

DATA VISUALIZATION

Plotting pitfalls: the data vis hall of shame

Plot critique

The grammar of graphics

The five most important plots

Enriching plots (color, faceting, labels, etc)

THE DATA VIS HALL OF SHAME

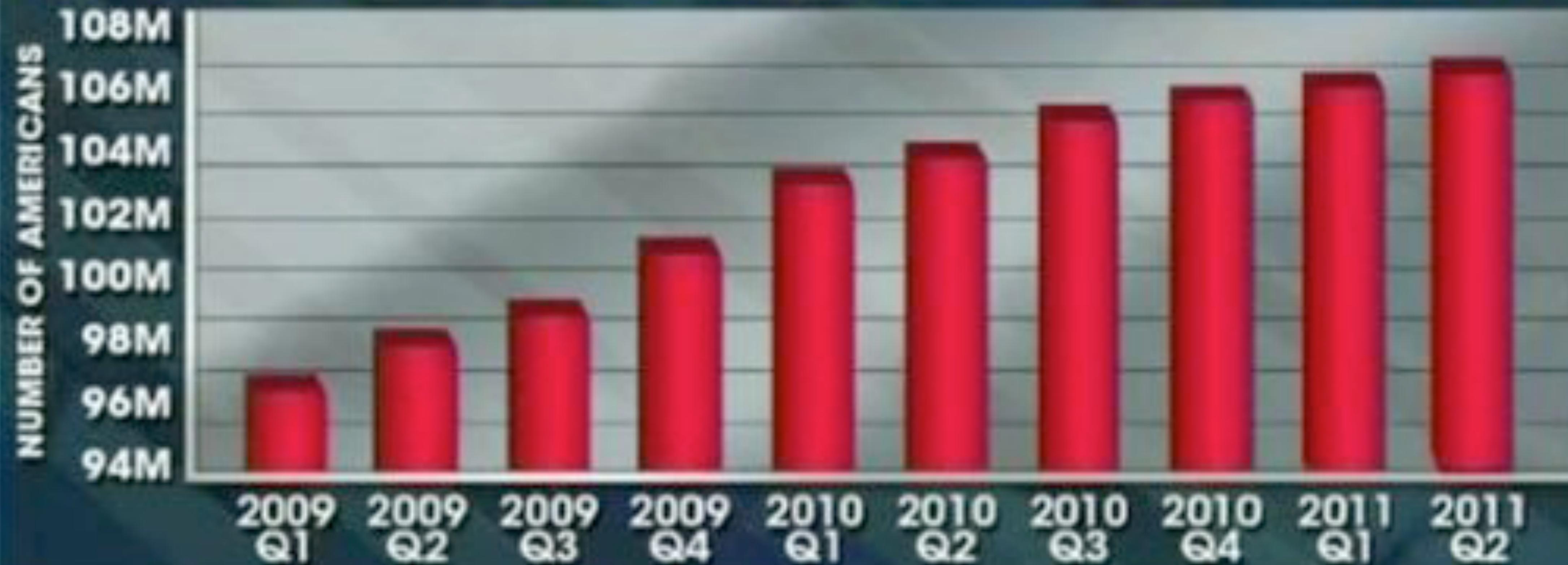
PLOTTING PITFALLS

- **Axis trickery**
- **Violations of basic math**
- **Nearly content-free figures**
- **Gratuitous chartjunk**
- **Poorly chosen 3D graphics**
- **Bad design choices**

PLOTTING PITFALLS

- **Axis trickery (a.k.a. “little y lies”)**
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FEDERAL WELFARE RECEIVED IN U.S.



FOX NEWS FOX
NEWS NETS
.COM

SOURCE: U.S. CENSUS SURVEY

:LIST TYLER HAMILTON OF HIS GOLD MEDAL FRO!

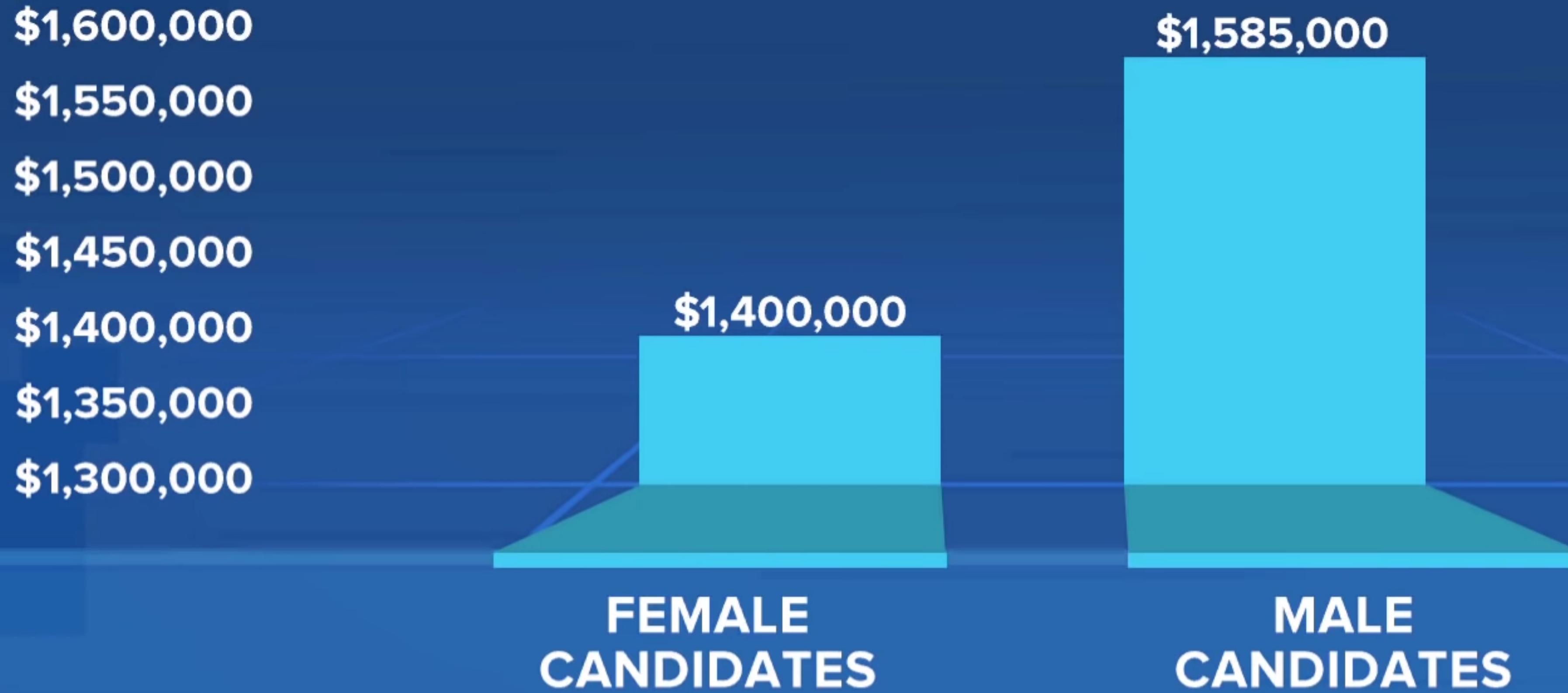
NAS



6.61

DEMOCRATIC WOMEN RAISE LESS MONEY THAN DEMOCRATIC MEN

AVERAGE RAISED BY HOUSE PRIMARY WINNERS



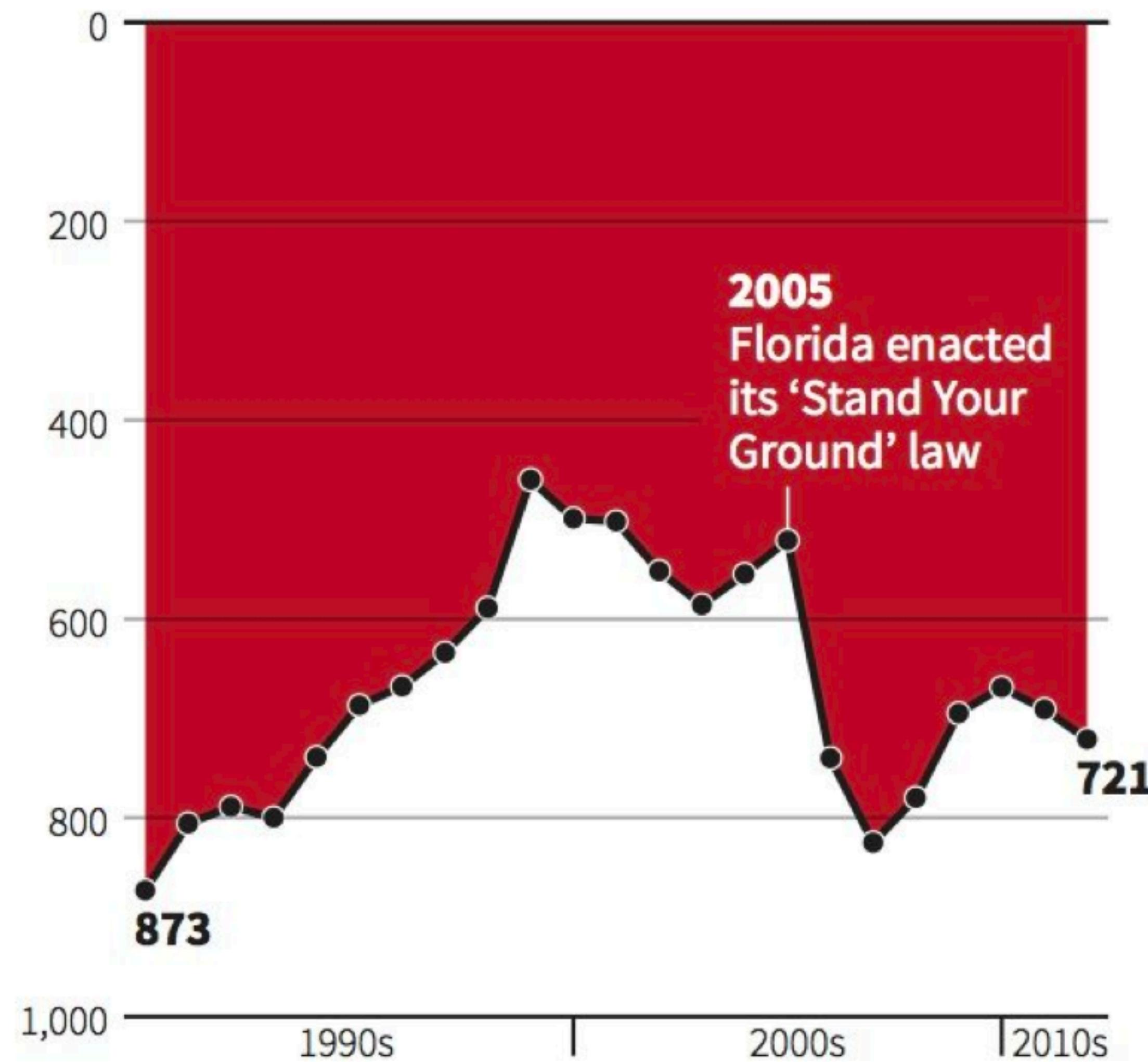
SOURCE: CENTER FOR RESPONSIVE POLITICS

SHOULD BRITAIN LEAVE EU?



Gun deaths in Florida

Number of murders committed using firearms



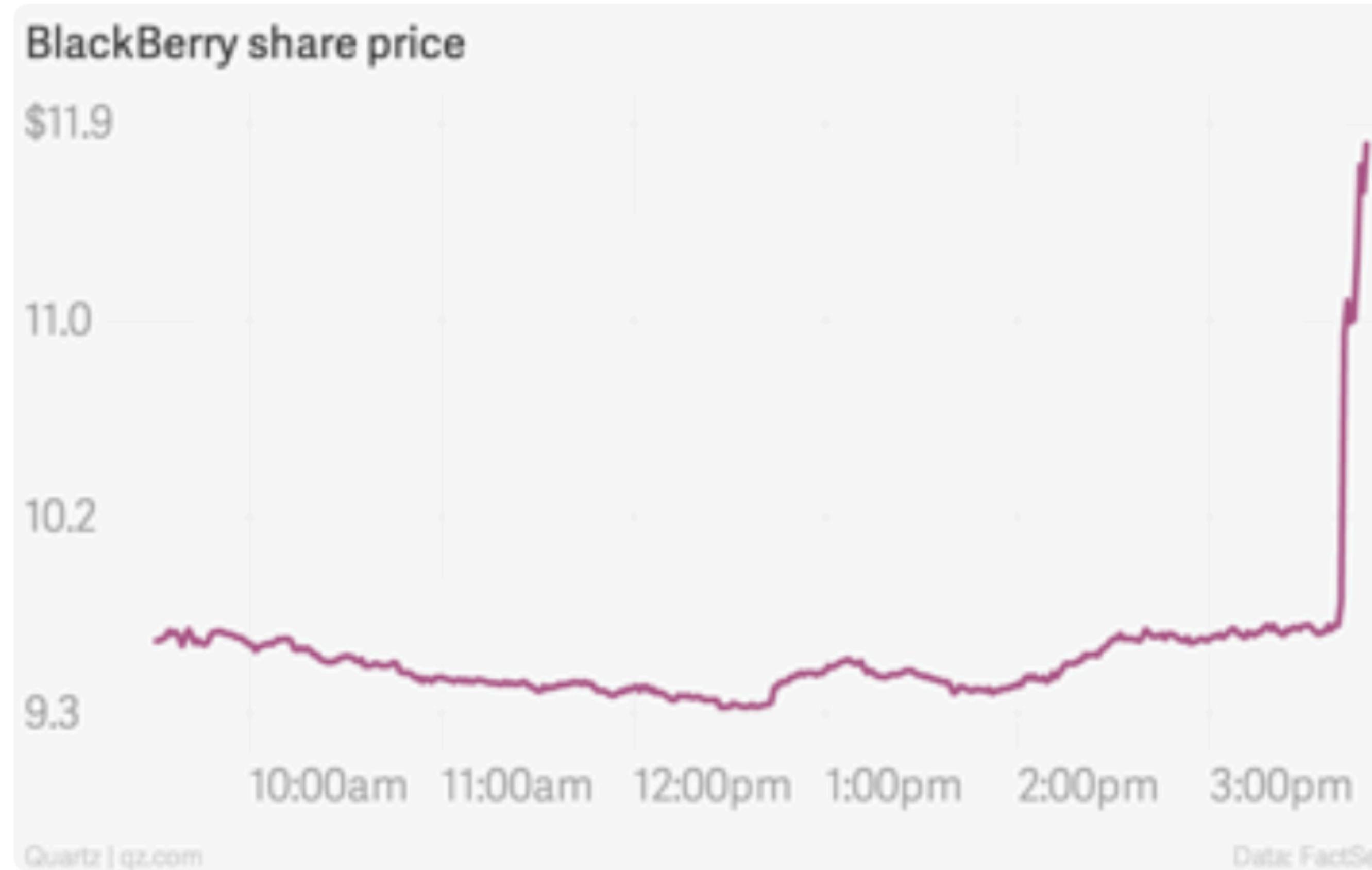
Source: Florida Department of Law Enforcement

AND YET...



Quartz @qz

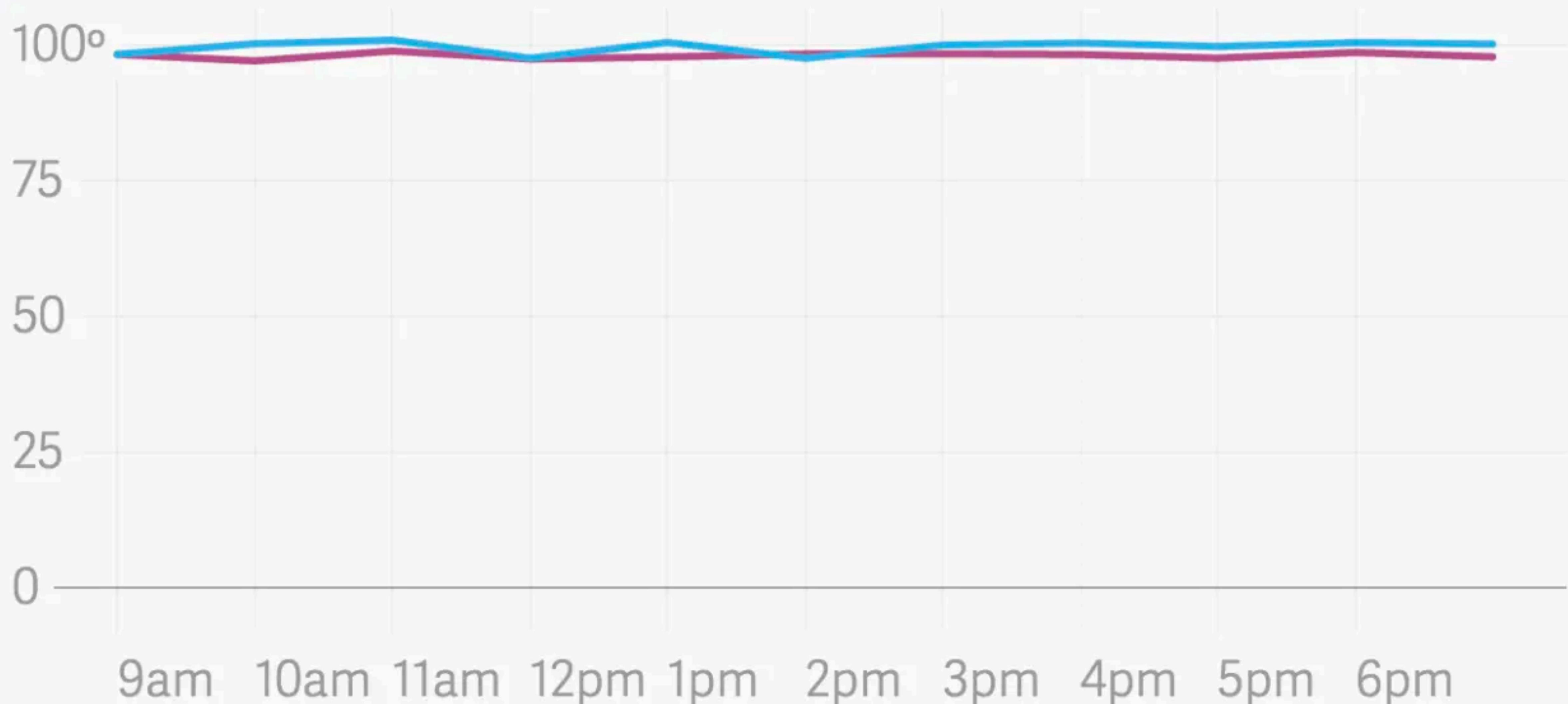
Acquisition rumors light a fire under BlackBerry's stock.
qz.com/note/326942/



6 4:44 PM - Jan 14, 2015

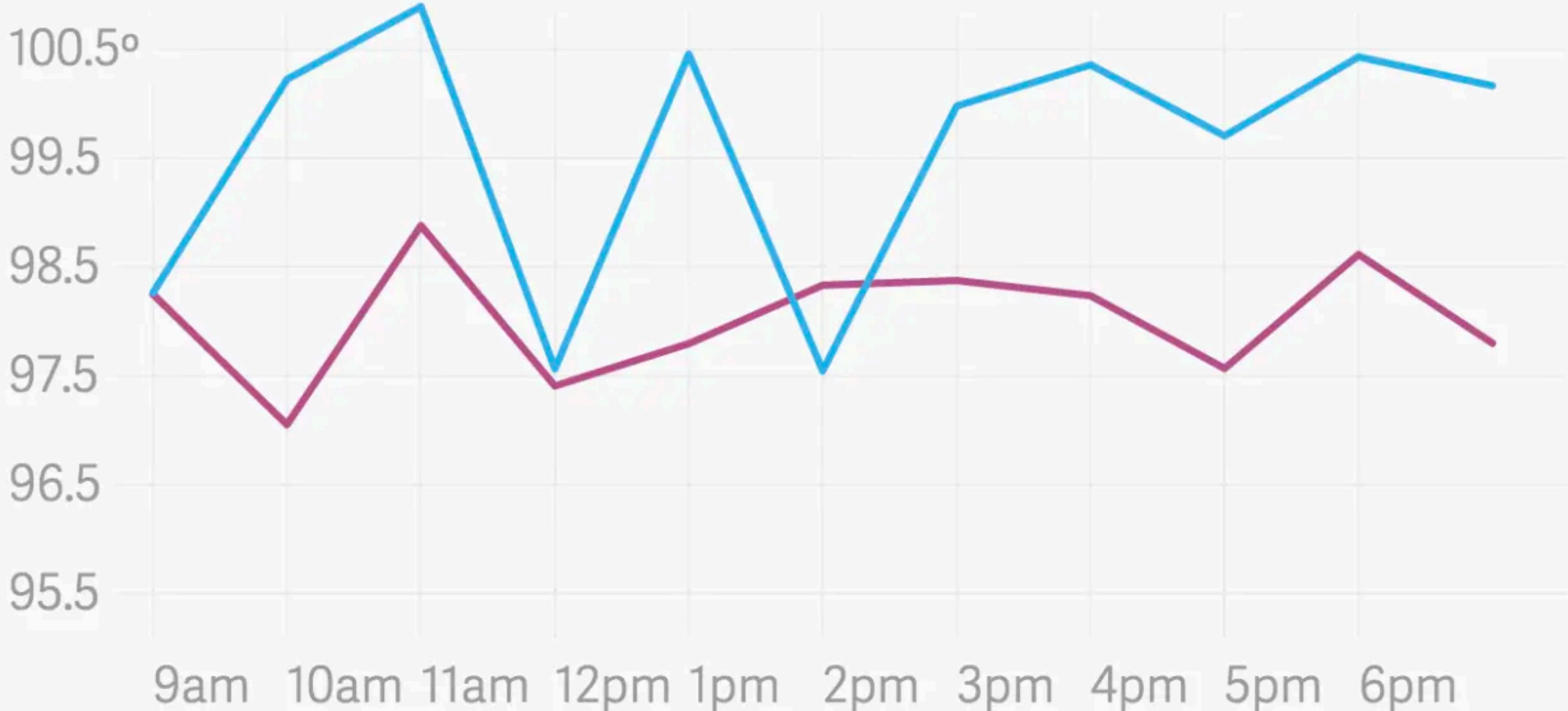
Oral temperature

Sara Bob



Oral temperature

Sara Bob



TRUNCATING THE Y AXIS IS SOMETIMES OK

- When you're trying to emphasize change, rather than relative magnitude.
- When you're plotting data over time.
- When zero is not a sensible baseline for comparison.

Bottom line: use your judgment; don't mislead people; watch out for “little y lies.”

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RASMUSSEN REPORTS POLL

Did scientists falsify research to support their own theories on Global Warming?

