



DSCI 554 LECTURE 1

COURSE OVERVIEW, INTRODUCTION TO DATA VISUALIZATION

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USC Viterbi

School of Engineering
Integrated Media Systems Center

OUTLINE

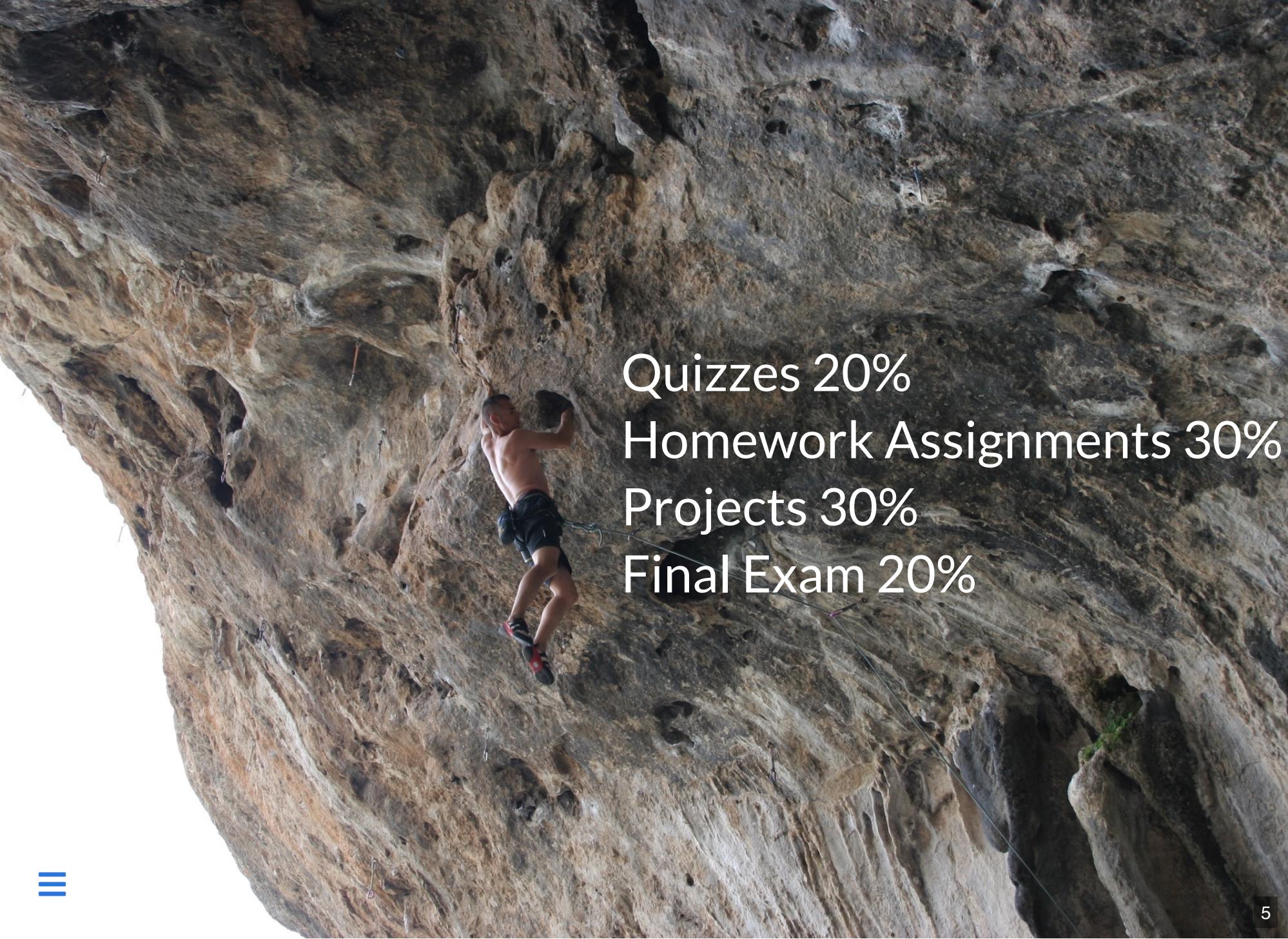
- Course information
- Data visualization
- Examples and uses
- Tools and software

COURSE OBJECTIVE

- Learn design principles and guidelines
- Learn to critique and evaluate visualizations
- Understand visualization tools and techniques
- Learn how to create interactive visualizations

COURSE MATERIALS

<http://pdms.usc.edu/dsci-554>

A shirtless man is climbing a large, textured rock face. He is wearing dark shorts and red climbing shoes. He is positioned in the center-left of the frame, facing away from the camera. The rock face is light-colored with darker, weathered patches. Several metal carabiners are attached to the rock, serving as handholds and footholds. A rope is visible, likely part of a safety harness or belay system.

Quizzes 20%
Homework Assignments 30%
Projects 30%
Final Exam 20%

QUIZZES

- 20% of grade
- 20min
- On previous class content & readings
- The worst quiz score will not count. No retake!
- MCQ
- Some coding questions

HOMEWORK

- 30% of grade
- 1-4 hours to complete
- One week to complete
- In GitHub **using your USC email!**
- See rubric in starter repositories for more details

FINAL EXAM

- 20% of grade
- Cumulative
- Quiz questions
- According to University schedule:
<https://classes.usc.edu/term-20213/finals/>

Classes meeting 2 or 2:30 MWF Friday, December 10, 2-4 p.m.

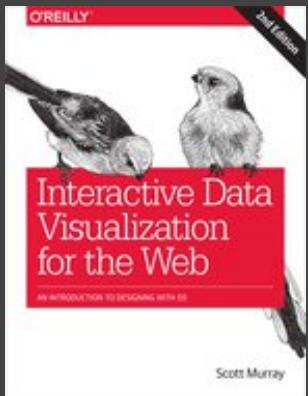
PROJECTS

- 30% of grade
- Groups of 3-4: start to form groups!
- Design and implement interactive, responsive data visualizations (e.g., dashboard)
- Website, video, paper and presentation

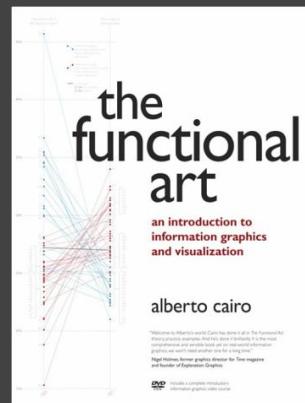
CLASS COMMUNICATION

On Slack at [#fall21-dsci-554-general](#)

REQUIRED READINGS

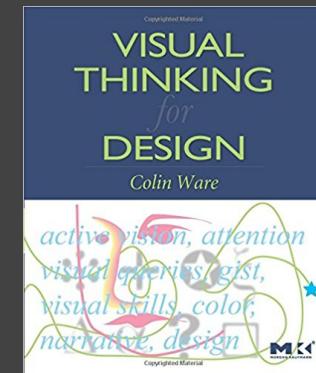


Murray S. Interactive Data Visualization for the Web, 2nd Edition. 2nd ed. O'Reilly Media, Inc; 2017. †



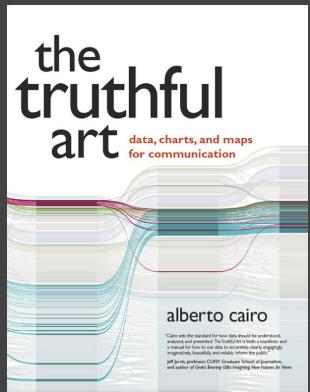
Alberto Cairo. The Functional Art: An Introduction to Information Graphics and Visualization. First. New Riders; 2012. †

† online through USC Libraries

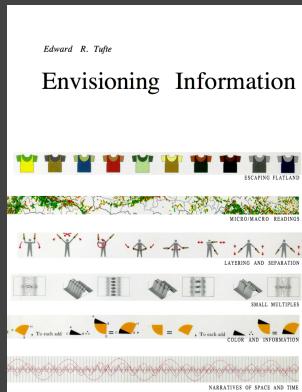


Colin Ware. Visual Thinking: For Design. 1st ed. Morgan Kaufmann Publishers Inc; 2008. †

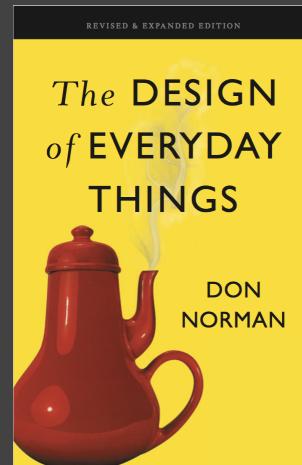
OTHER RELATED READINGS



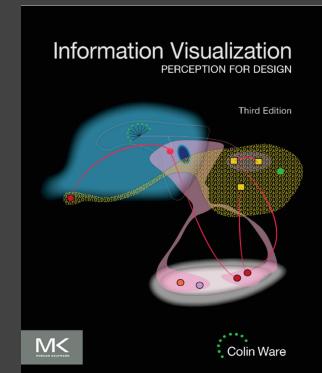
Cairo A. *The Truthful Art*.
Pearson Education; 2016. †



Tufte ER. *Envisioning Information*. Graphics Press;
1990.



Norman DA. *The Design of Everyday Things*. 1st Basic paperback ed. Basic Books;
2002.

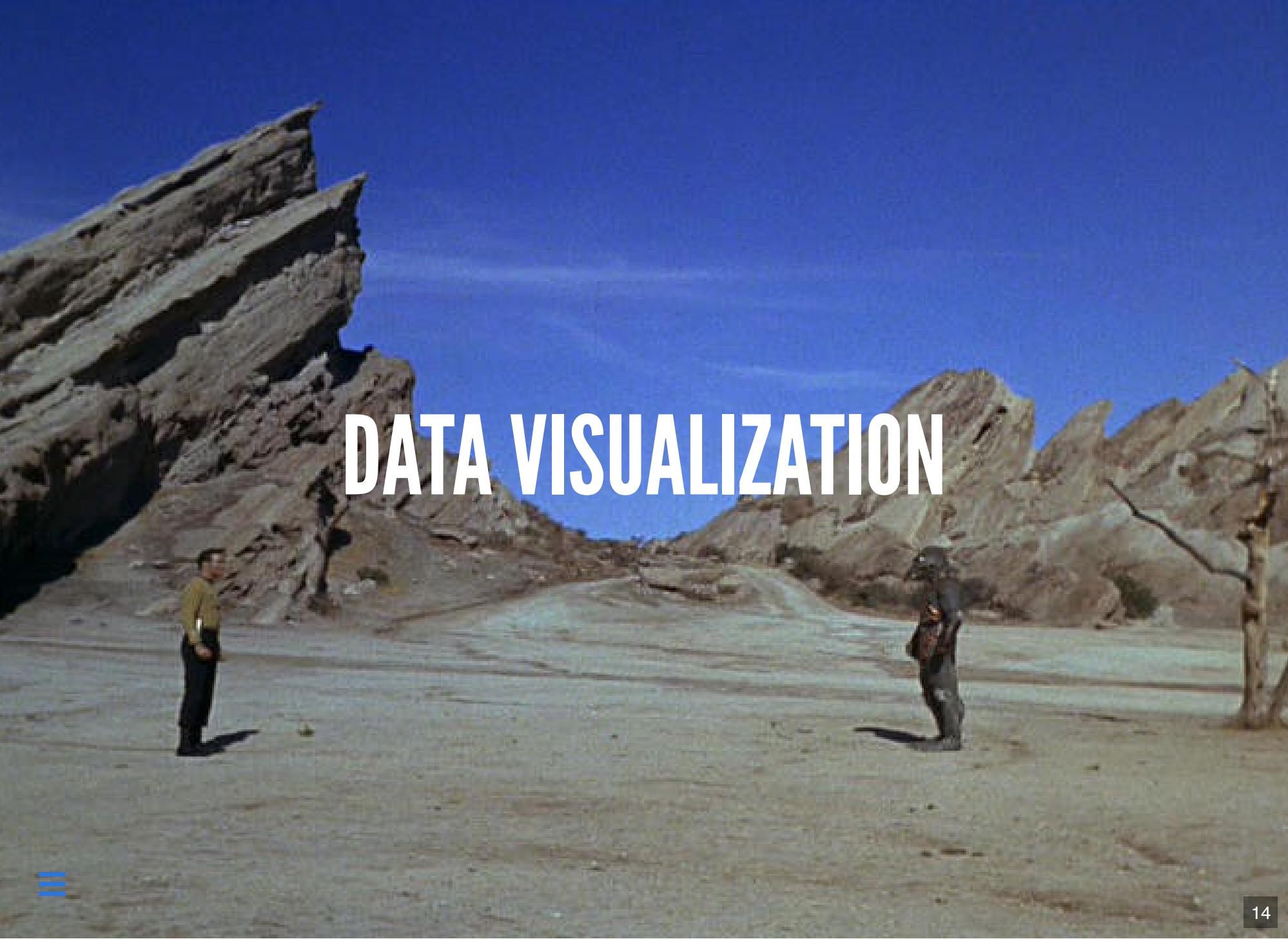


Ware C. *Information Visualization Perception for Design*. 3rd ed. Elsevier/MK;
2013. †

