EMERGING PATTERNS

Data Visualization Throughout History

EMERGING PATTERNS

Data Visualization Throughout History

Exhibition and Catalogue

by

Aurora Mendelsohn,
Anthony Gray,
and Kelly Schultz

The Thomas Fisher Rare Book Library,
University of Toronto
23 May–18 August 2023

Exhibition and catalogue by Aurora Mendelsohn, Anthony Gray, and Kelly Schultz
Edited by Grant Hurley and Marie Korey
Exhibition designed and installed by Linda Joy
Digital photography of items in UTL collections by Paul Armstrong
Catalogue designed by David Moratto
Catalogue printed by Andorra Graphics

ISBN 978-0-7727-1062-8

Cover image: 'Chart Showing for the United States and for Each State, with Distinction of Sex, the Ratio between the Total Population over 10 Years of Age and the Number of Persons Reported as Engaged in Each Principal Class of Gainful Occupations and Also as Attending School.' United States Census Office, compiled under the authority of Congress by Francis A. Walker (1840–1897). *Statistical Atlas of the United States Based on the Results of the Ninth Census 1870*. New York: Julius Bien, 1874.

Library and Archives Canada Cataloguing in Publication

Title: Emerging patterns : data visualization throughout history / exhibition and catalogue by Aurora Mendelsohn, Anthony Gray, and Kelly Schultz.
Names: Mendelsohn, Aurora Alma, author, organizer. | Gray, Anthony (Director of strategic research), author, organizer. | Schultz, Kelly, author, organizer. | Thomas Fisher Rare Book Library, host institution, publisher.
Description: The publication is a catalogue for the exhibition "Emerging Patterns: Data Visualization Throughout History" held at the Thomas Fisher Rare Book Library, the University of Toronto, May 23 to August 18, 2023. | Includes bibliographical references.
Identifiers: Canadiana 20230161251 | ISBN 9780772710628 (softcover)
Subjects: LCSH: Information visualization—History—Exhibitions. | LCSH: Visual communication—History—Exhibitions. | LCSH: Graphic methods—History Exhibitions. | LCGFT: Exhibition catalogs.
Classification: LCC QA76.9.I52 M46 2023 | DDC 001.4/226074713541—dc23

EMERGING PATTERNS

Data Visualization Throughout History

INTRODUCTION

It is common to regard the science and art of data visualization as a distinctively modern—or at least newly sophisticated—practice. The increasing importance and availability of data, new technologies, and powerful digital tools only add to this perception. But the perception is mistaken. *Emerging Patterns: Data Visualization Throughout History* explores the history of data visualization as it is captured in the holdings of the Thomas Fisher Rare Book Library and other libraries at the University of Toronto. It is a rich and fascinating history, replete with successes and failures, uses and abuses, and important lessons and insights for a modern audience.

The idea of exploring data visualizations through library exhibitions, particularly those that focus on rare works, is relatively recent. There have been only a few such exhibitions in libraries with sufficiently broad collections to support such a wide-ranging topic. Notable examples include exhibitions at the British Library in 2014 and Stanford University in 2020. *Emerging Patterns* is the first exhibition of its kind in Canada. It includes historically significant items from many countries, as well as uniquely Canadian items, and it draws on the University of Toronto's—and especially the Thomas Fisher Rare Book Library's—extraordinary collection. We are fortunate in Ontario to have access to one of the few libraries capable of mounting such an exhibition.

In curating *Emerging Patterns*, we selected exhibits that represent the reach and range of data visualizations spanning centuries, disciplines, and formats. The exhibition displays maps, scrolls, atlases, small textbooks, large posters, foldouts, and book covers, dating from the eleventh century to the present day, and drawing on disciplines from astronomy, demography, and economics to literary criticism, social work, and political activism. In addition, we included many exhibits in *Emerging Patterns* to showcase influential visualizations created by individuals from historically excluded groups. These individuals, including Florence Nightingale (1820–1910), W.E.B. De Bois (1868–1963), and Mary Eleanor Spear (1897–1986), have exerted significant influence on the development of data visualization and they were leaders or pioneers in their day. Despite significant barriers to inclusion—especially before and during what historian Howard Funkhouser (1898–1984) called the 'Golden Age of Data Visualization' in the nineteenth century—this exhibition celebrates the work of people of colour, LGBTQ+ people, women, and Indigenous peoples.

We hope *Emerging Patterns* expands the audience of the Thomas Fisher Rare Book Library and physical libraries in general. People who work and study in fields typically associated with charts and graphs often do not see their disciplines represented in library exhibitions and may view rare books as irrelevant to their work. By showing the significance and beauty of items from a broad range of fields, we hope to foster an appreciation for the wealth of the Library's collections and convey their lasting, multidisciplinary relevance. Moreover, we hope *Emerging Patterns* will inspire a feeling of belonging and evoke a comforting sense of solidarity and cross-generational identification with people from diverse backgrounds, across many fields, who have been wrestling with the graphical representation of information for centuries—as we continue to do today.

A Definition of Data Visualization

What is a data visualization? This is a foundational question for *Emerging Patterns*. Various definitions are possible, and the academic and professional literature contains numerous examples. For our purposes, we began with the history of data visualization, asked how the practice evolved, and considered what the best examples had in common.

The practice of visualizing data emerged from a growing understanding of the communicative efficacy of diagrams and illustrations in revealing relationships between scientific observations, theoretical concepts, or within social structures. As that intuitive understanding developed, methods and practices emerged, some of which were refined, standardized, and codified informally or formally. International gatherings were organized to establish global protocols (mostly unsuccessfully); pioneering textbooks by Willard Brinton (1880–1939), Mary Eleanor Spear, and others, helped elucidate and advance the burgeoning field.

One way to understand the evolution of data visualization—from its earliest examples in the eleventh and fifteenth centuries, through its flourishing in the eighteenth and nineteenth centuries, to its present ubiquity and sophistication today—is to observe how data visualizations have been used over time. Reflecting upon on how, by whom, for what purpose, and according to what rules visualizations were developed and used, and then identifying common threads among them, led us to the following working definition: a data visualization, as it is considered in *Emerging Patterns*, is a visual depiction of the relationships between elements of data. Those data elements could be scientific or astronomical observations. They could be people or armies. They could be abstract mathematical objects. An essential aspect of a data visualization is that it depicts at least one non-spatial or abstract element in two (or higher) dimensional space. Examples of such elements include time, connection, scale, or membership in a category. In a data visualization, elements are represented pictorially or graphically in a way that allows an audience to see relationships and patterns that would be much harder to notice or understand without the pictorial or graphical representation. A simple map or an anatomical diagram of the human body depicts information visually, but because these depictions do not reveal relationships and patterns between constituent data elements, they are not data visualizations in our sense.

Data visualizations are thus designed to help people discover and understand connections between the elements they depict. They accomplish this by capitalizing on the largely unconscious information processing capabilities of human visual perception systems. These capabilities were intuitively clear well before we were able to explain them scientifically. William Playfair (1729–1823), often described as the inventor of statistical data visualizations, anticipated the study of modern human visual cognition when he wrote that one of the goals of charts and graphs was to convey information 'without the fatigue and trouble of studying the particulars of which [they are] composed'.[1] Modern science has confirmed Playfair's claim. Studies in the field of human perception have demonstrated that we process visual information more quickly and in far greater density than information from the other senses.[2] We perceive visual cues and recognize patterns without conscious access to the underlying processes. We don't perceive the act of comparison, only our judgements about concepts like relative sizes or lengths (this box is bigger, that line is longer). This information processing occurs in the background, reducing cognitive load and leaving more time and energy for higher-level processing, analysis, and evaluation. In other words, we can process complex relational patterns presented visually more readily than we can discern those patterns from lists, tables, or words.

It follows from our definition that data visualizations have a specific purpose. A data visualization helps an observer make judgements about the relationships and patterns among data, and therefore helps readers move towards exploration, understanding, sense-making, communication, and reasoning about the data. We are prompted to form or evaluate hypotheses. It makes sense to ask, 'what is this visualization showing me?'

In considering whether to include a candidate image in the *Emerging Patterns* exhibition, we relied on our definition and asked ourselves the following questions: what are the elements of data in this image? What are the relationships being depicted among them? What are we intended to learn or understand? The resulting collection of data visualizations can be loosely divided into two general themes we have called 'The Evolution of Data Visualization' (Part One) and 'Making People See' (Part Two).

Emerging Patterns is not simply a history of data visualization. There are historically significant images in the Fisher collection that do not appear in the exhibition. Rather, *Emerging Patterns* is a thematic history of data visualization. Considering the thematic evolution of data visualization, as explored in Part One, we can better understand the nature of data visualization itself, how it has been used, and from where its persuasive power stems. Part Two will explore the nature and use of data visualization's persuasive capacity to assert or advocate for political power. These two themes are complementary, intersecting and amplifying each other.

The Evolution of Data Visualization

Emerging Patterns highlights significant steps in the thematic evolution of data visualization. The exhibition focuses on the development of various kinds of visualizations and how the stylistic evolution of a type of visualization relates to the purpose for which it was designed. Visualizing data today is a seemingly simple task, well-understood by both creators and audiences. Complex visualizations can be made at the push of a button and can rely on widely understood norms and rules. But these are modern developments. As recently as one hundred years ago, data visualizations required considerable expertise to make and asked sceptical audiences to invest time and attention to interpret them.

One of the exhibition's goals is to encourage its audience to consider what they are doing when creating data visualizations today. The modern tools that have made data visualization easier have, at the same time, stripped some of the thought from the process and thereby devalued or diminished the visualizations themselves. The results have all too often been confusing, poor, or at worst, misleading. The thematic evolution of data visualization recounted in *Emerging Patterns* helps explain how violating norms and rules can lead to these sorts of failures and deceptions.

When data visualizations took days or even years to make—from collecting and interpreting data, to conceptualizing, drawing, and printing—the result had to be worth the effort. Indeed, economist Karl Knies (1821–1898) captured a popular attitude in 1850 when he wrote of the 'pictorial method': 'Outside of its use as a pedagogic means, it is only a plaything without importance'.[3] In the face of such challenges, it is worth considering how and why the practice of data visualization evolved over time.

Emerging Patterns will expose our modern audience to the depth of thought and the painstaking effort it took to conceptualize and create, often by hand, graphics that are both meaningful and beautiful. The exhibition prompts important questions. What can we learn from the evolution of data visualization? Why did early geographers, astronomers, courtiers, and others visualize data?

Making People See

Data visualizations display data, but they also convey information, guiding the viewer towards a specific hypothesis. It is a natural step from recognizing patterns in a collection of data to drawing conclusions about those patterns. Data visualizations are implicit arguments which makes them powerful persuasive tools. The power to change people's minds, or to enable them to see matters from a particular perspective, is itself a form of power. As the celebrated American mathematician, John Tukey (1915–2000), wrote: 'The greatest value of a picture is when it forces us to notice what we never expected to see'.[4]

The exhibits in Part Two collectively show how, by harnessing the persuasive power of data visualization, creators displayed or asserted power, or more compellingly, claimed power and public attention for those who lacked it. In the fifteenth century, European monarchies exploited visualizations created with the newest technologies (the printing press and the ability to combine illustrations and text in printed matter) to assert political legitimacy and authority by showing their connections to the linage of Charlemagne. Later, in the nineteenth century, William Farr (1807–1883), W.E.B. De Bois, and Florence Nightingale, spurred by their era's popular and political fascination with new kinds of charts, created innovative, ground-breaking ways of visualizing data in part to advocate for changes in public policy, public health, military policy, and racial justice.

Maps of urban areas overlayed with colour-coded demographic and economic metrics created by Charles Booth (1840–1916), W.E.B. De Bois, Jane Addams (1860–1935), Florence Kelley (1859–1932), and the Hull-House residents drew public and political attention to issues of inequity in living conditions, health, and economic opportunity as they related to race, ethnicity, gender, and immigration status.

Data visualizations are often regarded as impartial displays of data. However, looking at historical examples illustrates how data visualization helped achieve (or impede) important social improvements and can help us understand the power of data visualization today. The exhibits highlighted in 'Making People See' are not impartial; they are persuasive. Indeed, their persuasive power draws on the authority of the form itself, with its historic associations with education, power, and wealth. The way the visualizations are made—the chosen design elements, colours, chart types, and visual conventions—is intended to add persuasive force to the content of the visualizations and the arguments that accompany them.

