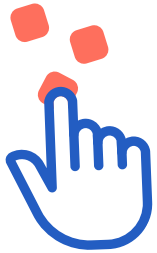
Turning research data into powerful visuals

Producing and designing data visuals

Koen Van den Eeckhout - Baryon



All the slides and all the links:

baryon.be/dataviz-resources

Session 1

Communicating with data

Graphical representation of data

homework assignment part 1

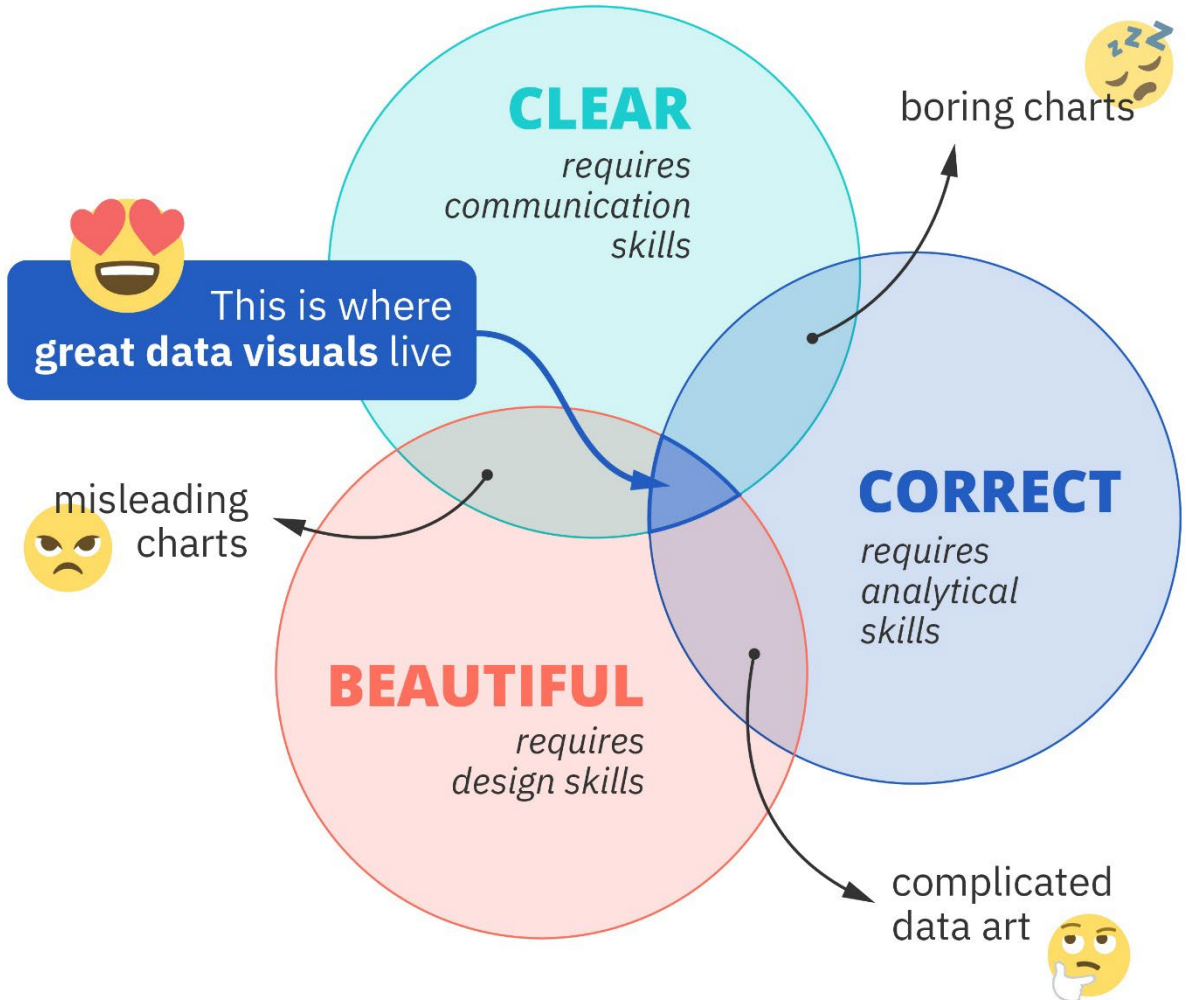
Session 2

Producing and designing data visuals

homework assignment part 2

Session 3

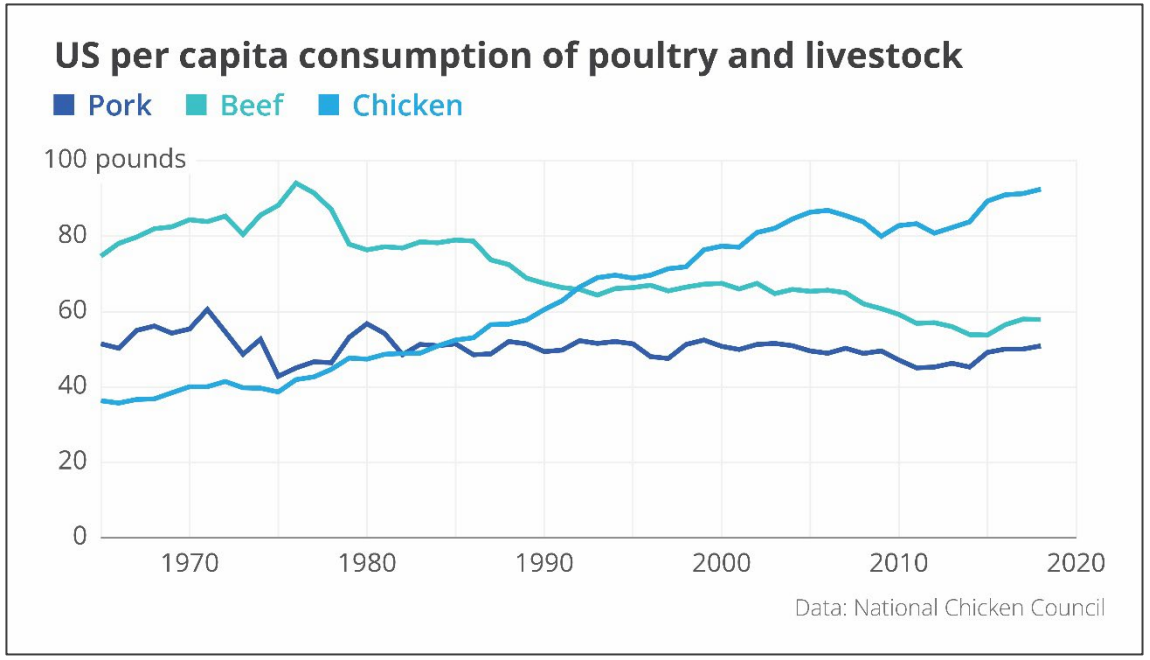
Visualizing scientific research

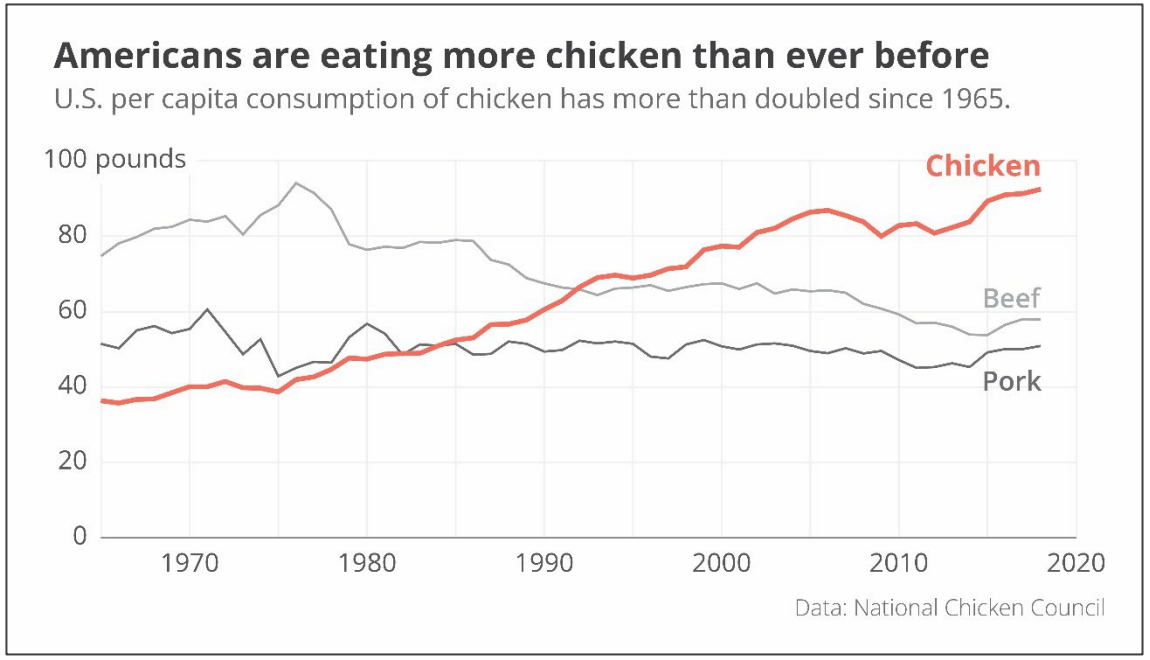

CLEAR
requires communication skills
boring charts
This is where great data visuals live
CORRECT
requires analytical skills
misleading charts
BEAUTIFUL
requires design skills
complicated data art

Communication principles

1. Identify your **message**
2. Adapt to your **audience**
3. Improve the **signal-to-noise** ratio

~~data~~ → **story**


US per capita consumption of poultry and livestock
Pork
Beef
Chicken
100 pounds
80
60
40
20
0
1970
1980
1990
2000
2010
2020
Data: National Chicken Council

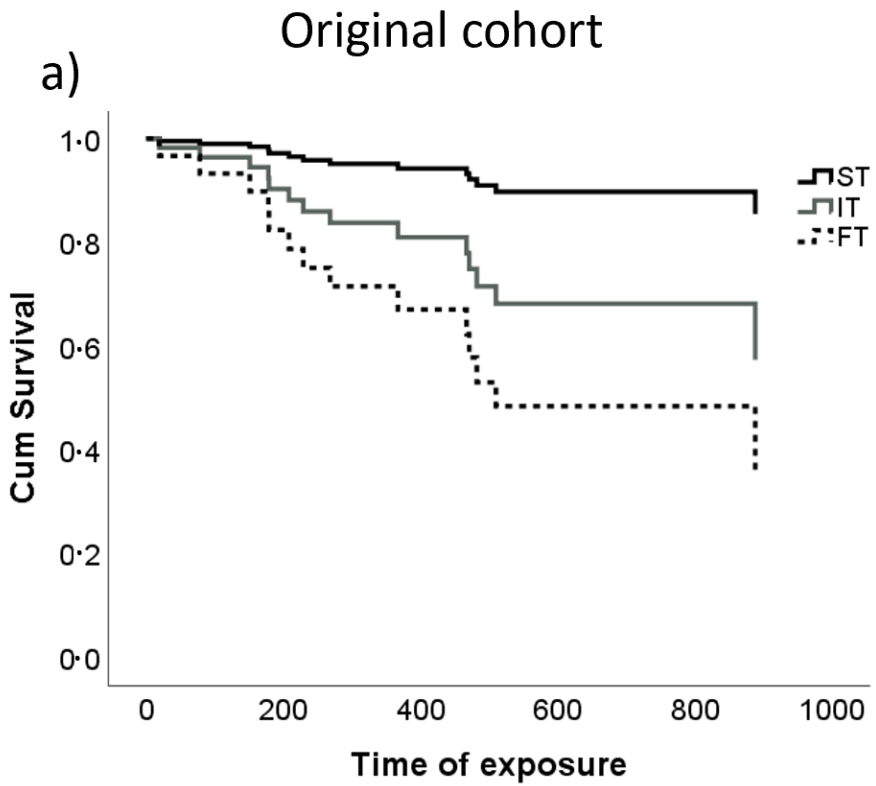

Americans are eating more chicken than ever before
U.S. per capita consumption of chicken has more than doubled since 1965.
100 pounds
80
60
40
20
0
Chicken
Beef
Pork
1970
1980
1990
2000
2010
2020
Data: National Chicken Council

Noise = physical noise

elements which are on the visual
but are not helpful

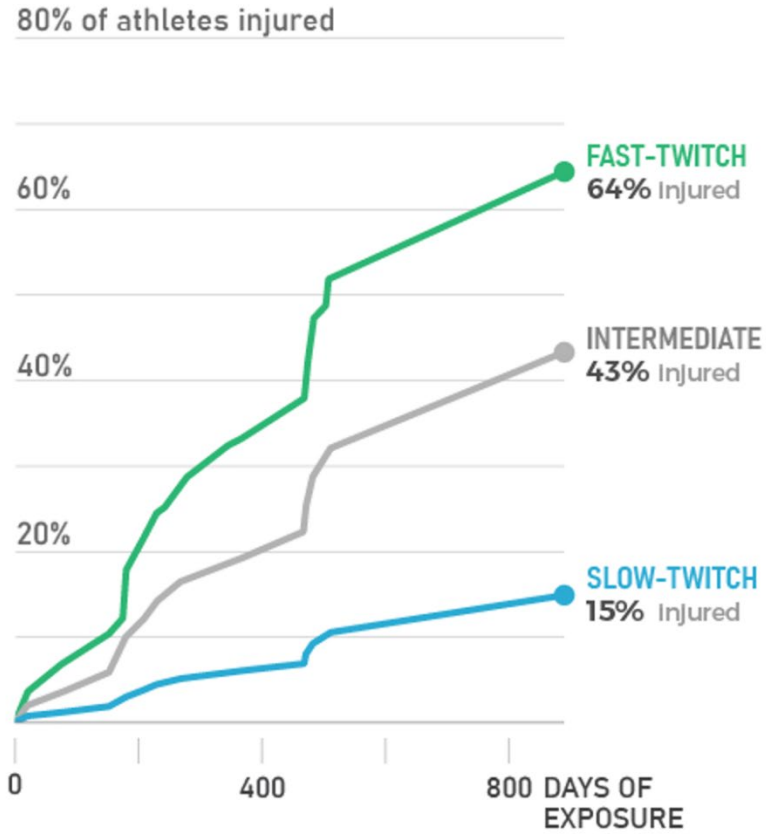
+ mental noise

thinking work required
from your audience



ORIGINAL COHORT

Increased injury rates in athletes with fast-twitch muscle typology



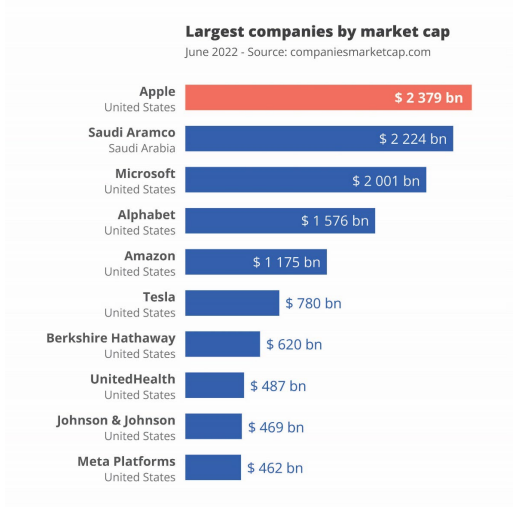
graphical representation categories

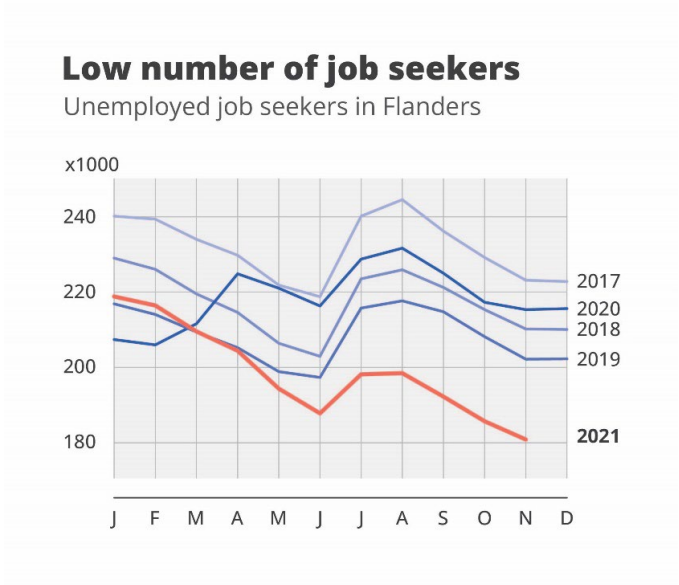
What do we want to do with our data?

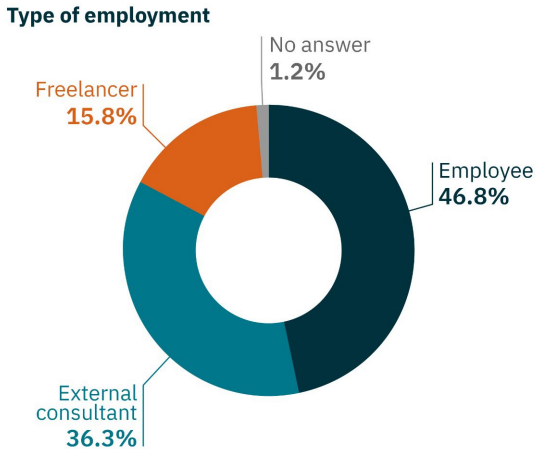
visual variables

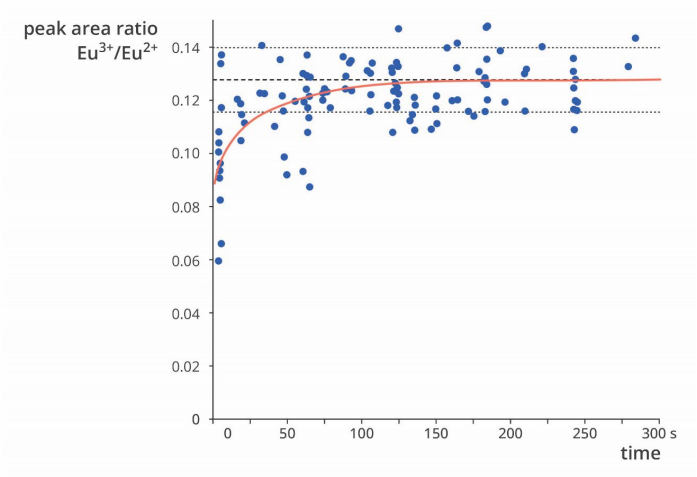
How can we turn raw numbers into shapes?

Chart types


Largest companies by market cap
June 2022 - Source: companiesmarketcap.com
Apple
United States
$ 2 379 bn
Saudi Aramco
Saudi Arabia
$ 2 224 bn
Microsoft
United States
$ 2 001 bn
Alphabet
United States
$ 1 576 bn
Amazon
United States
$ 1 175 bn
Tesla
United States
$ 780 bn
Berkshire Hathaway
United States
$ 620 bn
UnitedHealth
United States
$ 487 bn
Johnson & Johnson
United States
$ 469 bn
Meta Platforms
United States
$ 462 bn


Low number of job seekers
Unemployed job seekers in Flanders
x1000
240
220
200
180
J F M A M J J A S O N D
2017
2020
2018
2019
2021


Type of employment
No answer
1.2%
Freelancer
15.8%
Employee
46.8%
External
consultant
36.3%


peak area ratio
Eu3+/Eu2+
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
0 50 100 150 200 250 300 s
time


Search by Function
View by List
Arc Diagram
Area Graph
Bar Chart
Box & Whisker Plot
Brainstorm
Bubble Chart
Bubble Map
Bullet Graph
Calendar
Candlestick Chart
Chord Diagram
Choropleth Map
Circle Packing
Connection Map
Density Plot
Donut Chart
Dot Map
Dot Matrix Chart
Error Bars
Flow Chart
Flow Map
Histogram
Illustration Diagram
Kagi Chart
Line Graph
Marimekko Chart
Multi-set Bar Chart
Network Diagram
Nightingale Rose Chart
Non-ribbon Chord Diagram

Feedback

Feedback on homework assignment part 1

15’ break

Tools

Workflow

Available tools

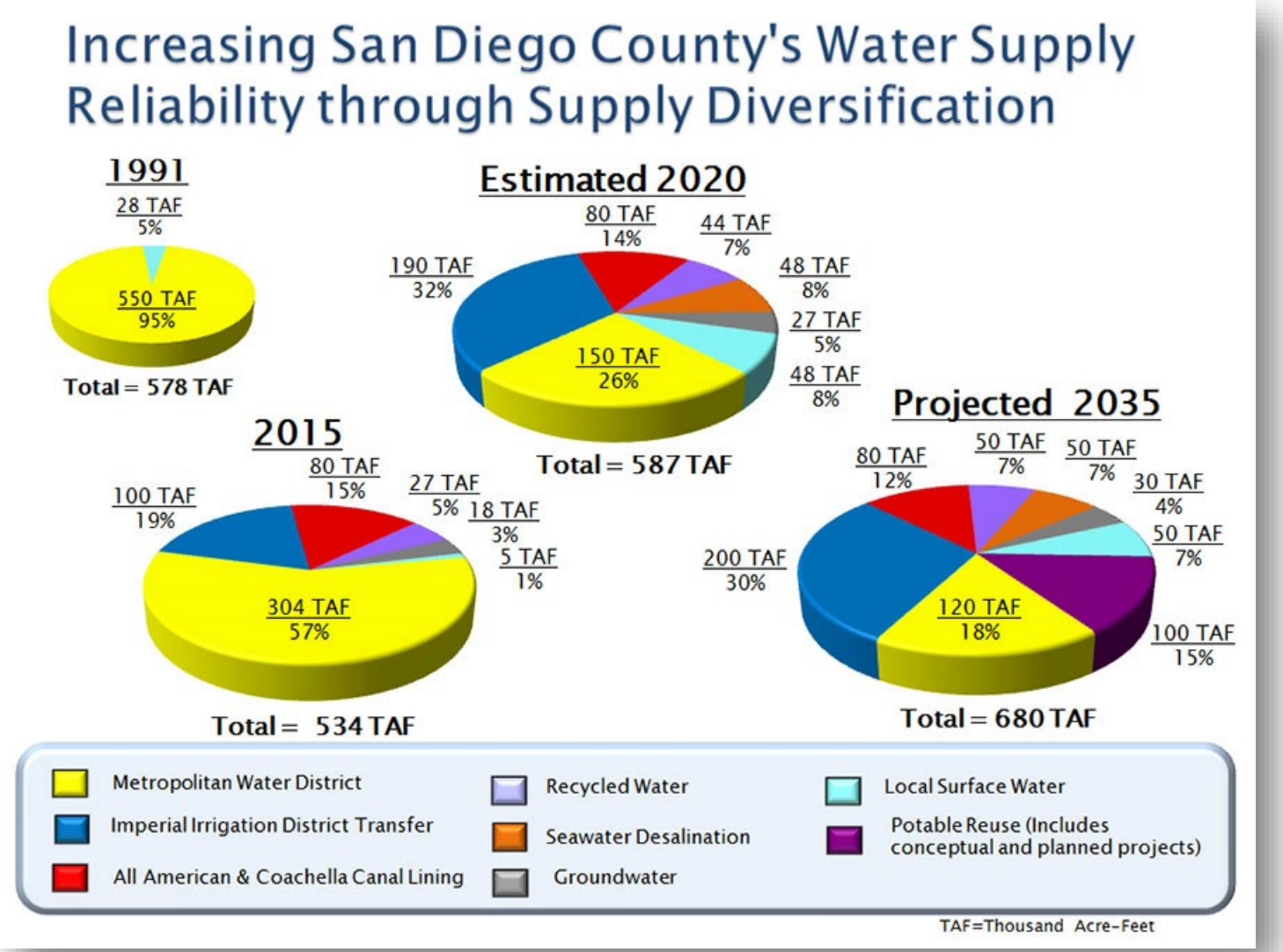
Feedback

Naam

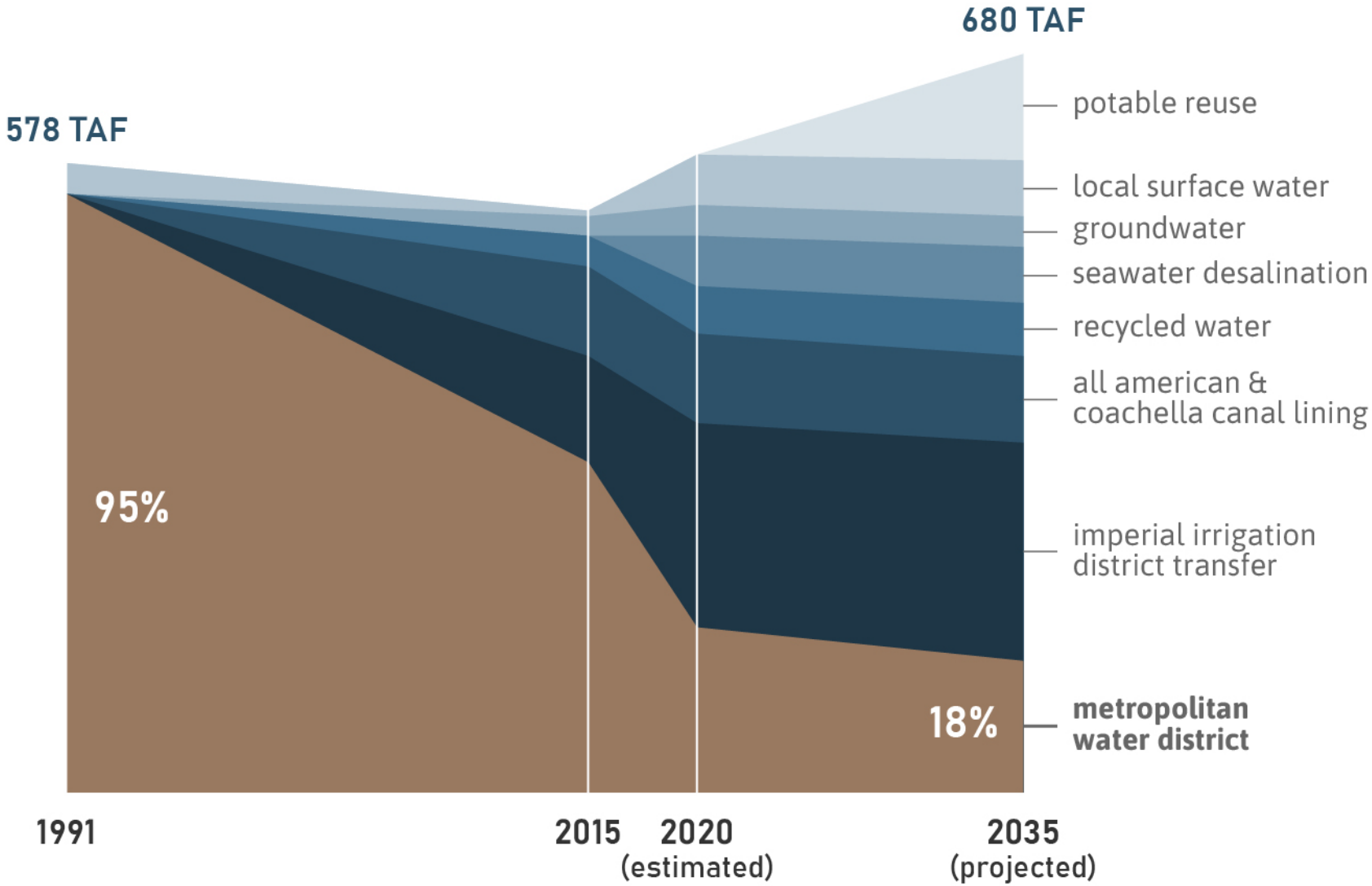
How would you do it?

Share what you **don't like** about this visual

What would you change to **improve it**?



Supply diversification will increase
San Diego County's water supply reliability



Break

All the slides and all the links:

baryon.be/dataviz-resources

Feedback

Feedback on homework assignment part 1

15’ break

Tools

Workflow

Available tools

Tools

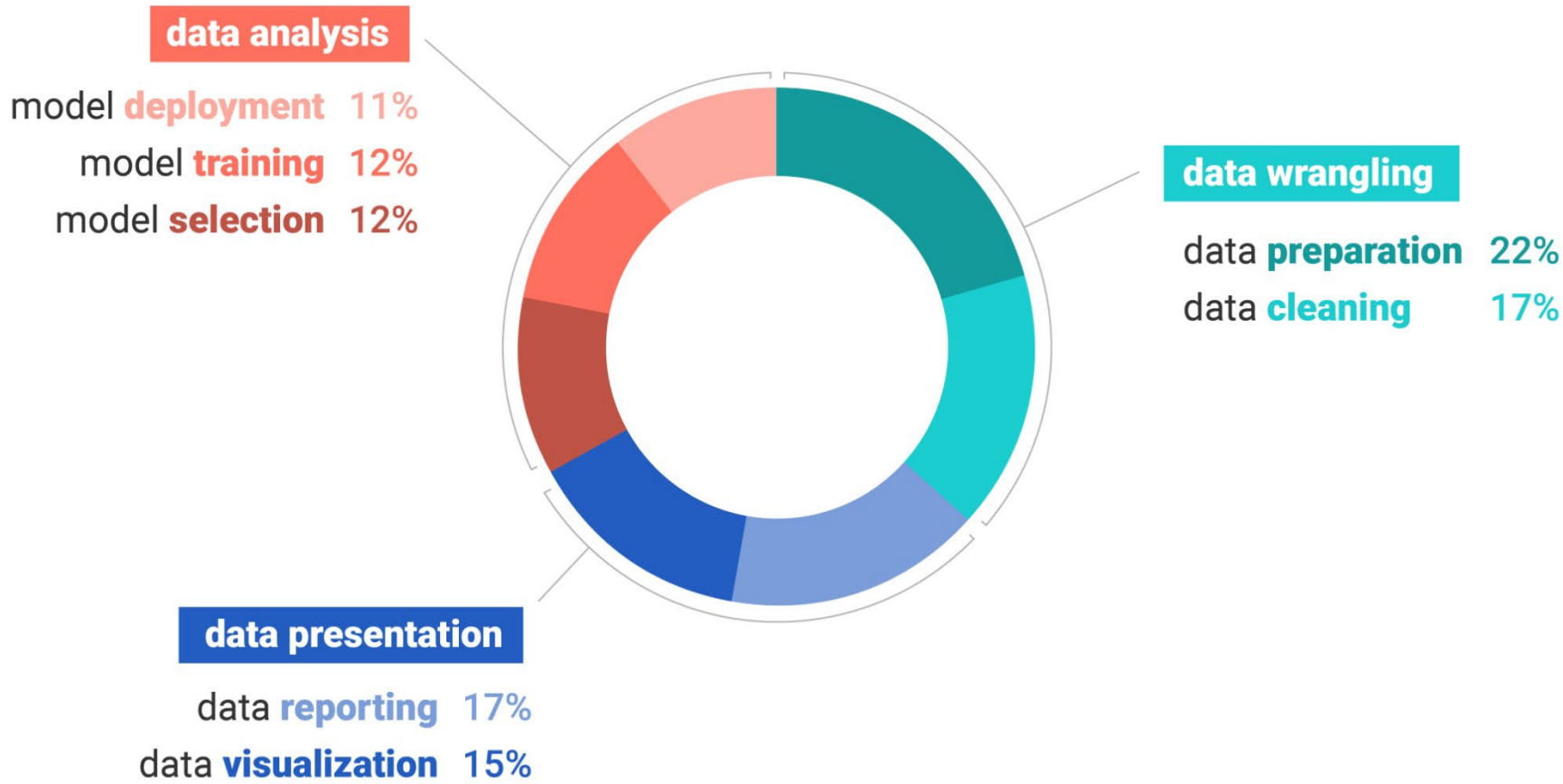
Which tools do you currently use to produce data visuals?

Workflow

prepare your data

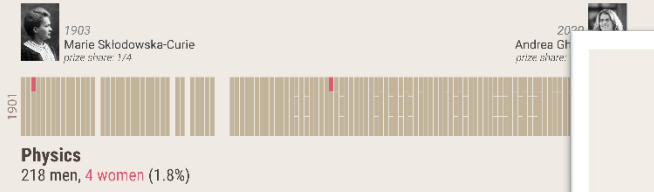
create the chart

improve the design

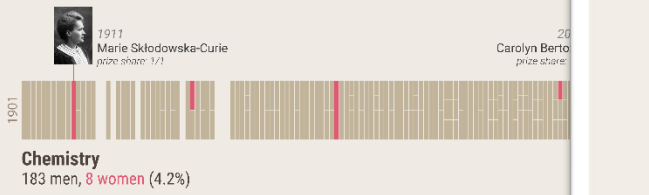


Source: Anaconda State of Data Science report 2021

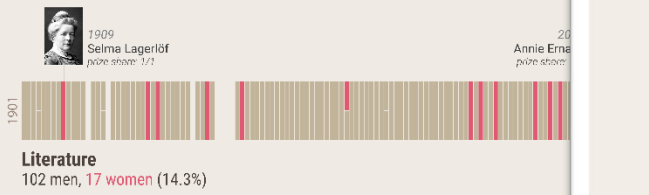
Medicine
213 men, 12 women (5.3%)



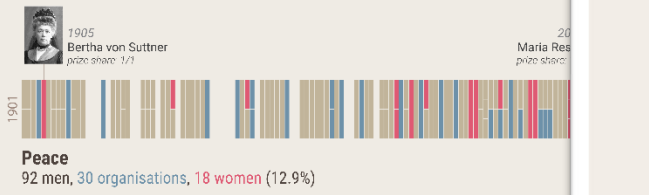
Physics
218 men, 4 women (1.8%)



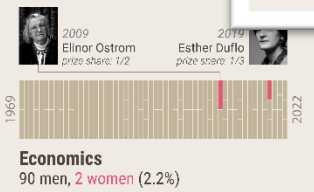
Chemistry
183 men, 8 women (4.2%)



Literature
102 men, 17 women (14.3%)



Peace
92 men, 30 organisations, 18 women (12.9%)



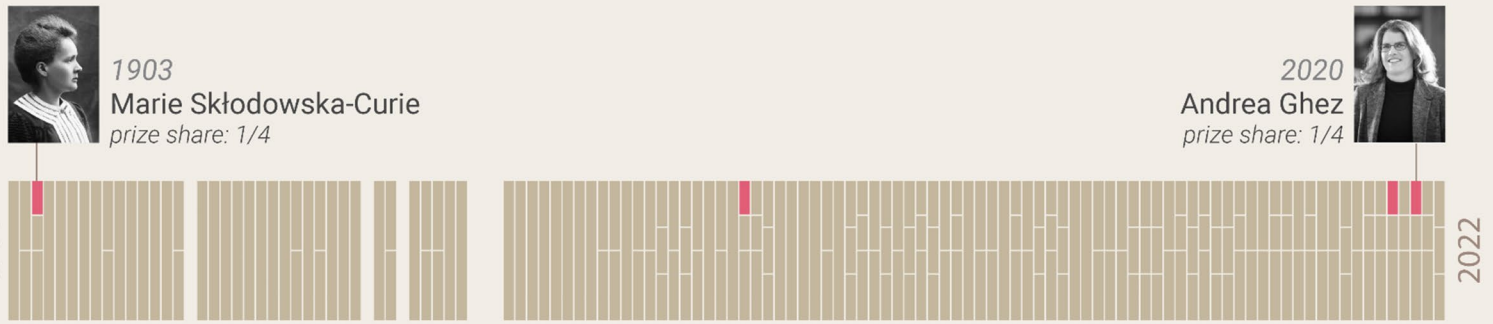
Economics
90 men, 2 women (2.2%)

Women of the Nobel Prize

The Nobel Prize exists since 1901. In those 122 years, the Prize was awarded 898 times to a man, but only 61 times to a woman. 2009 was a record year, with 5 women winning a Prize.

In 2022, only 2 women received the Prize: Annie Ernaux won the Literature Prize, and Carolyn Bertozzi won the Chemistry Prize together with Morten Meldal and K. Barry Sharpless, for their groundbreaking work on click chemistry and bioorthogonal chemistry - chemical reactions that can occur inside of living systems.

Source: nobelprize.org
Infographic design: Koen Van den Eeckhout (@koen_vde | www.baryon.be)



Physics
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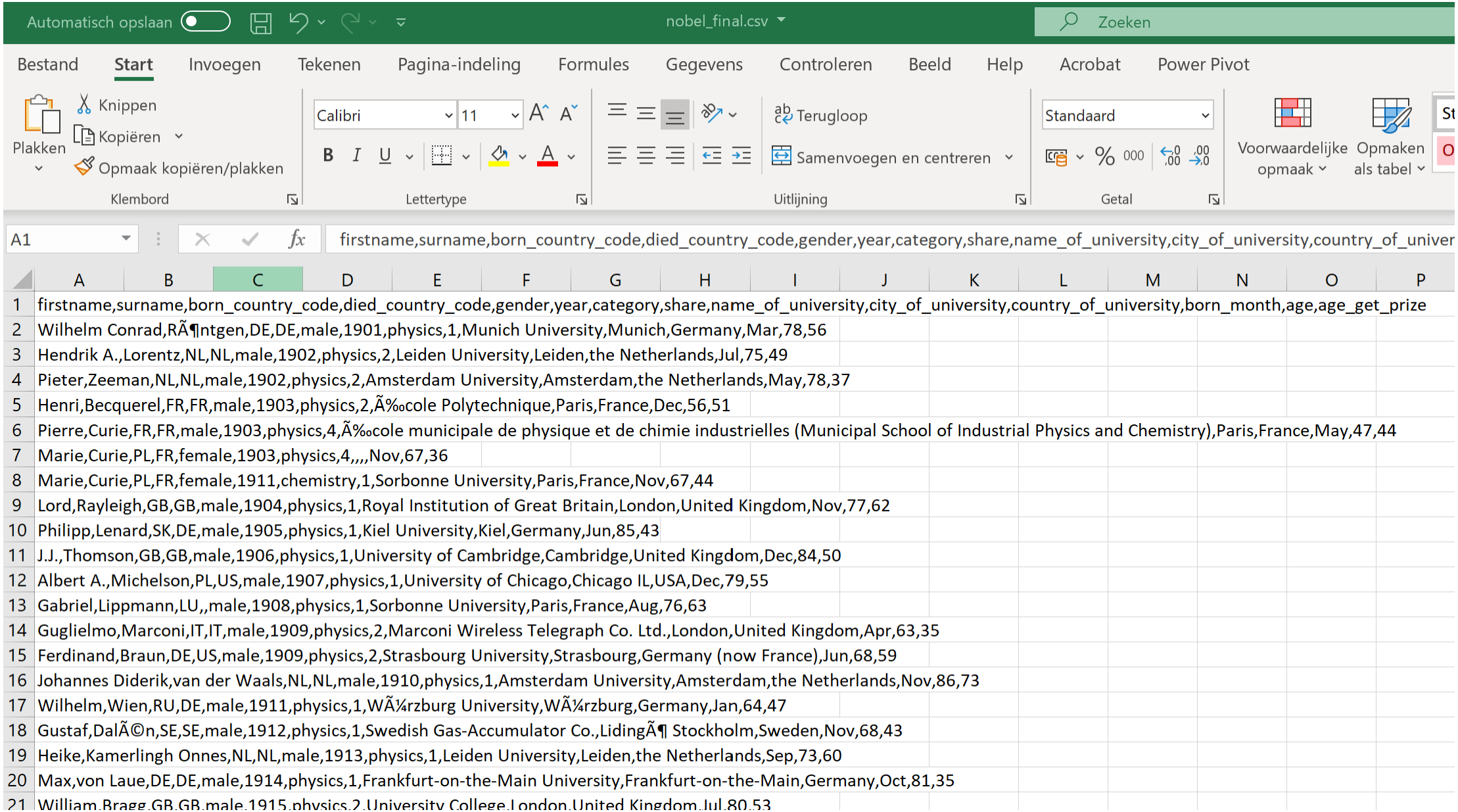
Women of the Nobel Prize

Infographic design: Koen Van den Eeckhout (@koen_vde | www.baryon.be)
Source: nobelprize.org



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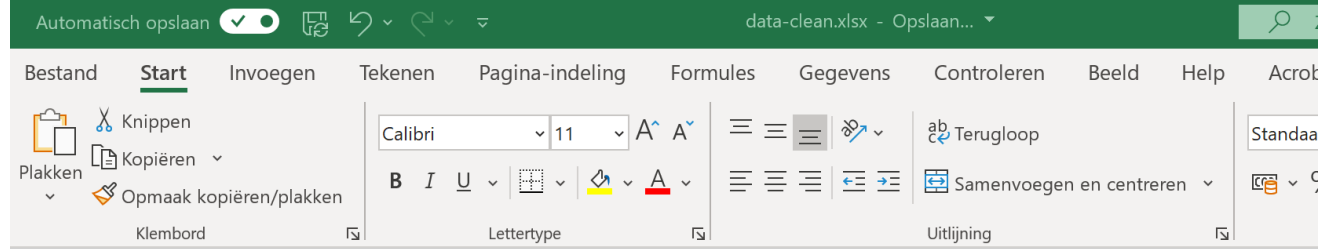
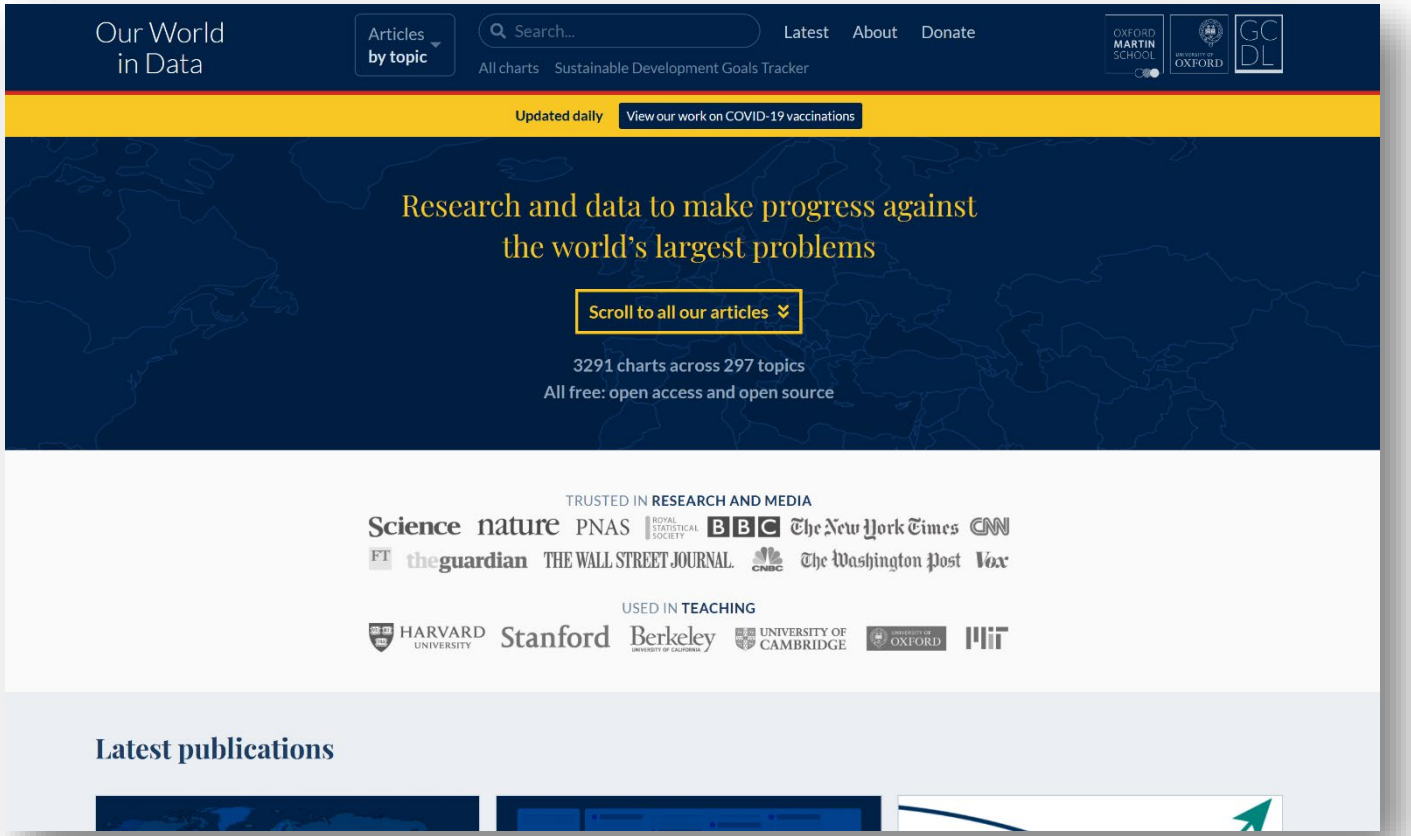
2	Wilhelm Conrad,RÃ¶ntgen,DE,DE,male,1901,physics,1,Munich University,Munich,Germany,Mar,78,56															
3	Hendrik A.,Lorentz,NL,NL,male,1902,physics,2,Leiden University,Leiden,the Netherlands,Jul,75,49															
4	Pieter,Zeeman,NL,NL,male,1902,physics,2,Amsterdam University,Amsterdam,the Netherlands,May,78,37															
5	Henri,Becquerel,FR,FR,male,1903,physics,2,Ã‰cole Polytechnique,Paris,France,Dec,56,51															
6	Pierre,Curie,FR,FR,male,1903,physics,4,Ã‰cole municipale de physique et de chimie industrielles (Municipal School of Industrial Physics and Chemistry),Paris,France,May,47,44															
7	Marie,Curie,PL,FR,female,1903,physics,4,,,,Nov,67,36															
8	Marie,Curie,PL,FR,female,1911,chemistry,1,Sorbonne University,Paris,France,Nov,67,44															
9	Lord,Rayleigh,GB,GB,male,1904,physics,1,Royal Institution of Great Britain,London,United Kingdom,Nov,77,62															
10	Philipp,Lenard,SK,DE,male,1905,physics,1,Kiel University,Kiel,Germany,Jun,85,43															
11	J.J.,Thomson,GB,GB,male,1906,physics,1,University of Cambridge,Cambridge,United Kingdom,Dec,84,50															
12	Albert A.,Michelson,PL,US,male,1907,physics,1,University of Chicago,Chicago IL,USA,Dec,79,55															
13	Gabriel,Lippmann,LU,,male,1908,physics,1,Sorbonne University,Paris,France,Aug,76,63															
14	Guglielmo,Marconi,IT,IT,male,1909,physics,2,Marconi Wireless Telegraph Co. Ltd.,London,United Kingdom,Apr,63,35															
15	Ferdinand,Braun,DE,US,male,1909,physics,2,Strasbourg University,Strasbourg,Germany (now France),Jun,68,59															
16	Johannes Diderik,van der Waals,NL,NL,male,1910,physics,1,Amsterdam University,Amsterdam,the Netherlands,Nov,86,73															
17	Wilhelm,Wien,RU,DE,male,1911,physics,1,WÃ¼rzburg University,WÃ¼rzburg,Germany,Jan,64,47															
18	Gustaf,DalÃ©n,SE,SE,male,1912,physics,1,Swedish Gas-Accumulator Co.,LidingÃ¶ Stockholm,Sweden,Nov,68,43															
19	Heike,Kamerlingh Onnes,NL,NL,male,1913,physics,1,Leiden University,Leiden,the Netherlands,Sep,73,60															
20	Max,von Laue,DE,DE,male,1914,physics,1,Frankfurt-on-the-Main University,Frankfurt-on-the-Main,Germany,Oct,81,35															
21	William,Bragg,GB,GB,male,1915,physics,2,University College London,United Kingdom,Jul,80,53															

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	firstname	surname	born	died	gender	year	category	share	name_of_university	city_of_university	country_of_university	born_month	age	age_get_prize
2	Wilhelm Conrad	Röntgen	DE	DE	male	1901	physics	1	Munich University	Munich	Germany	Mar	78	56
3	Hendrik A.	Lorentz	NL	NL	male	1902	physics	2	Leiden University	Leiden	the Netherlands	Jul	75	49
4	Pieter	Zeeman	NL	NL	male	1902	physics	2	Amsterdam University	Amsterdam	the Netherlands	May	78	37
5	Henri	Becquerel	FR	FR	male	1903	physics	2	École Polytechnique	Paris	France	Dec	56	51
6	Pierre	Curie	FR	FR	male	1903	physics	4	École municipale de physique et de chimie inc	Paris	France	May	47	44
7	Marie	Curie	PL	FR	female	1903	physics	4				Nov	67	36
9	Lord	Rayleigh	GB	GB	male	1904	physics	1	Royal Institution of Great Britain	London	United Kingdom	Nov	77	62
10	Philipp	Lenard	SK	DE	male	1905	physics	1	Kiel University	Kiel	Germany	Jun	85	43
11	J.J.	Thomson	GB	GB	male	1906	physics	1	University of Cambridge	Cambridge	United Kingdom	Dec	84	50
12	Albert A.	Michelson	PL	US	male	1907	physics	1	University of Chicago	Chicago IL	USA	Dec	79	55
13	Gabriel	Lippmann	LU		male	1908	physics	1	Sorbonne University	Paris	France	Aug	76	63
14	Guglielmo	Marconi	IT	IT	male	1909	physics	2	Marconi Wireless Telegraph Co. Ltd.	London	United Kingdom	Apr	63	35
15	Ferdinand	Braun	DE	US	male	1909	physics	2	Strasbourg University	Strasbourg	Germany (now France)	Jun	68	59
16	Johannes Diderik	van der Waals	NL	NL	male	1910	physics	1	Amsterdam University	Amsterdam	the Netherlands	Nov	86	73
17	Wilhelm	Wien	RU	DE	male	1911	physics	1	Würzburg University	Würzburg	Germany	Jan	64	47
18	Gustaf	Dalén	SE	SE	male	1912	physics	1	Swedish Gas-Accumulator Co.	Lidingö Stockholm	Sweden	Nov	68	43
19	Heike	Kamerlingh Onnes	NL	NL	male	1913	physics	1	Leiden University	Leiden	the Netherlands	Sep	73	60
20	Max	von Laue	DE	DE	male	1914	physics	1	Frankfurt-on-the-Main University	Frankfurt-on-the-Main	Germany	Oct	81	35
21	William	Bragg	GB	GB	male	1915	physics	2	University College	London	United Kingdom	Jul	80	53
22	Lawrence	Bragg	AU	GB	male	1915	physics	2	Victoria University	Manchester	United Kingdom	Mar	81	25
23	Charles Glover	Barkla	GB	GB	male	1917	physics	1	Edinburgh University	Edinburgh	United Kingdom	Jun	67	40
24	Max	Planck	DE	DE	male	1918	physics	1	Berlin University	Berlin	Germany	Apr	89	60
25	Johannes	Stark	DE	DE	male	1919	physics	1	Greifswald University	Greifswald	Germany	Apr	83	45
26	Charles Edouard	Guillaume	CH	FR	male	1920	physics	1	Bureau International des Poids et Mesures (In	Sèvres	France	Feb	77	59
27	Albert	Einstein	DE	US	male	1921	physics	1	Kaiser-Wilhelm-Institut (now Max-Planck-Inst	Berlin	Germany	Mar	76	42
28	Niels	Bohr	DK	DK	male	1922	physics	1	Copenhagen University	Copenhagen	Denmark	Oct	77	37
29	Robert A.	Millikan	US	US	male	1923	physics	1	California Institute of Technology (Caltech)	Pasadena CA	USA	Mar	85	55
30	Manne	Siegbahn	SE	SE	male	1924	physics	1	Uppsala University	Uppsala	Sweden	Dec	92	38
31	James	Franck	DE	DE	male	1925	physics	2	Goettingen University	Göttingen	Germany	Aug	82	43
32	Gustav	Hertz	DE	DE	male	1925	physics	2	Halle University	Halle	Germany	Jul	88	38
33	Jean Baptiste	Perrin	FR	US	male	1926	physics	1	Sorbonne University	Paris	France	Sep	72	56
34	Arthur H.	Compton	US	US	male	1927	physics	2	University of Chicago	Chicago IL	USA	Sep	70	35
35	C.T.R.	Wilson	GB	GB	male	1927	physics	2	University of Cambridge	Cambridge	United Kingdom	Feb	90	58
36	Owen Willans	Richardson	GB	GB	male	1928	physics	1	London University	London	United Kingdom	Apr	80	49
37	Louis	de Broglie	FR	FR	male	1929	physics	1	Sorbonne University Institut Henri Poincaré	Paris	France	Aug	95	37
38	Sir Chandrasekhara Venkata	Raman	IN	IN	male	1930	physics	1	Calcutta University	Calcutta	India	Nov	82	42
39	Werner	Heisenberg	DE	DE	male	1932	physics	1	Leipzig University	Leipzig	Germany	Dec	75	31
40	Erwin	Schrödinger	AT	AT	male	1933	physics	2	Berlin University	Berlin	Germany	Aug	74	46
41	Paul A.M.	Dirac	GB	US	male	1933	physics	2	University of Cambridge	Cambridge	United Kingdom	Aug	82	31
42	James	Chadwick	GB	GB	male	1935	physics	1	Liverpool University	Liverpool	United Kingdom	Oct	83	44

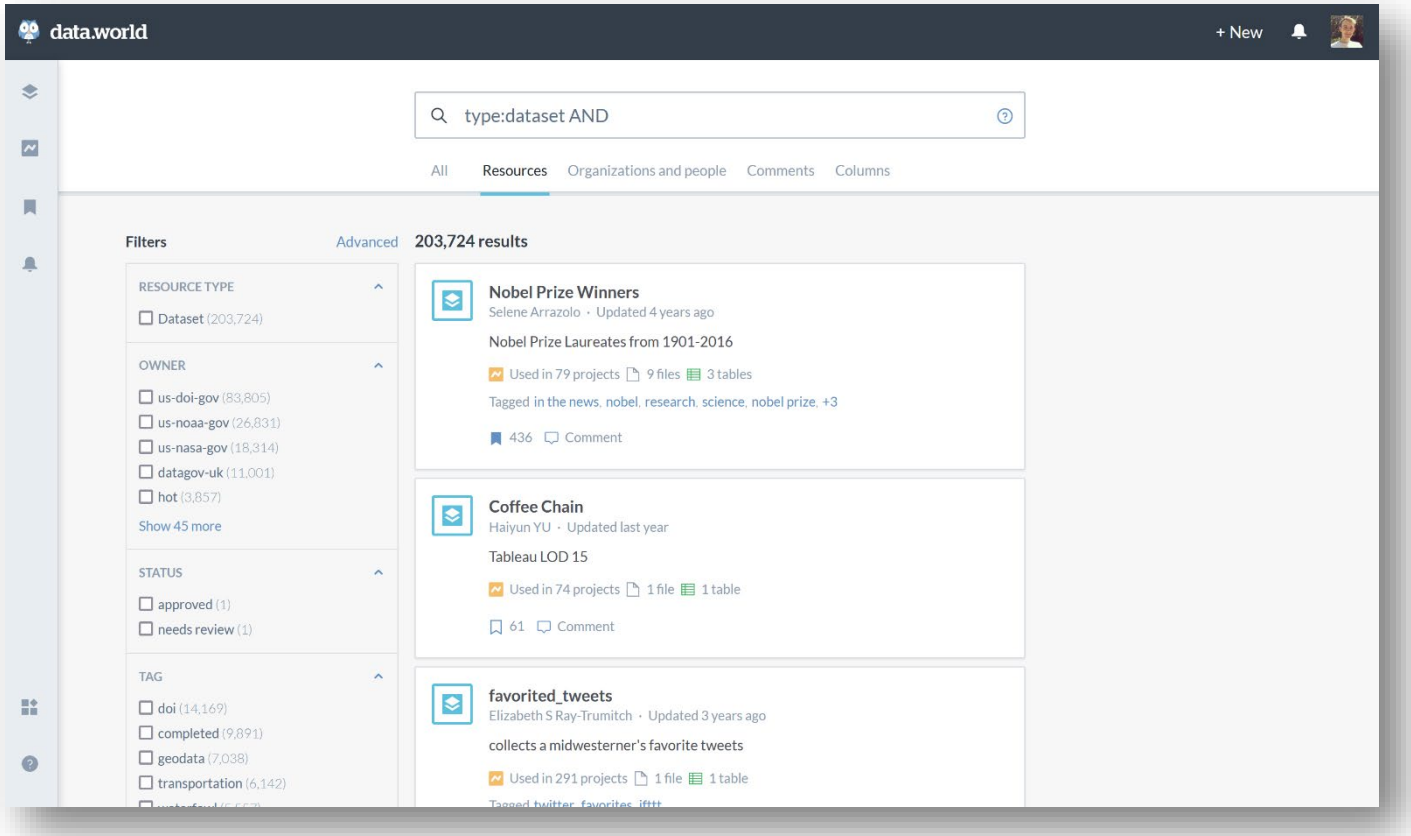
https://datasetsearch.research.google.com/



