EMERGING PATTERNS

Data Visualization Throughout History

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Exhibition and Catalogue

by

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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.

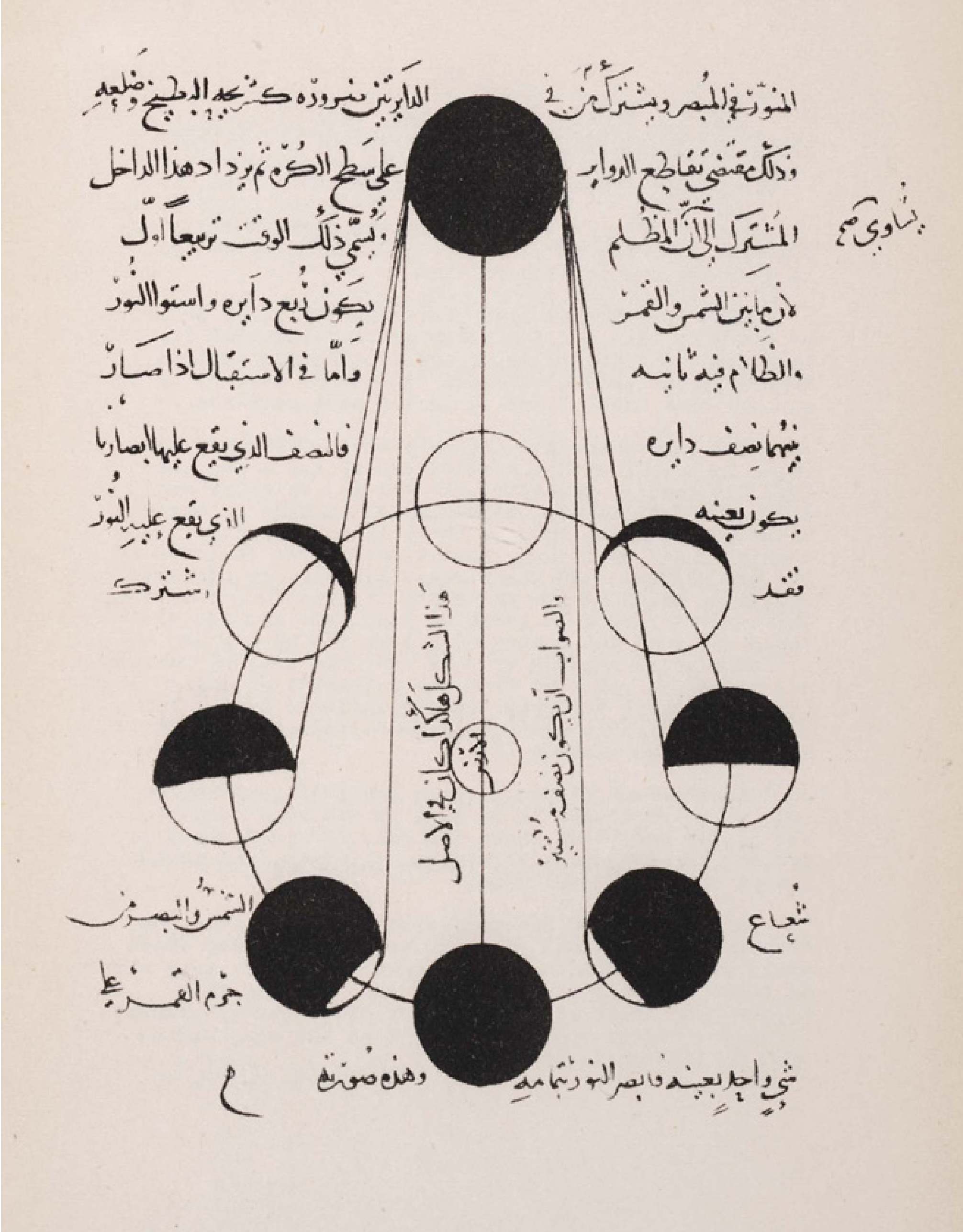
Thematic Cartography

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).

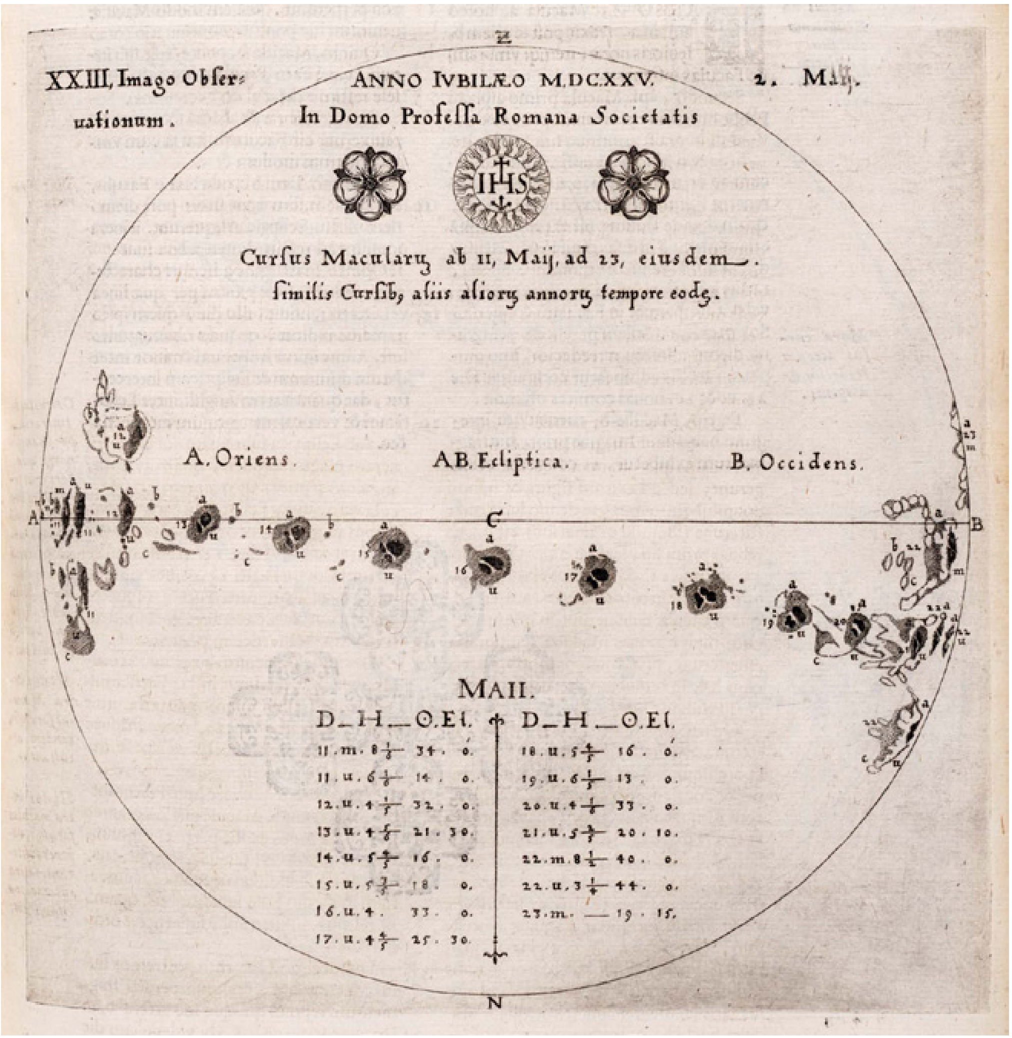
What is most interesting from a data visualization perspective is that al-Bīrūnī's diagram is a *time series map* of the sky. Each phase of the moon represents a distinct, consecutive, and uniform interval of time represented together in a single two-dimensional image. But the image is an abstraction: 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



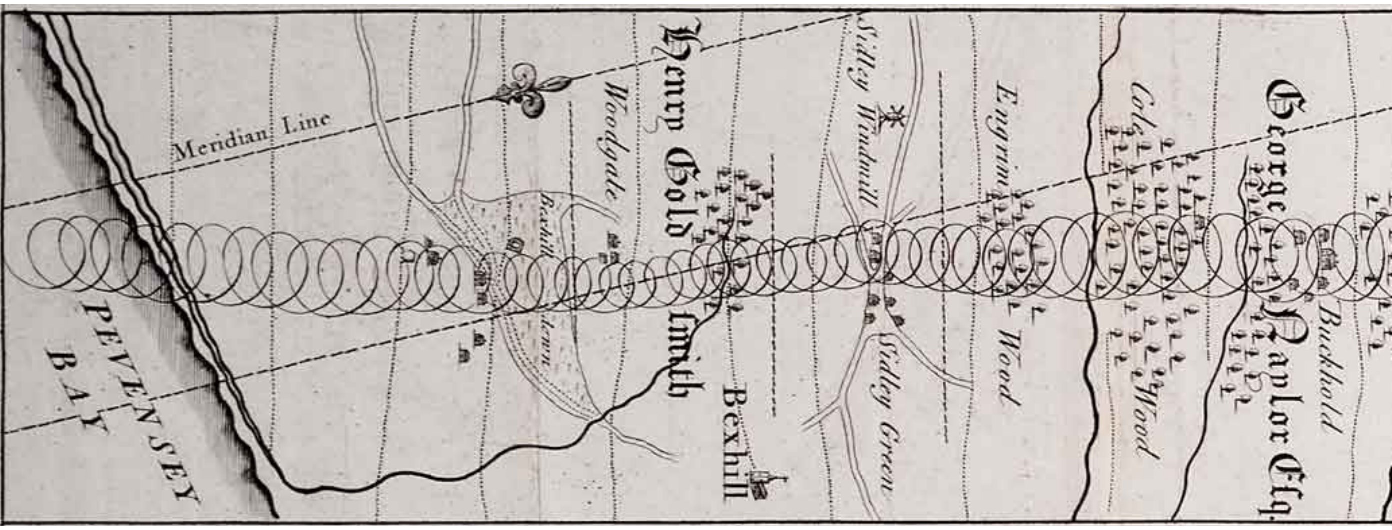
[Figure 2]

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.

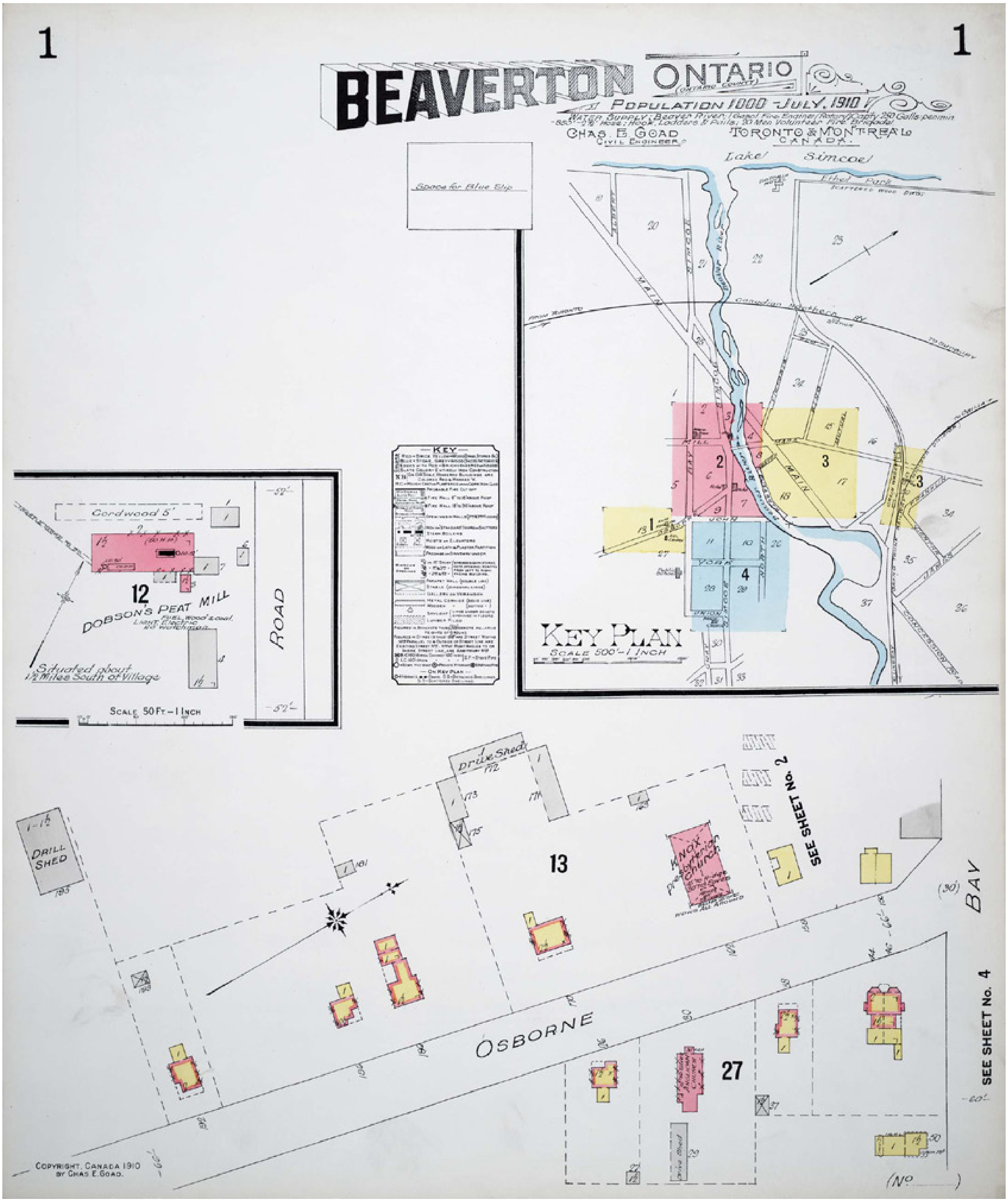
> **Richard Budgen (1730–1789).** ***The Passage of the Hurricane from the Sea-Side at Bexhill in Sussex to Newingden-Level, the Twentieth Day of May 1729, between Nine and Ten in the Evening*****. London: John Senex, 1730.**

> **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,


1
1
BEAVERTON
ONTARIO
(ONTARIO COUNTY)
POPULATION 1000 - JULY, 1910
CHAS. E. GOAD
CIVIL ENGINEER
TORONTO & MONTREAL
CANADA.
Lake Simcoe
Space for Blue Slip
KEY
KEY PLAN
SCALE 500'-1 INCH
Cordwood 5'
12
DOBSON'S PEAT MILL
ROAD
Situated about 1½ Miles South of Village
SCALE 50 FT. - 1 INCH
Drive Shed
DRILL SHED
13
KNOX Presbyterian Church
SEE SHEET No. 2
OSBORNE
27
BAY
SEE SHEET No. 4
COPYRIGHT, CANADA 1910 BY CHAS E. GOAD.

[Figure 4]

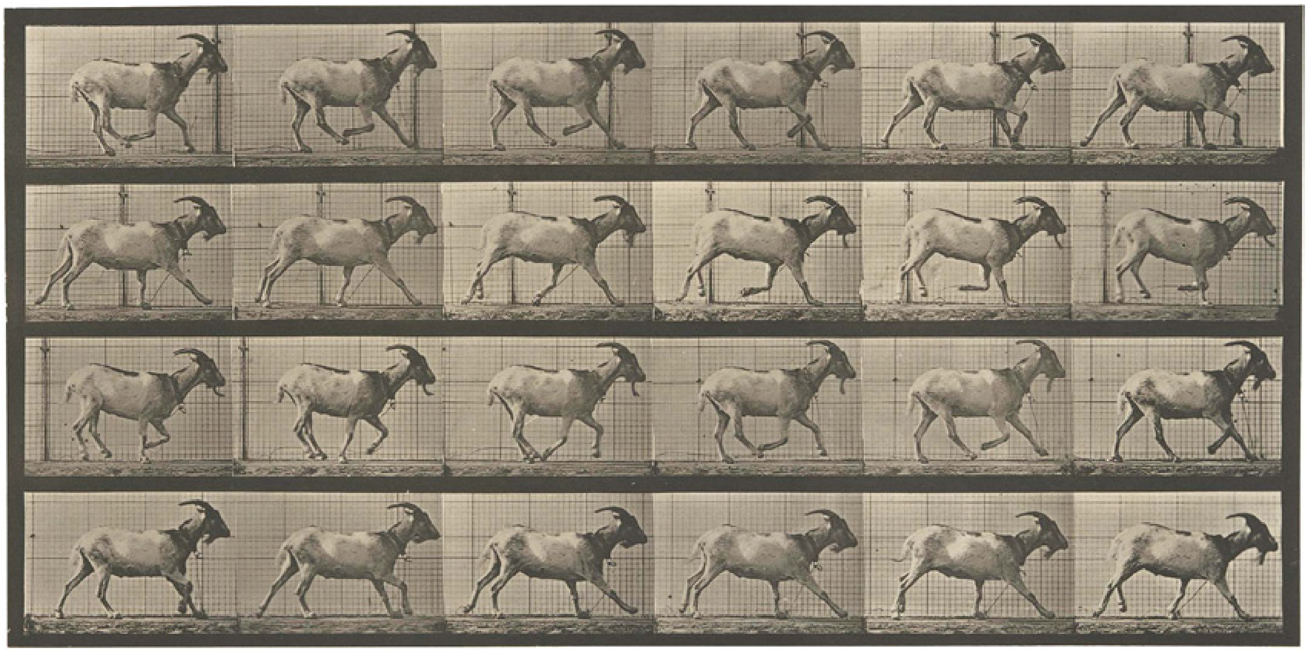
and location as it travelled roughly 20 kilometers inland. As in the al-Bīrūnī and Scheiner examples, time is represented as a variable plotted on a map. The storm's position and size are depicted on the map as a connected series of events. It is a time series data visualization and a direct predecessor of modern weather maps. Modern weather maps animate the variable of time by showing a succession of images one after another, each with a different and consecutive time stamp. Such technology was not available to Budgen, of course, so he displayed the succession of images simultaneously, asking his audience to imagine the sequence.

In collecting and analyzing data for his map, Budgen relied upon the direct participation of a community. The visualization depended upon the community's active involvement in providing and describing the data it displayed. This kind of community involvement in the creation of a map will be revisited in the Hull-House maps (**Figure 54**).

Budgen's *The Passage of the Hurricane* presages another kind of data visualization. Beginning in the late eighteenth century, several companies began producing detailed maps of cities and towns to assist insurance companies in assessing the risk of fire. These maps—or plans—are data visualizations and instances of thematic cartography. **Figure 4** is a typical example created by the Charles E. Goad Company, the largest producer of fire insurance plans in Britain and Canada. Such plans meticulously plot building locations, uses, construction materials, roads, and other features to determine insurance rates and claims. Budgen's map can be seen in a similar light. The description of the damage to various estates and properties was presented to the Royal Society and became a matter of public record. It is a short step from recording and mapping storm damage and noting how different kinds of construction in different locations withstood the storm, to recording and mapping different kinds of construction in different locations with a view to assessing and underwriting risk.

Eadweard Muybridge (1830–1904). *Animal Locomotion: An Electro-photographic Investigation of Consecutive Phases of Animal Movements*. Philadelphia: University of Pennsylvania, 1887.

Though it is neither a traditional example of thematic cartography nor remotely proximate in time to its predecessors in this section, Eadweard Muybridge's photos of human and animal motion are direct descendants of al-Bīrūnī's image of the phases of the moon and Scheiner's sunspot maps. Muybridge was an English photographer during the late nineteenth century when a central question captivating a portion of the population revolved around the movement of horses. The most vexing question concerned what was called 'unsupported transit': was there ever a time



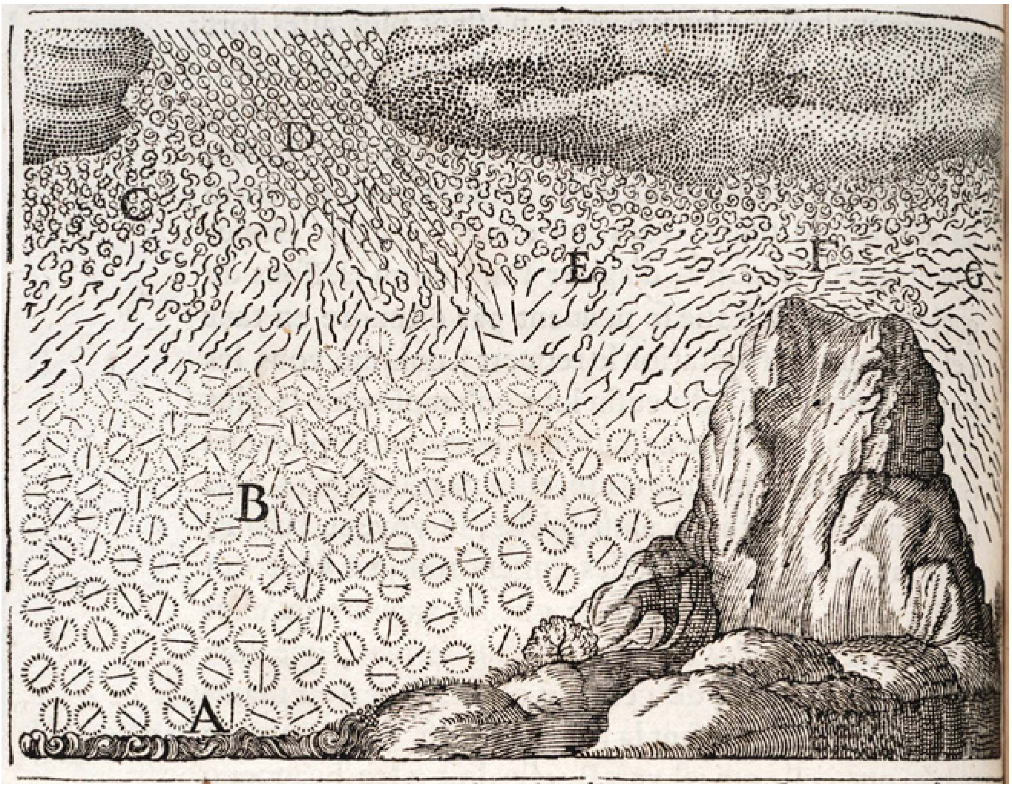
[Figure 5]

while a horse was galloping that all four of its hooves were off the ground? Muybridge was hired in 1878 to answer the question. He set up a series of cameras arranged in a line parallel to a track. Their shutters were attached to strings that stretched across the track and could be triggered by an animal passing by. When the horse 'Sally Gardner' galloped down the track, Muybridge's cameras made a series of photographs capturing the horse in motion. An analysis of the photos proved the 'unsupported transit' hypothesis was true![9]

Muybridge turned his cameras to study the motion of all sorts of animals. **Figure 5** shows a series of images depicting the locomotion of a goat. The background, containing gridlines, remains substantially uniform as the goat passes, creating a time series visualization remarkably similar to Scheiner's sunspot maps.

Muybridge took the project one step further. Realizing that static images were less compelling than moving images, he turned his sequential photos into a kind of animation. He had silhouettes of the photos painted onto glass discs that could be rotated by crank past a light source, thus projecting the images onto a screen and making them appear to move. His invention was an early version of a cinematograph. He called it a 'Zoöpraxiscope'. That fact that Zoöpraxiscopes have fallen out of use is a loss to the world of data visualization.[10]

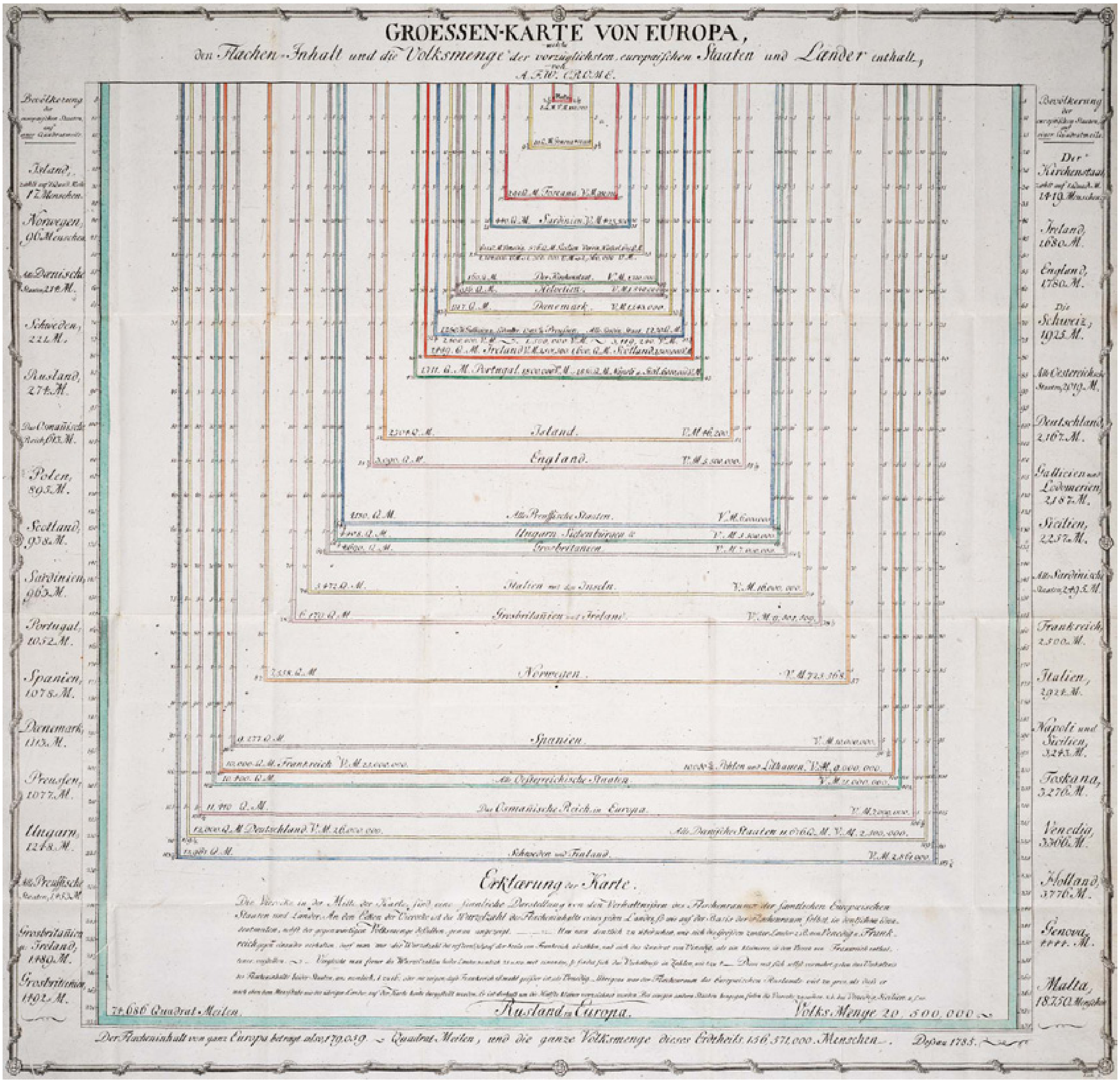
> **René Descartes (1596–1650). *Discours de la méthode: Pour bien conduire sa raison et chercher la vérité dans les sciences. Plus La dioptrique, Les météores, et La géométrie*. Leiden: Ian Maire, 1637.**



[Figure 6]

René Descartes' 'Les météores' (Meteorology) was first published in 1637 as part of his work *Discours de la methode*. In the second discourse of 'Les météores', 'Des vapeurs et des exhalaisons' (Of Vapours and Exhalations), Descartes considers how water vapour moves in the air, touching on topics such as air density and what would later be understood as air pressure. **Figure 6** appears in 'Les météores' accompanying a description of the size and flow of water particles in the air. He describes the different regions—labeled 'A' through 'G'—as containing water particles of differing 'agitations' and 'compressions'. These descriptions are based loosely on experience, observation, and imagination rather than on measurements or data, and so **Figure 6** is more diagram than data visualization. Nevertheless, the diagram might be considered a proto-visualization as it shows a relationship between 'hypothetical' data in the different regions, a relationship that would later be explained by Benjamin Franklin (1706–1790) and others. If Descartes had collected the data he plotted, rather than hypothesizing them, **Figure 6** would have been a data visualization and we might have had a theory of atmospheric air currents a century or so earlier than we did.

August Crome (1753–1833). ***Ueber die Grösse und Bevölkerung der sämtlichen europäischen Staaten: ein Beytrag zur Kenntniss der Staatenverhältnisse, und zur Erklärung der neuen Grössen-Karte von Europa*. Leipzig: Weygand, 1785.**



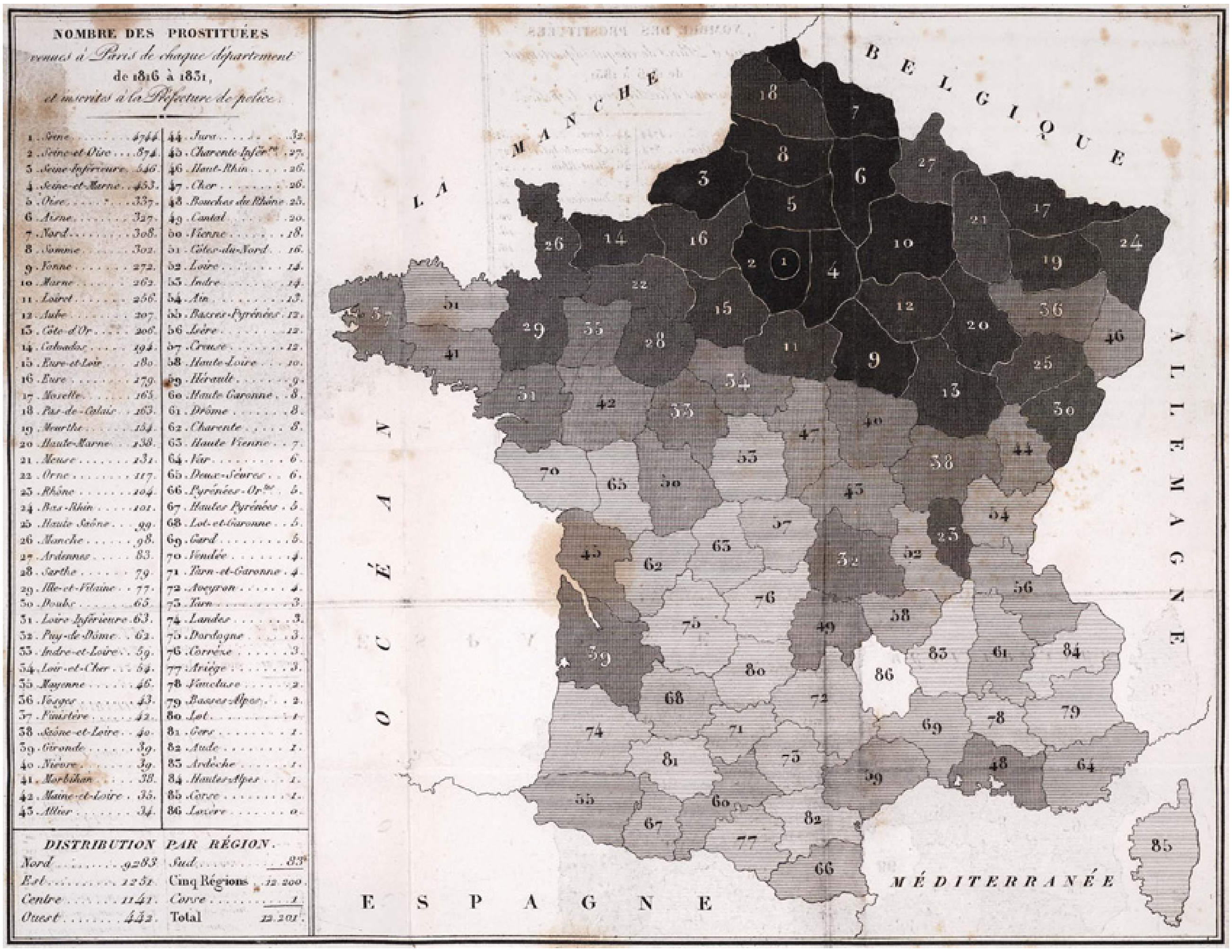
[Figure 7]

August Friedrich Wilhelm Crome extended the idea of thematic cartography into greater abstraction. His 1785 map, ‘Groessen Karte von Europa’, **Figure 7**, depicts population and area statistics for the countries and states in Europe. Without some background, it is unrecognizable as a map. The large, superimposed squares that dominate the visualization represent the relative area of each state or country abstracted into squares for ease of comparison. (The units are given in 'Q.M.' for 'Quadrat-Meilen' or 'square miles' in English). Crome had argued that a ratio of population to geographic area—something he called 'proportional population of a state', and what we now know as 'population density'—was a more useful approximation of a nation's wealth than geographic area alone, so he had added population statistics to his area maps in columns to the left and right. (The units are given in 'V.M.' for 'Volksmenge', literally meaning 'crowds' with the sense of 'population'). 'Groessen Karte von Europa' is among the first so-called 'comparison diagrams' or 'comparison charts', further examples of which we will see later in this section.

After the Congress of Vienna in 1815, Crome revisited and expanded upon the methodology behind 'Groessen Karte von Europa'. His 'Verhaeltniss Karte von den deutschen Bundesstaaten' (Ratio map of the German states) depicted population and area statistics for the various German states and principalities. At the bottom of the visualization, Crome also included pie charts and rudimentary bar charts depicting population density, land area, and tax revenue, the same chart William Playfair had invented in 1801 (**Figure 30**). The power of data visualization was attracting a wider audience. Crome's work was motivated, in part, by a recognition of the importance of seeking a balanced federal arrangement of German states under the direction of the Kingdom of Prussia.[11] His abstracted visualizations helped people see patterns of political and economic regional relationships in the context of growing turmoil among the German states in the nineteenth century.

> **Alexandre Parent-Duchâtelet (1790–1836).** ***De la prostitution dans la ville de Paris, considérée sous le rapport de l'hygiène publique, de la morale et de l'administration*****. Paris: J.B. Baillière, 1836.**

Choropleths involve the mapping of a continuous or categorical variable onto existing geographic regions. These are different from isobar or isarithmic maps like weather maps (as seen, for example in **Figure 9**), where the shapes of shaded areas are not determined by political or regional boundaries, but only by the relative values of the relevant variables in a given location. The first choropleth map was created by Charles Dupin for the French government in 1826 and depicted literacy rates by French province. Each province on the map was coloured or shaded according to its rate of literacy. These new choropleth maps were especially important to French researchers of the time who studied the causes of crime. They were looking for connections between various demographic variables like education and occupation that they hoped would lead to an explanation of crime. To find these connections between different variables, researchers had to rely on direct visual



[Figure 8]

comparisons using maps like these because at that time methods of inferential statistics, such as estimation, correlation, and regression, had not been invented yet.[12]

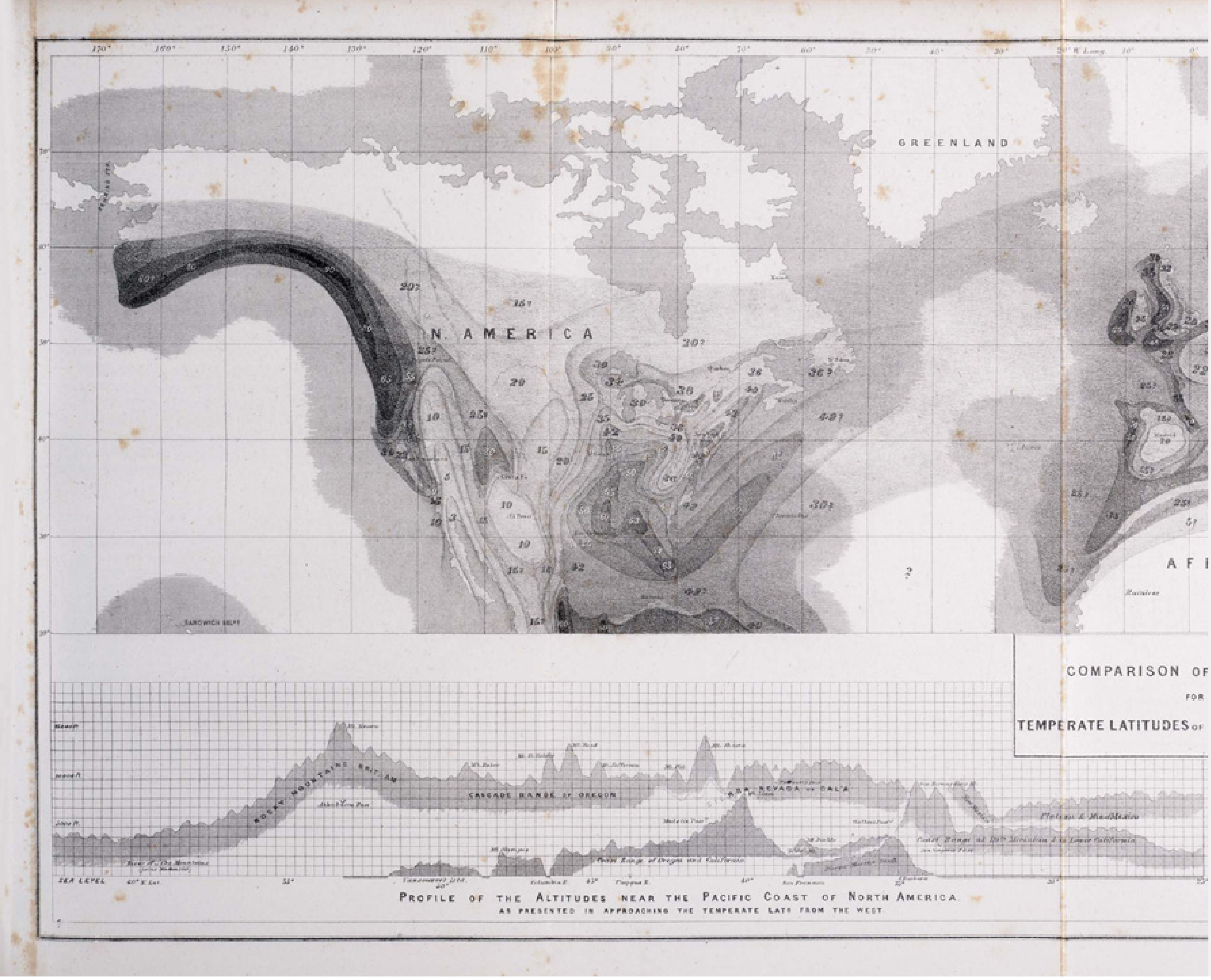
One set of such crime-rate-by-area maps was published in 1836 by Alexandre Parent-Duchâtelet on prostitution in the city of Paris and related to public health, morality, and administration. Parent-Duchâtelet was concerned with the spread of sexually transmitted diseases and with the notion of social propriety. He believed that prostitution was a necessary evil that was required for 'learning about masculinity', but one that needed to be contained, as he viewed prostitutes as responsible for spreading sexually transmitted diseases. To better understand the issue, he collected data and interviewed thousands of prostitutes over an eight-year period. One result was the map in **Figure 8**, showing the number of Parisian prostitutes from each French department. This map was an early example of a survey map. Later and equally influential survey maps can be seen in **Figures 53** to **55**.

Parent-Duchâtelet used this analysis of demographic choropleth maps to argue for both the necessary legality and the tight regulation of prostitution. He advocated for the imposition of mandatory health checks, physical examinations, and for increases in police supervision. These recommendations were codified in French legislation. Unregistered prostitutes were arrested and jailed. Prostitutes who were found to be suffering from sexually transmitted diseases were mandated to treatment at designated hospitals. These measures to contain sexually transmitted diseases were not as successful as they might have been had the regulations applied equally to the customers.

While many of the goals and outcomes of Parent-Duchâtelet's study related to the control of prostitutes, his detailed empirical studies challenged many myths about prostitutes. He combined his vast interview data with the comparisons afforded by the new maps. For the first time, prostitution rates by area were compared to other demographics, including national origin, income, education, and occupation. Based on these combined sources Parent-Duchâtelet dispelled the following myths: that most prostitutes were not native Parisians; that they had unmarried parents; that they were infertile; that they had physical deformities; and that they began prostitution because of pregnancy. These myths were meant to suggest individual failures as the impetus for prostitution. Parent-Duchâtelet concluded that the reasons were simpler and more systemic. 'Lack of work and poverty,' he wrote, 'which is the inevitable consequence of low wages, are the unhappy source of prostitution'.[13]

Lorin Blodget (1823–1901). *Climatology of the United States, and of the Temperate Latitudes of the North American Continent*. Philadelphia: J.B. Lippincott, 1857.

Lorin Blodget's *Climatology of the United States* was the first and most influential work in climatology by an American. The visualizations are superb examples of thematic cartography. **Figure 9** plots contour lines indicating precipitation levels (isohyets) over a large part of the northern hemisphere, drawing on a tradition established by Edmund Halley (1656–1742) at the beginning of the seventeenth century. What makes Blodget's maps stand out is that they were accompanied by hundreds of pages of observations, data tables, and textual explanations. There were varying standards for collecting and reporting atmospheric climate data and the task of assembling and cleaning those data was monumental. Yet the maps capture the data and display it clearly and elegantly in such a way that patterns are instantly visible. **Figure 9** shows the effects of coastal areas on precipitation. The profile diagrams of the altitudes along the Pacific coast of North America and along the west coast of Europe is reminiscent of examples from G.H. Swanston (1814–1872, **Figure 10**) and William Woodbridge (1794–1845, **Figure 11**), but Blodget took the idea further, inviting viewers to hypothesize about the relationship between coastal altitudes and coastal precipitation. Thematic maps like Blodget's climatology maps are common today, but they were rare in early nineteenth century. This was the beginning of modern weather maps.

