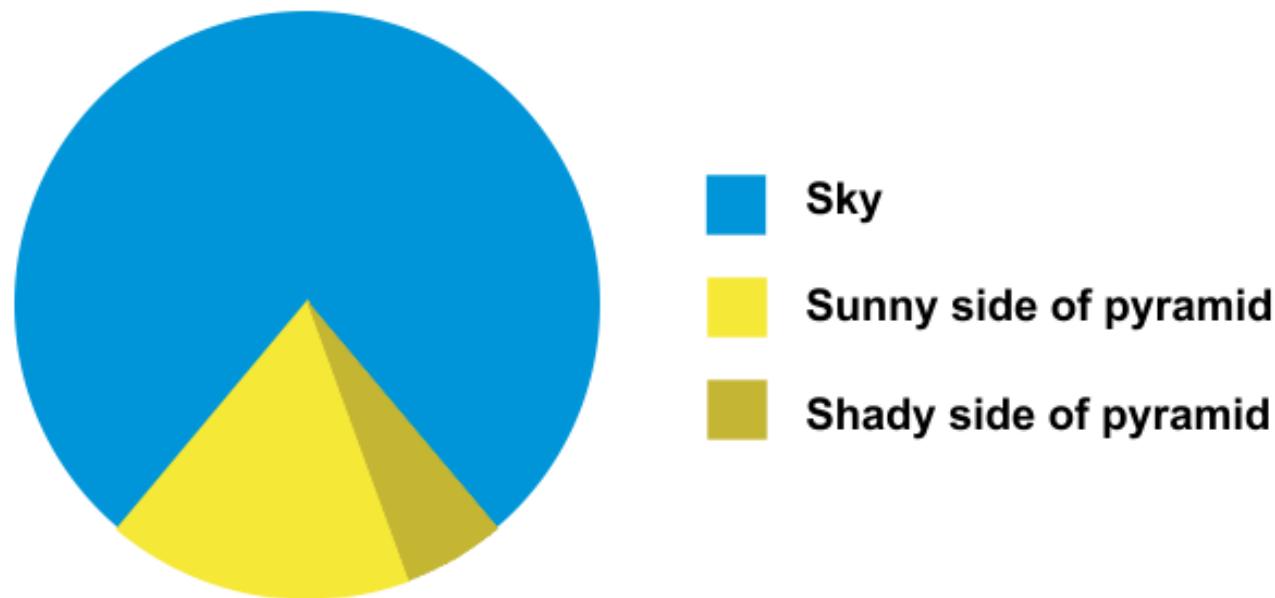


# Introduction to data visualization with R

Andrew Heiss, PhD  
Brigham Young University  
SLC RUG • July 11, 2018  
@andrewheiss



# Plan for today

Why visualize data?

Types of visualizations

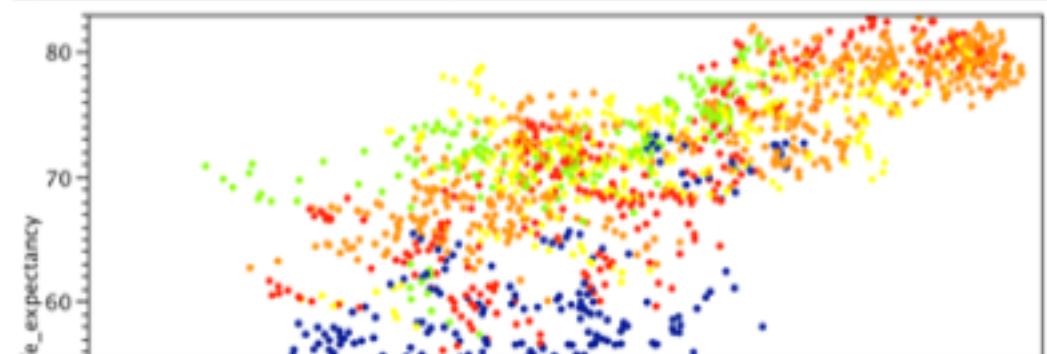
Aesthetics and design

♫♫ Take a sad plot and make it CRAPier ♫♫

[talks.andrewheiss.com/utah-rug-dataviz/](https://talks.andrewheiss.com/utah-rug-dataviz/)



Figure 7: Life expectancy plotted by governance



## Winners from Nathan's Hot Dog Eating Contest

Since 1916, the annual eating competition has grown substantially attracting competitors from around the world. This year's competition will be televised on July 4, 2008 at 12pm EDT live on ESPN.

70 Hot dogs and buns (HDBs)

■ NEW WORLD RECORD



For the first time since 1999, an American reclaims the title when Joey Chestnut consumes 66 HDBs, a new world record.



Through 2001-2005, Takeru Kobayashi wins by no less than 12 HDBs. In 2006, he only wins by 1.75. After winning 6 years in a row and setting the world record 4 times, Kobayashi places second in 2007.

Frank DellaRosa eats 21 and a half HDBs over 12 minutes, breaking the previous record of 19 and a half.

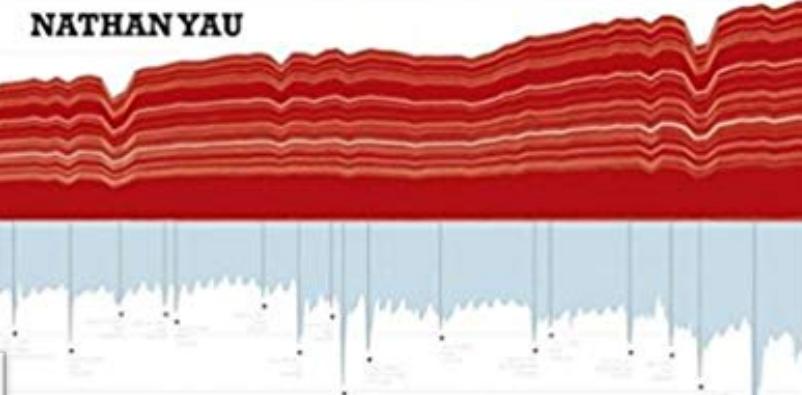
Walter Paul sets a new world record with 17 HDBs.

James Mullen wins the inaugural contest, scarfing 13 HDBs. Length of contest is unavailable.

Data for 1916 and 1972 were unavailable.

Sources: Wikipedia and Nathan's Famous

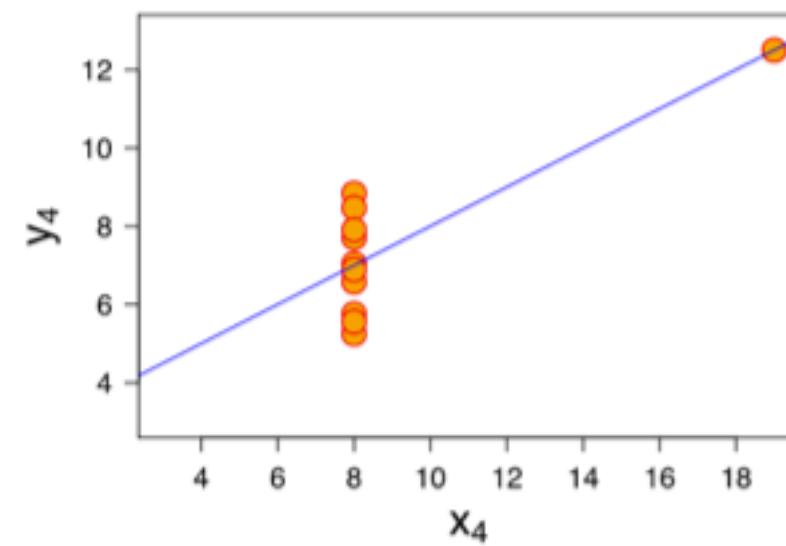
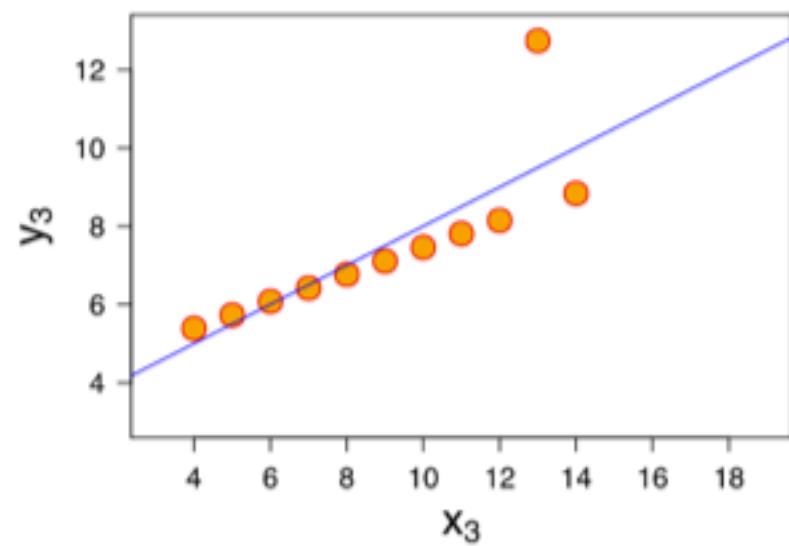
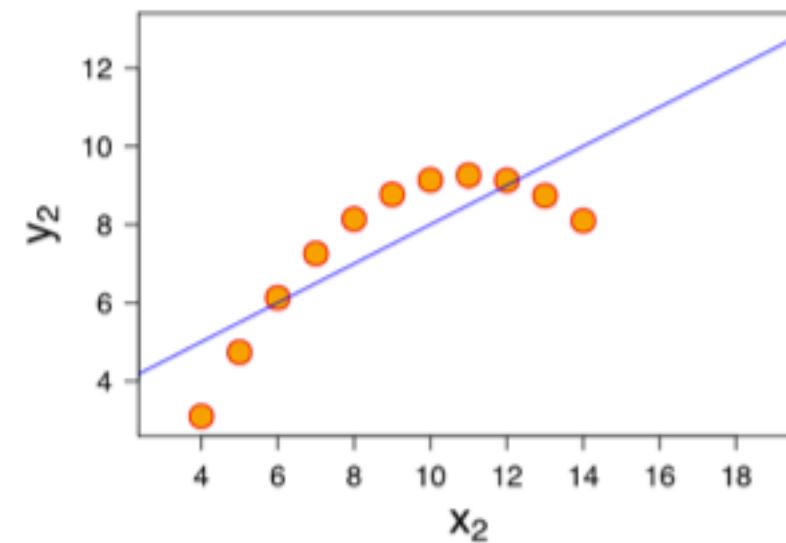
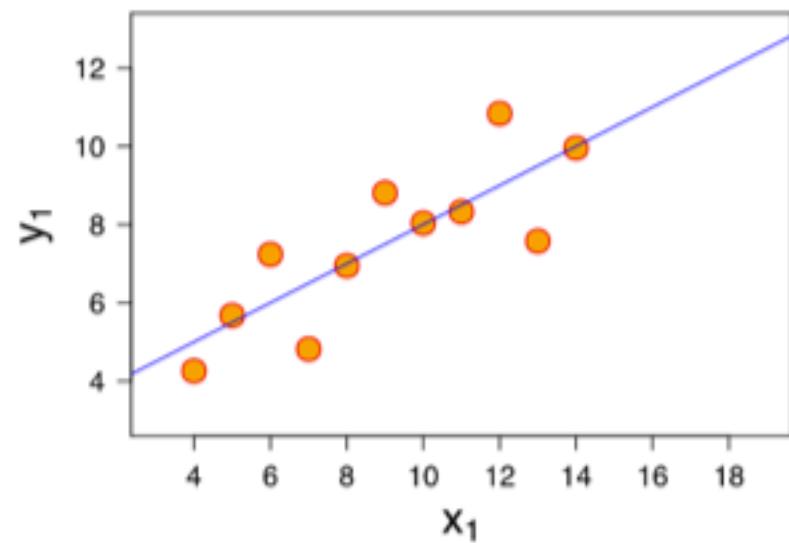
FlowingData



