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TEMPORAL STRUCTURES: TIMELINES AND FLOWS

Jussi Ängeslevä and Ross Cooper, U.K.: "Last Clock," 2002.

Similar to an analog clock, the interface has three concentric circles, each representing a measure of time, with the outermost ring standing for seconds. The interface is connected to a video source that feeds the clock at each level, so that at every second a new image is added, coinciding with the clock "hand." The video can be any source devised by the authors, including a recent application for the iPad, which allows anyone to create their clocks with personal footage (https://itunes.apple.com/us/app/last-clock/id460584423?mt=8).

17:42:54 Ebisu, Tokyo, Japan

Time is an abstract concept and, thus, not inherently visual. Much of the terminology we use for time is based on our concrete experience of space and of the physical environment. In the seminal book *Metaphors We Live By*, Lakoff and Johnson explain that the expressions we use to describe temporal experiences in most idioms emerge from our concepts of "containers" and "moving objects." "The 'time is a moving object' metaphor is based on the correlation between an object moving towards us and the time it takes to get to us. The same correlation is a basis for the 'time is a container' metaphor (as in 'he did it *in* ten minutes'), with the bounded space traversed by the object correlated with the time the object takes to traverse it. Events and actions are correlated with bounded time spans, and this makes them 'container objects.'"[1]

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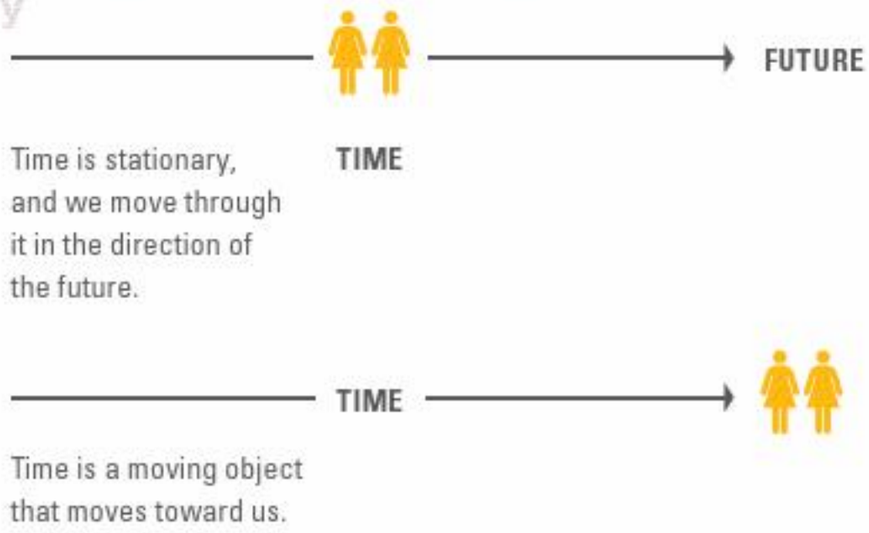
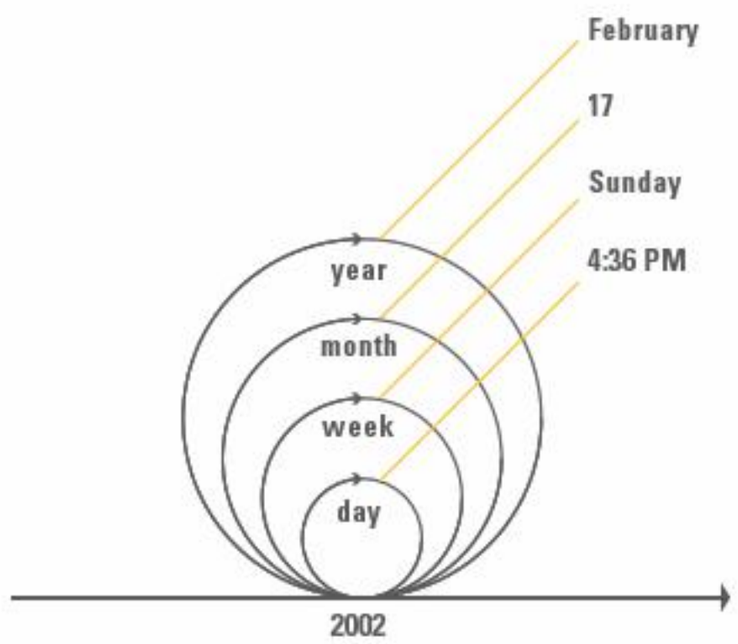


The diagram depicts two subcases of the same metaphor "time goes past us, from front to back." In both cases, the relative motion happens in relation to us, with the future in front and the past behind.



This diagram, after Zerubavel, shows the linear and circular visions of time. He explains, "Locating a particular historical instant in 2002, for example, does not preclude it from also being designated as 4:36 PM on Sunday, 17 February, thereby placing it on four different wheels that are nevertheless rolling along an unmistakably straight road."[22] Another way to depict linear and cyclical time is portrayed in the diagram below, in which recurrence is understood if we read it vertically.

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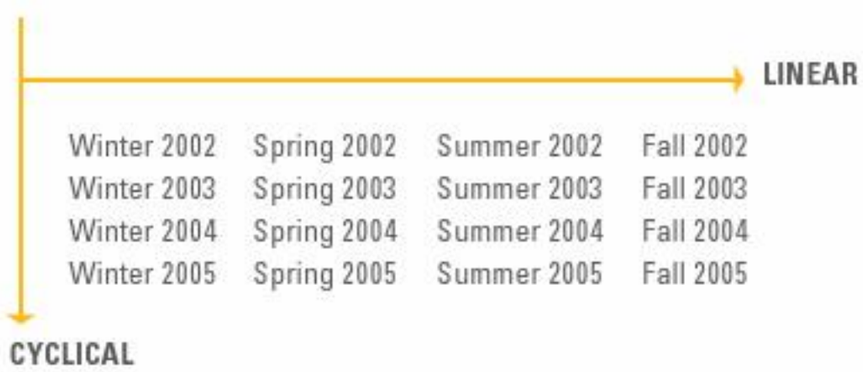

There are two ways in which we conceive of time moving:

- The subject is moving (ego-motion) and time is stationary, as in the expressions "the weeks *ahead*" (expressing the future); "all is *behind* us" (past);
- Time is moving and we are stationary, as in the expressions "the *following* weeks" (future); "the *preceding* weeks" (past).

These two orientations are used without contradiction, such as when we say, "We are looking *ahead* to the *following* weeks." As Lakoff and Johnson explain, we tend to assign a front/back orientation to moving objects, with the front facing the direction of motion.[2] For example, we designate a "front" to a satellite, which is spherical, based on the direction of its orbit. The same holds true when using the moving object metaphor to reason about time, such that if we are the moving targets, we move in the direction of time, as in "time is ahead" or "I look forward." If we consider time moving toward us, then time faces us, as in expressions like "the time has arrived" and "I face the future." In other words, how the motion is viewed, whether the subject or time is moving, will determine the front/back relationship: "What we have here are two subclasses of 'time passes us': in one case, we are moving and time is standing still; in the other, time is moving and we are standing still. What is in common is relative motion with respect to us, with the future in front and the past behind."[3]

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MEASURING TIME

It's interesting to note that most of our systems for measuring time are cyclical, such as clocks and calendars. Furthermore, these systems are also anchored in our physical experiences, as Umberto Eco recalls: "All the 'clocks' used by man, at least until the invention of mechanical time-pieces, were in their way linked to our bodily location. Time was measured against the visible motion of the stars and the 'rising' and 'setting' of the Sun, that is, movements that only exist in relation to our point of view (indeed, objectively speaking, it was the Earth that was moving, of course, but we did not know it and we did not really care)."[4]

The history of measuring time is a rich one, and unfortunately outside the scope of this book. But, it is worth recalling that these are conventions established and agreed upon. For example, according to the U.S. Naval Observatory, there are six principal calendars in current use around the world: Gregorian, Hebrew, Islamic, Indian, Chinese, and Julian calendars. However, most countries in the world have adopted the Gregorian calendar for their daily civic activities and international interactions. Pope Gregory XIII introduced the calendar in 1582, which is based on a solar set of rules, with days as the elemental cycle provided by the rotation

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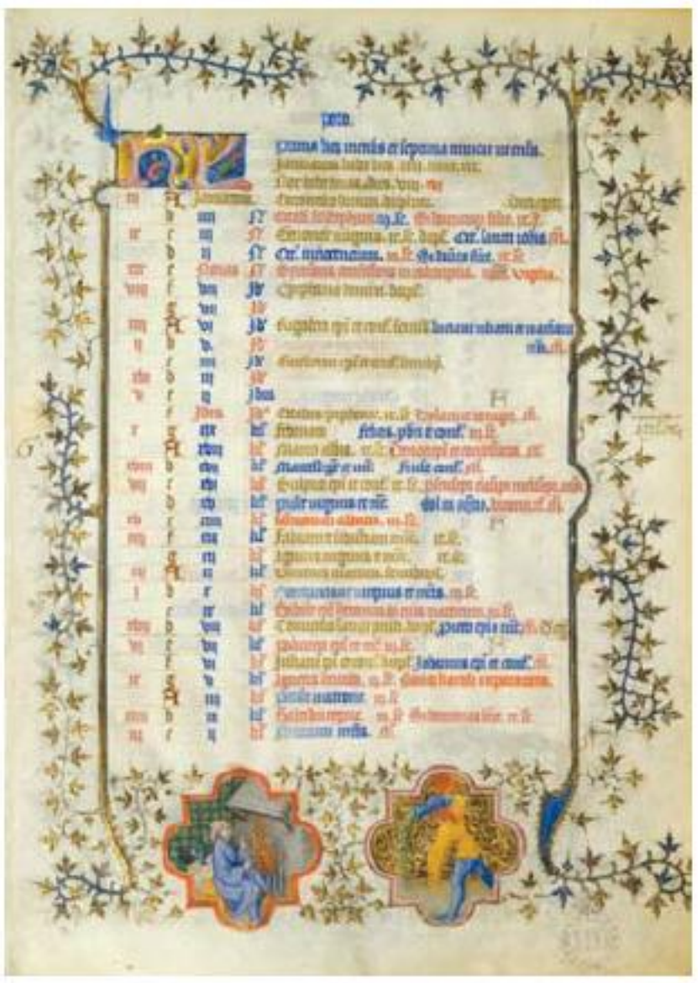
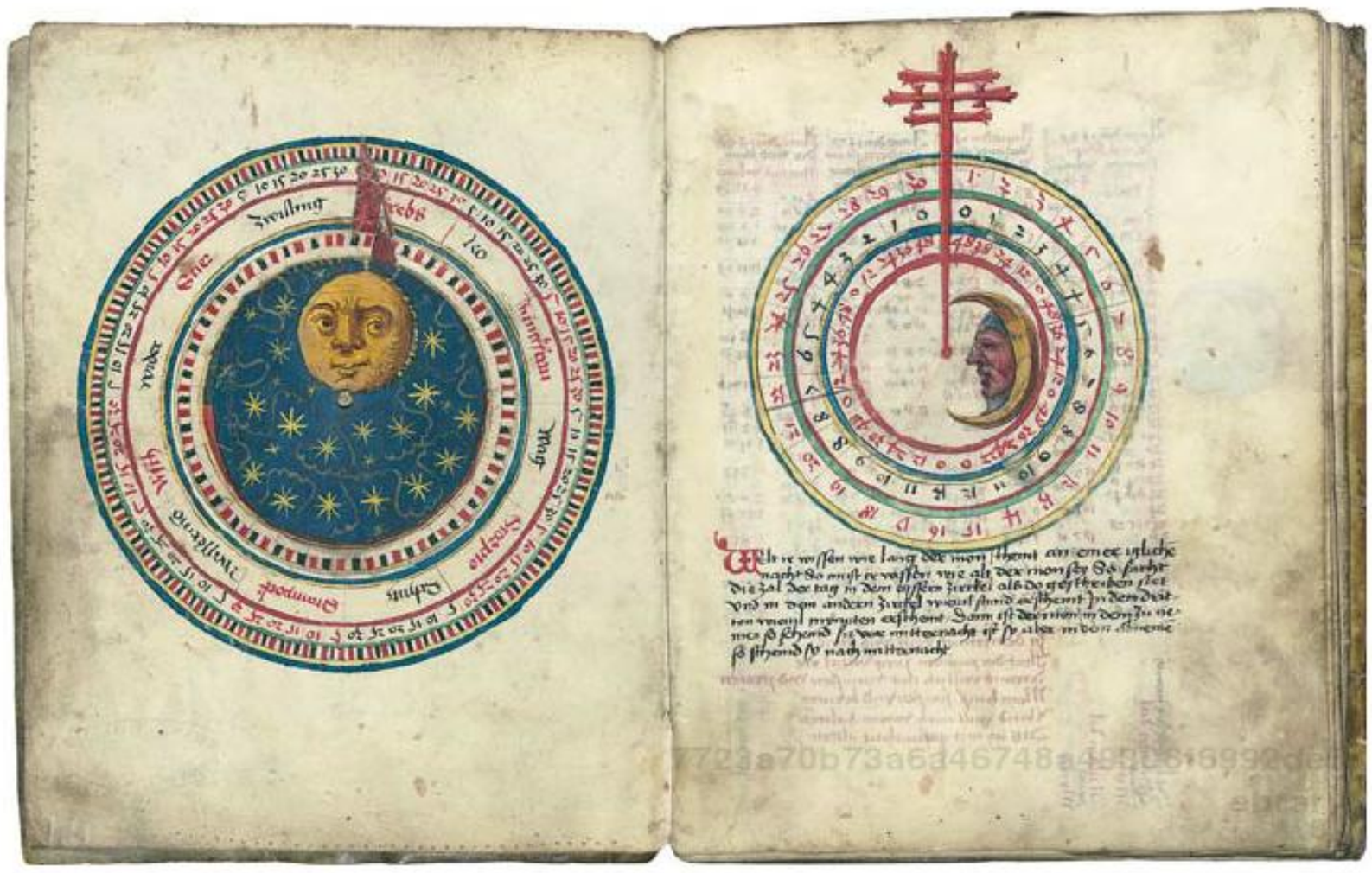


Fourteenth-century *Calendarium Parisiense* indicating holidays according to the Roman tradition.



This 1496 manuscript shows medieval calendars with depictions of the positions of the Sun and the Moon.

of the Earth on its axis. Because of its roots in Christianity, many countries have kept their original calendars for religious purposes, such as the Islamic lunar calendar, and the Hebrew, Indian, and Chinese lunisolar calendars.[5]

Another aspect of our temporal experiences is the time perceived, as when we express that "the day was too long." Discussions around the nature of time can be traced back to the fourth century, as Eco describes: "Augustine tells us, we can measure neither the past, nor the present, nor the future (since these never exist), and yet we do measure time, whenever we say that a certain time is long, that it never seems to pass or that it has passed by very quickly. In other words, there is a nonmetric measure, the sort we use when we think of the day as boring and long or when a pleasurable hour has gone by too swirly. And here, Augustine pulls off an audacious coup de théâtre: He locates his nonmetric measure in our memory. The true measure of time is an inner measure. Centuries later, Henri Bergson would also contrast metric time with the time of our consciousness or 'inner durée.'"[6]

Beginning again and again is a natural thing even when there is a series. Beginning again and again and again explaining composition and time is a natural thing.

Gertrude Stein

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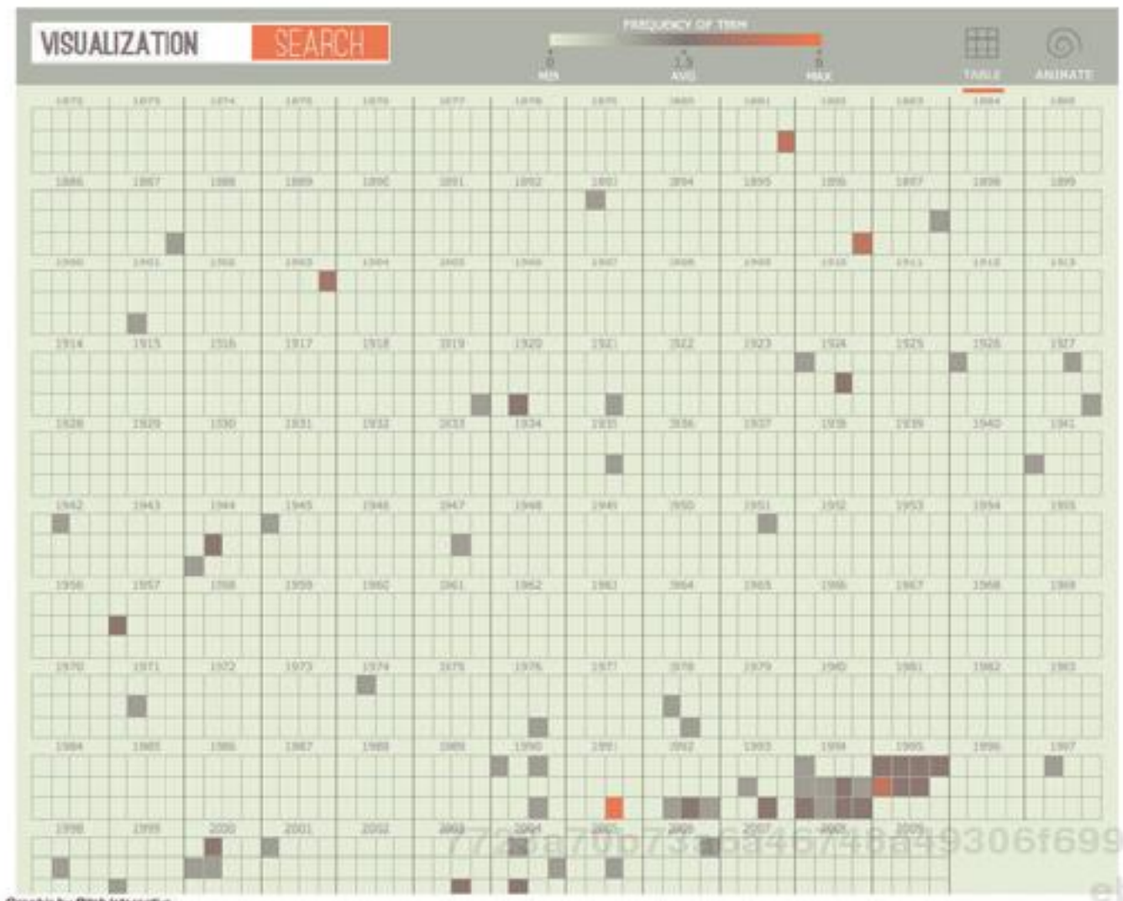
Graphic by Pitch Interactive



Graphic by Pitch Interactive

Wesley Grubbs (creative director), Nicholas Yahnke (programmer), Mladen Balog (concept artist) at Pitch Interactive, U.S.: "*Popular Science* Archive," 2009.