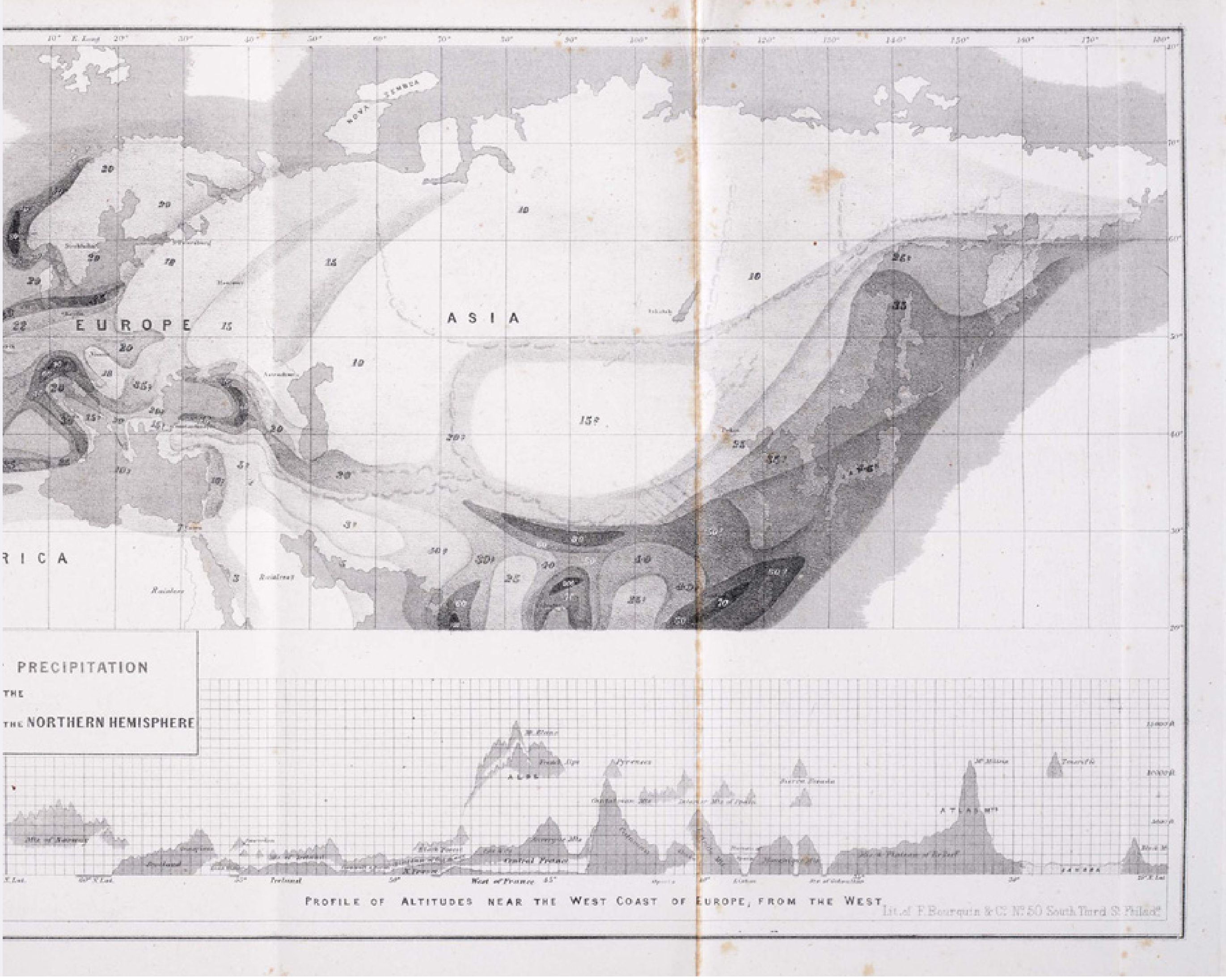


[Figure 9]

George H. Swanston (1814–1872). *The World in Hemispheres: With Comparative Views of the Heights of the Principal Mountains and Basins of the Principal Rivers on the Globe*. Edinburgh: A. Fullarton, 1852.

William C. Woodbridge (1794–1845). *Rudiments of Geography, on a New Plan, Designed to Assist the Memory by Comparison and Classification*. Hartford: O.D. Cooke, 1829.

G. H. Swanston's map from 1852 adds, literally, another dimension to thematic cartography (**Figure 10**). To the central map of the globe, shaded by political divisions, Swanston added rudimentary indications of topography by sketching on the map various mountain ranges as if in three-dimensional relief. He also highlighted the basins of 'principal rivers' by making the river deltas and networks artificially dark and large. More notably, Swanston's map includes a line chart, with the lines drawn as mountains. The x-axis represents latitude and the y-axis represents altitude above sea-level. Note that the chart is not a bar chart. Swanston makes no attempt to make



the relative area occupied by each mountain meaningful, as it should be if the mountains represented bars and not lines. It is a comparison chart, like Crome's map, but on a single axis only. In this respect, the chart is somewhat misleading: by giving the mountains area, it looks as though they might be compared by this measure as well as by their height, though the data clearly don't support such comparison.

Nevertheless, Swanston's mountains have width as well as height for a reason. They are divided into regions of vegetation at different elevations, adding a third variable to the bar chart. One can easily see that, as a mountain's location approaches the globe's warmer latitudes, biodiversity increases along with the elevation at which one is likely to find snow. Each major mountain range is directly annotated, the peaks are named, and at least some volcanoes are distinguished from other mountains by whimsical puffs of smoke. It is a gorgeous visualization.

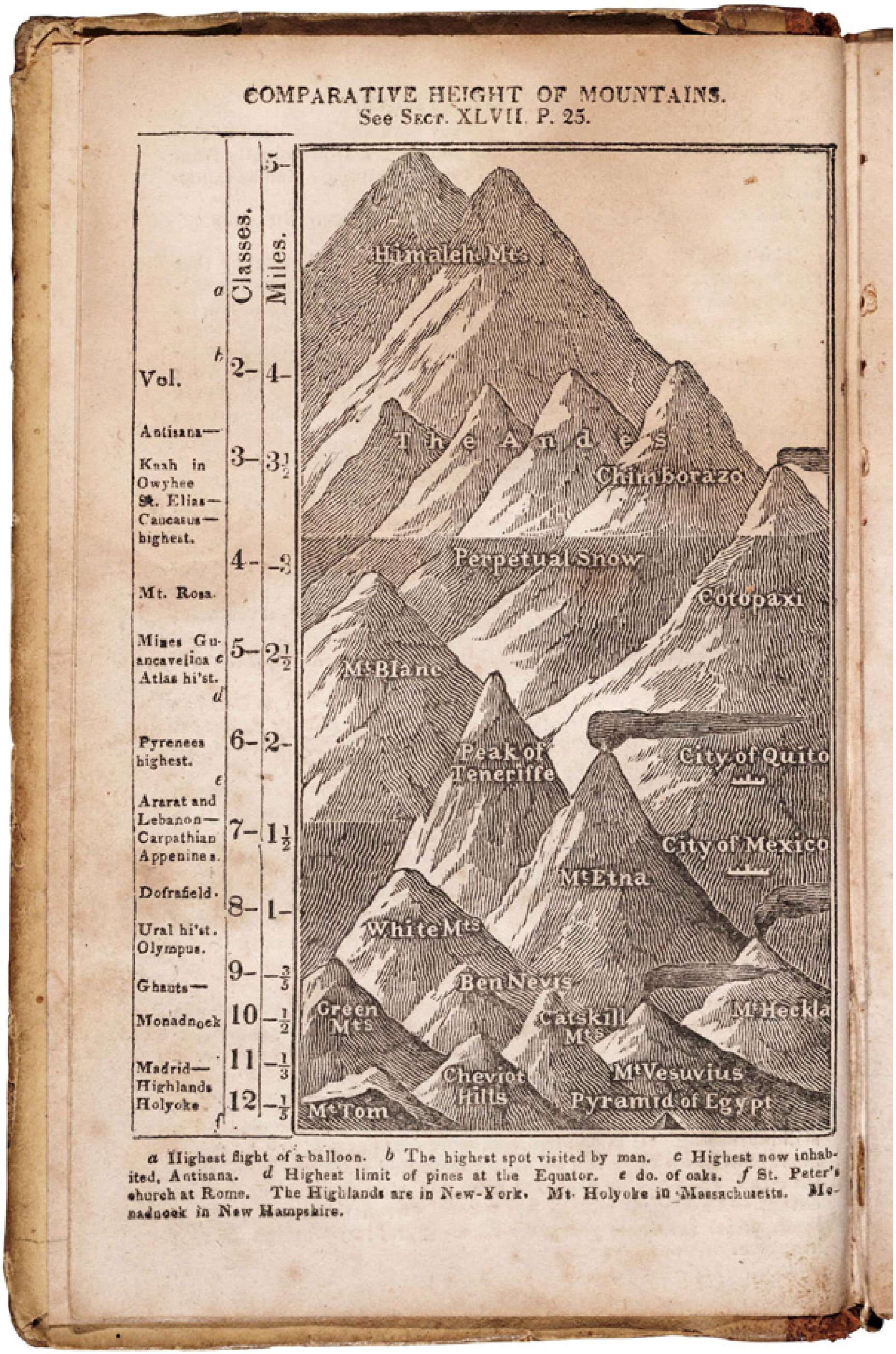
It is interesting to compare Swanston's mountains with an earlier, similar but more rudimentary treatment by William Woodbridge. Woodbridge created a chart depicting the 'comparative heights of mountains' (**Figure 11**) for his *Rudiments of Geography*, first published in 1821. Woodbridge's visualization is a one-dimensional comparison chart or line graph, with the y-axis representing elevation in miles (and

I.


Basins of the AMAZON AND TOCANTINS
1
Area: 2,275,000
Length: 3,350
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: 320,000
Length: 2,070
WITH COMPARATIVE VIEWS OF
and Basins of
BY G.H.
WESTERN HEMISPHERE
North Pole
ARCTIC OCEAN
NORTH AMERICA
NORTH PACIFIC OCEAN
NORTH ATLANTIC OCEAN
GULF OF MEXICO
WEST INDIES
CARIBBEAN SEA
Tropic of Cancer
Equator
OCEANIA
POLYNESIA
SOUTH AMERICA
SOUTH PACIFIC OCEAN
SOUTH ATLANTIC OCEAN
Tropic of Capricorn
AUSTRALASIA
NEW ZEALAND
Antarctic Circle
ANTARCTIC OCEAN
South Pole
3
Area: 1,333,000
Length of Mississippi & Missouri 4,100
Gulf of Mexico
Basin of the MISSISSIPPI & MISSOURI
III. ANDES
a Palm
b Tree Ferns
c Pinus
d Limit of Great Trees
e Cinchona
g Gramineae (Grass)
h Calcitium rubicarum
i Maize
j Hordeum (Barley)
IV. TENERIFFE
a Palmae Musa (Banana)
b
c Laurus (Laurel)
d Pinus canariensis
e Cytisus fragrans
f
g Covered with snow three Months in the Year
h One Month snow
i Occasional snow
NOTE
The figures denote the mean annual temperature in degrees of Fahrenheit.
Scale of English Feet
Mt Erebus (Active Volc.)
Antarctic Circle
ANTARCTIC OCEAN
Andes of Chile
Tropic of Capricorn
10
ANDES III.
South Latitude


ORLD
isphieres
THE HEIGHTS OF THE PRINCIPAL
NTAINS
he principal Rivers
E GLOBE
WANSTON.
burgh
Basins of the
RHINE, DANUBE & DNIEPER
9
Basins of the
VOLGA & URAL
8
Area: 528.000
Length: 2.350
Basin of the
INDUS
7
Area: 410.000
Length: 2.260
Area: 416.000
Length: 1.940
6
Basins of the
GANGES & IRAWADY
EASTERN HEMISPHERE
ARCTIC OCEAN
EUROPE
ASIA
AFRICA
INDIAN OCEAN
PACIFIC OCEAN
SOUTH ATLANTIC OCEAN
SOUTHERN OCEAN
AUSTRALIA
OCEANIA
ARABIAN SEA
BENGAL SEA
Equator
Tropic of Cancer
Tropic of Capricorn
Antarctic Circle
ANTARCTIC OCEAN
South Pole
(2)
HIMALAYA II.
10
I. ALPS
II. HIMALAYA
ALPS I.
ASIA
TENERIFFE
LAPLAND
Interior of Norway
Level of the Sea
Scale of English Feet
North Latitude
Basin of the
YENESEI
5
Area: 1.040.000
Length: 3.230

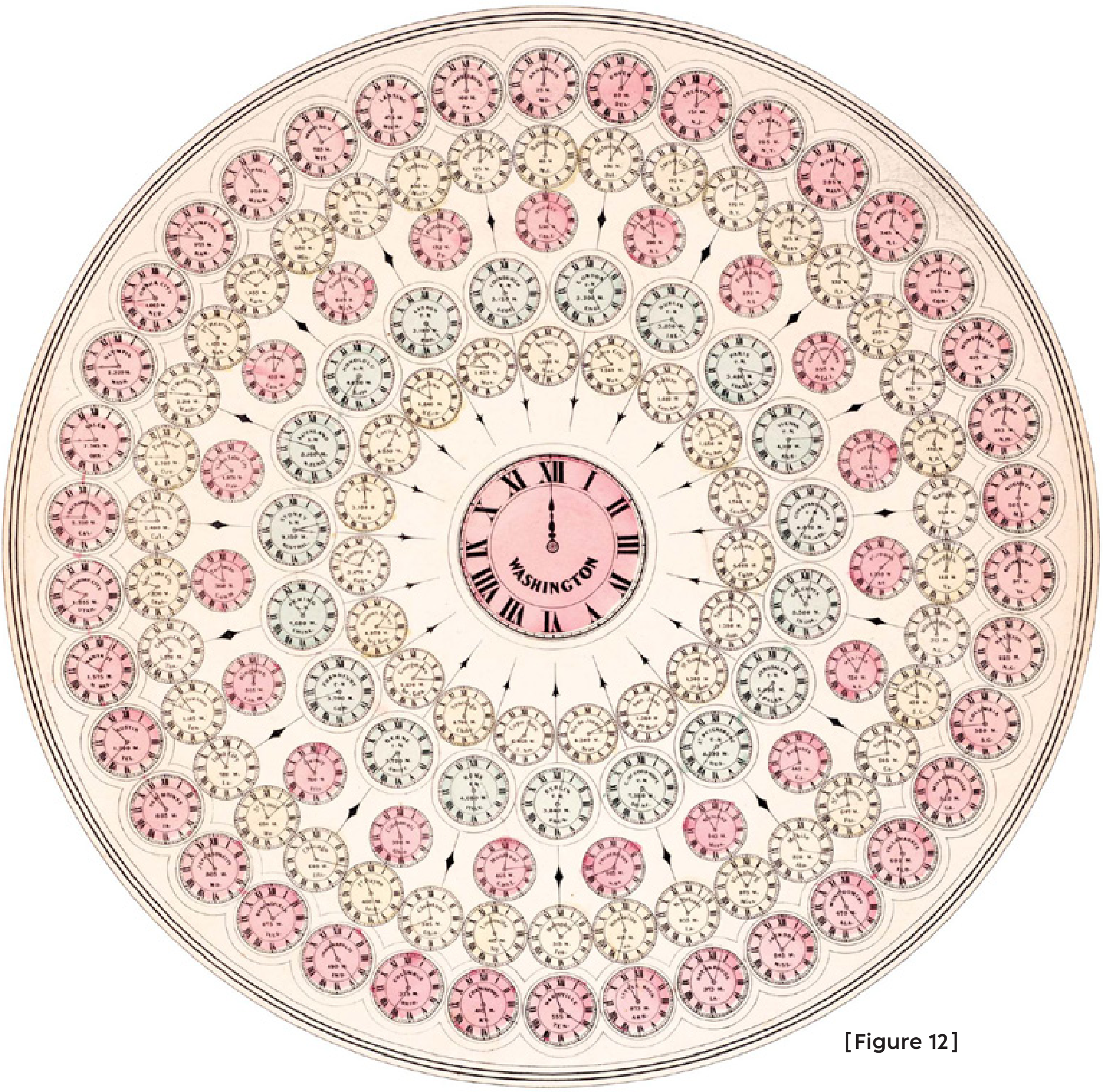
[Figure 10]



[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 when enthusiasm for 'the graphic method' led some designers to create extravagant graphics that sacrificed function for form. We will return to this theme later.

Network Diagrams

Network diagrams are visualizations of mathematical relationships that depict the connections or relationships among objects. In this section there are early examples of both node-based network diagrams—kinship diagrams, timetrees, sociograms, and semantic networks—and examples of flow-based network diagrams, specifically Sankey diagrams.

In node-based network diagrams, elements (often people) are represented by shapes, and the diagram illustrates the connections between them using lines of various thickness and, sometimes, direction. Tree diagrams show relationships between elements where each item in the tree can have only a single ancestor but any number of descendants, and where all elements in the tree are connected to each other through links of ancestor/descendant relations. Timetrees are tree diagrams where the elements or nodes are groups of organisms or species and the connecting lines depict evolutionary relationships over thousands of generations. One of the earliest timetrees, featured in this section, was created by Charles Darwin (1809–1882) to illustrate aspects of the theory of evolution.

Despite the colloquial use of the term 'family tree', tree diagrams are not suitable to record family relationships because they do not allow for more than one parent and do not have a mechanism for depicting non-descendant relationships such as marriage. The technical name for a diagram that shows more than one parent per child, as well as marriages, is a 'kinship diagram'. Early kinship diagrams, such as the two featured in this section, were used to show important relationships, spanning long time periods, between past religious or royal figures and a contemporary religious or political situation.

When viewing kinship diagrams or family trees, modern audiences are familiar with the visual metaphor of a tree with branches mapping from ancestors to their decedents. The modern canonical form of these kinship diagrams uses abstract shapes (often circles, squares or triangles) to denote the nodes (items or people) and simple lines (often unadorned straight lines of varying thickness) to denote the connections and relationships between them, as we see in **Figures 13** and **14**. In contrast, the early network diagrams in the *Nuremberg Chronicle* of 1493, an illustrated encyclopedia of history, geography and religion, retain many visual cues to orient viewers to a metaphor that may have been new to them—detailed leaves and branches, representative drawings of people, and branches emerging directly from women's bodies to indicate birth of the next generation (see **Figure 49**). Part of the evolution of a visualization from something interesting and novel to something canonical and generally accessible is marked by the transition from having to highlight the metaphorical aspects of the form (leaves and branches, for example) to relying upon a shared understanding of the metaphor embedded in the norms associated with the visualization. As the form became better understood, and the metaphor more abstract, the diagrams assumed greater complexity. While kinship diagrams were first used for genealogies and linages, when they began to be used in anthropology, ethnography, and sociology in the late nineteenth and early twentieth centuries, there were many variations of the symbols assigned to men and women in the diagrams, replacing the pictorial representations of earlier times.

While timetrees and kinship diagrams have a clear top or beginning and depict a process over time, sociograms are a subset of network diagrams that show the relationship between people in social situations, such as who is friendly with whom, with no such ordering. Any node can be connected to any other node. Because of this, the resulting diagrams look more like webs than trees. In these network diagrams, the thickness of lines connecting nodes and the relative distance between them often convey information about relationships. Similarly, in semantic network diagrams, the items depicted are usually words and the connections between them denote similarity in meaning. In this section, there is an early example of a sociogram showing friendships and loneliness amongst at-risk girls by the inventor of sociograms, sociologist Jacob Moreno (1888–1974). Node-based network diagrams have evolved tremendously in size, complexity, and power over the past fifty years, intersecting with genomics, graph theory, and other disciplines.

In contrast to these node-based network diagrams, Sankey diagrams are a type of network flow map. They depict the rate of flow of an element (people, products, energy) across space or time, through processes, or between conceptual categories. Rather than singular nodes for discrete elements, their main features are bands or arrows showing the direction of flow and the changing volume (or amount) of the diagram's elements. The width of the bands or arrows is proportional to the flow rate of the elements. Three Sankey diagrams are featured in this section: one of the first Sankey diagrams, a map of the invasion of Russian in the Napoleonic Wars; a diagram of the rise and fall of nations; and a diagram illustrating the mechanical production of these visualizations.

Richard C. Shimeall (1802–1874). *A Complete Historical, Chronological, Geographical & Genealogical Chart of the Sacred Scriptures from Adam to Christ*. Philadelphia, H.S. Tanner, 1832.

The centrepiece and purpose of the large infographic in **Figure 13**, published in 1832 by Richard Shimeall, is a giant kinship diagram of people in the Christian Bible. In that diagram, Shimeall uses circles to represent men and triangles to represent women. (Interestingly, this is an inversion of the conventional format of circles for women and triangles for men, which did not become standard in the field until the 1930s in the United States and later elsewhere[14]). Shimeall's diagram

A COMPLETE
HISTORICAL
CHRONOLOGICAL GEOGRAPHICAL &
CHAR
OF THE SACRED SCRIPTU
ADAM TO CH
NATION, TRIBE, FAMILY, LINEA
Posterity of every Person mentioned
No 1. ADAM & EVE
No 3. JAPHETH.
No 4. SHEM.
No 6. HAM.
No 8. ABRAHAM, ISAAC, JACOB.
INDEX.
REUBEN
SIMEON
LEVI
JUDAH
KORAH
HEZRON
CALEB
COVENANT
A MAP OF CANAAN, or the HOLY LAND;
No IV.
No V.
A MAP of the Journeyings of the ISRAELITES, From EGYPT to the LAND of CANAAN.
No III.
No 9. JOSEPH, MANASSEH, EPHRAIM
SALVATION IS
CANAAN,
GENESIS.
No II.
No 13.

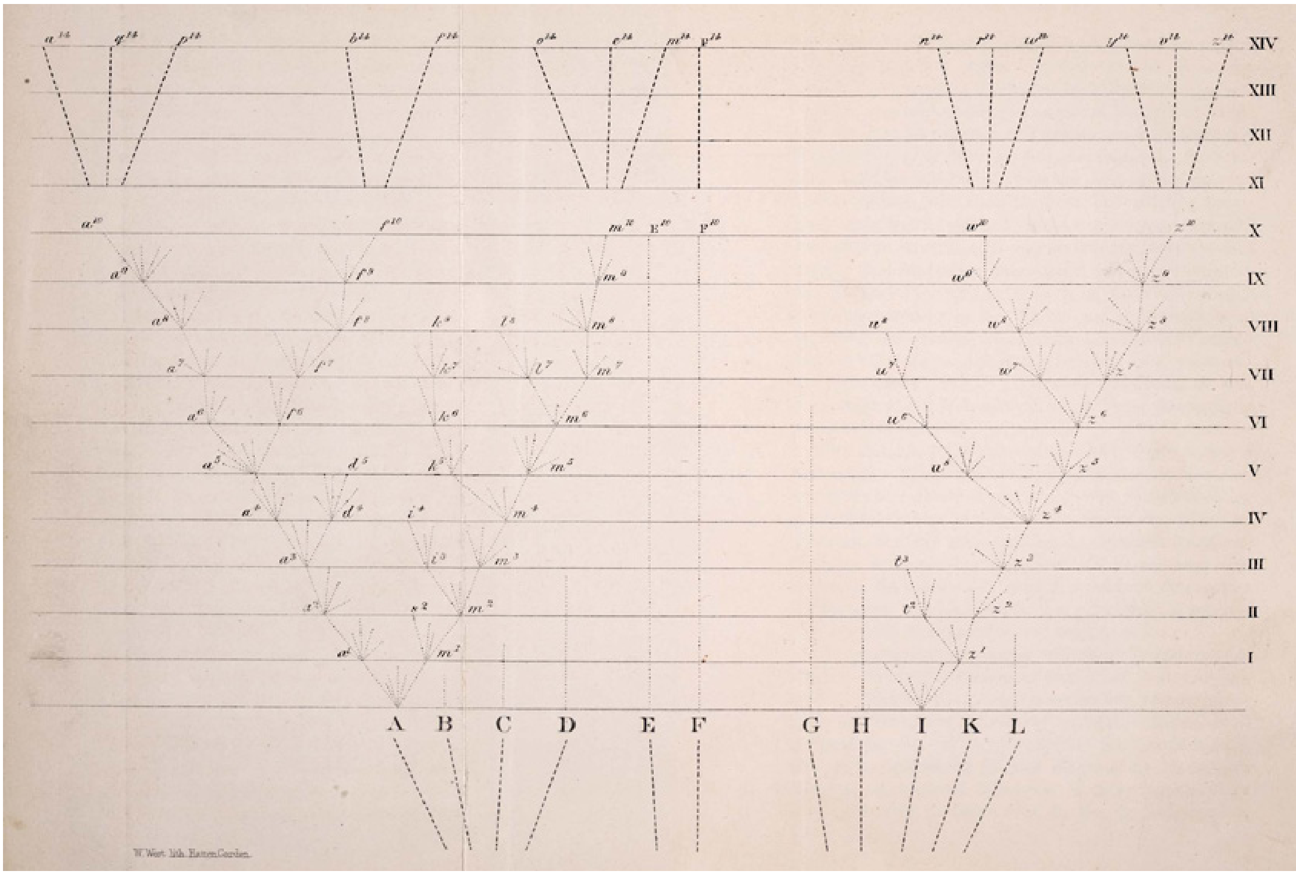
NOAH
EPHRAIM
MANASSEH
JOSEPH
BENJAMIN
DAVID
AMMINADAB
EXPLANATION
CANAAN

[Figure 13]

borrows from an aesthetic informed by scientific notions of the time and the era's fascination with charts to lend authority to biblical stories. In addition, through its sheer size and density of information, this early infographic is designed to overwhelm the senses as means of authority (a practice widely adopted today).

> **Charles Darwin (1809–1882).** ***On the Origin of Species by Means of Natural Selection, or, The Preservation of Favoured Races in the Struggle for Life*. London: J. Murray, 1859.**

Charles Darwin used the metaphor of a 'tree of life' to add explanatory power to his theory of evolution. In *On the Origin of Species* there is only one illustration. The Tree of Life in **Figure 14** is an abstract diagram of a portion of a larger timetree. A timetree differs from a typical tree diagram or genealogical diagram in that it shows the evolutionary relationships of a group of organisms in a timeframe covering thousands of years and generations. (A clearer version of the diagram is reproduced in **Figure 15**). Each section of the vertical axis of the diagram (I–XIV) represents a thousand generations. The horizontal axis delineates thirteen initial species (A–L)

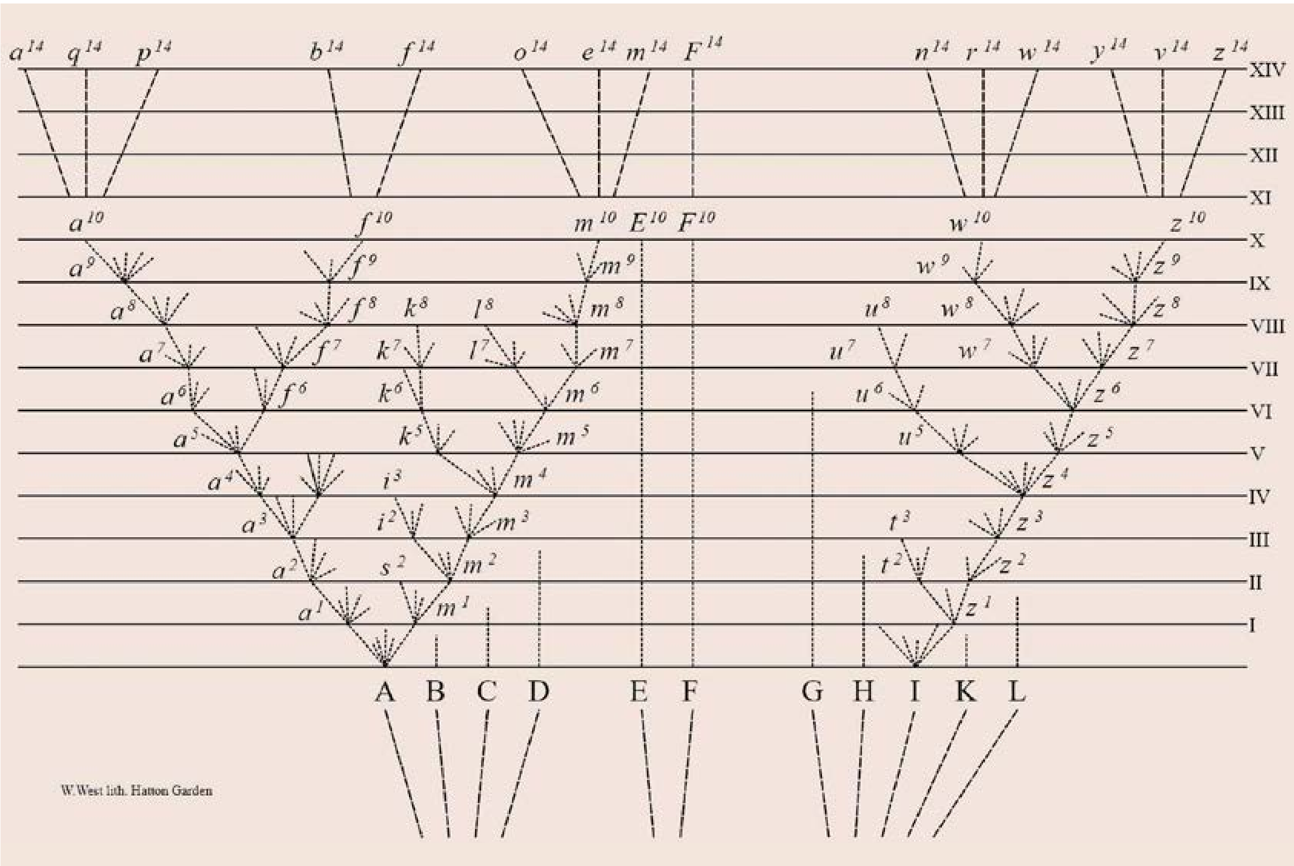


[Figure 14]

that evolved from a common ancestor (not pictured in the segment of the timetree) and how they evolved through time. Spacing on the horizontal axis indicates similarity. At the bottom of the diagram, after fourteen thousand generations, species B, C, D, E, G, H, K, and L have become extinct. The descendants of A and I have become fourteen new species. Species F remains more or less unchanged.

Darwin eloquently describes how the metaphor of a tree applies beyond ancestors and descendants to the idea of natural selection, growth, and interspecies competition:

> The affinities of all the beings of the same class have sometimes been represented by a great tree. I believe this simile largely speaks the truth. The green and budding twigs may represent existing species; and those produced during each former year may represent the long succession of extinct species. At each period of growth all the growing twigs have tried to branch out on all sides, and to overtop and kill the surrounding twigs and branches, in the same manner as species and groups of species have tried to overmaster other species in the great battle for life. The limbs divided into great branches, and these into lesser and lesser branches,



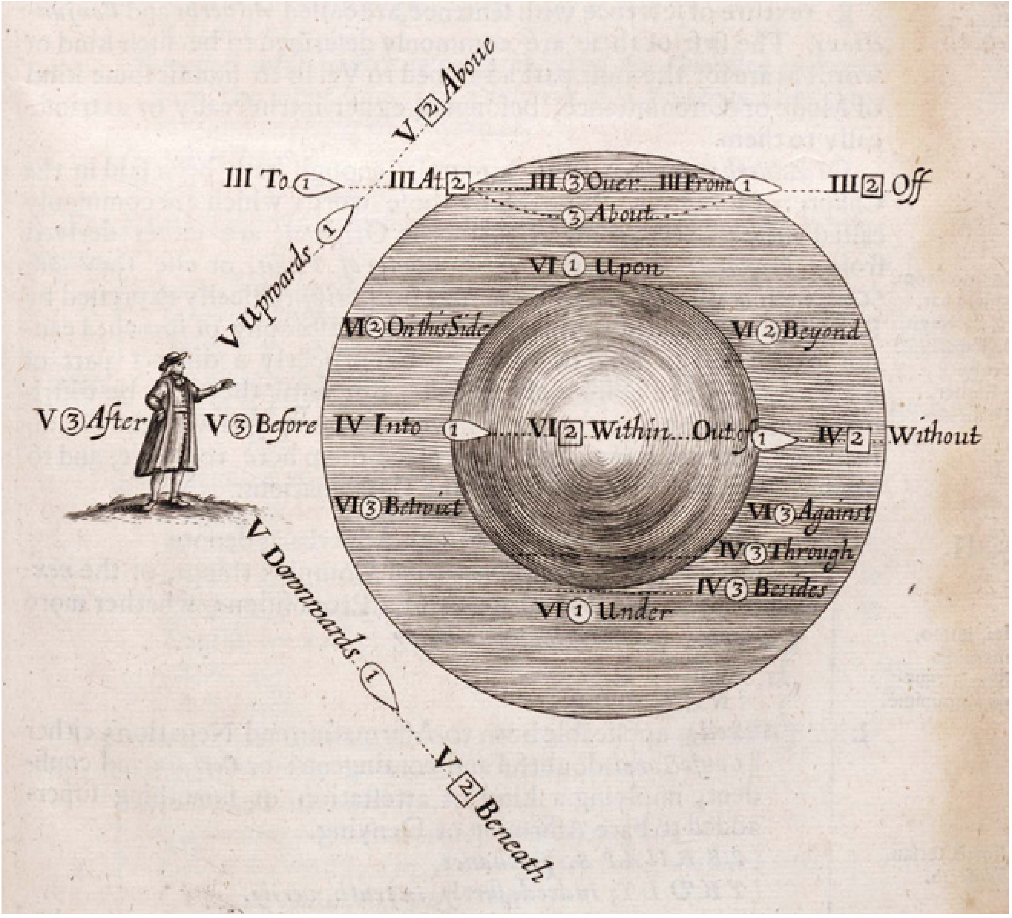
[Figure 15]

> were themselves once, when the tree was small, budding twigs; and this connexion of the former and present buds by ramifying branches may well represent the classification of all extinct and living species in groups subordinate to groups. Of the many twigs which flourished when the tree was a mere bush, only two or three, now grown into great branches, yet survive and bear all the other branches; so with the species which lived during long-past geological periods, very few now have living and modified descendants. From the first growth of the tree, many a limb and branch has decayed and dropped off; and these lost branches of various sizes may represent those whole orders, families, and genera which have now no living representatives, and which are known to us only from having been found in a fossil state. … As buds give rise by growth to fresh buds, and these, if vigorous, branch out and overtop on all sides many a feebler branch, so by generation I believe it has been with the great Tree of Life, which fills with its dead and broken branches the crust of the earth, and covers the surface with its ever branching and beautiful ramifications.[15]

John Wilkins (1614–1672). *Essay Towards a Real Character and a Philosophical Language*. London: Royal Society, 1668.

In 1668, John Wilkins proposed a new universal artificial language to be used for communication between speakers of different languages. The book was an amazing achievement for its time, creating a dictionary, grammar, and phonetic system for the artificial language. It contained hundreds of tables clarifying words by superordinate categories and the mapping of a phonemic structure to those categories.

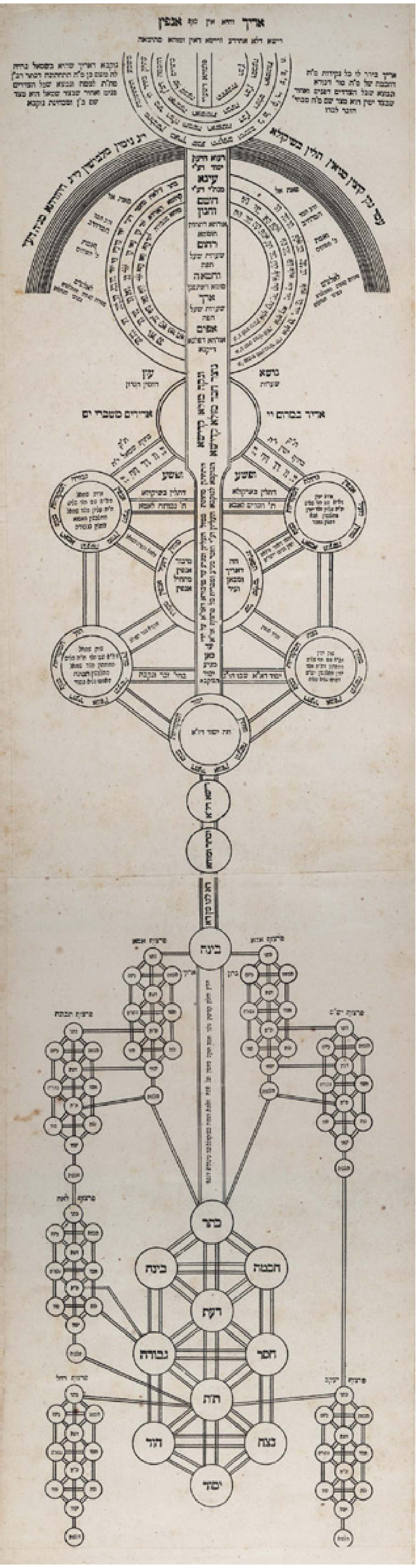
The diagram in **Figure 16** describes the locative prepositions of the new language, such as *before, after, up, down, over, under, beyond, through, above*, and *below* by creating a semantic network. In the network, the location of the prepositions relative to the central circle relates to their meaning. For example, *within* is within the circle and *under* is under the inner circle. Proximity is also used to indicate closeness in meaning so that *upwards* and *downwards* are close to each other because they both mean something about vertical location. Similarly, the preposition *within* is on the same horizontal position as *without* because both share the semantic element of being about containment. The shape of the nodes also indicates whether the preposition involves motion. Ovals indicate motion, squares indicate no motion, and circles denote prepositions that fit in both categories. Semiotician Umberto Eco (1932–2016) called it 'the first semiotic approach to an artificial language'.[16] Some of the strategies of classification and representations of semantic concepts though their relationships, as developed by Wilkins in his work, are still employed today in natural language processing for artificial intelligence.



[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]



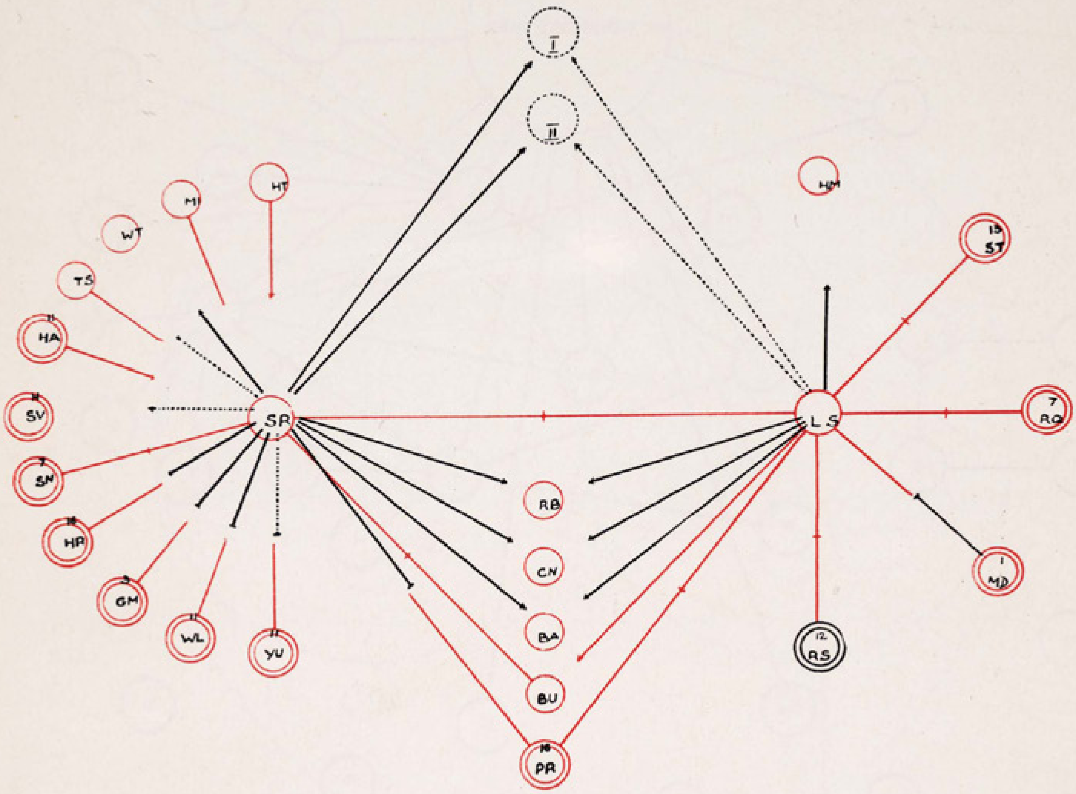
[Figure 17]

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



A Runaway Pair, SR and LS

The sociogram indicates mutual attraction between SR and LS. Except for the relation of SR to BU, they form an *isolated* pair in their cottage. Both reject RB, CN, and BA, girls in the same cottage. BU, whom SR likes, is also liked by LS. SR rejects I (the housemother) and II (the kitchen supervisor) and LS is indifferent to them. LS forms mutual pairs with individuals in other cottages, RQ in C7, ST in C13, and RS, a colored girl, in C12. SR is indifferent to or rejects attractions coming from outside the home group, PR of C16, YU of C11, WL of C11, GM of C3, HR of C16, HA of C11. She is indifferent to SV of the Hospital but mutually attracted to SN of C7, of whom she makes an exception. Towards members of her own group (aside from LS and BU) she is indifferent (HT, MI, TS) and she rejects WT. Both girls, SR and LS, appear cut off from the main currents and blocked, isolated and limited mainly to each other. SR is attracted to a man outside of the community, who in turn is attracted to her (not plotted on this chart) and this persisting attraction finally precipitated the running away of both girls. It can be seen that their position within the school community predisposed them to this action. Not being integrated into the community they had no resistance to overcome and thus they could more easily respond to goals and aspirations outside.