Each visualization compels patterns to emerge before our eyes. We are invited to make inferences and to learn something. Each visualization draws us to into the art of its construction. We are called to make judgements and urged or inspired to change how we see the world. William Playfair understood this. 'The best way to capture the imagination', he wrote, 'is to speak to the eyes'.[5]

Part One:

THE EVOLUTION OF DATA VISUALIZATION

There are several ways to think about the evolution of data visualization. One approach offers a historical review by telling the story of who did what, where, and when. Instead, *Emerging Patterns* examines the evolution of data visualization *thematically*. The exhibition invites audiences to consider thematically illustrative examples of data visualization throughout its developmental history. How and why did certain kinds of data visualizations develop into their modern, canonical forms? What is the developmental connection between the subject of a visualization and the techniques used to visualize it? Why were some methods successful, spawning a legacy of continued refinement and currency, while others were abandoned? How did the modern norms and rules of data visualization evolve and why? *Emerging Patterns* does not attempt to answer these questions directly. Rather, the exhibits, together with this catalogue, are intended to help us think about the evolution of data visualization through history and, in the end, change our encounters with modern data visualizations.

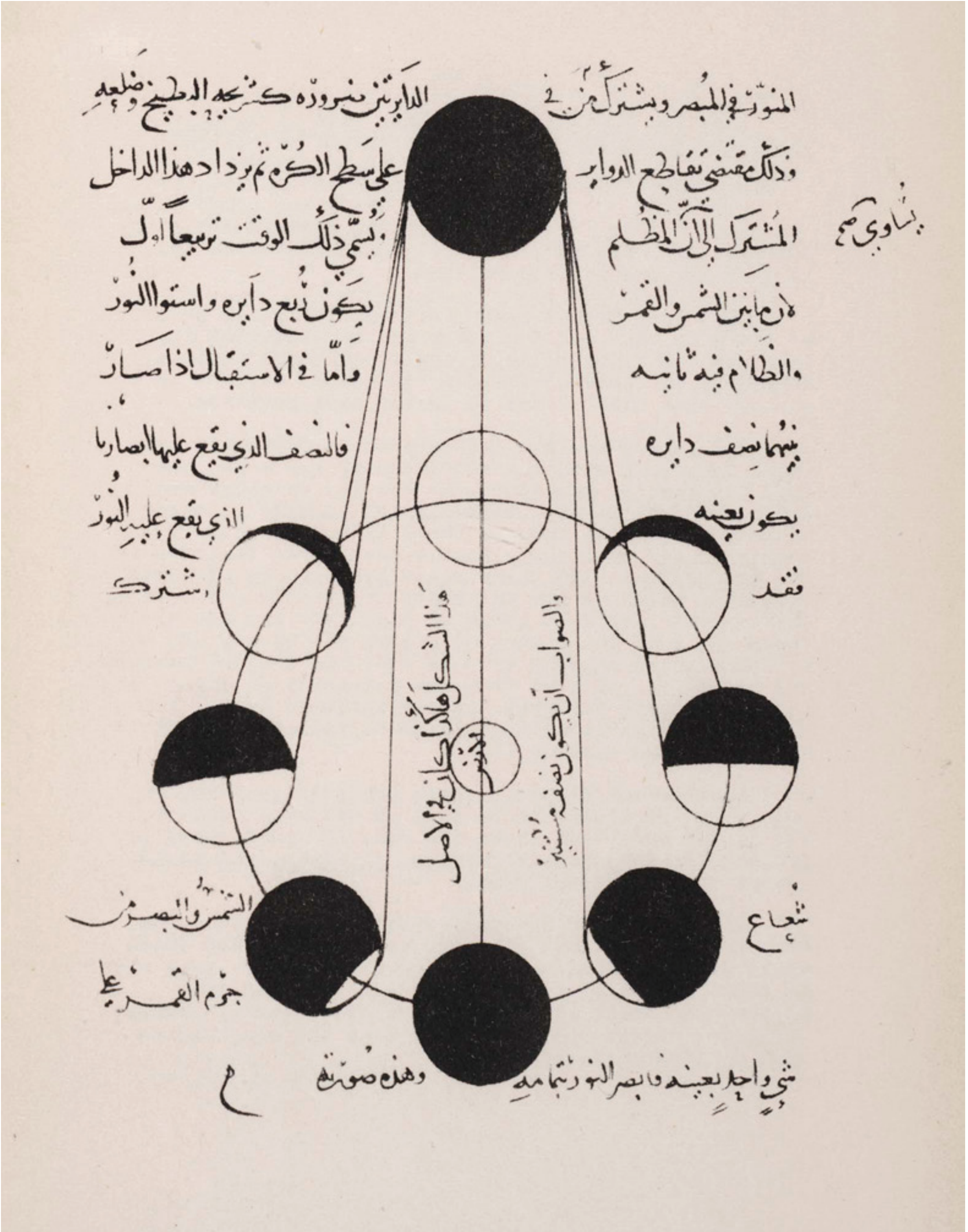
Thematic Cartography

Some of the first data visualizations were motivated by attempts to reconcile astronomical observations with theological or religious beliefs and the worldviews they entailed or simply to make sense of astronomical observations in the first place. Examples of thematic cartography are not merely maps or diagrams of geospatial objects. They depict non-spatial or abstract elements of data in two-dimensional space, often, but not always, in the form of a traditional map. Thematic cartography uncovers patterns and relationships among data elements. Elizabeth Clutton's explanation of thematic cartography calls to mind aspects of the definition of data visualization employed by *Emerging Patterns*. The 'thematic map', she writes, 'presents a mental ordering of space, generalizing and arranging beyond the limitations of the original data to offer a visual image of more abstract truths'.[6] Many early data visualizations are hard to recognize as data visualizations (or even maps) in the modern sense, but the constituent elements of data visualization are present and help us understand both the images themselves and the development of thematic cartography as a kind of data visualization.

> **Abū al-Rayḥān Muḥammad ibn Aḥmad al-Bīrūnī (973?–1048).**
> ***The Book of Instruction in the Elements of the Art of Astrology*.**
> **Translated by R. Ramsay Wright (1852–1933). London: Luzac, 1934.**

One of the earliest examples of thematic cartography as data visualization comes from Abū al-Rayḥān Muḥammad ibn Aḥmad al-Bīrūnī, known as al-Bīrūnī. Al-Bīrūnī was an eleventh-century Persian polymath and one of the founders of the field of geodesy. Among his many contributions is a data visualization of the phases of the moon (**Figure 1**). One of the debates of the period concerned the luminosity of the planets and the stars. Were they luminous themselves? Or did they reflect the light of the sun as the moon did? What could we learn about luminosity by looking at the moon? In thinking about these questions, al-Bīrūnī wrote about how observations of the moon's phases confirmed that the moon reflected the sun's light. He visualized the phenomenon by depicting the moon at eight stages of its orbit around the Earth. The Sun, pictured at the top, illuminates by means of its rays, the lines connecting the Sun to the moon at each stage of its orbit. The darker portions of the moon in the diagram represent the parts of the moon illuminated by the sun in each phase. The new moon, when the moon is located between the earth and the sun, is entirely obscured. As al-Bīrūnī writes in *Kitāb al-tafhīm li-awā'il ṣinā'ah al-tanjīm* (*The Book of Instruction in the Elements of the Art of Astrology*, c. 1029), we are 'unable to distinguish the dark mass of the moon from the lapis-lazuli of the sky on account of the dazzling light from the sun'.[7] But as the moon moves, the illuminated parts of its surface become increasingly visible from the earth, growing from a small crescent to a full orb (and back).

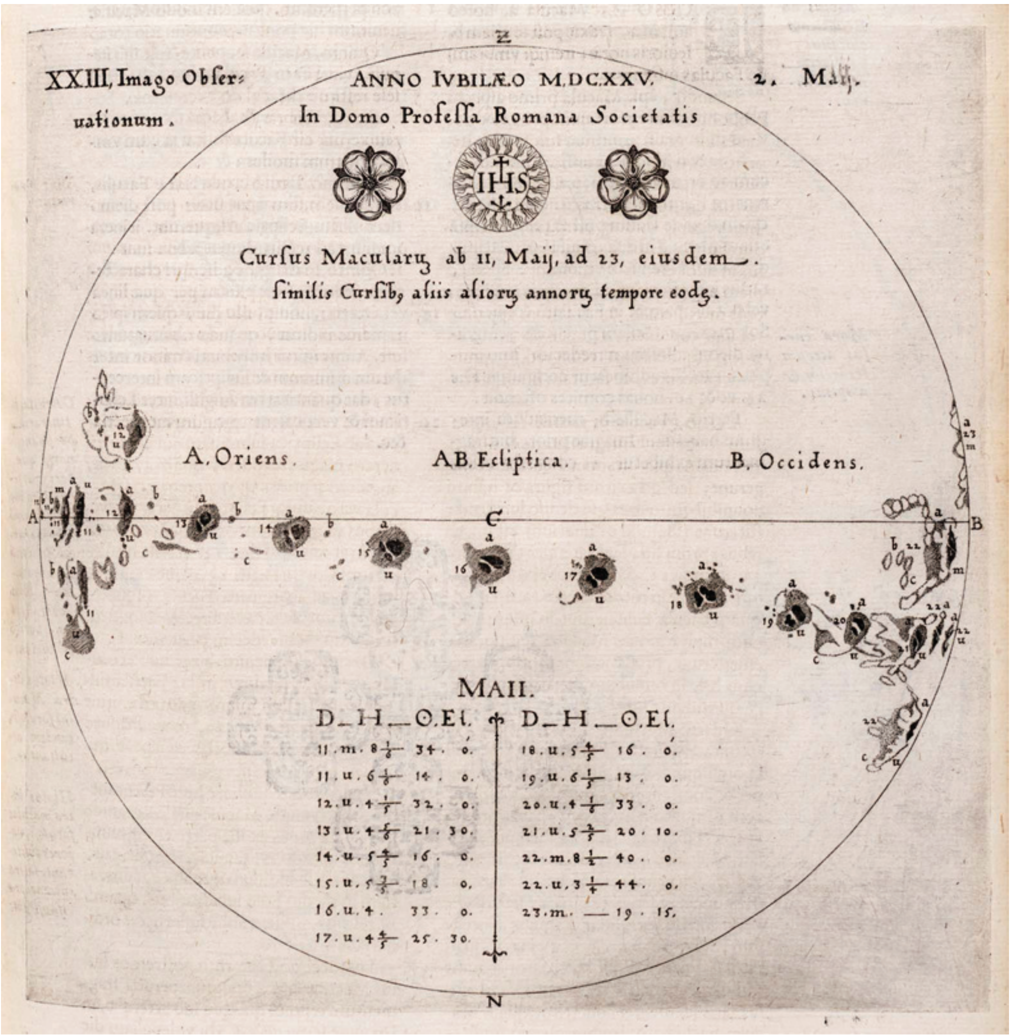
What is most interesting from a data visualization perspective is that al-Bīrūnī's diagram is a *time series map* of the sky. Each phase of the moon represents a distinct, consecutive, and uniform interval of time represented together in a single two-dimensional image. But the image is an abstraction: the night sky never actually looks that way. Rather, al-Bīrūnī collected and displayed the series of eight images together to show the pattern of the moon's travel over time and the relationship of each moment in time to the observed phenomena from Earth. Al-Bīrūnī's genius was creating a visualization—one of the earliest data visualizations—to help his audience understand what they were seeing in the sky.