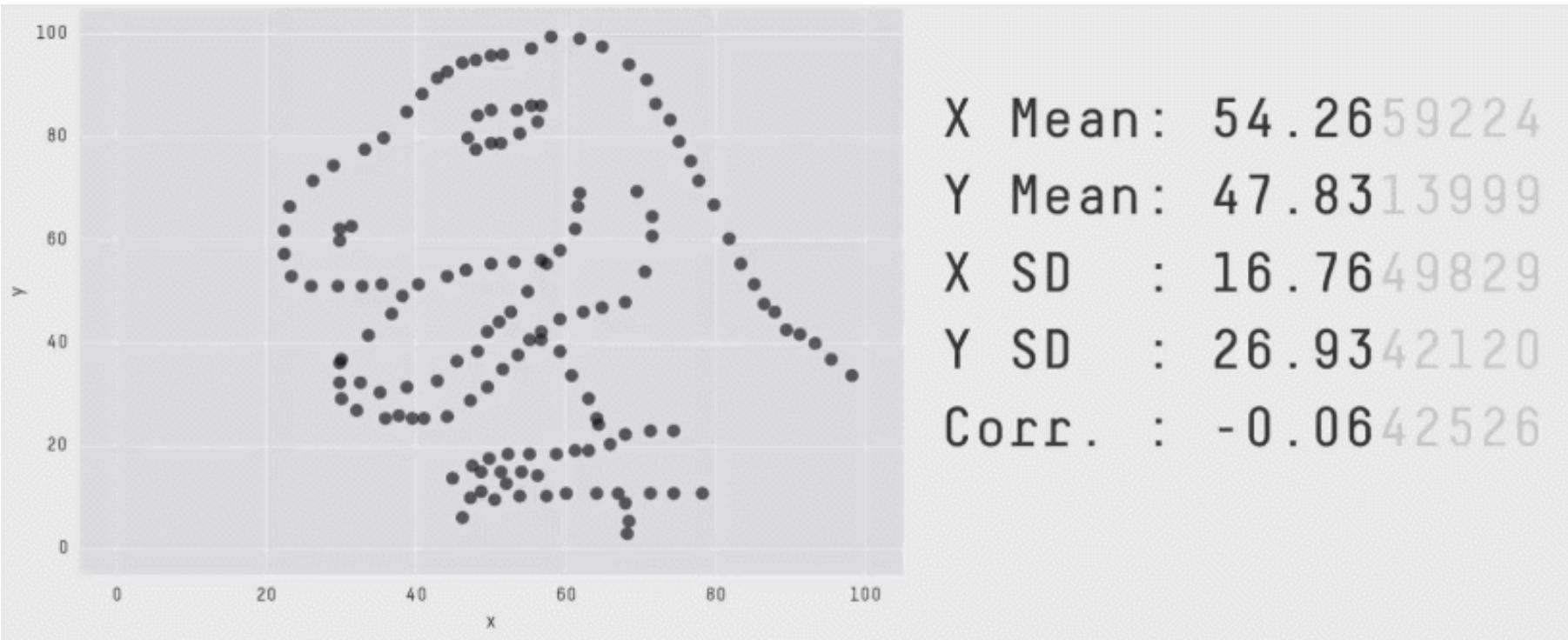
# Why visualize data?

**Data alone cannot tell  
stories or prove theories**

I		II		III		IV		
x	y	x	y	x	y	x	y	
10	8,04	10	9,14	10	7,46	8	6,58	
8	6,95	8	8,14	8	6,77	8	5,76	
13	7,58	13	8,74	13	12,74	8	7,71	
9	8,81	9	8,77	9	7,11	8	8,84	
11	8,33	11	9,26	11	7,81	8	8,47	
14	9,96	14	8,1	14	8,84	8	7,04	
6	7,24	6	6,13	6	6,08	8	5,25	
4	4,26	4	3,1	4	5,39	19	12,5	
12	10,84	12	9,13	12	8,15	8	5,56	
7	4,82	7	7,26	7	6,42	8	7,91	
5	5,68	5	4,74	5	5,73	8	6,89	
SUM	99,00	82,51	99,00	82,51	99,00	82,50	99,00	82,51
AVG	9,00	7,50	9,00	7,50	9,00	7,50	9,00	7,50
STDEV	3,32	2,03	3,32	2,03	3,32	2,03	3,32	2,03



# Never trust summary statistics alone



# Humans are visual creatures

frontiers in  
NEUROSCIENCE

REVIEW ARTICLE  
published: 22 August 2014  
doi: 10.3389/fnhns.2014.00265

## Superior pattern processing is the essence of the evolved human brain

Mark P. Mattson<sup>1,2\*</sup>

<sup>1</sup> Laboratory of Neurosciences, National Institute on Aging Intramural Research Program, Baltimore, MD, USA

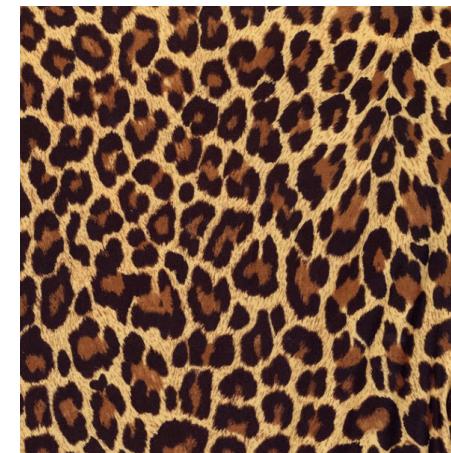
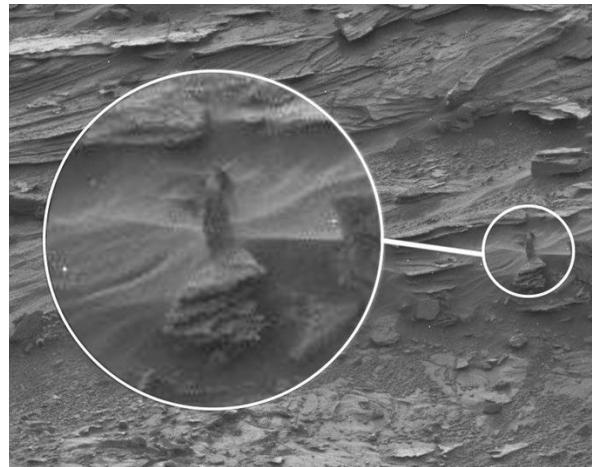
<sup>2</sup> Department of Neuroscience, Johns Hopkins University School of Medicine, Baltimore, MD, USA

Edited by:

J. Michael Williams, Drexel University, USA

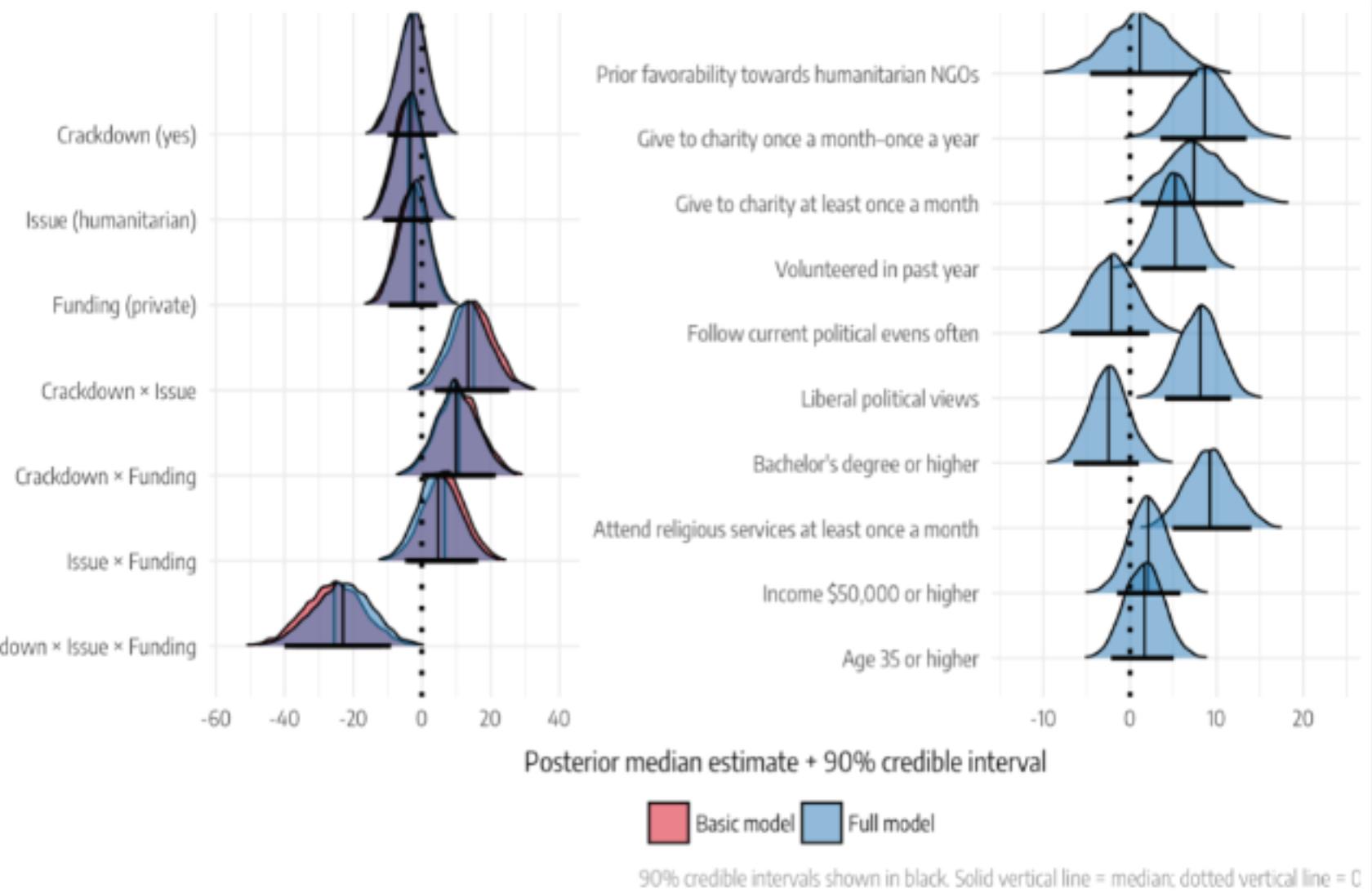
• • •

Humans have long pondered the nature of their mind/brain and, particularly why its capacities for reasoning, communication and abstract thought are far superior to other species, including closely related anthropoids. This article considers superior pattern