It is interesting to note that in the previous test of C14 on p. 276, SR chose BU who did not reciprocate. There may have been, however, a latent mutuality already then because when the test was repeated shortly before the parole of BU the latter formed a mutual pair with SR. Since BU was gone at the time of the runaway, her relationship with SR represents another pull away from the Hudson community.

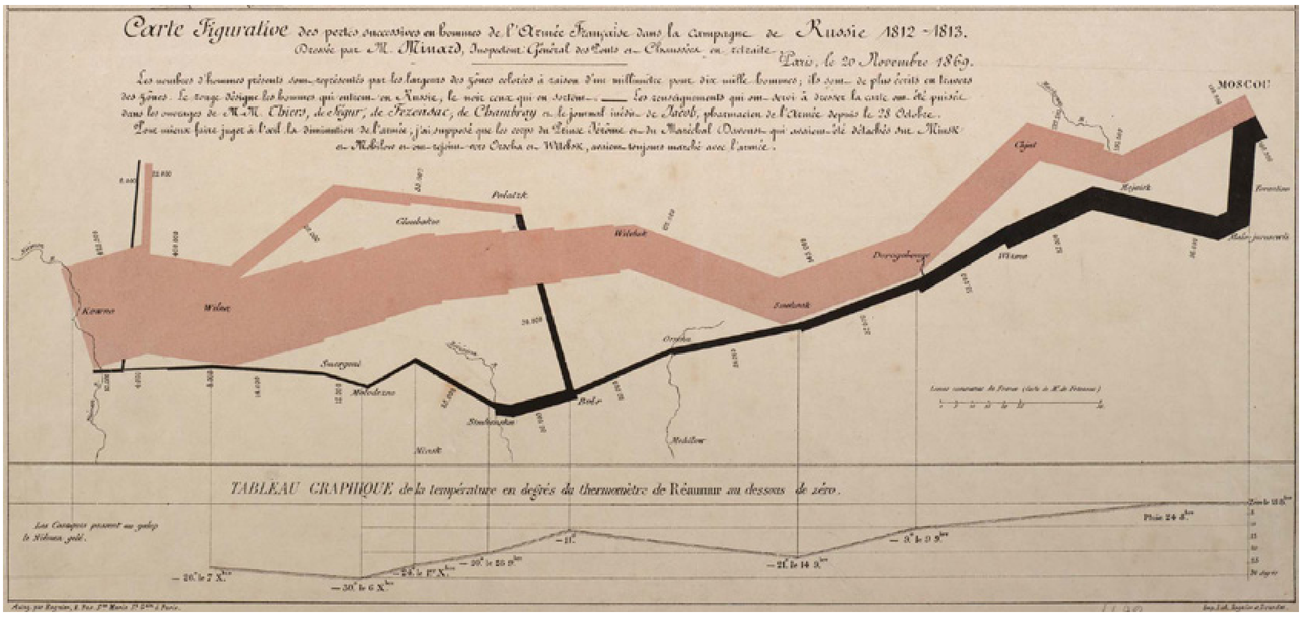
[Figure 18]

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.

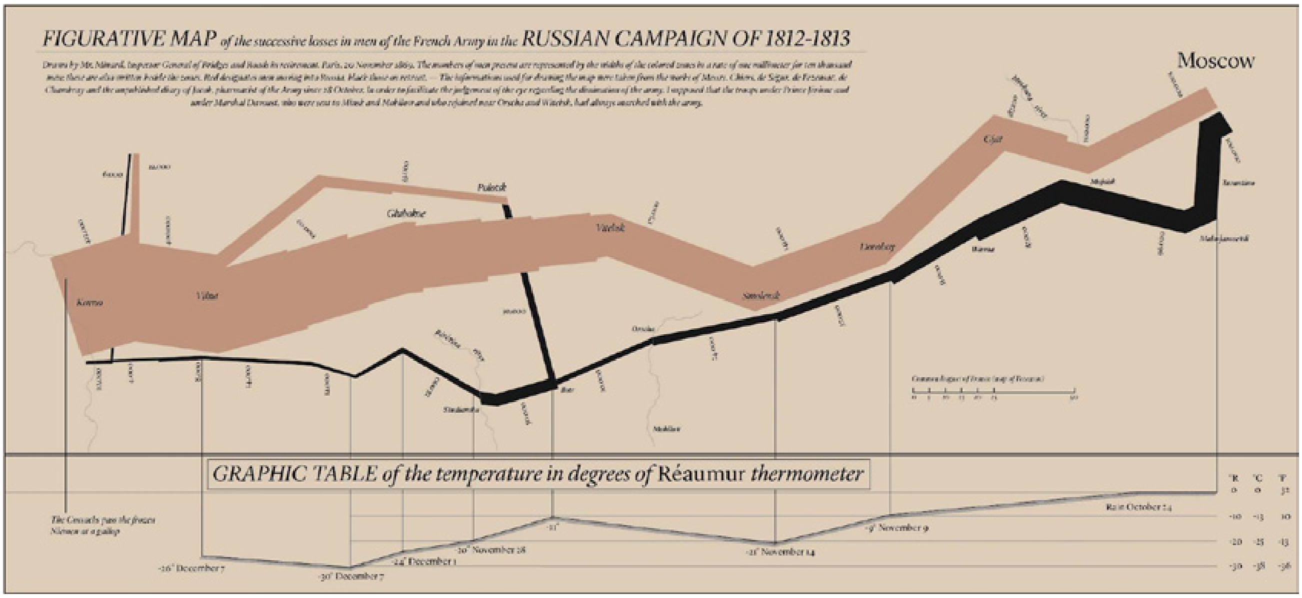
> **Charles Joseph Minard (1781–1870).** ***Carte figurative des pertes successives en hommes de l'armée française dans la Campagne de Russie 1812–13*****. Paris, Régnier & Dourdet, 1869.**

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]

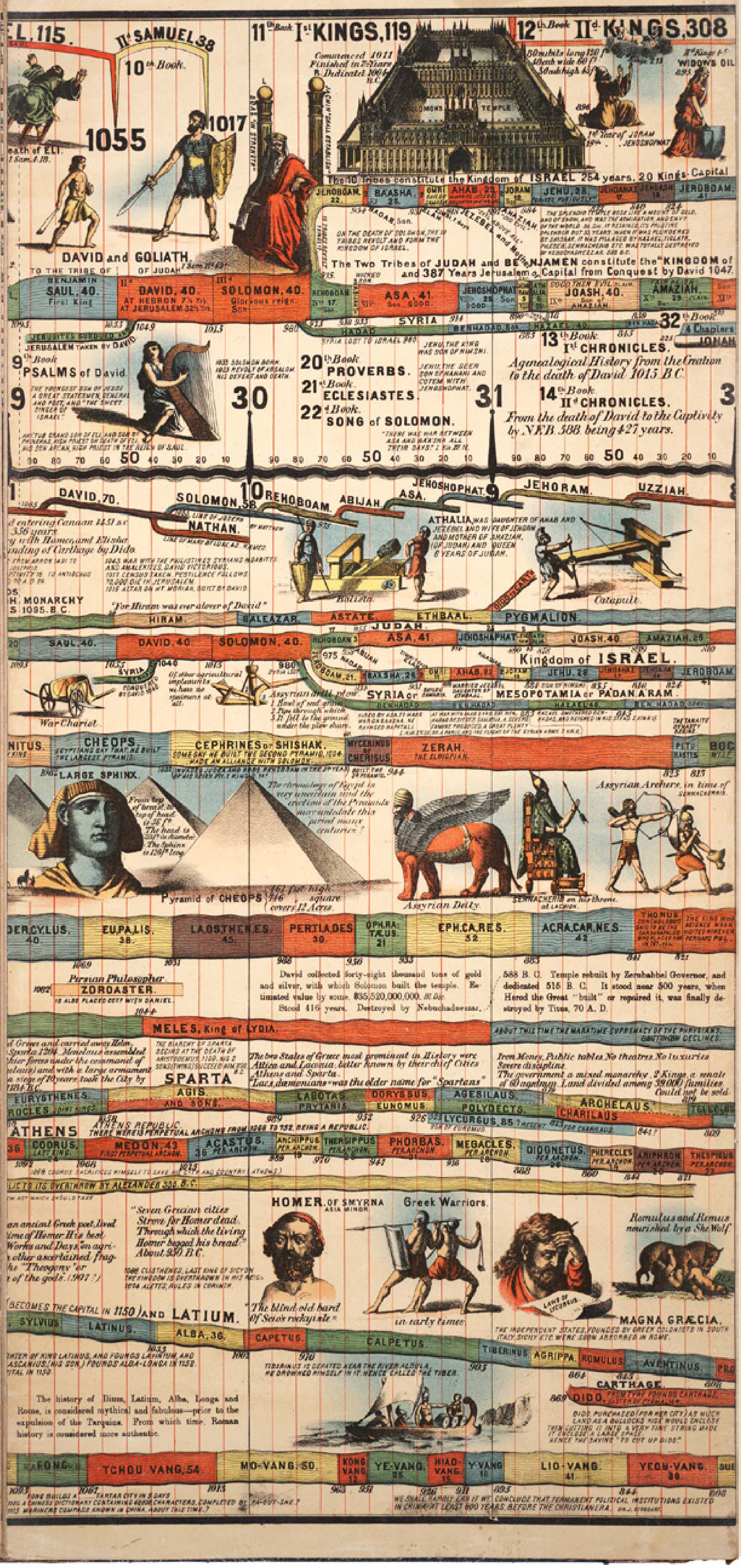


[Figure 20]

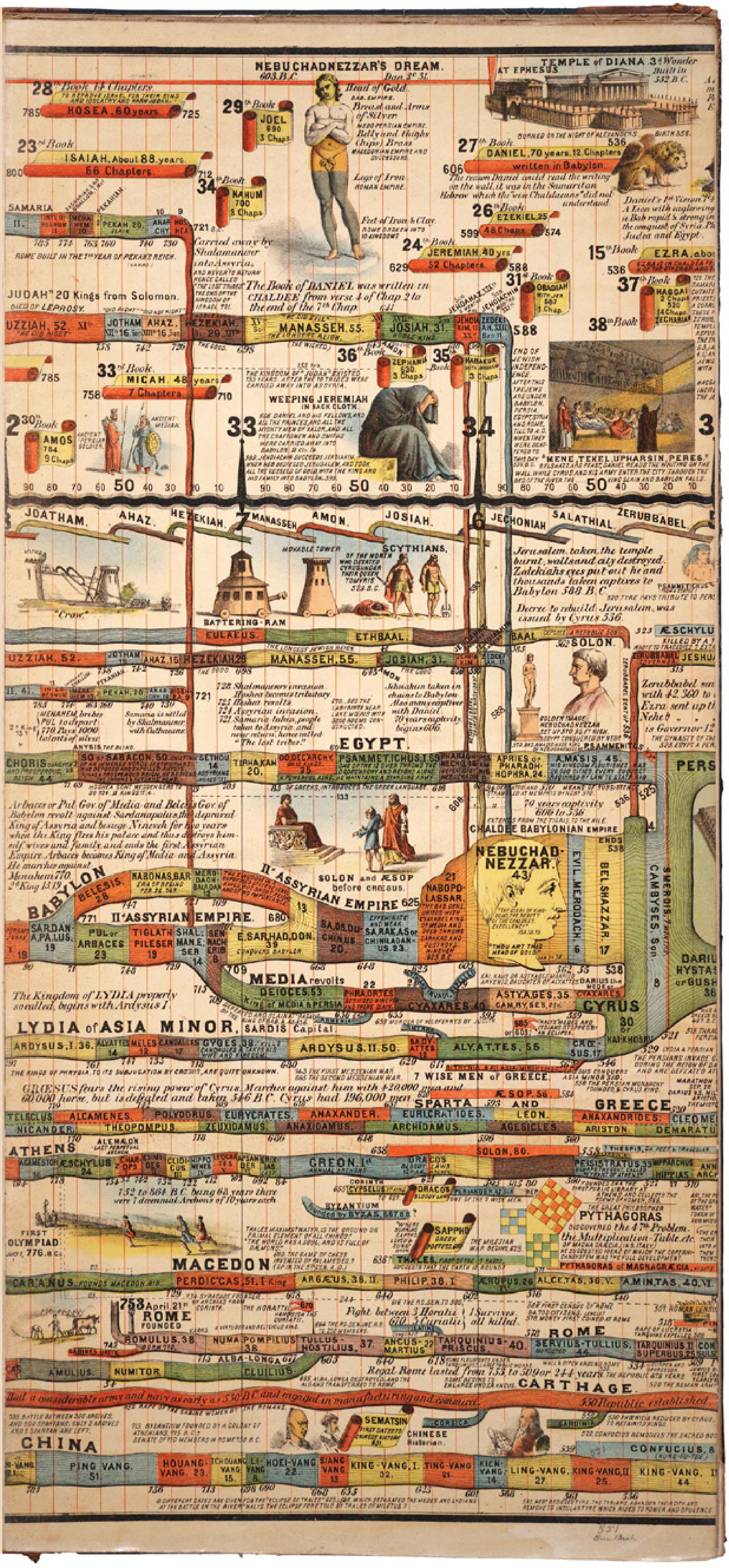
as ‘probably the best statistical graphic ever drawn’.[19] Upon viewing the many examples in this exhibition, readers are invited to decide if they agree!

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.



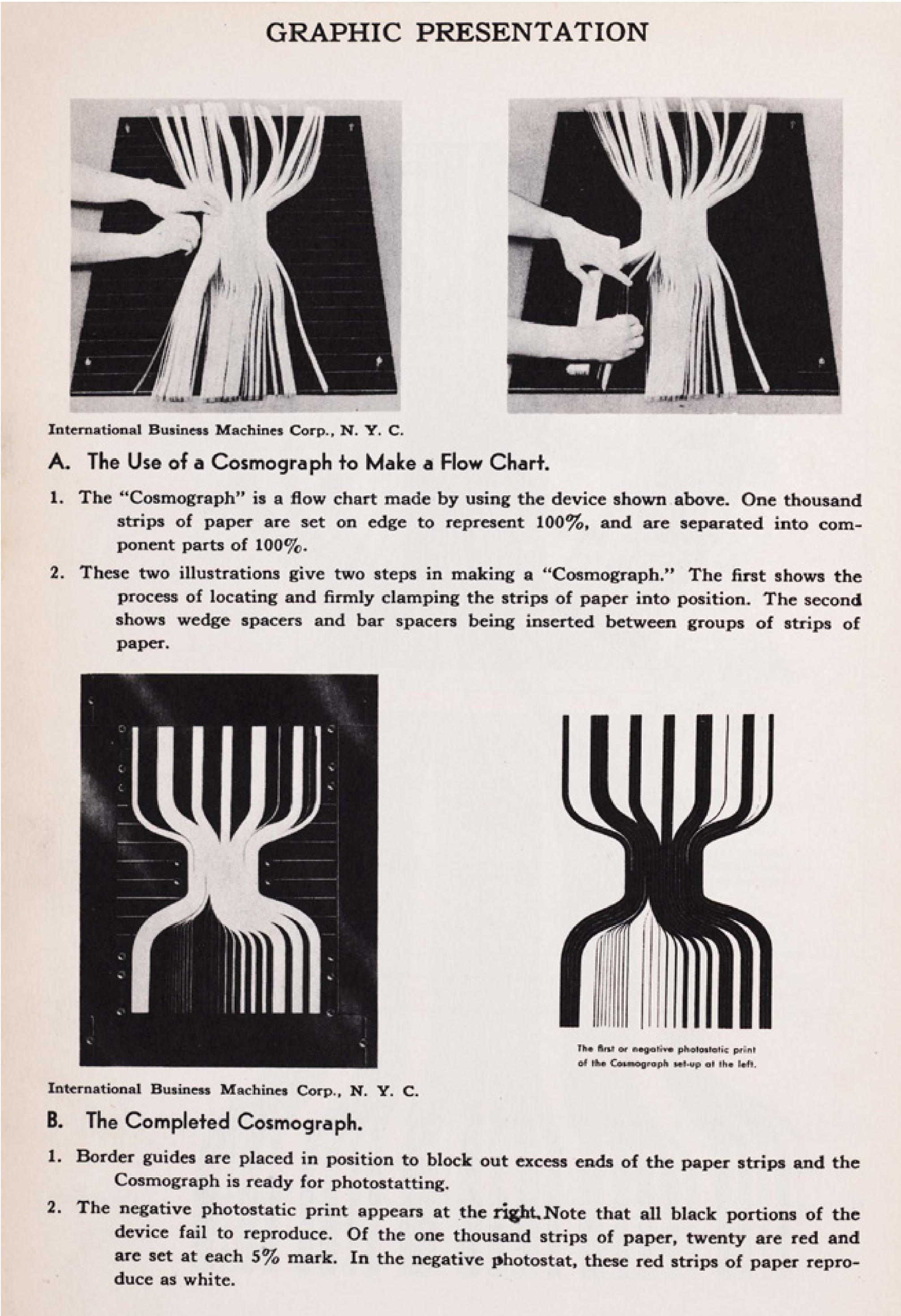
EL, 115.
IId SAMUEL 38
10th Book.
1055
1017
Death of ELI.
1 Sam. 4.18.
DAVID and GOLIATH.
11th Book Ist KINGS, 119
Commenced 1011
Finished in 7½ Years
& Dedicated 1004
SOLOMON'S TEMPLE
12th Book IId KINGS, 308
WIDOWS OIL
1st Year of JORAM
JEHOSHOPHAT
The 10 Tribes constitute the Kingdom of ISRAEL 254 years. 20 Kings. Capital
JEROBOAM, 22.
BAASHA, 25.
OMRI
AHAB, 22.
JORAM
JEHU, 28.
JEHOAHAZ, 17.
JEHOASH
JEROBOAM, 41
ON THE DEATH OF SOLOMON, THE 10 TRIBES REVOLT AND FORM THE KINGDOM OF ISRAEL.
JEZEBEL
The Two Tribes of JUDAH and BENJAMEN constitute the "KINGDOM of JUDAH" and 387 Years Jerusalem Capital from Conquest by David 1047.
TO THE TRIBE OF BENJAMIN
OF JUDAH
SAUL, 40. First King
IId DAVID, 40. AT HEBRON 7½ Yrs. AT JERUSALEM 32½ Yrs.
IIId SOLOMON, 40. Glorious reign. Son
REHOBOAM 17 Son
ASA, 41. Son. 2000.
JEHOSHOPHAT 25 Son
JOASH, 40.
AMAZIAH 29
SYRIA
HADAD
BENHADAD
HAZAEL
SYRIA LOST TO ISRAEL 980
JEBUSITES SUBDUED AND JERUSALEM TAKEN BY DAVID
9th Book PSALMS of David.
THE YOUNGEST SON OF JESSE A GREAT STATESMEN, GENERAL AND POET, AND "THE SWEET SINGER OF ISRAEL."
1033 SOLOMON BORN.
1023 REVOLT OF ABSALOM. HIS DEFEAT AND DEATH.
20th Book PROVERBS.
21st Book ECLESIASTES.
22d Book SONG of SOLOMON.
"THERE WAS WAR BETWEEN ASA AND BAASHA ALL THEIR DAYS." 1 Kin. 15.16.
JEHU, THE KING WAS SON OF NIMSHI.
JEHU, THE SEER SON OF HANANI AND COTEM WITH JEHOSHOPHAT.
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.
32d Book 4 Chapters JONAH
9
30
31
3
90 80 70 60 50 40 30 20 10
90 80 70 60 50 40 30 20 10
90 80 70 60 50 40 30 20 10
DAVID, 70.
SOLOMON, 58
10 REHOBOAM.
ABIJAH.
ASA.
JEHOSHOPHAT.
9
JEHORAM.
UZZIAH.
LINE OF JOSEPH NATHAN.
LINE OF MARY BY LUKE
ATHALIA, WAS DAUGHTER OF AHAB AND JEZEBEL AND WIFE OF JEHORAM AND MOTHER OF AHAZIAH, (OF JUDAH) AND QUEEN 6 YEARS OF JUDAH.
1053 WAR WITH THE PHILISTINES SYRIANS MOABITES AND AMALEKITES. DAVID VICTORIOUS.
1017 CENSUS TAKEN. PESTILENCE FOLLOWS. 70,000 DIE IN JERUSALEM.
1015 ALTAR ON MT. MORIAH, BOUGHT BY DAVID.
Balista.
Catapult.
MONARCHY 1095. B.C.
"For Hiram was ever a lover of David"
HIRAM.
BALEAZAR.
ASTATE.
ETHBAAL.
DIDO'S CART
PYGMALION.
JUDAH
SAUL, 40.
DAVID, 40.
SOLOMON, 40.
REHOBOAM
ABIJAH
ASA, 41.
JEHOSHAPHAT
JOASH, 40
AMAZIAH, 29
Kingdom of ISRAEL.
JEROBOAM, 21.
BAASHA, 24
OMRI
AHAB, 22
JEHU, 28.
JEHOAHAZ
JEHOASH
JEROBOAM
SYRIA or ARAM.
MESOPOTAMIA or PADAN ARAM.
BENHADAD
HAZAEL
BEN HADAD
Of other agricultural implements we have no specimens at all.
Assyrian drill plow
War Chariot.
NITUS.
CHEOPS. EGYPTIANS SAY THAT HE BUILT THE LARGEST PYRAMID.
CEPHRINES or SHISHAK. SOME SAY HE BUILT THE SECOND PYRAMID, 1054. MADE AN ALLIANCE WITH SOLOMON.
MYCERINUS or CHERISUS
ZERAH. THE ETHIOPIAN.
LARGE SPHINX.
From top of breast to top of head is 56 ft. The head is 28½ ft. in diameter. The Sphinx is 120 ft. long.
The chronology of Egypt is very uncertain and the erection of the Pyramids may antedate this period many centuries!
Pyramid of CHEOPS 481 feet high 746 square covers 12 Acres.
Assyrian Deity.
SENNACHERIB on his throne. at LACHISH.
Assyrian Archers, in time of SENNACHERIB.
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 Zerubbabel 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.
ABOUT THIS TIME THE MARATIME SUPREMACY OF THE PHRYGIANS, EGYPTIANS DECLINES.
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"
SPARTA
Iron Money. Public tables. No theatres. No luxuries. Severe discipline. The government a mixed monarchy. 2 Kings, a senate of 60 aged men. Land divided among 39,000 families. Could not be sold.
EURYSTHENES.
PROCLES
AGIS. AND SONS.
LABOTAS.
PRYTANIS
DORYSSUS.
EUNOMUS.
AGESILAUS.
POLYDECTS.
LYCURGUS, 85
ARCHELAUS.
CHARILAUS
TELECLUS
ATHENS
ATHENS REPUBLIC. THERE WERE 13 PERPETUAL ARCHONS FROM 1069 TO 752, BEING A REPUBLIC.
CODRUS. LAST KING.
MEDON, 43 FIRST PERPETUAL ARCHON.
ACASTUS, 36
ARCHIPPUS
THERSIPPUS
PHORBAS.
MEGACLES.
DIOGNETUS.
PHERECLES
ARIPHRON
THESPIEUS
TO ITS OVERTHROW BY ALEXANDER 335 B.C.
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.
an ancient Greek poet, lived time of Homer. His best Works and Days on agriother ascertained frag the "Theogony" or of the gods. (901?)
"The blind old bard of Scio's rocky isle."
in early times.
LAWS OF LYCURGUS.
Romulus and Remus nourished by a She Wolf.
MAGNA GRÆCIA.
THE INDEPENDENT STATES, FOUNDED BY GREEK COLONISTS IN SOUTH ITALY, SICILY ETC. WERE SOON ABSORBED IN ROME.
BECOMES THE CAPITAL IN 1150 AND LATIUM.
SYLVIUS
LATINUS.
ALBA, 36.
CAPETUS.
CALPETUS.
TIBERINUS
AGRIPPA.
ROMULUS
AVENTINUS.
TIBERINUS IS DEFEATED NEAR THE RIVER ALBULA, HE DROWNED HIMSELF IN IT. HENCE CALLED THE TIBER.
CARTHAGE.
DIDO
DIDO PURCHASED (FOR HER CITY) AS MUCH LAND AS A BULLOCKS HIDE WOULD ENCLOSE THEN CUTTING IT INTO A VERY FINE STRING MADE IT ENCLOSE A LARGE SPACE. HENCE THE SAYING "TO CUT UP 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 12
YE-VANG 25
HIAO-VANG. 15.
Y-VANG 16
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
28th Book 14 Chapters
HOSEA, 60 years.
29th Book
JOEL
23rd Book
ISAIAH, About 88 years.
66 Chapters.
34th Book
NAHUM
27th Book
DANIEL, 70 years, 12 Chapters
written in Babylon.
26th Book
EZEKIEL, 25
24th Book
JEREMIAH, 40 yrs
52 Chapters.
15th Book
EZRA
31st Book
OBADIAH
37th Book
HAGGAI
38th Book
SAMARIA
PEKAH, 20.
ROME BUILT IN THE 7TH YEAR OF PEKAH'S REIGN.
Carried away by Shalmaneser into Assyria.
JUDAH 20 Kings from Solomon.
The Book of DANIEL was written in CHALDEE from verse 4 of Chap. 2 to the end of the 7th Chap.
UZZIAH, 52.
JOTHAM
AHAZ.
HEZEKIAH.
MANASSEH, 55.
JOSIAH, 31.
36th Book
ZEPHANIA
35th Book
HABAKUK
33rd Book
MICAH. 48 years
7 Chapters
WEEPING JEREMIAH
IN SACK CLOTH.
30th Book
AMOS
33
34
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.
ÆSCHYLUS
EGYPT.
PSAMMETICHUS
APRIES or PHARAOH-HOPHRA, 24.
AMASIS, 45.
PERS
CHALDEE BABYLONIAN EMPIRE
NEBUCHADNEZZAR. 43
EVIL-MERODACH
BELSHAZZAR.
CAMBYSES, Son.
79 years captivity 606 to 536
SOLON and ÆSOP before CRŒSUS.
BABYLON
BELESIS.
NABONASAR.
IInd ASSYRIAN EMPIRE
SARDANAPALUS.
PUL or ARBACES
TIGLATH PILESER
SHALMANESER
SENNACHERIB
ESARHADDON.
NABOPOLASSAR.
MEDIA revolts
DEIOCES, 53.
PHRAORTES
CYAXARES 40
ASTYAGES, 35.
CYRUS
DARIUS HYSTASPES
The Kingdom of LYDIA properly so called, begins with Ardysus I.
LYDIA of ASIA MINOR, SARDIS Capital.
ARDYSUS, I. 36.
ARDYSUS, II. 50.
ALYATTES, 55.
CRŒSUS, 17
7 WISE MEN of GREECE.
CRŒSUS fears the rising power of Cyrus. Marches against him with 420,000 men and 60,000 horse, but is defeated and taken 546 B.C. Cyrus had 196,000 men.
ÆSOP, 56.
SPARTA AND GREECE
ALCAMENES.
POLYDORUS.
EURYCRATES.
ANAXANDER.
EURICRATIDES.
LEON.
ANAXANDRIDES.
CLEOMENES
NICANDER.
THEOPOMPUS.
ZEUXIDAMUS.
ANAXIDAMUS.
ARCHIDAMUS.
AGESICLES.
ARISTON.
DEMARATUS
ATHENS
SOLON, 80.
ÆSCHYLUS
CREON, 1st
DRACO
PEISISTRATUS, 33
HIPPIAS
752 to 684 B.C. being 68 years there were 7 decennial Archons of 10 years each
BYZANTIUM
SAPPHO
PYTHAGORAS
PYTHAGORAS of MAGNA GRÆCIA.
FIRST OLYMPIAD 776 B.C.
MACEDON
CARANUS
PERDICCAS, 51. I King
ARGÆUS, 38. II.
PHILIP, 38. I
ÆROPUS, 26
ALCETAS, 29. V.
AMINTAS, 40. VI.
753 April 21st
ROME FOUNDED
Fight between 3 Horatii and 3 Curiatii 1 Survives all killed.
ROME
ROMULUS, 38.
NUMA POMPILIUS
TULLUS HOSTILIUS, 37.
ANCUS MARTIUS
TARQUINIUS PRISCUS, 40.
SERVIUS TULLIUS, 44.
TARQUINIUS II SUPERBUS, 25
AMULIUS.
NUMITOR
ALBA-LONGA
CLUILIUS
Regal Rome lasted from 753 to 509 or 244 years.
CARTHAGE.
Built a considerable army and navy as early as 550 B.C. and engaged in manufacturing and commerce.
550 Republic established.
SEMATSIN
CHINESE Historian.
CORSICA
SARDINIA
CHINA
CONFUCIUS, 8
PING VANG. 51.
HOUANG-VANG. 23.
TCHOUANG VANG 15.
LI-VANG 5.
HOEI-VANG 25.
SIANG VANG 33.
KING-VANG, I. 32.
TING-VANG 21
KIEN VANG, 14.
LING-VANG, 27.
KING-VANG, II 25.
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.

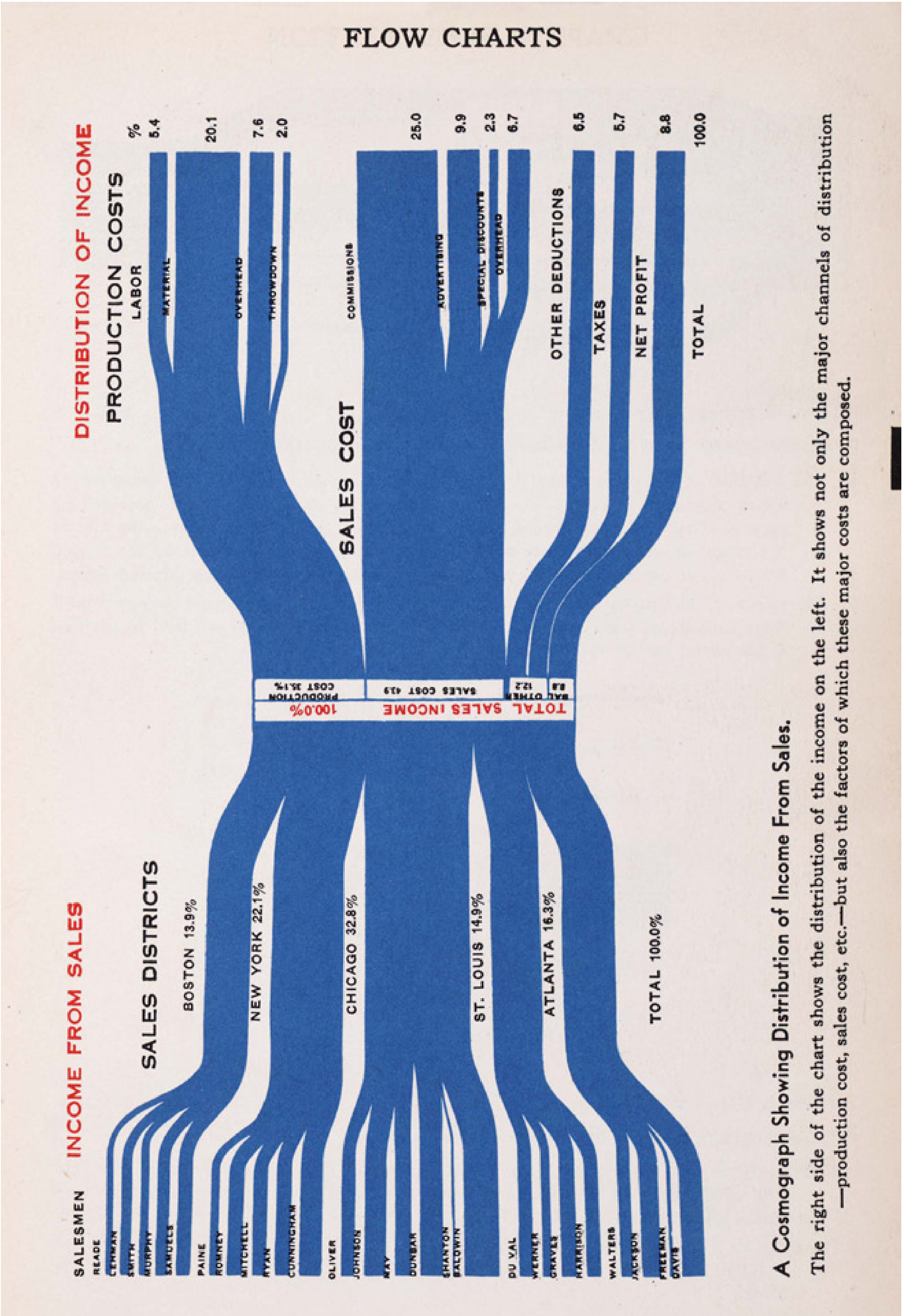
International Business Machines Corp., N. Y. C.

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



A Cosmograph Showing Distribution of Income From Sales.

The right side of the chart shows the distribution of the income on the left. It shows not only the major channels of distribution—production cost, sales cost, etc.—but also the factors of which these major costs are composed.

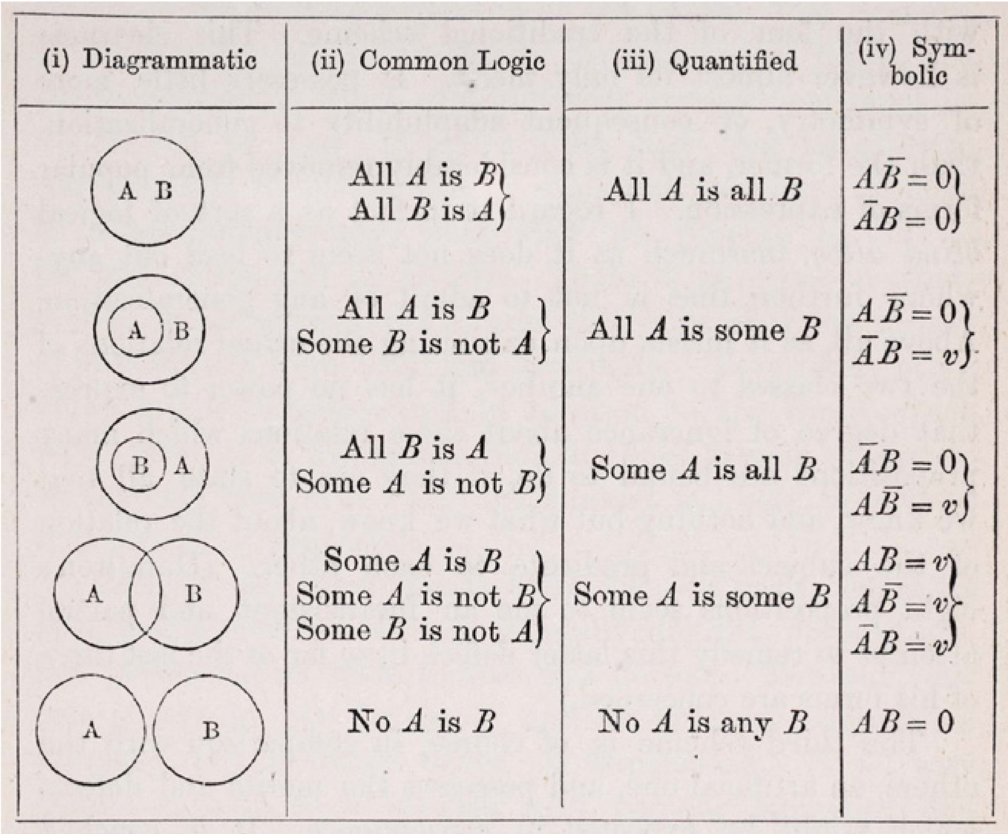
sales districts in the United States and then the flow of that income to various costs and profits. The chart was created by using one thousand paper strips and directing their paths with pins so that the number of strips in each section and at each point of grouping or change corresponded to the percentage 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.



(i) Diagrammatic	(ii) Common Logic	(iii) Quantified	(iv) Symbolic
A B	All A is B All B is A	All A is all B	$A\bar{B}=0$ $\bar{A}B=0$
A B	All A is B Some B is not A	All A is some B	$A\bar{B}=0$ $\bar{A}B=v$
B A	All B is A Some A is not B	Some A is all B	$\bar{A}B=0$ $A\bar{B}=v$
A B	Some A is B Some A is not B Some B is not A	Some A is some B	$AB=v$ $A\bar{B}=v$ $\bar{A}B=v$
A B	No A is B	No A is any B	$AB=0$

[Figure 23]

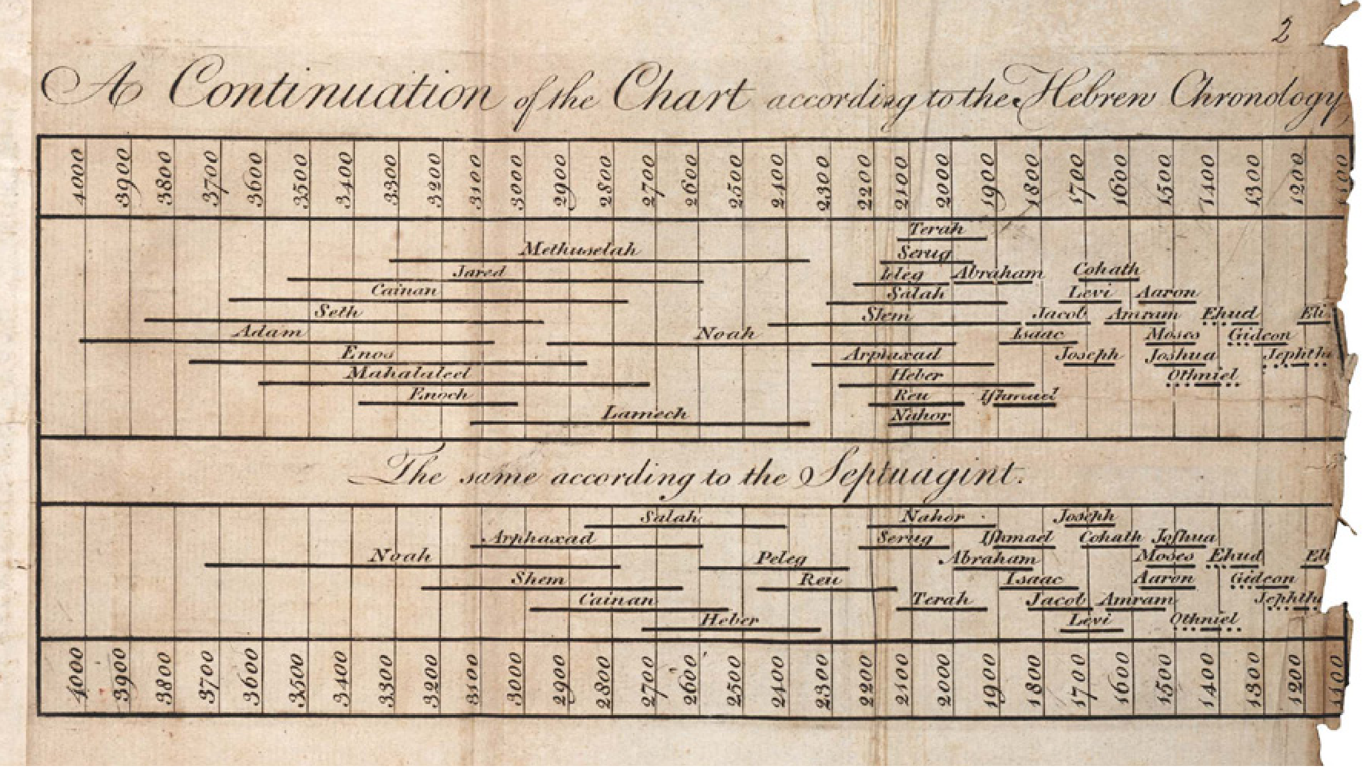
Timelines

Joseph Priestley (1733–1804). *A Description of a Chart of Biography*. London: J. Johnson, 1785.

James Playfair (1736–1819). *A System of Chronology*. Edinburgh: William Creech, 1784.

Percy Robertson (1874–1960). *Contemporary Authors of Former Times: A Chart and Index*. Toronto, 1944?