[Figure 1]

Christoph Scheiner (1573–1650). ***Rosa Ursina*****. Bracciano: Apud Andream Phaeum, 1630.**

When Galileo (1564–1642) pointed his telescope into the sky at the dawn of the seventeenth century, he made a number of staggering discoveries. Among his most famous was the discovery of sunspots. If the sun were perfect and the embodiment



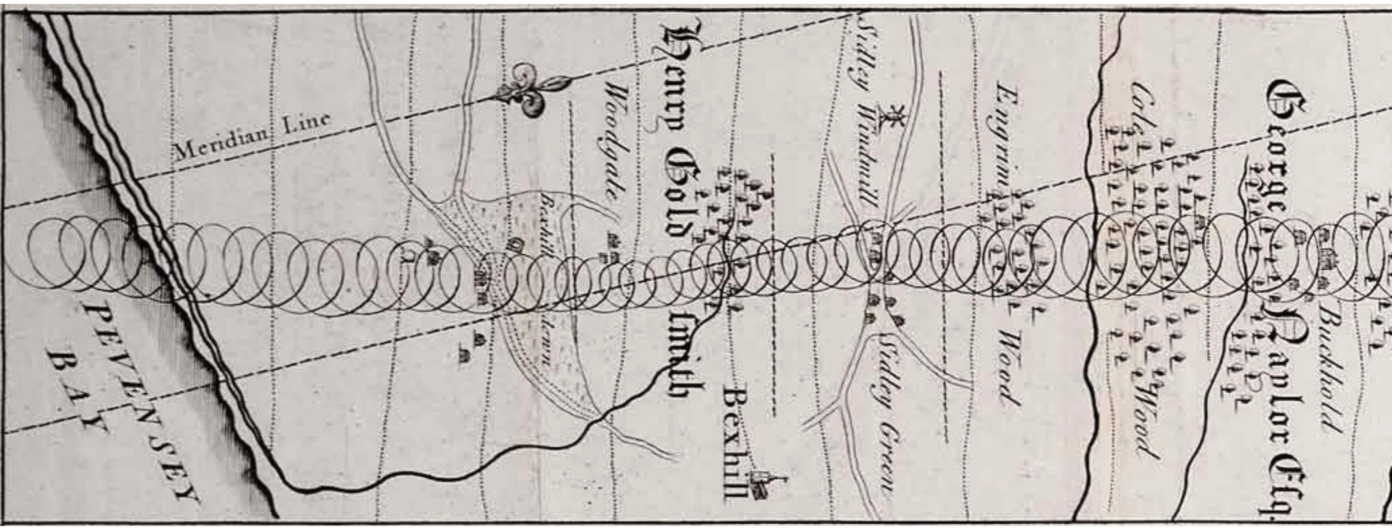
[Figure 2]

of the Good, as aspects of Greek philosophy and early cosmology and theology suggested, it was disconcerting to discover that it had spots. Christoph Scheiner, a Jesuit priest and accomplished mathematician, attempted to redeem the sun's perfection. He invented a pantograph, a mechanical device to copy and enlarge drawings, and, ingeniously, used it to draw observations he made of sunspots. He confirmed Galileo's discovery but suggested that the spots were actually shadows of satellites orbiting the sun. There followed a lengthy and acrimonious correspondence between Scheiner and Galileo. By 1630, after hundreds of meticulous observations, Scheiner was convinced that the spots were not shadows, but instead located on or near the surface of the sun itself. The way the spots moved, how they partially appeared or disappeared, rotated, and changed had convinced him.[8]

Scheiner published *Rosa Ursina* in 1630. It included scores of hand- and pantograph-drawn observations as seen, for example, in **Figure 2**. The drawings followed multiple sunspots as they traversed the surface of the sun over multiple days and months. To show the way the spots changed as they moved, he drew each successive observation against the backdrop of a single image of the sun. One can see the letters denoting the same sunspot over time and the dates of each observation. As al-Bīrūnī had done before him, Scheiner visualized his observations as a time series. His drawings matched no single observation. As Clutton might say, Scheiner's sunspot maps reflect an intellectual rather than physical ordering of space to represent a sequence of temporal events in two physical dimensions, making the relationship between the events apparent to the eye. This sort of abstraction is at the heart of data visualization and, certainly in the seventeenth century and earlier, marked rare conceptual insight.

Richard Budgen (1730–1789). ***The Passage of the Hurricane from the Sea-Side at Bexhill in Sussex to Newingden-Level, the Twentieth Day of May 1729, between Nine and Ten in the Evening*. London: John Senex, 1730.**

Charles E. Goad (1848–1910). ***Beaverton, Ontario (Ontario County)*. Toronto: Charles E. Goad Company, 1910.**



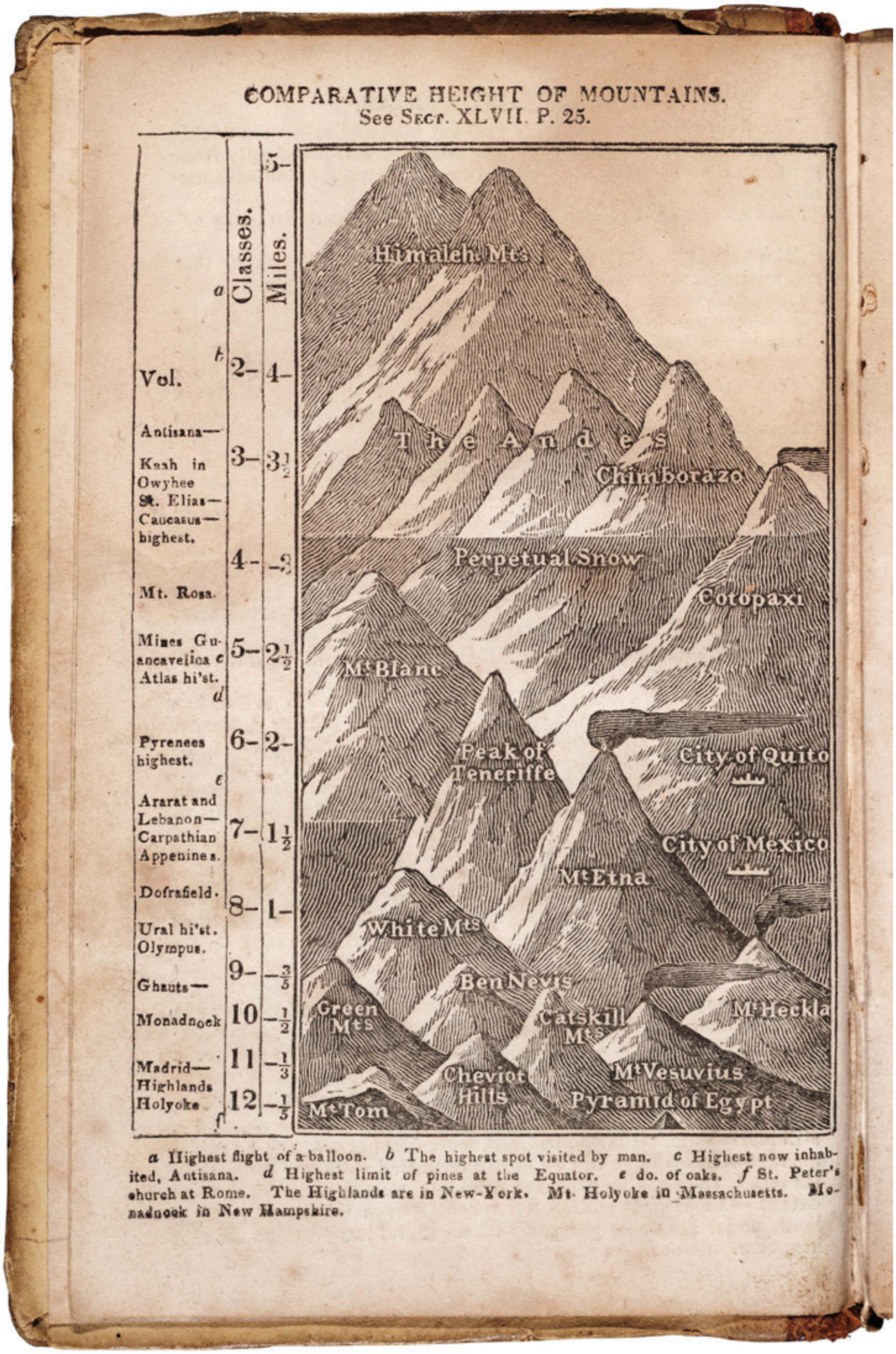
[Figure 3]

In 1729, a storm described as a 'tornado or a hurricane' by Richard Budgen, an estate surveyor, made landfall near Bexhill on the southern coast of England. Budgen published a detailed account of the hurricane's passage, consulting witnesses and documenting the damage done to various properties and estates. The book contains a foldout data visualization that is the thematic offspring of al-Bīrūnī and Scheiner. **Figure 3** shows a graphical representation of the storm's path, size,


Basins of the AMAZON AND TOCANTINS
1
Area: 2.275.000
Length: 3.550
Area: 381.000
Length: 1.500
2
Area: 1.242.000
Length: 2.210
Basin of the LA PLATA
Atlantic Ocean
GT LAKES & ST LAWRENCE
4
Area: 520.000
Length: 2.070
THE
WITH COMPARATIVE VIEWS OF
MOU
and Basins of
ON THE
BY C.H.
WESTERN HEMISPHERE
90
North Pole
ARCTIC OCEAN
DANISH AMERICA
GREENLAND
ICELAND
ASIA
KAMTCHATKA SEA
RUSSIAN AMERICA
HUDSON BAY
BRITISH AMERICA
NEWFOUNDLAND
NORTH AMERICA
UNITED STATES
NORTH PACIFIC OCEAN
NORTH ATLANTIC OCEAN
Tropic of Cancer
GULF OF MEXICO
WEST INDIES
CARIBBEAN SEA
MEXICO
Sandwich Isles
Equator
OCEANIA
POLYNESIA
SOUTH PACIFIC OCEAN
Tropic of Capricorn
SOUTH AMERICA
BRAZIL
SOUTH ATLANTIC OCEAN
AUSTRALASIA
NEW ZEALAND
Antarctic Circle
ANTARCTIC OCEAN
South Pole
90
3
Area: 1.333.000
Length: 4.100
Basin of the MISSISSIPPI & MISSOURI
Gulf of Mexico
Scale of English Feet
III. ANDES
IV. TENERIFFE
NOTE
The figures denote the mean annual temperature in degrees of Fahrenheit.
10
ANDES III.
ANTARCTIC OCEAN
South Latitude


I.
Basins of the
RHINE, DANUBE & DNIEPER
Area: 311,000
Length: 1,725
Black Sea
Basins of the
VOLGA & URAL
Area: 528,000
Length: 2,350
Caspian Sea
Basin of the
INDUS
Area: 410,000
Length: 2,260
Arabian Sea
Area: 416,000
Length: 1,940
Bengal Sea
Basins of the
GANGES & IRAWADY
ORLD
ispheres
THE HEIGHTS OF THE PRINCIPAL
NTAINS
he principal Rivers
E GLOBE
WANSTON,
burgh
TON & Cº
EASTERN HEMISPHERE
North Pole
ARCTIC OCEAN
EUROPE
ASIA
TARTARY
TURKESTAN
MONGOLIA
CHINESE EMPIRE
CHINA
TIBET
JAPAN SEA
OKHOTSK SEA
ARABIA
ARABIAN SEA
BENGAL SEA
HINDOOSTAN
SAHARA or Great Desert
SOUDAN OR NIGRITIA
AFRICA
GULF OF GUINEA
Tropic of Cancer
Tropic of Capricorn
Equator
NORTH PACIFIC OCEAN
OCEANIA
MALAYSIA
BORNEO
CELEBES SEA
NEW GUINEA
ARAFURA SEA
SOUTH ATLANTIC OCEAN
INDIAN OCEAN
MADAGASCAR
AUSTRALIA
WESTERN AUSTRALIA
SOUTH AUSTRALIA
QUEENSLAND
NEW SOUTH WALES
Victoria
TASMANIA
SOUTHERN OCEAN
Antarctic Circle
ANTARCTIC OCEAN
South Pole
(2)
HIMALAYA II.
ASIA
ALPS I.
TENERIFFE
LAPLAND
I. ALPS
a Glacier
b Quercus (Oak)
c Fagus sylv. (Beech)
d Betula alba (Birch)
e Pinus Picea
f Pinus Abies
g Pinus Cembra
h Rhododendron
i Alnus viridus
II. HIMALAYA
a Below this point snow is unknown
b Upper limit of Pinus longifolia
c Quercus (Oak)
d Lower limit of Pinus Neoza
e Snow disappears before the rainy season. Tropical vegetation ceases
f Upper limit of Pinus Neoza
g Upper limit of Pinus Deodara
h Betula alba. Sorbus. Quercus.
i Juniperus. Rhododendron.
j Pyrus Malus (Pear Apple)
k Juglans regia (Walnut)
l Triticum (Wheat)
m Secale cereale (Rye)
n Hordeum (Barley)
o Lower limit of Pinus Deodara
p Pinus Neoza
q Upper limit of Pinus Deodara
r Betula alba (Birch)
s Juniperus
Scale of English Feet
North Latitude
Level of the Sea
Area: 1,040,000
Length: 3,230
Basin of the
YENESEI