† online through USC Libraries

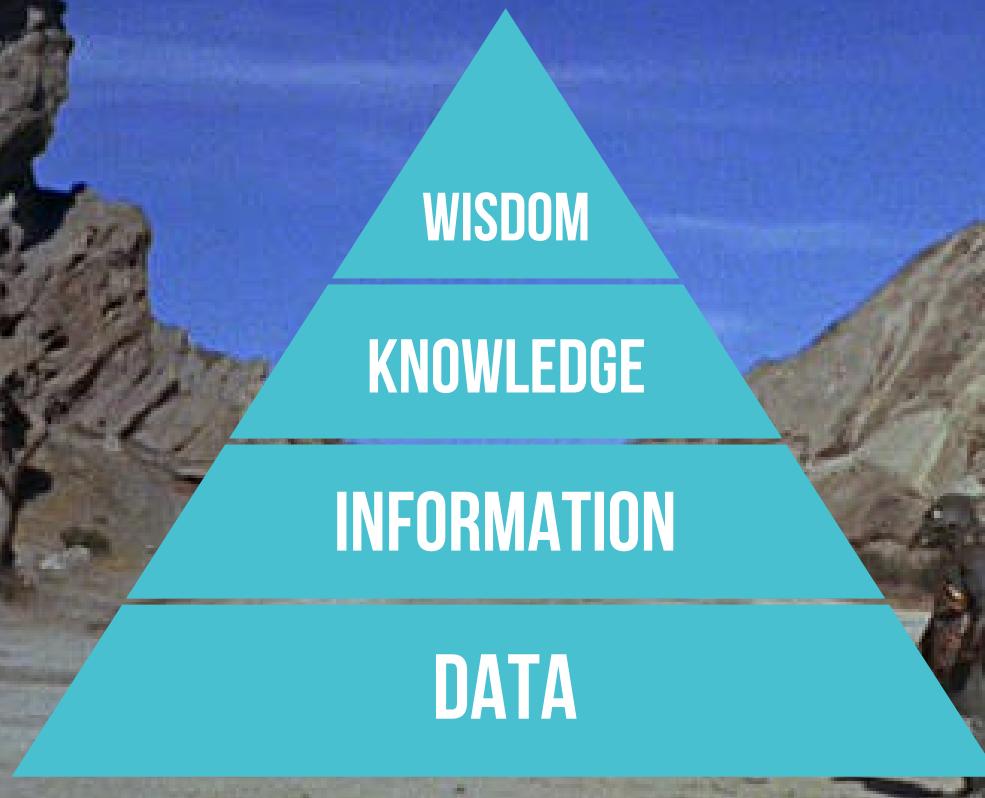
OUTLINE

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- Examples and uses
- Tools and software



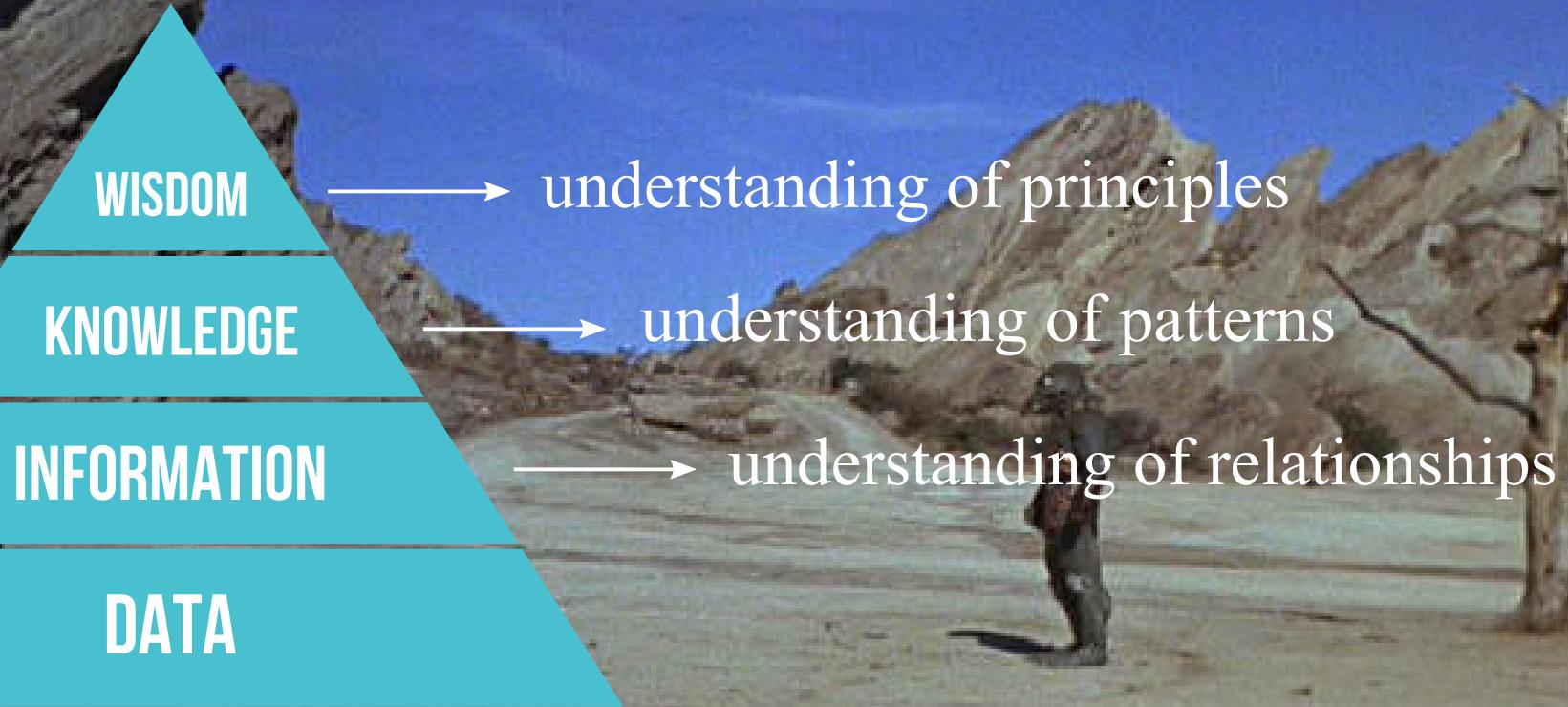
DATA VISUALIZATION

DATA VISUALIZATION



DIKW MODEL [ACKOFF 1989]

DATA VISUALIZATION



The background image shows the Griffith Observatory's stone structure with its characteristic tiered, cantilevered design. The sky is a clear, vibrant blue.

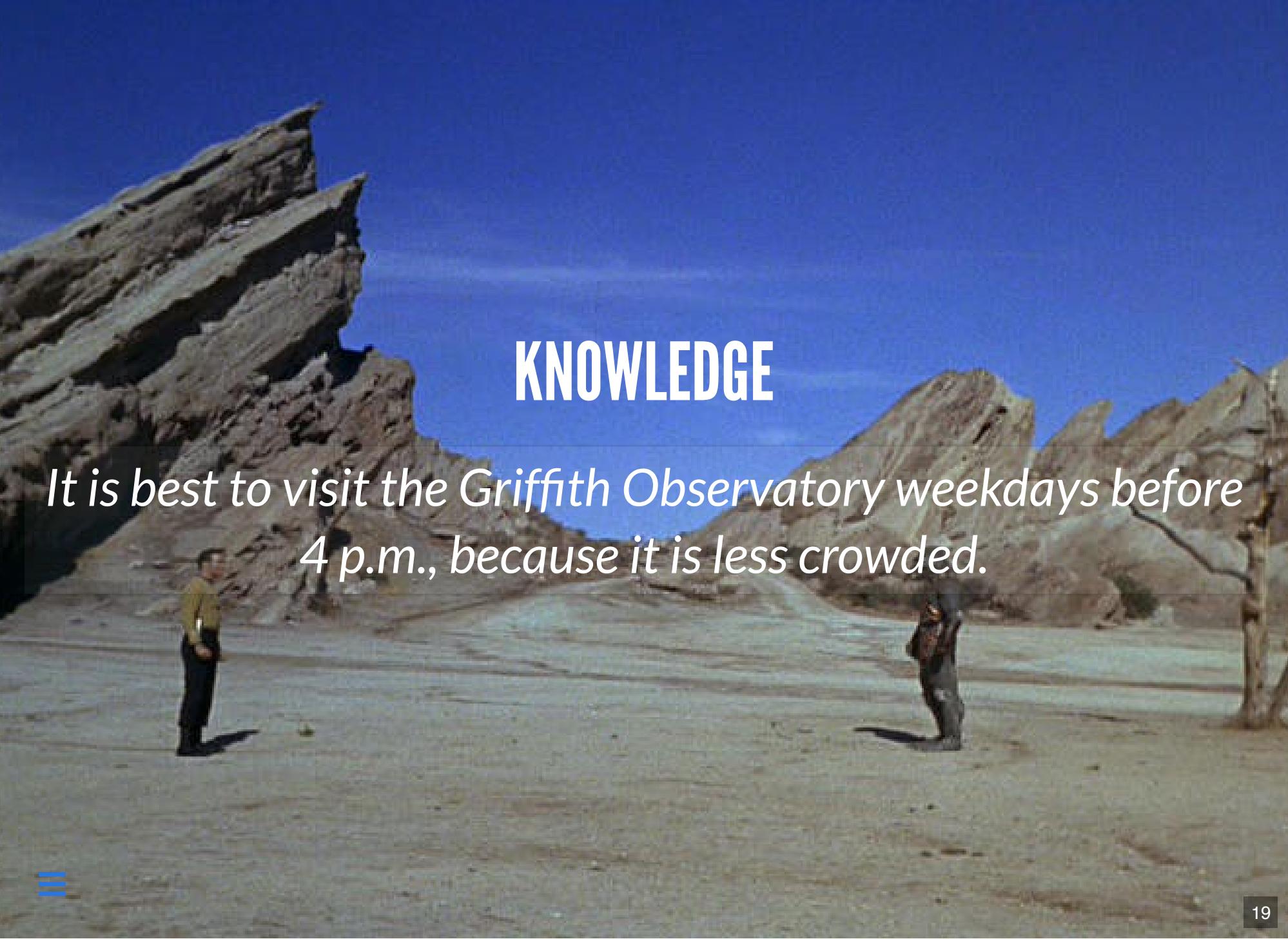
DATA

The Griffith Observatory is open Tuesday to Friday during
12:00 noon - 10:00 p.m., admission to building and
grounds is always FREE.

A scenic view of Griffith Observatory's iconic stone steps leading up a hillside. The steps are made of large, light-colored stones and lead from a grassy area up towards a building. A person is walking up the steps, providing a sense of scale to the massive structure.

INFORMATION

The Griffith Observatory is open Tuesday to Friday during 12:00 noon - 10:00 p.m., admission to building and grounds is always FREE.



KNOWLEDGE

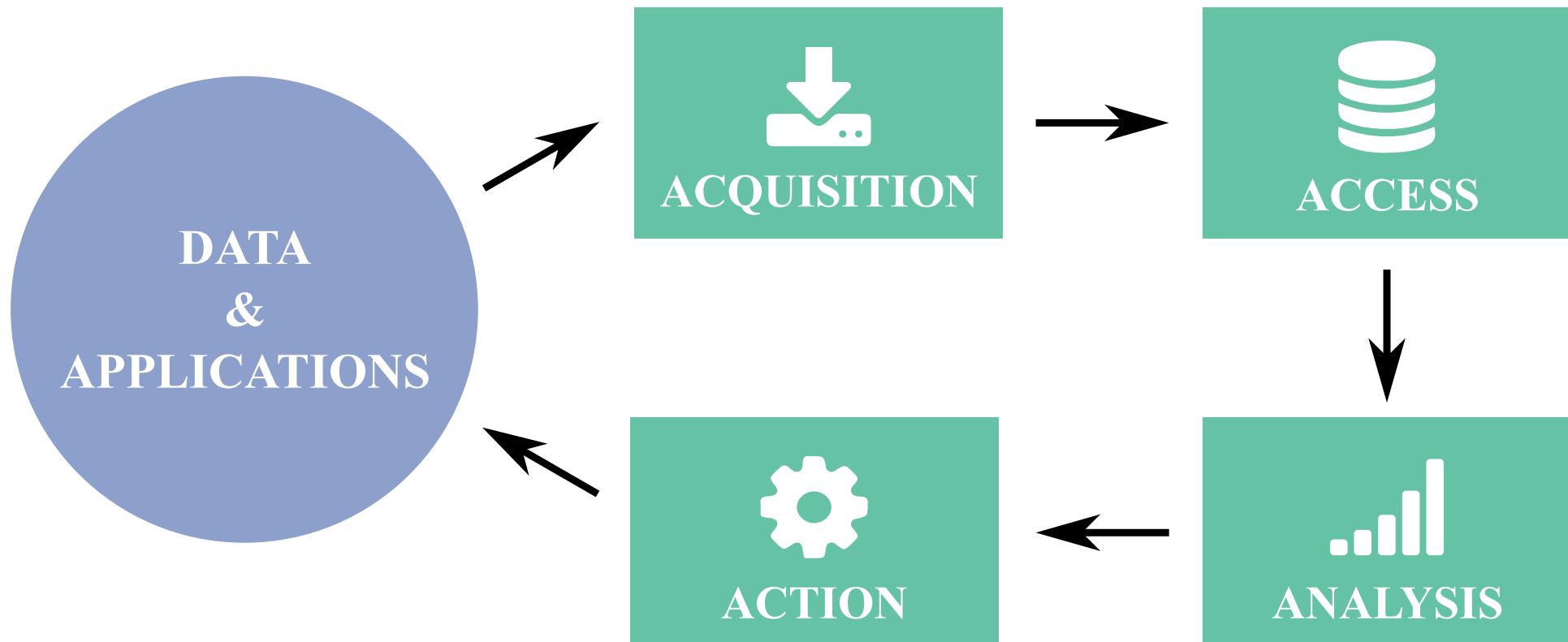
It is best to visit the Griffith Observatory weekdays before 4 p.m., because it is less crowded.



