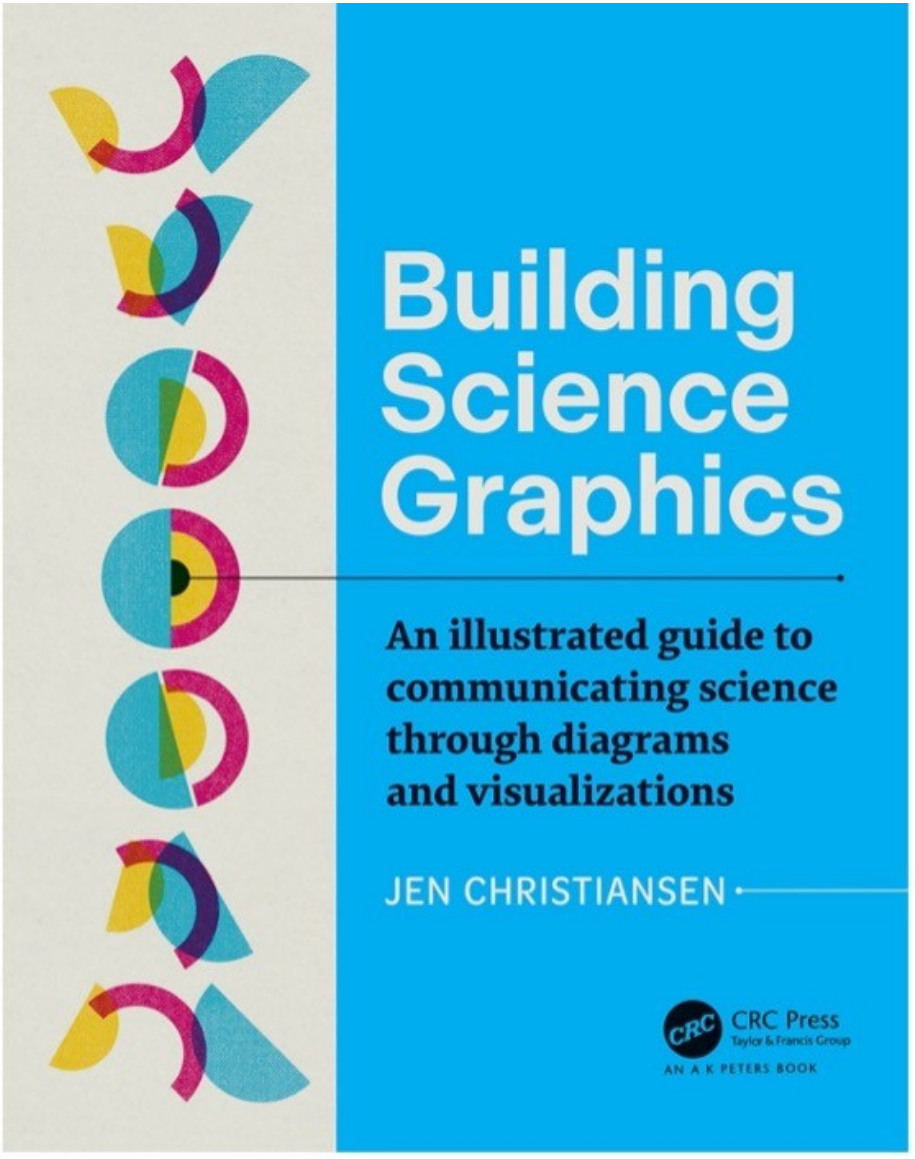
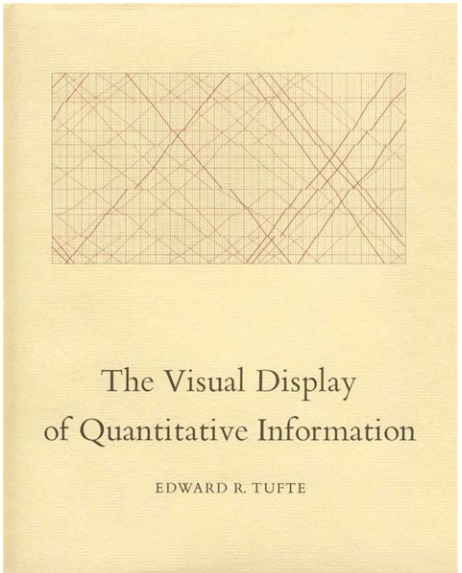
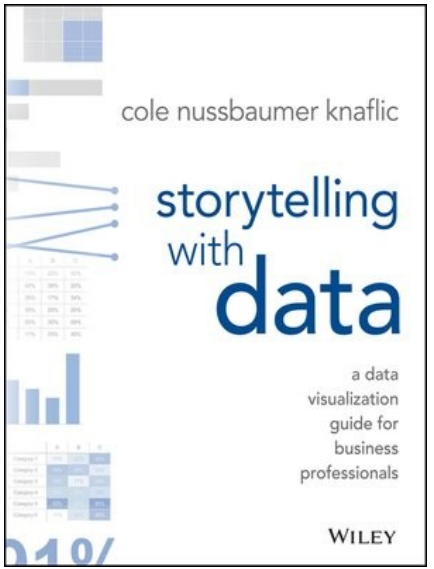


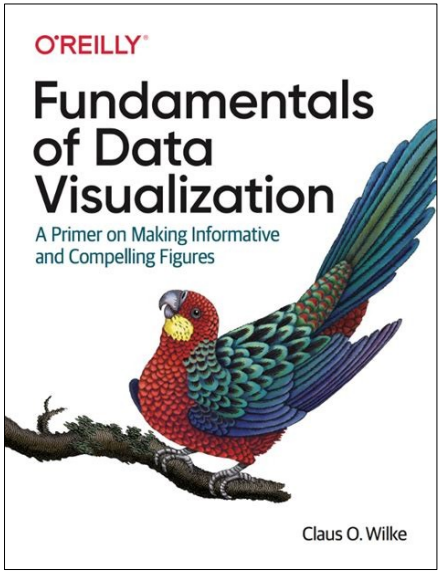
Visual science communication

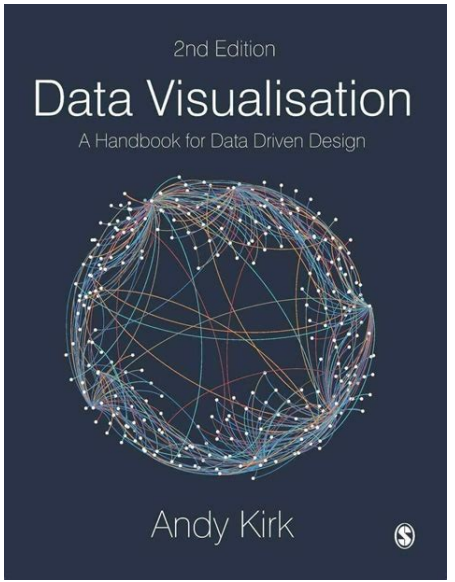
based on:
Building Science Graphics
by Jen Christiansen

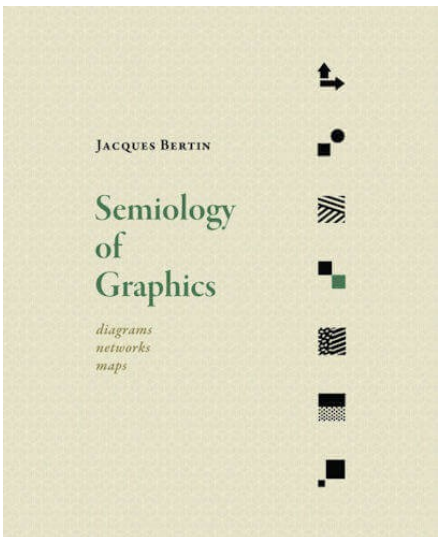
Lili Gasser, December 14, 2023
Data science meeting

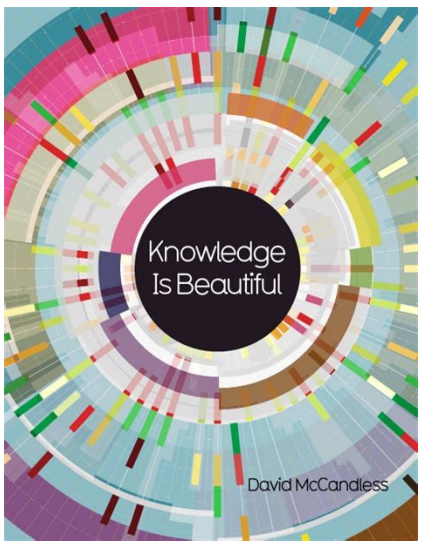

The Visual Display
of Quantitative Information
EDWARD R. TUFTE

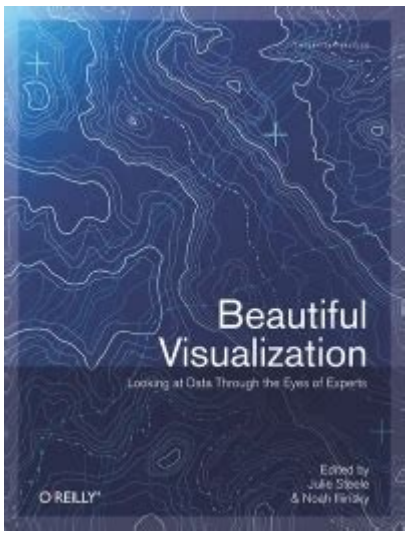

cole nussbaumer knaflic
storytelling
with
data
a data
visualization
guide for
business
professionals
WILEY


O'REILLY
Fundamentals
of Data
Visualization
A Primer on Making Informative
and Compelling Figures
Claus O. Wilke

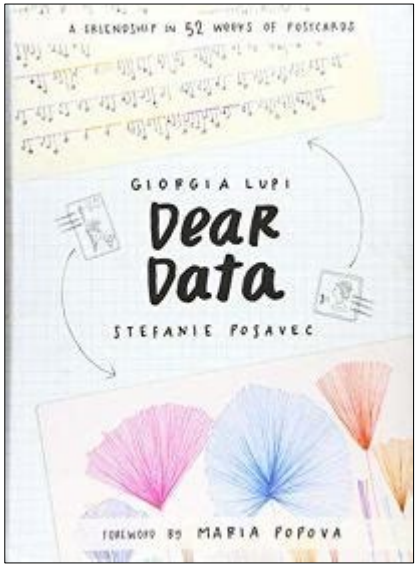

2nd Edition
Data Visualisation
A Handbook for Data Driven Design
Andy Kirk

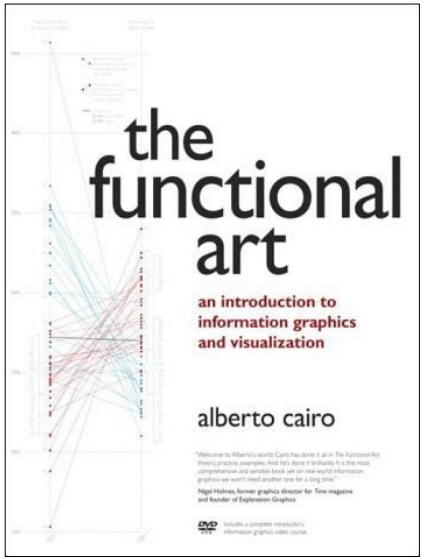

JACQUES BERTIN
Semiology
of
Graphics
diagrams
networks
maps

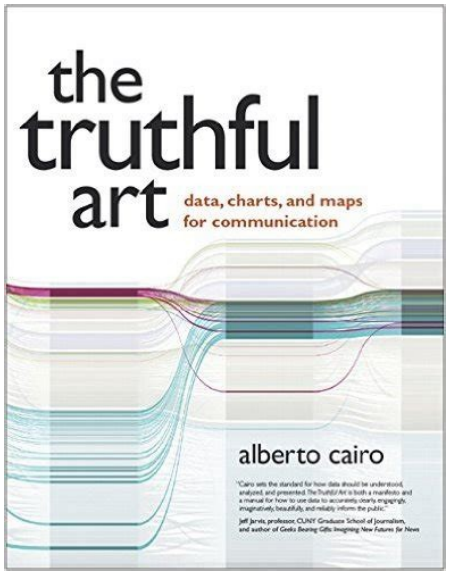

Knowledge
Is Beautiful
David McCandless

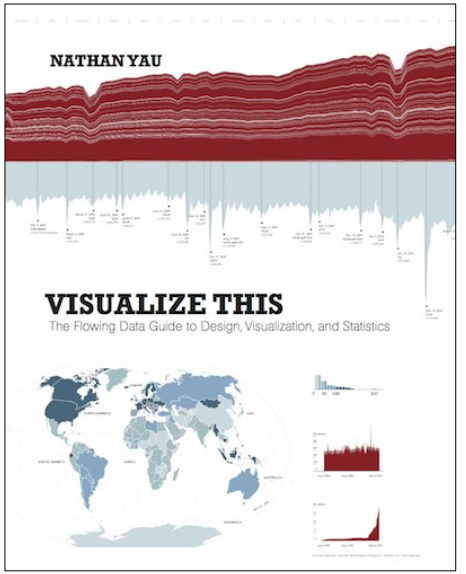

Beautiful
Visualization
Looking at Data Through the Eyes of Experts
O'REILLY
Edited by
Julie Steele
& Noah Iliinsky

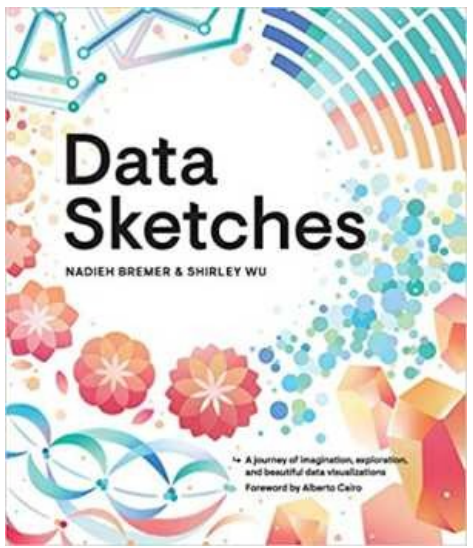

GOOD
CHARTS
SCOTT
BERINATO
The HBR Guide
to Making
Smarter, More
Persuasive Data
Visualizations
HARVARD
BUSINESS
REVIEW
PRESS

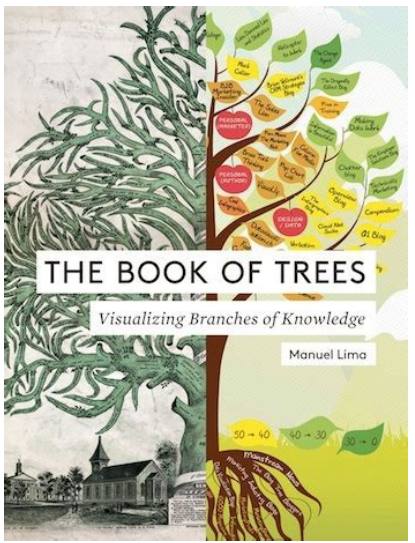

A FRIENDSHIP IN 52 WEEKS OF POSTCARDS
GIORGIA LUPI
Dear Data
STEFANIE POSAVEC
FOREWORD BY MARIA POPOVA

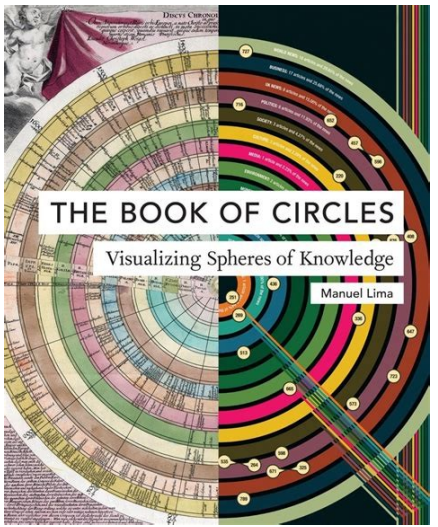

the functional art
an introduction to information graphics and visualization
alberto cairo


the truthful art
data, charts, and maps for communication
alberto cairo


NATHAN YAU
VISUALIZE THIS
The Flowing Data Guide to Design, Visualization, and Statistics


Data Sketches
NADIEH BREMER & SHIRLEY WU
A journey of imagination, exploration, and beautiful data visualizations
Foreword by Alberto Cairo


THE BOOK OF TREES
Visualizing Branches of Knowledge
Manuel Lima


THE BOOK OF CIRCLES
Visualizing Spheres of Knowledge
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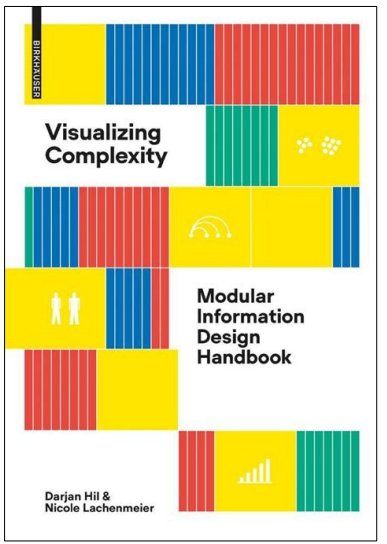
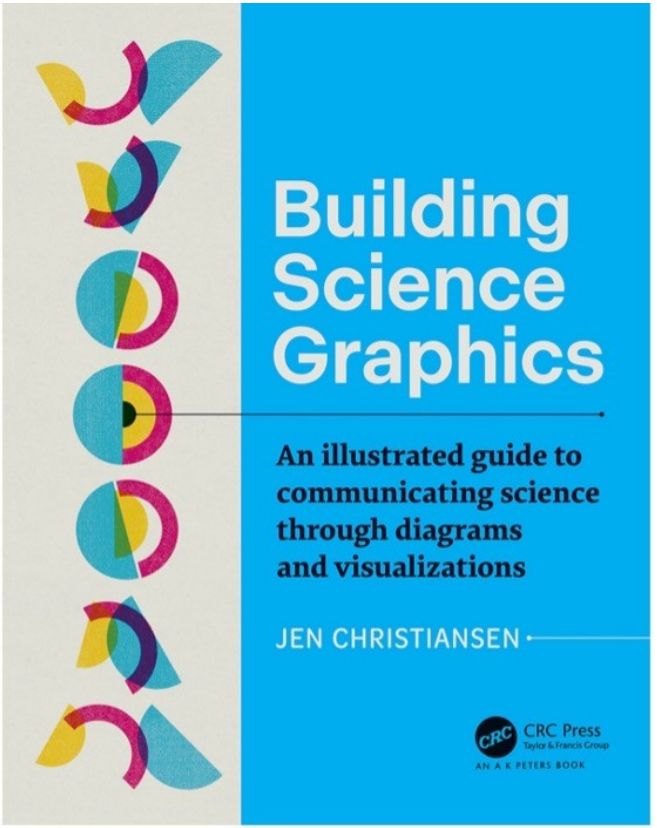

BIRKHÄUSER
Visualizing Complexity
Modular Information Design Handbook
Darjan Hil & Nicole Lachenmeier

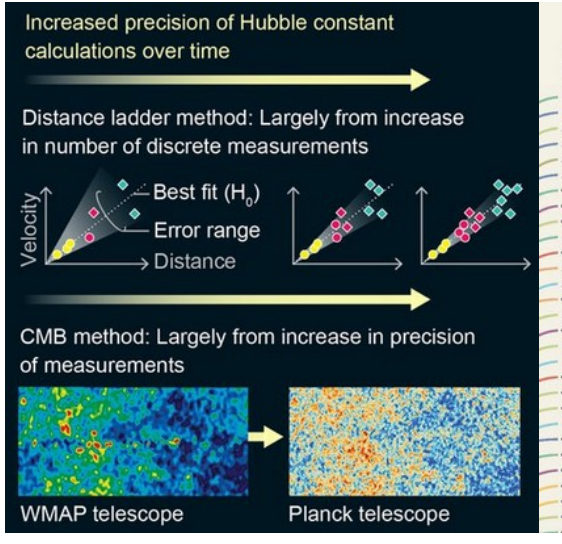
But no book focused on visualizing science...

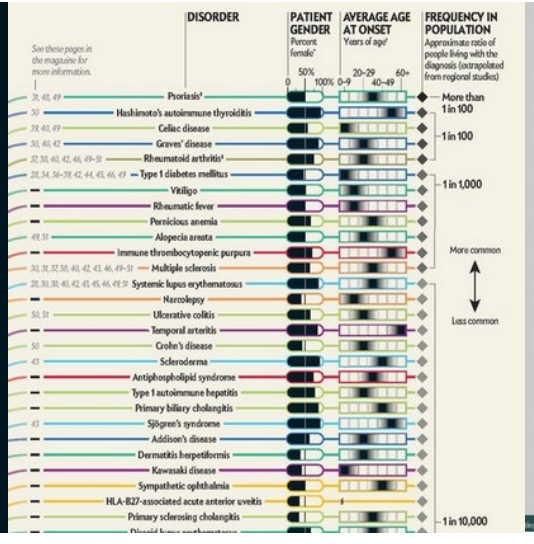


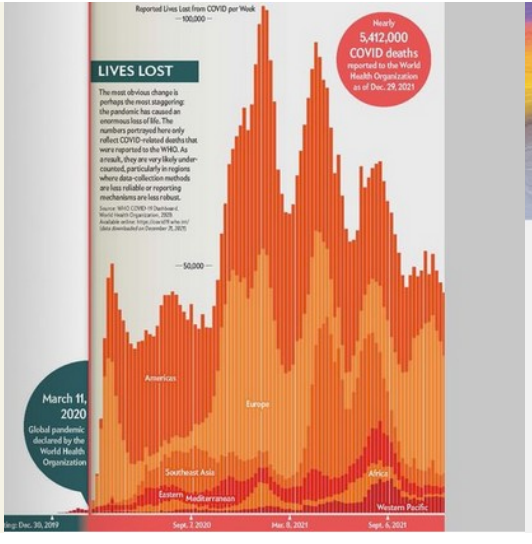
Jen Christiansen

- Senior graphics editor at Scientific American
- “science communicator of the visual variety”
- www.jenchristiansen.com

- started her career in 1996 and has worked
  - for Scientific American
  - for National Geographic
  - as a freelancer

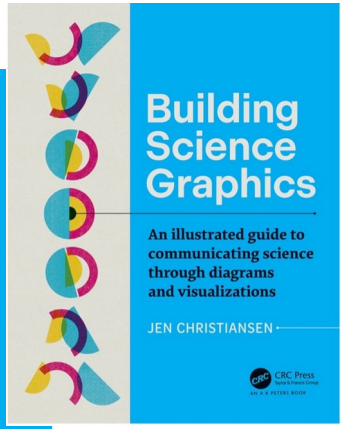






Building Science Graphics

Part 1: Underpinning



Part 2: Illustrating Science

Part 3: Do It Yourself

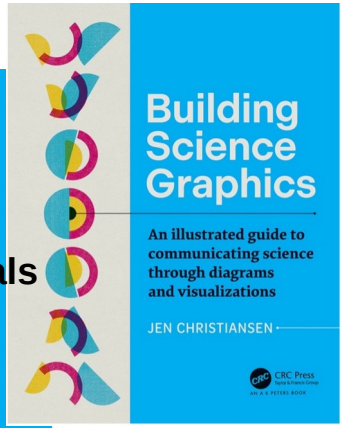
Part 4: Joint efforts

Graphics and quotes are from the book, unless stated otherwise.