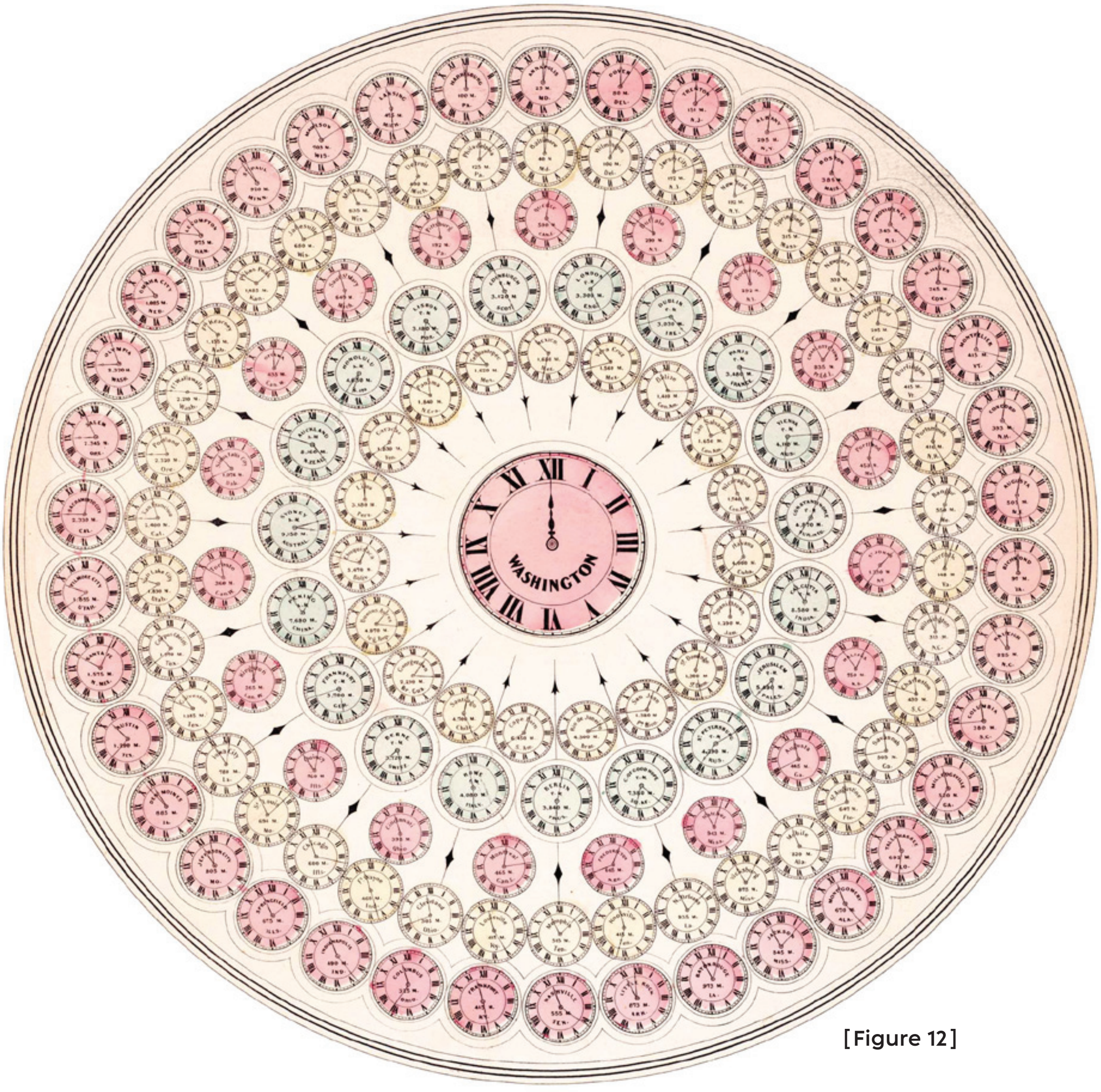
[Figure 10]



[Figure 11]

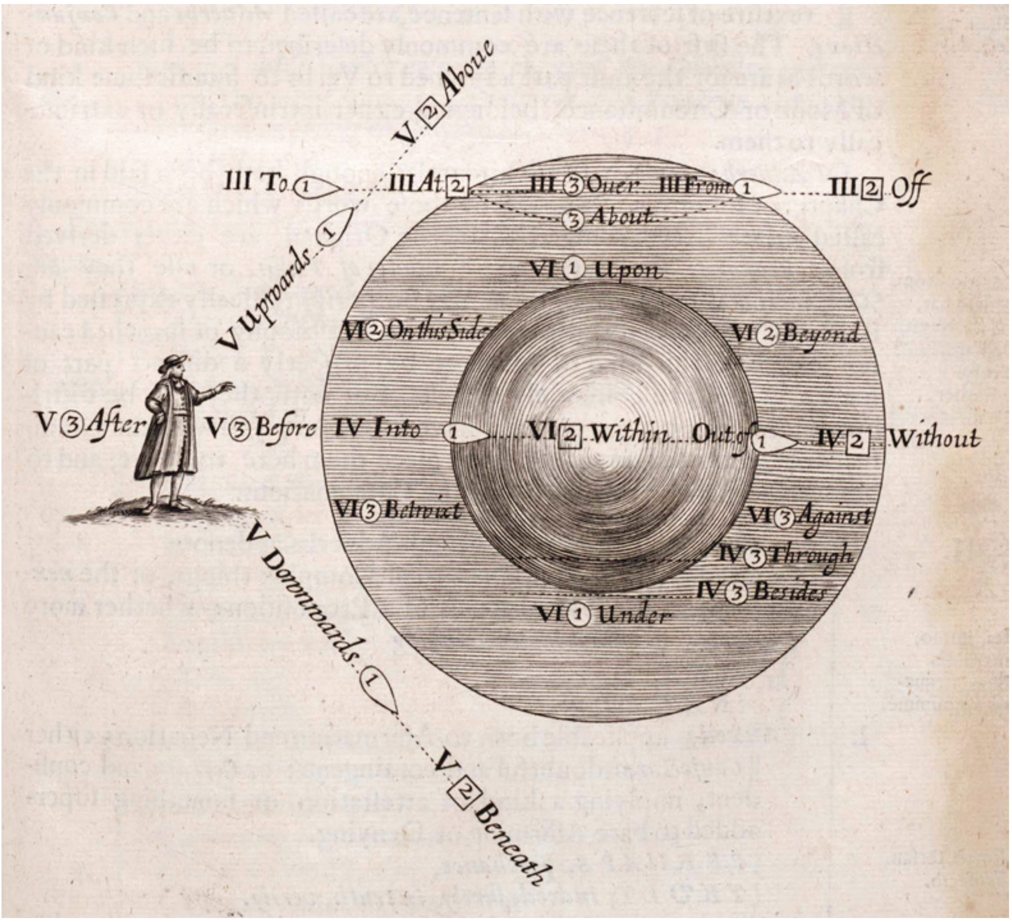
divided into classes). There is no x-axis *per se*, though the various mountains are arrayed along a putative x-axis for ease of display. This technique is called 'dodging' in modern parlance whereby data points are shifted slightly in one dimension or another not as a result of a mapping, but in order to avoid over-plotting (i.e. drawing elements on top of one another). The altitude of 'perpetual snow' is indicated with a line, but it is not adjusted for latitude as Swanston's visualization was 40 years later.

Alvin J. Johnson (1827–1884). ***Johnson's New Illustrated (Steel Plate) Family Atlas: With Descriptions, Geographical, Statistical, and Historical*****. New York: Johnson and Browning, 1861.**



[Figure 12]

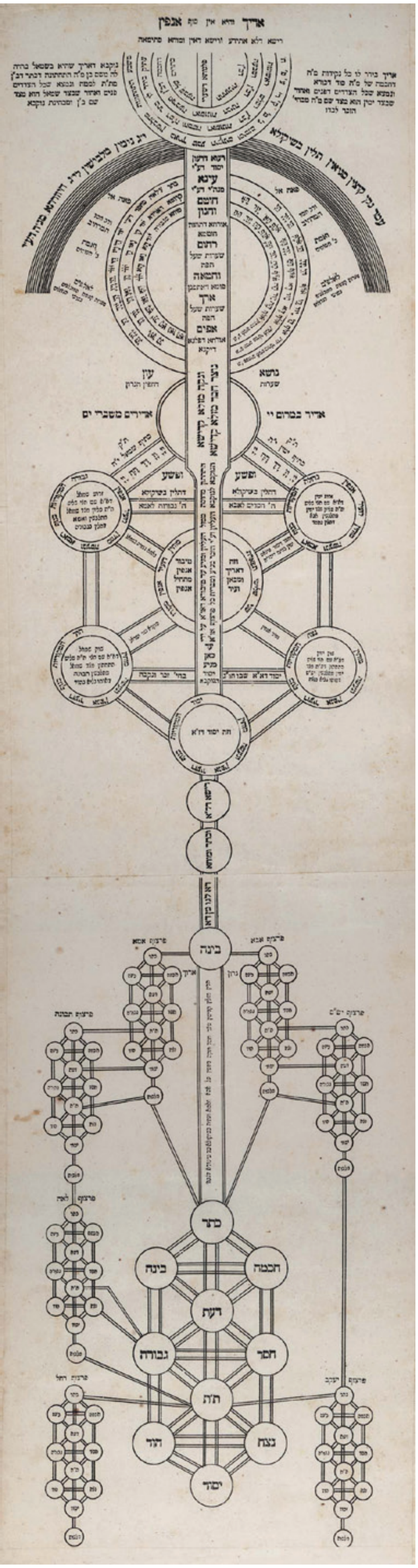
Figure 12 shows an example from 1861 of Alvin Johnson's famous visualization of time differences from Washington D.C. The graphic appeared in his *Family Atlas* and depicts the times in different cities around the world relative to twelve o'clock in Washington, D.C. Before time zones were used in the United States, figuring out what time it was in different cities was an important and tricky challenge. Johnson's graphic is an example of a thematic map, and the various clocks are arranged according to time and distance, though the exact methodology remains unclear. This beautiful, if bewildering, data visualization comes from a period



[Figure 16]

> **Meir ben Judah Leib Poppers (c. 1624–1662).**
> ***Ilan ha-gadol*. Warsaw? 1864.**

Kabbalah is a Jewish mystical tradition dating back to the twelfth and thirteenth centuries. Kabbalist theosophy involves four planes of being and ten luminous emanations known as *sefirot*. The order and the interconnections of the *sefirot* are an important element of the belief structure. Kabbalists chose a tree-like diagram to represent their system. The chart in **Figure 17**, drawn in 1864, inspired from earlier versions of the mystical trees, is called *Ilan ha-Gadol*, which translates to 'The Great Tree'. Though the Kabbbalists called the diagram a tree, it is a more general network diagram in that any node may connect to any other node, despite the hierarchical structure. The network also contains nodes that are themselves smaller trees or networks. These kinds of permutations, networks within networks, are important to the Kabbalistic belief system.[17]



[Figure 17]

Jacob Moreno (1888–1974). ***Who Shall Survive? Foundations of Sociometry, Group Psychotherapy and Sociodrama*****. Beacon, New York: Beacon House, 1953.**

Sociograms were developed by Jacob Moreno as diagrams to reflect people and their interactions in social settings. He first used sociograms to show how actors in plays overlapped in scenes with lines in the diagrams connecting actors who had shared a scene together in a 'co-occurrence network'. This example of a social network is still used as an accessible entry point to explain the concept; the game and internet meme 'Six Degrees of Kevin Bacon' is an excellent illustration. The computer scientist Donald Knuth (1938–) originally compiled a dataset of characters in the scenes of the play *Les Miserables* in 1993 for a book and associated tools for combinatorial computing and network graphing.[18] Since then, most computer network analysis software and software programs designed to visualize and analyze social networks use the *Les Miserables* dataset as a standard instructional example.

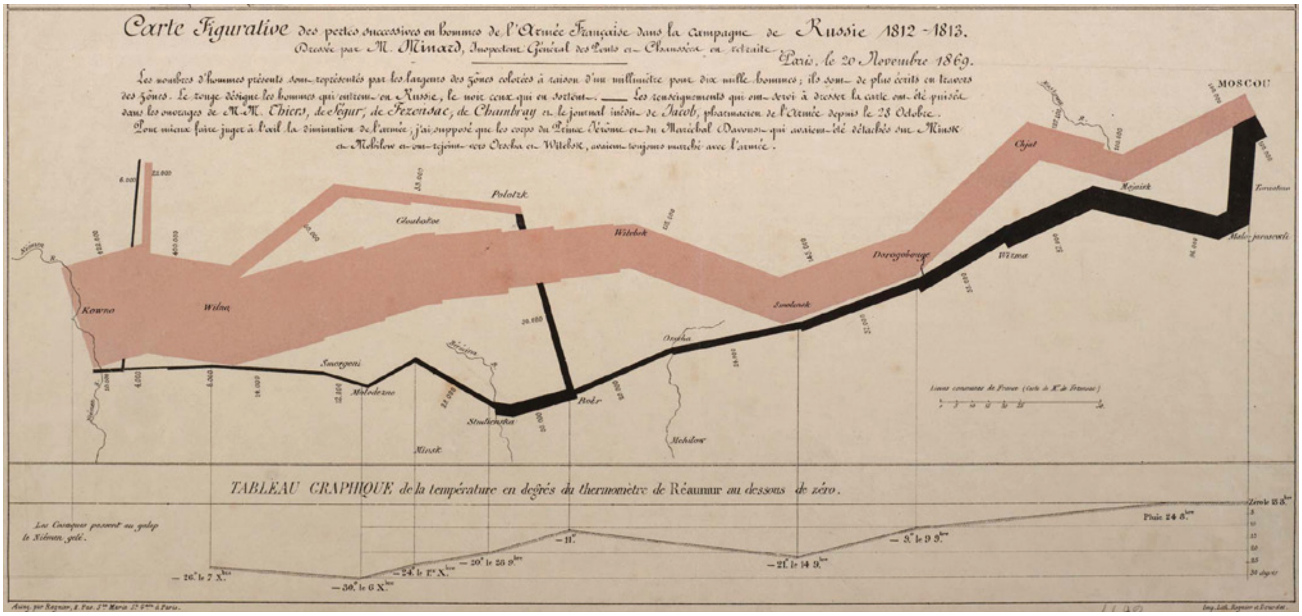
In developing his analytic system, Moreno was not only the inventor of sociograms but also one of the founders of the field of social network analysis. Social network analysis is the formal, quantitative study of an individual's role in a group or community by analyzing the network of connections between them and others in the network along with quantitative descriptions of various communities created by those connections.