The first biographic timeline was created by British theologian Joseph Priestley in 1765. People had been creating timelines for centuries before him and Jacques Barbeu-Dubourg (1709–1779) had produced a timeline similar to Priestley's in 1753. However, Barbeu-Dubourg's work, and the work of his predecessors, lacked a critical element introduced by Priestley: the use of individual bars to represent a person's life-span. Priestley's timeline was perhaps the first data visualization to plot an explicit



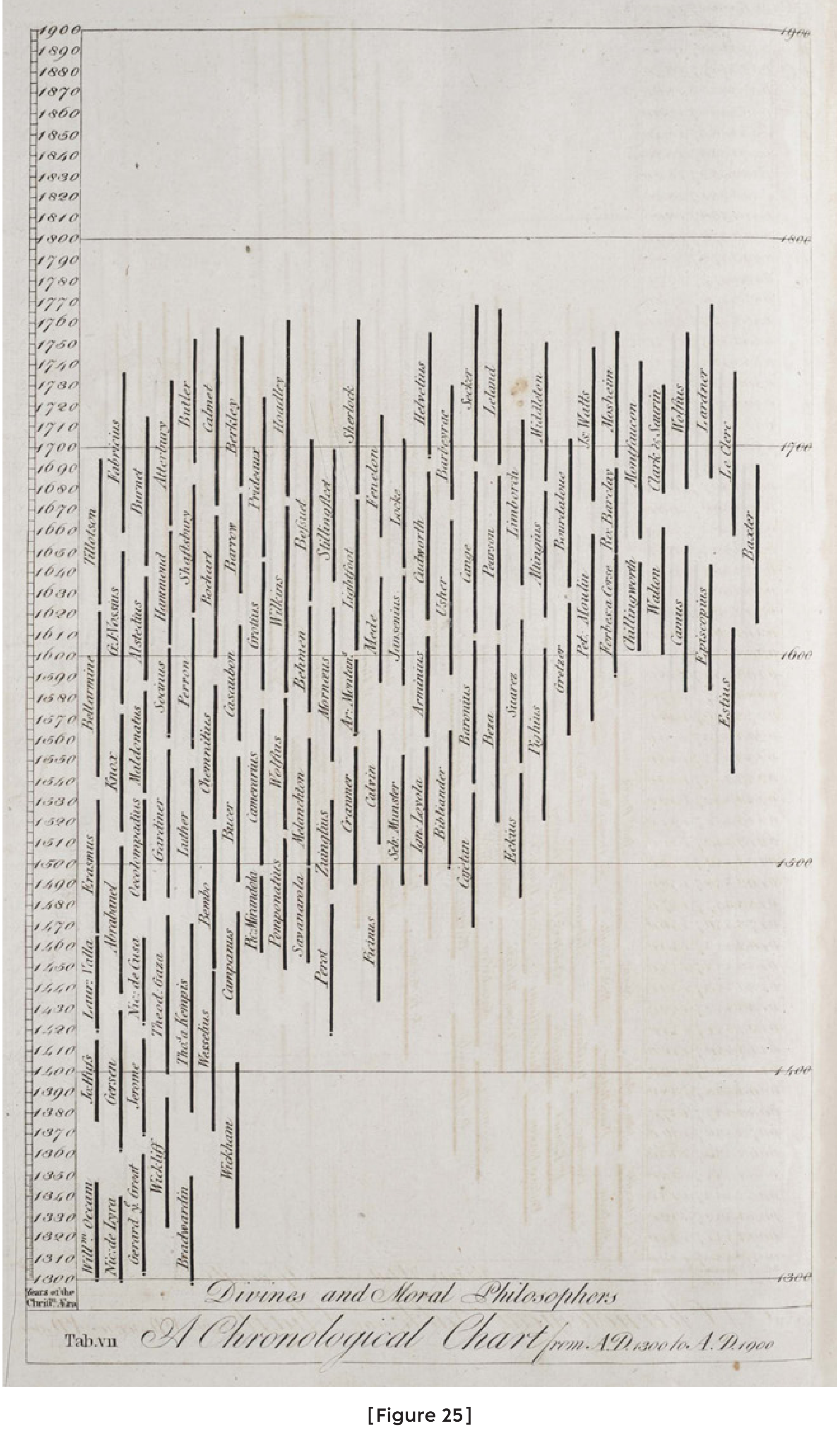
[Figure 24]

variable, lifespan in this case, against an axis expressing time. Priestley's initial chart had a horizontal axis representing time that spanned around 3,000 years. The lifespans of some 2,000 famous people were represented as individual bars parallel to that axis. The chart was also divided vertically into various disciplines: Statesman and Warriors; Divines and Metaphysicians; Mathematicians and Physicians; Poets and Artists; Orators and Critics; and Historians and Antiquarians.

In his later book, *A Description of a Chart of Biography* (1765), Priestley described the benefits of his innovative visualization: the ability tell at a glance whose lifetimes were contemporaneous, noting that 'as soon as you have found the names, you see at one glance, without the help of Arithmetic, or even of words, and in the most clear and perfect manner possible, the relation of these lives to one another.'[21] While it may seem intuitive to modern audiences that a lifespan could be represented by a line segment relating to an axis with a time scale, Priestley felt that the novel concept would be difficult to accept and devoted at least seven pages of his book to convince his readers of the possibility.[22] Priestley's guidebook also contains an abridged version of the full chart, as seen in **Figure 24**.

As we will see, Priestley's biographical timeline inspired William Playfair in his development of the bar chart. His work also influenced James Playfair, the brother of William Playfair, who created a number of huge, detailed timelines around twenty years after Priestley's chart. A chart of political and religious leaders in **Figure 25** comprises six full pages of James Playfair's massive *A System of Chronology*.

Priestley's innovation remained popular centuries later. The Adams Synchronological chart in **Figure 21** depicts the lifespans of important people in the history of Christianity in the top third of the infographic. The chart in **Figure 26**, *Contemporary Authors of Former Times*, was made by Percy Robertson in Toronto,


Divines and Moral Philosophers
Tab.vii A Chronological Chart from A.D. 1300 to A.D. 1900

[Figure 25]

Reigns of British Sovereigns—1485 Henry VII | 1509 Henry VIII | 1547 Ed. VI | 1553 Mary | 1558 Elizabeth | 1603 Jas. I. | 1625 Chas. I | 1649 C'wealth | 1660 Cha

BORN BEFORE 1500

Bacon, Roger	1214-1292	
Becket, Thomas	fl. 1152	
Bede	673- 735	
Botticelli	1447	1510
Chaucer	1328-1400	
Columbus	1445	1506
Coverdale	1488	1568
Cranmer (Bishop)	1489	1556
Dante	1265-1321	
Erasmus	1467	1536
Holbein	1497	1543
Kempis, Thos. A'	1380-1471	
Latimer	1485	1555
Leonardo	1452	1519
Luther	1483	1546
Marco Polo	1254-1324	
Michaelangelo	1475	1564
More, Sir Thos.	1479	1535
Petrarch	1304-1374	
Raphael	1483	1520
Savanarola	1452-1498	
Wycliffe	1324-1384	
Wolsey, Cardinal	1475?	1530

SIXTEENTH CENTURY — SEVENTEENTH CENTUR[Y]

1561 Bacon, Francis ... 1626 ... 167
1505 Knox ... 1572 | 1586 Beaumont .. 1616
1547 Cervantes ... 1616 | 1628 Bunyan, John ...
1599 Cromwell, Oliver ... 1658
1571 Donne ... 1631 | 1661 Def
1579 Fletcher ... 1625
1631 Dryden ...
1620 Evelyn, John ...
1564 Galileo ... 1642
1591 Herrick ... 167
1572 Jonson, Ben ... 1637
1632 Locke, John
1608 Milton ... 167
1622 Moliere ... 167
1642 Newton, Isaac ...
1644 Penn ...
1552 Raleigh ... 1618
1633 Pepys ...
1577 Rubens ... 1640
1639 Racine ...
1564 Shakespeare ... 1616
1632 Spinosa ... 167
1552 Spenser ... 1599
1613 Taylor, Jeremy ... 1667
1599 Van Dyck ... 1641
1599 Valesquez ... 1660
1593 Walton, Izaak ...
1632 Wren, Sir Christopher
167
1667 Swi

EARLIER PERIODS
(not in index)

Aesop	6 cent. B.C.
Aeschylus	525-456 B.C.
Archimedes	287-212 B.C.
Aristophanes	c. 444-c. 380 B.C.
Aristotle	384-322 B.C.
Cicero	104-43 B.C.
Diogenes	c. 380 B.C.
Euclid	fl. c. 300 B.C.
Homer	fl. c. 900 B.C.
Horace	65-8 B.C.
Julius Caesar	102?-44 B.C.
Juvenal	c. 60-130 A.D.
Lucian	?-120 A.D.
Marcus Aurelius	121-180 A.D.
Nero	37-68 A.D.
Ovid	B.C. 43-18? A.D.
Pheidias	died 432 B.C.
Plato	428-347 B.C.
Pliny	23-79 A.D.
Praxitiles	born c. 390 B.C.
Seneca	died 65 A.D.
Socrates	469-399 B.C.
Tacitus	c. 55-117 A.D.
Thucydides	born c. 471 B.C.
Virgil	70-19 B.C.

CONTEMPORARY AUTHORS
OF FORMER TIMES
A CHART AND INDEX

Compiled and arranged by
PERCY ROBERTSON
18 Toronto Street, Toronto 1, Canada

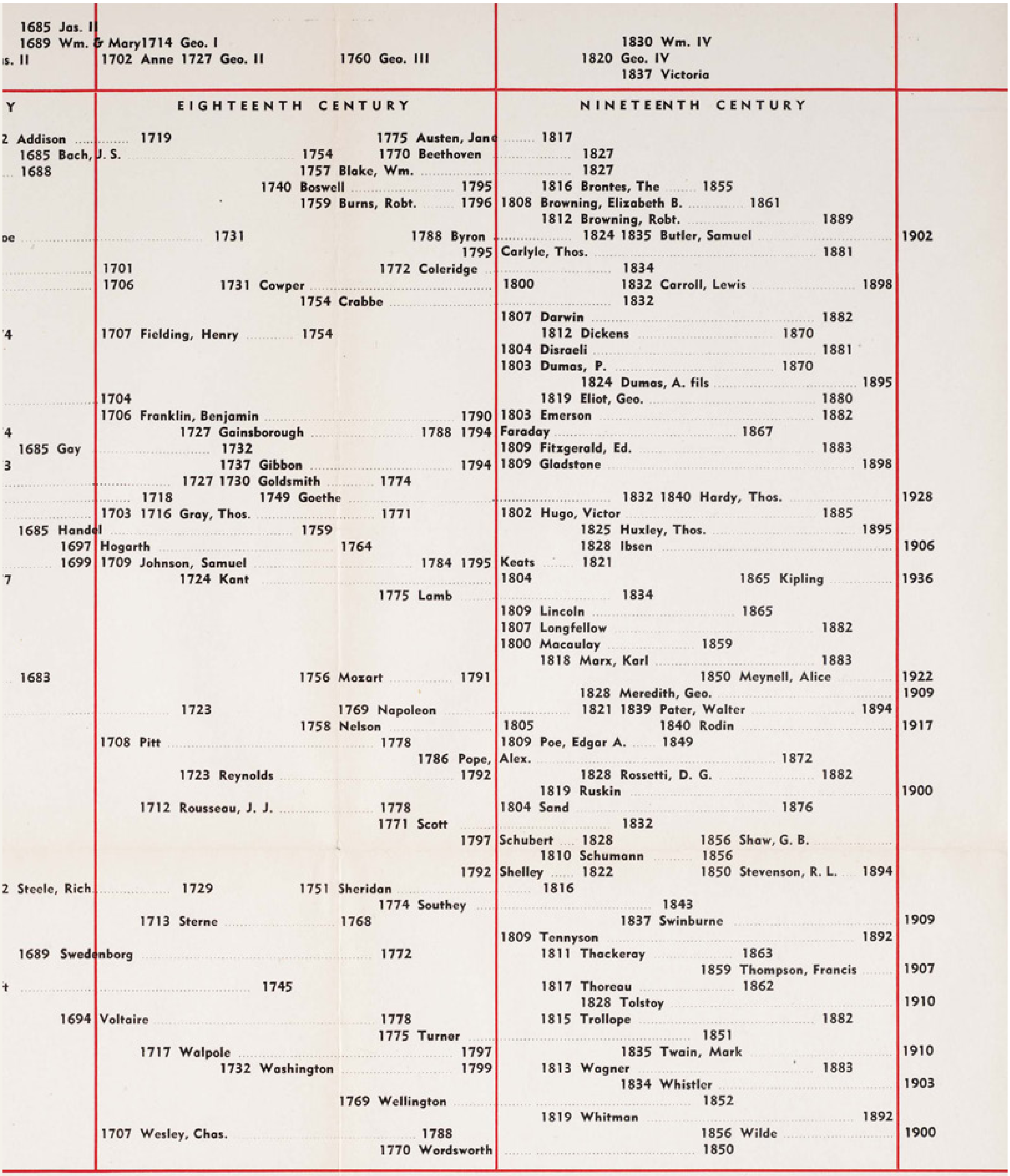
Being a correlation in a chart of the lives of the most important authors and of other prominent personages.

The Index is of wider scope and includes the dates of many who do not appear in the chart, where their most important contemporaries will be found.

The chief object of chart and index is to enable readers to see at a glance those who were contemporaries at any period.

It has been found impossible to include in the chart or index more than a few important authors and personages of recent times.

GENERAL INDEX (NAM

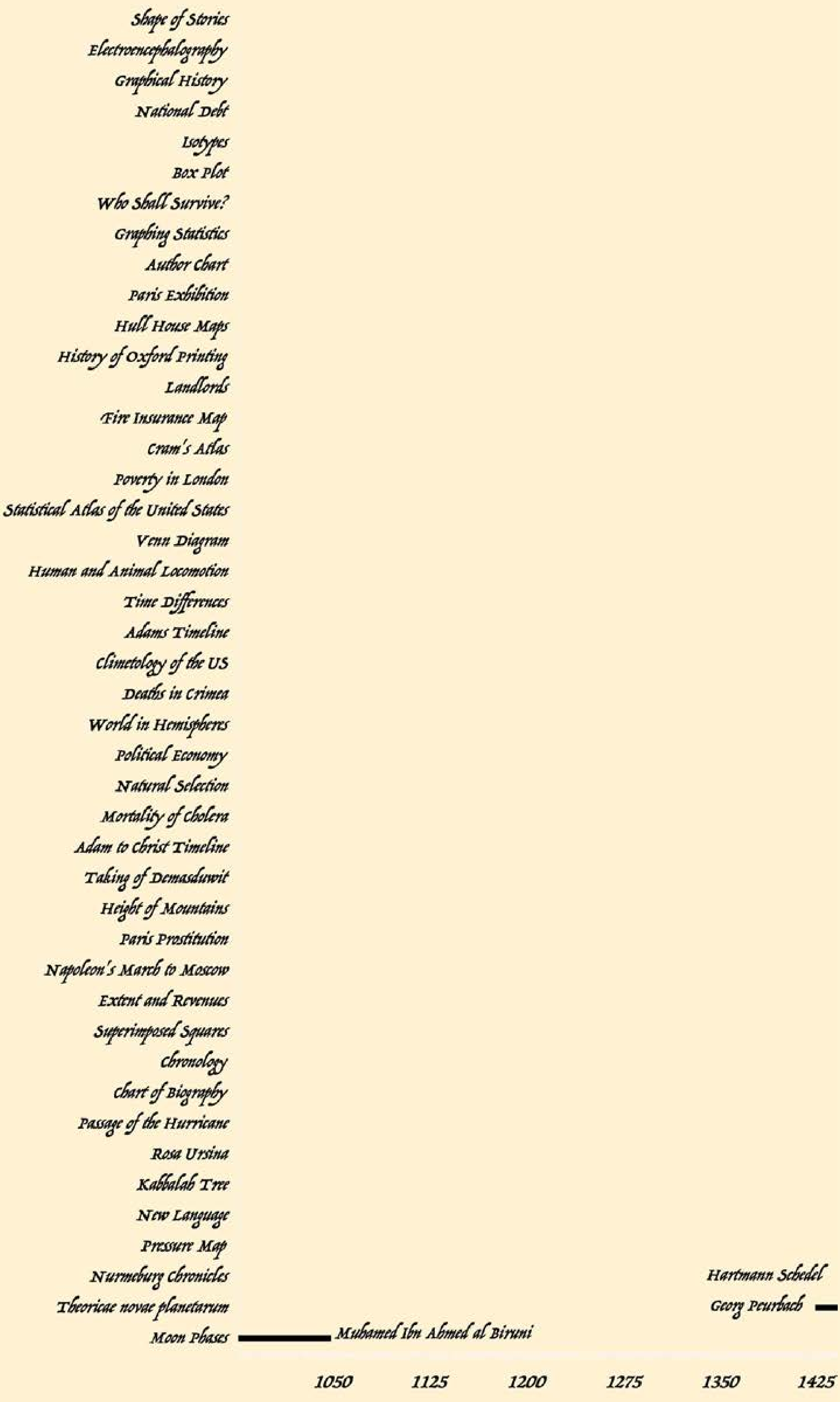


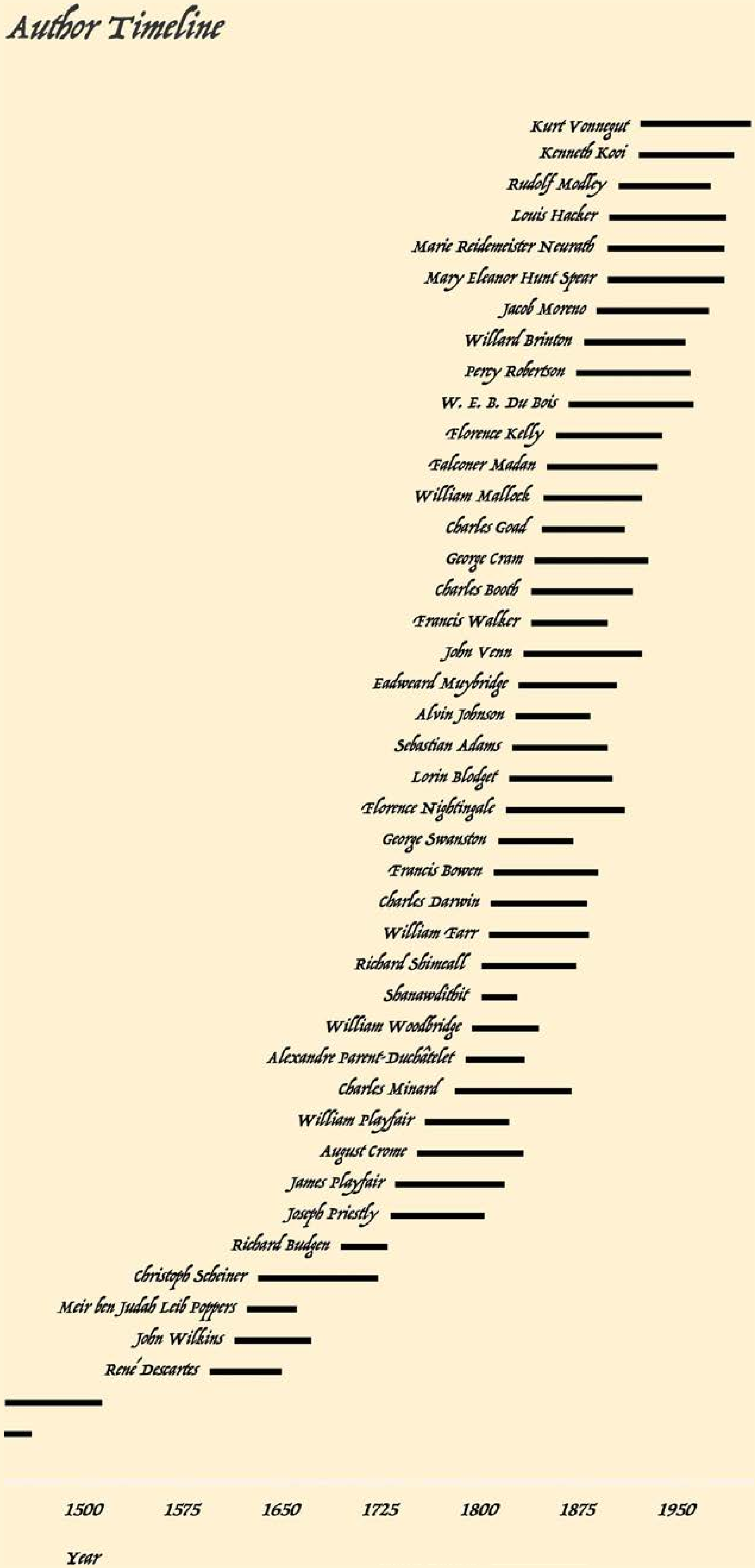
ES IN CAPITALS APPEAR IN CHART)

1859-1936	Maeterlinck	1862-	Patti, Adeline	1843-1919	Sheraton	1751-1806	VAN DYCK	1599-1641
1802-1885	Malory	1433-1475	PENN	1644-1718	SHERIDAN, Rich. B.	1751-1816	Vasari	1511-1574
1711-1776	Manet	1832-1883	PEPYS	1633-1703	Siddons, Mrs.	1755-1831	VELASQUEZ	1599-1660
1825-1895	Mansfield, Katherine	1888-1923	PETRACH	1304-1374	Sidney, Sir Philip	1554-1586	Verdi	1814-1901
1828-1906	MARCO POLO	1254-1324	Pinero	1855-1934	Smiles, Samuel	1812-1904	Verne, Jules	1828-1905
1838-1905	Marlowe	1564-1593	PITT	1708-1778	Smith, Adam	1723-1790	VOLTAIRE	1694-1778
1783-1857	Marryat	1792-1848	POE, Edgar A.	1809-1849	Smith, Goldwin	1823-1910	WAGNER	1813-1883
1842-1910	MARX, Karl	1818-1883	POPE, Alexander	1786-1872	Smith, Sydney	1771-1845	WALPOLE, Horace	1717-1797
1843-1916	Maupassant, Guy de	1850-1893	Prescott	1796-1859	Smollett	1721-1771	WALTON, Izaak	1593-1683
1743-1826	Maurier, George du	1834-1896	Pusey	1800-1882	SOUTHEY	1774-1843	Ward, Artemus	1834-1867
1859-1927	Mendelssohn	1809-1847	Pushkin	1799-1837	Spencer, Herbert	1820-1903	WASHINGTON	1732-1799
1709-1784	MEREDITH, Geo.	1828-1909	Quiller-Couch	1863-	SPENSER, Edmond	1552-1599	Watts, Isaac	1674-1748
1573-1652	MEYNELL, Alice	1850-1922	Quincey, de	1785-1859	SPINOZA	1632-1677	Watts, Geo. F.	1820-1904
1572-1637	MICHAELANGELO	1475-1564	RACINE, JEAN	1639-1699	Stael, Madame de	1766-1817	Webster, Daniel	1782-1852
1724-1804	Mill, J. S.	1806-1873	Raeburn	1758-1823	STEELE, Sir Richard	1672-1729	Wedgewood	1730-1795
1795-1821	Millais	1829-1896	RALEIGH	1552-1618	STERNE	1713-1768	WELLINGTON	1769-1852
1792-1866	Millet	1814-1875	RAPHAEL	1483-1520	STEVENSON, R. L.	1850-1894	Wells, H. G.	1866-
1380-1471	MILTON	1608-1674	Reade, Chas.	1814-1884	Stowe, Harriet B.	1812-1896	WESLEY, Chas.	1707-1788
1819-1875	MOLIERE	1622-1673	REYNOLDS	1723-1792	Sullivan, Sir A.	1842-1900	Wesley, John	1703-1791
1865-1936	Monet	1840-1926	Richardson	1689-1761	Surtees	1803-1864	WHISTLER	1834-1903
1505-1572	Montaigne	1533-1592	Riley, J. W.	1852-1916	SWEDENBORG	1689-1772	WHITMAN	1819-1892
1775-1834	Moore, Thos.	1779-1852	Roberts, Chas. G. D., Sir	1860-1943	SWIFT	1667-1745	Whittier	1807-1892
1861-1899	MORE, Sir Thos.	1479-1535	RODIN	1840-1917	SWINBURNE	1837-1909	Wilberforce	1759-1833
1775-1864	Morris, Wm.	1834-1896	Rossetti, Christina	1830-1894	TAYLOR, JEREMY	1613-1667	WILDE	1856-1900
1802-1873	Motley, J. L.	1814-1877	ROSSETTI, Dante Gab.	1828-1882	Tcheho	1860-1904	WOLSEY, Card.	1475?-1530
1485-1555	MOZART	1756-1791	ROUSSEAU, Jean J.	1712-1778	TENNYSON	1809-1892	WORDSWORTH	1770-1850
1817-1864	NAPOLEON	1769-1821	RUBENS	1577-1640	Terry, Ellen	1848-1928	WREN, Sir Chris.	1632-1723
1452-1519	NELSON	1758-1805	RUSKIN	1819-1900	THACKERAY	1811-1863	Wycherley, Wm.	1640-1716
1809-1872	Newman, Card.	1801-1890	SAND, Geo.	1804-1876	THOMPSON, Frances	1859-1907	WYCLIFFE	1324-1384
1809-1865	NEWTON, Isaac	1642-1727	Sankey	1840-1908	Thomson, James	1700-1748	Yeats	1865-1939
1811-1887	Nietzsche	1844-1900	Sargent	1856-1925	THOREAU	1817-1862	Young, Arthur	1741-1820
1632-1704	North, Sir Thos.	1535-1601	SAVANAROLA	1452-1498	Titian	1477-1576	Zola	1840-1920
1807-1882	Noyes, Alfred	1880-	Schiller	1759-1805	TOLSTOY	1828-1910		
1618-1658	Ouida	1839-1908	SCHUBERT	1797-1828	Trevelyan, Sir Geo.	1838-1928		
1819-1891	Palgrave, Francis	1824-1897	SCHUMANN	1810-1856	TROLLOPE	1815-1882		
1483-1546	Palmerston	1784-1865	SCOTT	1771-1832	Turgenev	1818-1883		
1554-1606	Parkman, Francis	1823-1859	SHAKESPEARE	1564-1616	TURNER	1775-1851		
1803-1873	PATER, WALTER	1839-1894	SHAW, G. B.	1856-	TWAIN, Mark	1835-1910		
1800-1859	Patmore	1823-1896	SHELLEY	1792-1822	Tyndale	1490-1536		

[Figure 26]

Emerging Patterns




Author Timeline
Kurt Vonnegut
Kenneth Kooi
Rudolf Modley
Louis Hacker
Marie Reidemeister Neurath
Mary Eleanor Hunt Spear
Jacob Moreno
Willard Brinton
Percy Robertson
W. E. B. Du Bois
Florence Kelly
Falconer Madan
William Mallock
Charles Goad
George Cram
Charles Booth
Francis Walker
John Venn
Eadweard Muybridge
Alvin Johnson
Sebastian Adams
Lorin Blodget
Florence Nightingale
George Swanston
Francis Bowen
Charles Darwin
William Farr
Richard Shimeall
Shanawdithit
William Woodbridge
Alexandre Parent-Duchâtelet
Charles Minard
William Playfair
August Crome
James Playfair
Joseph Priestly
Richard Budgen
Christoph Scheiner
Meir ben Judah Leib Poppers
John Wilkins
René Descartes
1500
1575
1650
1725
1800
1875
1950
Year

[Figure 27]

Canada, around 1944. Though produced almost one hundred and sixty years later, the form of the chart is remarkably similar to the initial chart made by Priestley. In honour of the Priestly timeline, we have made a timeline of all the creators of data visualizations in the *Emerging Patterns* exhibition (**Figure 27**).

Bars, Lines, Boxes, and Circles—Oh My!

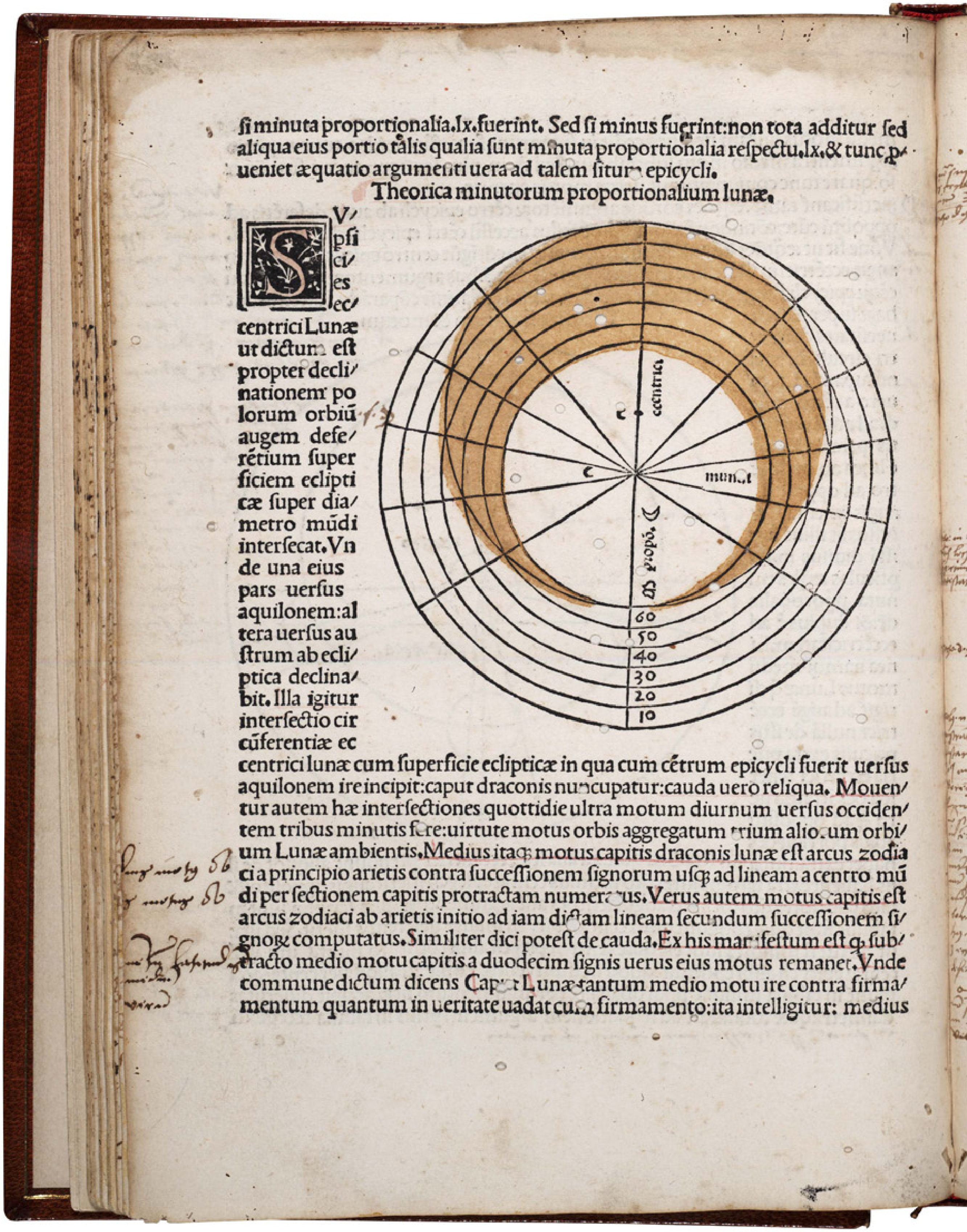
> **Johannes de Sacrobosco (c. 1195–c. 1256). *Sphaera mundi* with Johannes Regiomontanus (1436–476), *Disputationes contra Cremonensia deliramenta* and Georg von Peurbach (1423–1461), *Theoricae novae planetarum*. Venice: Bonetus Locatellus, 1490.**

> **William Playfair (1759–1823). *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.**

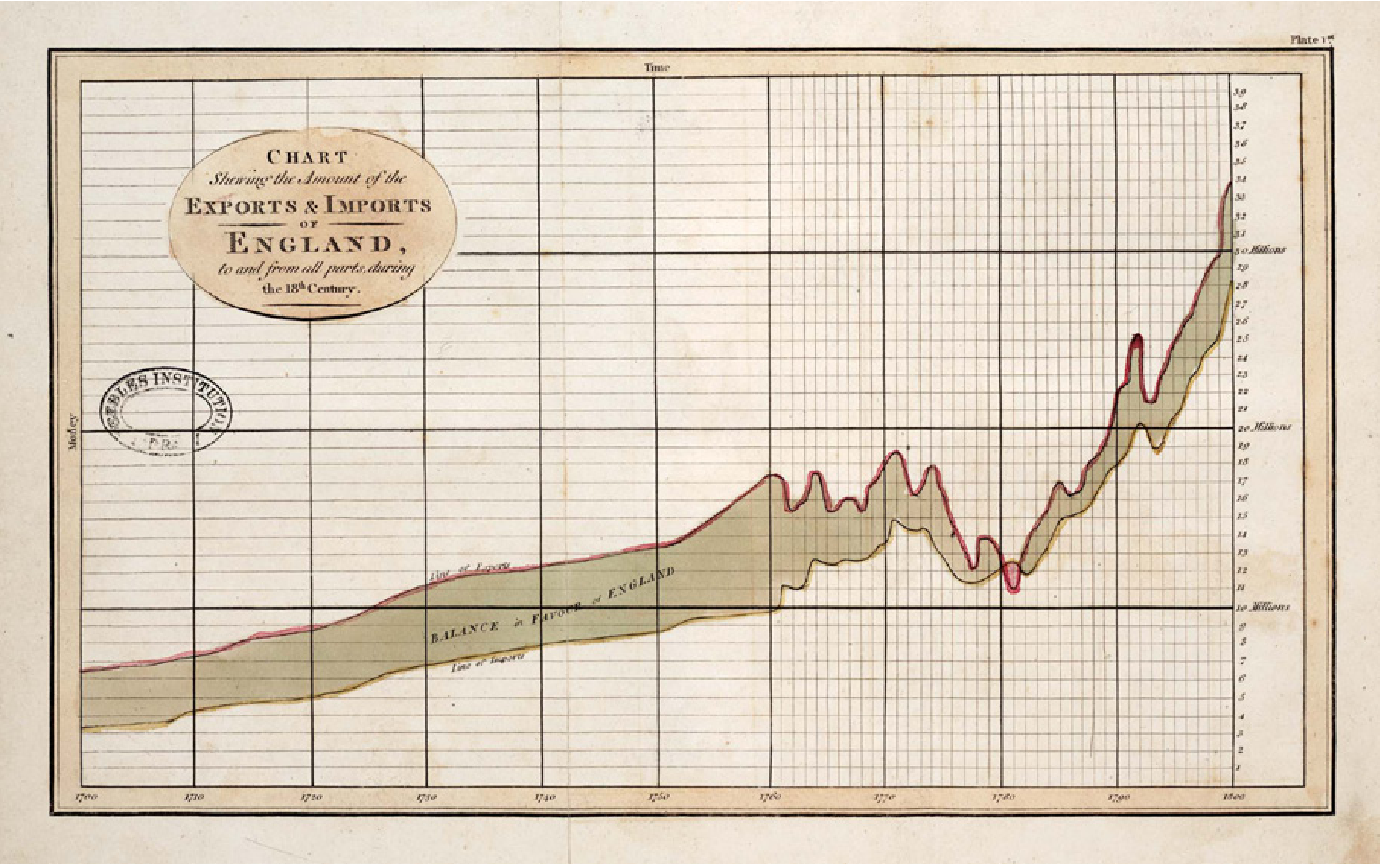
> **–––. *The Statistical Breviary; Shewing, on a Principle Entirely New, the Resources of Every State and Kingdom in Europe*. London: T. Bensley, 1801.**

William Playfair is among the most important and influential people in the history of data visualization. He is widely credited with inventing several significant types of data visualizations around the turn of the nineteenth century, including the bar, circle, pie, line, and area charts. Playfair cites Joseph Priestley's 1765 biographic timeline (**Figure 24**) as inspiration for what became the (now ubiquitous) bar chart. Playfair had import and export data from multiple countries that he was hoping to graph as multiple line graphs over time, but he was missing detailed data from one country. Recalling the timeline charts of Priestley, he opted to graph the data for a single year as a series of bars: the first bar chart.[23]

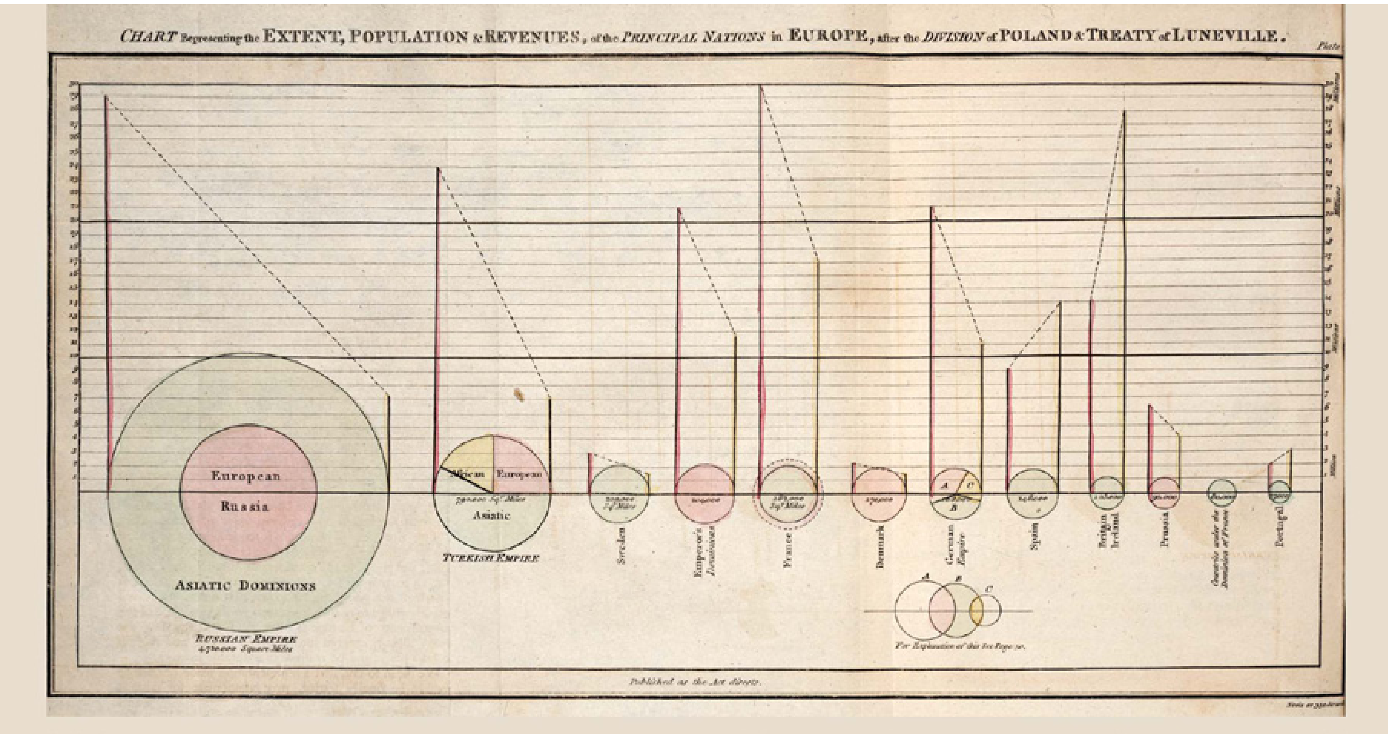
While Playfair is nearly universally acknowledged to have invented the bar chart, we believe Austrian astronomer Georg Peurbach (1423–1461) may have at least a partial claim. In his 1454 work *Theoricae novae planetarum* (New Theories of the Planets), Peurbach includes a diagram titled 'Thoerica minutorum proportionalium lunae' (The Theory of the Proportional Minutes of the Moon), **Figure 28**, in which he shows the orbit of the moon (in its crystalline sphere, following in the tradition of Ptolemy) around the earth. The orbit is eccentric, passing closer to the earth at its perigee and further at its apogee. Peurbach's diagram shows the area of the orbit coloured in yellow. One can easily compare the distance between the earth



[Figure 28]



[Figure 29]



[Figure 30]

and the moon at various points along its orbit, measured against the diagram's scale expressed in degrees, by comparing the area of the coloured region circumscribed by the orbit of the moon. It is not a bar chart (there are no bars!), but it might be a proto-bar chart, made 332 years before Playfair.

In any event, Playfair was not enamoured of his bar chart. He argued that it was 'much inferior' to charts that have a temporal span and he dropped the bar chart from the third edition of *The Commercial and Political Atlas,* the book in which it first appeared.[24] **Figure 29** is a combination of two of Playfair's other inventions: the line chart and the area chart. This chart shows England's imports and exports over the course of the eighteenth century. Unlike his bar chart, this line chart compares three continuous variables, time, imports, and exports. The shape, to use Playfair's word, of the quantities is clearly visible. The long, steep decline in England's exports and imports is immediately visible across the course of the 1770s—during a period of economic, political, and military turmoil, not least with the colonies in America—resulting in a brief negative trade balance around 1781. It is also noteworthy that when more accurate and reliable data became available from 1760 onwards, Playfair included the more granular data and added gridlines on the x-axis by year, rather than by decade. As a result, that section of the graph is more detailed.

In the chart, the area coloured green (or, for a short burst, pink) represents the balance of trade. It is easy to compare the area at different times as it shrinks and grows. This, according to Playfair, is the great strength of these kinds of charts. He called his work *Lineal Arithmetic* and explained his motivation:

> As the eye is the best judge of proportion, being able to estimate it with more quickness and accuracy than any other of our organs, it follows, that wherever *relative quantities* are in question, a gradual increase or decrease of any revenue, receipt or expenditure of money, or other value, is to be stated, this mode of representing it is particularly applicable; it gives a simple, accurate, and permanent idea, by giving form and shape to a number of separate ideas, which are otherwise abstract and unconnected. In a numerical table there are as many distinct ideas given, and to be remembered, as there are sums, the order and progression, therefore, of those sums are also to be recollected by another effort of memory, while this mode unites *proportion*, *progression*, and *quantity* all under one single impression of vision, and consequently one act of memory.[25]

Playfair's insight about the ability of graphical representations to convey 'proportion, progression, and quantity' resonates through the centuries. Indeed, this idea is central to understanding how data visualizations work and, as mentioned in the introduction, it anticipates a modern understanding of cognitive science, visual perception, and psychology. It is also central to an appreciation of how data visualizations can fail or mislead. Charting errors or misleading charts typically fall into one of two categories. The first kind are charts that challenge or confound human perceptual tendencies, making proportion, progression, and quantity harder to measure or compare, as in pie charts, radial charts, and centre-aligned bar charts. The second kind are graphs that misrepresent some aspect of proportion, progression, and quantity, violating norms or expectations: charts where the x-axis does not start at zero or dual axis charts, for example.

One final note about **Figure 29** (and speaking of data visualization errors): the chart appears to report nominal, rather than real, inflation-adjusted, figures for the values of the exports and imports and makes no account for purchasing power parity. For example, inflation had reduced the value of a British pound by over fifty per-cent from 1700 to 1800.[26] Hence, the data in Playfair's chart misrepresent actual differences in value over time. Playfair can be forgiven. The economics of inflation and purchasing power were still in their infancy in the eighteenth century. A similar error can be seen centuries later in **Figure 46**.