Building Science Graphics

Part 1: Underpinning

- 1: Introduction
- **2: What are science graphics?**
- **3: Science communication fundamentals**
- 4: Graphic design fundamentals
- 5: Perception science
- **6: Making sense of visual complexity**
- **7: Organization and emphasis**
- **8: Color**
- **9: Typography**
- 10: Visual style
- 11: Storytelling strategies
- 12: Practicalities



Part 2: Illustrating Science

- 13: Special considerations for sci. graphics
- 14: Types of science graphics

Part 3: Do It Yourself

- 15: The process of building graphics
- 16: Step-by-step guide for building your own scientific graphic
- 17: Step-by-step guide for adapting your graphic for a different purpose

Part 4: Joint efforts

- 18: Collaborations

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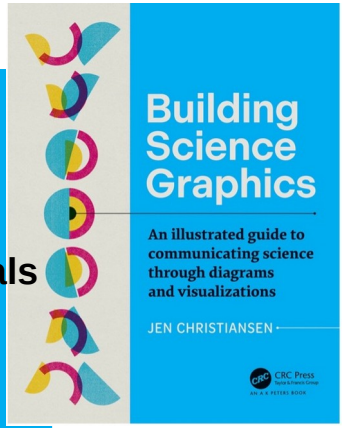
Building Science Graphics



Part 1: Underpinning

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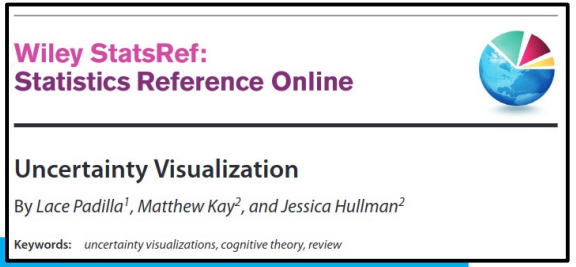
+


Wiley StatsRef:
Statistics Reference Online

Uncertainty Visualization

By *Lace Padilla*[1], *Matthew Kay*[2], *and Jessica Hullman*[2]

Keywords: *uncertainty visualizations, cognitive theory, review*

Part 2: Illustrating Science

- **13: Special consid. for sci. graphics**
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Part 4: Joint efforts

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Graphics and quotes are from the book, unless stated otherwise.

Chapter 2: What are science graphics?

"This book is about using **imagery** in
the service of **communication**, not analysis.
Although many of the lessons within apply to both."
p. 13

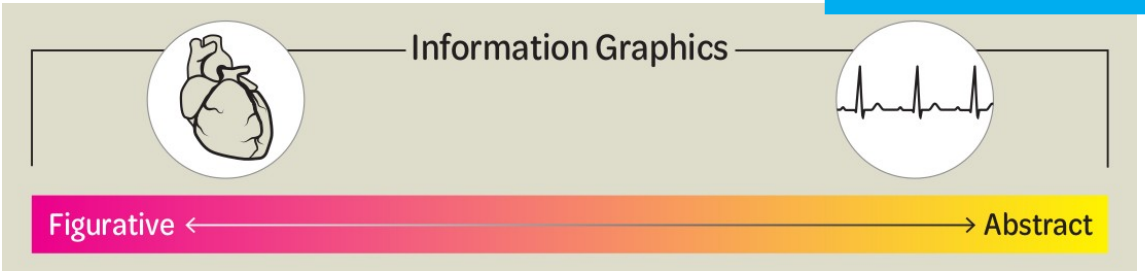
e.g., for posters, graphical abstracts, overviews of studies and datasets

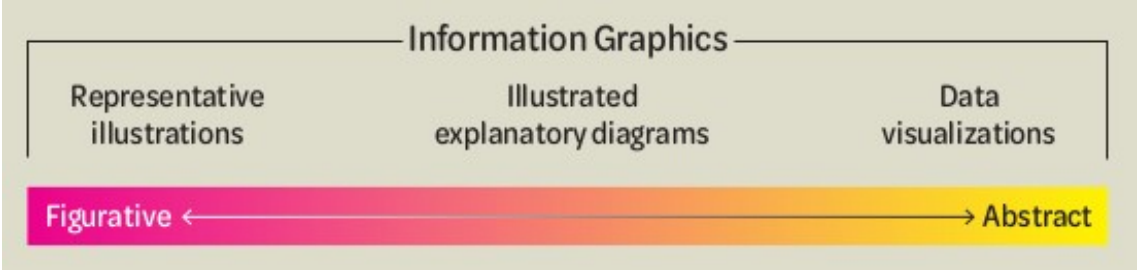
A continuum of science graphics

2: What are science graphics, p. 13

"Information graphics are images
- built on a foundation of research -
that are constructed primarily
to convey information."

p. 16





A continuum of science graphics

2: What are science graphics, p. 13

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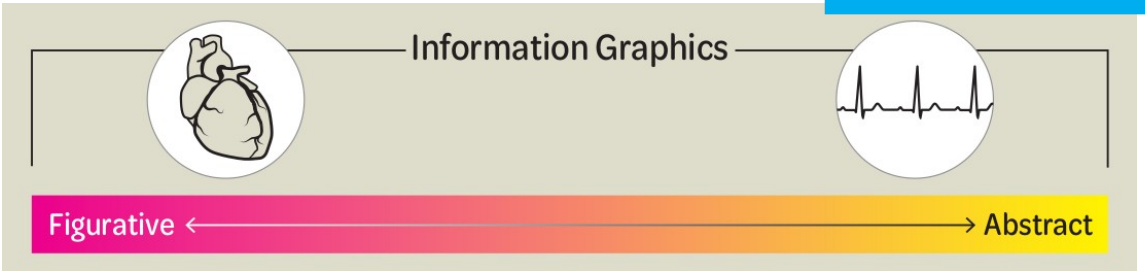
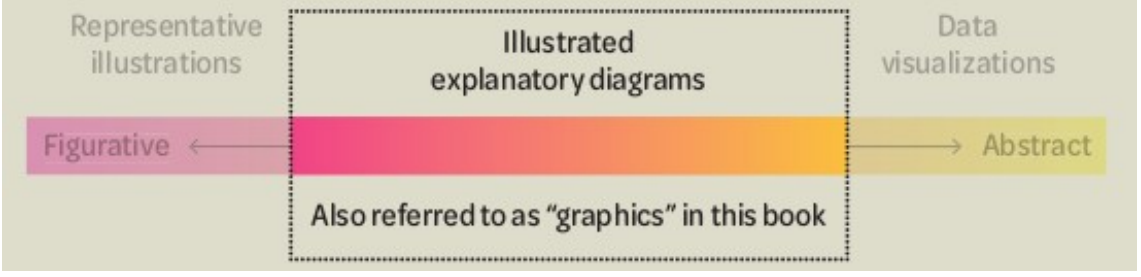
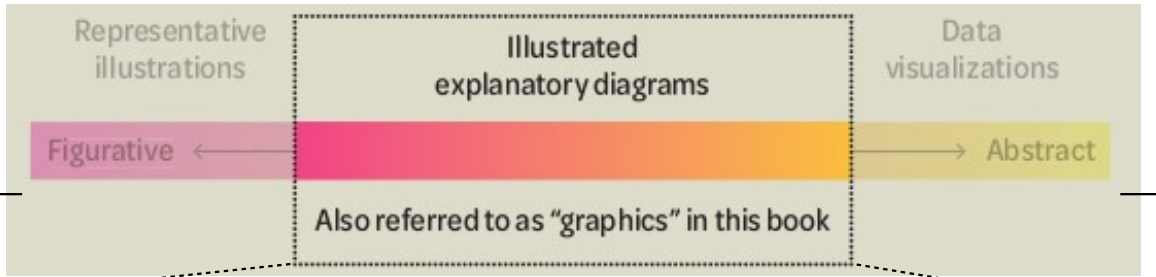
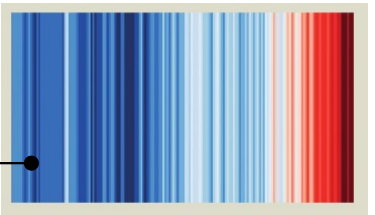


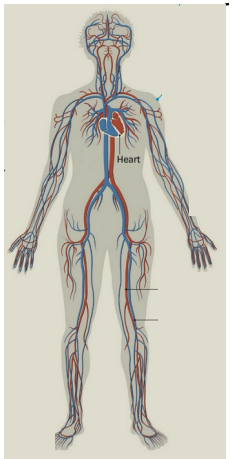


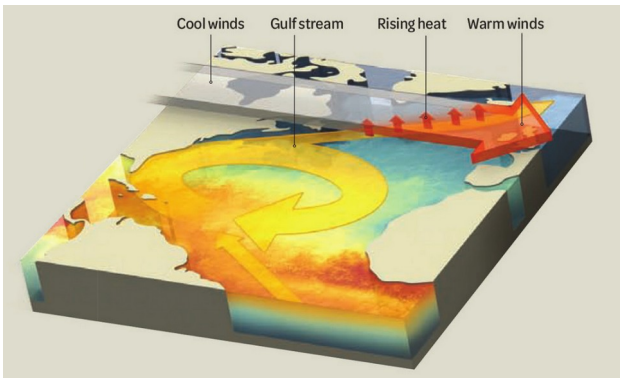
A continuum of science graphics

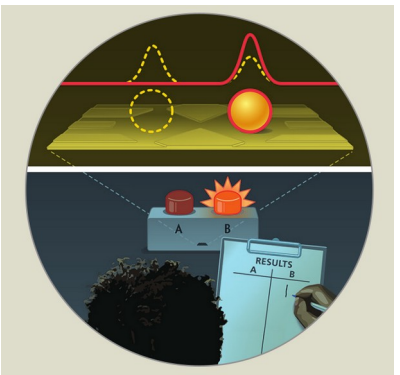
2: What are science graphics, p. 13

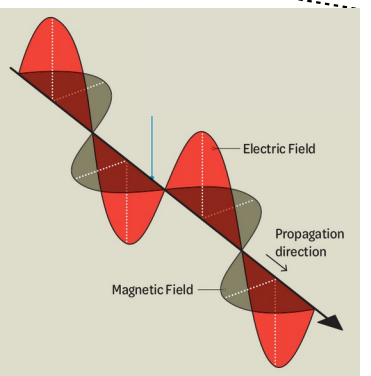








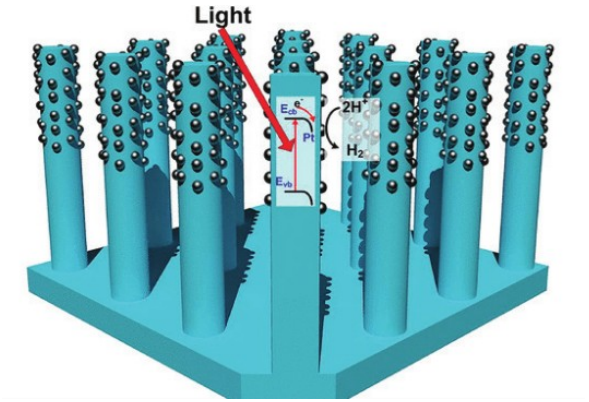




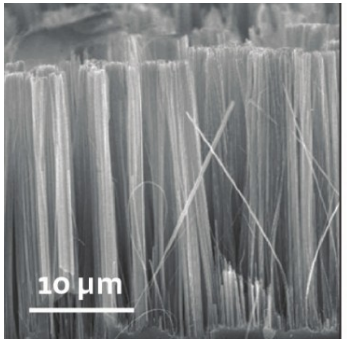
Redesign improves perception

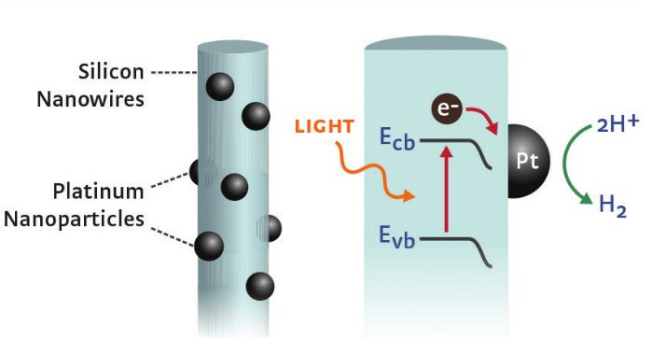
3: Science communication fundamentals, p. 23

- original graphical abstract:



after redesign:





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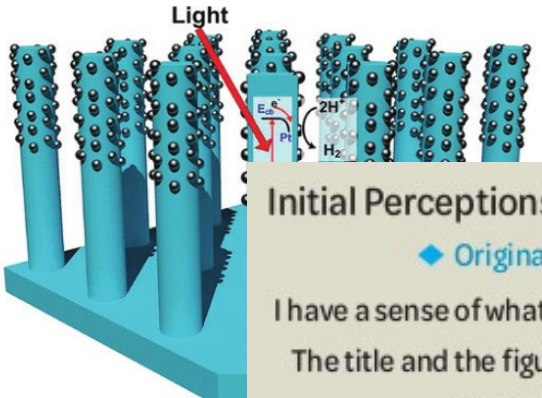
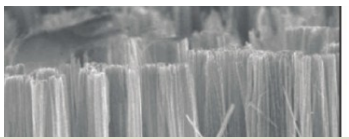
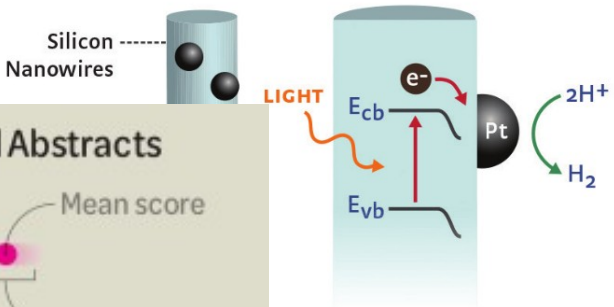
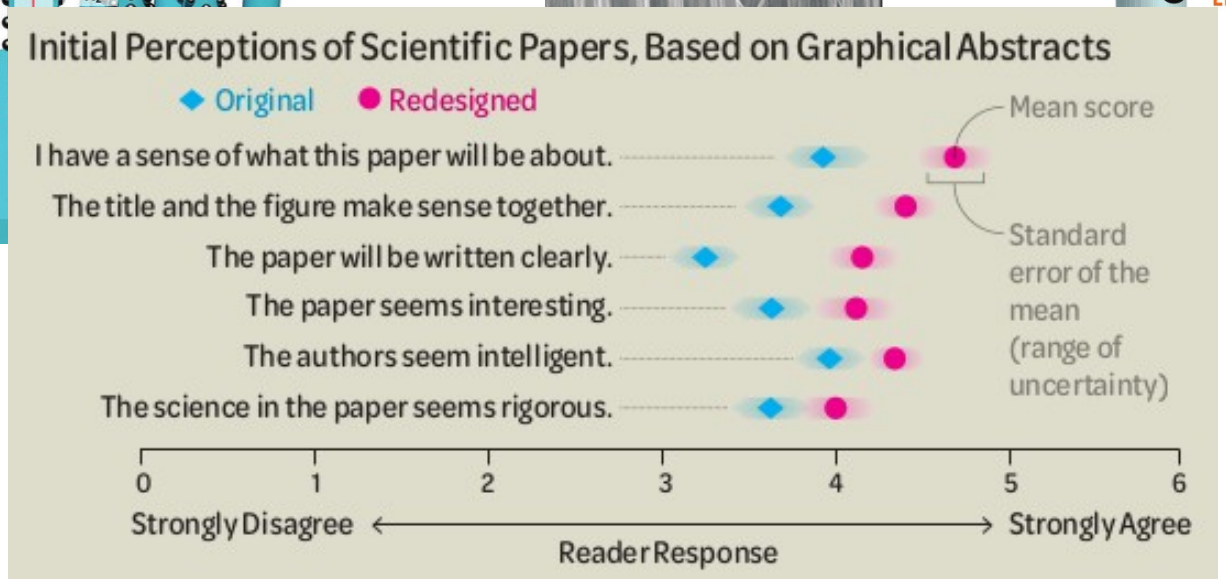


after redesign:







results from 50 survey participants on 10 redesigned graphical abstracts

Disclaimer

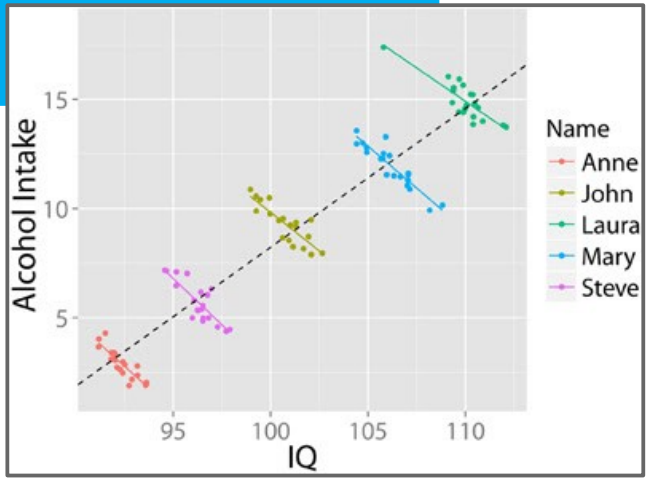
- These are best practices and recommendations, but there is **no ground-truth**.
- A good choice depends on
  - discipline-specific conventions,
  - cultural background,
  - personal preferences,
  - …

Chapter 6: Making sense of visual complexity

"We mustn't simplify stories; we must clarify them."

Alberto Cairo, Nigel Holmes

http://www.thefunctionalart.com/2016/09/we-mustnt-simplify-stories-we-must.html



Chapter 6: Making sense of visual complexity

- A step back to the elements used for complex visual designs.
  - relationships
  - symbols
  - arrows

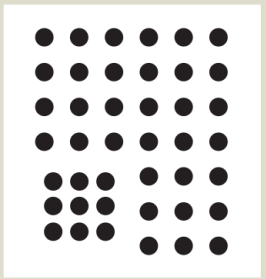
- Also check Sekhar’s presentation on data visualization from July 2020.
  https://sdsc.atlassian.net/wiki/spaces/ACADEMIA/pages/572358657/2020-07-02+-+Sekhar+-+Data+Visualization

Relationships

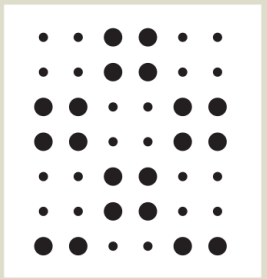
6: Making sense of visual complexity, p. 62

- Visual Gestalt principles: “the whole is more than the sum of its parts”

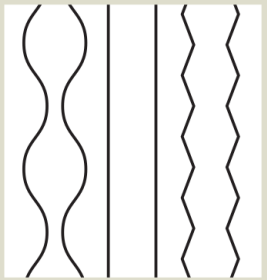
Perceptual Grouping refers to effects that cause people to perceive elements within an image as belonging with each other. These associations can result in perceived pairings, patterns, or dominant shape and path interpretations.



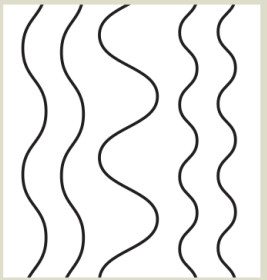
Proximity • Equally spaced dots are generally perceived as a uniform block. When spacing is irregular, we perceive the dots that are closer to each other as belonging to the same sub-unit.



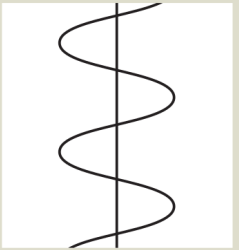
Similarity (of color, of size, of orientation) • All else being equal, we perceive objects that share a common visual attribute (color, size, or orientation for example) as belonging to the same group.



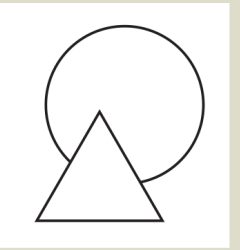
Symmetry • All else being equal, we tend to perceive lines that are symmetrical as a unit.



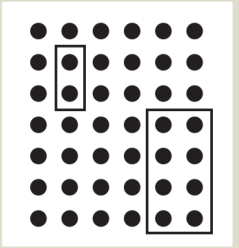
Parallelism • All else being equal, we tend to perceive lines that are parallel as a unit.



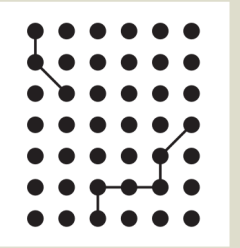
Continuity • We tend to favor tracking smooth and continuous lines, rather than following a path that includes abrupt angles.



Closure • We tend to complete closed shapes, seeing this arc as a full circle behind a triangle.



Common region • We tend to perceive elements that lie within the same bounded area as a unit.



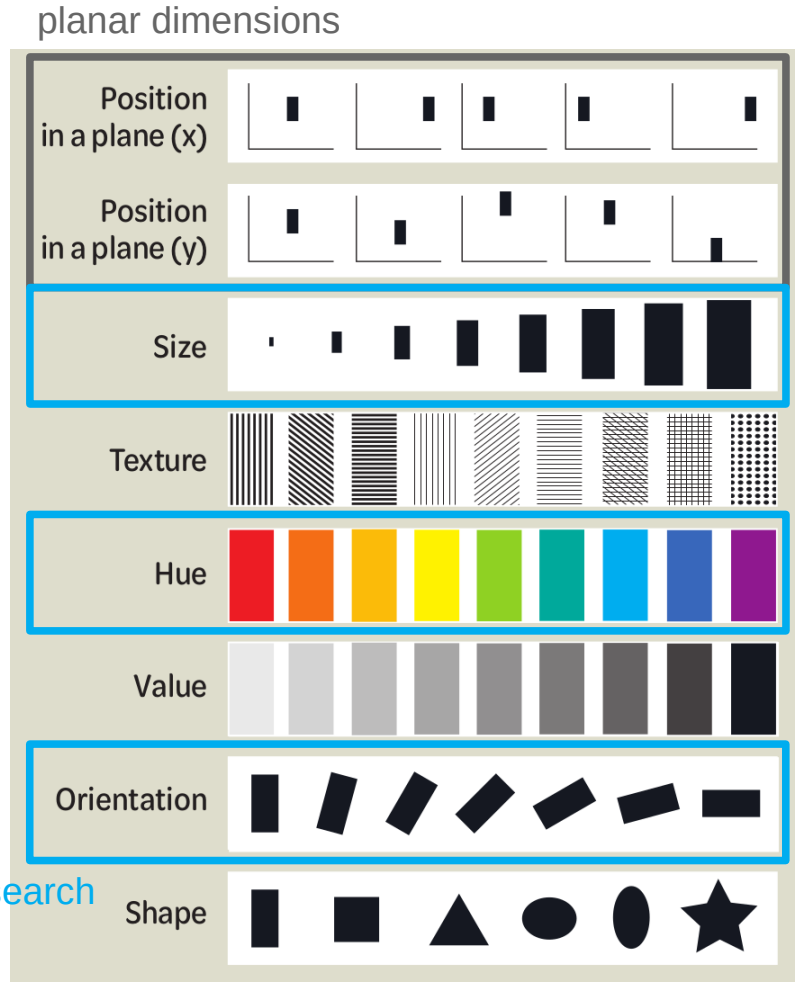
Element connectedness • We tend to perceive elements that are connected as a unit.