Moreno used sociograms in his 1934 book *Who Shall Survive? A New Approach to the Problem of Human Interrelation* to describe the relationships between girls at the New York Training School for Girls in Hudson, New York, mapping attraction and revulsion between each pair of 500 girls. He identified and named patterns of relationships: people in a sociogram who have many friends were called 'stars'. Those with few or no friends were called 'isolates'. Cliques were defined as groups of three or more people within a larger group who are all friends. The chart in **Figure 18** shows the sociogram for two girls who ran away from the school. The black lines indicate dislike or rejection, the red lines indicate a positive relationship. A friendship is illustrated by red lines that connect two nodes. Moreno used these social networks and the analysis of the structures within them to explain why there was a sudden escalation of runaways from the school. His work contained some of the earliest graphic depictions of complex networks, data visualization methods later applied to numerous other disciplines like computer science, genetics, bibliometrics, and history.

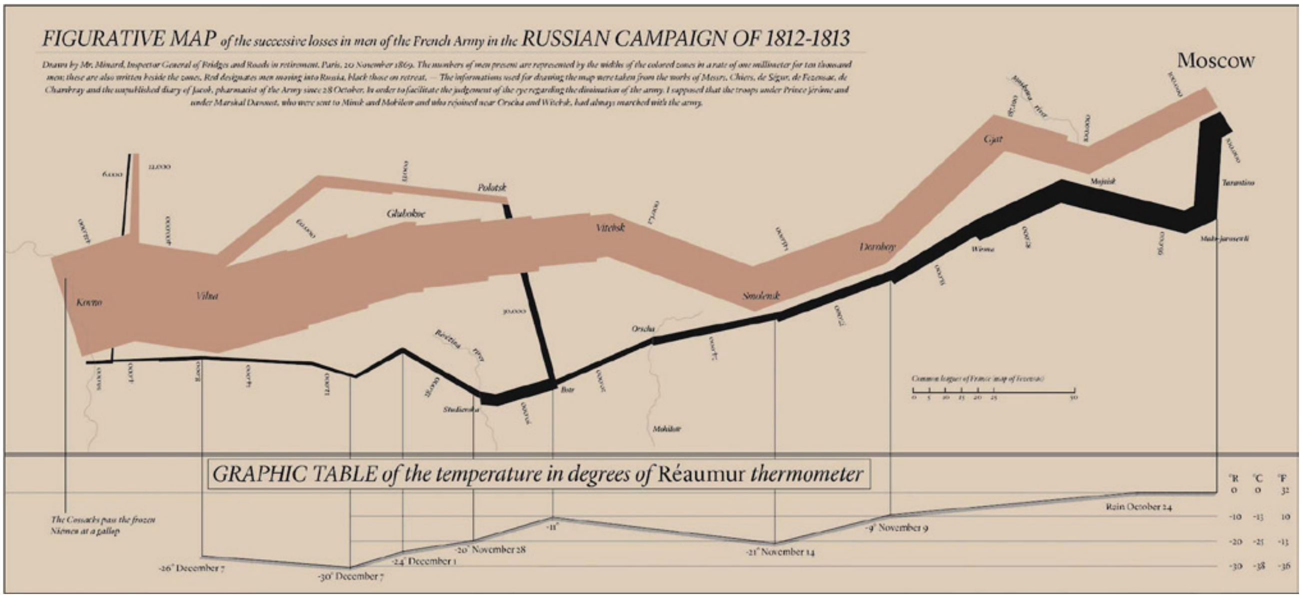
> **Charles Joseph Minard (1781–1870).** ***Carte figurative des pertes successives en hommes de l'armée française dans la Campagne de Russie 1812–13*****. Paris, Régnier & Dourdet, 1869.**

In 1869, Charles Minard created the famous map in **Figure 19** (translated version in **Figure 20**) of Napoleon's invasion of Russia in 1812. The thick band illustrates the size of Napoleon's army at various locations during their advance and retreat. The width of the band is proportional to the number of soldiers in the army at each point, with each millimetre representing ten thousand men. The beige colour represents the army's advance and the black its retreat. The temperature during the retreat is shown on the line graph at the bottom. The map displays numerous variables: the number of troops; the distance traveled; temperature; latitude and longitude; and the direction of travel. The loss of life looms in the thinning of the bands. The effect of temperature on the outcome of the battles emerges easily from Minard's design, which would have been much harder to glean from a table of values.

While the modern Sankey diagram gets its name from Matthew Sankey (1853–1925), who used this type of flow diagram in 1898 to show the energy efficiency of a steam engine, Minard's map predates Sankey's by twenty-nine years. The Minard map was heralded by data visualization expert Edward Tufte (1942–)



[Figure 19]

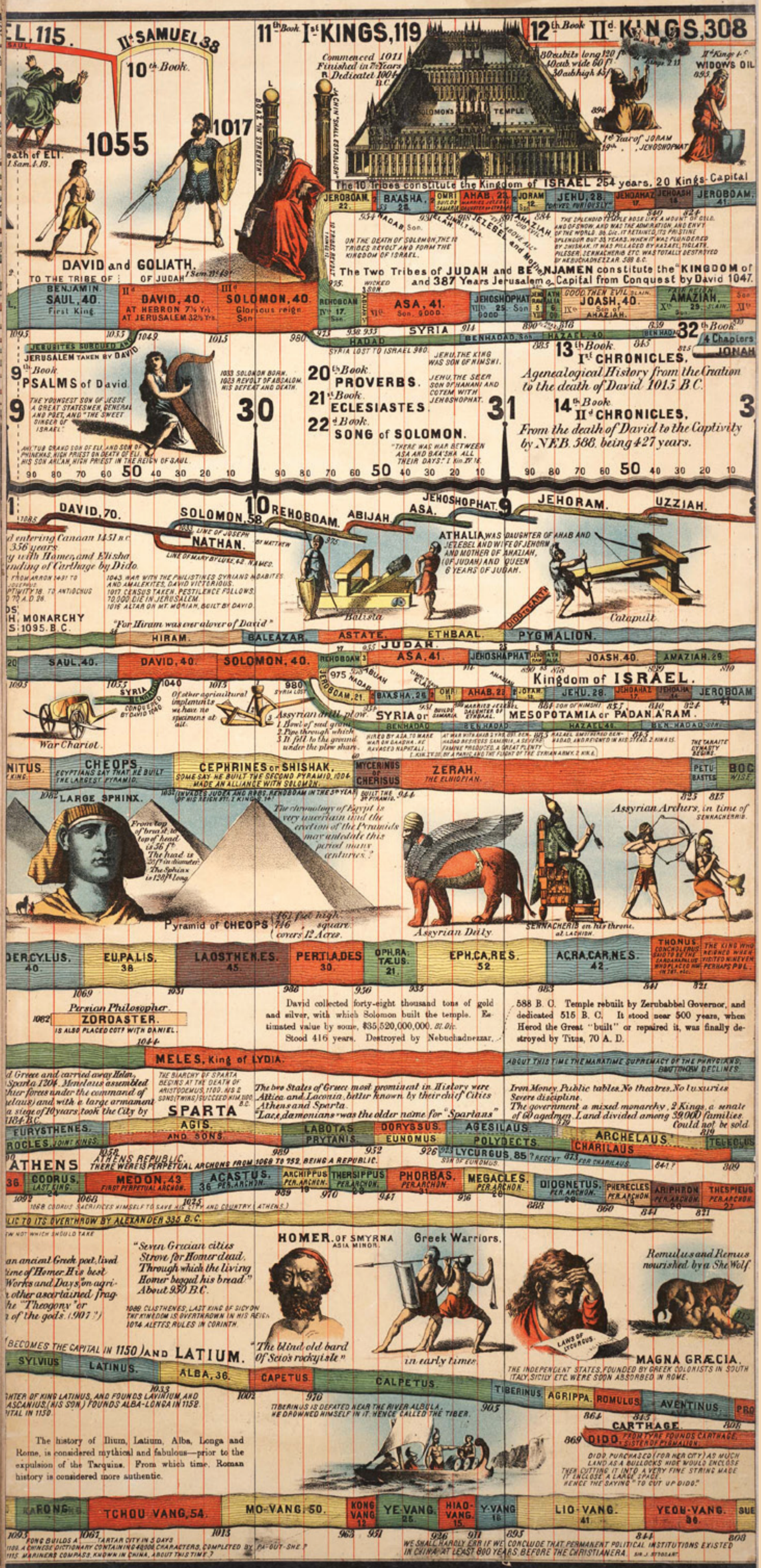


[Figure 20]

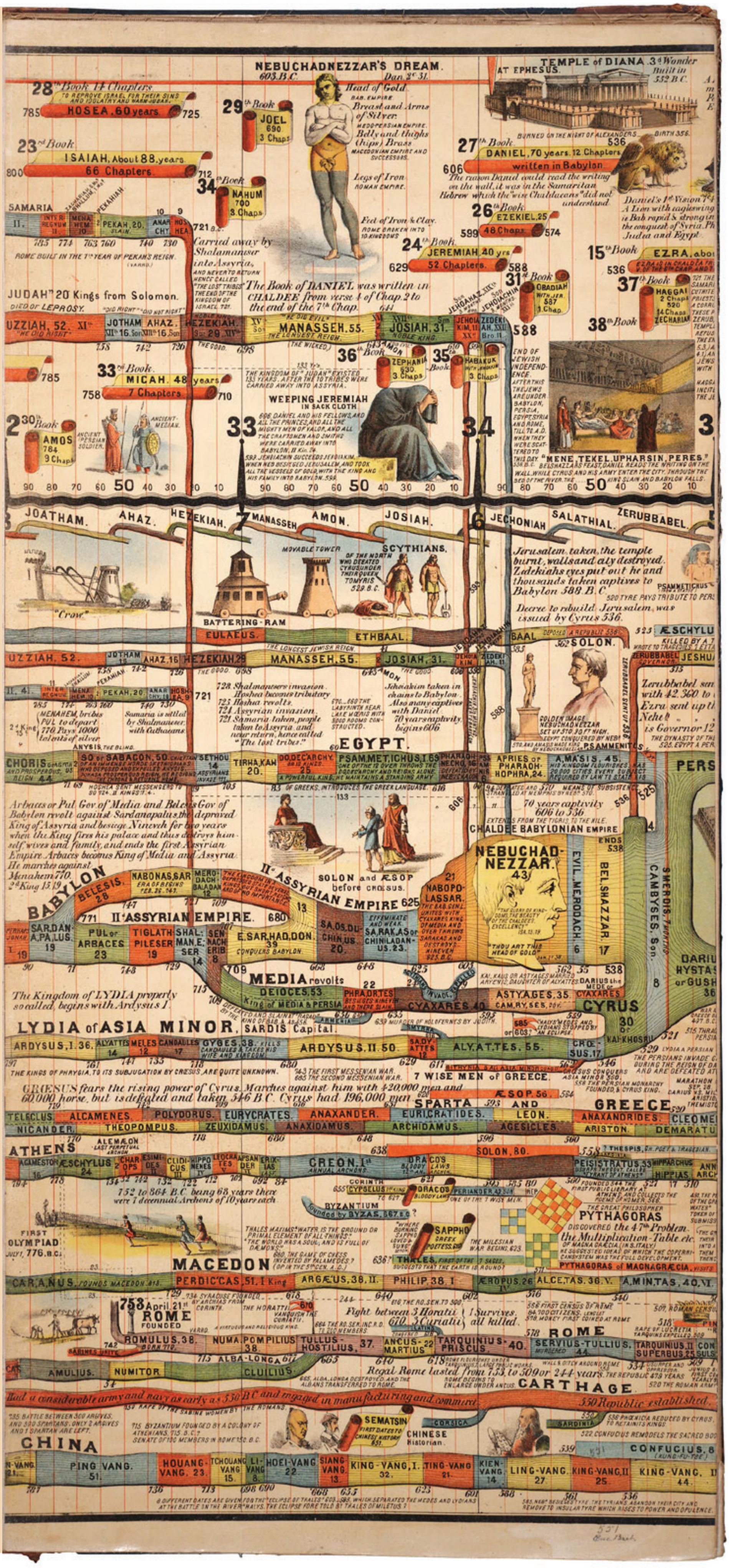
as ‘probably the best statistical graphic ever drawn’.[19] Upon viewing the many examples in this exhibition, readers are invited to decide if they agree!