59%

SOMEWHAT LIKELY

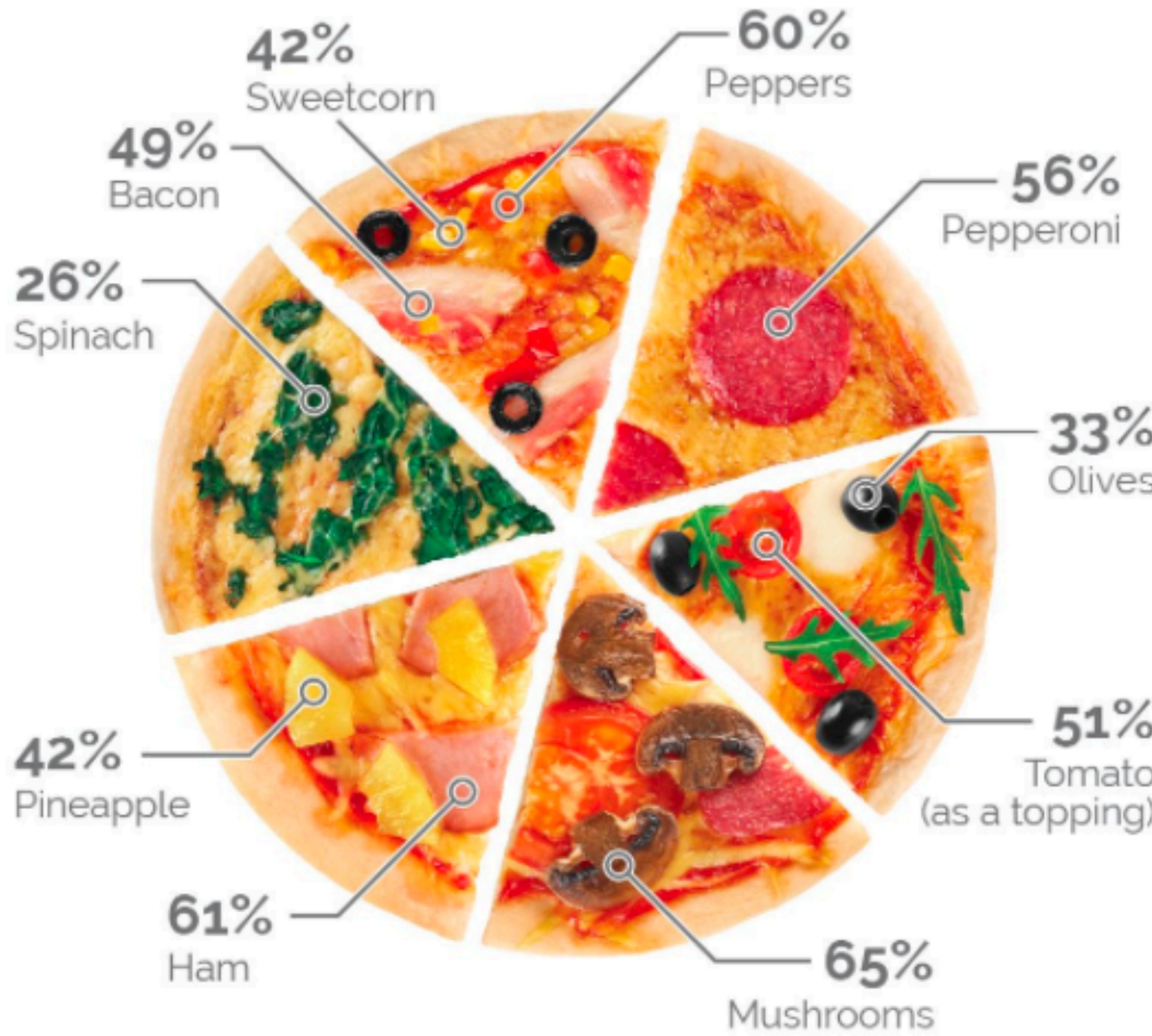
35%

VERY LIKELY

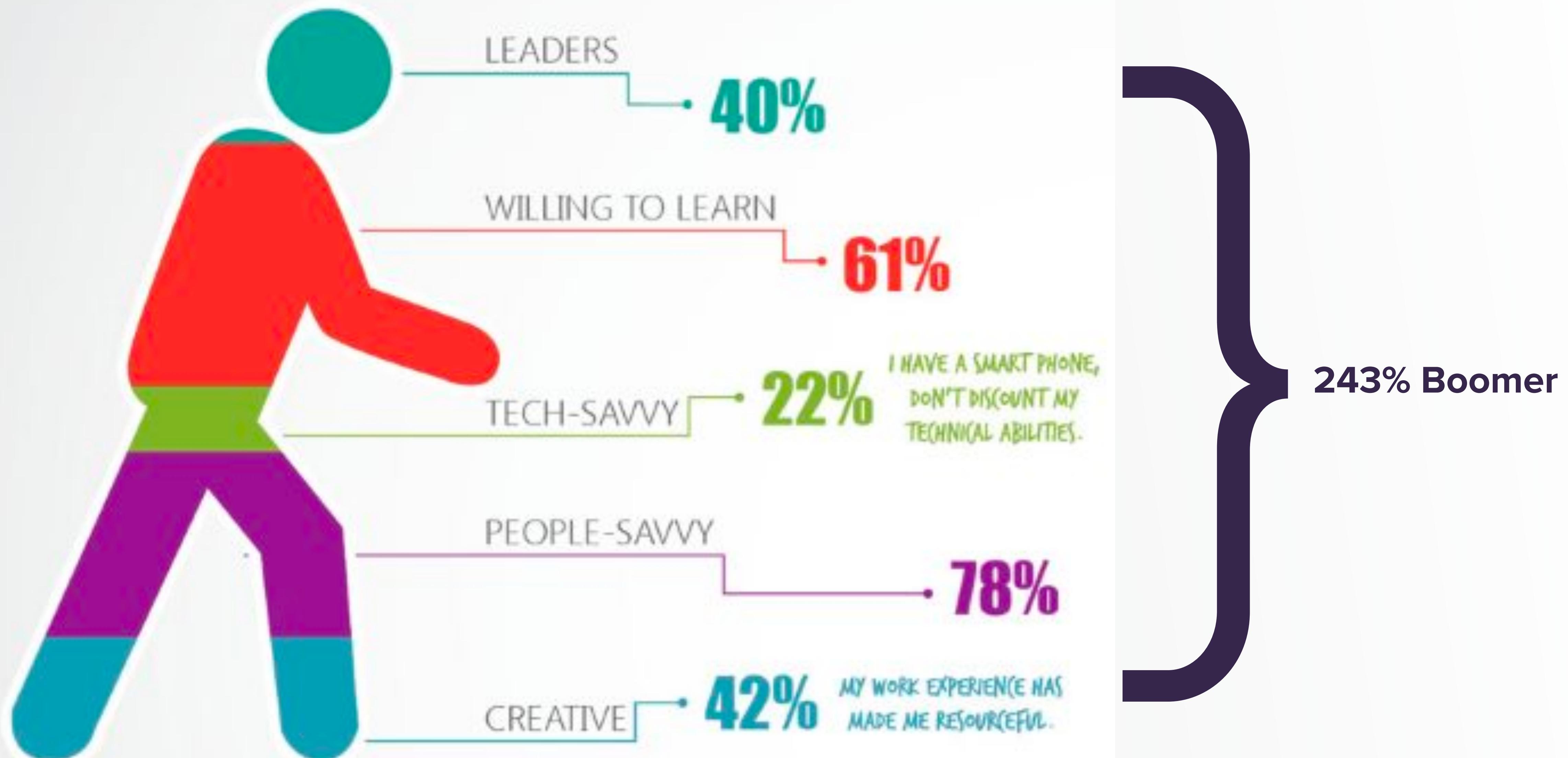
26%

NOT VERY LIKELY





HOW BABY BOOMERS DESCRIBE THEMSELVES



UNEMPLOYMENT RATE UNDER PRESIDENT OBAMA



WHAT IS YOUR FAVORITE SEASON? @FCNMIKE

53%

FALL

17%

SUMMER

17%

WINTER

13%

SPRING



75°
6:51

FIRST COAST
NEWS

#KATIESCOMMUTERS

DEADLY CRASH

DEADLY HOME INVASION

DAILY FORECAST

LOW: 64° / HIGH: 77°

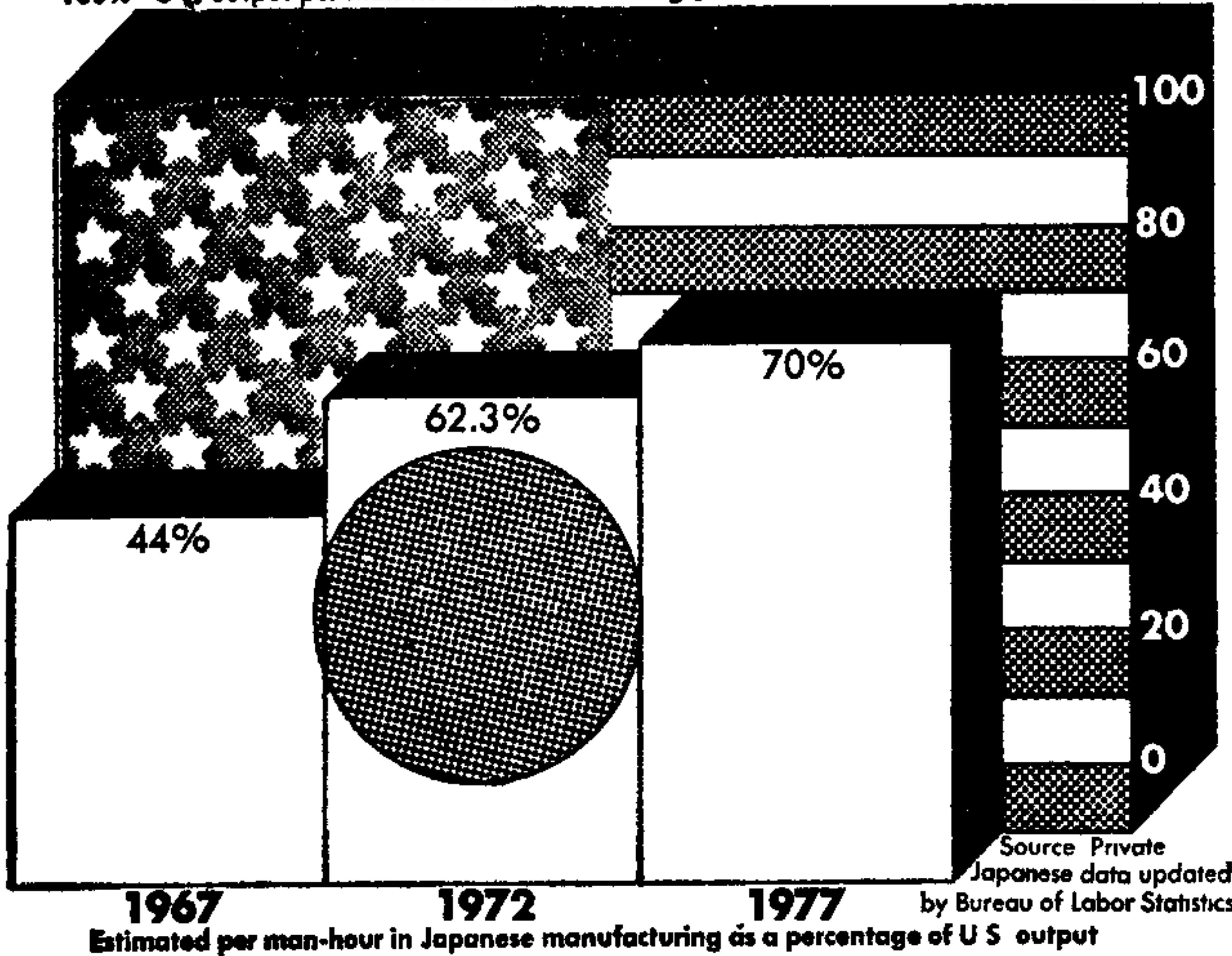
LOW: 64° / HIGH: 77°

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Labor Productivity: U.S. vs Japan

100% = U.S. output per man-hour in manufacturing

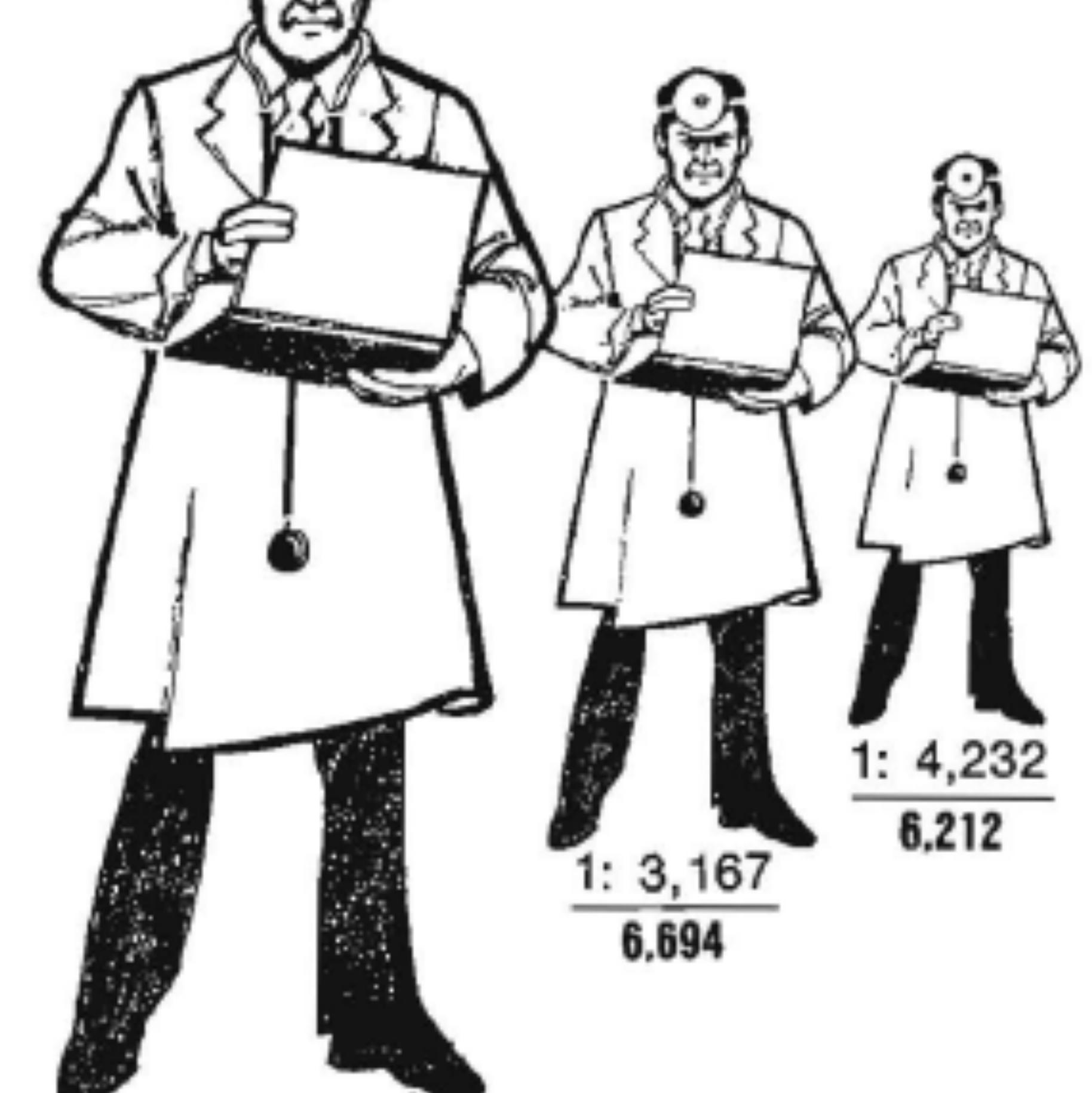


THE SHRINKING FAMILY DOCTOR

In California

Percentage of Doctors Devoted Solely to Family Practice

1964	1975	1990
27%	16.0%	12.0%



TRUMP TWEETS MENTIONING MUELLER BY NAME

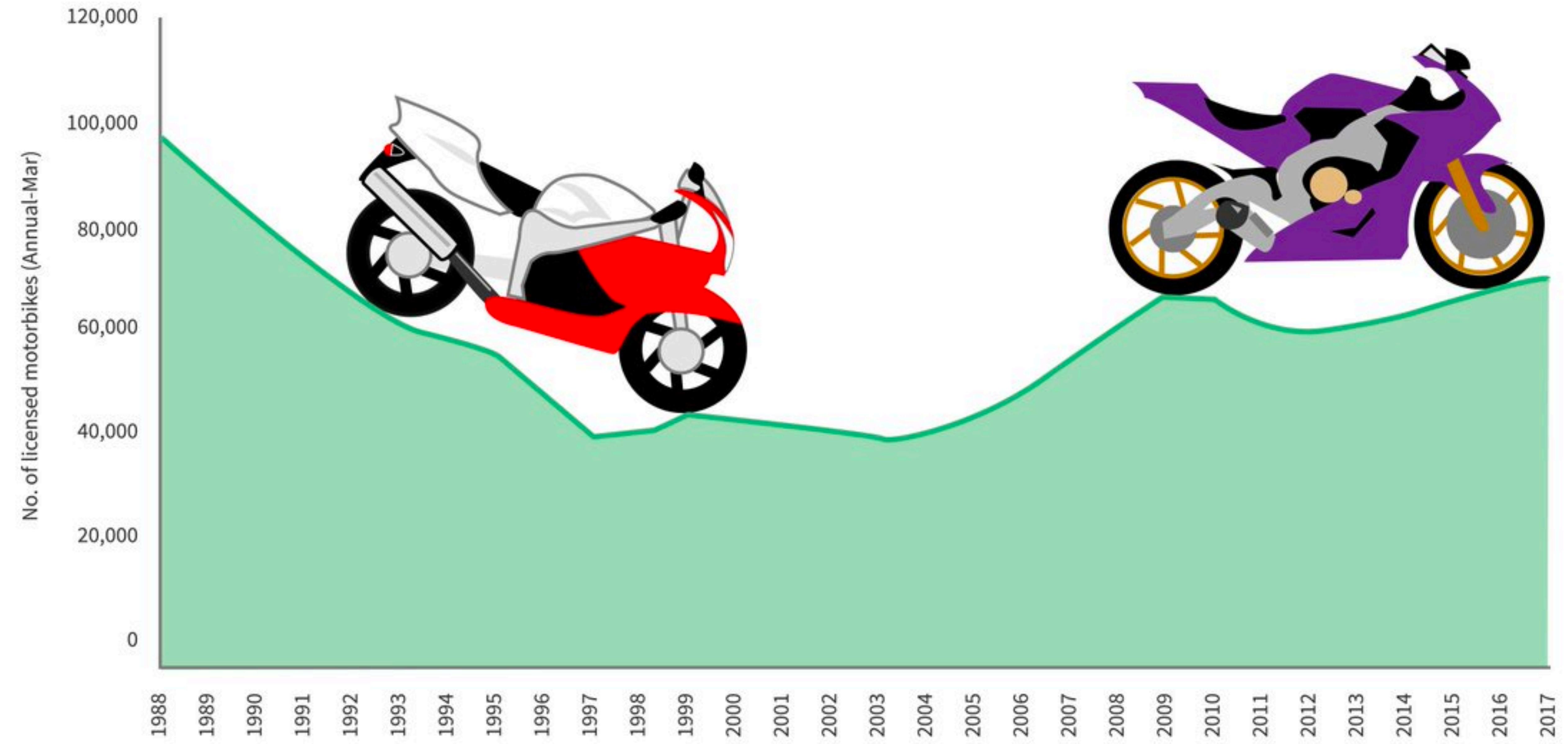


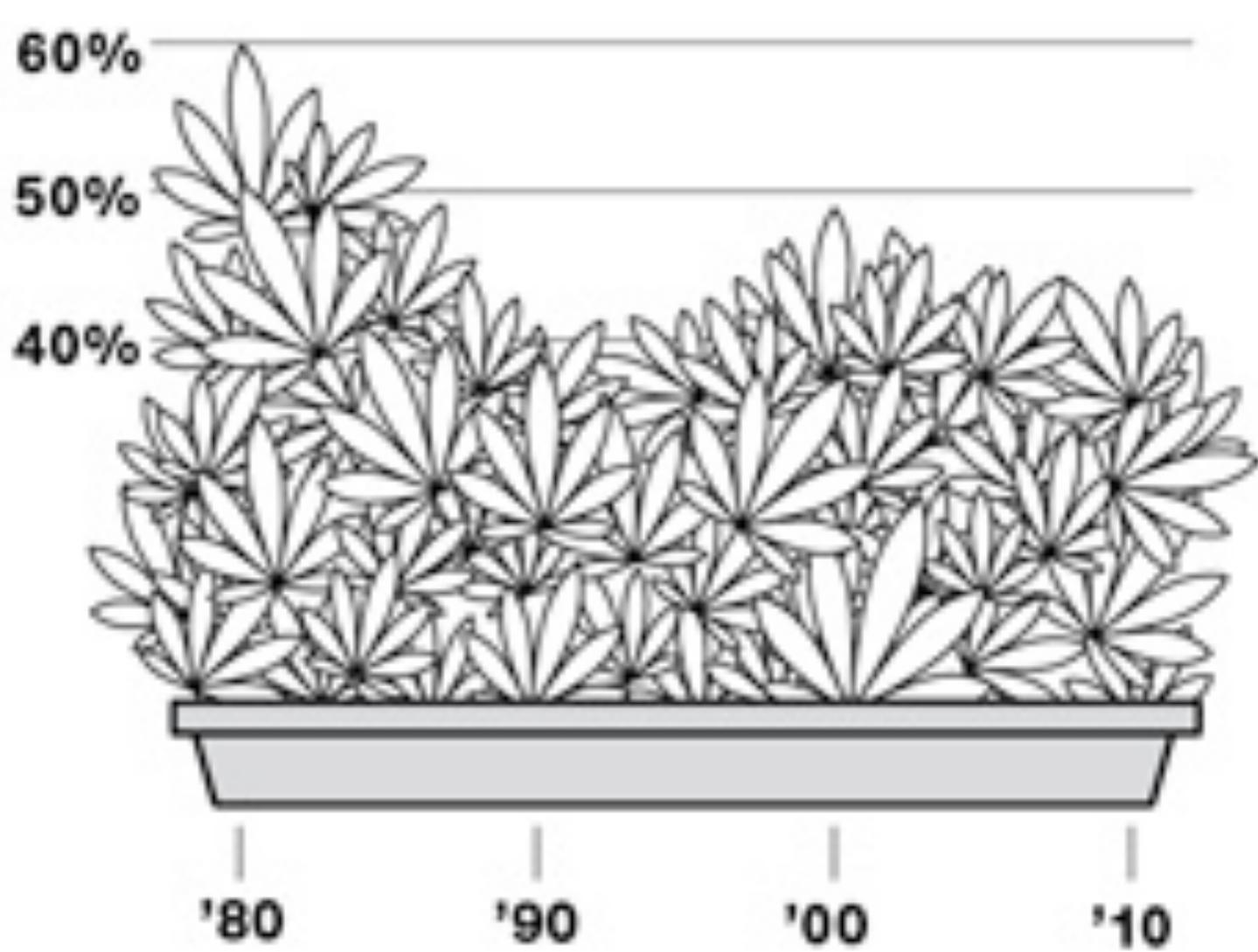
LIVE

 MSNBC

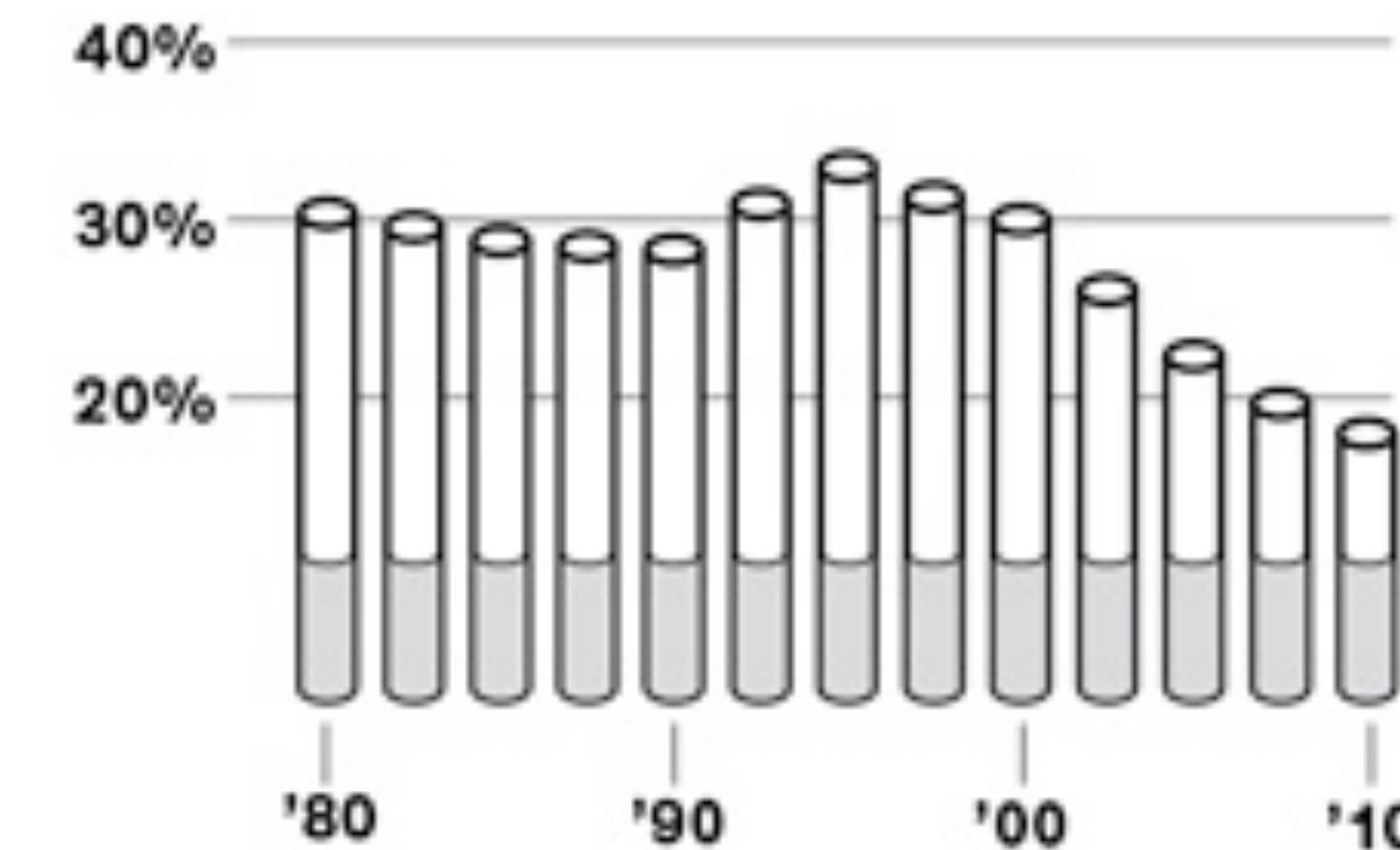
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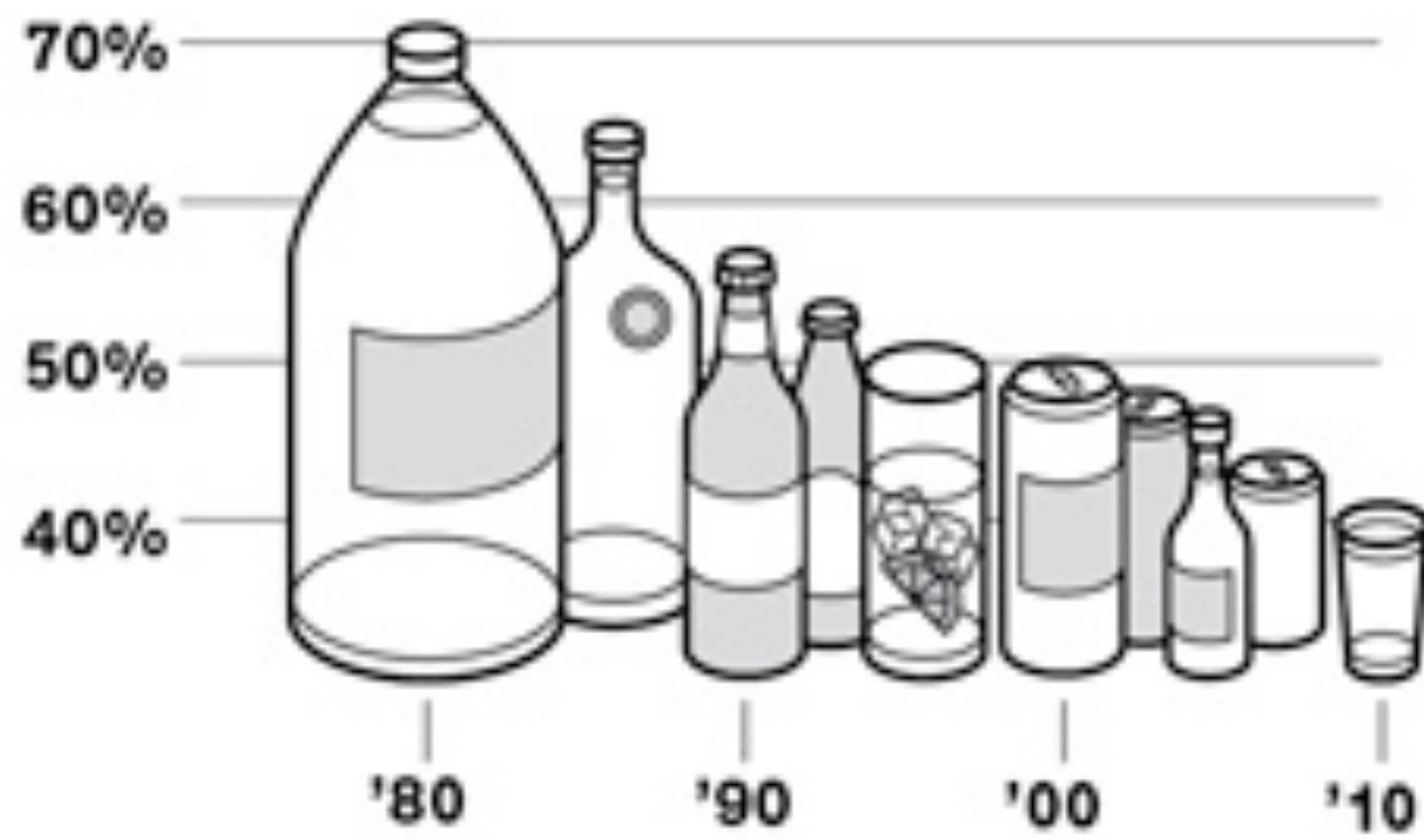