In 2009, *Popular Science* magazine worked with Google to digitize the magazine's archives back to its inception in 1872, transforming 1,563 issues into searchable data. The *Popular Science Archive* Explorer is an interactive online tool created by Pitch Interactive, where one can access the data, including reading the issues. It is possible to search for any single word (the example reproduced here is for "visualization") and to check the frequency of its appearance over the years. The frequency of words is color coded from gray to orange, and, in the case of the circular diagram, the area size of circles also stand for frequency. It is interesting to compare how trends are revealed in the two temporal structures available—calendar-based grid and the cyclical concentric circles—even though the latter does not present the years aligned.

www.popsci.com/content/wordfrequency#war

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STRUCTURING MODELS

Our philosophical notions of time also affect how we spatially structure time. Our conceptual models and corresponding visual structures are organized around the dichotomy between linear and cyclical times, as Stephen Jay Gould explains, "At one end of the dichotomy—I shall call it time's arrow—history is an irreversible sequence of unrepeatable events. Each moment occupies its own distinct position in a temporal series, and all moments, considered in proper sequence, tell a story of linked events moving in a direction. At the other end—I shall call it time's cycle—events have no meaning as distinct episodes with causal impact upon a contingent history. Fundamental states are immanent in time, always present and never changing. Apparent motions are parts of repeating cycles, and differences of the past will be realities of the future. Time has no direction."[7]

Gould's discussion attests to the ongoing philosophical debate over the topologies of time. But, as we shall see in this chapter, in the modern world there has been a predominance of the linear model when depicting historical time. This is mainly due to the influence of Isaac Newton's *Principia* (1687), and his definition of an absolute, true and mathematical time (in opposition to time as measured in cycles). On the other hand, we find the cyclical model used in visualizations mostly portraying periodic patterns in the data. A recent example is the *New York Times*' interactive graph depicting "How Different Groups Spend Their Day," and examined in the case

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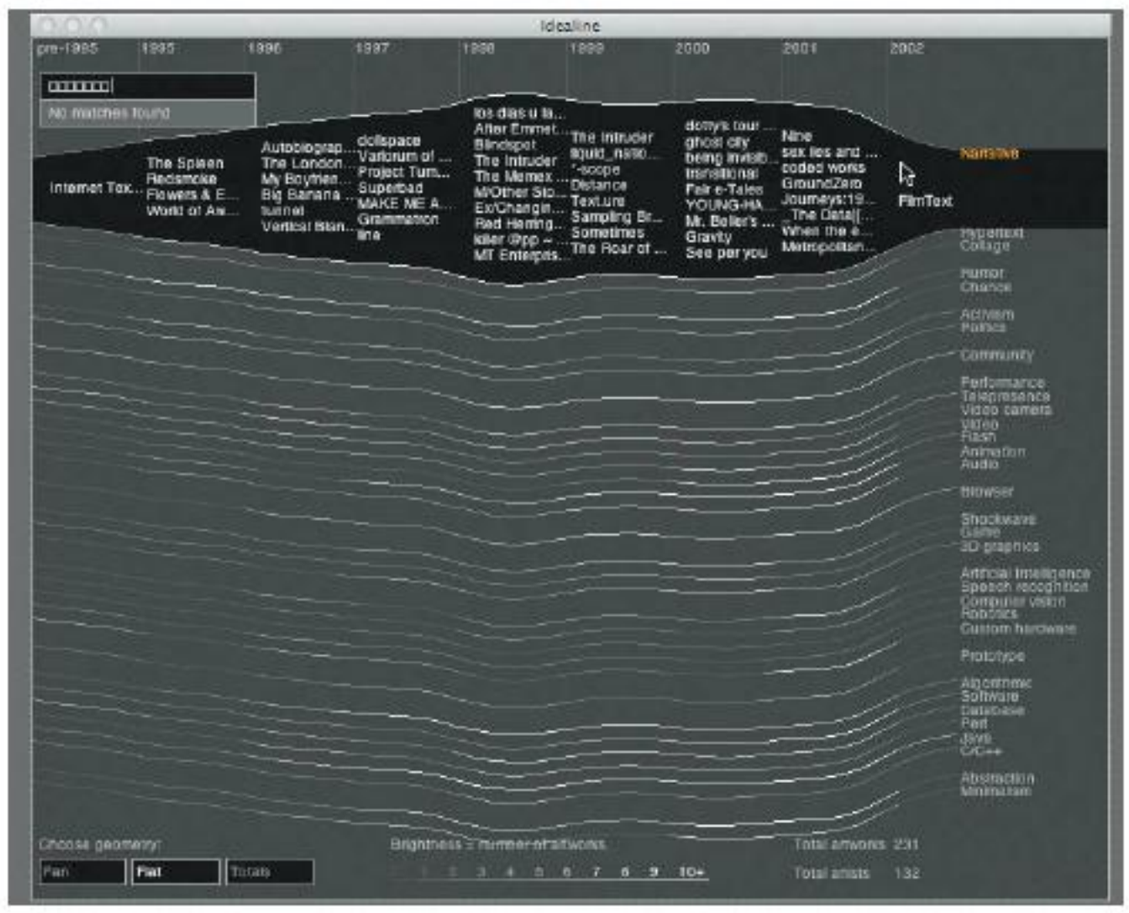

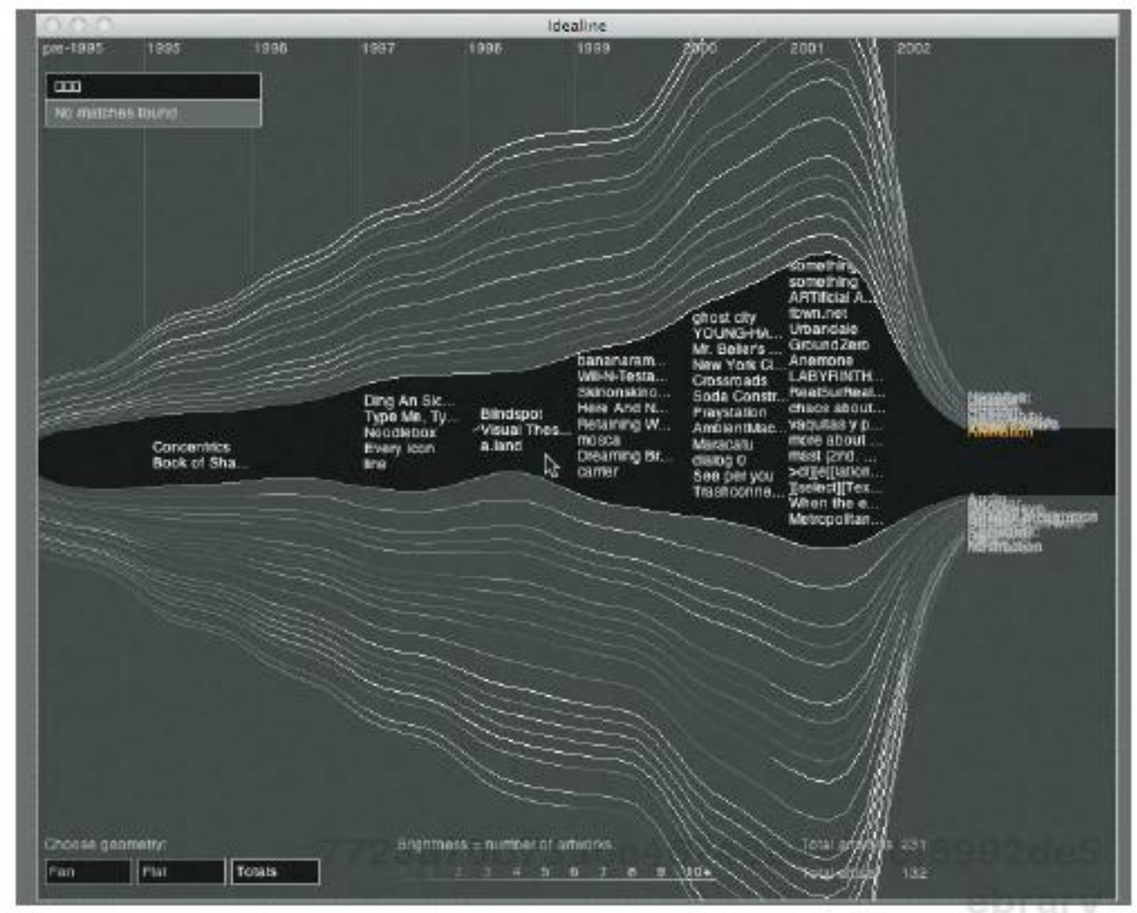

Martin Wattenberg, U.S.: "Idea Line," 2001.

"Idea Line" was the first web commission by the Whitney Museum of American Art. Martin Wattenberg created it in 2001 as a visualization of the history of software and Internet art during the early years of net artworks. Works are arranged in a fanned timeline, in which the dividing luminous lines stand for the amount of works in that yearly period. Connections between works are also highlighted, as invitations for further explorations. Wattenberg explains, "The Idea Line was designed to let you follow these threads of thought yourself, and discover how each work is part of a larger tapestry."[23]

http://whitney.org/Exhibitions/Artport/Commissions/IdeaLine

study section. It is within this functional framework, rather than the philosophical one, that the models will be discussed in the book: when to structure data so as to reveal periodicity, sequence, or a combination of both.

REPRESENTATIONS OF HISTORICAL TIME

Historical time is typically represented with the graphical form of timelines, which are chronological and sequential narratives of relevant historical events. Although ubiquitous nowadays, timelines were not invented until the eighteenth century. Initially, chronologies were represented as lists and tables, and we still see large use of these graphical structures, as one can attest by incursions on the web, or by looking at our own résumés, for example.

Different from lists, where each line stands for an event independent of the temporal interval between them, in timelines, space communicates temporal distances, and negative space becomes a relevant graphical element pregnant with meaning. Units of space may represent uniform or nonuniform temporal intervals. In the first case, all spatial units stand for the same temporal interval, whereas in the latter, spatial and temporal intervals vary.

Timelines tend to facilitate comparison between the temporal and other attributes of events. For example, timelines might reveal meaningful patterns by enhancing the perceptual grasp of events clustered in time, but at different locations, in the world.

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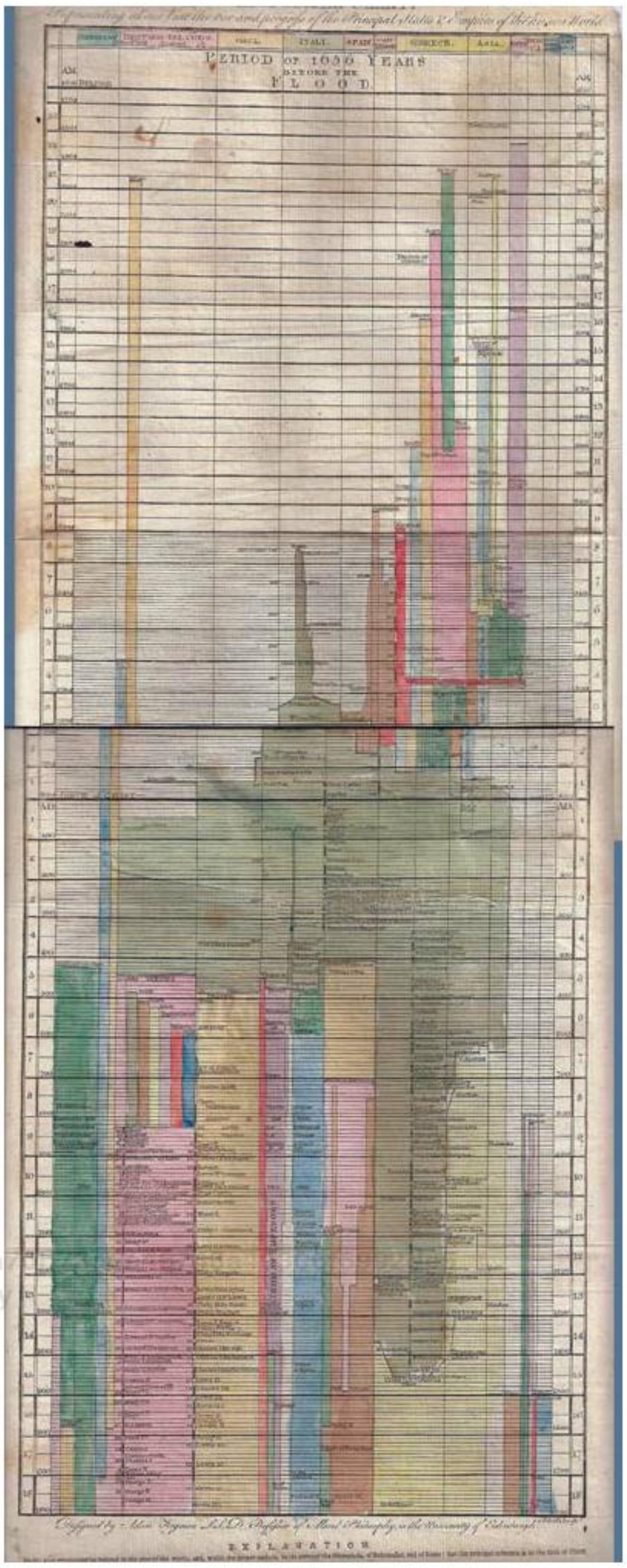

Scottish historian and philosopher Adam Ferguson (1723–1816) created this timeline of historical events to accompany his article titled "History," published in the second edition of the *Britannica Encyclopedia* in 1780. Time is depicted vertically, with the earliest time at the top, 2344 BCE. The timeline focuses on the birth and death of civilizations, that are organized horizontally and color coded to help differentiate between nations.

VERTICAL VERSUS HORIZONTAL AXES

We tend to order items using either a vertical or a horizontal orientation. Tversky explains that our preferences are grounded in perception: "The perceptual world has two dominant axes: a vertical axis defined by gravity and by all the things on earth correlated with gravity; and a horizontal axis defined by the horizon and by all things on earth parallel to it. Vision is especially acute along the vertical and horizontal axes. Memory is poorer for the orientation of oblique lines, and slightly oblique lines are perceived and remembered as more vertical or horizontal than they were."[8]

The vertical orientation has precedence over the horizontal, as we see in the dominance of language expressions associated with up/down orientation. Lakoff and Johnson have shown that we tend to naturally correspond "up" with positive feelings such as good, happy, strong, whereas "down" is identified with bad, sad, weak, and so on.[9] In representations of time, however, the horizontal orientation is prevalent.

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In chronological lists, time is ordered vertically, and in all cultures we start at the top of the page. In tables and timelines, we find time ordered either vertically or horizontally. The first graphical timelines that appeared in the mid-eighteenth century depicted time horizontally, with time moving from left to right, as we shall see below. The orientation corresponds to the horizontal preference for depicting time, and the directionality of the authors' European writing systems. Literature in perception and cognition has shown that we tend to use the direction of our writing systems to order events over time. Studies conducted by Tversky and colleagues have shown that "people who wrote from left to right tended to map temporal concepts from left to right and people who wrote from right to left tended to map temporal concepts from right to left. This pattern of findings fits with the claim that neutral concepts such as time tend to be mapped onto the horizontal axis. The fact that the direction of mapping time corresponded to the direction of writing but the direction of mapping preference and quantitative variables did not may be because temporal sequences seem to be incorporated into writing more than quantitative concepts, for example, in schedules, calendars, invitations, and announcements of meetings."[10]

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THE BEGINNING OF UNIFORM TIMELINES

In uniform timelines, time is represented following Newton's mathematical notion of an absolute and uniform container of events. The innovation brought first by Jacques Barbeu-Dubourg and then by Joseph Priestley, who added lines to show duration, emphasizes the visual perception of time in a unifying structure provided by the simultaneity of events. Priestley acknowledged the influence of "chronological tables" done by the seventeenth-century scholars Francis Tallents and Christoph Helvig (Helvicus), who depicted

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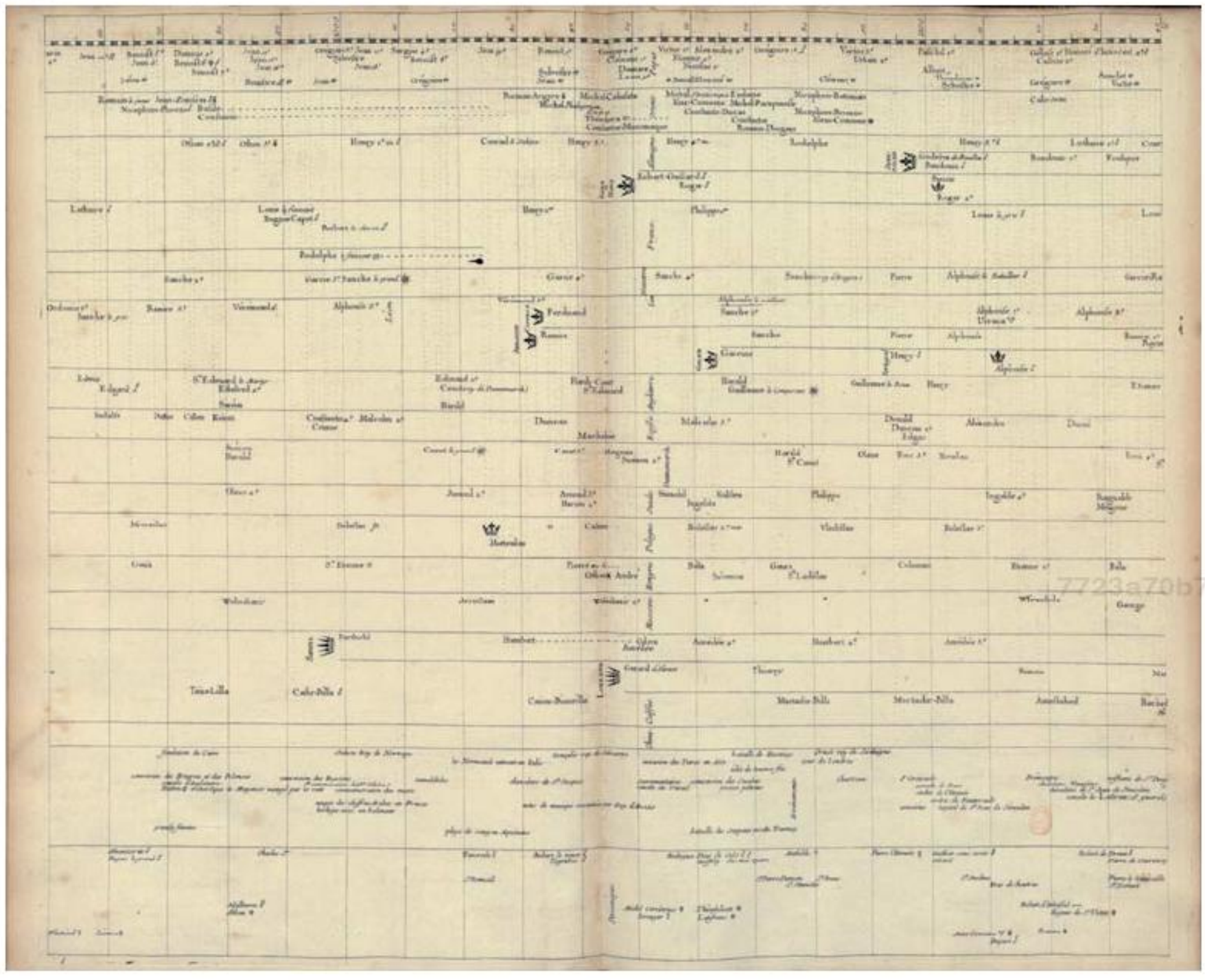

not only dates and events but also information on kingdoms and geography.[11] The tables used a grid with uniform spatial structure, but space did not stand for uniform temporal intervals. Intervals were defined according to meaningful events, such as shifting dates in historical periods.

