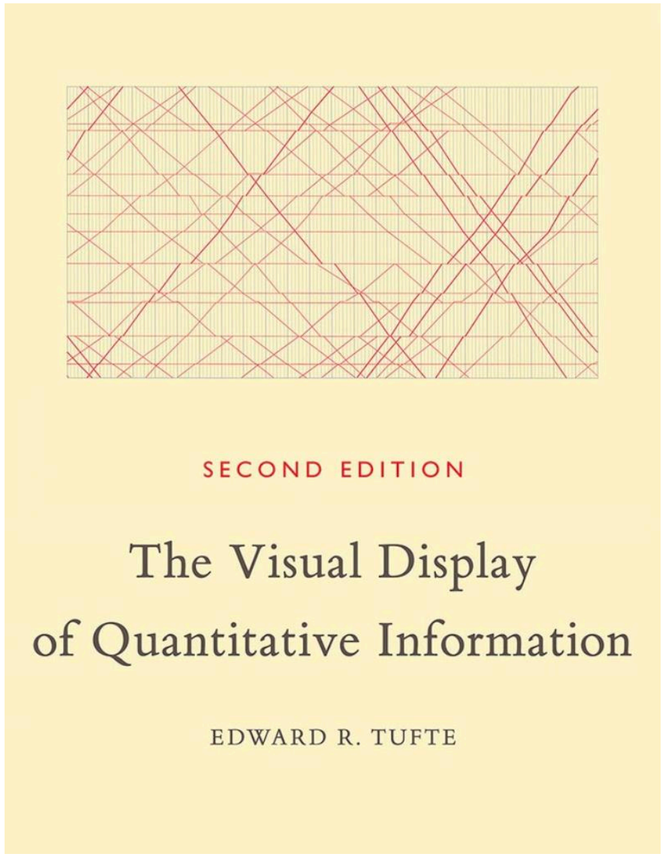

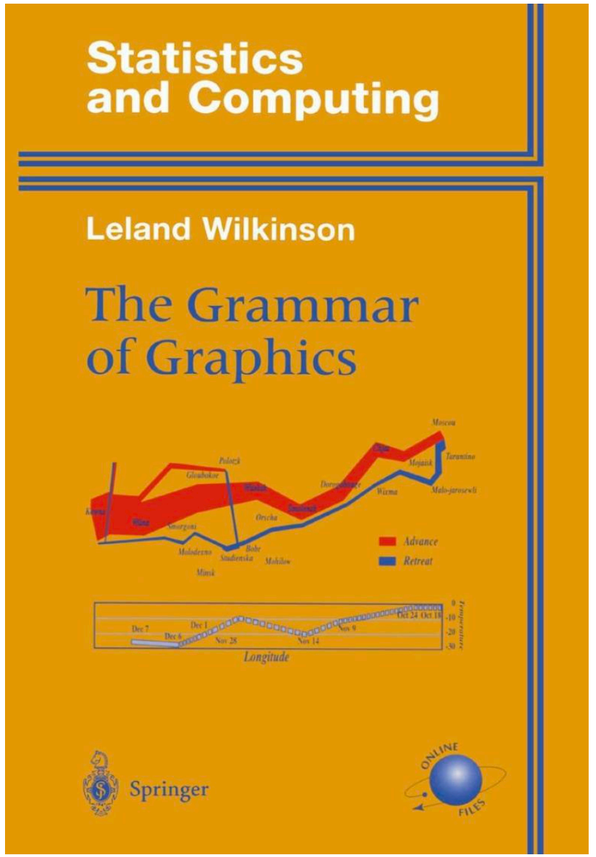

1967
Principles

1983
Clarity

1999
Formalize

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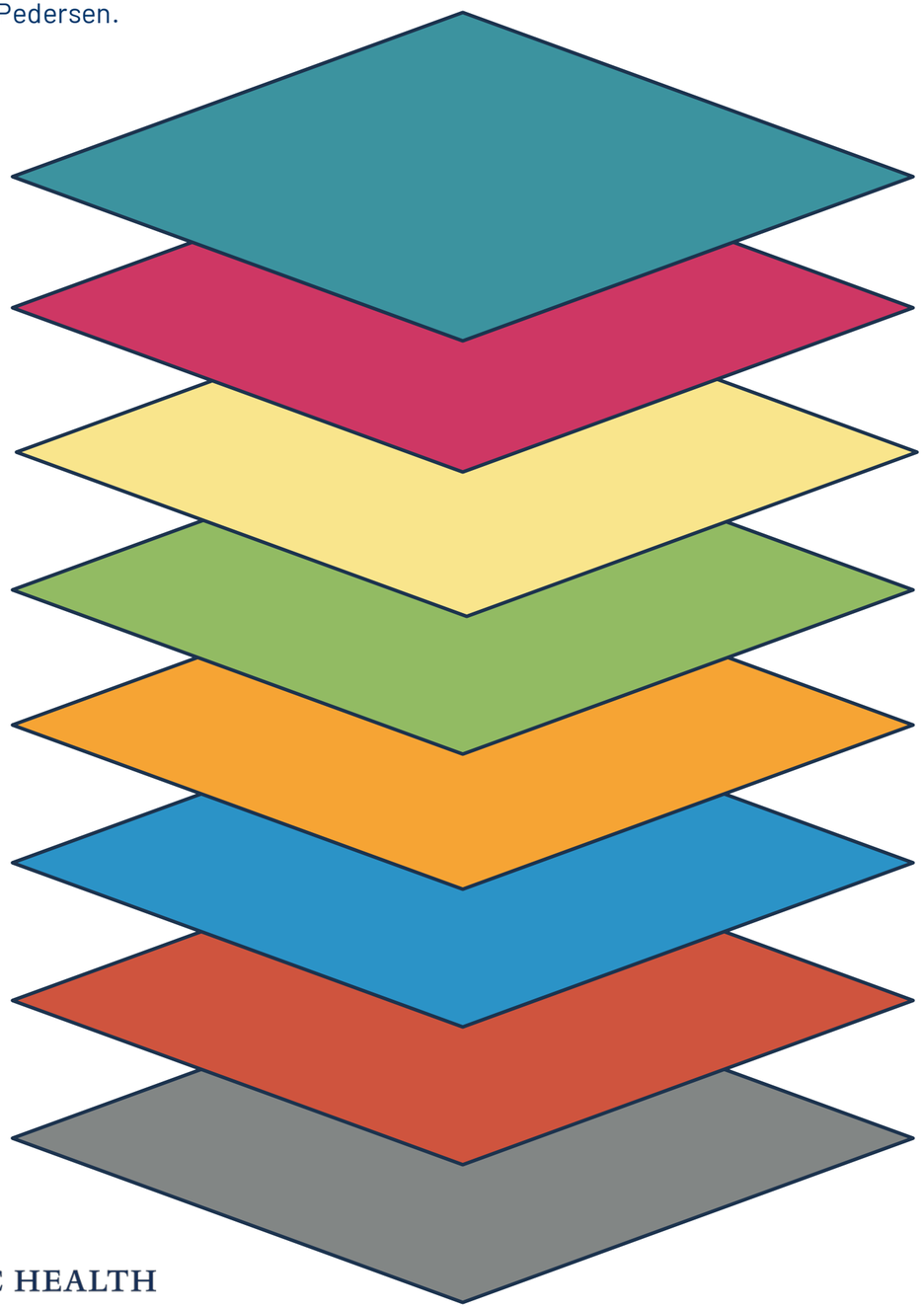
Semiology of Graphics: Diagrams, Networks, Maps by Jacques Bertin. Accessed March 2nd, 2025.

The Visual Display of Quantitative Information 2nd Edition by Edward R. Tufte. Accessed March 2nd, 2025.