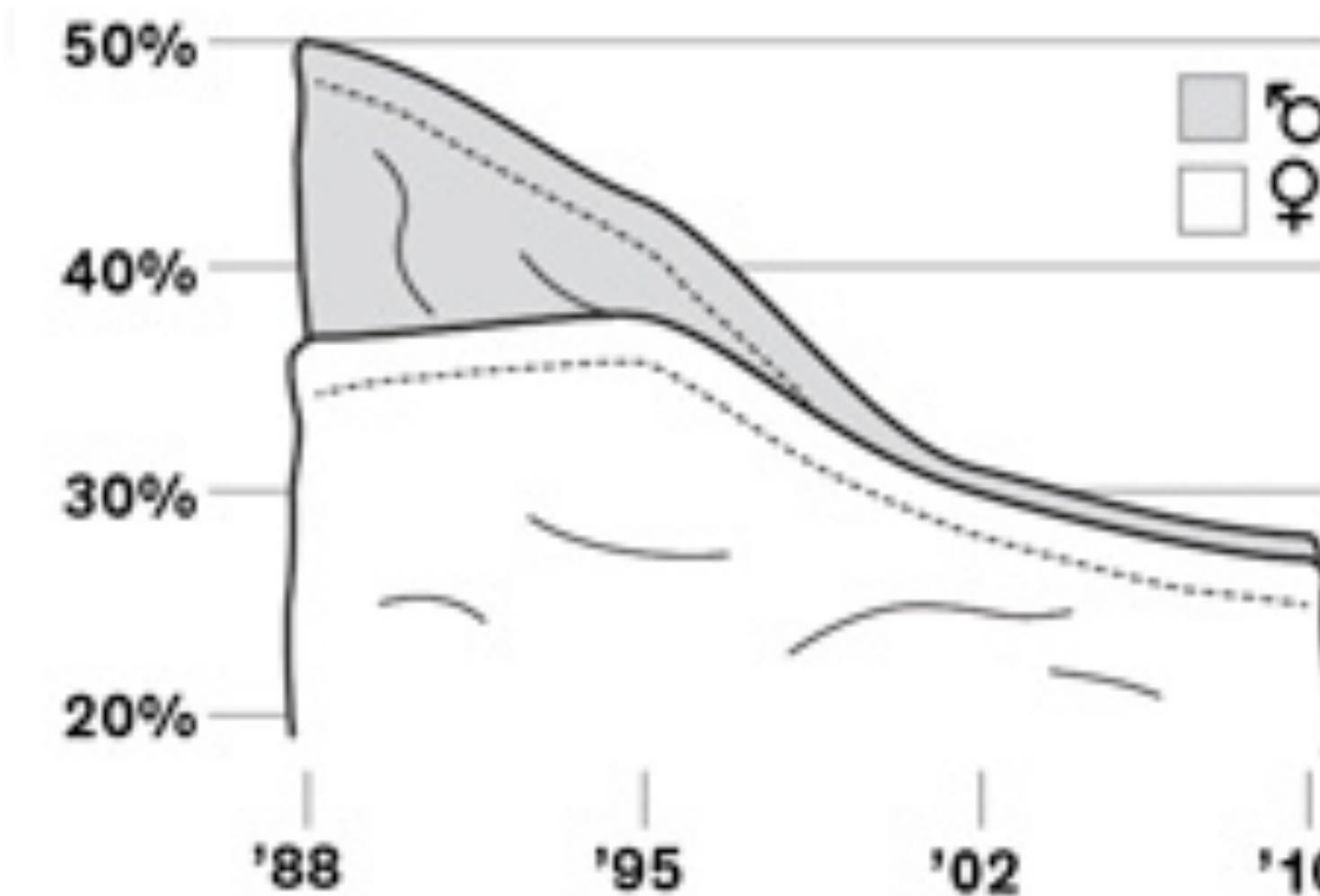
▲ Percentage of high-school seniors
who have ever tried pot.



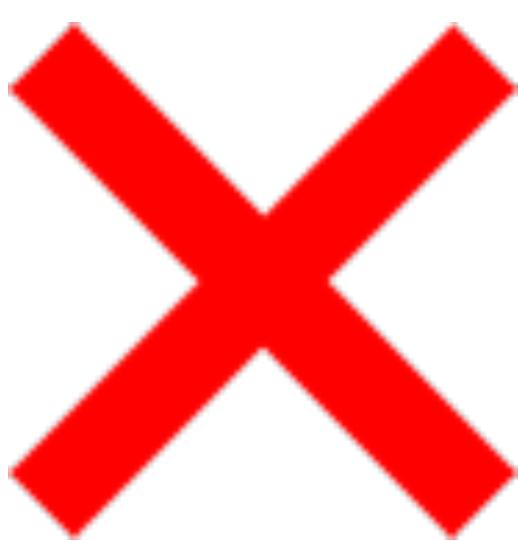
▣ Smoking habits of high-school
seniors over time.



○ Alcohol use by high-school
seniors over time.

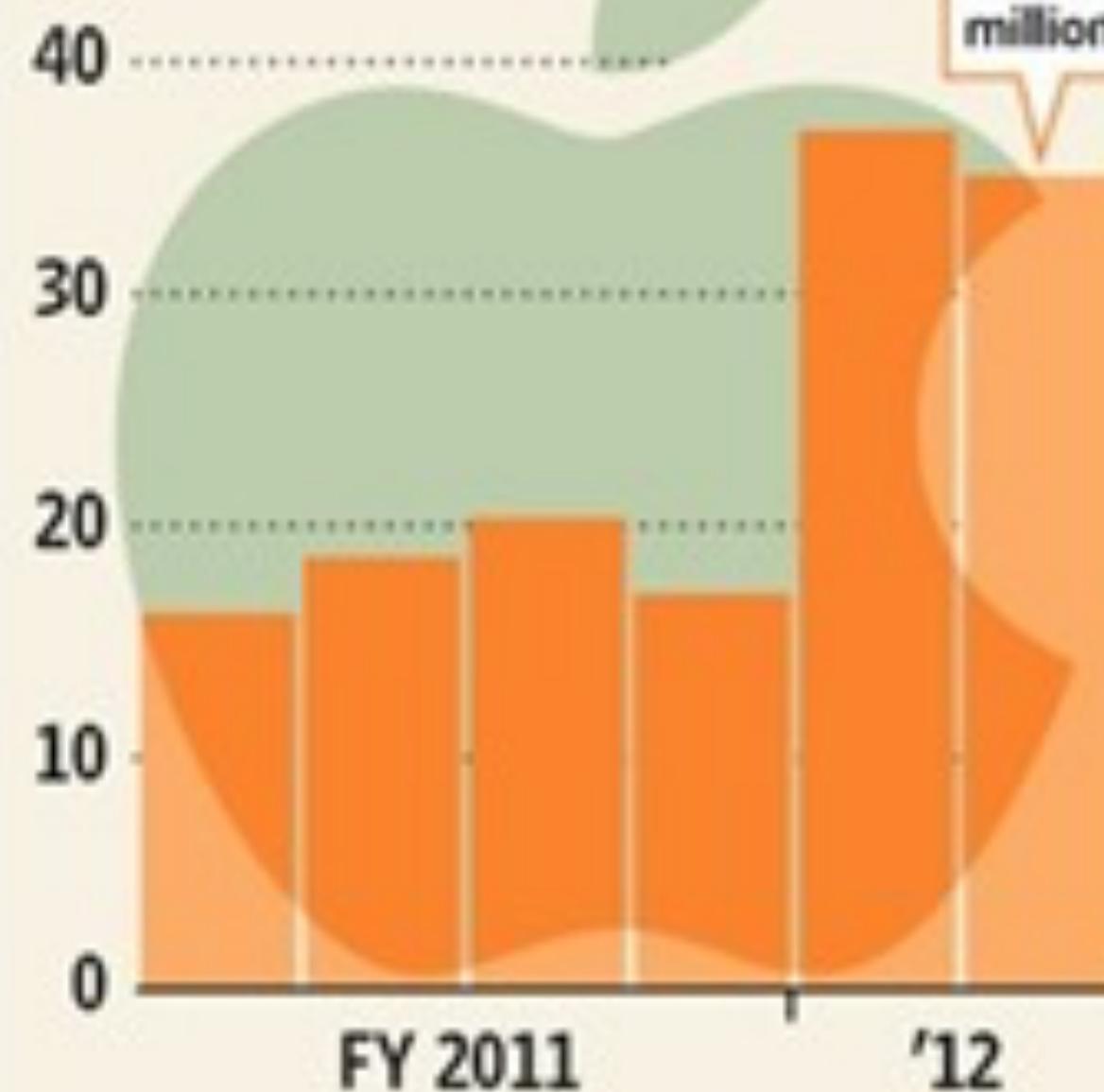


♂ Percentage of 15-to-17-year-olds
who have had sex.



Juicy Sales

Quarterly iPhone
shipments, in millions



Source: the company

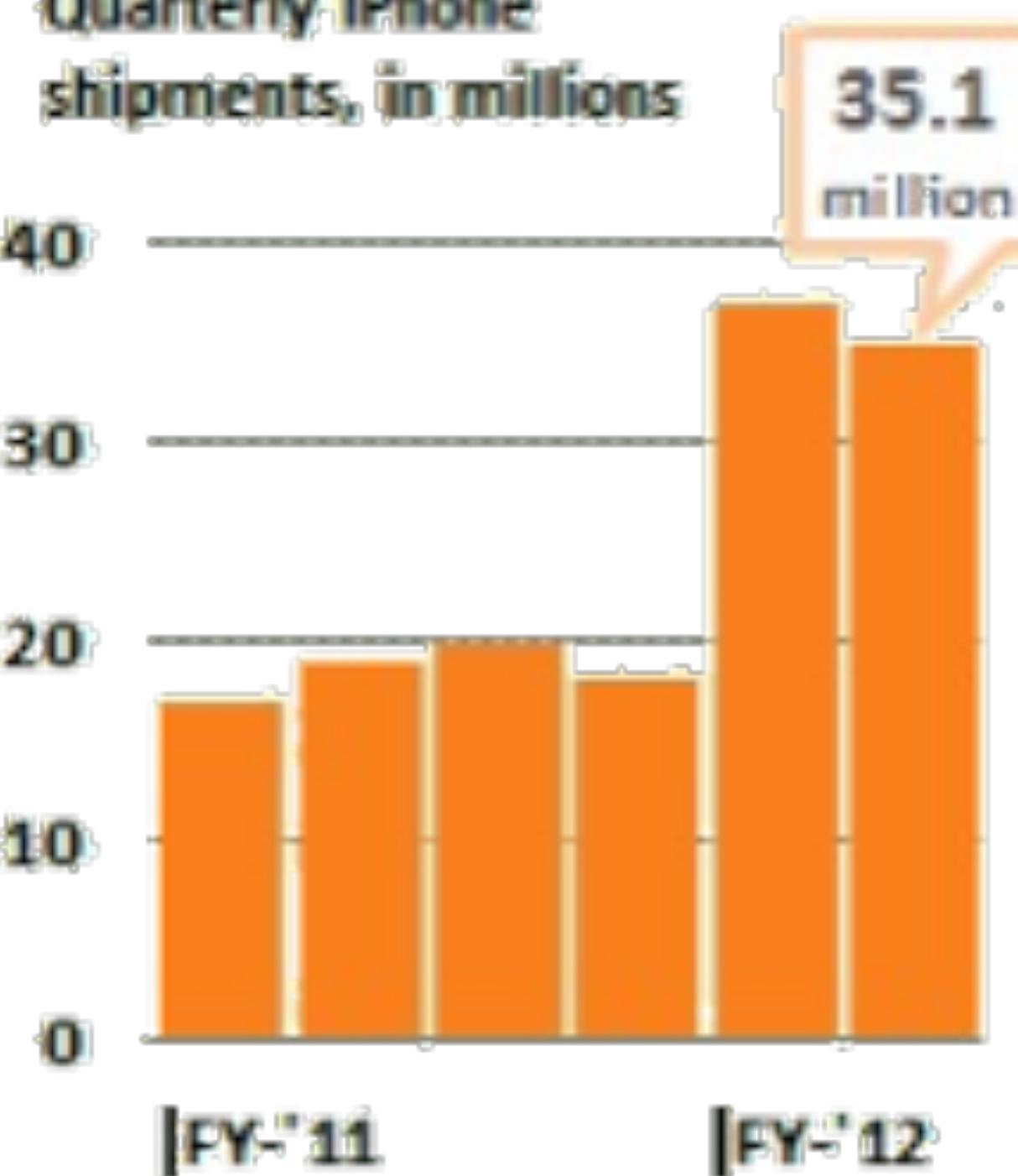
"Be **clear** first and **clever** second. If you have to throw one of those out, throw out **clever**.

— Jason Fried



Apple's Juicy Sales

Quarterly iPhone
shipments, in millions

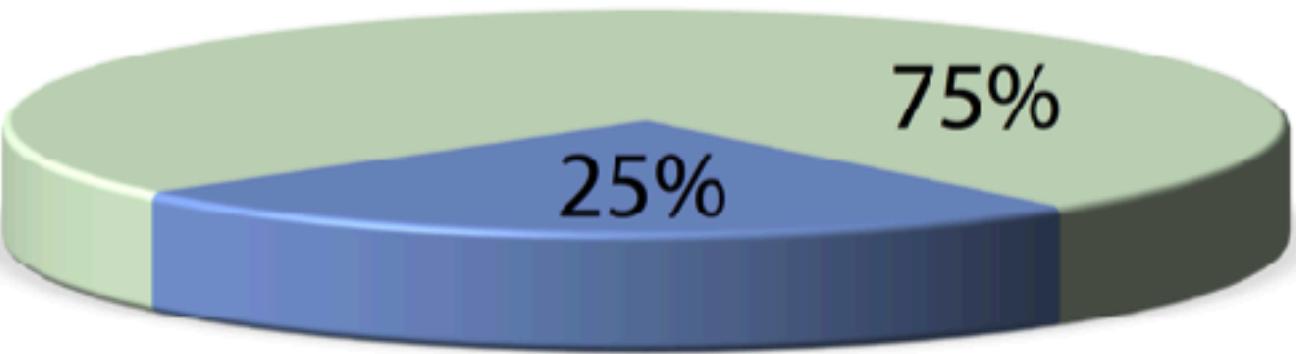


Source: the company

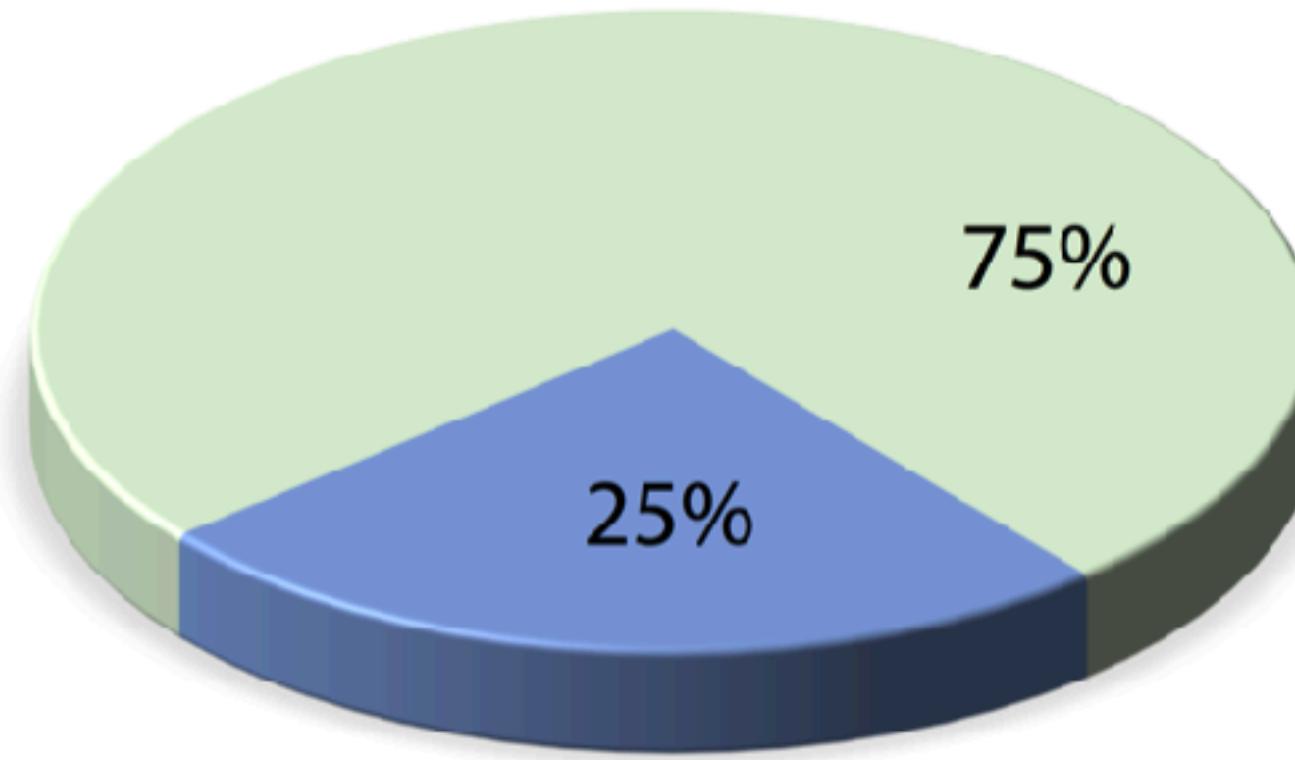
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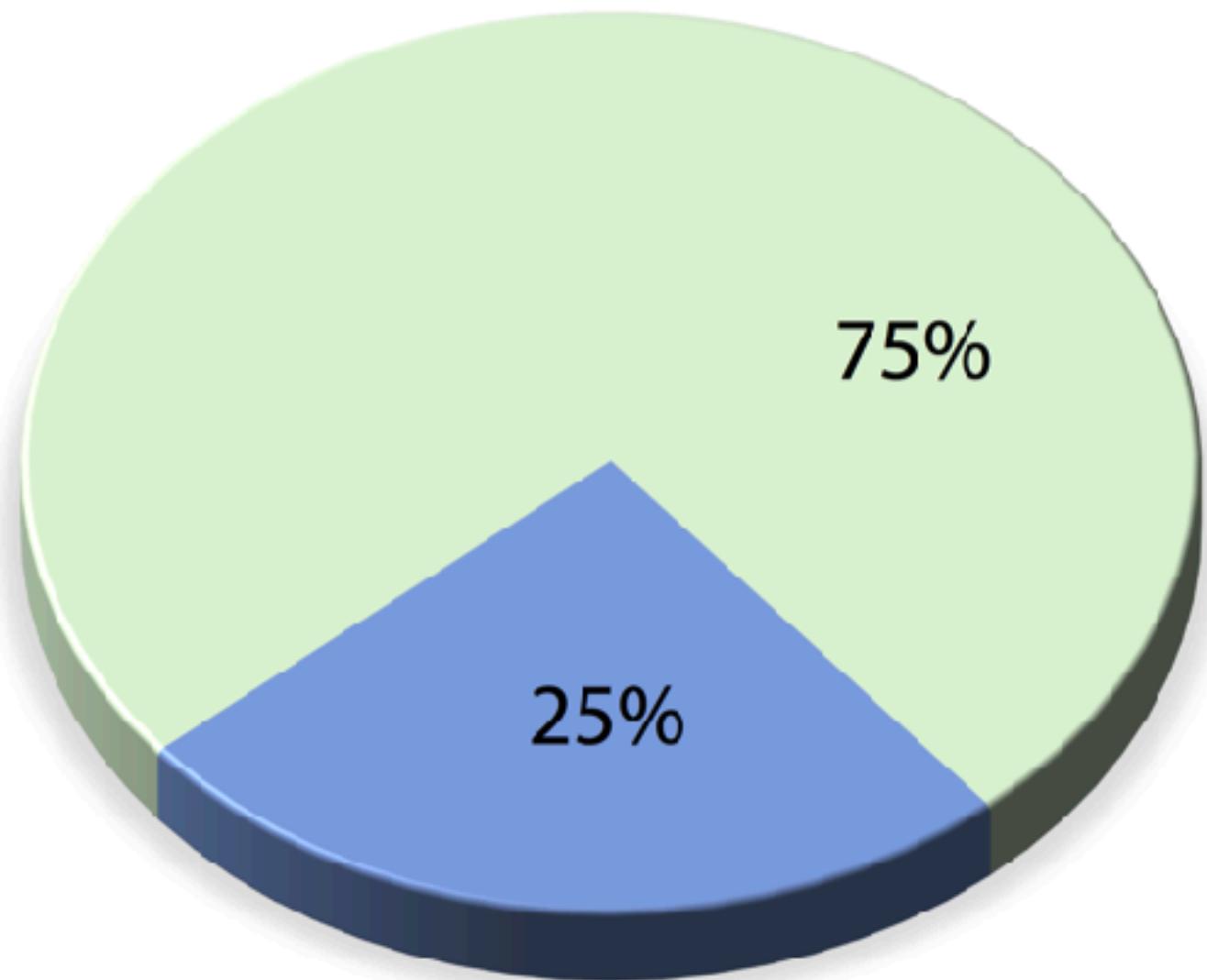
a