WISDOM

*To go from USC Park Campus to the Griffith Observatory
at this time takes 45 min with traffic.*

DATA VISUALIZATION IN DATA SCIENCE



Data science process flowchart

UNITS OF DATA & INFORMATION

1 byte = 8 bits

Ex: ASCII characters encoded using 1 byte: $2^8 = 256$ possible values

Multiples of bytes					
Decimal			Binary		
Value	Metric	Label	Value	IEC	Label
1000	kB	kilobyte	1024	KiB	kibibyte
1000^2	MB	megabyte	1024^2	MiB	mebibyte
1000^3	GB	gigabyte	1024^3	GiB	gibibyte
1000^4	TB	terabyte	1024^4	TiB	tebibyte
1000^5	PB	petabyte	1024^5	PiB	pebibyte
1000^6	EB	exabyte	1024^6	EiB	exbibyte
1000^7	ZB	zettabyte	1024^7	ZiB	zebibyte
1000^8	YB	yottabyte	1024^8	YiB	yobibyte

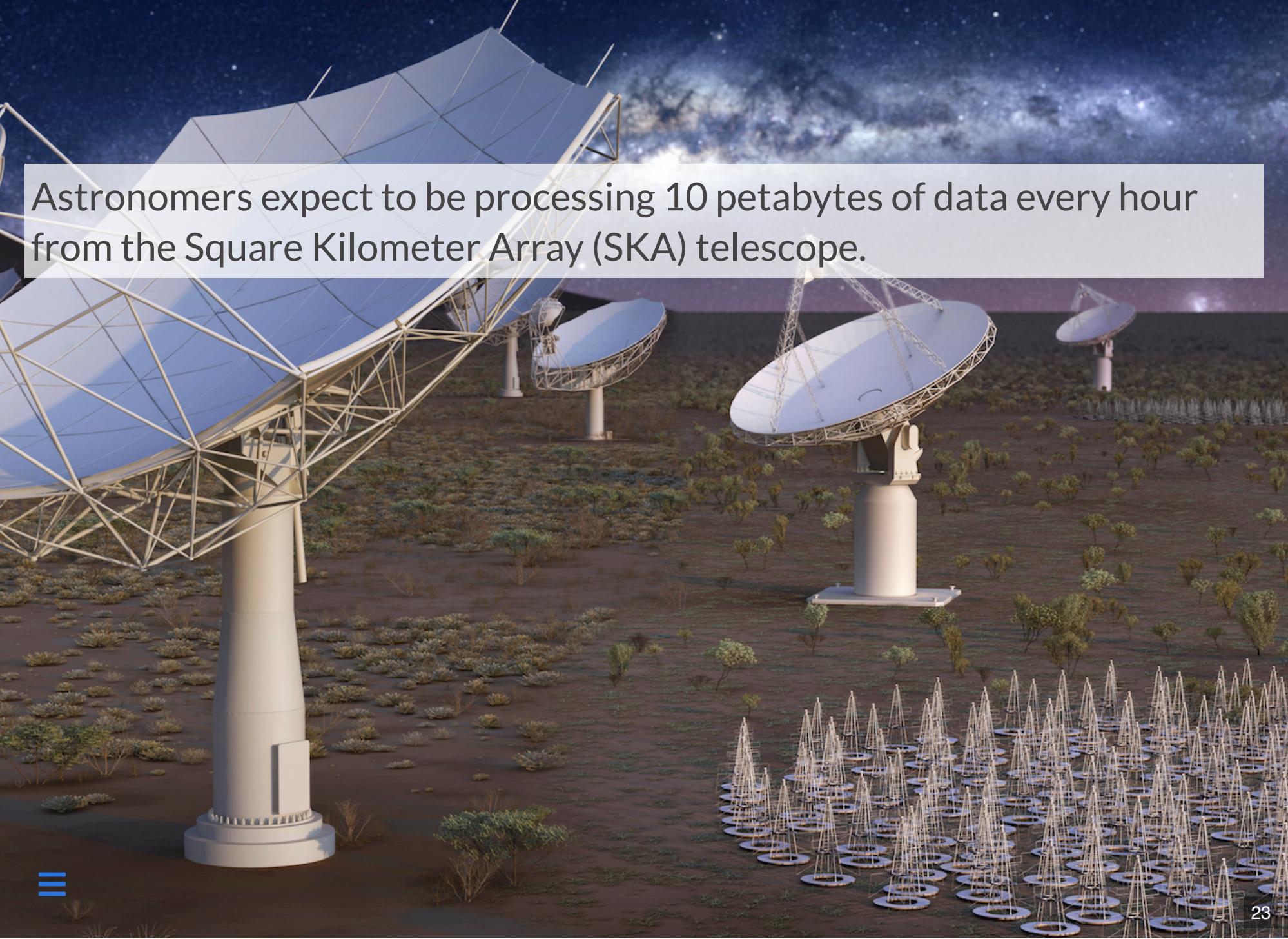
Prefix	Symbol	Associated Value
Tera	T	4
Peta	P	5
Exa	E	6
Zetta	Z	7
Yotta	Y	8



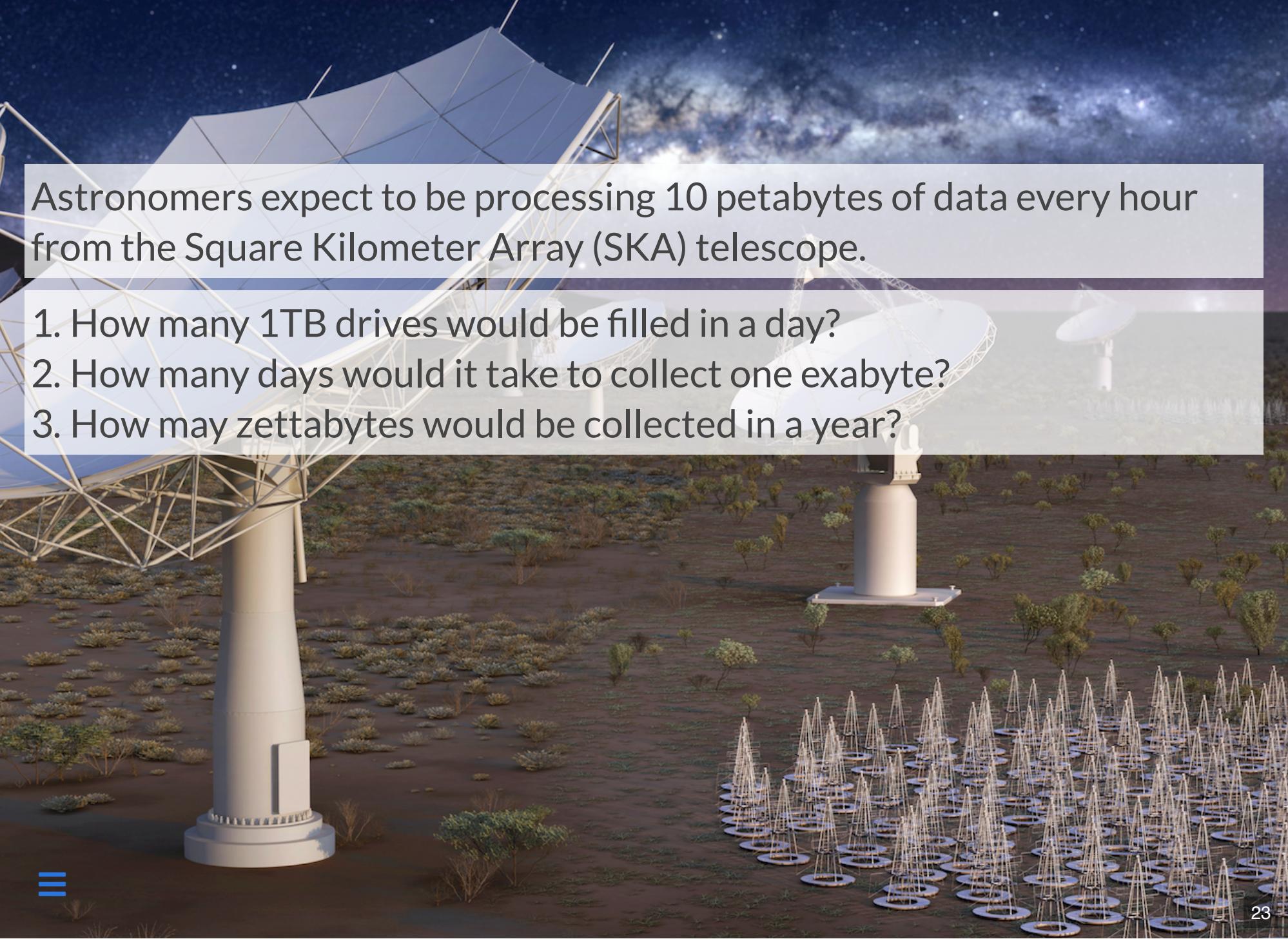
Convert between metric values using powers of kilobytes (kB)

Ex: $1\text{PB} = 1000^5\text{bytes} = 10^{15}\text{bytes}$



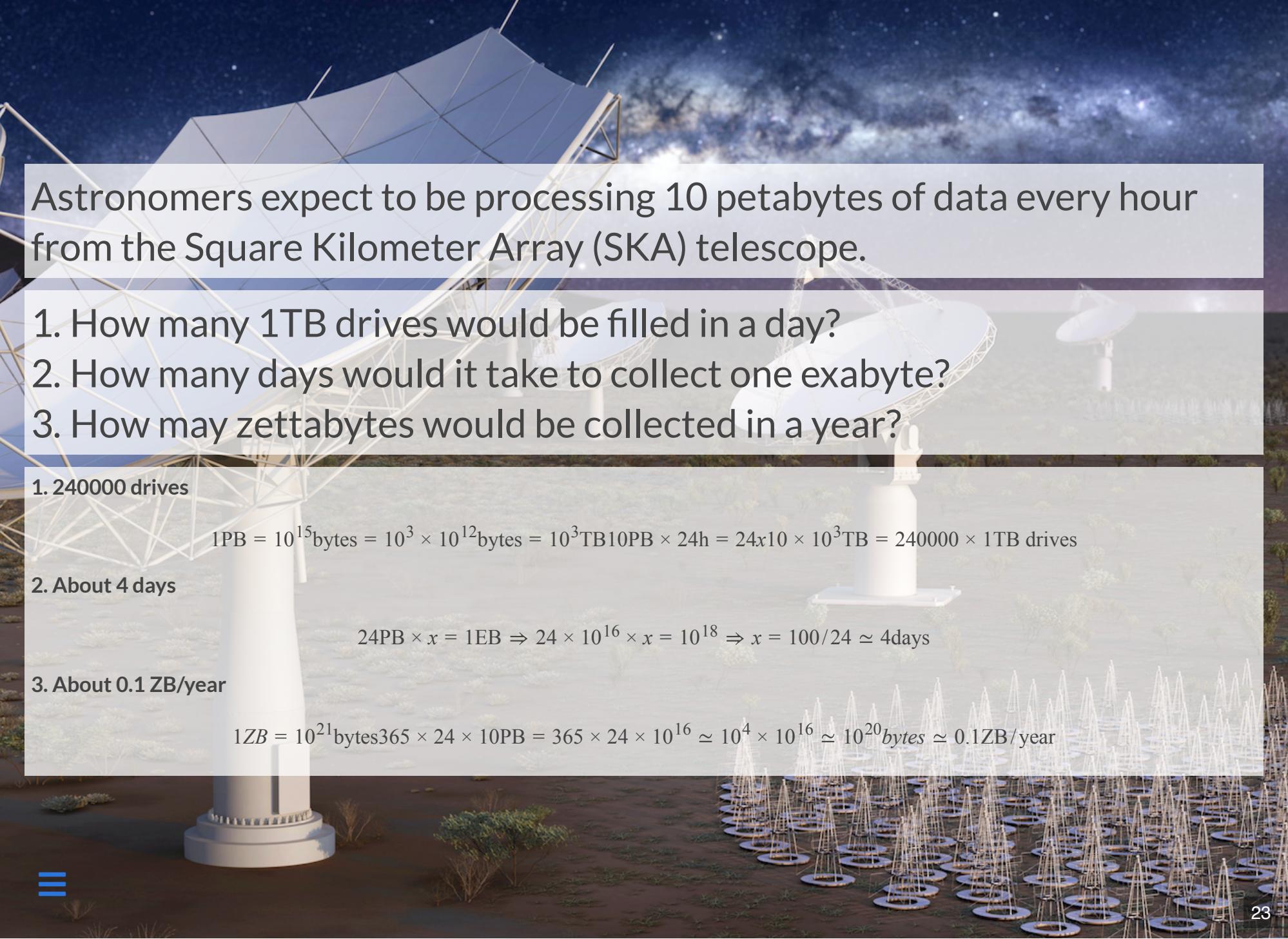
A large array of radio telescopes is shown in a desert landscape under a starry sky. The telescopes are white dish antennas mounted on tall, thin towers. In the foreground, a large telescope is prominent, angled towards the left. Behind it, several other telescopes are visible, some partially obscured by low-lying desert shrubs. In the far background, a city skyline is visible under a dark, cloudy sky.