The Grammar of Graphics 1st Edition by Leland Wilkinson. Accessed March 13th, 2025.

ggplot2 workshop part 1 by Thomas Lin Pedersen.
Accessed March 15th, 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

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

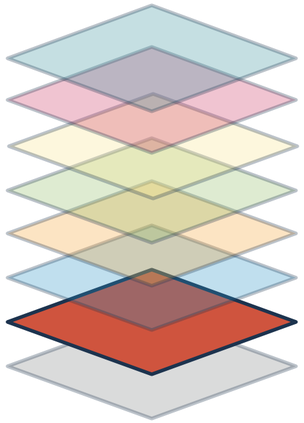
Country	Year	Cases	Pop
AFG	1999	745	20 M
AFG	2000	2667	20.5 M
Brazil	1999	37737	172 M
Brazil	2000	80488	174.5 M
China	1999	212258	1,272 M
China	2000	216766	1,280 M

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, …
```

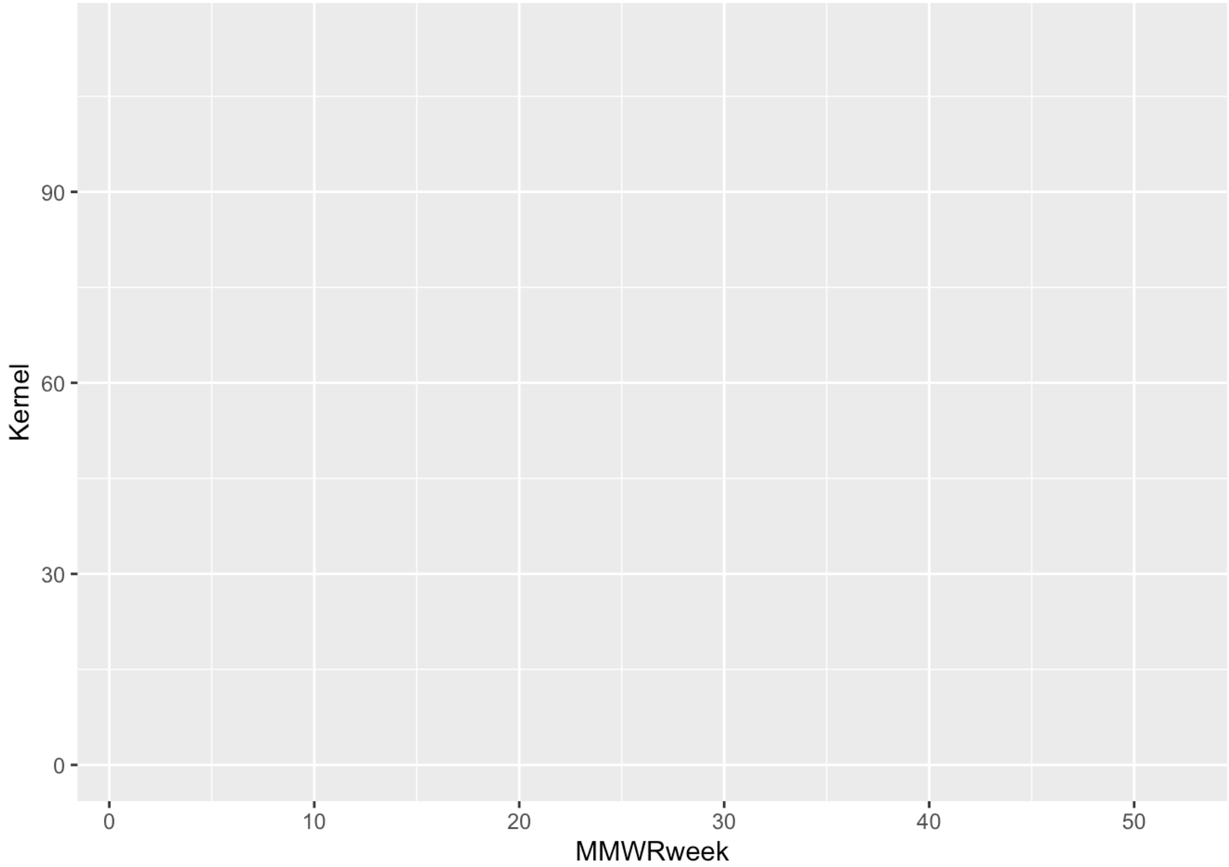

R for Data Science (2e) - Introduction Figure 5.1 by Hadley Wickham, Mine Çetinkaya-Rundel, and Garrett Grolemund. Accessed March 16th, 2025.

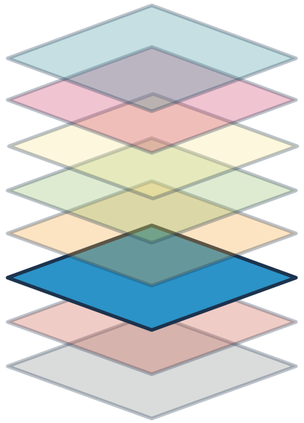


Mapping tells the function which variables get used for which aesthetic feature.

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

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

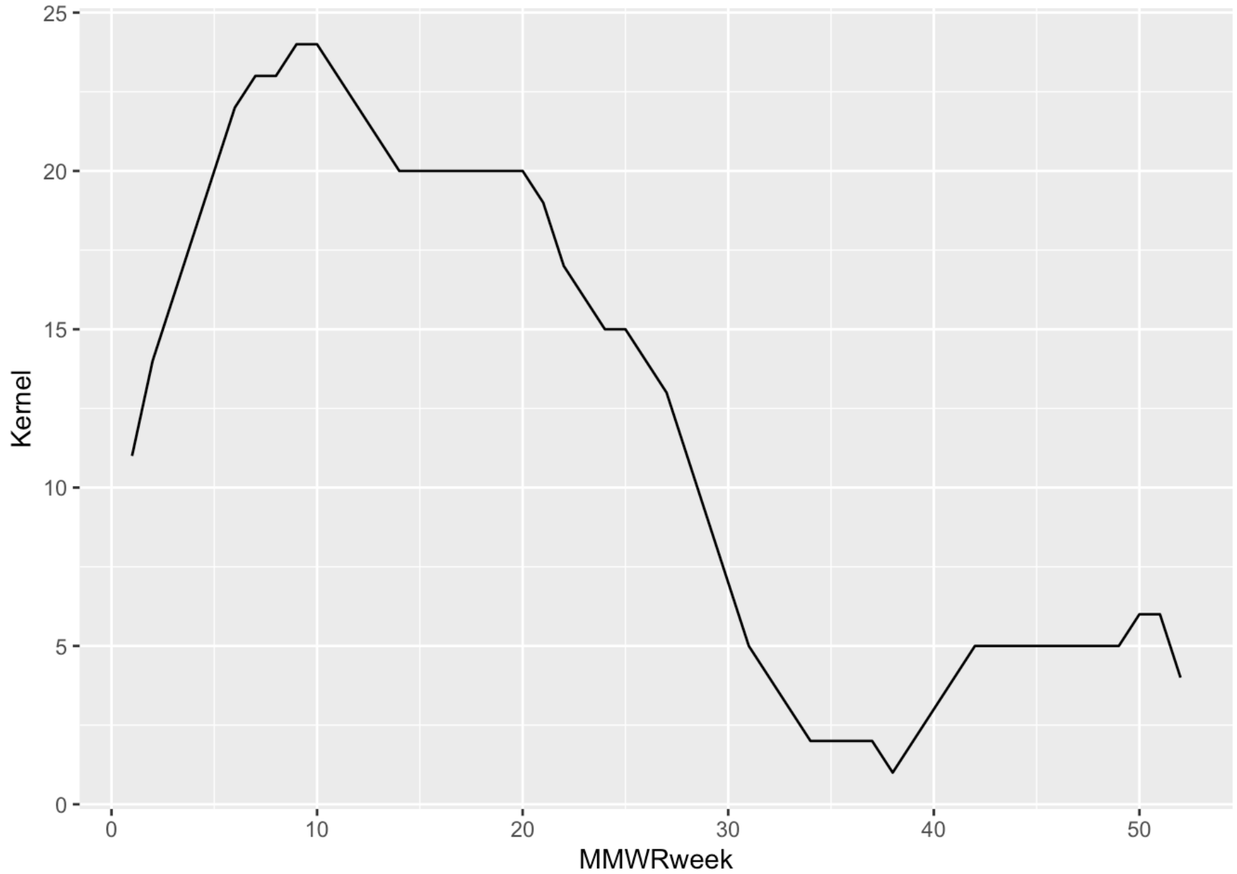




Geometry functions are engines that process data mappings into the defined plot type.

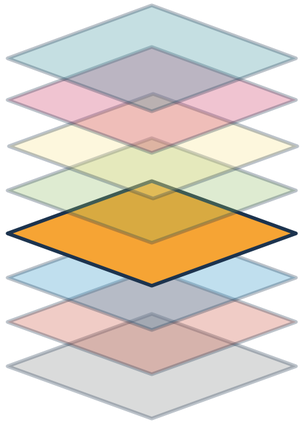
`ggolot() + geom_*(data, aes(), position, statistics)`

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



Discussion:

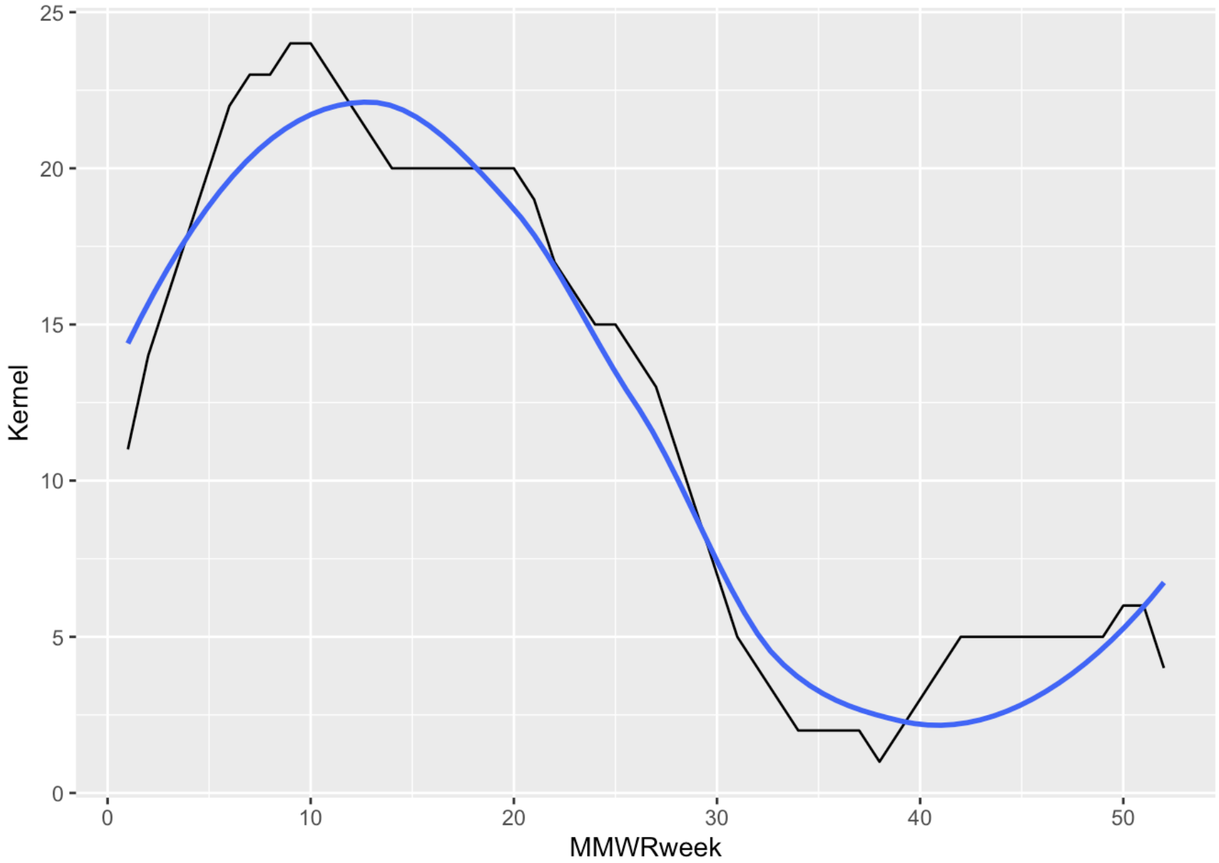
Can you think of reasons why you would choose one over the other?

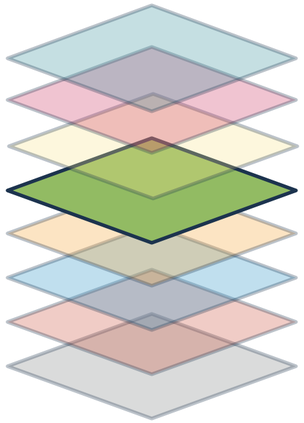


Statistics layers do the statistical calculations used in geometric engines. Many are interchangeable with a comparable geometry.

`ggolot(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)
```