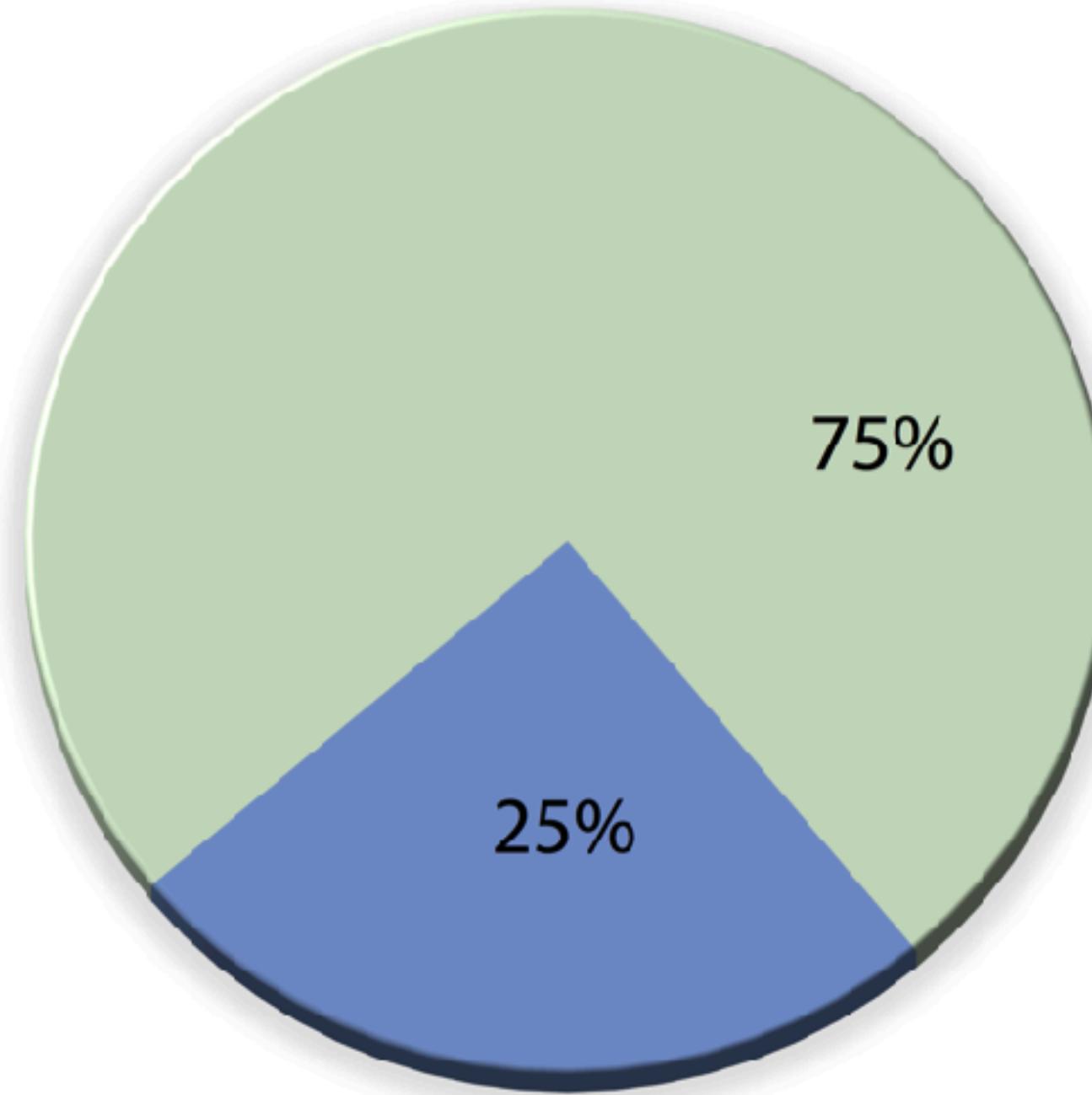
b



c



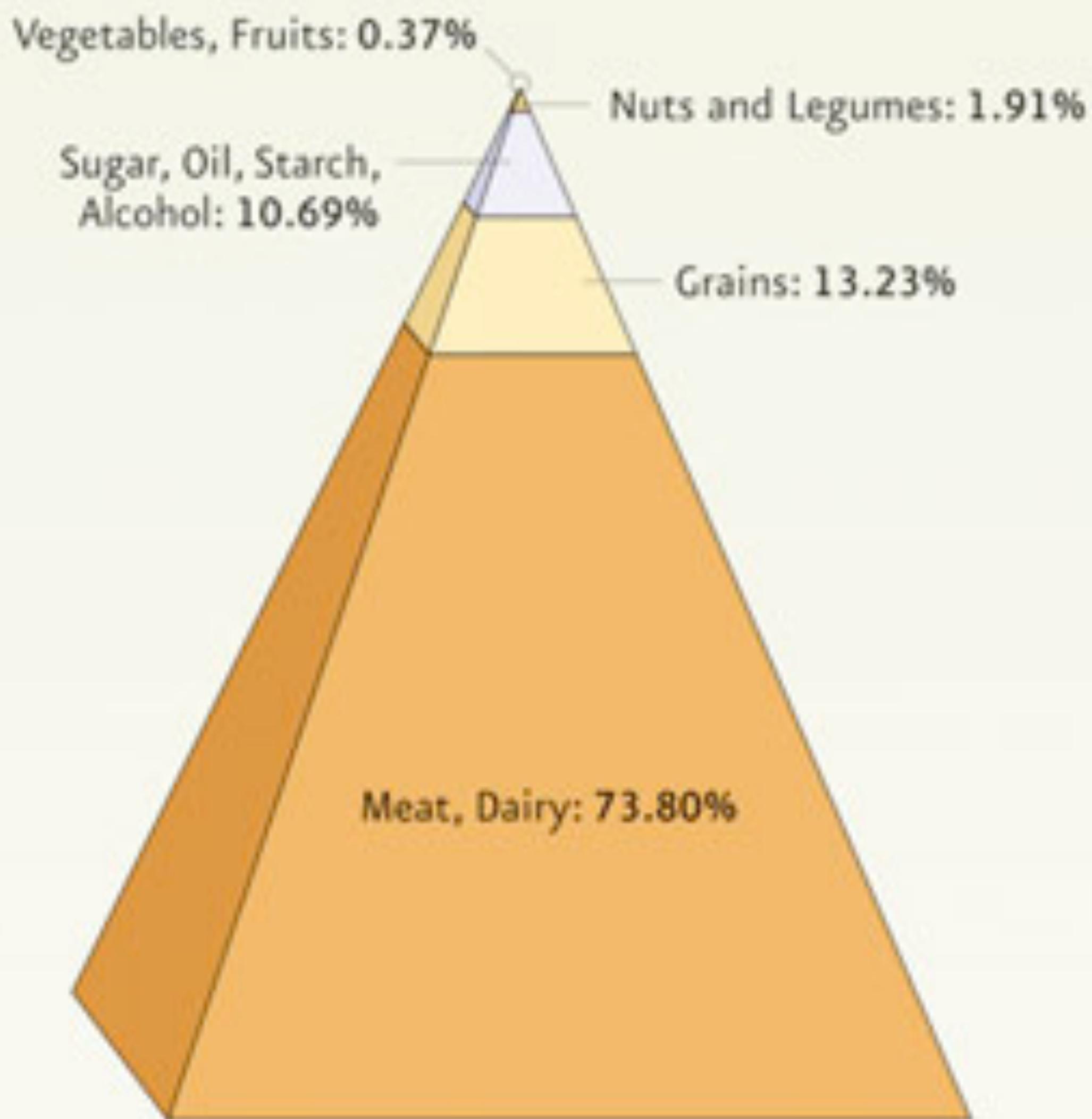
d



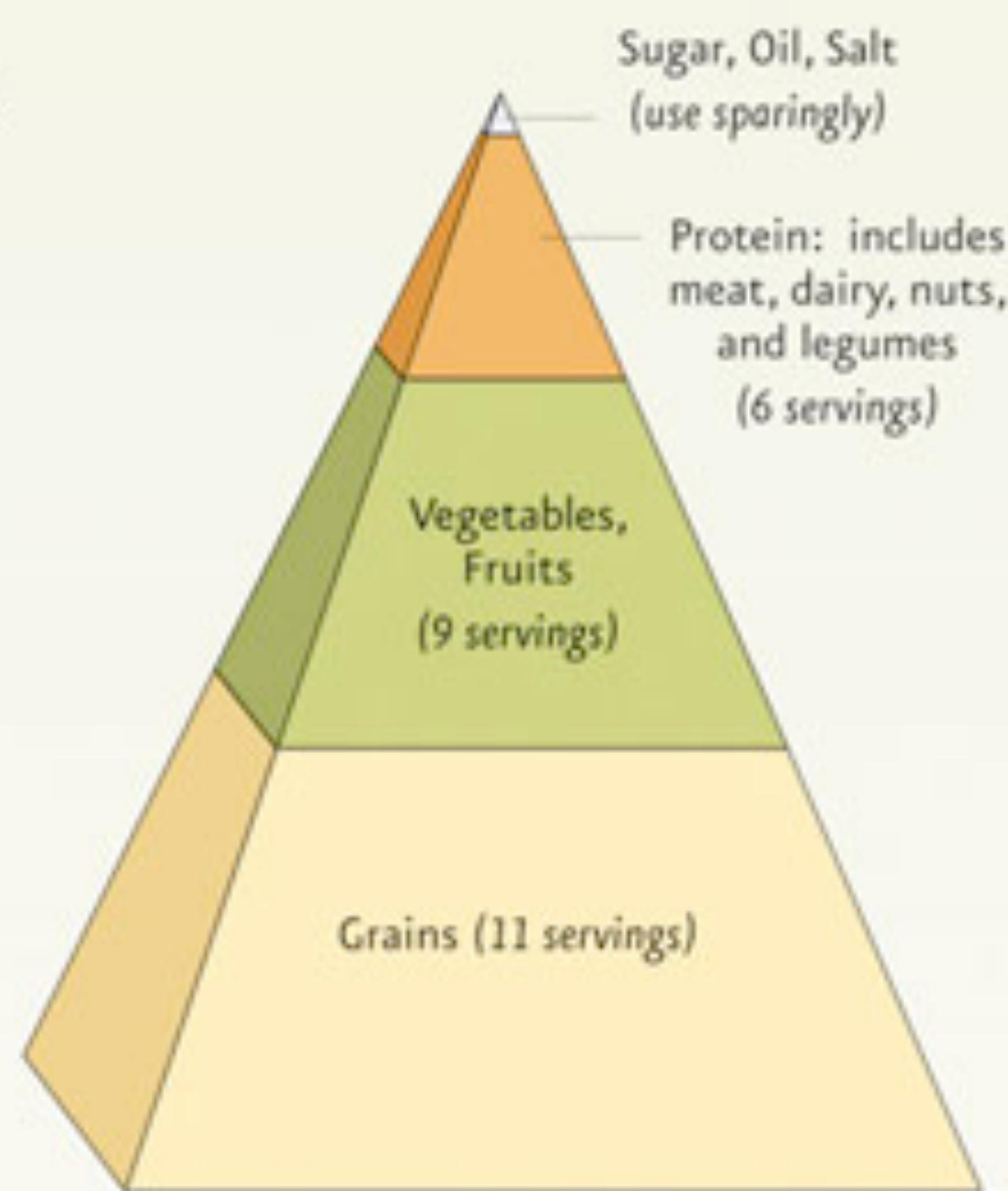
Same chart, four angles

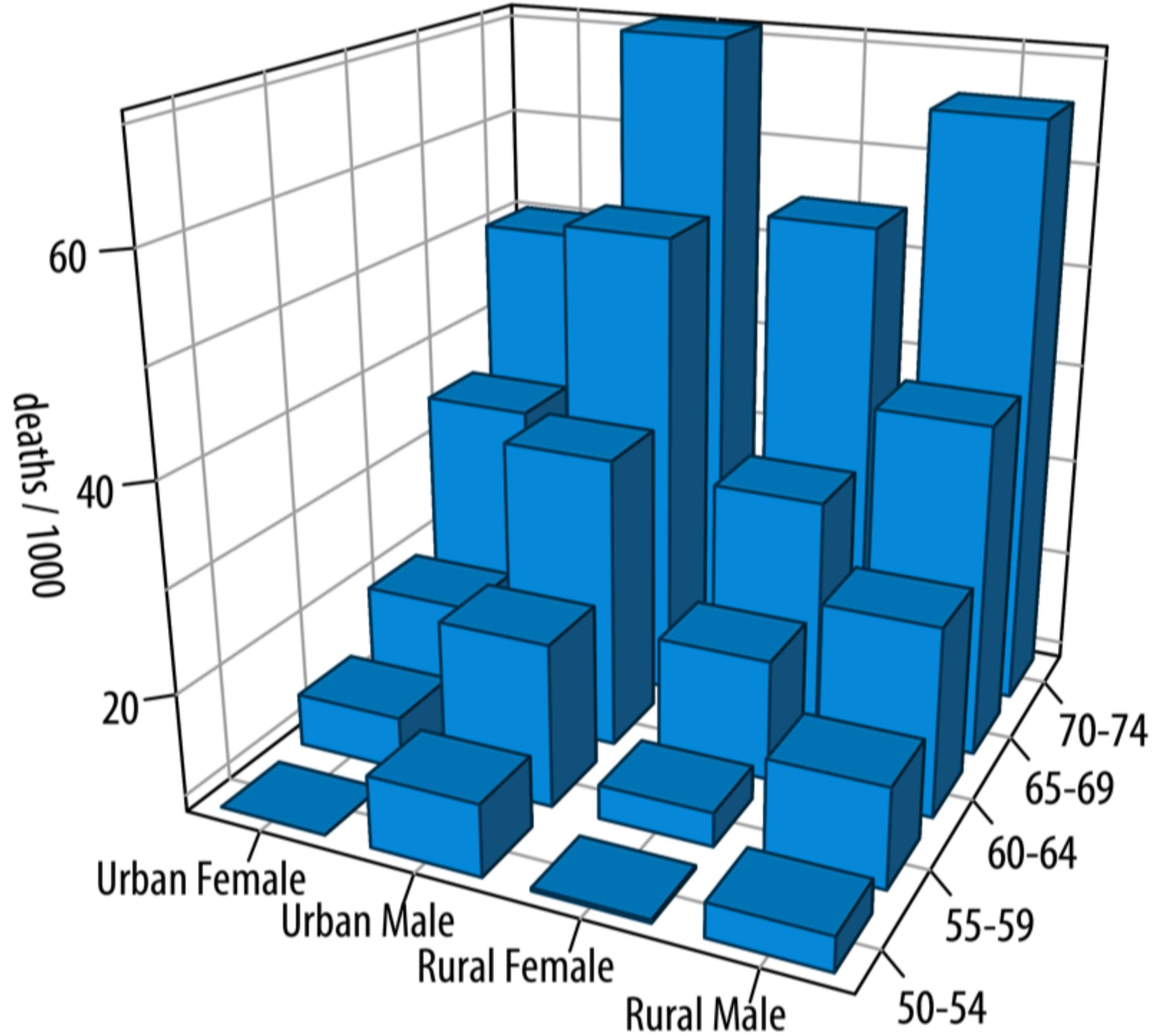
Why Does a Salad Cost More Than a Big Mac?

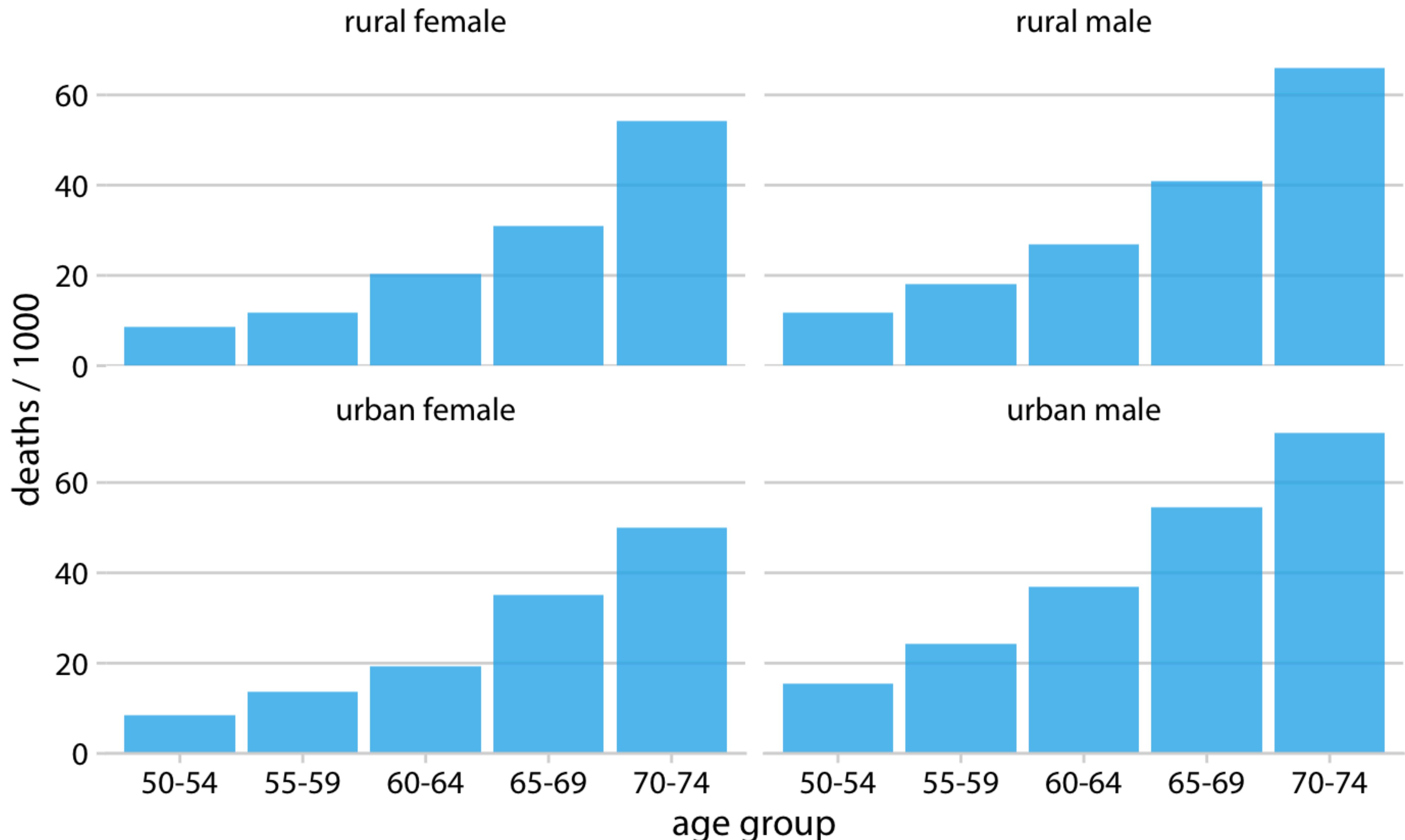
Federal Subsidies for Food Production, 1995-2005[®]



Federal Nutrition Recommendations



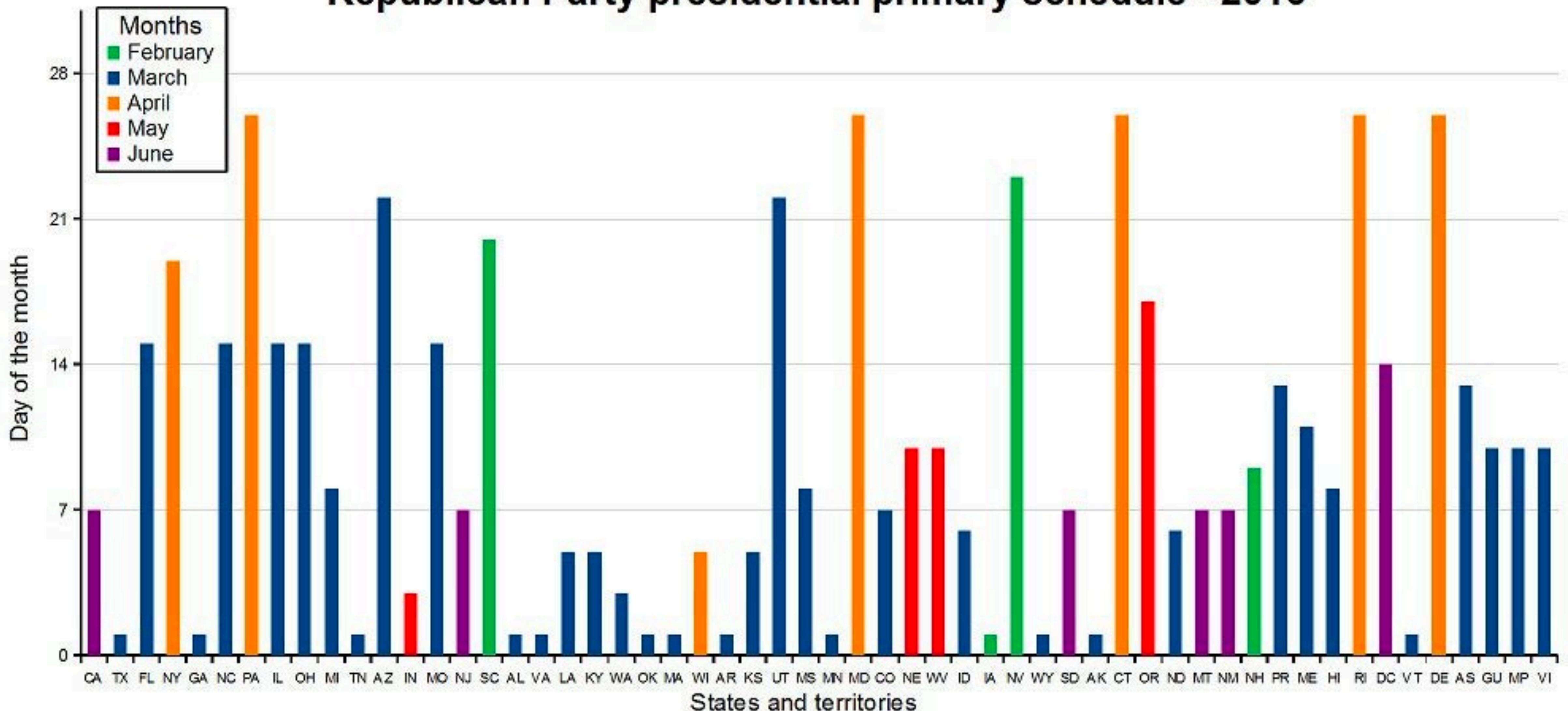




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Republican Party presidential primary schedule - 2016



May we suggest... a calendar³⁵

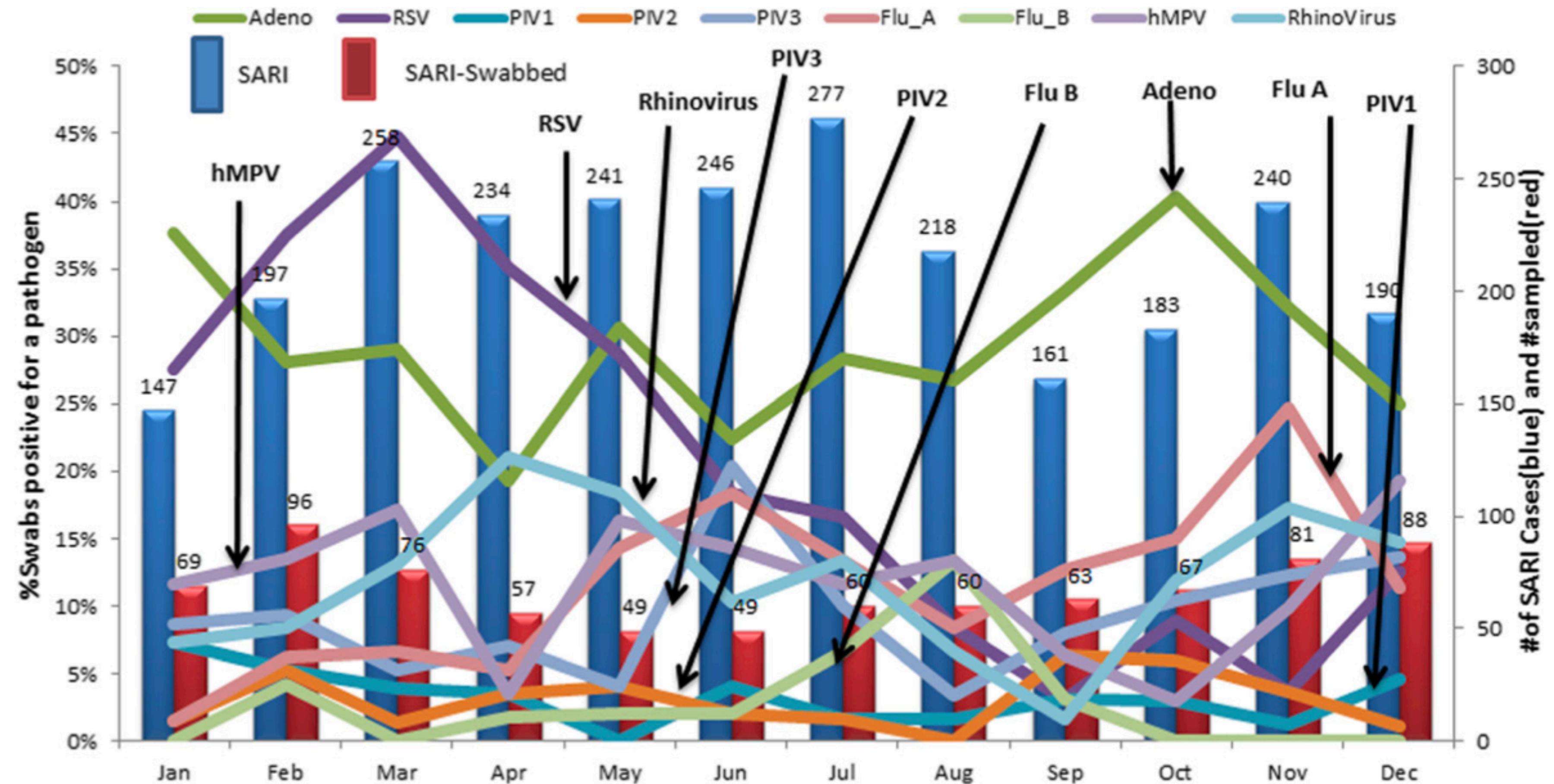
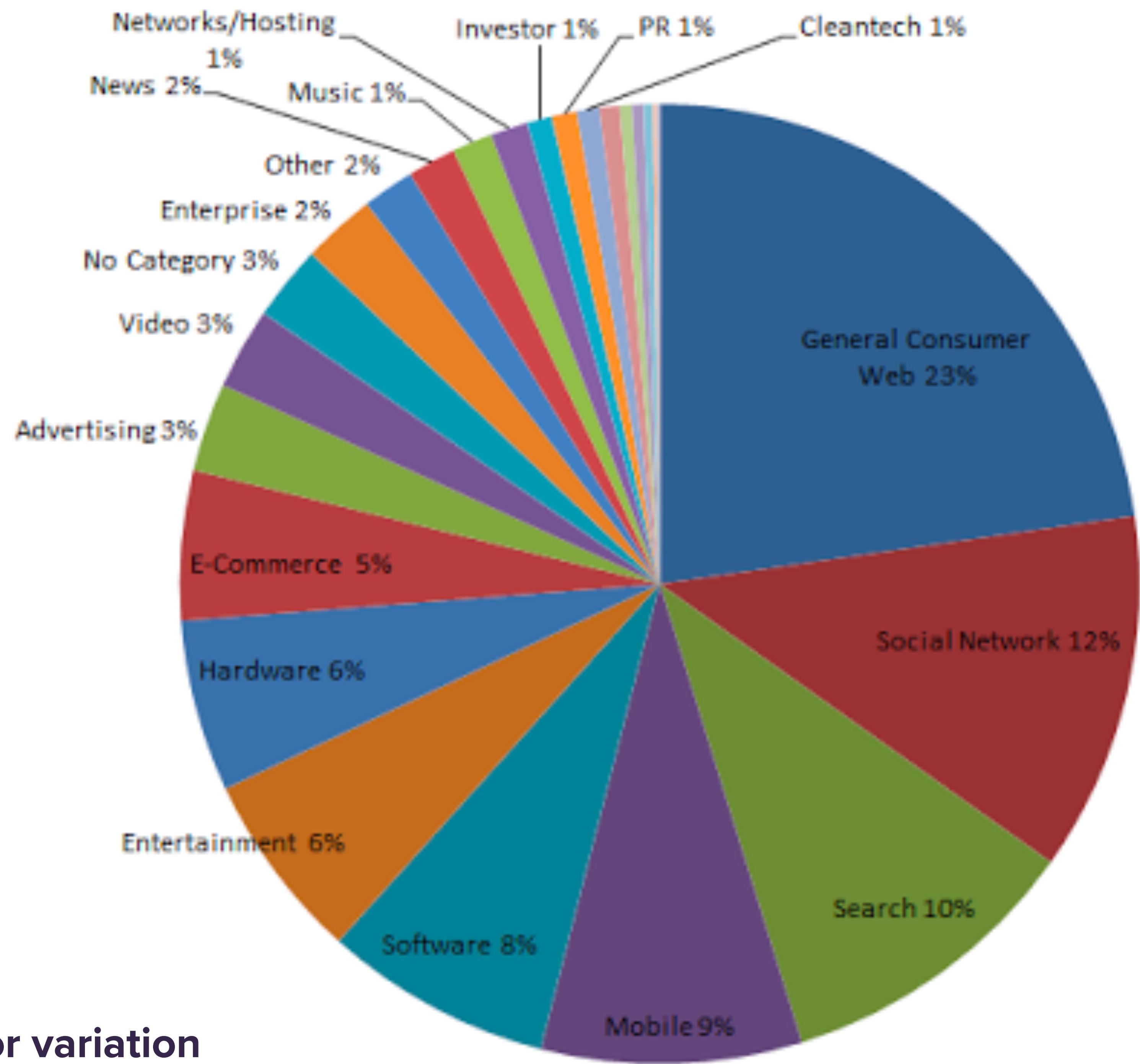
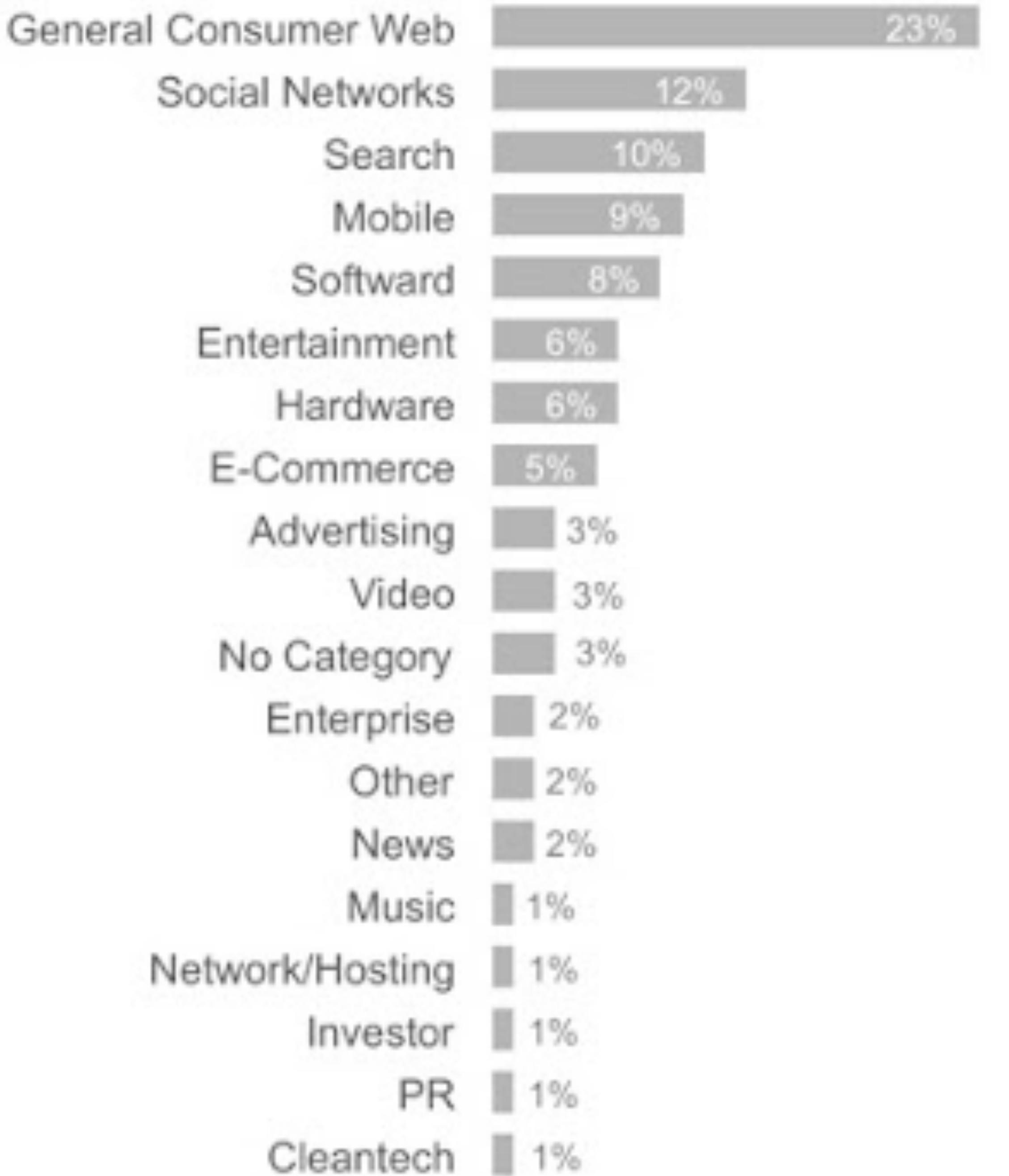