Astronomers expect to be processing 10 petabytes of data every hour from the Square Kilometer Array (SKA) telescope.



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1. How many 1TB drives would be filled in a day?
2. How many days would it take to collect one exabyte?
3. How many zettabytes would be collected in a year?



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3. How many zettabytes would be collected in a year?

1. 240000 drives

$$1\text{PB} = 10^{15}\text{bytes} = 10^3 \times 10^{12}\text{bytes} = 10^3\text{TB}$$
$$10\text{PB} \times 24\text{h} = 24 \times 10 \times 10^3\text{TB} = 240000 \times 1\text{TB drives}$$

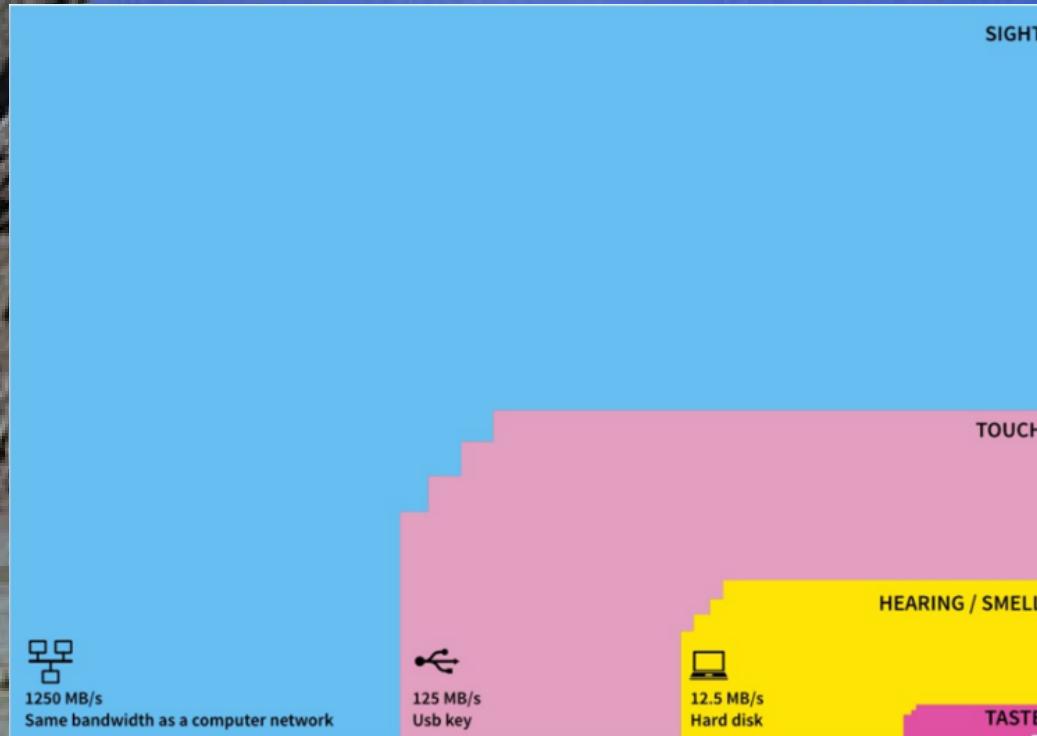
2. About 4 days

$$24\text{PB} \times x = 1\text{EB} \Rightarrow 24 \times 10^{16} \times x = 10^{18} \Rightarrow x = 100/24 \simeq 4\text{days}$$

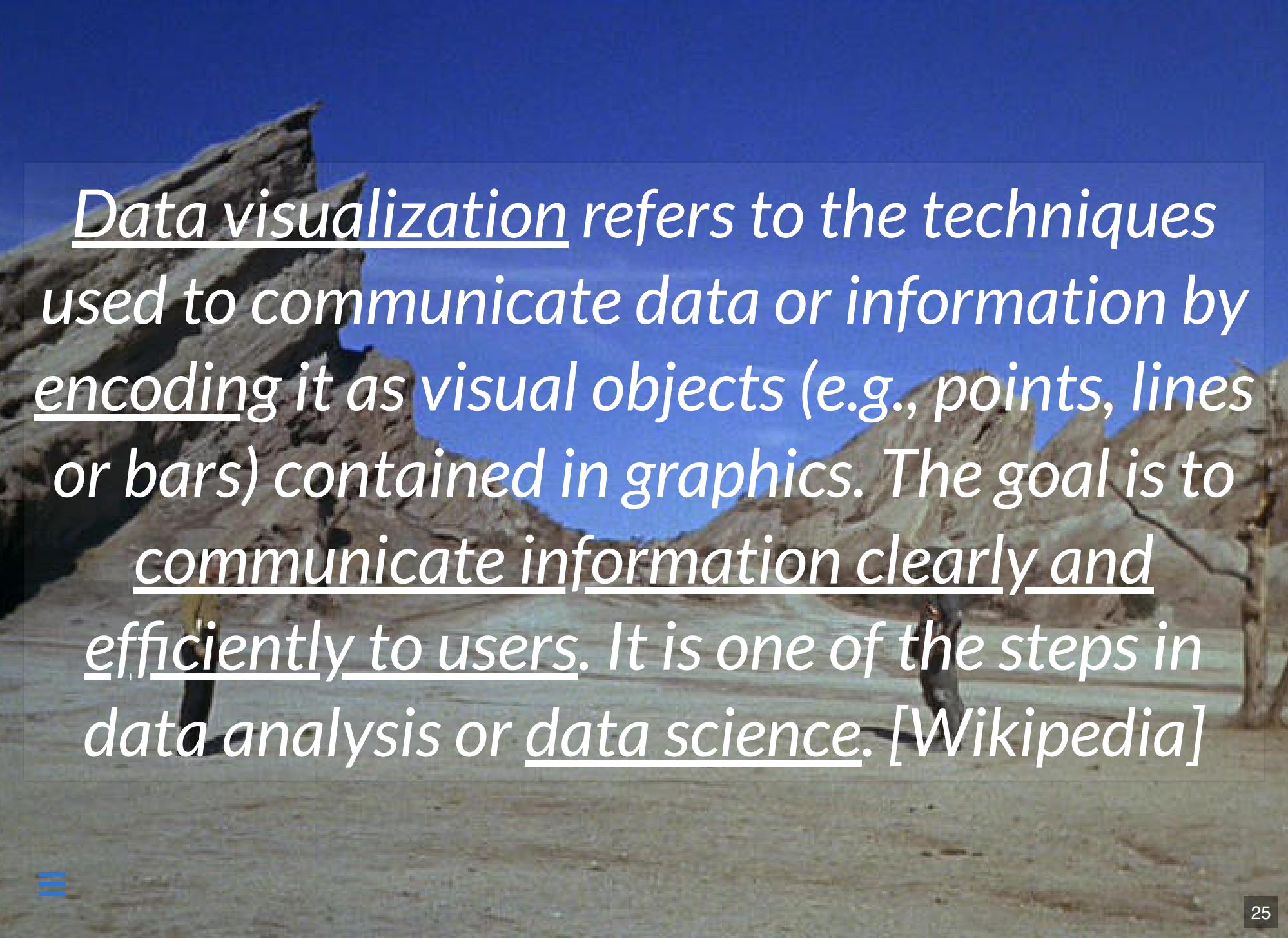
3. About 0.1 ZB/year

$$1\text{ZB} = 10^{21}\text{bytes}$$
$$365 \times 24 \times 10\text{PB} = 365 \times 24 \times 10^{16} \simeq 10^4 \times 10^{16} \simeq 10^{20}\text{bytes} \simeq 0.1\text{ZB/year}$$