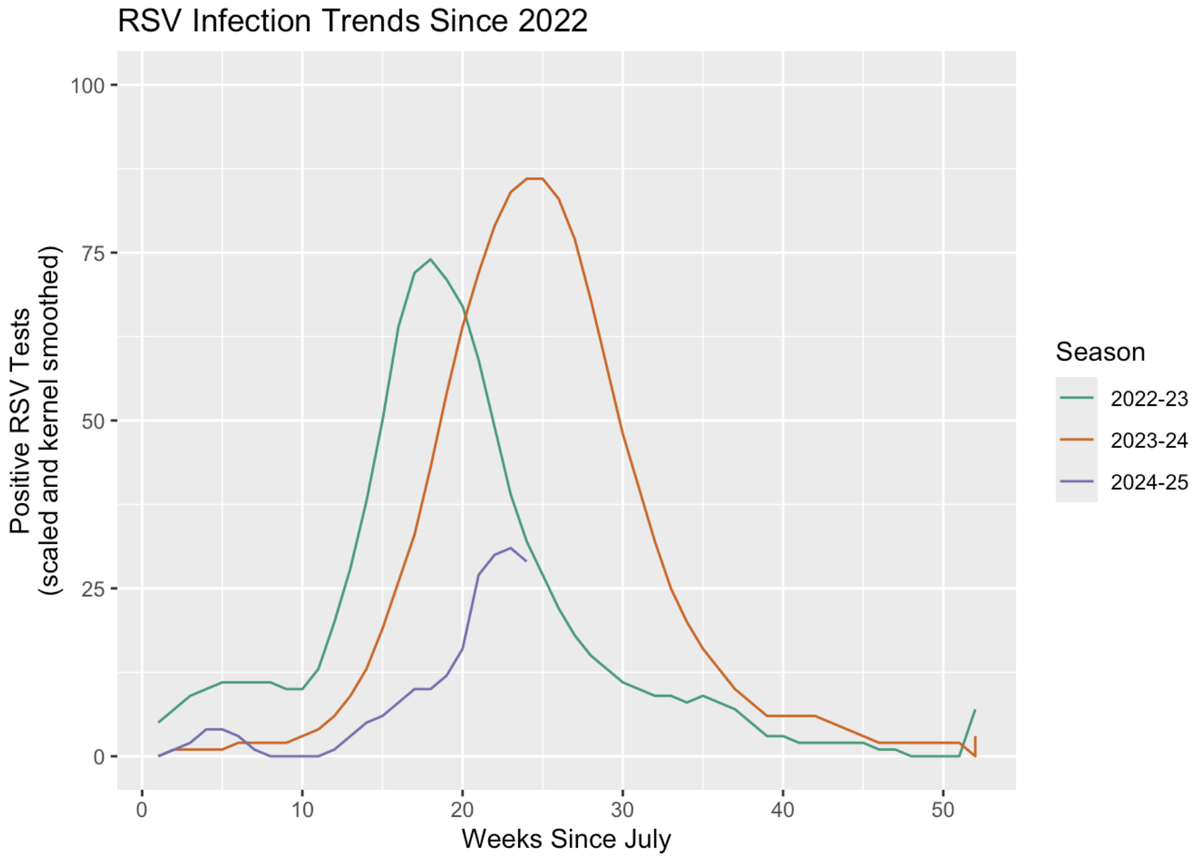




Scales interpret an aesthetic mapping into plottable values. This layer offers the most opportunity for plot customization.

```
ggolot(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")
```



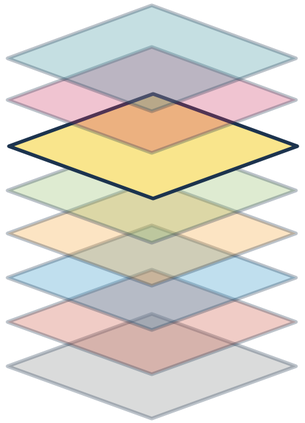
Discussion:

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?