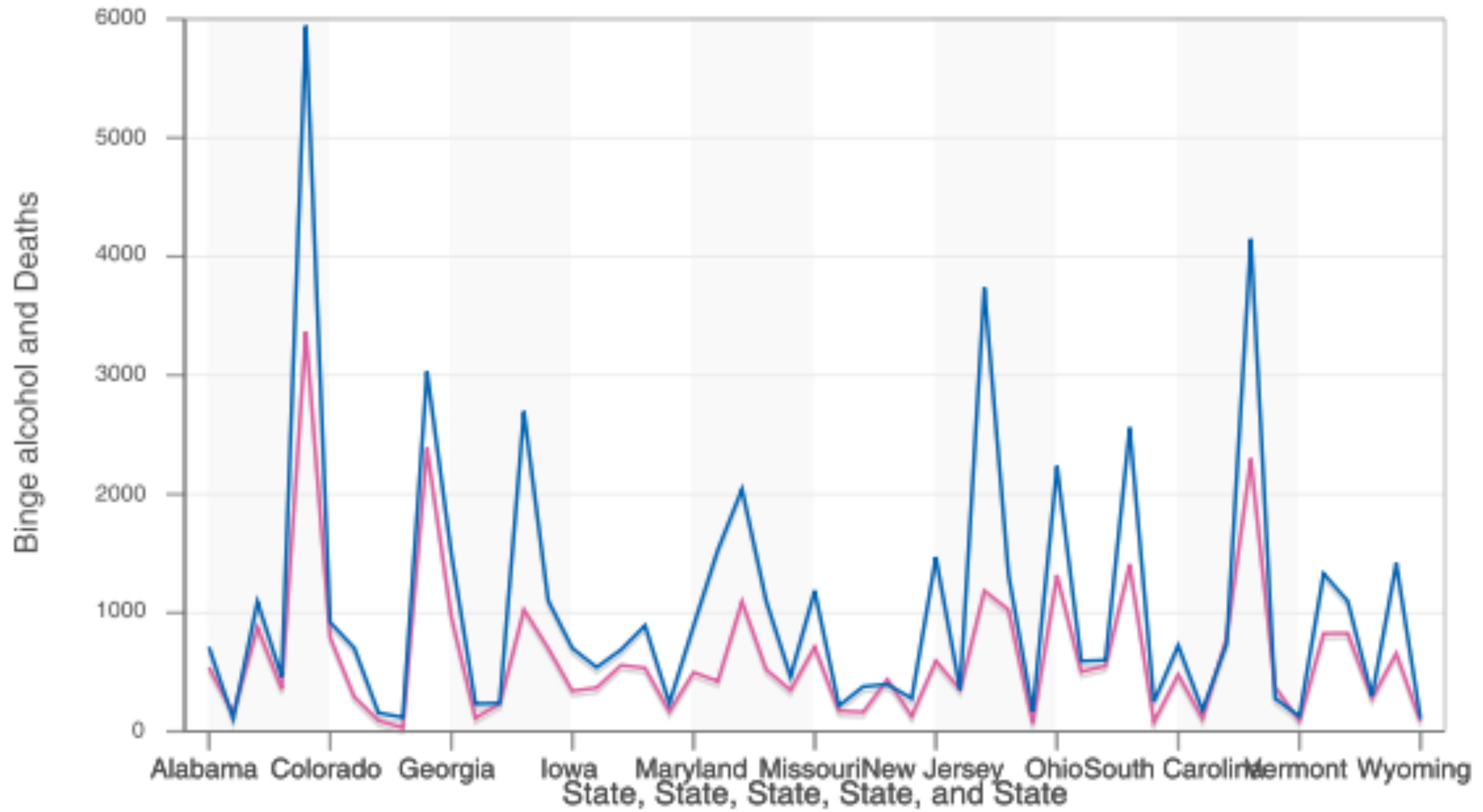
Figure 1 Monthly (aggregate) distribution of viral pathogens, March 1, 2007-Feb 28, 2011.



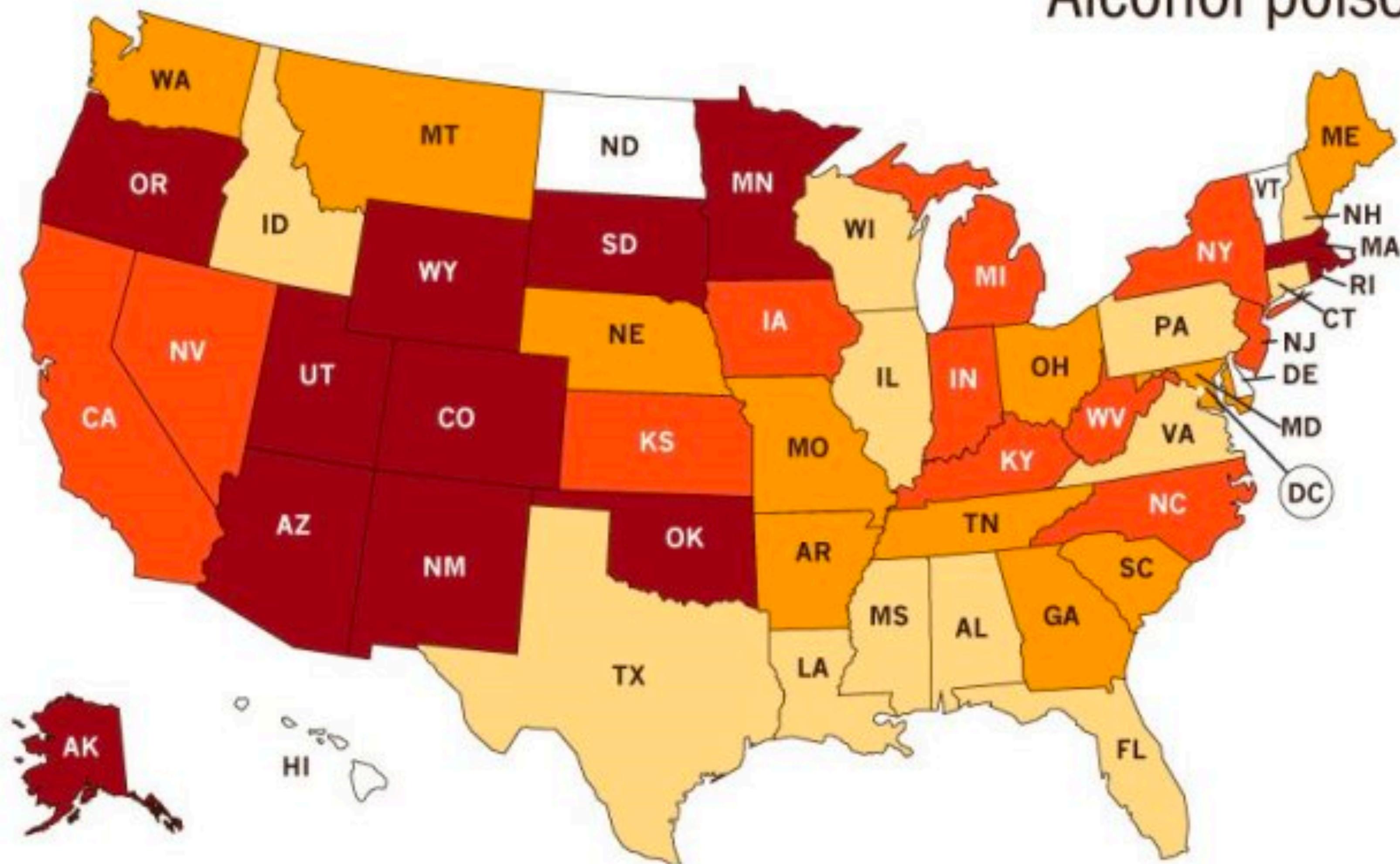
Meaningless color variation



As a bar plot



Alcohol poisoning deaths vary by state



Deaths by state
per million people

11.9 - 46.5

8.6 - 11.8

6.8 - 8.5

5.3 - 6.7

Not calculated

SOURCE: National Center for Health Statistics Mortality Multiple Cause Files, 2010-2012.

TAKE-HOME LESSONS

- **Make relevant comparisons and avoid irrelevant ones.**
- **Be truthful about magnitude.**
- **Minimize distractions.**
- **Stay 2D (unless visualizing an actual 3D object, like a mountain or a building).**
- **Avoid meaningless variation (e.g. color differences that don't encode information).**
- **Have clear axis labels and informative titles/annotations.**
- **Be sensitive to the knowledge and limitations of the viewer.**

KEEP IT SIMPLE...

- Simple and effective plots:

- Scatter plots

- Line graphs

- Boxplots

- Histograms

- Bar plots

- Simple and effective strategies for enriching these plots:

- Variation in size, shape, and/or color (but be colorblind-friendly and don't go crazy)

- Faceting: showing the same basic plot across multiple conditions

- Labels

YOUR TURN!

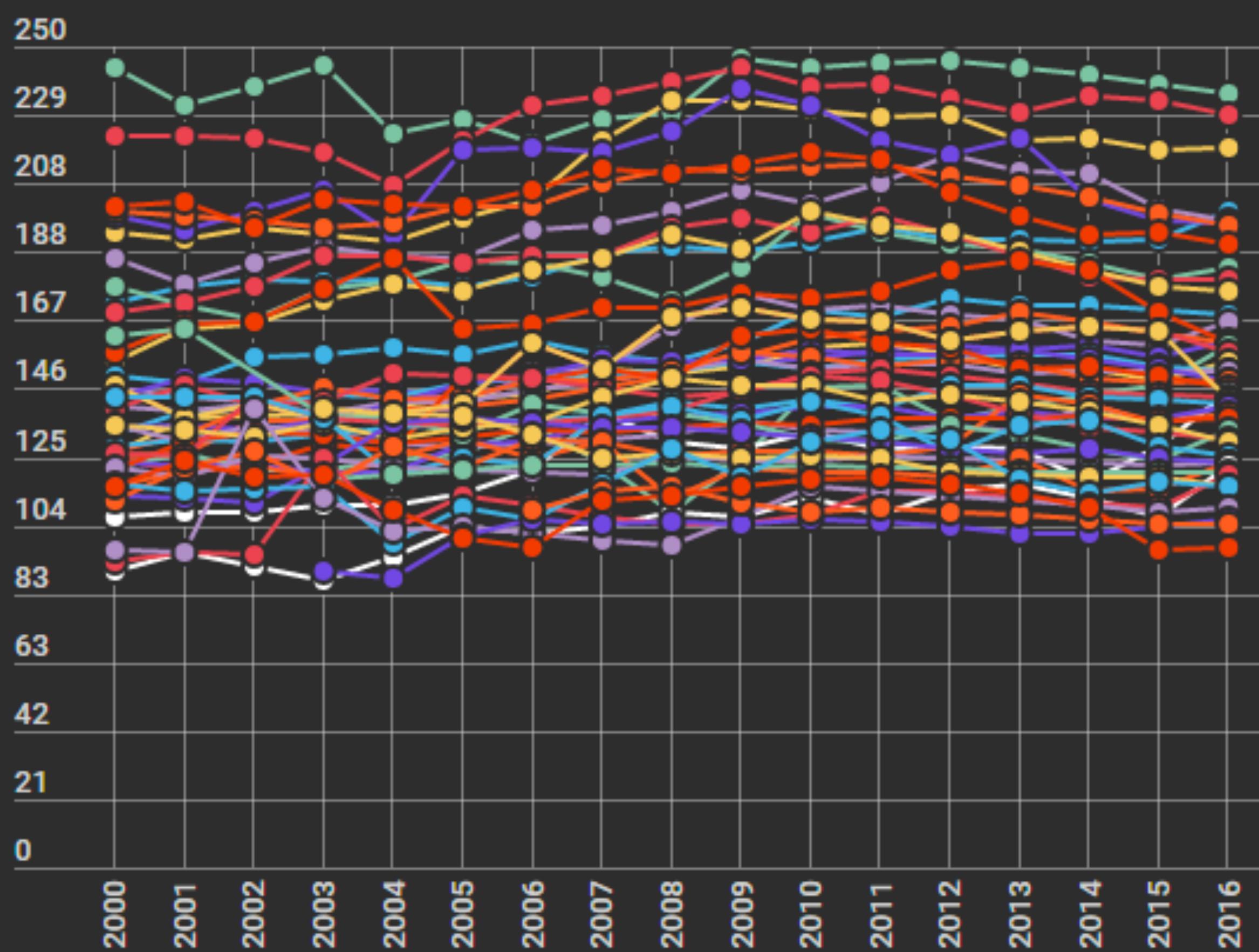
- Let's look at a plot.
- Try to answer three questions:

What message(s) is the plot trying to convey?

Is the plot successful? If so, what choices make it successful? If not, what's wrong?

Any changes you'd suggest?

Canada's most heavily-policed cities (x per 100,000)



- Victoria
- Montreal
- Halifax
- Thunder Bay
- Winnipeg
- Vancouver
- Windsor
- Toronto
- Edmonton
- Regina
- Saskatoon
- Calgary
- St. John's
- Greater Sudbury
- Barrie
- Lethbridge Region
- Red Deer
- Niagara Region
- Kingston
- Chatham-Kent
- Hamilton
- London
- Guelph
- Abbotsford
- Surrey
- Peel Region
- Delta
- Waterloo Region
- Laval
- York Region
- Kelowna
- S

THE GRAMMAR OF GRAPHICS

- Consider sentences that an English learner (e.g. a toddler) might say:

“Squirrel climbs tree.”

“Anna eats cake.”

“Jimmy needs potty.”

- These sentences obey a simple, consistent grammar with three core elements:

a **subject** that performs an action (squirrel, Anna).

an **object** that receives the action (tree, cake).

a **verb**, i.e. the action itself (climbs, eats).

- If you swap out different subjects/objects/verbs in the basic grammar, you can generate lots of different, fully comprehensible sentences.

THE GRAMMAR OF GRAPHICS

- Statistical plots are just the same.
- They obey a simple, consistent grammar with three basic elements
 - Variables* in a data set (like the weight or engine size of a vehicle). These are like the subject of a sentence.
 - Objects*: specifically, geometric objects (like dot or lines or bars). These are like the object of a sentence.
 - Mappings* from the data variables to aesthetic properties of the geometric objects (like their size, location, or color). These are like the verb in a sentence.
- If you swap out different variables/objects/mappings in the basic grammar, you can generate lots of different plots.

EXAMPLE: BIKE SHARE DATA

Here you see the first several rows of a data set on median hourly demand for bike-share rentals in Washington, DC's Capital Bikeshare program, stratified by whether it's a working day (1) or not (0).

hr	workingday	median_rentals
0	0	94
0	1	33
1	0	71
1	1	14
2	0	54
2	1	7

EXAMPLE: BIKE SHARE DATA

- Variables:

- Hour

- Median rentals

- Working day

- Objects:

- Points/lines

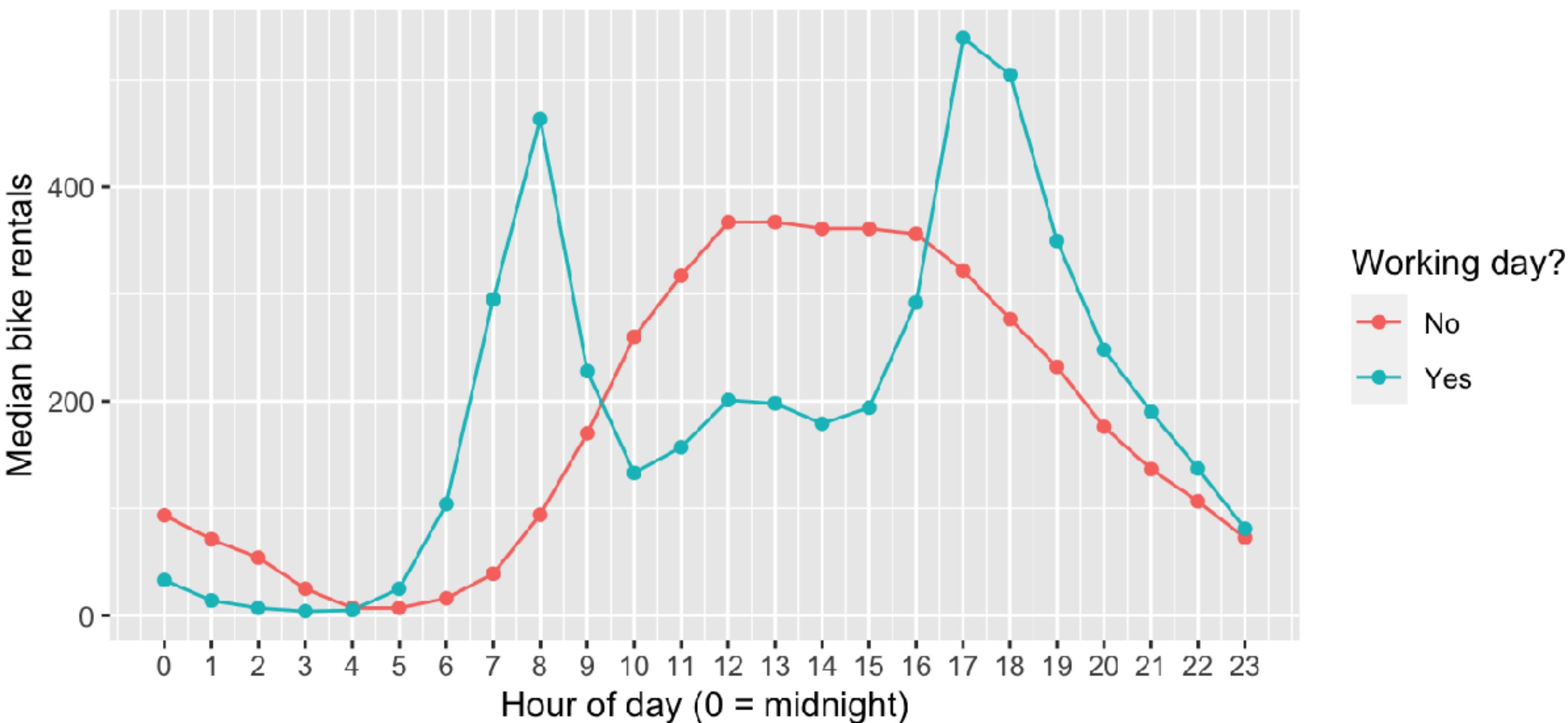
- Mappings:

- Hour → x

- Median rentals → y

- Working day → color

Bike-share rentals in Washington, DC (2011-12)



EXAMPLE: BIKE SHARE DATA

- Variables:

- Hour

- Median rentals

- Working day

- Objects:

- The two panels

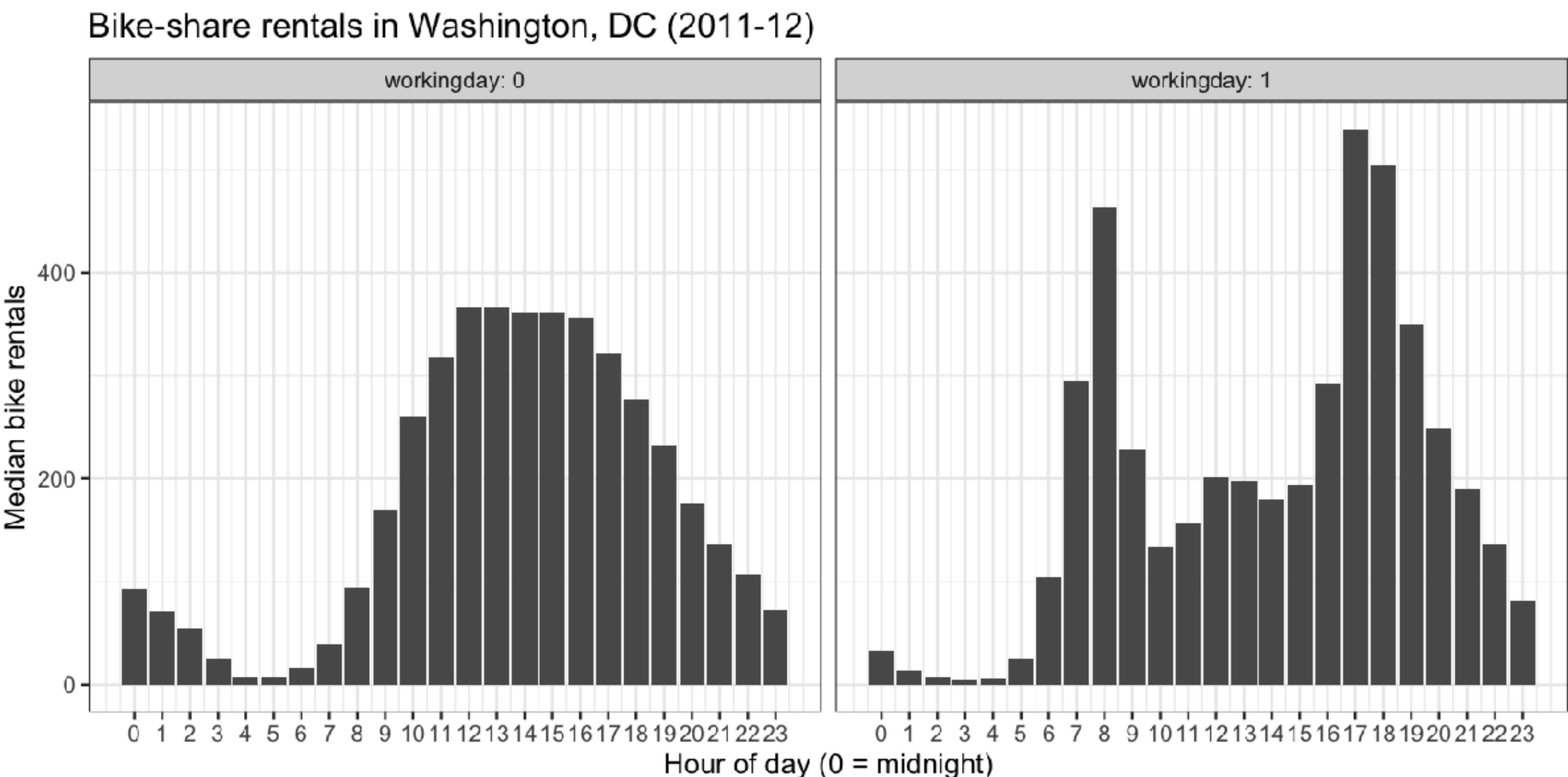
- The bars in each panel

- Mappings:

- Hour → location of bar

- Median rentals → height of bar

- Working day → left vs. right panel



Same variables, but different objects/
mappings, and so a different plot.

A plot is a mapping of data variables to the aesthetic properties of geometric objects.