One of Playfair's most remarkable works is his 'Chart Representing the Extent, Population & Revenues, of the Principal Nations in Europe, after the Division of Poland & Treaty of Luneville' (**Figure 30**). It contains several innovations in data visualization, including the first pie chart, the first circle chart, a dubious dual-axes mechanism, and what appears to be the first Venn diagram, 80 years before John Venn.[27]

The chart shows circles representing the principal nations of Europe, scaled in proportion to their geographic area. The lines rising tangentially from each circle represent population on the left, in red, and revenue on the right, in yellow. These lines share an ordinal scale, but the left scale is measured in millions of people and the right scale in millions of pounds. Playfair used dotted lines to connect the population and revenue lines and argued that dotted lines with a negative slope indicated that a nation was under-taxed while dotted lines with a positive slope indicated that a nation was over-taxed.

He pointed out that the dotted line for 'Britain & Ireland' had the steepest positive slope in Europe and that, consequently, they had the largest, and most unfair, tax burden. As ingenious as this argument is, it is clearly flawed. First, the chart's dual scale is aligned arbitrarily. As we will see in more detail later, Playfair could stretch or shrink either scale independently and so alter the steepness of the slopes any way he wished. This is now considered inappropriate in data visualization: at best an error, at worst a deception. (For a similar error in a modern context see **Figure 42**). More obviously, the diameter of each circle determines how far apart the various lines showing population and revenue are drawn and hence how the steep the dotted lines connecting them are. (Slope is equal to rise over run.

Thank you, high-school math!). But of course, the geographic area of a nation has no meaningful bearing on its revenue.

Playfair's *Lineal Arithmetic* received virtually no attention in England. Several theories have been advanced to explain this, including noting that Playfair was a scoundrel. In England, statistical data, whether demographic, economic, or otherwise, continued to be reported in tables and analyzed or discussed in sentences until well after Playfair died in 1823. Even in Western Europe where Playfair's reception was favourable, it was not always flattering. In 1805, the French statistician Jacques Peuchet (1758–1830) wrote: 'No one will ever believe that such methods can serve any useful purpose in the study of statistics. They are but plays of the imagination'.[28] Perhaps he was taunting Playfair. Time has proved Playfair correct and Peuchet very, very wrong.

The Golden Age of Data Visualization: Huzzah, Charts, Huzzah!

In the mid-eighteen hundreds, data visualizations began to be used in a new way. Graphic displays became the currency of serious political and scientific discussion. An early historian of data visualization, Howard Funkhouser (1898–1984), described the era from 1860 to 1890 as the 'Golden Age' of graphic representations because of 'the unrestrained enthusiasm not only of statisticians but of government and municipal authorities, by the eagerness with which the possibilities and problems of graphic representation were debated and by the graphic displays which became an important adjunct of almost every kind of scientific gathering'.[29] Funkhouser points to political, mathematical, and technological reasons for these advances. Governments were collecting and publishing significant amounts of demographic and economic data. The era heralded great strides in the mathematical fields of probability and statistics. At the same time, the commercial availability of chromolithography in the 1850s allowed for faster printing and finer gradations of tones and colours, increasing access to visualizations that used shading or filled areas as indicators.

> **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.**

Among the finest examples of compelling 'Golden Age' graphics came from the United States. In 1872, the Secretary of the Interior wrote to the House of Representatives


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.
Compiled from the Returns of Population at the Ninth Census 1870
BY
FRANCIS A. WALKER.
Engaged in Agriculture.
Attending School.
THE UNITED STATES
ALABAMA
ARKANSAS
CALIFORNIA
CONNECTICUT
DELAWARE
FLORIDA
GEORGIA
ILLINOIS
INDIANA
IOWA
KANSAS
KENTUCKY
LOUISIANA
MAINE
MARYLAND
MASSACHUSETTS
MICHIGAN
MINNESOTA
MISSISSIPPI
MISSOURI
NEBRASKA
NEVADA
NEW HAMPSHIRE
NEW JERSEY
NEW YORK
NORTH CAROLINA
OHIO
OREGON
PENNSYLVANIA
RHODE ISLAND
SOUTH CAROLINA
TENNESSEE
TEXAS
VERMONT
VIRGINIA
WEST VIRGINIA
WISCONSIN
DISTRICT OF COLUMBIA
NORTH WEST TERRITORIES
SOUTH WEST TERRITORIES

[Figure 31]

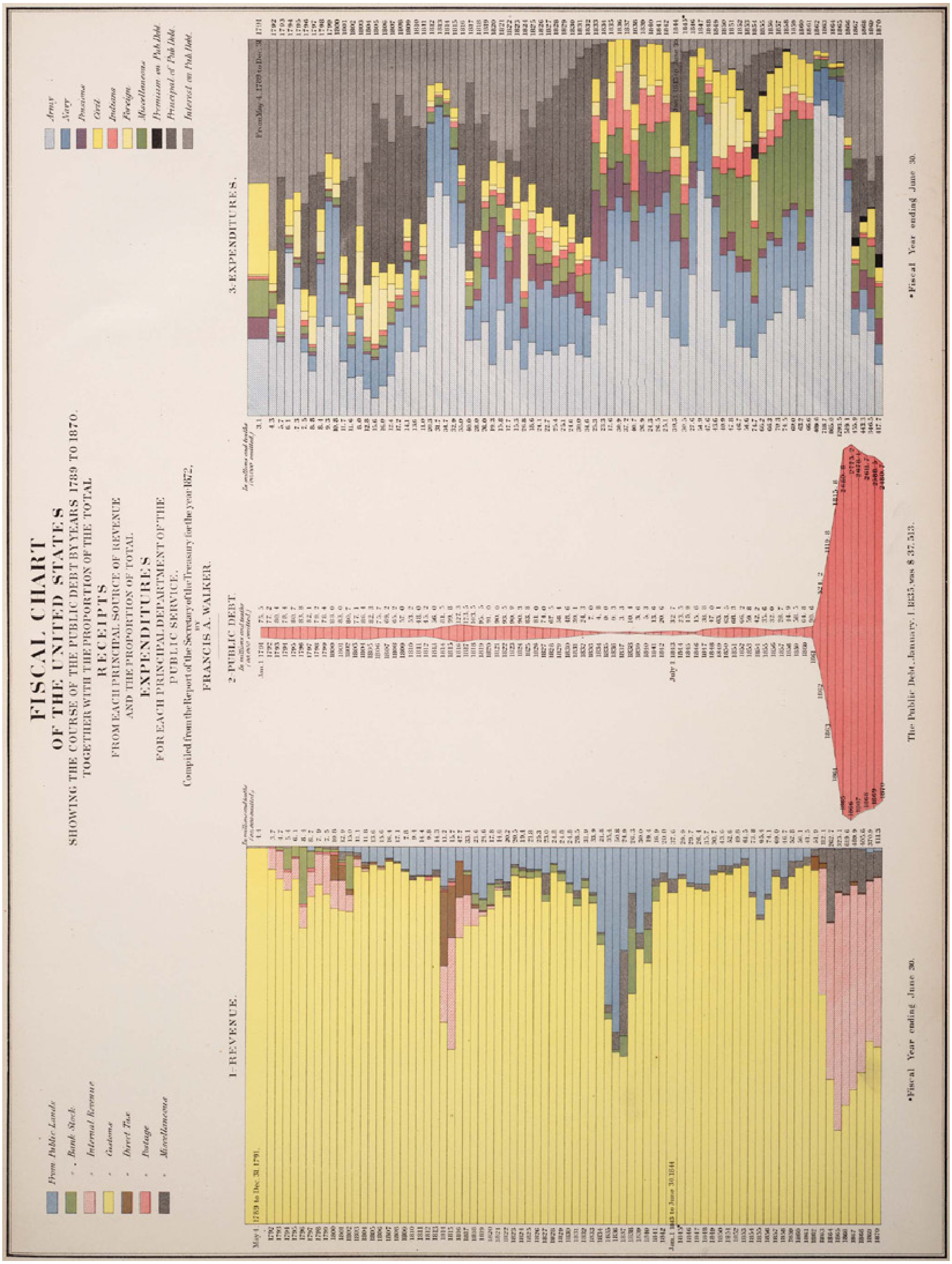
about the 'importance of graphically illustrating' the ninth census of the United States (1870) with maps and other visualizations that would 'exhibit to the eye' various demographic features of the country.[30] Francis A. Walker, chief of the Bureau of Statistics in 1869 and superintendent of the ninth census, led the effort.

The product was unprecedented. The atlas contains 54 technically and aesthetically beautiful maps and charts. The example shown in **Figure 31** (and on the cover of this *Catalogue*) was an innovation for the time.[31] It showed the share of the population engaged in 'gainful occupations' or attending school nationally and by state and broken out by gender. Each square is divided into proportional bars representing the different occupations. The grey, shaded area surrounding each square indicates the share of the population neither gainfully employed nor attending school. One can see straight away the difference between the agricultural-intensive southern states and the more industrial, professional, and education-focused northeast states and California. It is a brilliant and beautiful visualization and an early example of what Tufte would later call 'small multiples'.[32] There is very little extraneous information; every element in the graphic serves the goal of communicating the data clearly and efficiently. The audience's attention is directed to the data and patterns in the data rather than the charting machinery organizing and displaying the data.

The *Atlas* is replete with similar examples. The Secretary of the Smithsonian Institution praised the *Atlas* in a letter to Walker: 'You need not be told', he wrote, 'that it is the best thing of the kind ever attempted for a graphic representation of a vast multitude of important facts'.[33]

Emerging Patterns contains two other examples from the *Atlas*. **Figure 32**, 'Fiscal Chart of the United States' shows national revenue, expenditures, and public debt from 1791 to 1870. Revenue and expenditures are displayed as opposing stacked bar area charts, while public debt is represented by a centre-aligned bar chart that sits between them. The centre-aligned bar chart is unusual, but effective in this instance. (It is a style of visualization that has been abandoned, and we will see why when we consider **Figures 37** and **39**). The effects of the War of 1812, the Mexican-American War of 1847, and the United States Civil War are vividly reflected in each chart.

Figure 33 shows the distribution by age and sex of the deaths that occurred in each state and nationally during the census year 1870, ending June 1. These stacked histograms are immediately recognizable to a modern audience as population or age pyramids, but they were a novelty at the time. Infant mortality was a national blight, the depiction of which is moving. The mid-west was a dangerous place for young and middle-aged men. This is another lovely example of clear, compelling, and informative small multiples.


FISCAL CHART
OF THE UNITED STATES
SHOWING THE COURSE OF THE PUBLIC DEBT BY YEARS 1789 TO 1870.
TOGETHER WITH THE PROPORTION OF THE TOTAL
RECEIPTS
FROM EACH PRINCIPAL SOURCE OF REVENUE
AND THE PROPORTION OF TOTAL
EXPENDITURES
FOR EACH PRINCIPAL DEPARTMENT OF THE
PUBLIC SERVICE.
Compiled from the Report of the Treasury for the year 1872,
BY
FRANCIS A. WALKER.
1-REVENUE.
2-PUBLIC DEBT.
3-EXPENDITURES.
From Public Lands
Bank Stock
Internal Revenue
Customs
Direct Tax
Postage
Miscellaneous
Army
Navy
Pensions
Civil
Indians
Foreign
Miscellaneous
Premium on Pub. Debt.
Principal of Pub. Debt.
Interest on Pub. Debt.
*Fiscal Year ending June 30.
The Public Debt, January 1, 1835, was $ 37,513.

[Figure 32]

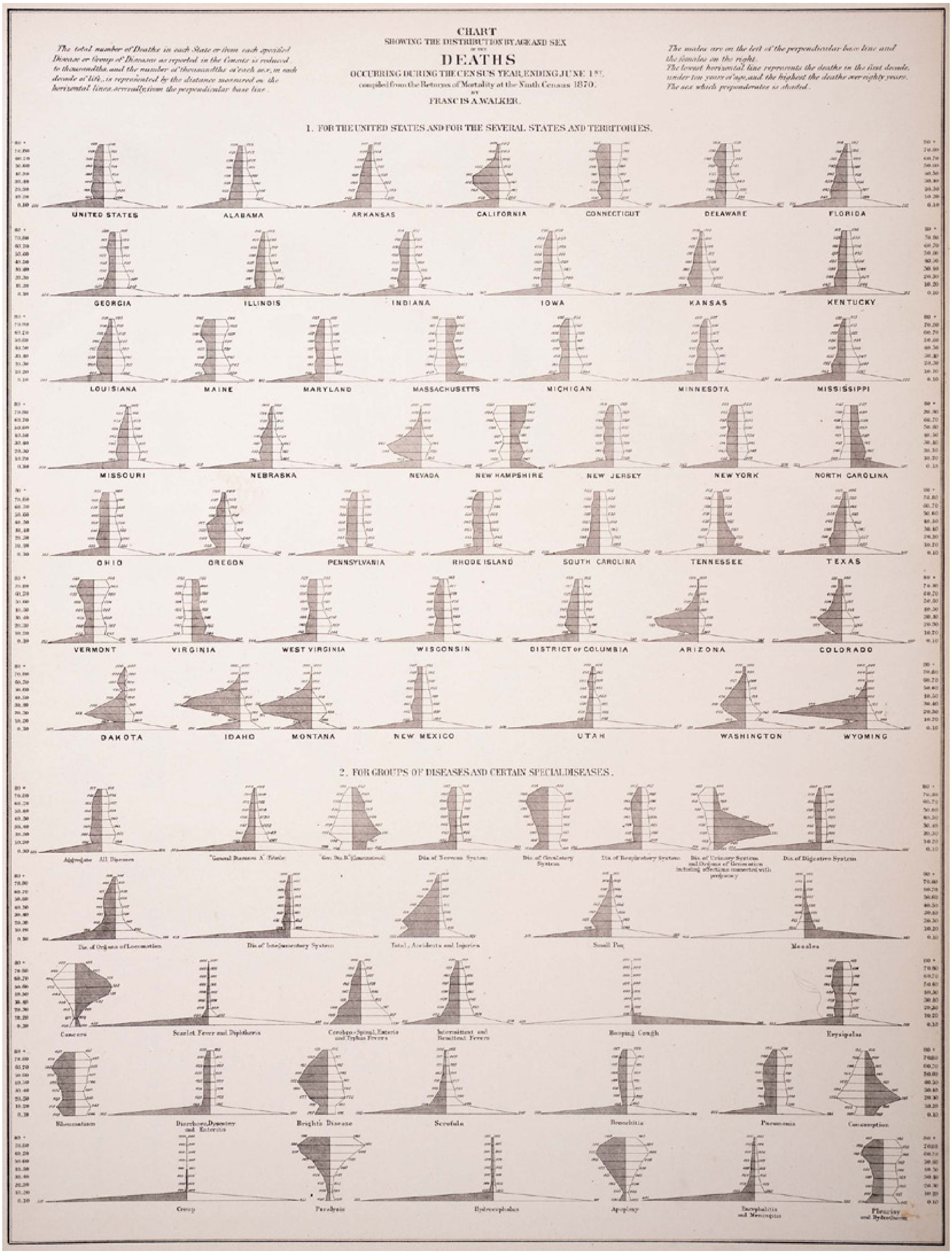
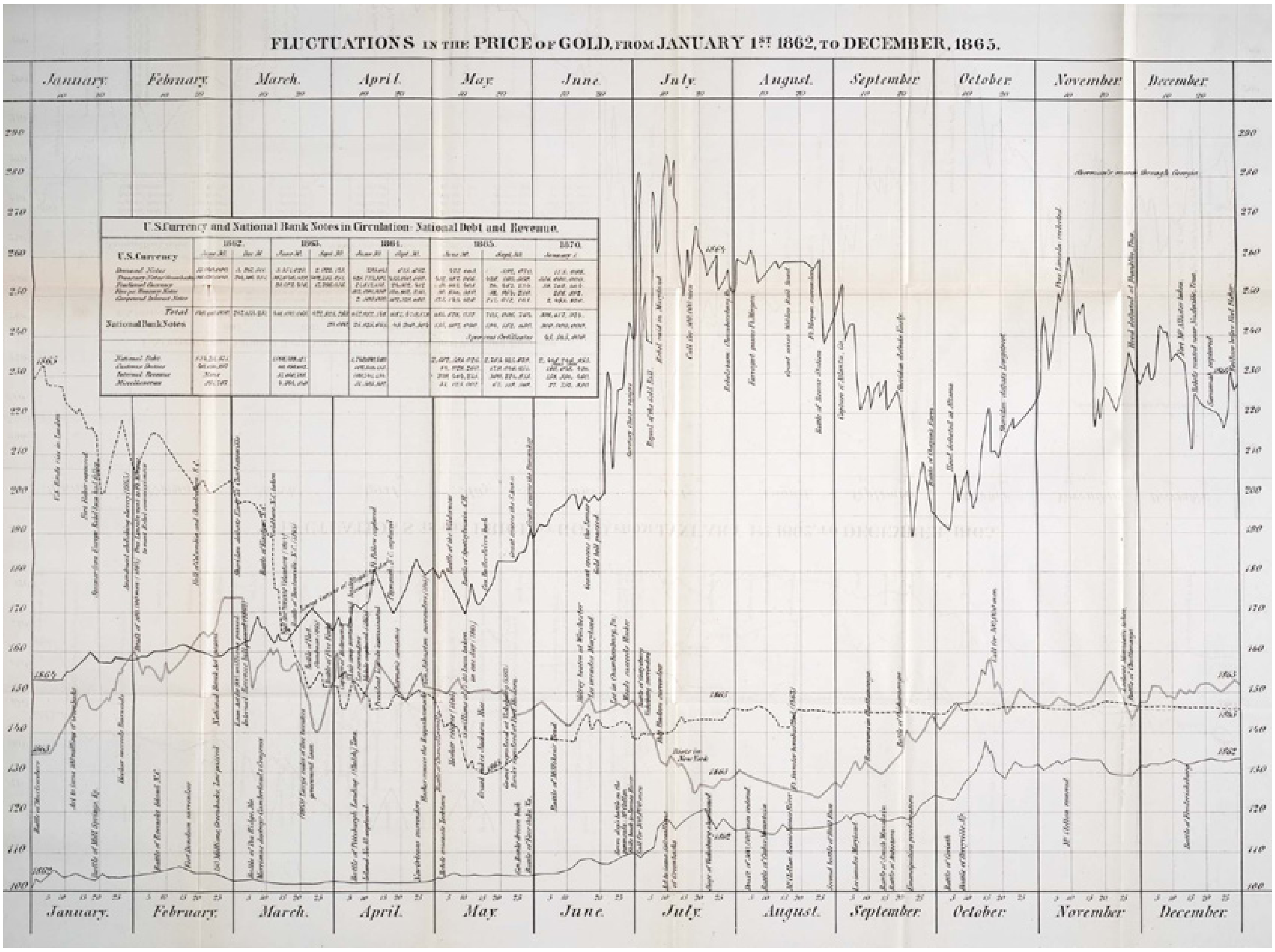


CHART
SHOWING THE DISTRIBUTION BY AGE AND SEX
DEATHS
OCCURRING DURING THE CENSUS YEAR ENDING JUNE 1ST.
compiled from the Returns of Mortality at the Ninth Census 1870.
FRANCIS A. WALKER.
1. FOR THE UNITED STATES AND FOR THE SEVERAL STATES AND TERRITORIES.
2. FOR GROUPS OF DISEASES AND CERTAIN SPECIAL DISEASES.

[Figure 33]

> **Francis Bowen (1811–1890).** ***American Political Economy: Including Strictures on the Management of the Currency and the Finances since 1861: With a Chart Showing the Fluctuations in the Price of Gold*. New York: Scribner, 1870.**

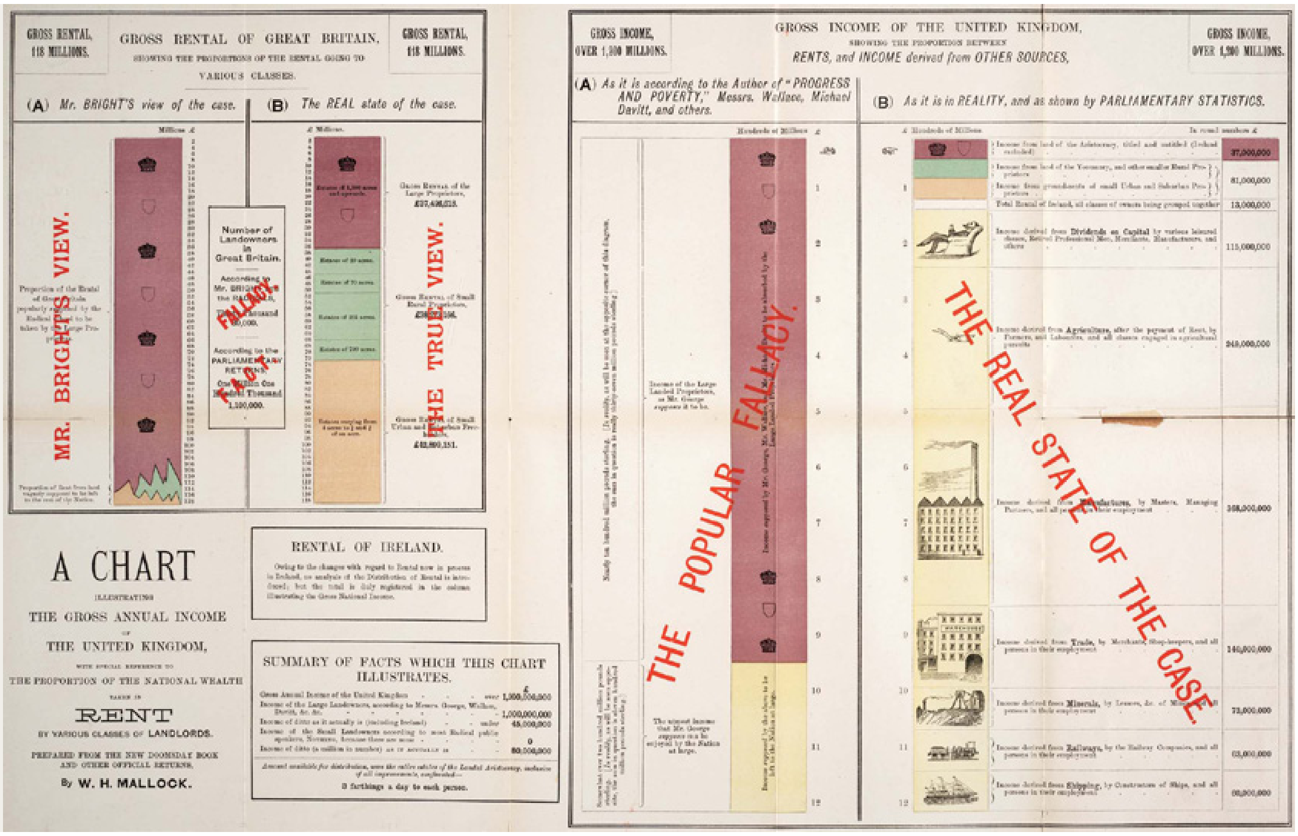
The chart in **Figure 34** is from a textbook for students of political economy (economics) at Harvard University for a class taught by the book's author, Francis Bowen. The book's subtitle highlights the chart itself. In this chart, the month of the year comprises the horizontal axis and the price of gold is plotted on the vertical axis. Four lines represent the fluctuation of gold prices by month for the years 1862, 1863, 1864, and 1865. The way this chart is arranged would be ideal if it were intended to show patterns of how the time of the year affects gold prices, though there does not seem to be a pattern. Because of the design choice to make month of the year the main variable, basic and more interesting questions such as, 'which year had the highest or lowest gold prices?' or 'did gold prices generally go up from year to year?' are not easily answered by looking at this confusing chart.



[Figure 34]

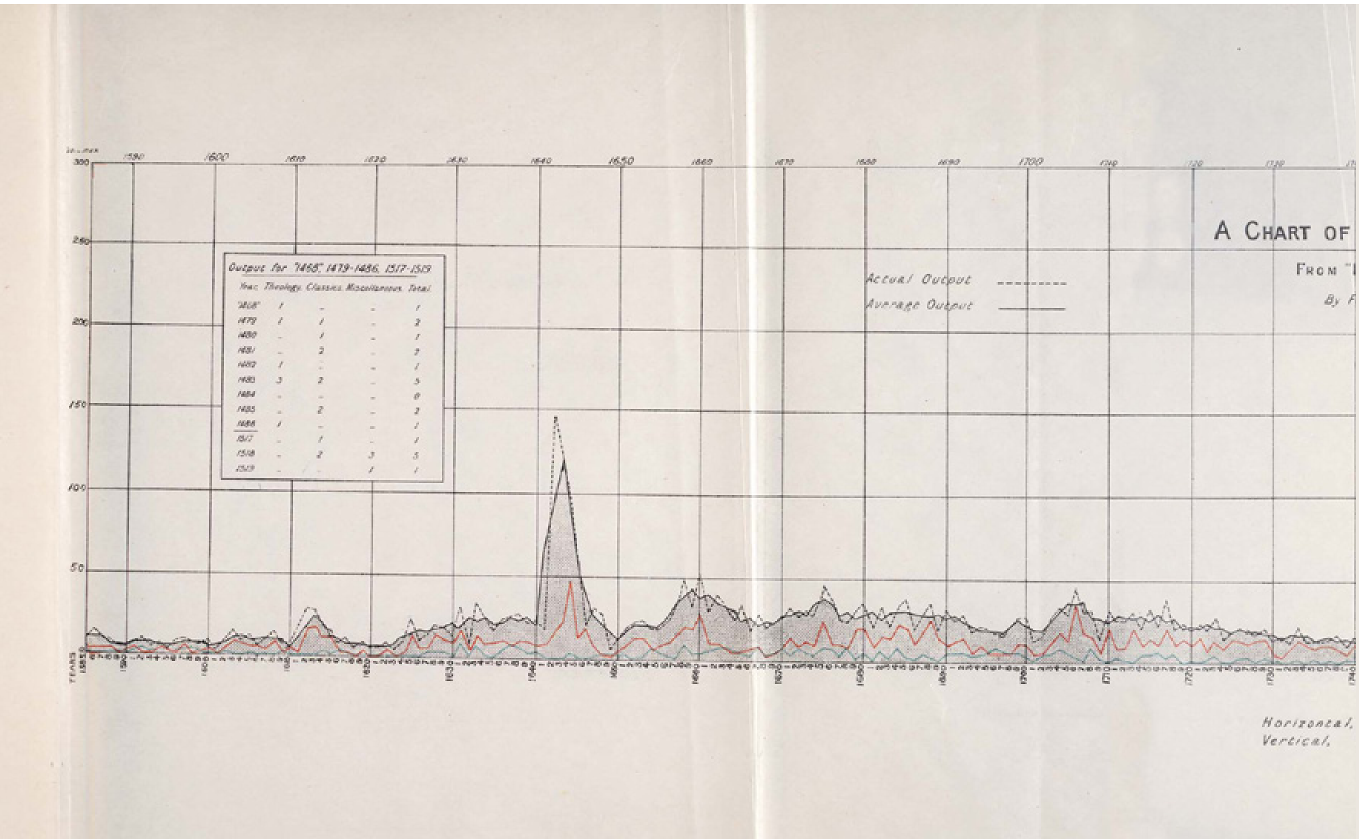
> **William H. Mallock (1849–1923).** ***The Landlords and the National Income: A Chart Showing the Proportion Borne by the Rental of the Landlords to the Gross Income of the People*. London: W.H. Allen, 1884.**

Beyond displaying a stacked bar chart with infographic features, this pamphlet by William Mallock (**Figure 35**), contains overtly persuasive rhetorical elements. The bold language, matched by bold uppercase red letters declaring that one view is 'The Popular Fallacy' while the other is 'The Real State of Affairs', command notice. While an explanation of the data and the interpretations of the Wage Theory of Henry George (1839–1897) accompanies the chart, our focus is dominated by the chart's glitz, which overrides the value of the data. This is also a problem in the infographics from Shimeall (**Figure 13**) and Adams (**Figure 21**), as well as the many modern infographics that follow in the footsteps of this shiny but uninformative style of visualization.



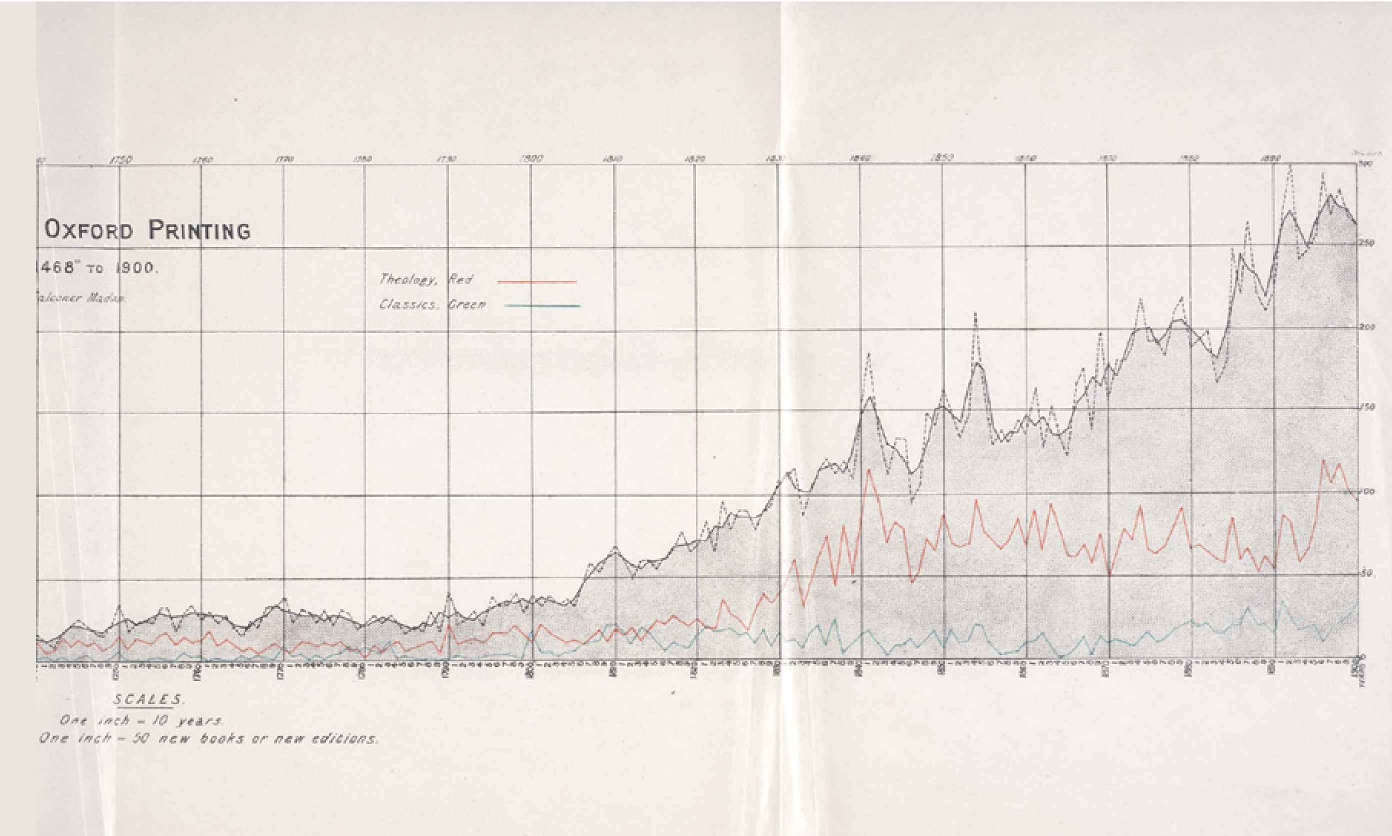
[Figure 35]

Falconer Madan (1851–1935). *A Chart of Oxford Printing, '1468'–1900*. London: Oxford University Press, 1903.



[Figure 36]

Oxford University Press was an early adopter of the printing press and published its first book in 1478. Given the labour involved in early printing and the yet-un-developed audience for printed books, the number of books published was quite low for a long time. The chart in **Figure 36** describing the history of printing at Oxford was created in 1903 by Falconer Madan, the librarian of the Bodleian Library of Oxford University and a lecturer in palaeography. The chart shows the three-year average of number of books published as a grey-filled area graph. Superimposed on the graph as individual line graphs are annual totals with a dashed line, the number of theological books with a red line, and the number of books in the field of Classics with a green line. The theological and Classical books are a subset of the total number. Note that this is not a stacked area graph as the areas below the red and green lines are not shaded; they are separate charts. That this looks at all out-of-the-ordinary is a sign that modern graphic designers have too often turned good line charts into incorrect stacked area charts by arbitrarily adding colour in an attempt to improve a chart's attractiveness. While the chart begins with the first book published in 1478, it was many years before printing books became more common. Until 1520, the Press published, on average, one book

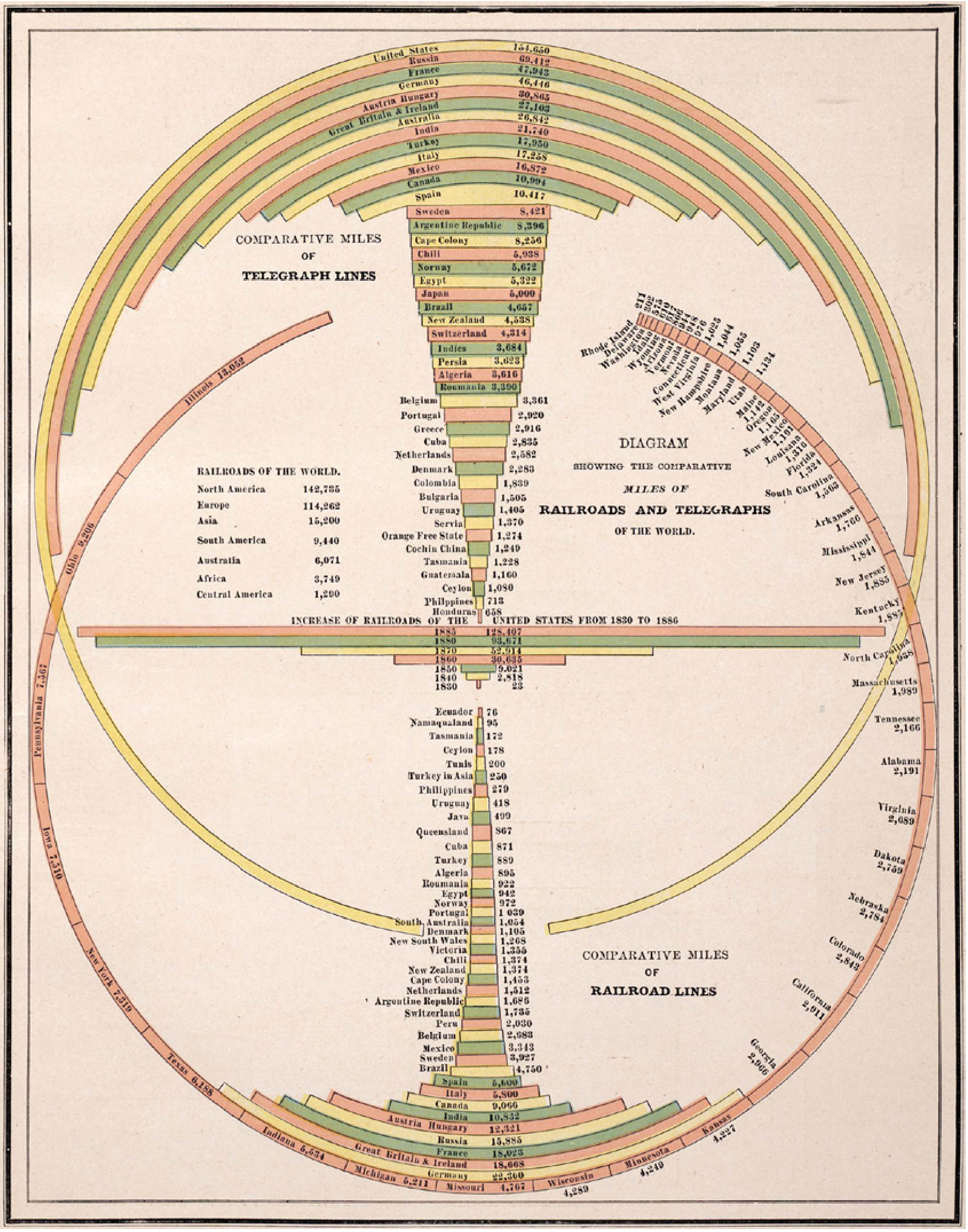


or fewer every two years. The first large jump in publication numbers came in 1642 from the many proclamations, letters and pamphlets issued when King Charles I moved his court to Oxford during the English Civil War.

George Franklin Cram (1841–1928). *Cram's Unrivaled Family Atlas of the World*. Chicago: G. F. Cram, 1886.

***The Home Knowledge Atlas: Geographical, Astronomical, Historical, Showing the Greatest Number of Maps of Any Atlas Published in the World*. Toronto: Home Knowledge Association, 1888.**

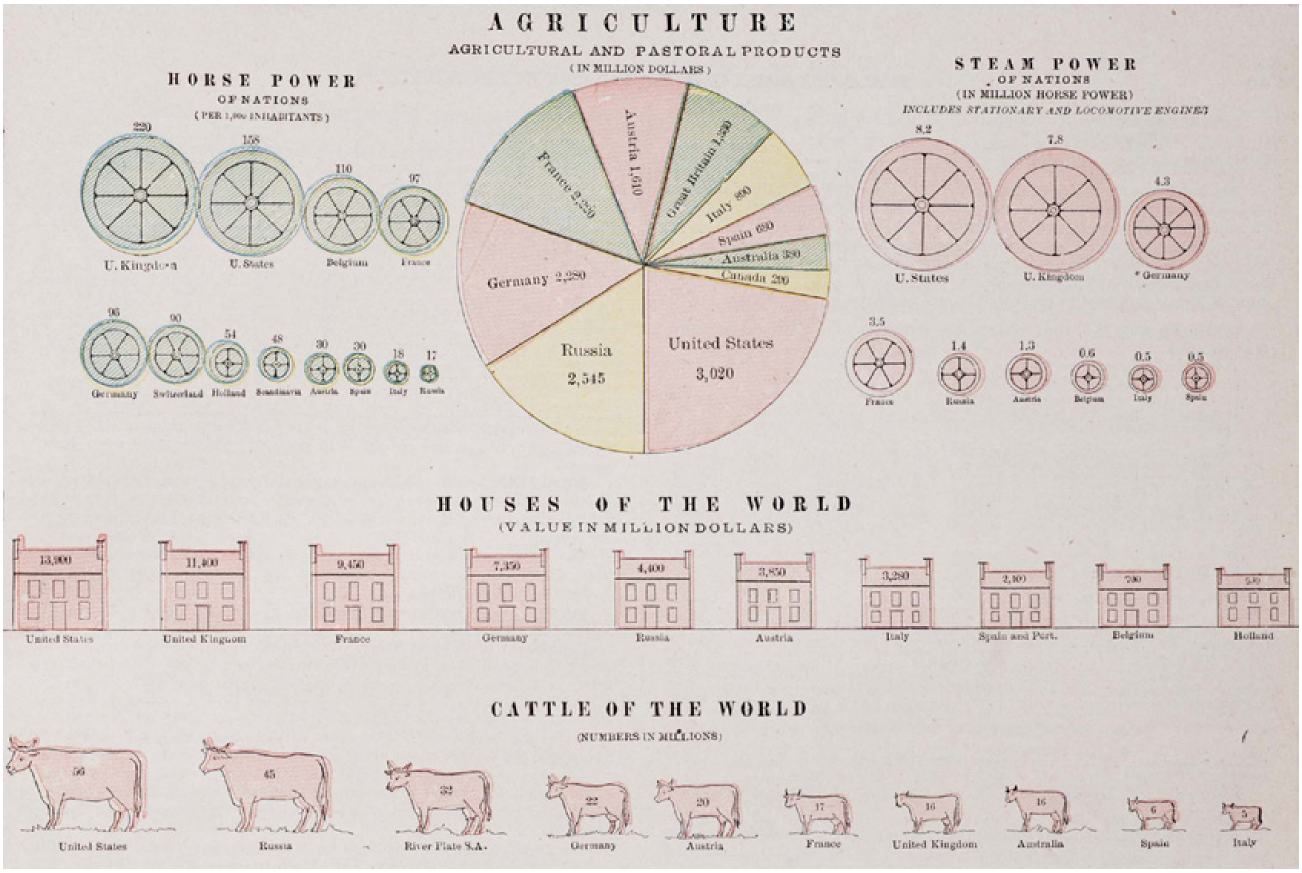
George F. Cram was a map and atlas publisher in late nineteenth century America. His wonderfully-named *Unrivaled Family Atlas of the World* saw many editions and, thanks to advances in publishing, was affordable enough to receive a wide distribution.