Sebastian C. Adams (1825–1898). *A Chronological Chart of Ancient, Modern and Biblical History*. Chicago: J. Andrews, 1878.

Also pre-dating the work of Sankey is the Adams Synchronological Chart (**Figure 21**). It is a large wallchart scroll depicting a timeline of history first published in 1871. The chart is a set of timelines beginning with people and events from the Christian Bible that are later merged into (mostly) historical material. While the biblical genealogies are presented in a timeline chart on the top half of the infographic, the bottom half of the infographic is dominated by an early version of a Sankey diagram showing the rise, merging, and fall of nations from ancient civilizations. Question marks are used to indicate uncertainty about the dates or events, particularly in the earlier parts of the timeframe. Centuries are marked by thick black lines, decades by thin red bars. The long snaking bands represent various nations and their relative size and strength. The bands are segmented into different colours indicating the reign of various leaders or changes in government. When one nation conquers another, their bands merge, and when areas gain independence, a single branch divides. Adams’ Synchronological Chart is an early infographic as well as a data visualization. It is similar to Shimeall’s 1832 *Genealogical Chart* in **Figure 13**. Adams’ chart also employs the scientific aesthetic of the mid-nineteenth century to lend credence and authority to biblical and popular accounts of history. The infographic is also similar to Shimeall’s in the way that biblical accounts share the stage with historical events to suggest their historical accuracy.



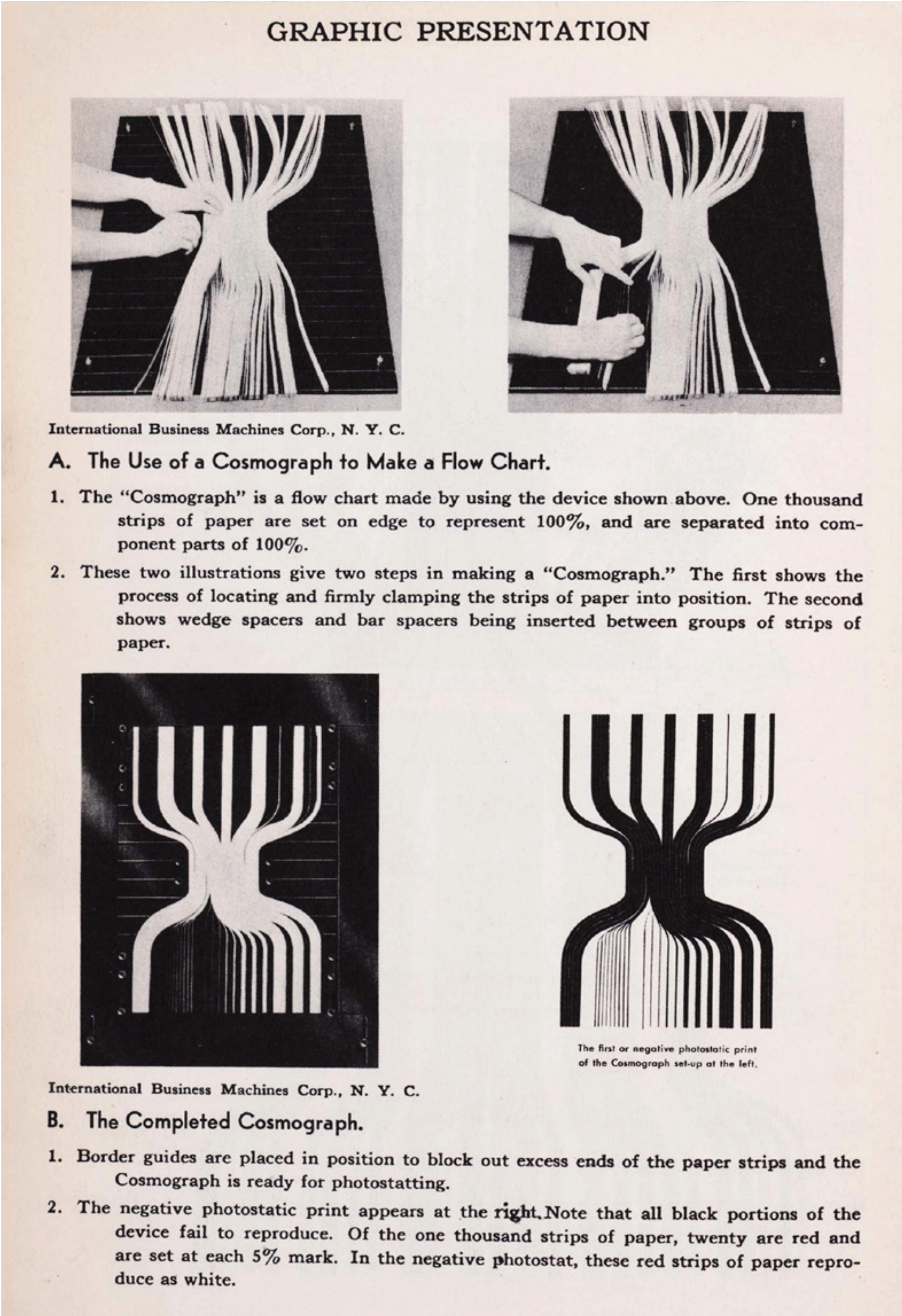
EL, 115.
IId SAMUEL 38
10th Book.
1055
1017
Death of ELI.
DAVID and GOLIATH
11th Book Ist KINGS, 119
Commenced 1011
SOLOMON'S TEMPLE
12th Book IId KINGS, 308
WIDOWS OIL
The 10 Tribes constitute the Kingdom of ISRAEL 254 years. 20 Kings
JEROBOAM, 22.
BAASHA, 24.
AHAB, 22.
JEHU, 28.
JEROBOAM, 41
The Two Tribes of JUDAH and BENJAMEN constitute the "KINGDOM of JUDAH" and 387 Years Jerusalem a Capital from Conquest by David 1047.
SAUL, 40. First King.
DAVID, 40. AT HEBRON 7½ Yrs. AT JERUSALEM 32½ Yrs.
SOLOMON, 40. Glorious reign.
REHOBOAM
ASA, 41.
JEHOSHOPHAT
JOASH, 40.
AMAZIAH, 29.
SYRIA
HADAD
BENHADAD
HAZAEL
32d Book 4 Chapters JONAH
JERUSALEM TAKEN BY DAVID
9th Book PSALMS of David.
20th Book PROVERBS.
21st Book ECLESIASTES.
22d Book SONG of SOLOMON.
13th Book Ist CHRONICLES.
A genealogical History from the Creation to the death of David 1015 B.C.
14th Book IId CHRONICLES.
From the death of David to the Captivity by NEB. 588, being 427 years.
29
30
31
DAVID, 70.
SOLOMON, 58
REHOBOAM.
ABIJAH.
ASA.
JEHOSHOPHAT.
JEHORAM.
UZZIAH.
NATHAN.
ATHALIA, WAS DAUGHTER OF AHAB AND JEZEBEL AND WIFE OF JEHORM AND MOTHER OF AHAZIAH, (OF JUDAH) AND QUEEN 6 YEARS OF JUDAH.
Balista
Catapult
"For Hiram was ever a lover of David"
HIRAM.
BALEAZAR
ASTATE.
ETHBAAL.
PYGMALION.
SAUL, 40.
DAVID, 40.
SOLOMON, 40.
ASA, 41.
JEHOSHAPHAT
JOASH, 40.
AMAZIAH, 29.
Kingdom of ISRAEL.
SYRIA or
MESOPOTAMIA or PADAN ARAM.
War Chariot.
Assyrian drill plow.
CHEOPS. EGYPTIANS SAY THAT HE BUILT THE LARGEST PYRAMID.
CEPHRINES or SHISHAK. SOME SAY HE BUILT THE SECOND PYRAMID. 1004 MADE AN ALLIANCE WITH SOLOMON.
MYCERINUS CHERISUS
ZERAH. THE ETHIOPIAN.
LARGE SPHINX.
Pyramid of CHEOPS
Assyrian Archers, in time of SENNACHERIB.
Assyrian Deity
SENNACHERIB on his throne.
DERCYLUS. 40.
EUPALIS. 38
LAOSTHENES. 45.
PERTIADES 30.
OPHRATÆUS. 21.
EPHCARES. 52
ACRACARNES. 42
THONUS.
Persian Philosopher.
ZOROASTER.
David collected forty-eight thousand tons of gold and silver, with which Solomon built the temple. Estimated value by some, $35,520,000,000.
Stood 416 years. Destroyed by Nebuchadnezzar.
588 B. C. Temple rebuilt by Zerubabbel Governor, and dedicated 515 B. C. It stood near 500 years, when Herod the Great "built" or repaired it, was finally destroyed by Titus, 70 A. D.
MELES, King of LYDIA.
SPARTA
The two States of Greece most prominent in History were Attica and Laconia, better known by their chief Cities Athens and Sparta.
"Lacedæmonians" was the older name for "Spartans"
Iron Money, Public tables, No theatres, No luxuries. Severe discipline.
EURYSTHENES.
AGIS. AND SONS.
LABOTAS
PRYTANIS.
DORYSSUS.
EUNOMUS
AGESILAUS.
POLYDECTS.
ARCHELAUS.
CHARILAUS
LYCURGUS, 85
ATHENS
ATHENS REPUBLIC. THERE WERE 13 PERPETUAL ARCHONS FROM 1068 TO 752, BEING A REPUBLIC.
CODRUS. LAST KING.
MEDON, 43 FIRST PERPETUAL ARCHON.
ACASTUS, 36
ARCHIPPUS
THERSIPPUS
PHORBAS.
MEGACLES.
DIOGNETUS.
PHERECLES
ARIPHRON
THESPIEUS
HOMER, OF SMYRNA ASIA MINOR.
Greek Warriors.
"Seven Grecian cities Strove for Homer dead, Through which the living Homer begged his bread." About 950 B.C.
The blind old bard Of Scio's rocky isle"
in early times
Romulus and Remus nourished by a She Wolf.
MAGNA GRÆCIA.
LATIUM.
SYLVIUS
LATINUS.
ALBA, 36.
CAPETUS.
CALPETUS
TIBERINUS
AGRIPPA.
ROMULUS
AVENTINUS.
CARTHAGE.
DIDO.
The history of Ilium, Latium, Alba, Longa and Rome, is considered mythical and fabulous—prior to the expulsion of the Tarquins. From which time, Roman history is considered more authentic.
TCHOU VANG, 54.
MO-VANG, 50.
KONG VANG
YE-VANG, 25.
HIAO-VANG, 15.
Y-VANG
LIO-VANG. 41.
YEOU-VANG. 36.
WE SHALL HARDLY ERR IF WE CONCLUDE THAT PERMANENT POLITICAL INSTITUTIONS EXISTED IN CHINA AT LEAST 800 YEARS BEFORE THE CHRISTIAN ERA.