@FacesPics

	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	20.207 (1.597)	20.641 (2.239)	22.033 (3.049)	4.324 (4.5)	-4.740 (2.1)	6.346 (2.1)
Crackdown (yes)	3.797 (2.254)	2.636 (3.055)	-2.692 (4.337)	3.1 (2.1)		
Issue (humanitarian)		-0.993 (3.094)	-4.030 (4.312)			Crackdo
Funding (private)			-2.867 (4.444)			Issue (hum
Crackdown × Issue		2.418 (4.366)	15.090 (5.969)			
Crackdown × Funding			10.831 (6.274)			Funding
Issue × Funding			6.595 (6.013)			Crackdow
Crackdown × Issue × Funding			-25.544 (8.628)			
Prior favorability towards humanitarian NGOs				1.2 (3.6)		Crackdown ×
Give to charity once a month–once a year				8.6 (3.1)		Issue ×
Give to charity at least once a month				7.4 (3.6)		Crackdown × Issue ×
Volunteered in past year				5.4 (2.2)		
Follow current political events often				-2.8 (2.7)		
Liberal political views				8.2 (2.3)		
Bachelor's degree or higher				-2.4 (2.2)		
Attend religious services at least once a month				9.817 (2.262)	9.833 (2.254)	9.230 (2.262)



# What makes a good visualization?

*Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.*  
 Dressée par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite à Paris, le 20 Novembre 1869.

Les nombres d'hommes présents sont représentés par les largeurs des zones colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en travers des zones. Le rouge désigne les hommes qui entrent en Russie; le noir ceux qui en sortent. — Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M. M. Chiers, de Segur, de Fezensac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre.

Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davout qui avaient été détachés sur Minsk et Mobilow et qui rejoignirent Orscha en Witelsk, avaient toujours marché avec l'armée.

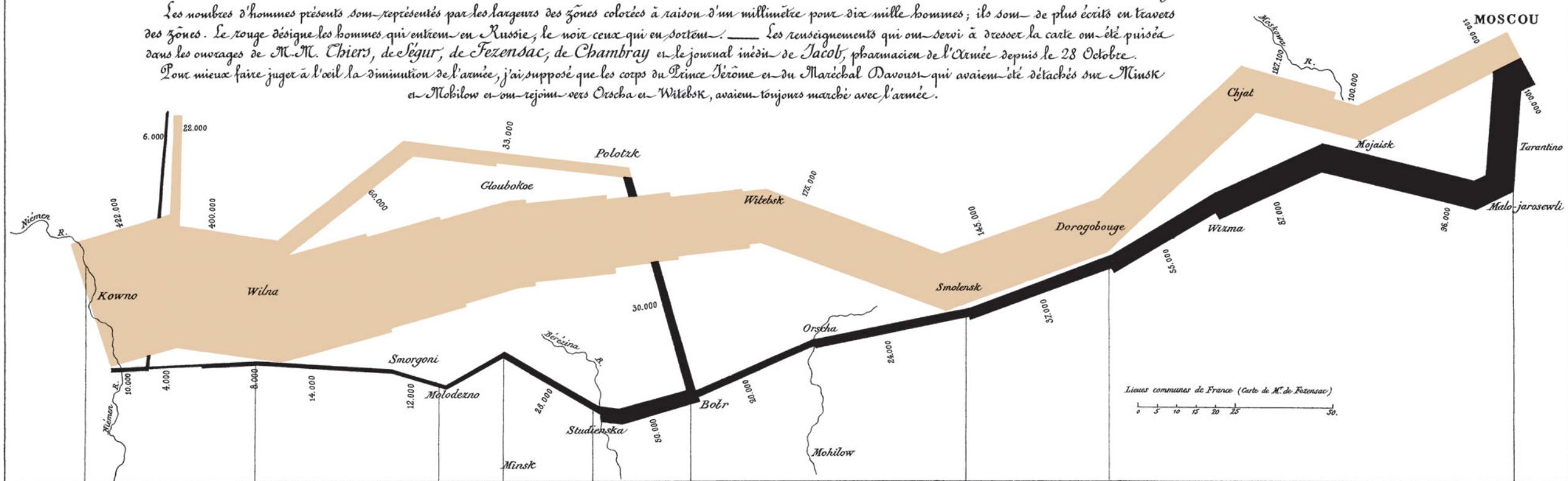
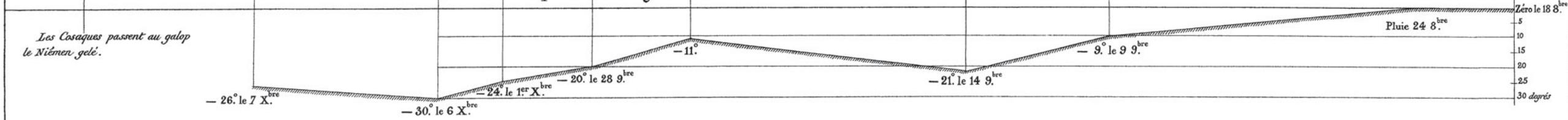


TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.



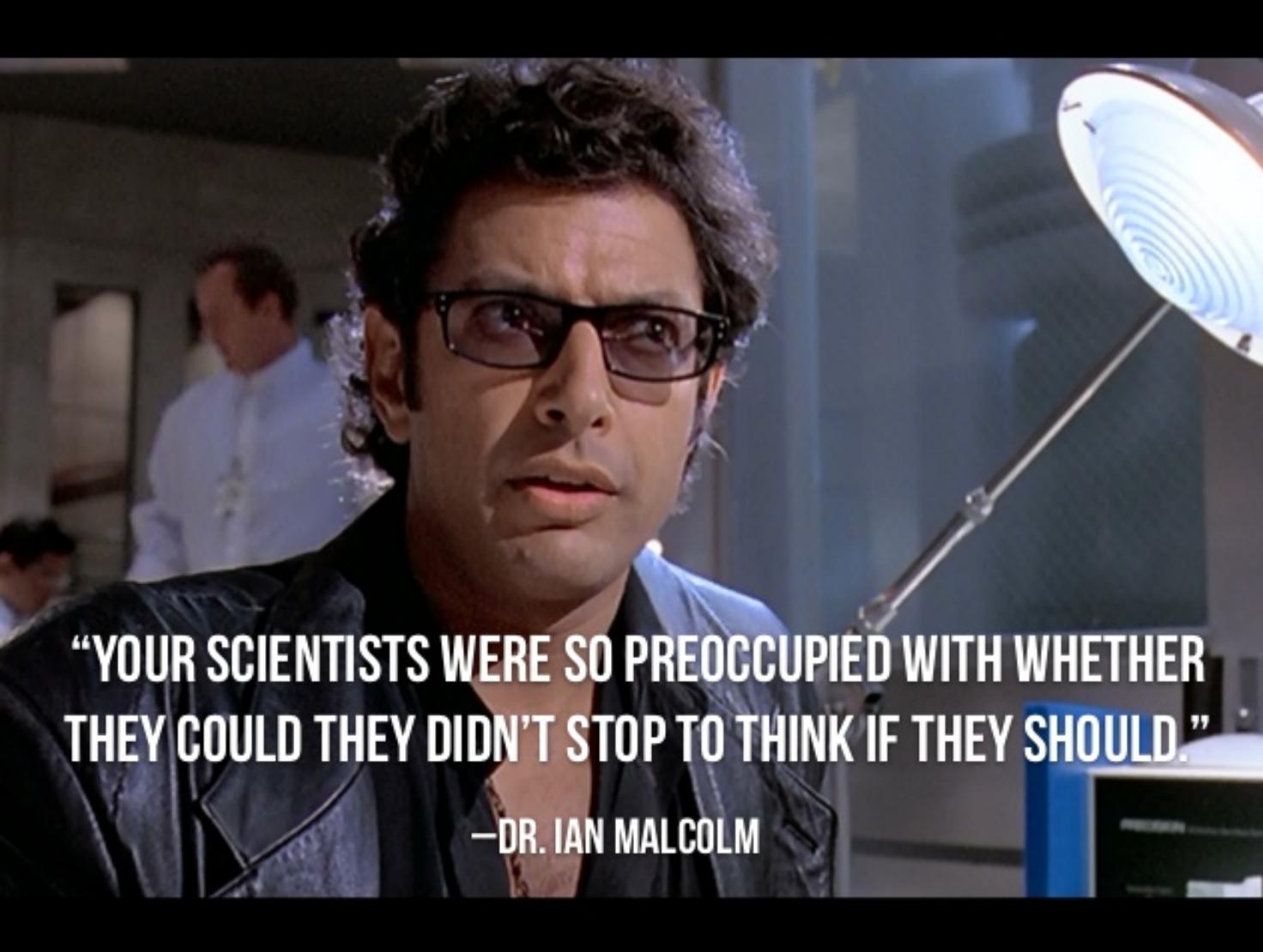
# Characteristics of graphical excellence

1. “... the well-designed presentation of interesting data—a matter of substance, statistics, and design.”
2. Complex ideas communicated with clarity, precision, and efficiency.
- 3. That which gives the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space.**
4. Nearly always multivariate.
5. Requires telling the truth about the data.