COMPARATIVE MILES OF TELEGRAPH LINES
DIAGRAM SHOWING THE COMPARATIVE MILES OF RAILROADS AND TELEGRAPHS OF THE WORLD.
COMPARATIVE MILES OF RAILROAD LINES
RAILROADS OF THE WORLD.
North America 142,735
Europe 114,262
Asia 15,200
South America 9,440
Australia 6,071
Africa 3,749
Central America 1,290
INCREASE OF RAILROADS OF THE UNITED STATES FROM 1830 TO 1886
1885 128,407
1880 93,671
1870 52,914
1860 30,635
1850 9,021
1840 2,818
1830 23
United States 154,650
Russia 69,412
France 47,943
Germany 46,446
Austria Hungary 30,865
Great Britain & Ireland 27,103
Australia 26,842
India 21,740
Turkey 17,950
Italy 17,258
Mexico 16,872
Canada 10,994
Spain 10,417
Sweden 8,421
Argentine Republic 8,396
Cape Colony 8,256
Chili 5,938
Norway 5,672
Egypt 5,322
Japan 5,000
Brazil 4,657
New Zealand 4,538
Switzerland 4,314
Indies 3,684
Persia 3,623
Algeria 3,616
Roumania 3,390
Belgium 3,361
Portugal 2,920
Greece 2,916
Cuba 2,835
Netherlands 2,582
Denmark 2,283
Colombia 1,839
Bulgaria 1,505
Uruguay 1,405
Servia 1,370
Orange Free State 1,274
Cochin China 1,249
Tasmania 1,228
Guatemala 1,160
Ceylon 1,080
Philippines 713
Honduras 658
Ecuador 76
Namaqualand 95
Tasmania 172
Ceylon 178
Tunis 200
Turkey in Asia 250
Philippines 279
Uruguay 418
Java 499
Queensland 867
Cuba 871
Turkey 889
Algeria 895
Roumania 922
Egypt 942
Norway 972
Portugal 1 039
South Australia 1,054
Denmark 1,105
New South Wales 1,268
Victoria 1,355
Chili 1,374
New Zealand 1,374
Cape Colony 1,453
Netherlands 1,512
Argentine Republic 1,686
Switzerland 1,735
Peru 2,030
Belgium 2,683
Mexico 3,343
Sweden 3,927
Brazil 4,750
Spain 5,600
Italy 5,800
Canada 9,066
India 10,832
Austria Hungary 12,321
Russia 15,885
France 18,023
Great Britain & Ireland 18,668
Germany 22,300
Illinois 13,052
Ohio 9,206
Pennsylvania 7,367
Iowa 7,510
New York 7,310
Texas 6,188
Indiana 5,634
Michigan 6,211
Missouri 4,767
Wisconsin 4,289
Minnesota 4,249
Kansas 4,227
Georgia 2,966
California 2,911
Colorado 2,843
Nebraska 2,784
Dakota 2,759
Virginia 2,689
Alabama 2,191
Tennessee 2,166
Massachusetts 1,989
North Carolina 1,938
Kentucky 1,887
New Jersey 1,885
Mississippi 1,844
Arkansas 1,766
South Carolina 1,565
Florida 1,324
Louisiana 1,310
New Mexico 1,161
Oregon 1,165
Maine 1,142
Rhode Island
Delaware
Washington
Idaho
Wyoming
Arizona
Vermont
Nevada
Connecticut
West Virginia
New Hampshire
Montana
Maryland
Utah
1,023
1,044
1,055
1,103
1,134

[Figure 37]

Unfortunately, many of the *Atlas'* data visualizations, while attractive, were difficult to interpret. **Figure 37**, 'Diagram Showing the Comparative Miles of Railroads and Telegraphs of the World', is a typical example. It is a bar chart, centre-aligned, curved to fit on the page and coloured using only three colours in repetition. The lengths of arcs are notoriously difficult for the human eye to compare. Psychologists had just started describing and cataloging such visual challenges and illusions in the late 1800s in their efforts to study human perception and cognition. Joseph Jastrow (1863–1944) reported on the problems of comparing adjacent arcs in 1892.[34] Moreover, the longest bar in the chart of railroad lines, the bar representing the United States, is subdivided into many smaller, same-coloured segments representing individual states, compounding the visual challenges.

In **Figure 38**, the total value of housing in millions of dollars, total number of cows in millions, and the total amount of capital invested in railways in millions of dollars in various countries are depicted by pink house, cow, and train wheel icons. There is one icon per country, with the size of the icons corresponding to the relative value of each variable for that country. This display is suggestive of later designs using Isotypes (such as **Figures 43–46**). The key difference is that in Isotypes values are represented by multiple numbers of identically sized icons, as opposed



[Figure 38]

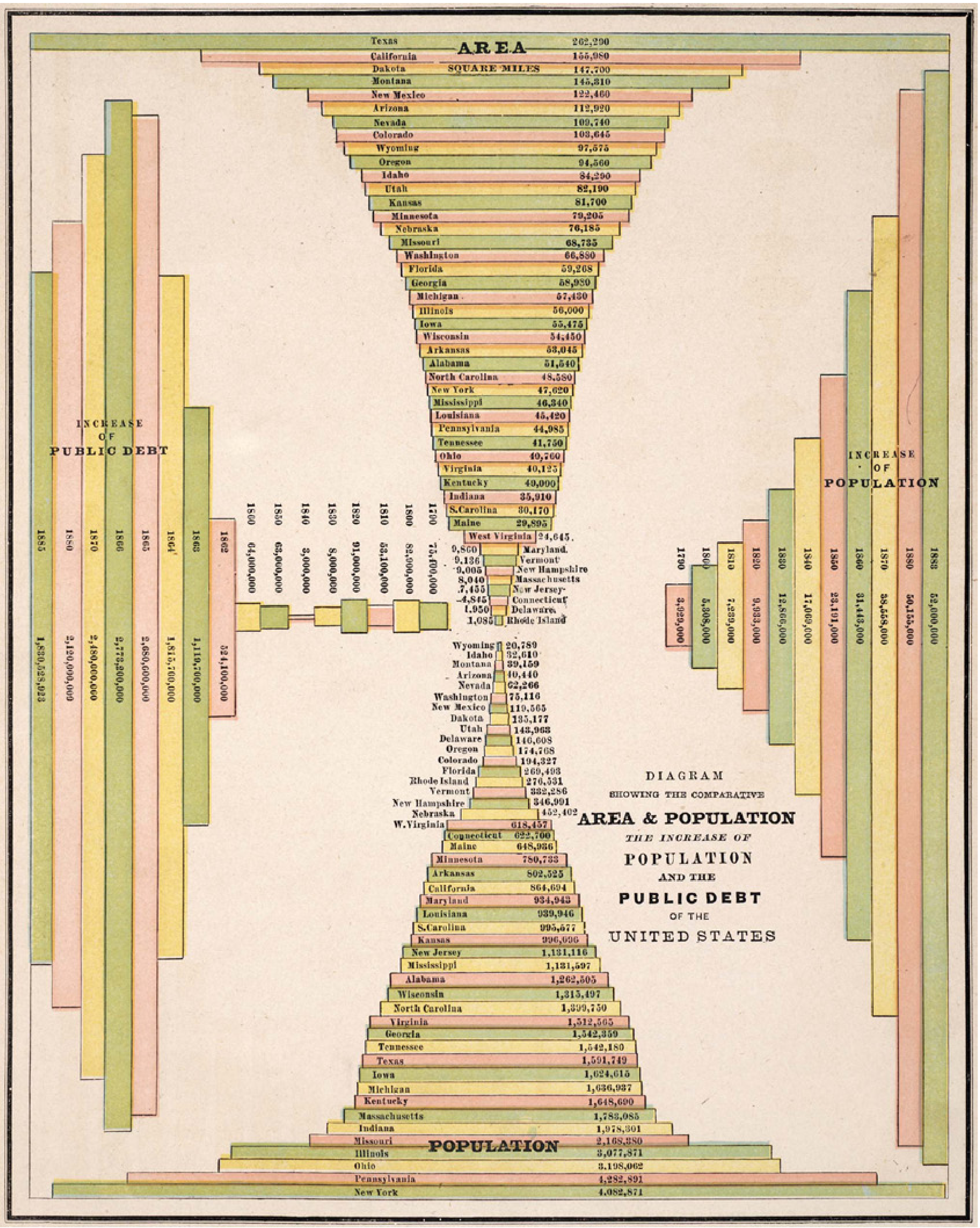


DIAGRAM
SHOWING THE COMPARATIVE
AREA & POPULATION
THE INCREASE OF
POPULATION
AND THE
PUBLIC DEBT
OF THE
UNITED STATES
AREA
SQUARE MILES
Texas 262,290
California 155,980
Dakota 147,700
Montana 145,310
New Mexico 122,460
Arizona 112,920
Nevada 109,740
Colorado 103,645
Wyoming 97,575
Oregon 94,560
Idaho 84,290
Utah 82,190
Kansas 81,700
Minnesota 79,205
Nebraska 76,185
Missouri 68,735
Washington 66,880
Florida 59,268
Georgia 58,980
Michigan 57,430
Illinois 56,000
Iowa 55,475
Wisconsin 54,450
Arkansas 53,045
Alabama 51,540
North Carolina 48,580
New York 47,620
Mississippi 46,340
Louisiana 45,420
Pennsylvania 44,985
Tennessee 41,750
Ohio 40,760
Virginia 40,125
Kentucky 40,000
Indiana 35,910
S.Carolina 30,170
Maine 29,895
West Virginia 24,645
9,860 Maryland
9,136 Vermont
9,005 New Hampshire
8,040 Massachusetts
7,455 New Jersey
4,845 Connecticut
1,950 Delaware
1,085 Rhode Island
INCREASE OF PUBLIC DEBT
1885 1,830,528,923
1880 2,120,000,000
1870 2,480,000,000
1866 2,773,200,000
1865 2,680,600,000
1864 1,815,700,000
1863 1,119,700,000
1862 524,100,000
1860 64,000,000
1850 63,000,000
1840 3,000,000
1830 8,000,000
1820 91,000,000
1810 53,100,000
1800 82,900,000
1790 75,400,000
INCREASE OF POPULATION
1790 3,929,000
1800 5,308,000
1810 7,239,000
1820 9,633,000
1830 12,866,000
1840 17,069,000
1850 23,191,000
1860 31,443,000
1870 38,558,000
1880 50,155,000
1883 53,000,000
Wyoming 20,789
Idaho 32,610
Montana 39,159
Arizona 40,440
Nevada 62,266
Washington 75,116
New Mexico 119,565
Dakota 135,177
Utah 143,963
Delaware 146,608
Oregon 174,768
Colorado 194,327
Florida 269,493
Rhode Island 276,531
Vermont 332,286
New Hampshire 346,991
Nebraska 452,402
W.Virginia 618,457
Connecticut 622,700
Maine 648,936
Minnesota 780,733
Arkansas 802,525
California 864,694
Maryland 934,943
Louisiana 939,946
S.Carolina 995,577
Kansas 996,096
New Jersey 1,131,116
Mississippi 1,131,597
Alabama 1,262,505
Wisconsin 1,315,497
North Carolina 1,399,750
Virginia 1,512,565
Georgia 1,542,359
Tennessee 1,542,180
Texas 1,591,749
Iowa 1,624,615
Michigan 1,636,937
Kentucky 1,648,690
Massachusetts 1,783,085
Indiana 1,978,301
Missouri 2,168,380
POPULATION
Illinois 3,077,871
Ohio 3,198,062
Pennsylvania 4,282,891
New York 4,082,871

[Figure 39]

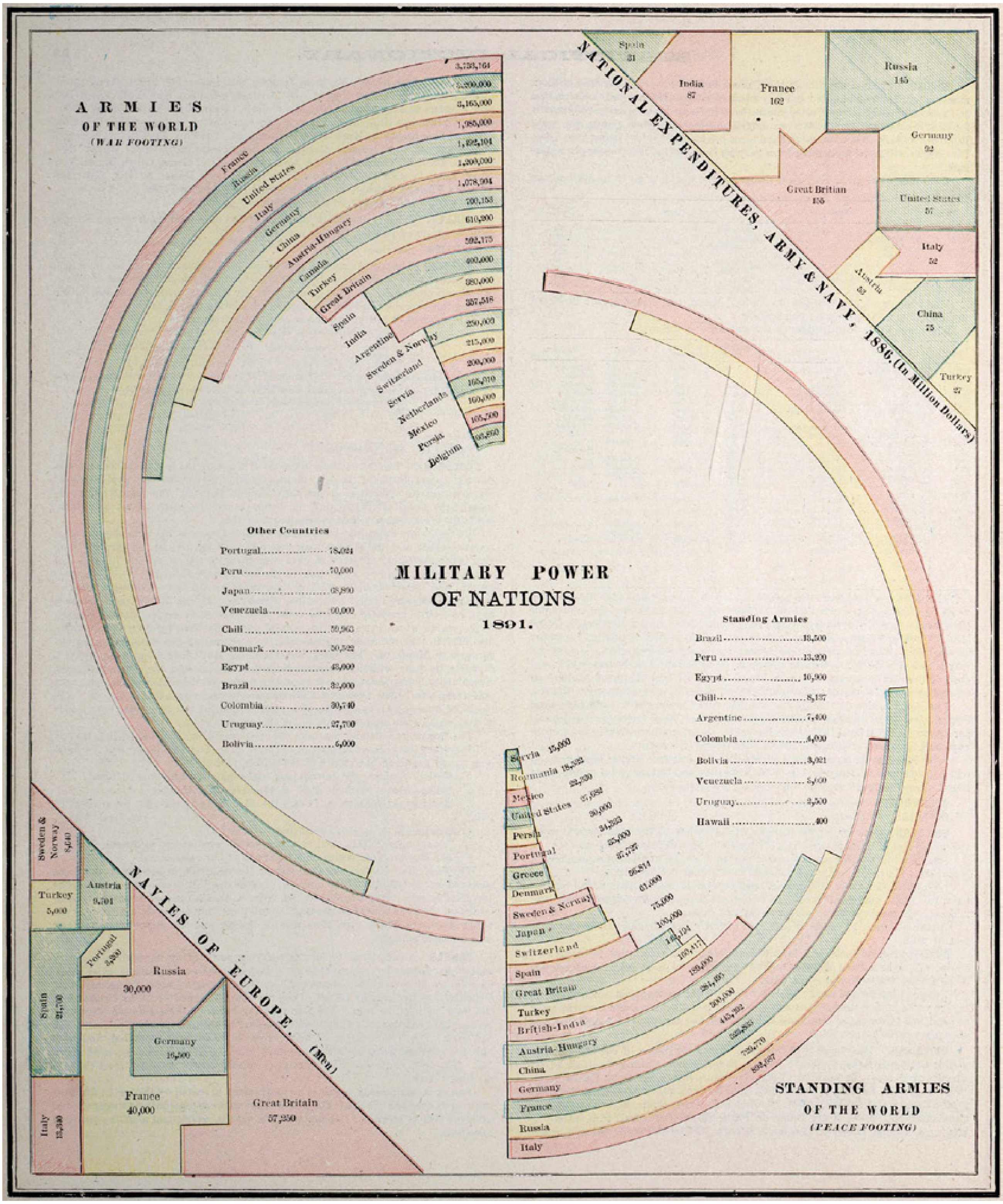
icons of different sizes, so that comparisons can be made by using the cardinality, length, or height of the clusters of icons. In **Figure 38**, comparing the area of one pink cow to another is extremely difficult, beyond the simple observation that one is bigger than another. How much bigger is impossible to say. The Isotype method solves this problem.

Figure 39 showing area, population, and public debt is another set of centre-aligned bar charts. The main problem with such charts is that, without a common starting point as a reference, it is difficult to compare the lengths of the bars. On the area chart, the bar representing Texas is clearly longer than the bar representing Dakota. As with the pink cows, we can say one bar is bigger than the other, but how much bigger? Is it twice as long? It is hard to say. The chart of public debt on the left recalls Francis Walker's version we encountered earlier from the *Statistical Atlas* (**Figure 32**). But why does Cram use different colours? By invoking the same schema Cram used to indicate different states or countries in other charts, the audience is easily misled into thinking the different colours represent different states or countries in this chart. But the bars represent different years. In fact, one has only to compare Cram's chart of public debt with Walker's to appreciate the superiority of the latter.

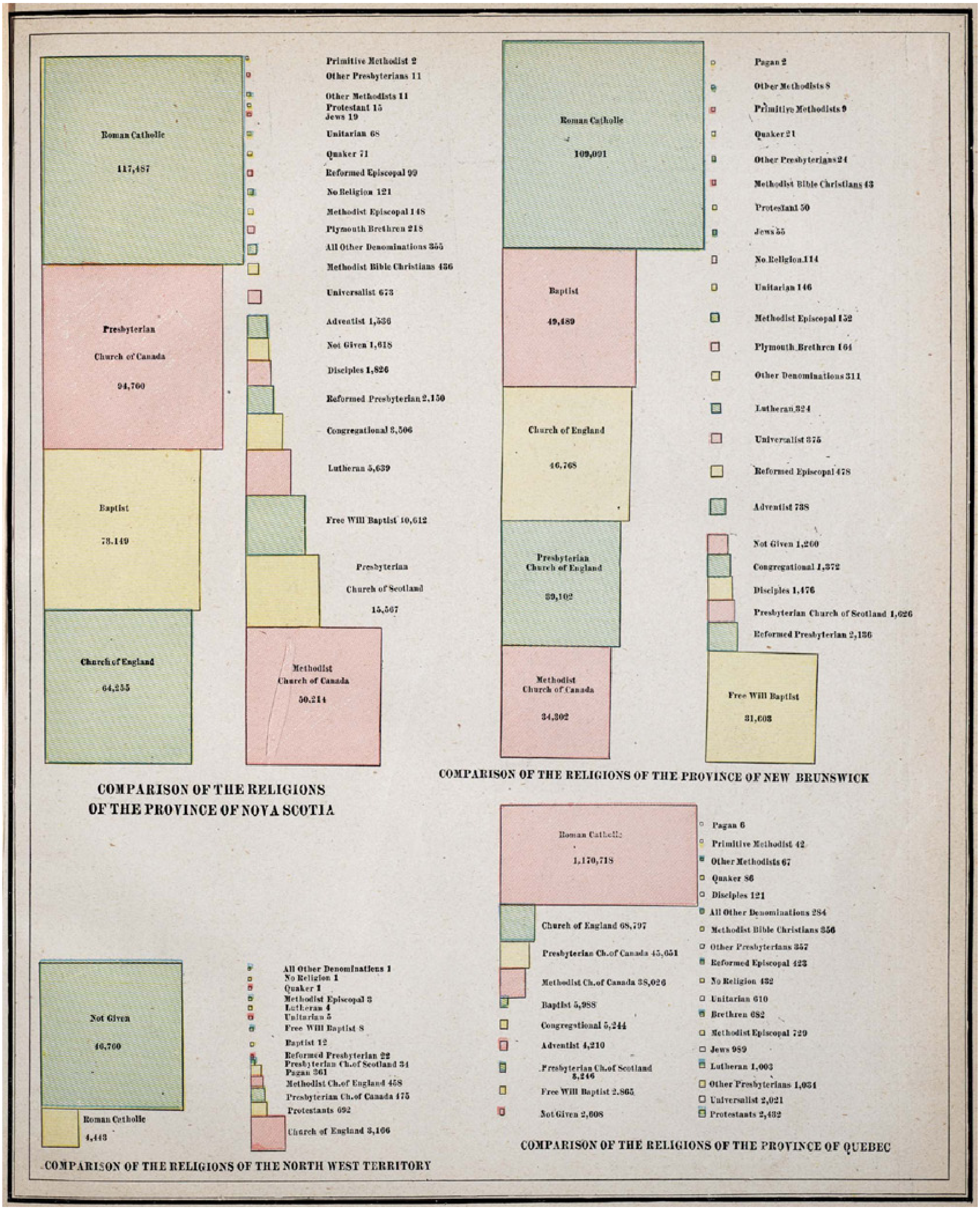
Figure 40 displays especially confusing area charts with oddly subdivided regions. As with the other examples from Cram's *Atlas*, it appears the designers prized form over function. The shapes of the data visualizations allowed a greater number of visualizations to appear on each page, each in interesting or attractive patterns. But, consequently, the content was harder to interpret. In this respect, Cram was decades ahead of his time: designers today often choose shiny interfaces and fancy graphics over easy-to-interpret data visualizations.

The George F. Cram Company published a version of the *Unrivaled Atlas* in Canada called *The Home Knowledge Atlas*. The Canadian edition was published in Toronto and contained several charts specific to Canada. **Figure 41** shows a comparison chart using squares of different sizes (again in the same three-colour theme). The chart depicts the relative sizes of various religious denominations as a proportion of the populations of several Canadian provinces. But, as with the other examples from Cram's *Atlas*, the sizes of the boxes are hard to compare. To make matters worse, in this instance, the graphical elements of the visualization are disproportionately scaled. The 'Roman Catholic' box in the Nova Scotia section is 3,500 times as large as the 'Primitive Methodist' box, but according to the data accompanying the chart, there are roughly 59,000 times as many Roman Catholics in Nova Scotia as there are Primitive Methodists.

Cram's atlases reflect the wide popularity of data visualization in his time. The charts and graphs command attention and are visually interesting. But as data visualizations they were flops. Data visualizations are not, or are not supposed to be, pretty diagrams bearing some imprecise or arbitrary relation to data elements


ARMIES
OF THE WORLD
(WAR FOOTING)
France
Russia
United States
Italy
Germany
China
Austria-Hungary
Canada
Turkey
Great Britain
Spain
India
Argentine
Sweden & Norway
Switzerland
Servia
Netherlands
Mexico
Persia
Belgium
NATIONAL EXPENDITURES, ARMY & NAVY, 1886. (In Million Dollars)
Spain 31
India 87
France 162
Russia 145
Germany 92
Great Britian 155
United States 57
Italy 52
Austria 53
China 75
Turkey 27
Other Countries
Portugal 78,024
Peru 70,000
Venezuela 60,000
Denmark 50,522
Egypt 48,000
Brazil 32,000
Colombia 30,740
Uruguay 27,700
Bolivia 6,000
MILITARY POWER
OF NATIONS
1891.
Standing Armies
Brazil 18,500
Peru 13,200
Egypt 10,900
Argentine 7,400
Colombia 4,000
Bolivia 3,021
Uruguay 2,500
Hawaii 400
NAVIES OF EUROPE. (Men)
Sweden & Norway
Turkey 5,000
Austria 9,701
Portugal 3,200
Russia 30,000
Spain
Germany 16,500
France 40,000
Great Britain 57,250
Italy
Servia 15,000
Roumania
Mexico
United States
Persia
Portugal
Greece
Denmark
Sweden & Norway
Japan
Switzerland
Spain
Great Britain
Turkey
British-India
Austria-Hungary
China
Germany
France
Russia
Italy
STANDING ARMIES
OF THE WORLD
(PEACE FOOTING)

[Figure 40]


Roman Catholic
117,487
Presbyterian
Church of Canada
94,760
Baptist
73.149
Church of England
64,255
Primitive Methodist 2
Other Presbyterians 11
Other Methodists 11
Protestant 15
Jews 19
Unitarian 68
Quaker 71
Reformed Episcopal 99
No Religion 121
Methodist Episcopal 148
Plymouth Brethren 218
All Other Denominations 355
Methodist Bible Christians 436
Universalist 673
Adventist 1,536
Not Given 1,618
Disciples 1,826
Reformed Presbyterian 2,150
Congregational 3,506
Lutheran 5,639
Free Will Baptist 10,612
Presbyterian
Church of Scotland
15,567
Methodist
Church of Canada
50.214
COMPARISON OF THE RELIGIONS
OF THE PROVINCE OF NOVA SCOTIA
Roman Catholic
109,091
Baptist
49,489
Church of England
46,768
Presbyterian
Church of England
39,102
Methodist
Church of Canada
34,302
Pagan 2
Other Methodists 8
Primitive Methodists 9
Quaker 21
Other Presbyterians 24
Methodist Bible Christians 43
Protestant 50
Jews 55
No Religion 114
Unitarian 146
Methodist Episcopal 152
Plymouth Brethren 164
Other Denominations 311
Lutheran 324
Universalist 375
Reformed Episcopal 478
Adventist 738
Not Given 1,260
Congregational 1,372
Disciples 1,476
Presbyterian Church of Scotland 1,626
Reformed Presbyterian 2,136
Free Will Baptist
31,603
COMPARISON OF THE RELIGIONS OF THE PROVINCE OF NEW BRUNSWICK
Roman Catholic
1,170,718
Church of England 68,797
Presbyterian Ch.of Canada 45,051
Methodist Ch.of Canada 38,026
Baptist 5,988
Congregational 5,244
Adventist 4,210
Presbyterian Ch.of Scotland
5,246
Free Will Baptist 2.865
Not Given 2,608
Pagan 6
Primitive Methodist 42
Other Methodists 67
Quaker 86
Disciples 121
All Other Denominations 284
Methodist Bible Christians 356
Other Presbyterians 357
Reformed Episcopal 423
No Religion 432
Unitarian 610
Brethren 682
Methodist Episcopal 729
Jews 989
Lutheran 1,003
Other Presbyterians 1,034
Universalist 2,021
Protestants 2,432
COMPARISON OF THE RELIGIONS OF THE PROVINCE OF QUEBEC
Not Given
46,700
Roman Catholic
4,443
All Other Denominations 1
No Religion 1
Quaker 1
Methodist Episcopal 3
Lutheran 4
Unitarian 5
Free Will Baptist 8
Baptist 12
Reformed Presbyterian 22
Presbyterian Ch.of Scotland 34
Pagan 361
Methodist Ch.of England 458
Presbyterian Ch.of Canada 475
Protestants 692
Church of England 3,166
COMPARISON OF THE RELIGIONS OF THE NORTH WEST TERRITORY

[Figure 41]

referred to in the diagrams. As we noted in the introduction, data visualizations are designed to help observers make judgements about relationships and patterns in collections of data. They are supposed to help audiences understand and reason about data. When they confuse or lead audiences to make erroneous judgements, they are failures or, worse, deceptions.

Calls for Standardization

As is so often the case with new technology, enthusiasm accompanied popularity. Cram's atlases typify the trend. Funkhouser described this phenomenon with characteristic aplomb: 'In addition to its more serious applications in the study and analysis of statistical data in the work of professional statisticians, it became a fascinating plaything in the hands of many others who had little or no statistical training. Everyone ventured boldly into this new language, there being no restrictions but the limits of one's imagination and ingenuity'.[35] This enthusiasm spawned many beautiful and influential examples of data visualization as well as several new and ingenious innovations. It also spawned exuberant failures, confusions, and abuses. These sorts of challenges attracted the attention of professionals. With the increasing popularity of statistics and data visualization, and with each author or national bureau creating their own styles of graphic using their own interpretations of data, comparisons among the various works of individuals or nations became difficult or impossible.

It is not surprising, therefore, that professional statisticians began to call for international standards. Between 1853 and 1880 a series of International Statistical Congresses were held and standards for 'the graphical method' were on the agenda at many of them. There were debates over how to classify visualizations, what sorts of curves should be used, how to standardize charts and data for comparability, and more. No standards were ever agreed upon. Ultimately, as one participant argued in 1869, the Congresses were approaching the problem from the wrong direction. He suggested that they had been mistaken to insist on the comparability of *graphs*. Rather, he wrote, 'the same end can be obtained by a shorter route. It is not a question of rendering diagrams uniform; it is rather a question of applying the graphic method to comparable statistics ... There must reign in this domain the greatest freedom of the imagination and of the mind. Let uniformity be applied where it is good and proper, but leave to our statistical diagrams their national and individual habit'.[36] This is correct, but it left open the question of what norms and conventions data visualizations should abide by. What was the grammar of this new language? To a large degree, the answer to this question was left to evolution. Successful visualizations were refined and improved. Unsuccessful ones were abandoned. Generations of statisticians, researchers, designers, and communications professionals would shape the field of data visualization as they continue to do today.

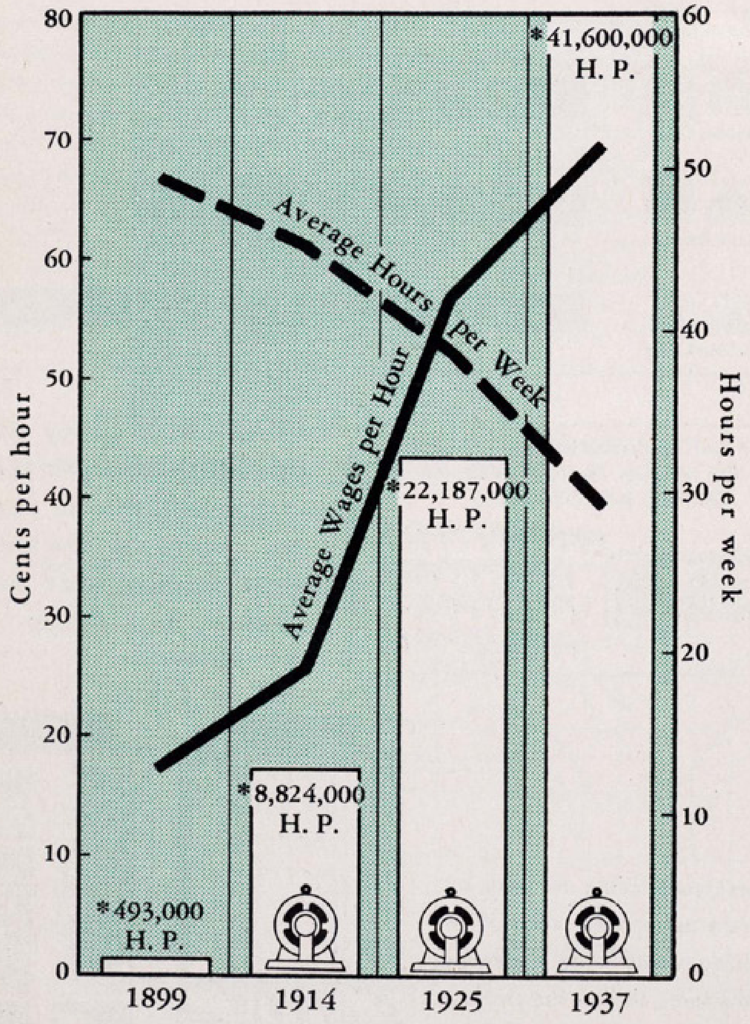
Willard C. Brinton. *Graphic Presentation*. New York: Brinton Associates, 1939.

The first textbook written on data visualization, *Graphic Methods for Presenting Facts*, was written by engineer and statistician Willard Brinton in 1914. In 1916, Briton led a commission of the American Statistical Association to produce standards for graphic presentation. It contained both technical advice on how to create heatmaps or how to use drafting tools, and critiques of methods by, for example, advocating for stacked bar charts over pie charts (a sensible idea). His overview and critiques of visualizations from the past with the goal of creating principles for good graphic presentations were echoed by Edward Tufte decades later. *Graphic Methods for Presenting Facts* was also the first such book to be written for a general audience, as opposed to fellow statisticians. He wrote of his 'constant effort to present the subject to suit the point of view of the business man, the social worker, and the legislator'.[37]

The soundness and comprehensiveness of the book make it all the more disappointing to find an example of a dual axis graph in his 1939 revamped edition, *Graphic Presentation*. A dual axis graph is one in which two unrelated variables are plotted on the same graph, each measured against a different vertical axis. In the example in **Figure 42**, three variables are plotted on one graph: the amount of electrical power used in factories each year, the average wage of factory workers per hour, and the average number of hours worked per week for factory workers. It is intended to show that as electrical power use increases, wages increase and hours per week decrease, though the graph cannot support such conclusions.

When two scales share the same graph for different sets of data, there is no reason the scales need to be positioned in any particular way. Aligning them as in **Figure 42** is entirely arbitrary. Therefore, the relationship between the two lines in terms of where they intersect and the angle of their slopes is also arbitrary. By cleverly choosing the scales of the two variables, a designer can create graphs where the variables have either steep or shallow slopes with respect to one another and can manipulate where the lines will cross or if they cross at all. In the example in **Figure 42**, the slopes of the lines indicating increasing wages and decreasing hours per week can be completely altered by choosing different scales for each line, and by selecting different increments or different start and end points.

Dual axis graphs are deceptive because in a canonical graph, steep slopes or intersecting lines are meaningful cues that have particular interpretations and afford specific inferences. In a dual axis graph those inferences cannot be drawn because the cues upon which they are based can be manipulated. Refraining from making such inferences requires conscious effort to override the norms and



Electrical World, October 8, 1938. Part of an Editorial on Public Relations Entitled "What Electricity Means to America."

SCALE .6

A Comparison of the Status of Labor in the Electrical Industry and the Increased Production in That Industry in 1899, 1914, 1925, and 1937.

1. The implication of this chart is that with the increase in use of electrical horsepower in factories, average wages per hour go up and average hours per week go down.
2. Note that the two curves and the bars have a common zero line, but the scales are different.

[Figure 42]

experience we bring to interpreting data visualizations, as well as resisting some of the pre-reflective and learned responses of the human visual and cognitive processing systems. Additionally, dual axis graphs highlight (possibly spurious) correlations between variables implied by their placement on the same graph. Correlation, of course, does not imply causation, but the dual axis graph uses the language of graphic design and visual processing to suggest just that.

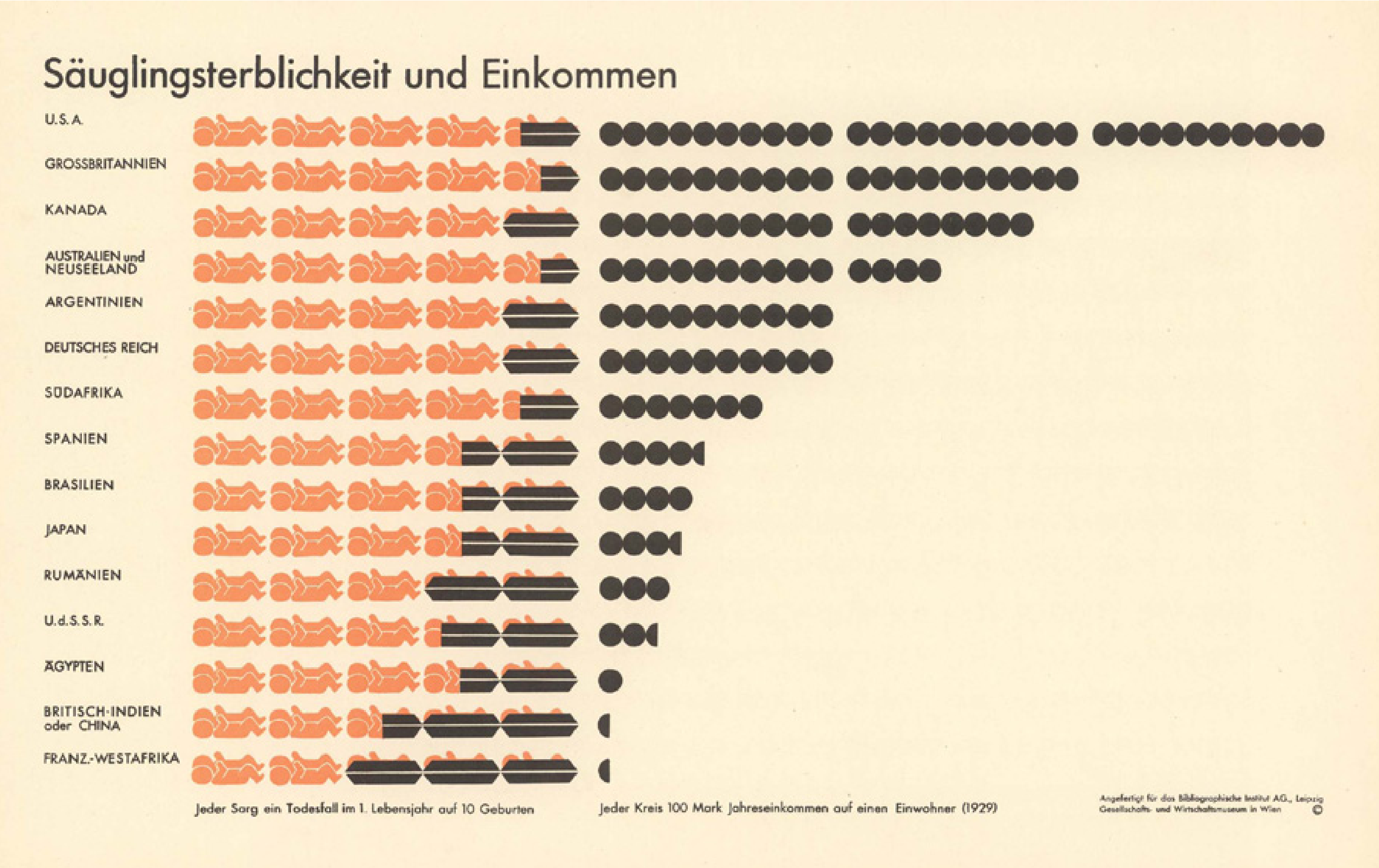
> **Gesellschafts- und Wirtschaftsmuseum. *Gesellschaft und Wirtschaf: Bildstatistisches Elementarwerk*. Leipzig: Bibliographisches Institut, 1930.**

> **International Foundation for Visual Education. "How Long Do Animals Live?" in *Compton's Pictured Encyclopedia*. Chicago: F.E. Compton, 1939.**

> **Louis M. Hacker (1899–1987), Rudolf Modley (1906–1976), and George R. Taylor (1895–1983). *The United States: A Graphic History*. New York: Modern Age Books, 1937.**

Marie Neurath (born Marie Reidemeister) was an innovative graphic designer. She analyzed complex sets of data and processes, distilled the essential elements, and transformed them into clear data visualizations. She was a member of a team that developed a pictographic methodology for charts and diagrams. The purpose of this movement and methodology was to share technical and scientific knowledge with lay audiences and the public. Picture-based graphics were chosen because they were easy to interpret and simple to communicate across languages and cultures. They had the added benefit of being able to reach the many members of the public who were, at that time, functionally illiterate. The movement began when Otto Neurath (1882–1945) opened the Museum for Social and Economic Affairs in Vienna in 1925. Marie Reidemeister joined the staff a few months later. German artist Gerd Arntz (1900–1988) followed in 1928. Together the trio established a highly influential movement in graphic design for quantitative data known as the Vienna Method of Pictorial Statistics or later, 'The Vienna School'. Otto Neurath collected the information, Reidemeister converted the information and data into a visually understandable presentation, and Arntz developed the pictograms and graphics to be used in the diagrams.[38]

Marie Neurath referred to herself as 'The Transformer', which is also the title of her book about the history of the development of Isotypes, *The Transformer: Principles of Making Isotype Charts.* The role of 'transformer' referred to an early version of a data scientist who specialized in data visualizations. Marie Neurath described the role as follows: 'It is the responsibility of the transformer to understand

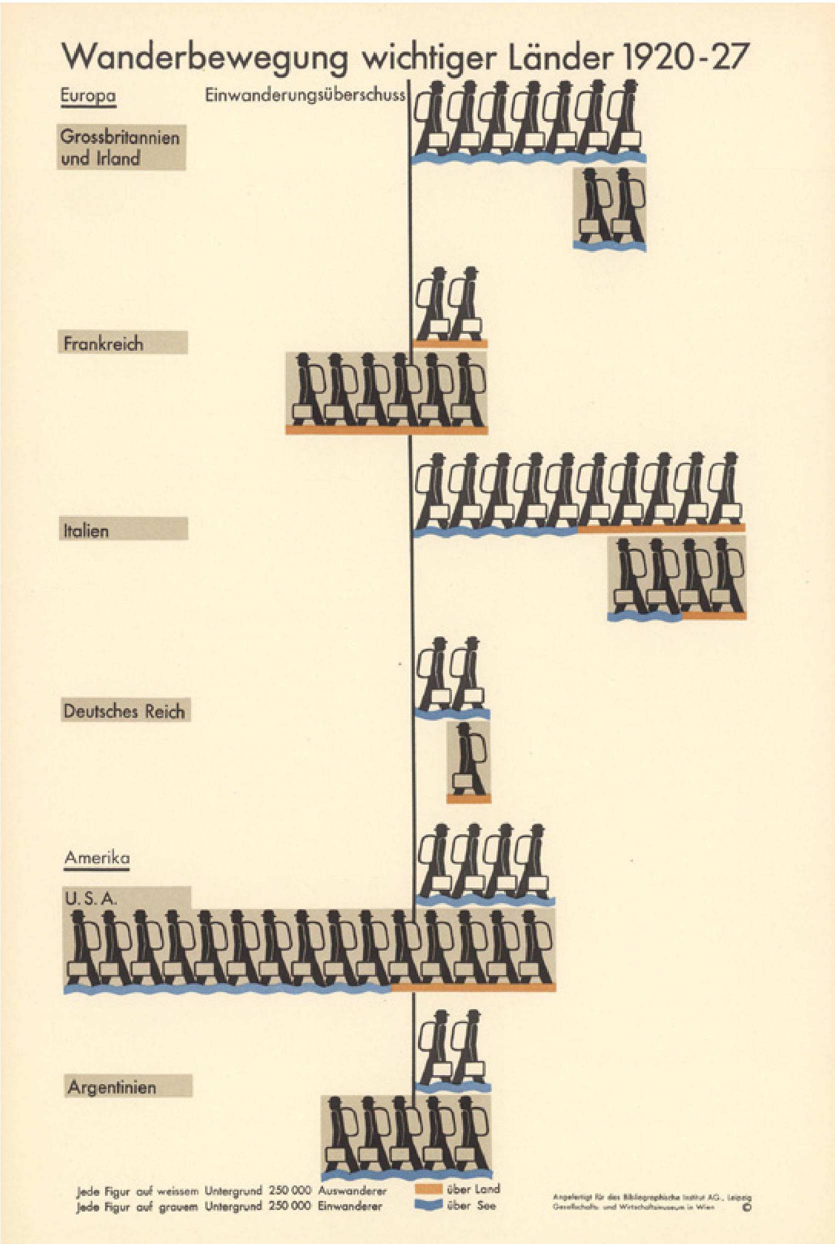


[Figure 43]

the data, to get all necessary information from the expert, to decide what is worth transmitting to the public, how to make it understandable, how to link it with general knowledge or with information already given in other charts. In this sense, the transformer is the trustee of the public. He has to remember the rules and to keep them, adding new variations where advisable, at the same time avoiding unnecessary deviations which would only confuse'.[39]

The progress of this design movement was set back by war. In 1934, Austrian Fascists seized Vienna, and with it, the Museum for Social and Economic Affairs. Its exhibits, charts, and sculptures were all burned and the museum destroyed. The founders moved to the Netherlands. Given those events, 'The Vienna School' was no longer a suitable name, so Marie Reidemeister developed the acronym 'Isotype' (International System of Typographic Picture Education) in 1935. In 1941 Reidemeister and Neurath escaped to England where they married and re-established their design institute in Oxford.