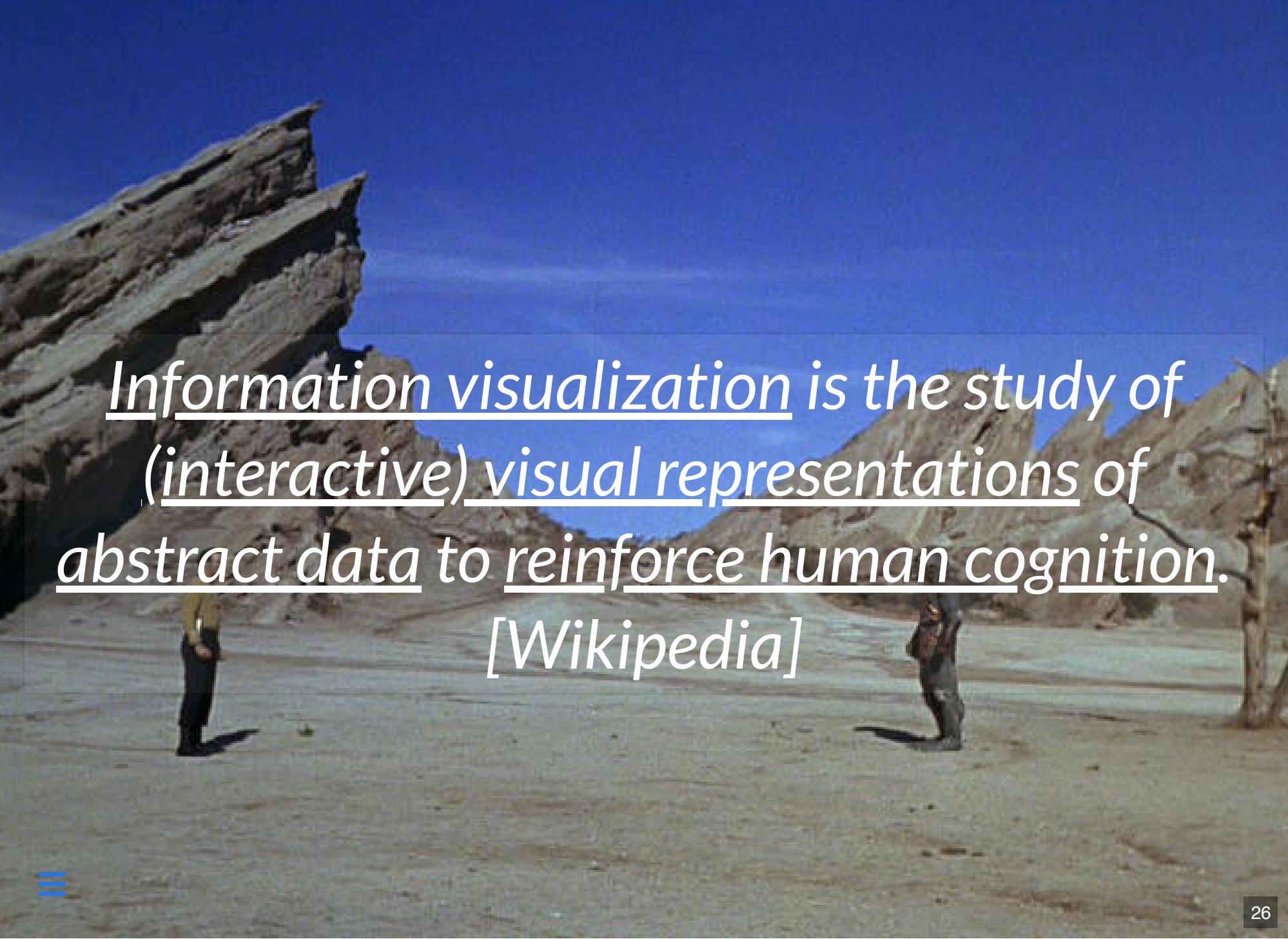
DATA VISUALIZATION



Nørrestrand's bandwidth of senses Graphic by David McCandless

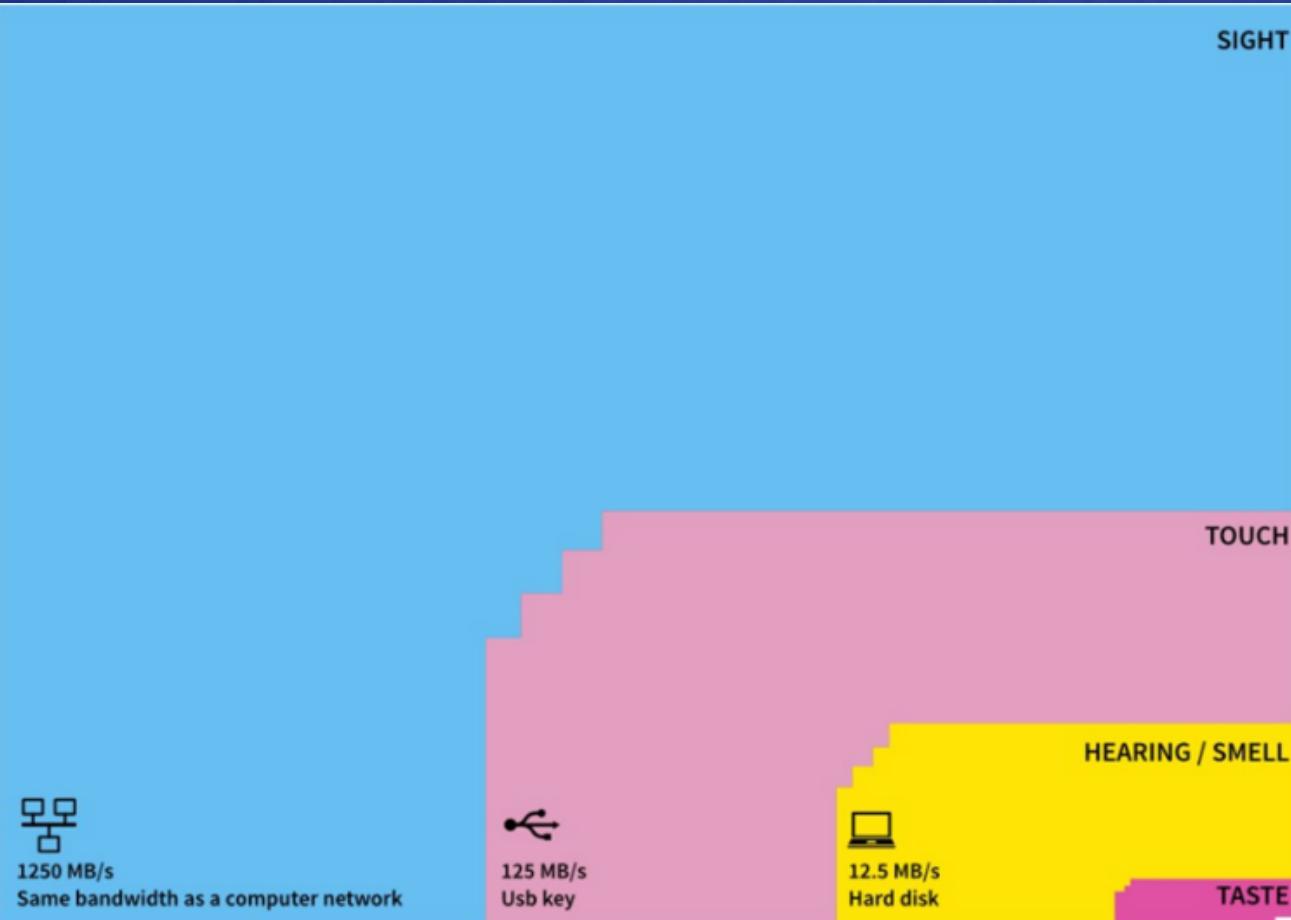
A landscape photograph showing a dry, cracked earth surface in the foreground and middle ground, under a clear blue sky. The terrain appears arid and textured.

Data visualization refers to the techniques used to communicate data or information by encoding it as visual objects (e.g., points, lines or bars) contained in graphics. The goal is to communicate information clearly and efficiently to users. It is one of the steps in data analysis or data science. [Wikipedia]

A landscape painting by Claude Monet, "The Magpie", depicting two figures in a field under a blue sky with rocky hills.

Information visualization is the study of
(interactive) visual representations of
abstract data to reinforce human cognition.

[Wikipedia]



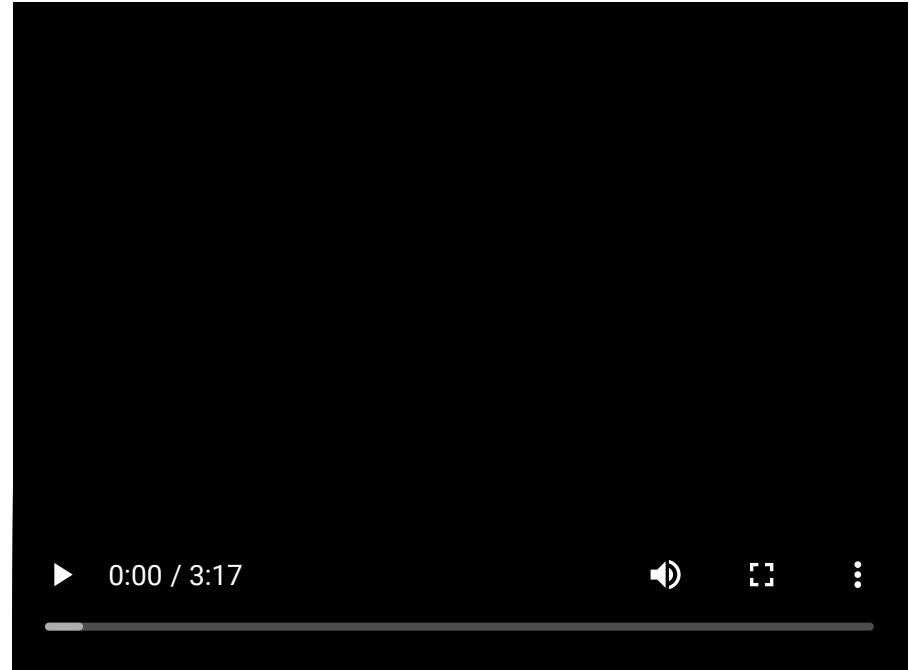
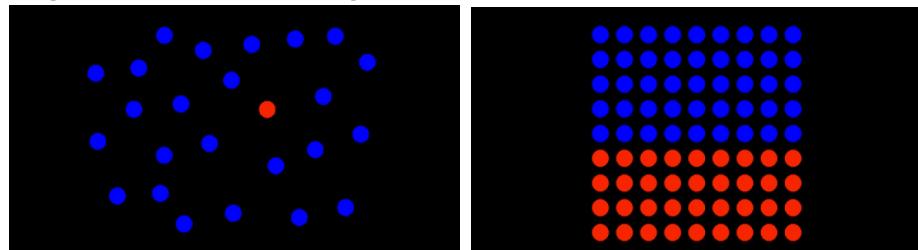
Nørretranders bandwidth of senses - Graphic by David McCandless

You are aware of 0.7% of what you experience:

- High-res limited to central 3° of visual field
- Finite cognitive capabilities

PREATTENTIVE FEATURES (UNIVERSAL CAPABILITY)

- Typically in less than 1/10s
- Does not require eye movements
- Does not require focused attention
- Color and boundary can be detected preattentively



Christopher G. Healey - Preattentive features and tasks

Other examples of universal capabilities:

- Some color combinations are differentiated by everyone 
- Some symbols are understood across cultures 😊

COLOR INTERPRETATION (INDIVIDUAL CAPABILITY)



https://en.wikipedia.org/wiki/The_dress

- We interpret lighting differently
- Not everyone can differentiate certain colors 
- Not everyone understands certain symbols ↗
- Not everyone can read or read small text!

INFORMATION VS. SCIENTIFIC VISUALIZATION

Infovis Scivis

Representation chosen given

Examples

OUTLINE

- Course information
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SIGNAGE ON MOVING WALKWAYS

Affordances define what actions are possible.

*Signifiers specify how people discover those possibilities:
signifiers are signs, perceptible signals of what can be done.*

The Design of Everyday Things - Don Norman

VISUALIZATION USES

Scope

Actions

Examples

VISUALIZATION USES

Scope	Actions	Examples
Communicate Information	<ul style="list-style-type: none">○ Inform○ Communicate○ Explain	<ul style="list-style-type: none">○ Presentations○ Hand-outs○ Instructions○ Infographics○ Signage

VISUALIZATION USES

Scope	Actions	Examples
Communicate Information	<ul style="list-style-type: none">○ Inform○ Communicate○ Explain	<ul style="list-style-type: none">○ Presentations○ Hand-outs○ Instructions○ Infographics○ Signage
Analyze & Model Data	<ul style="list-style-type: none">○ Explore○ Analyze○ Discover○ Decide	<ul style="list-style-type: none">○ Spreadsheets○ Dashboards○ Notebooks○ Interactive graphics

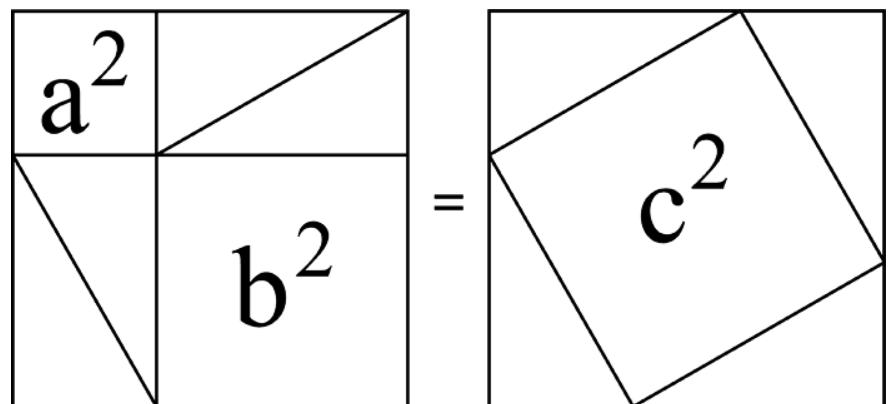
Which information visualization use most relates to communicating information?

- A. Explore
- B. Analyze
- C. Explain
- D. Decide

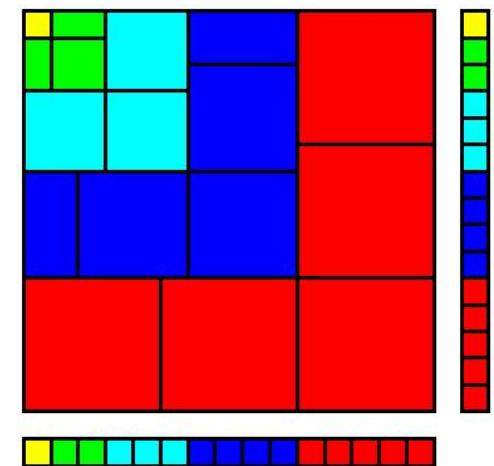
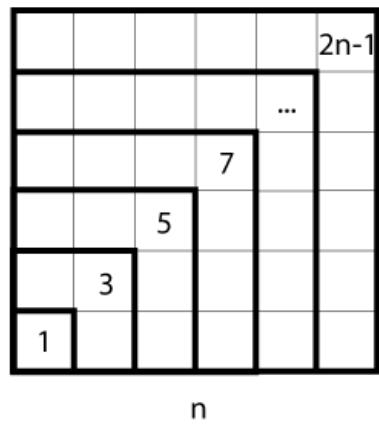
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- A. Explore
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- C. Explain ←
- D. Decide

CAN REPLACE COMPLEX CALCULATIONS



$$a^2 + b^2 = c^2$$



$$1 + 3 + 5 + \dots + (2n - 1) = n^2$$

$$\sum_{k=1}^n k^3 = \left(\sum_{k=1}^n k\right)^2$$

CAN REVEAL COMPLEX PATTERNS, TRENDS AND OUTLIERS

193

189

297

311

247

351

223

413

342



CAN REVEAL COMPLEX PATTERNS, TRENDS AND OUTLIERS

193



189



297



311



247



351



223



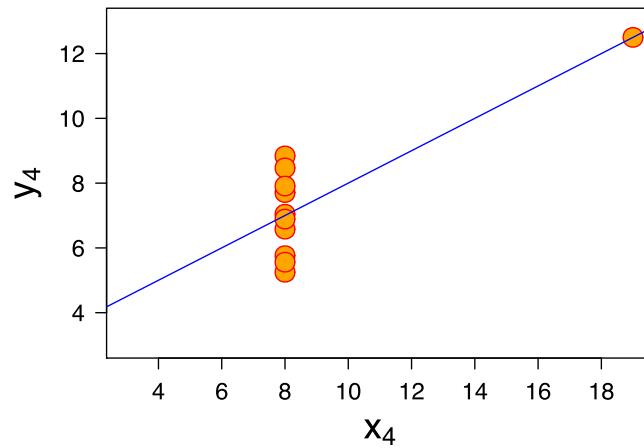
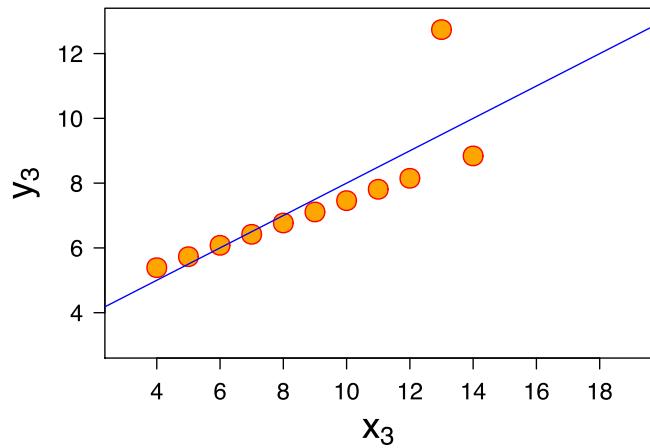
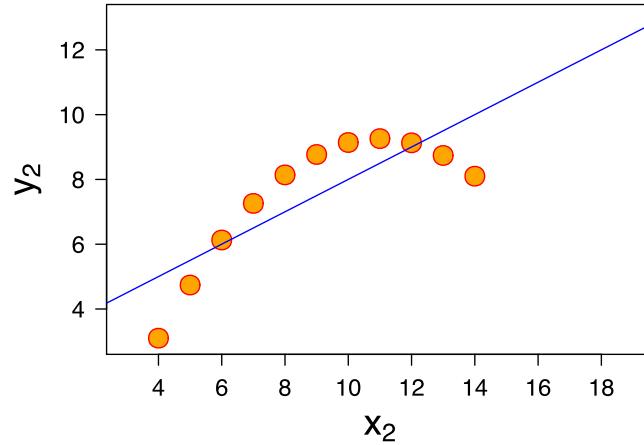
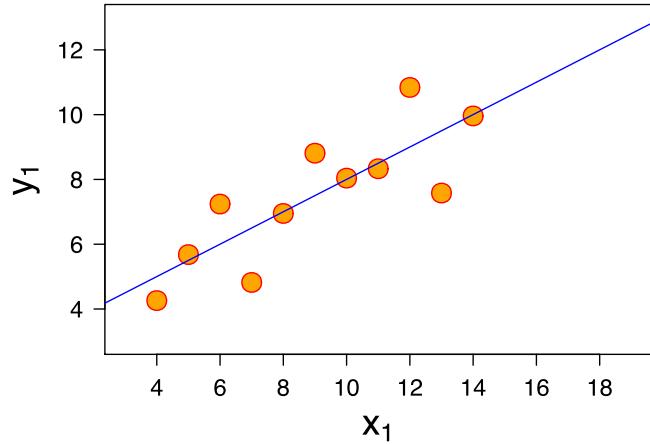
413