## What makes Minard's graph so great?

$$\text{Data:Ink ratio} = \frac{\text{Ink}_{\text{Data}}}{\text{Ink}_{\text{Total}}}$$

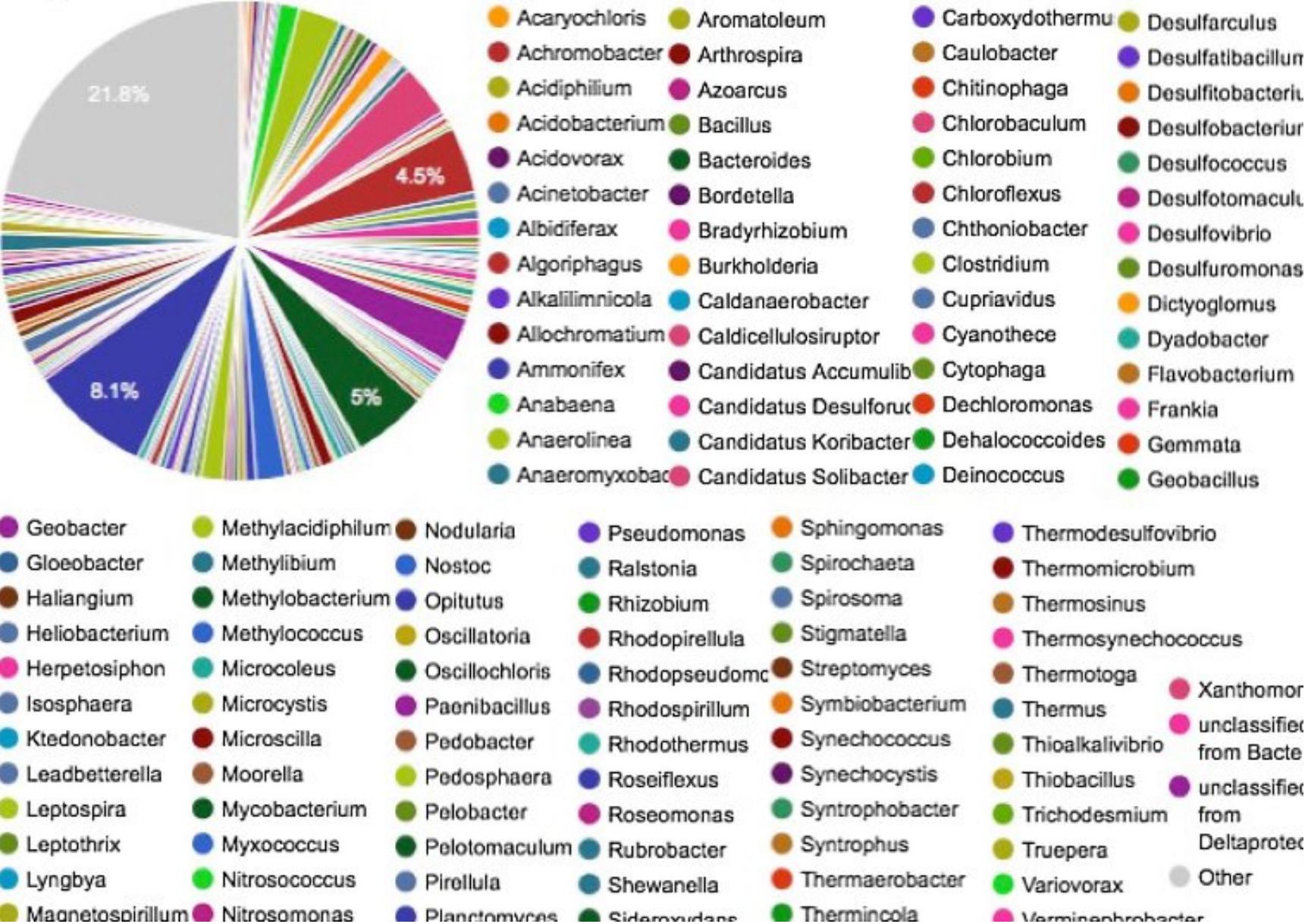
# We forget this!



**“YOUR SCIENTISTS WERE SO PREOCCUPIED WITH WHETHER THEY COULD THEY DIDN’T STOP TO THINK IF THEY SHOULD.”**

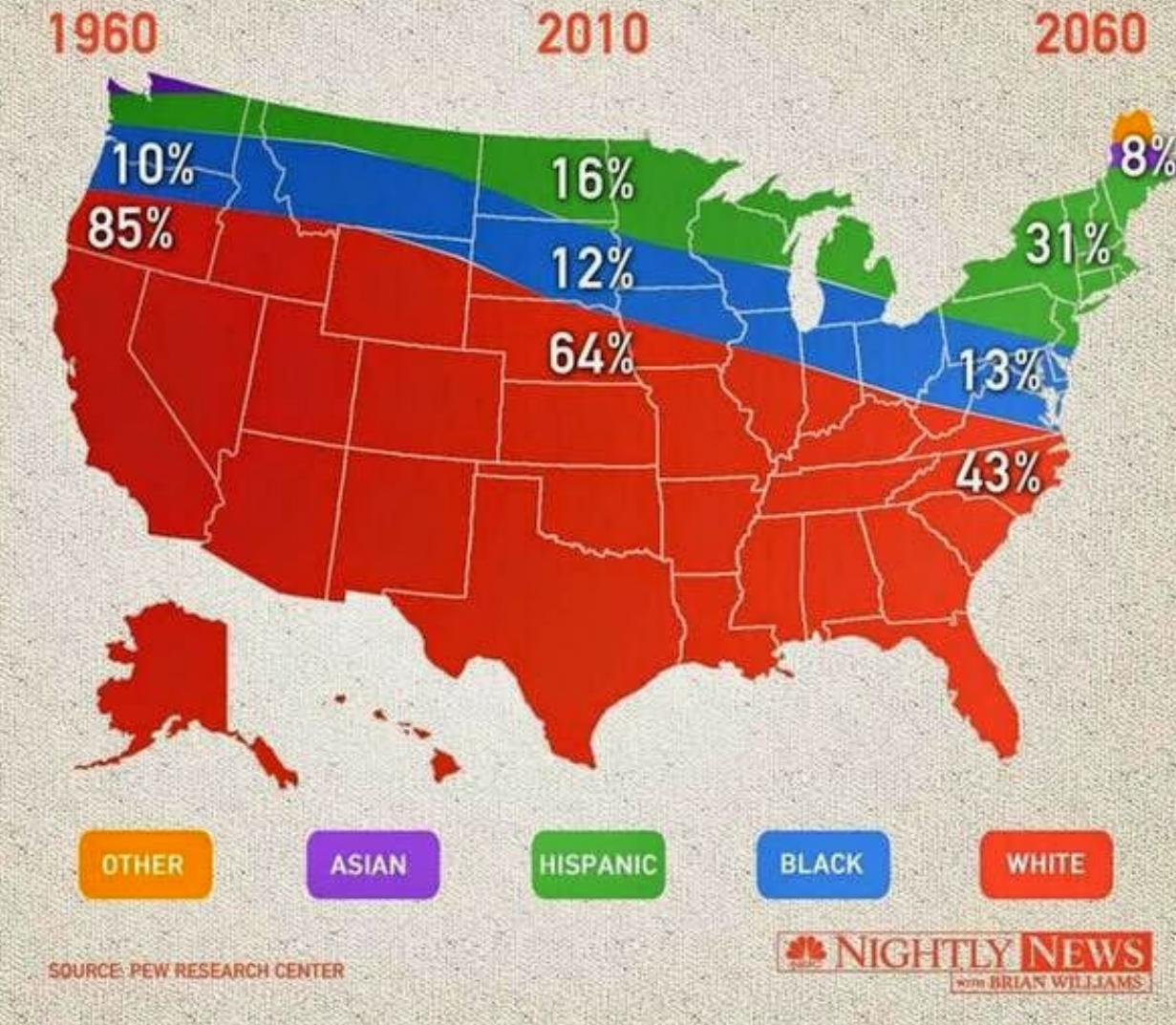
**—DR. IAN MALCOLM**

### (f) Distribution of Genus



# CHANGING FACE OF AMERICA

Percent of total U.S. population by race and ethnicity, 1960-2060



# Types of visualizations

# Exploratory visualizations

**Academic-ish**

Quick scatterplots, histograms, other charts to help understand your data

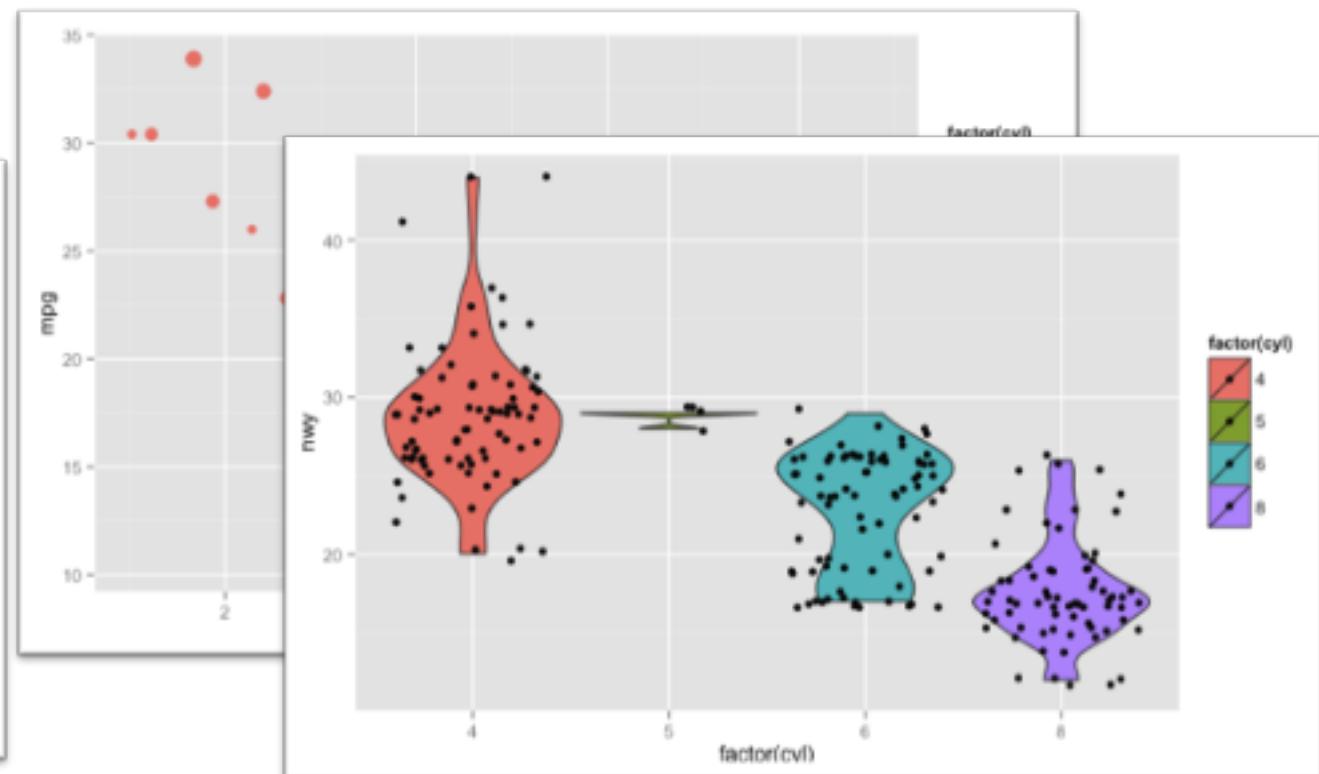
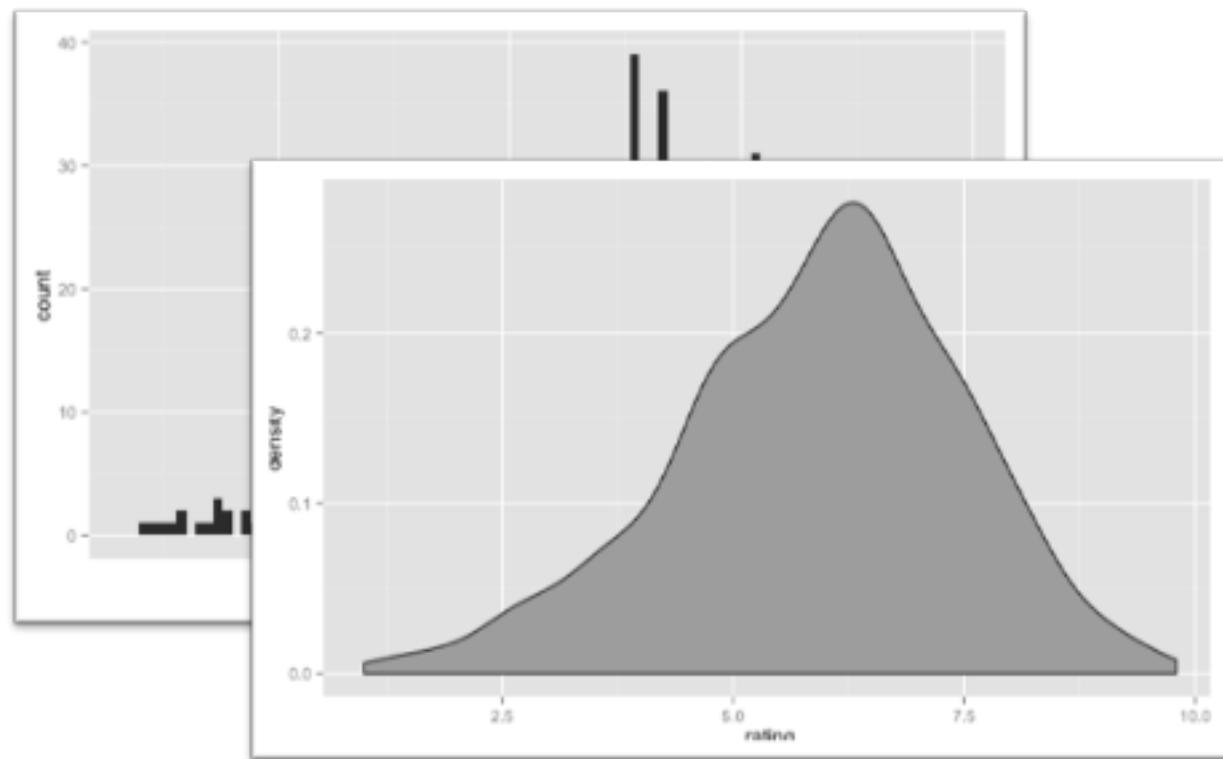
# Explanatory visualizations