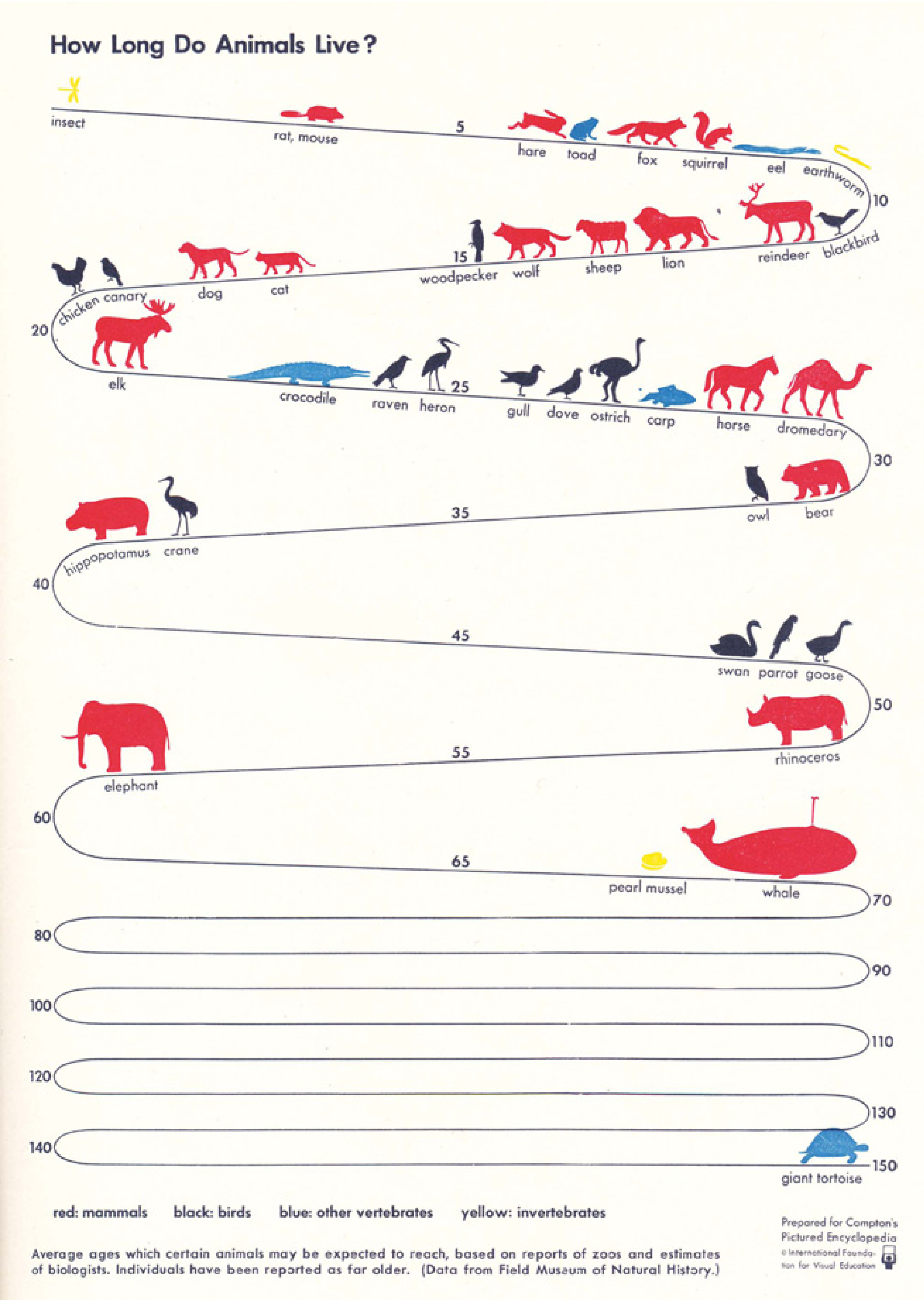
The chart in **Figure 43** is typical of the Isotype design. On the left side of the graph, national infant mortality rates for every ten births are represented by orange baby icons arranged in five rows of two. Black coffins cover the average number out of ten who die. On the right, each country's wealth is plotted by coins representing income per person in one-thousand-mark units. The clustering of individual numbers into groups of five or ten is designed to allow for easy tracking and calculating, similar to the function of tick marks on an axis. It is easy to see the relationship between infant mortality and wealth, especially as per capita measures were chosen so that the differing sizes of the countries would not be a barrier to comparisons. This kind of clarity and sophistication comes from the synthesis of data analysis and theories of design, that 'transform', in Marie Neurath's vision, the data into knowledge. Similar synthesis can be seen in the chart in **Figure 44**. This chart displays emigration and immigration statistics for several countries in the aftermath of World War I, with



[Figure 44]

each 'traveling person' icon representing two hundred thousand people. The design element that allows for meaningful comparisons is the choice of a central axis so each country's relative gain or loss of people can be easily determined.

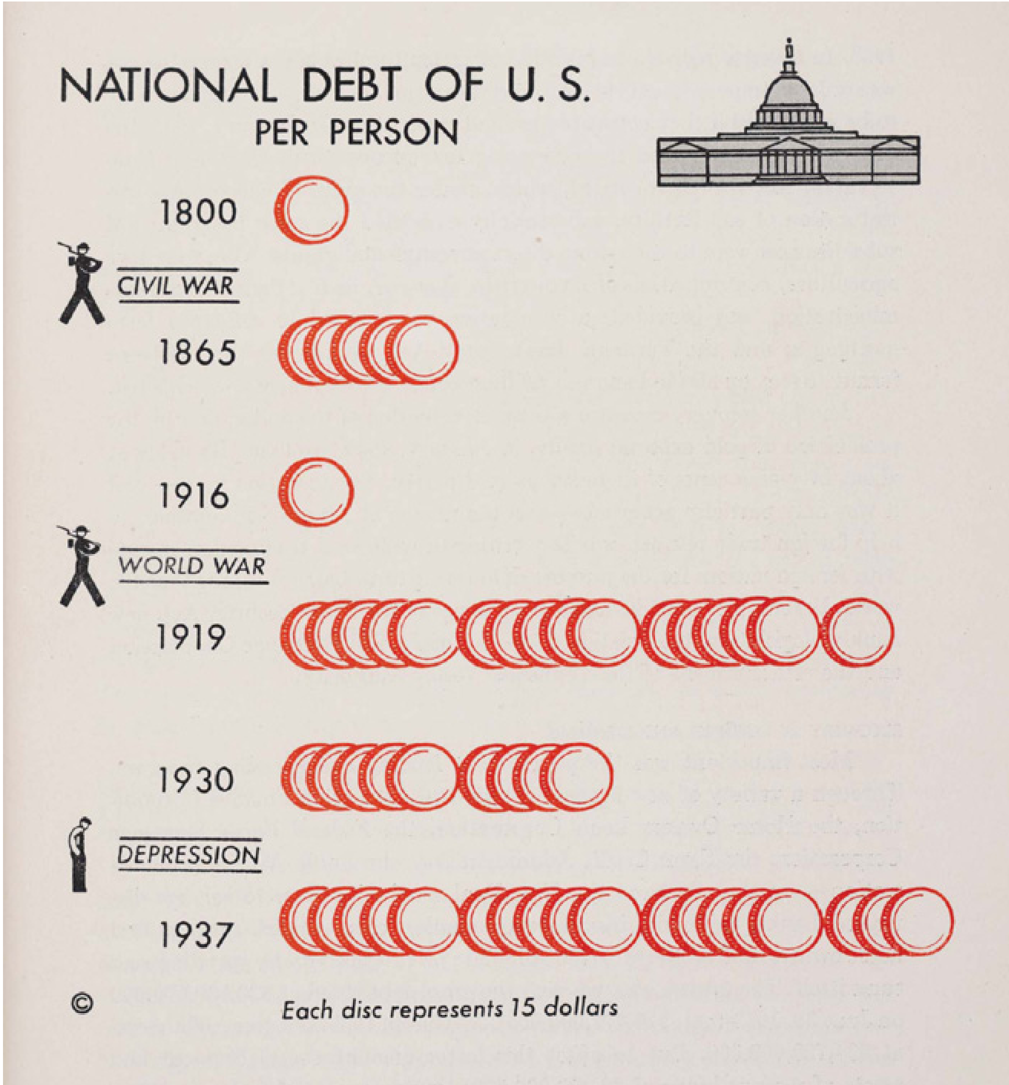
In Oxford, the Neuraths developed ideas for children's books about science, technology, and other non-fiction topics. After Otto Neurath's death in 1945,



[Figure 45]

Marie Neurath directed the Isotype Institute in London until the late 1960s, as well as creating infographics for *Future* magazine and for public health and voter education posters for the governments of Western Nigeria, Sierra Leone, and Ghana. She also directed a team of writers and illustrators who produced more than eighty children's books. While most of the diagrams were loyal to technical accuracy as well as clear and accessible pictures, the example in **Figure 45** has a flaw. While it is easy for a pre-literate child to discern the relative lifespans of various animals, the length of the lines and the spaces between them are inconsistent in scale.[40]

A student of Otto Neurath's, Rudolf Modley (1906–1976), brought the Isotype methodology to the United States and founded a company, Pictorial Statistics Inc., which specialized in Isotype-based charts. He founded a syndicated service for newspapers, Telechart, featuring Isotype charts relevant to the news of the day for which



[Figure 46]

he produced hundreds of charts and through which many Americans were introduced to this kind of visualization. Modley created the graphic in **Figure 46**, included in *The United States: A Graphic History*. It shows the per capita national debt in the United States before and after the Civil War, the First World War, and the Depression. Each red coin represents fifteen dollars. The coins are clustered into groups of five to aid with calculation. The chart is flawed, however, though the flaw lies with the data collection and analysis, rather than with the design. The data the chart is based on do not consider the effects of inflation, which makes comparing the (nominal) values in the 1870s to those in the 1930s problematic.[41] While Playfair's neglect of the effects on inflation in **Figure 29** might have been understandable in the early nineteenth century, this information was well known by the 1930s.

Mary Eleanor Spear (1897–1986). *Charting Statistics*. New York: McGraw-Hill, 1952.

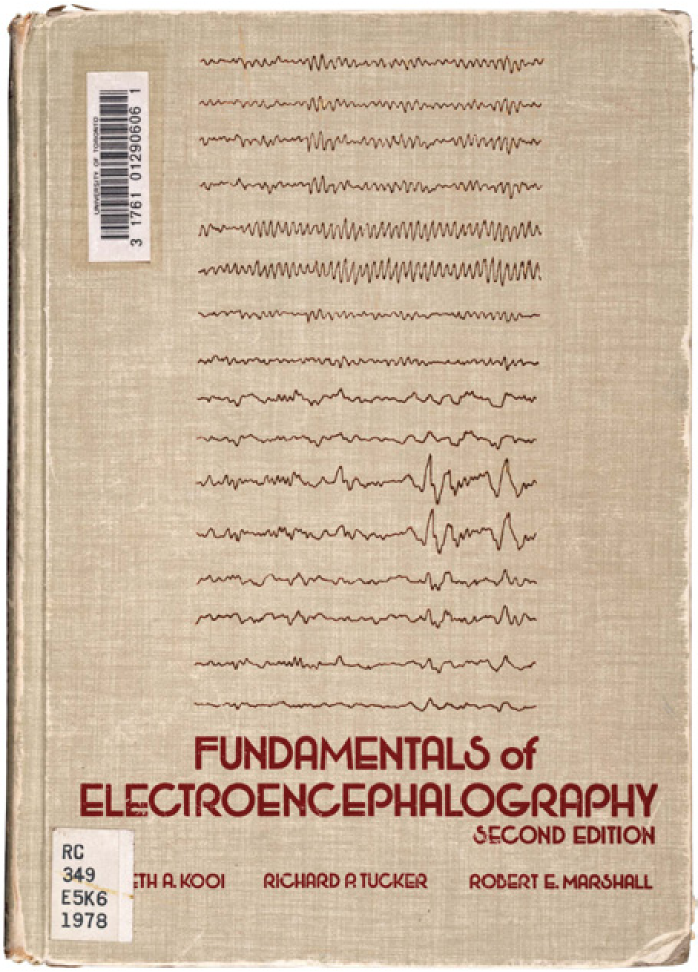
A box plot is a way showing the distribution of a set of numbers in a simple diagram. To describe the distribution of the data in the set of values, a box plot uses five numbers: the minimum number, the maximum number, the median, the twenty-fifth percentile, and the fiftieth percentile. The box is drawn from the twenty-fifth to the seventy-fifth percentile, called the interquartile range, with a line in the middle of the box showing the median. This box contains half of the values in the dataset. A line or 'whisker' is extended from each side of the box to the minimum and maximum values. Box plots are ways to compare both the values and the distributions of different sources of data easily and in a visual format that facilitates recognizing patterns.

The first published box plot was created by Mary Eleanor Hunt Spear (displayed in the exhibition, though not included in this catalogue). Spear was one of the first people formally employed in what is now the field of data visualization. She worked for the American government as a 'Visual Information Specialist' for both the Internal Revenue Service and for the Bureau of Labor Statistics. She also had a data visualization company for which she created custom charts made by hand in her studio using custom-made drafting tools, including a handmade pantograph much like the one used by Scheiner centuries before. Spear taught courses in the graphic representation of statistics at American University. She also wrote two popular textbooks in data visualization techniques, *Charting Statistics* (1952) and *Practical Charting Techniques* (1969).

Spear's early insight was identifying the process of moving from data collection to knowledge translation though visual design. She identified roles needed for the successful development and presentation of charts: a graphic analyst, a draftsman, and a communicator. While a modern data visualization team might include more data collectors and analyzers, the discussion about the kinds of skills and amount of labour that go into successful data visualizations is still remarkably important.

Until recently, Spear was not credited with the development of the box plot despite publishing the first one in 1952 in *Charting Statistics* and discussing them in the countless courses she taught. While Edward Tufte mentions Spear's role in the invention of the box plot in passing in his data visualization book, *The Visual Display of Quantitative Information* (1983), for many decades credit was exclusively given to statistician John Tukey who published them in 1977.[42] Spear did not even have a Wikipedia entry until 2019. Due to a campaign by the data visualization community, recognition of her contributions is now growing, and in 2021 the British Royal Statistical Society named a data visualization contest in her honour.

> **Kenneth A. Kooi (1922–1993), Richard P. Tucker (1934–) and Robert E. Marhsall (1927–2017). *Fundamentals of Electroencephalography*. Hagerstown, MD: Harper & Row, 1978.**



[Figure 47]

Sparklines are small line charts, with neither axes nor coordinates. They are drawn that way to highlight the pattern of change more than absolute or specific values. In this they present a level of abstraction that is beyond typical line charts. Usually, sparklines are presented in a series of small multiples such as the ones in **Figure 47**. Though used in brain imaging for decades before, the term 'sparklines' was introduced by Edward Tufte in 1983 with the idea that their primary use was to embed them in text or spreadsheets.

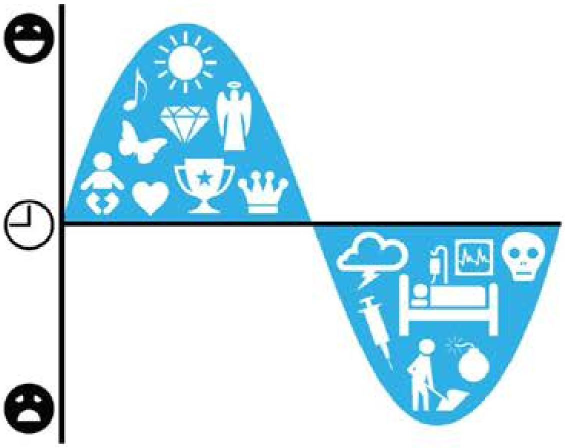
The field of human brain imaging began in 1924 with the invention of the electroencephalogram, a method of applying electrodes to the head and recording the electrical activity in the human brain. The patterns of change in electrical impulses (colloquially known as 'brainwaves') are more important than the amount of electricity passing through, which can vary widely from person to person. Because of this variation, sparklines became the standard way to display data in the field of electroencephalography by the 1970s, so much so that the first edition of the standard textbook in the field, *Fundamentals of Electroencephalography* (1971), had an ECG sparkline graphic in its cover and the 1978 edition enlarged it into a cover-spanning set of shiny golden sparklines (**Figure 47**).

Kurt Vonnegut (1922–2007). *A Man Without a Country*. New York: Seven Stories, 2005.

Maya Eilam. (1984–). The Shapes of Stories by Kurt Vonnegut. New York: Tender Human, 2012.

Before Kurt Vonnegut became famous as an American author, he studied anthropology at the University of Chicago. His rejected master's thesis claimed that across cultures all stories could be classified as having one of a standard set of eight shapes. He suggested that studying the distribution of stories by shape within a culture and across cultures could provide information about each culture. Vonnegut wrote that 'The fundamental idea is that stories have shapes which can be drawn on graph paper, and that the shape of a given society's stories is at least as interesting as the shape of its pots or spearheads'.[43] What did Vonnegut mean by the 'shape' of a story? He plotted time or progress though the story on the horizontal axis and relative good fortune or happiness versus bad fortune or unhappiness on the vertical axis. The resulting shapes encapsulate the emotional arc of the stories, which are different from previous literary diagrams that sought to summarize plots. These diagrams also expand the level of abstraction of line graphs where a variable is plotted against time. In a story diagram the x-axis represents progress through the story where the duration of the story could be long or short, and where the units of progress may not map linearly onto the passage of time within the story.

The Shapes of Stories
by Kurt Vonnegut



Kurt Vonnegut gained worldwide fame and adoration through the publication of his novels, including *Slaughterhouse-Five, Cat's Cradle, Breakfast of Champions,* and more.

But it was his rejected master's thesis proposal in anthropology that he called his prettiest contribution to his culture.

The basic idea of his thesis was that a story's main character has ups and downs that can be graphed to reveal the story's shape.

The shape of a society's stories, he said, is at least as interesting as the shape of its pots or spearheads. Let's take a look.

Man in Hole

The main character gets into trouble then gets out of it again and ends up better off for the experience.

Examples:
Arsenic and Old Lace
Harold & Kumar Go To White Castle

Boy Meets Girl

The main character comes across something wonderful, gets it, loses it, then gets it back forever.

Examples:
Jane Eyre
Eternal Sunshine of the Spotless Mind

From Bad to Worse

The main character starts off poorly then gets continually worse with no hope for improvement.

Examples:
The Metamorphosis
The Twilight Zone

Which Way Is Up?

The story has a lifelike ambiguity that keeps us from knowing if new developments are good or bad.

Examples:
Hamlet
The Sopranos

[Figure 48]

Creation Story

In many cultures' creation stories, humankind receives incremental gifts from a deity. First major staples like the earth and sky, then smaller things like sparrows and cell phones. Not a common shape for Western stories, however.

Old Testament

Humankind receives incremental gifts from a deity, but is suddenly ousted from good standing in a fall of enormous proportions.

Example:
Great Expectations with original ending

New Testament

Humankind receives incremental gifts from a deity, is suddenly ousted from good standing, but then receives off-the-charts bliss.

Example:
Great Expectations with revised ending

Cinderella

It was the similarity between the shapes of Cinderella and the New Testament that thrilled Vonnegut for the first time in 1947 and then over the course of his life as he continued to write essays and give lectures on the shapes of stories.

Vonnegut outlined six main story shapes that he felt covered most human stories, and two others that were outliers. **Figure 48** presents an infographic based on Vonnegut's work called *The Shapes of Stories* by Maya Eilam. The 'Cinderella' (or 'Rise-Fall-Rise') story has the main character starting off in ill fortune and then receives good fortune only to lose it and fall downward again until finally achieving a happy ending and a life of good fortune. On the other hand, the 'Man in Hole' story (or 'Fall') story, such as Franz Kafka's *The Metamorphosis*, has the main character begin in bad fortune only to fall further and further.

Vonnegut's story diagrams have since been used in literary analysis. In 2016, a group of computational linguists decided to test Vonnegut's theory of the universality of the types of story shapes across publicly available English language stories (a noted limitation). Using over a thousand works of fiction from Project Gutenberg, they broke up each story into ten-thousand-word sections. They assigned a 'happiness score' to each segment by an analysis of the frequency of use of happiness-related words as measured by the hedonometer algorithm. Then each score was plotted from the beginning to the end of the story to create a story shape. Using several computational techniques, they found that all the story shapes in their set conformed to one of the six of the Vonnegut shapes, a result that would have intrigued and pleased Vonnegut.[44] More remarkably, parts of the underlying structure of the hedonometer and other algorithms used in semantic networks share basic elements with the artificial language described by Wilkins in 1668 (**Figure 16**).[45]

Part Two:

MAKING PEOPLE SEE

Data visualizations are arguments. They are persuasive tools and, used effectively, have the power to change peoples' minds. Part Two of *Emerging Patterns* focuses on this persuasive power. The exhibits in 'Making People See' explore the roles that data visualizations have played directly and intentionally in the public sphere. Each of the data visualizations exhibited in *Emerging Patterns* required unseen investments of time and resources to collect and organize data, plan and design representations, and physically craft images, often over many iterations and using the newest technologies of the day. The visualizations were created not only for their authors and associates as tools to aid thought or facilitate new connections between ideas; these visualizations were published in books, scrolls and newspapers, distributed in pamphlets, emblazoned on book covers and printed on posters and large wall friezes. The intent was to affect public understanding. Choosing to spend the time and resources not only to create a visualization but also to ensure that it is widely seen sends an important message to the viewing public: *this warrants attention*. Publishing or exhibiting a data visualization is a way of stipulating that its contents are worth the effort to create it, share it, and invite people to understand it. Along with the content of a visualization, audiences absorb the messages of value, authority, and often power that accompany its creation. A line or two of text might make the same point, but not with the same power.

When the compilers of the *Nuremberg Chronicle* (**Figure 49**) chose which concepts to illustrate, with great beauty and at tremendous cost, they included lineages of the royal families of Europe and their connections to the Roman Empire. The message to the viewer is that the royal families *and their connection to past authority and power*, are important and warrant the space, resources, and attention. Capitalizing on the underlying messages a publicized visualization conveys, Shanawdithit created complex maps of battles that destroyed much of her nation. In the very act of creating and sharing her visualizations using a medium associated with power and respect, she claimed authority, attention, and a place in history for her people. Several decades later, a similar strategy appears in the work of advocates like William Farr and Florence Nightingale, who campaigned for improved health and social policy. They took advantage of their era's fascination with charts and the weight of authority that charts held in government and scientific spheres to craft new charts not only to report information, but as instruments for political change.

The later part of the 'Golden Age' of data visualization overlapped with the Progressive Era, a social and political movement focused on improving social welfare, labour rights and reducing poverty. During this era, three influential maps—of London, parts of Chicago, and Philadelphia—were created by a wealthy British shipping merchant, early American social workers and social activists, and a Black sociologist and civil rights leader, respectively. The authors believed that, by presenting accurate, authoritative, and accessible visualizations, they could make people see the social and economic conditions they wanted to change in a more visceral, immediate, and undeniable way than would have been possible using only words. Historian Ruth Crocker (1943–) notes how these three endeavours shared this same belief: '*Hull-House Maps and Papers* exemplifies the Progressive-era confidence that reform begins with fact-finding and publicity, a tradition that runs from Charles Booth in England to W.E.B. Du Bois'.[46] It is this power to make people see that sets data visualization apart as a tool for claiming authority or changing minds.

The Power of Lineage

Hartmann Schedel (1440–1514). *Liber Chronicum*. Nuremberg: Anton Koberger, 1493.

In the era of incunables, the period of early printing using movable type in the West from the 1450s to 1500, printed books were an emergent technology available mainly to the very wealthy or heads of state. One of the first European books of this period to successfully incorporate both text and illustrations was the *Nuremberg Chronicle* of 1493, an illustrated encyclopedia of history, geography, and religion. Because of the new technology of movable type in combination with the printing press, text could be integrated with woodcut illustrations, as they both created raised surfaces and thus could be printed together on a single page.[47] The *Nuremberg Chronicle* used 645 distinct woodcut illustrations that were reused to produce over 1,800 images.

Given the scarcity of this technology and the intensive resources and multiple years required to produce a book, the choices made by its author Hartmann Schedel in consultation with the printers about which topics garnered hand-carved illustrations shed light on what was viewed as important or worthy of emphasis. Illustrations were reserved only for significant subjects and concepts; the fact that

[Figure 49]

something was selected for illustration conferred importance upon it. Because it was prohibitively expensive to produce exact physical likenesses of all the subjects being illustrated, the images of cities, family trees, and portraits were reused for many different illustrations. Physical likeness was not the only point. Illustrations were also used to represent—or *visualize*—concepts, as in **Figure 49**.

Along with many initial illustrations of European cities, of biblical scenes and maps, several illustrations of biblical and royal linages are featured. The European kings of the time are shown to be descended from Charlemagne in traceable lines. Because Charlemagne is shown as descendant of St. Arnulf, who was thought to be of Roman descent, these diagrams proclaim the legitimacy and power of the contemporary leaders through their connection to the Roman Empire, the Roman

Church, and the divine right of kings. This connection between biblical and religious figures, and the linages of the ruling houses of Europe at the time, is amplified by the use of the same type of visualization: tree diagrams, which were in fact reused for figures from past and present and from biblical and historical accounts.

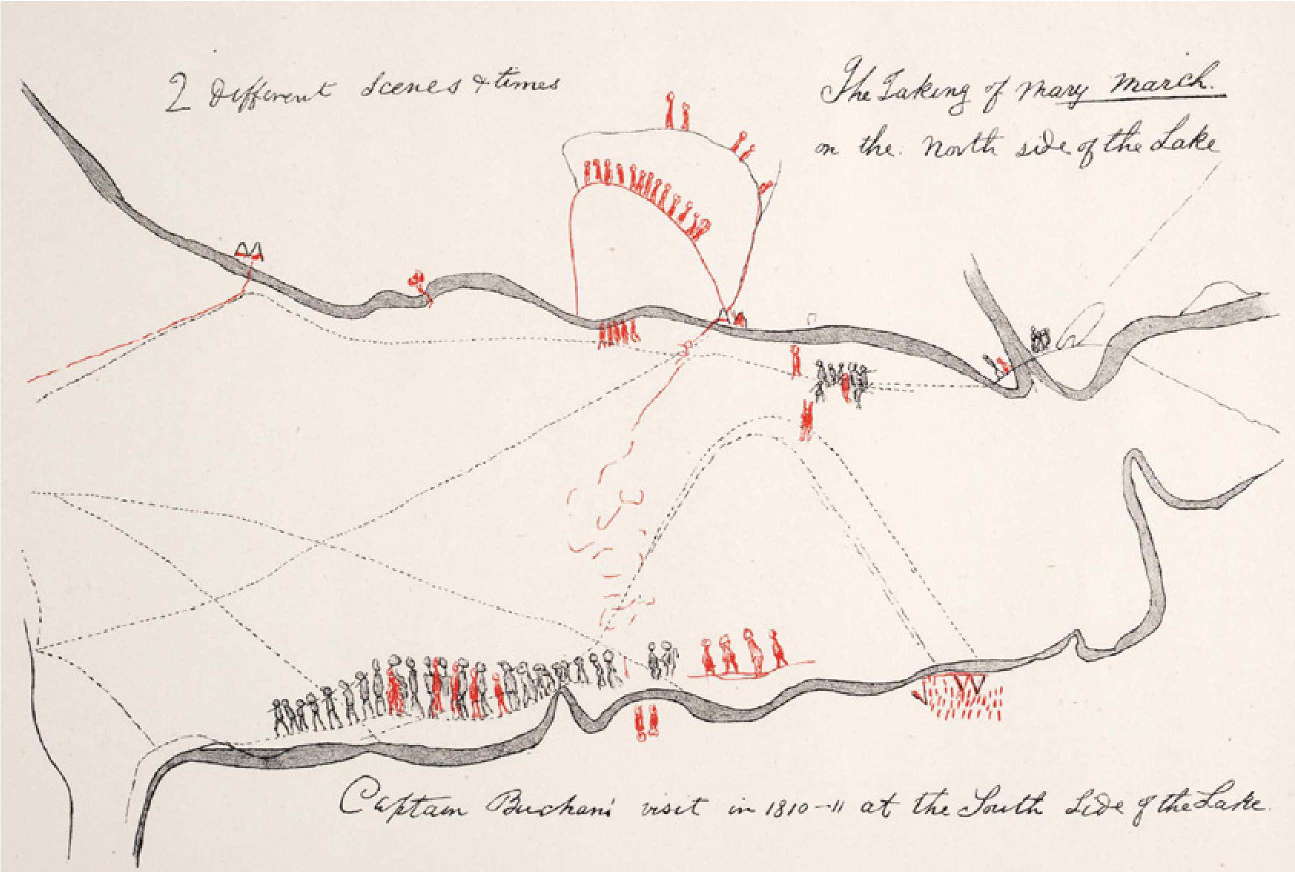
The Power of Memory

> **James P. Howley (1847–1918). *The Beothucks or Red Indians: The Aboriginal Inhabitants of Newfoundland*. Cambridge: Cambridge University Press, 1915.**

In the early nineteenth century, the Beothuk people who lived in Newfoundland suffered great cumulative damage from the combined effects of the loss of their territory, reduced access to food because of European encroachment, infectious diseases, and attacks from both European and Indigenous peoples. The last surviving Beothuk person was a young women named Shanawdithit (1801–1829). After losing her family and nation, she documented her experiences and her culture and history. Despite her relative lack of power as a person living in the culture of those who destroyed her people, Shanawdithit was able to claim an important power, the power of memory and a place in history, not just for herself, but for other Beothuk people as well. In 2007, the Canadian Government issued a Historic Sites and Monuments Board of Canada plaque recognizing Shawnadithit's importance to Canadian history. Researcher Ingeborg Marshall (1929–) notes that without Shanawdithit's accounts the historical record would be bereft of a Beothuk voice. A primary way her accounts caught the attention of the Europeans of the time was through her compelling maps depicting significant events in the capture of her family and the Beothuk.

In the map in **Figure 50**, Shanawdithit drew the Beothuk people in red and their British attackers in black. The map captions alert us that it is depicting action occurring in different places and times. In the north is the capture of her aunt Demasduwit (c. 1796–1820), wife of the Beothuk leader Nonosbawsut (d. 1819), and, later in time but in the same space, Nonosbawsut's return with men to negotiate her release. Nonosbawsut is represented by the larger red figure as well as the prone figure after he is shot and killed in his attempt.

Though the map was drawn decades after the events it depicts, the geography of the lakes and rivers is rendered with great accuracy. Beyond the important work of ensuring a place in history for a conquered people, Shanawdithit should be seen as someone with a talent for data visualization. Her maps contain elements that were ahead of her time. The person-shaped figures on her map correspond to the number of people in each location and they are colour-coded by category, presaging the



[Figure 50]

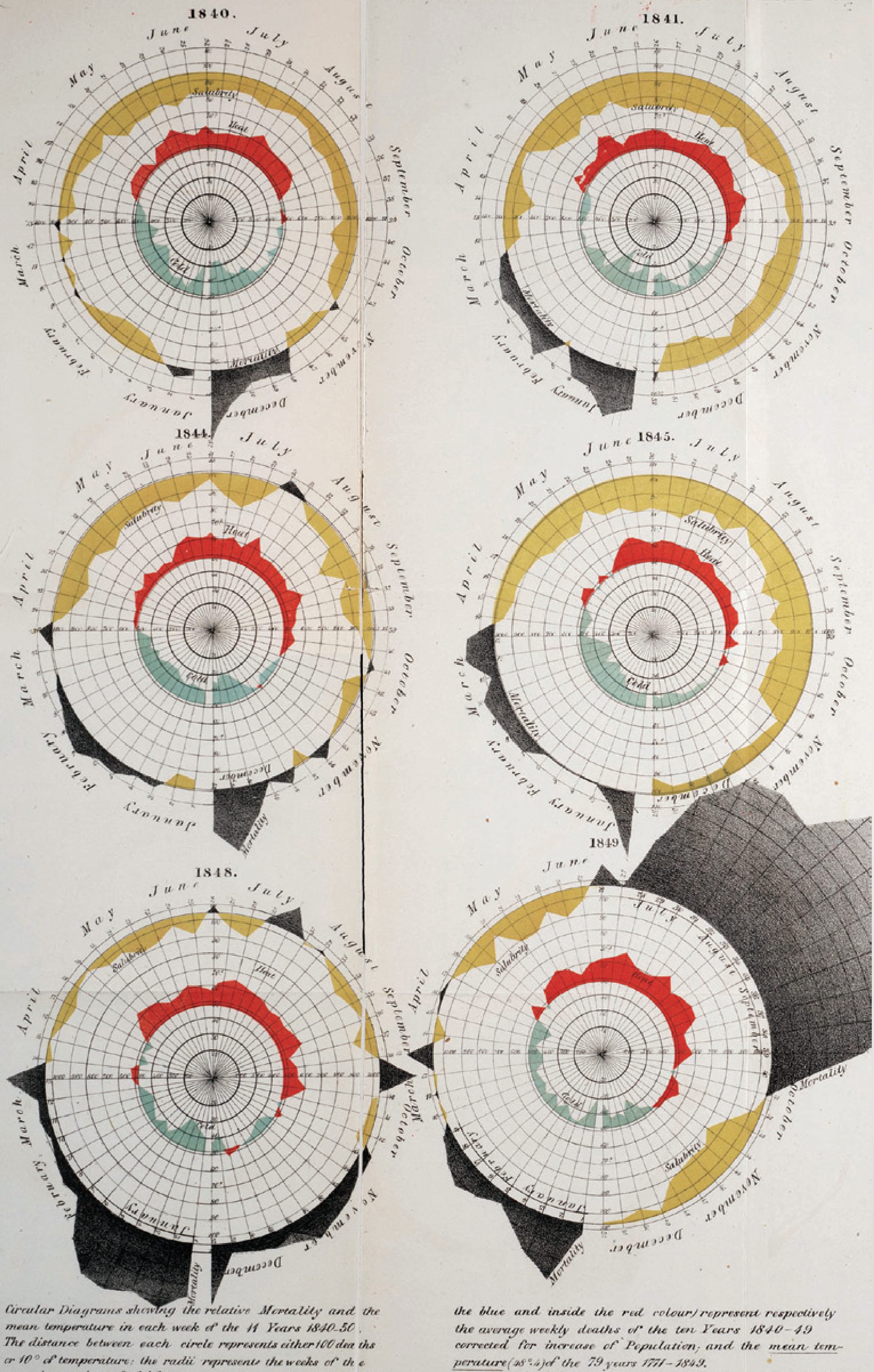
invention of Isotypes by Otto and Marie Neurath. (**Figures 43–45**). The depiction of different groups in conflict moving across both space and time predate the Minard map (**Figures 19** and **20**) by several decades. When she died of tuberculosis at age of twenty-eight, her obituary in the *London Times* noted that Shanawdithit 'exhibited extraordinary strong natural talents'.[48] Her visualizations commanded attention. One can only speculate as to what this history of data visualization might have contained had her life circumstances been different.

Charting Changes

William Farr (1807–1883). ***Report on the Mortality of Cholera in England*****, 1848–49. London: Clowes and Sons, 1852.**

William Farr was a doctor and statistician and the first British government official tasked with compiling statistical abstracts. One of the pressing public health issues of his day was cholera. In 1849 cholera had killed fifteen thousand people in

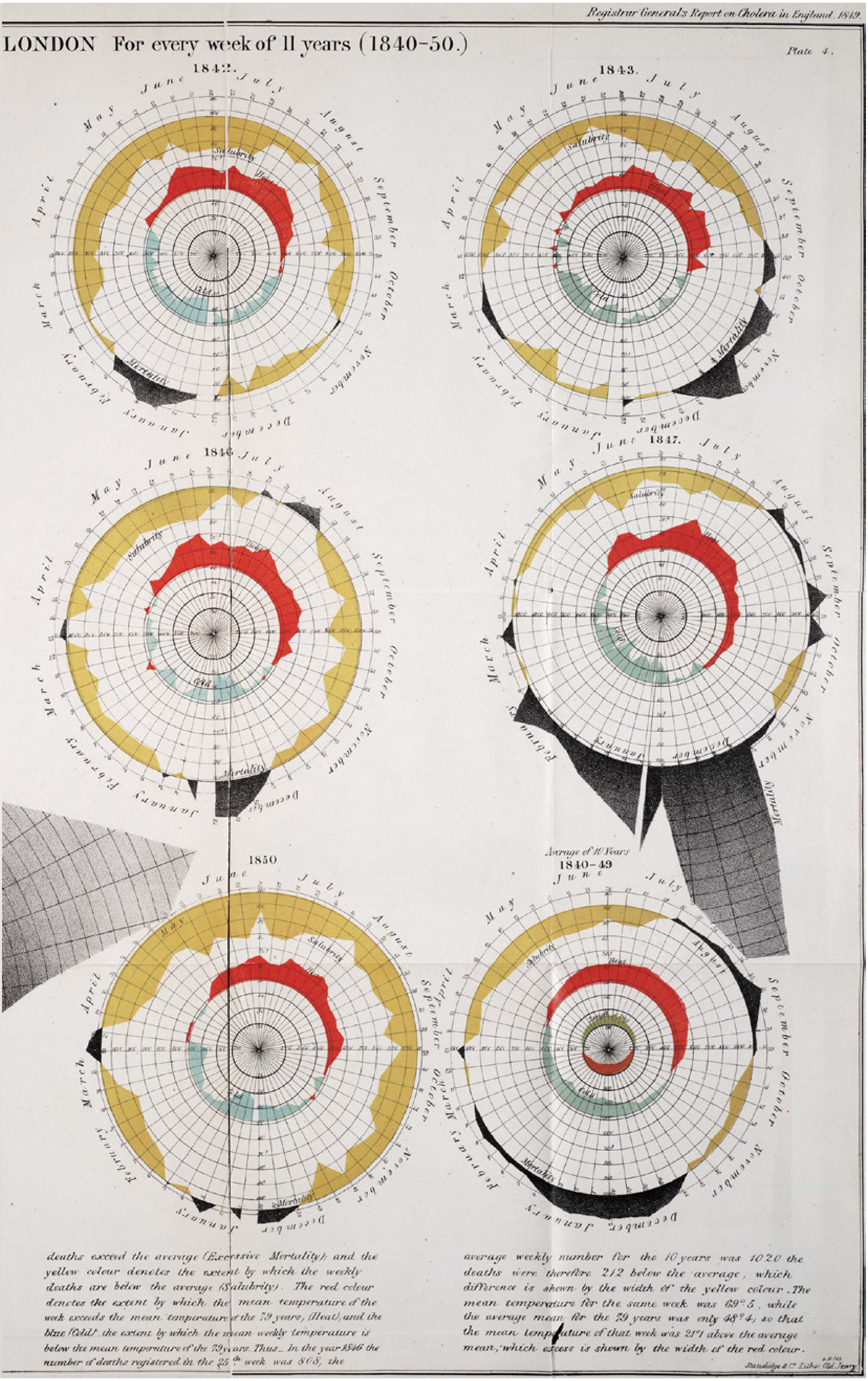
TEMPERATURE AND MORTALITY OF



Circular Diagrams showing the relative Mortality and the mean temperature in each week of the 11 Years 1840-50. The distance between each circle represents either 100 deaths or 10° of temperature: the radii represents the weeks of the year the numbers of which are arranged round the outside circle from 1 to 52. Besides these circles which serve for a scale there are two others. The two extra circles, the one running outside the yellow colour and inside the black; the other outside the blue and inside the red colour) represent respectively the average weekly deaths of the ten Years 1840–49 corrected for increase of Population, and the mean temperature (48°.4) of the 79 years 1771–1849.

The outer irregular line represents the Deaths, and the inner irregular line the mean temperature in each week of the year.