NEBUCHADNEZZAR'S DREAM.
TEMPLE of DIANA. 3d Wonder
AT EPHESUS.
HOSEA. 60 years.
ISAIAH. About 88 years.
66 Chapters.
JOEL
NAHUM
DANIEL, 70 years. 12 Chapters
written in Babylon
EZEKIEL. 25
JEREMIAH. 40 yrs
52 Chapters.
EZRA
HAGGAI
OBADIAH
SAMARIA
JUDAH 20 Kings from Solomon.
UZZIAH, 52.
JOTHAM
AHAZ.
HEZEKIAH.
MANASSEH. 55.
JOSIAH. 31.
MICAH. 48 years
7 Chapters
AMOS
ZEPHANIA
HABAKUK
WEEPING JEREMIAH
IN SACK CLOTH
"MENE, TEKEL, UPHARSIN, PERES."
JOATHAM.
AHAZ.
HEZEKIAH.
MANASSEH.
AMON.
JOSIAH.
JECHONIAH
SALATHIAL.
ZERUBBABEL.
SCYTHIANS.
BATTERING-RAM
Jerusalem taken, the temple burnt, walls and city destroyed. Zedekiahs eyes put out he and thousands taken captives to Babylon 588 B.C.
Decree to rebuild Jerusalem, was issued by Cyrus 536.
ETHBAAL.
SOLON.
EGYPT.
PSAMMETICHUS. 1. 69
APRIES or PHARAOH-HOPHRA. 24.
AMASIS. 45.
PERS
CHALDEE BABYLONIAN EMPIRE
NEBUCHADNEZZAR.
EVIL-MERODACH
BELSHAZZAR.
CAMBYSES. Son.
BABYLON
II. ASSYRIAN EMPIRE.
SOLON and ÆSOP before CRŒSUS.
MEDIA revolts
DEIOCES. 53.
CYAXARES 40
ASTYAGES. 35
CYRUS
LYDIA of ASIA MINOR, SARDIS Capital.
ARDYSUS. II. 50.
ALYATTES. 55.
7 WISE MEN of GREECE.
ÆSOP. 56.
SPARTA AND GREECE
ATHENS
SOLON. 80.
PISISTRATUS
PYTHAGORAS
SAPPHO
BYZANTIUM
FIRST OLYMPIAD JULY 1, 776 B.C.
MACEDON
PERDICCAS. 51. I. King
ARGÆUS. 38. II.
PHILIP. 38. I
ÆROPUS. 26
ALCETAS. 36. V.
AMINTAS. 40. VI.
753 April 21st ROME FOUNDED
ROMULUS. 38.
NUMA POMPILIUS
TULLUS HOSTILIUS. 37.
ANCUS MARTIUS
TARQUINIUS PRISCUS. 40.
SERVIUS-TULLIUS. 44.
ROME
Fight between 3 Horatii & 3 Curiatii 1 Survives. all killed.
Regal Rome lasted from 753 to 509 or 244 years.
CARTHAGE
550 Republic established.
CHINA
PING VANG. 51.
CONFUCIUS
KING-VANG. 44.

[Figure 21]

Willard C. Brinton (1880–1939). *Graphic Presentation*. New York: Brinton Associates, 1939.

The Sankey diagrams of Minard, Adams, and Sankey were meticulously crafted by hand using rulers and drafting tools. The ones in use today are created using data


GRAPHIC PRESENTATION

International Business Machines Corp., N. Y. C.

A. The Use of a Cosmograph to Make a Flow Chart.

1. The "Cosmograph" is a flow chart made by using the device shown above. One thousand strips of paper are set on edge to represent 100%, and are separated into component parts of 100%.
2. These two illustrations give two steps in making a "Cosmograph." The first shows the process of locating and firmly clamping the strips of paper into position. The second shows wedge spacers and bar spacers being inserted between groups of strips of paper.

The first or negative photostatic print of the Cosmograph set-up at the left.

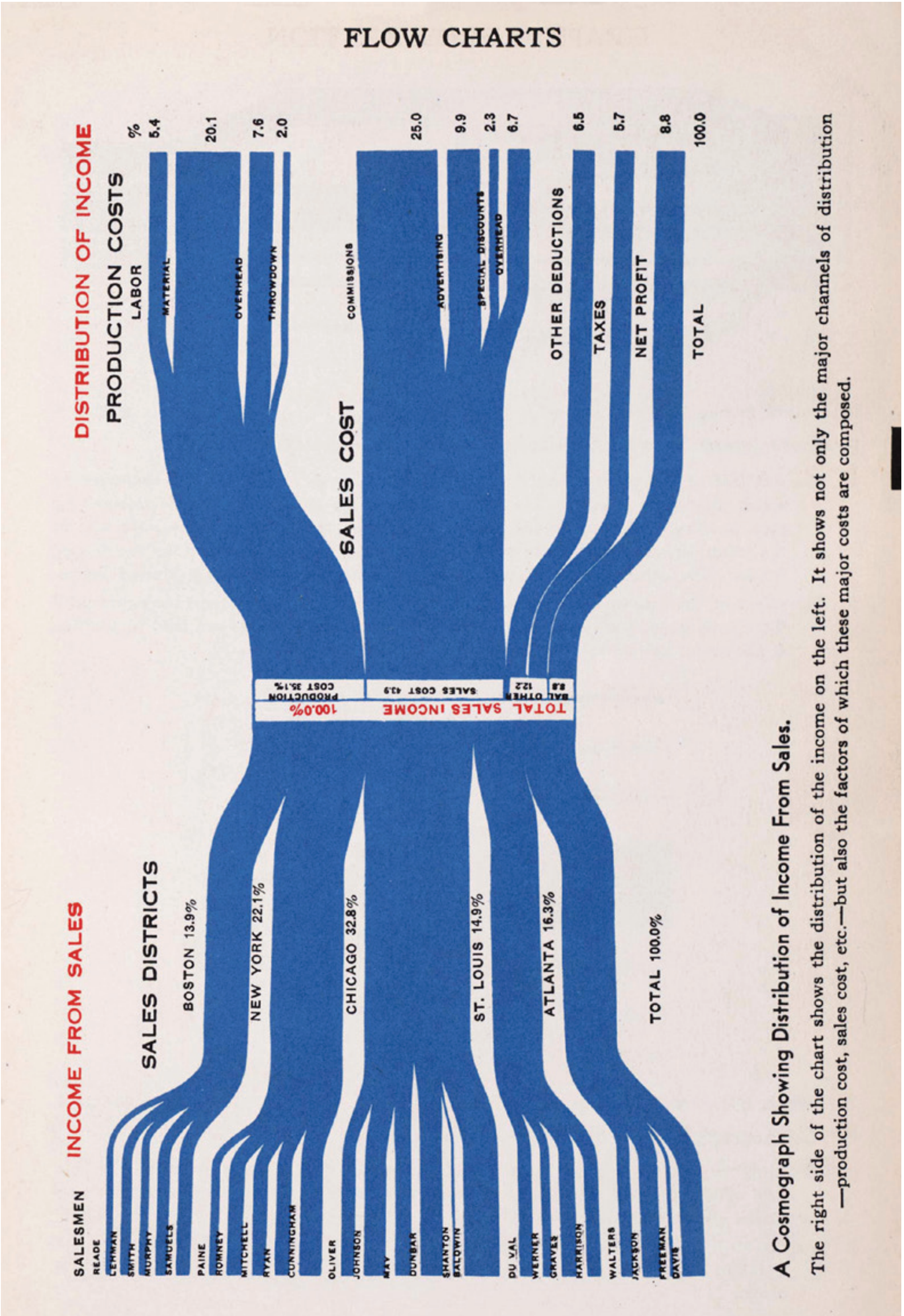
International Business Machines Corp., N. Y. C.

B. The Completed Cosmograph.

1. Border guides are placed in position to block out excess ends of the paper strips and the Cosmograph is ready for photostatting.
2. The negative photostatic print appears at the right. Note that all black portions of the device fail to reproduce. Of the one thousand strips of paper, twenty are red and are set at each 5% mark. In the negative photostat, these red strips of paper reproduce as white.

[Figure 22]

visualization software. Before the rise of computer-based graphics, attempts were made to automate and standardize the process of making Sankey diagrams. The method used to create the diagram in **Figure 22** in 1939 was described in the early data visualization textbook *Graphic Presentation* by Willard Brinton and was advanced technology for its day. The chart shows the percentage of income from



sales districts in the United States and then the flow of that income to various costs and profits. The chart was created by using one thousand paper strips and directing their paths with pins so that the number of strips in each section and at each point of grouping or change corresponded to the percentage of income in that category. The red strips were then photographed in black and white film on a black background so that shape of the chart was visible and smooth. Then the photograph was reversed for a black graph on a white background. The machine that was patented to create these graphs was called the 'Cosmograph' and the diagrams were also called 'cosmographs'. The replacement of that name with 'Sankey' is another loss to the world of data visualization.

Venn Diagrams

A Venn diagram is a diagram made of two or more circles that overlap to show the logical relationships among sets of items (*inclusion*, *exclusion* and *union* or variations of *some*, *all,* and *none*). Venn diagrams use overlapping and intersecting circles to show all the possible relationships between sets. In these diagrams, each circle represents a set. Elements inside the circle are members of the set; elements outside the circle are not members of the set. Items in the intersection of more than one circle belong to more than one set. These diagrams were invented by John Venn in 1880 to simplify the way set relationships were conveyed at the time, an approach that usually involved long lists of sentences describing relationships of sets and their elements (such as: 'all A are in B', 'some C are in A', 'none of D are in C').[20] Venn's visualization allowed for much more intuitive inferences. Venn diagrams were an improvement upon the previous circle-based set diagrams, called Euler diagrams, which did not show all of the possible relationships between elements.

John Venn (1834–1923). *Symbolic Logic. London*: Macmillan, 1881.

Compare the ease of interpretation of the items in the fourth row in **Figure 23** in the column labeled 'Diagrammatic' versus the notations in the other columns. Venn diagrams are ubiquitous today, a testament to the way they visually encapsulate abstract logical relationships. As noted in the definition of data visualization, the ability to reveal relationships, even abstract logical relationships among types or classes of data, is one of the field's most salient features.

ACKNOWLEDGEMENTS

We would like to express our sincere appreciation for the tremendous help we received from Grant Hurley for guiding novice curators though the process of mounting an exhibition and for his suggestions, advice, and patience with our many questions. We would also like to thank Alexandra Carter and Timothy Perry with their assistance guiding this exhibition. We also extend our thanks to Reading Room Coordinators Andrew Stewart and Dustin McMurphy, as well as all the Fisher staff and students who helped us in the reading room with item care and stacks retrievals. We had the great pleasure of working with conservator Linda Joy who accommodated our strangely shaped objects and many changes. Grant Hurley and Marie Korey supported this endeavour through many hours spent editing this catalogue. Thank you also to Nadav Sharon for his consultation on the Kabbalah diagrams.

The Friends of the Fisher Library is a wonderful organization. Their support for exhibitions in the Library is an inspiration and *Emerging Patterns* would have been impossible without the Friends. We are tremendously grateful. We would also like to express or appreciation of the Thomas Fisher Rare Book Library itself: it is a privilege to be able to work and study in such an extraordinary place. Few libraries in the world could have mounted *Emerging Patterns*.

We would also like to thank the Office of the President and the Division of the Vice President, Research for their support of our work on this project, for making space for the sometimes esoteric professional development of University of Toronto staff, and for providing us with the opportunity to interact with such compelling colleagues.

We would also like to acknowledge the contributions of our co-author and co-curator Kelly Schultz whose knowledge of data visualization framed the scope of this exhibition and whose expertise in library and information science underpinned our organization and selection of materials.

(EXTERNAL IMAGE CITATIONS)

Figure 5. Eadweard Muybridge, *A Goat Running* [*Animal Locomotion*, *Plate 679*], 1887, photograph, Wellcome Collection, accessed April 6, 2023, https://wellcomecollection.org/works/dtwgegzt.

Figure 15. Inductiveload, *Diagram in Darwin's* On the Origin of Species*, 1859*," 2009, diagram, Wikimedia Commons, accessed March 15, 2023, https://commons.wikimedia.org/w/index.php?curid=5868113.

Figure 19. Charles Joseph Minard, *Carte figurative des pertes successives en hommes de l'armée française dans la Campagne de Russie 1812–13*, 1869, diagram, Europeana—Bibliothèque nationale de France, accessed March 15, 2023, https://www.europeana.eu/item/9200517/ark__12148_btv1b52504201x.

Figure 20. Indio Lopez Vazquez, *Modern Redrawing of Napoleon 1812 Russian Campaign Including a Table of Degrees in Celsius and Fahrenheit and Translated to English*," 2015, diagram, Wikimedia Commons, accessed March 15, 2023, https://commons.wikimedia.org/wiki/File:Redrawing_of_Minard%27s_Napoleon_map.svg.

Figure 27. Aurora Mendelsohn & Anthony Gray, *Emerging Patterns Author Timeline*, 2023, diagram, supplied by authors.

Figure 43. Otto Neurath, *Säuglingsterblichkeit und Einkommen*, 1930, diagram, David Rumsey Map Collection, David Rumsey Map Center, Stanford Libraries, accessed April 25, 2023, https://www.davidrumsey.com/luna/servlet/detail/RUMSEY~8~1~325238~90094190.

Figure 44. Otto Neurath, *Wanderbewegung wichtiger Länder, 1920–27*, 1930, diagram, David Rumsey Map Collection, David Rumsey Map Center, Stanford Libraries, accessed April 25, 2023, https://www.davidrumsey.com/luna/servlet/detail/RUMSEY~8~1~325220~90094178.