**Publishable**

Consumable by the general public; Vox, NYT, Washington Post, FiveThirtyEight, etc.

# Exploratory data analysis

Find analytical insight in data (even causal inference 🤯)



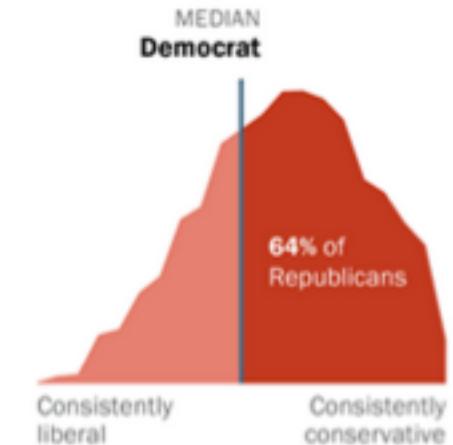
# Explanatory data analysis

Annotate and tell a story

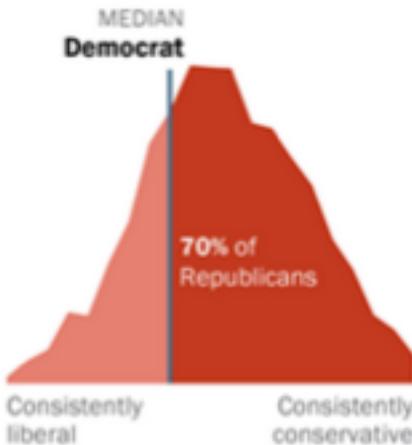
## Republicans Shift to the Right, Democrats to the Left

*Distribution of Republicans and Democrats on a 10-item scale of political values*

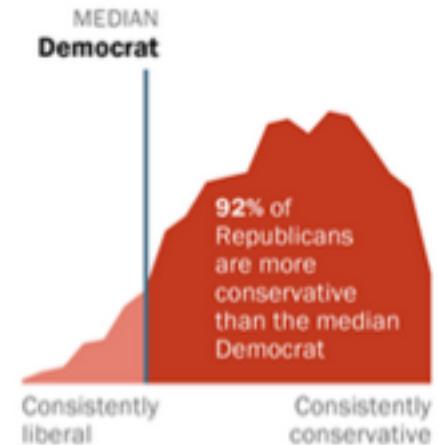
1994



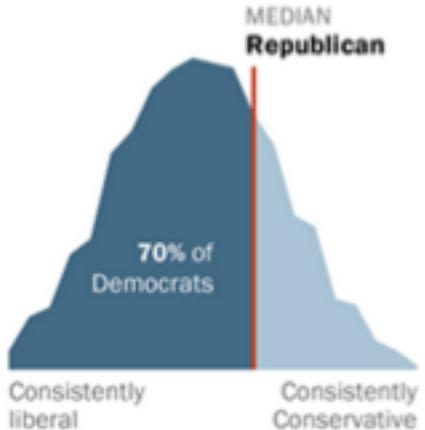
2004



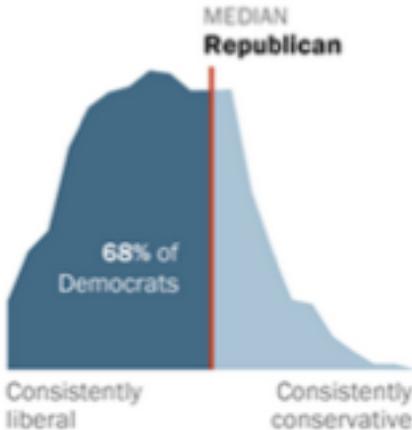
2014



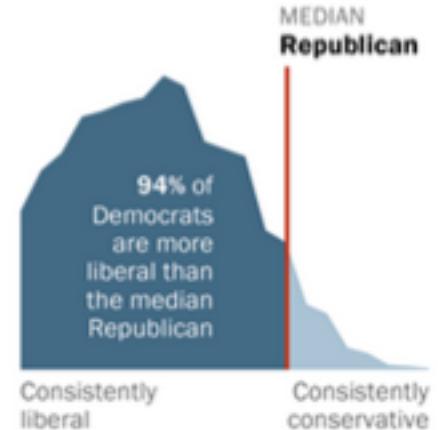
MEDIAN  
Republican



MEDIAN  
Republican



MEDIAN  
Republican



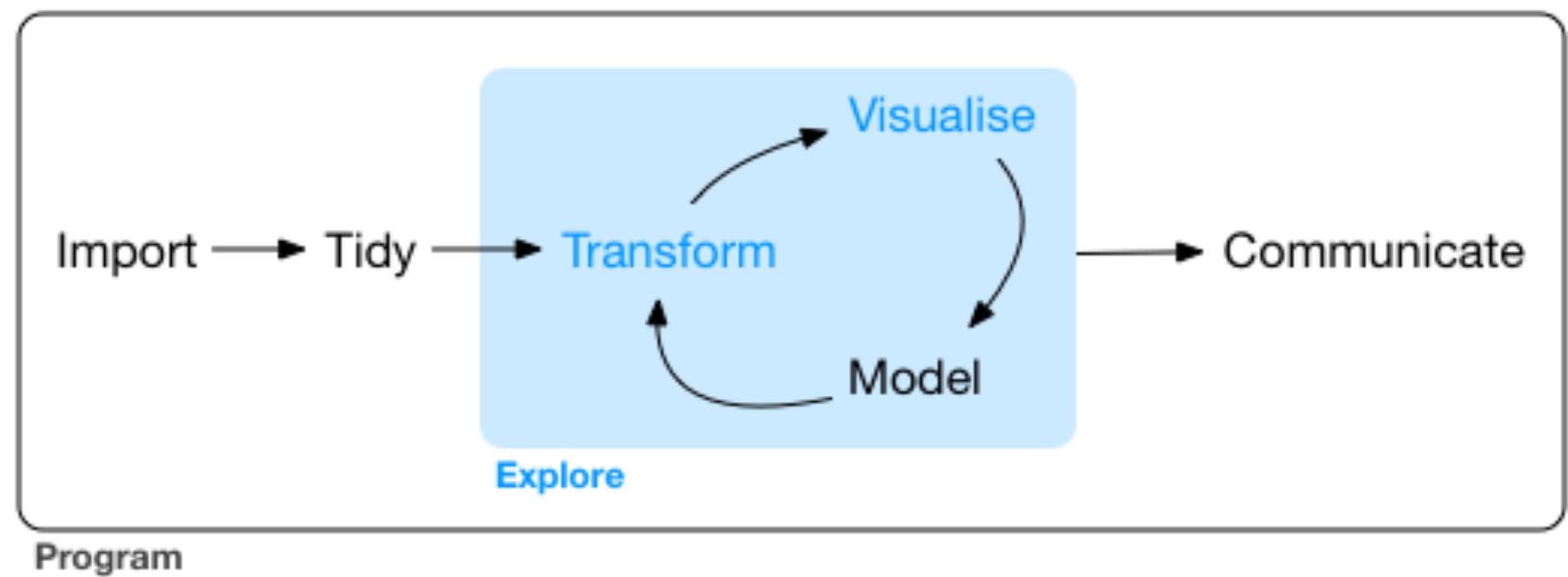
Source: 2014 Political Polarization in the American Public.

Notes: Ideological consistency based on a scale of 10 political values questions (see Appendix A). Republicans include Republican-leaning independents; Democrats include Democratic-leaning independents (see Appendix B).

PEW RESEARCH CENTER

# Exploratory

# Explanatory



# Which chart type do I use?

Numeric Categoric Num & Cat Maps Network Time series

Distribution

Filter by chart name or AKA

Reference Type: ● Example ● Solution | Chart Families: ● Categorical ● Hierarchical

	Amazon QuickSight	ArcGIS	ChartJS	D3.js	Data Illustrator	Datawrapper	Flourish	FusionCharts	Gephi	Google Charts
Bar chart	●			●	○	●	○	○		●
Clustered bar chart	●			●	○	●	○	○		●
Bullet chart				●		●		○		
Connected dot plot				●		●				

Legend: ● Example ● Solution | Chart Families: ● Categorical ● Hierarchical

Icons on the left: Bar chart, Clustered bar chart, Bullet chart, Connected dot plot.