	A	B	D	E	F	G	J	K	L
1	**firstname**	**surname**	**gender**	**year**	**category**	**share**	**age_get_prize**		
2	Wilhelm Conrad	Röntgen	male	1901	physics	1	56		
3	Hendrik A.	Lorentz	male	1902	physics	2	49		
4	Pieter	Zeeman	male	1902	physics	2	37		
5	Henri	Becquerel	male	1903	physics	2	51		
6	Pierre	Curie	male	1903	physics	4	44		
7	Marie	Curie	female	1903	physics	4	36		
8	Marie	Curie	female	1911	chemistry	1	44		
9	Lord	Rayleigh	male	1904	physics	1	62		
10	Philipp	Lenard	male	1905	physics	1	43		
11	J.J.	Thomson	male	1906	physics	1	50		
12	Albert A.	Michelson	male	1907	physics	1	55		
13	Gabriel	Lippmann	male	1908	physics	1	63		
14	Guglielmo	Marconi	male	1909	physics	2	35		
15	Ferdinand	Braun	male	1909	physics	2	59		
16	Johannes Diderik	van der Waals	male	1910	physics	1	73		
17	Wilhelm	Wien	male	1911	physics	1	47		
18	Gustaf	Dalén	male	1912	physics	1	43		
19	Heike	Kamerlingh Onnes	male	1913	physics	1	60		
20	Max	von Laue	male	1914	physics	1	35		
21	William	Bragg	male	1915	physics	2	53		
22	Lawrence	Bragg	male	1915	physics	2	25		
23	Charles Glover	Barkla	male	1917	physics	1	40		
24	Max	Planck	male	1918	physics	1	60		
25	Johannes	Stark	male	1919	physics	1	45		
26	Charles Edouard	Guillaume	male	1920	physics	1	59		
27	Albert	Einstein	male	1921	physics	1	42		
28	Niels	Bohr	male	1922	physics	1	37		
29	Robert A.	Millikan	male	1923	physics	1	55		
30	Manne	Siegbahn	male	1924	physics	1	38		
31	James	Franck	male	1925	physics	2	43		
32	Gustav	Hertz	male	1925	physics	2	38		
33	Jean Baptiste	Perrin	male	1926	physics	1	56		
34	Arthur H.	Compton	male	1927	physics	2	35		
35	C.T.R.	Wilson	male	1927	physics	2	58		
36	Owen Willans	Richardson	male	1928	physics	1	49		
37	Louis	de Broglie	male	1929	physics	1	37		



ourworldindata.org


data.world
+ New
type:dataset AND
All
Resources
Organizations and people
Comments
Columns
Filters
Advanced
203,724 results
RESOURCE TYPE
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us-noaa-gov (26,831)
us-nasa-gov (18,314)
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STATUS
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TAG
doi (14,169)
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Nobel Prize Winners
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436 Comment
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Haiyun YU · Updated last year
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favorited_tweets
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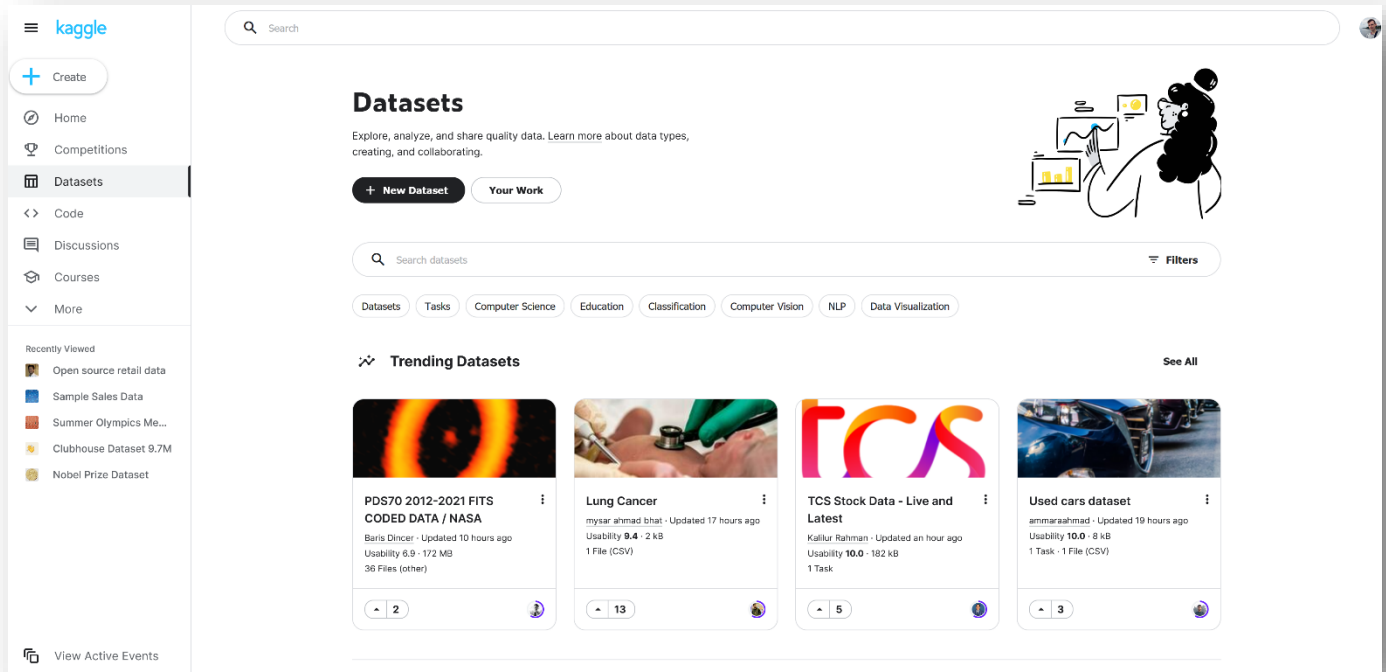
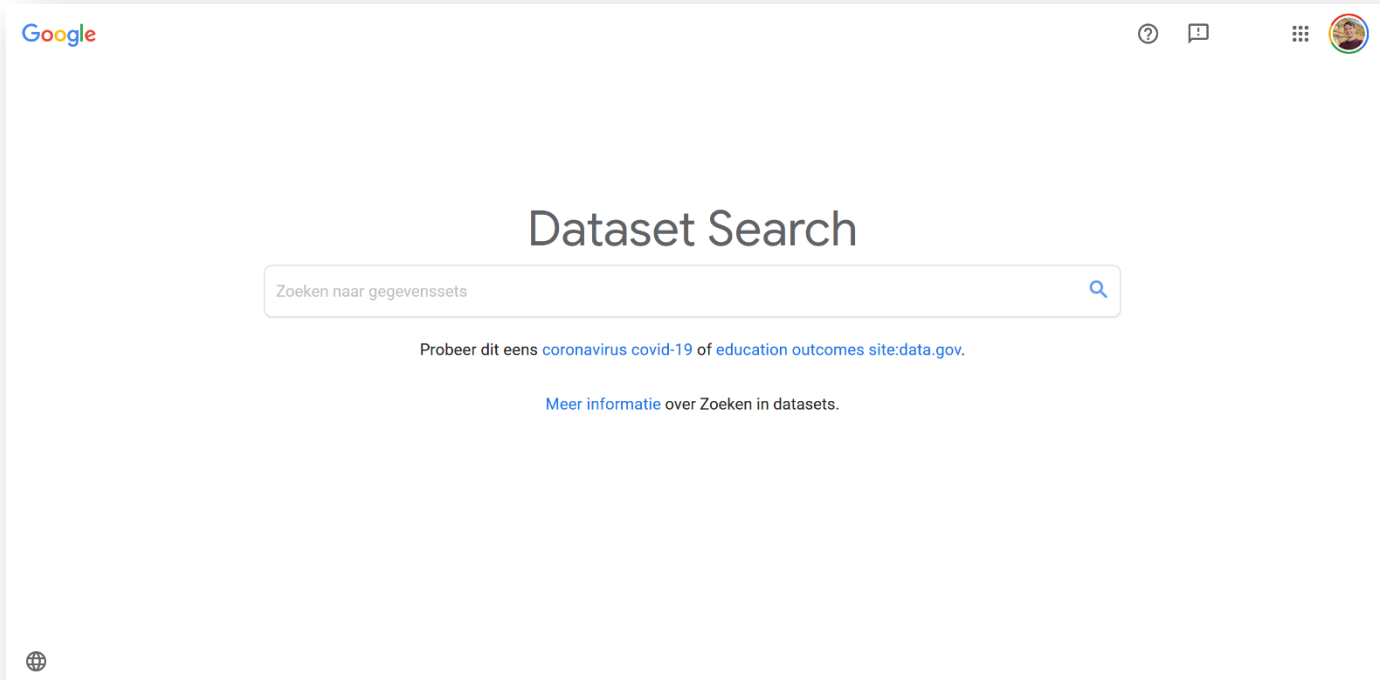
collects a midwesterner's favorite tweets
Used in 291 projects 1 file 1 table

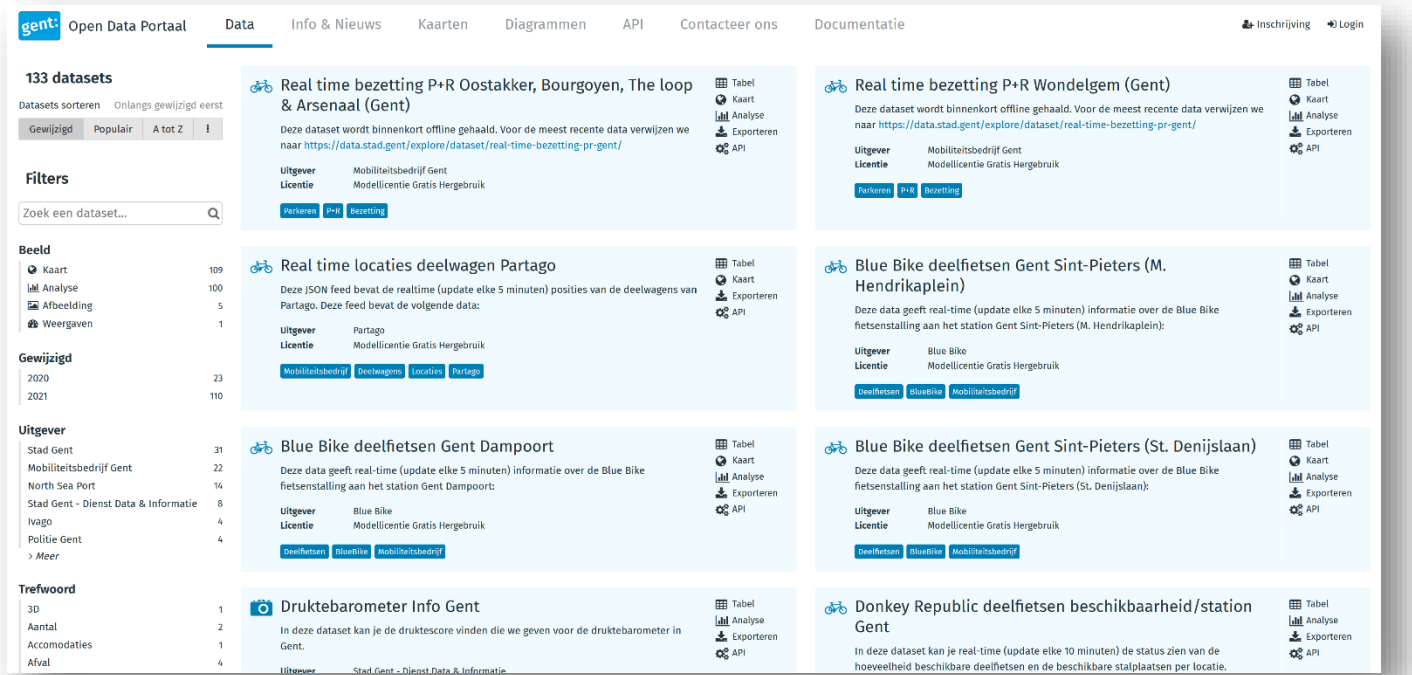
[data.world]



kaggle.com/datasets



datasetsearch.research.google.com



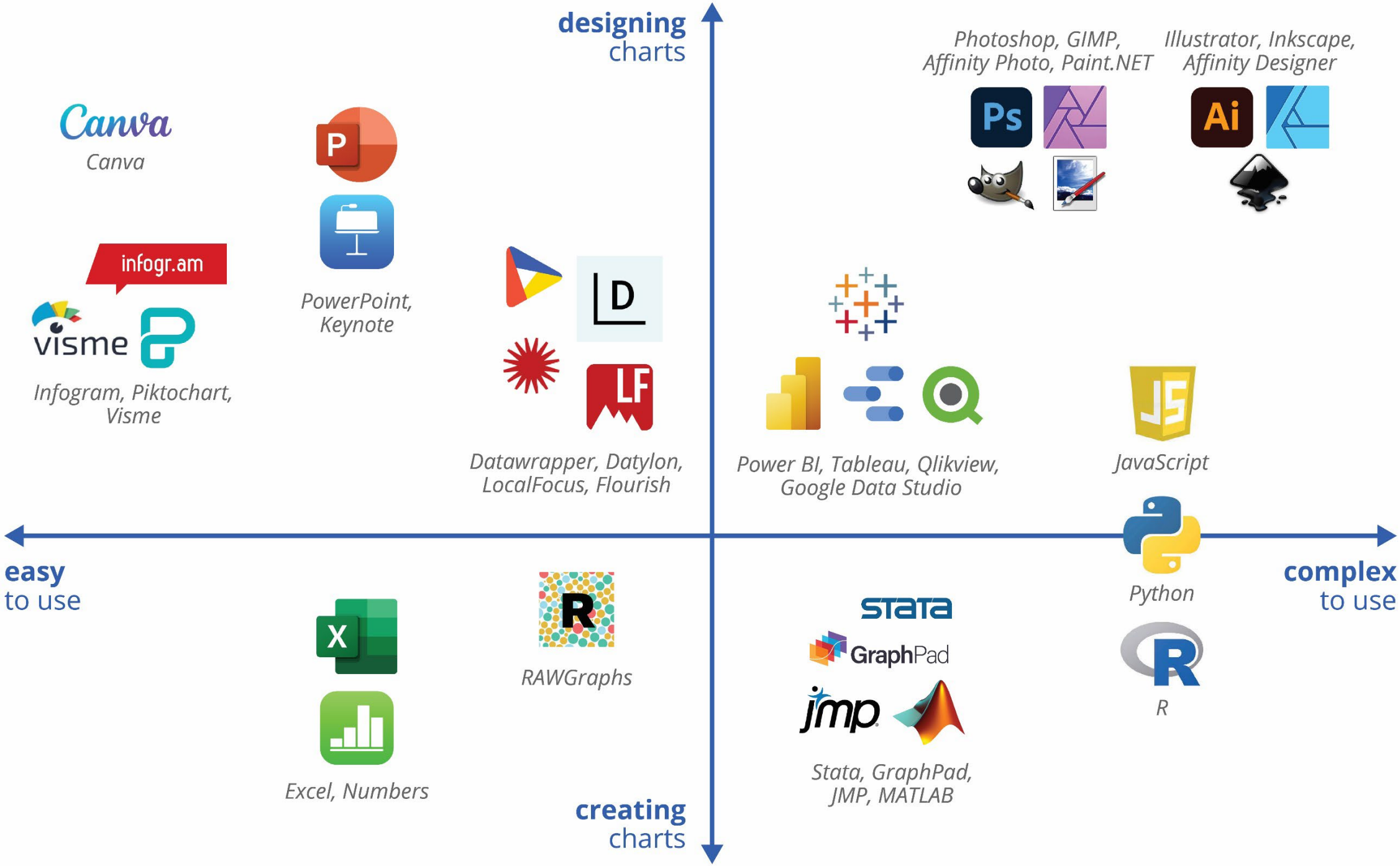
data.stad.gent

Workflow

prepare your data

create the chart

improve the design


designing
charts
Photoshop, GIMP,
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Illustrator, Inkscape,
Affinity Designer
Canva
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infogr.am
visme
Infogram, Piktochart,
Visme
PowerPoint,
Keynote
Datawrapper, Datylon,
LocalFocus, Flourish
Power BI, Tableau, Qlikview,
Google Data Studio
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to use
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to use
Python
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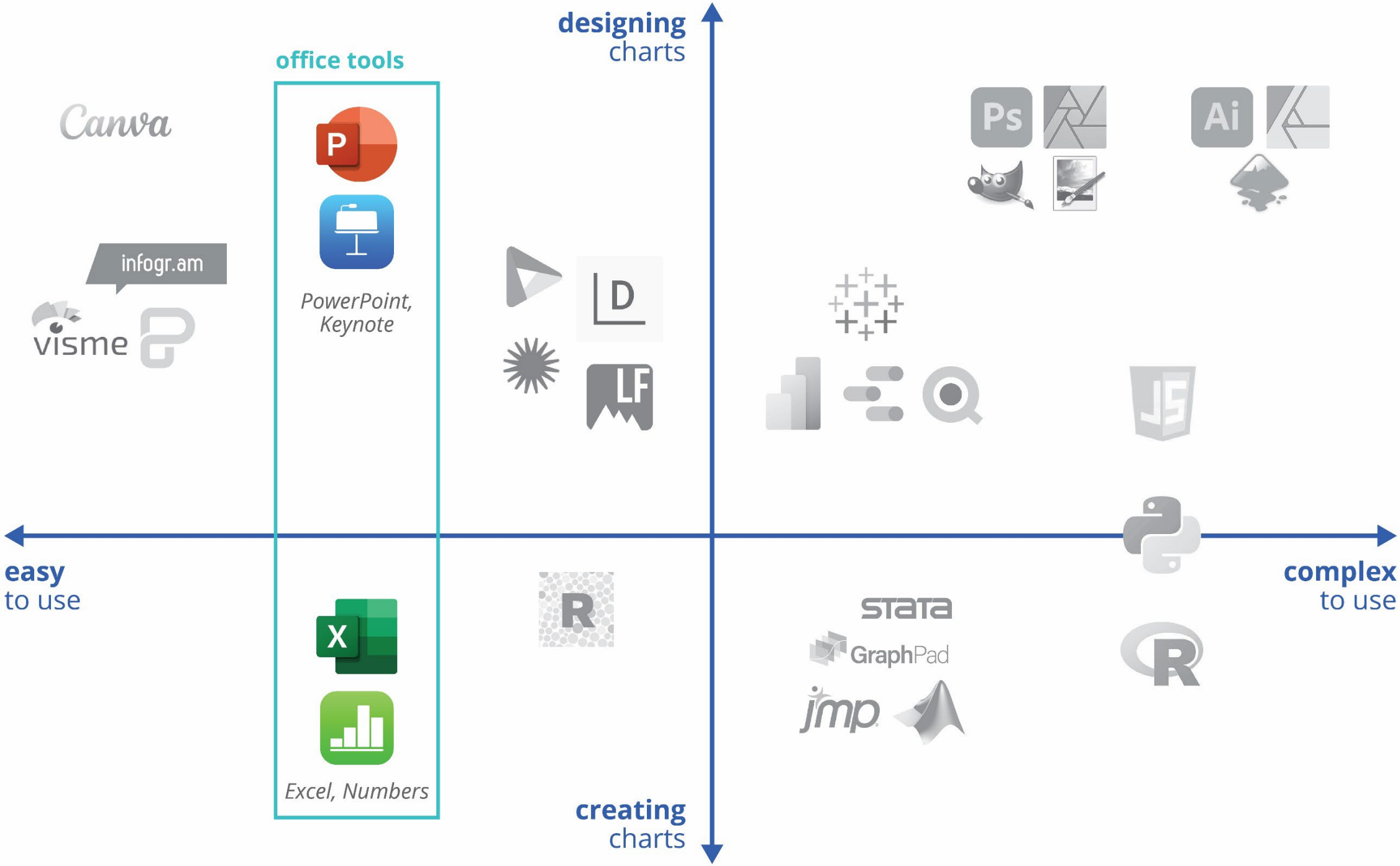
Excel, Numbers
Stata, GraphPad,
JMP, MATLAB
creating
charts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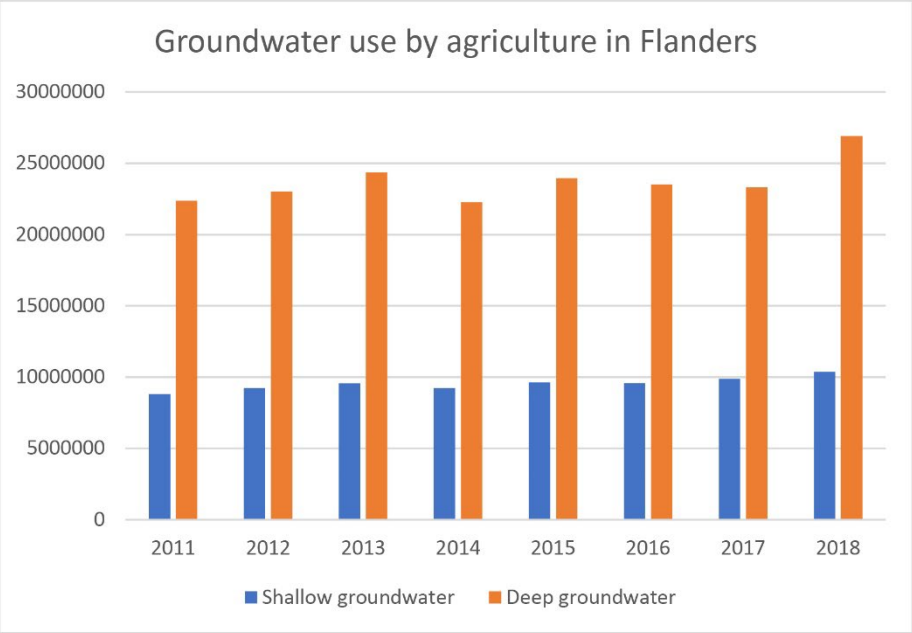
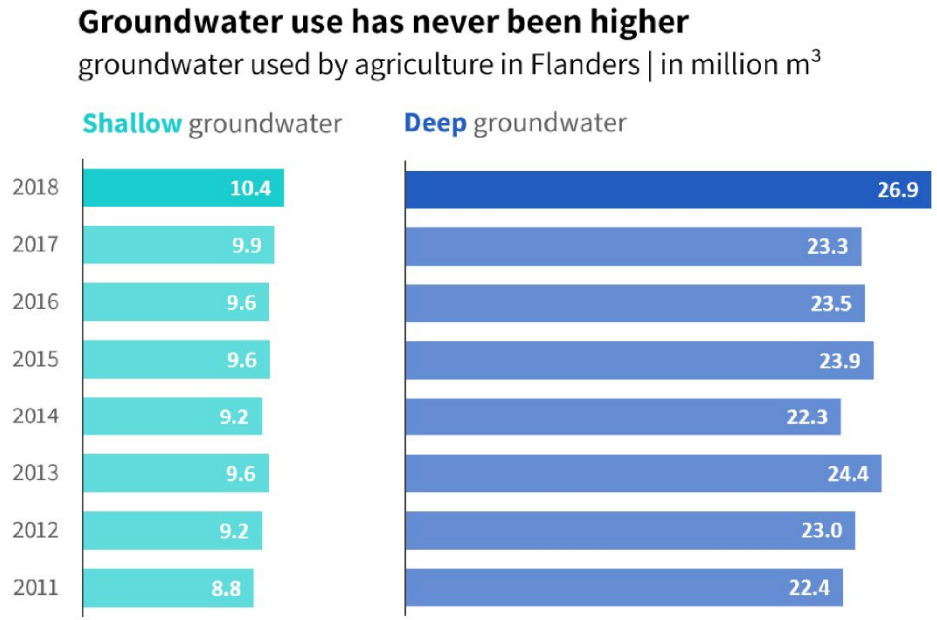
office tools
Canva
infogr.am
visme
PowerPoint,
Keynote
Excel, Numbers
easy
to use
complex
to use
creating
charts
STATA
GraphPad
jmp

Available tools

Spreadsheet tools

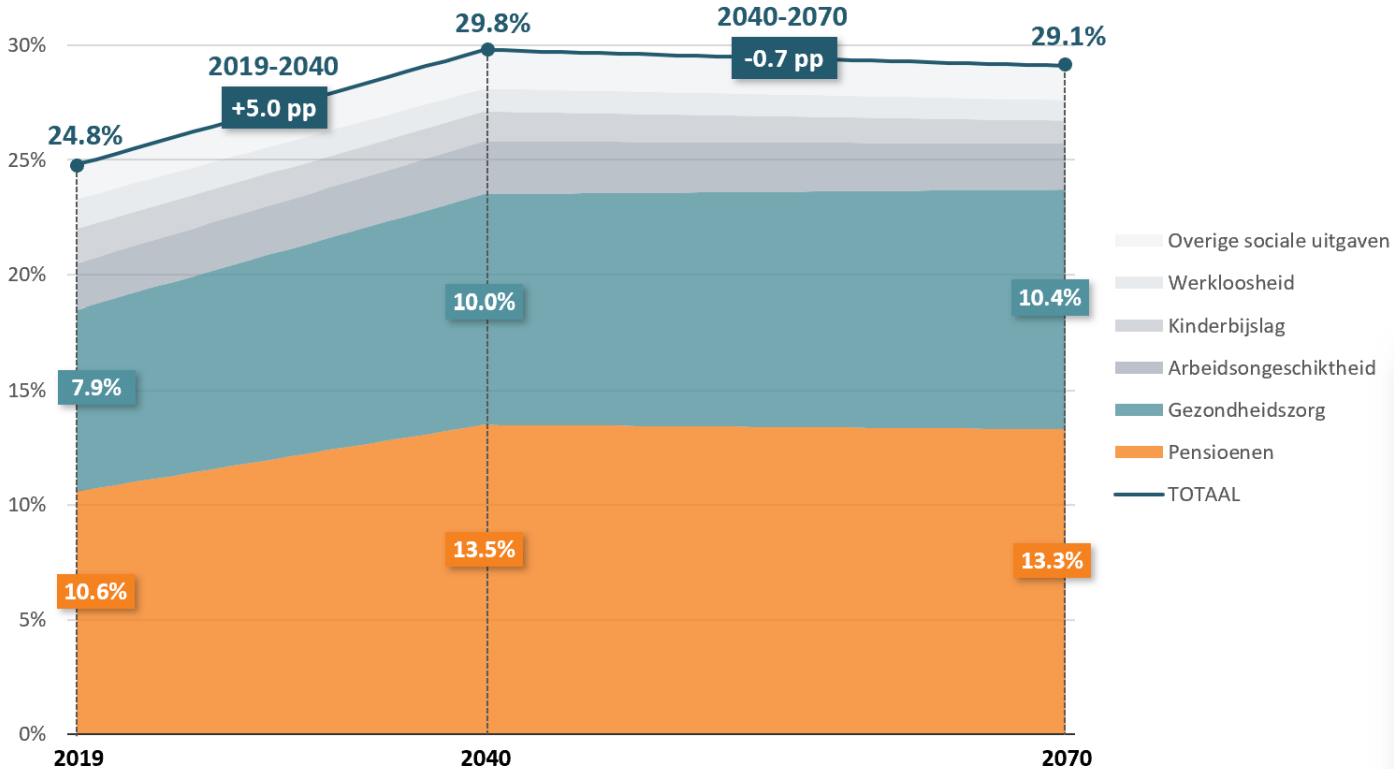




Evolutie van de budgettaire kosten van de vergrijzing op lange termijn

Volgens het SCvV-referentiescenario van juli 2020

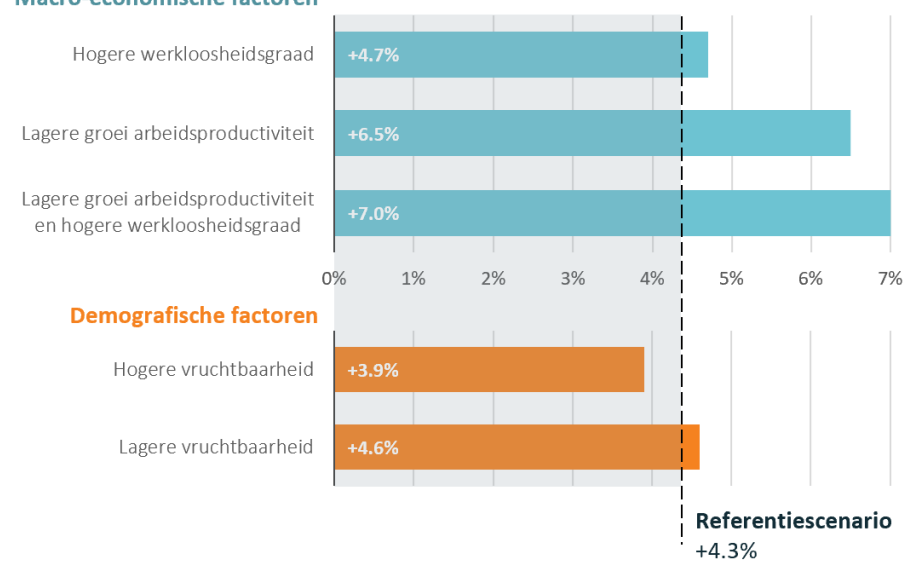
in procent van het bbp

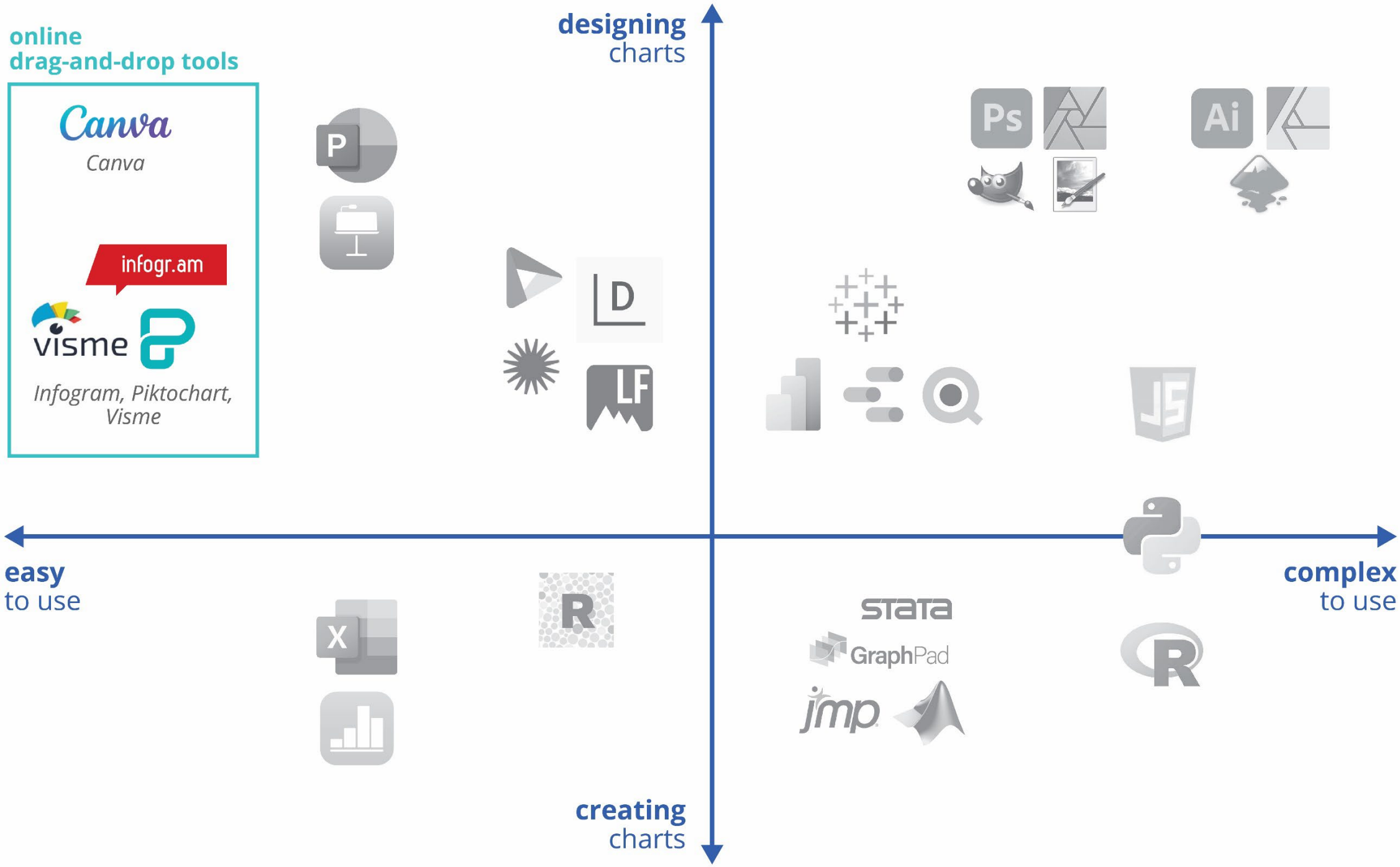


Evolutie van de budgettaire kosten van de vergrijzing tussen 2019 en 2070

Volgens het referentie- en alternatieve scenario's

in procentpunt van het bbp




online
drag-and-drop tools
Canva
Canva
infogr.am
visme
Infogram, Piktochart,
Visme
designing
charts
creating
charts
easy
to use
complex
to use
Ps
Ai
LD
LF
JS
STATA
GraphPad
jmp
R

Freemium drag-and-drop tools

Canva

canva.com

lots of templates, fonts, images,... - also in free version

limited chart options

paid version:
€ 110/year

Infogram

infogram.com

better for charts, even real-time/interactive

no downloads in free version

paid version:
$ 228/year

Piktochart

piktochart.com

pretty complete for starters, good chart options

limited number of visuals and downloads in free version

paid version:
€ 168/year

educational license: € 40/year

Visme

visme.co

pretty complete for starters, good chart options

no downloads in free version

paid version:
$ 147/year

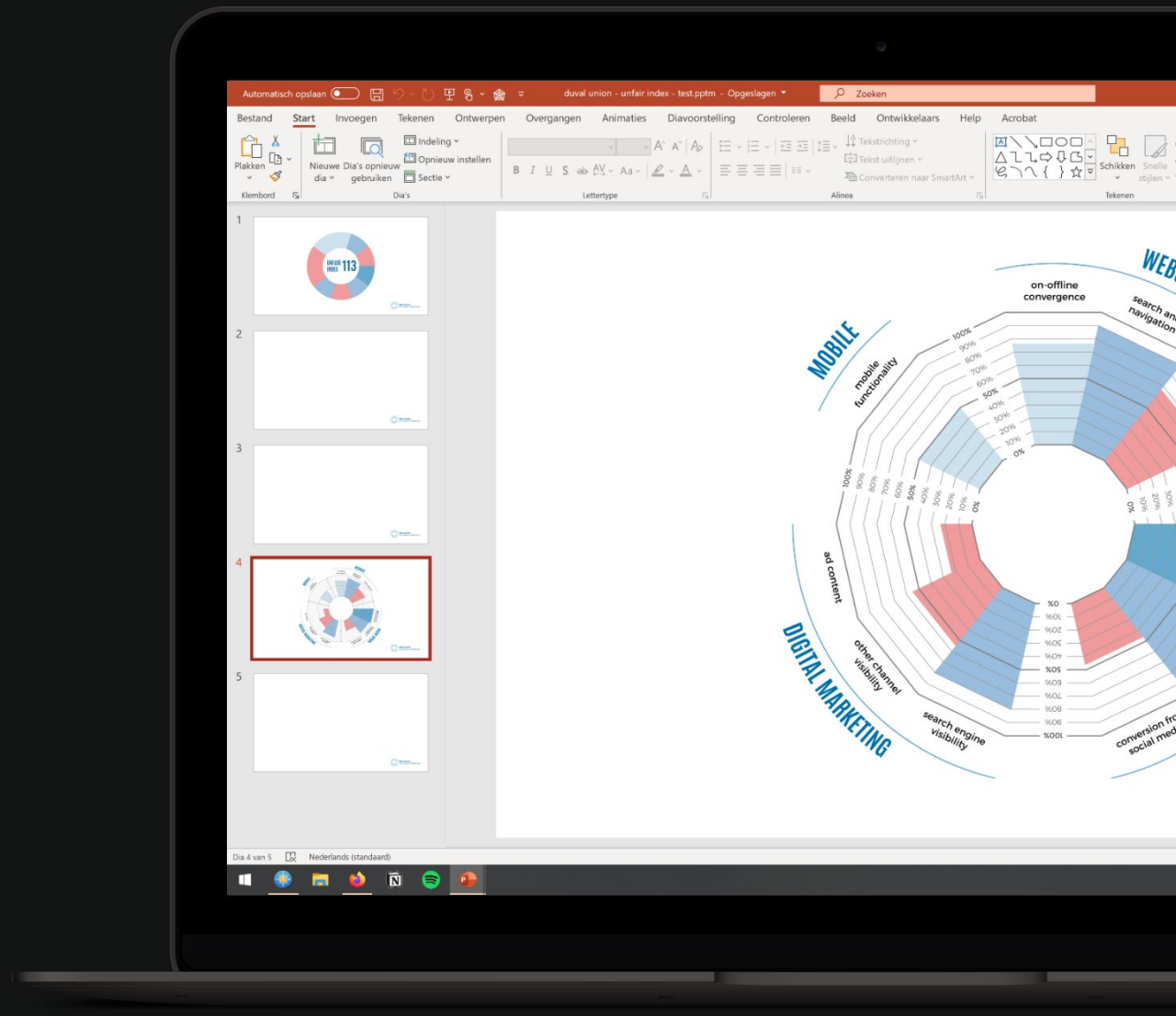
Microsoft PowerPoint

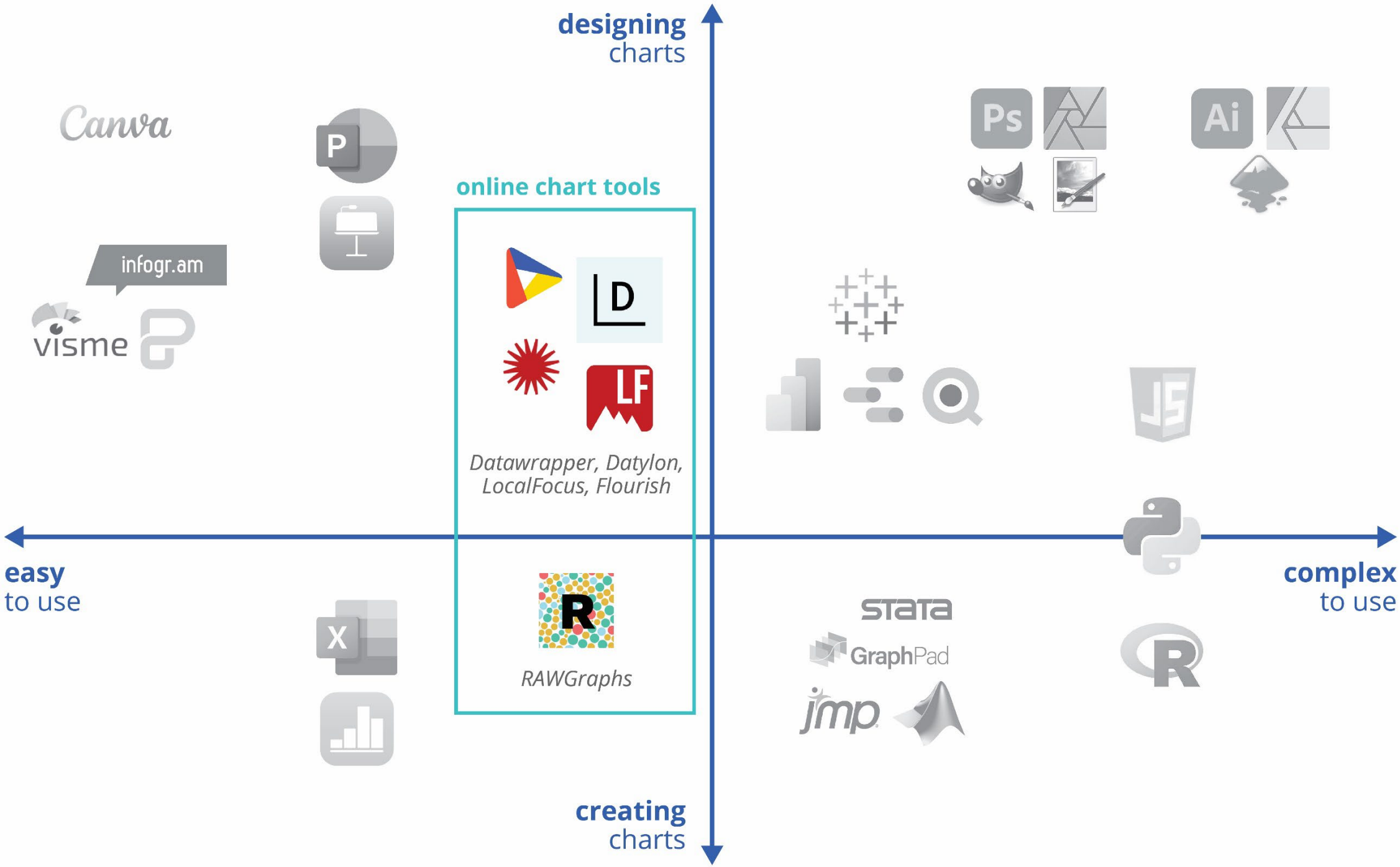
drag-and-drop, easy to use

you already have it, and know it

templates available

charts linked with spreadsheets

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infogr.am
visme
online chart tools
Datawrapper, Datylon,
LocalFocus, Flourish
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to use
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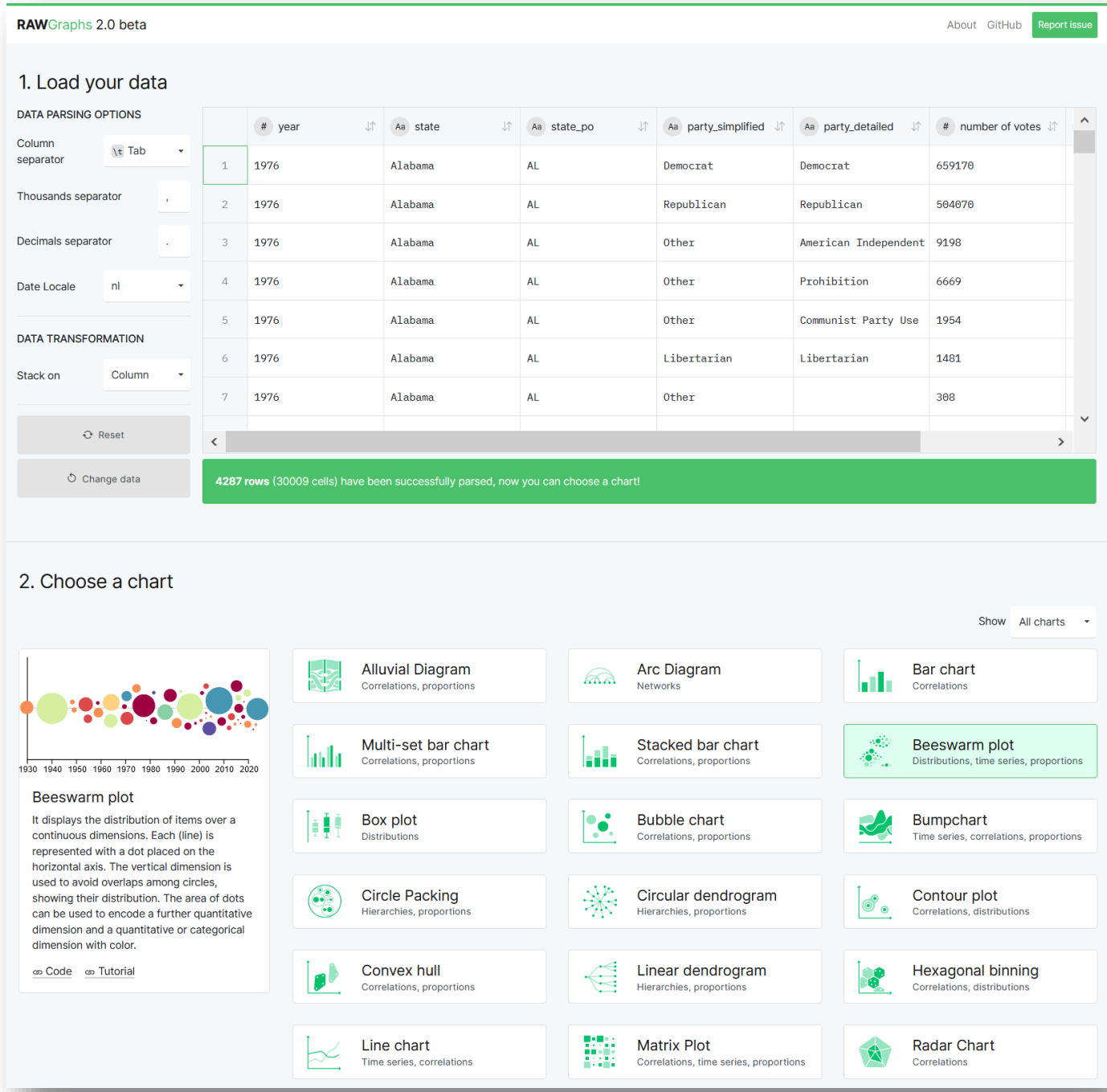
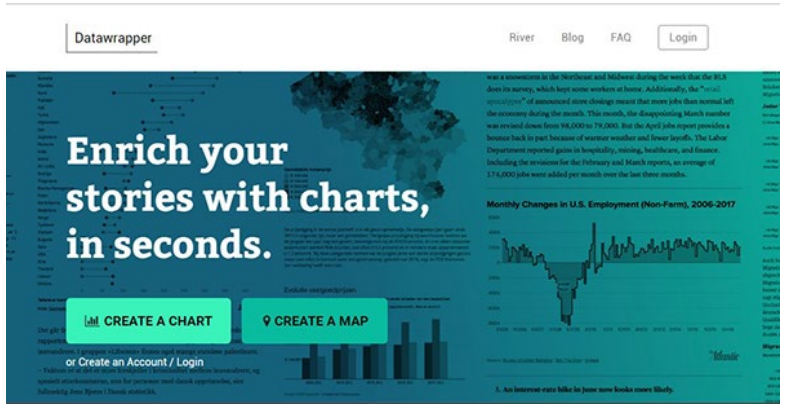
creating
charts



app.rawgraphs.io

Available tools

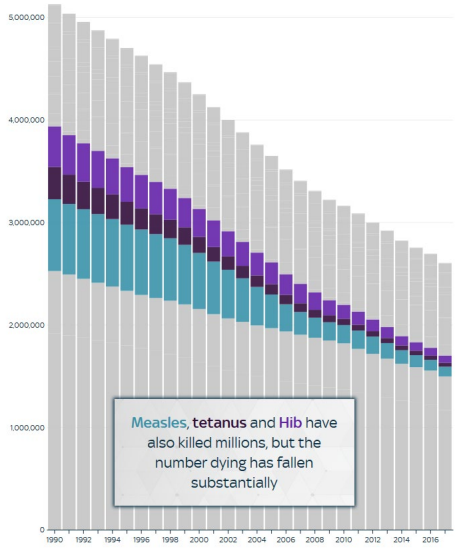
Interactive chart tools



Datawrapper

datawrapper.de

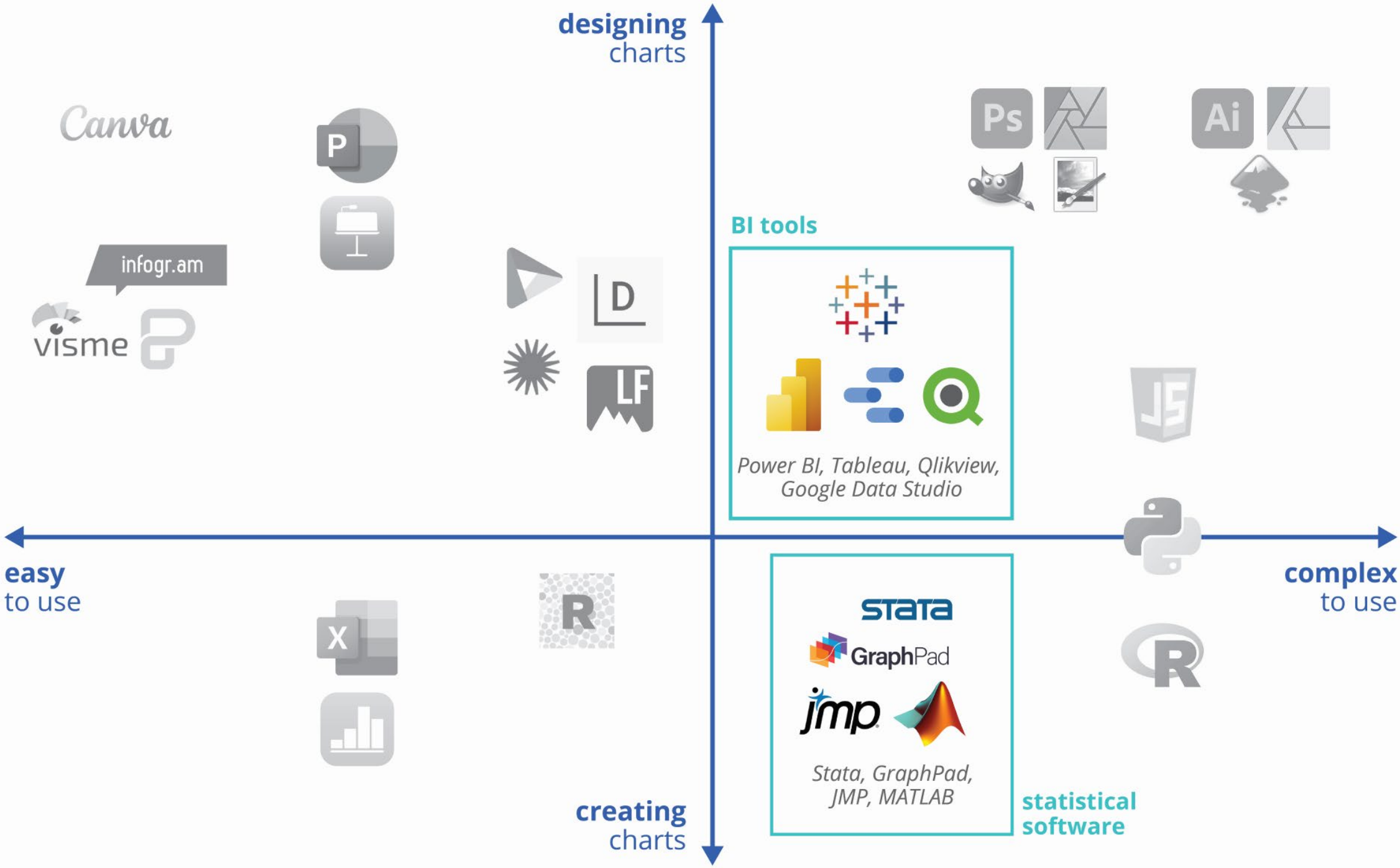
charts to embed in a website,
charts with tooltips



Flourish

flourish.studio

storytelling
with charts


designing
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visme
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Power BI, Tableau, Qlikview,
Google Data Studio
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GraphPad
jmp
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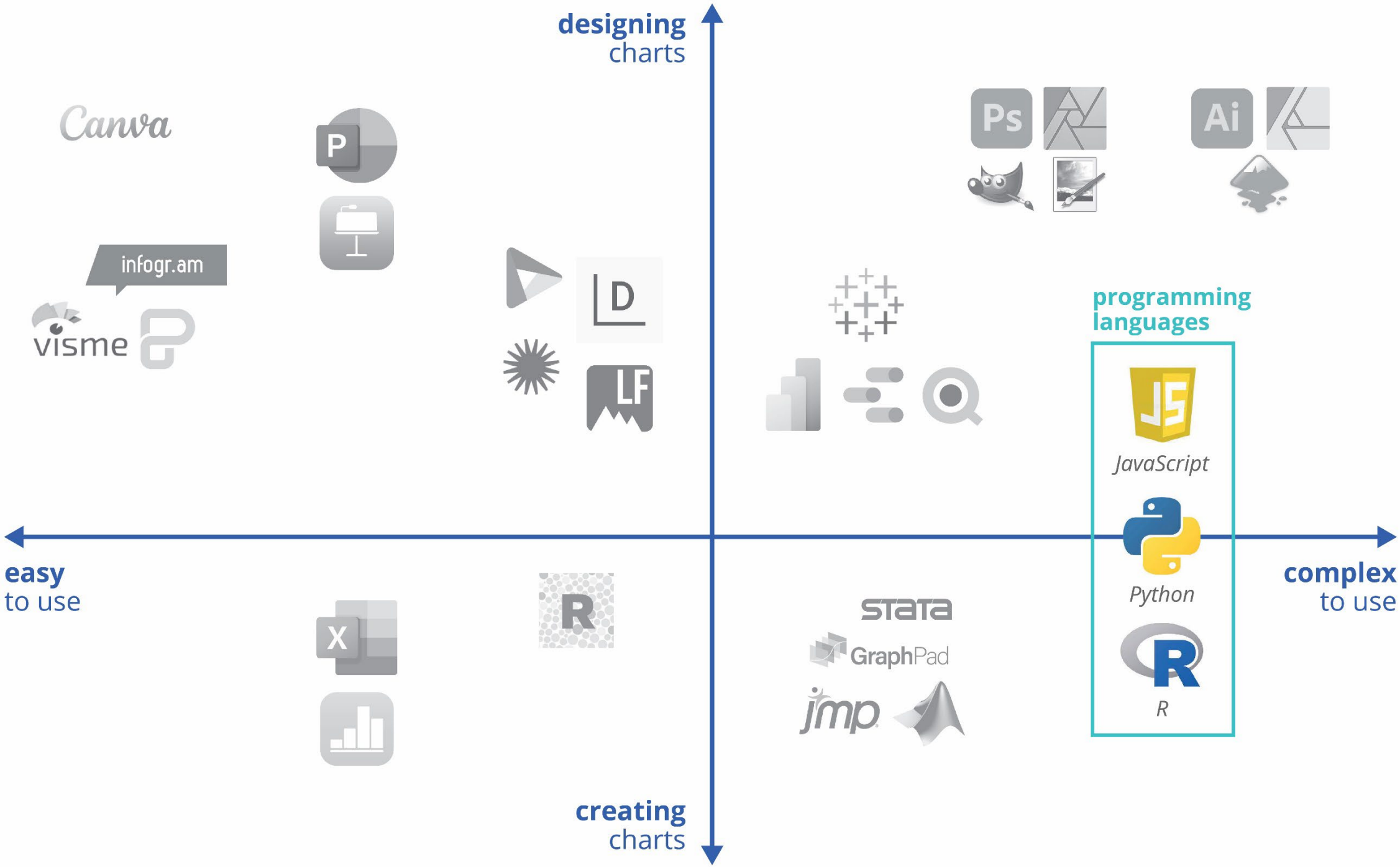
JMP, MATLAB
statistical
software
creating
charts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to use
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GraphPad
jmp
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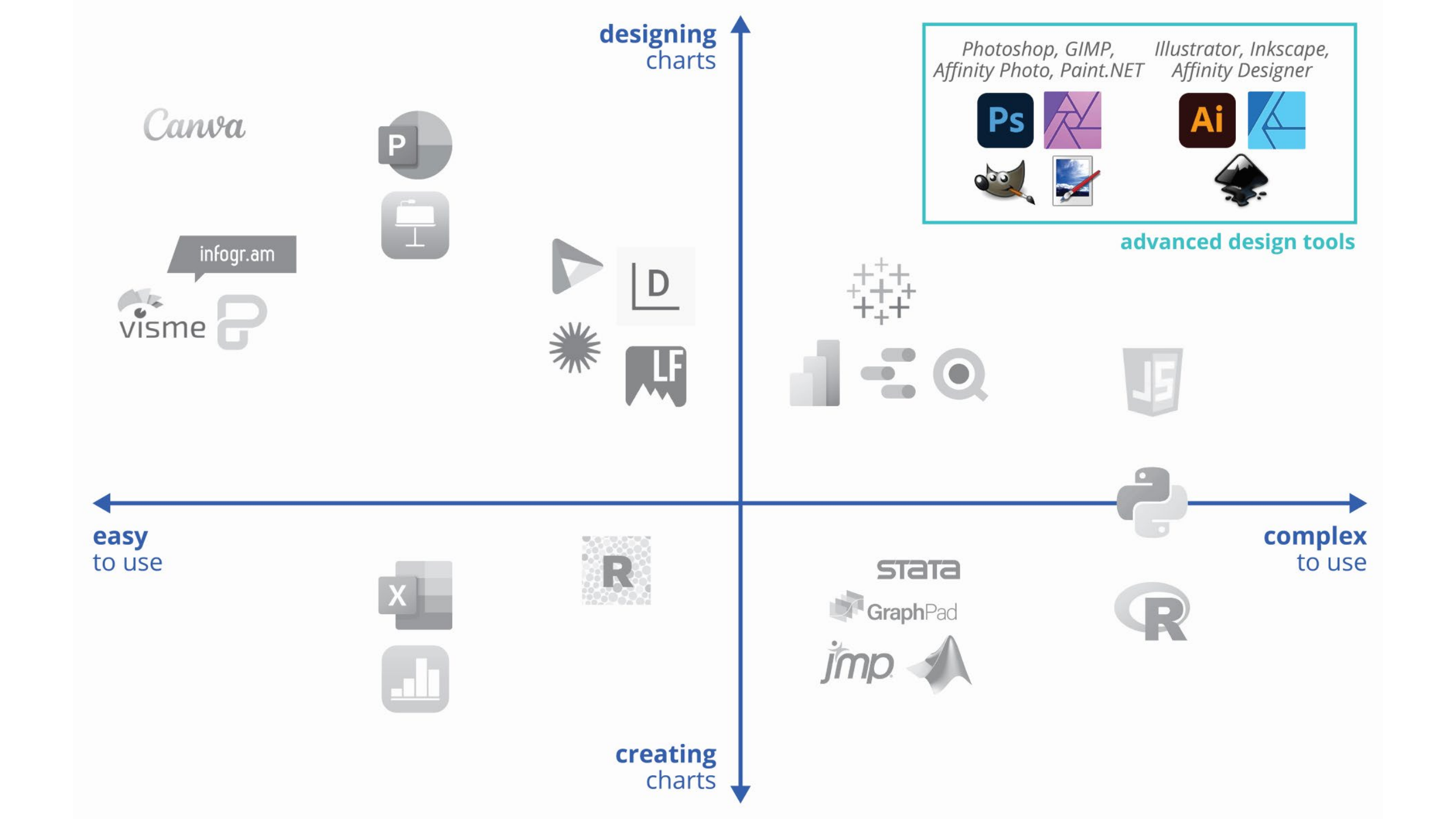
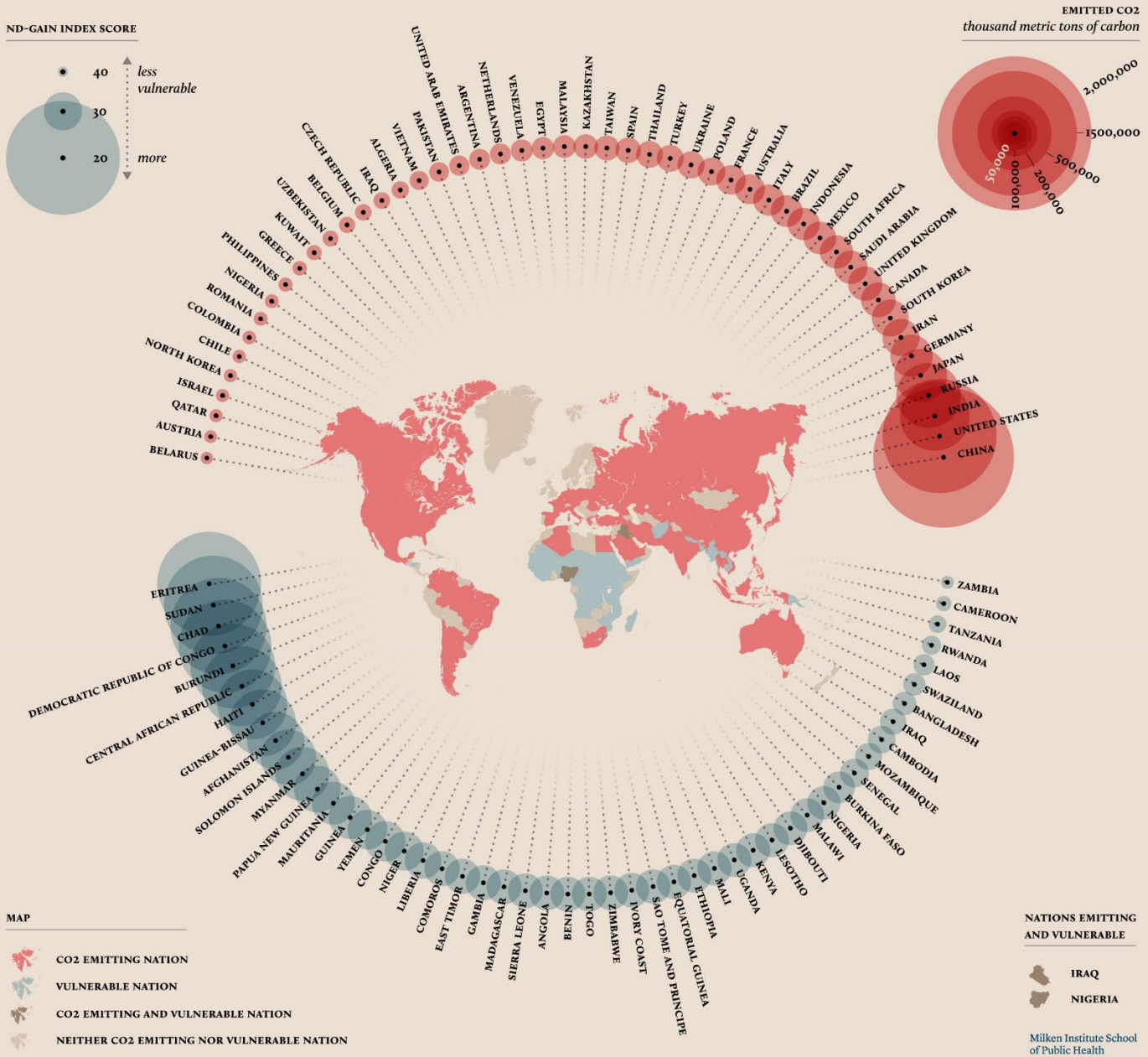
charts


designing
charts
Photoshop, GIMP,
Affinity Photo, Paint.NET
Illustrator, Inkscape,
Affinity Designer
advanced design tools
Canva
infogr.am
visme
easy
to use
complex
to use
creating
charts
STATA
GraphPad
jmp