Symbols

6: Making sense of visual complexity, p. 64

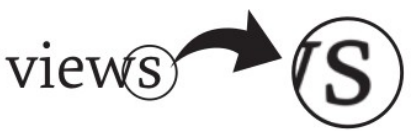
- Jacques Bertin's visual variables
  - for static, two-dimensional representations
  - from "Sémiologie Graphique", 1967
  - 2 planar dimensions: positions
  - well-supported by research: size, color, orientation

- Semiotics: the study of signs and symbols, and how they impart meanings



Arrows

6: Making sense of visual complexity, p. 66

- Arrows are powerful symbols to show
  - a change in state or position: A→B
  - causality: C→D
  - movement: ●→
  - rotation: 
  - relative values: more ↑, and less ↓
  - expanded views: 

  - discipline-specific uses

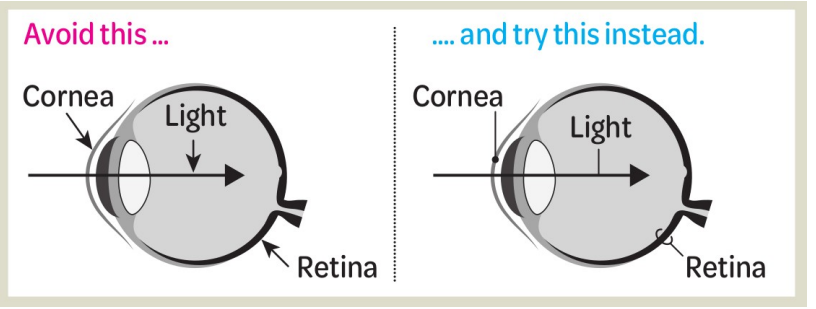
Arrows

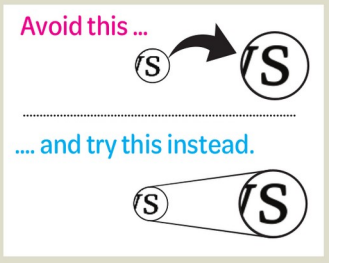
6: Making sense of visual complexity, p. 66

- Arrows are powerful symbols to show
  - a change in state or position: A→B
  - causality: C→D
  - movement: ● →
  - rotation: ↷
  - relative values: more ↑, and less ↓
  - expanded views: views → (S)
  - discipline-specific uses

"Since arrows imply directionality, I generally recommend that you avoid using them as a way to convey labels, or as a way to connect expanded views to the origin."

p. 66 (Jen's opinion)

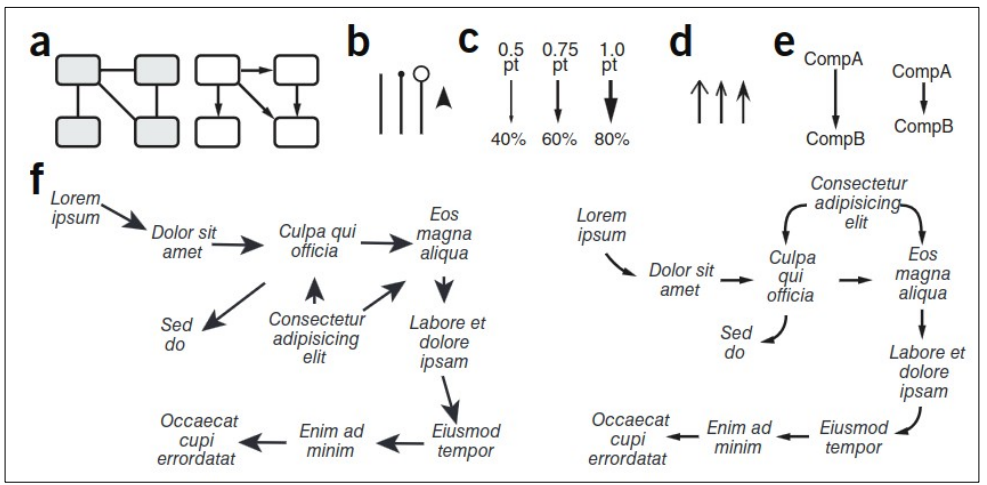




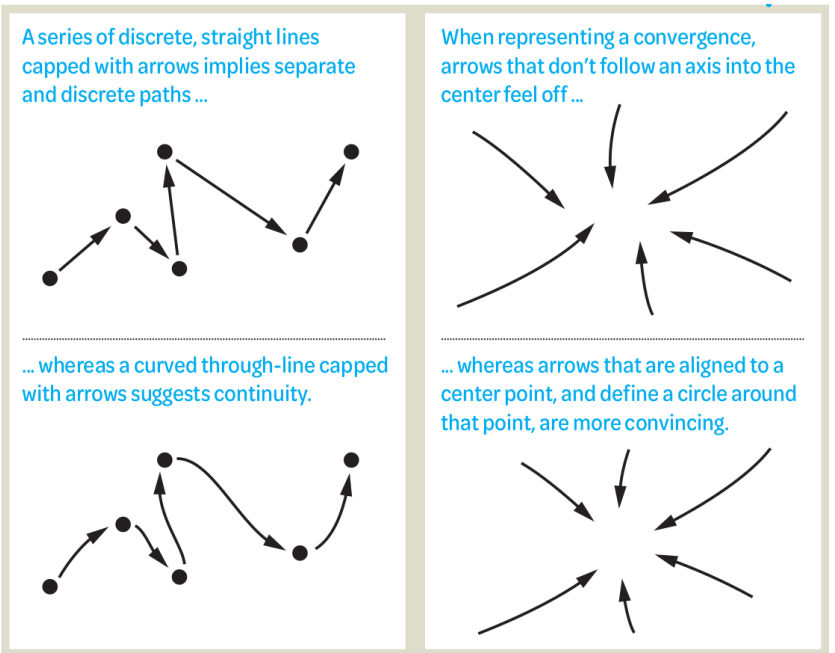
Arrows

6: Making sense of visual complexity, p. 66

- Bang Wong



Jacques Bertin:



Bang Wong, Arrows, Nature methods, Vol. 8 No. 9, 2011 https://www.nature.com/articles/nmeth.1676

Chapter 7: Organization and Emphasis

“Think about taking a reader by the hand,
and walking them through your graphic,
one step at a time.”
p. 71

Chapter 7: Organization and Emphasis

- How to organize a graphic and guide the reader’s attention
  - composition
  - grids and alignments
  - negative space
  - visual hierarchy
  - flow of information
- Demonstration: Composition makeover

Composition

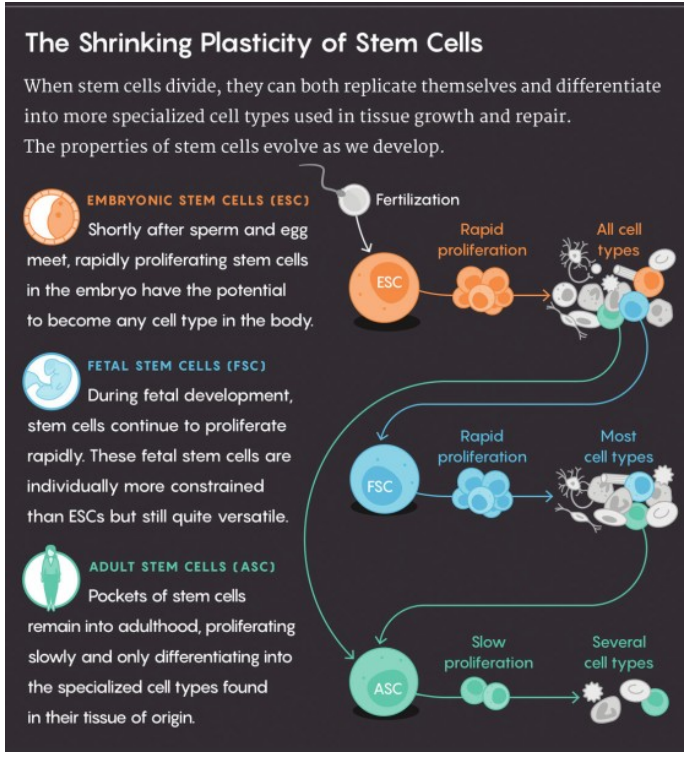
7: Organization and Emphasis, p. 70

- Consider whether audience reads from left to right or from right to left.

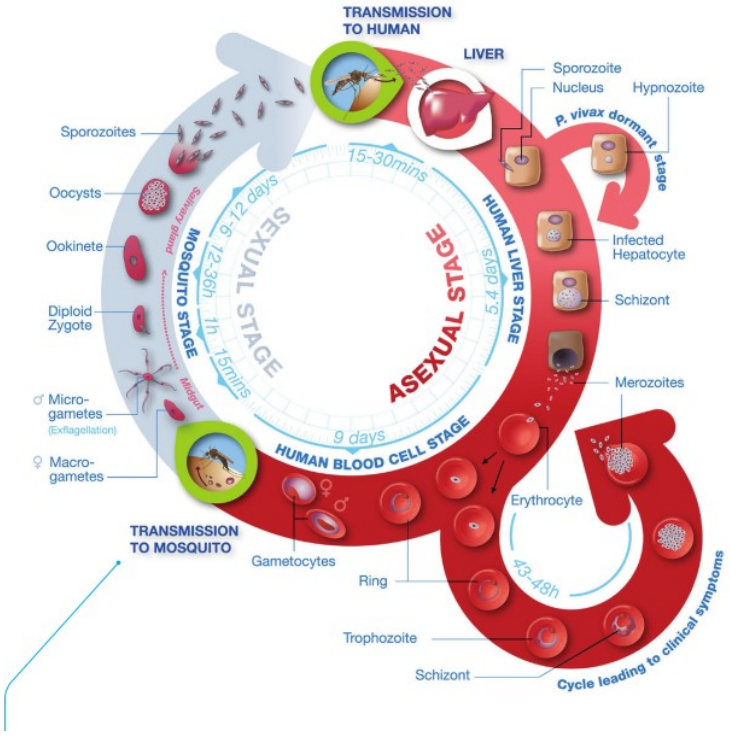
Composition

7: Organization and Emphasis, p. 70

- Provide a clear path to follow.



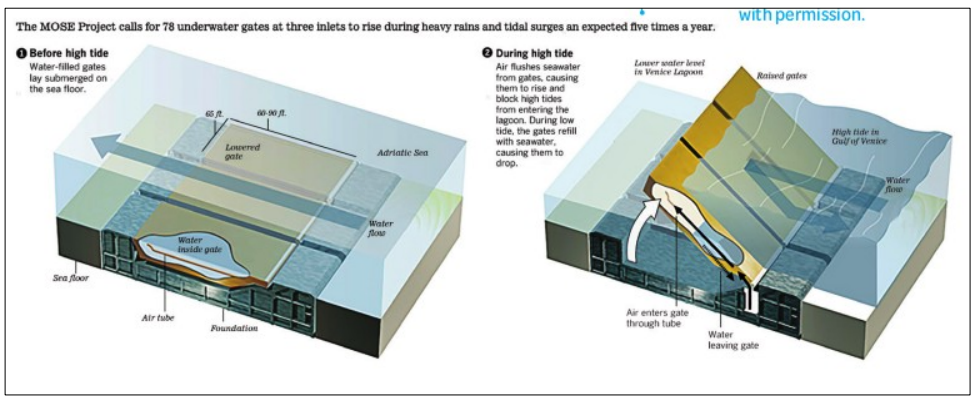
- Reinforce a cyclical process with a cyclical composition



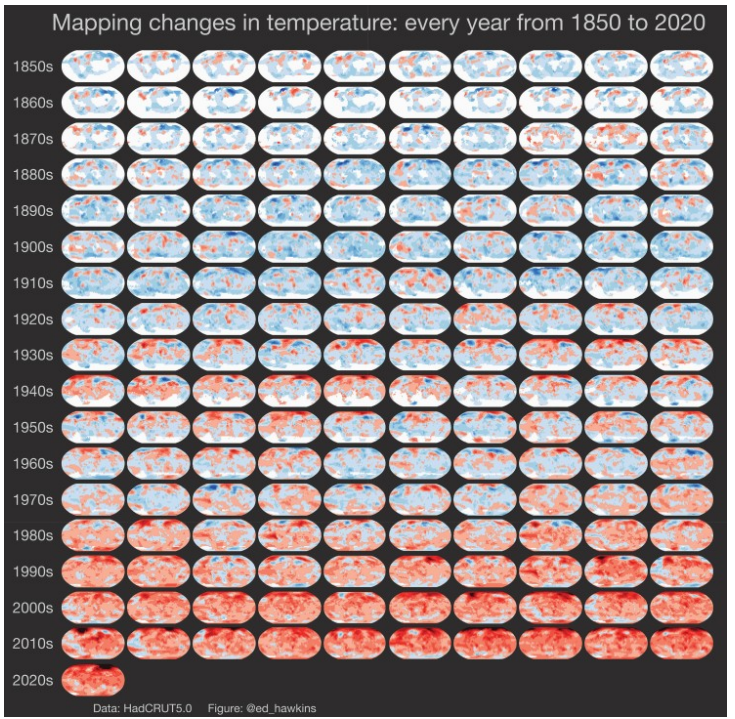
Composition

7: Organization and Emphasis, p. 70

- When comparing and contrasting, show the different vignettes in the same manner.



- “small multiples”: “The audience learns how to read one element, then can efficiently apply that knowledge to the other elements.”

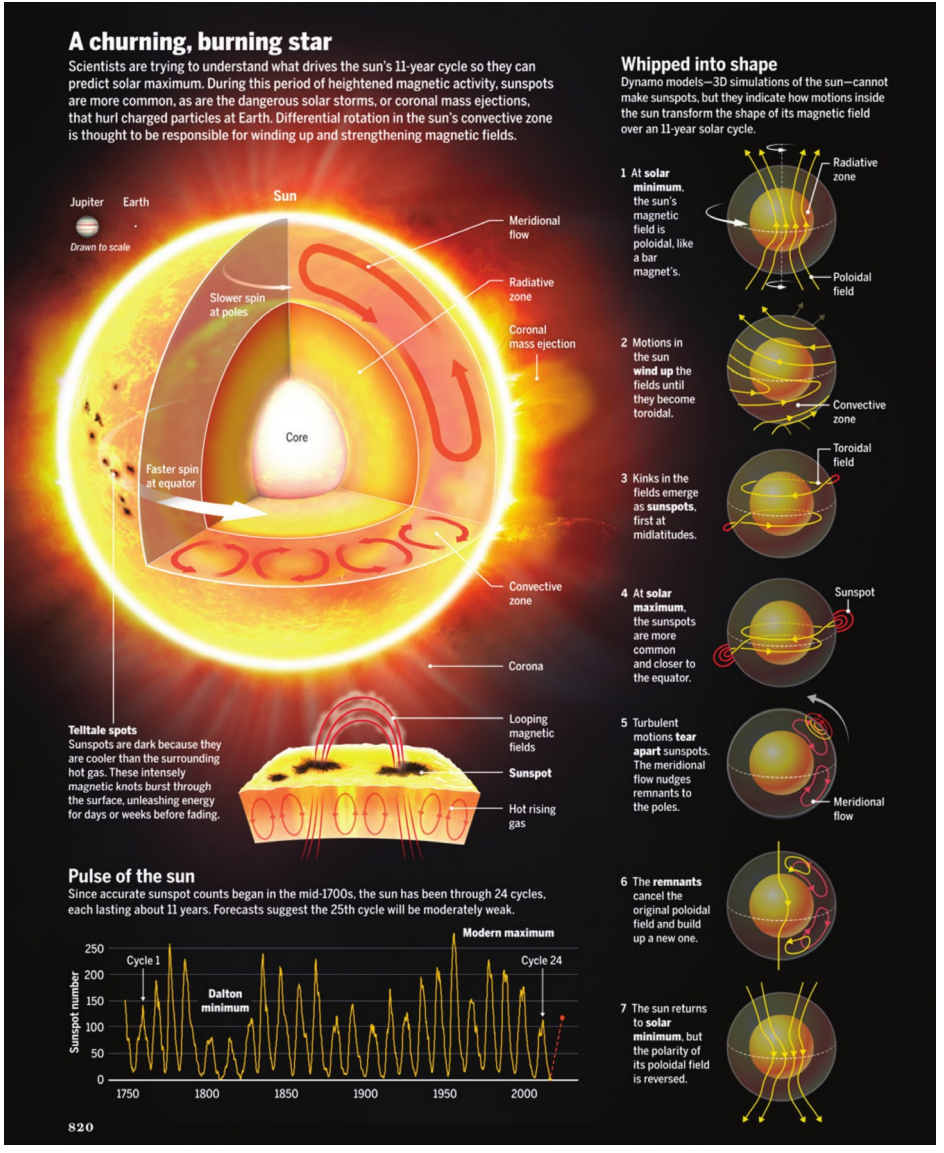


Grids and Alignments

7: Organization and Emphasis, p. 75

- A grid helps to structure information.

- NB check the use of arrows.

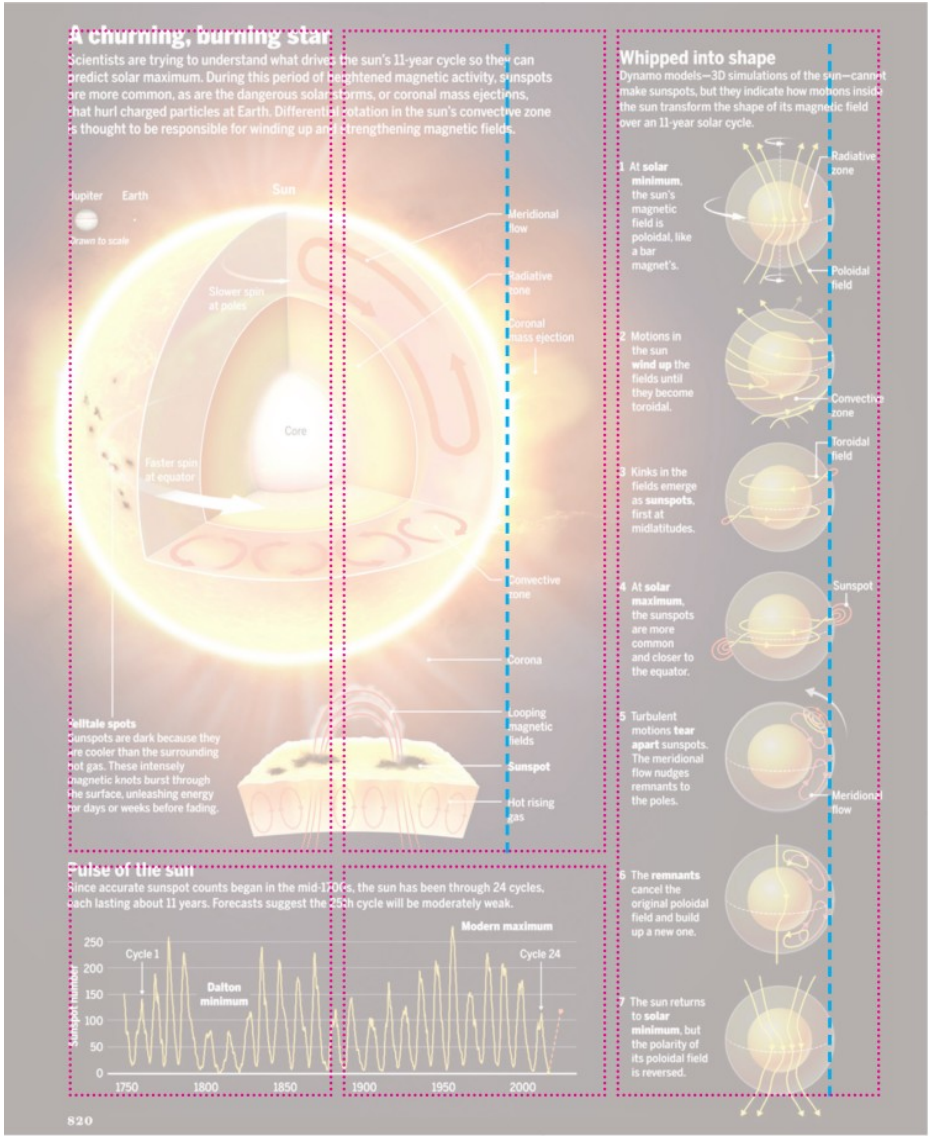


Grids and Alignments

7: Organization and Emphasis, p. 75

- A grid helps to structure information.
  - 3 modules, organized in 3 columns (pink)
  - labels are aligned (blue)
    to reinforce an overall sense of clarity.

- NB check the use of arrows.



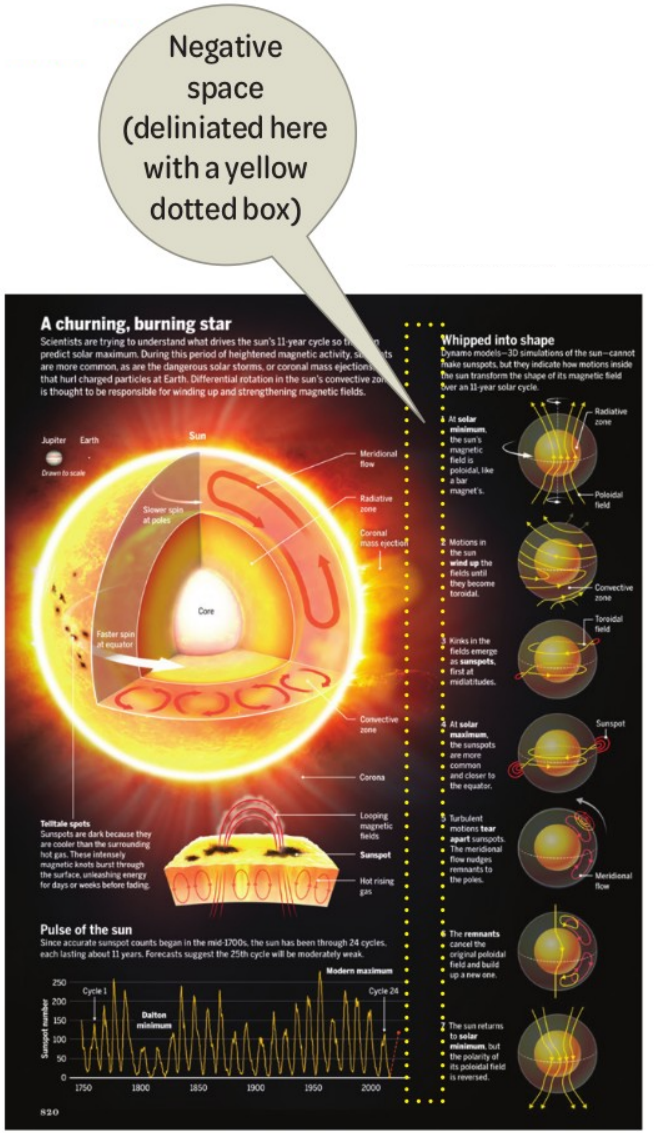
Negative space

7: Organization and Emphasis, p. 80

- = the empty zones around elements

“Lines and frames can be useful, especially if you’re cropping in on an detail within a larger scene. But if you’re simply hoping to **corral objects together, negative space may do the trick** without introducing additional visual noise. Remember the Gestalt law of proximity?”

p. 80



Visual hierarchy

7: Organization and Emphasis, p. 82

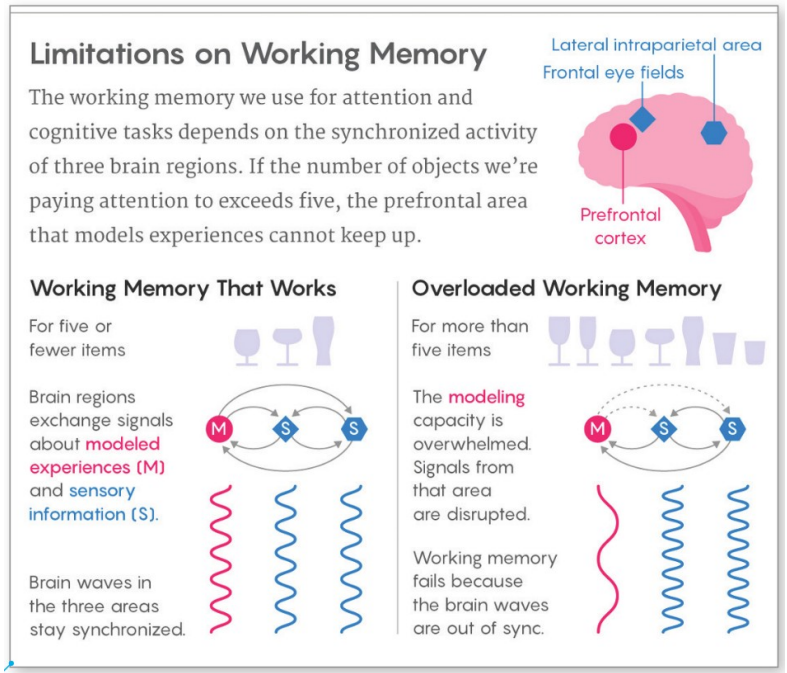
> “Expressing order is a central task of a graphic designer.”
> Ellen Lupton, p. 82

- Typically expressed through variation in
  - position,
  - scale,
  - and color.