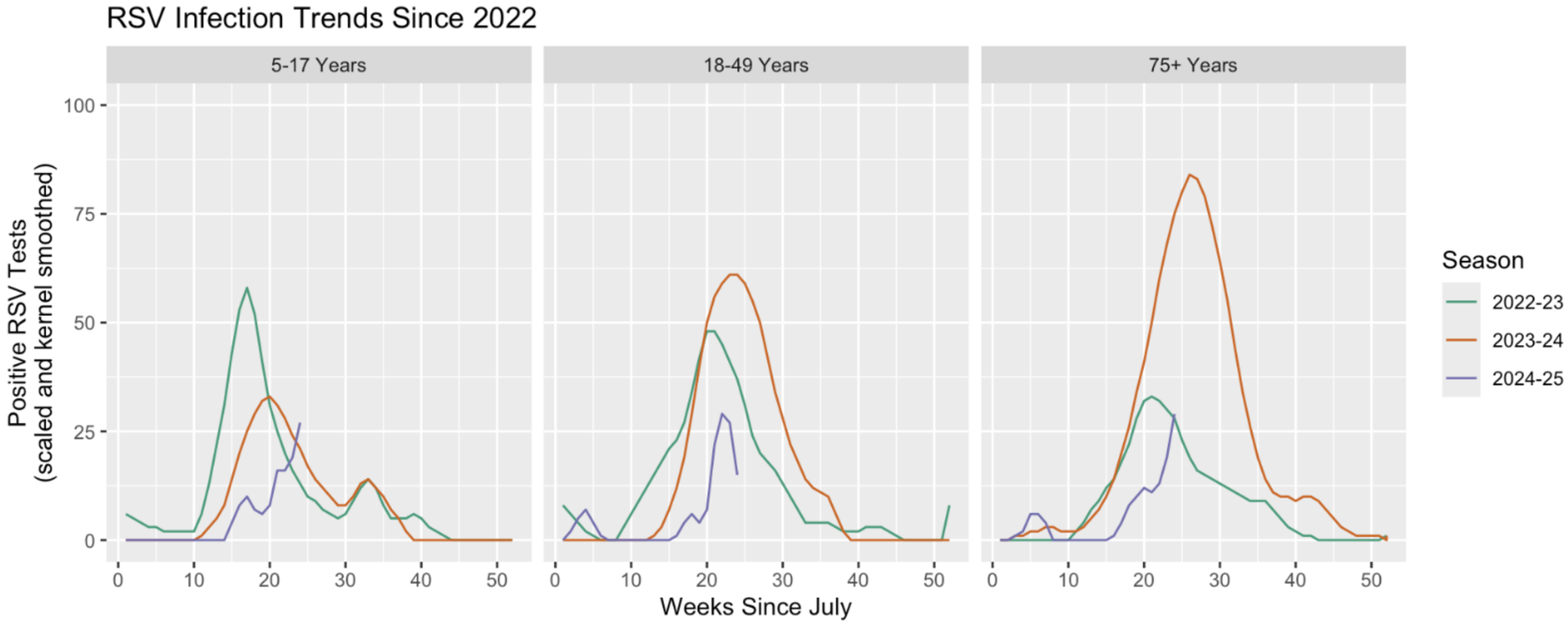
c) Why do we get the result we do?

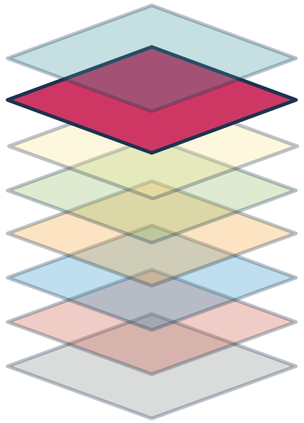


Facets spread out the same plot over subgroups in a discrete variable.

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

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

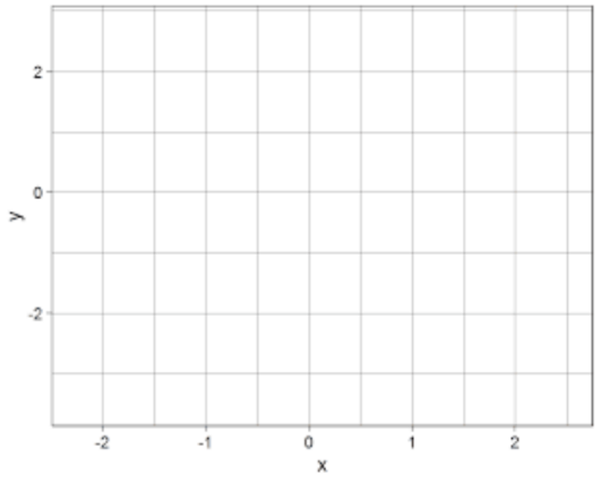




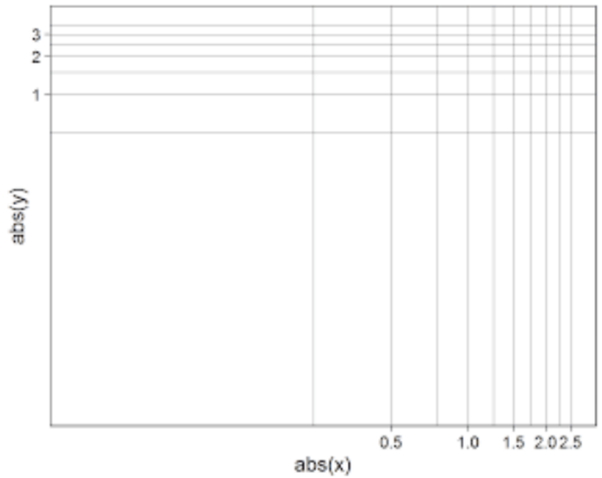
Coordinates plots the values prepared by preceding layers in a specified coordinate system.