CO2 EMISSION VS. VULNERABILITY TO CLIMATE CHANGE, BY NATION (2010)



SOURCES: CARBON DIOXIDE INFORMATION ANALYSIS CENTER; RESEARCH INSTITUTE FOR ENVIRONMENT, ENERGY AND ECONOMICS; ND-GAIN INDEX

Milken Institute School of Public Health
THE GEORGE WASHINGTON UNIVERSITY
MHA@GW

Adobe Illustrator

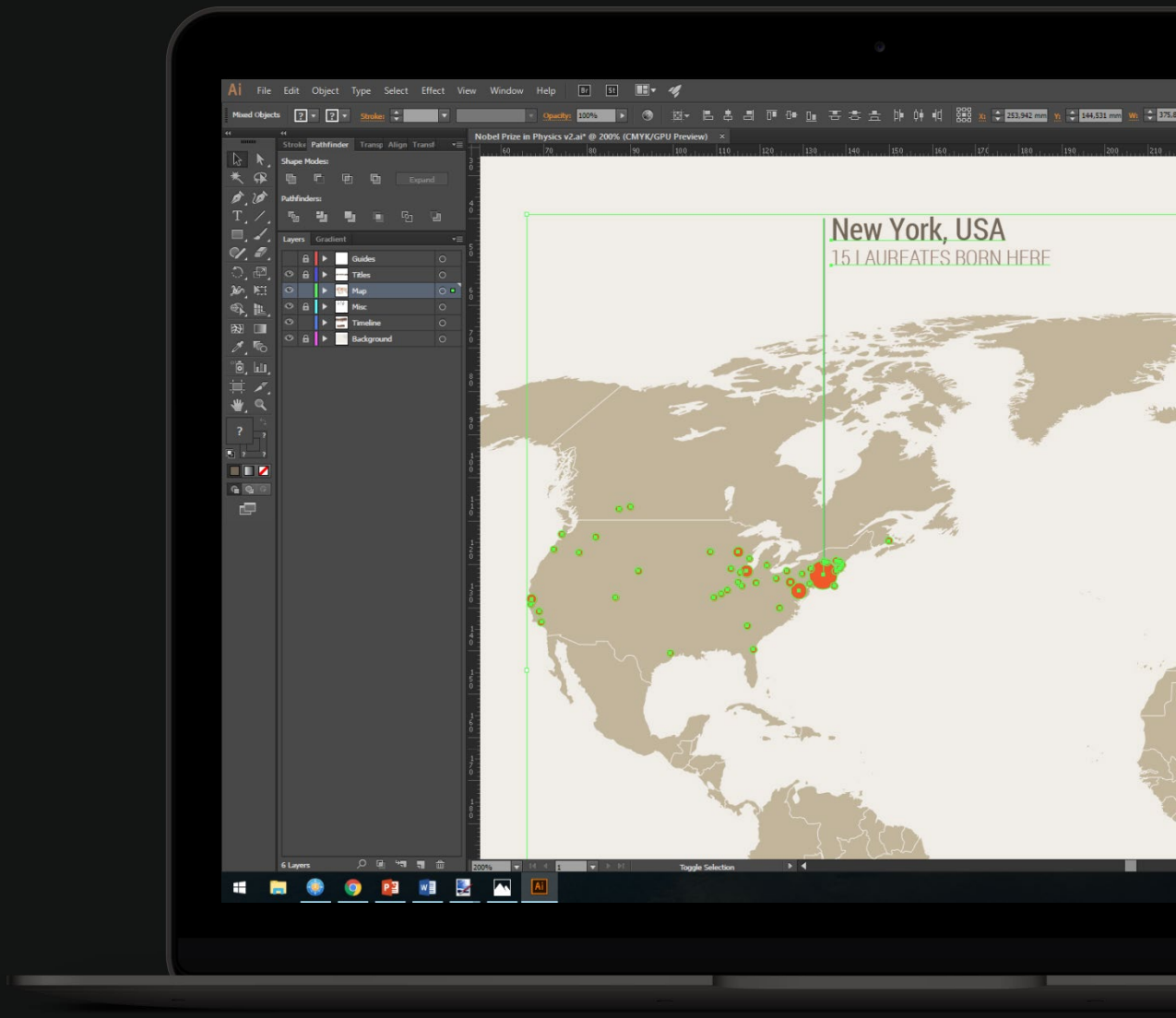
“industry standard”

very powerful

steep learning curve

expensive subscription

adobe.com/illustrator



Adobe Photoshop

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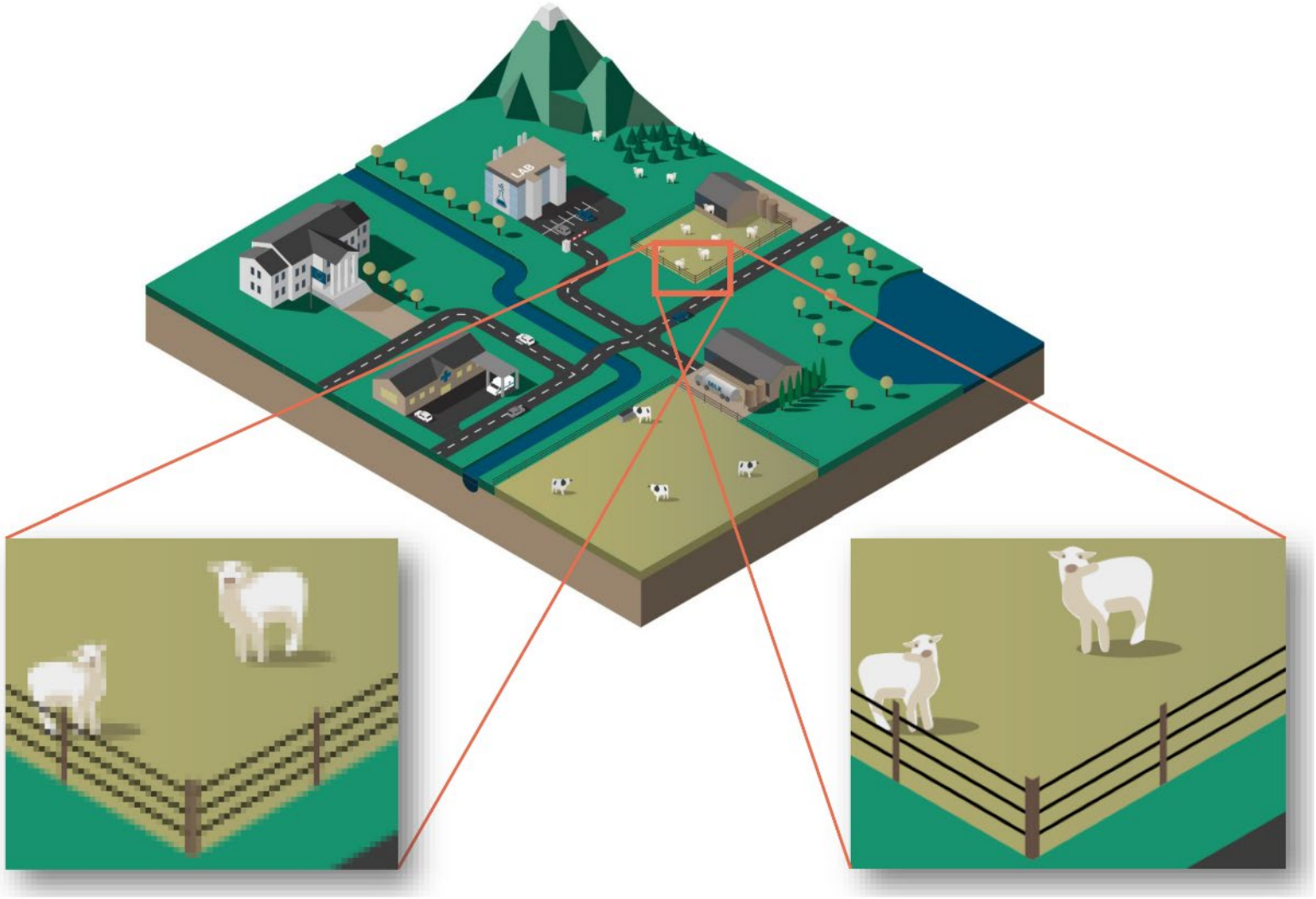
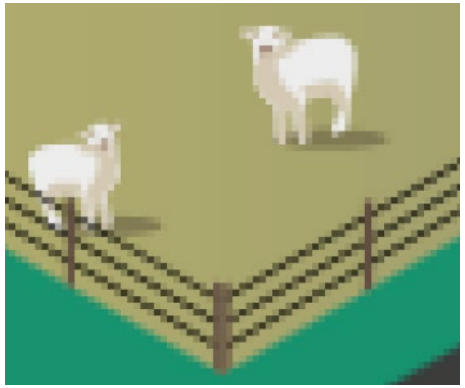
adobe.com/photoshop



bitmap image
jpg, png, bmp, tiff, gif, psd, etc.

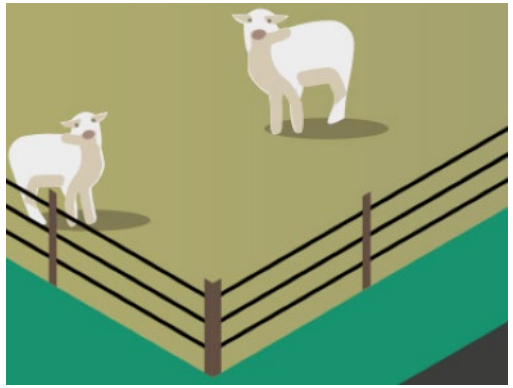
vector image
svg, pdf, eps, ai, etc.



bitmap image

jpg, png, bmp, tiff, gif, psd,...

- built from **pixels**
- photographs
- illustrated made by hand
- illustrations with lots of textures, brush strokes,...



vector image

svg, pdf, eps, ai,...

- built from **shapes**
- illustrations made digitally
- (large-scale) printing
- easier to edit, recolor,...

Affinity Designer

nearly as powerful
as Adobe Illustrator

still a steep learning curve

one-off payment
(currently € 49)

affinity.serif.com

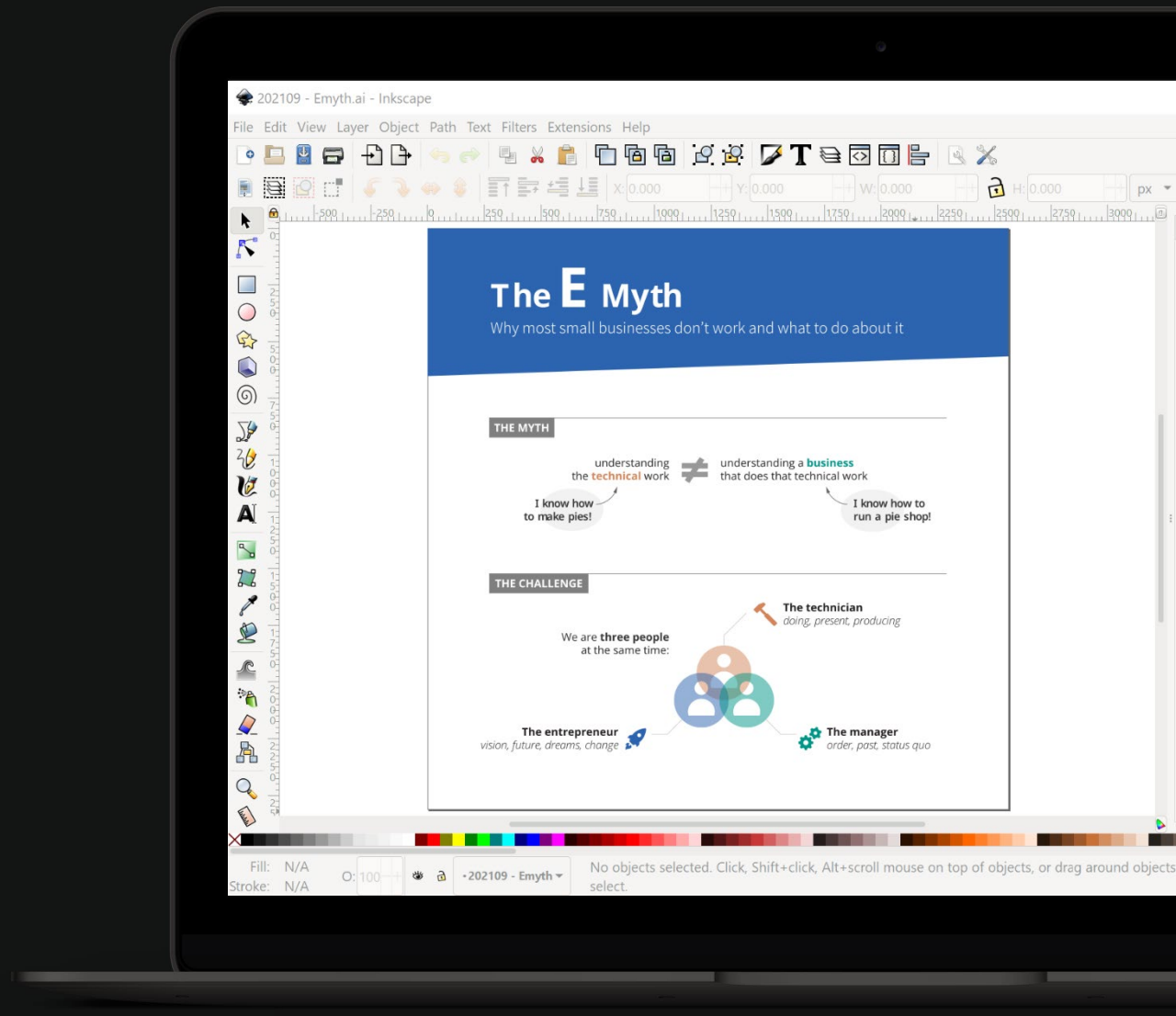
Inkscape

free alternative

all the features you need

can be a bit finicky

inkscape.org/en/release



Affinity Photo

nearly as powerful
as Adobe Photoshop

still a steep learning curve

one-off payment
(currently € 49)

affinity.serif.com

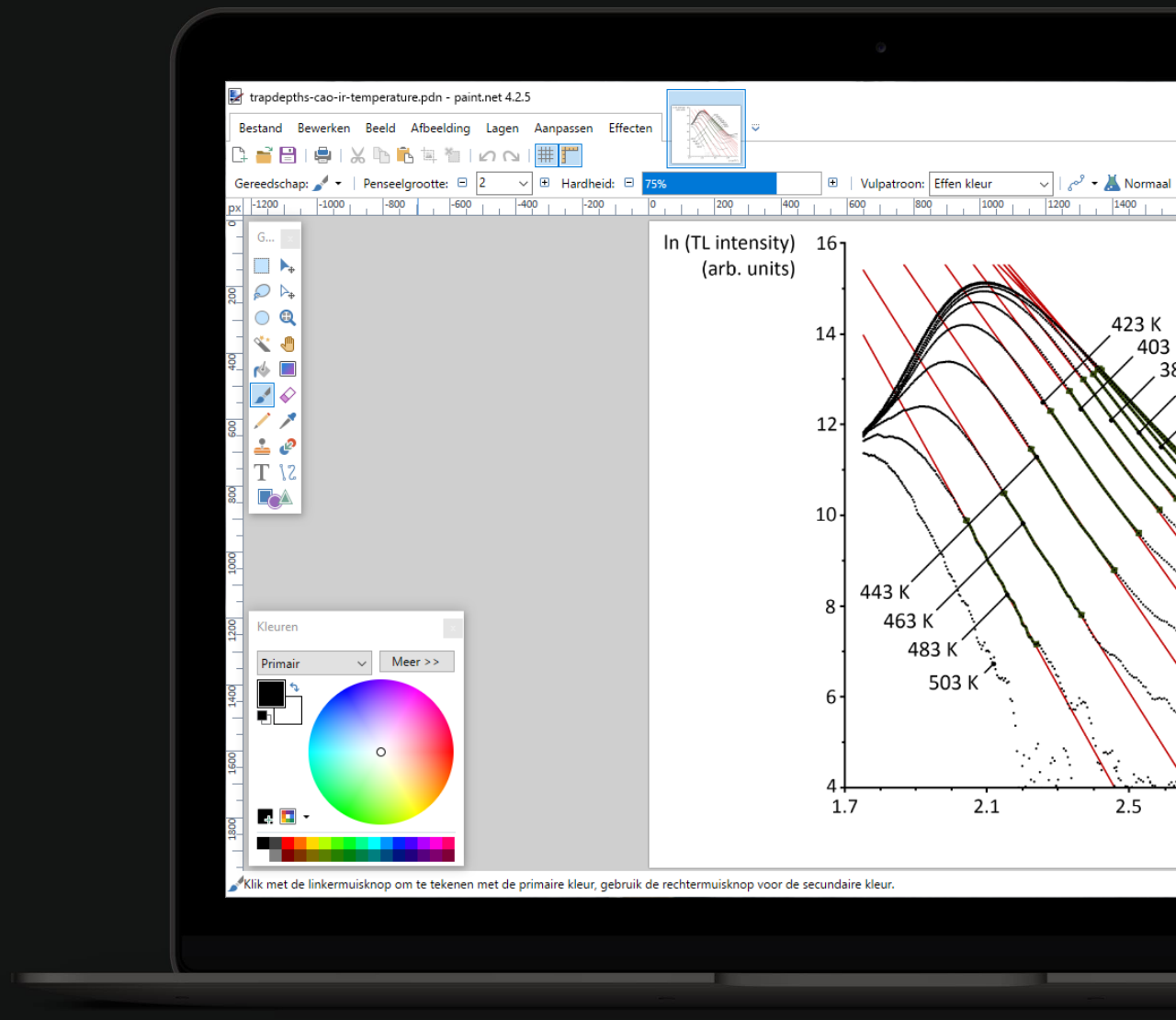
Paint.NET

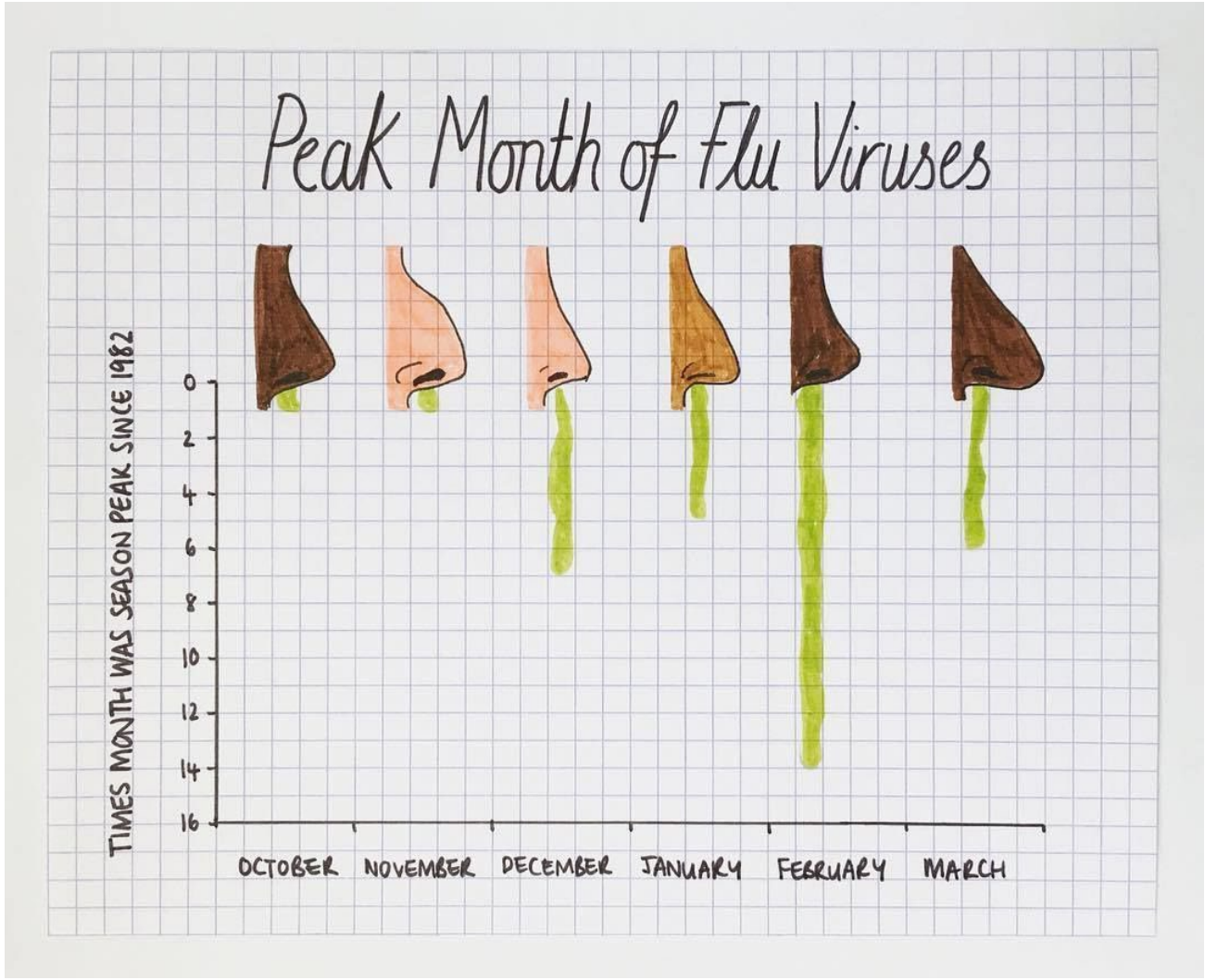
free alternative

“Paint on steroids”

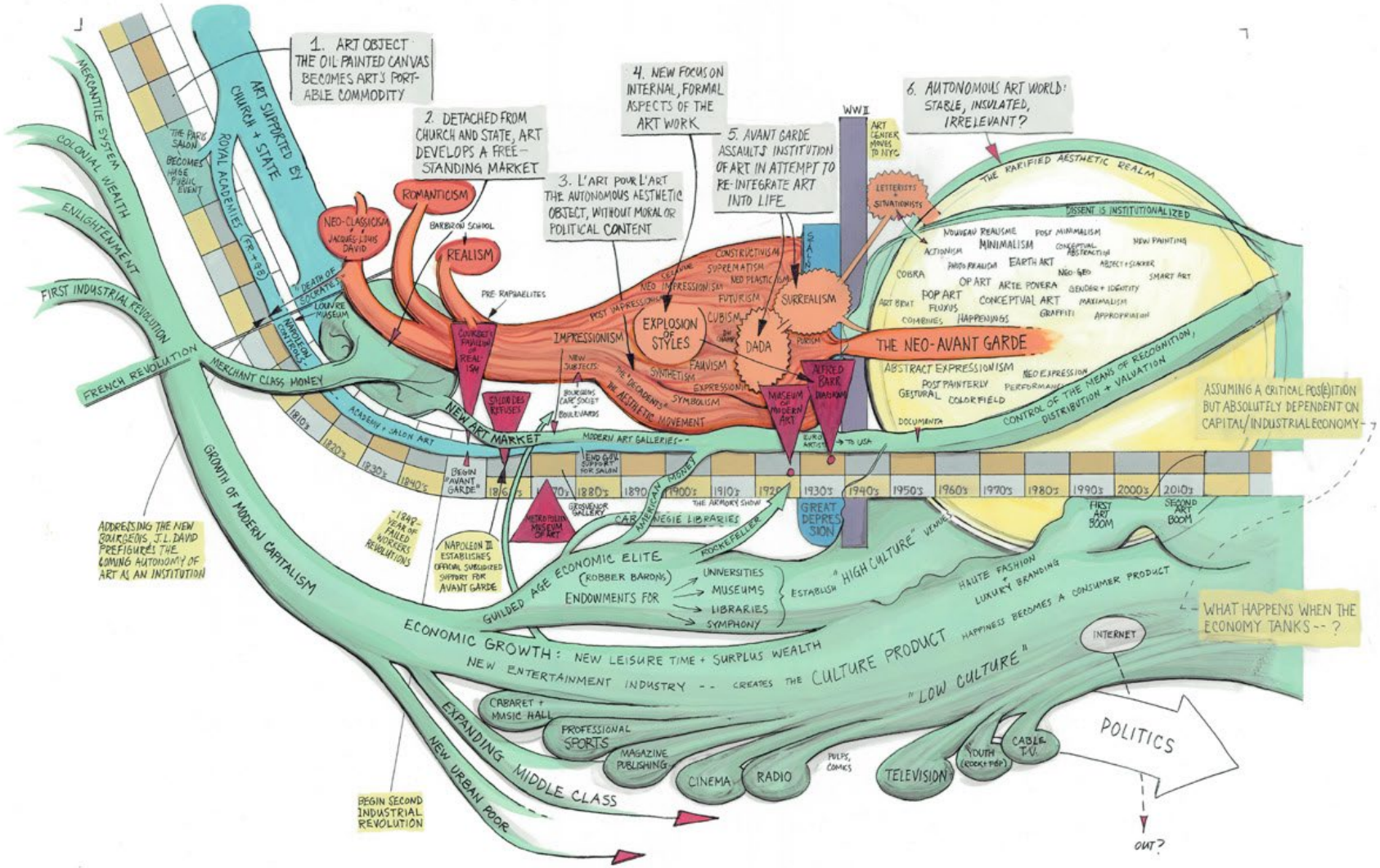
image editing with layers

getpaint.net

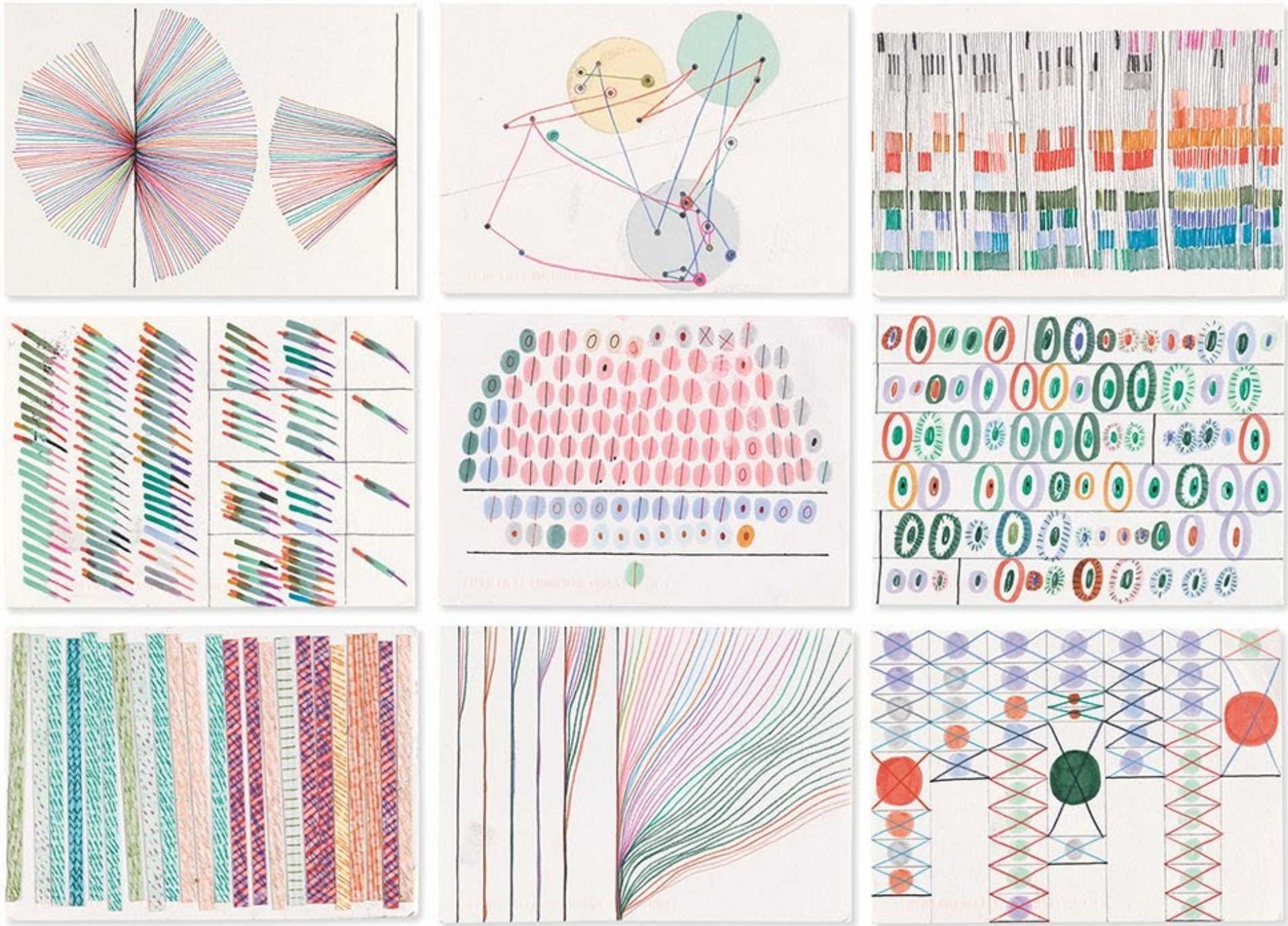




Mona Chalabi



Ward Shelley



dear-data.com

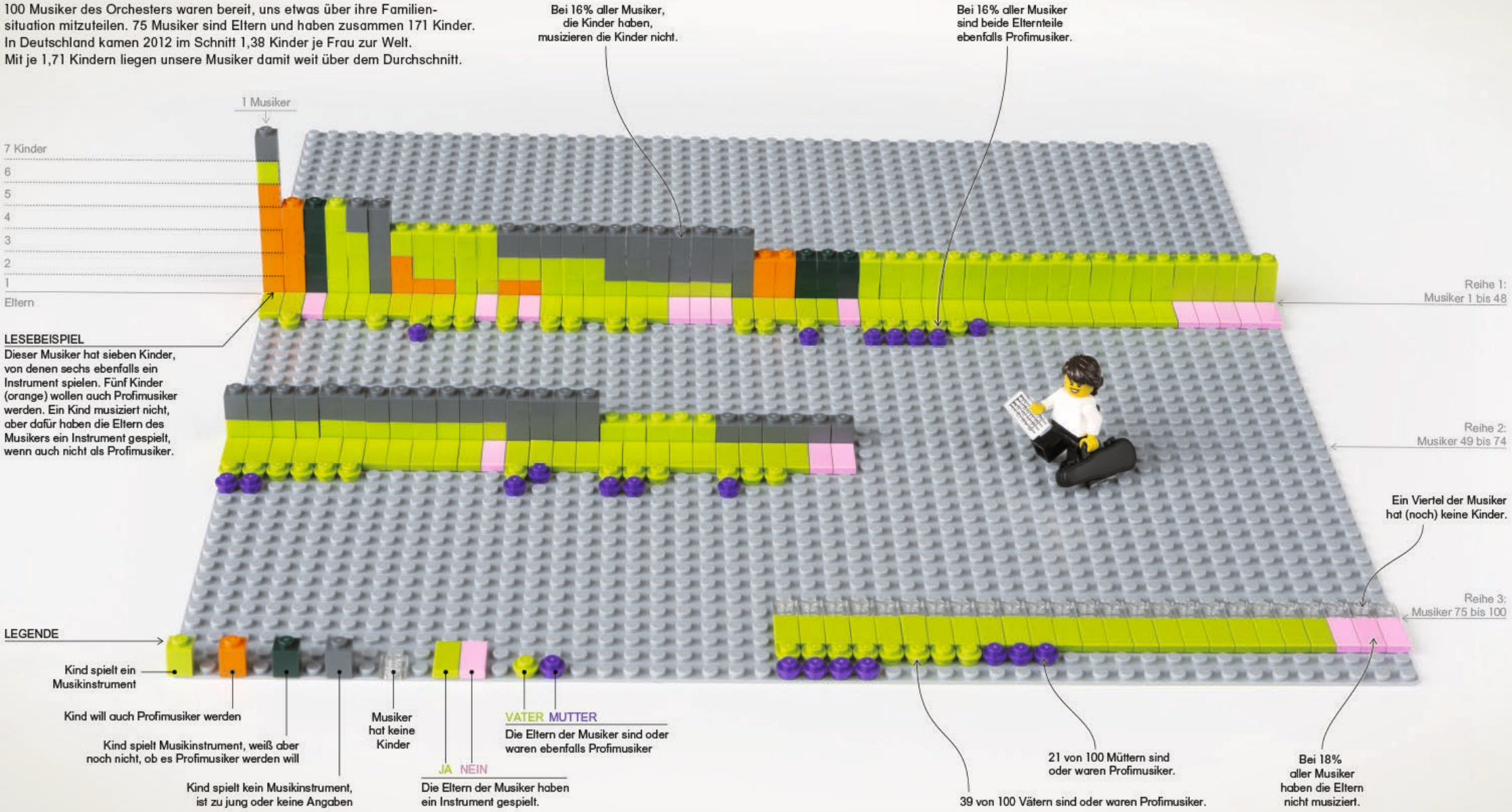
Fish Pharm
These pills represent the relative amounts of four pharmaceutical drugs found in fish pulled from Chicago's North Shore Channel and tested by Baylor scientists.

The traditional foe of water quality is waste from factories and farms, but now environmental regulators are eyeing a new pollution source: our medicine chests. Fish caught downstream from sewage treatment plants in five U.S. cities contained traces of pharmaceuticals and toiletries, Baylor University researchers found in a recent study. You'd have to eat tons of fish for such small concentrations to affect human health, but the products could pose a threat to marine life. To assess the risk, the EPA has expanded monitoring to 150 sites, with results due in 2011.

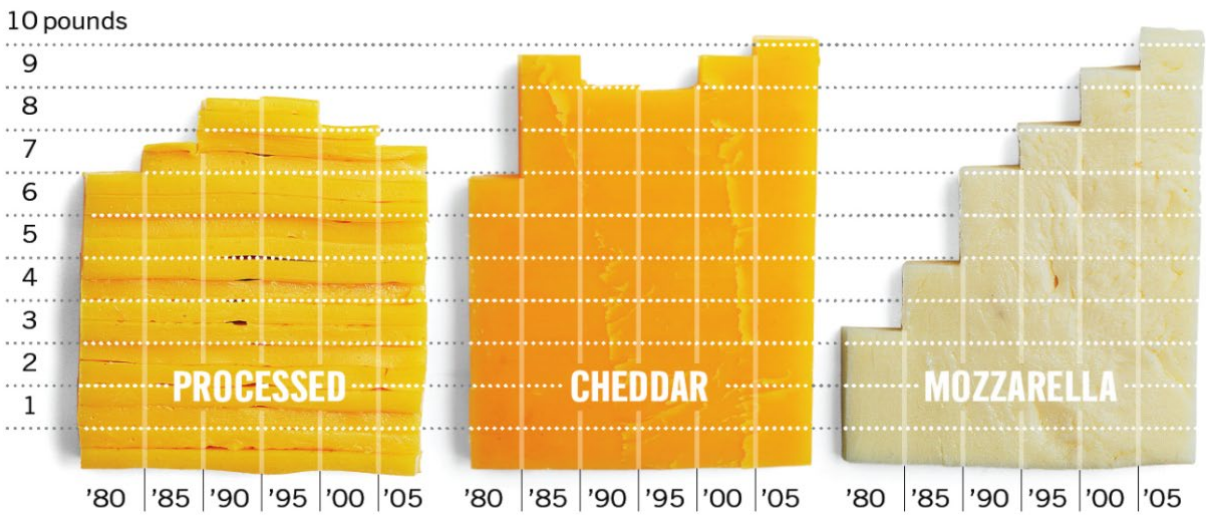
National Geographic Magazine

Die Kinder und Eltern der Musiker

100 Musiker des Orchesters waren bereit, uns etwas über ihre Familiensituation mitzuteilen. 75 Musiker sind Eltern und haben zusammen 171 Kinder. In Deutschland kamen 2012 im Schnitt 1,38 Kinder je Frau zur Welt. Mit je 1,71 Kindern liegen unsere Musiker damit weit über dem Durchschnitt.



Jan Schwochow

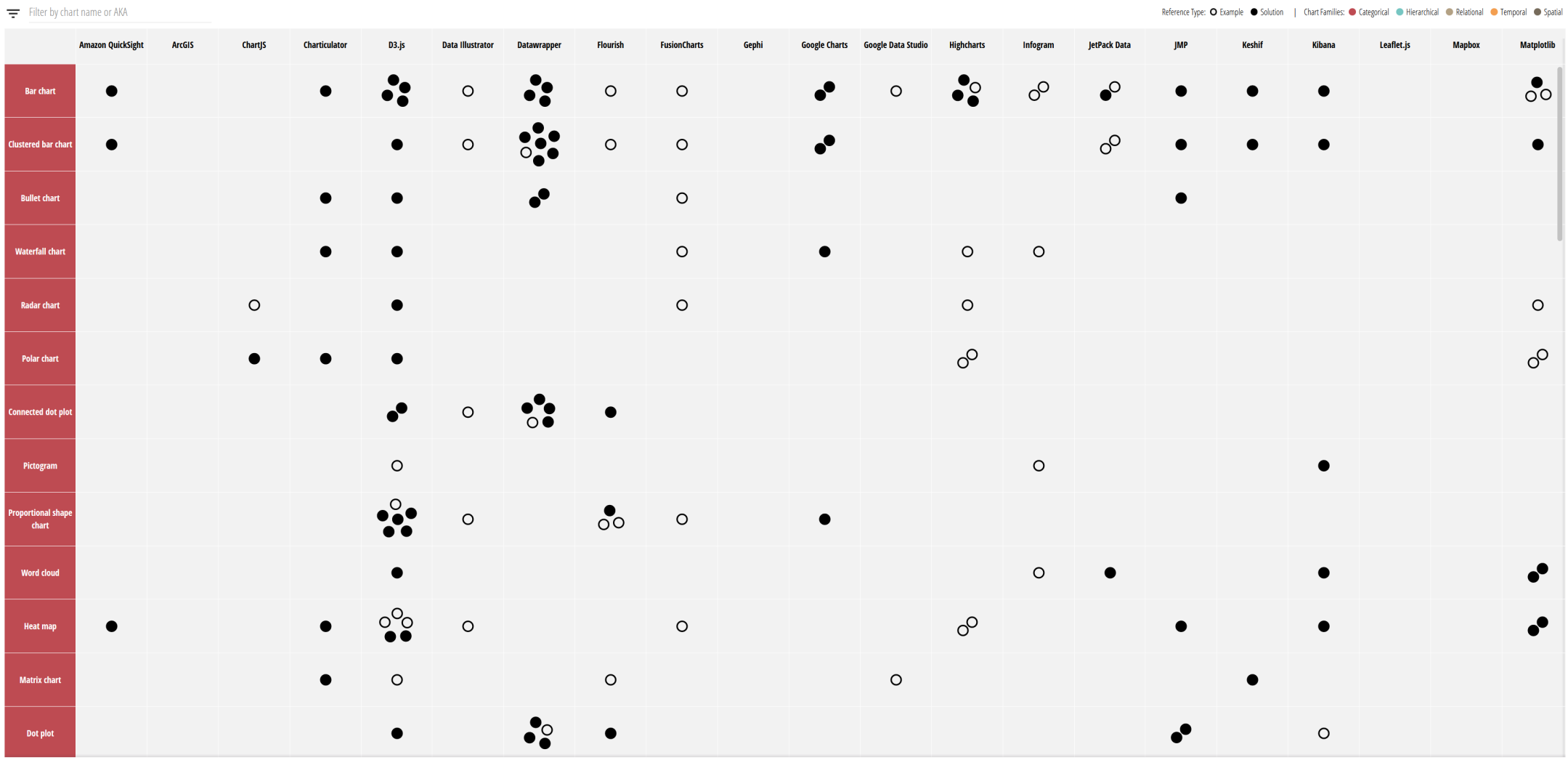

Per capita cheese consumption in the U.S.
10 pounds
9
8
7
6
5
4
3
2
1
PROCESSED
CHEDDAR
MOZZARELLA
'80 '85 '90 '95 '00 '05
'80 '85 '90 '95 '00 '05
'80 '85 '90 '95 '00 '05


Pie I have eaten
Pie I have not yet eaten


REASONS I LOVE CHEESE BURGERS
BREAD
MEAT
KETCHUP
CHEESE

THE CHARTMAKER DIRECTORY

ABOUT

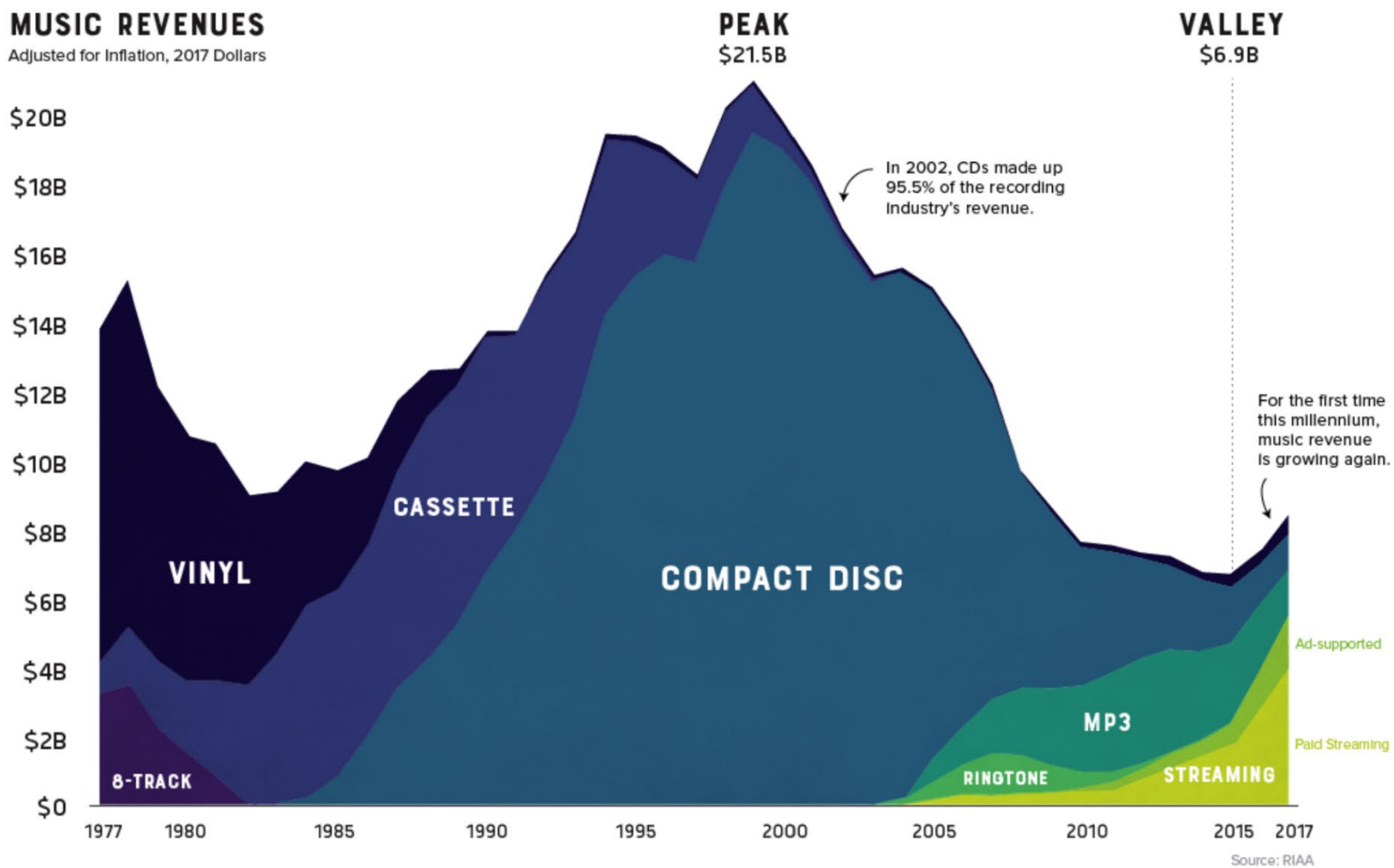


chartmaker.visualisingdata.com

Visualizing 40 Years of Music Industry Sales

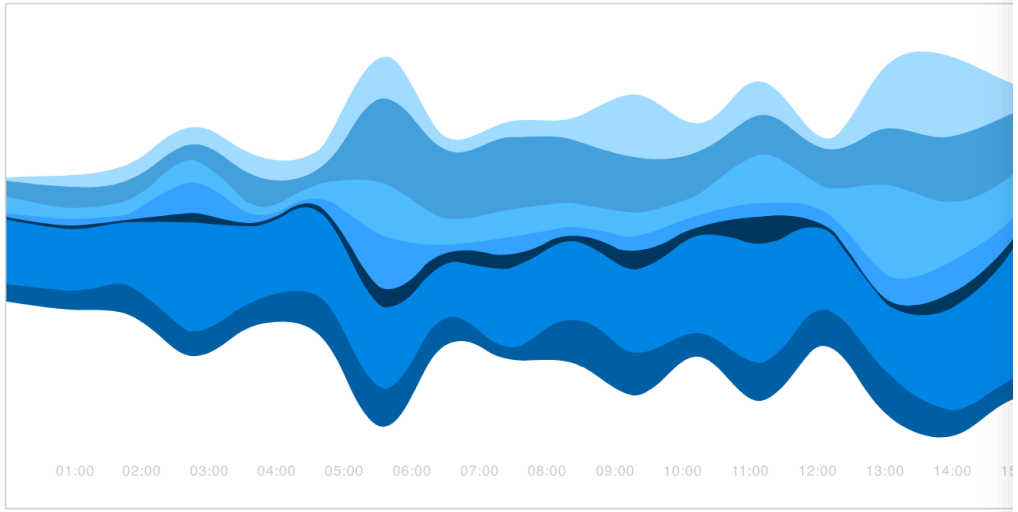
Published 3 years ago on October 6, 2018

By **Nick Routley**



The Data Visualisation Catalogue

Stream Graph



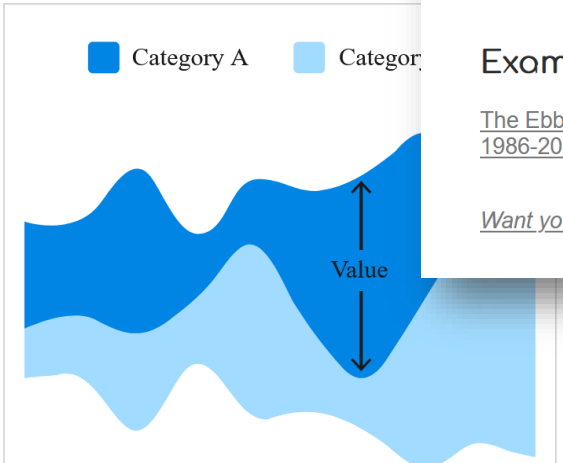
Description

Also known as a *ThemeRiver*.

This type of visualisation is a variation of a Stacked Area Graph, but instead of plotting values against a fixed, straight axis, a Stream Graph has values displaced around a varying central baseline. Stream Graphs display the changes in data over time of different categories through the use of flowing, organic shapes that somewhat resemble a river-like stream. This makes Stream Graphs aesthetically pleasing and more engaging to look at.

In a Stream Graph, the size of each individual stream shape is proportional to the values in each category. The axis that a Stream Graph flows parallel to, is used for the timescale. Colour can be used to either distinguish each

Anatomy



Functions

Data over time | Patterns

Similar Charts

Stacked Area Graph

Tools to Generate Visualisation

Bob Rudis' GitHub (code)
D3 (code)
Infogram
JSFiddle (code)
Lee Byron's GitHub (code)
NVD3.js (code)
plotDB
RAWGraphs
Stream graph generator (code)

Examples

The Ebb and Flow of Movies: Box Office Receipts 1986-2008, The New York Times

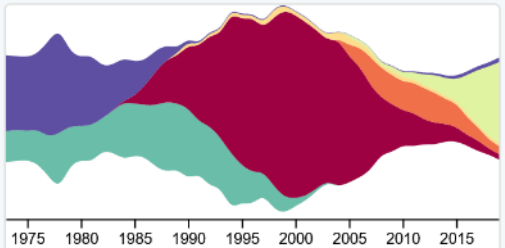
Want your work linked on this list? Click Here

Need to access this page offline? Download the eBook from here.

Merchandise & other related dataviz products can be found at the store

2. Choose a chart

Show All charts



Streamgraph (area chart)

It allows the comparison of multiple categories over a continuous dimension.