The use of space to denote the historical temporal dimension, and more specifically temporal intervals, appears in the mid-eighteenth century. In 1753, Jacques Barbeu-Dubourg (1709–1779), French doctor, botanist, and philologist, created a 5.4-foot chart (1.6 m) depicting history from the Creation to his time. The chart is considered the first to have depicted a uniform timescale by dividing space arithmetically. To view sections of this long paper diagram, Barbeu-Dubourg constructed a device with a manual scrolling mechanism. His objective, as described in the accompanying explanatory document, was to use vision to amplify cognition, in that by looking at his chart, one would not need to use one's memory; rather, it would suffice to scroll the chart to the desired point in time. By mapping time uniformly, the chronography (graph of chronological time) enabled easy comparison of temporal intervals.[12]

The "*Chronographie Universelle*" by Frenchman Jacques Barbeu-Dubourg (1709–1779) was published in 1753. In this 5.4-foot (1.6 m) paper roll, Barbeu-Dubourg depicts the main events for each century starting at the time of Creation, a total of 6,480 years. This timeline is considered the first to have used a uniform timescale to represent historical events, with each year represented by 0.1 inch (2.5 mm). Barbeu-Dubourg constructed a device to facilitate viewing the long diagram, as depicted in the diagram above. Names and events are positioned horizontally according to when they occurred in time and grouped vertically either by country or under the general category of "*événments mémorables*." Barbeu-Dubourg understood history as having two ancillary fields, geography and chronology, as Wainer explains: "By wedding the methods of geography to the data of chronology he could make the latter as accessible as the former. Barbeu-Dubourg's name for his invention, chronographie, tells a great deal about what he intended, derived as it is from *chronos* (time) and *graphein* (to write). Barbeu-Dubourg intended to provide the means for chronology to be a science that, like geography, speaks to the eyes and the imagination."[24]

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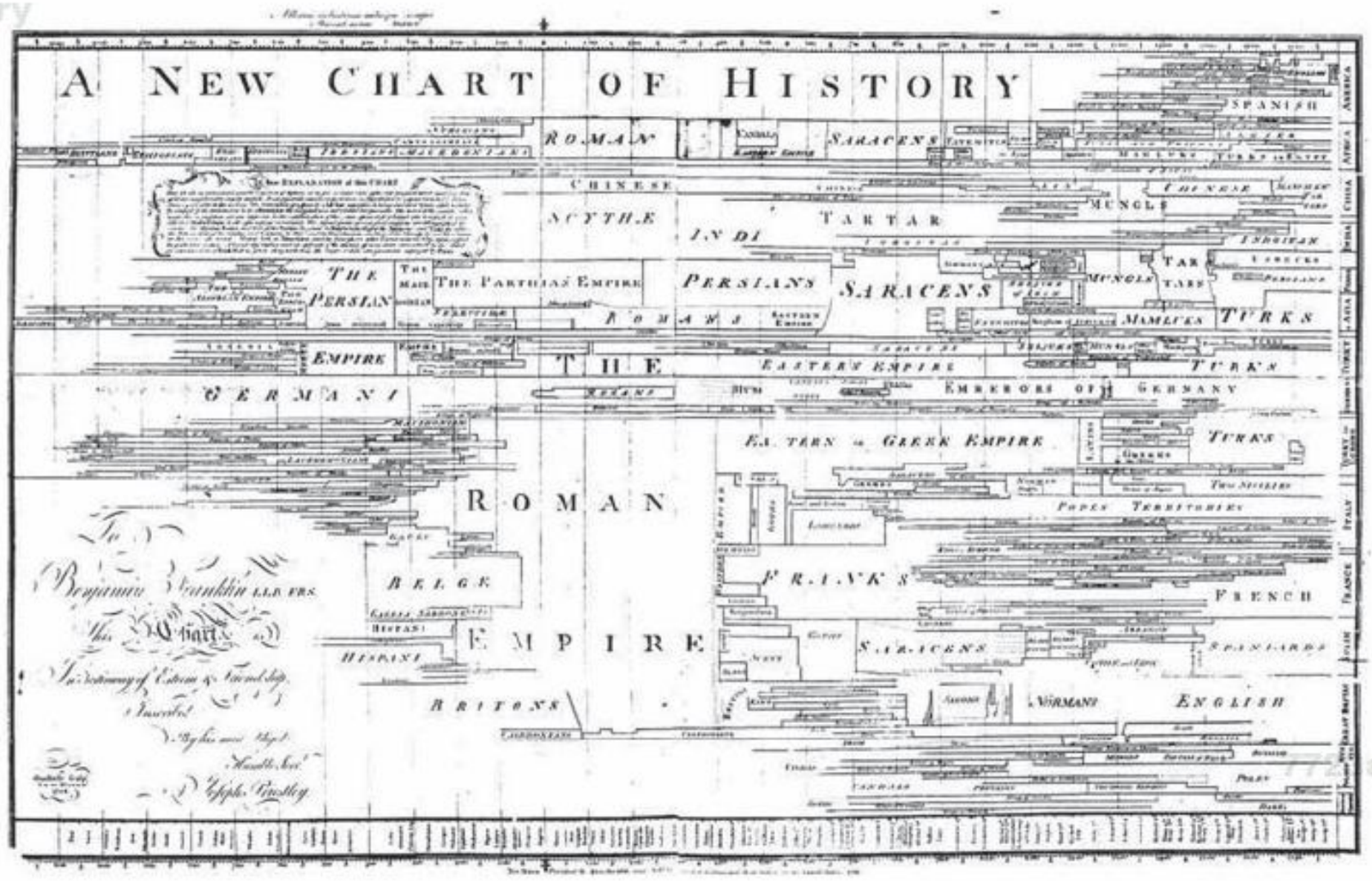

"A New Chart of History" by Joseph Priestley was published in 1769. Designed for a general public and with a pedagogical purpose, some versions of the graph add color codes to the previous conventions devised by Priestley to depict historical events over time. The colors visually enhance the perception of empires that crossed different geographical boundaries—in this graph, depicted horizontally.

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PRIESTLEY'S TIMELINES OF HISTORICAL DATA

Joseph Priestley (1733–1804), British theologian, scientist, and philosopher, published in 1765 the first of a series of timelines, the "Chart of Biography." Similar to Barbeu-Dubourg, Priestley represented time linearly using equal intervals throughout the chart. Among Priestley's innovations is the use of lines to represent duration: line lengths stand for the duration of depicted lives, thus resulting in a chart of lifelines. In the accompanying essay, "A Description of a Chart of Biography," Priestley asserts that we make use of spatial expressions such as "short" and "long" to describe periods of time, expressions that naturally fit into the visual representation of lines and intuitively describe quantities as measurable distances. He points to the cognitive advantages of his linear representation of time: "It follows from these considerations that to express intervals of time by lines facilitates an operation which the minds of all men have recourse to, in order to get a just and clear idea of them; and that the view of a number of lines, drawn exactly in proportion to a number of intervals of time to which they correspond, will present to the mind of any person a more just and distinct idea of the relative lengths of the times they represent than he could have formed to himself without that assistance."[13]

The "Chart of Biography" is 3 X 2 feet (90 X 60 cm) and depicts a period between 1200 BCE and Priestley's own time in the eighteenth century, covering around 3,000 years and the lives of 2,000 famed persons. The names are organized into six themes, divided by lines and ordered from top to bottom as follows:

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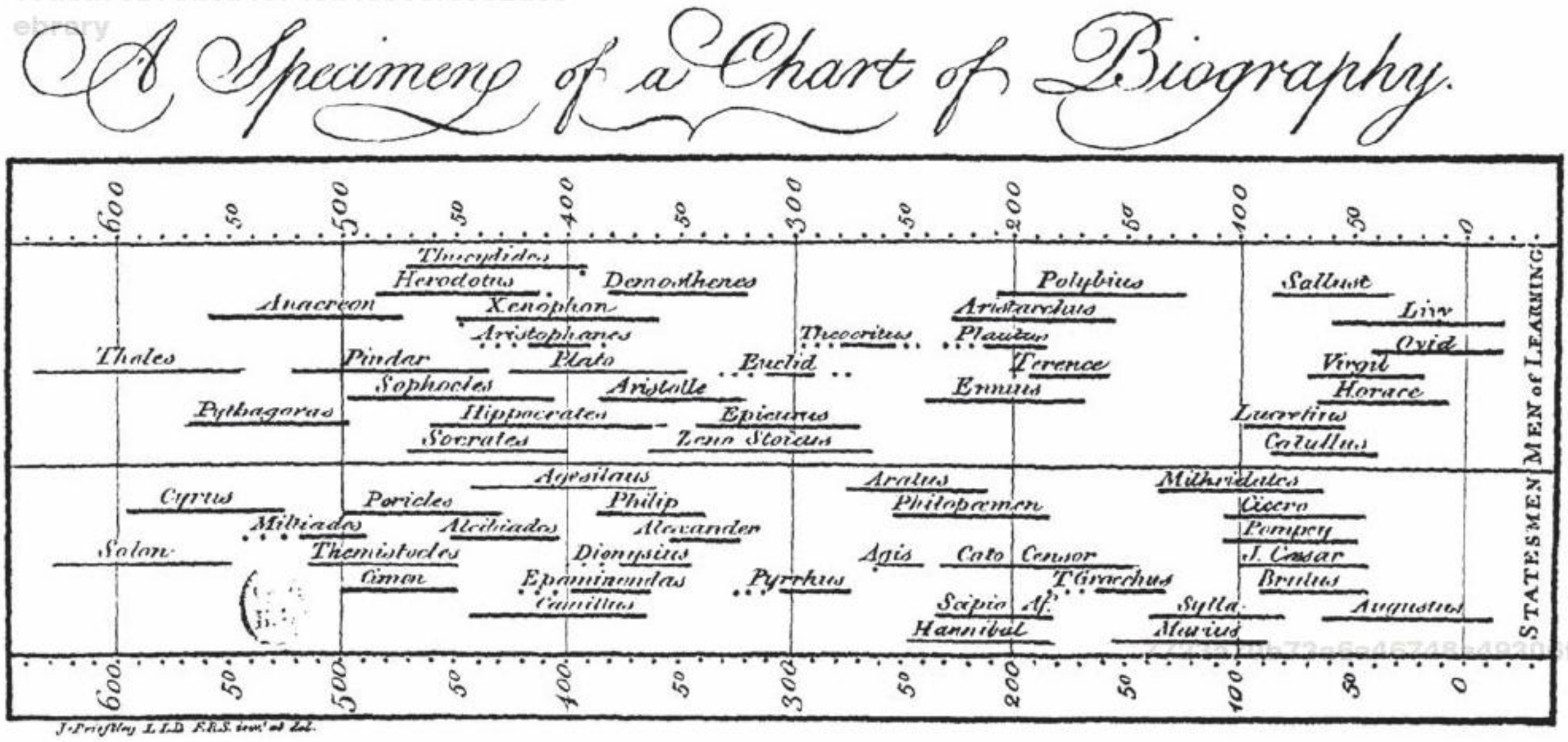

This diagram is a sample of the "Chart of Biography" created by Joseph Priestley and published in 1765. Note the conventions devised by Priestley to depict uncertainty in the lives of famed persons, with dots placed at the beginning or the end of lifelines.

Historians, Antiquaries, and Lawyers; Orators and Critics; Artists and Poets; Mathematicians and Physicians; Divines and Metaphysicians; Statesmen and Warriors. The criterion for the order was that of relevance, with the Statesmen as the most important group placed at the bottom for easy access. To facilitate comparisons, Priestley located the lifelines of persons with connections near each other, the same for people for whom he considered closeness to be advantageous: "Almost any number of lives may be compared with the same ease, to the same perfection, and in the same short space of time."[14]

Priestley acknowledged that not all dates had the same level of accuracy, for which he devised a graphical system to differentiate uncertainties: lives with known dates for birth and death were depicted with solid lines, and uncertain dates were represented with dots. Dates known to be "about" a certain time were depicted by a dot below the line. Lines starting or ending with dots represented uncertainty of dates for birth or death, respectively. Finally, for the case when nothing was known, Priestley drew a dashed line where he believed to be the most probable date.[15] The only verbal notations were the written names placed above the lines.

Another graphical element used by Priestley was a solid line under a lifeline to depict the period when an author was considered to have flourished: "When it is said that a writer flourished at or about a particular time, a short full line is drawn about two thirds before and one third after that particular time, with three dots before and two after it; because, in general, men are said to flourish much nearer the time of their death than the time of their birth."[16]

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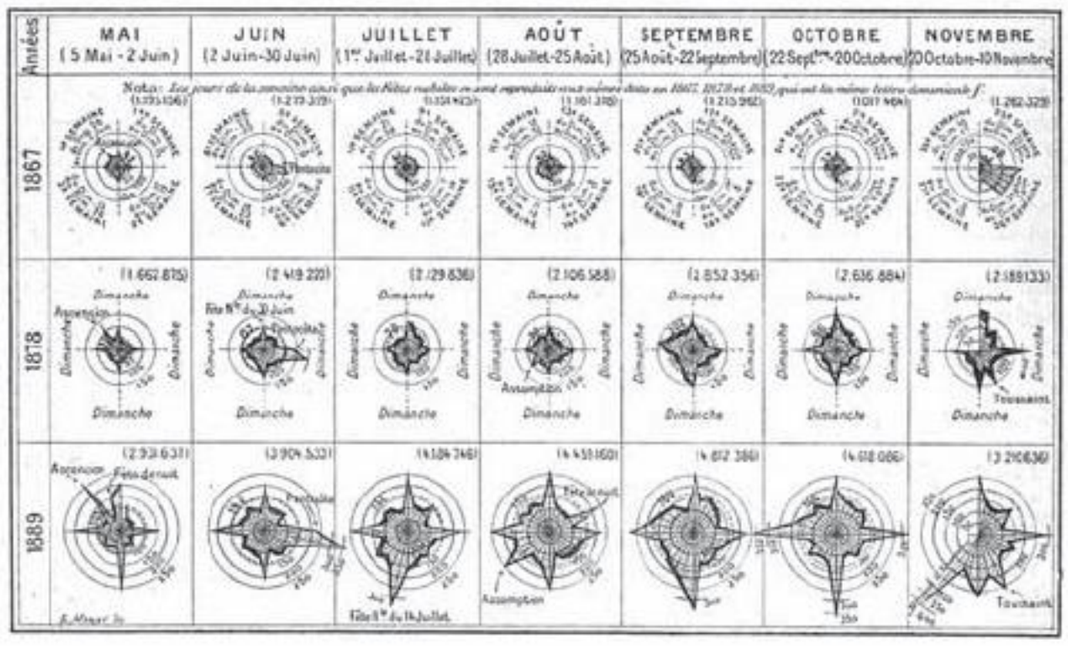

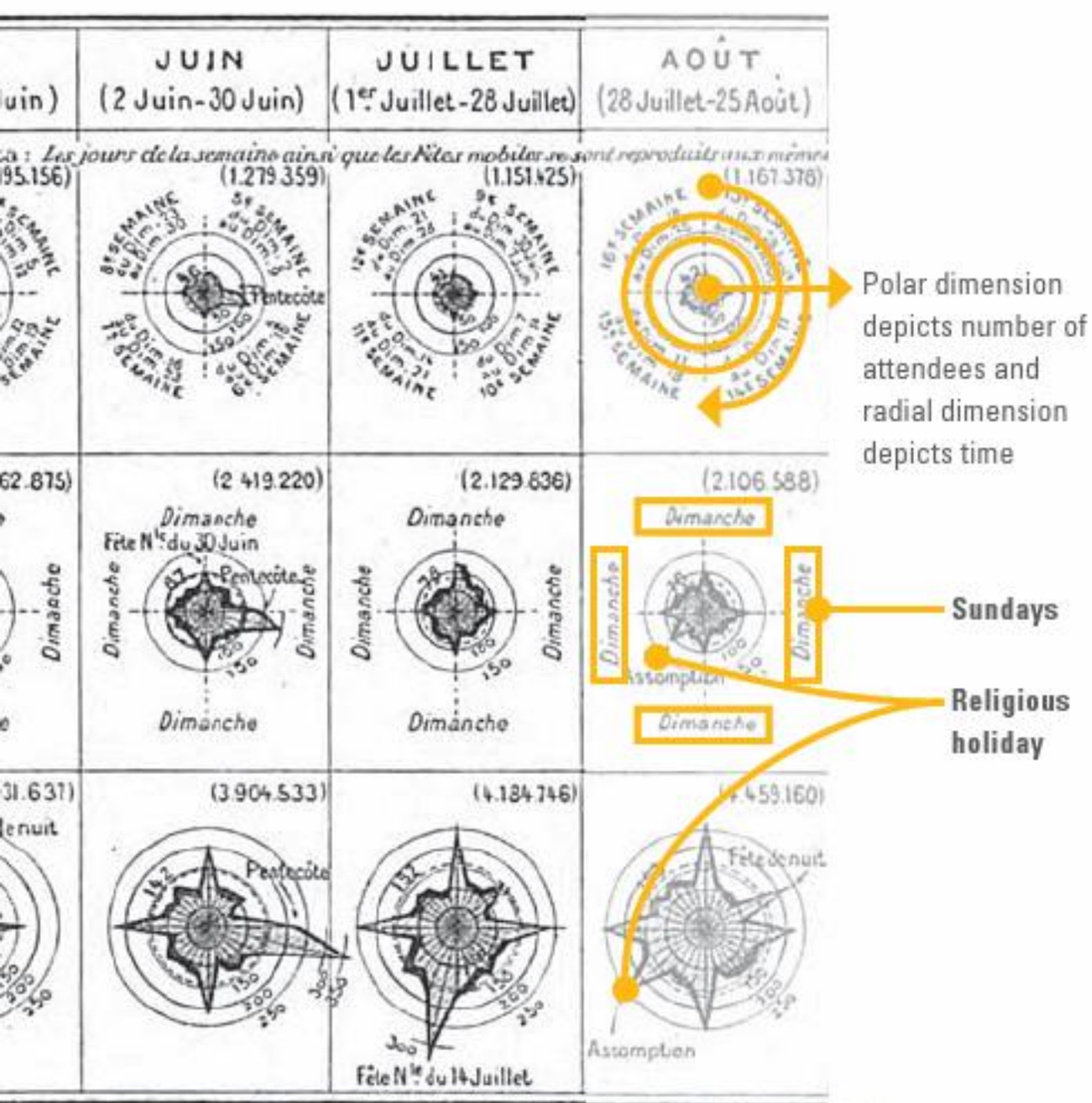

The diagram "Statistics of the Universal Exhibitions in Paris" by Émile Cheysson was compiled soon after the 1889 exhibition and compares its attendance to the previous two events in Paris in 1867 and 1878 (vertical axis) by depicting statistics month by month (horizontal axis). To facilitate comparison across the years, the position of Sundays and other holidays are kept in the same location in all graphs, also highlighted with additional notes.

Priestley originally drew the "Chart of Biography" as a visual device to facilitate understanding of his "Lecture upon the Study of History," during which he presented it for the first time. Later, Priestley decided to print the chart to provide his students with the pedagogical material.[17] Both the "Chart of Biography" (1765) and "A New Chart of History" (1769) were devised for the general public as reference aids of historical context and were used with this purpose by teachers for several decades (both went through more than twenty editions). Priestly used the same timescale and graphical encoding in the two charts to enable the reader to move between them: they cover the same historic period, beginning and ending at the same dates, and they depict the same statesmen.[18]

The charts, however, are too big in dimensions and, consequently, they are hard to reproduce, or even to look at the whole at once. But, sectioning the charts obliterates their significance, because the purpose is to provide historic context to the topics depicted. The charts make sense only when viewed as a whole: It is the broad view that communicates the historic content and context. This is a paradox that anyone attempting to create timelines faces, especially when using uniform timescales.