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

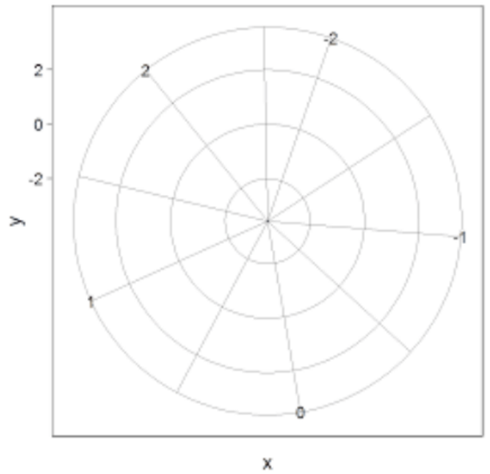
Cartesian



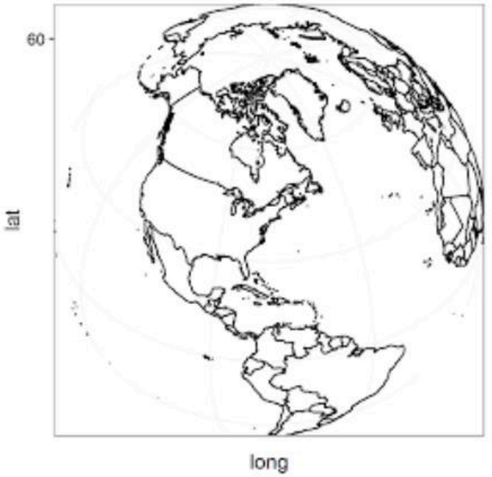
Transformed (log10)



Polar



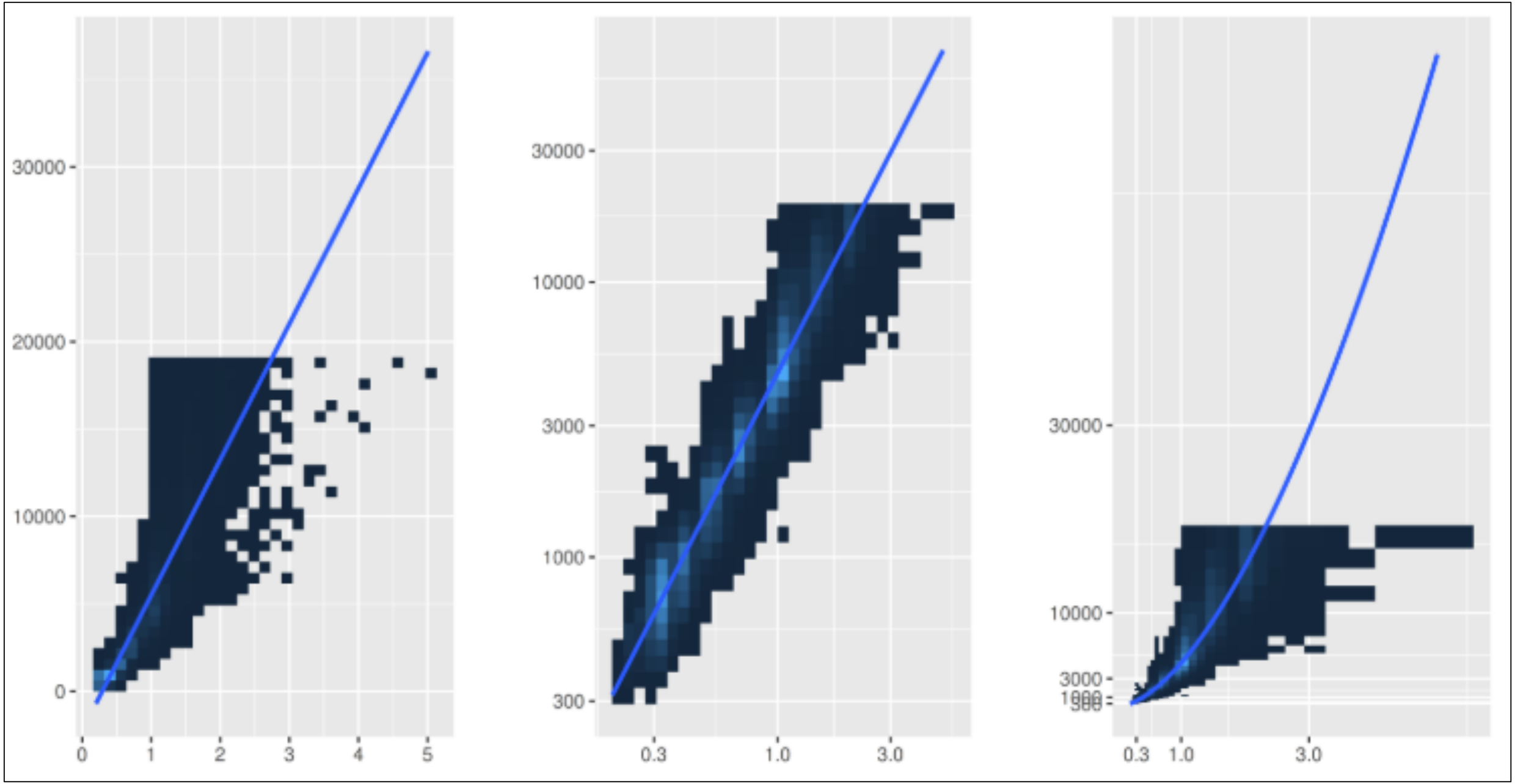
Map



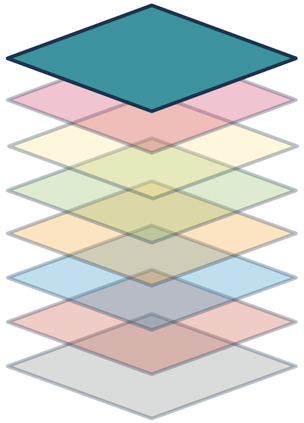
[Data Visualisation: From Theory to Practice Figure 5.5](#) by James Baglin. Accessed March 22nd, 2025.

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?



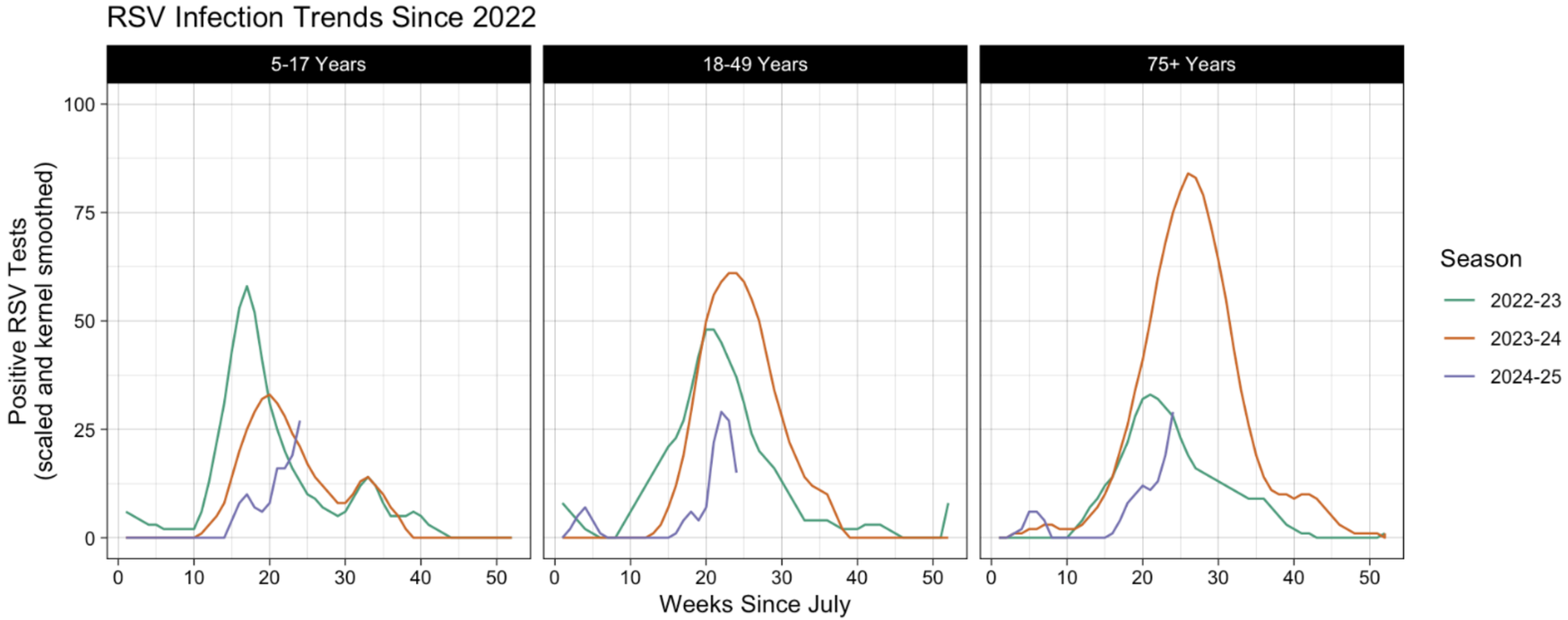
15.2.1 Transformations with coord_trans() from "ggplot2: Elegant Graphics for Data" by Hadley Wickham, Danielle Navarro, and Thomas Lin Pedersen. Accessed March 24th, 2025.