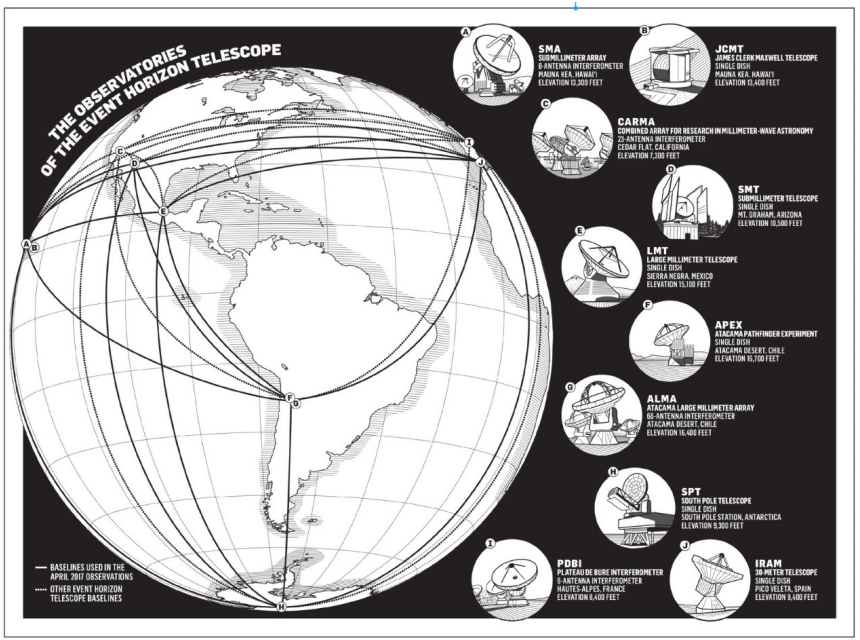
Visual hierarchy

7: Organization and Emphasis, p. 82

- Position
  - top part spanning the content below like an umbrella is read first



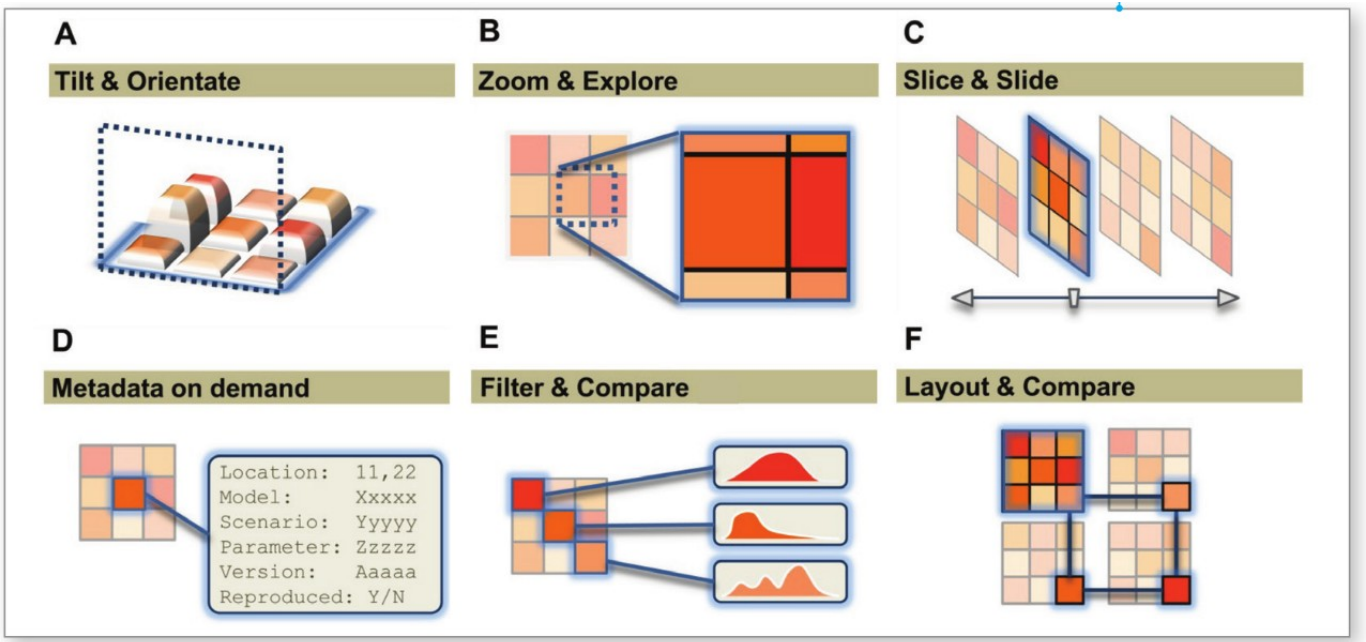
- Scale
  - thicker lines are more relevant than thinner lines



Visual hierarchy

7: Organization and Emphasis, p. 82

- Color
  - lighter and darker version of the same color
  - a blue glow to enforce selection



Flow of Information

7: Organization and Emphasis, p. 87

- Combining the hierarchival elements
  - position
    - an “umbrella” title and introduction
    - cloud spanning the width
  - scale
    - large cloud vs 3 small objects
  - color
    - bold orange line of airplane
    - yellow numbering enforces order
    - 3 black objects vs grey cloud

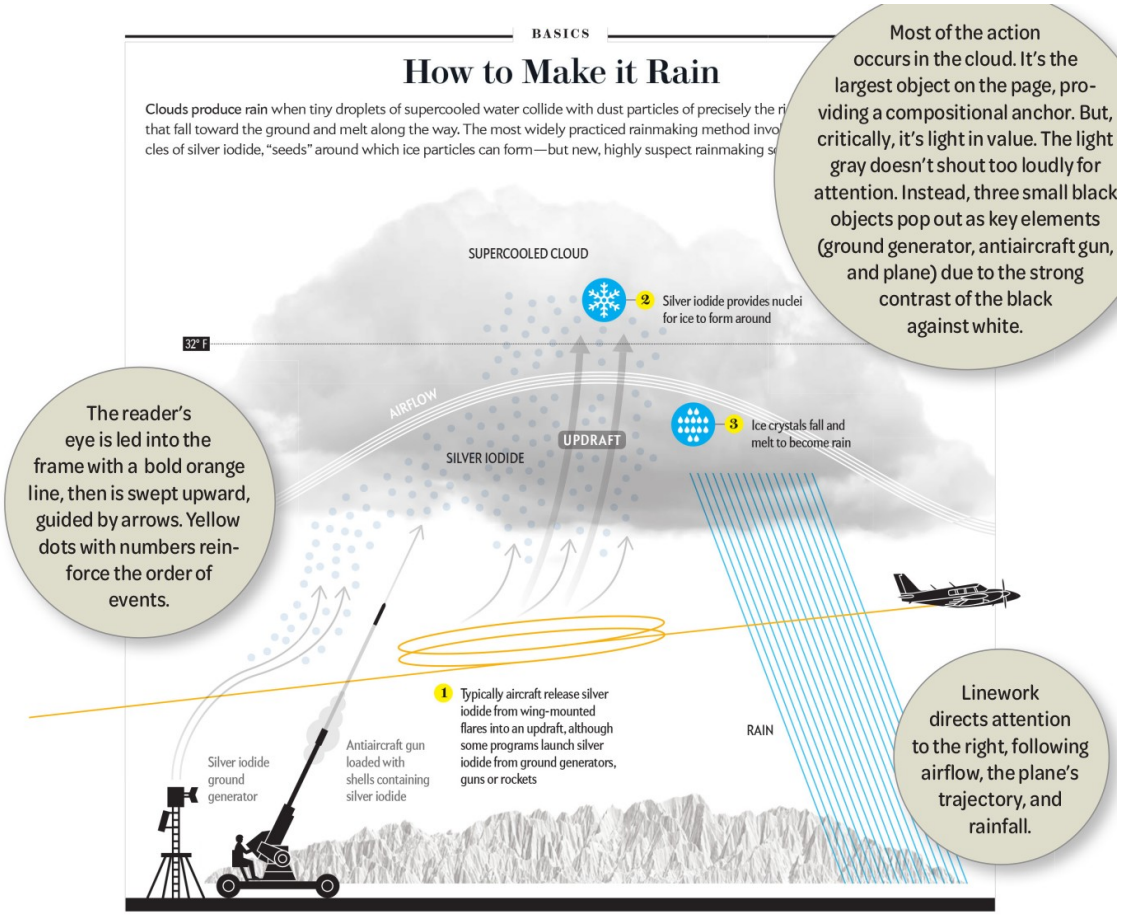


Image Credit: John Grimwade, as published in “Summon the Rain,” by Dan Baum, *Scientific American* (June 2014). Reproduced with permission. © 2014 Scientific American, a Division of Nature America, Inc. All rights reserved.

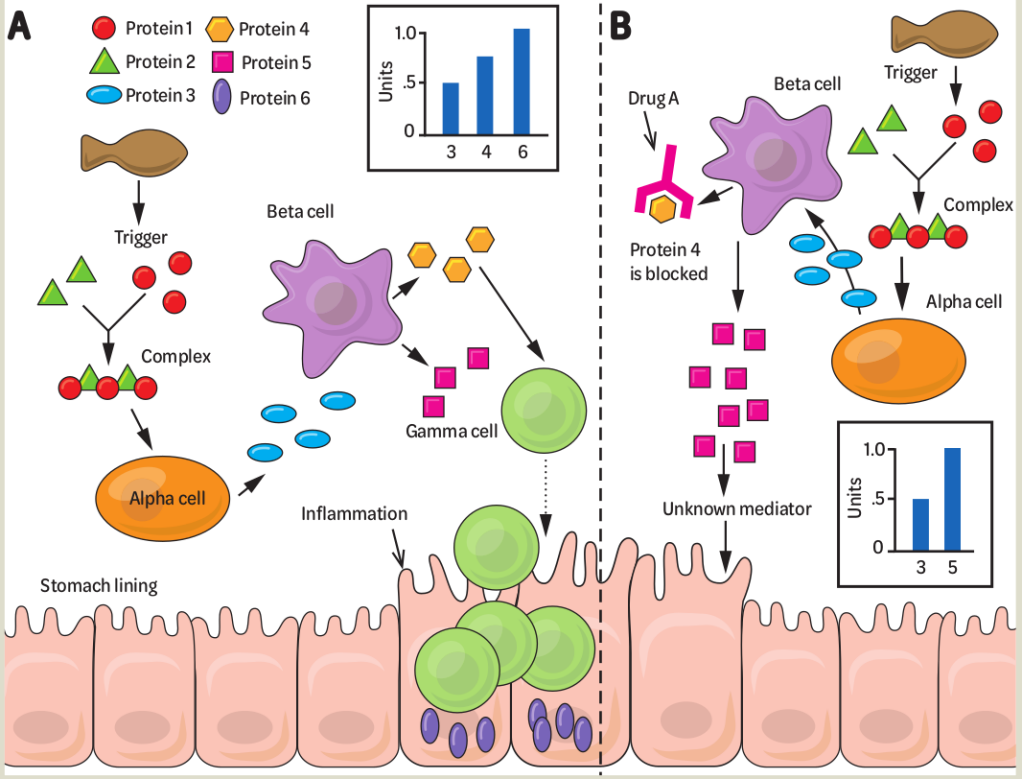
Composition Makeover

7: Organization and Emphasis, p. 88

- Hypothetical example: cat treat disease

BEFORE

Figure 1. Pathogenesis of classical cat treat disease and paradoxical cat treat disease. (A) Classical: Protein one, which is produced by the gut upon the ingestion of a treat, forms complexes with protein two. These complexes trigger alpha cells to produce large amounts of protein three. Protein three stimulates beta cells, which releases proteins four and five. Protein four triggers gamma cells to start massing in the gut's lining. Gamma cells then release protein six, pushing gut lining cells into a hypergrowth state, resulting in a grumpy cat. This condition can be confirmed by testing for levels of proteins three, four, and six. (B) Paradoxical: The introduction of drug A successfully blocked classical cat treat disease in most cats, by inhibiting the production of protein four. However, some cats were still grumpy. In 1 to 3 percent of cats, paradoxical cat treat disease may arise due to an increase in production of protein five, a side effect of drug A. The full pathway of paradoxical cat treat disease is not yet understood, but can be confirmed by testing for levels of proteins three and five.



Composition Makeover

7: Organization and Emphasis, p. 88

- Hypothetical example: cat treat disease
- Comparison of two scenarios (**A** and **B**)
  - **A** seems more important than **B**

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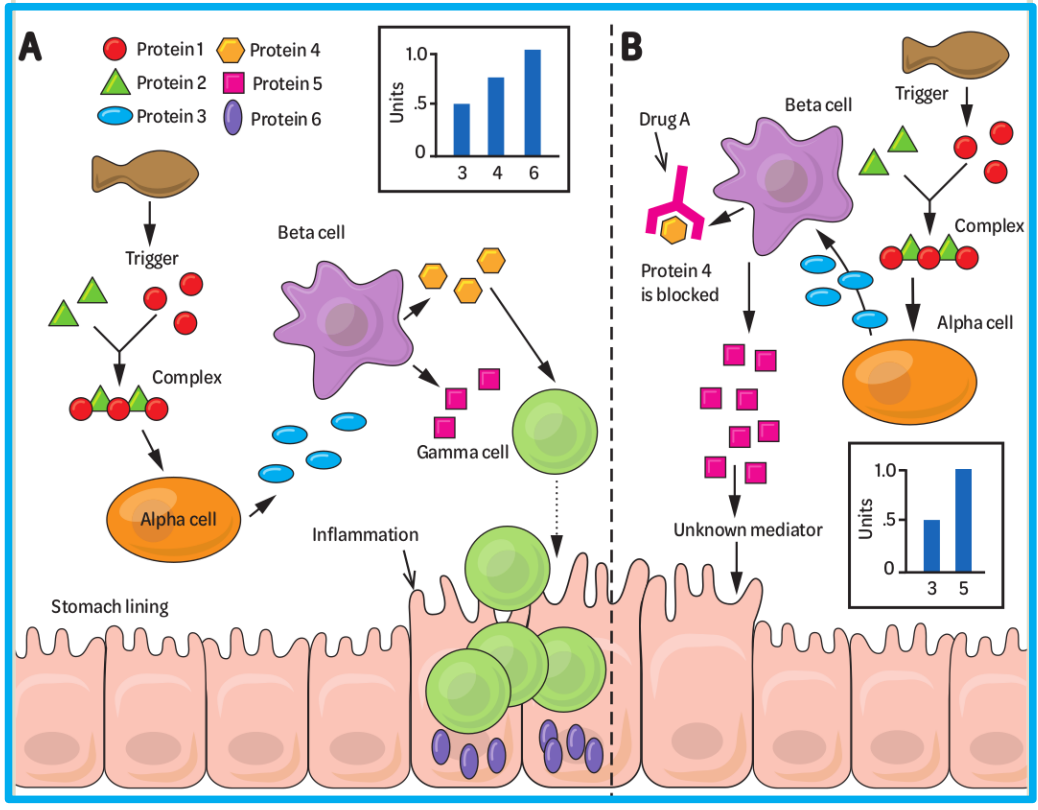

Composition Makeover

7: Organization and Emphasis, p. 88

- Hypothetical example: cat treat disease
- Comparison of two scenarios (**A** and **B**)
  - **A** seems more important than **B**
- 6 proteins and 3 cell types

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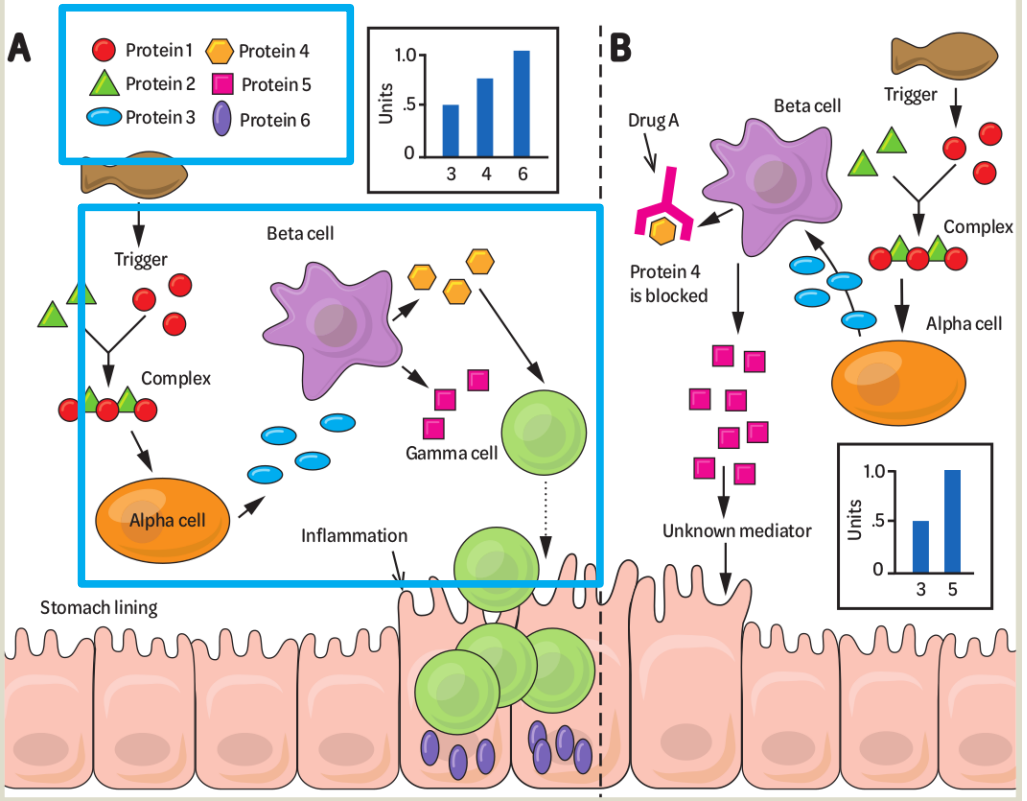

Composition Makeover

7: Organization and Emphasis, p. 88

- Hypothetical example: cat treat disease
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- Cat treat triggers a multi-stage reaction

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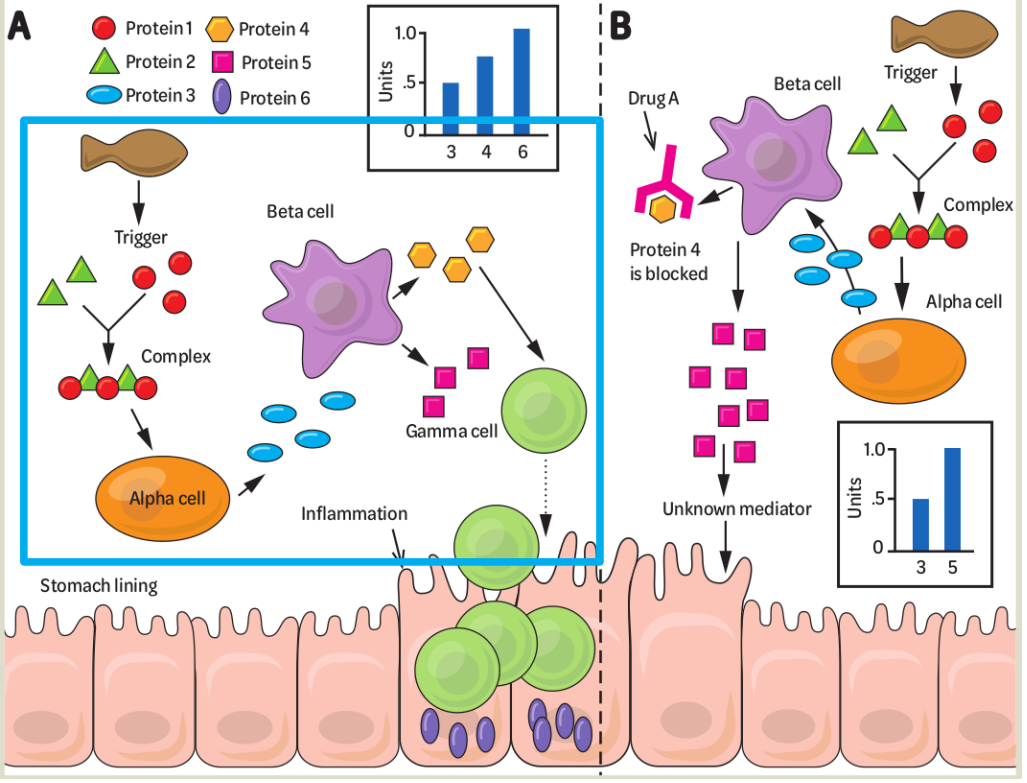

Composition Makeover

7: Organization and Emphasis, p. 88

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- Scenario **B**: Drug A blocks protein 4 and therefore the production of gamma cells and the inflammation?