Rosenberg writes about Priestley's influence during and after his time: "As aids to the study of history, Priestley's charts were recommended by numerous pedagogical manuals of the day. As models for the graphic presentation of data, they exerted a deep influence: They were, in fact, the only precedent recognized by William Playfair, the central figure in the early development of statistical graphics. Perhaps the most important interpretation of Priestley's timelines occurs in Playfair's *Commercial and Political Atlas* of 1786 and his *Inquiry into the Permanent Causes of the Decline and Fall of Powerful and Wealthy Nations* of 1805. In these works, Playfair explicitly juxtaposes historical timelines of the sort pioneered by Priestley with the line graphs that had, by then, become Playfair's own stock and trade."[19]

EARLY TEMPORAL STRUCTURES IN OTHER DISCIPLINES

William Playfair (1759–1823) created several line graphs to represent economic data as a function of time, which were first published in his *Commercial and Political Atlas* in 1786. It is interesting to note that out of the forty-four charts published in this volume, only one chart was not a line graph. Due to a lack of temporal data for the exports and imports of Scotland, Playfair saw the need to devise a graphical representation in which time was not one of the dimensions, and the innovation resulted in the first known bar chart. Initially, Playfair considered it a less effective representation,

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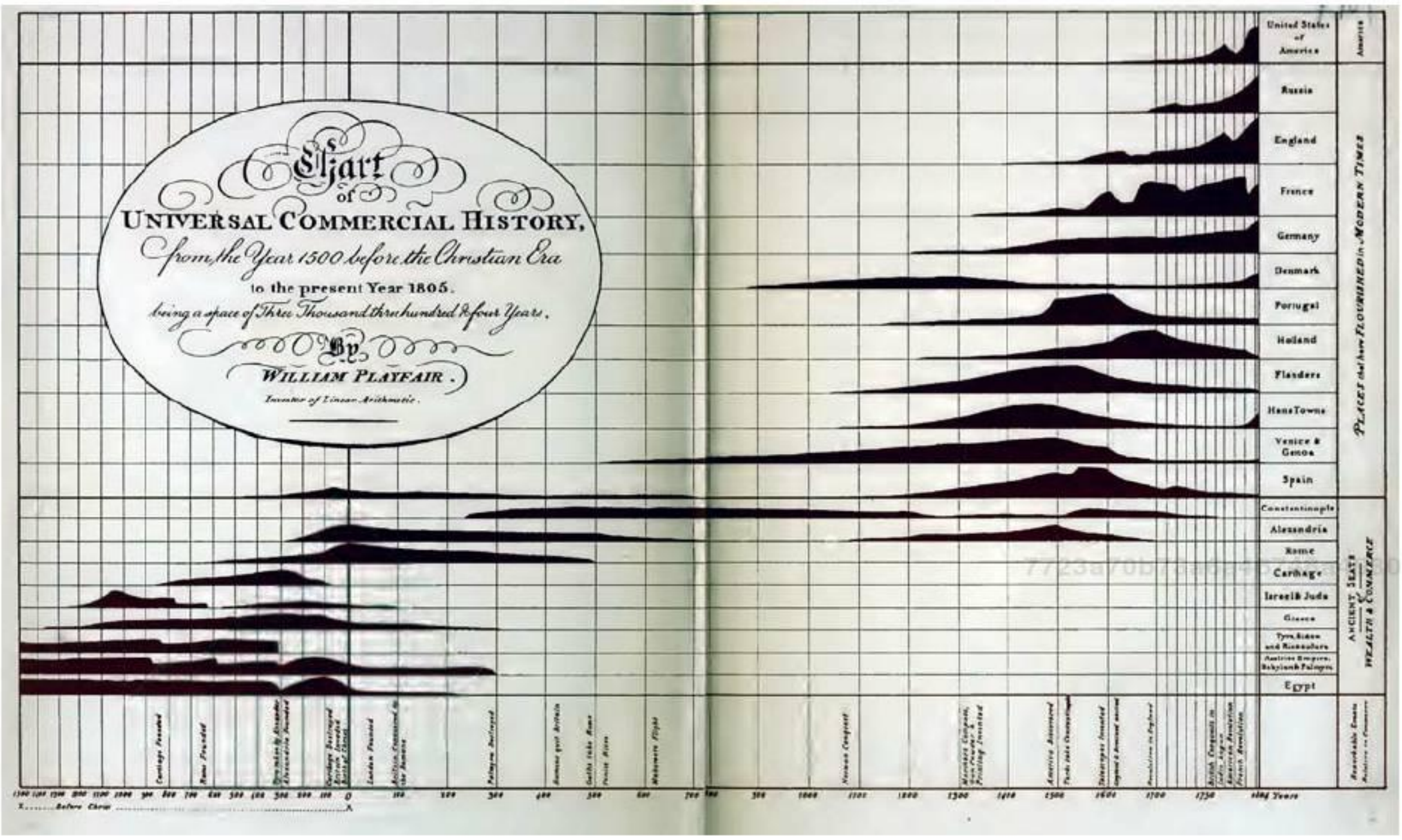

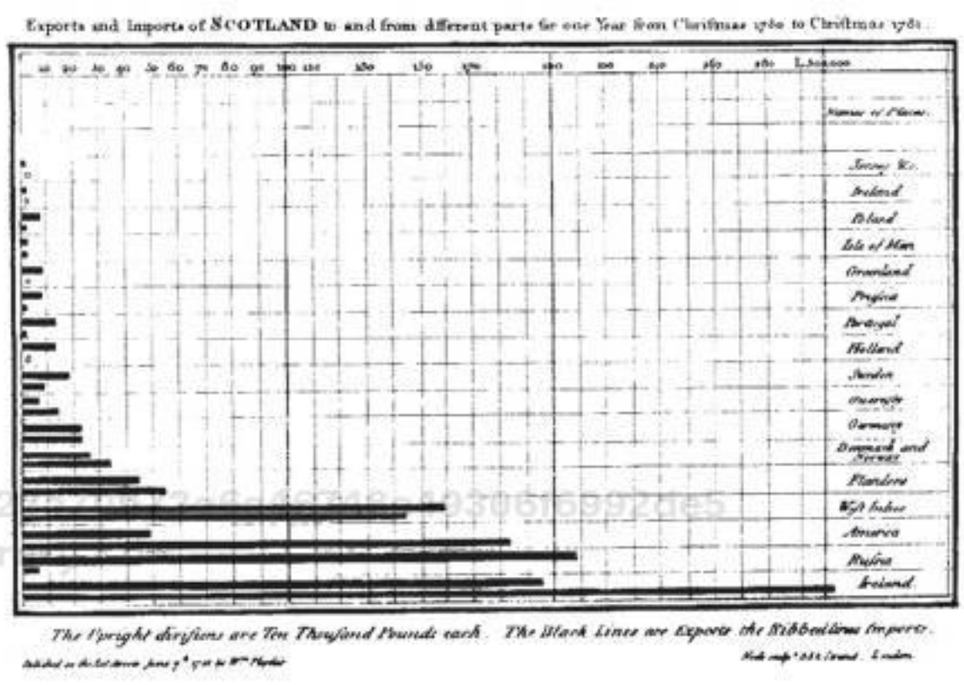

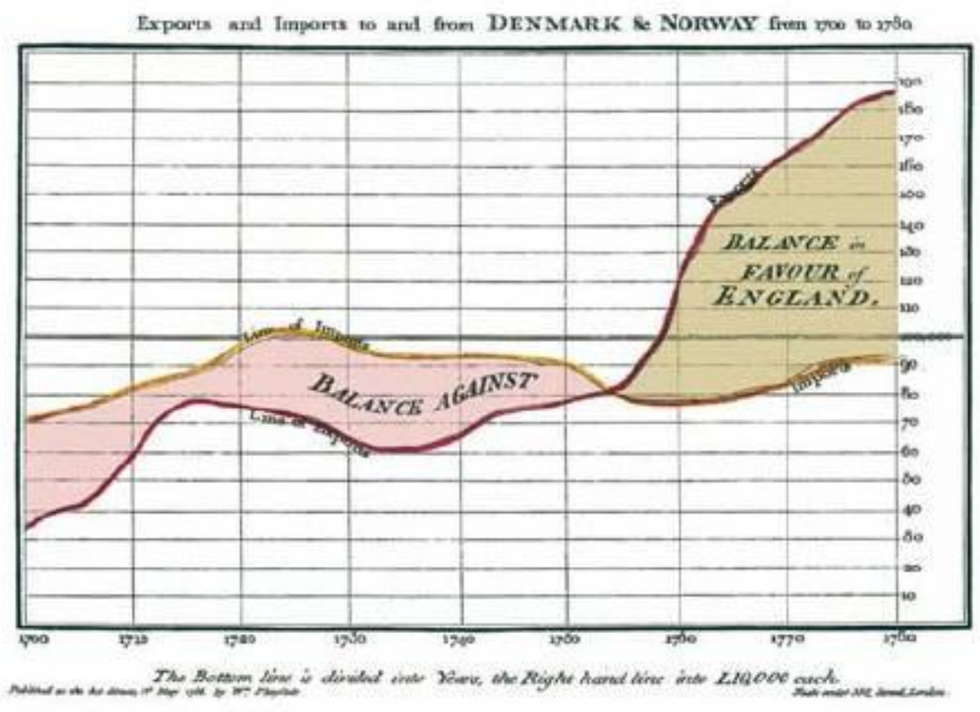

The first known bar graph was designed by William Playfair and published in his *The Commercial and Political Atlas*. It depicts the Exports and Imports of Scotland to and from different parts for one year, from Christmas 1780 to Christmas 1781. Different from all other graphical representations in the book, this was the only bar graph, because Playfair had to be inventive in the face of the lack of temporal data. At first, he thought the bar graph was "much inferior in utility" than the timelines, a position he changed in later editions of the atlas.[25] The other two graphs show data depicted over time: Exports and Imports to and from Denmark and Norway from 1700 to 1780 (bottom), and Universal Commercial History from 1500 BCE to 1805 (top). The latter was influenced by Priestley's timelines, and it depicts the rise and fall of nations over 3,000 years. It is interesting to note the change in the temporal scale. Wainer and Spence explain that Playfair's graphs "were remarkably similar to those in use today; hachure, shading, color coding, and grids with major and minor divisions were all introduced in the various editions of the Atlas. Actual, missing, and hypothetical data were portrayed, and the kind of line used, solid or broken, differentiated the various forms. Playfair filled the areas between curves in most of the charts to indicate accumulated or total amounts. All included a descriptive title either outside the frame or in an oval in the body of the chart. The axes were labeled and numbered where the major gridlines intersected the frame."[26]

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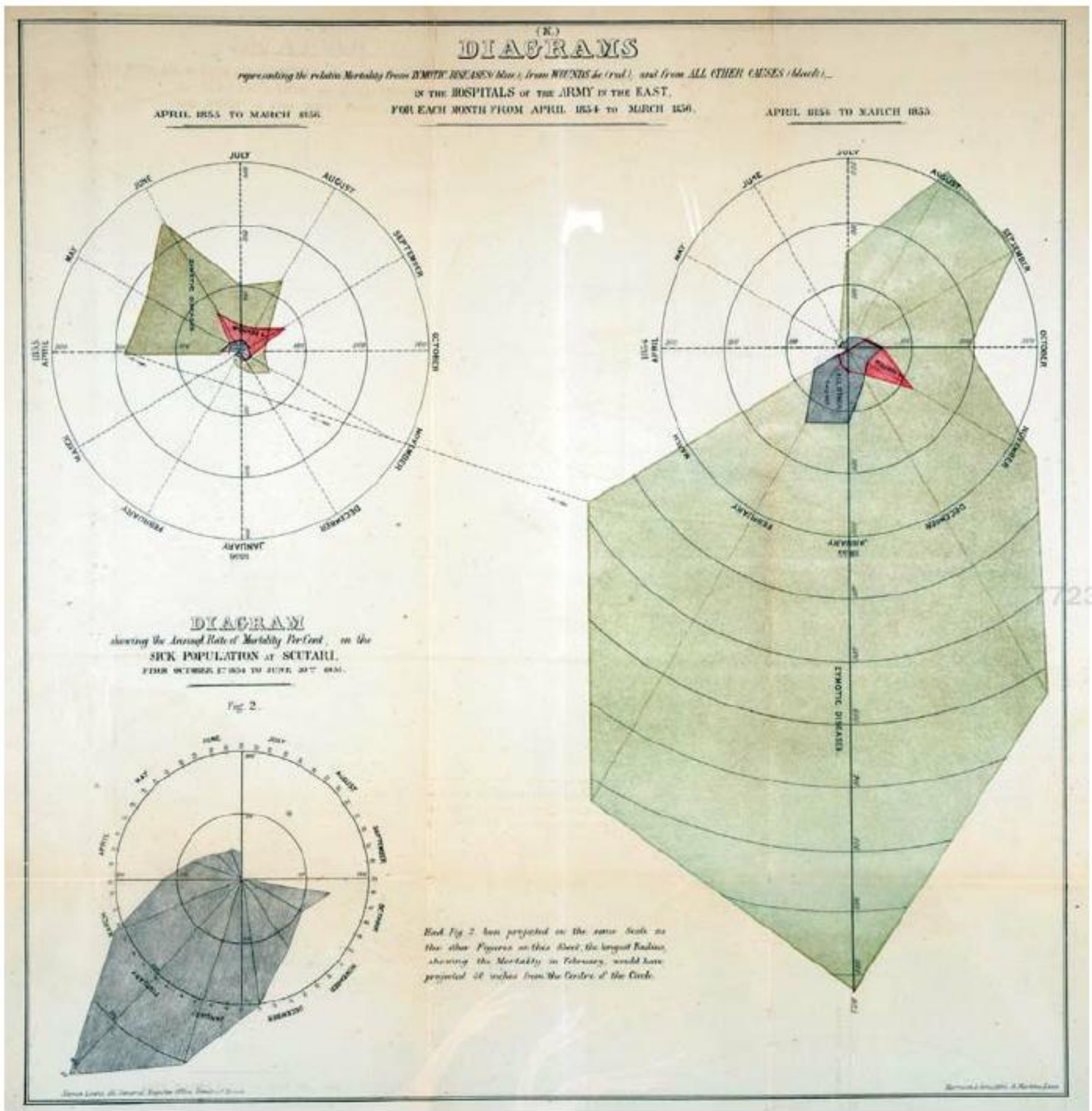

The British nurse, Florence Nightingale, published in 1858 the "Diagrams Representing the Relative Mortality from Zymotic Diseases (blue), from Wounds &c. (red), and from All Other Causes (black), in the Hospitals of the Army in the East, for Each Month from April 1854 to March 1856" with the intent to promote better sanitation and administration in civilian and military hospitals. Later, Nightingale changed the technique to "coxcomb" graphs reproduced on the right.

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as he writes in the first edition of the atlas: "The chart … does not comprehend any portion of time, and it is much inferior in utility to those that do."[20] The pie chart, another graphical invention by Playfair, was described in chapter 1 (page 36).

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The British nurse Florence Nightingale used a cyclic model of time to represent medical data. Published in 1858, the "Diagram of the Causes of Mortality in the Army in the East" depicts the causes of death by plotting mortality data using a polar graph, also known as "rose charts." Unlike pie charts, in rose charts all wedges have the same angle, and each stands for a time period. The circumference is divided into twelve wedges, each standing for a month of the year. The quantitative data are represented in the polar axis, and depicted by the length of each radius, not the area, as expected. Despite that the graph presents two-dimensional elements (the wedges), the amounts are depicted linearly, which is disguising at first, especially considering that the graph does not provide a measuring scale.

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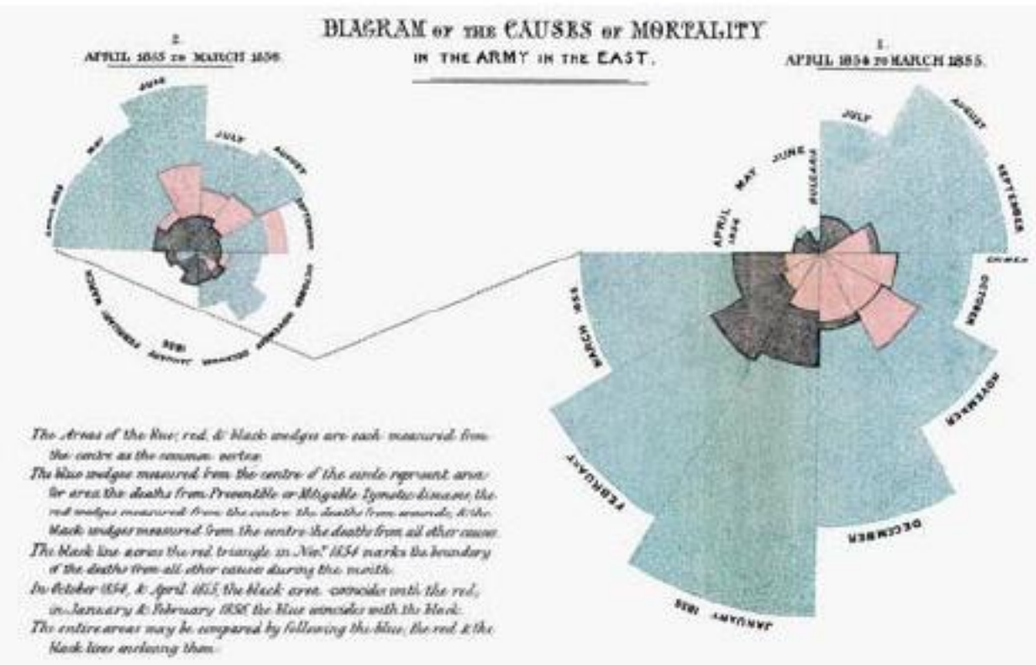

This "Diagram of the Causes of Mortality in the Army in the East" was devised by the British nurse Florence Nightingale and published in 1858. It is a polar graph, not a pie chart, such that the radius of each wedge depicts the number of deaths for each month. Color stands for the types of death causes: preventable diseases are in blue, war wounds in red, and fatalities in black.

Although Nightingale didn't invent rose charts, her graph became a landmark in medicine because it was instrumental in persuading the British government of the need for better health care systems. The graph efficiently demonstrates that the majority of deaths were not the result of accidents of war; rather, they were caused by preventable factors, such as lack of hygiene and infectious diseases. According to Friendly, the method was devised by Guerry, who published in 1829 the first known rose diagram "to show seasonal and daily variation in wind direction over the year and births and deaths by hour of the day."[21]

Other early examples of graphical representations portraying temporal data are medical reports, such as fever curves in the nineteenth century. Time schedules and productivity diagrams became common graphical devices in the second half of the nineteenth century with advances in industrialization. Page 8 shows an early example of the Paris–Lyon train schedule designed by Etienne-Jules Marey in 1885.

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GRAPHICAL CONVENTIONS

Most of the graphical inventions discussed previously, such as timelines and line graphs, are remarkably similar to their contemporary counterparts, as we see in the visualizations in this chapter. It is worth noting the graphical conventions devised by Priestley, which continue unchanged to this day when we create timelines. Priestley's graphical system comprises the following main graphical elements:

- **Timescale:** Timescale is uniform and represented arithmetically, following Newton's notion of absolute time.
- **Time indicators:** Dates are inscribed at the top and at the bottom, and connected by lines to facilitate perception of the temporal divisions. In Priestley's timelines, the grid is that of a century, with decades marked with dots.
- **Thematic sections:** Horizontal thematic sections are separated by lines. In the "Chart of Biography," the divisions are thematic (Statesmen, Artists, etc.), and in "A New Chart of History," the divisions are geographic.
- **Line indicators:** Line lengths are used to depict duration. In Priestley's timelines, they stand for lifelines.
- **Line differentiators:** Levels of uncertainty in the data are graphically depicted by the quality of lines (solid or broken lines), and with the addition of dots.
- **Color code:** Color was added to "A New Chart of History" to encode the empires that are noncontiguous spatially.