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

```
ggolot(data, aes()) + geom_*()/stat_*() +
   theme_*()
```

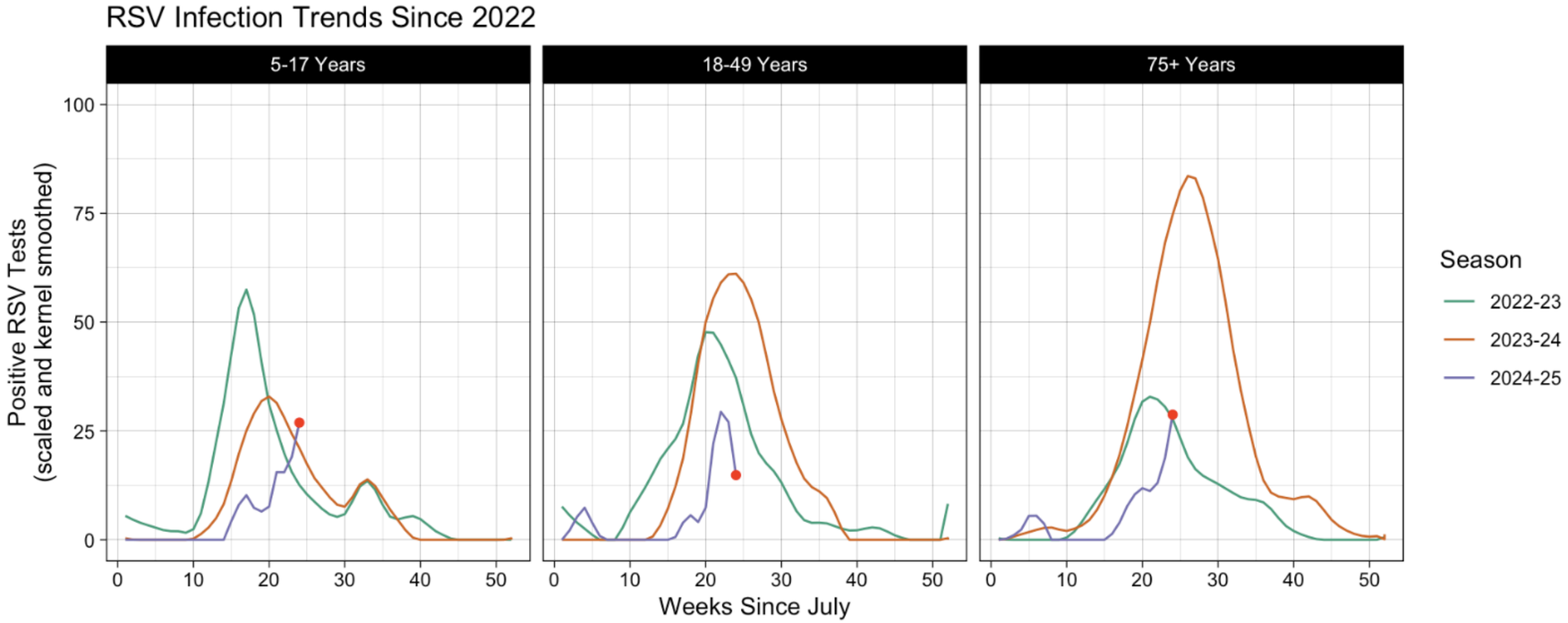
```
df |>
  ggplot(aes(…)) +
    geom_line() +
    …
    theme_linedraw()
```