# Aesthetics and design



Edward Tufte

@EdwardTufte



Following

#Rstats coders and users just can't do words on graphics and typography. Proof: 40 years of clunky, even recent Stanford Statistics textbooks. Publication-quality work requires: R + Adobe Illustrator + reasoning about words on graphics + respect for audience/readers/viewers  
<https://t.co/tqFYoZAH5v>



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8:31 AM - 26 Jun 18 · Embed this Tweet



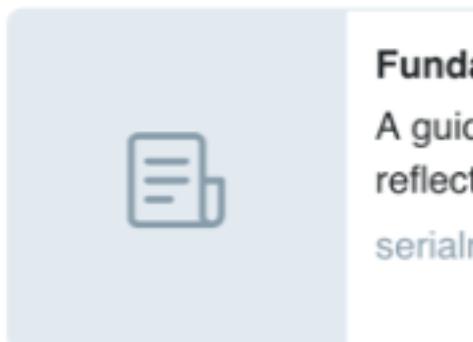
Claus Wilke

@ClausWilke



Sad to announce I'll have to abandon my project of writing a book on **#dataviz** entirely in **#rstats**, with all figures programmatically generated. I just learned it is not possible. Ignore the 21 chapters already online. They are a mirage.  
[serialmentor.com/dataviz/](http://serialmentor.com/dataviz/) [twitter.com/EdwardTufte/st...](https://twitter.com/EdwardTufte/st...)

11:02 AM - Jun 26, 2018



1 753 97 people are talking about this



Nihilist Data Scientist

@nihilist\_ds



Most **#DataScience** folks eventually learn that while we all aspire to create **#dataviz** that meets Tufte's approval, we are all doomed to fall short under his watchful gaze.

So as with all other things in life it's healthier to give up. Embrace your failure, for it is inevitable.

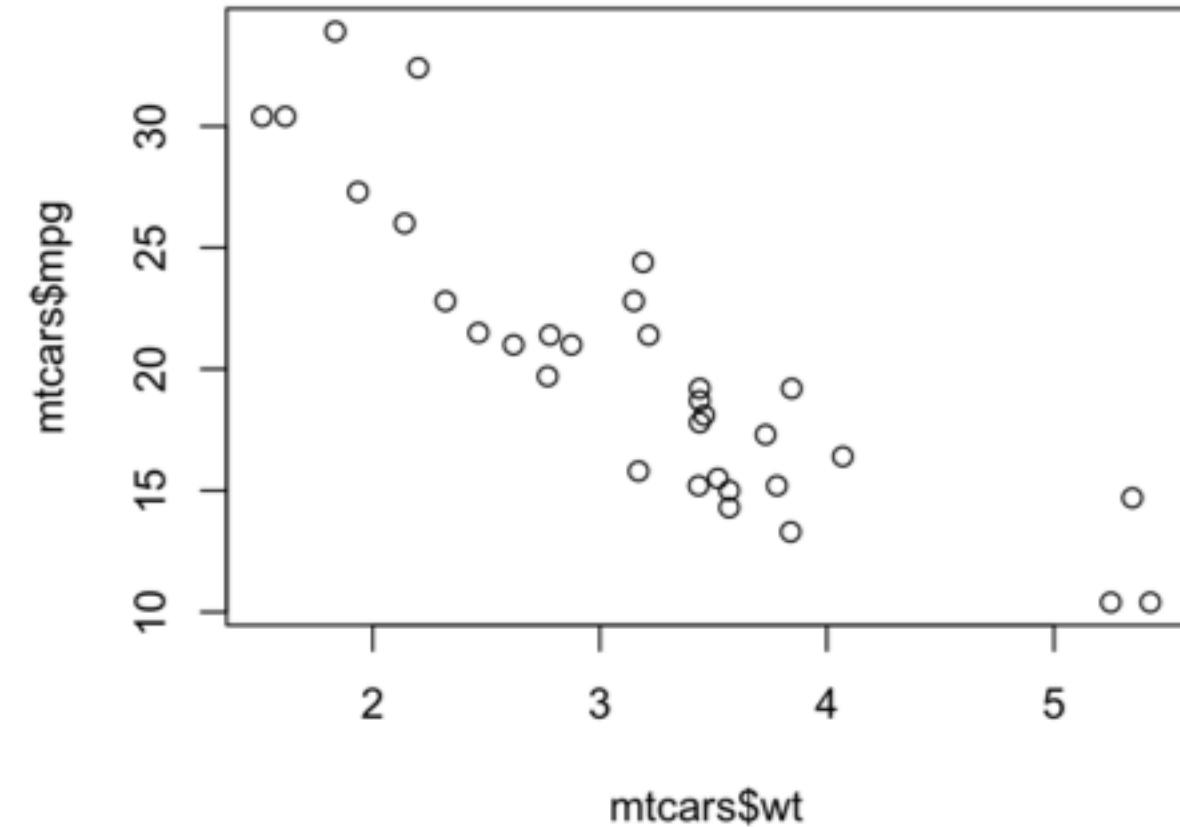
3:56 PM - Jun 26, 2018

1 138 33 people are talking about this



# Is he maybe a little right?

```
plot(mtcars$wt, mtcars$mpg)
```



# R can't do everything

There's still a place for  
Illustrator, InDesign, et al.

1 2 3 4 5 6 7 8 9 10

1 2 3 4 5 6 7 8 9 10

1 2 3 4 5 6 7 8 9 10

1 2 3 4 5 6 7 8 9 10

The affluent official fly fished in cutoffs  
The affluent official fly fished in cutoffs

# But R can do a *lot*

And it can automate  
most of the hard work

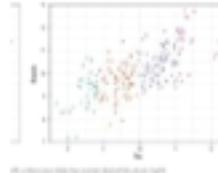
Kieran Healy  
@kjhealy

Follow

After Edward Tufte's remarks about graphs and text in R, by happy coincidence I just got the proofs for my @PrincetonUPress book. All the graphs were made programmatically. The pipeline for the book ms and the website ([socviz.co](http://socviz.co)) start from the same Rmd sources.

Island is stronger than it is on the shape channel. In the past, the number of observations is again applied to me at. Usually the single blue dot may take automatically longer than one is on the first or second pass. It may require a few efforts to automatically send the issue in order to find a clear path. There are no other choices. If there are more than 1000 observations on the shape channel, upgrade only the fifth pass or more often and change the large number of observations. Again there is only one blue dot on the graph, so single there are many blue triangles and others from the random field value we are looking for. That is, according to me, the large number of observations can be very

other effects can be demonstrated for search engine optimization, with new, single, characters, and never used for particular kinds of machine vision channels. For example, there are many ways to use these fields as some kinds of color constants. *Vista* (2008, 27–45) also discusses such examples. The consequences of the data visual are clear enough. As shown in Figure 1.16, adding multiple lines to a graph is likely to quickly increase the density of lines. Even if one additional object in the set, we could make it better, but it is often difficult to distinguish them from each other, colors, and position all at once. It is possible for these morphisms, in particular for those in the second panel of



1:02 PM - 27 Jun 2018

Kieran Healy  
@kjhealy

Follow

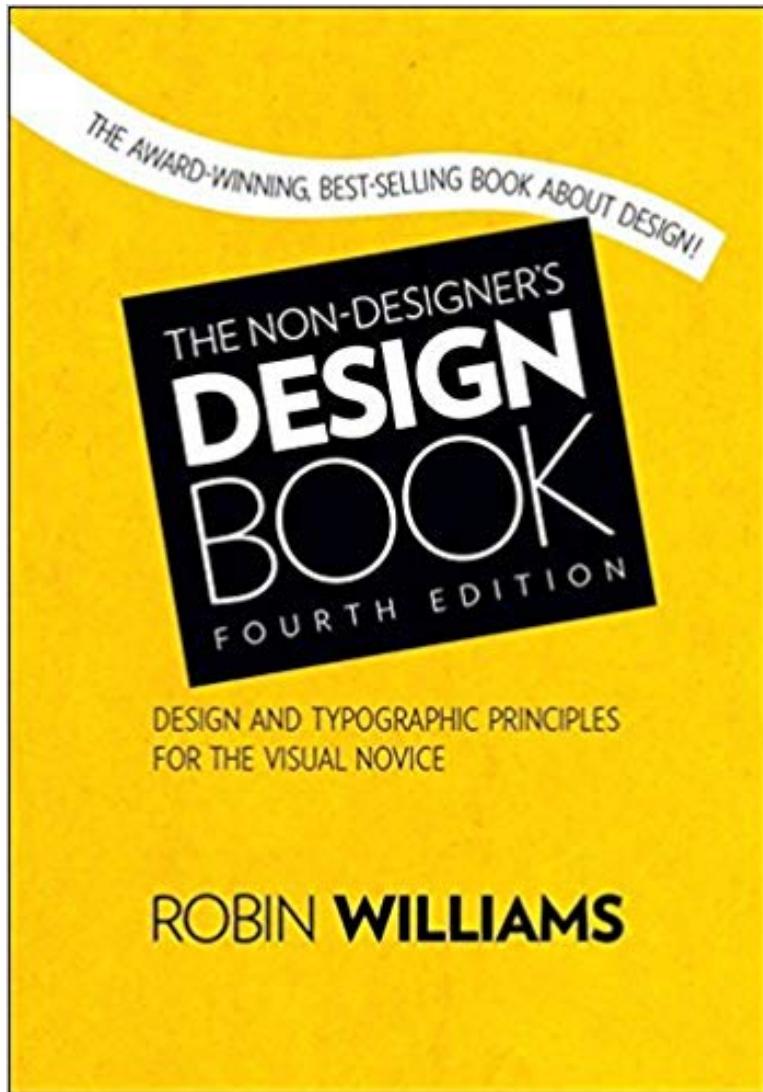
The typesetters at @PrincetonUPress are pros, of course, and did superb work well beyond my own page layout abilities. At the same time, it's all plain text and plain data, with the end result produced using open-source tools from start to finish.

1:02 PM - 27 Jun 2018

1 Retweet 41 Likes

3 1 41

# What constitutes good design?



# Four core design principles

Contrast

Repetition

Alignment

Proximity

## Contrast

“If two items are not exactly the same, make them different. **Really different.**”

Don’t be a wimp!