Code Tutorial

- **Alluvial Diagram** — Correlations, proportions
- **Arc Diagram** — Networks
- **Bar chart** — Correlations
- **Multi-set bar chart** — Correlations, proportions
- **Stacked bar chart** — Correlations, proportions
- **Beeswarm plot** — Distributions, time series, proportions
- **Box plot** — Distributions
- **Bubble chart** — Correlations, proportions
- **Bumpchart** — Time series, correlations, proportions
- **Circle Packing** — Hierarchies, proportions
- **Circular dendrogram** — Hierarchies, proportions
- **Contour plot** — Correlations, distributions
- **Convex hull** — Correlations, proportions
- **Linear dendrogram** — Hierarchies, proportions
- **Gantt chart** — Time series, correlations
- **Hexagonal binning** — Correlations, distributions
- **Horizon graph** — Time series, correlations
- **Line chart** — Time series, correlations

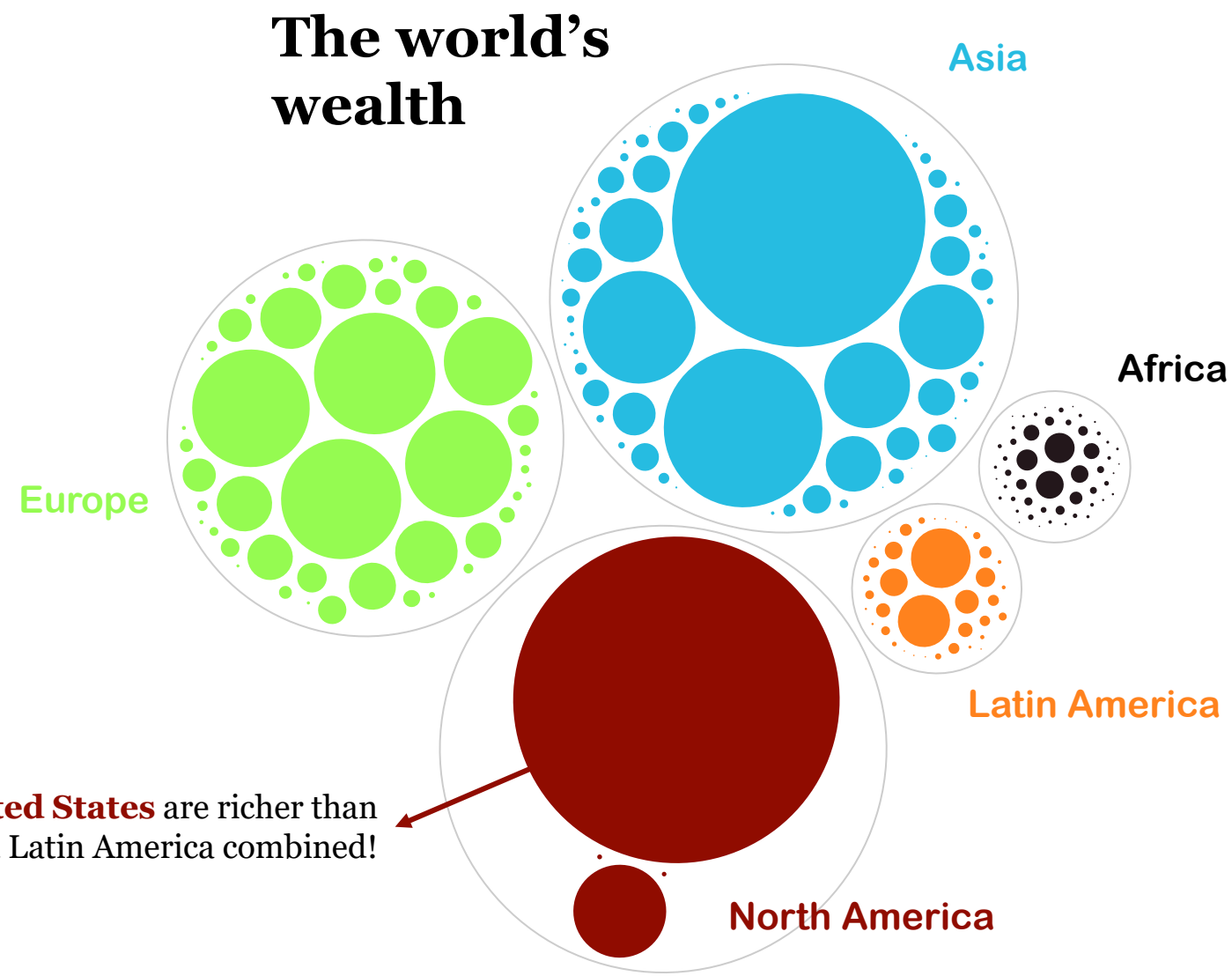
Time to play

Individual exercise

Download the data file
baryon.be/files/workshop/wealth.xlsx

Use **RAWGraphs** and **PowerPoint**
to mimic the chart on the right

Or feel free to play around and
explore a tool of your choice

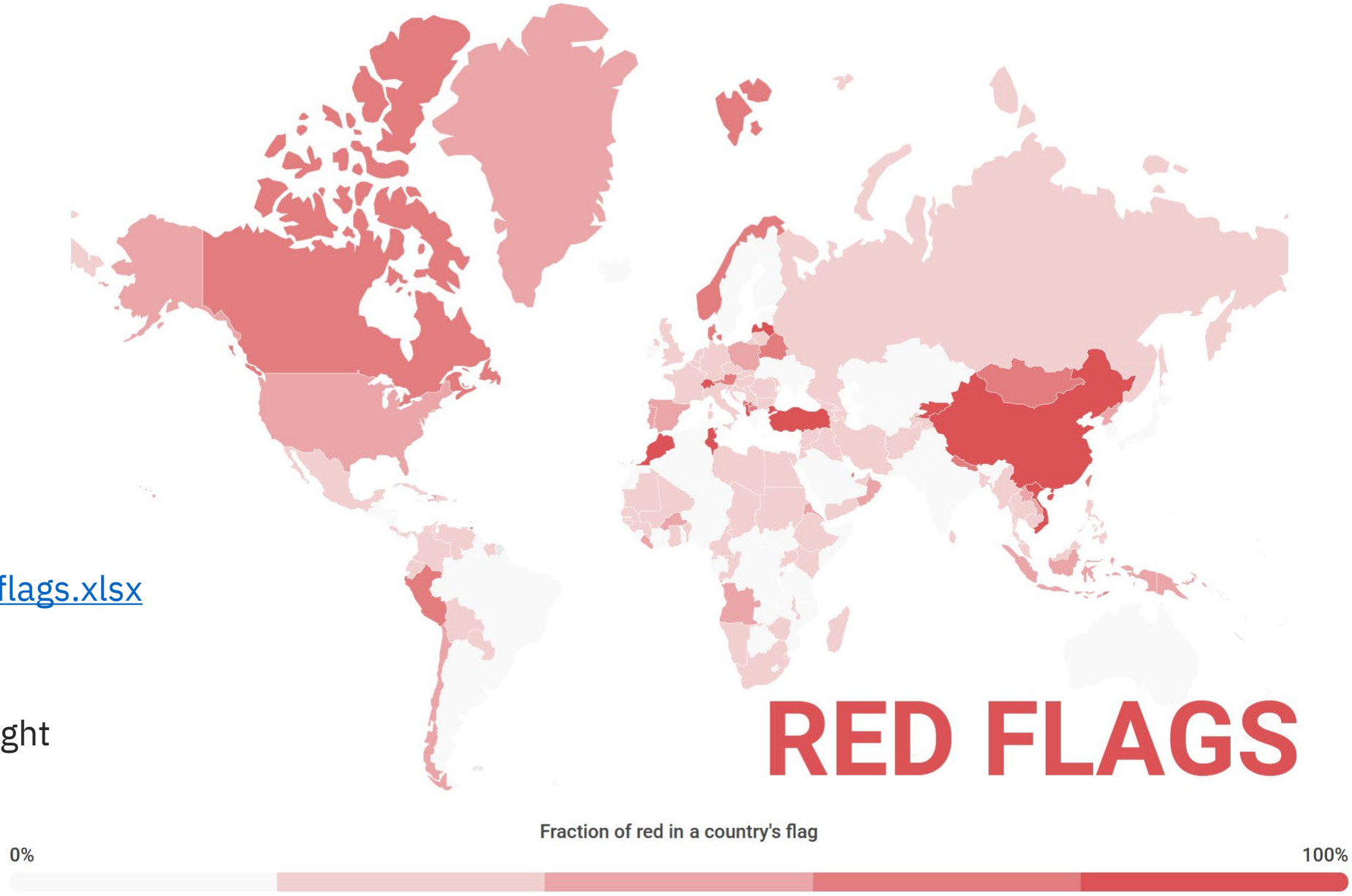


Time to play

Individual exercise

Download the data file
baryon.be/files/workshop/flags.xlsx

Use **Infogram**
to mimic the chart on the right



Session 1

Communicating with data

Graphical representation of data

homework assignment part 1

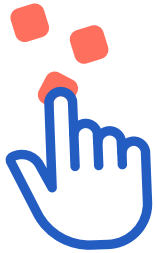
Session 2

Producing and designing data visuals

homework assignment part 2

Session 3

Visualizing scientific research



All the slides and all the links:

baryon.be/dataviz-resources

Components

Colors

Illustrations

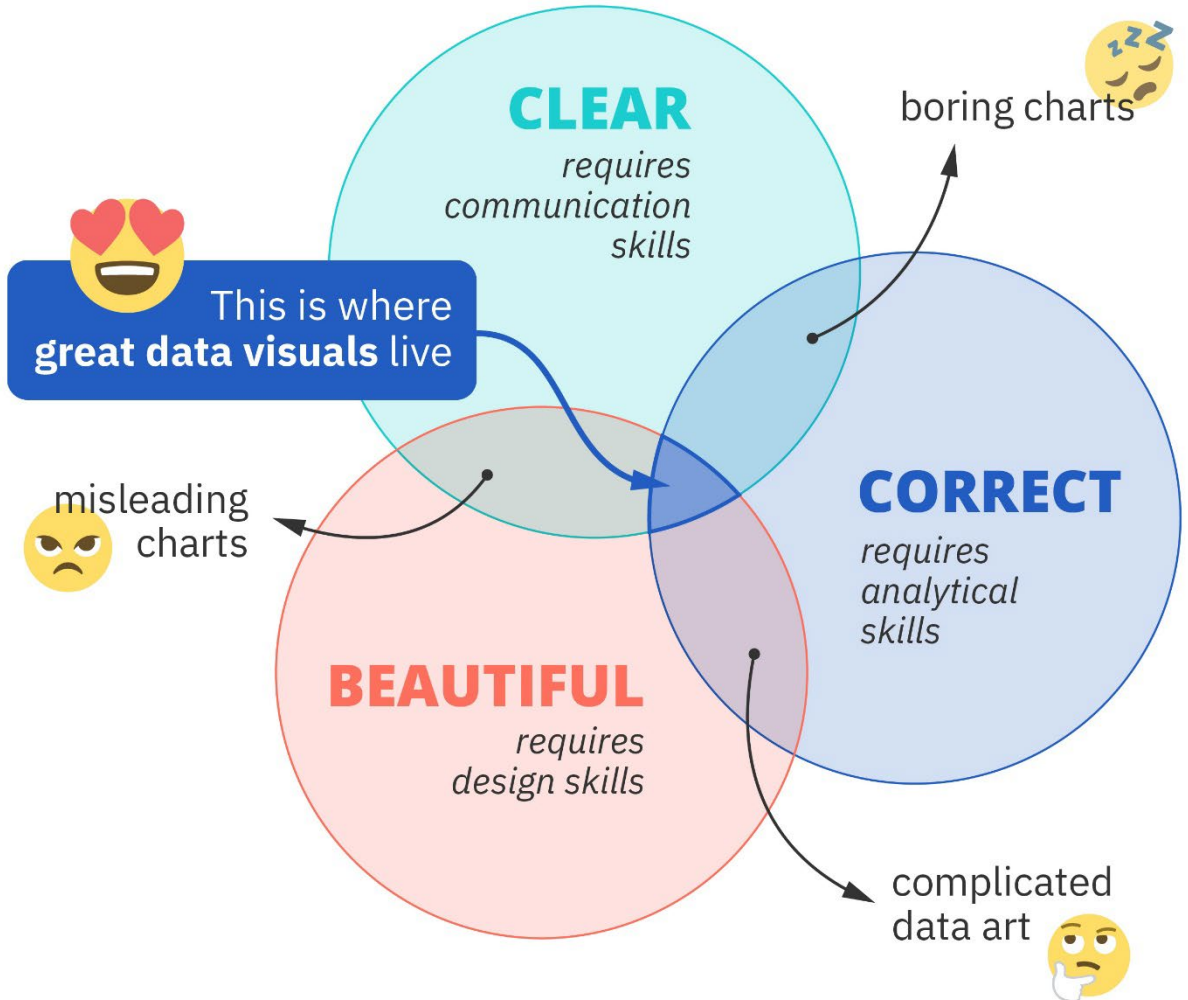
Typography

15’ break

Advanced data visualization

Interactive data visuals

Programming data visuals


CLEAR
requires communication skills
boring charts
This is where great data visuals live
CORRECT
requires analytical skills
misleading charts
BEAUTIFUL
requires design skills
complicated data art

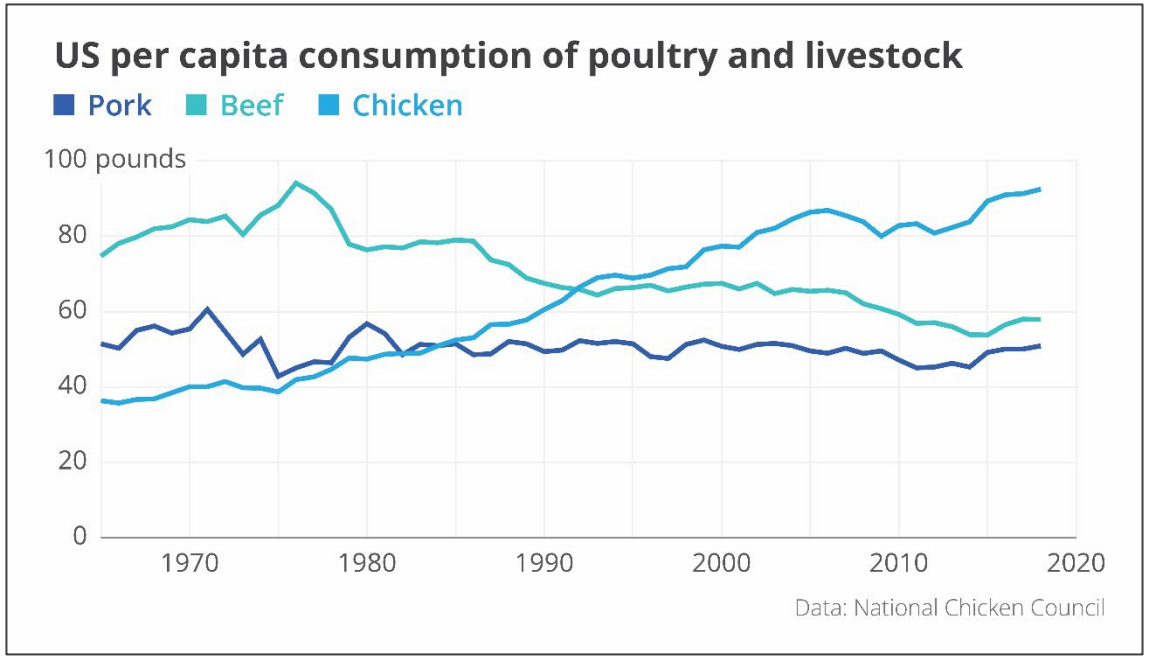
Components

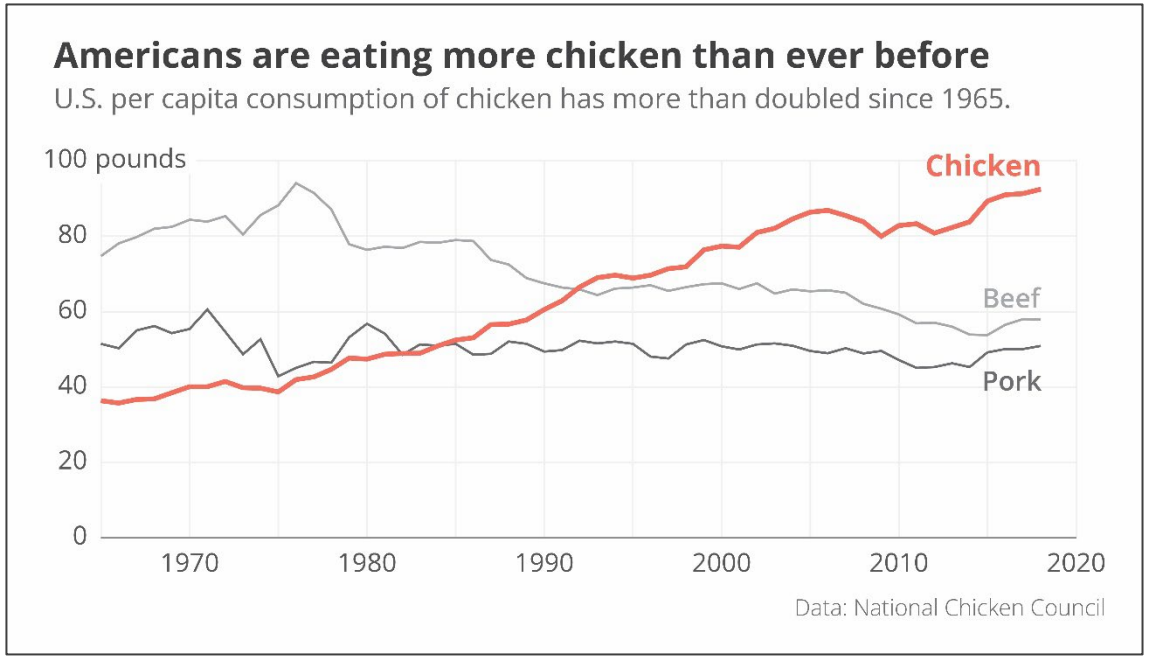
THE IMPORTANCE OF

COLOUR

STEPHENWILDISH.CO.UK

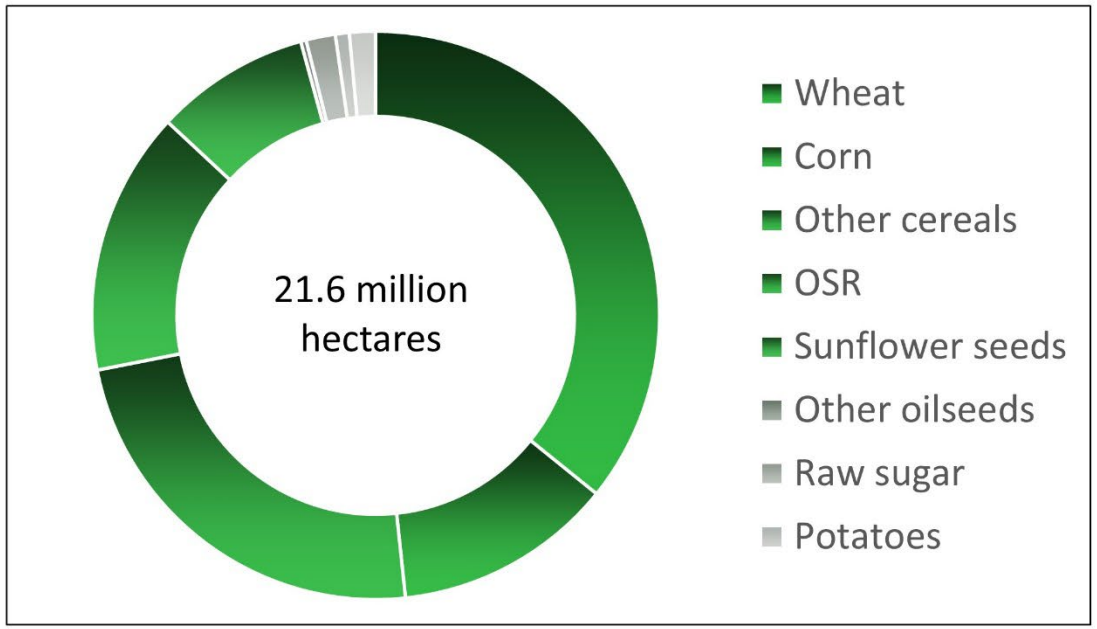
~~data~~ → **story**


US per capita consumption of poultry and livestock
Pork
Beef
Chicken
100 pounds
80
60
40
20
0
1970
1980
1990
2000
2010
2020
Data: National Chicken Council

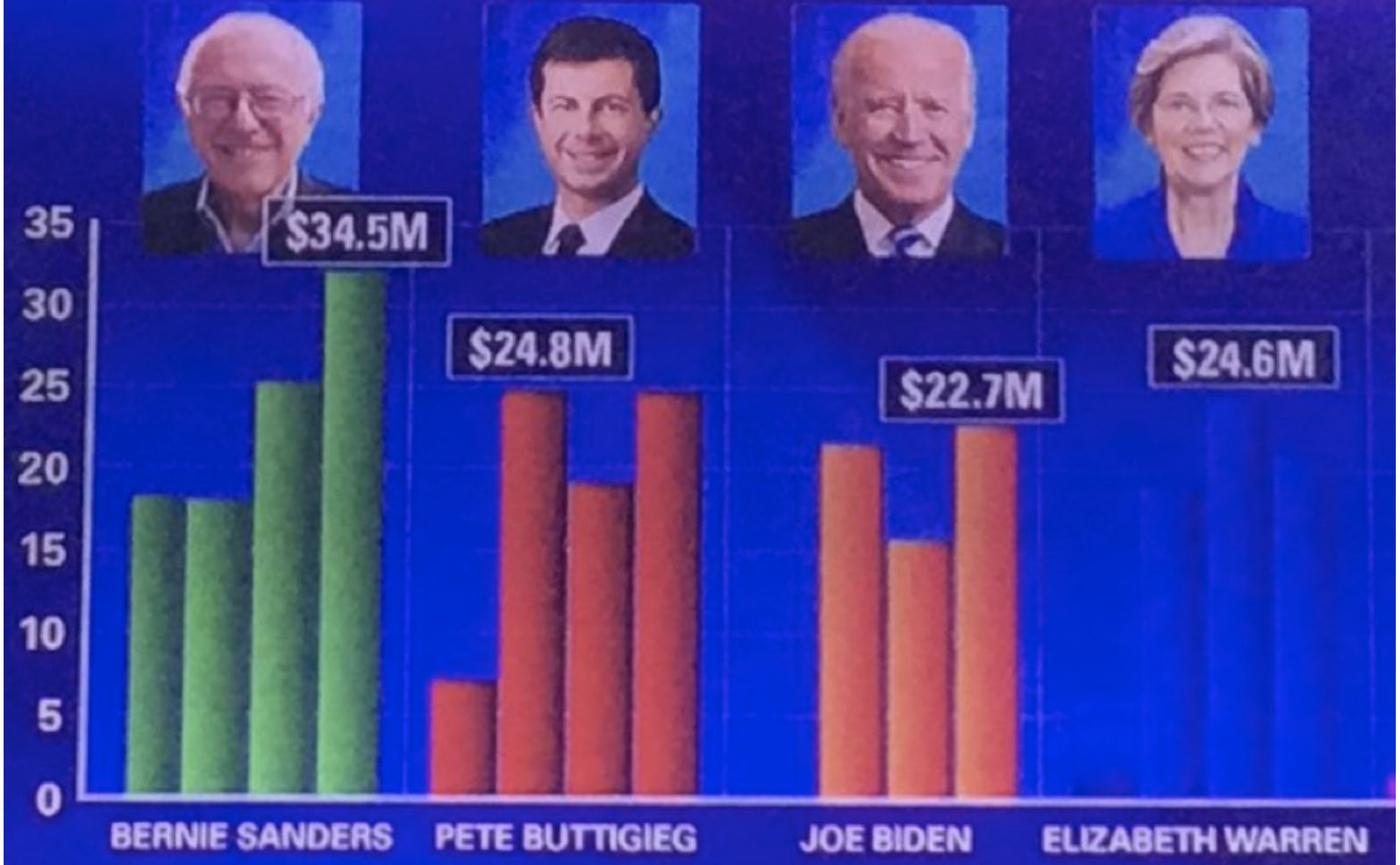

Americans are eating more chicken than ever before
U.S. per capita consumption of chicken has more than doubled since 1965.
100 pounds
80
60
40
20
0
Chicken
Beef
Pork
1970
1980
1990
2000
2010
2020
Data: National Chicken Council

Without 20 years of plant breeding in the EU 22 million hectares of additional land would be needed

Additional global land use without plant breeding in the EU

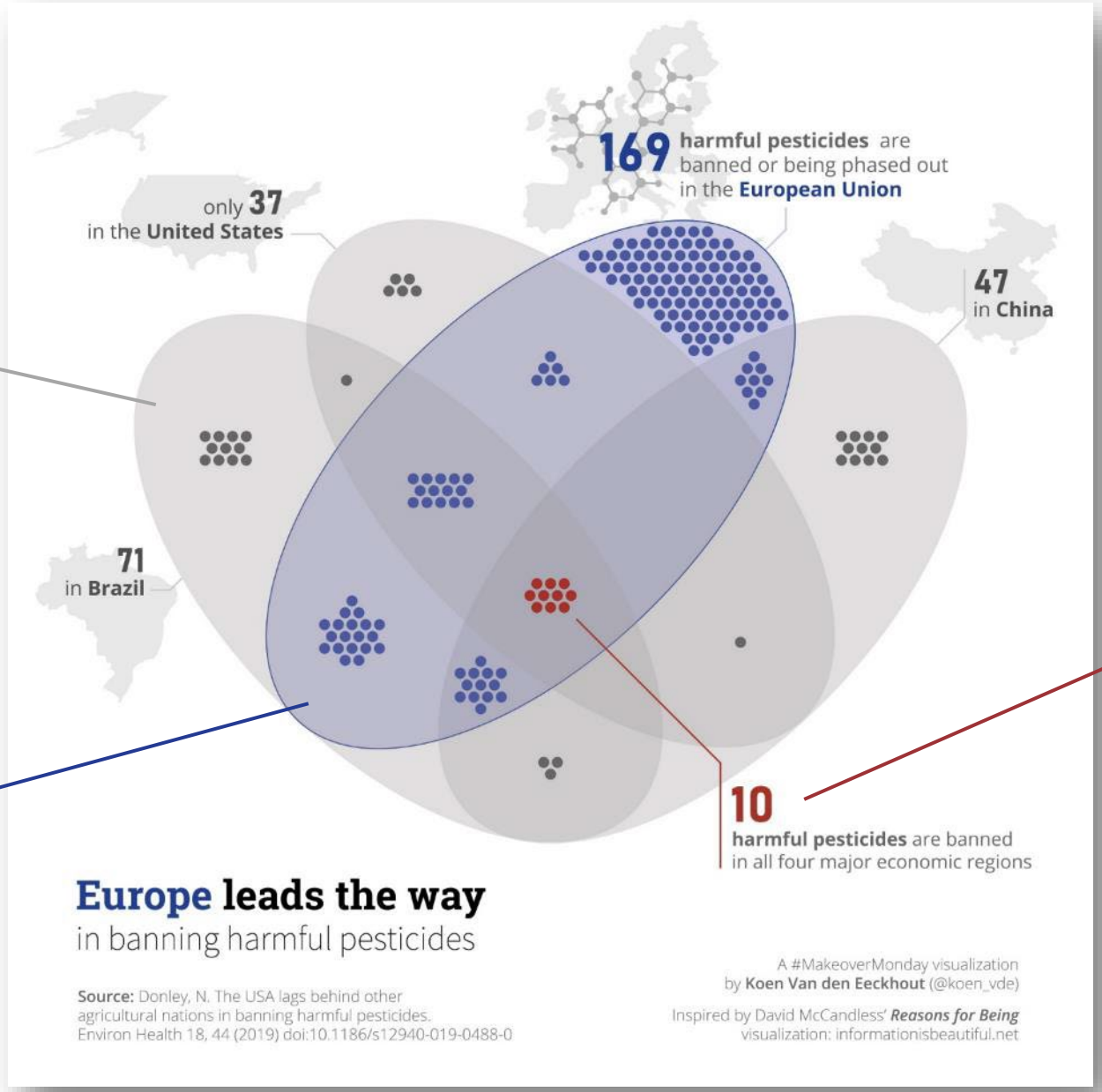


- Without 20 years of plant breeding scarce global resources would additionally be exploited:
  - → N. Am.: 2.4 million ha
  - → S. Am.: 1.8 million ha
  - → Asia: 2.9 million ha
  - → MENA: 3.6 million ha
  - → SSA: 2.3 million ha
  - → Oceania: 2.7 million ha
  - → CIS: 5.3 million ha
  - → RoW: 0.5 million ha


$34.5M
$24.8M
$22.7M
$24.6M
35
30
25
20
15
10
5
0
BERNIE SANDERS
PETE BUTTIGIEG
JOE BIDEN
ELIZABETH WARREN

background color

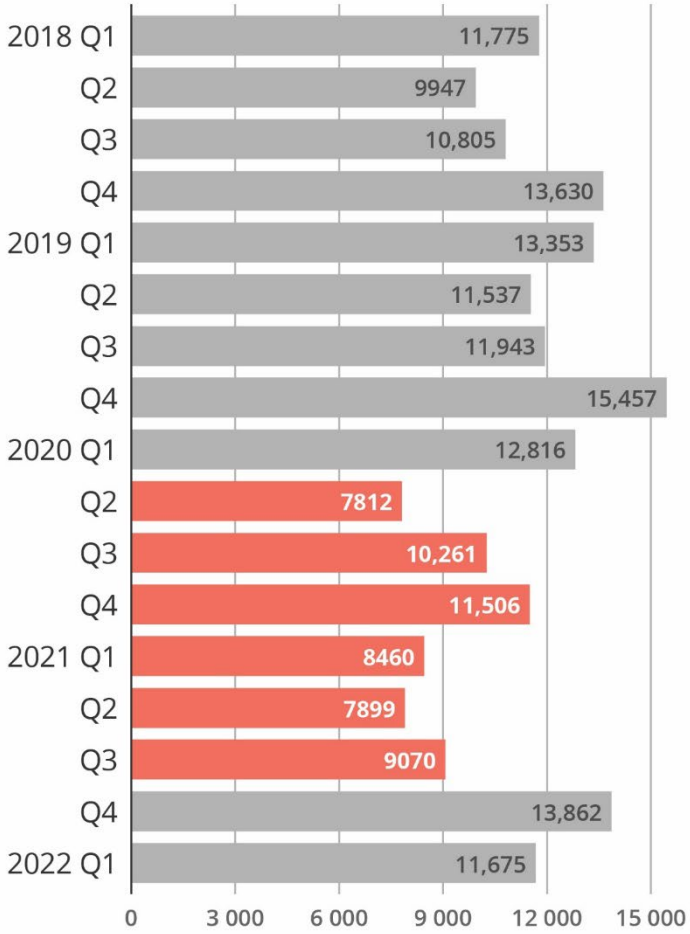
thematic color



accent color

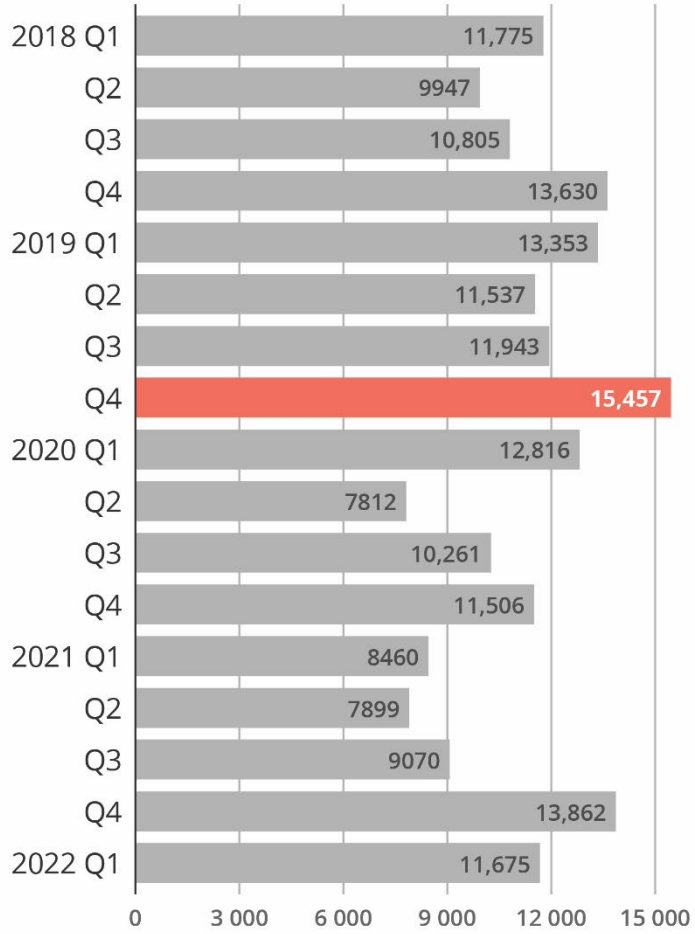
Immigration in Flanders

Source: Agentschap Integratie & Inburgering



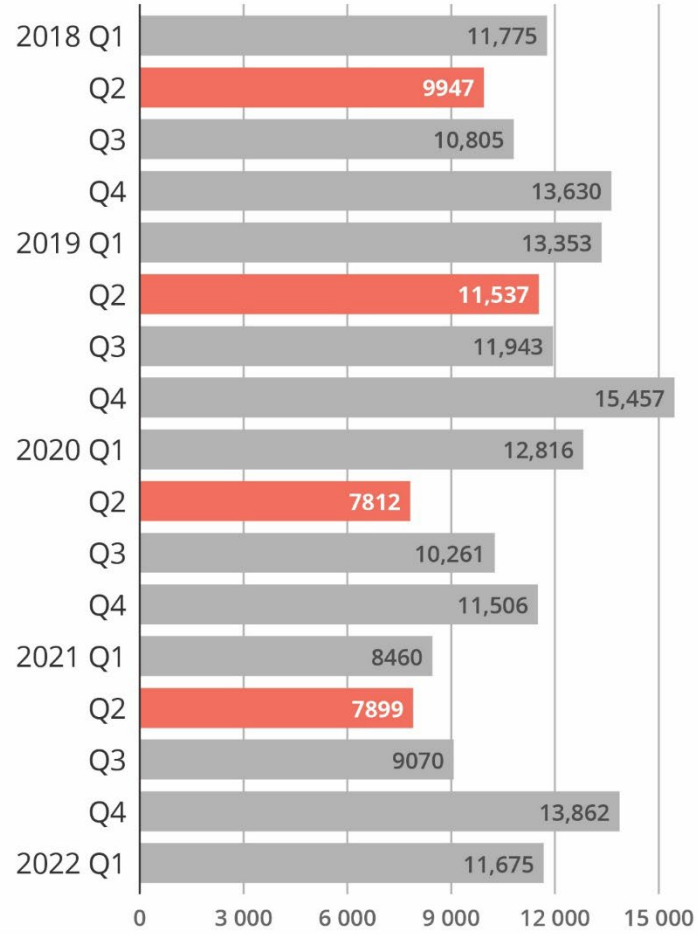
Immigration in Flanders

Source: Agentschap Integratie & Inburgering



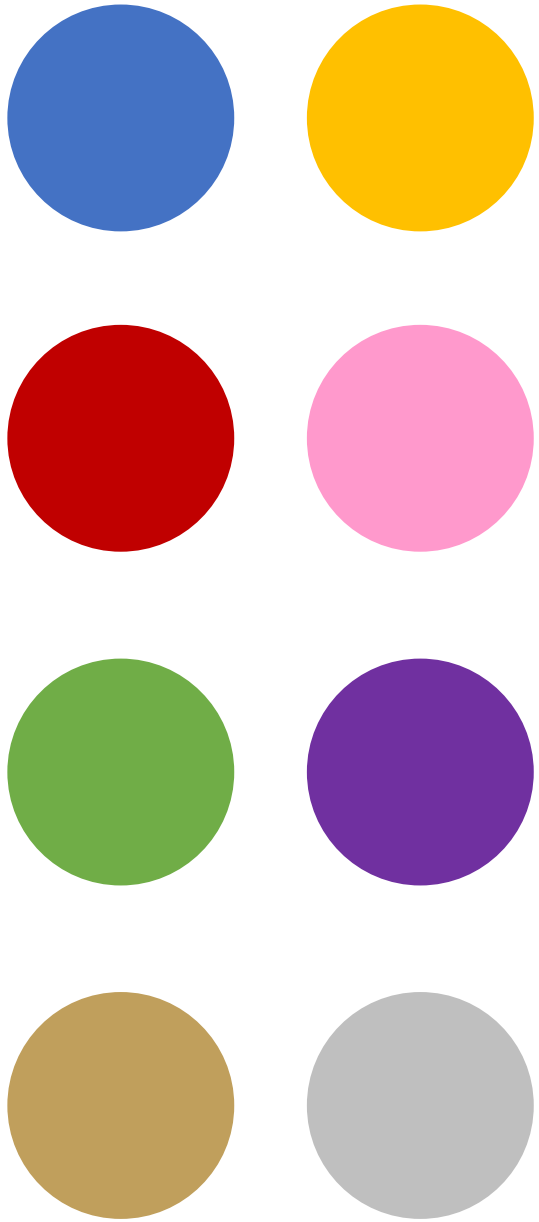
Immigration in Flanders

Source: Agentschap Integratie & Inburgering



Finding a color scheme

What do colours represent?



Jul 10, 2018
by Lisa Charlotte Rost

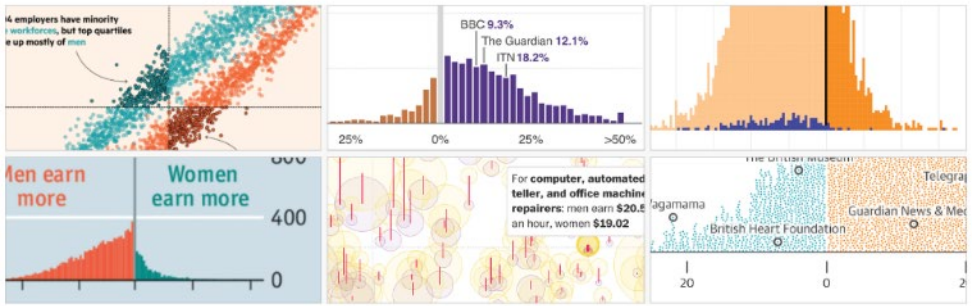
Thoughts & How To's

An alternative to pink & blue: Colors for gender data

JeongMee Yoon's "The Pink & Blue Project"

blog.datawrapper.de/gendercolor

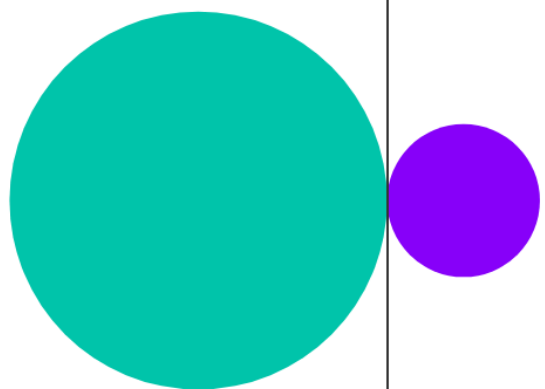
2 Many newsrooms stay away from pink & blue



Here's the good news: While some still use it, **pink & blue isn't the norm anymore, at least not in big news organizations.** When the gender pay gap data came out in the UK this year, graphics reporters used a very diverse color palette. I had assumed they would still use blue for men and just a rather warm color for women. But I was surprised: The Economist, Guardian, Telegraph, Washington Post, and others **used a cooler color for women than for men**. Respect! You can't go further away from the norm. Here are some examples (not exclusively from this year's gender pay gap data).

https://blog.datawrapper.de/gendercolor/

Of the 884 English Heritage blue plaques

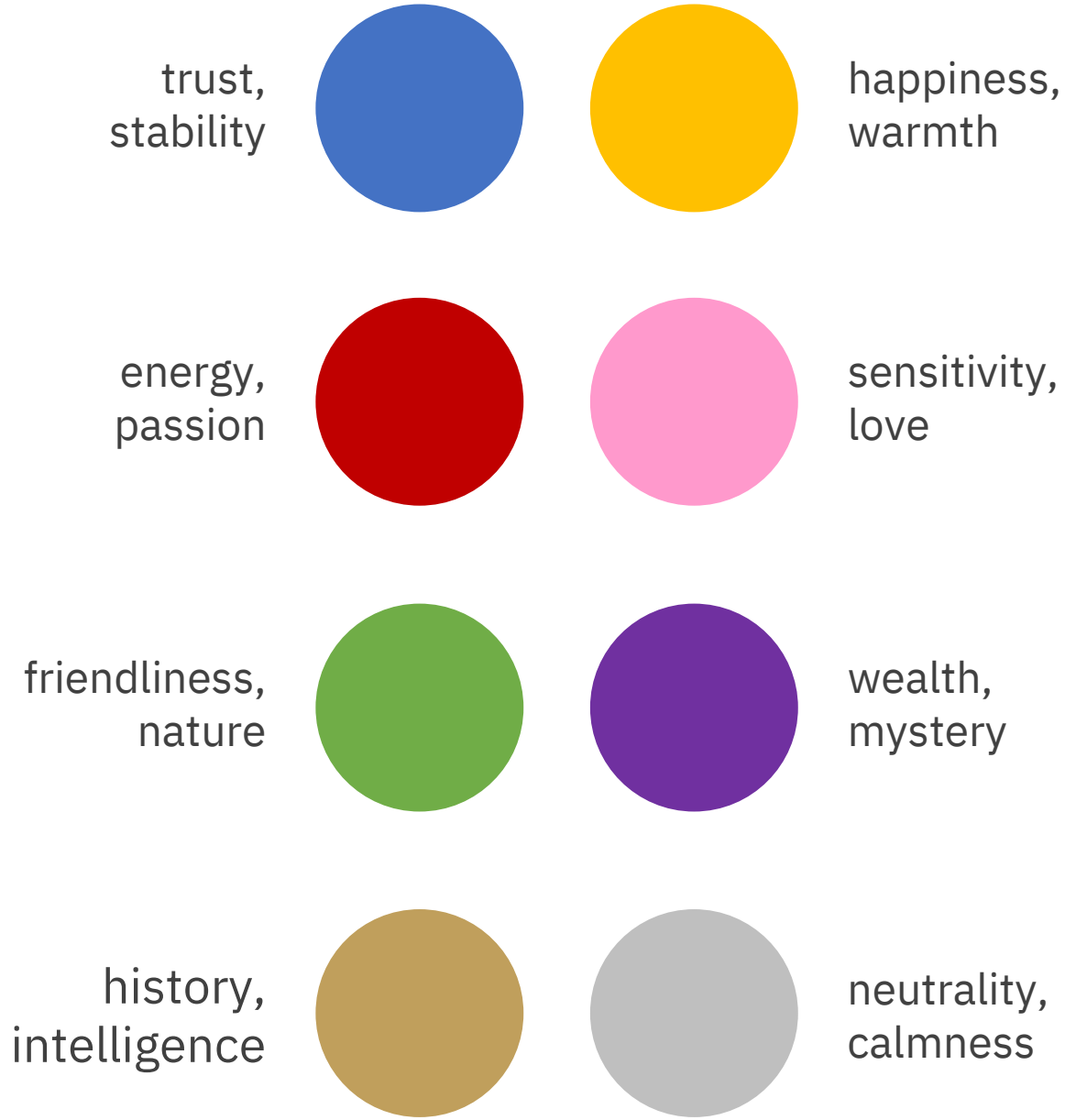


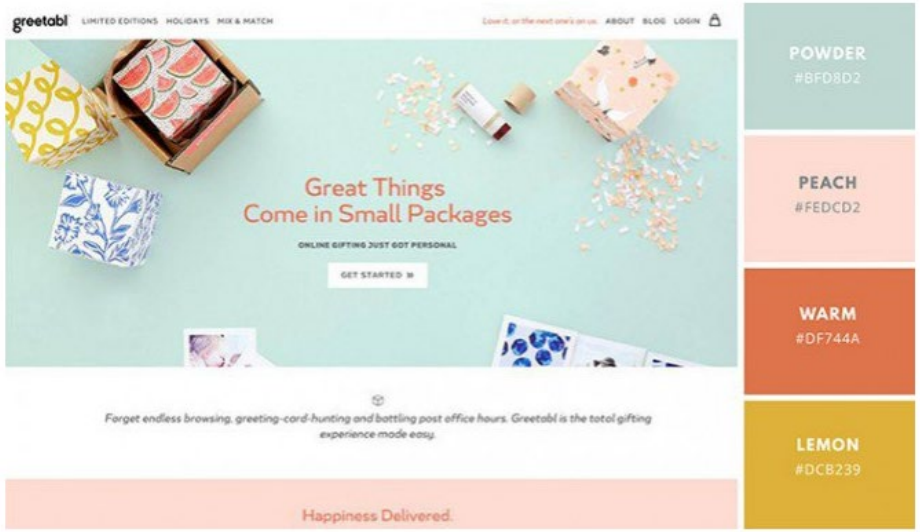
The fight for gender parity in the UK is set against a cultural history of inequality. English Heritage's Blue Plaques are an example of this; the vast majority commemorate men. While many deserving women are undoubtedly missing out, positions of more obvious influence have traditionally belonged overwhelmingly to men.

Men	Women
757	127
86%	14%

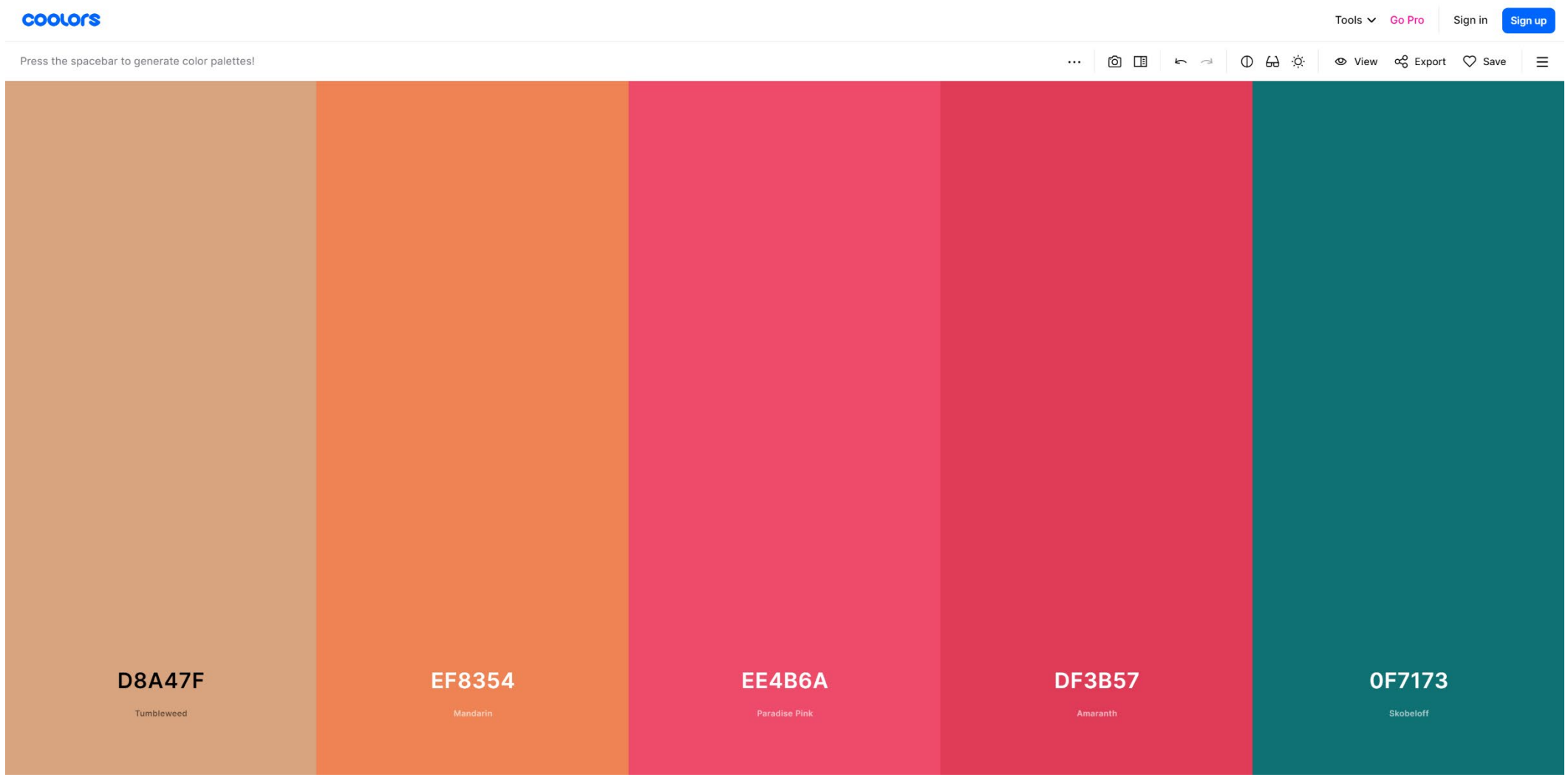
Finding a color scheme

What do colours represent?





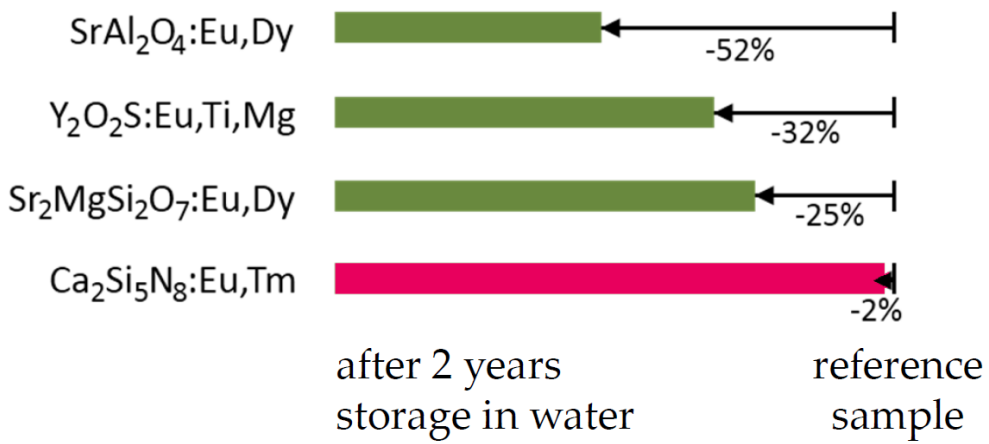
canva.com/learn/100-color-combinations

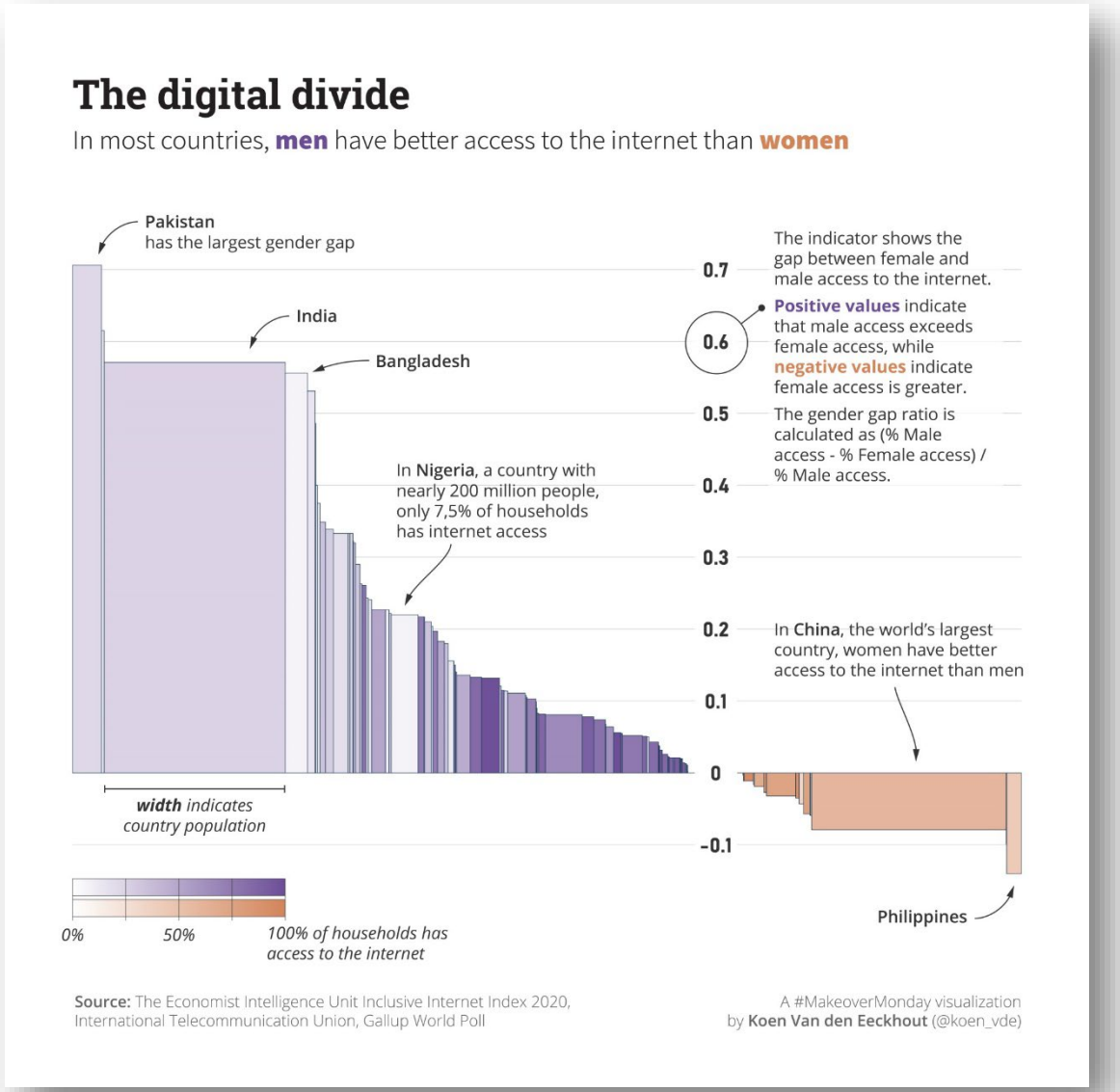

coolors
Tools
Go Pro
Sign in
Sign up
Press the spacebar to generate color palettes!
View
Export
Save
D8A47F
Tumbleweed
EF8354
Mandarin
EE4B6A
Paradise Pink
DF3B57
Amaranth
0F7173
Skobeloff

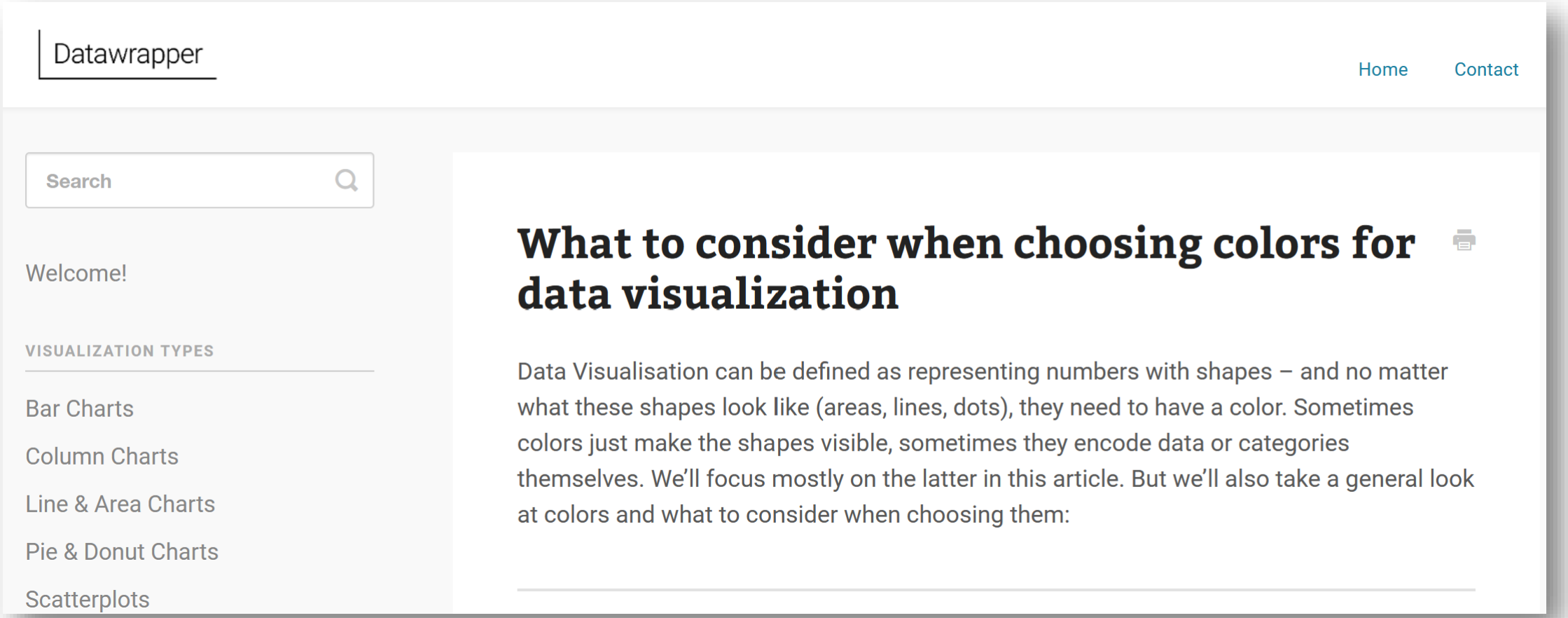
coolors.co

Clever color use

Compared to other common host materials, the nitrido-silicates are **very stable** and hence well suited for *in vivo* applications.







academy.datawrapper.de/article/140-what-to-consider-when-choosing-colors-for-data-visualization