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) +
    …
```



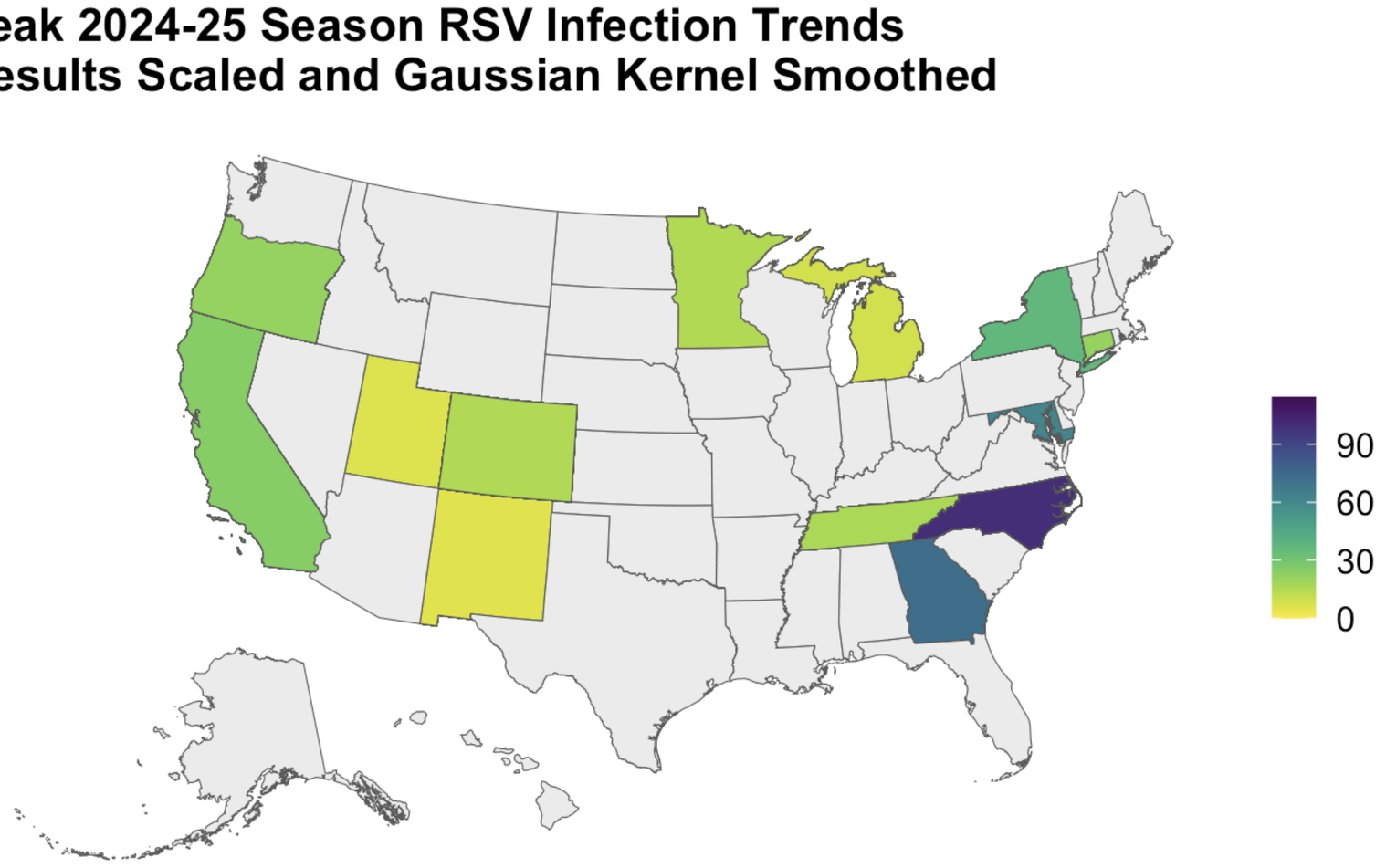
Advanced use of ggplot2

Going beyond the basics

- Community managed ggplot2 extensions list
- R Graph Gallery – fucuses on applications with ggplot2
- Additional topics from ggplot2: Elegant Graphics for Data Analysis: annotations, statistical summaries, spacial networks, and programming with ggplo2, and writing your own extensions to ggplot2
- Extending ggplot2 vignette
- Using ggplot2 in packages vignette

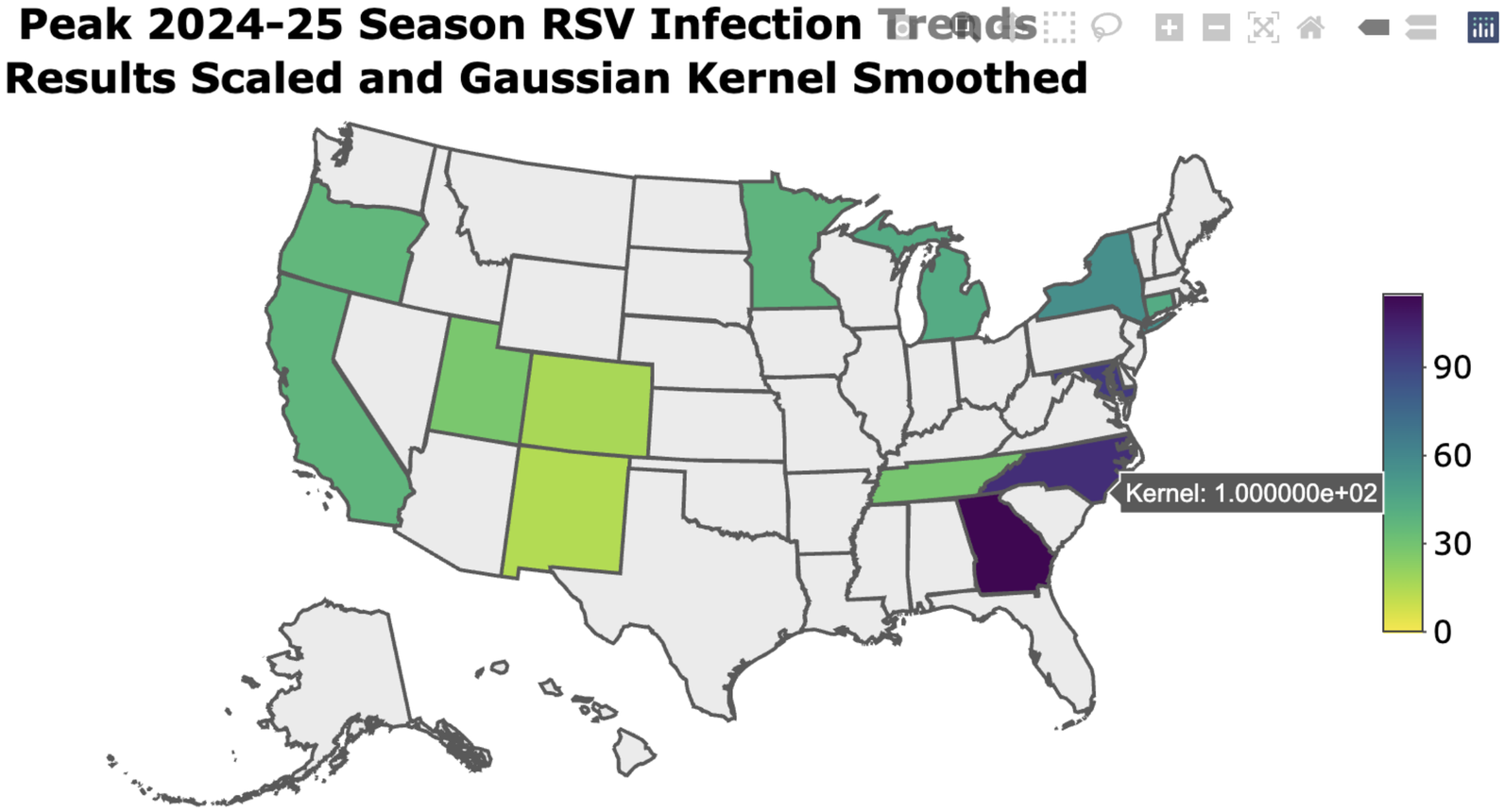
Use vector data, sf, to tell `geom_sf()` where on a map the data gets fille.

```
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

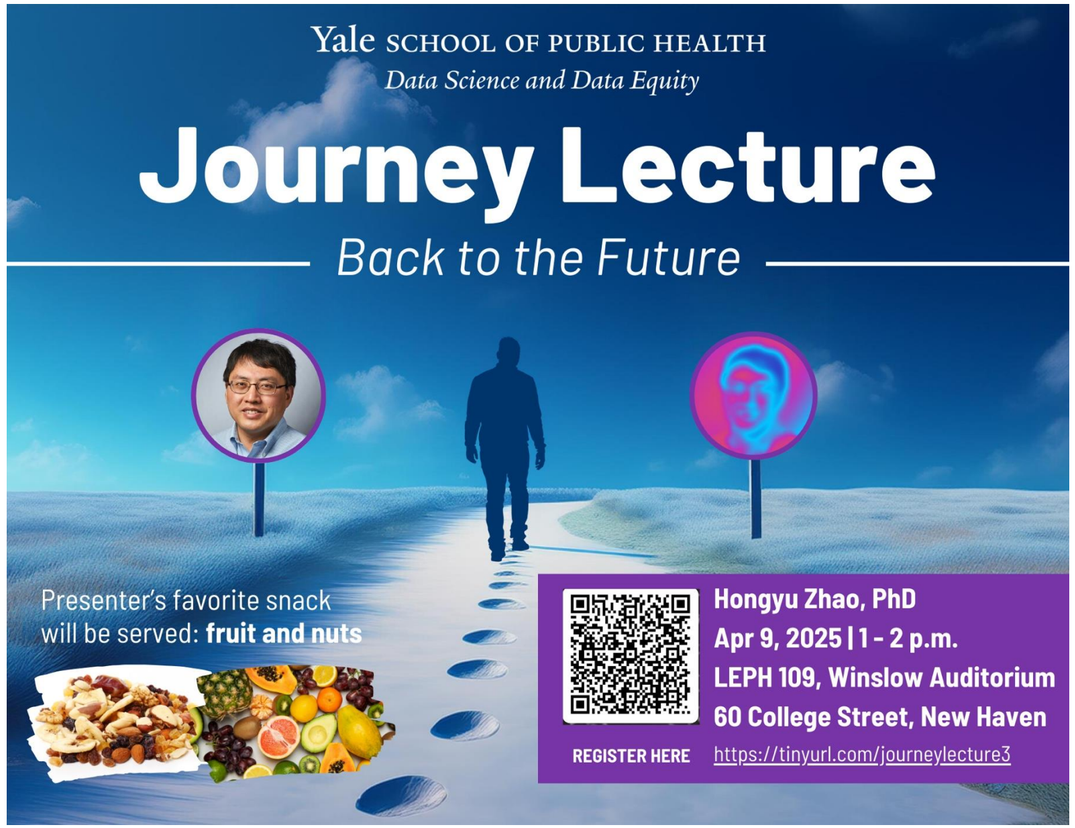
1. Take a screenshot of one of the plots from the workshop or one of your own.
2. Navigate to https://ai-chat.yale.edu/signin-oidc
3. Upload the screenshot into the chat and ask " Suggest R code that could make this plot in ggplot2."

Discuss – how did the AI chatbot do?