Serif

**Lore*mm* ipsum dolor sit amet**

Sans Serif

**Lore*mm* ipsum dolor sit amet**

Slab Serif

**Lore*mm* ipsum dolor sit amet**

Script

*Lore*mm* ipsum dolor sit amet*

Decorative

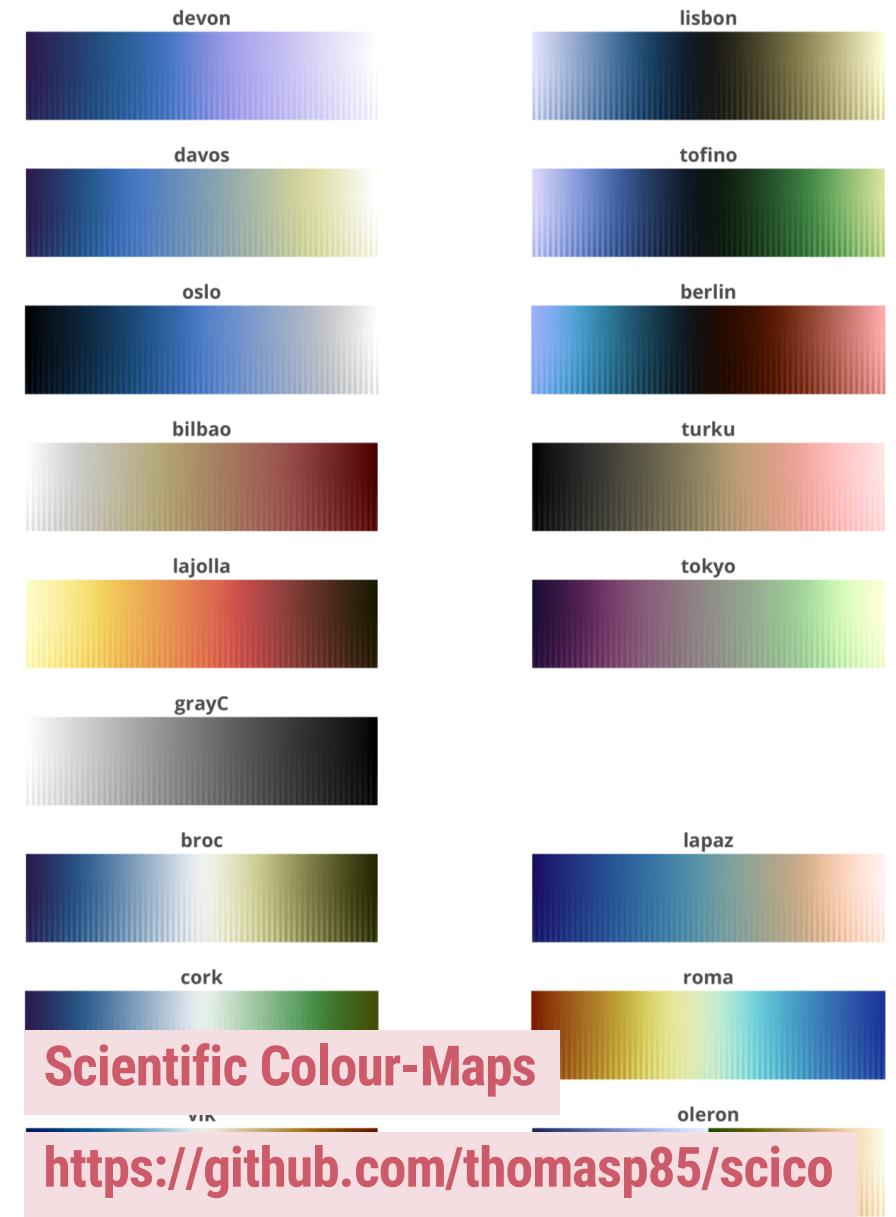
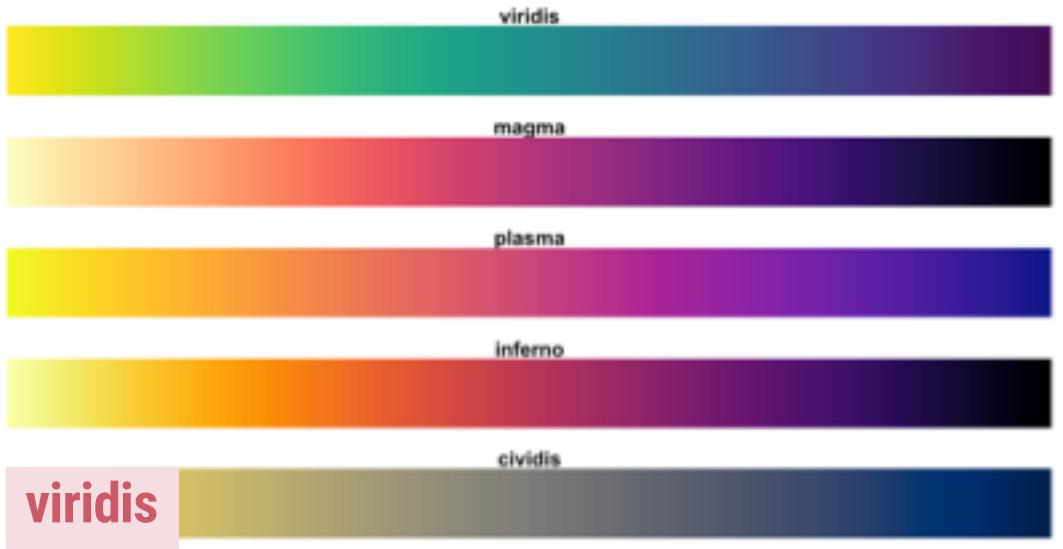
*Lore*mm* ipsum dolor sit amet*

Light

**Lore*mm* ipsum dolor sit amet**

Black

**Lore*mm* ipsum dolor sit amet**



**James Clifton Thomas**  
123 Penny Lane  
Portland, OR 97211  
(888) 555-1212



#### PROFILE:

A multi-talented, hard-working young man, easy to get along with, dependable, and joyful.

#### ACCOMPLISHMENTS:

January 2006-present Web designer and developer, working with a professional team of creatives in Portland.

May 2000-January 2006 Pocket Full of Posies Day Care Center. Changed diapers, taught magic and painting, wiped noses, read books to and danced with babies and toddlers. Also coordinated schedules, hired other teachers, and developed programs for children.

Summer 2006 Updated the best-selling book, *The Non-Designer's Web Book* with my mom (Robin Williams) and John Tollett.

1997-2000 Developed and led a ska band called Lead Veins. Designed the web site and coordinated a national tour.

#### EDUCATION:

2002-2005 Pacific Northwest College of Art, Portland, Oregon: B.A. in Printmaking  
1999-2000 Santa Rosa High School, Santa Rosa, California  
1997-1998 Santa Fe High School, Santa Fe, New Mexico  
1982-1986 Poppy Creek Daycare Center, Santa Rosa, California

#### PROFESSIONAL AFFILIATIONS:

Grand National Monotype Club, Executive Secretary, 2000-2002  
Jerks of Invention, Musicians of Portland, President, 1999-present  
Local Organization of Children of Robin Williams, 1982-present

#### HOBBIES:

Snowboarding, skateboarding, tap dancing, cooking, magic, music (trumpet, drums, vocals, bass guitar), portrait drawing

References available on request.

## James Clifton Thomas



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Portland, Oregon 97211  
(888) 555-1212

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## Repetition

“Repeat some aspect  
of the design throughout  
the entire piece.”

FALL 2004

# Jamba Whirl

DISCOVER MORE

• FRESH SQUEEZED •

## Start The Day

Bored with breakfast?  
Skipping it altogether?  
Wake up to a new way to start your day:

**Jamba Juice!**

## Delicious!

Jamba is the perfect place to pick up that all-important morning meal. First, our fruit-filled products are overflowing with vital vitamins and minerals to give your body the breakfast boost it needs. Even better, you can grab them on the go—and they taste great, too!

**New Fantastic Functional Smoothies.** Still sleepy? Get Up & Mango™! This new energy smoothie blends brilliant mangos and perky peaches with soymilk, nonfat frozen yogurt and our special Energy Boost™—a potent combination of ginseng, gingko biloba, and other fatigue-fighting herbs, as well as four energy-essential B vitamins. Get Up & Mango™ will get you moving—and give you plenty of potassium, calcium and vitamins C and A, as well as 15 grams of protein\*.

**Want more protein?** Our Blue Banana Blast™ smoothie is bursting with blueberries and bananas, plus soymilk, nonfat plain yogurt, nonfat frozen yogurt, and Jamba's Protein Boost™. You get 22 grams of protein, plus lots of dietary fiber, calcium and vitamin D. Drink up!

**New Yummy Yogurt Blends.** These sweet and creamy creations blend nonfat plain yogurt and soymilk with your favorite fresh fruits and fruit juices. These drinkable yogurts are a good source of protein and an excellent source of calcium and vitamins C and D. Yogurt's "friendly bacteria" helps aid in digestion, too. Choose from Sunrise Strawberry™, Bright Eyed & Blueberry™ and Pick-Me-Up Peach™.

**Tomorrow morning, don't let the first meal of the day put you to sleep! Go to Jamba—and give yourself a fresh start!**

\* Nutritional information based on Original size smoothie.

Visit [jambajuice.com](http://jambajuice.com) for a complete list of store locations!

• BEHIND THE BLENDER •

## The Secret To Jamba Smoothies

**E**ver wonder why Jamba smoothies taste so terrific? The secret is in the fruit—and how we pick it.

It starts in the fields. Jamba's suppliers pick produce at the peak of perfection, and within hours, that fruit is "individually quick frozen" to lock in its fresh flavor, juices and nutrients. Soon, it's on its way to Jamba stores, ready to be mixed into one of our splendid smoothies!

Of course, not all fruits are created equal. And when Jamba searches the globe for the best bananas, berries, peaches and more, we're pretty hard to please. We're not only picky about the fruit itself—we insist on a specific variety of strawberry, and each one must adhere to our strict standards for color and flavor—we're also choosy about the people who supply it.

Our suppliers must meet a long list of stringent standards for ensuring quality and food safety. We require vendors to detail all of their quality and safety processes and pass a rigorous third-party audit before we'll even agree to taste-test their fruit. In addition, Jamba officials visit supplier facilities and continue reviewing processes even after a contract is signed. Many of our vendors have been our trusted partners for years. Why all the fuss? Jamba is committed to providing only the highest quality products to our customers. After all, the better the fruit, the better the smoothie!

## FRESH CROP Opening This Fall!

Rancho Cucamonga, California  
Ft. Lauderdale, Florida  
Charlotte, North Carolina  
Honolulu, Hawaii  
Fifth Avenue, New York  
Orland Park, Illinois

• JAMBATUDE •

## Spreading The Jamba Spirit

**J**amba General Manager Ray Sterling is a big believer in supporting the local community. So when Ray, who manages the Jamba store at 9th and Irving streets in San Francisco, saw that the 2004 AIDS Walk San Francisco fundraising event was approaching, he sprang into action.

Ray volunteered to captain a team of walkers and, with the help of the Jamba's Northern California marketing department, quickly spread the word about the event to all the stores in Northern California. His goal: Raise \$10,000 for AIDS Walk, which benefits the San Francisco AIDS Foundation and other organizations that provide services, support and education to AIDS patients. His enthusiasm turned out to be contagious. On July 18, the day of the walk, he found himself leading a team of more than 40 people, including Jamba team members, customers and friends and family. Two team members donned BananaMan costumes, and the rest of the team sported bright yellow Jamba t-shirts as they walked 6.2 miles through Golden Gate Park. Total money raised: \$16,019.