The black colour denotes the extent by which the weekly


Registrar General's Report on Cholera in England. 1849.
LONDON For every week of 11 years (1840-50.)
Plate 4.
1842.
1843.
1846
1847.
1850
Average of 10 Years
1840-49
Salubrity
Heat
Cold
Mortality
January
February
March
April
May
June
July
August
September
October
November
December
deaths exceed the average (Excessive Mortality); and the yellow colour denotes the extent by which the weekly deaths are below the average (Salubrity). The red colour denotes the extent by which the mean temperature of the week exceeds the mean temperature of the 79 years, (Heat), and the blue (Cold), the extent by which the mean weekly temperature is below the mean temperature of the 79 years. Thus_ In the year 1846 the number of deaths registered in the 25th week was 808, the
average weekly number for the 10 years was 1020 the deaths were therefore 212 below the average, which difference is shown by the width of the yellow colour. The mean temperature for the same week was 69°5, while the average mean for the 79 years was only 48°4; so that the mean temperature of that week was 21°1 above the average mean, which excess is shown by the width of the red colour.
Standidge & Co Litho Old Jewry

[Figure 51]

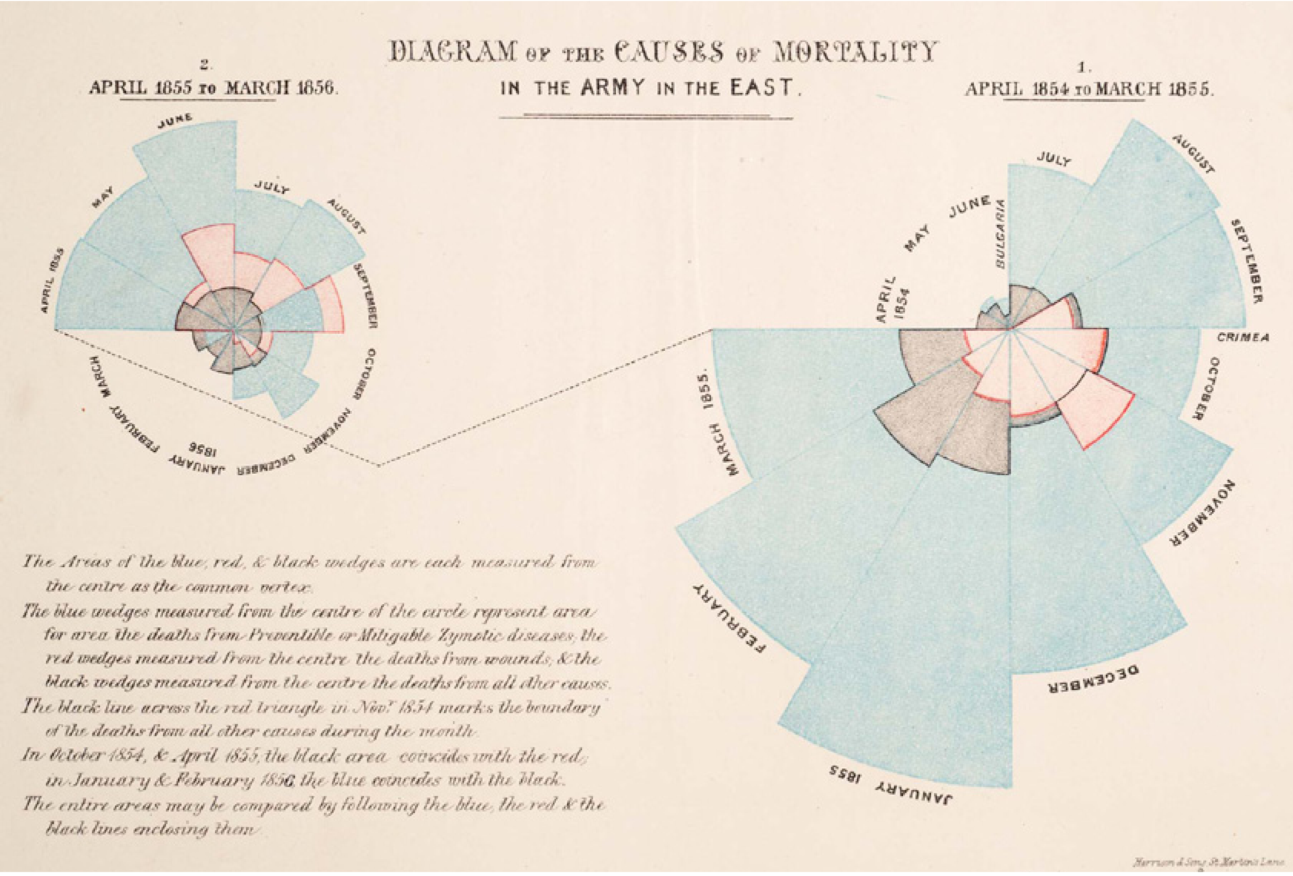
London. Farr attempted to use the tools of statistics and data visualization to determine the cause of cholera. He correlated temperature and mortality for each week of the 1840s and plotted them in an innovative radial chart, seen in **Figure 51**. While his theory of elevation and temperature as causes of cholera was not correct and his radial chart was defective, the methodology and the data collection apparatus supported a similar approach that led to John Snow's famous map. Snow plotted cholera cases on a map of the Soho region of London. The map revealed that deaths from cholera were clustered in proximity to a particular pump. His map, together with clever epidemiological sleuthing and statistical analysis, helped people see that contaminated water, not 'miasma', was the source of the cholera outbreak. Farr's principal legacy resides in the idea that public health could be served by investing in the collection and examination of epidemiological data, an idea Snow proved.

> **Florence Nightingale (1820–1910).** ***A Contribution to the Sanitary History of the British Army during the Late War with Russia*****.**
> **London: Harrison, 1859.**

While Farr was a pioneer in the development of radial diagrams, he is not credited with the invention of the modern, canonical radial chart. That credit goes to his friend and colleague Florence Nightingale, who turned to him for advice and strategy in compiling and displaying the mortality statics she collected during the Crimean War. In 1854 there were reports of terrible conditions in military hospitals in Crimea. Trained as a nurse, Nightingale was sent to the front by the British Secretary of War to bring female nurses there and to improve care of the wounded. Her innovations in nursing earned her initial fame as the 'Lady with the Lamp' for her constant attendance to wounded soldiers.

When Nightingale arrived at the battle hospitals she was horrified at the conditions she found: the lack of systematic hygiene (including hand washing) and poorly trained and overworked staff. She was also dismayed at the lack of clear hospital records. There were three separate death registers making calculations or comparisons impossible. She introduced standard reporting protocols and data systems for causes of death as well as standards for patient care and hygiene.

During her service, she collected statistics that demonstrated that soldiers were approximately ten times more likely to die from disease in the hospitals than from their war-inflicted wounds. After the war she conferred with Farr and analyzed the data. Like Farr, she used a radial design where a year was represented by the circle. Each segment of the circle represented a month. The size of the segments corresponded to the number of deaths in that month. The causes of death are coded by colour: blue for disease, red for death from wounds, and black for everything else. In **Figure 52** the pattern of mortality and the difference in causes is undeniable.



[Figure 52]

It is Nightingale's chart, and not Farr's, that is noted as the first instance of a radial or rose diagram because Farr's chart contained a structural error. Farr's chart failed to take into account how people perceive differences in two dimensional diagrams, which is through differences in area, not length. Farr's chart used a linear scale so that, for each unit increase in the death count, the area of the corresponding segment increases exponentially. This produced a visualization that greatly exaggerated the rates. For example, a doubling of the death rate yielded an area four times as large, thus significantly distorting the chart's proportions, exactly what the audience is being asked to consider and compare. Data visualizations should make judgements about data easier, not harder. Nightingale's diagram in **Figure 52** uses a scale that corresponds to the square root of distance from the center, so that each increase in deaths would correspond to commensurate increase in area. This vital insight created accurate, interpretable diagrams and earned Nightingale the credit as the inventor of the rose diagram.

In 1859, through the public prominence she commanded in the field of military healthcare, armed with methodically collected and analyzed data, and with the authority conferred by this new chart type, she was able to convince the government of the time to establish a Royal Commission on the Health of the Army. Her involvement with the Commission led it to establish many public health reforms and saved innumerable lives. Nightingale was the first woman elected to the Royal Statistical Society of England (in part due to Farr's campaigning). Her work also inspired the founding of the Red Cross which still awards medals in her name.

Survey Maps

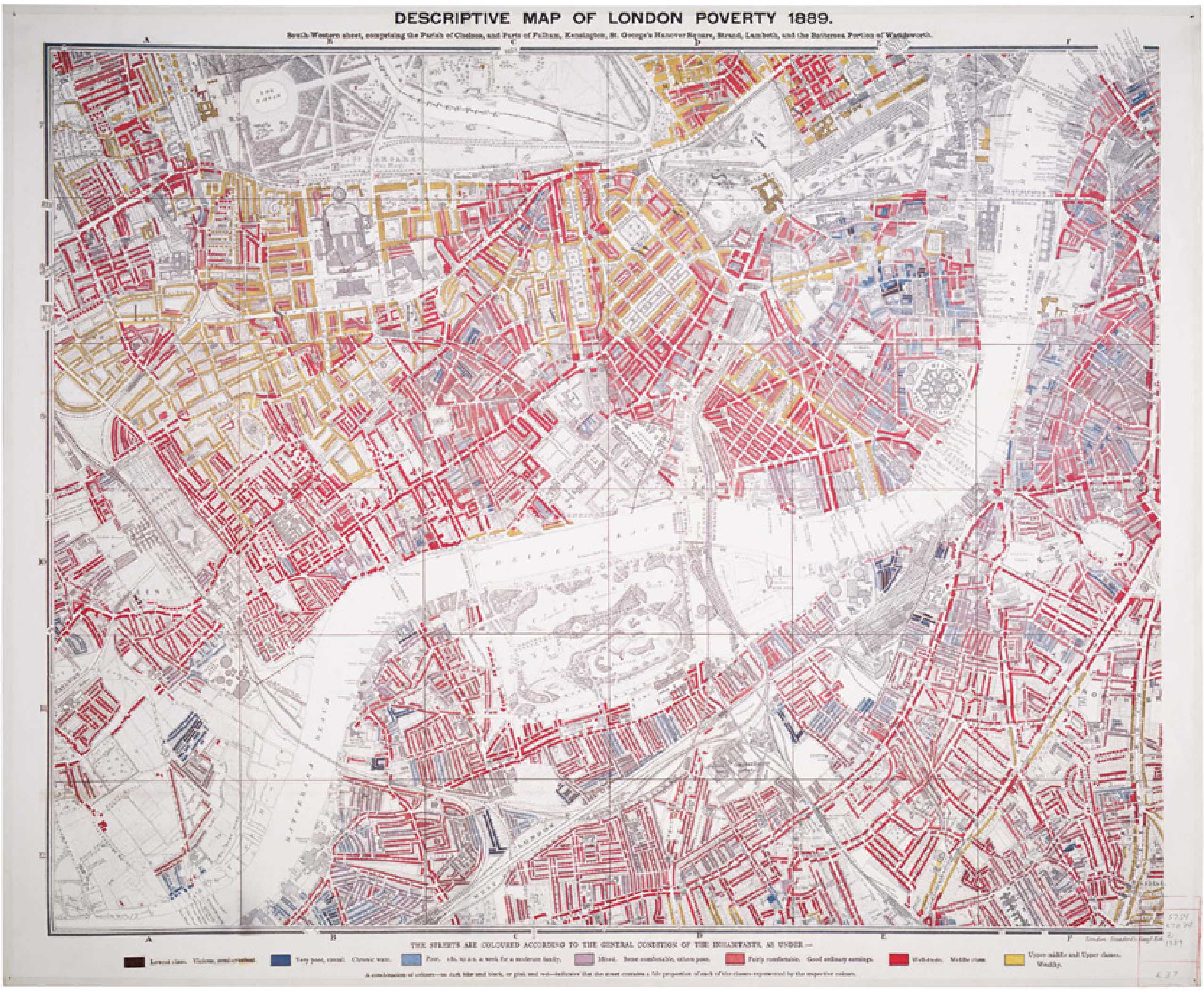
The three choropleth maps in this section depict socio-economic data (mainly wages, ethnic origin, and occupation) at the level of neighbourhood, street, and address. The data were all collected though census information or door-to-door surveys. The publication of these maps in quick succession (1889, 1895, and 1899), using very similar data collection and data visualization techniques was not a coincidence as each map and its underlying techniques was studied by the creator of the next, sometimes through personal correspondence. The collective work of these three diverse authors established a standard methodology for mapping social, economic, and demographic characteristics of a population within a geographical area. The methodology was trailblazing in the fields of social work, sociology, and cartography. These visualizations led to significant changes in public perceptions, attitudes, and eventually, public policy.

> **Charles Booth (1840–1916). *Descriptive Map of London Poverty*. London: London Topographical Society, 1889.**

The first map, in **Figure 53**, was created by in 1889 by Charles Booth who was interested in the percentage of Londoners living in abject poverty, a rate that was defined by the London School Board. Initially Booth was sceptical of the rates of poverty reported through census information. Booth expanded and improved upon the London School Board's existing surveys and hired additional staff. The resulting data indicated that levels of poverty were much higher than he expected.

The data collected were categorized into seven classes using a combination of wage information, occupation states, and other qualitative markers of class. These classes were plotted by location onto detailed maps of London like those in **Figure 53**. The detail of the colour-coding went beyond the seven classes; combinations of colours were used to denote streets with proportions of each of the classes represented by those colours.

The maps and their accompanying texts were published as *Life and Labour of the People* (1889–1891) and quickly became influential in the political discourse of the time. The visualization was extremely effective and forced many people, Booth included, to revise their beliefs. His surveys and maps were some of the first to



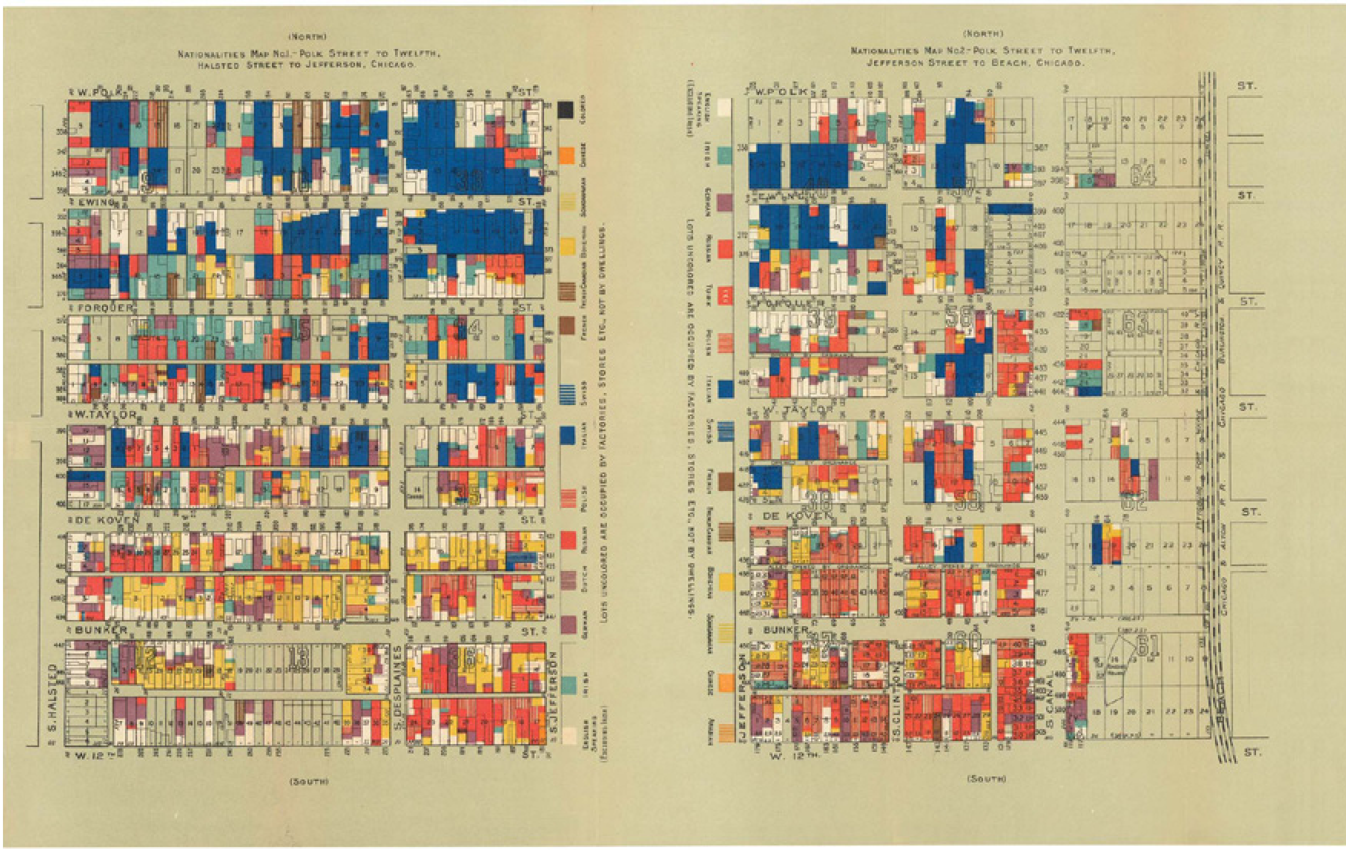
[Figure 53]

include the unemployed and residents of workhouses, providing a more comprehensive picture of poverty. Booth later used his work to successfully advocate for the introduction of an Old Age Pension in 1908.[49]

> **Residents of Hull-House. *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*. New York: Thomas Y. Crowell, 1895.**

The second map, in **Figure 54**, was created in 1895 by Florence Kelly (1859–1939), Jane Addams (1860–1935), and the residents of the Hull-House settlement house in Chicago. Settlement houses were part of the reformist social movement designed to reduce poverty and its associated physical and social challenges by providing poor, marginalized, and immigrant communities with childcare, health care, English education, and cultural programs. Jane Addams was not only the founder of the Hull-House settlement house but also the leader of the non-religious settlement movement in the United States that later included hundreds of such institutions across the county.

To draw attention to the extent of poverty and discrimination (and their ruinous effects) on the residents of the Hull-House neighbourhood and to gain support for further services and actions, Addams, Kelly, and survey and map designer Agnes Sinclair Holbrook (1867–1896) produced a study of the neighbourhood, modelling their work on Booth's and improving the survey and statistical methodology. They ensured that the colour-coding was based on clearly defined, quantitative measures and that missing data were coded and indicated in the maps (represented in purple) so that viewers could see an approximation of response rates. Because their study covered a neighbourhood and not a whole city, they were able to expand the granularity of the study from city blocks to individual houses. Multiple families living in the same house but occupying different wage categories were coded by splitting the diagram of the house into sections, each proportionate to the number of people in each wage category and shaded with the relevant colour. Hence, a house with two families having one average wage and a third family with



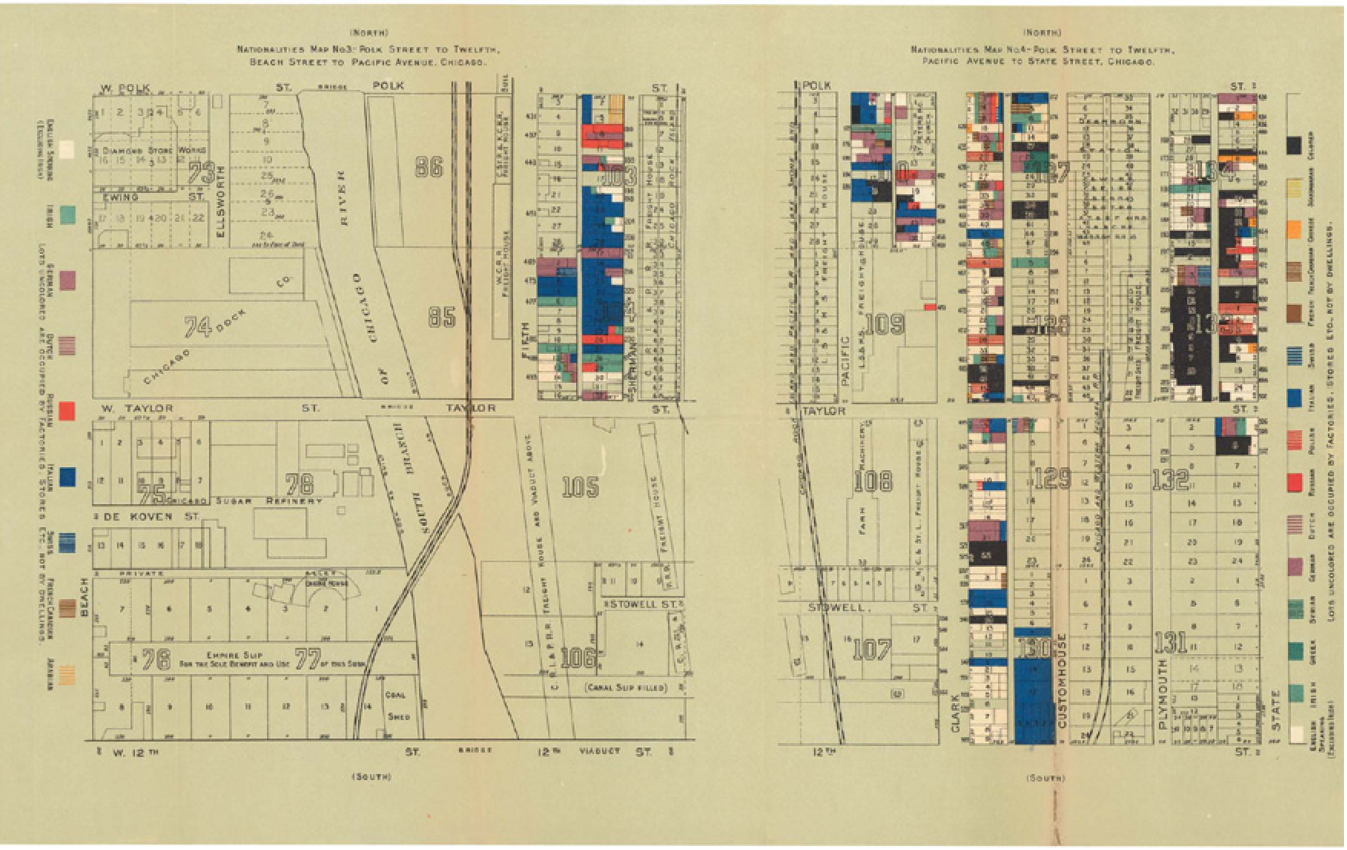
[Figure 54]

a different average wage would be coloured with one third in one colour and two thirds in another colour.[50]

Hull-House did not have the resources of Booth to hire private surveyors. The Hull-House survey was partially financed by the Department of Labor, as part of a national study of *The Slums of Baltimore, Chicago, New York and Philadelphia*, commissioned by the United States Congress in 1892.[51] The labour was supplied by Kelly, Addams, and the residents of the neighbourhood themselves.

The involvement of community members reflected the philosophy of Addams and the settlement movement in general. The upper- and middle-class reformers conducted immersive and engaged research: they lived amongst the people they served and studied, forged friendships and comprised a community, and built trust in the surveyed population, affording insights otherwise unavailable to researchers. Settlement house programs and offerings, as well as research programs and advocacy initiatives, were guided by the needs and knowledge of its community members. This type of consultation and participation was a shift from the more hierarchical approaches practiced in academic settings of the time and was a precursor to participatory, community-engaged, and citizen-driven research models in use today.[52]

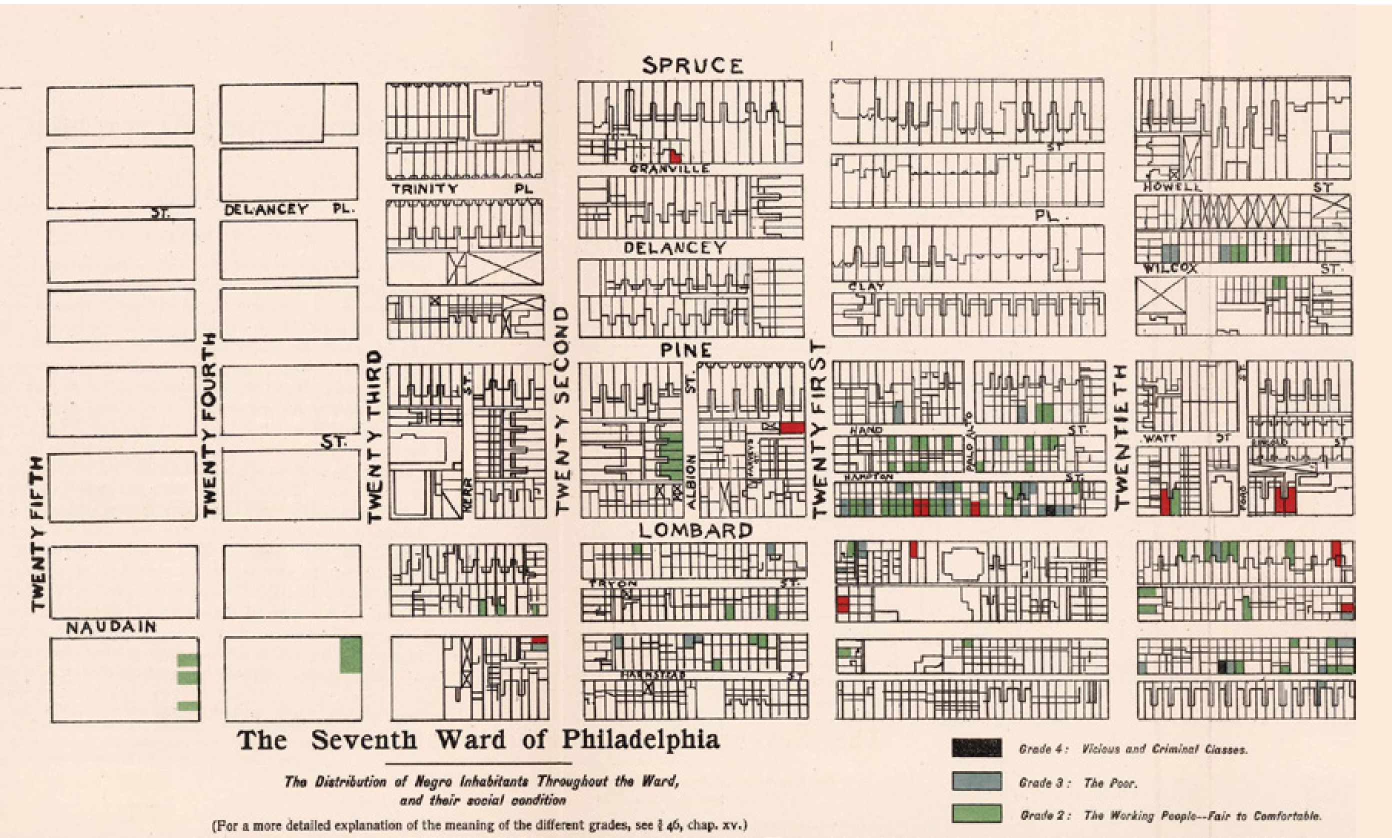
The publication of these maps and studies helped establish the social workers of Hull-House as authorities on social welfare. This work and the settlement



movement changed the nature of social work as a discipline. Previously, social work typically involved wealthy women visiting, assessing, and providing aid to poor people. The community-centred and research-informed model developed by Addams and her colleagues helped define modern social work as grounded in advocacy and social reform.[53] The publication of the Hull-House works also influenced public opinion to secure support for the establishment of the United States' first public playgrounds and first juvenile court, the creation of the Federal Children's Bureau in 1912, and the passage of federal child labor laws in 1916.[54] The Hull-House maps, like the Booth maps, challenged preconceptions and changed opinions by *showing* people data rather than just telling them statistics.

W.E.B. Du Bois (1868–1963). *The Philadelphia Negro: A Social Study*. Philadelphia: University of Pennsylvania, 1899.

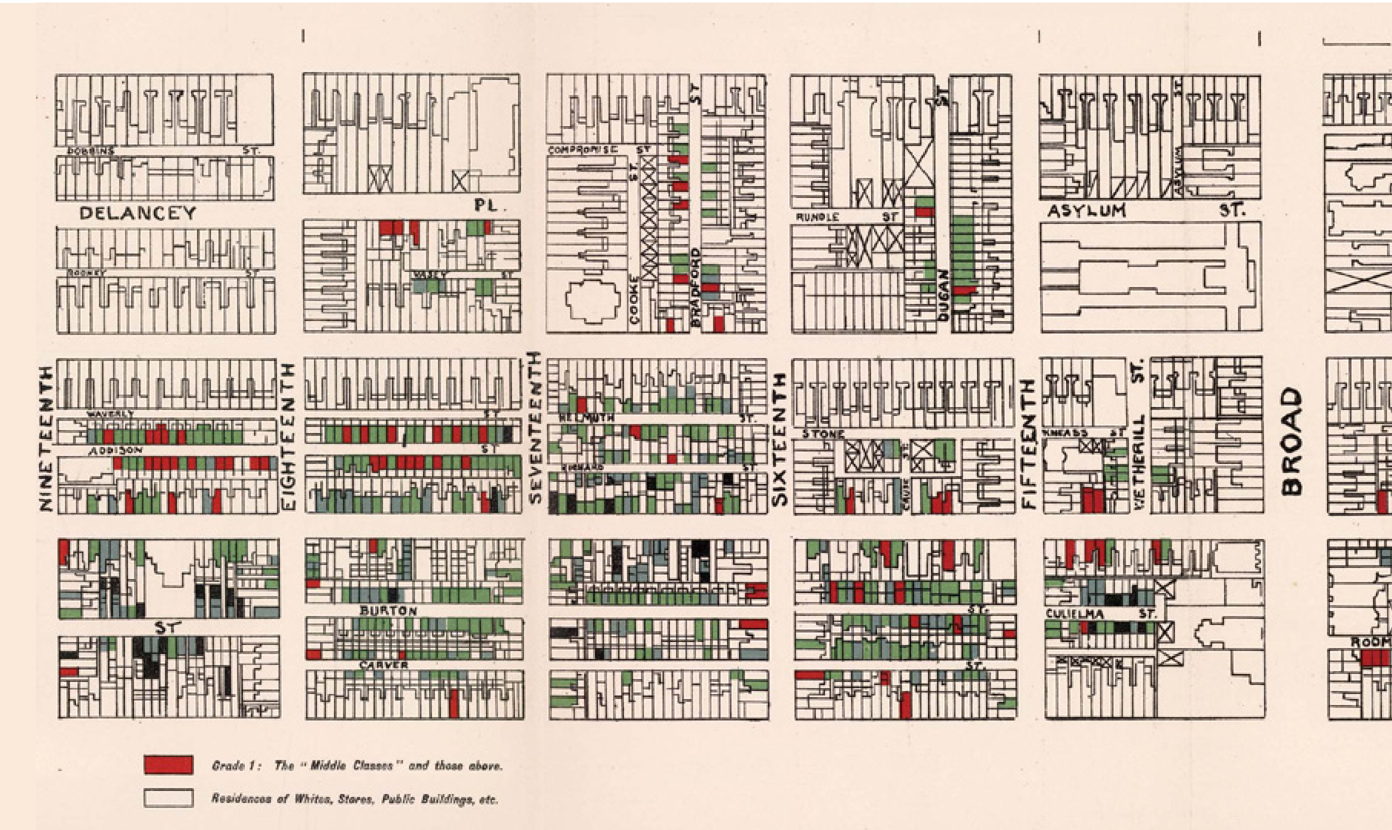
The third map, **Figure 55**, was created in 1899 by W.E.B. Du Bois and depicts the Seventh Ward of Philadelphia. It is the first sociological case study of a Black community in the United States and the first study of any kind examining the Seventh Ward. Du Bois and his collaborator Isabel Eaton (1863–1938) individually conducted



[Figure 55]

thousands of interviews of the residents. His methodology was influenced by Booth and more directly by Addams through personal correspondence and many meetings. Booth and Addams shared natural bonds. They were both marginalized from the field of sociology and the academic world more generally and they shared an understanding of the importance of social structures in addressing the needs of the people for whom they advocated. Addams invited Du Bois to speak and visit her at Hull-House. Du Bois invited Addams to speak at conferences he organized and was a catalyst for her involvement in civil rights advocacy and the NAACP.

Du Bois' Philadelphia study demonstrated the roles that discrimination, both historical and contemporary, played in the socioeconomic challenges facing Black Americans, especially lack of access to higher paying jobs and to affordable housing. It provided compelling visual evidence of these challenges and called attention to sociological structures that challenged segregation. Like the work of the settlement house movement, Du Bois's work led to changes in public perception about poverty and its associated problems. The prevailing (and prejudiced) view that poverty and its ills were caused by personal moral failure or inherent lack of potential became increasingly untenable in the face of clear evidence of the pernicious effects of the social, legal, and economic barriers so prevalent in neighbourhoods that were studied.



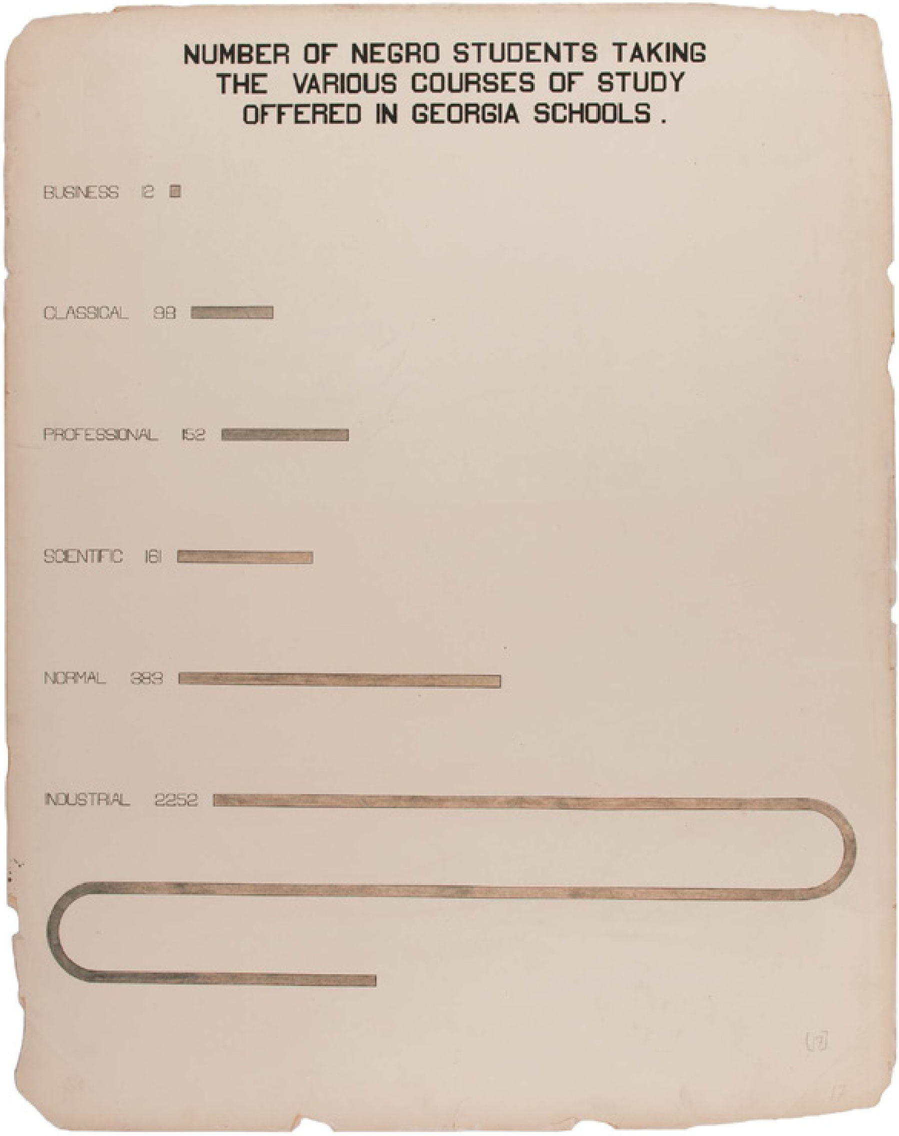
Showing the World

> **W.E.B. Du Bois. *Number of Negro Students Taking the Various Courses of Study Offered in Georgia Schools*. [Atlanta], 1900.**

> **–––. *Proportion of Freemen and Slaves Among American Negroes*. [Atlanta], 1900.**

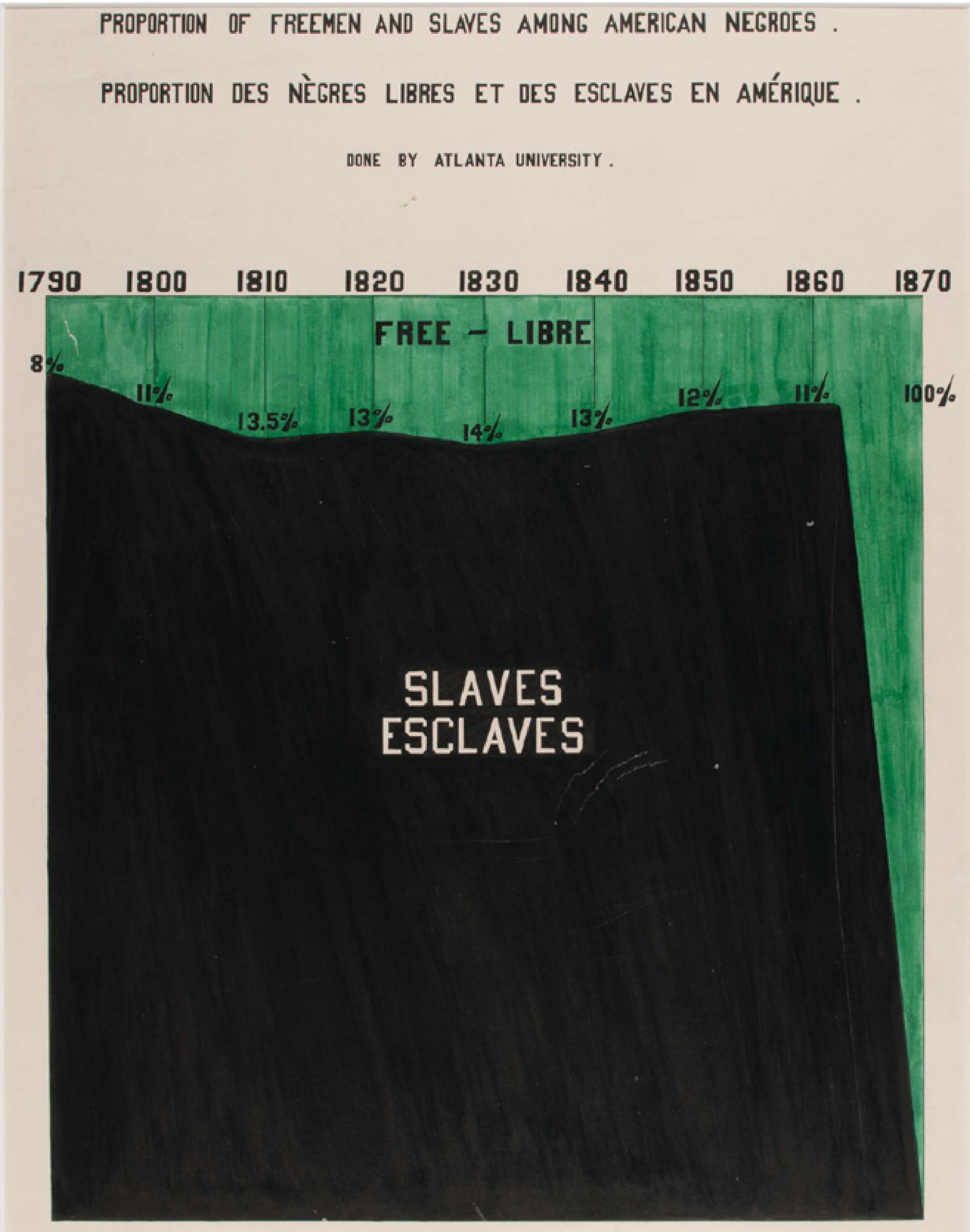
[Figure 56]

An exhibit on Black Americans for the 1900 World's Fair in Paris was the brainchild of Thomas Calloway (1866–1930), a prominent lawyer and educator. After a nation-wide appeal to Black leadership, he gained the support of Booker T. Washington (1856–1915) who took the appeal directly to President William McKinley (1843–1901). That appeal resulted in a budget allocation that arrived four months before the fair. Washington and Calloway quickly assembled Du Bois and his Atlanta University students, and Daniel Murray (1852–1925), Assistant to the Librarian of Congress, to create the exhibit with them. Du Bois directed the construction of an



[Figure 57]

extraordinary set of data visualizations. It was a rare opportunity to focus both national and international attention on the progress and plight of Black people in the United States thirty-seven years after the end of slavery. Du Bois and his students prepared sixty handmade poster-sized graphs for exhibition at the Fair, an event attended by fifty million people. Notably, the exhibition was purposely given prominence over several other exhibits in the main pavilions of a fair where the exhibits of the colonies of Africa and Asia were housed in a separate area from the main national pavilions site.[55]



[Figure 58]

The exhibit, pictured in **Figure 56**, won many awards, including one specifically for the visualizations. The American government report on the exhibition noted that 'The material presented was not only of high scientific value but was shown in the most graphic way. There was no better example at the Exposition of the appreciation of the Exposition idea that exhibits must be made attractive and interesting'.[56]

Du Bois understood that the charts in such a space must be immediately engaging and the charts he created are masterpieces of modern art as well as outstanding data visualizations. One of the charts has been re-interpreted as a neon sculpture, *Light of Progress,* by contemporary artist Theaster Gates (1973–).[57] In the chart in **Figure 57**, the inverted scale is intended to make the message more dramatic, as is the association of darkness with slavery and bright green with freedom. This chart forces the viewer to see the appalling extent of slavery in the United States. In 1863 almost ninety percent of Black people in America were slaves. The chart also confronts the viewer with the slow pace of change. While the Emancipation Proclamation was signed on 1 January 1863, it was not until at least five years later that all American slaves were freed following the enactment of the 13th and 14th amendments to the United States constitution in 1865 and 1868.

The chart in **Figure 58** delineates the kinds of educational training open to Black students at the time. It uses a technique employed several times by Du Bois and his team that breaks the convention of horizontal lines in bar charts. While it hampers the viewer's ability to compare the numbers in the different categories accurately, the snakelike line conveys a message: the number in the last category, 'Industrial Training', is much greater than all the other categories, so much so that it can't even fit on the same page with a normal scale. More than a century later these visualizations remain striking. Their underlying statistics are still being tracked.[58]

Though the exhibit won many awards, it was only partially successful in its aim to use international attention to influence cultural change in the United States. Mainstream American newspapers did not cover the exhibition nor did American academics give it much due.

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(EXTERNAL IMAGE CITATIONS)

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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.

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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.

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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.

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