342

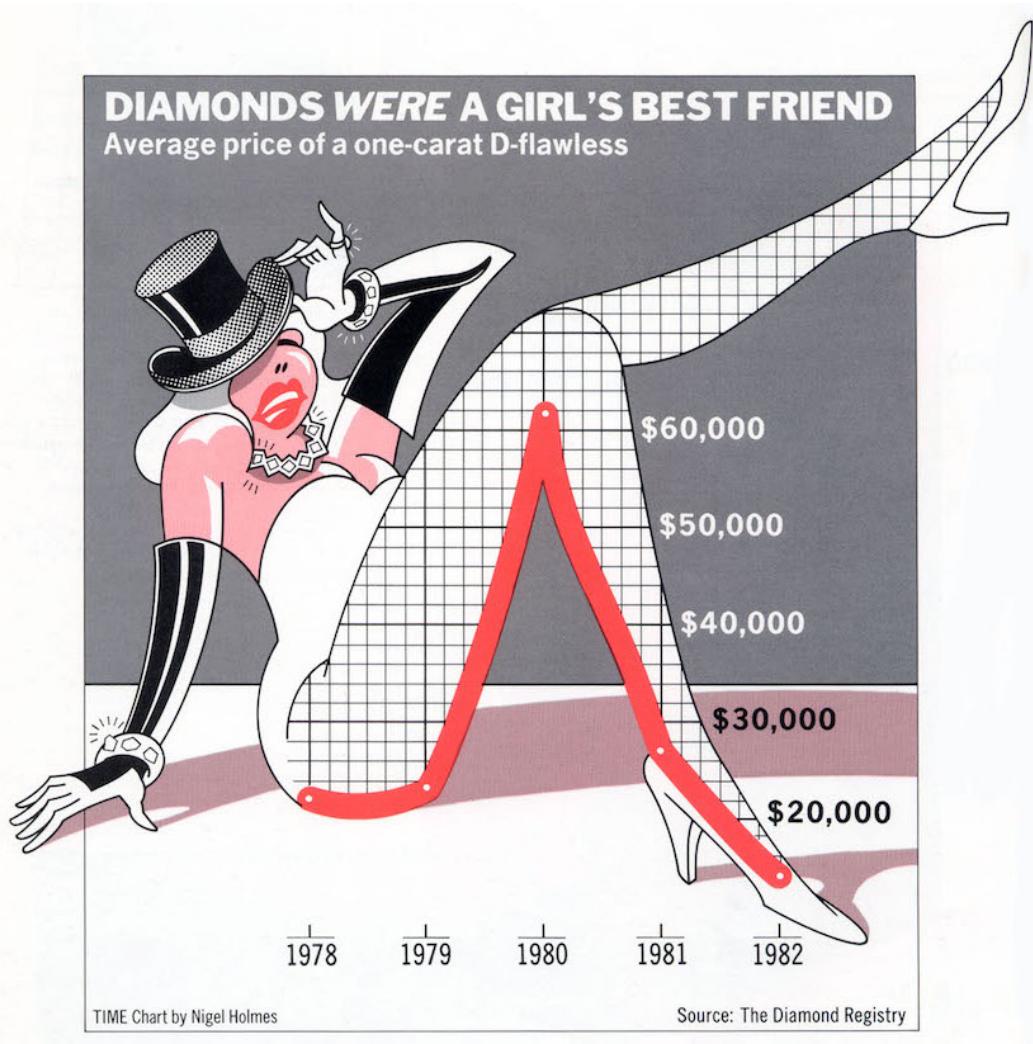


CAN REVEAL FEATURES NOT OTHERWISE APPARENT



Anscombe's quartet (1973): importance of graphing data before analysis

CAN SUPPORT MEMORY AND COMPREHENSION



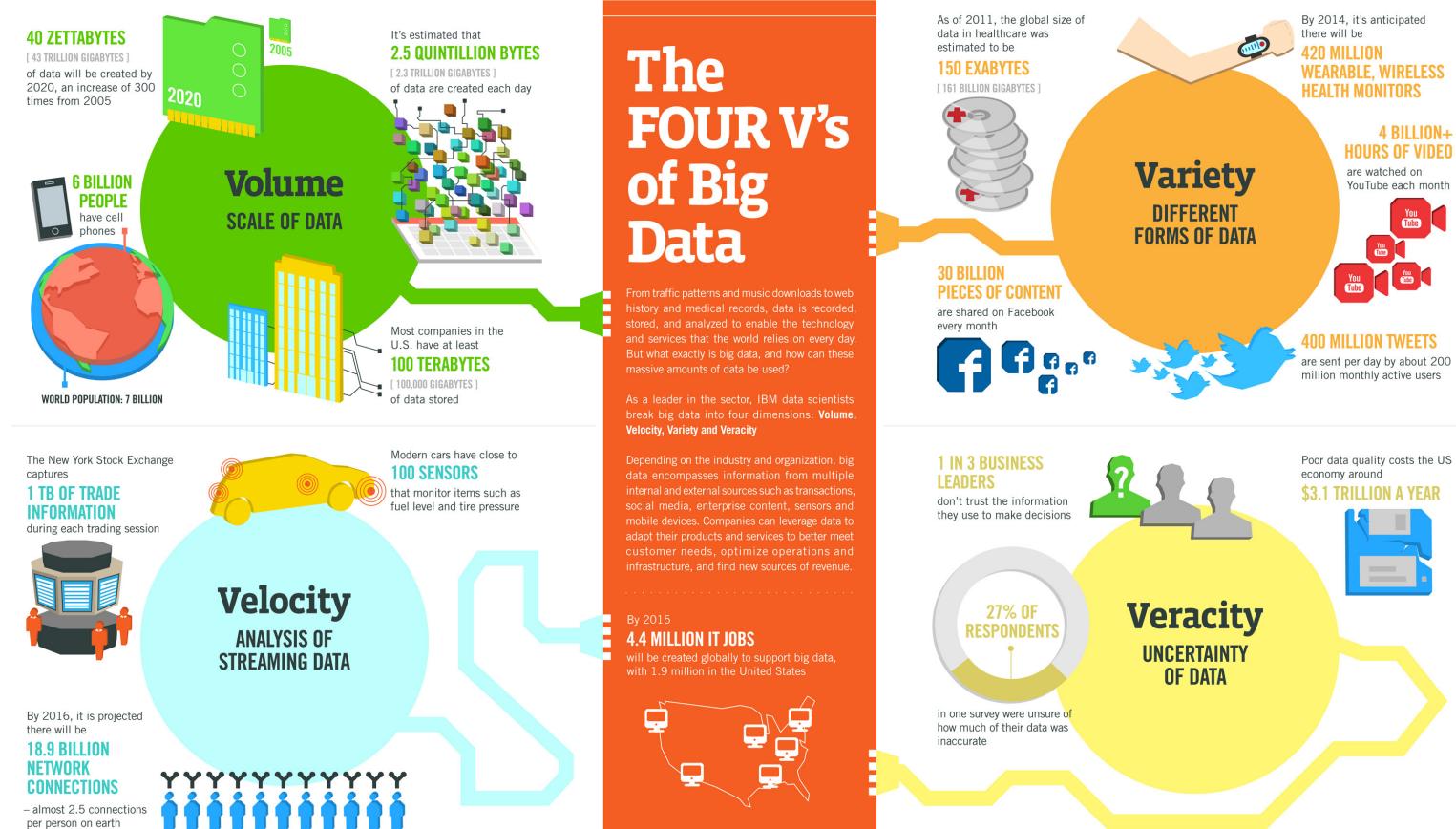
CAN TELL A STORY

▶ 0:00 / 4:42



Hans Rosling's 200 Countries, 200 Years
🔗 <https://youtu.be/jbkSRLYSojo>

CAN INFORM AND ENGAGE MORE DIVERSE AUDIENCES



Sources: McKinsey Global Institute, Twitter, Cisco, Gartner, EMC, SAS, IBM, MEPTEC, QAS



IBM Big Data & Analytics Hub - Infographics & Animations



VISUALIZATIONS ARE MEANS TO REACH GOALS



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SHARE

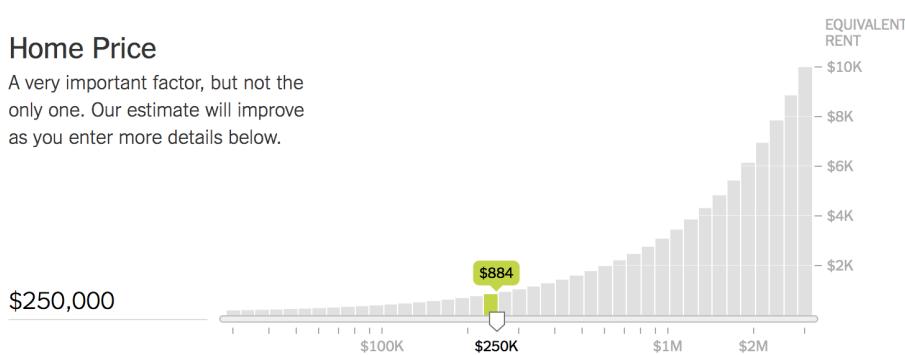
Is It Better to Rent or Buy?

By MIKE BOSTOCK, SHAN CARTER and ARCHIE TSE

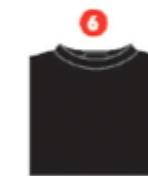
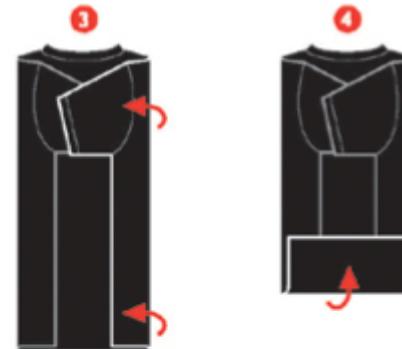
The choice between buying a home and renting one is among the biggest financial decisions that many adults make. But the costs of buying are more varied and complicated than for renting, making it hard to tell which is a better deal. To help you answer this question, our calculator takes the most important costs associated with buying a house and computes the equivalent monthly rent. [RELATED ARTICLE](#)

Home Price

A very important factor, but not the only one. Our estimate will improve as you enter more details below.

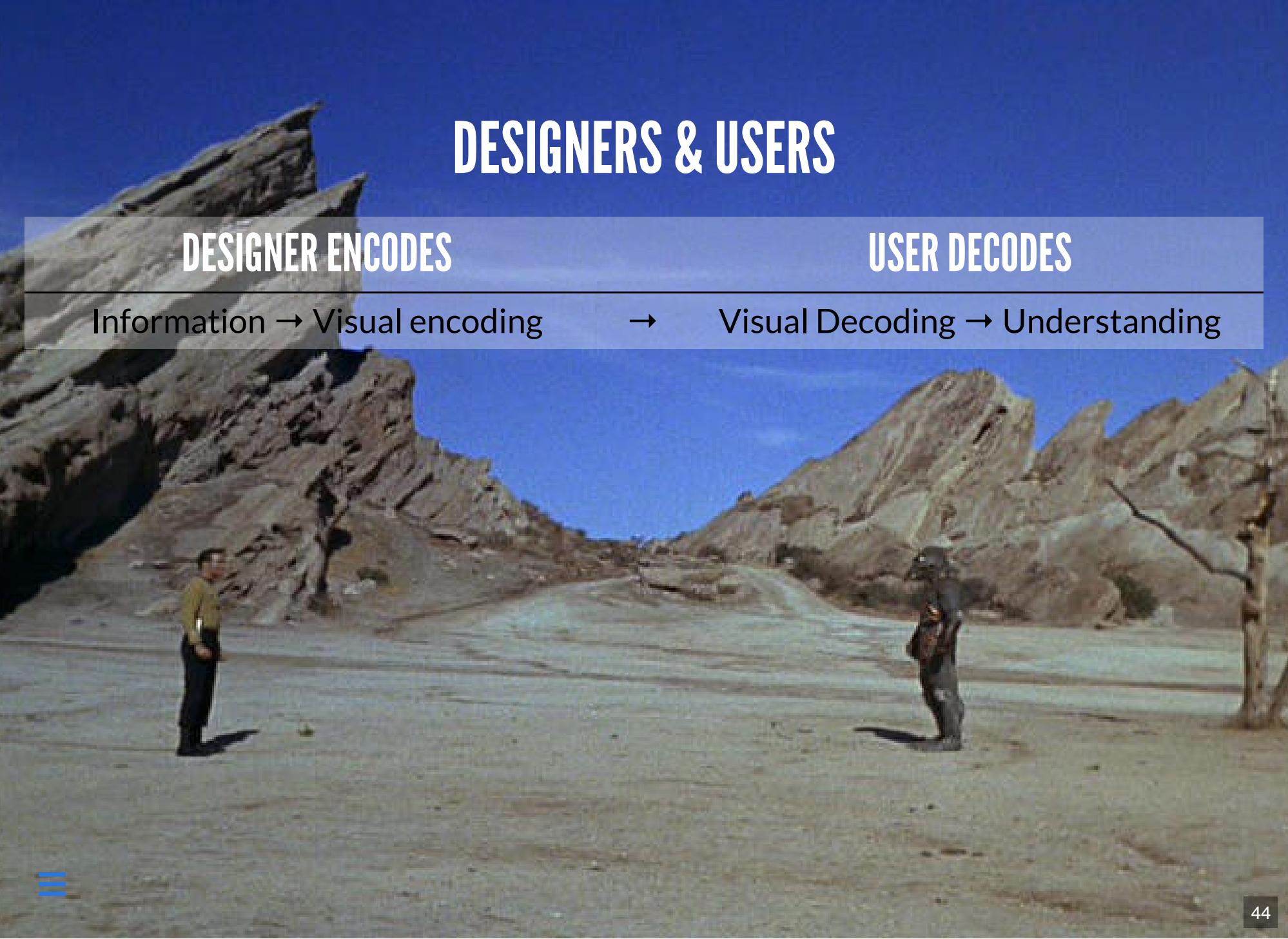


INFORMATION GRAPHICS (INFOGRAPHICS) ARE DEVICES WHOSE AIM IS TO HELP AN AUDIENCE COMPLETE CERTAIN TASKS



Wordless Diagrams (2005) by Nigel Holmes.