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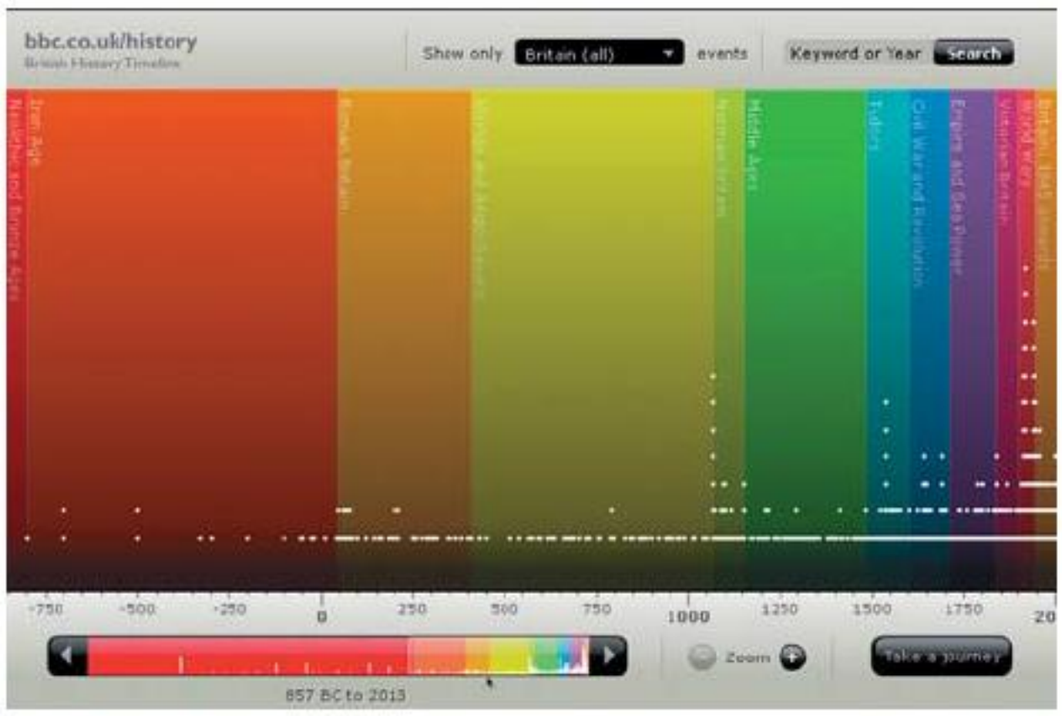

The online *British History Timeline* by the BBC provides a great pedagogical tool to learn about events taking place in the United Kingdom from the Neolithic era to the present day. It allows visitors to explore historical events that can be filtered by regions of the United Kingdom as well as by date. Detailed information on events appears connected when they have developed over time. It was designed and built by AllofUs and conceived by the BBC History website team.

www.bbc.co.uk/history/interactive/timelines/british/index_embed.shtml

Most of the graphical conventions devised by Playfair for his several graphical inventions, including the pie chart, the bar graph, and the line and area graphs, are also preserved in current visualizations without many changes.

NONUNIFORM TIMESCALES

Timescales facilitate comparison over time, including our understanding of events diachronically. However, not all data are suited for depictions using a uniform timescale. The early timelines examined are good examples of how uneven the densities across the diagrams are, especially when depicting large spans of time. It is not uncommon that the most recent periods in history tend to have more information, whereas older times are almost devoid of events. As such, some representations benefit from the use of nonlinear timescales. For example, when using a logarithmic scale, the wider regions in the timeline can be used for depicting the periods with denser data.

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Among the most innovative possibilities opened up by computerized interactivity is the ability to scale time, in other words, the ability to zoom in and out in time in similar ways to how we zoom in space. Take for example, the online tool BBC *British History Timeline*, which uses a uniform timescale but enables the viewer to delve into the data and learn about events synchronically.

TIMELINES IN THE DIGITAL ENVIRONMENT

Similar to their printed ancestors, digital timelines enable navigation through time by means of sliding back and forth along the linear structure, not much different from how one moved the timeline in Barbeu-Dubourg's mechanical device.

The inclusion of other contexts, which Priestley initiated by adding historical context to his charts, has been expanded in the digital realm with associating diverse datasets toward new insights. Nontemporal categories (e.g., geographical, philosophical, etc) are often mapped in the opposite axis and layered to allow easy comparison within the ordered temporal dimension.

There are other enhancements to timelines brought forward by computerized interactivity, such as the ability to filter data according to specified thresholds, to delve into content, and to zoom in and out of time, as mentioned earlier.

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Magical Number Seven

George A. Miller published in 1956 the seminal article "The Magical Number Seven, Plus or Minus Two," where he examines our limited capacity for receiving, processing, and remembering information. The article introduces three areas that, despite showing similar span capacities, should not be considered uniformly, because each involves different cognitive processes:

1. Our span of absolute judgment can distinguish about seven categories.
2. Our span of attention encompasses six objects at a glance.
3. Our span of working memory is about seven items in length.

Miller distinguishes between absolute judgment and immediate memory, in that the first is limited by the amount of information, while the latter is limited by the number of items, independent of the amount of bits. He continues, "In order to capture this distinction in somewhat picturesque terms, I have fallen into the custom of distinguishing between bits of information and chunks of information. Then I can say that the number of bits of information is constant for absolute judgment and the number of chunks of information is constant for immediate memory. The span of immediate memory seems to be almost independent of the number of bits per chunk, at least over the range that has been examined to date."[27]

Miller stresses the importance of grouping the input into meaningful units as a mechanism to increase our capacities for memory. Some strategies of grouping are discussed throughout the book in the boxes dedicated to the Gestalt principles. Another powerful strategy discussed by Miller, and borrowed from communication theory, is recoding, or devising a code to the input to contain fewer chunks with more bits per chunk. To illustrate the point, he shows how we could increase the amount of information by recoding a sequence of eighteen binary digits:

Binary Digits (Bits)		1 0 1 0 0 0 1 0 0 1 1 1 0 0 1 1 1 0
2:1	Chunks	10 10 00 10 01 11 00 11 10
	Recoding	2 2 0 2 1 3 0 3 2
3:1	Chunks	101 000 100 111 001 110
	Recoding	5 0 4 7 1 6
4:1	Chunks	1010 0010 0111 0011 10
	Recoding	10 2 7 1
5:1	Chunks	10100 01001 11001 110
	Recoding	20 9 25

When encoding data, we should consider our small capacity for making unidimensional judgments, despite that our capacity increases with the number of dimensions, but not by a large amount. For example, Miller shows that our capacity for judging the position of a dot in a square is 4.6 bits, which is larger than the 3.25 bits for the position of a point in an interval.[28] Although our total capacity increases with the combination of dimensions, our accuracy for a particular variable decreases. He concludes, "People are less accurate if they must judge more than one attribute simultaneously."[29]

Furthermore, Miller suggests three basic devices we can use to increase the accuracy of our judgments and the limits of our span:[30]

1. To make relative rather than absolute judgments;
2. Or, if that is not possible, to increase the number of dimensions along which the stimuli can differ;
3. Or to arrange the task in such a way that we make a sequence of several absolute judgments in a row (which introduces mnemonic processes).

Considering that we have limited capacity to perceive information accurately, his results are crucial to the process of visualizing data. First, visualizations should rely mostly on relative judgment rather than on absolute ones. The latter can be provided as additional information, especially in interactive applications. A number of experiments have been conducted to examine our relative judgments of visual variables, and a summary is presented on page 129 discussing two fundamental laws: Weber's and Steven's. Second, we should be careful not to exceed our own perceptual and cognitive limits by presenting more than seven levels of data at once.

When more than seven levels are needed, we should strive to group information into familiar units to expand our limited working memory capacity. For example, the design and use of glyphs depicting integrated variables can extend our visual working memory capacity. However, we need to pay attention not to incur mismatches, as illustrated by the Stroop effect image below.[31]

RED GREEN YELLOW BLUE BLACK GREEN PURPLE BLUE BLACK
ORANGE GREEN RED GREEN YELLOW BLUE BLACK GREEN PURPLE

GREEN RED BLUE YELLOW PURPLE RED BLACK GREEN BLUE
BLACK ORANGE GREEN RED GREEN YELLOW BLUE BLACK GREEN

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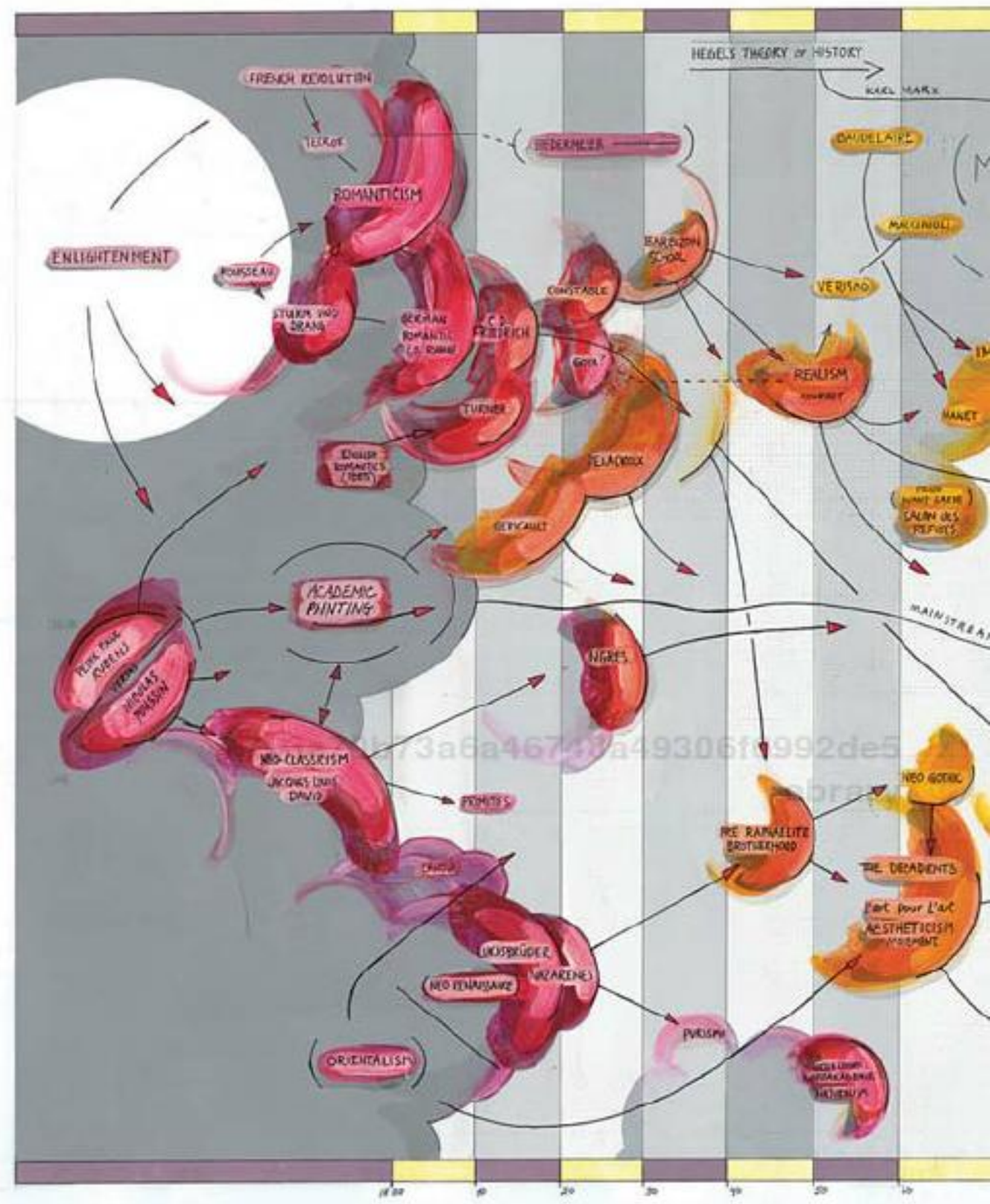
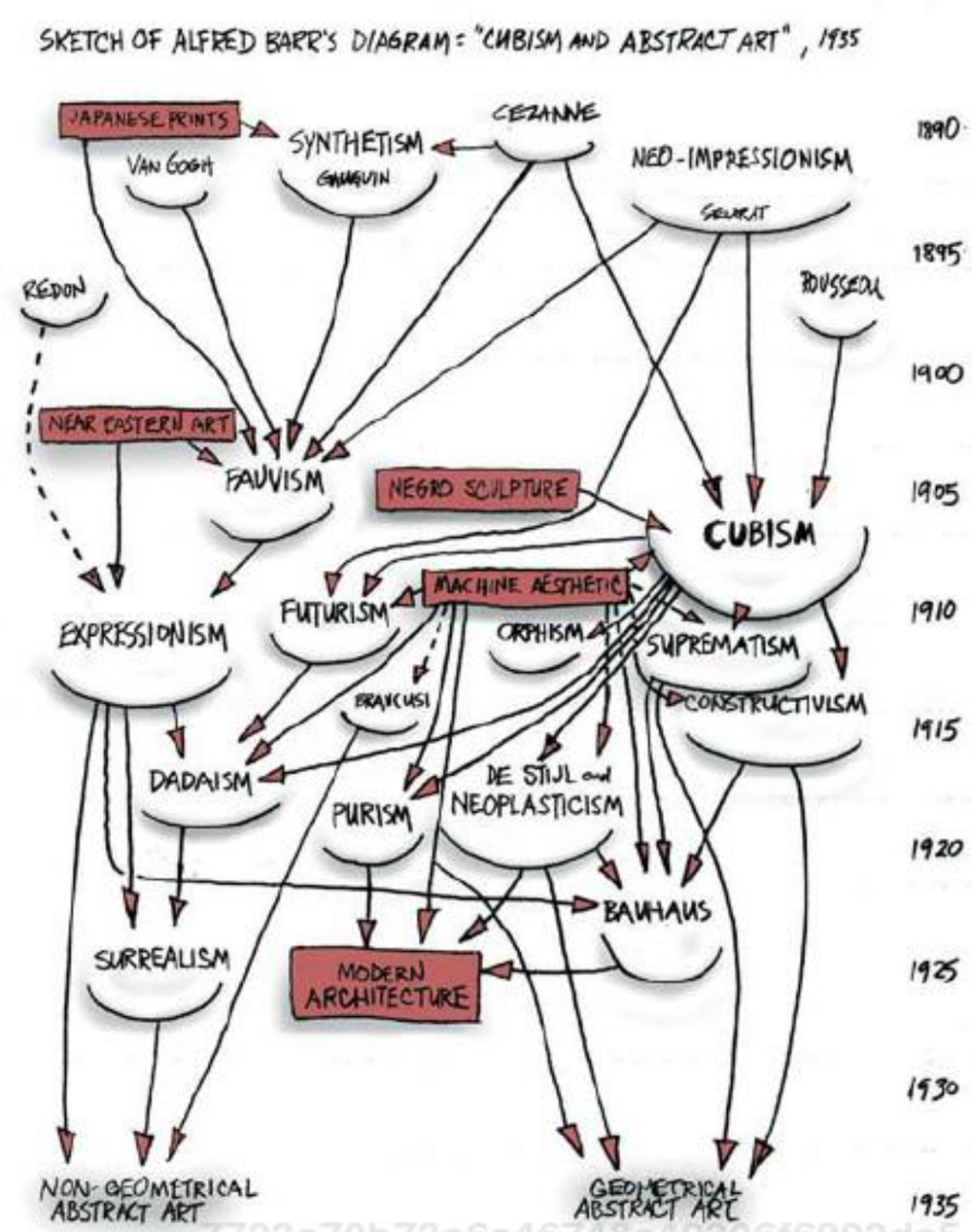
REPRESENTING EVENTS OVER TIME



As we saw in the introduction to this chapter, the most common use of temporal structures is found in representations of historical events. Timelines might have a uniform and a nonuniform scale, as well as be organized horizontally or vertically. Another common metaphor used throughout history is the branching tree, presented extensively in the first chapter on Hierarchies. Similar to the linear vectorized structure of timelines, tree-structures organize time in one direction, mostly spacing elements nonuniformly, while emphasizing notions of progress and causality. The examples in this section focus on visualizations imparting a sense of narrative to the diagrammatic representation of events over time. Although the selected visualizations are static, the sense of immersion is emphasized by the expressive visual vocabulary contextualizing the events depicted.



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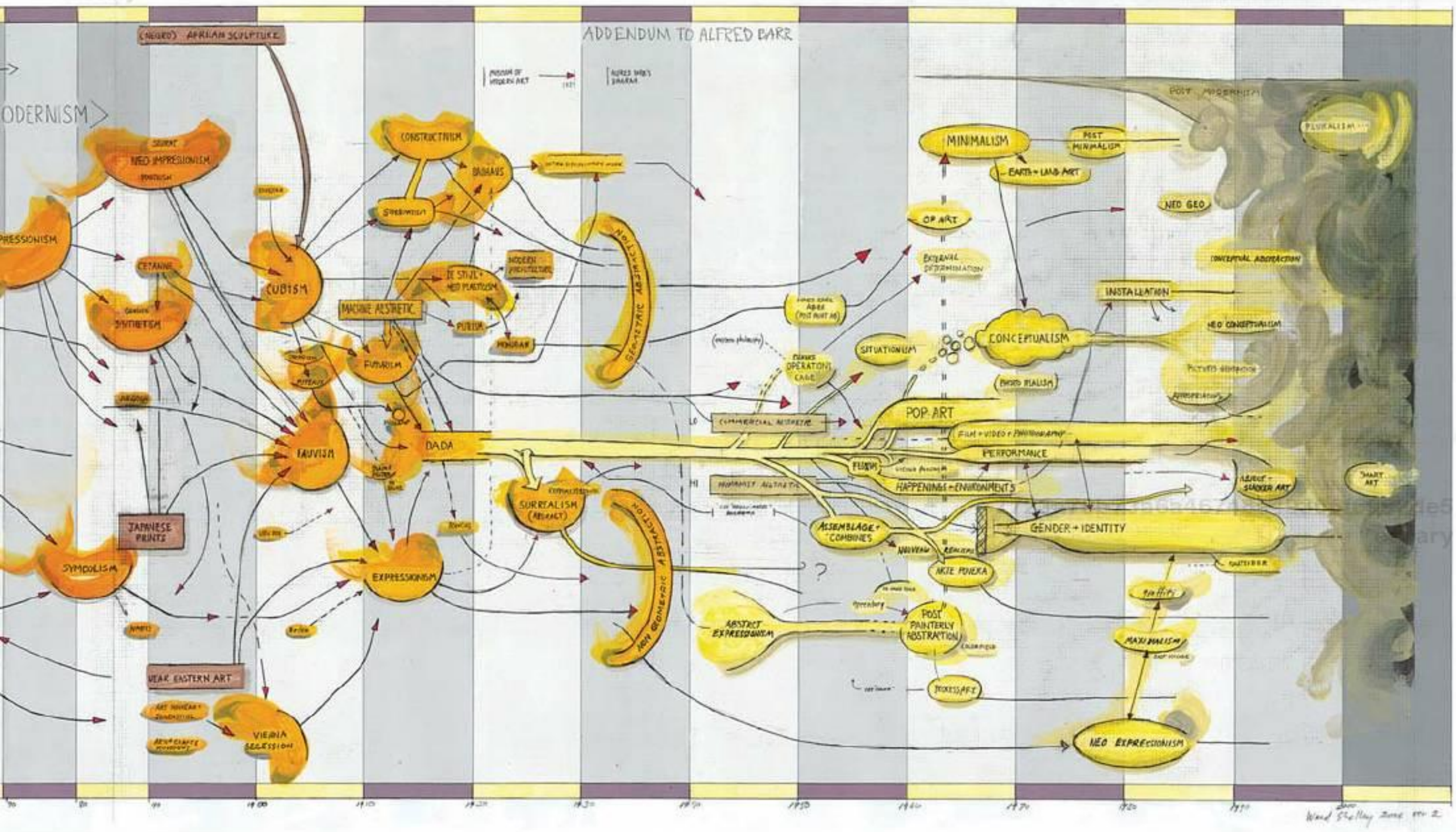

Alfred Barr, the first director of the Museum of Modern Art in New York City, drew this "Diagram of Stylistic Evolution from 1890 until 1935" to explain the origins of abstract art. We see it here in a sketch by artist Ward Shelley, who was largely influenced by how Barr sets forth his diagrammatic narrative.