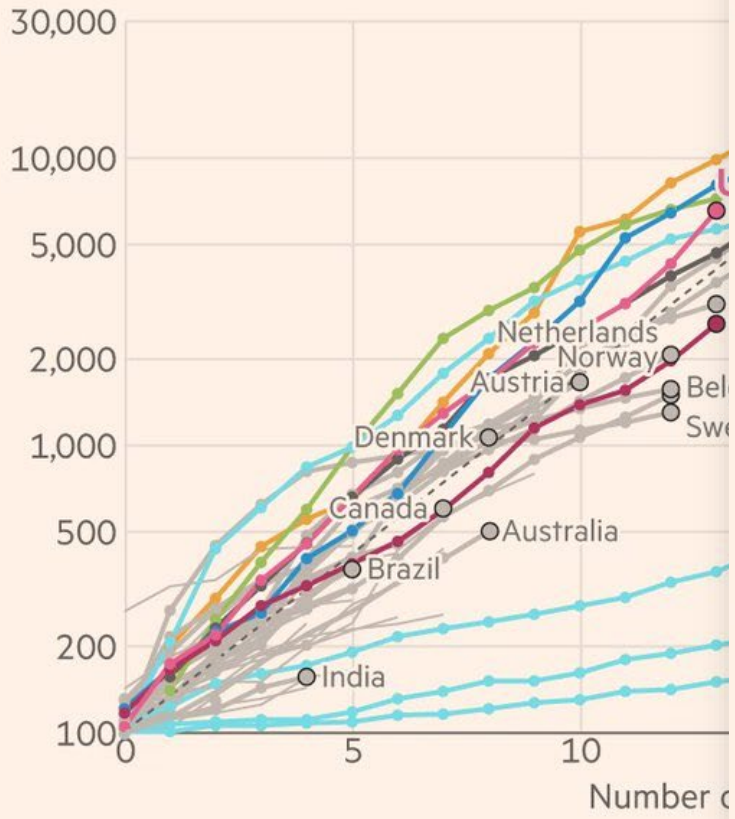
gray is the most powerful color

NOT IDEAL

BETTER

Most western countries are on t
and Singapore have limited the s

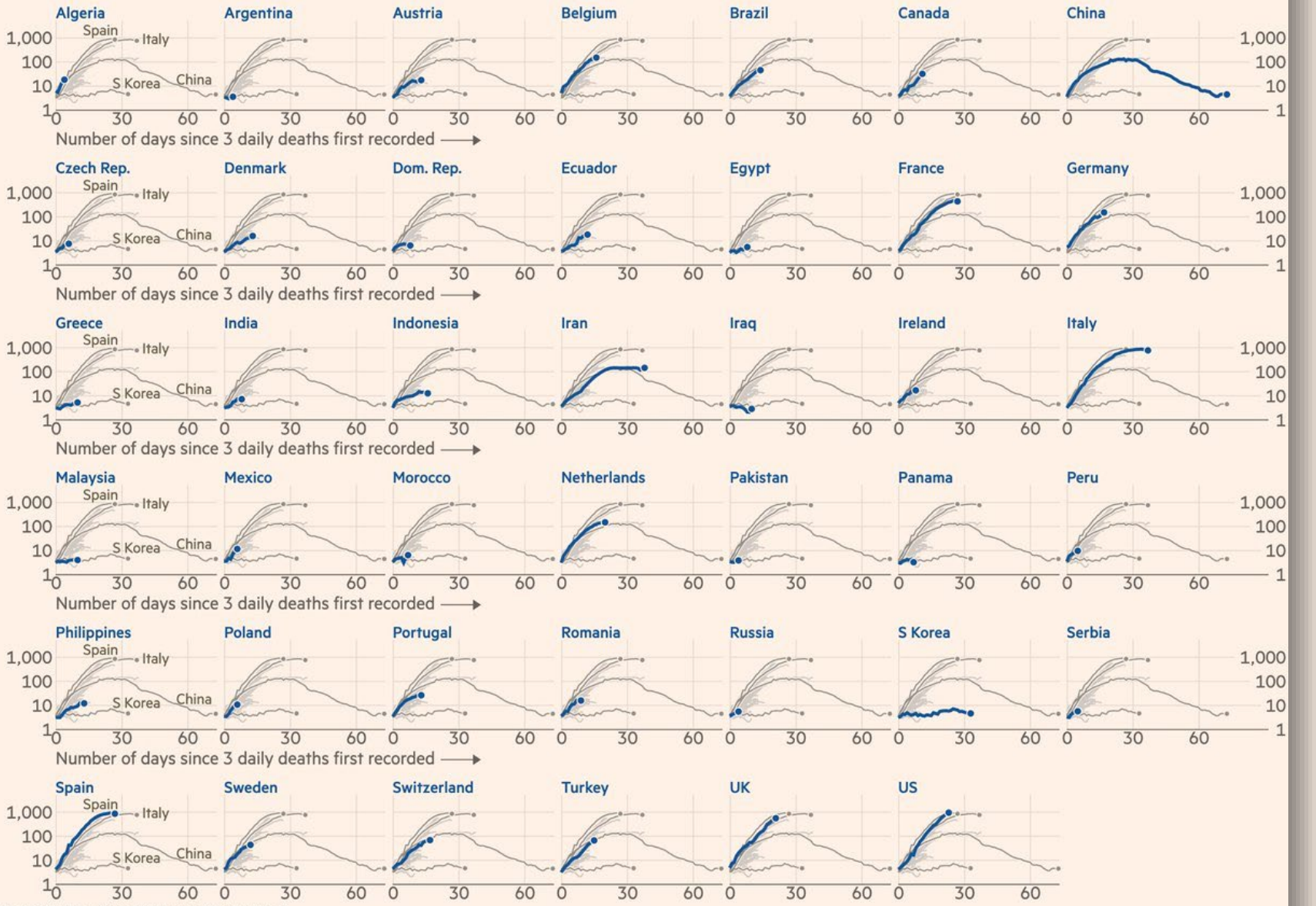
Cumulative number of cases, by number of



FT graphic: John Burn-Murdoch / @jburnmurdoch
Source: FT analysis of Johns Hopkins University, CSSE; Wor

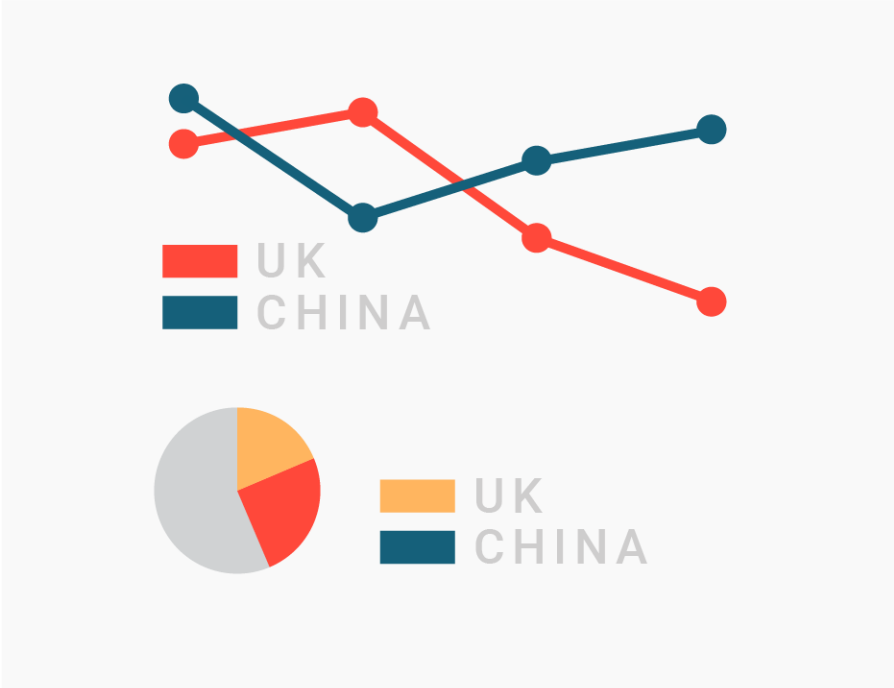
Daily death tolls are still accelerating in most countries

Daily deaths with coronavirus (7-day rolling average), by number of days since 3 daily deaths first recorded

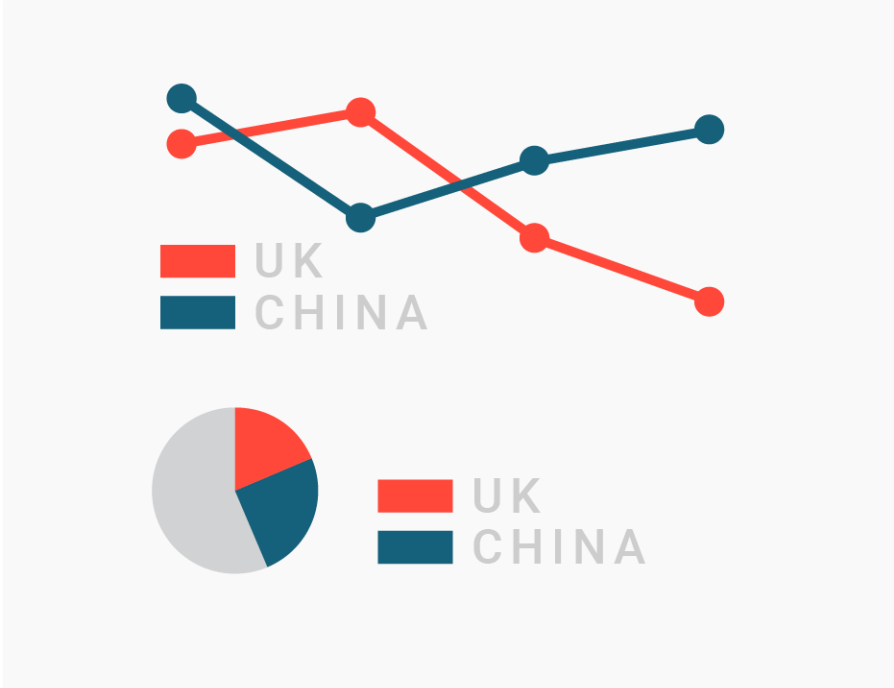


FT graphic: John Burn-Murdoch / @jburnmurdoch
Source: FT analysis of European Centre for Disease Prevention and Control; Worldometers; FT research. Data updated April 05, 19:00 GMT

use consistent colors



NOT IDEAL



BETTER

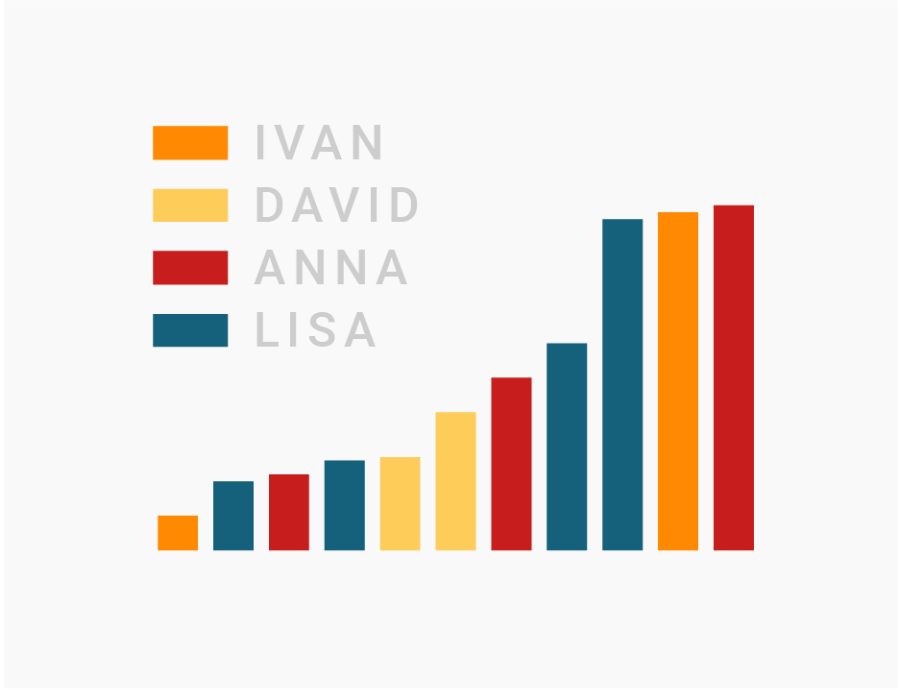
use logical colors

NOT IDEAL

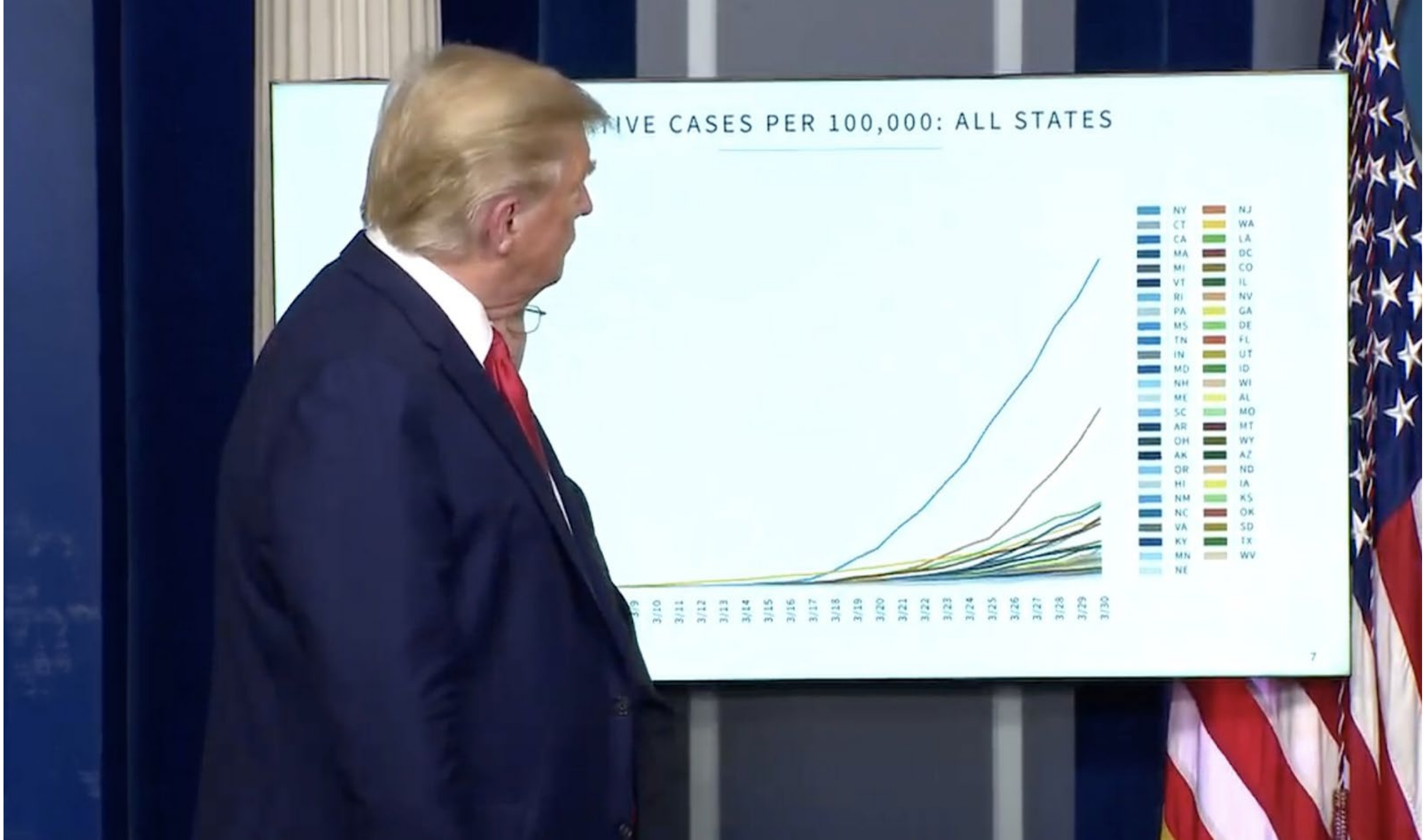
BETTER

use different color hues for different categories

NOT IDEAL



BETTER

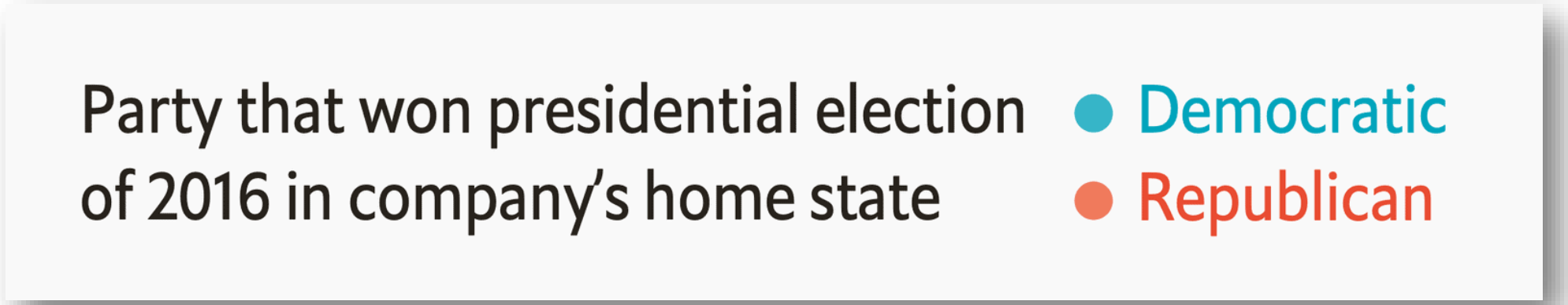

IVE CASES PER 100,000: ALL STATES
NY
CT
CA
MA
MI
VT
RI
PA
MS
TN
IN
MD
NH
ME
SC
AR
OH
AK
OR
HI
NM
NC
VA
KY
MN
NE
NJ
WA
LA
DC
CO
IL
NV
GA
DE
FL
UT
ID
WI
AL
MO
MT
WY
AZ
ND
IA
KS
OK
SD
TX
WV
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
3/23
3/24
3/25
3/26
3/27
3/28
3/29
3/30
7

Different types of color scales

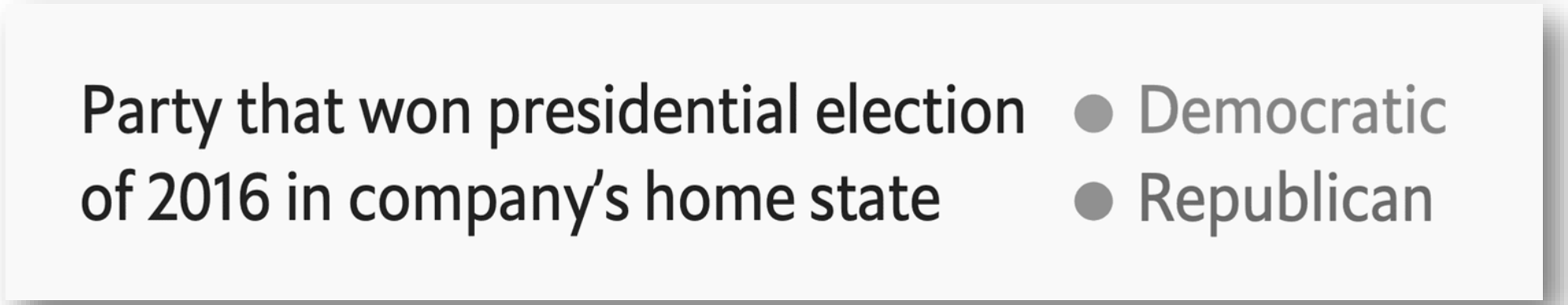
Categorical 

Sequential 

Diverging 



- Use different **hues** for different categories
- Give your hues different **lightnesses**, so they work in greyscale too



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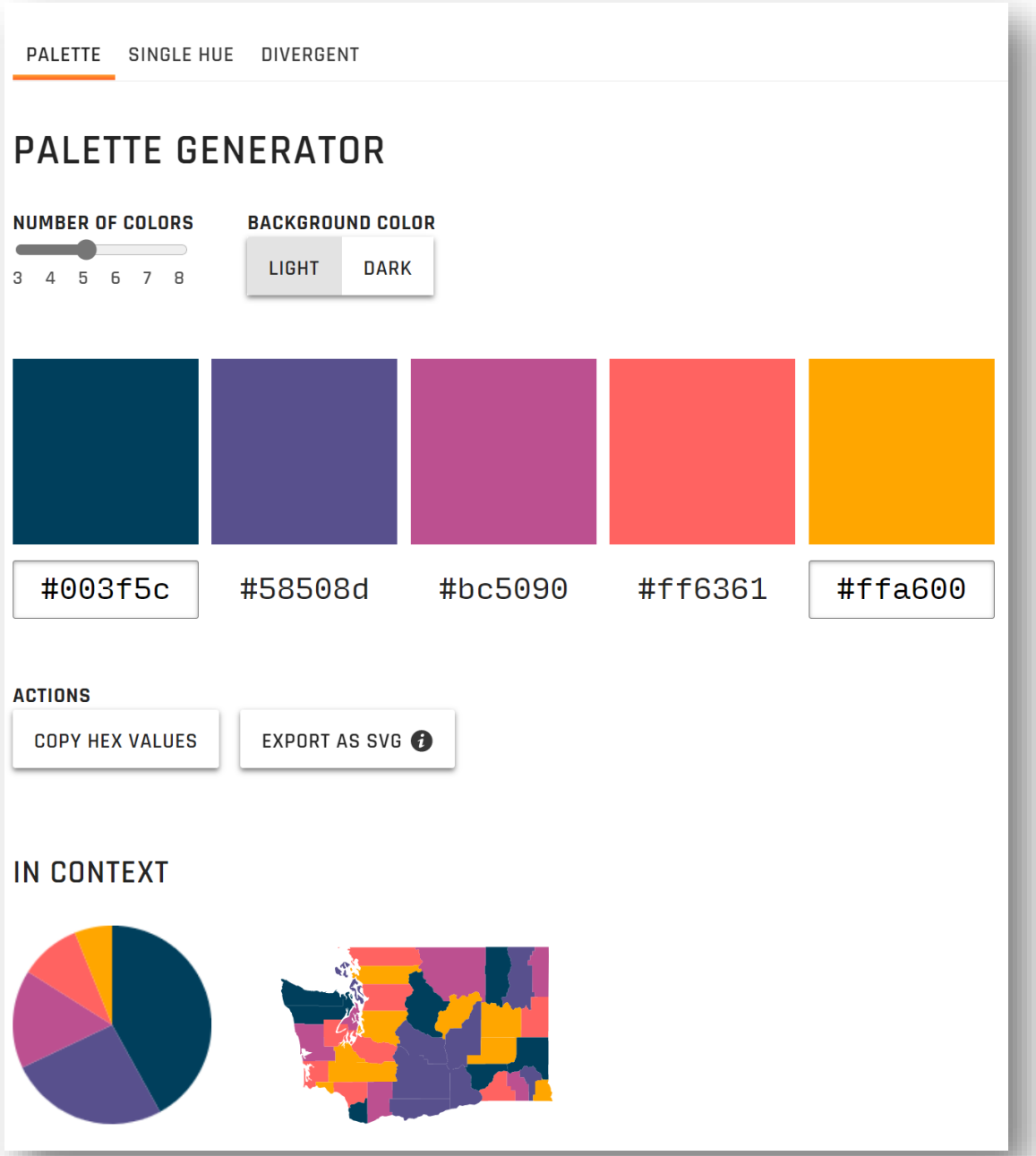
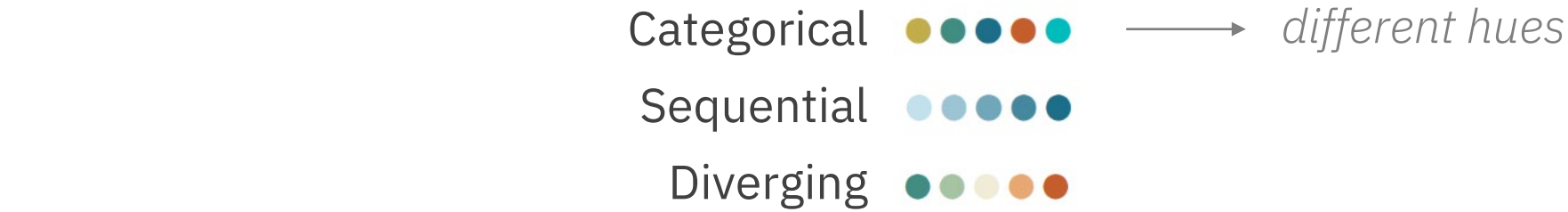


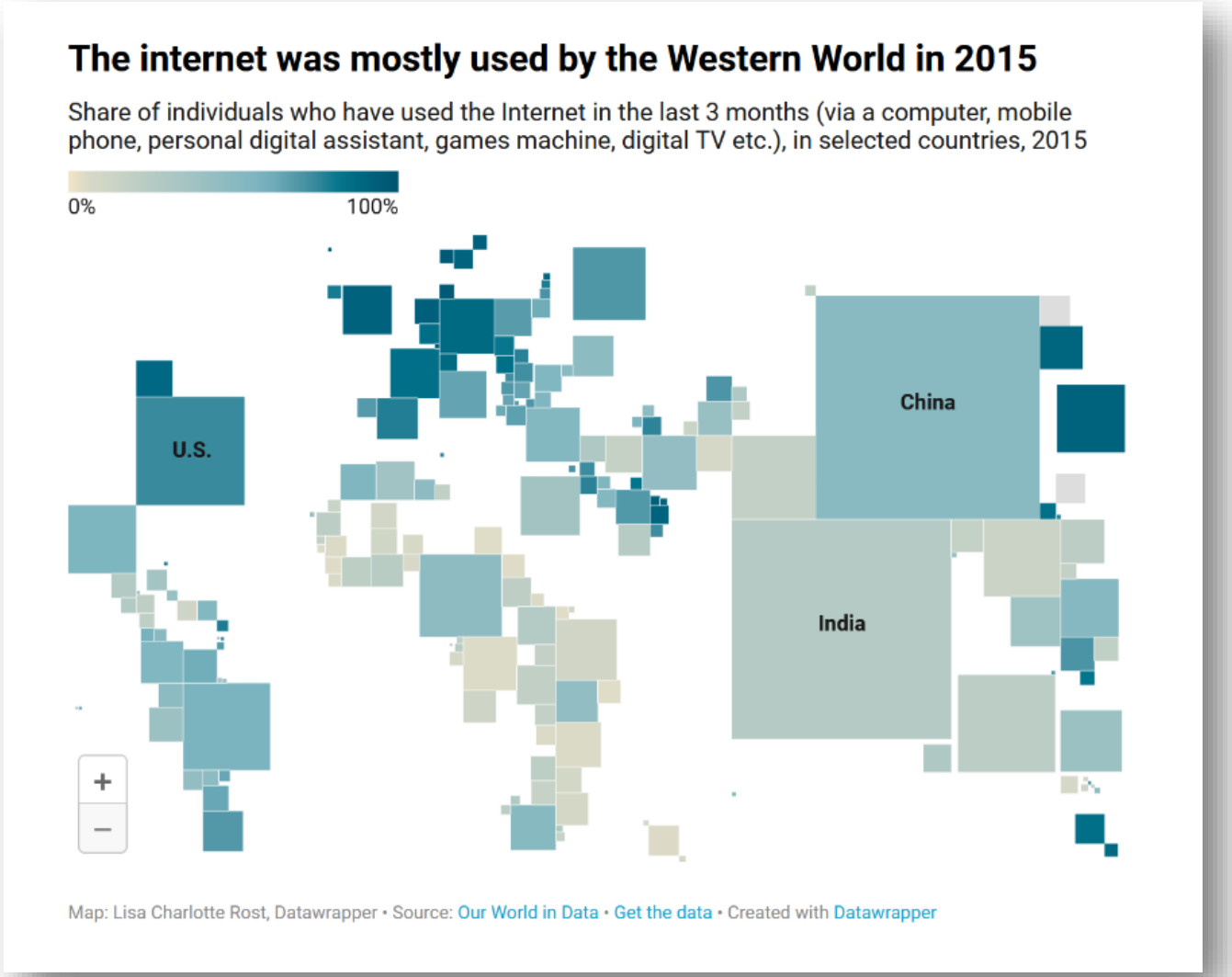
learnui.design/tools/data-color-picker.html

Different types of color scales



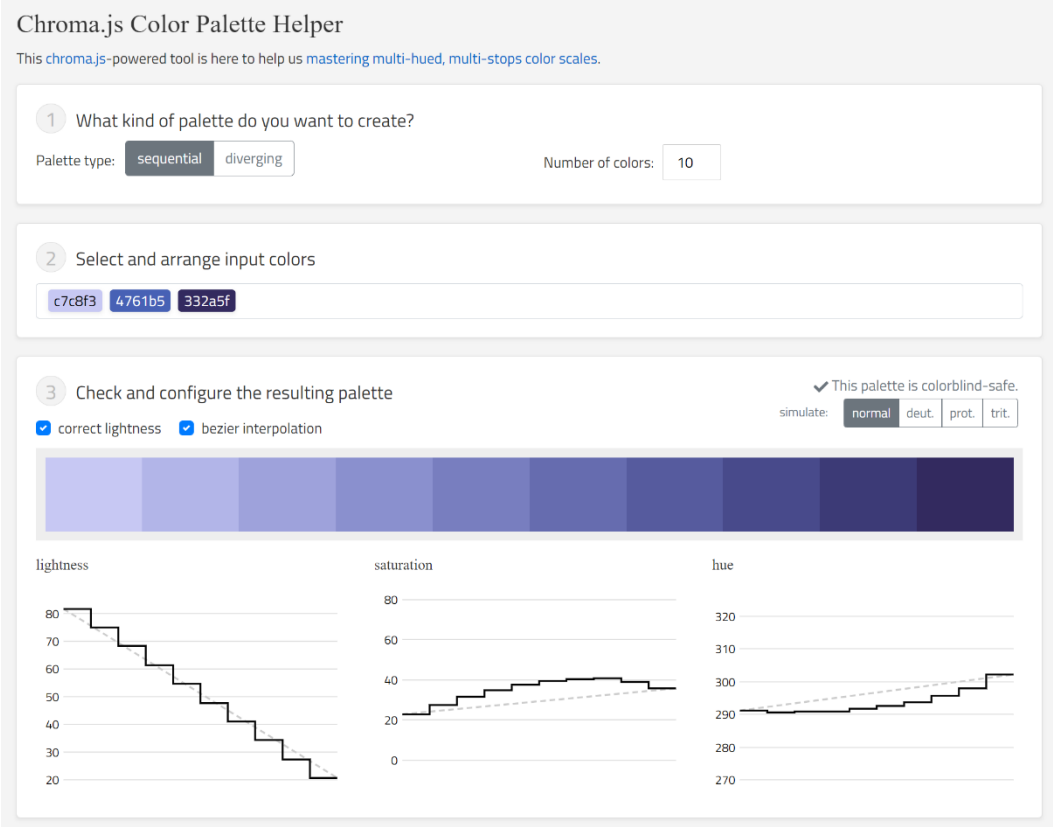
A **sequential** color scale goes from brightest to darkest, or the other way around.

You can use only **one hue**, or **two or more hues** (which might be even clearer).



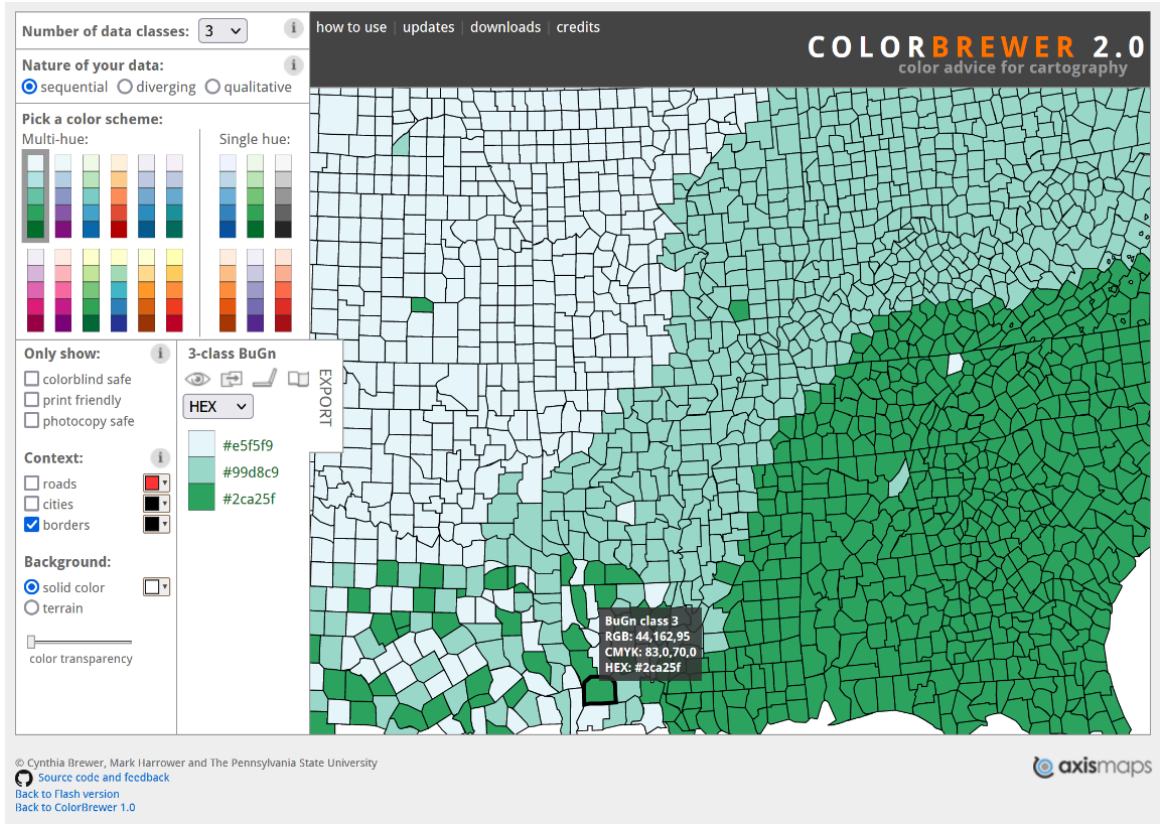
Helpful tools

chroma.js: a nice tool to create a sequential color scheme



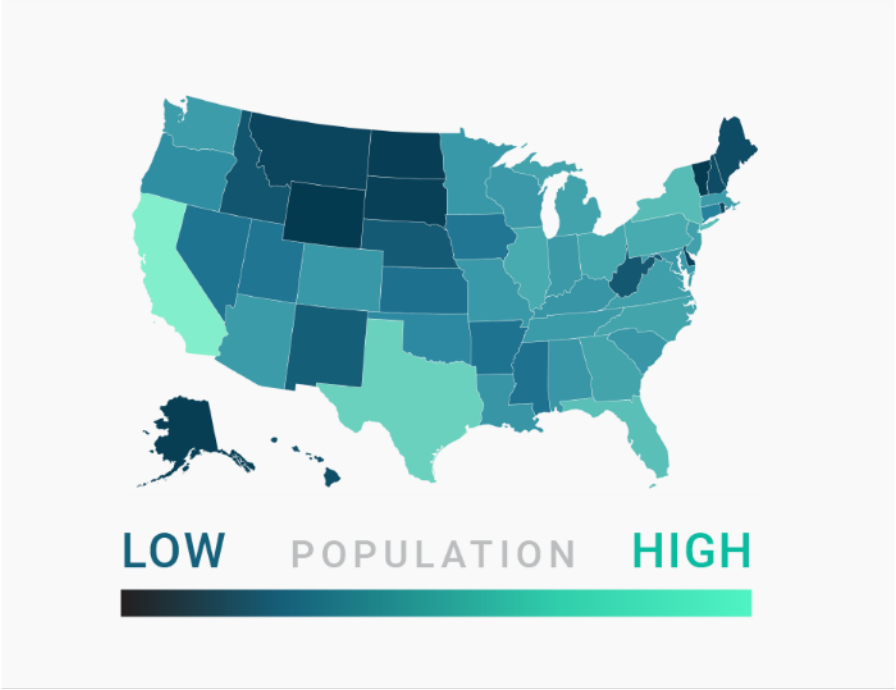
vis4.net/palettes

Color Brewer: a good source for strong color schemes

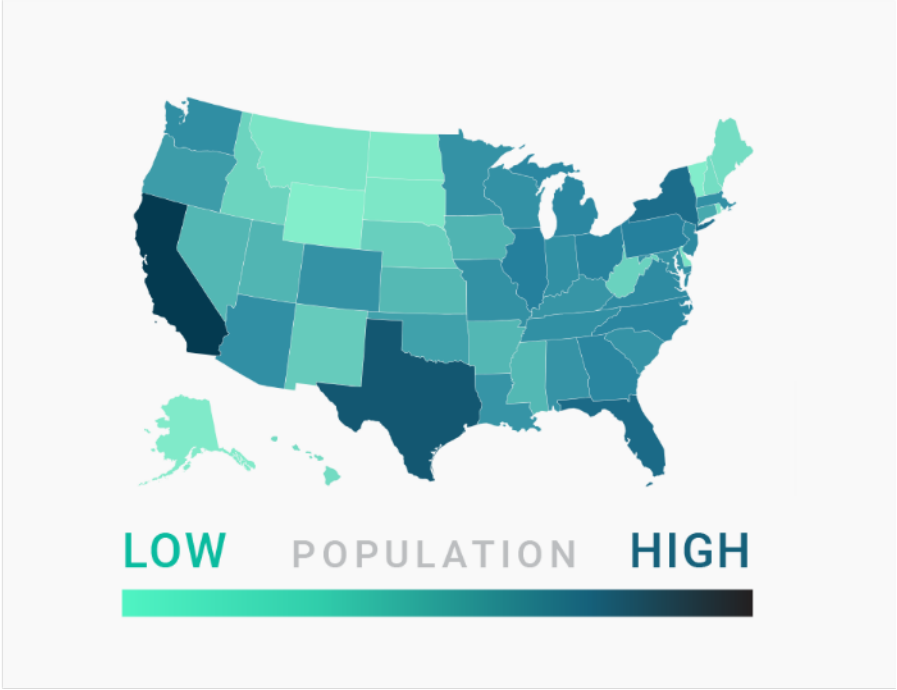


colorbrewer2.org

dark colors = high values *



NOT IDEAL

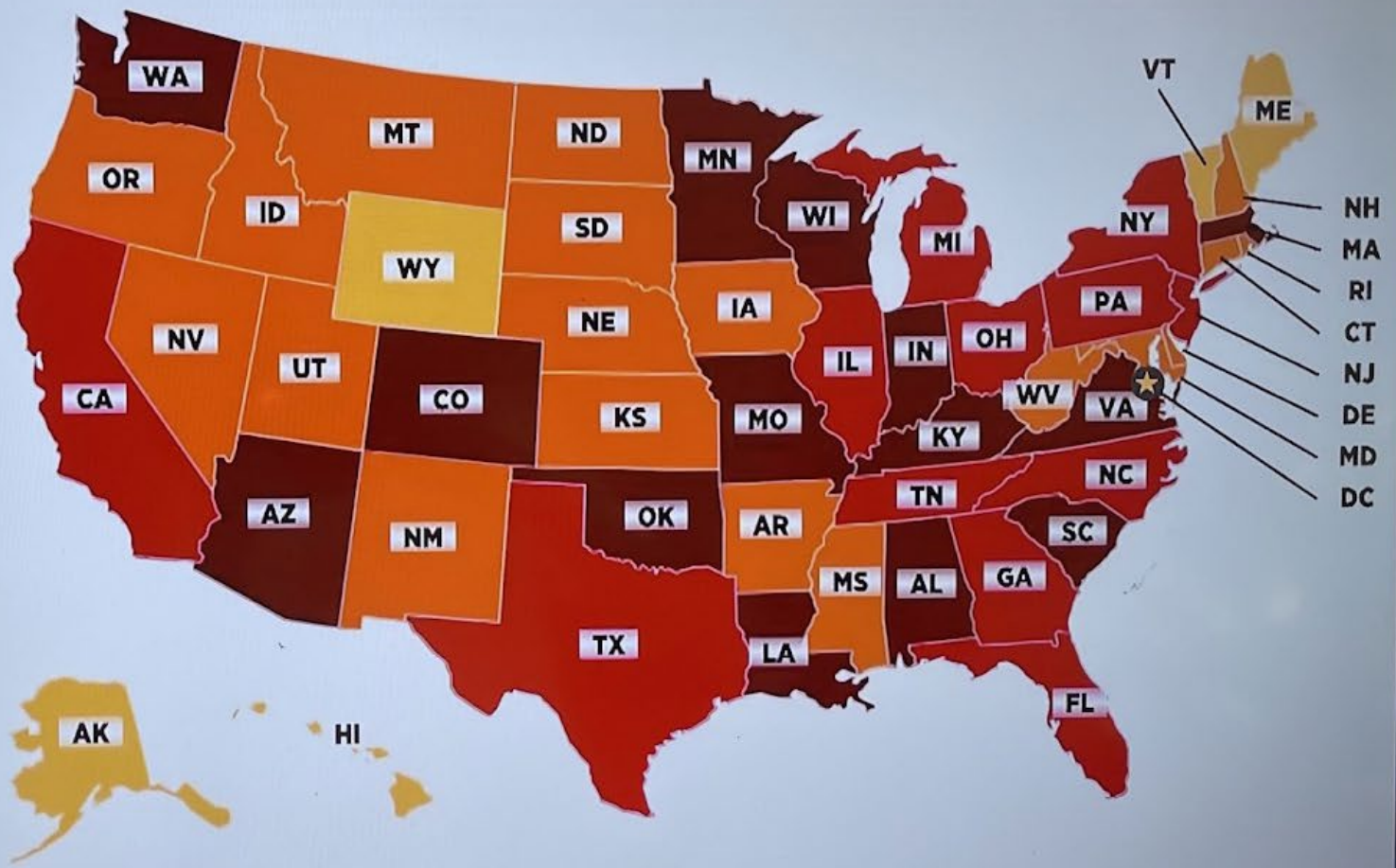


BETTER

*on a light background

38,227,970 CONFIRMED CASES

1,000,000+ CASES
500,000+ CASES
100,000+ CASES
1,000+ CASES

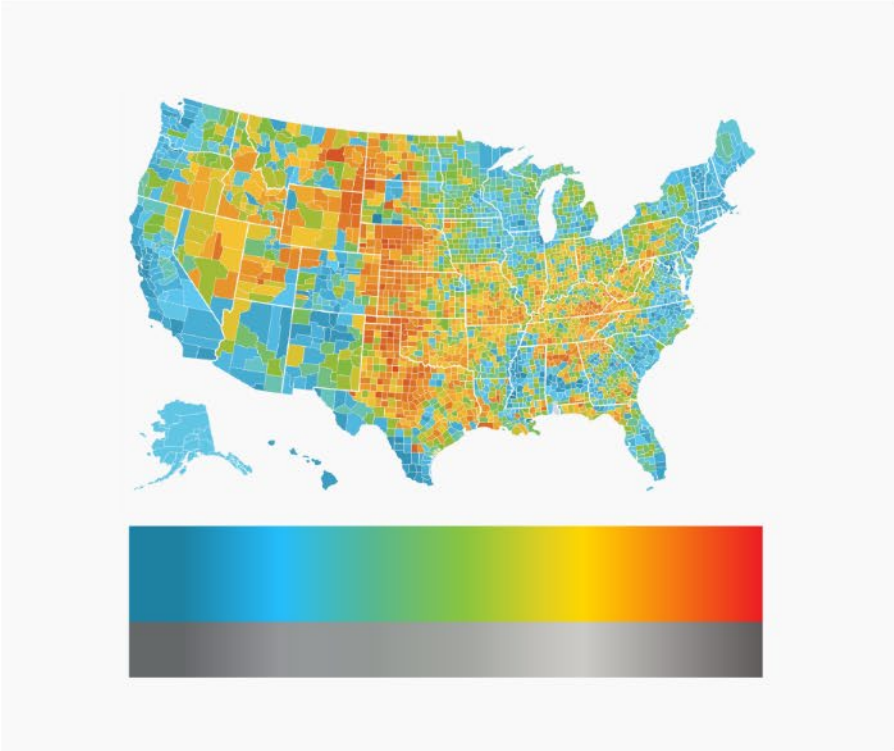


TOTAL FATALITIES
634,698

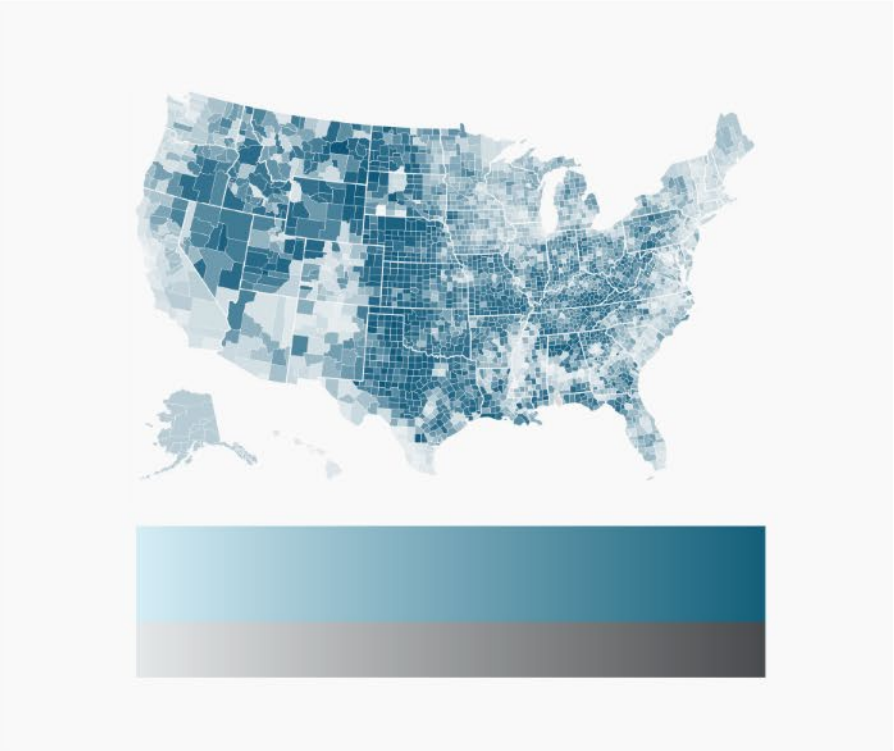
SOURCE: NBC NEWS | UPDATED 8/25/2021 3:09 AM ET

MSNBC
LIVE > 7:38 AM ET

rainbow scales can be confusing

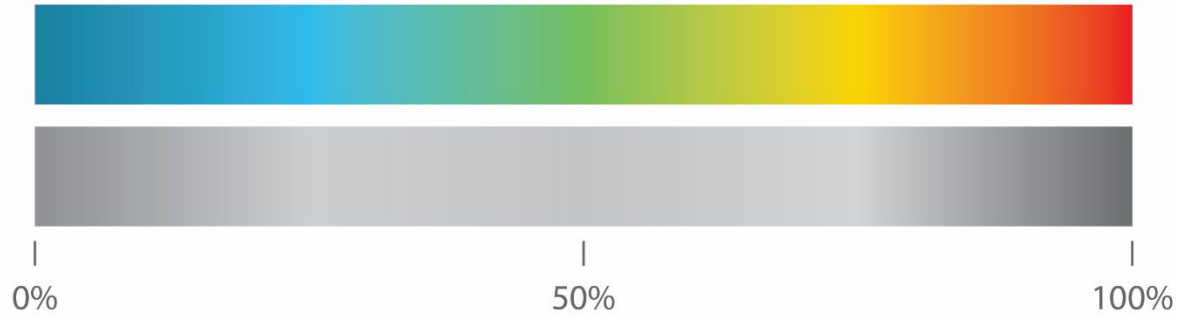


NOT IDEAL

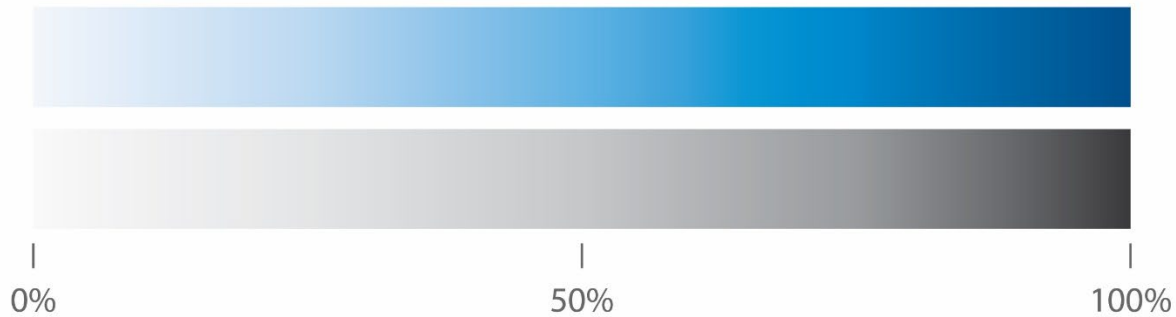


BETTER

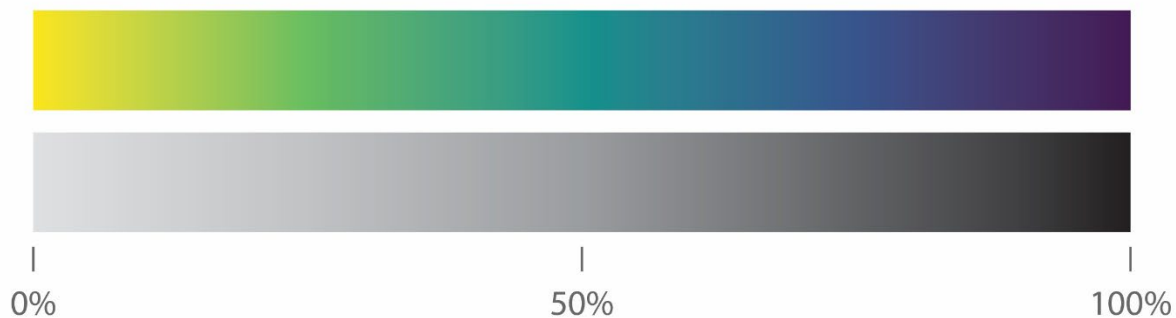
Rainbow scale



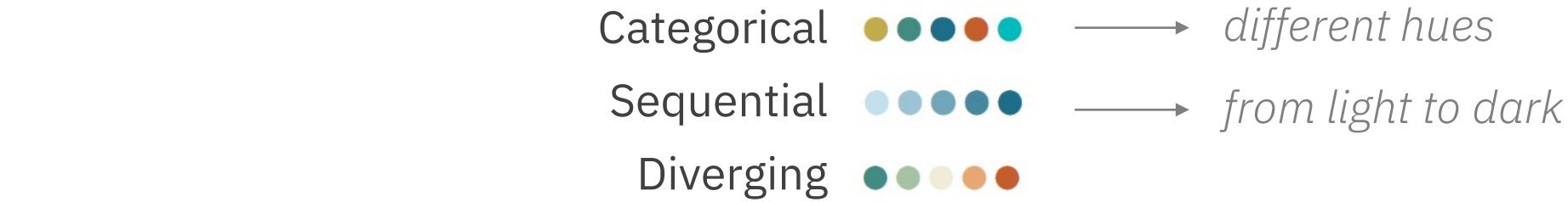
Single hue sequential scale

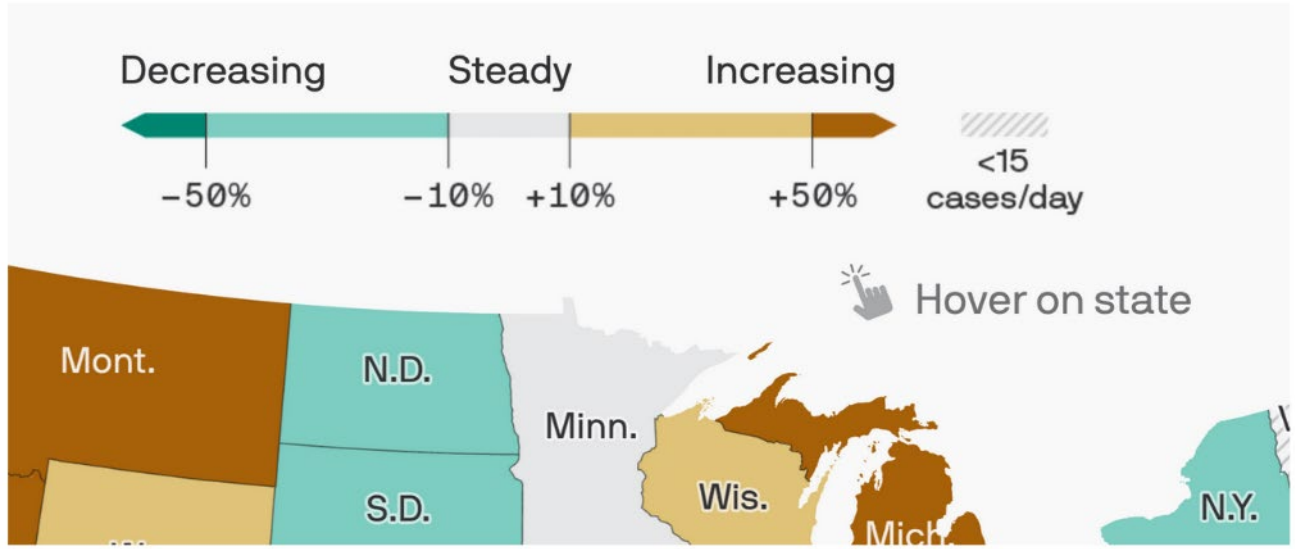


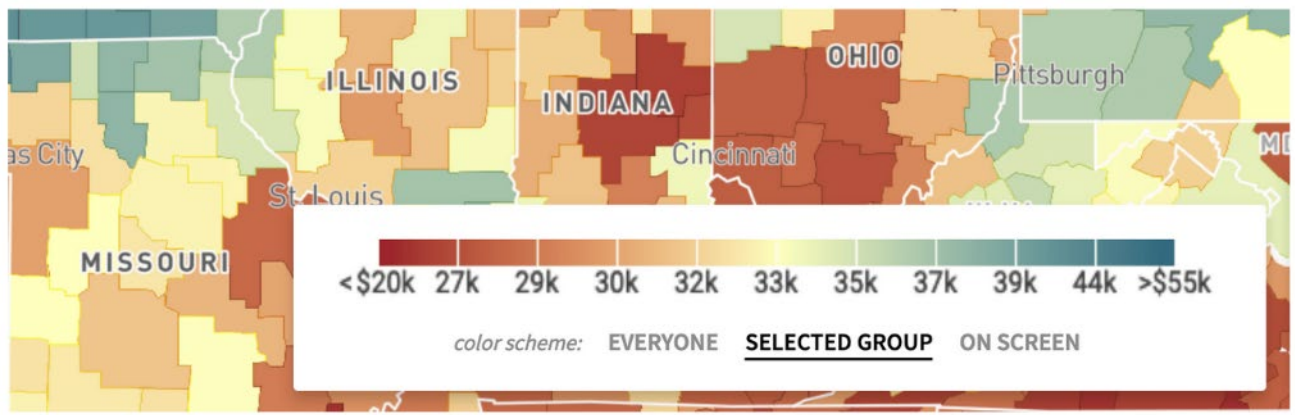
Viridis scale



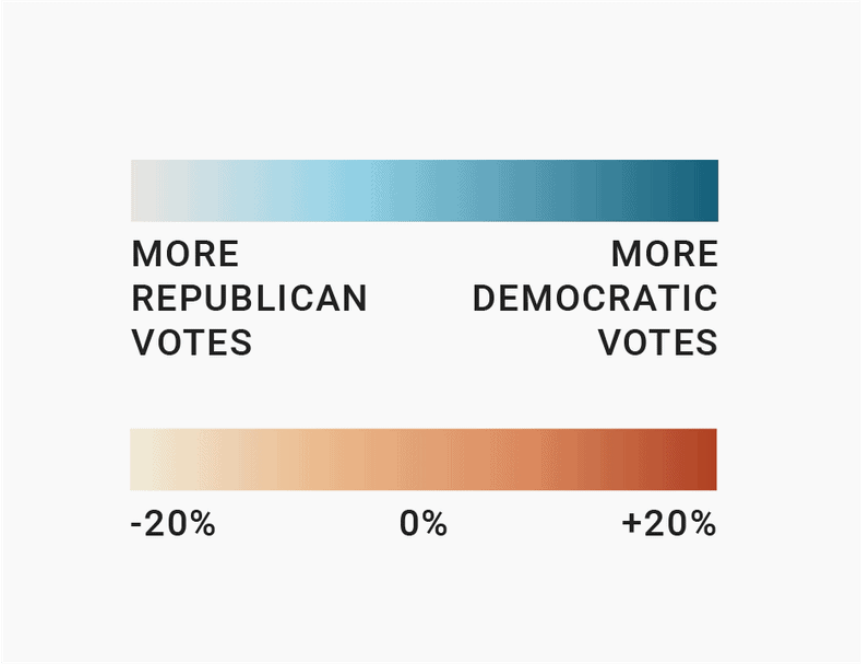
Different types of color scales



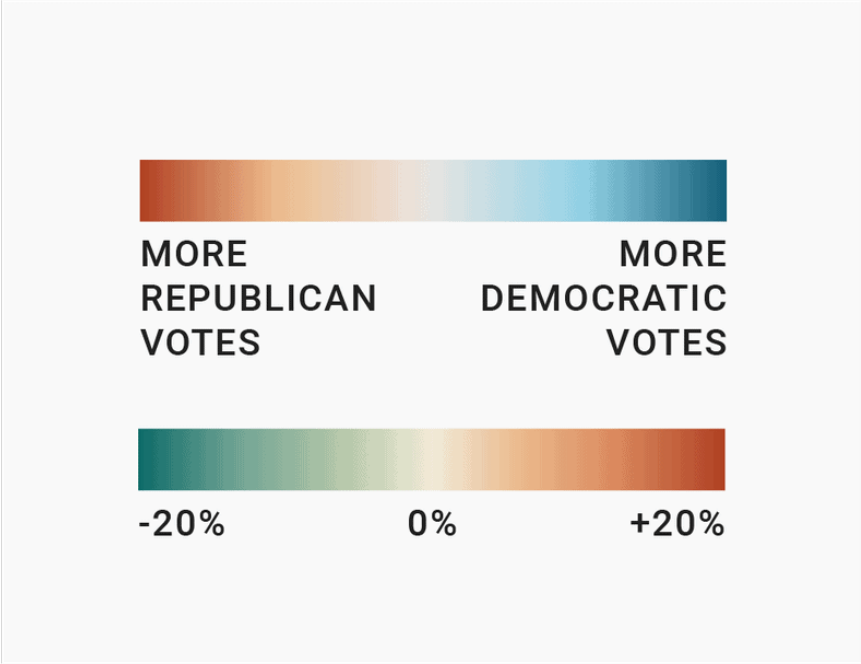

Decreasing
Steady
Increasing
−50%
−10%
+10%
+50%
<15 cases/day
Hover on state
Mont.
N.D.
S.D.
Minn.
Wis.
N.Y.