THE FIVE MOST IMPORTANT PLOTS

If you have...	Consider a...
Numerical y and numerical x	Scatter plot
Numerical y and sequential x	Line graph
Numerical y alone	Histogram
Numerical y and categorical x	Boxplot
Summary statistics by group	Bar plot

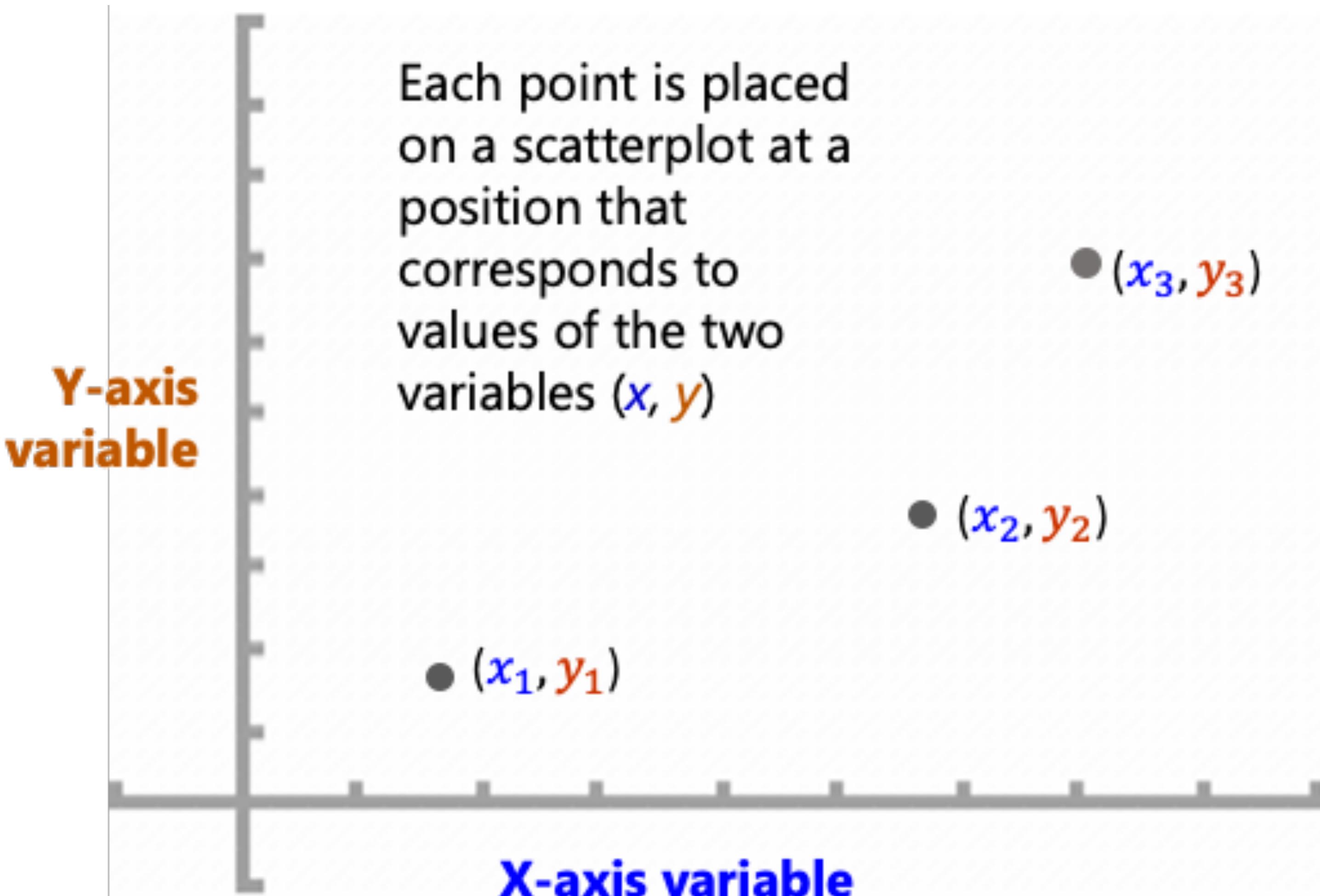
In the table, x refers to an explanatory variable and y refers to a response variable (i.e. the variable whose behavior is being “explained” by x).

THE FIVE MOST IMPORTANT PLOTS

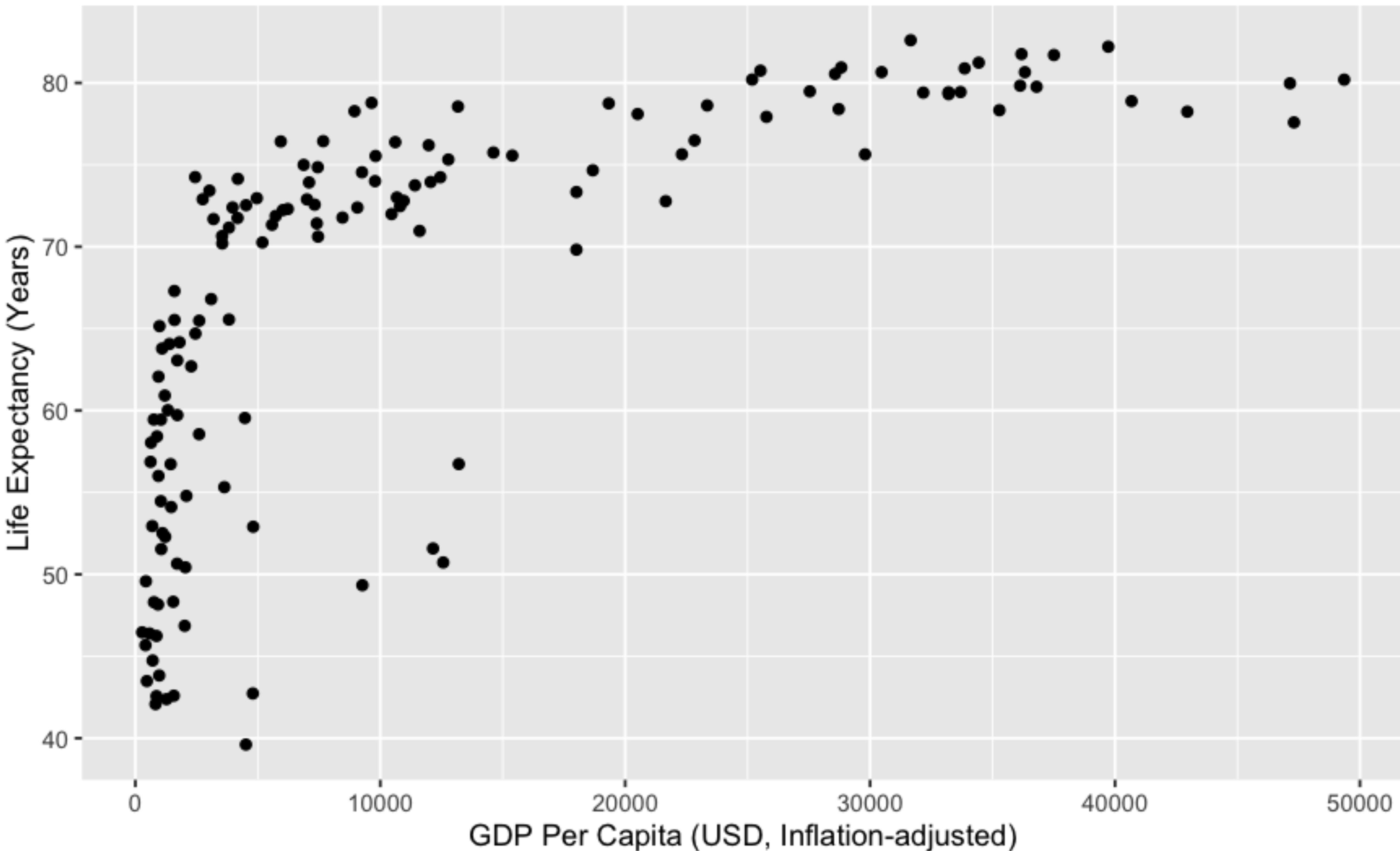
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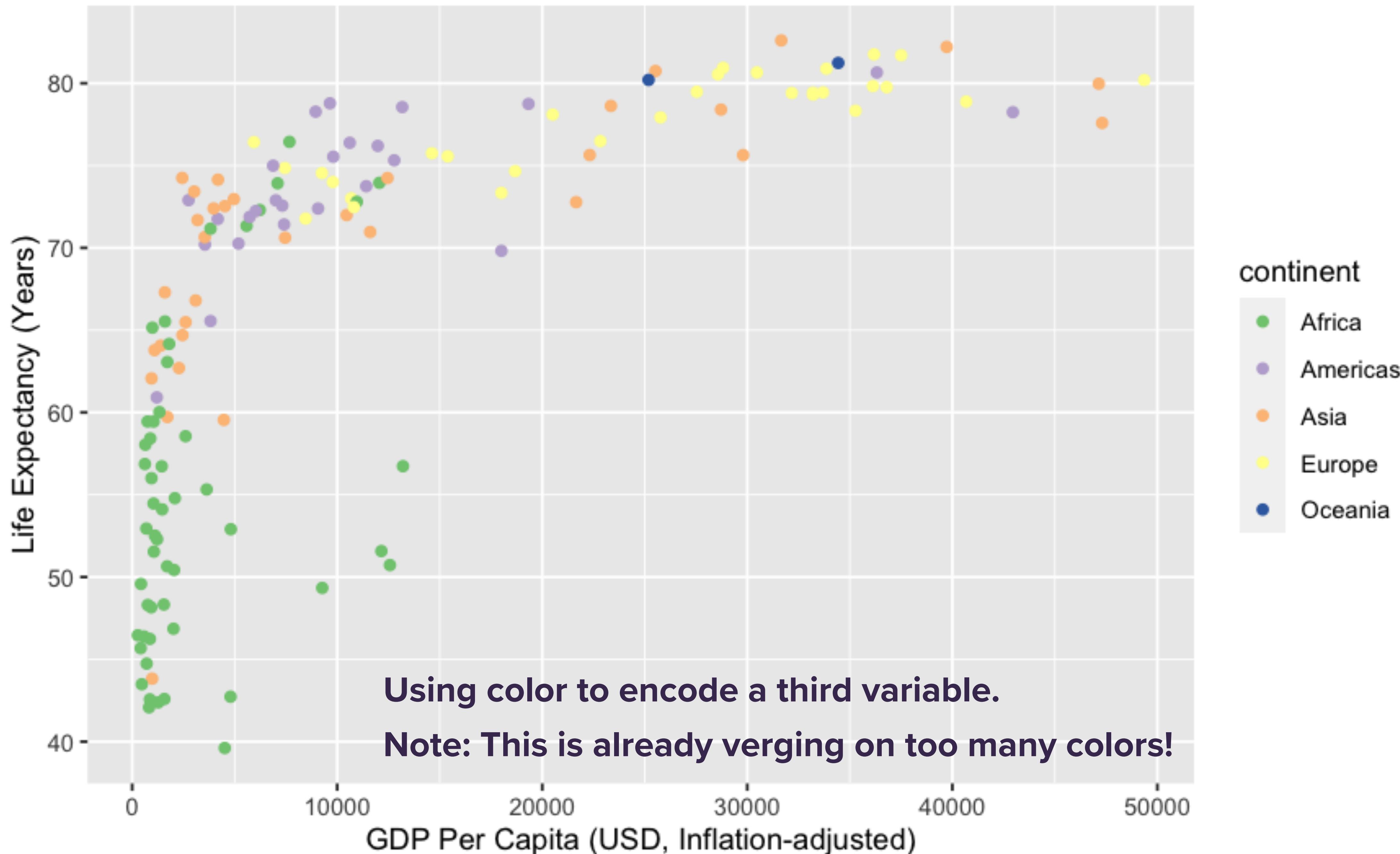
SCATTER PLOTS



Health versus Wealth for 142 Countries: 2007



Health versus Wealth for 142 Countries: 2007



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LINE GRAPHS

- Are used to show how a numerical variable (y) changes as a function of another numerical variable (x).
- Are like a scatter plot, but where you connect the dots in order of the x variable.
- Only make sense where there is an obvious sequential ordering to the x variable.

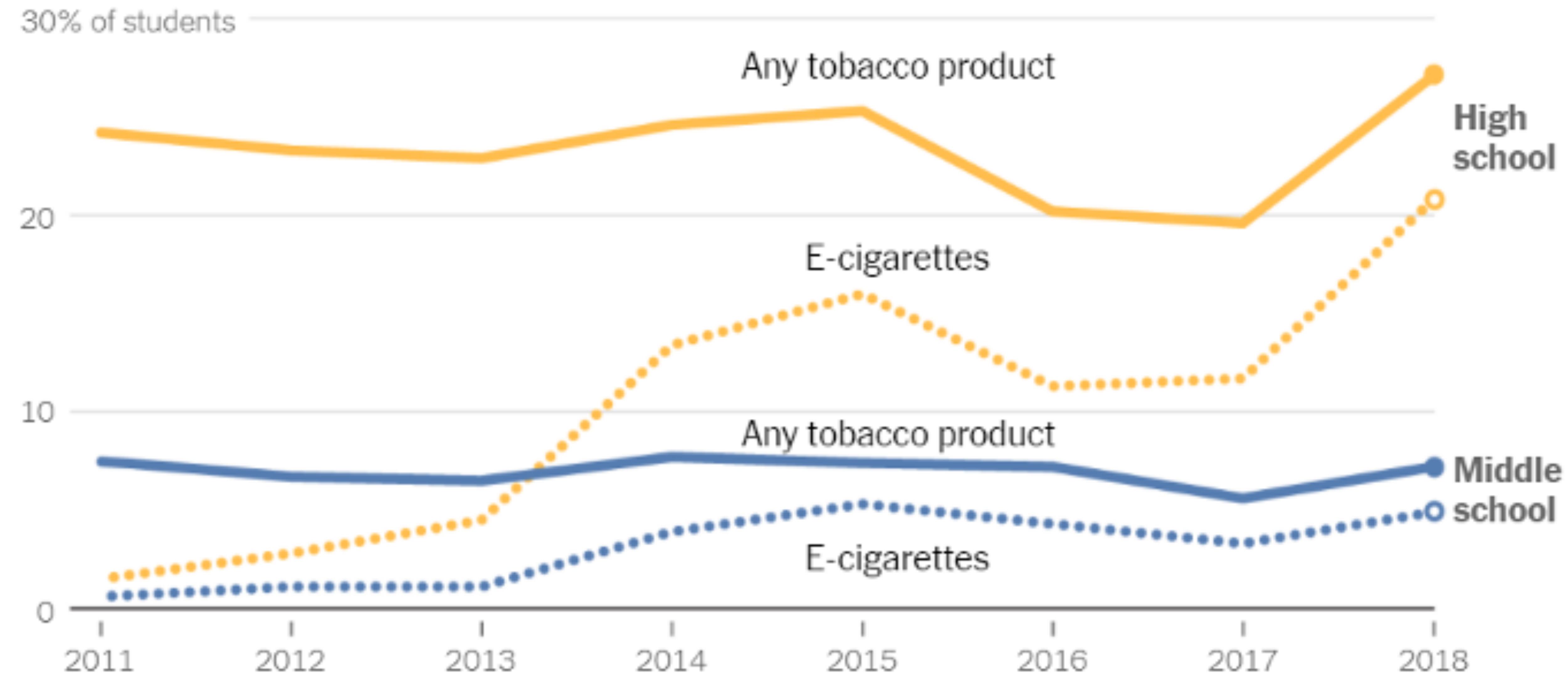
Time

Dosage levels of a drug

Distance

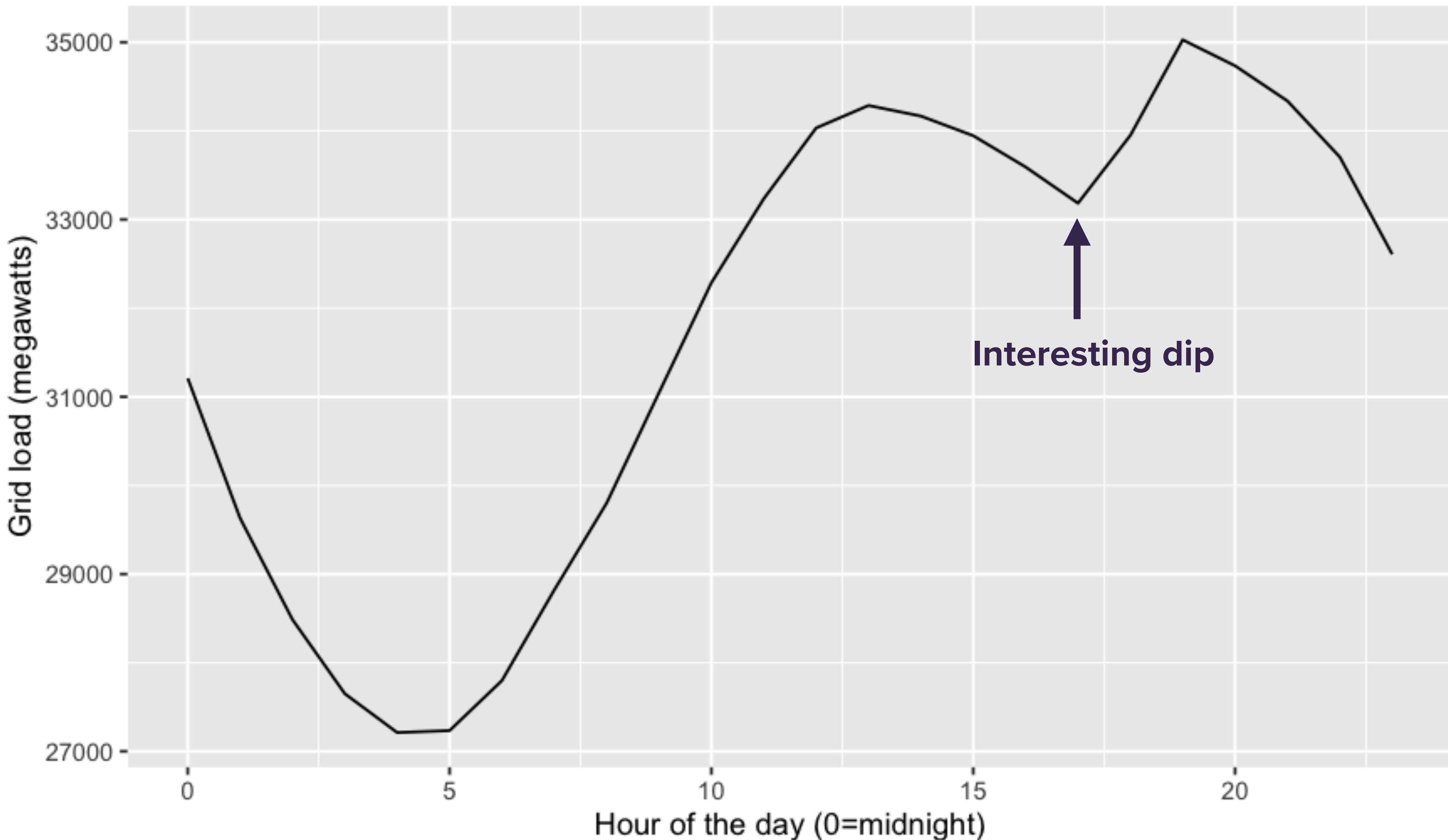
Etc.

Tobacco Consumption Among Students



Source: Centers for Disease Control and Prevention | By The New York Times

Load on the Texas power grid, Christmas Day 2015



We'll make this line graph ourselves.

Data from ERCOT

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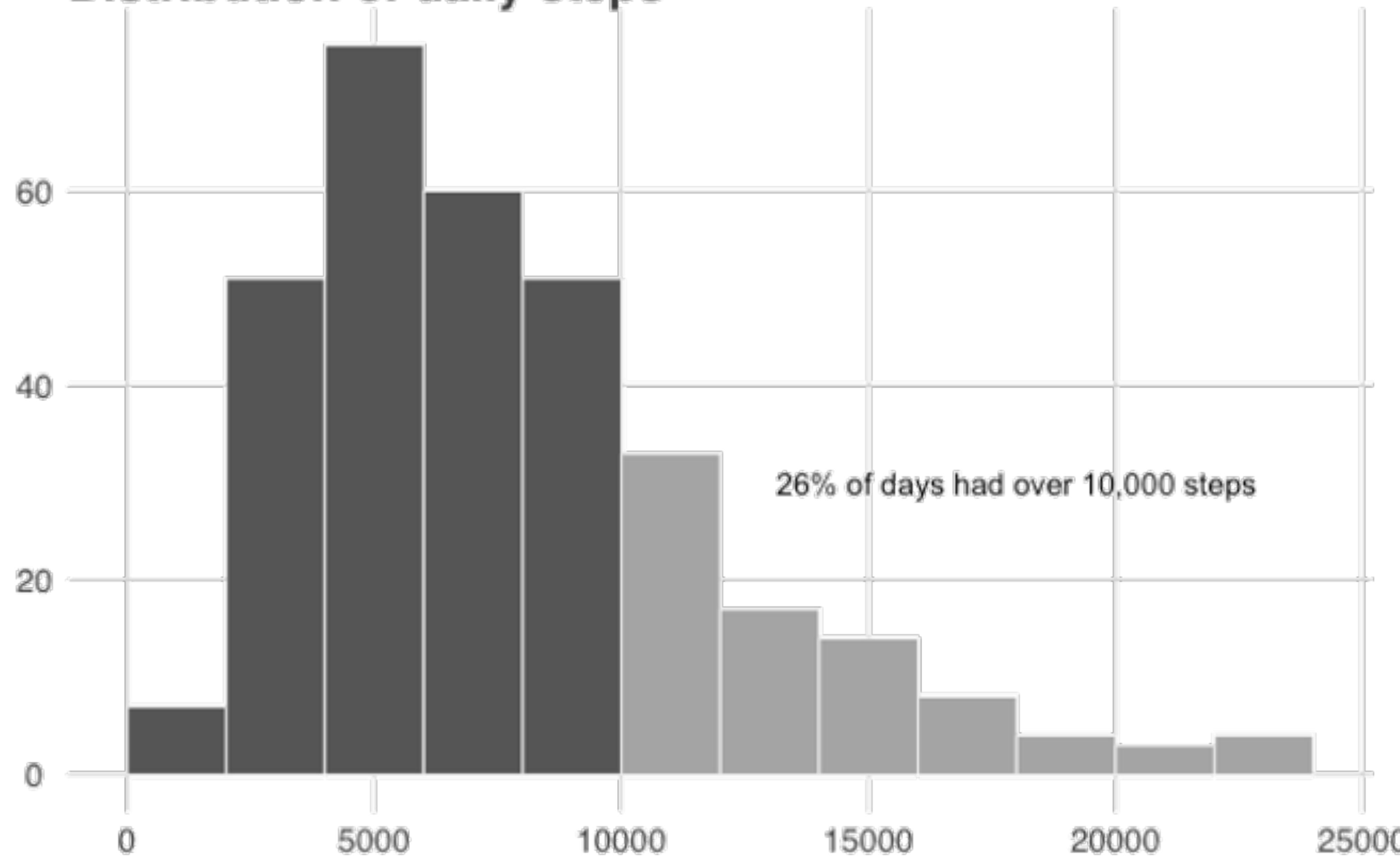
HISTOGRAMS

- Are used to visualize the data distribution of a single numerical variable.
- Show all the data, regardless of the number of cases.
- Allow you to see the location, spread, number of peaks, and symmetry/skewness of the data distribution.
- Allow you to compare data distributions across conditions, via *faceting*.
- Come in two flavors:

Count histograms: the height of each bar represents a count

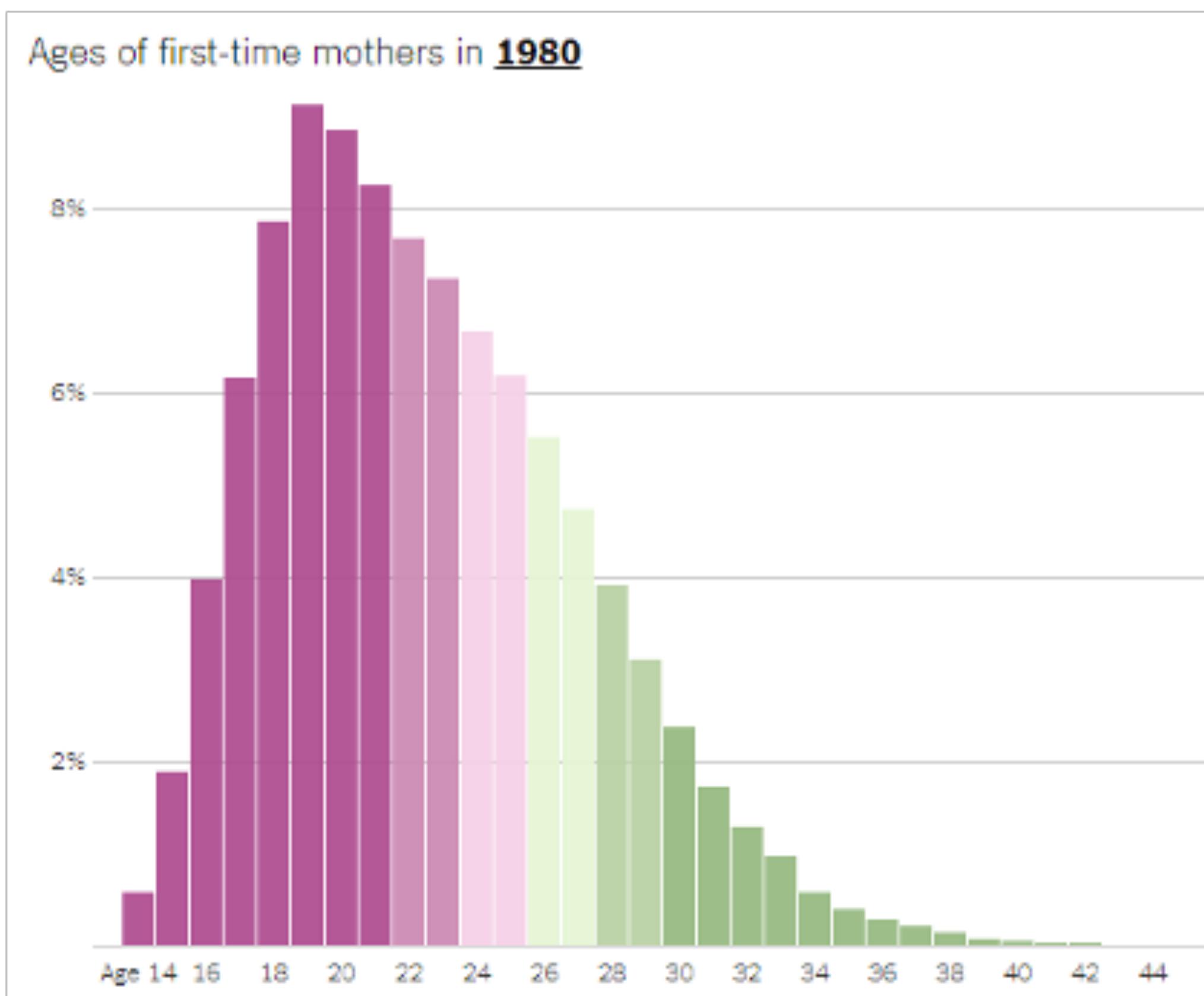
Density histograms: the height of each bar is rescaled so that the total area under the curve is 1