Ward Shelley created "Addendum to Alfred Barr, ver. 2" in 2007, which extends Barr's original diagram, positioning it at the center and depicting both past and future events around it. The chart starts with the Enlightenment and the rivalry between painters Peter Paul Rubens and Nicolas Poussin, and ends in 2000. The diagram keeps the original diagrammatic vocabulary of using arrows to show direction of influence. The three colors stand for separating the three components of the graph and separating before and after the original Barr diagram. Time is well demarcated on the top and bottom of the work, which is reinforced by the gray bands.

In describing this work, Shelley writes, "I like to present narratives with sprawling information-rich panoramas. Yet these diagrams are radical reductions of written sources I've researched. I have had to choose who and what to include, who and what not. Because the variables that I have to work with are extremely limited, the people and events I use are reduced to symbols that are plotted in relationship to each other in diagrams. Even within such limitations, it is possible to tell a compelling story."[32]

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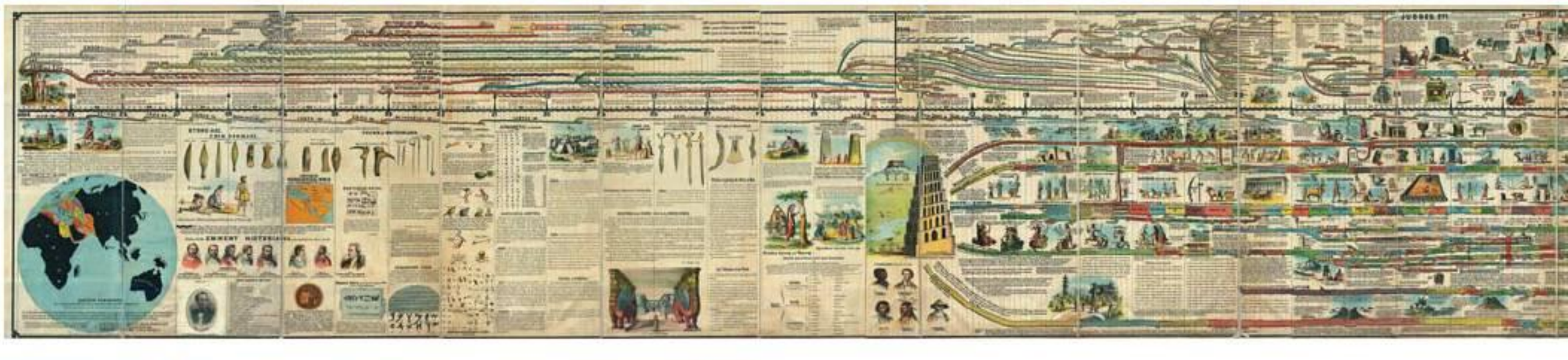

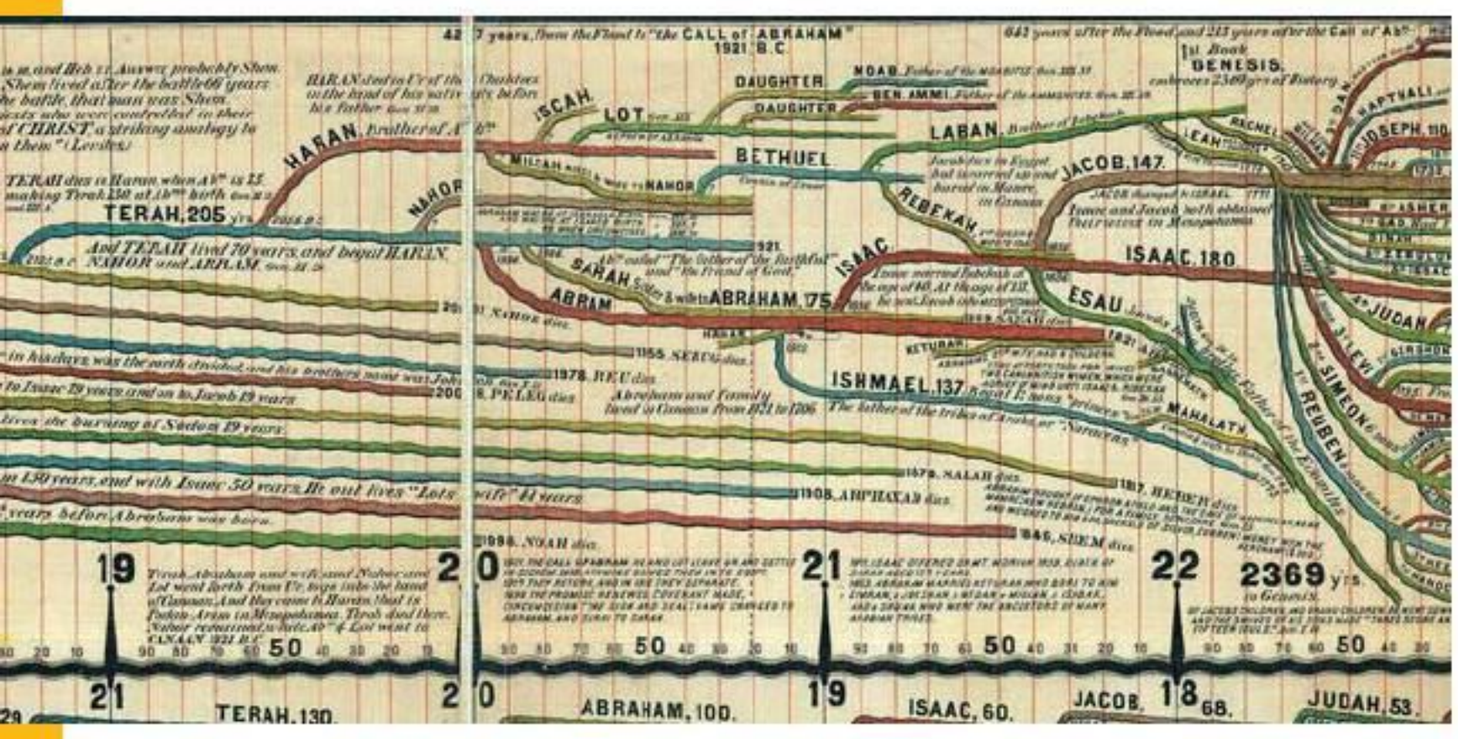

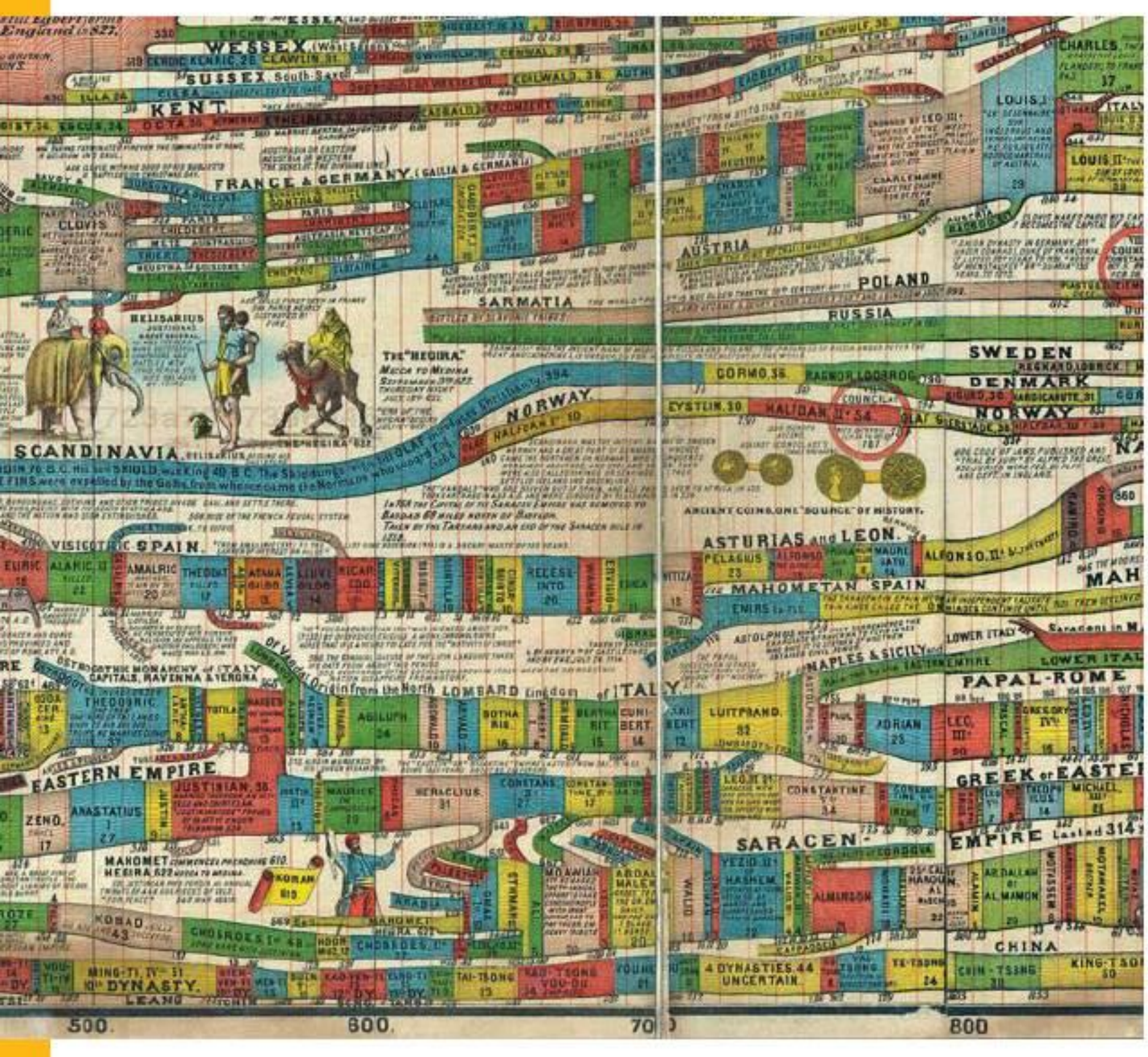

Sebastian C. Adams was an educator and a senator for Oregon who designed and first published the "Synchronological Chart of Universal History" in 1871. The timeline is monumental in scope, covering almost six millennia, as well as in size, measuring 27 inches in height by 260 inches in length (68.6 X 660.4 cm), and folded into twenty-one full-color panels. Adams based his research on *The Annals of the World* by James Ussher. Adams saw the chart as an educational tool for studying the places and times of religious and historical events. At the very beginning of the timeline it reads: "The object of this CHART is to assist the mind in clearly fixing, along down the stream of time, the time when the events of the world took place. The *time when* (i.e., Chronology) and the *place where* (i.e., Geography) 'are the two great eyes of history'"[35] (emphases in the original). It's interesting to note that Adams names the key to the chart an "Explanation of the Map," which provides detailed description of how the chart was constructed, including notes on the content. Time runs horizontally, with the earliest time at the far left. Time is uniformly depicted, starting at 4004 BCE, and ending at 1878 CE. Every century is clearly demarcated by century pillars and further subdivided into decades. Nations and kingdoms run parallel to time, with all sorts of annotations and illustrations. The images reproduced here are from the third edition of 1878, printed in the United States by Strobridge & Co., lithographers of Cincinnati, Ohio.

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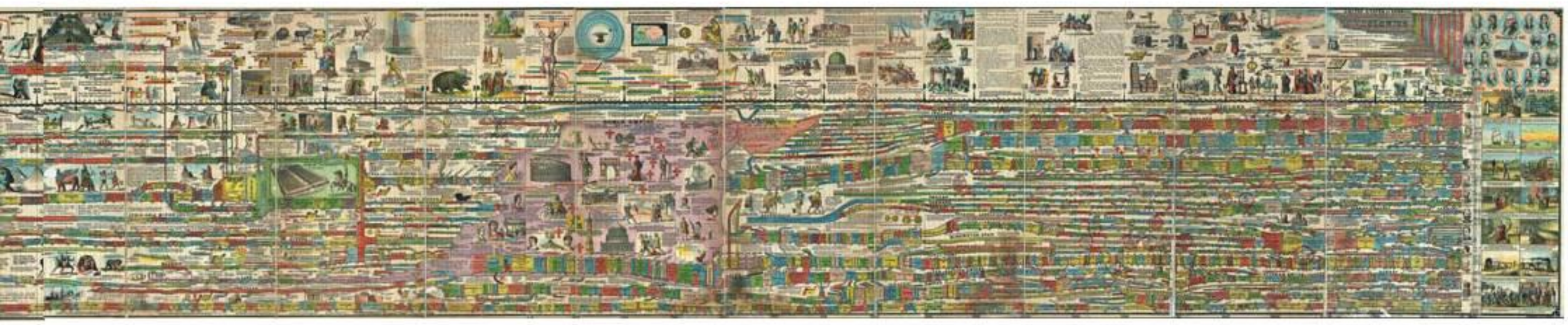

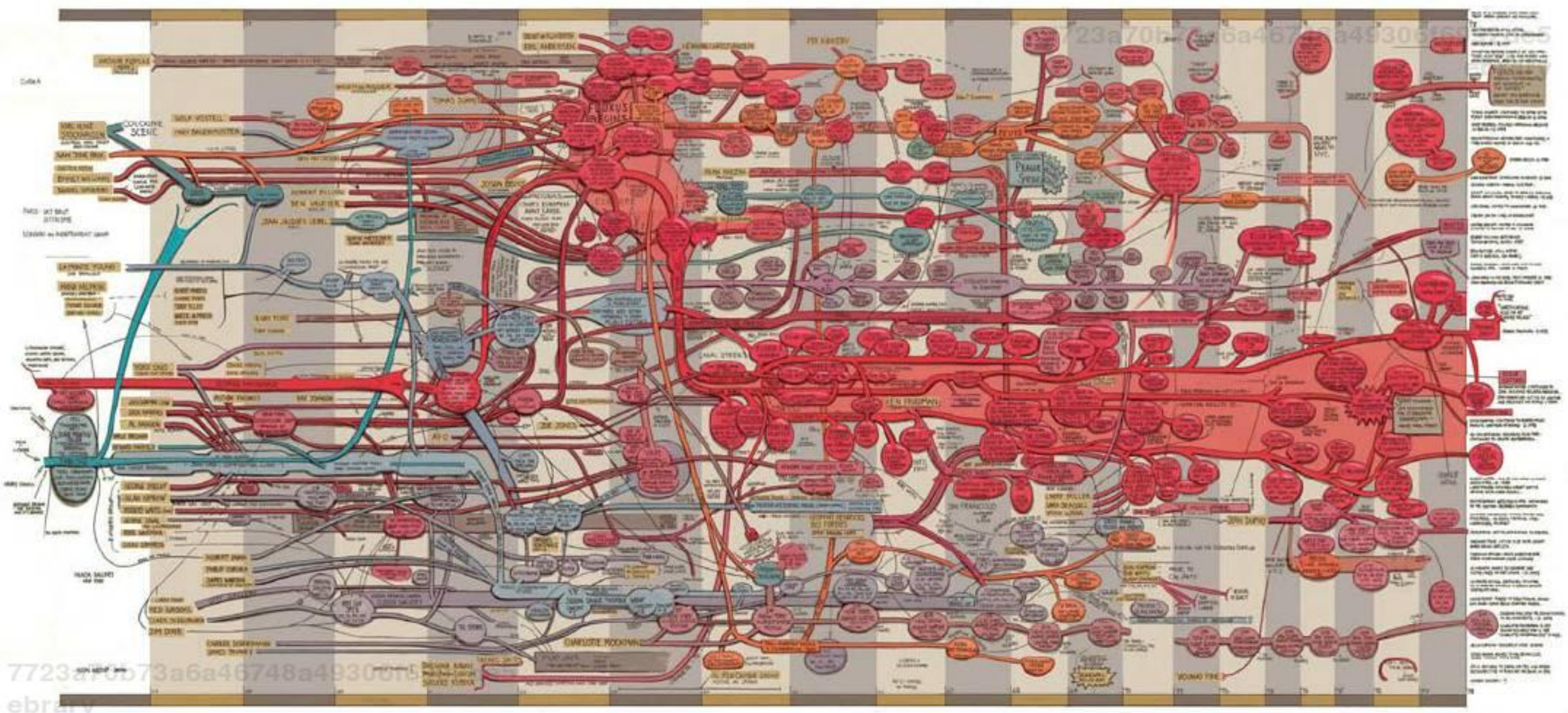

In the fascinating book *Maciunas' Learning Machines*, Schmidt-Burkhardt imparts the traditions of diagramming events over time, with a focus on the large work on charts and diagrams by Fluxus initiator George Maciunas. She goes on to write, "This work by Shelley presents data in such a way as to render explicit the continuity, coherence, and contingency of the history of Fluxus for a contemporary audience."[33] *The Extra Large Fluxus Diagram* illustrates the people and work involved with the experimental art movement Fluxus and pays homage to Maciunas. Shelley's diagram traces the Fluxus movement from its beginnings, with John Cage's 1956–58 composition classes at the New School and Karlheinz Stockhausen's seminars in Darmstadt, up to the death of Maciunas in 1978. Shelley writes about his practice, "My paintings/drawings are attempts to use real information to depict our understandings of how things evolve and relate to one another, and how this develops over time. More to the point, they are about how we form these understandings in our minds and if they can have, in our culture, some kind of shape."[34]

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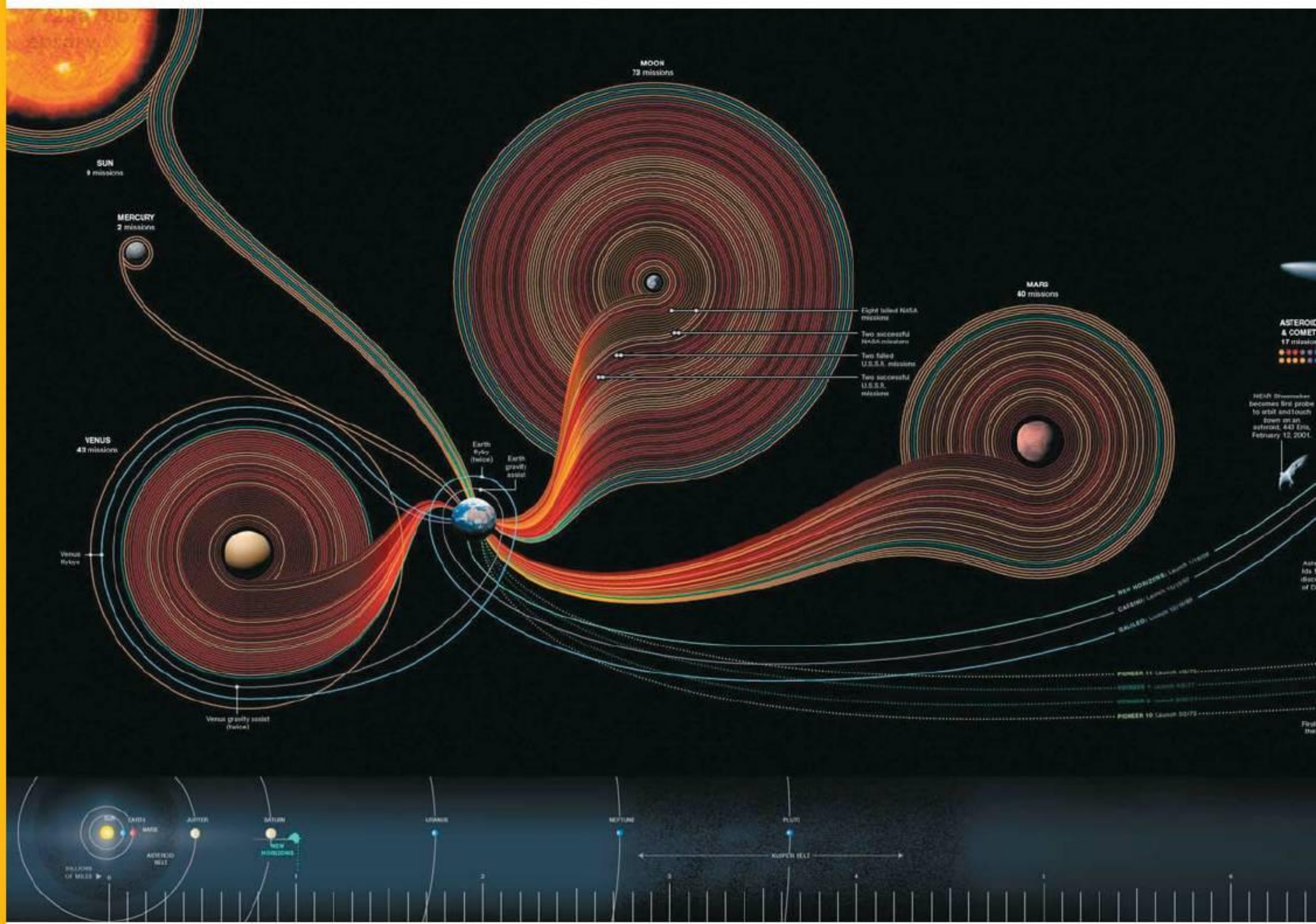

Sean McNaughton (*National Geographic* magazine) and Samuel Velasco (5W Infographics), U.S.: "Fifty Years of Space Exploration," 2010.