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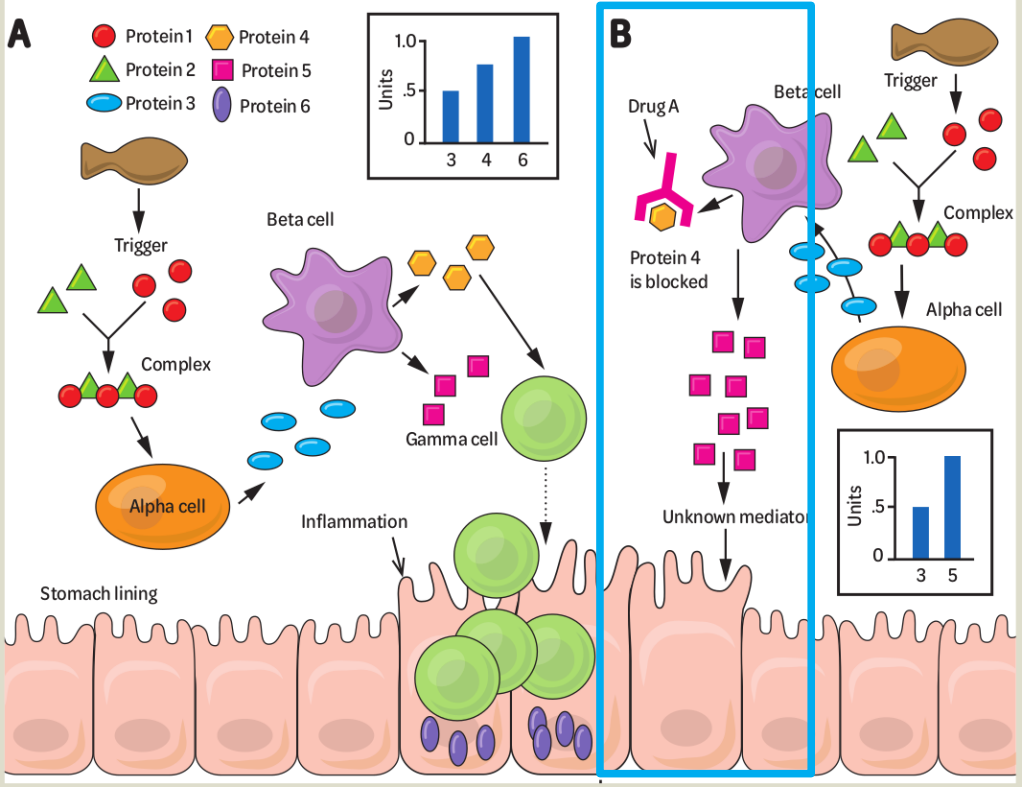
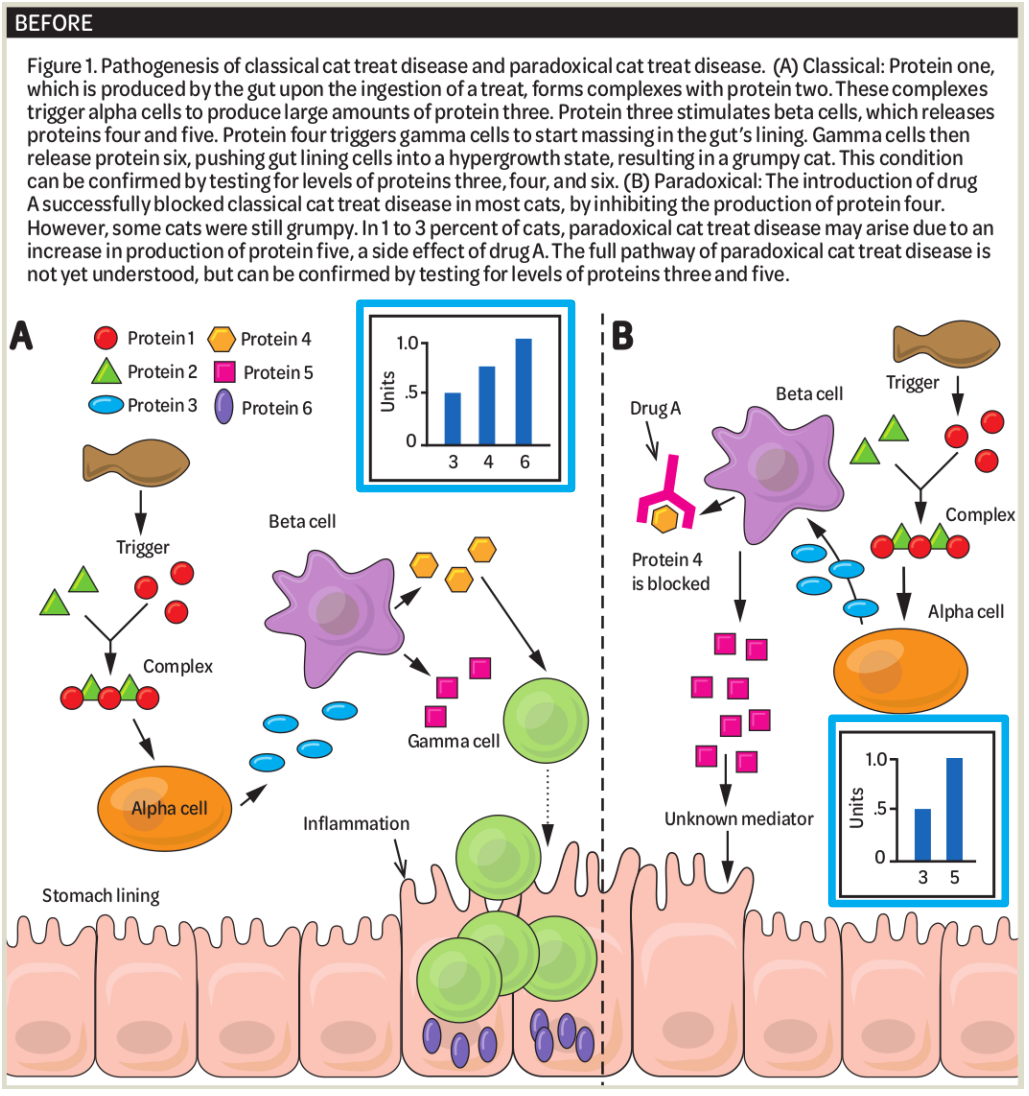


Composition Makeover

7: Organization and Emphasis, p. 88

- Hypothetical example: cat treat disease
- Comparison of two scenarios (**A** and **B**)
  - **A** seems more important than **B**
- 6 proteins and 3 cell types
- Cat treat triggers a multi-stage reaction.
- Scenario **B**: Drug A blocks protein 4 and therefore the production of gamma cells and the inflammation?
- Something has been measured, probably the proteins?



Composition Makeover

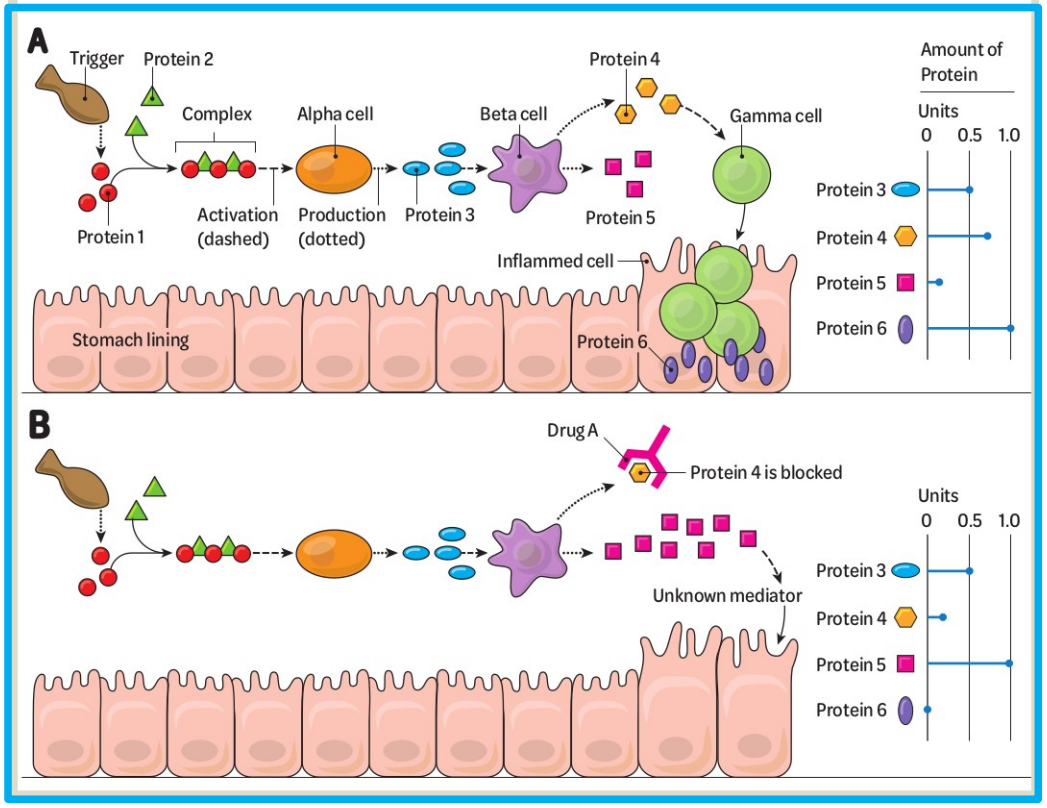
7: Organization and Emphasis, p. 88

- Two equally important scenarios can be easily compared (linear process).
  - with different proteins and cell types
  - triggered multi-stage reaction
  - drug A prevents inflammation

AFTER

(2) facilitating an easy and direct comparison between each scenario.

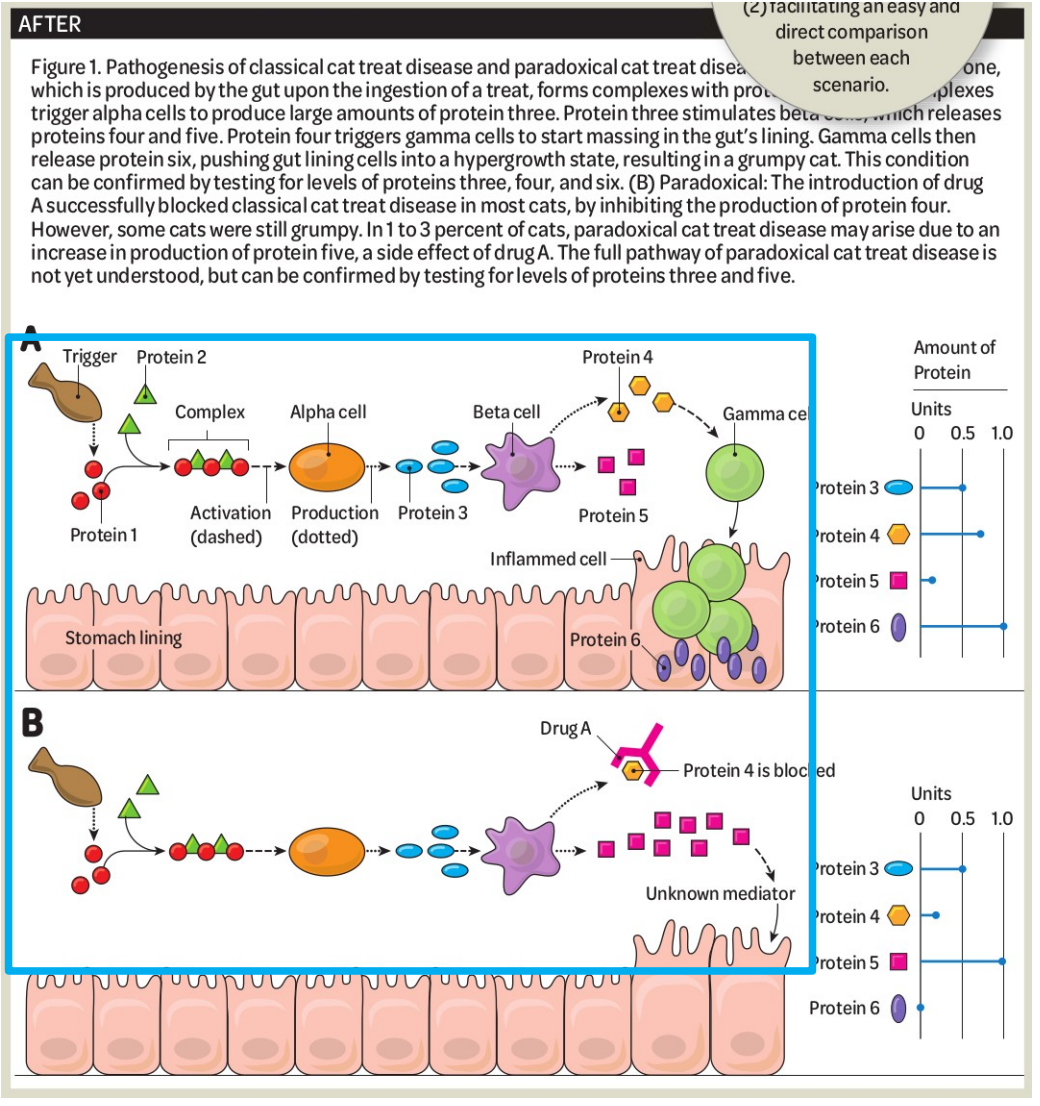
Figure 1. Pathogenesis of classical cat treat disease and paradoxical cat treat disea… one, which is produced by the gut upon the ingestion of a treat, forms complexes with pro… plexes trigger alpha cells to produce large amounts of protein three. Protein three stimulates beta … which releases proteins four and five. Protein four triggers gamma cells to start massing in the gut's lining. Gamma cells then release protein six, pushing gut lining cells into a hypergrowth state, resulting in a grumpy cat. This condition can be confirmed by testing for levels of proteins three, four, and six. (B) Paradoxical: The introduction of drug A successfully blocked classical cat treat disease in most cats, by inhibiting the production of protein four. However, some cats were still grumpy. In 1 to 3 percent of cats, paradoxical cat treat disease may arise due to an increase in production of protein five, a side effect of drug A. The full pathway of paradoxical cat treat disease is not yet understood, but can be confirmed by testing for levels of proteins three and five.



Composition Makeover

7: Organization and Emphasis, p. 88

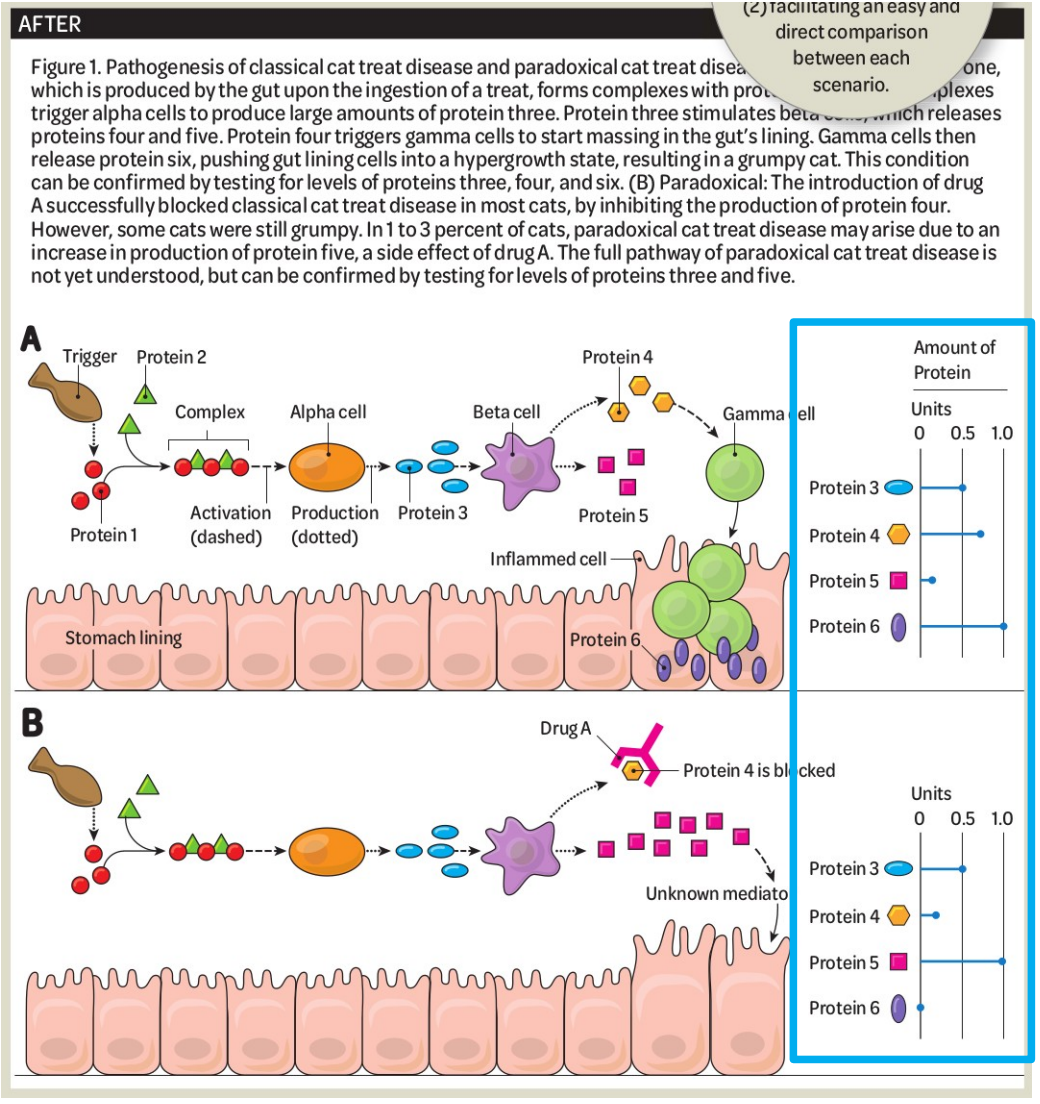
- Two equally important scenarios can be easily compared (linear process).
  - with different proteins and cell types
  - triggered multi-stage reaction
  - drug A prevents inflammation
- Legend replaced with labels.
- Arrows with different meanings.



Composition Makeover

7: Organization and Emphasis, p. 88

- Two equally important scenarios can be easily compared (linear process).
  - with different proteins and cell types
  - triggered multi-stage reaction
  - drug A prevents inflammation
- Legend replaced with labels.
- Arrows with different meanings.
- Amount of protein is measured.



Chapter 8: Color

"**I don't recommend color palettes** in this book,
as this depends on the content you're presenting,
the ultimate context, and your audience.
Rather, I simply encourage you to **pause and think**
about how you're using color in your graphic."
p. 99

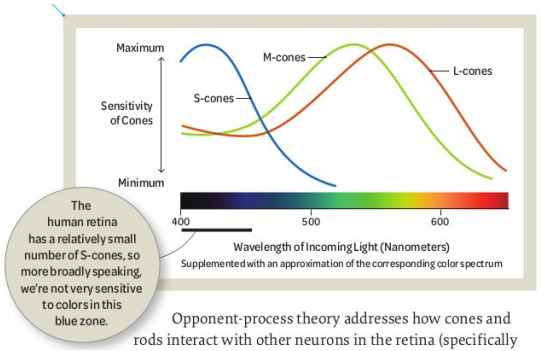
Chapter 8: Color

- Introduction / terminology
- Approaching color critically
- Strategies for using color
- Demonstration: Color makeover

Chapter 8: Color

8: Color, p. 97

- Color perception:
  - trichromacy theory



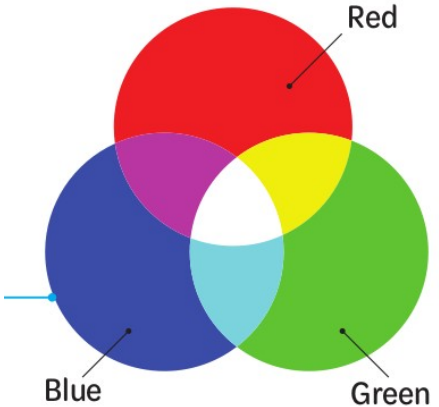
Opponent-process theory addresses how cones and rods interact with other neurons in the retina (specifically

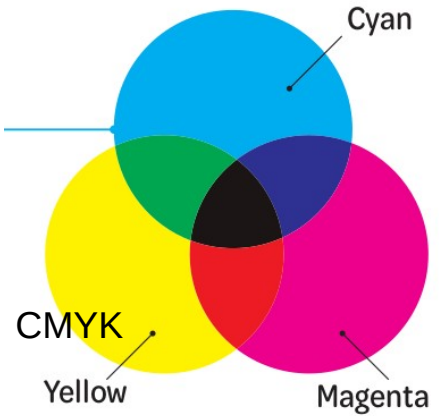
  - opponent-process theory
    - red/green, blue/yellow, black/white

- Karen Schloss: color is subject to
  - perceptual issues
    - e.g., color vision deficiency
  - aesthetic issues
  - semantics (meaning)
- “Color vision allows humans to more easily distinguish things from one another, remember those objects, and communicate with others about them.”

Color

- Primary colors
  - of light: red, green, blue (corresponding to the three cone types in human retina)
  - of pigment/paint: cyan, magenta, yellow
- Complementary colors (neutralize each other when mixed in equal measure)
  - complements made of light: make white light
  - complements mde of pigment/paint: make a neutral color
- Additive color models: how do colors of light mix together → RGB
  - computer screens, TVs, emitted from LEDs or other light sources (emitted light)
- Subtractive color models: how do colors of pigment mix (after light has hit a surface) → CMYK
  - paint, objects, ...



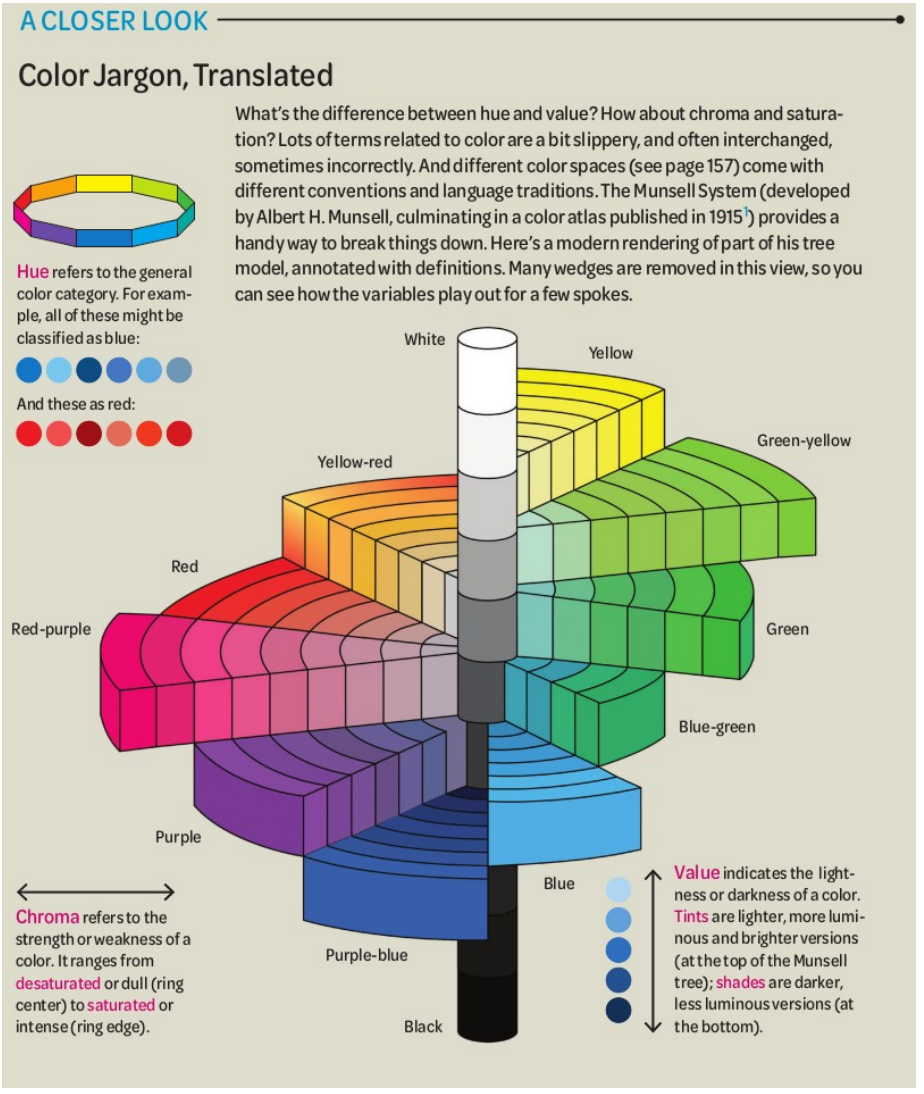


Arielle Eckstut, Joann Eckstut, What is color? - 50 Questions and Answers on the Science of Color, Abrams, New York, 2020

The Munsell system

8: Color, p. 99

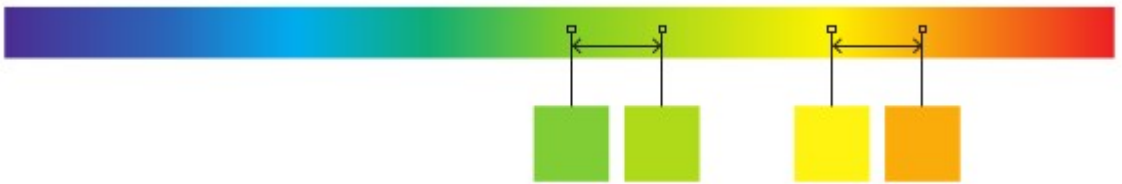
- Hue: color category, e.g., blue, red, …
- Value: lightness or darkness
  - tints: ligher, more luminous, brighter
  - shades: darker, less luminous
- Chroma: saturation
  - desatured (dull) to saturated (intense)
- Value and chroma can be difficult to dinguish.