"I think it's so important to support the local community," Ray explains. "This is a big event in San Francisco, and the money goes to help people and children right here. I felt it was essential for Jamba to be a part of it."

The AIDS Walk isn't the only community project Ray has been involved with since joining Jamba two-and-a-half years ago. He also works with a local chapter of The Arc, an organization that helps people with developmental disabilities. Through The Arc, Ray has hired several people with disabilities to work for him at Jamba. For his efforts, he was recognized as an "Employer of the Year" last year by the San Francisco Mayor's Committee for Employment of Persons with Disabilities.

"Ray exemplifies everything that Jamba stands for," says Gail DiSantis, a Jamba District Manager for San Francisco and Ray's boss. "He's friendly, fun and energetic, and when it comes to helping the community, he doesn't just talk. He's a doer."

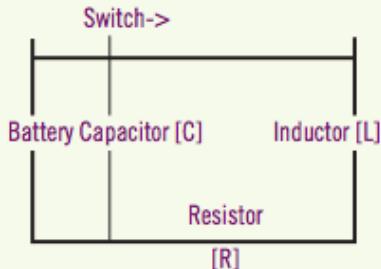


## Alignment

“Every item should have a visual connection with something else on the page.”

### Example 6: Value of a resistor in an electrical circuit.

Find the value of a resistor in an electrical circuit which will dissipate the charge to 1 percent of its original value within one twentieth of a second after the switch is closed.

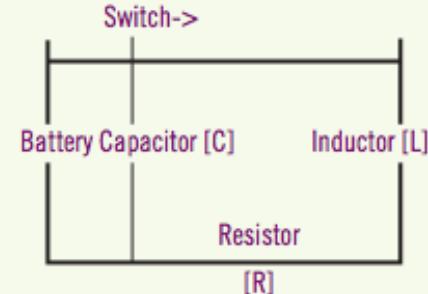


q0=	9	volts
q(t)=	0.09	volts
t=	0.05	seconds
L=	8	henrys
C=	0.0001	farads
R=	300	ohms
q(t)=	0.253889	

1/[L*C]	1250
[R_/(2*L)]^2	351.5625
SQRT(B15-B16)	29.973947
COS(T*B17)	0.07203653
-R_*T/(2*L)	-0.9375
Q0+EXP (B 19)	3.52445064

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## Fewer/Less

The Controversy: Some usage dictionaries state that fewer and less can be used synonymously while others say that there is a distinct difference in the usage between the two. Fewer cannot be used in place of less, but can less be used in place of fewer?

The Traditional Rule: Fewer refers to number among things that are counted, or readily distinguishable units (fewer people, ships, houses.) Less refers to quantity or amount among things that are measured (less sugar, time, energy).

History: The rule first originated in 1770 as a rule on less, "this word is commonly used in speaking of a number; where fewer would do better. Essentially less has been used of countables in English just about as long as there has been a written English language. After about 900 years Robert Baker opined that fewer might be more elegant and proper. Almost every usage writer since Baker has followed Baker's lead, and generations of English teachers have swelled the chorus. "No fewer than a hundred appears to me not only more elegant than no less than a hundred, but strictly more proper." – Baker 1770

Consensus: A substantial majority of panel members advocates retaining this distinction between less and fewer. The general consensus favors the traditional rule that fewer refers to countable things while less refers to things measured, though strong forces are pushing against it.

Examples:

"However fewer and fewer writers observe it, so the distinction is becoming less and less." –Vermont Royster

"...Dudek's car has fewer than 600 miles on the odometer." – Rick Reilly

"...has never gained fewer than 1,222 yards in a season." –Rick Telander

"The odometer showed less than ten thousand miles." – E.L. Doctoerow

"I was never in Europe for less than fourteen months at a time." – James Thurber

*not very important history*

## HISPANIC AWARENESS FILM SERIES

**HAROLD B. LEE LIBRARY**

**Tortilla Soup (2001)**

**WEDNESDAY  
OCTOBER 8  
5:00PM**

**LEE LIBRARY AUDITORIUM**

**1080 HBLL**

## Proximity

“Group related items together.”

**Ralph Roister Doister**

(717) 555-1212

# **Mermaid Tavern**

916 Bread Street

London, NM

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**Ralph Roister Doister**

916 Bread Street  
London, NM  
(717) 555-1212

# Your Attitude is Your Life

Lessons from  
raising three children  
as a single mom

**Robin Williams**  
October 9

# Your Attitude is Your Life ▶

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Contrast

Repetition

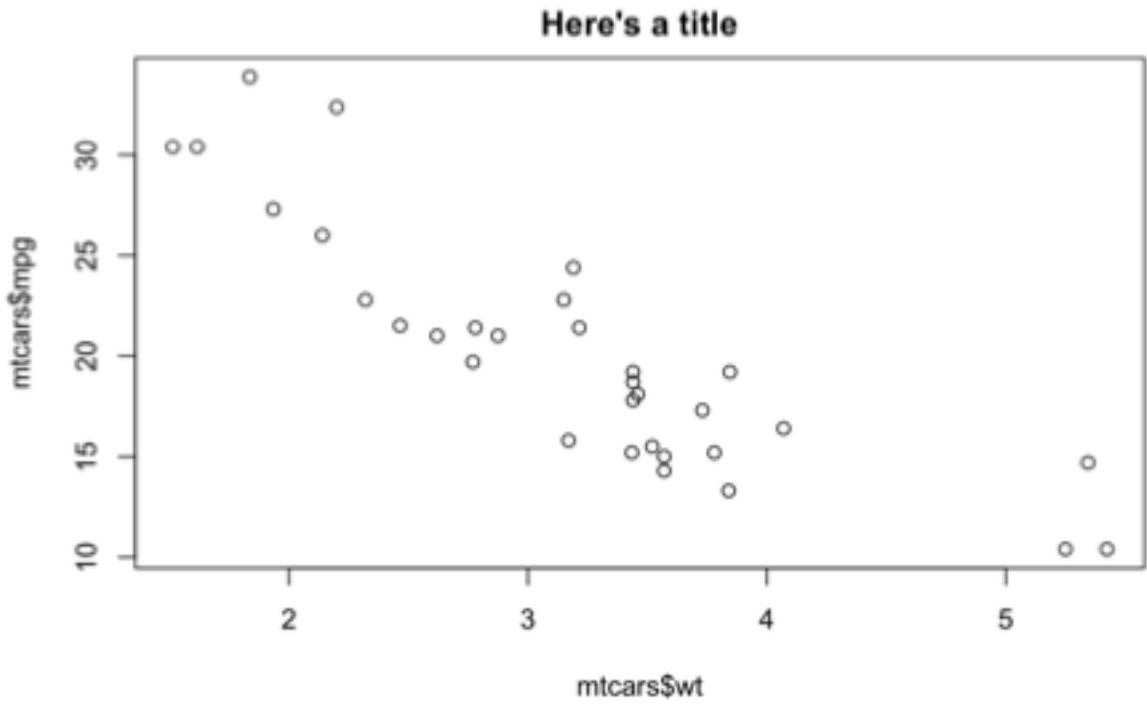
Alignment

Proximity

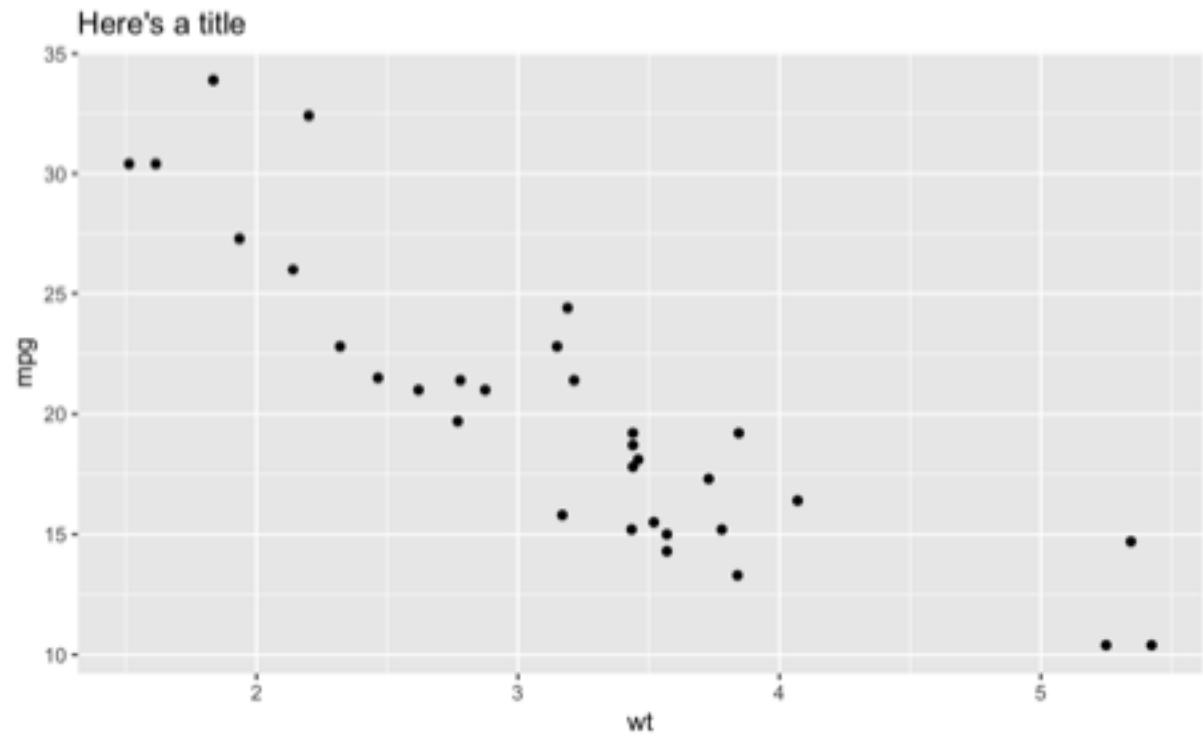
♪♪ Take a sad plot  
and make it CRAPier ♪♪

# By default, R graphics violate CRAP

```
plot(mtcars$wt, mtcars$mpg,  
     main = "Here's a title")
```



```
ggplot(mtcars, aes(x = wt, y = mpg)) +  
  geom_point() +  
  labs(title = "Here's a title")
```



**With ggplot's theme() and other  
functions, we can make beautiful  
CRAPy figures automatically with R**

You can also do this in base R, but I find ggplot's paradigm more intuitive

**[talks.andrewheiss.com/utah-rug-dataviz/](http://talks.andrewheiss.com/utah-rug-dataviz/)**

# Moral of the story

Graphics are essential for telling stories and gaining insight

Design principles (CRAP) make graphics better understandable

R + ggplot can follow CRAP and make beautiful, insightful graphics