Evaluation

Feedback Form for Workshop:
Data Visualization with ggplot2

Next DSDE Event



ysph.yale.edu
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Appendix

Glossary

Grammer 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 Grammer 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

References

Slide 11 continued

3. J. Bertin, Semiology of Graphics: Diagrams, Networks, Maps. Esri Press, 1967. Accessed: Mar. 13, 2025. [Online]. Available: https://www.esri.com/en-us/esri-press/browse/semiology-of-graphics-diagrams-networks-maps
4. E. Meeks, "3rd Wave Data Visualization," Medium. Accessed: Mar. 12, 2025. [Online]. Available: https://medium.com/nightingale/3rd-wave-data-visualization-824c5dc84967
5. J. M. Norman, "Chomsky's Hierarchy of Syntactic Forms : History of Information." Accessed: Mar. 14, 2025. [Online]. Available: https://www.historyofinformation.com/detail.php?id=745
6. 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/
7. L. Wilkinson, "The Grammar of Graphics," Springer, Jan. 1999, doi: 10.1007/0-387-28695-0.

References

Slide 12

1. “ggplot2,” Wikipedia. Accessed: Mar. 13, 2025. [Online]. Available: https://en.wikipedia.org/wiki/Ggplot2
2. T. L. Pedersen, “ggplot2 workshop part 1,” YouTube. Accessed: Mar. 12, 2025. [Online]. Available: https://www.youtube.com/watch?v=h29g21z0a68
3. H. Wickham, “A Layered grammar of graphics,” Journal of Computational and Graphical Statistics, vol. 19, no. 1, pp. 3–28, Mar. 2010, doi: 10.1198/JCGS.2009.07098.

Slide 13

1. W. S. Cleveland and R. McGill, “Graphical perception and graphical methods for analyzing scientific data,” Science, vol. 229, no. 4716, pp. 828–833, Aug. 1985, doi: 10.1126/SCIENCE.229.4716.828.
2. W. Cleveland, The Elements of Graphing Data, Second Edition., no. 814. Chicago, Illinois: Hobart Press, 1994.

References

Slide 13 continued

3. C. Kelleher and T. Wagener, “Ten guidelines for effective data visualization in scientific publications,” Environmental Modelling & Software, vol. 26, no. 6, pp. 822–827, Jun. 2011, doi: 10.1016/J.ENVSOFT.2010.12.006.
4. E. Tufte, Envisioning Information. Cheshire, CT: Graphics Press, LLC, 1990. Accessed: Mar. 14, 2025. [Online]. Available: https://www.edwardtufte.com/book/envisioning-information/
5. E. Tufte, Visual Explanations: Images and Quantities, Evidence and Narrative | Edward Tufte. Cheshire, CT: Graphics Press, LLC, 1996. Accessed: Mar. 14, 2025. [Online]. Available: https://www.edwardtufte.com/book/visual-explanations-images-and-quantities-evidence-and-narrative/

Slide 16

1. H. Wickham et al., “Aesthetic specifications vignette,” ggplot2 Documentation. Accessed: Mar. 22, 2025. [Online]. Available: https://ggplot2.tidyverse.org/articles/ggplot2-specs.html

References

Slide 24

1. J. Baglin, “Data Visualisation: From Theory to Practice.” Accessed: Mar. 21, 2025. [Online]. Available: https://dark-star-161610.appspot.com/secured/_book/index.html

Slide 27

1. M. Pickens, “Learning to create custom themes in ggplot2,” RPubs. Accessed: Mar. 22, 2025. [Online]. Available: https://rpubs.com/mclaire19/ggplot2-custom-themes

Slides 15-28

1. M. Freeman and J. Ross, “Chapter 13 The gglot2 Library | Technical Foundations of Informatics.” Accessed: Mar. 20, 2025. [Online]. Available: https://info201.github.io/ggplot2.html
2. 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/
3. Hadley Wickham et al., “Function references,” ggplot2 Documentation. Accessed: Mar. 09, 2025. [Online]. Available: https://ggplot2.tidyverse.org/reference/index.html

References

Slides 15-28

4. T. L. Pedersen, “ggplot2 workshop part 1,” YouTube. Accessed: Mar. 12, 2025. [Online]. Available: https://www.youtube.com/watch?v=h29g21z0a68
5. 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
6. 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/
7. 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/

Slide 30

1. M. Pickens, “Learning to

References

Slide 31

1. U. C. Bureau, “Understanding Geographic Identifiers (GEOIDs),” Aug. 2024, Accessed: Mar. 23, 2025. [Online]. Available: https://www.census.gov/programs-surveys/geography/guidance/geo-identifiers.html
2. U. C. Bureau, “Cartographic Boundary Files,” Apr. 2024, Accessed: Mar. 23, 2025. [Online]. Available: https://www.census.gov/geographies/mapping-files/time-series/geo/cartographic-boundary.html
3. U. C. Bureau, “TIGER/Line Shapefiles,” Oct. 2024, Accessed: Mar. 23, 2025. [Online]. Available: https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
4. J. Cheng, B. Schloerke, B. Karambelkar, and Y. Xie, “Create Interactive Web Maps with the JavaScript ‘Leaflet’ Library,” CRAN: Contributed Packages, vol. 2.2.2, Mar. 2024, doi: 10.32614/CRAN.PACKAGE.LEAFLET.
5. Office of Intergovernmental and External Affairs (IEA), “HHS Regional Offices,” HHS.gov. Accessed: Mar. 23, 2025. [Online]. Available: https://www.hhs.gov/about/agencies/iea/regional-offices/index.html

References

Slide 31

6. US Census Bureau, “Legal/Statistical Area Description (LSAD) Codes.” Accessed: Mar. 23, 2025. [Online]. Available: https://www2.census.gov/geo/pdfs/reference/LSADCodes.pdf

7. Various, “Topologically Integrated Geographic Encoding and Referencing,” Wikipedia. Accessed: Mar. 23, 2025. [Online]. Available: https://en.wikipedia.org/wiki/Topologically_Integrated_Geographic_Encoding_and_Referencing

Slide 32

1. “The R Graph Gallery - Interactive charts.” Accessed: Mar. 24, 2025. [Online]. Available: https://r-graph-gallery.com/interactive-charts.html

2. “Plotly r graphing library in R,” plotly Documentation. Accessed: Mar. 24, 2025. [Online]. Available: https://plotly.com/r/

3. “Plotly graphing library for ggplot2 in ggplot2,” plotly Documentation. Accessed: Mar. 24, 2025. [Online]. Available: https://plotly.com/ggplot2/

References

Slide 32 continued

4. “Plotly Open Source Graphing Libraries,” plotly Documentation. Accessed: Mar. 24, 2025. [Online]. Available: https://plotly.com/graphing-libraries/

Only used in the “Worked Through Example.qmd”

1. C. Wilke, “Streamlined Plot Theme and Plot Annotations for ggplot2 • cowplot.” Accessed: Mar. 20, 2025. [Online]. Available: https://wilkelab.org/cowplot/

Data and Data Processing

1. Answered by Hong Ooi, “lm() within mutate() in group_by(),” Stack Overflow. Accessed: Mar. 17, 2025. [Online]. Available: https://stackoverflow.com/questions/40060828/lm-within-mutate-in-group-by

2. Center for Disease Control (CDC), “MMWR Weeks Definition”, Accessed: Mar. 14, 2025. [Online]. Available: https://ndc.services.cdc.gov/wp-content/uploads/MMWR_week_overview.pdf

3. Center for Disease Control (CDC), “RSV-NET,” cdc.gov. Accessed: Mar. 24, 2025. [Online]. Available: https://www.cdc.gov/rsv/php/surveillance/rsv-net.html

References

Data and Data Processing

4. Center for Disease Control (CDC), “MMWR Weeks Definition”, Accessed: Mar. 14, 2025. [Online]. Available: https://ndc.services.cdc.gov/wp-content/uploads/MMWR_week_overview.pdf

5. R. Zhu, “Statistical Learning and Machine Learning with R.” Accessed: Mar. 17, 2025. [Online]. Available: https://teazrq.github.io/SMLR/kernel-smoothing.html

Glossary

1. Hadley Wickham et al., ggplot2: Elegant Graphics for Data Analysis Documentation. New York: Springer-Verlag, 2016. Accessed: Mar. 12, 2025. [Online]. Available: https://ggplot2.tidyverse.org/

2. 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

3. 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/