Approaching color critically

8: Color, p. 99

- Let’s talk about the rainbow palette
  - the same distance does not necessarily correspond to the same change in hue



  - it does not pass the grayscale test

Approaching color critically

8: Color, p. 99

- A phenomenon called **simultaneous contrast**
  - grayscale gradient:

  - the background/surrounding color influences the perception of a color (Bang Wong):

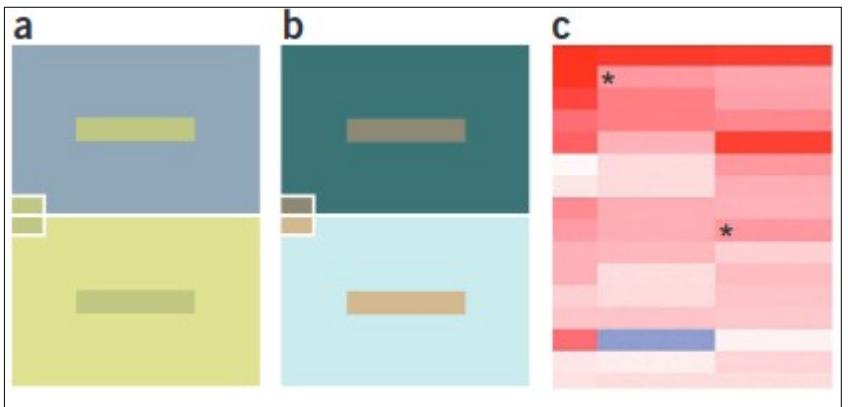


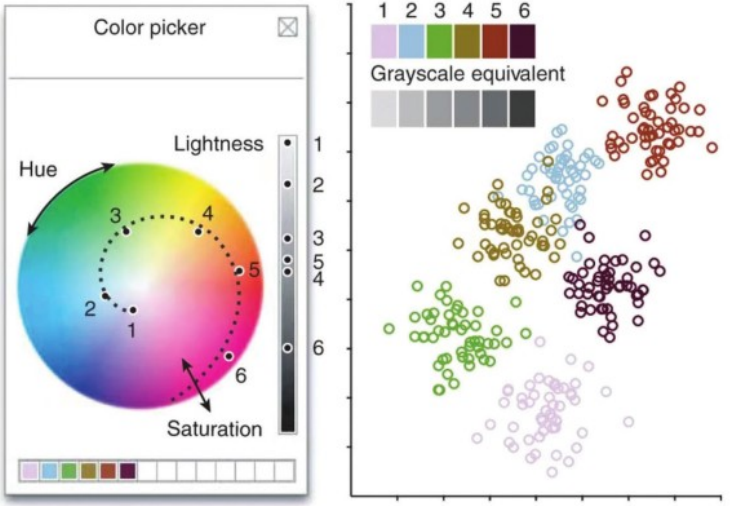
Figure 1 | Perception of color can vary. (**a**,**b**) The same color can look different (**a**), and different colors can appear to be nearly the same by changing the background color (**b**)[1]. (**c**) The rectangles in the heat map indicated by the asterisks (*) are the same color but appear to be different.

Bang Wong, Color coding, Nature methods, Vol. 7 No. 8, 2010 https://www.nature.com/articles/nmeth0810-573

Approaching color critically

8: Color, p. 99

- Choose your colors wisely
  - grayscale test
  - double-encode information
    - symbols: encode with color and shape or size
    - continuous area: directly define in shape and don't use a separate key (legend)
  - check for color deficiencies
    https://www.color-blindness.com/coblis-color-blindness-simulator/
  - Bang Wong: color picker



Bang Wong, Color coding, Nature methods, Vol. 7 No. 8, 2010 https://www.nature.com/articles/nmeth0810-573

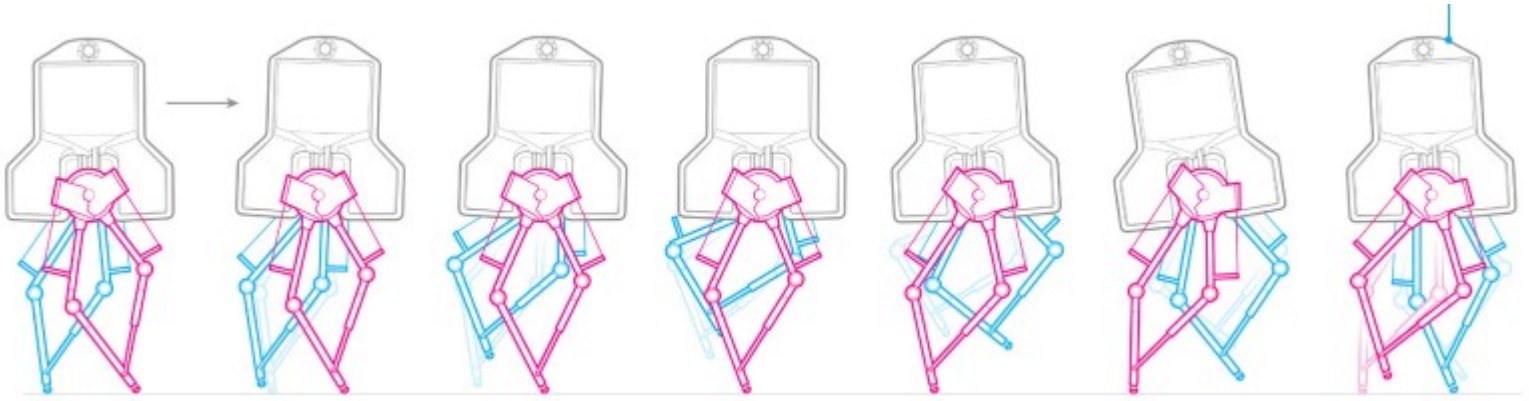
Color palettes (thanks for your suggestions!)

- an intro to the **viridis** color palette
  https://cran.r-project.org/web/packages/viridis/vignettes/intro-to-viridis.html
- the github page of the **cividis** color palette
  https://github.com/marcosci/cividis
- color palettes in oceanography (**cmocean**) https://matplotlib.org/cmocean/
- collection of perceptually accurate colormaps (**colorcet**) https://colorcet.holoviz.org/
- qualitative colors: https://personal.sron.nl/~pault/#sec:qualitative
- **colorbrewer**: https://colorbrewer2.org/
- matplotlib wrapper for making beautiful, publication-quality graphics (**proplot**)
  https://proplot.readthedocs.io/en/latest/index.html
- **Arts at CERN**: https://arts.cern/

Strategies for Using Color

8: Color, p. 99

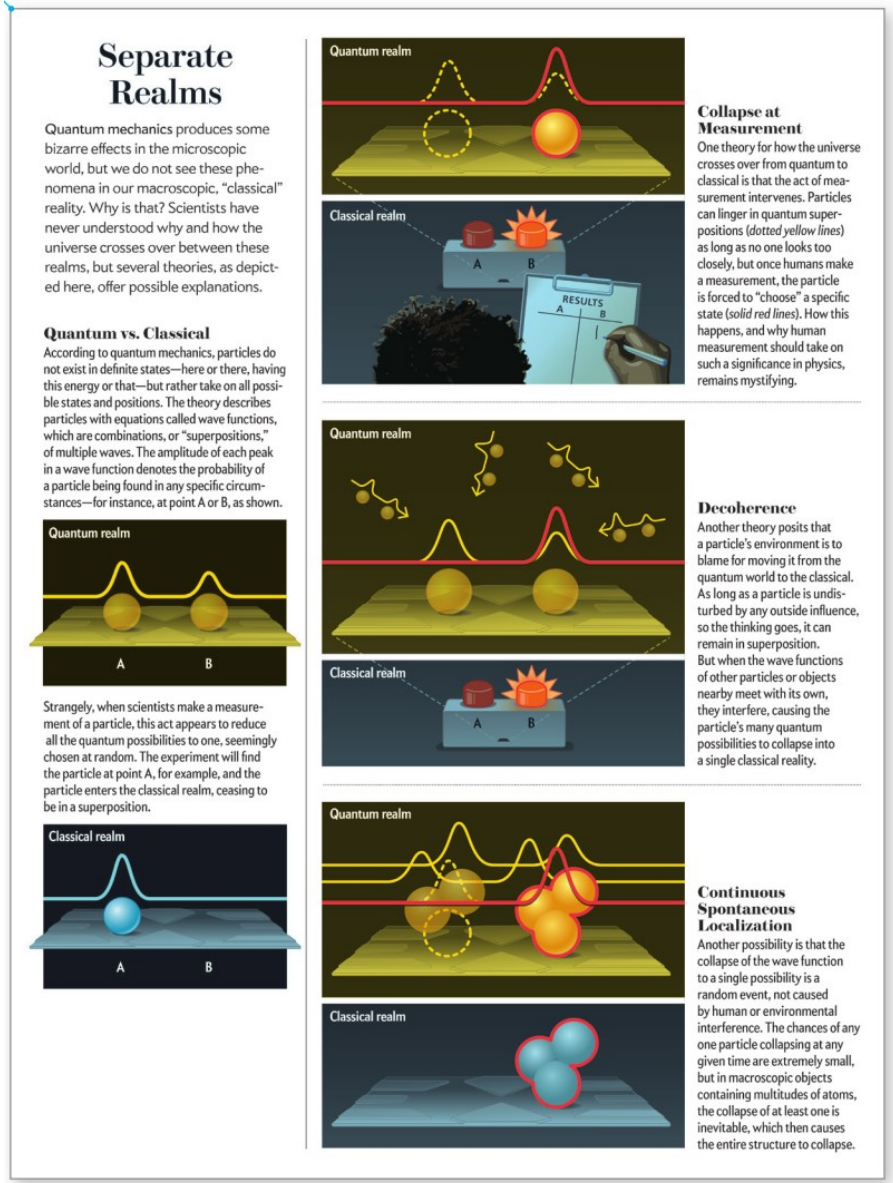
- as a tool for problem solving during the planning stages
- to help a reader track and compartmentalize elements



Strategies for Using Color

8: Color, p. 99

- to help folks more quickly and intuitively grasp new concepts



Separate Realms

Quantum mechanics produces some bizarre effects in the microscopic world, but we do not see these phenomena in our macroscopic, "classical" reality. Why is that? Scientists have never understood why and how the universe crosses over between these realms, but several theories, as depicted here, offer possible explanations.

Quantum vs. Classical

According to quantum mechanics, particles do not exist in definite states—here or there, having this energy or that—but rather take on all possible states and positions. The theory describes particles with equations called wave functions, which are combinations, or "superpositions," of multiple waves. The amplitude of each peak in a wave function denotes the probability of a particle being found in any specific circumstances—for instance, at point A or B, as shown.

Strangely, when scientists make a measurement of a particle, this act appears to reduce all the quantum possibilities to one, seemingly chosen at random. The experiment will find the particle at point A, for example, and the particle enters the classical realm, ceasing to be in a superposition.

Collapse at Measurement

One theory for how the universe crosses over from quantum to classical is that the act of measurement intervenes. Particles can linger in quantum superpositions (*dotted yellow lines*) as long as no one looks too closely, but once humans make a measurement, the particle is forced to "choose" a specific state (*solid red lines*). How this happens, and why human measurement should take on such a significance in physics, remains mystifying.

Decoherence

Another theory posits that a particle's environment is to blame for moving it from the quantum world to the classical. As long as a particle is undisturbed by any outside influence, so the thinking goes, it can remain in superposition. But when the wave functions of other particles or objects nearby meet with its own, they interfere, causing the particle's many quantum possibilities to collapse into a single classical reality.

Continuous Spontaneous Localization

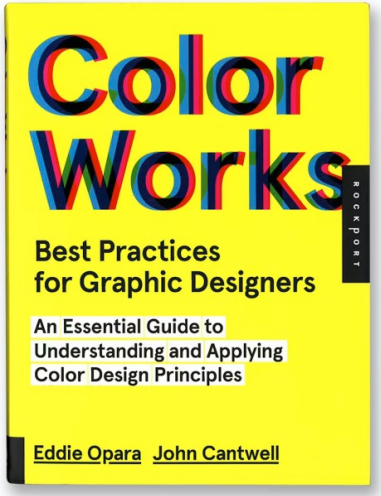
Another possibility is that the collapse of the wave function to a single possibility is a random event, not caused by human or environmental interference. The chances of any one particle collapsing at any given time are extremely small, but in macroscopic objects containing multitudes of atoms, the collapse of at least one is inevitable, which then causes the entire structure to collapse.

Strategies for Using Color

8: Color, p. 99

> “There is no single ‘correct’ solution for any given graphic.”
> p. 108

- Suggestions from Color Works by Eddie Opara and John Cantwell:
  - “Understand that various cultures and consumers symbolize colors differently.”
  - “There is no correct or incorrect way to perceive color; it’s an individual, highly personal matter.”
  - “Keep a record of colors that you have used and like to use.”
  - “Always look at other examples of how color is used by the likes of painters, fashion designers, and interior designers.”



Eddia Opara, John Cantwell, Color Works – Best Practices from Graphic Designers, Rockport Publishers, 2013

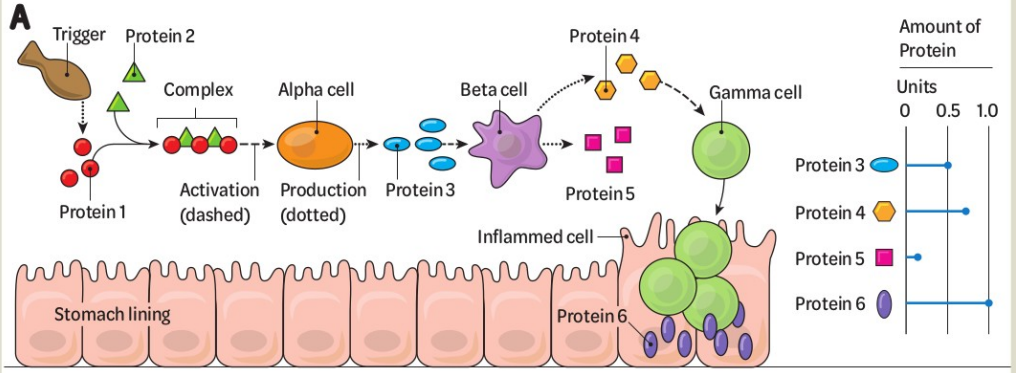
Color Makeover

8: Color, p. 110

- Many colors
- Which part is important?

BEFORE

Figure 1. Pathogenesis of classical cat treat disease and paradoxical cat treat disease. (A) Classical: Protein one, which is produced by the gut upon the ingestion of a treat, forms complexes with protein two. These complexes trigger alpha cells to produce large amounts of protein three. Protein three stimulates beta cells, which releases proteins four and five. Protein four triggers gamma cells to start massing in the gut's lining. Gamma cells then release protein six, pushing gut lining cells into a hypergrowth state, resulting in a grumpy cat. This condition can be confirmed by testing for levels of proteins three, four, and six. (B) Paradoxical: The introduction of drug A successfully blocked classical cat treat disease in most cats, by inhibiting the production of protein four. However, some cats were still grumpy. In 1 to 3 percent of cats, paradoxical cat treat disease may arise due to an increase in production of protein five, a side effect of drug A. The full pathway of paradoxical cat treat disease is not yet understood, but can be confirmed by testing for levels of proteins three and five.



Color Makeover

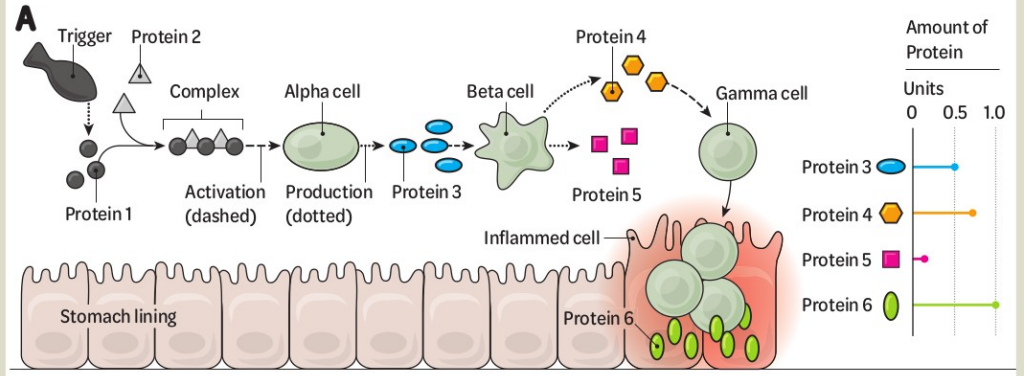
8: Color, p. 110

- A hierarchy of information facilitates the comparison of the two scenarios
  - fewer colors
  - saturated colors for important parts
  - desaturated colors for less important parts
  - same color for all cell types

AFTER

son between each scenario.

Figure 1. Pathogenesis of classical cat treat disease and paradoxical cat treat disease. ( ) Protein one, which is produced by the gut upon the ingestion of a treat, forms complexes with protein two. These complexes trigger alpha cells to produce large amounts of protein three. Protein three stimulates beta cells, which releases proteins four and five. Protein four triggers gamma cells to start massing in the gut's lining. Gamma cells then release protein six, pushing gut lining cells into a hypergrowth state, resulting in a grumpy cat. This condition can be confirmed by testing for levels of proteins three, four, and six. (B) Paradoxical: The introduction of drug A successfully blocked classical cat treat disease in most cats, by inhibiting the production of protein four. However, some cats were still grumpy. In 1 to 3 percent of cats, paradoxical cat treat disease may arise due to an increase in production of protein five, a side effect of drug A. The full pathway of paradoxical cat treat disease is not yet understood, but can be confirmed by testing for levels of proteins three and five.



Chapter 9: Typography

- Legibility and Readability
- Hierarchy
- Demonstration: Typography makeover

Chapter 9: Typography

- Butterick's practical typography: "the visual component of the written word."
  - typeface
  - size
  - placement
  - alignment
  - spacing
  - color
  - ...

"Start by choosing typefaces that are highly legible."
p. 117

https://practicaltypography.com/

Legibility and Readability

9: Typography, p. 114

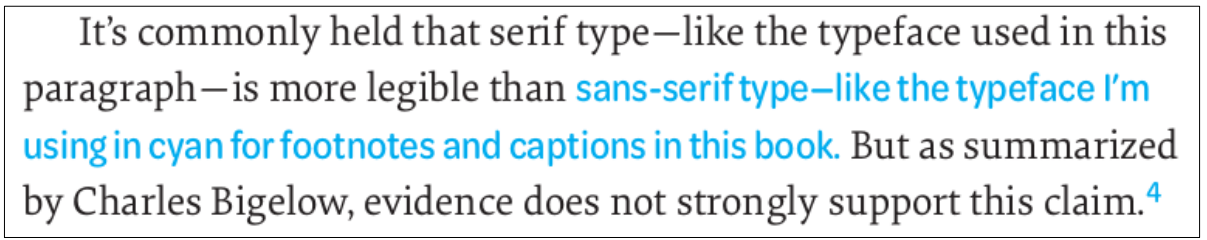
- Legibility: how easy it is to distinguish **one letter after another**
  - font, size, color, contrast

- Readability: how easy it is to distinguish **words, sentences, and paragraphs**
  - serif vs sans-serif, line spacing, justify columns (Blocksatz), rebreaking

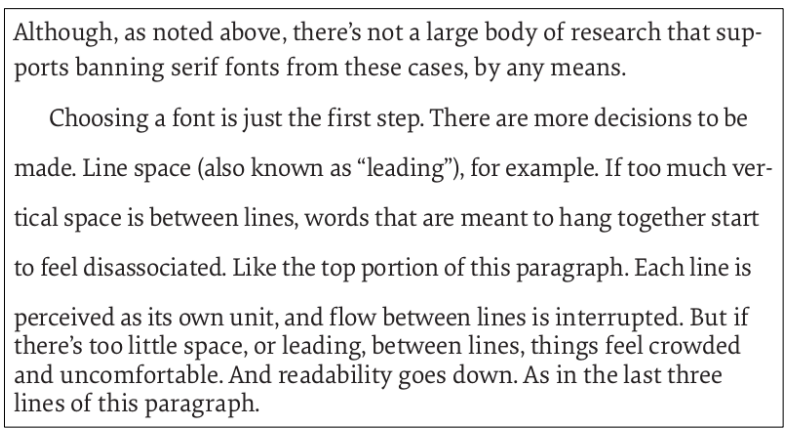
Legibility and Readability

9: Typography, p. 114

- Readability: how easy it is to distinguish words, sentences, and paragraphs
  - serif vs sans-serif



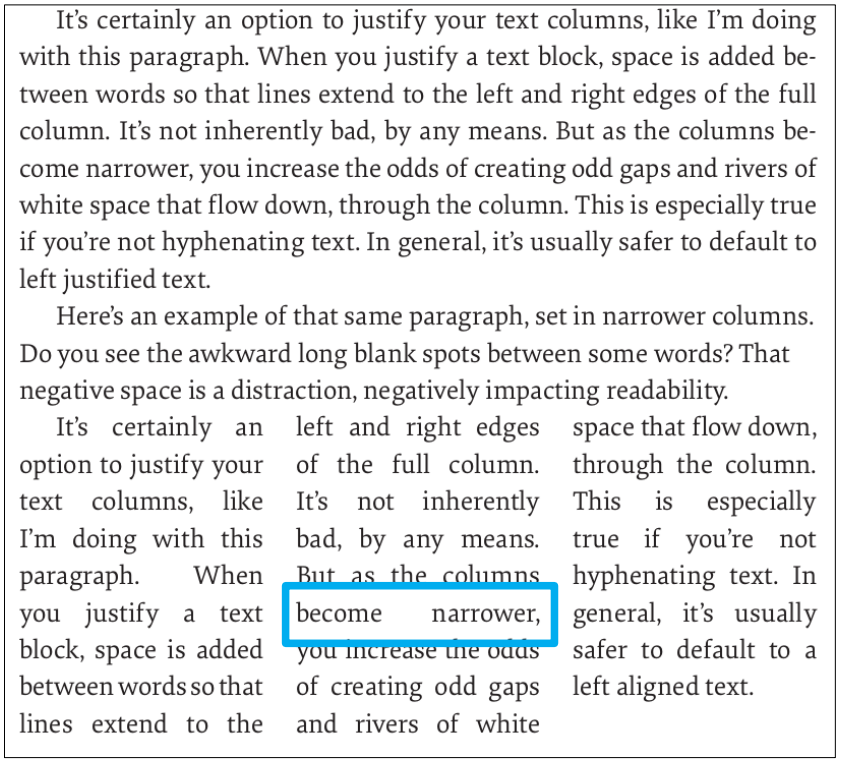
  - line spacing



Legibility and Readability

9: Typography, p. 114

- Readability: how easy it is to distinguish words, sentences, and paragraphs
  - justify columns (Blocksatz)



It's certainly an option to justify your text columns, like I'm doing with this paragraph. When you justify a text block, space is added between words so that lines extend to the left and right edges of the full column. It's not inherently bad, by any means. But as the columns become narrower, you increase the odds of creating odd gaps and rivers of white space that flow down, through the column. This is especially true if you're not hyphenating text. In general, it's usually safer to default to left justified text.