DESIGN CONSIDERATIONS

A landscape painting by Claude Monet, "The Magpie" (1864). It depicts two figures in a field with rocky hills in the background.

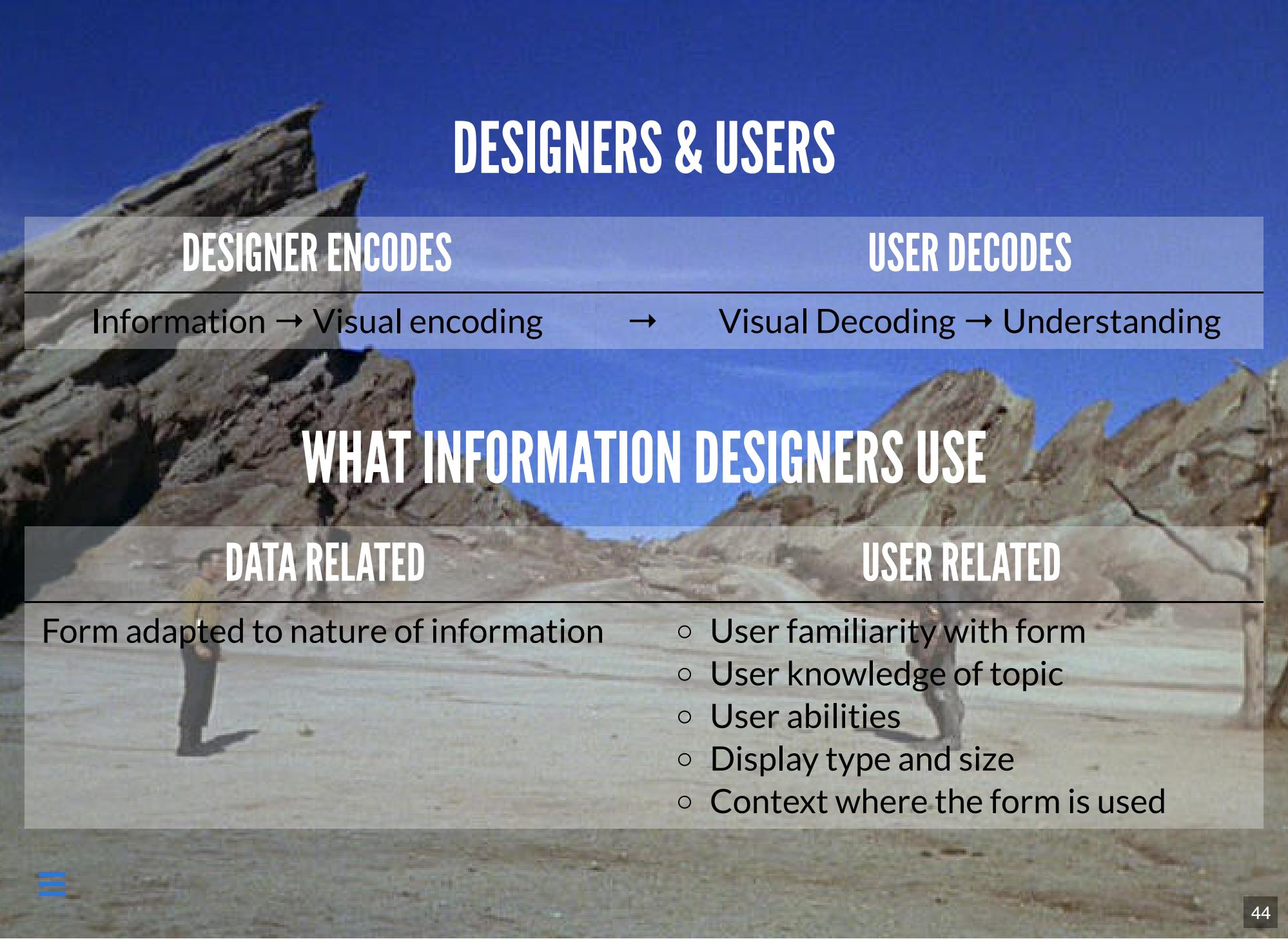
DESIGNERS & USERS

DESIGNER ENCODES

Information → Visual encoding

USER DECODES

Visual Decoding → Understanding



DESIGNERS & USERS

DESIGNER ENCODES

USER DECODES

Information → Visual encoding

→ Visual Decoding → Understanding

WHAT INFORMATION DESIGNERS USE

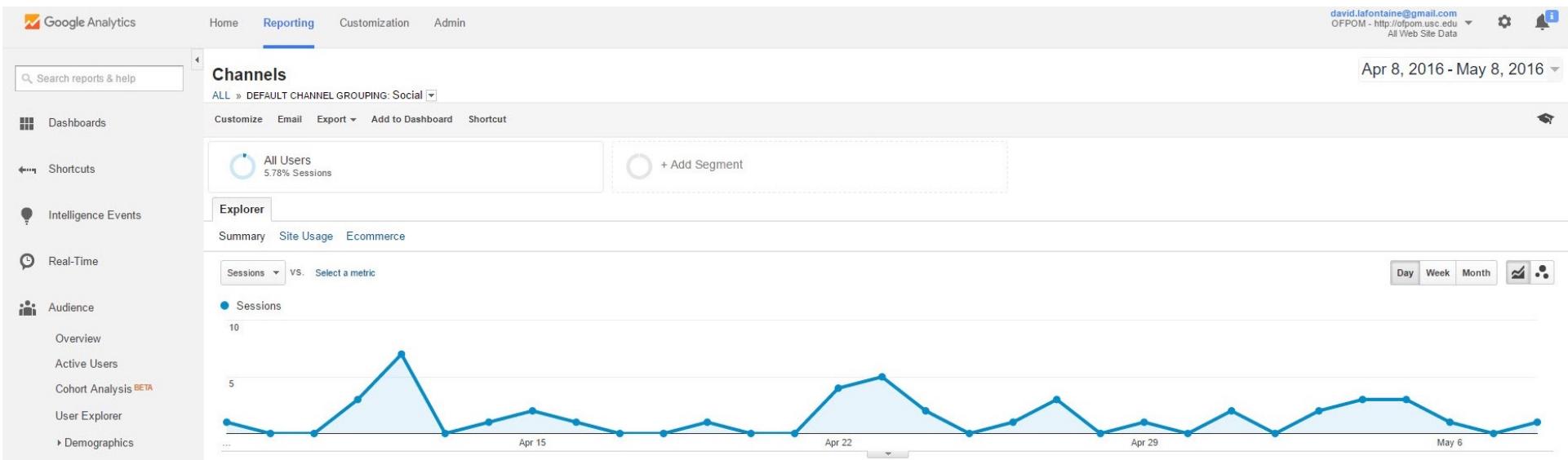
DATA RELATED

Form adapted to nature of information

USER RELATED

- User familiarity with form
- User knowledge of topic
- User abilities
- Display type and size
- Context where the form is used

THE FORM SHOULD BE CONSTRAINED BY THE GOALS OF THE VISUALIZATION



FORM FOLLOWS FUNCTION



20th-century modernist architecture and industrial design principle

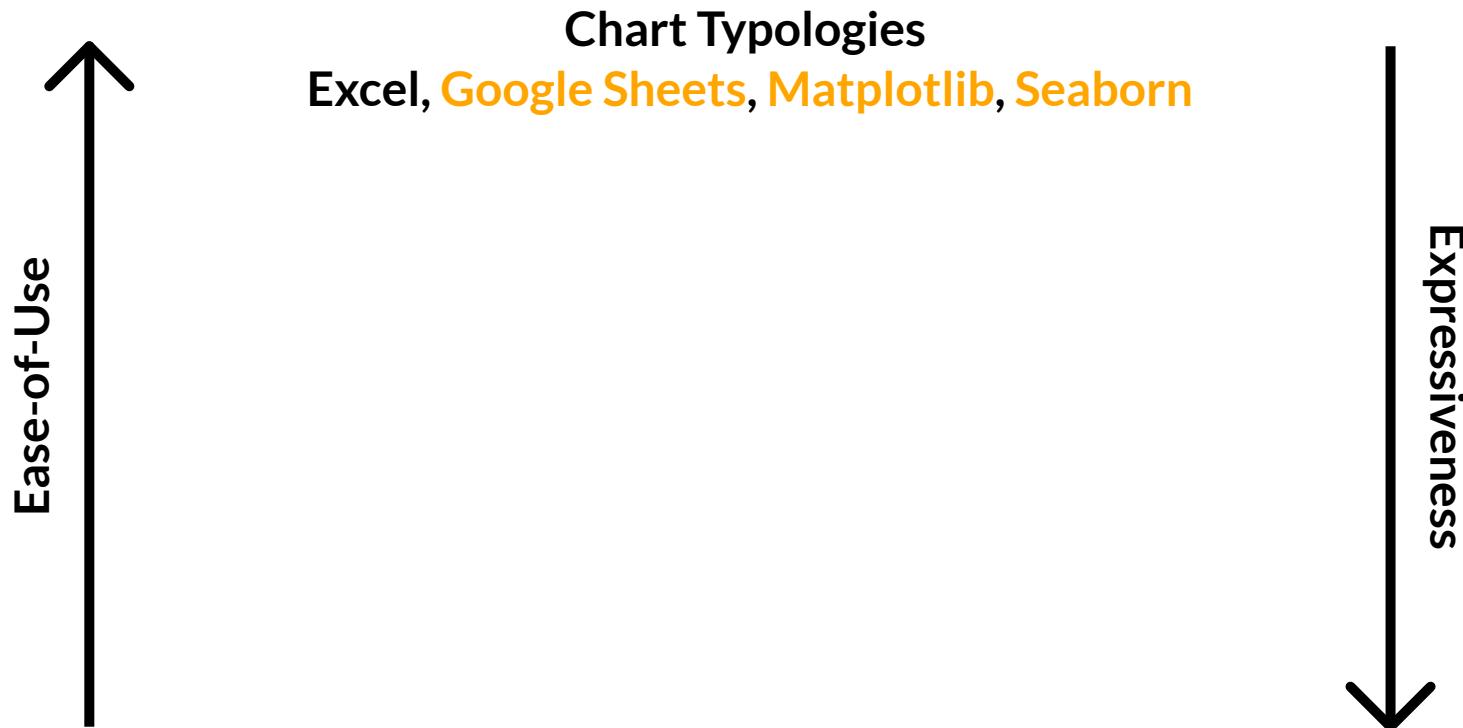
The shape of an object should primarily relate to its intended function or purpose

Sullivan, Louis H. (1896). "The Tall Office Building Artistically Considered". Lippincott's Magazine (March 1896).