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This magnificent infographic depicts exactly what the name indicates, "Fifty Years of Space Exploration." It shows nearly 200 solar, lunar, and interplanetary missions, starting with the first attempts to reach Mars in 1960 and Venus in 1961, up to our time. It includes ongoing missions, such as the *New Horizon* scheduled to enter in Pluto's orbit in 2015. Structured as a map, we learn about temporal events based on their spatial trajectories, and the paths that accumulate around their objects of interest. Take, for example, the large number of missions to the Moon, in total seventy-three. We learn about past and future interest in different planets, such as the new *MESSENGER* mission to Mercury. At the bottom of the graph, there is a line depicting the relative distances between the planets.

http://books.nationalgeographic.com/map/map-day/index

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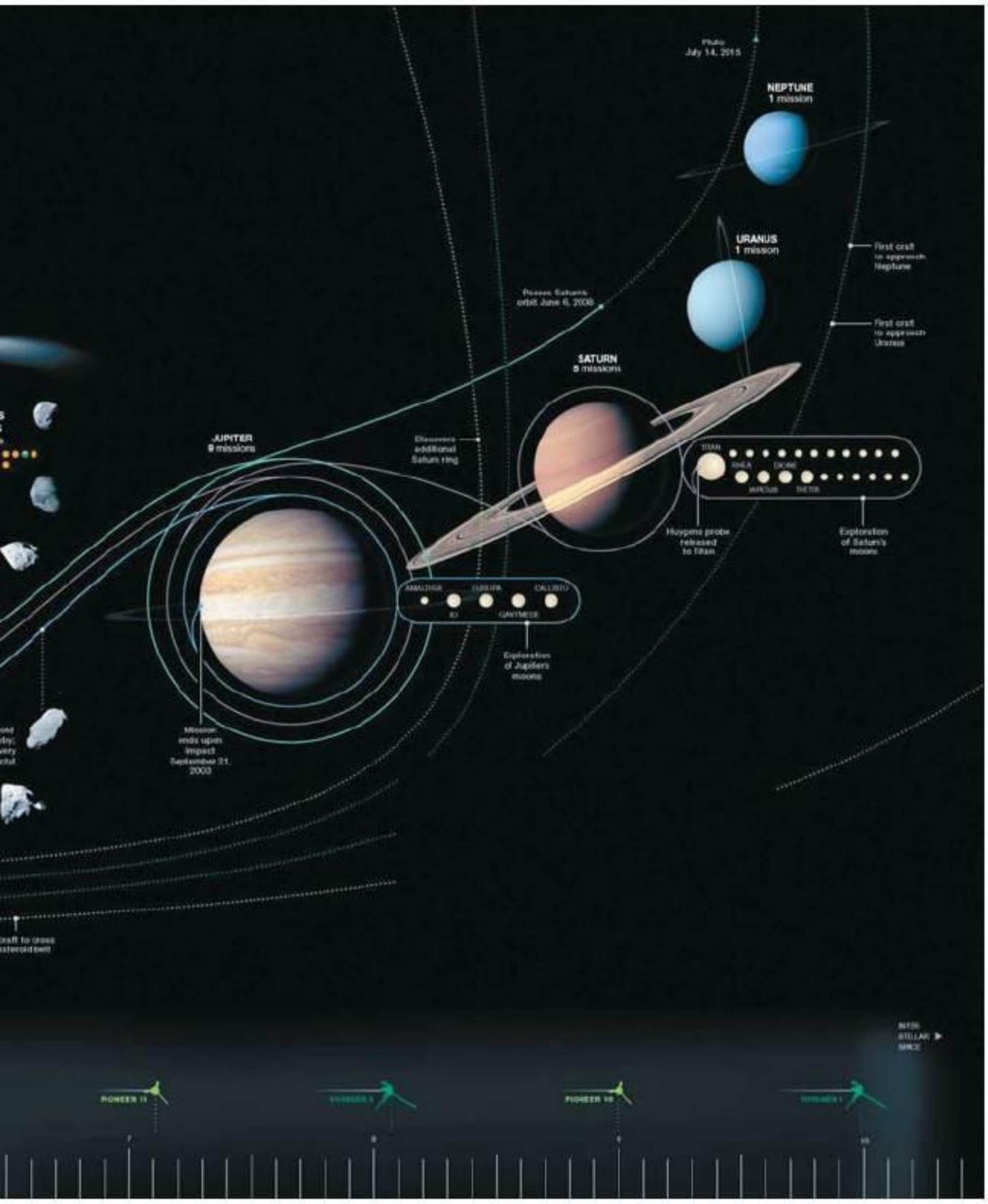

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Original design by Charles and Ray Eames, U.S.: iPad app "Minds of Modern Mathematics," 2012.

IBM has recently released an iPad version of the celebrated 50-foot (15 m) infographic on the history of math created by the husband-and-wife design team of Charles and Ray Eames. The timeline covers the period between 1000 and 1960, and it was part of the exhibition "Mathematica: A World of Numbers ... and Beyond" displayed at the IBM pavilion at the 1964 World's Fair in New York City. The app *Minds of Modern Mathematics* offers access to "more than 500 biographies, milestones and images of artifacts culled from the Mathematica exhibit, as well as a high-resolution image of the original timeline poster."[36] It is interesting to note the differences of affordances between the static long poster and the interactive timeline. The latter follows the original design, with additional functionality that facilitates reading the extensive material printed in the initial design.

https://itunes.apple.com/us/app/minds-of-modern-mathematics/id432359402?mt=8

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CASE STUDY

REPRESENTING AMOUNT OVER TIME

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It took several decades before the graphic methods devised by William Playfair at the end of the eighteenth century became widely known. Wainer and Spence explain the oppositions his inventions encountered in his own time both in the U.K. and in continental Europe: "Adoption of the new methods had to wait until the second half of the nineteenth century when Minard and Bertillon used some of Playfair's inventions in their cartographical work. In the United Kingdom, Playfair was almost completely forgotten until 1861, when William Stanley Jevons enthusiastically adopted Playfair's methods in his own economic atlas."[37] Nowadays, bar graphs, line graphs, pie charts, and area graphs are ubiquitous. We find them everywhere, from newspaper articles to textbooks, and depicting all sorts of content, from economic to entertainment data. More important, most people are familiar with these statistical schemes and know how to read them. As in other areas covered in this book, new methods have been devised for plotting quantitative data over time. The case study examines recent examples that have reached the general public beyond the confines of visualization research.

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Fernanda Viégas and Martin Wattenberg, U.S.:"History Flow," 2003.

History Flow is a visualization made by Martin Wattenberg and Fernanda Viégas in 2003 with the objective of examining the human dynamics behind group editing. It depicts how articles were written and edited by several authors in the collaborative environment of Wikipedia, just two years after its deployment online. When we read articles on Wikipedia, we are mostly unaware of the history behind the article's complex "manufacturing" process. This can be accessed through the link "history" at the bottom of each page, which provides a list of links to the full edit text of all previous versions, including the authors, as well as timestamps of their interventions, the data used in this project. For the text analysis, Viégas and Wattenberg used an algorithm by Paul Heckel that enabled them to track the movement of large passages of text, while also offering the possibility of keeping track of word-size tokens. Then came the encoding process aimed at visually documenting positions and correspondences between passages that had changed. After several iterations that are explained in detail in *Beautiful History: Visualizing Wikipedia* they arrived at the visualization reproduced here.[38]

Time runs horizontally, with earlier time at the far left. It is measured by editions rather than by normal temporal units, even though it can be spaced by date, which deemphasizes revisions happening in rapid succession of each other. In other words, each vertical line corresponds to a version of the article. Horizontal lines represent chunks of text that have been edited. Color encodes the authors. In this way, it is possible, for example, to see which parts were edited by a particular author in a singular version as well as across time. A list and key to the authors is positioned at the far left of the interface, and one can select a name to view that particular author's participation in the article. Given that they wanted to assign each author with a unique color identifier across the entire encyclopedia, they decided to assign colors randomly. They explain, "We settled on an unusual choice of encoding in which our software chose random bright, saturated colors for each user. These weren't genuinely random, but were based on the Java 'hashcode' of an author's name. This technique ensured that the colors were consistent across diagrams, and that there was the widest possible range of variation. For anonymous editors, we chose a light shade of gray."[39]

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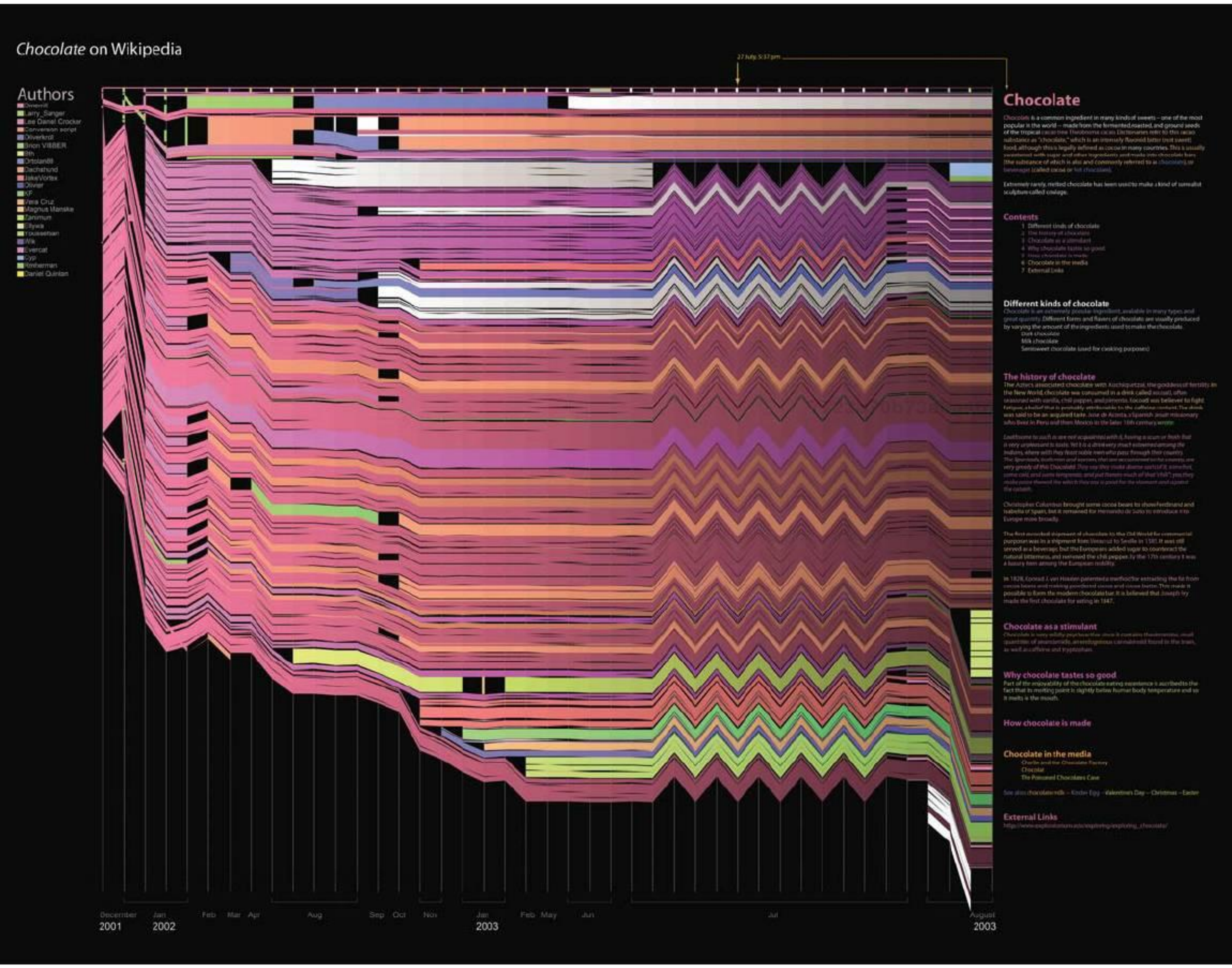

Looking at this image, it is possible to examine patterns of behaviors. For example, the zigzag lines reveal "edit wars," in which authors repeatedly reverted one another's changes. The image shows the history of the Wikipedia article on chocolate and, according to Viégas and Wattenberg, the zigzag depicts an argument on whether a certain type of surrealist sculpture exists or not. Another feature that we see implemented in this image is the possibility of accessing the text itself, which can be read at the right-hand side of the interface.

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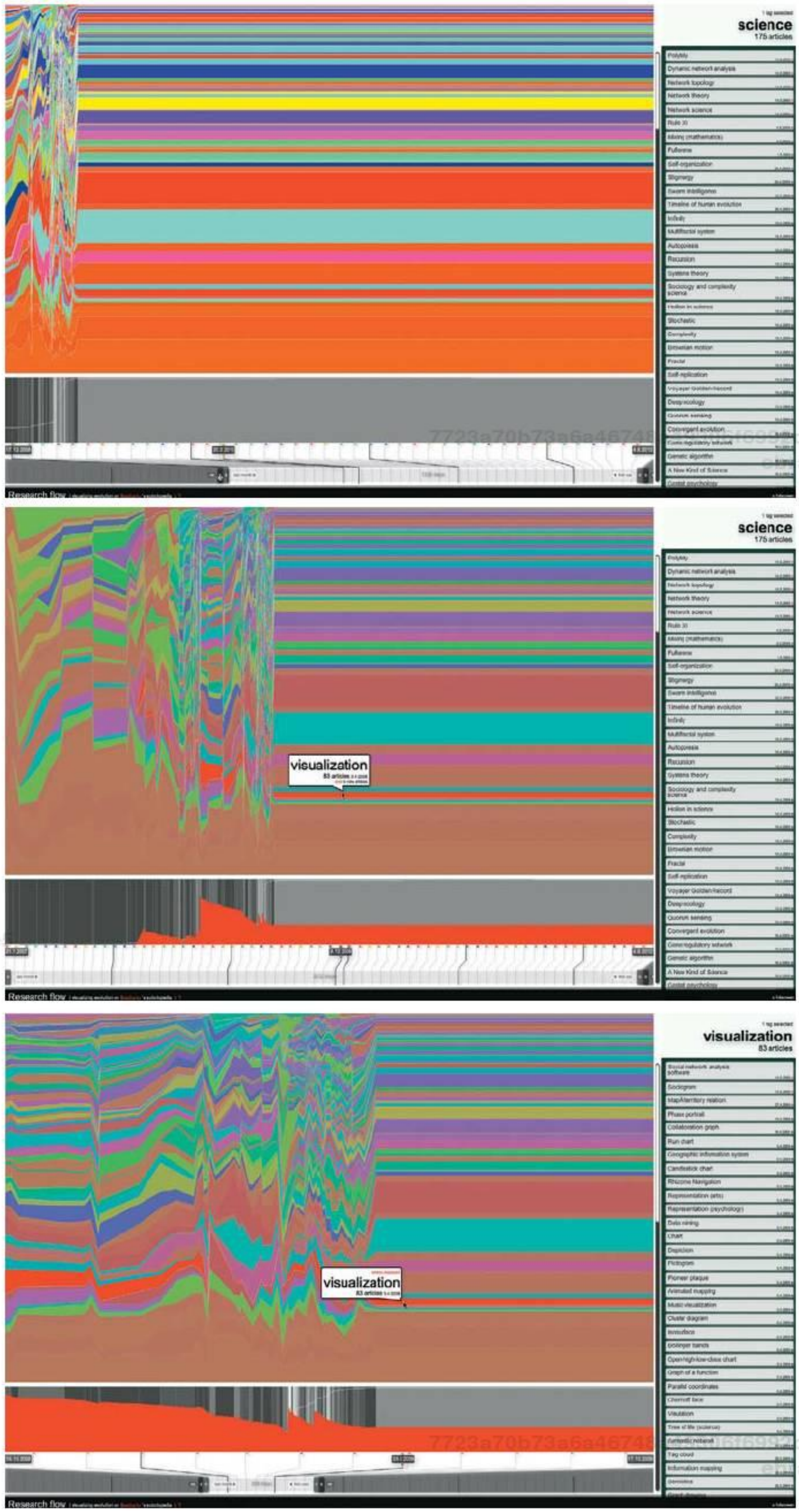
Bestiario, Spain: "Research Flow," 2009.