Here's an example of that same paragraph, set in narrower columns. Do you see the awkward long blank spots between some words? That negative space is a distraction, negatively impacting readability.

It's certainly an option to justify your text columns, like I'm doing with this paragraph. When you justify a text block, space is added between words so that lines extend to the

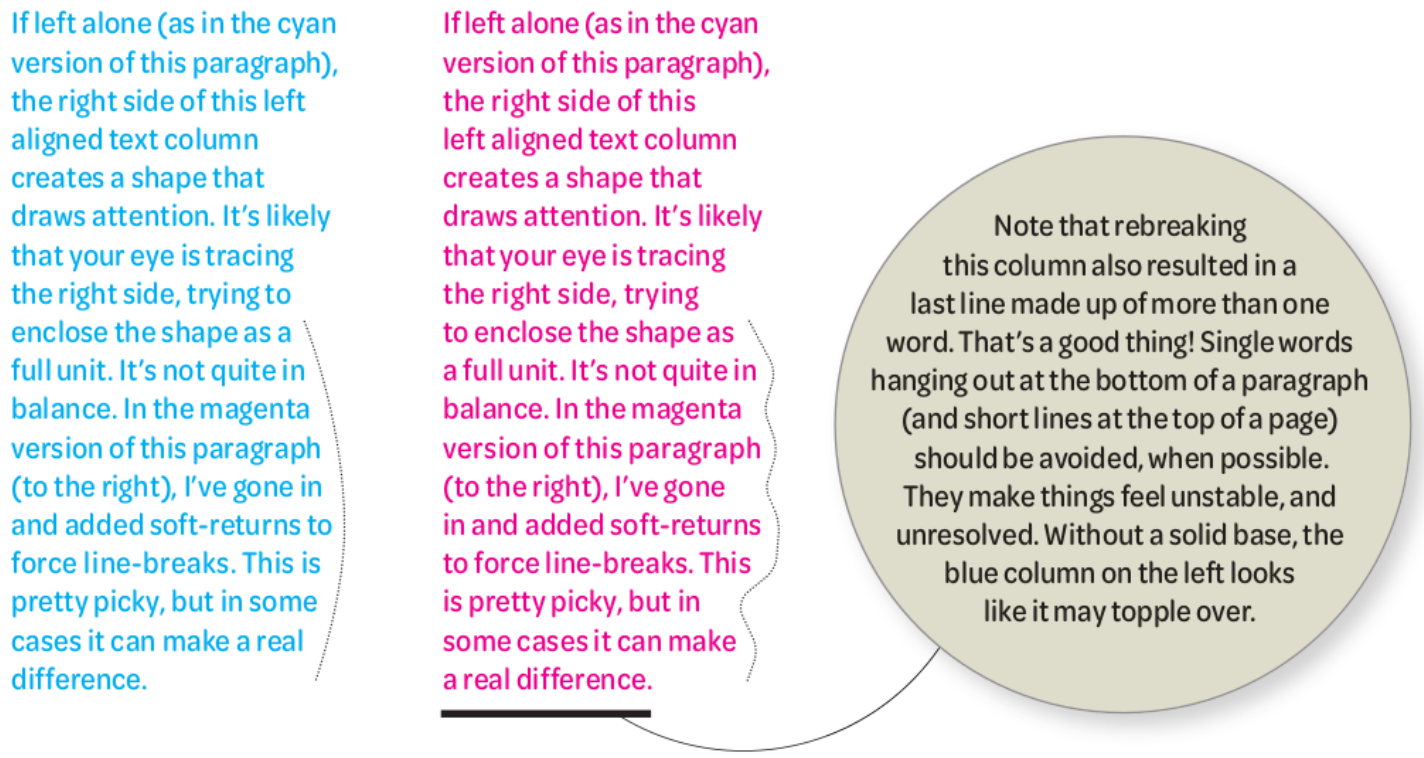
left and right edges of the full column. It's not inherently bad, by any means. But as the columns become narrower, you increase the odds of creating odd gaps and rivers of white

space that flow down, through the column. This is especially true if you're not hyphenating text. In general, it's usually safer to default to a left aligned text.

Legibility and Readability

9: Typography, p. 114

- Readability: how easy it is to distinguish words, sentences, and paragraphs
  - rebreaking



Hierarchy

9: Typography, p. 120

- Typography can be used for hierarchy
  - typeface
    - serif for title and introduction
    - sans-serif for details
  - size
  - bold, italic, condensed, etc.
  - line spacing, leading

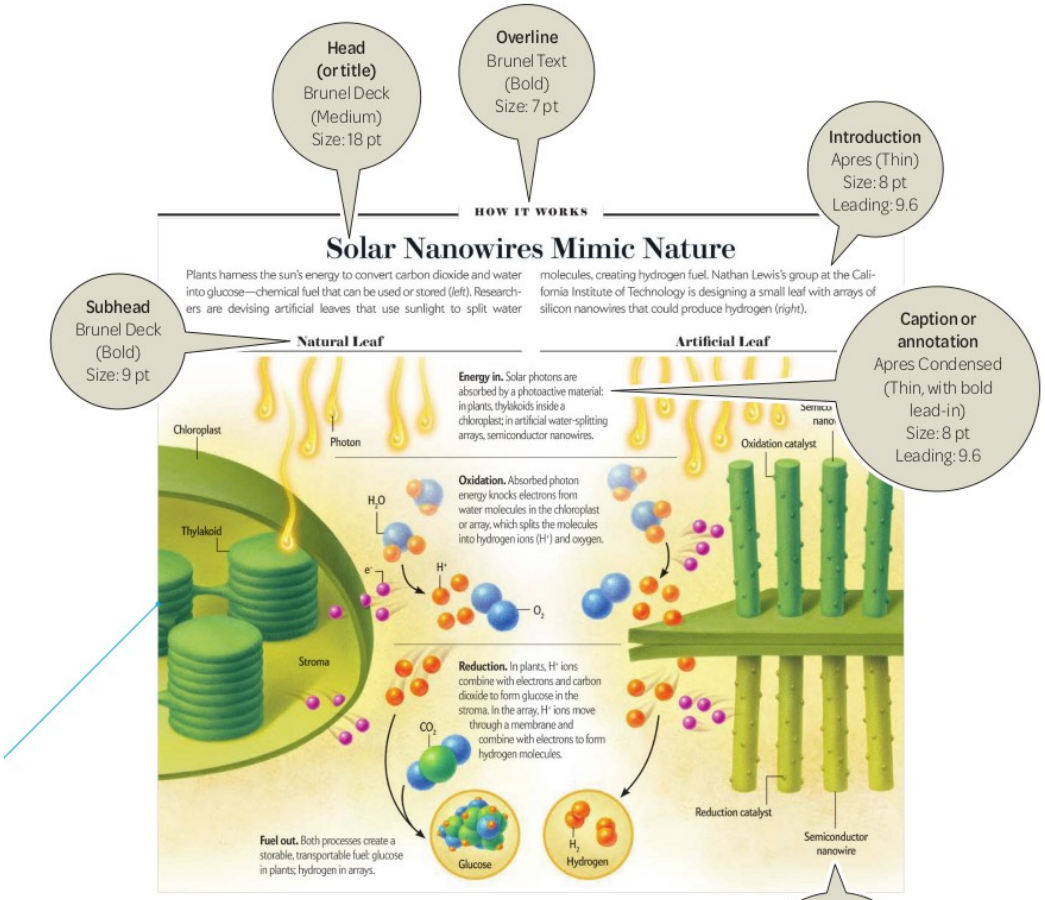


Image Credit: Cherie Sinnen, as published in "Reinventing the Leaf: Artificial Photosynthesis to Create Clean Fuel," by Antonio Regalado, Scientific American (October 2010). Reproduced with permission from the artist.

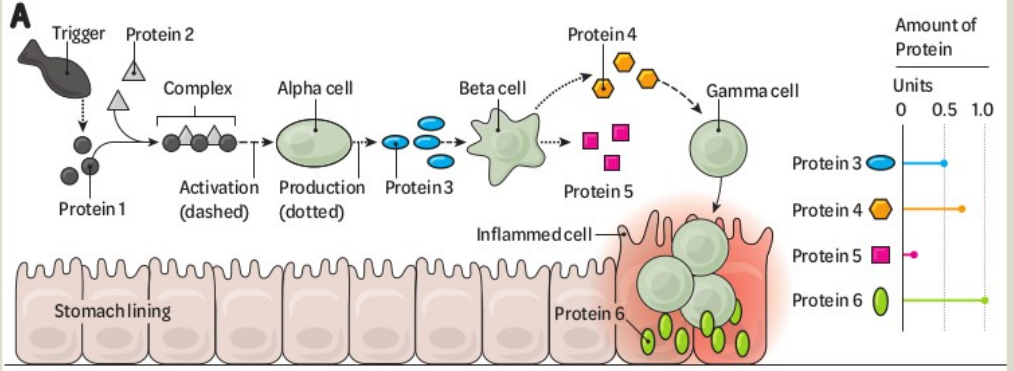
Typography Makeover

9: Typography, p. 124

- A big block of text at the top, which is difficult to read.
- The same font for everything.

BEFORE

Figure 1. Pathogenesis of classical cat treat disease and paradoxical cat treat disease. (A) Classical: Protein one, which is produced by the gut upon the ingestion of a treat, forms complexes with protein two. These complexes trigger alpha cells to produce large amounts of protein three. Protein three stimulates beta cells, which releases proteins four and five. Protein four triggers gamma cells to start massing in the gut's lining. Gamma cells then release protein six, pushing gut lining cells into a hypergrowth state, resulting in a grumpy cat. This condition can be confirmed by testing for levels of proteins three, four, and six. (B) Paradoxical: The introduction of drug A successfully blocked classical cat treat disease in most cats, by inhibiting the production of protein four. However, some cats were still grumpy. In 1 to 3 percent of cats, paradoxical cat treat disease may arise due to an increase in production of protein five, a side effect of drug A. The full pathway of paradoxical cat treat disease is not yet understood, but can be confirmed by testing for levels of proteins three and five.



Typography Makeover

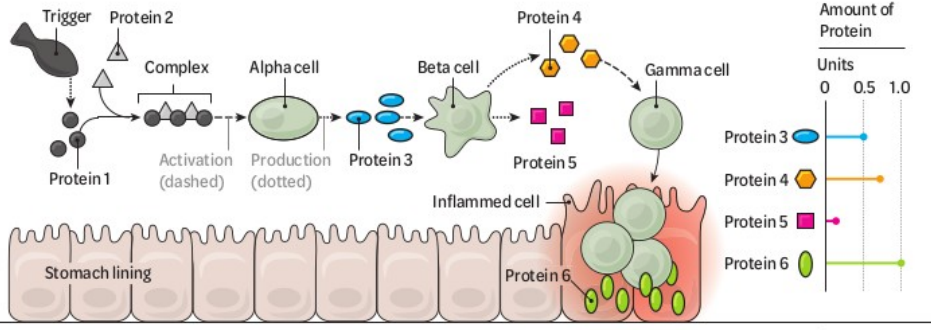
9: Typography, p. 124

- Improved legibility and readability
  - increased line spacing
  - two columns
- Established a hierarchy
  - figure title
  - separate descriptions for the two parts.
  - size and color

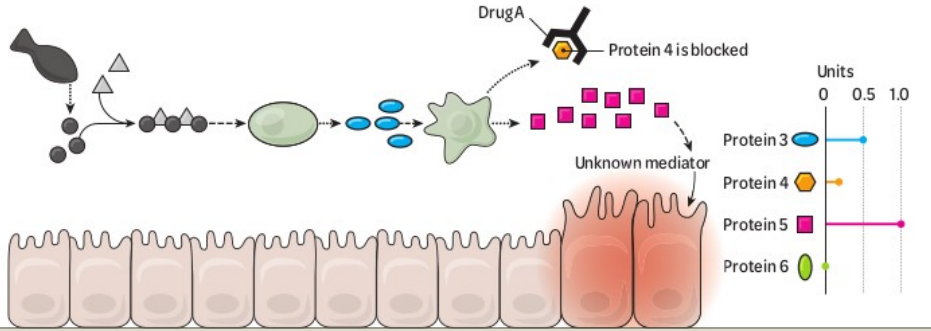
AFTER

Figure 1: Pathogenesis of classical cat treat disease and paradoxical cat treat disease

CLASSICAL: Protein one, which is produced by the gut upon the ingestion of a treat, forms complexes with protein two. These complexes trigger alpha cells to produce large amounts of protein three. Protein three stimulates beta cells, which releases proteins four and five. Protein four triggers gamma cells to start massing in the gut's lining. Gamma cells then release protein six, pushing gut lining cells into a hypergrowth state, resulting in a grumpy cat. This condition can be confirmed by testing for levels of proteins three, four, and six.



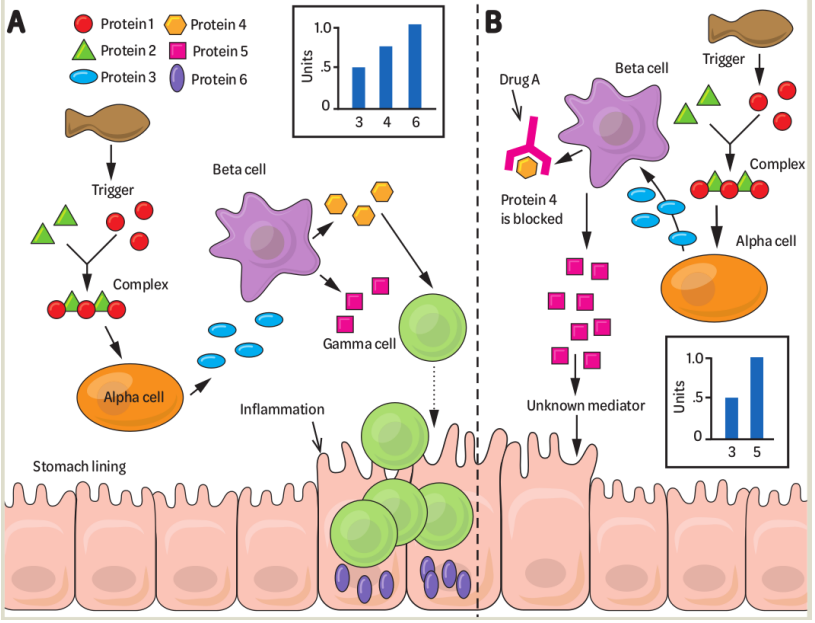
PARADOXICAL: The introduction of drug A successfully blocked classical cat treat disease in most cats, by inhibiting the production of protein four. However, some cats were still grumpy. In 1 to 3 percent of cats, paradoxical cat treat disease may arise due to an increase in production of protein five, a side effect of drug A. The full pathway of paradoxical cat treat disease is not yet understood, but can be confirmed by testing for levels of proteins three and five.



Makeovers: composition, color, and typography

BEFORE

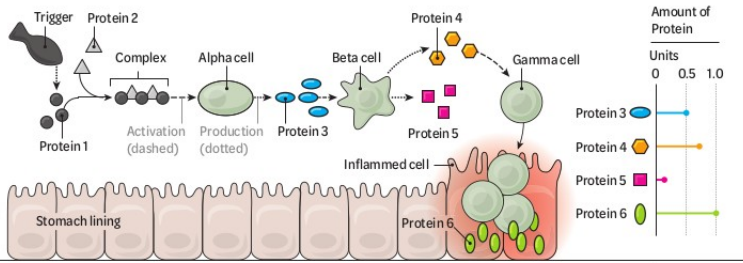
Figure 1. Pathogenesis of classical cat treat disease and paradoxical cat treat disease. (A) Classical: Protein one, which is produced by the gut upon the ingestion of a treat, forms complexes with protein two. These complexes trigger alpha cells to produce large amounts of protein three. Protein three stimulates beta cells, which releases proteins four and five. Protein four triggers gamma cells to start massing in the gut's lining. Gamma cells then release protein six, pushing gut lining cells into a hypergrowth state, resulting in a grumpy cat. This condition can be confirmed by testing for levels of proteins three, four, and six. (B) Paradoxical: The introduction of drug A successfully blocked classical cat treat disease in most cats, by inhibiting the production of protein four. However, some cats were still grumpy. In 1 to 3 percent of cats, paradoxical cat treat disease may arise due to an increase in production of protein five, a side effect of drug A. The full pathway of paradoxical cat treat disease is not yet understood, but can be confirmed by testing for levels of proteins three and five.



AFTER

Figure 1: Pathogenesis of classical cat treat disease and paradoxical cat treat disease

CLASSICAL: Protein one, which is produced by the gut upon the ingestion of a treat, forms complexes with protein two. These complexes trigger alpha cells to produce large amounts of protein three. Protein three stimulates beta cells, which releases proteins four and five. Protein four triggers gamma cells to start massing in the gut's lining. Gamma cells then release protein six, pushing gut lining cells into a hypergrowth state, resulting in a grumpy cat. This condition can be confirmed by testing for levels of proteins three, four, and six.



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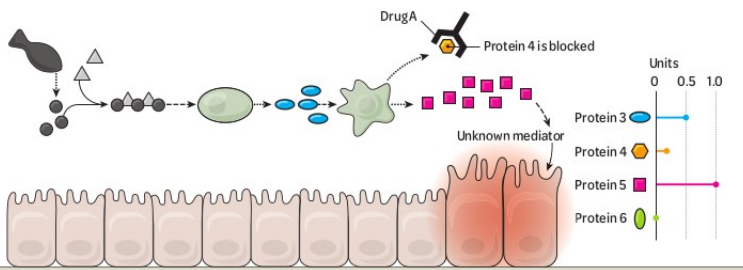
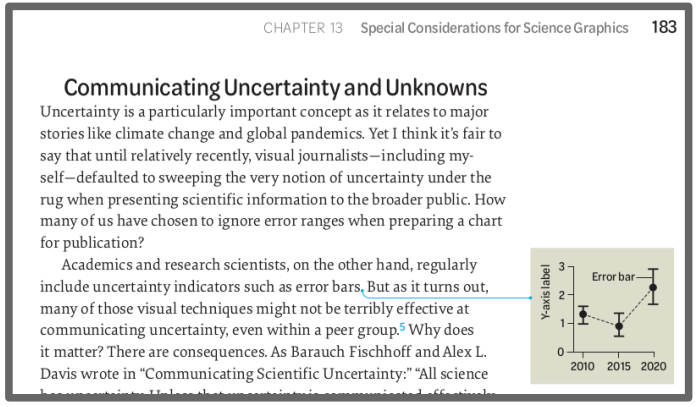


And now to Part 2: Uncertainty visualization

Visualization of Uncertainty and Unknowns

book



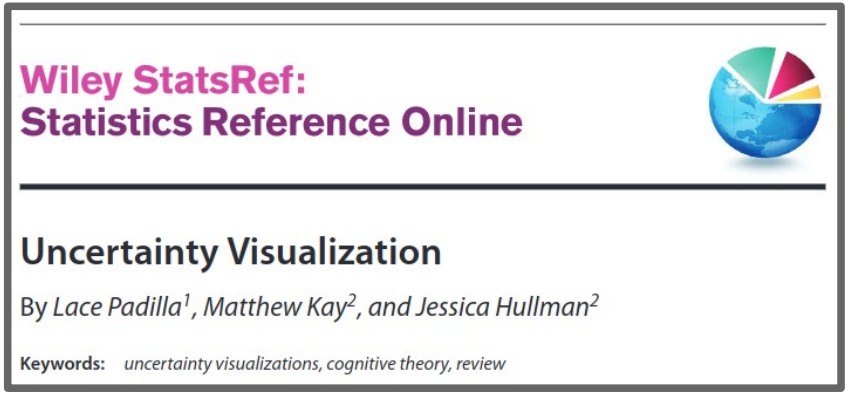
CHAPTER 13 Special Considerations for Science Graphics 183

Communicating Uncertainty and Unknowns

Uncertainty is a particularly important concept as it relates to major stories like climate change and global pandemics. Yet I think it's fair to say that until relatively recently, visual journalists—including myself—defaulted to sweeping the very notion of uncertainty under the rug when presenting scientific information to the broader public. How many of us have chosen to ignore error ranges when preparing a chart for publication?

Academics and research scientists, on the other hand, regularly include uncertainty indicators such as error bars. But as it turns out, many of those visual techniques might not be terribly effective at communicating uncertainty, even within a peer group.[5] Why does it matter? There are consequences. As Barauch Fischhoff and Alex L. Davis wrote in "Communicating Scientific Uncertainty:" "All science

paper



Wiley StatsRef:
Statistics Reference Online

Uncertainty Visualization

By *Lace Padilla*[1], *Matthew Kay*[2], *and Jessica Hullman*[2]

Keywords: *uncertainty visualizations, cognitive theory, review*

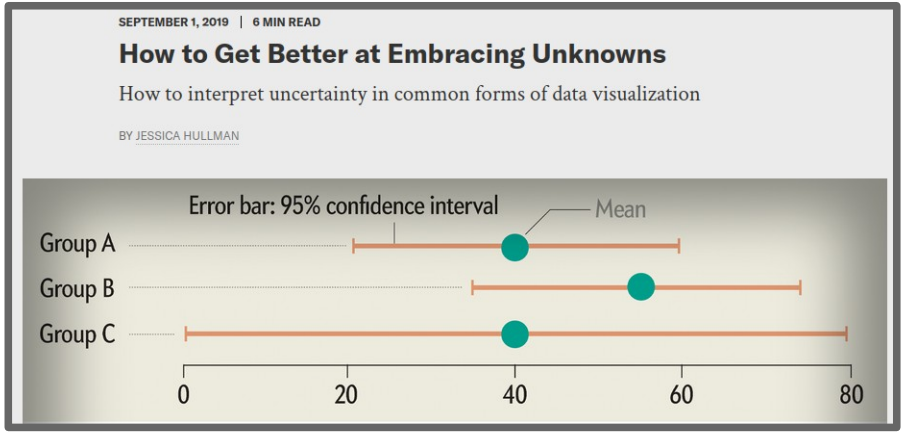
blogposts

Uncertainty + Visualization, Explained

Midwest Uncertainty (MU) Collective · Follow
Published in Multiple Views: Visualization Research Explained · 11 min read · Jun 4, 2019

1

Jessica Hullman and Matthew Kay (the MU Collective).