Distribution of daily steps



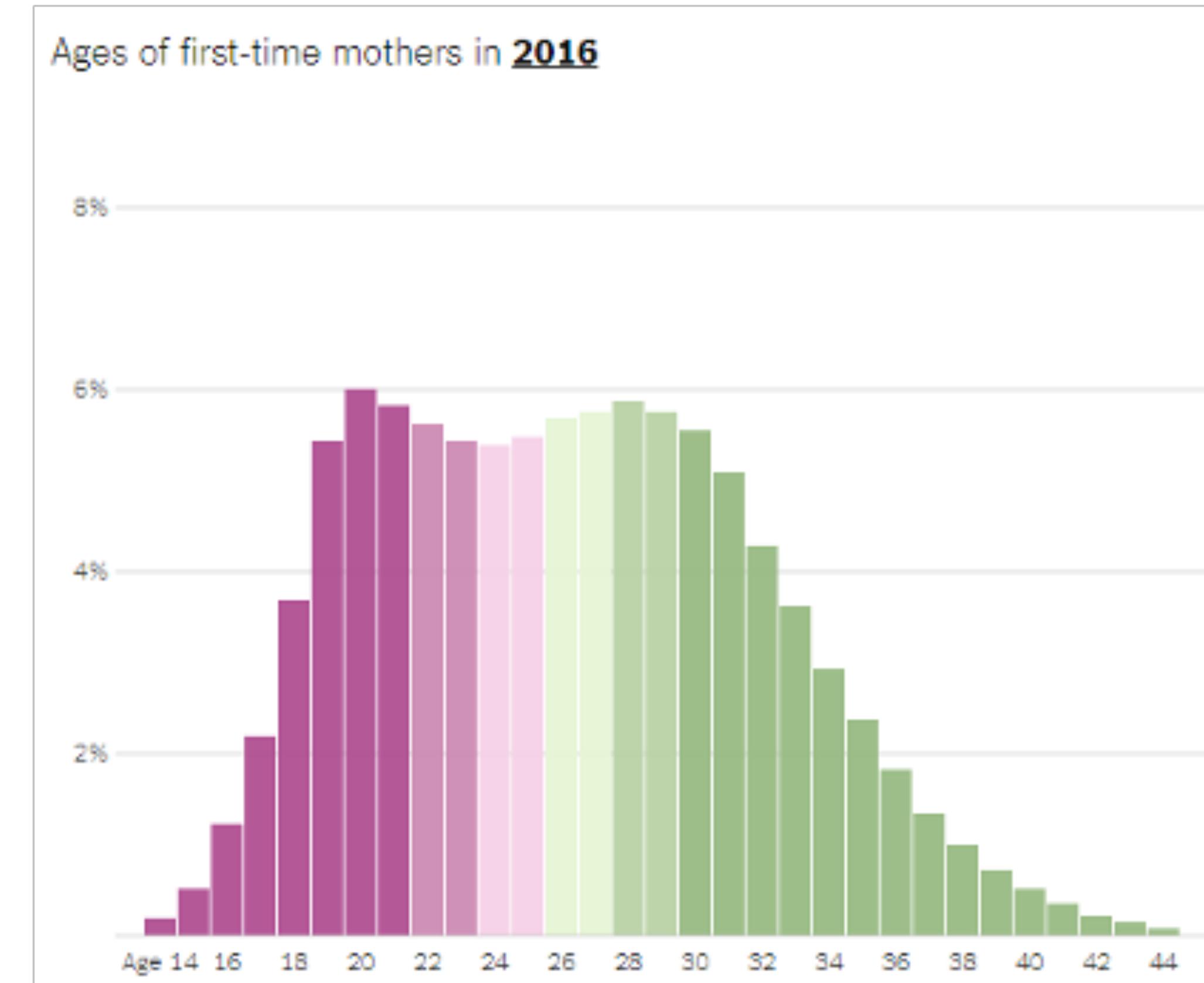
The Age That Women Have Babies: How a Gap Divides America

By QUOC TRUNG BUI and CLAIRE CAIN MILLER AUG. 4, 2018



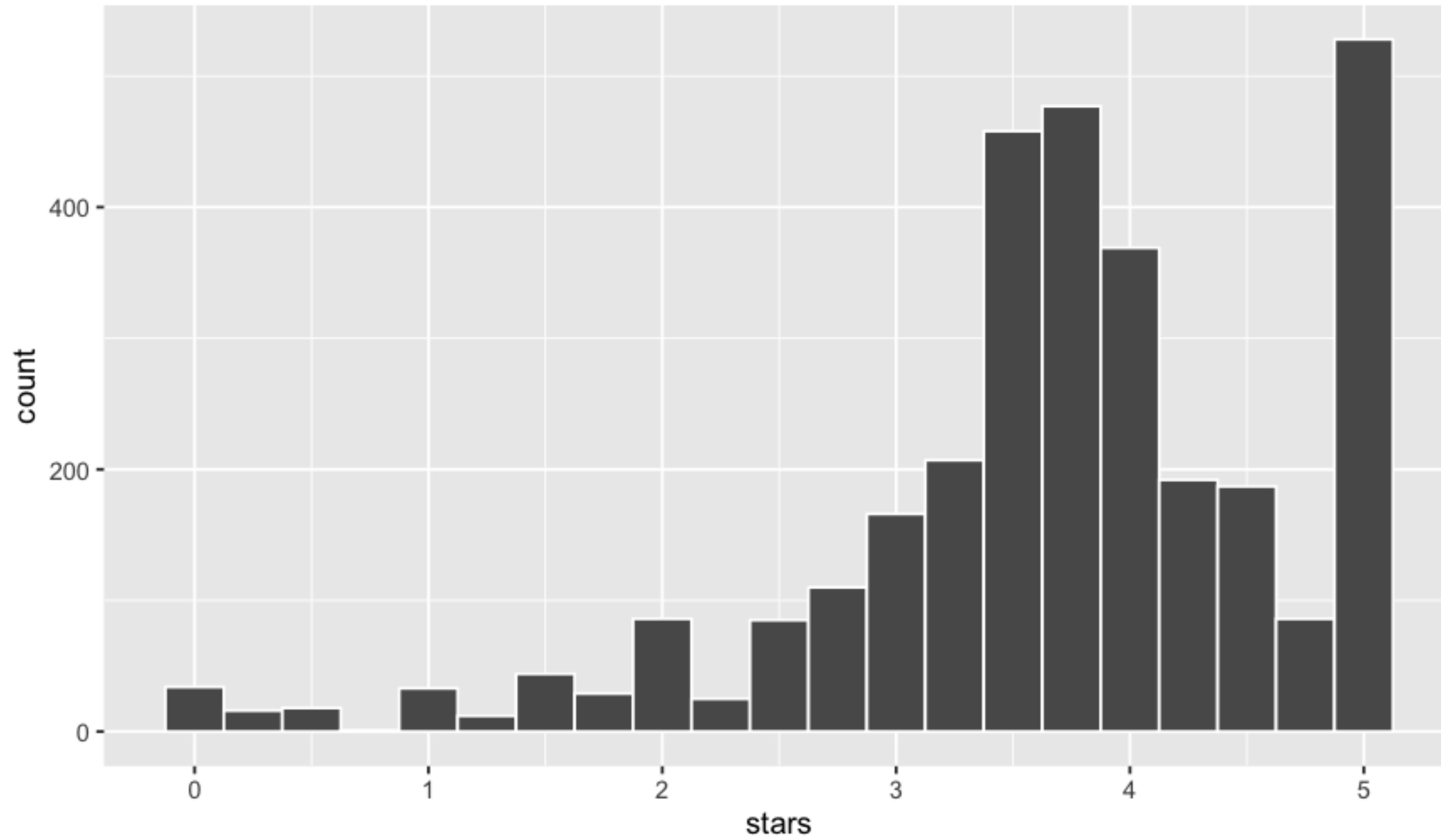
Incorporate a categorical variable (here, two “snapshots” of 1980 and 2016) with side-by-side *faceted histograms*.

The colors allow you to compare specific age ranges across the two years. The proportion of 30+ year-old moms really stands out this way.



These are density histograms; the total area under each curve is 1 (100%).

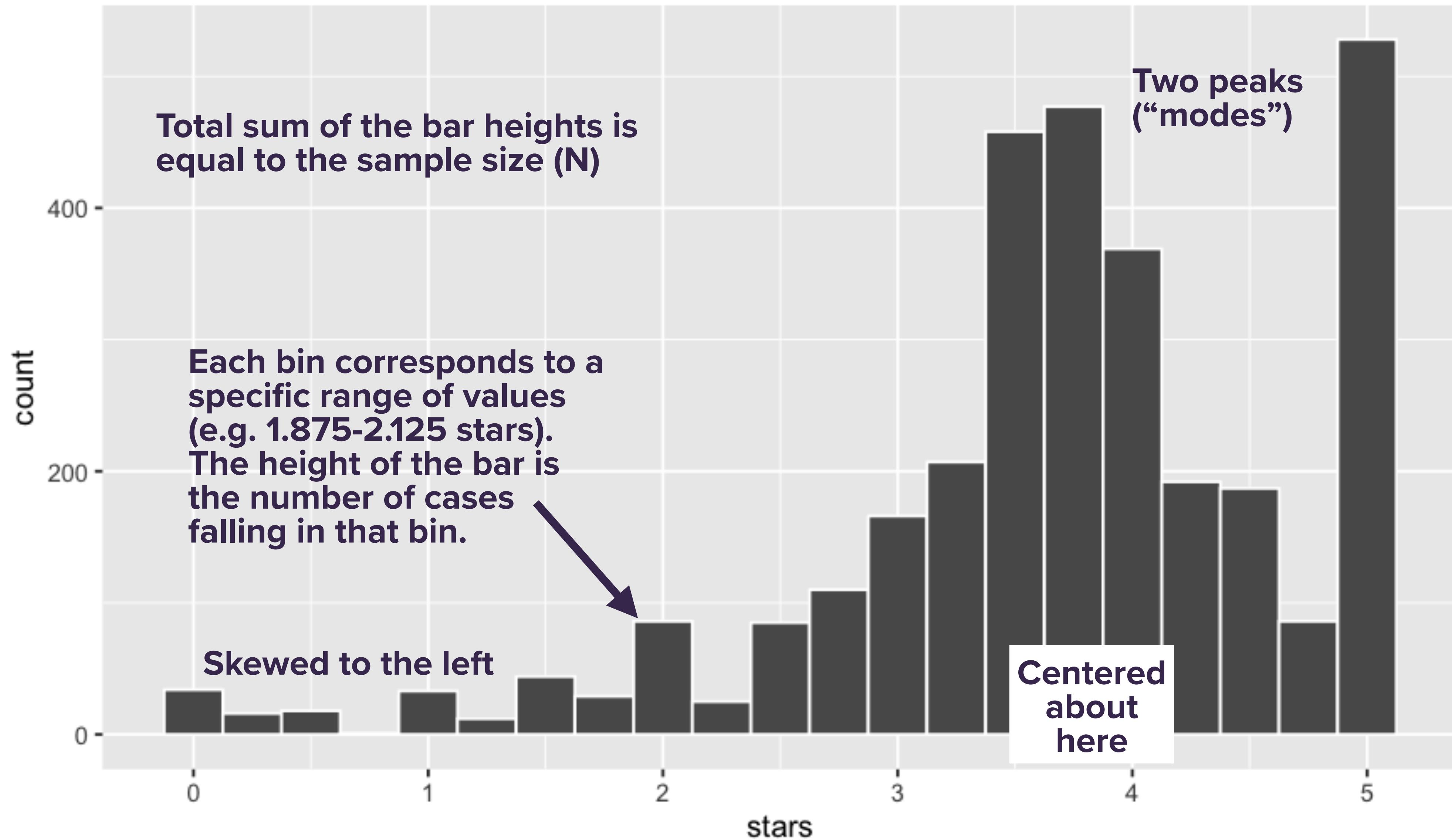
Distribution of ratings (0-5 scale) across 2764 ramen reviews



Data from The Ramen Rater, <https://www.theramenrater.com/resources-2/the-list/>

We'll make the next several histograms ourselves.

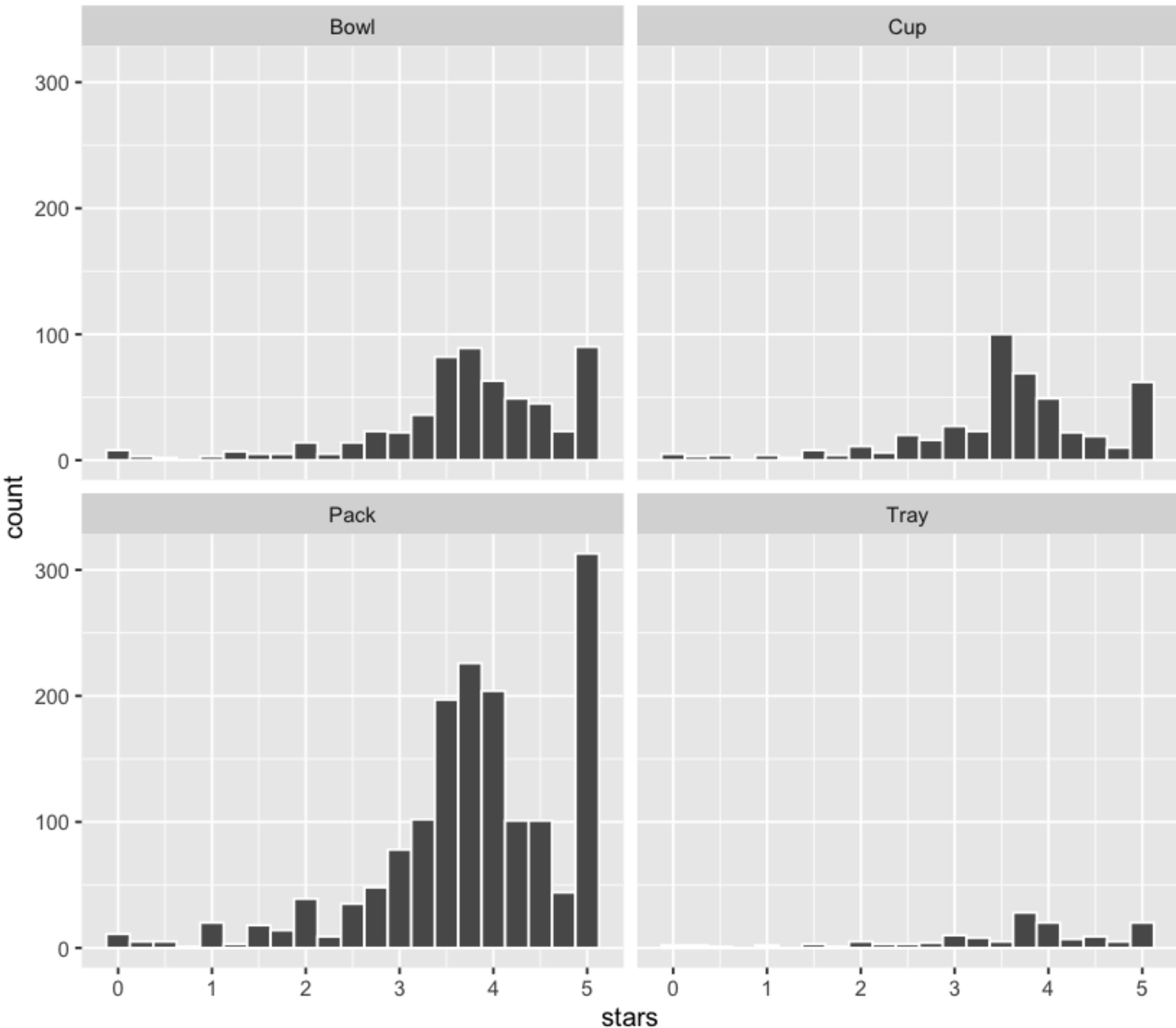
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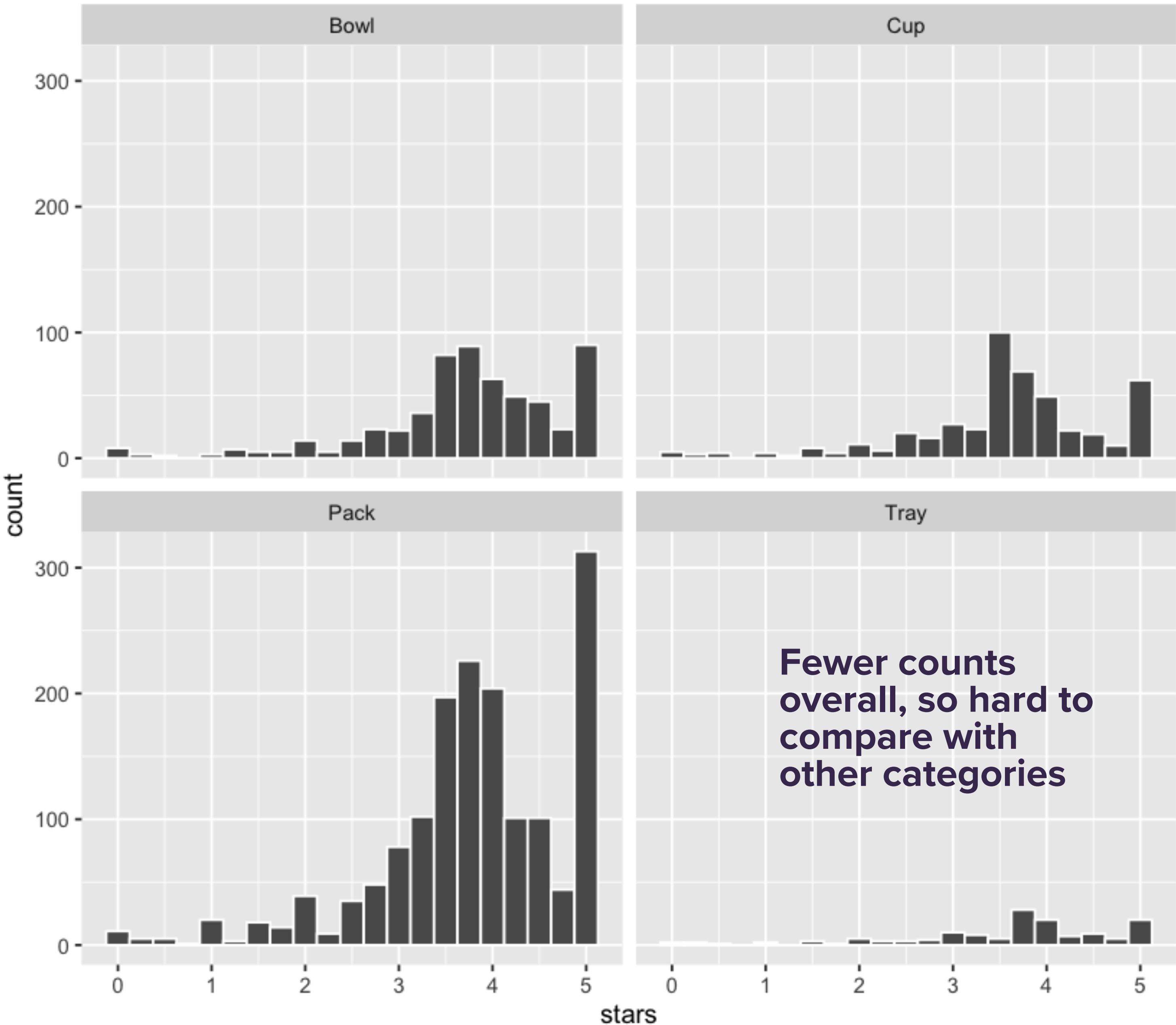
FACETING

- **Faceting is used when we'd like to split a particular visualization by the values of another variable.**
- We create multiple copies/panels of the same type of plot with matching x and y axes, but with different content.
- Here, our faceting variable is the style of container (bowl, cup, pack, tray).



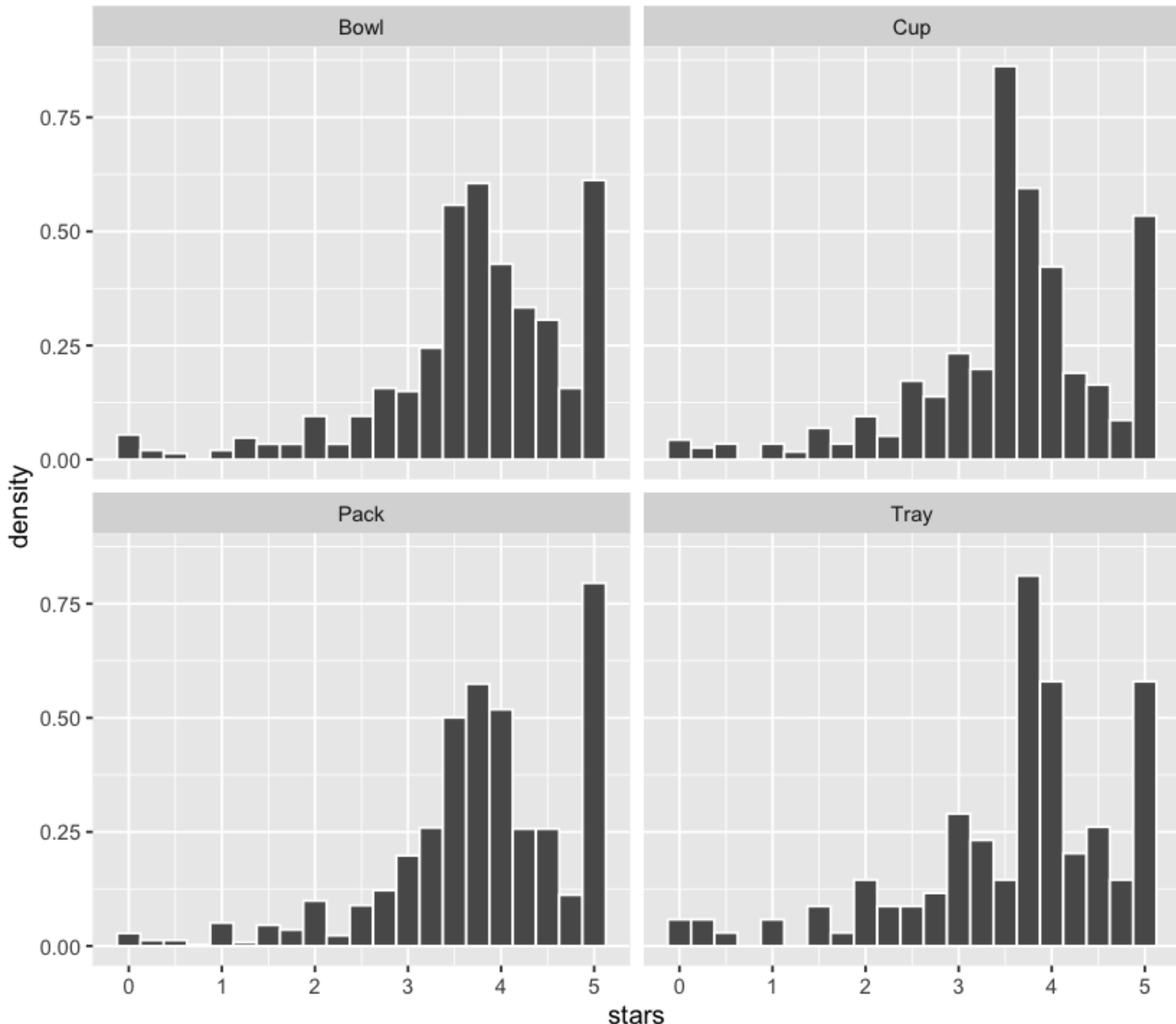
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DENSITY HISTOGRAM

- At the right, we see a density histogram, rather than a histogram of raw counts.
- This entails renormalizing the vertical scale of each panel so that the total area of the bars sums to 1.
- Now it's easier to compare distributions across categories with disparate sample sizes.



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BOXPLOTS

- Are used to compare the distribution of a numerical variable across groups.
- Show a five-number summary of the data distribution within each group

Median

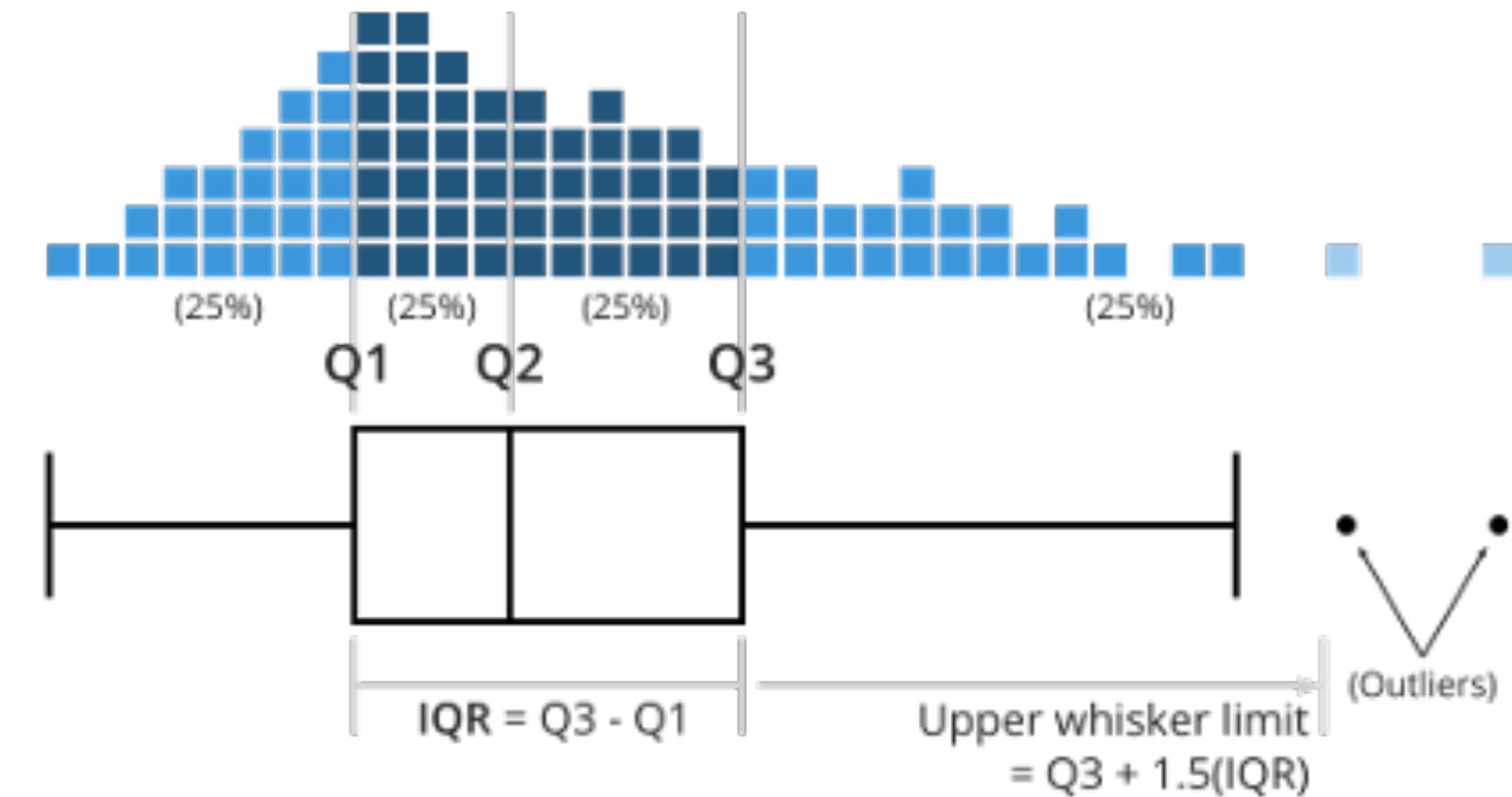
25th and 75th percentiles

Lower and upper extremes

- Are similar in spirit to faceted histograms, but don't show the entire data distribution.