ILLINOIS
INDIANA
OHIO
Pittsburgh
Cincinnati
MISSOURI
<$20k 27k 29k 30k 32k 33k 35k 37k 39k 44k >$55k
color scheme: EVERYONE SELECTED GROUP ON SCREEN

Use **diverging scales** when there's a logical 'middle point'



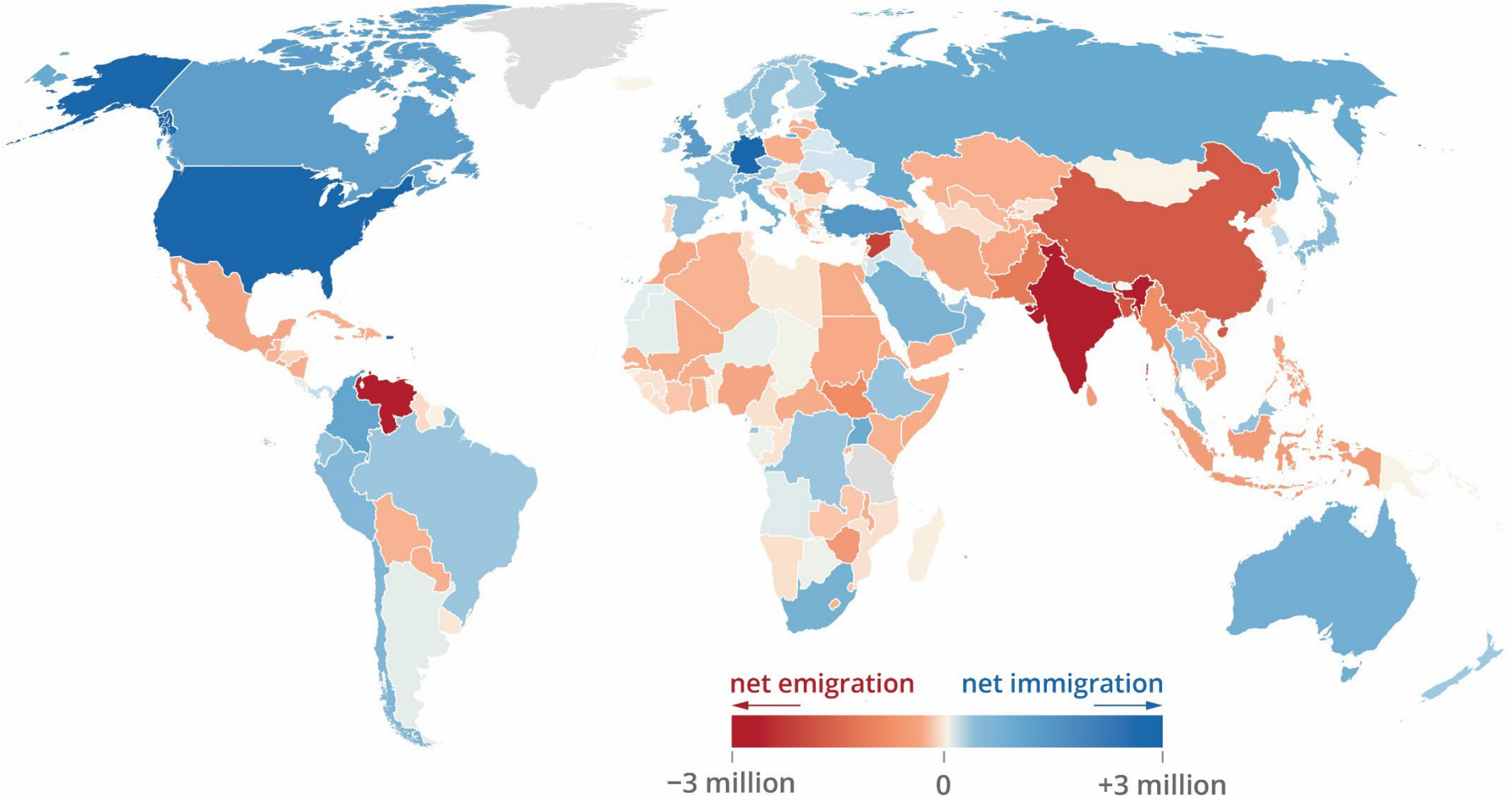
NOT IDEAL



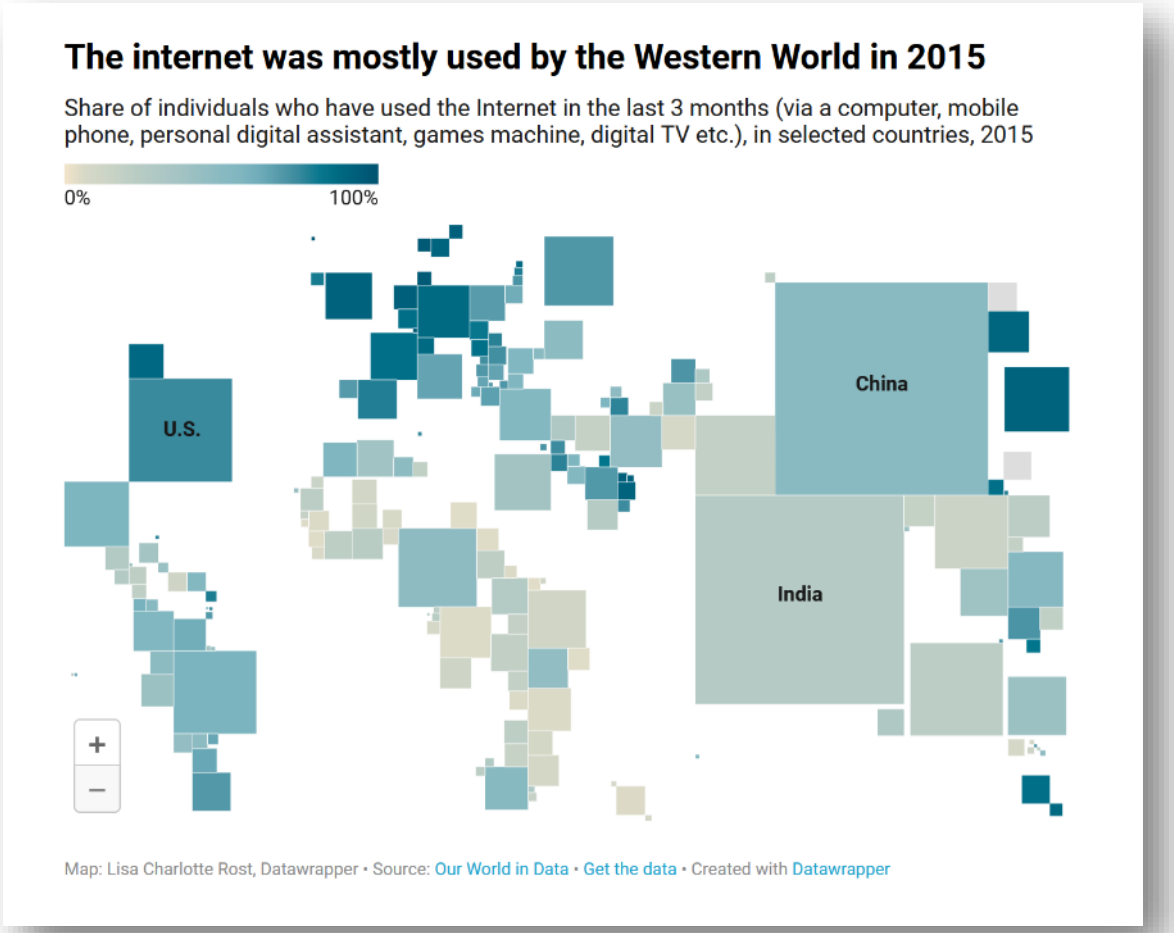
BETTER

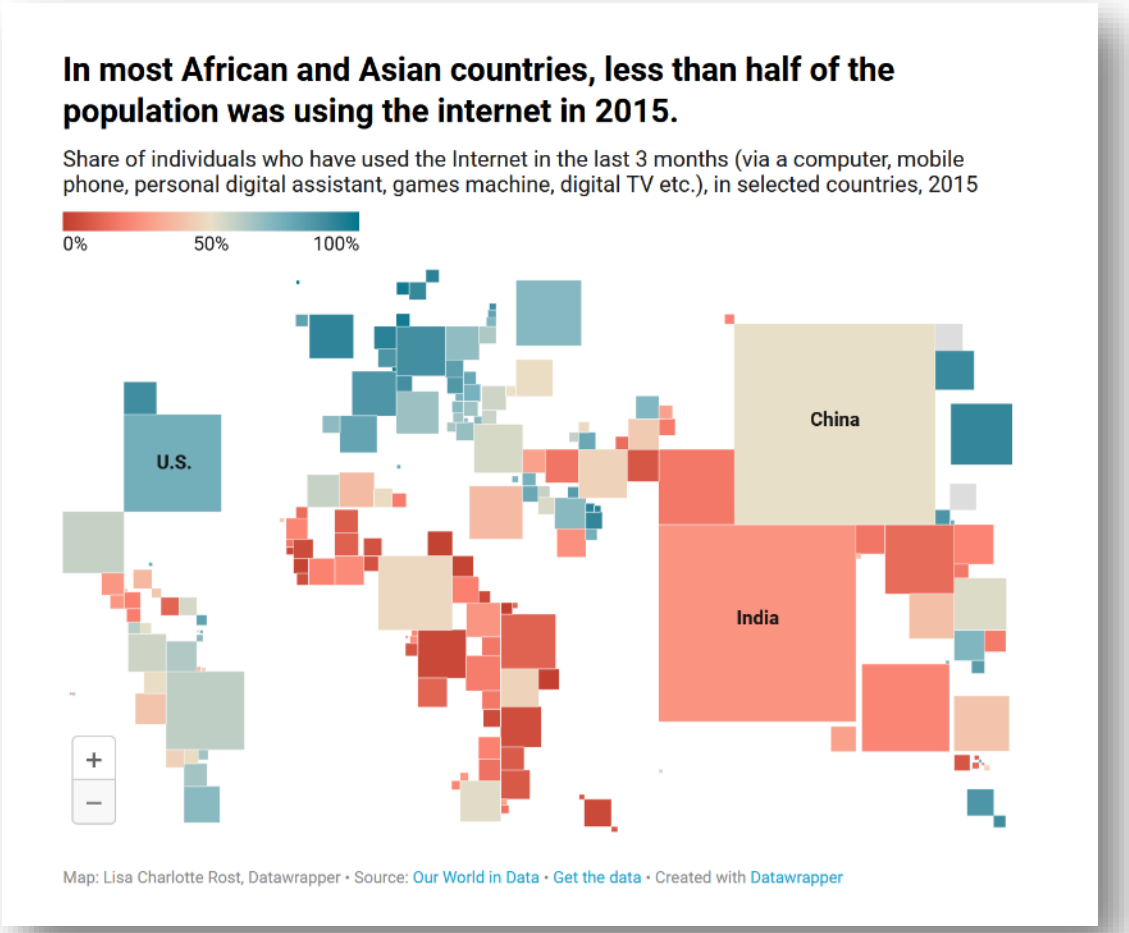
Net international migration

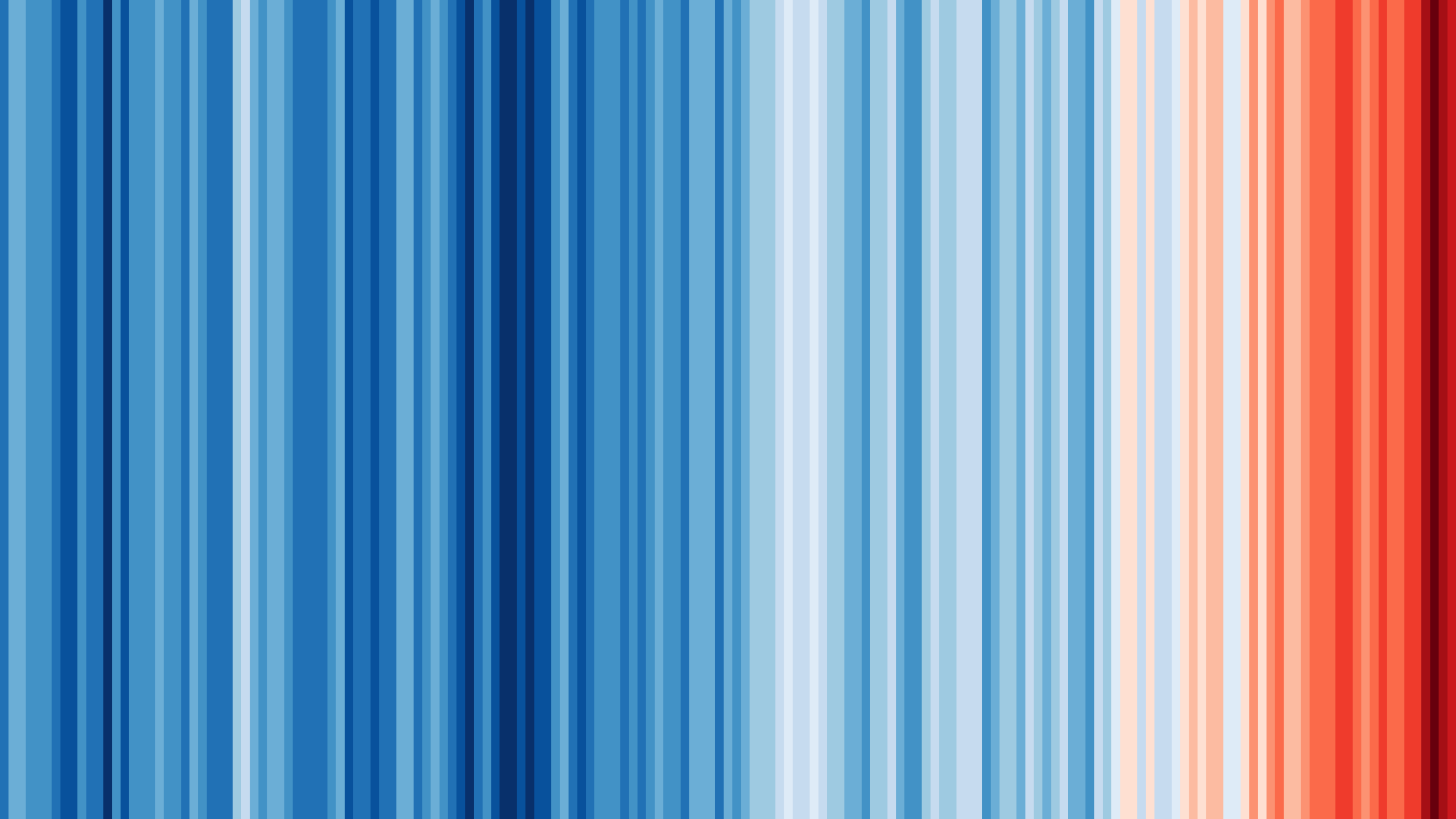
Source: Our World in Data



Use **diverging scales** when you want to highlight low values or details







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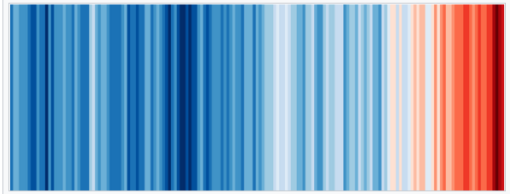
Warming stripes

From Wikipedia, the free encyclopedia

Warming stripes (sometimes referred to as **climate stripes**,[3][4][5][Note 1] **climate timelines**[6] or **stripe graphics**[7]) are data visualization graphics that use a series of coloured stripes chronologically ordered to visually portray long-term temperature trends.[2][Note 2] Warming stripes reflect a "minimalist"[2][5] style, conceived to use colour alone to avoid technical distractions and intuitively convey global warming trends to non-scientists.[8][9]

The initial concept of visualizing historical temperature data has been extended to involve animation,[10] to visualize sea level rise[11] and predictive climate data,[12] and to visually juxtapose temperature trends with other data such as atmospheric CO_2 concentration,[13] global glacier retreat,[14] precipitation,[4] progression of ocean depths,[15] and aviation emission's percentage contribution to global warming.[16]

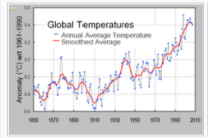


An early warming stripes graphic published by their originator, climatologist Ed Hawkins.[1] The progression from blue (cooler) to red (warmer) stripes portrays the long-term increase of average global temperature from 1850 (left side of graphic) to 2018 (right side of graphic).[2]

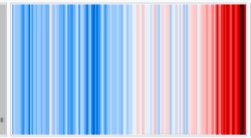
Contents [hide]

Background, publication and content [edit]

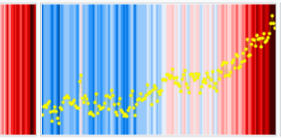
In May 2016, to make visualizing climate change easier for the general public, University of Reading climate scientist Ed Hawkins created an animated spiral graphic[19] of global temperature change as a function of time, a representation said to have gone viral.[9][20] Jason Samenow wrote in *The Washington Post* that the spiral graph was "the most compelling global warming visualization ever made",[21] before it was featured in the opening ceremony of the 2016 Summer Olympics.[10] Then, on 22 May 2018, Hawkins published[22] graphics constituting a chronologically ordered series of coloured vertical stripes that he called warming stripes.[9] Hawkins, a lead author for the IPCC 6th Assessment Report, received the Royal Society's 2018 Kavli Medal, in part "for actively communicating climate science and its various implications with broad audiences".[23]



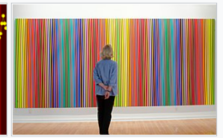
This conventional data visualization includes date ranges, explanatory legends, and technical terminology.



Warming stripes were designed to have "more aesthetic appeal and a lower barrier of entry for a casual viewer" than conventional data visualizations.[10]



This composite of a conventional line graph superimposed on a warming stripe graphic illustrates year-by-year correlation of data points and coloured stripes.[17]



A colour field abstract artwork[18]

As described in a BBC article, in the month the big meteorological agencies release their annual climate assessments, Hawkins experimented with different ways of rendering the global data and "chanced upon the coloured stripes idea".[24] When he tried out a banner at the Hay Festival, according to the article, Hawkins "knew he'd struck a chord".[24] The National Centre for Atmospheric Science (U.K.), with which Hawkins is affiliated, states that the stripes "paint a picture of our changing climate in a compelling way. Hawkins swapped out numerical data points for colours which we intuitively react to".[6]

> "I wanted to communicate temperature changes in a way that was simple and intuitive, removing all the distractions of standard climate graphics so that the long-term trends and variations in temperature are crystal clear. Our visual

Others have called Hawkins' warming stripes "climate stripes"[3][4] or "climate timelines".[6]

Warming stripe graphics are reminiscent of colour field painting, a style prominent in the mid 20th century, which strips out all distractions and uses only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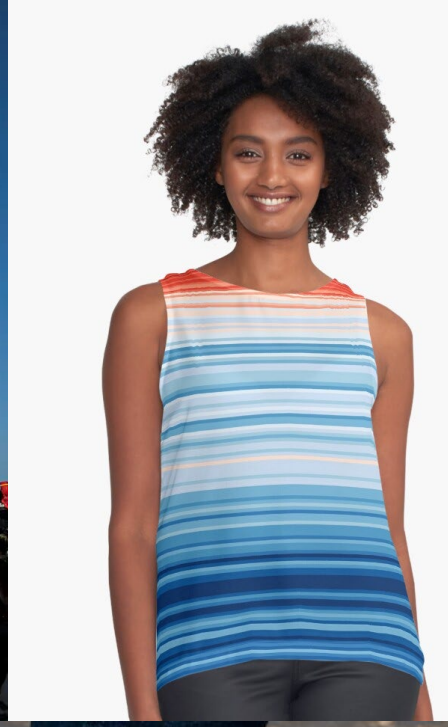
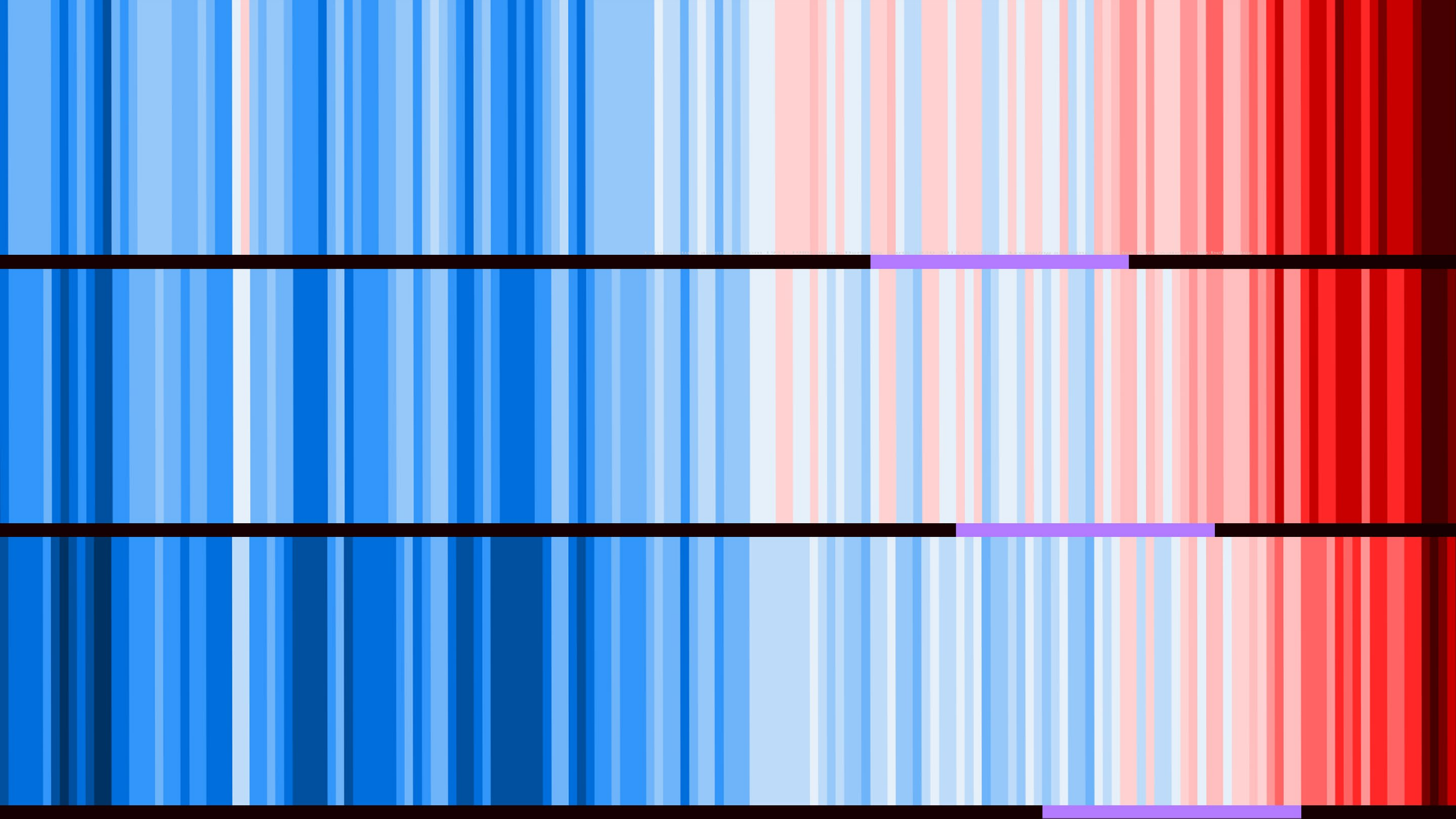
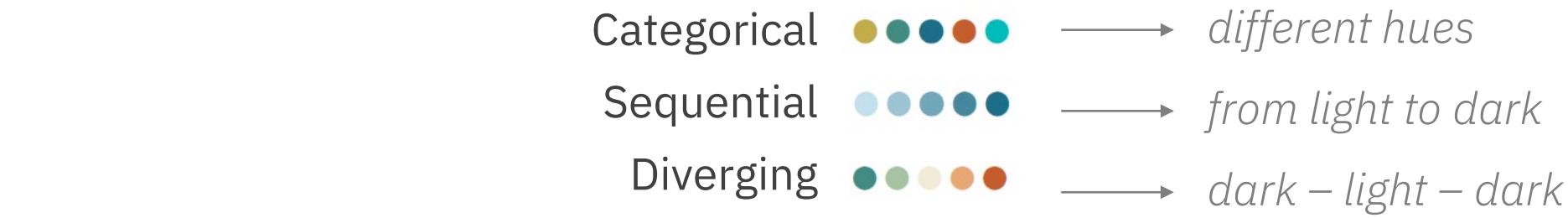


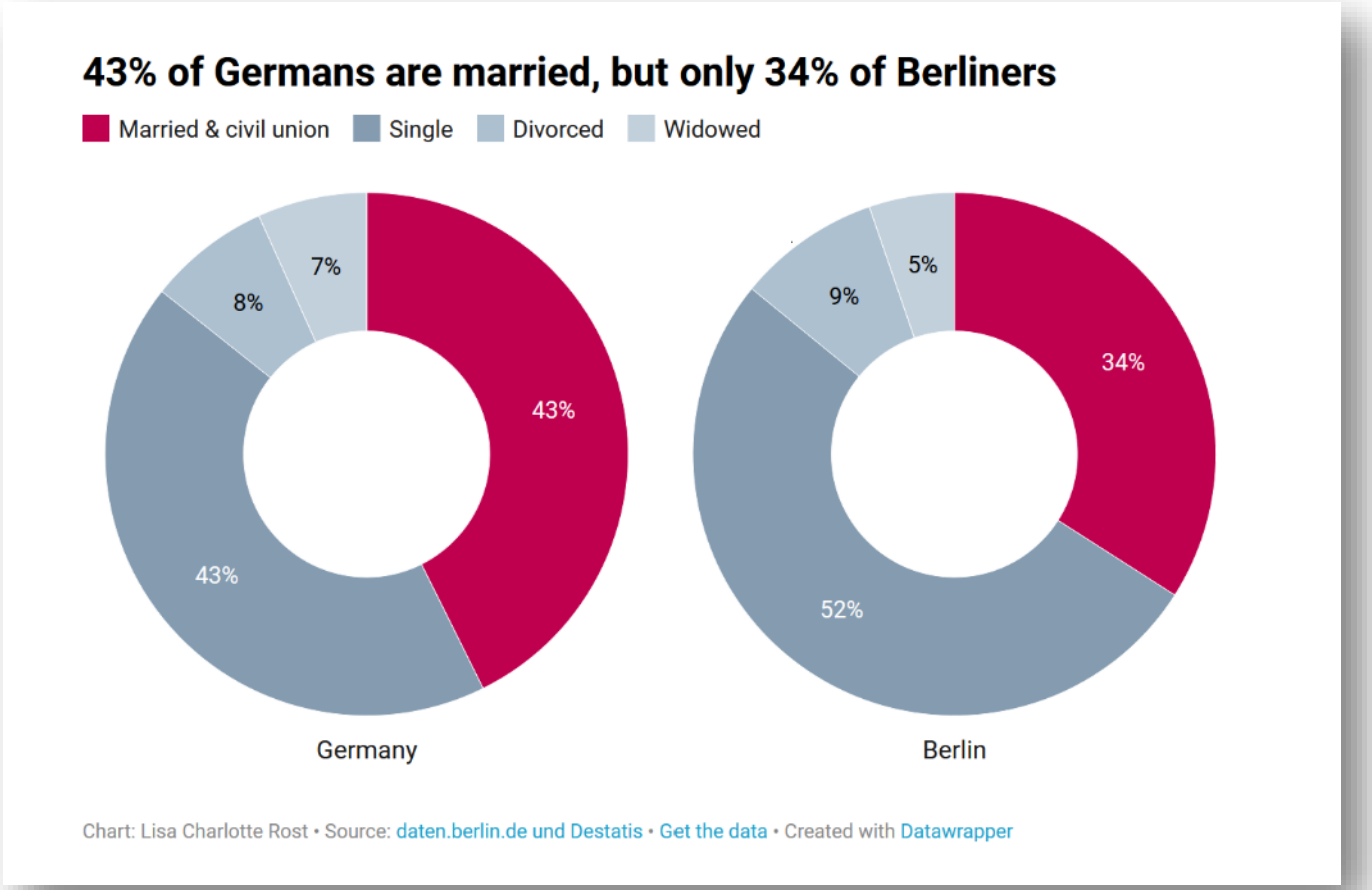


Different types of color scales



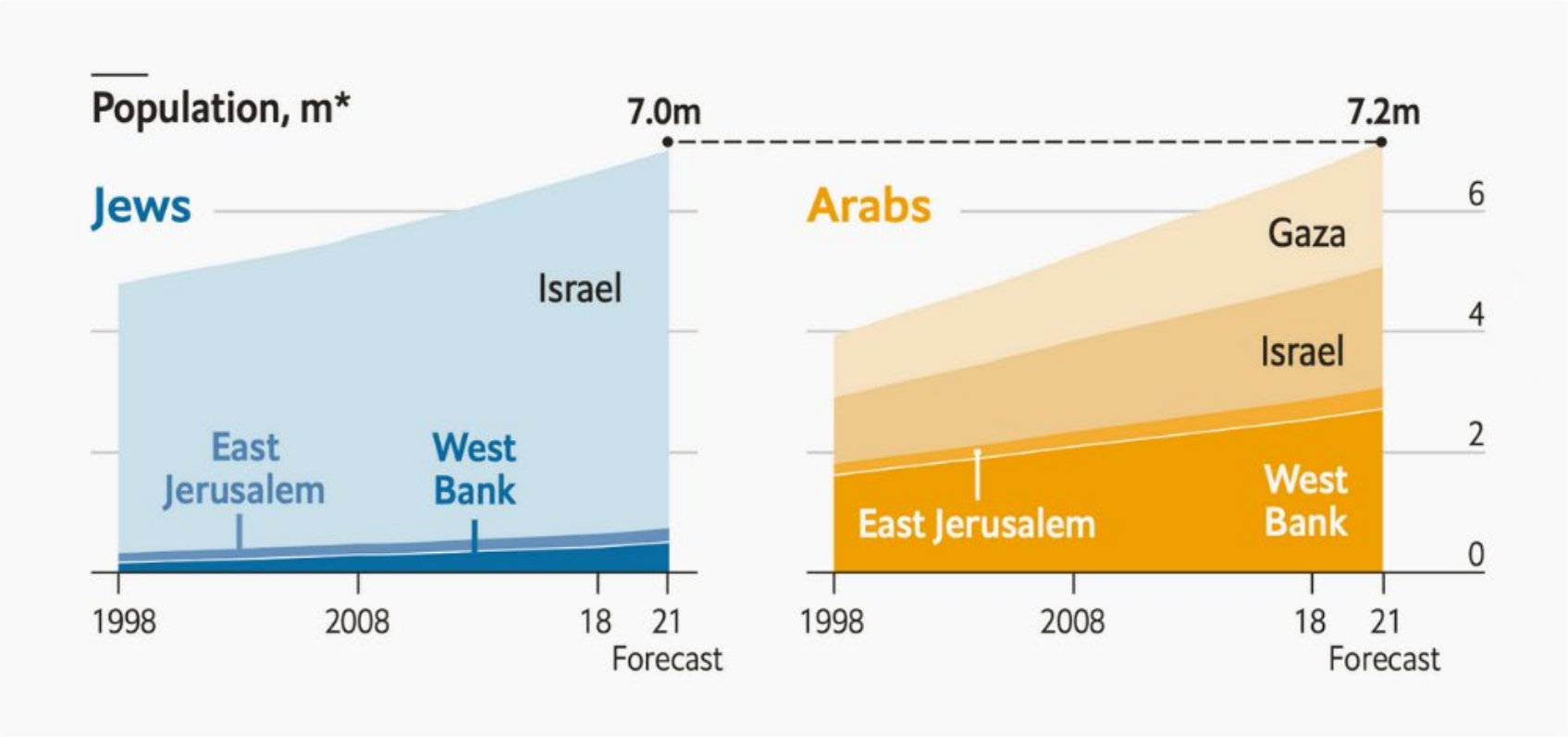
Final remarks

- Use hues to distinguish between highlighted and unhighlighted areas



Final remarks

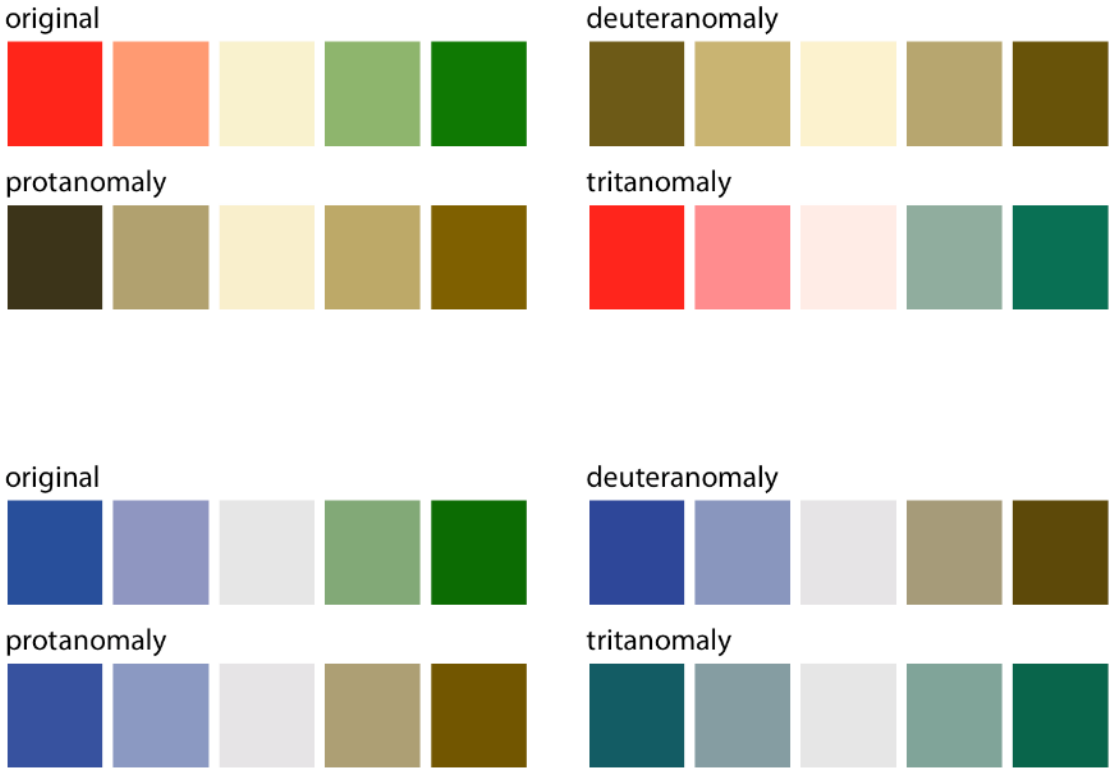
- Use hues to distinguish between categories,
  and shades to distinguish between subcategories

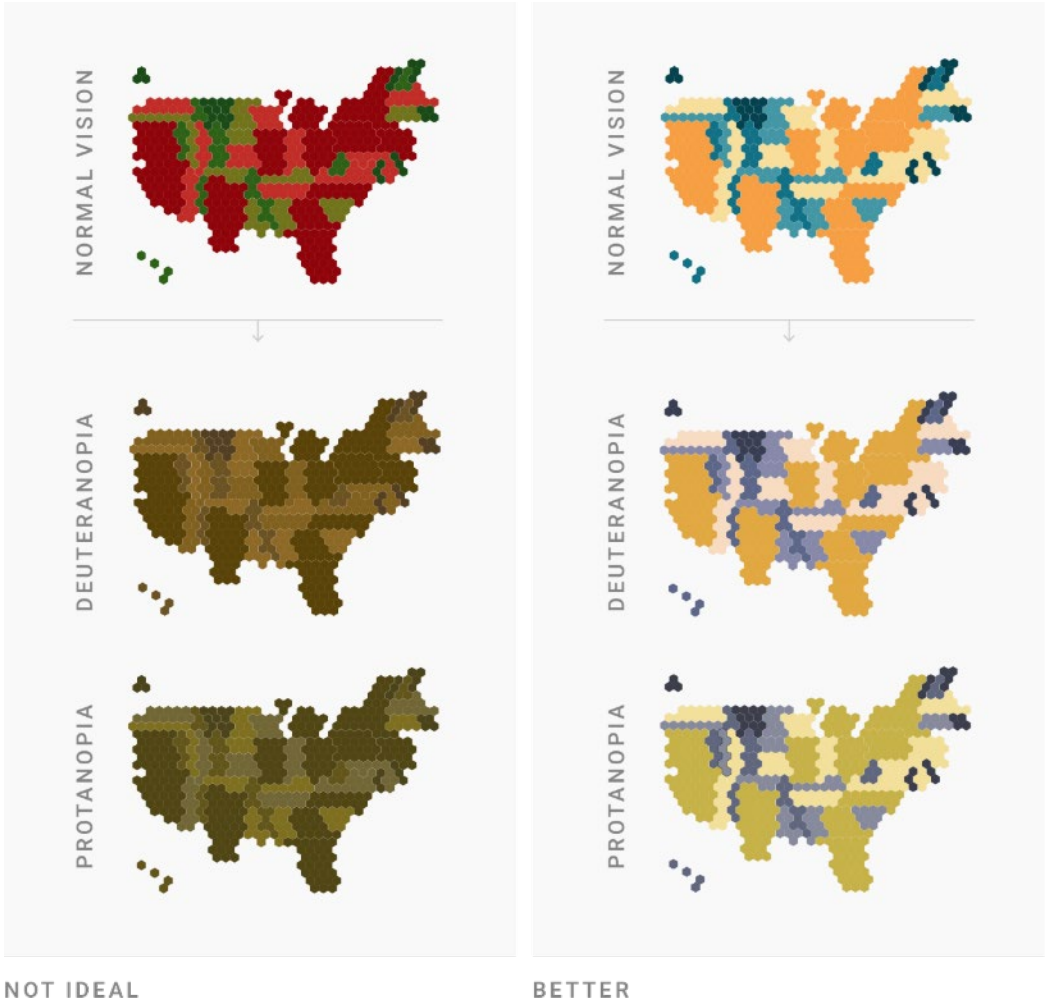


Population in occupied territories, grouped by religious affiliation, by The Economist (PDF)

Final remarks

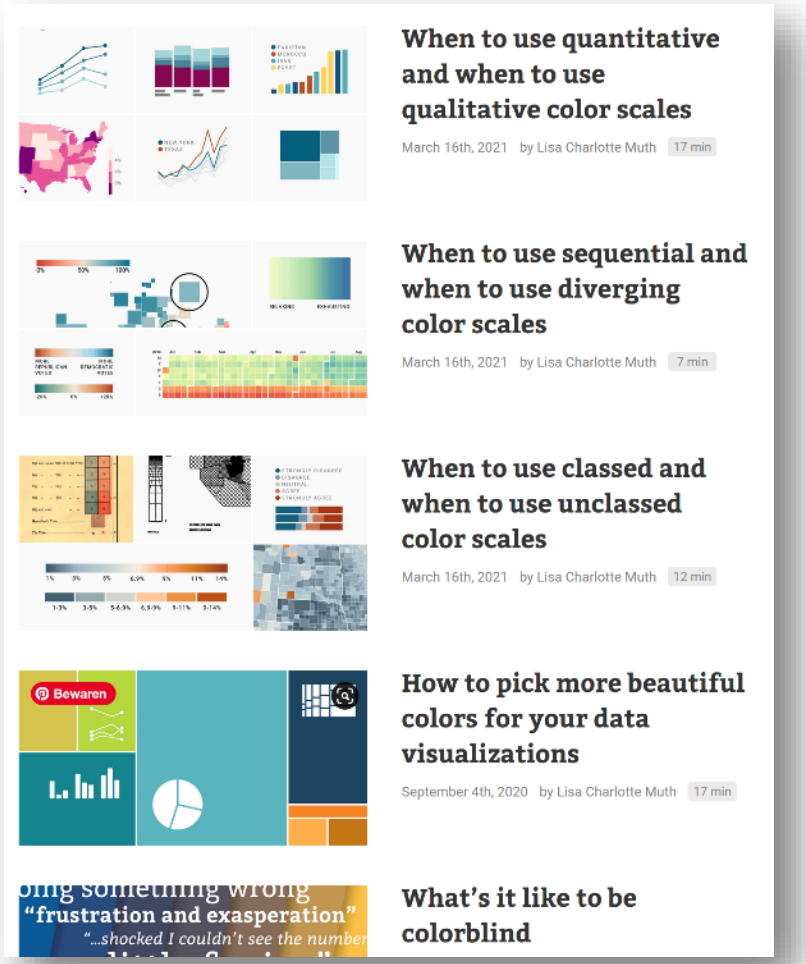
- **Accessibility**: check whether your color scheme is suitable for colorblind people





Final remarks

- Read blog.datawrapper.de/category/color-in-data-vis, it's the ultimate source for information on color use in dataviz



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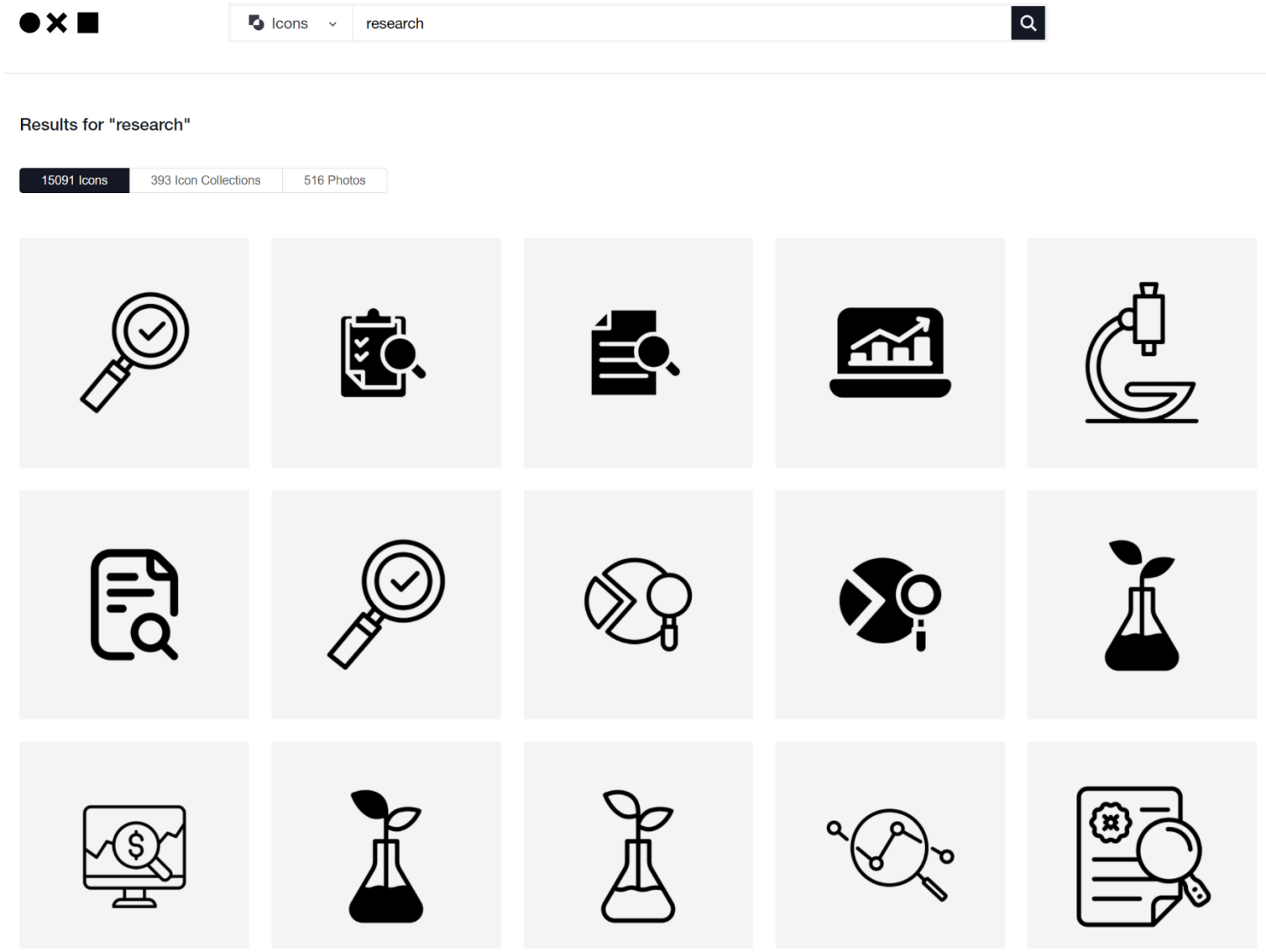

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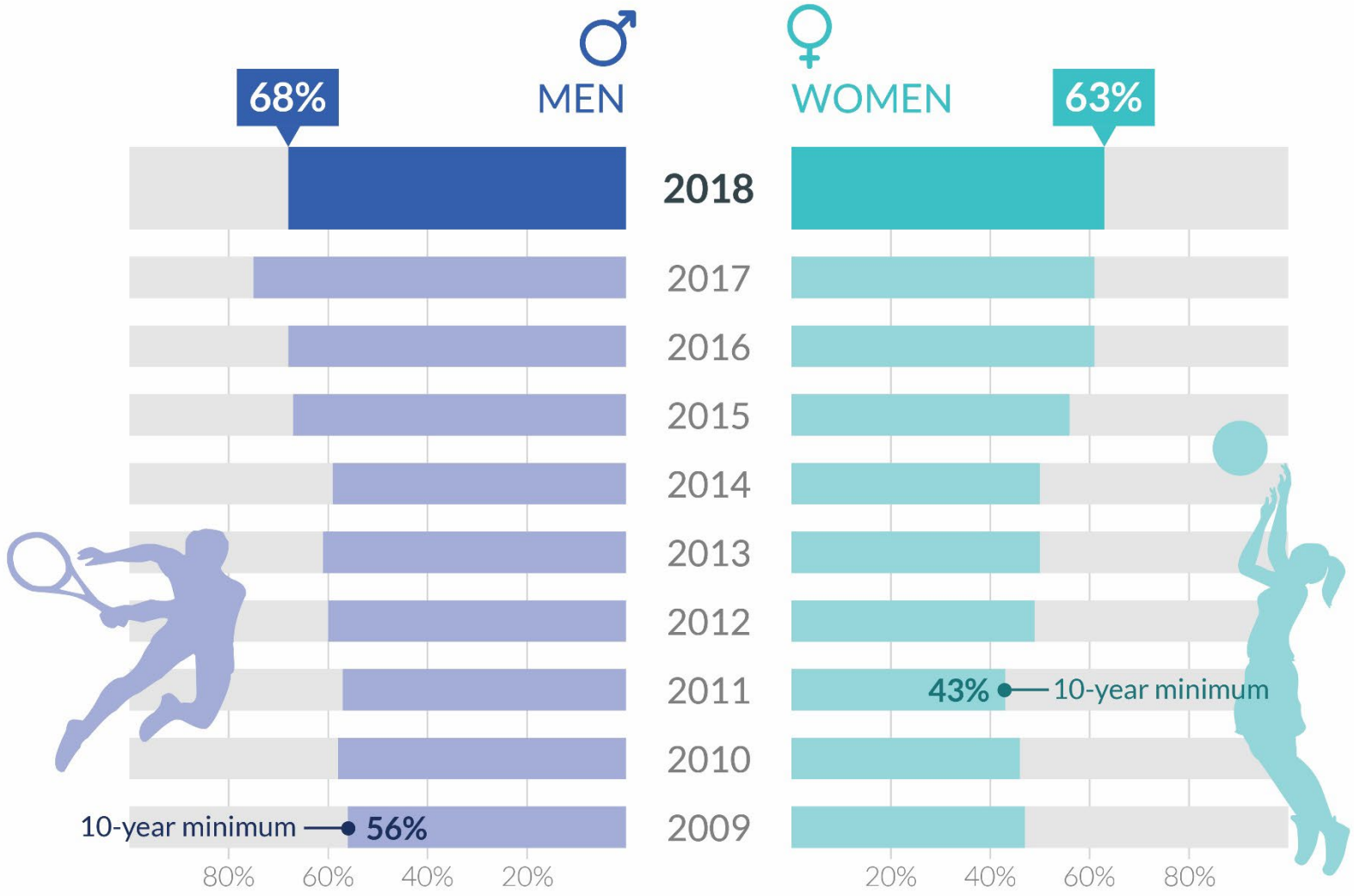
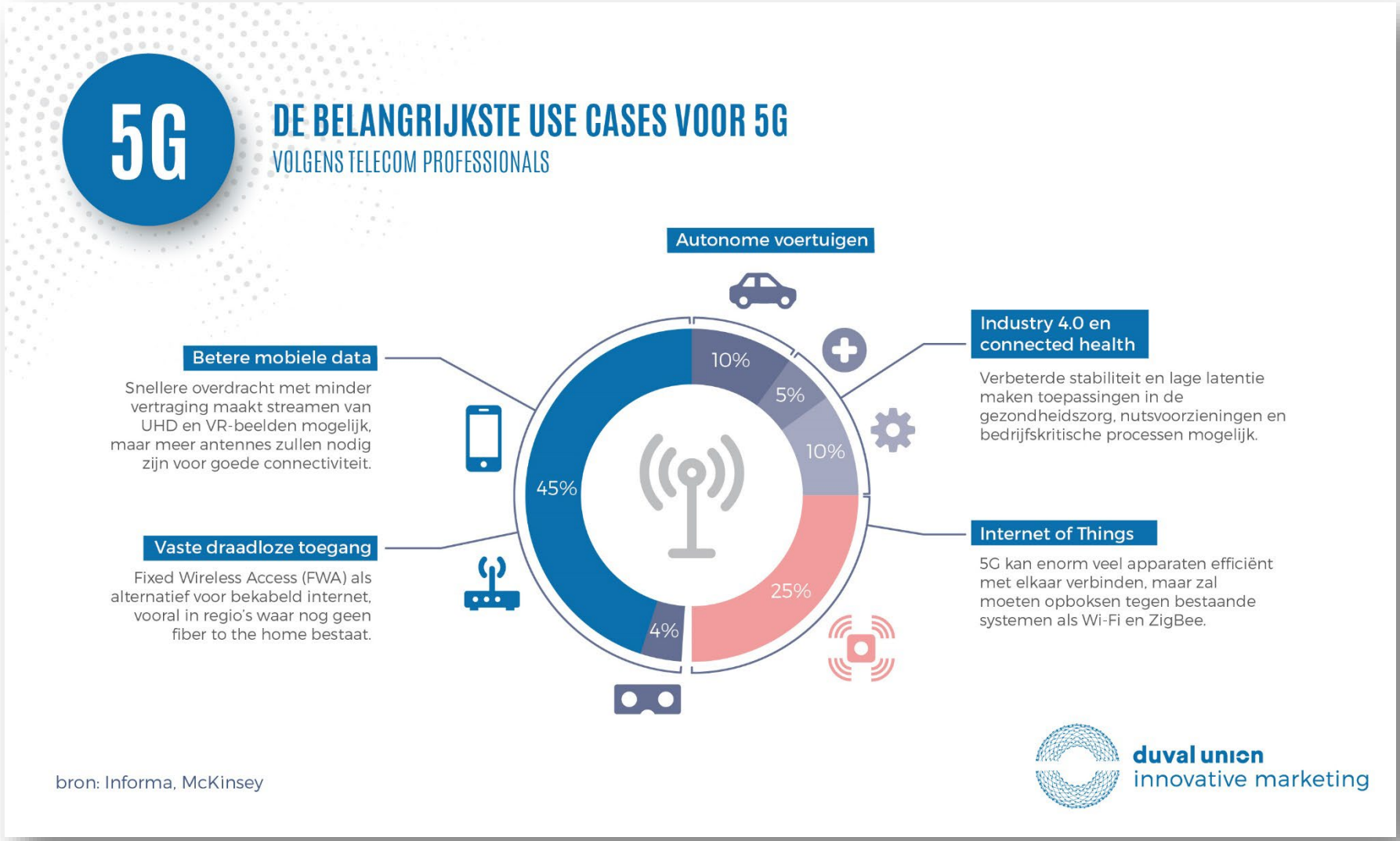
More men than women participate in sports, but the gap is shrinking

Residents of Flanders over 18 years old indicating they play one or more sports
Source: SCV survey, Statistics Flanders





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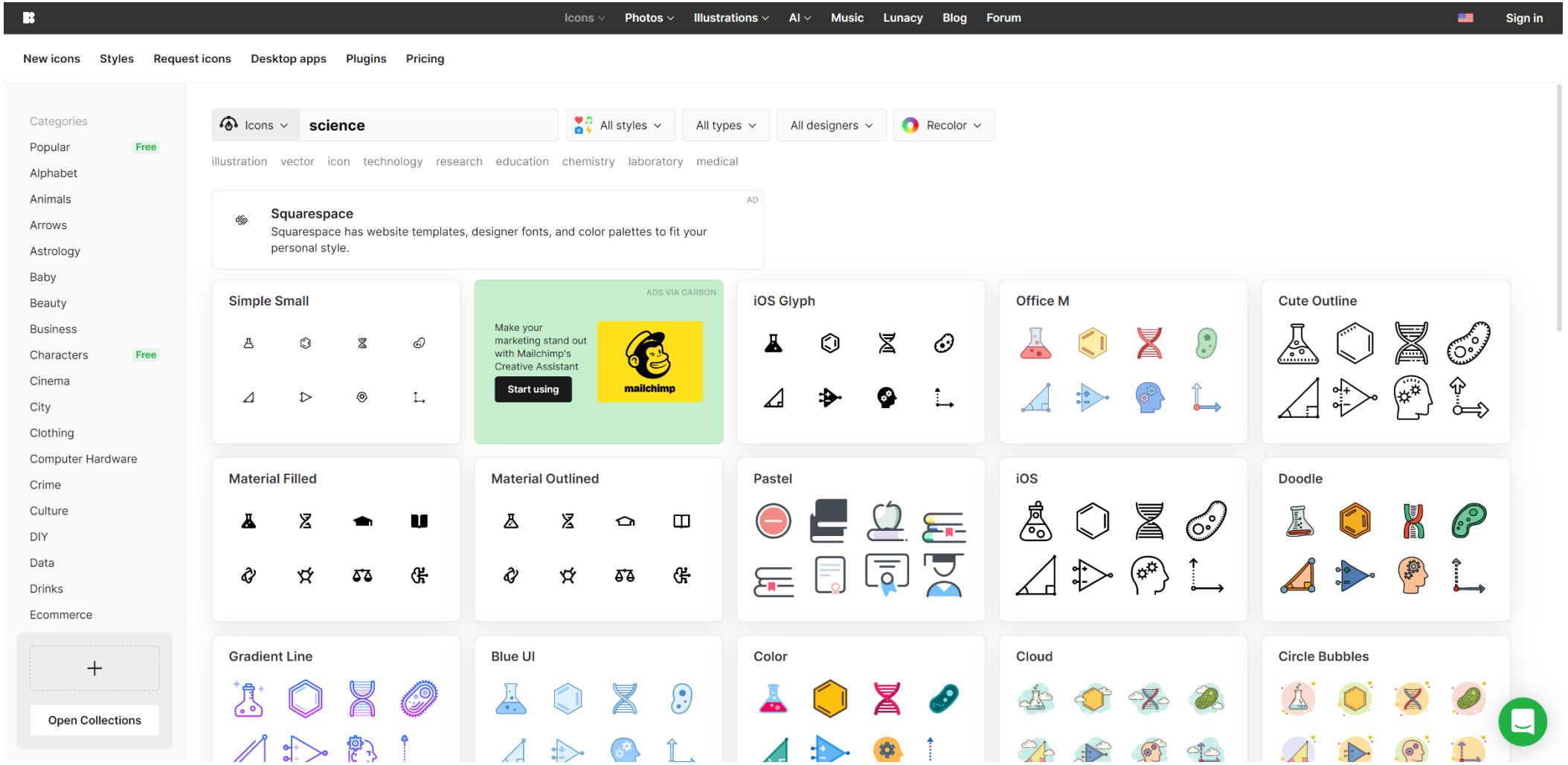