SEPTEMBER 1, 2019 | 6 MIN READ

How to Get Better at Embracing Unknowns

How to interpret uncertainty in common forms of data visualization

BY JESSICA HULLMAN

Uncertainty visualization

Padilla et al., 2021

- Uncertainty: “quantified uncertainty that can be visualized, most commonly a probability distribution” p. 1

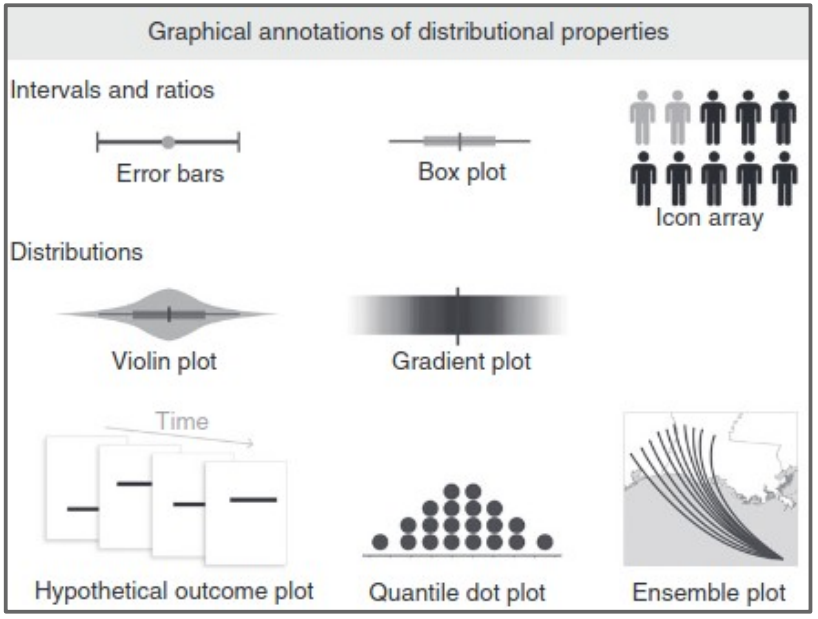
> “The goal is to provide readers with the necessary theoretical infrastructure to critically evaluate the various visualization techniques in the context of their own audience and design constraints. Importantly, **there is no one-size-fits-all uncertainty visualization approach**.”
>
> p. 2

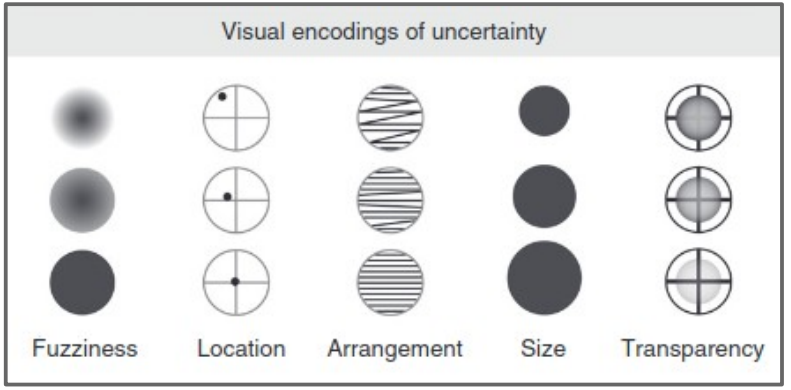
> “Therefore, visualization designers must think carefully about each of their design choices or risk adding more confusion to an already difficult decision process.”
>
> p. 2

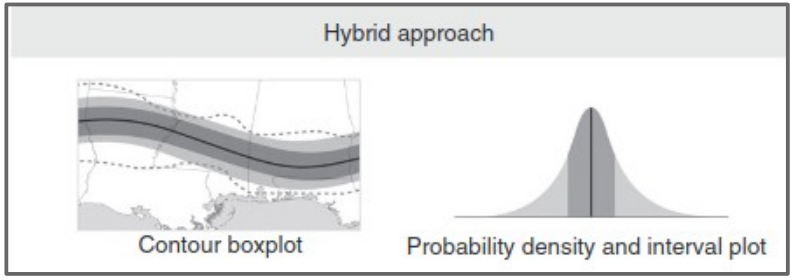
Uncertainty visualization design space

Padilla et al., 2021

- 2 categories and a hybrid approach







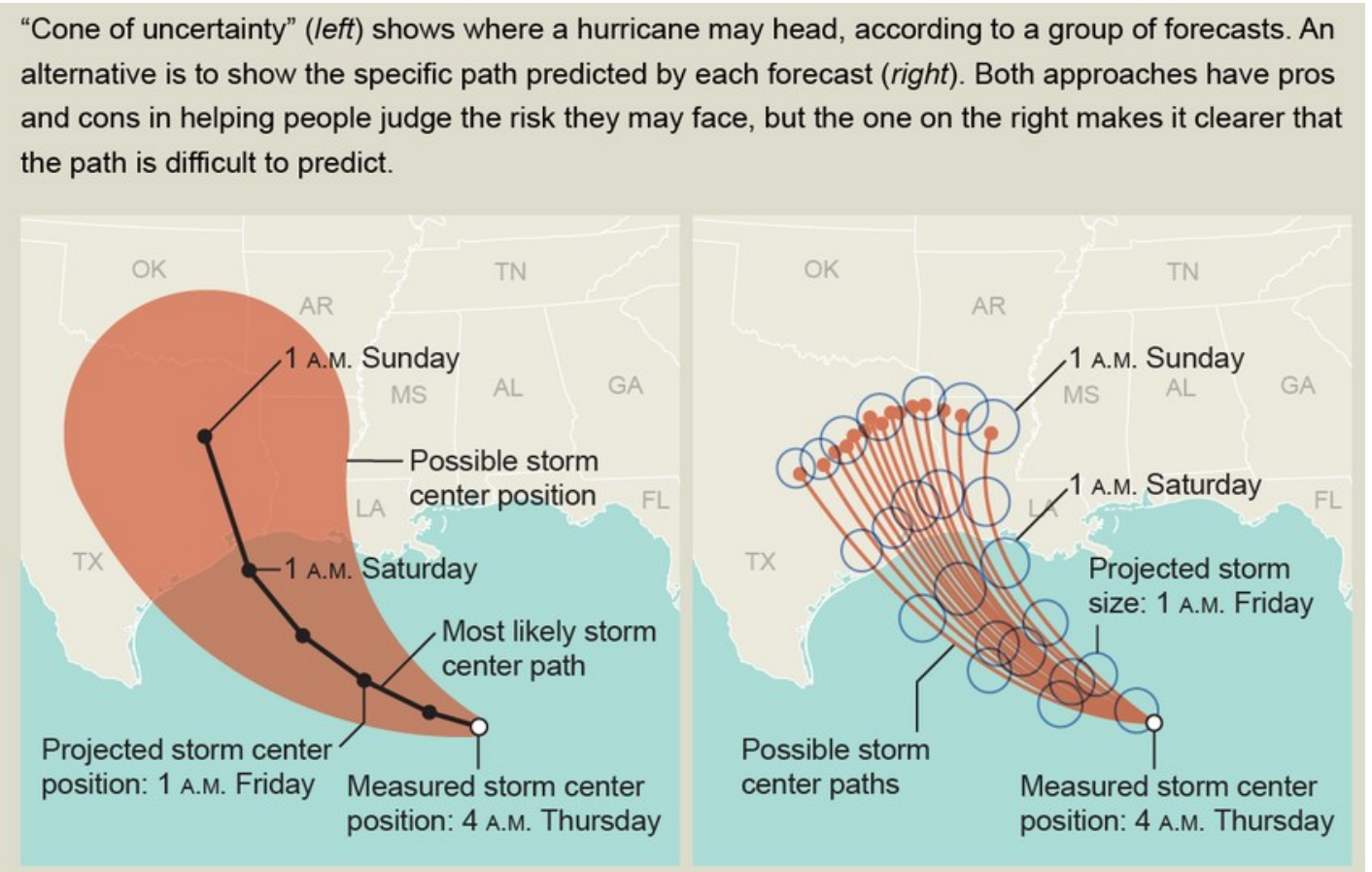
Unncertainty Visualization Theory

Padilla et al., 2021

Table 1. Summary of uncertainty visualization theory detailed in this article.

Theory	Summary	Visualization techniques
Frequency Framing[30] (Section 2.1)	Uncertainty is more intuitively understood in a frequency framing (1 out of 10) than in a probabilistic framing (10%)	Icon array[13] Quantile dotplot[11] Hypothetical outcome plots[16]
Attribute Substitution[31] Deterministic Construal Error[32] (Section 2.2)	If given the opportunity, viewers will mentally substitute uncertainty information for data that are easier to understand	Hypothetical outcome plots[16]
Visual Boundaries = Cognitive Categories[21] (Section 2.3)	Ranges that are represented by boundaries lead people to believe that data inside and outside the boundary are categorically different	Ensemble display[12] Error bar alternatives[7, 9]
Visual Semiotics[14] (Section 2.4)	Some encoding techniques naturally map onto uncertainty	Fuzziness, transparency, location, etc.[14] Value-suppressing color pallet[25]

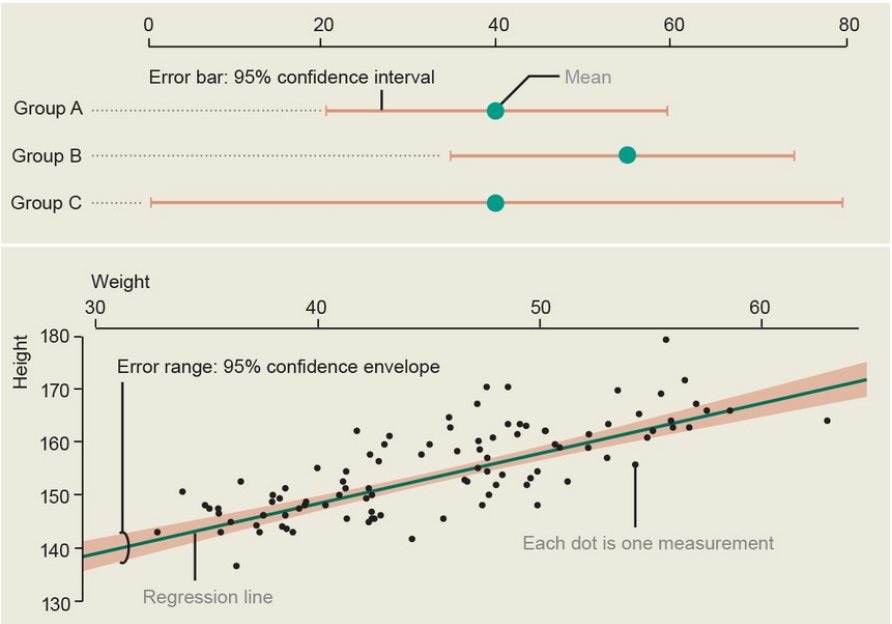
The cone of uncertainty



Jessica Hullmann, 2019, https://www.scientificamerican.com/article/how-to-get-better-at-embracing-unknowns/

The issue of error bars and confidence envelopes

- data as categorical / upper and lower limits



PROS

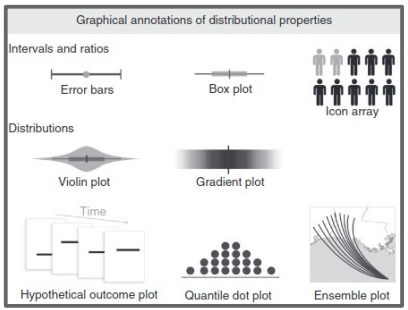
- Widely recognized as a representation of uncertainty.
- Offers a simple format for expressing the possibility of different values.
- The choice of interval can be customized for different types of questions about the same data set. For example, when one is making inferences about the range of values in a population, intervals based on standard deviation are helpful; for inferences about the range of values of a statistic like a mean, intervals based on standard error are appropriate.

CONS

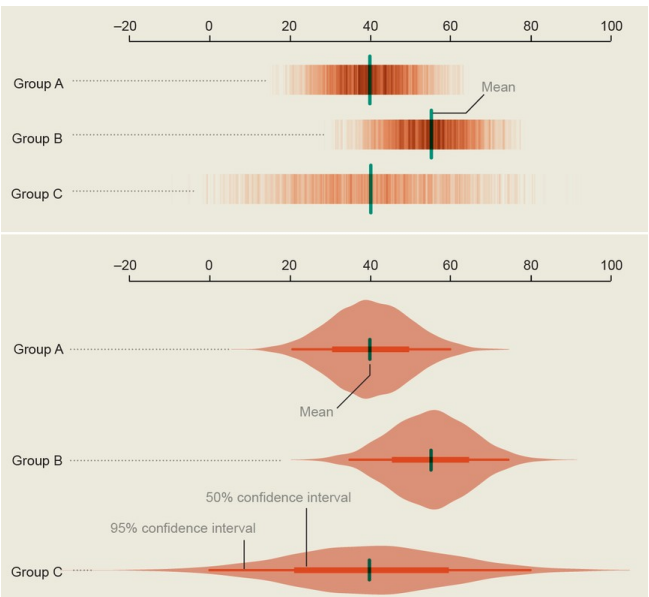
- Ambiguity in what is shown: intervals may represent standard deviation, standard error or something else. Each has a unique interpretation.
- Readers can make "deterministic construal errors"—interpreting the ends of the error bar as the high and low values in observed measurements rather than estimates denoting uncertainty.
- Error bars can lead to "within-the-bar bias," common in bar charts. Readers may see the bar values to the right of the dots as more probable than the bar values to the left.
- Easy to ignore the uncertainty regions in favor of the central tendency, which may lead to incorrect decisions.

Jessica Hullmann, 2019, https://www.scientificamerican.com/article/how-to-get-better-at-embracing-unknowns/

Alternatives for error bars



- It is recommended to display more representative information
  - scatterplot, violin plot, gradient plot, ensemble plot, quantile dot plot, HOP
- Combine several approaches helps to overcome issues of the approaches.



PROS

- Often well aligned with intuition: dark shading or hard boundaries are certain; light shading or fuzzy boundaries are uncertain.
- Avoids common biases such as those raised by intervals.

CONS

- Readers may not recognize that density reflects probability.
- Readers often equate the part of the visualization that is easiest to read (darkest, widest) with the data values themselves and misinterpret the parts that are harder to read (lightest, most narrow) as the uncertainty.
- Estimates can be biased to the darkest or highest points.
- Can be difficult to infer specific probability values.

Jessica Hullmann, 2019, https://www.scientificamerican.com/article/how-to-get-better-at-embracing-unknowns/

Chapter 13: Special Considerations for Sci. Gr.

- Honoring complexity
- Providing context
- Combating misinformation
- **Communicating Uncertainty and Unknowns**

Communicating Uncertainty and Unknows

13: Special Considerations for Science Graphics, p. 183

"All science has uncertainty.
Unless that uncertainty is communicated effectively,
decision makers may put too much or too little faith in it."

Barauch Fischhoff, Alex L. Davis, p. 183

"The extent to which something is known is a function of
what question was asked and how it was answered.
[…] Ambiguous or unclear answers may be just as common as
definitive results at the end of a scientific experiment or survey."

p. 183f

Communicating Uncertainty and Unknows

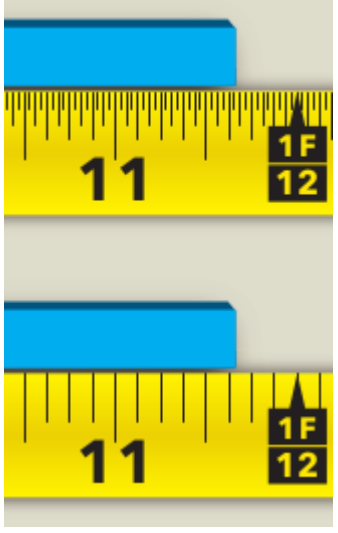
13: Special Considerations for Science Graphics, p. 183

- Six categories of uncertainties
  - measurement and scale
  - location
  - relationships and connections
  - processes
  - past and future
  - decision making

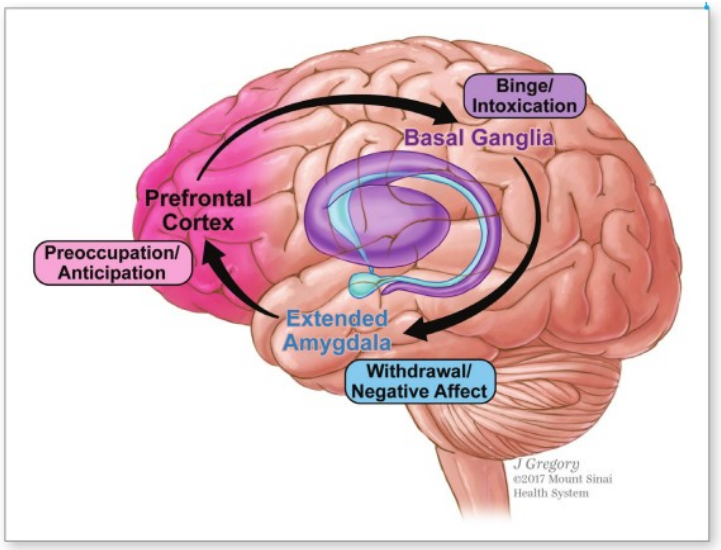
Communicating Uncertainty and Unknows

13: Special Considerations for Science Graphics, p. 183

- Measurement and scale
  - A higher level of precision corresponds to a lower level of uncertainty.
  - Uncertainty can be masked or introduced by modifying the scale or the resolution.



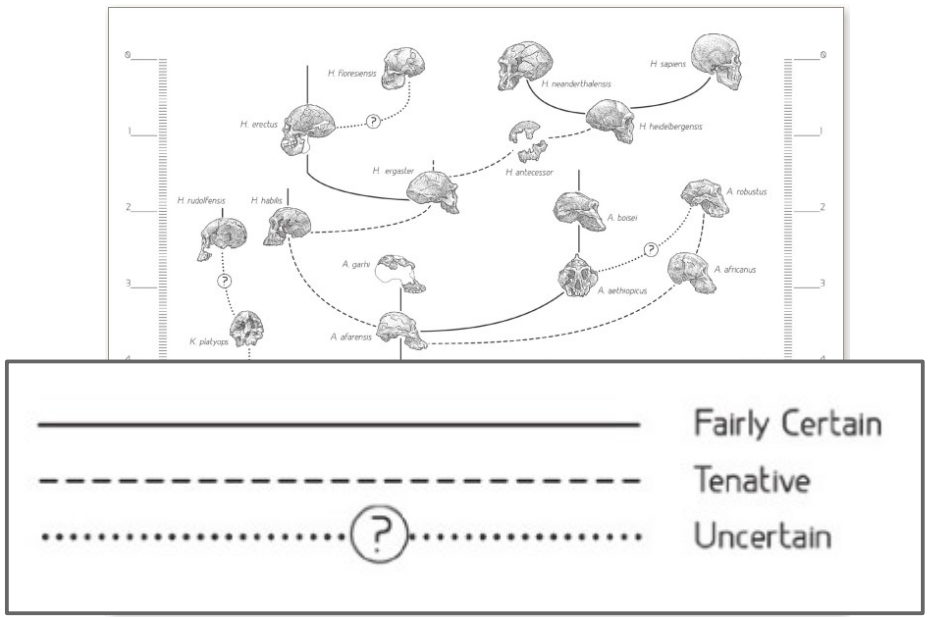
- Location
  - Rough assignment
  - Fuzzyness of color



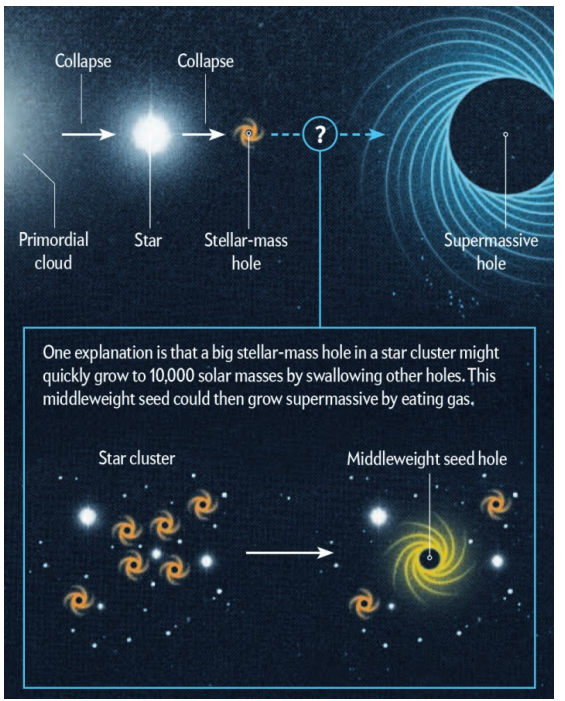
Communicating Uncertainty and Unknows

13: Special Considerations for Science Graphics, p. 183

- Relationships and connections
  - Solid symbols and darker colors suggest greater certainty than broken ones or lighter colors.



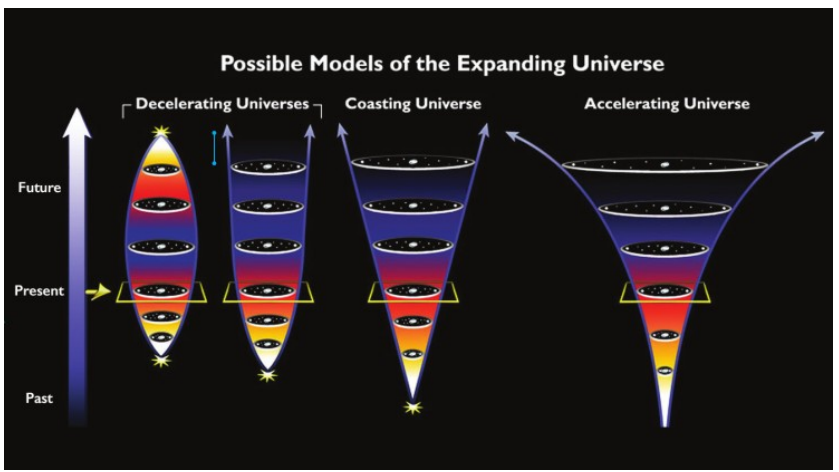
- Process
  - Mark unknown parts of the process with a question mark.



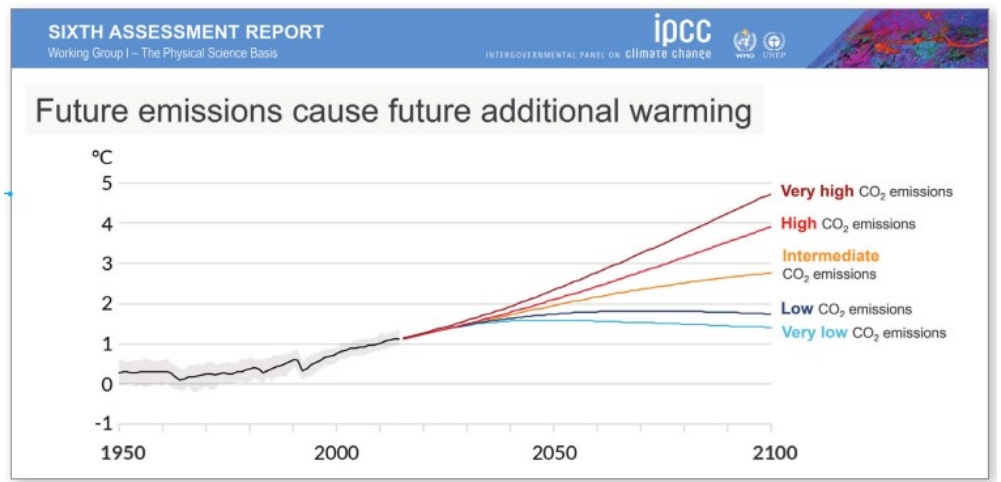
Communicating Uncertainty and Unknows

13: Special Considerations for Science Graphics, p. 183

- Past and future
  - Show competing hypotheses side-by-side. The present is consistent for all scenarios.



- Decision making
  - Show different scenarios.



The last slide

- There is no one-size-fits-all approach for any graphic.
- Pause and think about it carefully…
- … and show it others to see whether it works.

- If you could not remember everything,
  you'll find the "Building Science Graphics" pdf on Confluence.

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