Figure 45. International Foundation for Visual Education, *How Long Do Animals Live?*, 1939, diagram, The Otto and Marie Neurath Isotype Collection, Department of Typography and Graphic Communication, University of Reading. Reproduced with kind permission of the Department and with the assistance of Emma Minns

Figure 48. Maya Eilam*, The Shapes of Stories by Kurt Vonnegut*, Tender Human, accessed April 25, 2023, https://tenderhuman.com/shapes-of-stories-infographic, supplied by author with permission.

Figure 54. Samuel Greely & Hull-House Residents, *Nationalities map no. 1–4, Polk Street to Twelfth, Chicago*, 1895, map, Lionel Pincus and Princess Firyal Map Division—The New York Public Library, accessed March 27, 2023, https://digitalcollections.nypl.org/items/b31f7720-e5d5-0132-f9f9-58d385a7b928.

Figure 55. W.E.B. Du Bois, *The Seventh Ward of Philadelphia; The Distribution of Negro Inhabitants throughout the Ward and their Social Condition*, 1899, map, David Rumsey Map Collection, David Rumsey Map Center, Stanford Libraries, accessed March 27, 2023, https://www.davidrumsey.com/luna/servlet/detail/RUMSEY~8~1~327823~90096391:The-Seventh-Ward-of-Philadelphia--T#.

Figure 56. *Exhibit of the American Negroes at the Paris Exposition*, 1900, photograph, accessed March 28, 2023, https://www.loc.gov/resource/cph.3c32752/.

Figure 57. W.E.B. Du Bois, *Number of Negro Students Taking the Various Courses of Study Offered in Georgia Schools*, 1900, diagram, LOT 11931, no. 17, Library of Congress Prints and Photographs Division, accessed March 28, 2023, https://www.loc.gov/pictures/item/2013650436/.

Figure 58. W.E.B. Du Bois, *Proportion of Freemen and Slaves Among American Negroes*, 1900, diagram, LOT 11931, no. 51, Library of Congress Prints and Photographs Division, accessed March 28, 2023, https://www.loc.gov/pictures/item/2013650536/.

(ENDNOTES)

1 William Playfair, *The Commercial and Political Atlas, Representing, By Means of Stained Copper-Plate charts, the Progress of the Commerce, Revenues, Expenditure, and Debts of England, During the Whole of the Eighteenth Century* (London: T. Burton, 1801), xv.

2 See for example, Colin Ware, *Information Visualization: Perception for Design* (Cambridge, MA: Morgan Kaufmann, 2021) and Tor Nørretranders, *The User Illusion: Cutting Consciousness Down to Size* (New York: Viking, 1998).

3 Cited in H. Gray Funkhouser, "Historical Development of the Graphical Representation of Statistical Data," *Osiris* 3 (1937): 295, https://doi.org/10.1086/368480.

4 John Wilder Tukey, *Exploratory Data Analysis* (Reading: Addison-Wesley, 1977), vi.

5 William Playfair, *Elemens de statistique* (Paris: Batilliot et Genets, 1802), xx. (This remark is translated from the French: "le plus sûr moyen de frapper l'esprit, est de parler aux yeux.")

6 Cited in Michael Friendly and Gilles Palsky, "Thematic Maps and Diagrams: Visualizing Nature and Society," in *Maps: Finding Our Place in the World*, ed. James R. Akerman and Robert W. Karrow (Chicago: University of Chicago Press, 2007), 42.

7 Al-Bīrūnī, *The Book of Instruction in the Elements of the Art of Astrology*, trans. R. Ramsay Wright (London: Luzac, 1934), 154–155.

8 Al Van Helden, "Christoph Scheiner (1573–1650)", *The Galileo Project*, accessed February 24, 2023, http://galileo.rice.edu/sci/scheiner.html.

9 See Michael Friendly and Howard Wainer**,** *A History of Data Visualization and Graphic Communication* (Cambridge, MA: Harvard University Press, 2021).

10 Stephen Herbert, "The Zoopraxiscope Story," The Compleat Eadweard Muybridge, accessed February 14, 2023, http://www.stephenherbert.co.uk/mZoo.htm.

11 See Sybilla Nikolow, "A. F. W. Crome's Measurements of the 'Strength of the State': Statistical Representations in Central Europe around 1800", *History of*

Political Economy, 33 (Suppl_1): 23–56, https://doi.org/10.1215/00182702-33-Suppl_1–23.

12 Gilles Palsky, "Connections and Exchanges in European Thematic Cartography. The case of 19th Century Choropleth Maps," *Belgeo,* 3–4: 413–426, https://doi.org/10.4000/belgeo.11893.

13 Cited in Kathryn Norberg, "Prostitution," in *Encyclopedia of European Social History from 1350 to 2000,* ed. Peter. N. Stearns (Detroit: Scribner, 2001), 355.

14 Ara Wilson, "Visual Kinship," *History of Anthropology Newsletter* 42, July 24, 2018, https://histanthro.org/clio/visual-kinship/.

15 Charles Darwin, *On the Origin of Species by Means of Natural selection, or, The Preservation of Favoured Races in the Struggle forLlife* (London: J. Murray, 1859), 130.

16 Umberto Eco, *The Search for the Perfect Language* (Cambridge, MA: Blackwell, 1997), 311.

17 Yossi Chajes, "Kabbalistic diagrams in the British Library's Margoliouth Catalogue," *The Polonsky Foundation Catalogue of Digitised Hebrew Manuscripts*, February 29, 2016, https://www.bl.uk/hebrew-manuscripts/articles/kabbalistic-diagrams-in-the-british-librarys-margoliouth-catalogue.

18 Donald Knuth, *The Stanford Graph Base: A Platform for Combinatorial Computing* (New York: ACM Press, 1993).

19 Edward R. Tufte, *The Visual Display of Quantitative Information* (Cheshire, CT: Graphics Press, 2001), 40.

20 As we will see, there is evidence that William Playfair invented the Venn diagram in 1801, see footnote 30.

21 Joseph Priestley, *A Description of a Chart of Biography* (London: Johnson, 1790), 10.

22 Harro Maas and Mary Morgan, "Timing History: The Introduction of Graphical Analysis in 19th Century British Economics," *Revue D'histoire Des Sciences Humaines*, 7 (2002): 97–127, https://doi.org/10.3917/rhsh.007.0097.

23 James R. Beniger and Dorothy L. Robyn, "Quantitative Graphics in Statistics: A Brief History," *The American Statistician* 32, no. 1 (1978): 3, https://doi.org/10.1080/00031305.1978.10479235.

24 Funkhouser, "Historical Development," 283.

25 William Playfair, *Lineal Arithmetic Applied to Shew the Progress of the Commerce and Revenue of England during the Present Century* (London: , 1789), 7, emphasis in original.

26 Official Inflation Data, *Alioth Finance*, accessed February 24, 2023, https://www.officialdata.org/uk/inflation/ 1770?amount=1000.

27 There is a mistake in Playfair's description of the chart in the text that accompanies it. In the annotation under the three intersecting circles (beneath the main circle for 'German Empire'), Playfair accidentally switched the labels for

circle A, representing the 'dominions of the emperor', and Circle B, 'German empire as it now'. With this correction, the intersecting circles can be recognized as a Venn diagram, representing the logical relationship between three entities, Prussia, German princes, and Austria.

28 Cited in Funkhouser, "Historical Development," 295.

29 Funkhouser, "Historical Development," 330.

30 Cited in Funkhouser, "Historical Development," 338.

31 Paul FitzPatrick, "Leading American Statisticians in the Nineteenth Century," *Journal of the American Statistical Association* 52, no. 279 (1957): 301–321, https://doi.org/10.2307/2280901.

32 Tufte, *The Visual Display of Quantitative Information,* 170.

33 Cited in FitzPatrick, "Leading American Statisticians," 310.

34 Joseph Jastrow, "Studies from the Laboratory of Experimental Psychology of the University of Wisconsin. II." *The American Journal of Psychology* 4, no. 3 (1892): 398, https://doi.org/10.2307/1411617. The Jastrow Illusion is named for Jastrow's work on the difficulties in perceiving the comparative lengths of nested arcs.

35 Funkhouser, "Historical Development," 330.

36 Cited in Funkhouser, "Historical Development," 319.

37 Willard Brinton, *Graphic Methods for Presenting Facts* (New York: Engineering Magazine Co., 1923), v.

38 Marie Neurath and Robin Kinross, *The Transformer: Principles of Making Isotype Charts* (London: Hyphen Press, 2009).

39 Neurath and Kinross, *Transformer*, 77–78.

40 Jason Forrest, "*The Missing Legacy of Marie Neurath*," *Nightingale, Journal of the Data Visualization Society*, January 20, 2020, https://nightingaledvs.com/the-missing-legacy-of-marie-neurath/.

41 Jason Forrest, "*The Telefacts of Life: Rudolf Modley's Isotypes in American Newspapers 1938–1945*," *Nightingale, Journal of the Data Visualization Society*, January 20, 2020, https://nightingaledvs.com/the-telefacts-of-life-rudolf-modleys-isotypes-in-american-newspapers-1938–1945/.

42 Edward R.Tufte, *The Visual Display of Quantitative Information* (Cheshire, Conn.: Graphics Press, 1983), 123.

43 Kurt Vonnegut, *Palm Sunday: An Autobiographical Collage* (New York: Delacorte Press, 1981), 285.

44 Peter Sheridan Dodds, Kameron Decker Harris, Isabel M. Kloumann, Catherine A. Bliss, Christopher M. Danforth, "Temporal Patterns of Happiness and Information in a Global Social Network: Hedonometrics and Twitter," *PLOS ONE* 6, no. 12 (2011), https://doi.org/10.1371/journal.pone.0026752.

45 Andrew J. Reagan, Lewis Mitchell, Dilan Kiley, Christopher M. Danforth, and Peter Sheridan Dodds, "The Emotional Arcs of Stories are Dominated by

Six Basic Shapes," *EPJ Data Sci*. 5, no. 31 (2016), https://doi.org/10.1140/epjds/s13688-016-0093-1.

46 Ruth Crocker, review of Rima Lunin Schultz, ed., *Hull-House Maps and Papers: A Presentation of Nationalities and Wages in a Congested District of Chicago, Together With Comments and Essays on Problems Growing Out of the Social Conditions*, H-SHGAPE, H-Net Reviews. January, 2008, http://www.h-net.org/reviews/showrev.php?id=14047.

47 Donna Hirst, "Notes from the Rare Book Room—The Nuremberg Chronicle," *Hardin News*, The University of Iowa Libraries, October 6, 2008, https://blog.lib.uiowa.edu/hardin/2008/10/06/notes-from-the-rare-book-room-the-nuremberg-chronicle/.

48 Cited in James P. Howley, *The Beothucks or Red Indians: The Aboriginal Inhabitants of Newfoundland*, (Cambridge: Cambridge University Press, 1915), 231.

49 See "Charles Booth's London: Poverty Maps and Police Notebooks," London School of Economics, 2016, https://booth.lse.ac.uk/.

50 Sharon Lohar, "Agnes Sinclair Holbrook and the Hull-House Maps: Part 3," June 20, 2020, https://www.sharonlohr.com/blog/2020/6/11/hull-house-maps-agnes-holbrook.

51 United States Bureau of Labor, *Slums of Baltimore, Chicago, New York, and Philadelphia, Seventh Special Report of Commissioner of Labor* (New York: Arno Press, 1970).

52 Ann Oakley, "The Forgotten Example of 'Settlement Sociology': Gender, Research, Communities, Universities and Policymaking in Britain and the USA, 1880–1920," *Research for All* 1, no. 1 (2017): 20–34, https://doi.org/10.18546/RFA.01.1.03.

53 Nili Tannenbaum and Michael Reisch, "From Charitable Volunteers to Architects of Social Welfare: A Brief History of Social Work," University of Michigan School of Social Work, accessed February 24, 2023, https://ssw.umich.edu/about/history/brief-history-of-social-work.

54 James R. Grossman, Ann Durkin Keating, and Janice L. Reiff, *The Encyclopedia of Chicago* (Chicago: University of Chicago Press, 2004).

55 W.E.B. Du Bois, *W.E.B. Du Bois's Data Portraits: Visualizing Black America: The Color Line at the Turn of the Twentieth Century,* ed. Britt Rusert, and Whitney Battle-Baptiste (Amherst, Massachusetts: The W.E.B. Du Bois Center at the University of Massachusetts Amherst, 2018).

56 United States Commission to the Paris Exposition. *Report of the Commissioner-General for the United States to the International Universal Exposition, Paris, 1900* (Washington: Government Printing Office, 1901), 409.

57 Annie Radillo, "Artspace Opens Three Exhibitions Centering on W.E.B. Du Bois' Works," *Yale Daily News*, April 5, 2021, https://yaledailynews.com/blog/2021/04/05/artspace-opens-three-exhibitions-centering-on-w-e-b-du-bois-works/.