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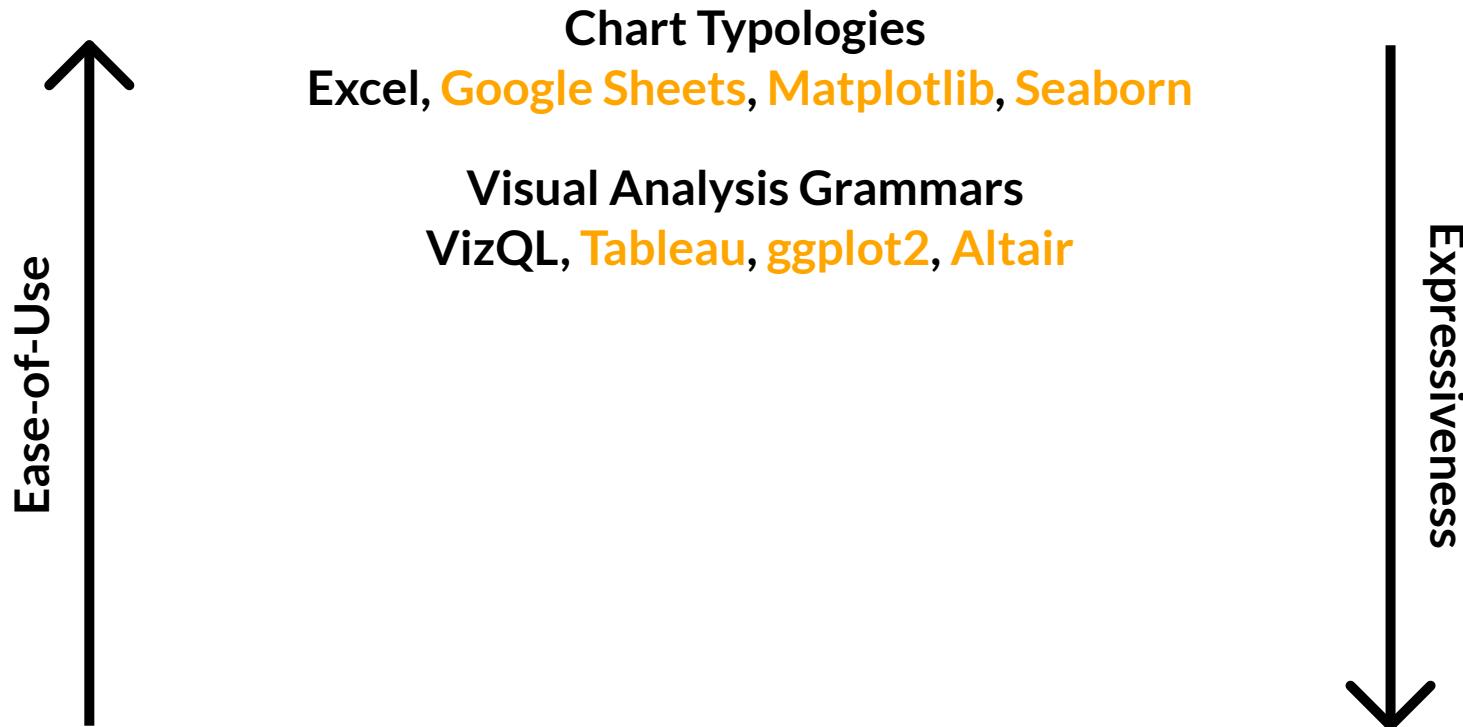
VISUALIZATION TOOLS



Adapted from [Heer 2014]

Satyanarayan, Arvind, and Jeffrey Heer. "Lyra: An interactive visualization design environment." In Computer Graphics Forum, 2014.

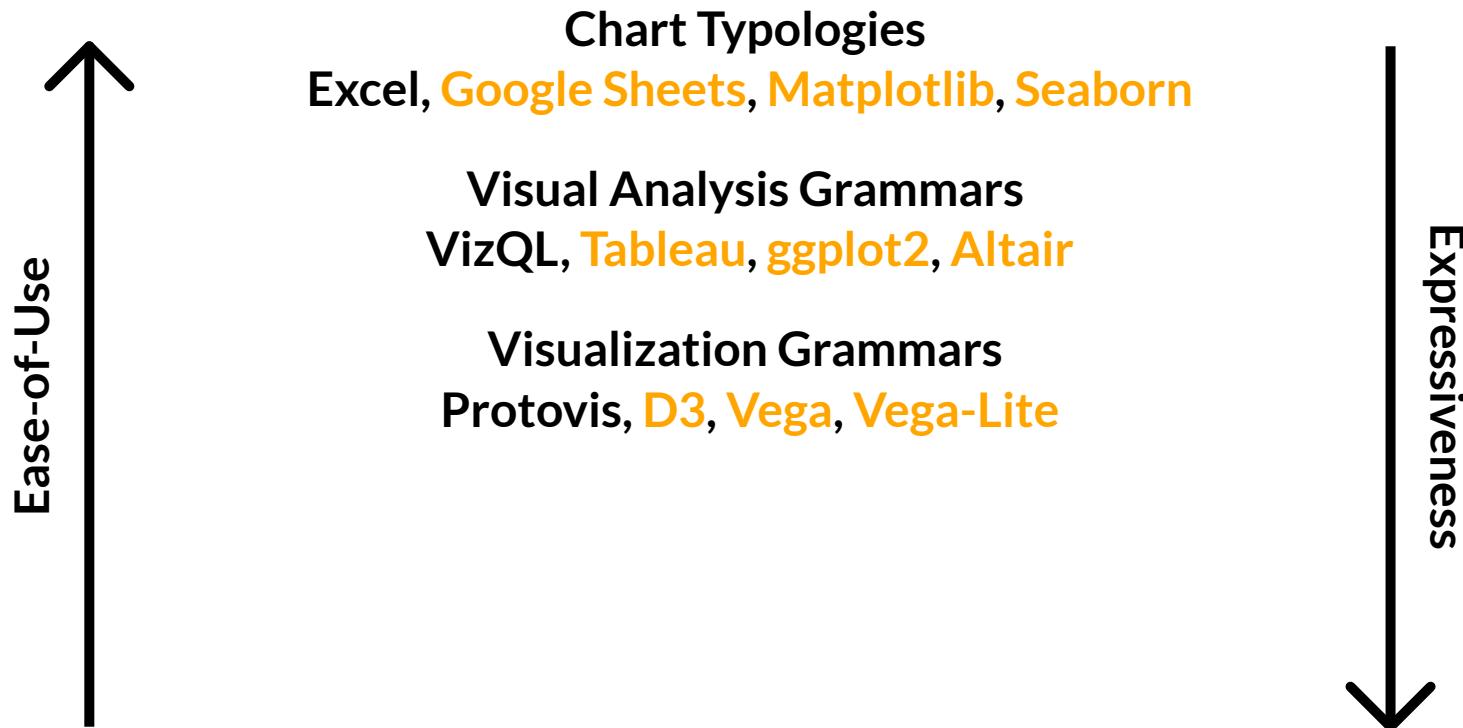
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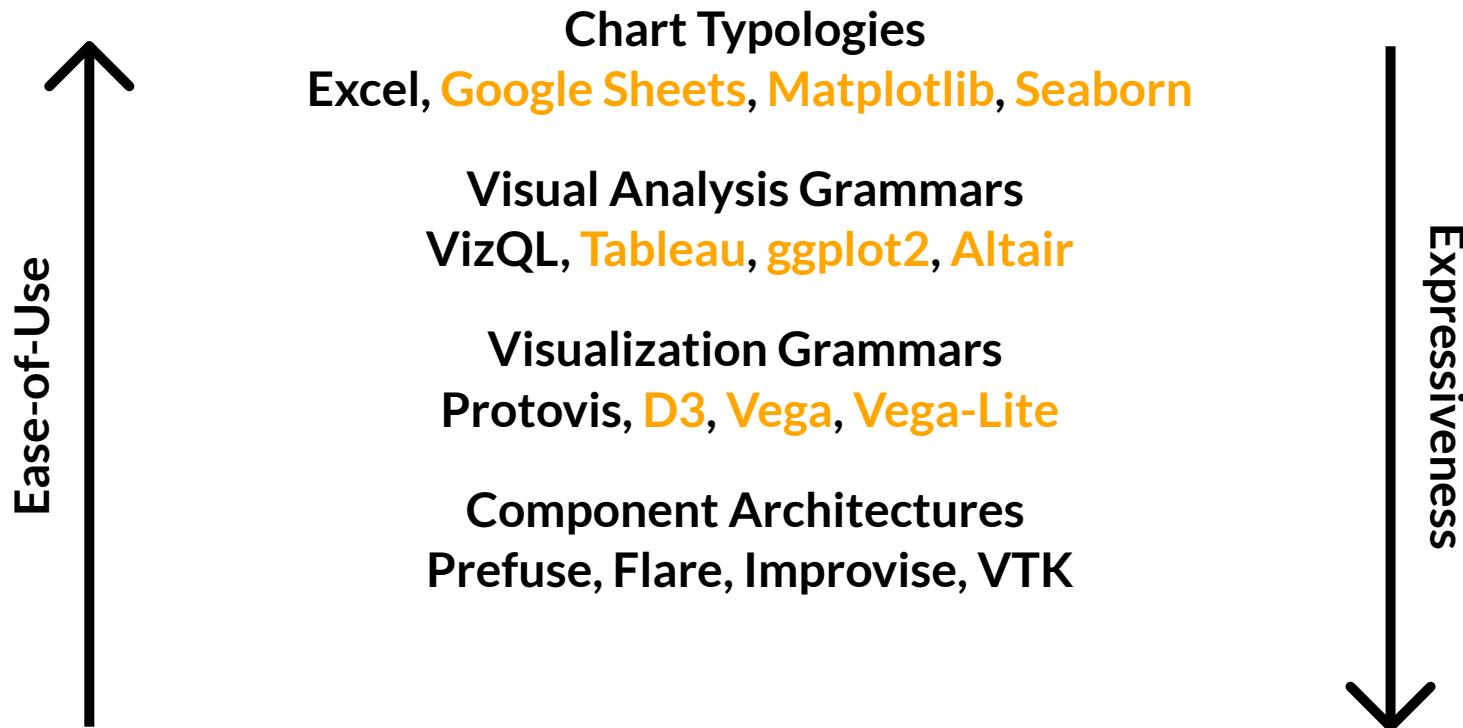
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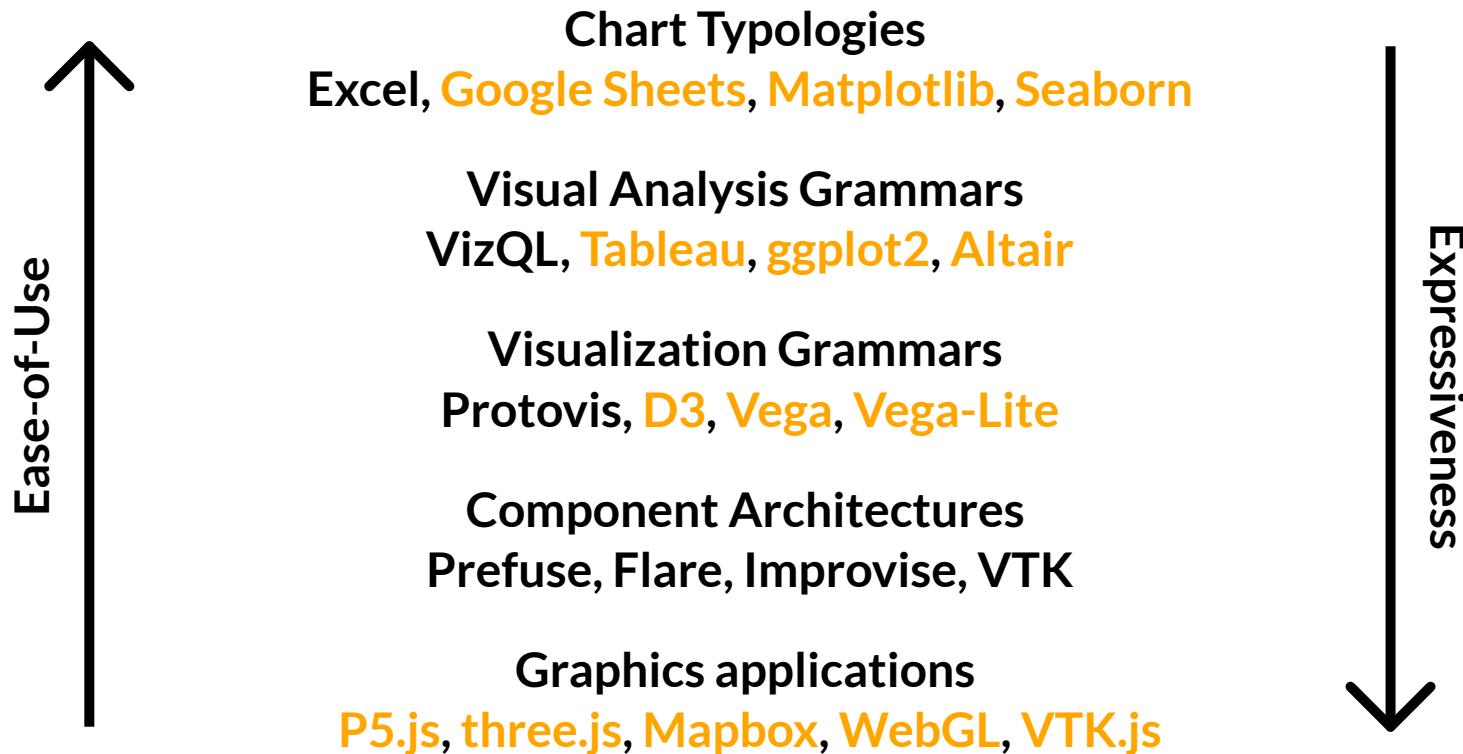
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D3.js

WHAT IT IS

- Javascript client-side library
- D3 stands for Data-Driven Documents
- Uses recent HTML, SVG, and CSS
- Primarily made to use SVG (not raster graphics, i.e., images)

WHAT IT DOES

- Loads data in the browser memory
- Create elements and bind data to elements within the document
- Transform and customize elements
- Transition elements in response to user input