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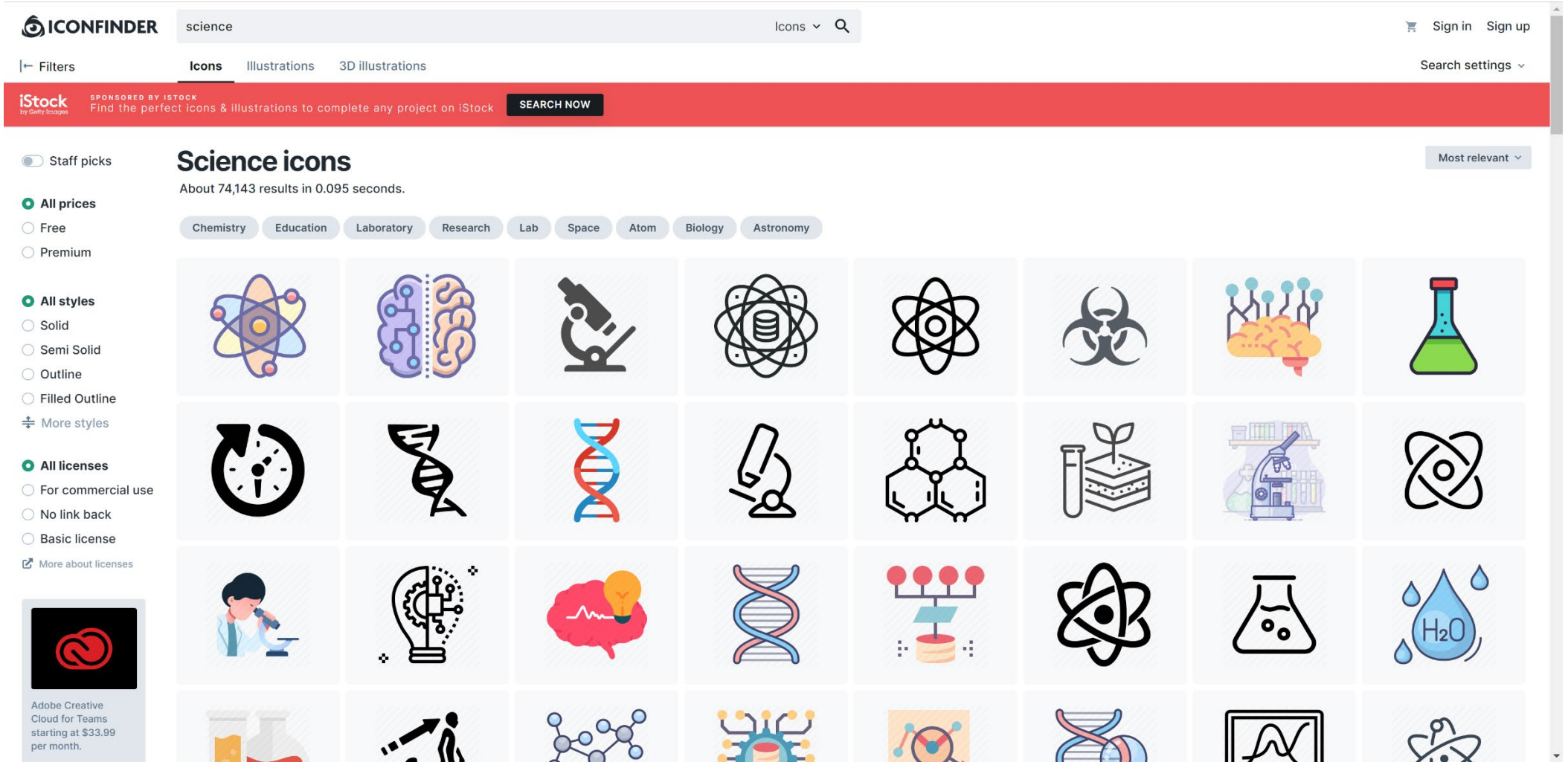

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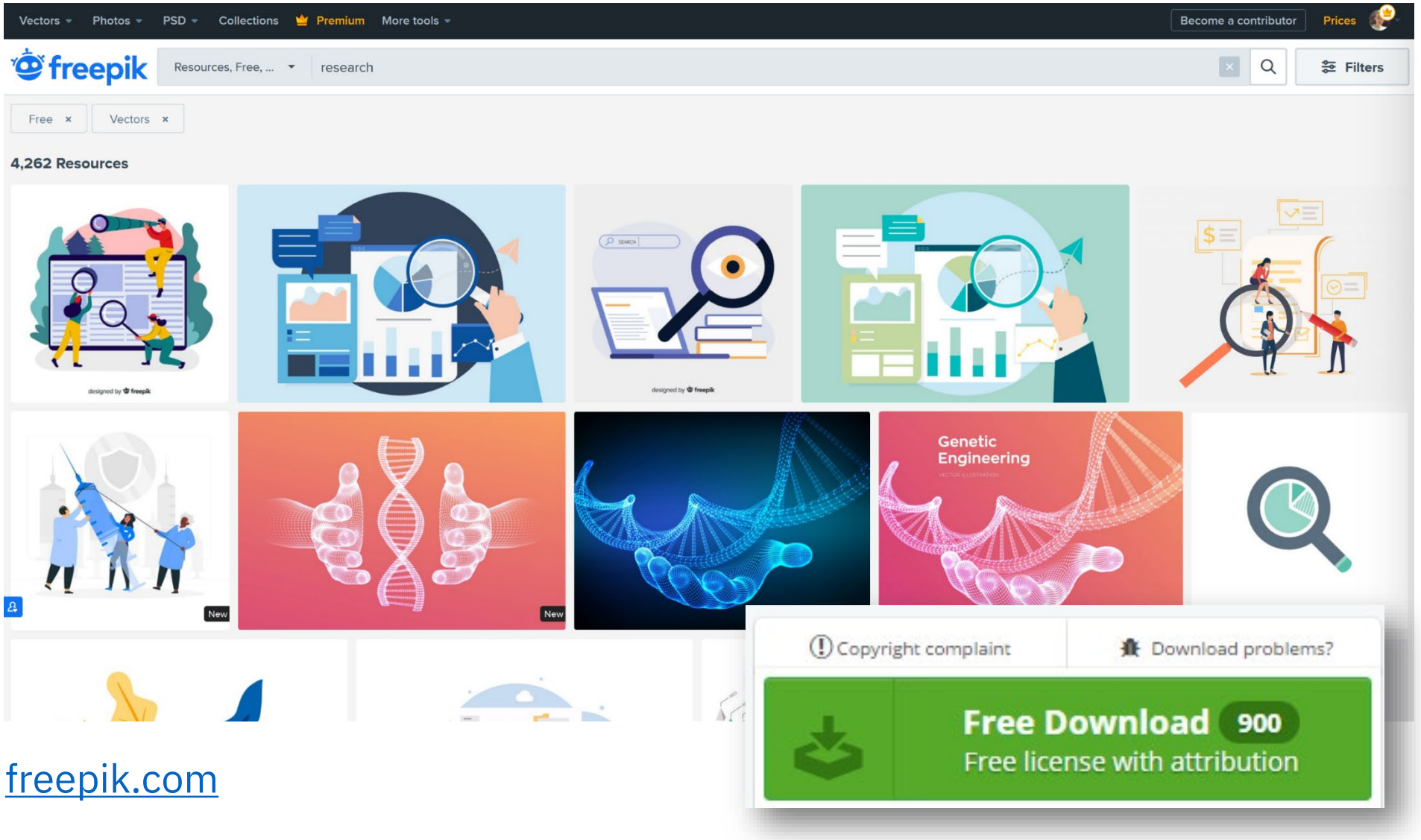

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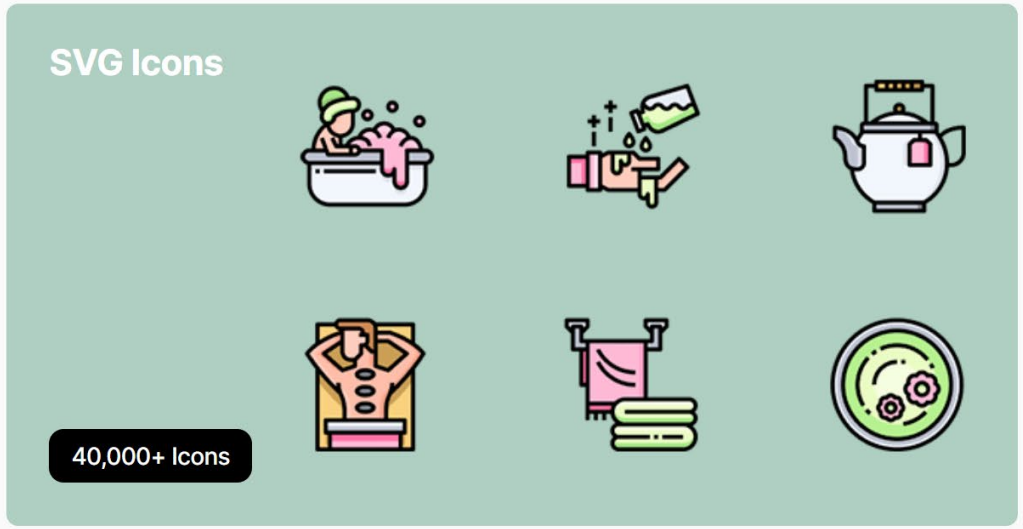

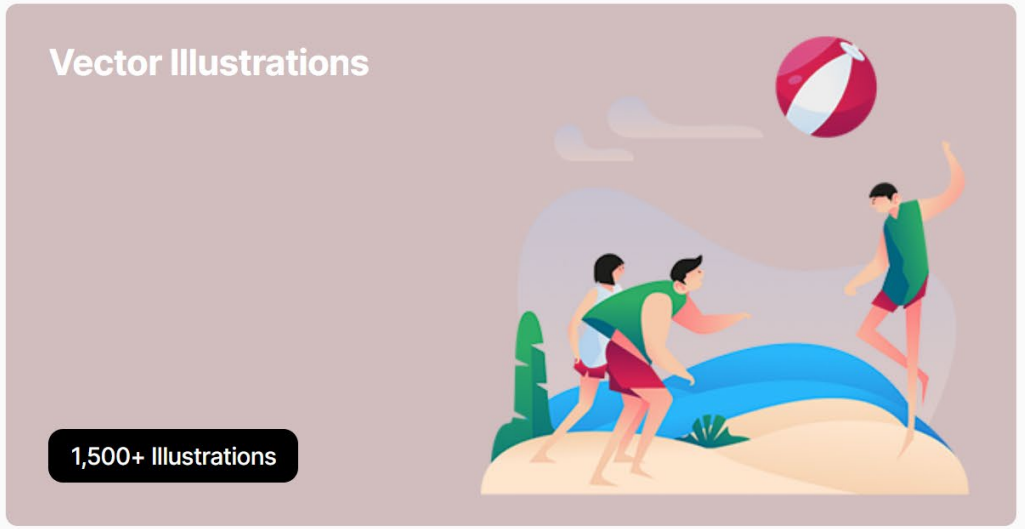

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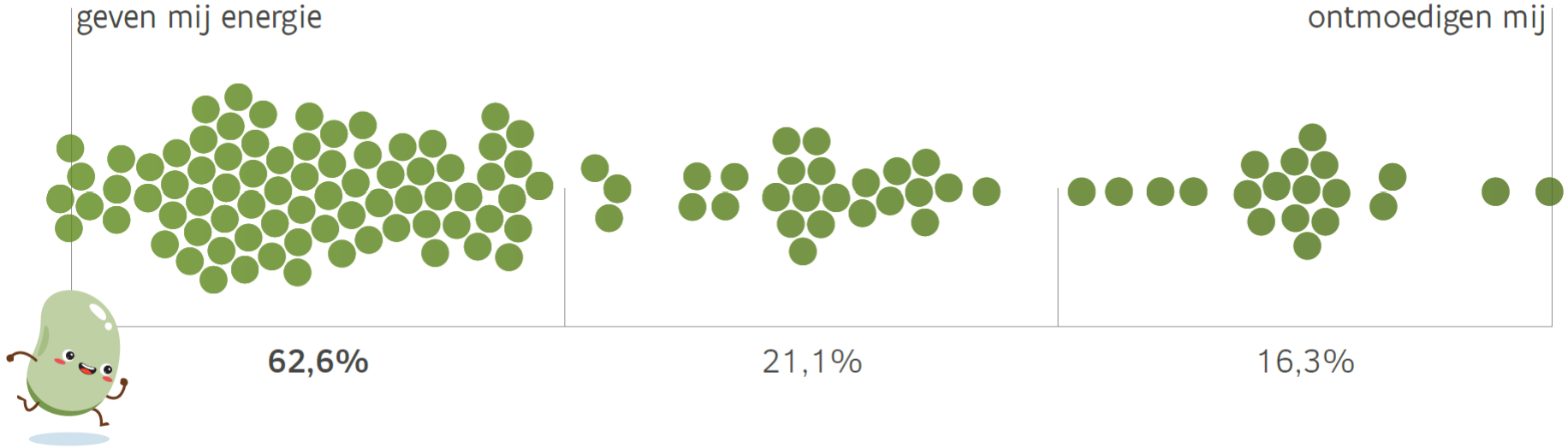
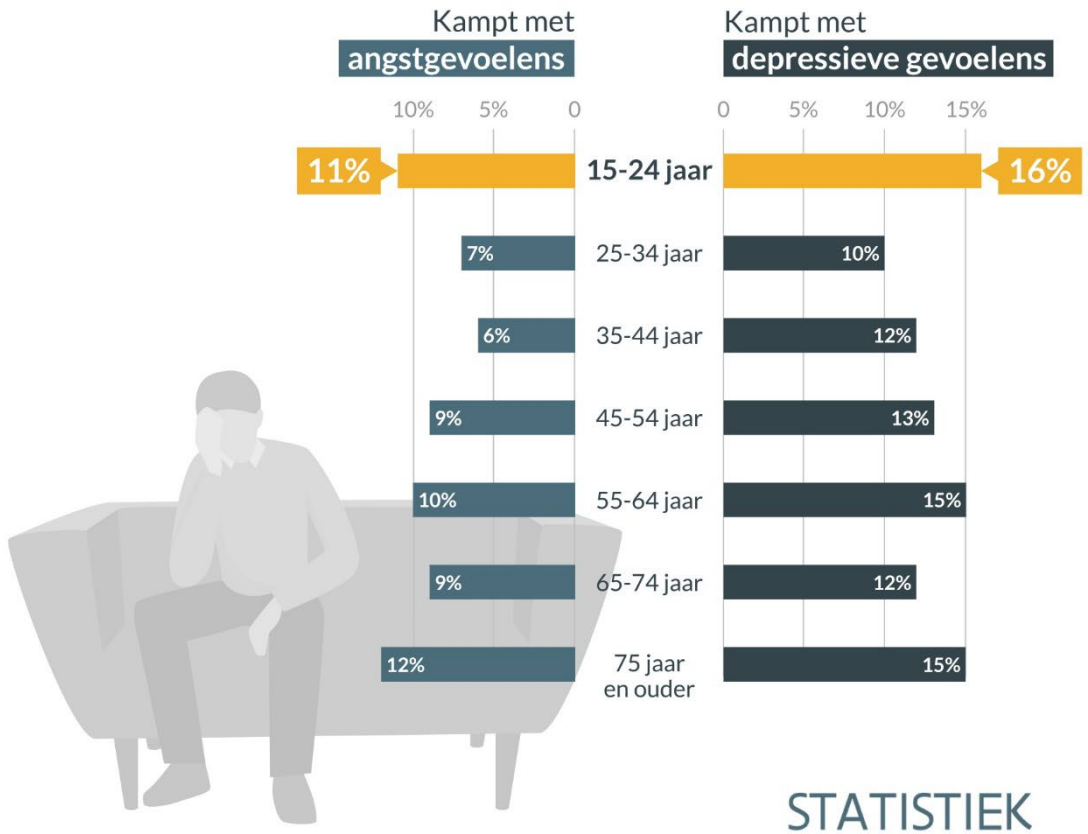


Meer psychische klachten bij jongeren tussen 15 en 24 jaar



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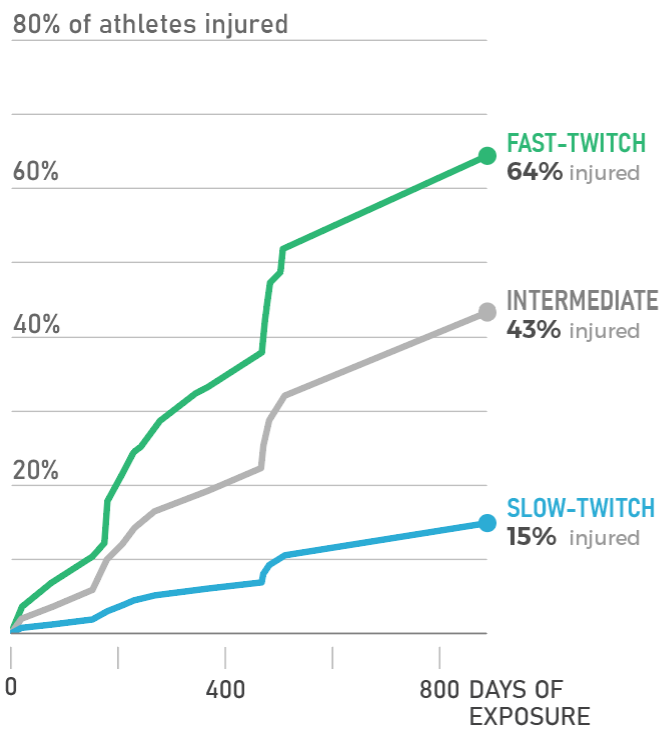

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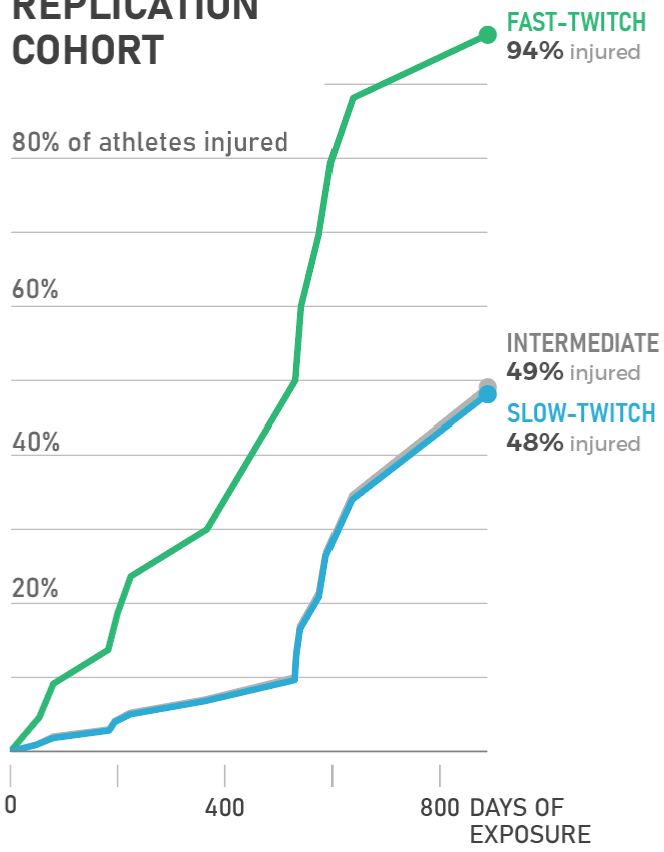

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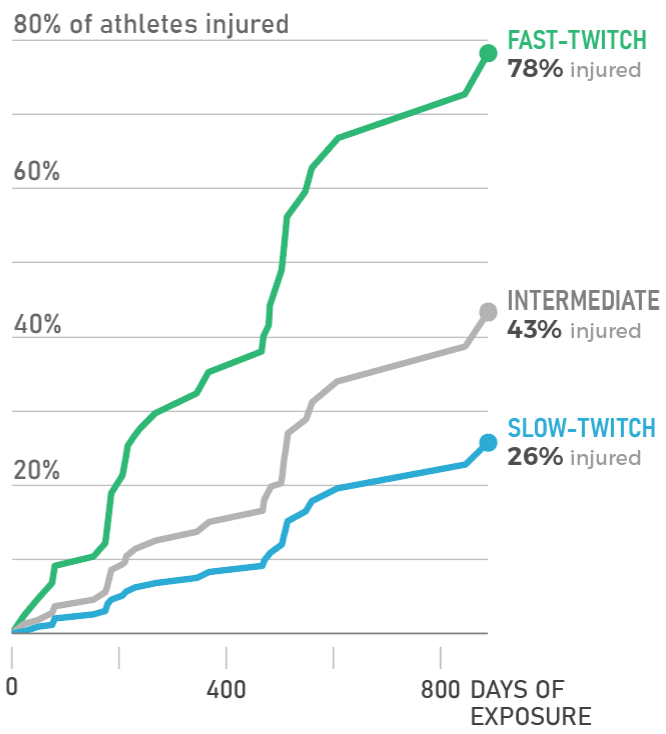

x-height

Data visualization

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Data visualization

serif

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The x-height of a typeface affects readability at small sizes. **Playfair Display** 10px

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Data visualization

counter

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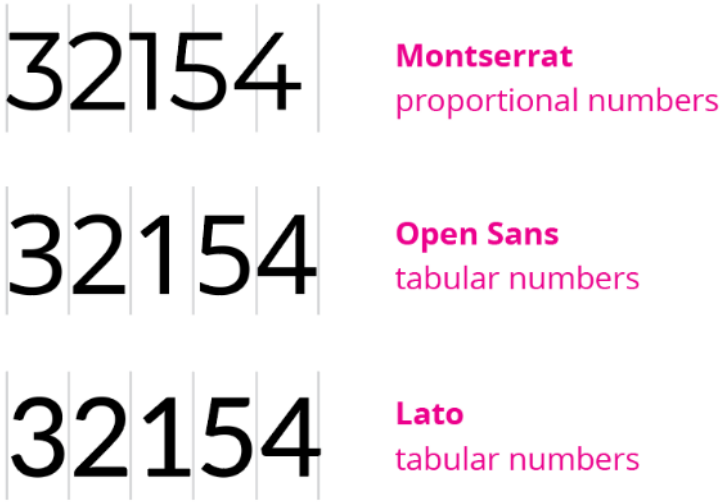

proportional vs **tabular** numbers

Proportional	Tabular
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Bahnschrift

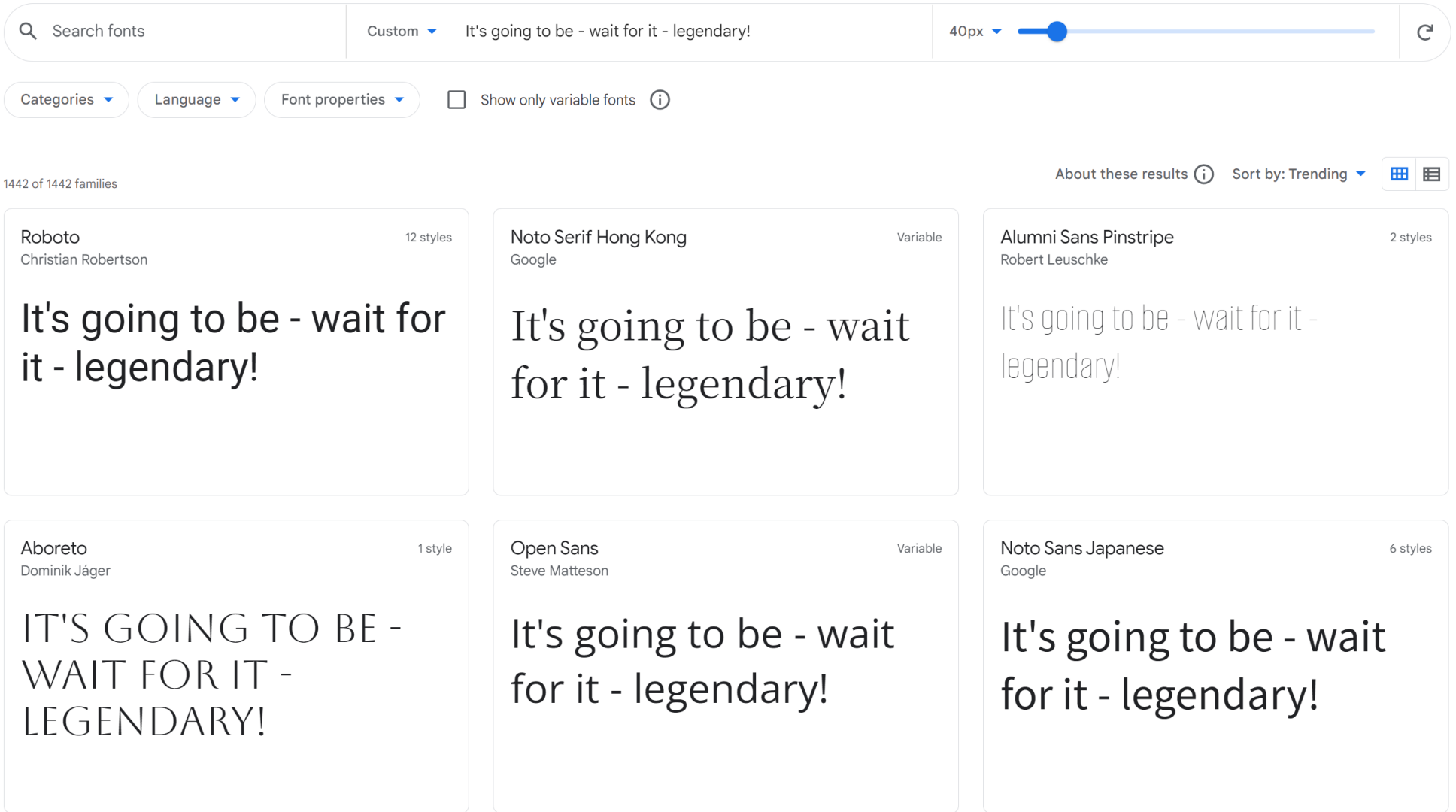
IBM Plex Sans

Lato

Noto Sans

Roboto

Source Sans Pro



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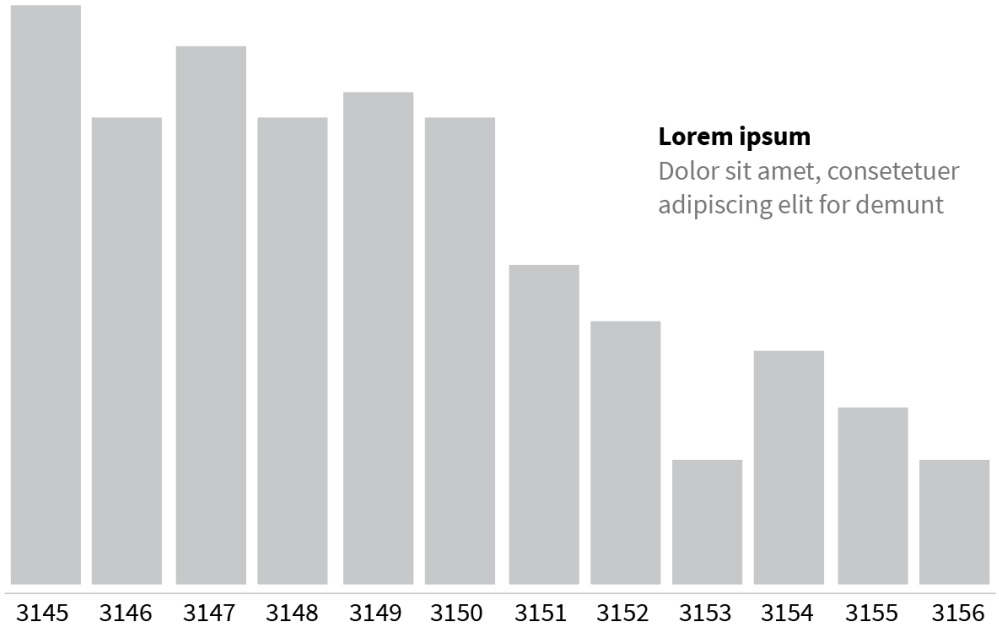

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Notes: wikipedia and census.org

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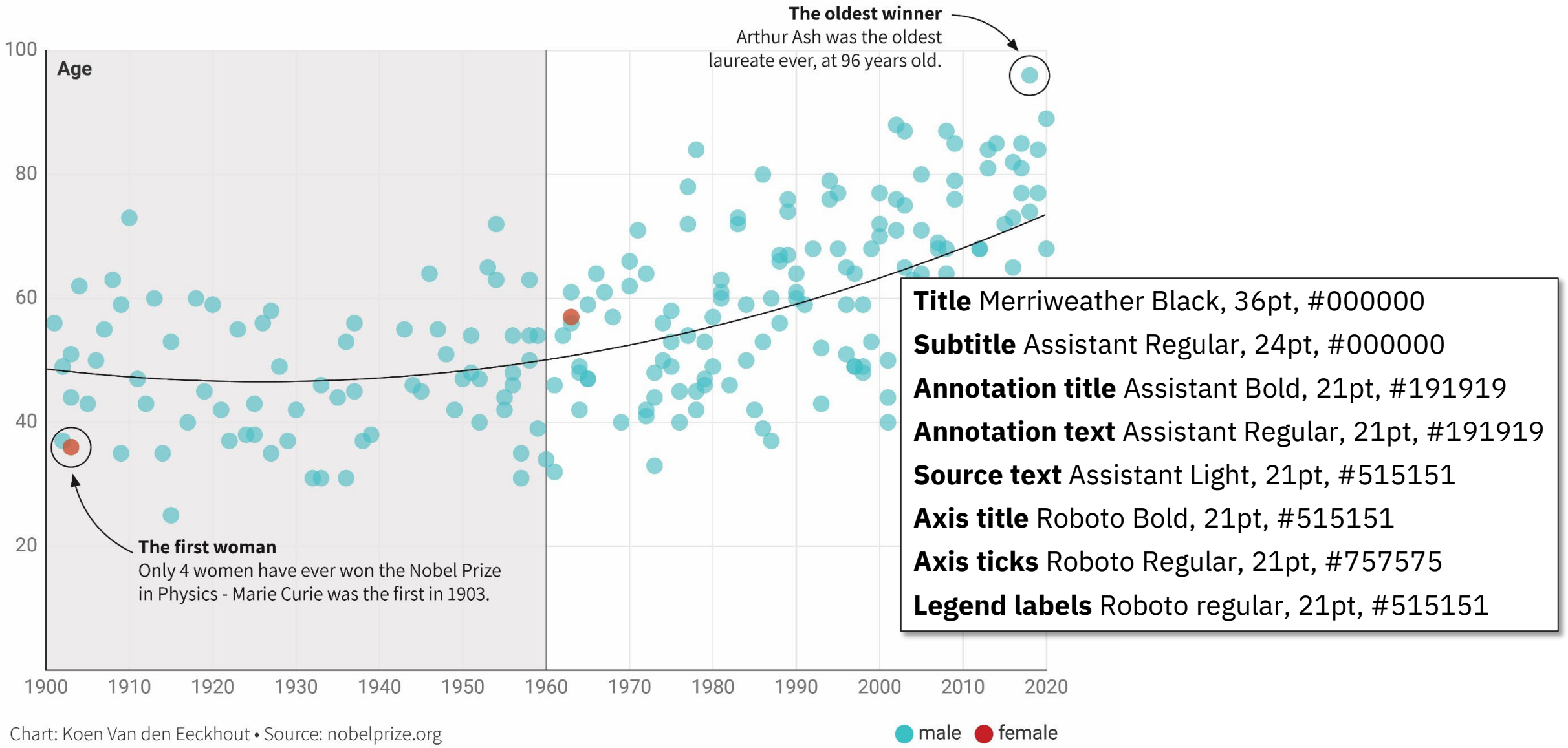
Nobel Prize winners are getting older

Before 1960, the average age of Nobel Prize in Physics laureates was 48 years.
Since 1960 this increased to 61 years, and the upward trend continues.



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Adapt to the situation – a presentation is different from an article, a poster or a social media post!

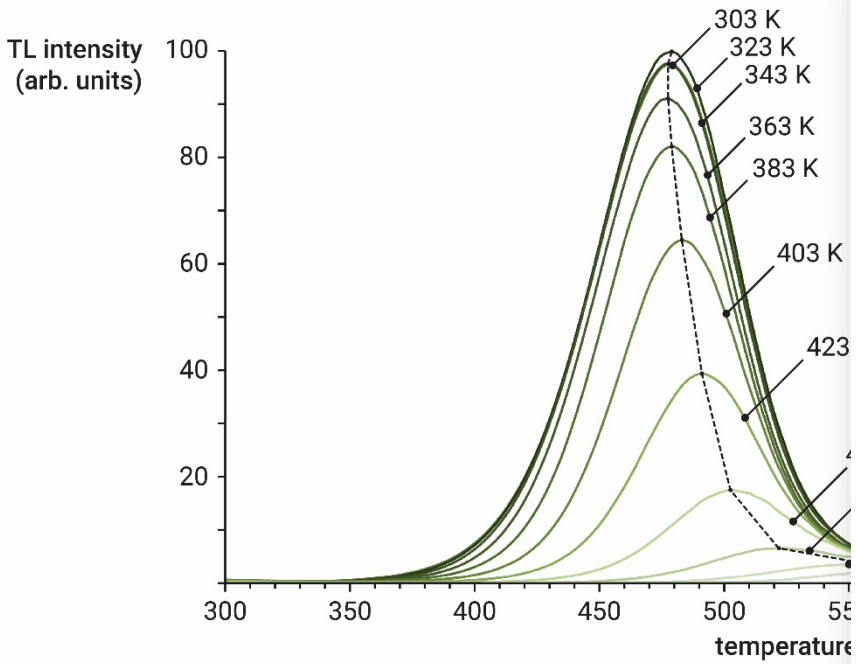
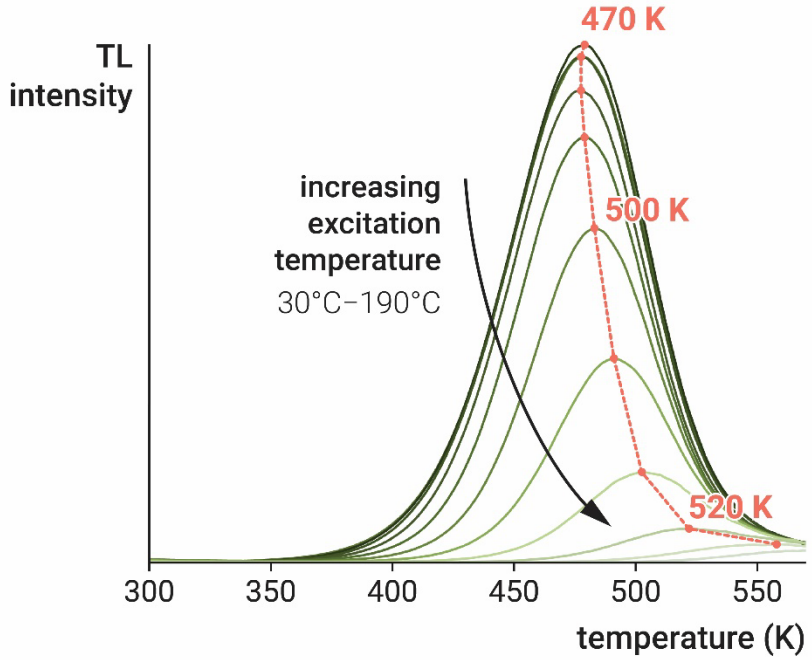


Figure 5.19: TL intensity of $CaAl_2O_4$:Eu,Nd for various excitat temperatures T0, as indicated. Samples were excited at T0 by nm light for 60 s. For increasing excitation temperatures, the intensity decreases due to a lower fraction of filled traps, and peak location shifts to higher temperatures.

Changing the excitation temperature reveals higher order behaviour



for higher excitation temperature:

- decrease in TL intensity due to lower fraction of filled traps
- shift of peak location to higher temperatures

Captions

Well-crafted captions can make a visual ‘self-contained’.

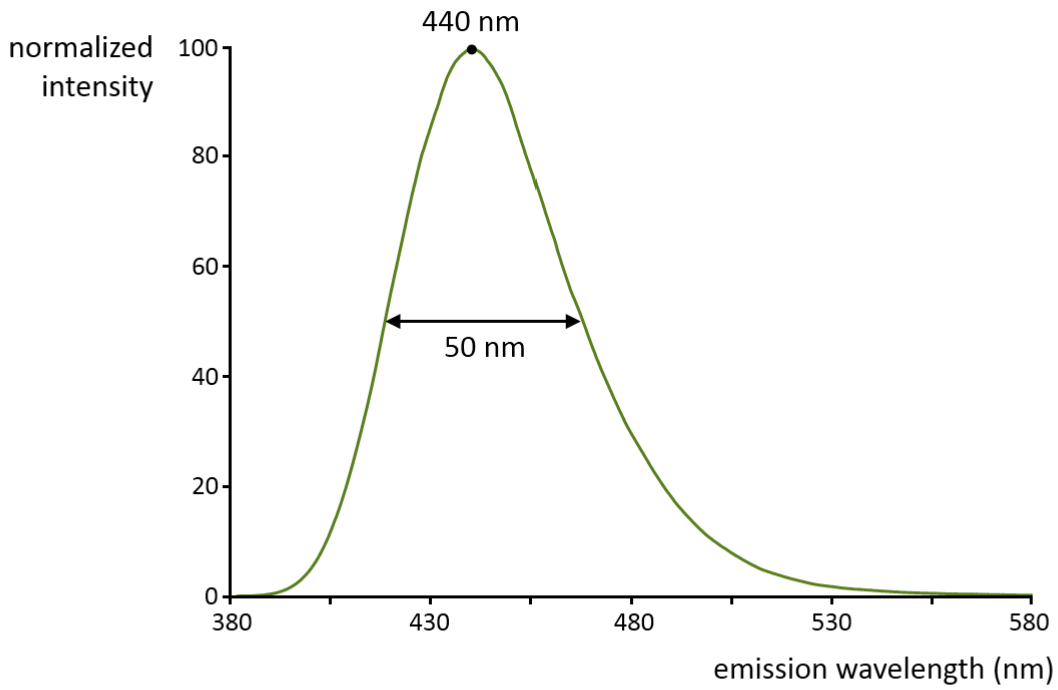


Figure 5.11: The emission spectrum of $CaAl_2O_4$:Eu,Nd consists of a single, unusually broad Eu^{2+}-based peak in the blue region of the visible spectrum, around a relatively low wavelength of 440 nm.

4 Trapping and detrapping kinetics

Some of the results of this chapter have been published in:

- **Luminescence and x-ray absorption measurements of persistent $SrAl_2O_4$:Eu,Dy powders: Evidence for valence state changes**
  Kathleen Korthout, Koen Van den Eeckhout, Jonas Botterman, Sergey Nikitenko, Dirk Poelman and Philippe F. Smet
  Physical Review B **84** (2011) 085140
- **Temperature and wavelength dependent trap filling in $M_2Si_5N_8$:Eu (M = Ca, Sr, Ba) persistent phosphors**
  Philippe F. Smet, Koen Van den Eeckhout, Adrie J.J. Bos, Erik van der Kolk and Pieter Dorenbos
  Journal of Luminescence **132** (2012) 682-689

The XANES analysis in this chapter (section 4.2.4) is part of the PhD research: "Site selective spectroscopy of rare earth doped luminescent materials", conducted by Kathleen Korthout (LumiLab research group) and was performed at the DUBBLE beamline BM26 at the ESRF in Grenoble, France.

To unravel the mechanism of persistent luminescence, we need to know what is happening inside the material during the afterglow, and also during the excitation phase. We want to know how charge carriers escape from the activators, how they move throughout the material to get caught by trap levels, and how they can be released again under the influence of thermal energy. In short, we want to know more about the kinetics of the charge carriers inside the persistent phosphor.

There are two complementary ways to find out more about these kinetics. On one hand, we can look at the behaviour of the luminescent intensity, both during and after the excitation. From the shape of these curves, and from the way this shape changes under various circumstances, we can draw conclusions on the behaviour of the charge carriers.

On the other hand, we can test our assumptions on the kinetics by building a basic model, and predicting how the associated charging and decay will behave. We can then try to modify our assumptions in order to obtain the best possible accordance between the expected and the observed behaviour.

In this chapter, these *bottom-up* and *top-down* approaches are closely intertwined. We will start by looking at the detrapping kinetics, and see how retrapping can influence

the shape of the afterglow decay. We will build some basic models to mimic the trapping kinetics and predict the shape of the emission intensity during excitation. We will probe the valence state changes of the luminescent centers during the excitation phase. Finally, we will try to make an estimate on the number of traps present in a persistent luminescent material.

4.1 Detrapping kinetics

First, we will consider the detrapping process. During the afterglow phase, there is no excitation of luminescent centers. The only charge carriers involved are those that were previously trapped, and are escaping from the trap levels they were caught at.

Even though we can describe this behaviour with a very basic three-level model, the related equations can become complicated very quickly, and it is necessary to make several assumptions in order to keep the problem manageable.

4.1.1 One trap/one center model

In the most basic model, known as the **one trap/one center** model, we only take three levels into account: the *ground state* of the luminescent center, the *trap level*, and an *excited state* which acts as an intermediate stage for the charge carriers. In practice, this excited state is a simplification of the conduction band, allowing transport between the luminescent centers and the traps. Only three processes are possible: *detrapping* (from the trap level into the excited state), *recombination* (from the excited to the ground state), and *retrapping* (from the excited state into a trap level). These three levels and three processes are shown schematically in figure 4.1.

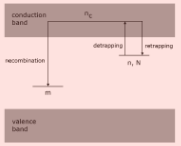


Figure 4.1: In a simple one trap/one center model, only three levels are taken into account and only three transitions are allowed: detrapping, retrapping and recombination.

The model in figure 4.1 assumes that electrons are the charge carriers, and that the transport to the traps occurs through the conduction band. However, all the equations

derived below are equally valid in the case of hole transport, and the transport does not necessarily have to happen through the conduction band.

We can write down rate equations for each of these three energy levels, based on the probability for each of the processes to occur and the occupation of each level. The details of these calculations are beyond the scope of this text, but an excellent explanation can be found in [1]. By assuming charge neutrality, time and temperature independence of the charge carriers concentrations and quasi-equilibrium (the free electron concentration in the excited level is quasi-stationary), we can derive the **General One Trap** (GOT) expression for the emission intensity:

$$I(t,T) = ns\exp\left(-\frac{E_T}{kT}\right)\left[1 - \frac{(N-n)\sigma_n}{(N-n)\sigma_n + m\sigma_{rec}}\right] \tag{4.1}$$

In this equation, σ_{rec} is the cross section for recombination, and σ_n that for retrapping. It is the ratio between these two cross sections that will mainly influence the shape of the afterglow decay. n is the concentration of filled traps, N the total concentration of traps (both filled and unfilled), and m the concentration of ionized luminescent centers, available for recombination (hole states). As usual, s is the frequency factor, E_T is the trap depth, k is the Boltzmann constant and T is the temperature.

Since n in equation 4.1 depends on the time and temperature, the GOT expression is a rather complex differential equation. At this point, it is common to introduce approximations in order to make solving the equation more manageable.

4.1.2 First and second order kinetics

As early as 1945, Randall and Wilkins [2] made the assumption that the retrapping probability is negligible. In other words, every escaped charge carrier will recombine, and $\sigma_n = 0$. This assumption is known as **first order kinetics**, and greatly simplifies the GOT expression to

$$I = ns\exp\left(-\frac{E_T}{kT}\right) \tag{4.2}$$

If we assume a constant temperature, we can predict the shape of the afterglow decay, which in this case will have an exponential shape:

$$I(t) = I_0\exp\left[-s\exp\left(-\frac{E_T}{kT}\right)t\right] \tag{4.3}$$

The expected exponential decay is shown in figure 4.2 for various trap depths.

In practice, a simple exponential decay is rarely observed in actual persistent luminescent materials. In fact, a power-law like behaviour is much more common [3]. This means that a simple one trap/one center model without retrapping is not sufficient.

Garlick and Gibson [4] therefore explored the possibility of recombination and retrapping having an equal probability. In other words, they assumed $\sigma_n = \sigma_{rec}$. Now, the GOT expression becomes

$$I = s\cdot\frac{n^2}{N}\cdot\exp\left(-\frac{E_T}{kT}\right) \tag{4.4}$$

The fact that the intensity is now proportional to the square of the density of filled traps n is the main reason that this assumption is known as **second order kinetics**. Now,

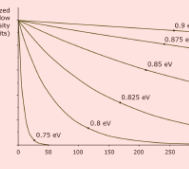


Figure 4.2: Afterglow decay in the case of first order kinetics for several different trap depths. The shape of the decay is exponential, the decay speed is determined by the trap depth. In this figure, $s = 10^{12}$ s^{-1} and T = 293 K. The curves are normalized for easy comparison.

the afterglow decay is no longer expontial, but has a power-law like behaviour:

$$I(t) = I_0\left[1 + \frac{n_0}{N}s\exp\left(-\frac{E_T}{kT}\right)t\right]^{-2} \tag{4.5}$$

This means that, when plotted in a double-logarithmic diagram, the afterglow decay will approach a straight line with a slope of -2. The second order decay shape is shown in figure 4.3 for various trap depths. Upon comparison with the exponential first order decay (figure 4.2), we can see that the intensity approaches zero much more slowly and gradually.

4.1.3 General order kinetics

It is clear from the above discussion that first and second order kinetics refer to two very specific cases: when the retrapping probability is negligable, or when it is exactly the same as the recombination probability. For intermediate situations, May and Partridge [5] and Rasheedy [6] developed an empirical expression based on equations 4.2 and 4.4:

$$I = s\cdot\frac{n^b}{N^{b-1}}\cdot\exp\left(-\frac{E_T}{kT}\right) \tag{4.6}$$

where b is the order of kinetics.

This expression, known as **general order kinetics**, leads to a smooth transition between the decay shapes of first ($b = 1$) and second ($b = 2$) order kinetics (and beyond). This is illustrated in figure 4.4 for various orders of kinetics b.

It should be noted that the general order kinetics expression is a purely mathematical interpolation between the cases of first and second order kinetics, and that a certain order b has no direct physical meaning.

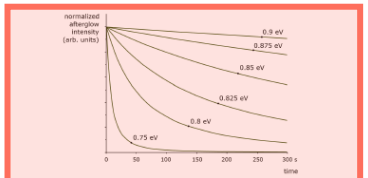


Figure 4.3: Afterglow decay in the case of second order kinetics for several different trap depths. The decay has a power-law like behaviour. On longer timescales, the decay drops to zero much slower than in the case of first order kinetics. In this figure, $s = 10^{12}$ s^{-1}, T = 293 K and $n_0/N = 1/2$. The curves are normalized for easy comparison.

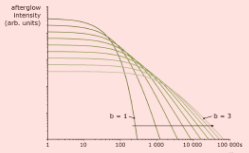


Figure 4.4: Afterglow decay for different orders of kinetics ranging from 1 to 3, assuming general order kinetics. The decay is plotted on a log-log scale. For $b = 1$, an exponential decay is obtained.

It is interesting to verify how well the general order kinetics expression compares to a more physical interpolation between the first and second order expressions. For this purpose, let us introduce the parameter R as the ratio between the retrapping and the recombination probability:

$$R = \frac{\sigma_n}{\sigma_{rec}} \tag{4.7}$$

which leads to the following simplification of the GOT expression:

$$I = s\cdot\frac{n^2}{(N-n)\cdot R + n}\cdot\exp\left(-\frac{E_T}{kT}\right) \tag{4.8}$$

If retrapping can be neglected, $R = 0$ and equation 4.8 reduces to the first order case. For equal probabilities of retrapping and recombination, $R = 1$ and the second order case is obtained.

Figure 4.5: Comparison between the functions x^b and $f(x) = x^2/(R-Rx+x)$ for various values of b and R. In the case of first ($b = 1$, $R = 0$) and second ($b = 2$, $R = 1$) order kinetics, the curves overlap.

Even though equation 4.8 is difficult to solve analytically, we can make a comparison with the general order case by comparing the functions x^b (for the general order case) and $f(x) = x^2/(R-Rx+x)$ (for the more physical expression). This comparison is made in figure 4.5. The value $x = 0$ corresponds to empty traps ($n = 0$), $x = 1$ is the situation where all traps are completely filled ($n = N$).

In the case of first ($b = 1$, $R = 0$) and second ($b = 2$, $R = 1$) order kinetics the curves for x^b and $f(x)$ overlap, but for intermediate values of b, and even more for high b values, there is a clear difference between both options. In this region, fitting an experimentally obtained afterglow decay or glow peak to a curve predicted by general order kinetics will yield less accurate results.

4.1.4 Influence of the excitation intensity

Figure 4.6 shows how the afterglow decay in $SrAl_2O_4$:Eu,Dy is influenced by the excitation intensity. The sample was excited by a Xe arc lamp for 1 minute, with intensities varying from 10 to 1000 lux.

The decay profiles are not exponential, but approach a straight line in a double-logarithmic diagram, indicating at least some influence of retrapping, the presence of a continuous trap distribution, or the possibility of tunneling processes. As could be

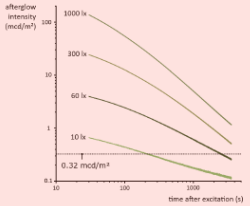


Figure 4.6: Afterglow decay in $SrAl_2O_4$:Eu,Dy for various excitation intensities of a Xe arc lamp (excited for 1 minute). At higher excitation intensities, the light output during the afterglow increases, but the decay becomes faster.

expected, the total light output increases with increasing excitation intensity, because more traps are being filled. However, a second phenomenon can also be discerned. At higher excitation intensities, the slope of the afterglow decay also increases. In other words, the decay of the luminescence becomes faster for higher excitation intensities.

To investigate this more accurately, the evolution of the light output versus the excitation intensity is plotted in figure 4.7, and the evolution of the afterglow duration, defined as the time between the end of the excitation and the moment the intensity drops below 0.32 mcd/m^2, in figure 4.8.

From figure 4.7, we can see that the light output is proportional to the excitation intensity. In other words, the number of filled traps increases linearly with increasing excitation intensity. However, the afterglow duration does not follow this trend. At around 600 lux, it reaches a saturation value of approximately 4 hours (figure 4.8).

The increasing slope of the decay tells us that the detrapping rate is increasing after excitation with higher intensities. This might mean that either shallower traps are being filled at higher excitation intensities, or that the larger number of filled traps leads to a faster detrapping.

The first explanation assumes that multiple trap levels, or even a continuous distribution of trap levels exist in the material. At low intensity, only the deeper levels would be filled, which explains the slower decay of the afterglow. However, in chapter 5 we will see that the excitation duration does not influence the depth of the traps that are filled, even in the presence of a continuous trap depth distribution. Of course, it is possible that increasing the excitation duration has a different effect on the trap filling

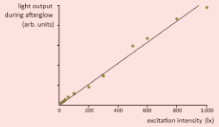


Figure 4.7: Integrated light output during the afterglow in $SrAl_2O_4$:Eu,Dy for various excitation intensities of a Xe arc lamp (excited for 1 minute). For increasing excitation intensities, the light output increases proportionally.

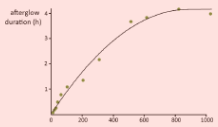


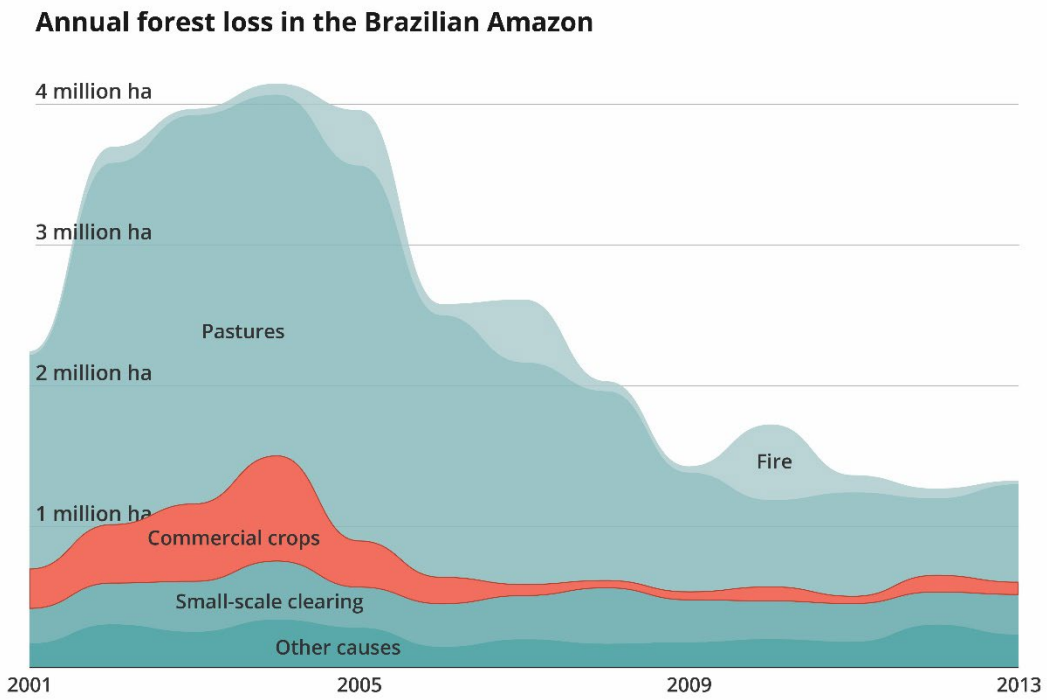
Figure 4.8: The afterglow duration in $SrAl_2O_4$:Eu,Dy for various excitation intensities of a Xe arc lamp (excited for 1 minute). For higher excitation intensities, a saturation value is reached.

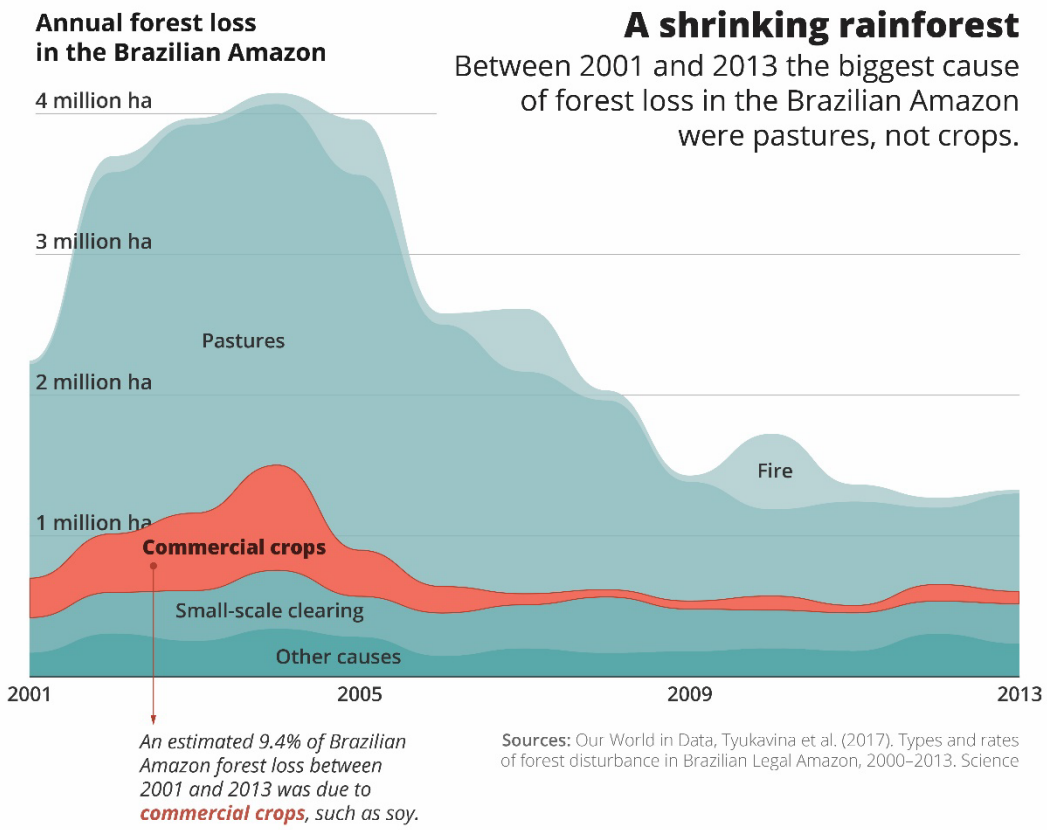
than increasing the excitation intensity.

To conclude this section, it is interesting to remark that even for very low excitation intensities, charge carriers can be trapped. In figure 4.9, the emission intensity is shown for a (previously thermally emptied) $CaAl_2O_4$:Eu,Nd sample subjected to a very low excitation intensity. Even though no emission from the sample is observed during the excitation phase, thermoluminescence (TL) reveals a glow peak, indicating that at least some traps were filled by the excitation light (see section 5.1.1 for an explanation of thermoluminescence). This observation indicates a remarkably high trapping probability in $CaAl_2O_4$:Eu,Nd, which will be confirmed in section 4.2.1.

Annotations

Well-crafted titles, captions and annotations can make a visual ‘self-contained’.