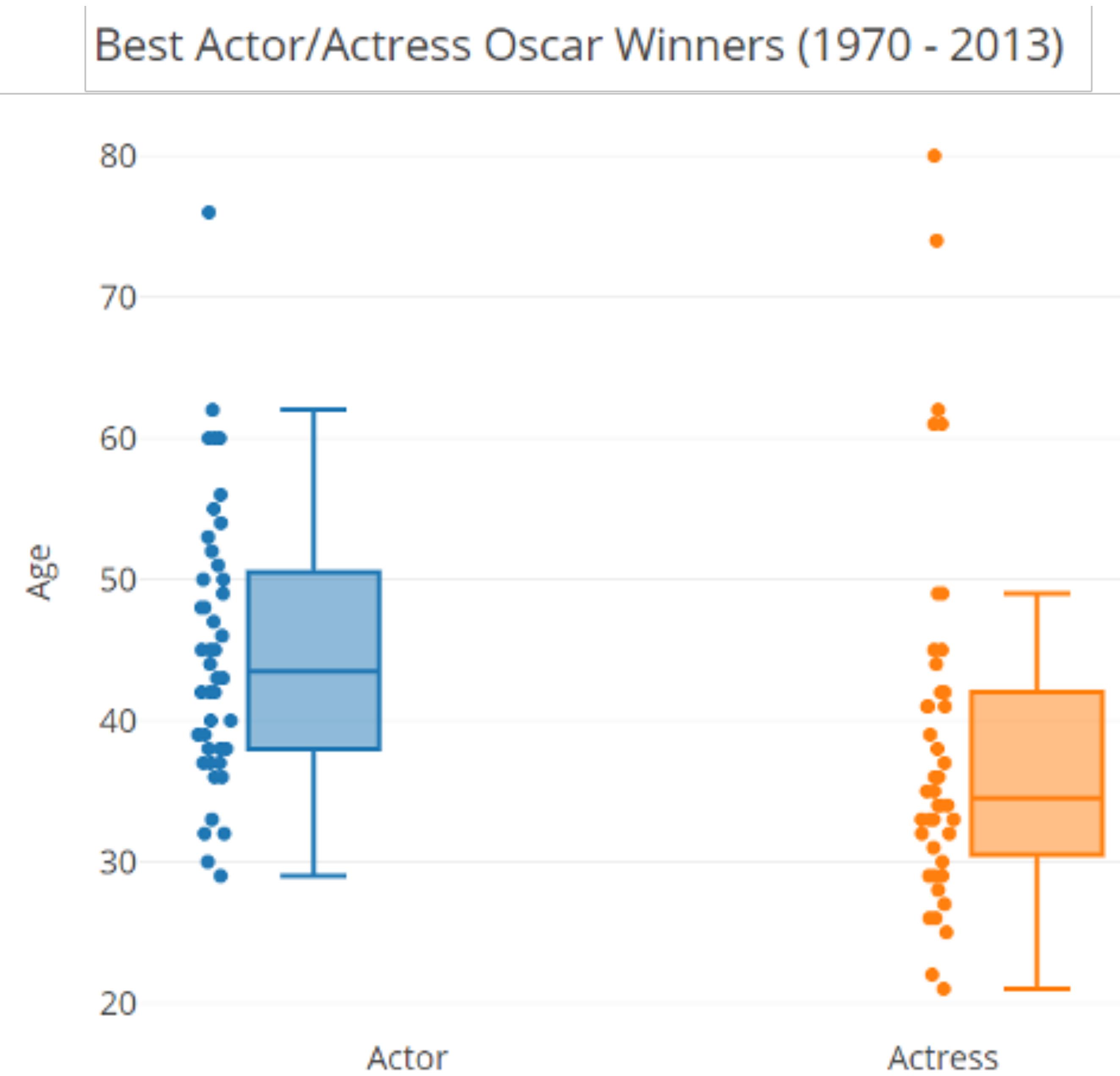
BOXPLOTS

- The central box shows the middle half of the data: 25th to 75th percentiles, the interquartile range (IQR).
- If the median is roughly centered in the box, the middle half of the data is roughly symmetric. Here we see some mild skewness.
- The whiskers also show skewness based on comparing their lengths.
- A common (though not universal) convention is to cut the whiskers off at 1.5 times the IQR, rather than min/max.

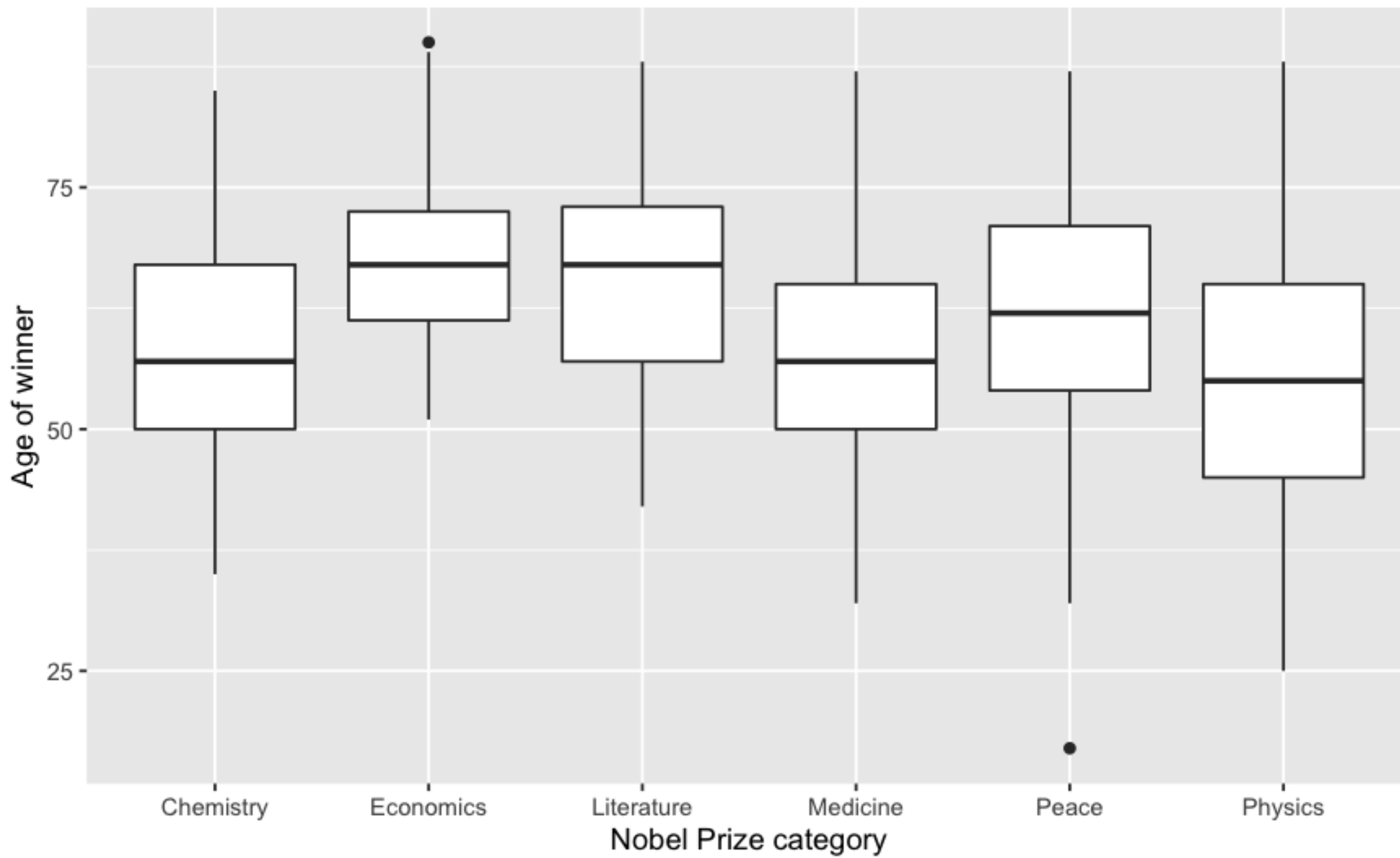


BOXPLOTS

- Use side-by-side boxplots to compare distributions with respect to some categorical variable
- Here we see a boxplot of ages of male vs. female winners of the Best Actor/Actress Oscar.
- The data points are shown individually to give you some intuition for how the boxes relate to the raw data. For smaller data sets, this juxtaposition can be effective.
- The color is redundant here; it doesn't encode any extra information.



Physics has the youngest Nobel laureates, on average



THE FIVE MOST IMPORTANT PLOTS

If you have...	Consider a...
Numerical y and numerical x	Scatter plot
Numerical y and sequential x	Line graph
Numerical y alone	Histogram
Numerical y and categorical x	Boxplot
Summary statistics by group	Bar plot

In the table, x refers to an explanatory variable and y refers to a response variable (i.e. the variable whose behavior is being “explained” by x).

BAR PLOTS

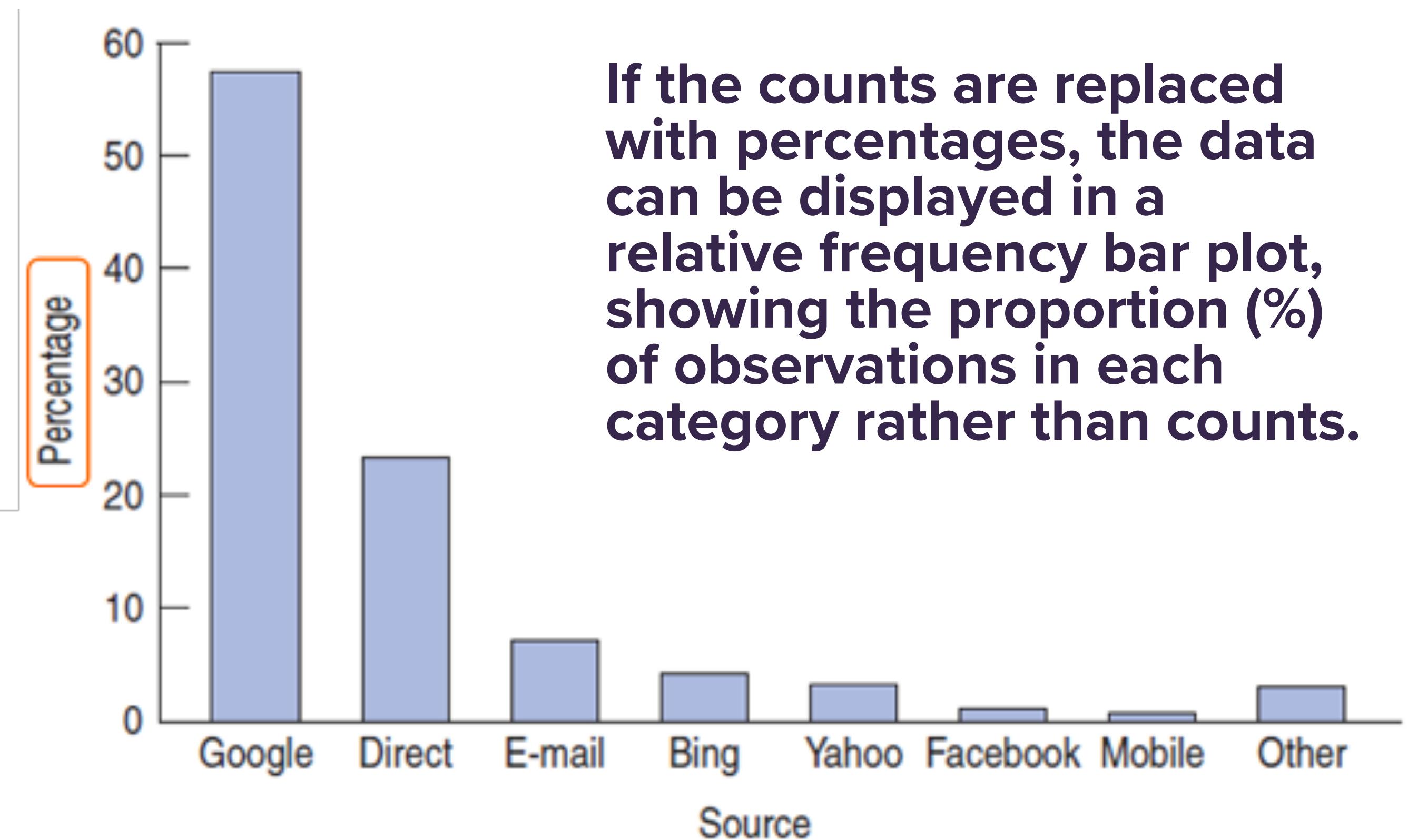
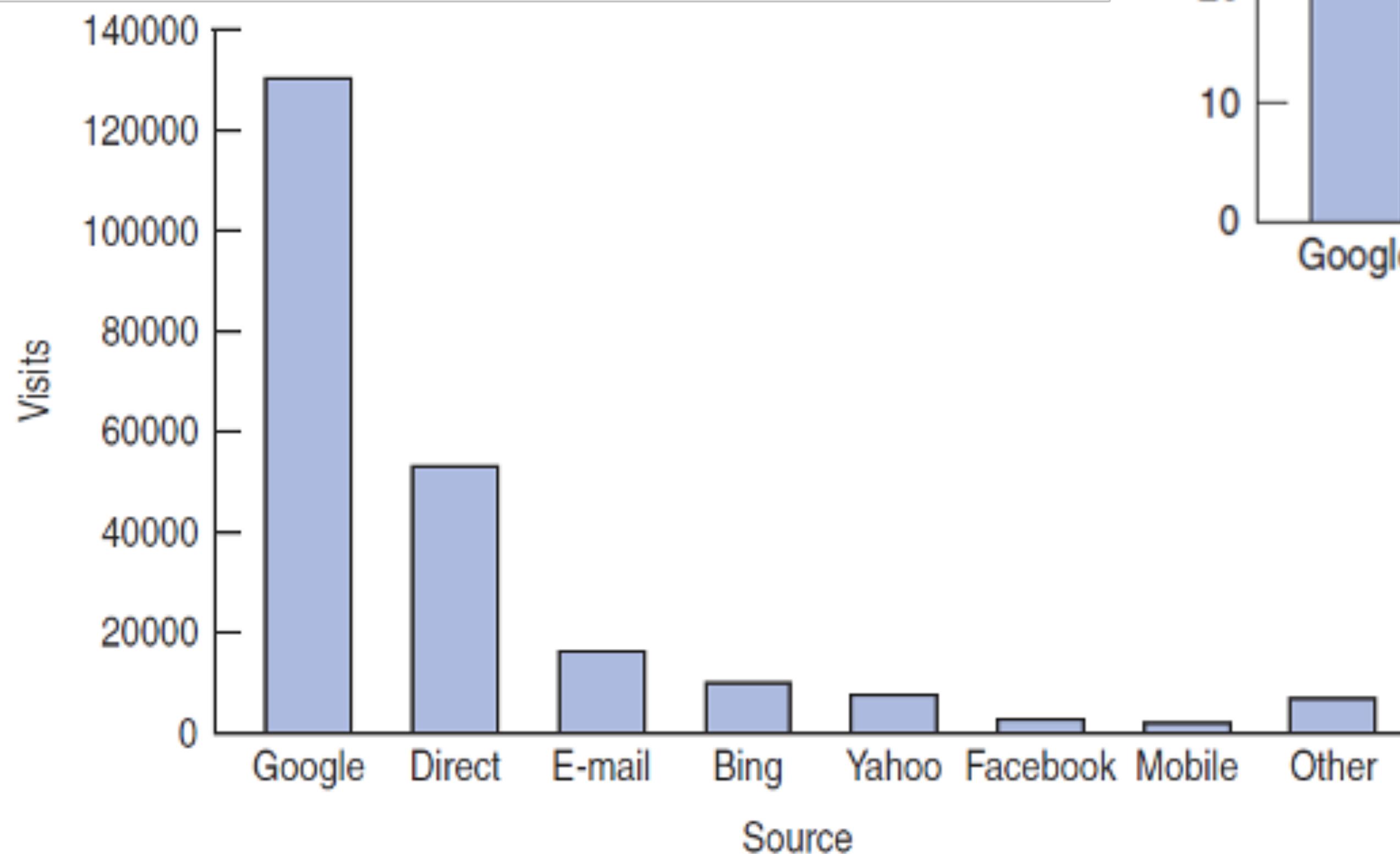
- Are typically used to compare summary statistics across groups.

Means or totals (for numerical variables)

Counts or proportions (for categorical variables)

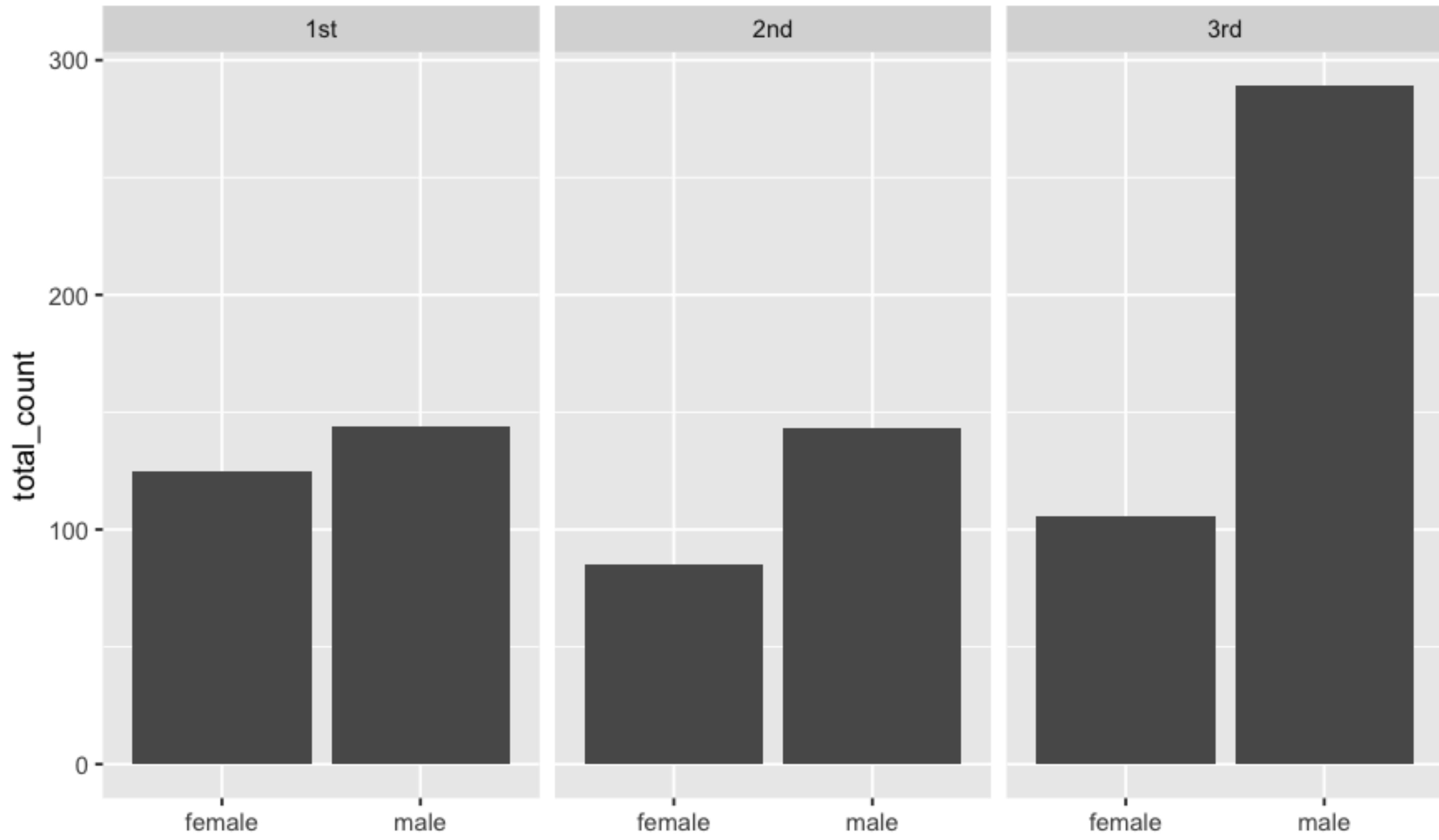
- Should always have a y axis that contains 0
- Generally require a two-stage process to make:
 - (1) **Summary stage: split your data set into subgroups and calculate summary statistics for each subgroup.**
 - (2) **Plotting stage: make a bar plot of those summary statistics, one bar per group.**
- Here we assume that stage 1 (calculating summaries), has been accomplished, and we start from stage 2 (plotting). Stage 1 comes later, in the lesson on Data Wrangling.

A bar plot displays the distribution of a categorical variable, showing the counts for each category next to each other for easy comparison.



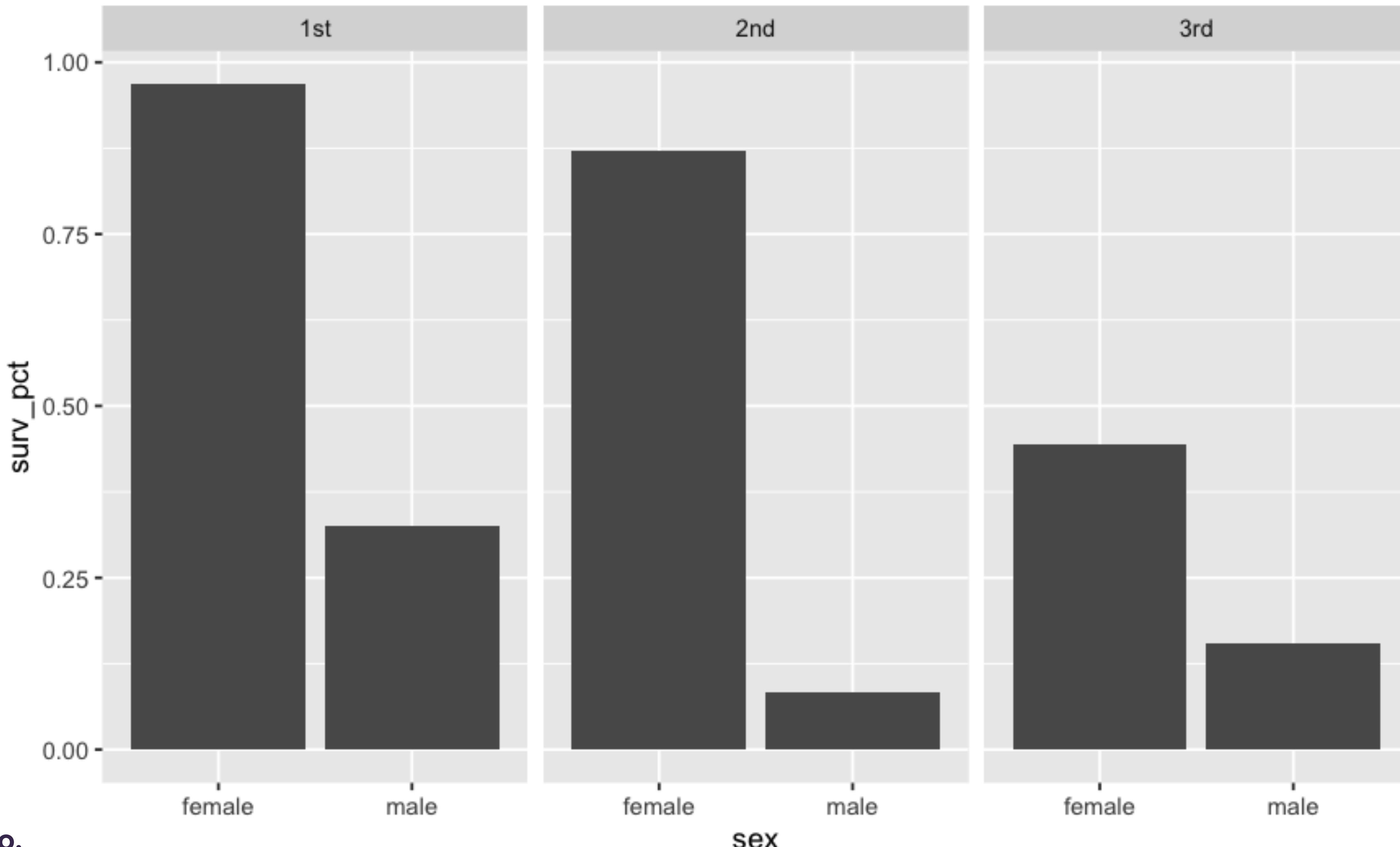
If the counts are replaced with percentages, the data can be displayed in a relative frequency bar plot, showing the proportion (%) of observations in each category rather than counts.

Who sailed the Titanic? Passenger count by class and sex



Here's a bar plot we'll make ourselves.

Who survived the Titanic? Survival percentages by class and sex



This too.

REVIEW: START WITH WHAT'S SIMPLE AND EFFECTIVE

- Simple and effective plots:

- Scatter plots

- Line graphs

- Boxplots

- Histograms

- Bar plots

- Simple and effective strategies for enriching these plots:

- Variation in size, shape, and/or color (but be colorblind-friendly and don't go crazy)

- Faceting: showing the same basic plot across multiple conditions

- Labels