Break

All the slides and all the links:

baryon.be/dataviz-resources

Components

Colors

Illustrations

Typography

15’ break

Advanced data visualization

Interactive data visuals

Programming data visuals

Advanced data visualization

Interactivity

Types of interactivity

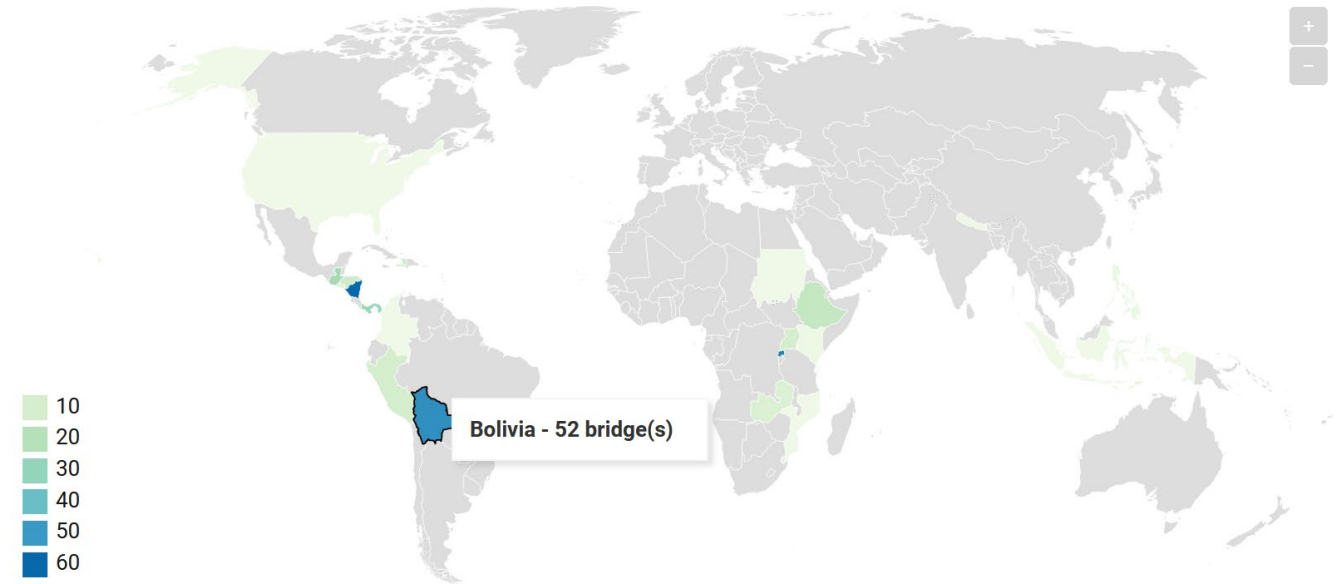
tooltips

filtering and navigation

storytelling

Key figures

Since 2001, Bridges to Prosperity has worked with communities in **20 countries** to build **318 bridges** that collectively provide safe access to **1.1 million people**:



Source: Bridges to Prosperity • Get the data • Created with Datawrapper

Bridges to Prosperity currently operates field programs in Bolivia, Rwanda, Uganda, and is currently in its first year of a scaling initiative in Rwanda, which will see the completion of more than 300 footbridges over a five-year period, creating new and safe access for more than a million people. Independent

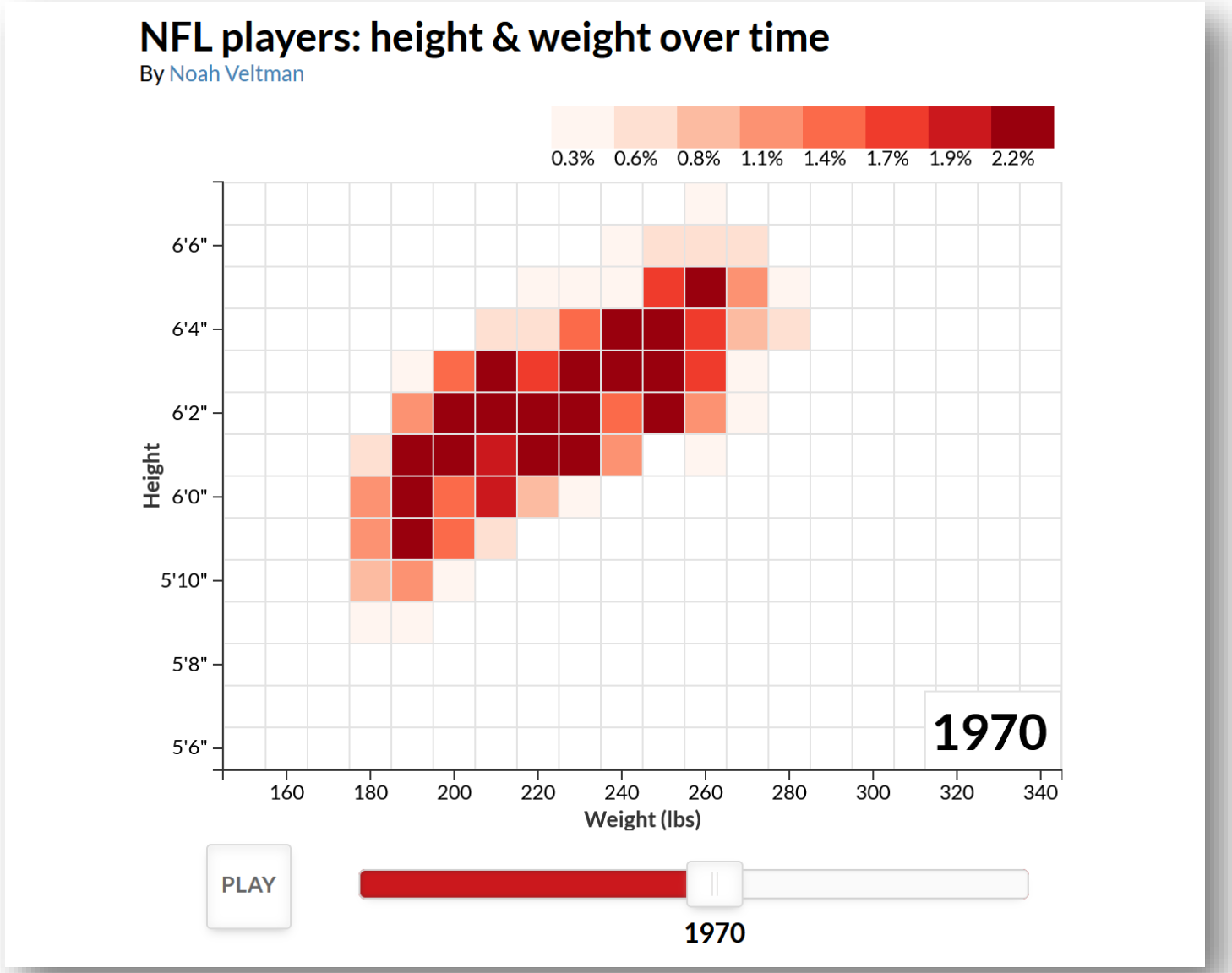
baryon.be/files/MM/2020/W04

Types of interactivity

tooltips

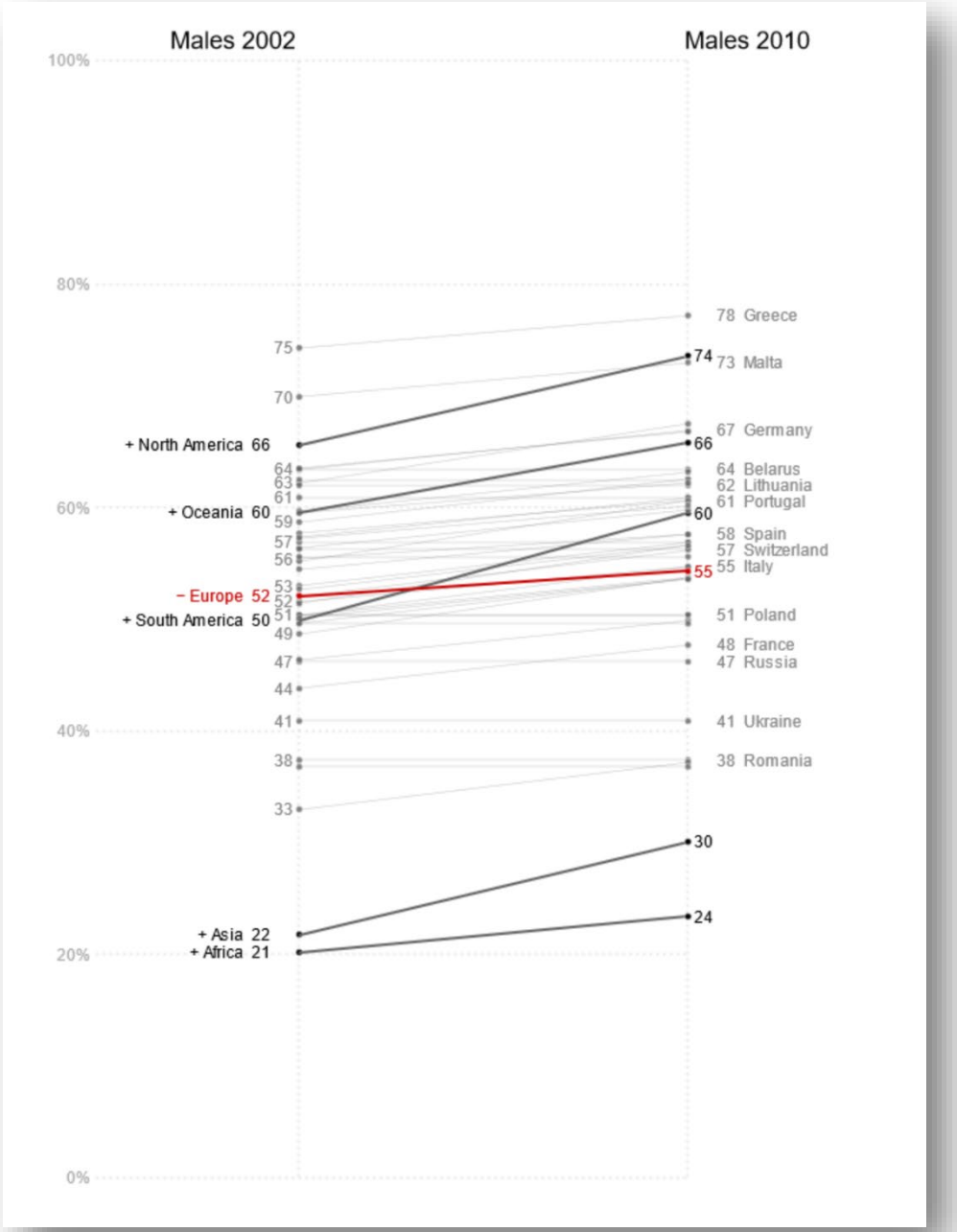
filtering and navigation

storytelling



Noah Veltman

noahveltman.com/nflplayers



Jeff Clark

neoformix.com/Projects/ObesitySlope

Types of interactivity

tooltips

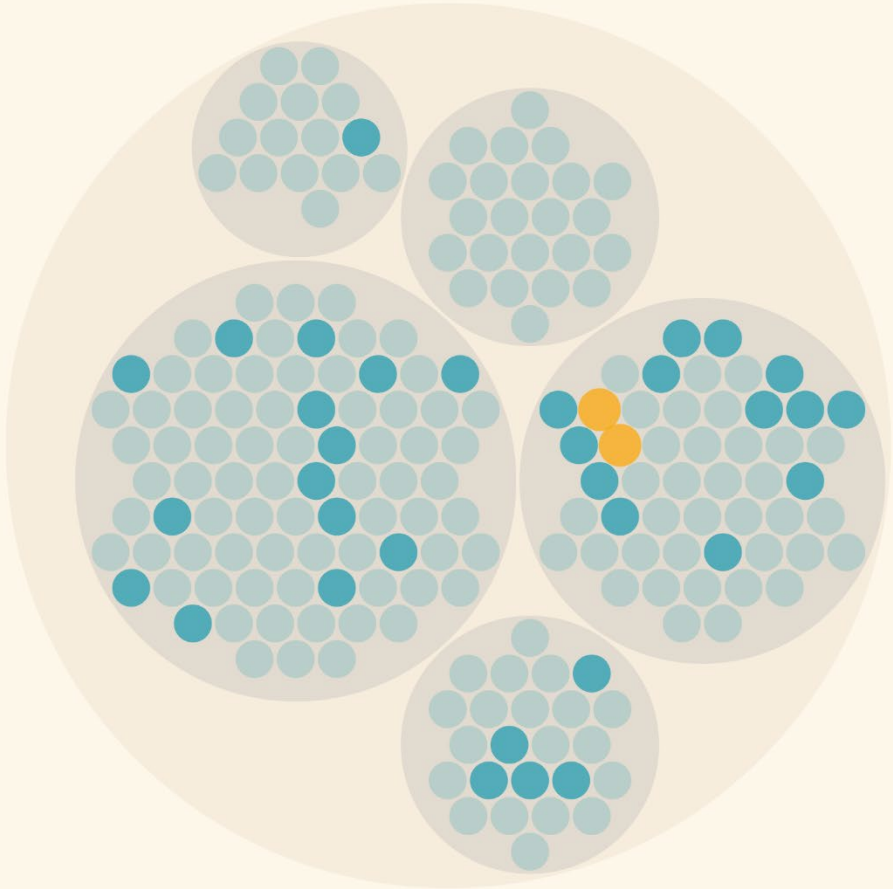
filtering and navigation

storytelling

DE TIJD

35 startups verleggen de grenzen

De voorbije vijf jaar zijn er **35 nieuwe biotechbedrijven** ontstaan in ons land. Ze ontdekken nieuwe technieken om ziektes aan te pakken. Soms zoeken ze heel gericht, zoals **Camel IDS**, dat kanker bestrijdt met elektrische fietsjes in het bloed. Maar soms verleggen ze grenzen voor alle ziektes, zoals **Confo Therapeutics**, dat schakelaars identificeerde die molecules aan en uit kunnen zetten om ziektes af te blokken.

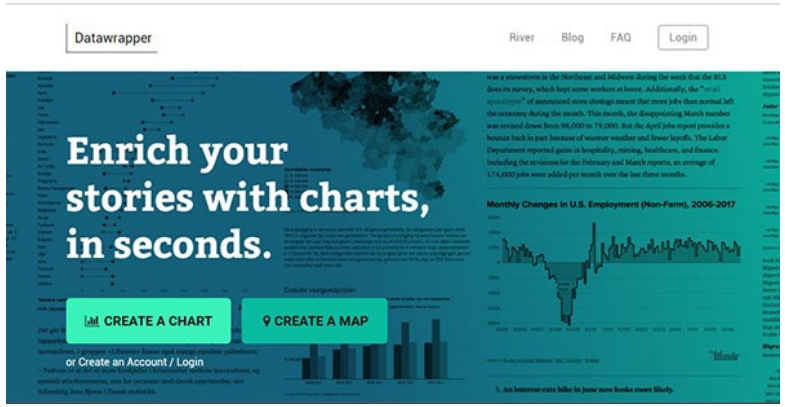


De Tijd

multimedia.tijd.be/biotechrevolutie

Available tools

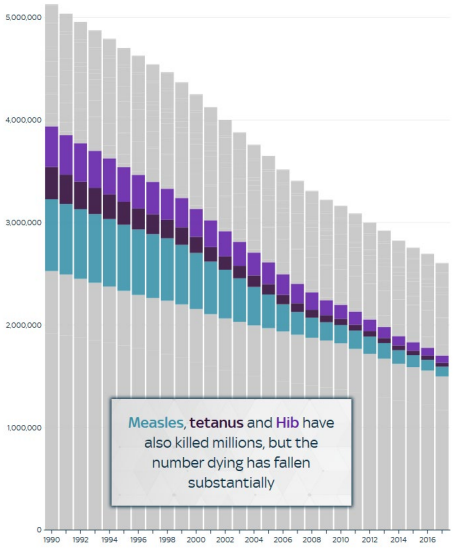
Interactive chart tools



Datawrapper

datawrapper.de

charts to embed in a website,
charts with tooltips



Flourish

flourish.studio

storytelling
with charts

baryon.be/data-visualization-tools-datawrapper

Demo

Nobel Prize winners are getting older

Before 1960, the average age of Nobel Prize in Physics laureates was 48 years.
Since 1960 this increased to 61 years, and the upward trend continues.

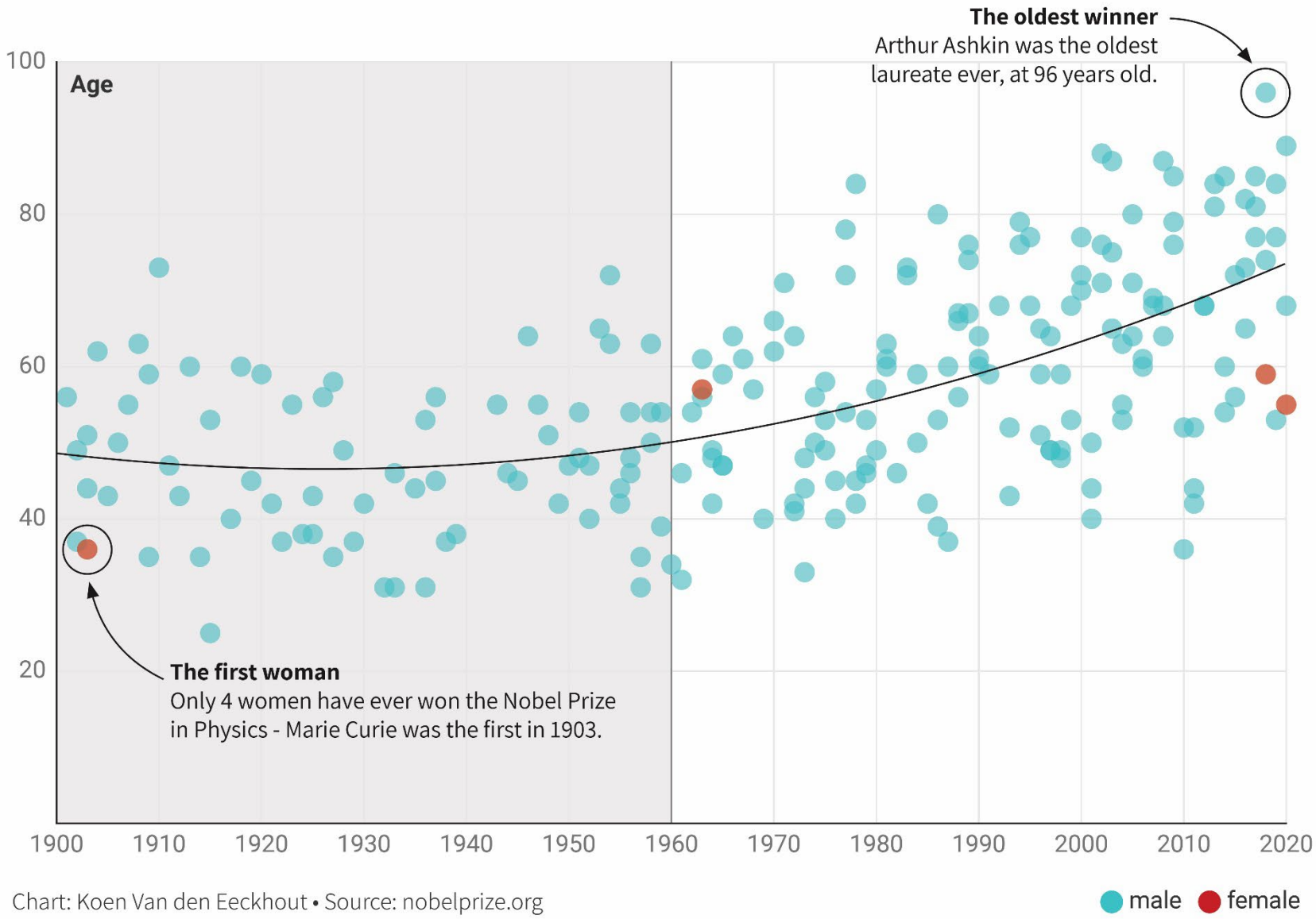


Chart: Koen Van den Eeckhout • Source: nobelprize.org

Embedding

into WordPress, Medium,...

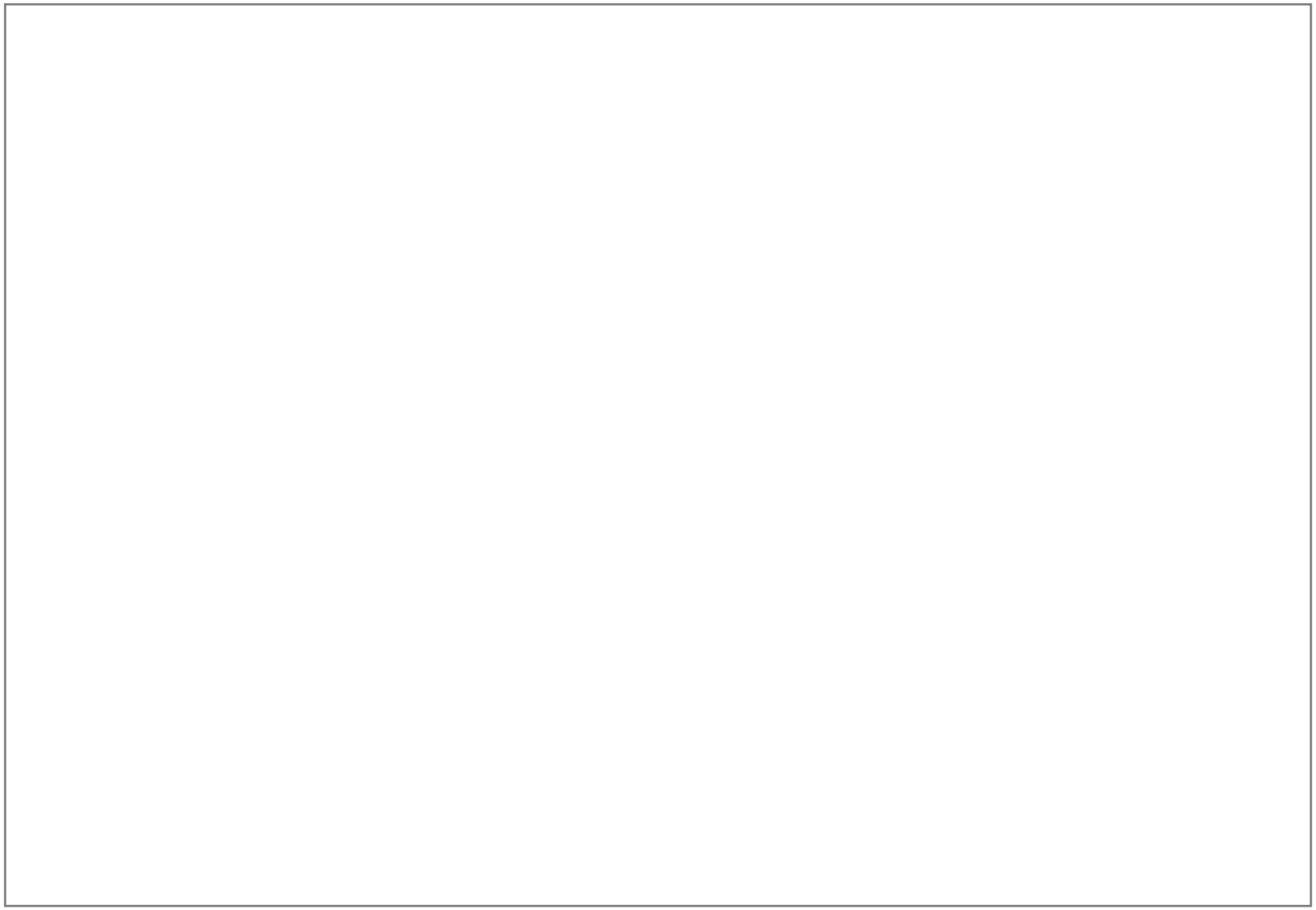
into PowerPoint

Nobel Prize winners are getting older and older

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Pellentesque a consectetur dolor. In pellentesque, risus at ullamcorper pellentesque, risus nisl faucibus sapien, sed elementum elit eros sed metus.

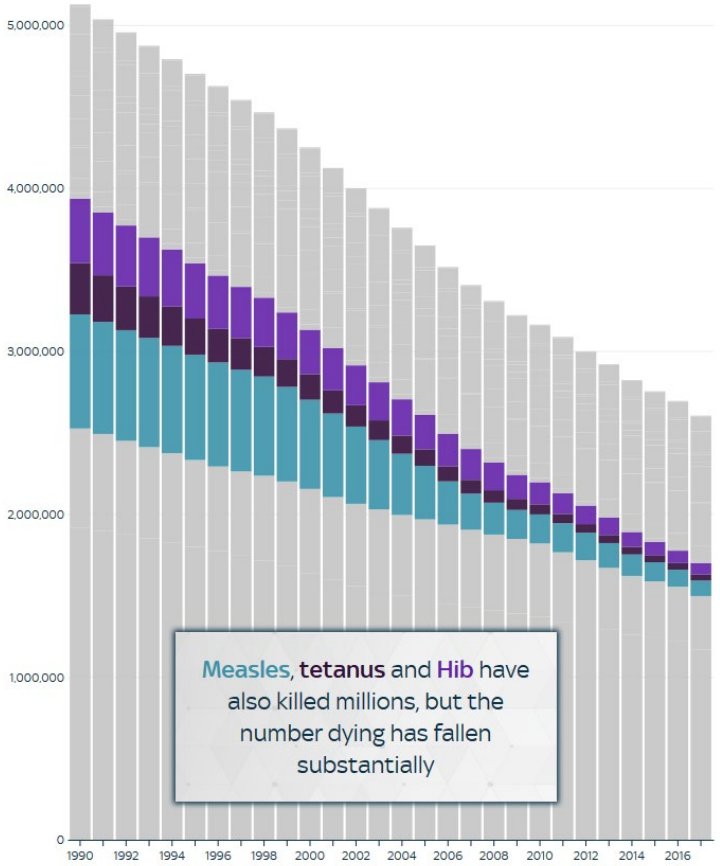
Mauris nunc turpis, iaculis quis purus quis, accumsan pellentesque arcu. Fusce malesuada ante eu nunc rhoncus cursus. Ut varius ligula elit, nec facilisis tortor condimentum id. Pellentesque id pulvinar neque. Ut scelerisque odio eget convallis vestibulum. Nullam ac ex dolor.

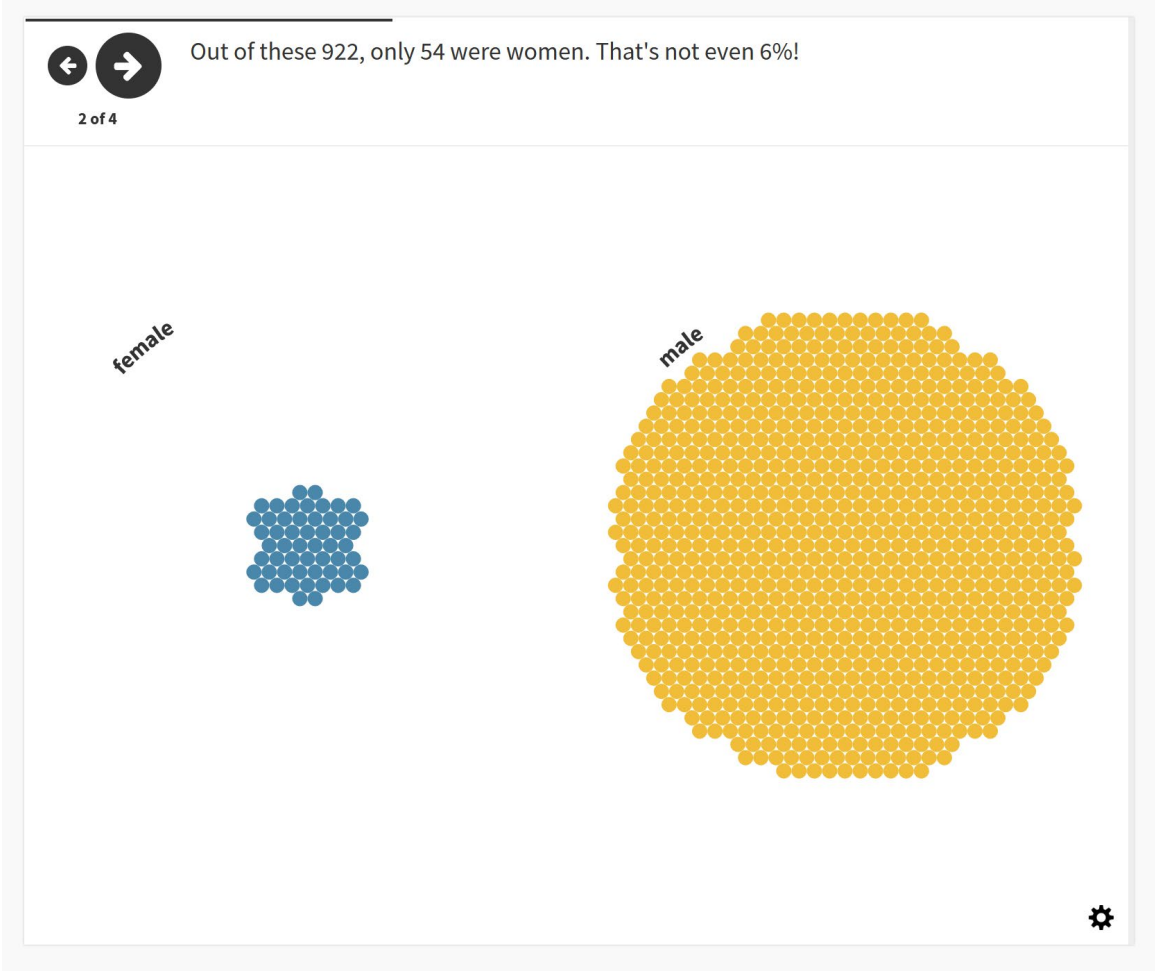
Praesent lacus massa, posuere id quam id, ullamcorper aliquam odio. In nibh leo, feugiat in rutrum vitae, semper a arcu. Curabitur pellentesque elit sed lacus condimentum, in aliquet lacus accumsan. Vestibulum fermentum tincidunt mattis. Donec nisi est, rhoncus vitae laoreet quis, elementum id nisi. Vestibulum porta ex vel pellentesque convallis.



Flourish

flourish.studio

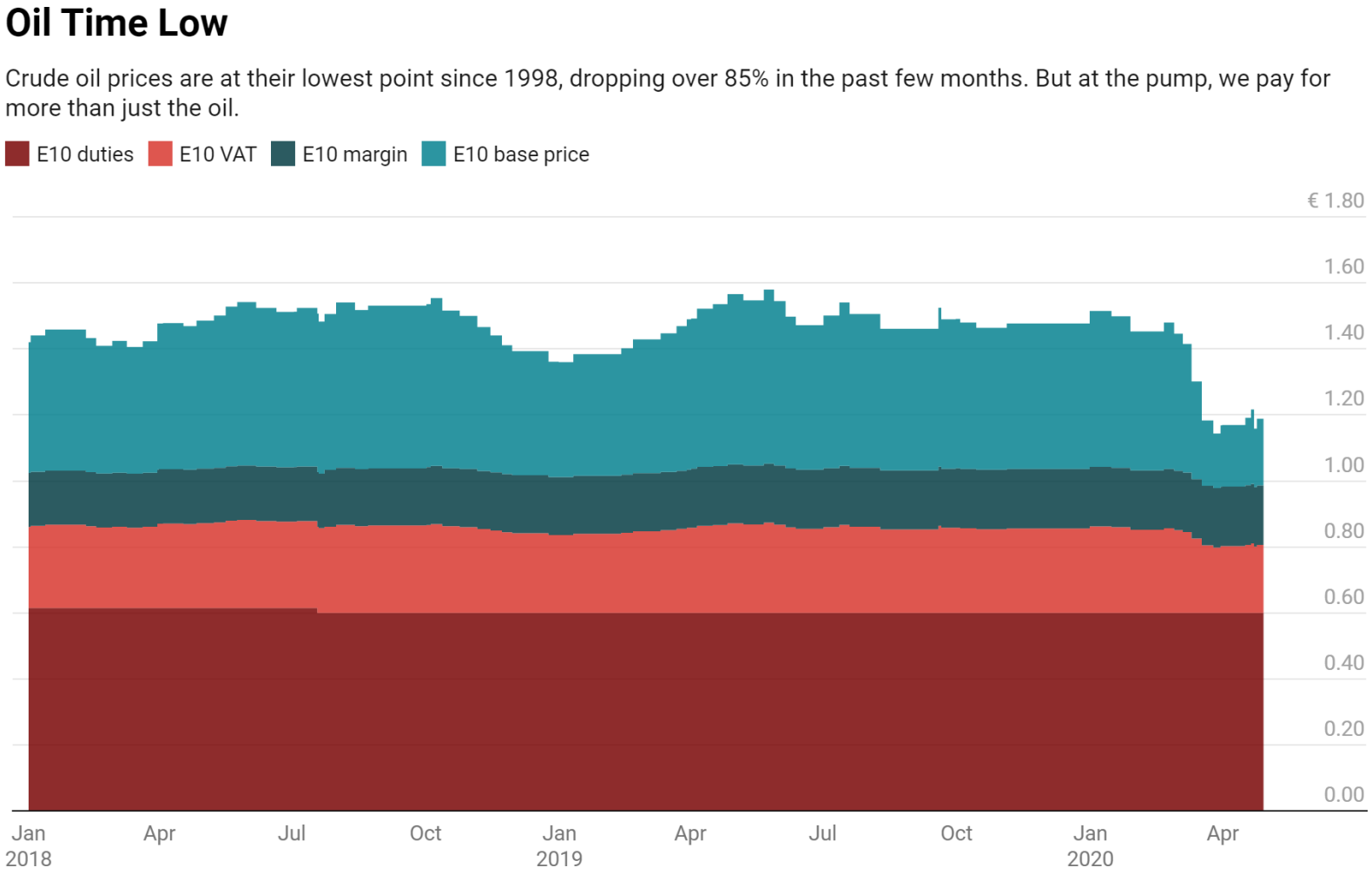




Exercise

Try to mimic the data visual on the right using Datawrapper.

You can find the data in a Google Sheet at: http://tiny.cc/datawrapper-demo

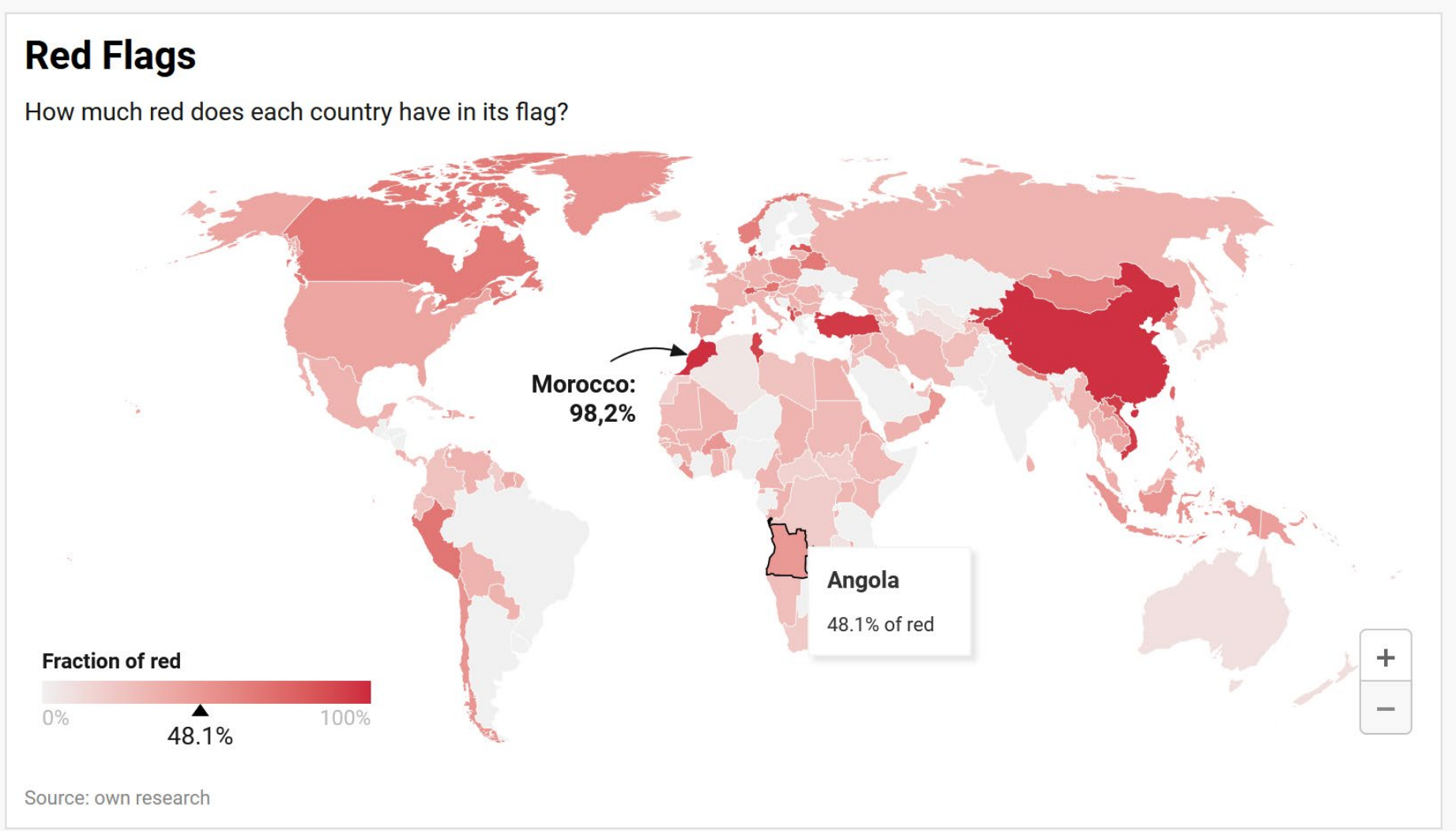


Exercise

Try to mimic the data visual on the right using Datawrapper.

You can find the data on https://baryon.be/files/workshop/flags.xlsx

(Pay attention to all the details!)



Programming

Programming languages for data visualization

R

Python

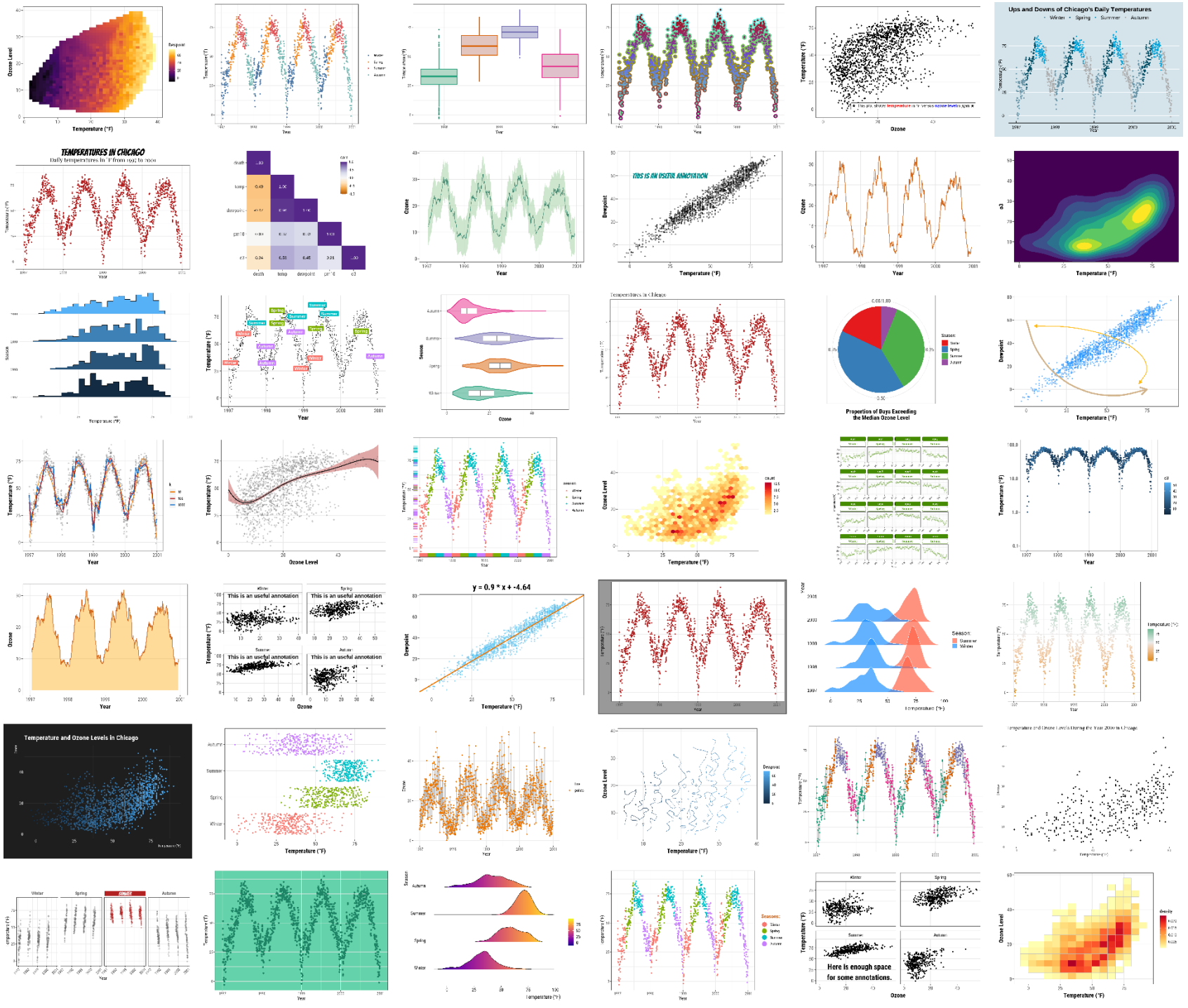
Javascript

R

ggplot2

r4ds.had.co.nz/data-visualisation.html

cedricscherer.com/2019/08/05/a-ggplot2-tutorial-for-beautiful-plotting-in-r



Python

Matplotlib

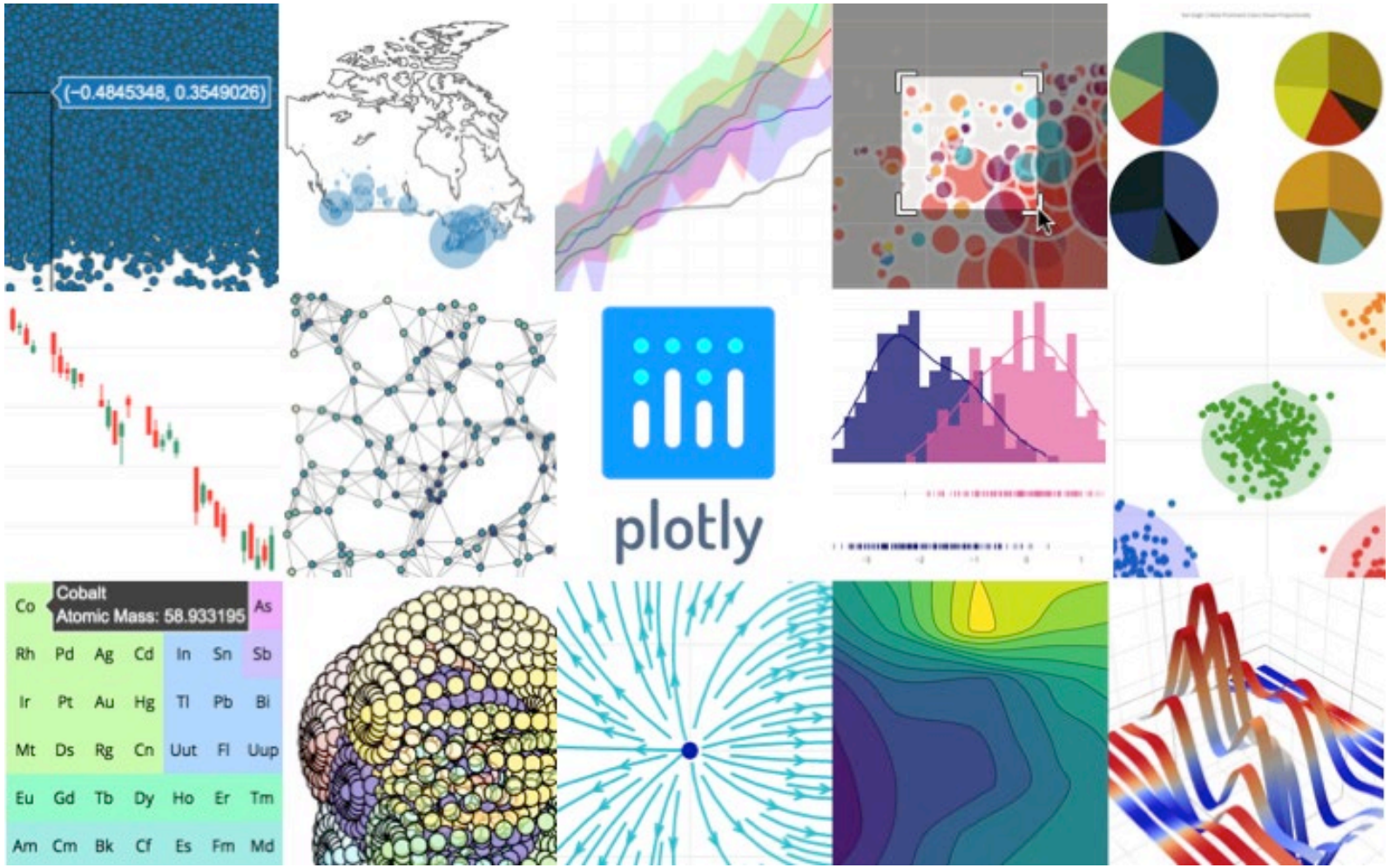
matplotlib.org/

Seaborn

web.stanford.edu/~mwaskom/software/seaborn/index.html

Plotly

plot.ly/python/



Javascript

d3.js

d3js.org

Highcharts

highcharts.com/docs/index

Chart.js

chartjs.org

Leaflet

leafletjs.com

Choosing a library

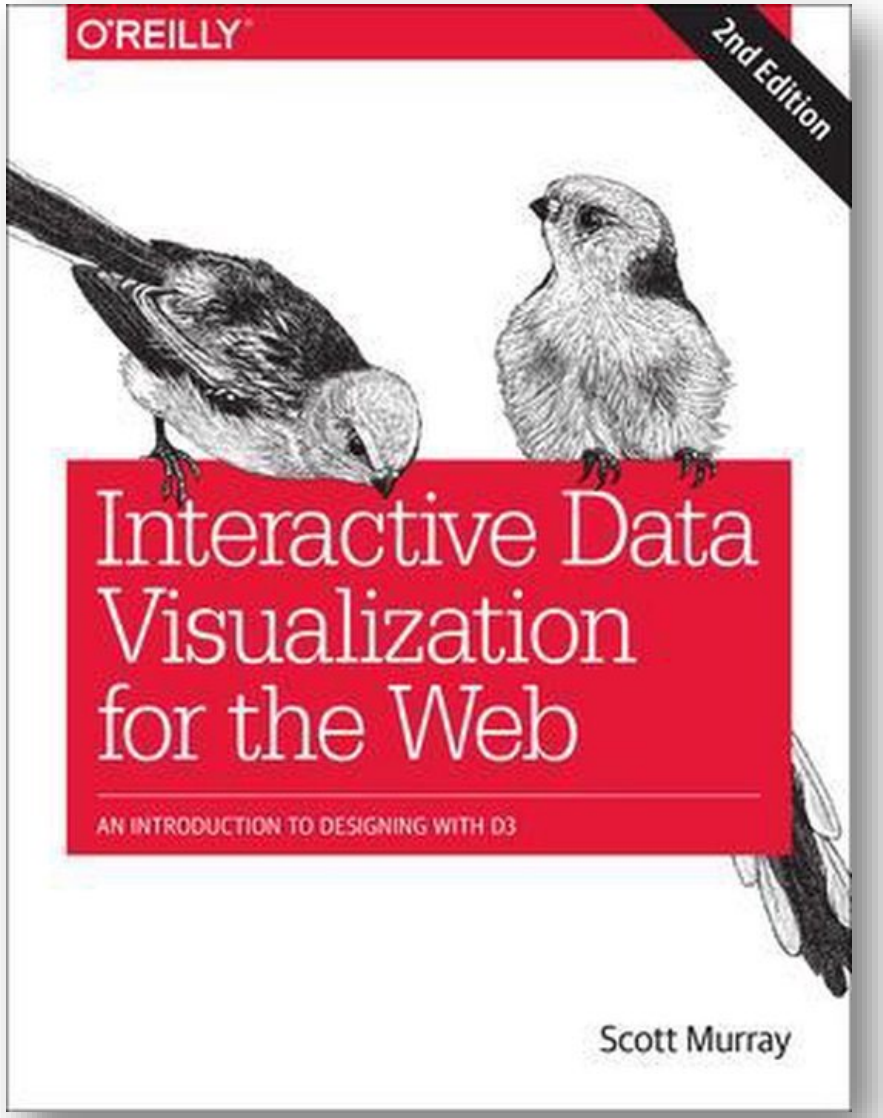
supported chart types

features

interactivity

ease of use

community support



freeCodeCamp(🔥)

Data Visualization

Data is all around us, but it doesn't mean much without shape or context.

In the Data Visualization Certification, you'll build charts, graphs, and maps to present different types of data with the D3.js library.

You'll also learn about JSON (JavaScript Object Notation), and how to work with data online using an API (Application Programming Interface).

Courses

Data Visualization with D3

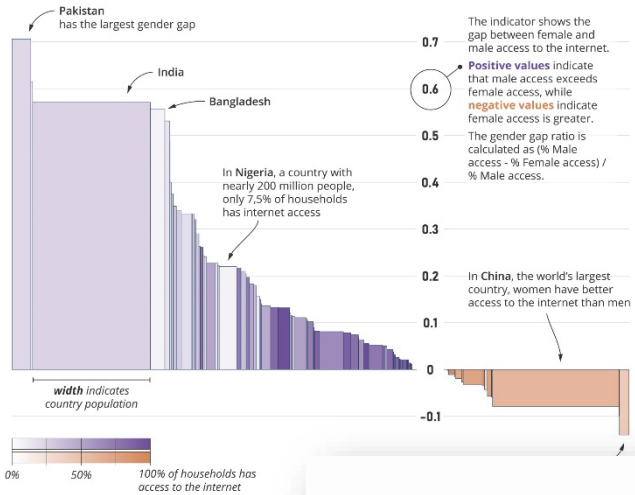
D3, or D3.js, stands for Data Driven Documents. It's a JavaScript library for creating dynamic and interactive data visualizations in the browser.

freecodecamp.org/learn/data-visualization

Homework assignment

The digital divide

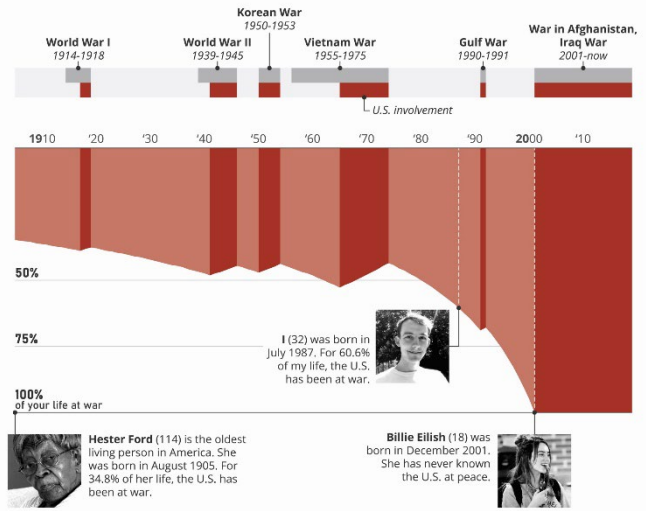
In most countries, **men** have better access to the internet than **women**



Source: The Economist Intelligence Unit Inclusive Internet Index, International Telecommunication Union, Gallup World Poll

A lifetime at war

No Americans born since 2001 have known their country at peace

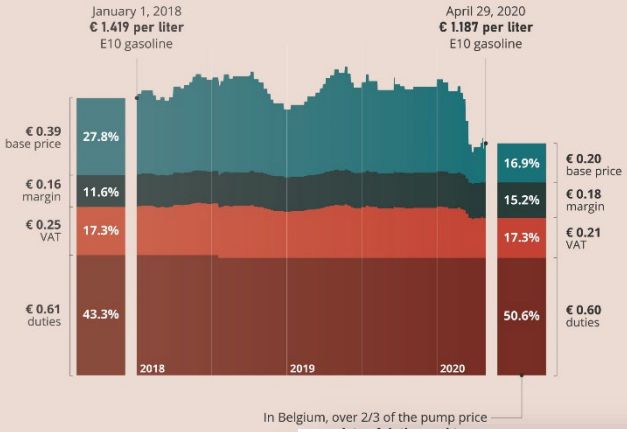


Source: Philip Bump for the Washington Post, "Nearly a quarter of Americans have never experienced the U.S. in a time of peace"

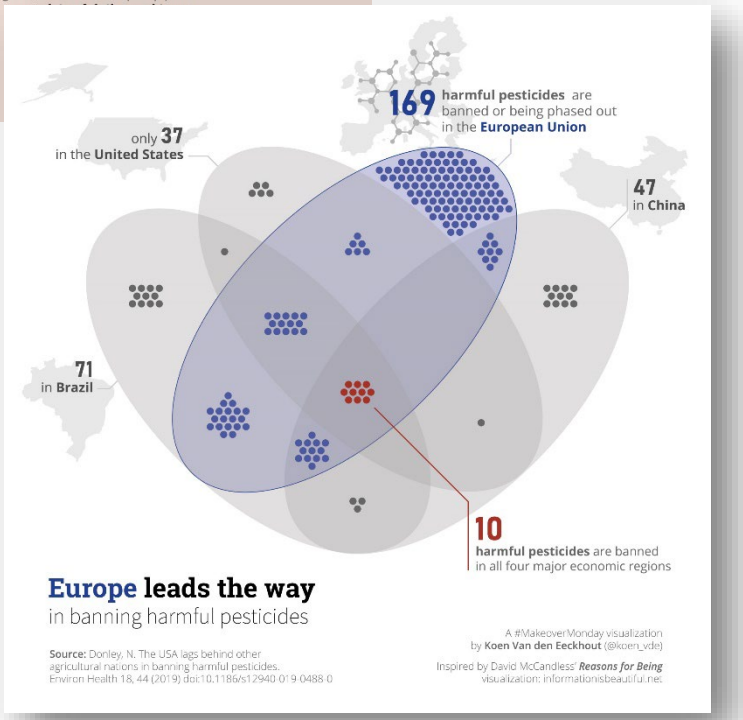
A #MakeoverMonday visualization by **Koen Van den Eeckhout** (@koen_vde)

Oil Time Low

Crude oil prices are at their lowest point since 1998, dropping over 85% in the past few months. But at the pump, we pay for more than just the oil.



Source: Belgian Petroleum Federation, FOD Economie, Statbel



Bringing it all together

Homework assignment

Revisit the **concept(s)** you sketched in the first part of the assignment.

Feel free to take feedback into account, modify the concept where needed.

Choose a tool you like to turn this concept into a data visual.

Think carefully about the use of **colors**, **typography**, **icons**,...

A data visual is never finished... **limit yourself** to about 2, but maximum 4 hours.

Send the visual as an **image file or link** to koen@baryon.be .

Session 1

Communicating with data

Graphical representation of data

homework assignment part 1

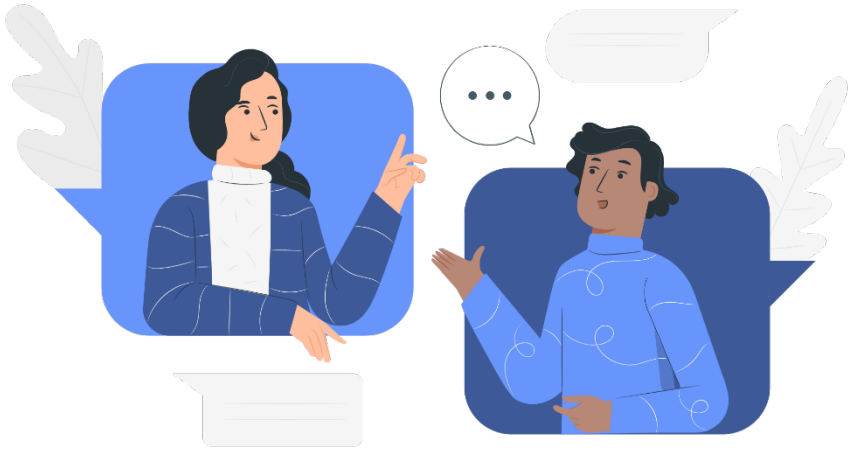
Session 2

Producing and designing data visuals

homework assignment part 2

Session 3

Visualizing scientific research



Q & A

All the slides and all the links:

baryon.be/dataviz-resources

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