The online exploratory tool designed by the Spanish studio Bestiario is a good example of the possibilities opened up by computerized interaction, such as the ability to filter data and to zoom in time.

www.bestiario.org/research/flow



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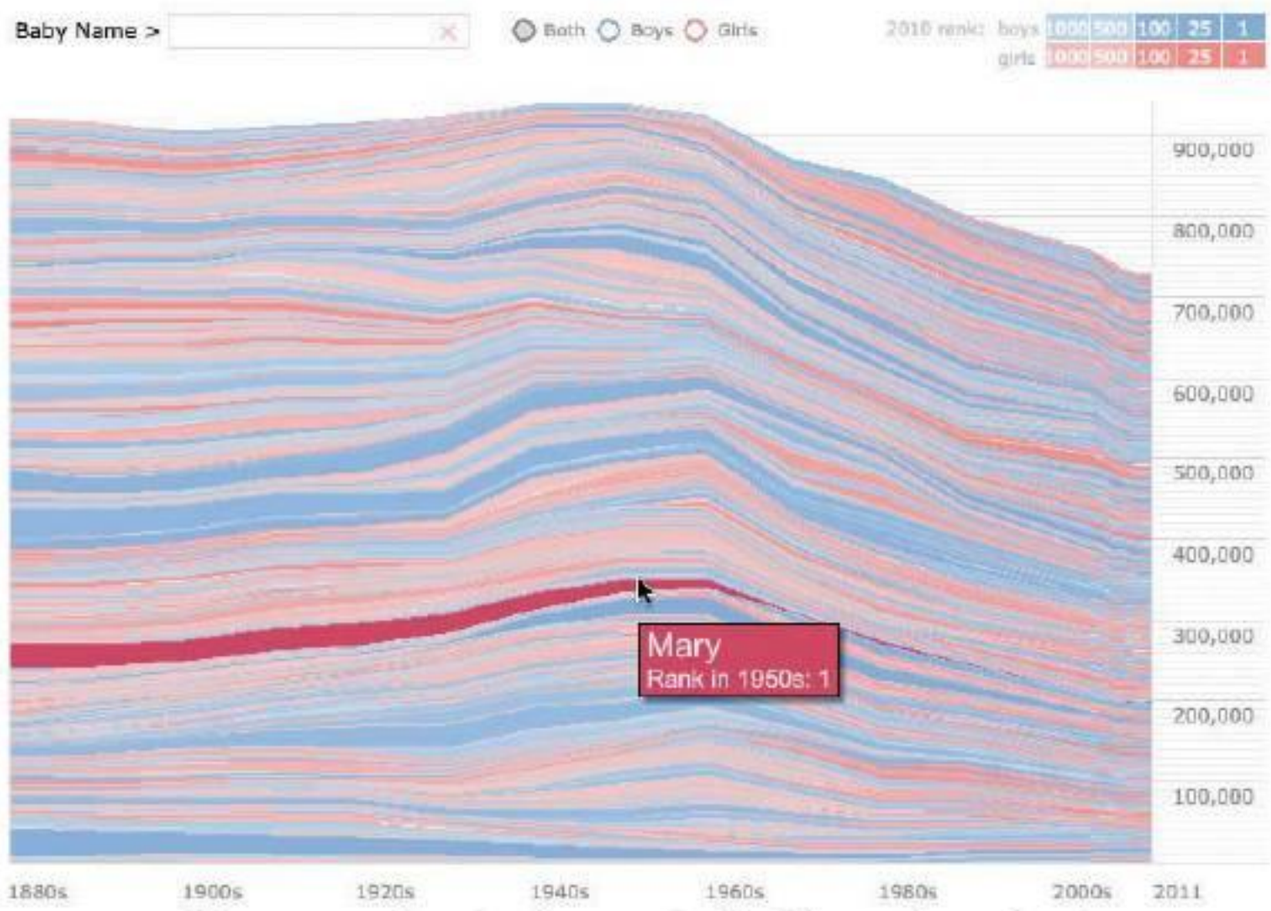

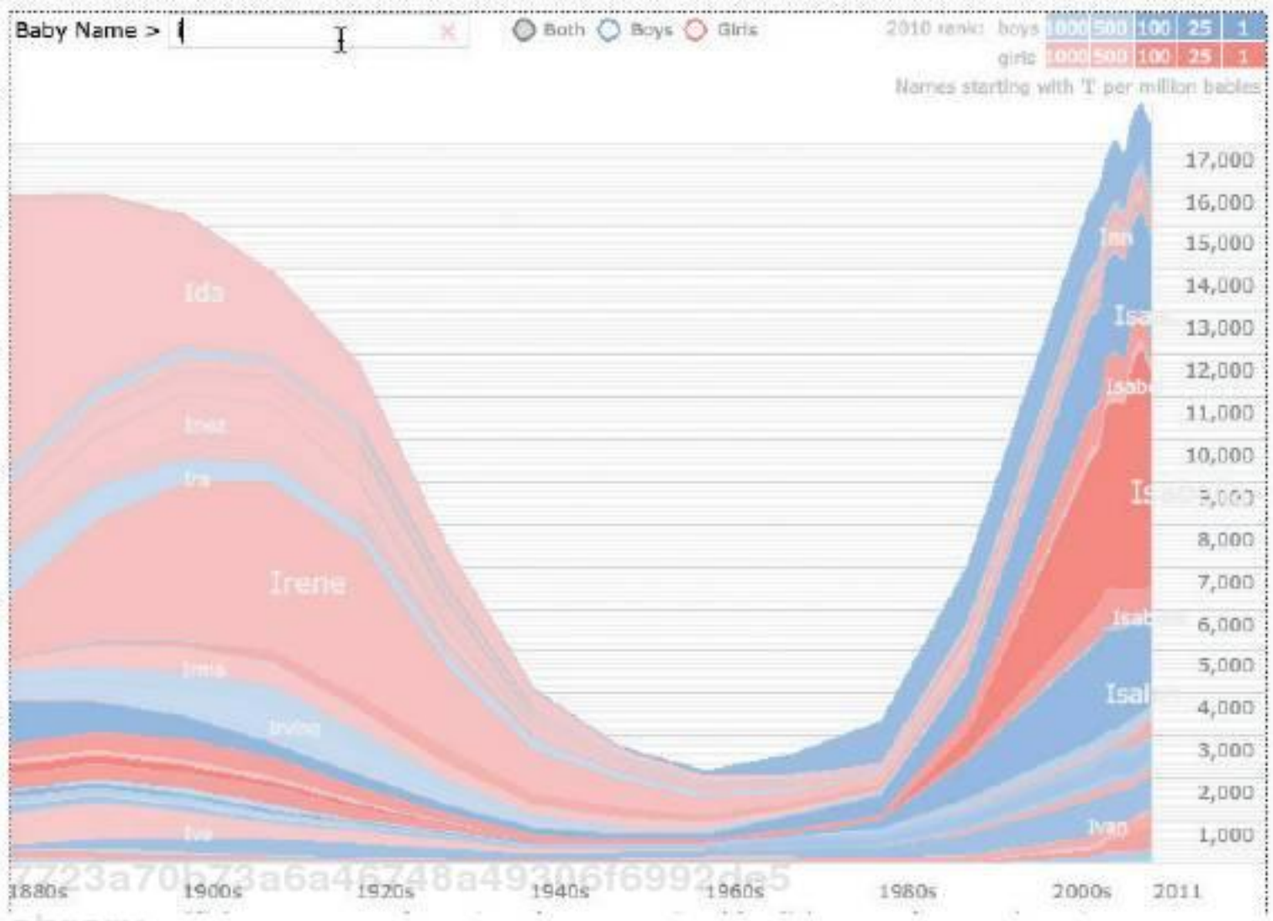

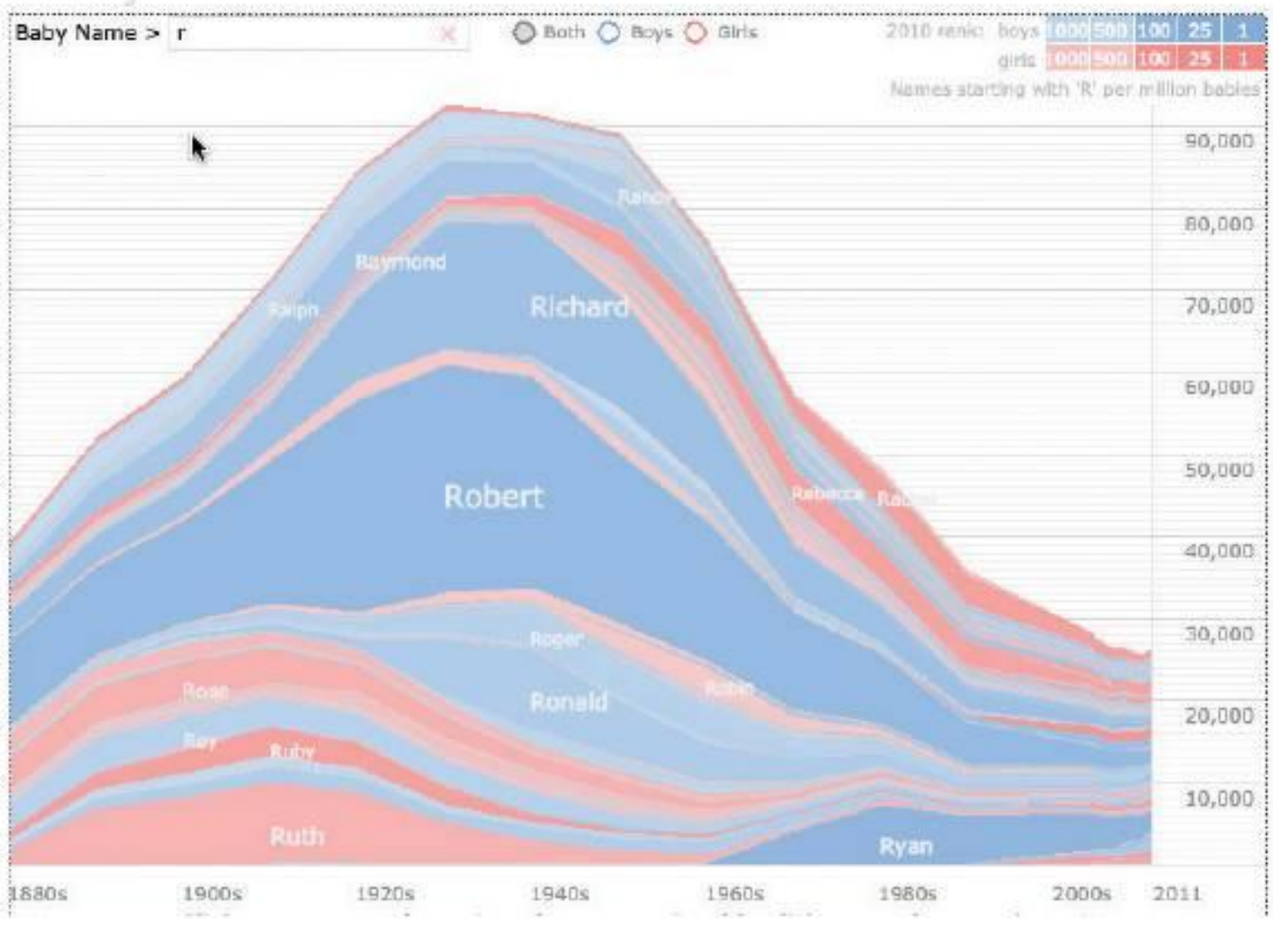

Martin Wattenberg, U.S.: "NameVoyager," 2005.

The *NameVoyager* is a web-based visualization of historical trends in baby naming designed by Martin Wattenberg in 2005. The visualization became very popular, and Wattenberg credits it to the public nature of the web-based application, because it enables social data analysis. The structure is familiar to most viewers, and for the quantitative time series it uses the stacked graph method. Time is represented horizontally from left to right. The vertical axis represents the frequency of occurrence for all names in view in terms of occurrences per million babies. Each stripe represents a name, and the thickness of a stripe is proportional to its frequency of use at the given time step. Girl names are color coded in pink and boys in blue. There is an additional attribute of brightness encoding the stripes for popularity; currently popular names are darkest and stand out the most. Wattenberg explains, "The idea behind this color scheme is twofold. First, names that are currently popular are more likely to be of interest to viewers—many people will probably want to know statistics on Jennifer, but few are looking for Cloyd. Second, the fact that the brightness varies provides a way to distinguish neighboring name stripes without relying on visually heavy borders."[40] Similar to search engines, *NameVoyager* lets you type in a name and see a graph of its popularity over the past century. Because it renders data as one types each letter, it is possible to see trends provided by name fashion, given by their similar sounds.

www.babynamewizard.com/voyager

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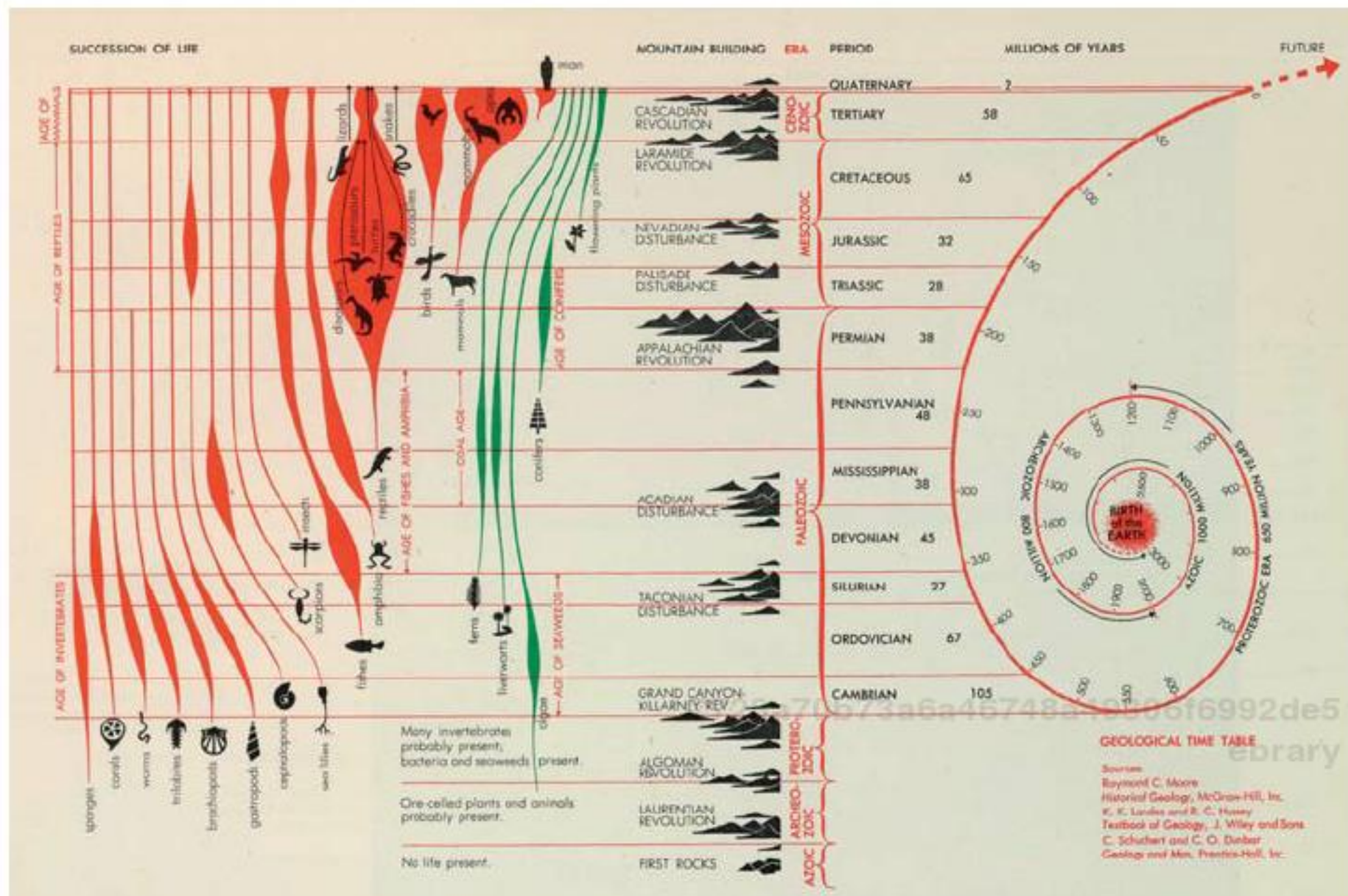
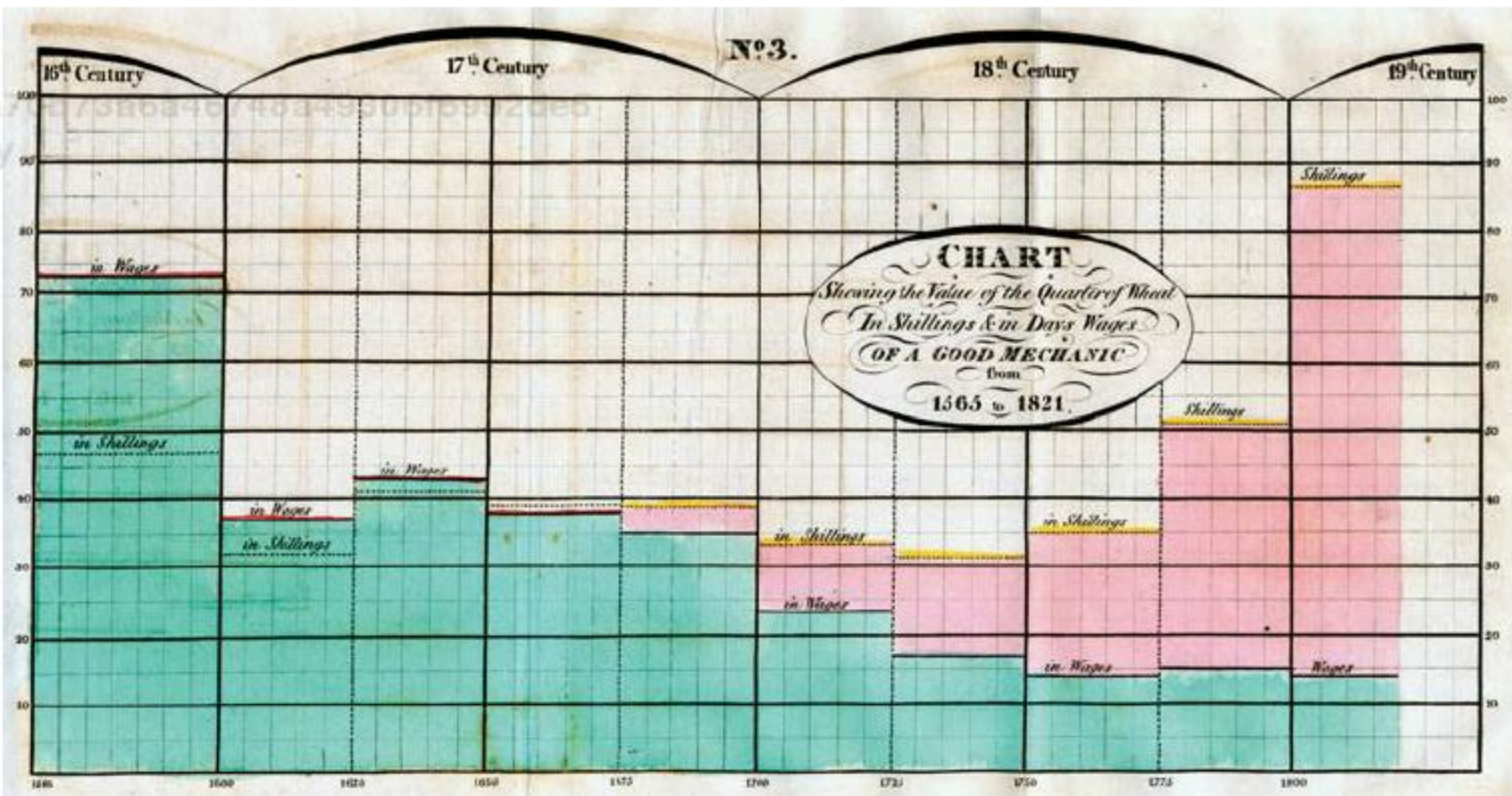
Herbert Bayer, U.S.: "Diagram of the Chronology of Life and Geology," 1953.

The "Diagram of the Chronology of Life and Geology" appeared in the spectacular *World Geo-Graphic Atlas* designed by well-known designer Herbert Bayer and published by the Container Corporation of America in 1953. It tells the story of geology and life on Earth as a function of time. On the right-hand side, the spiral represents time. Time is portrayed backward, with the starting point (or the end of data in the diagram) at the top right, when human life starts, closer to the label "future." It regresses to the beginning of our planet, millions of years back. The choice of the spiral is not arbitrary; rather, it enables, on one hand, the representation of such a huge span of time and, on the other, focus on the period when life occurs. The scale of time is in millions of years, with numbers positioned along the timeline. Horizontal lines connect specific times in the spiral with the whole diagram. The lines mark the different phases of the Earth's history. Each phase is labeled and presents numerical information about its duration (also in millions of years). Phases are grouped into Eras, labeled in red. From right to left, the diagram displays the chronology of geological formations (mountains in black), plant life (green vertical lines), and animal life (red vertical lines). Each categorical group is represented graphically (pictograms) and verbally. Line variations represent quantitative information about each species, including those that went extinct.





William Playfair created the "Chart Shewing the Value of the Quarter of Wheat in Shillings & in Days Wages of a Good Mechanic from 1565 to 1821" with the purpose to compare wages against the cost of wheat. It was published in *A Letter on Our Agricultural Distresses, Their Causes and Remedies: Accompanied with Tables and Copper-plate Charts, Shewing and Comparing the Prices of Wheat, Bread, and Labour, from 1565 to 1821.*

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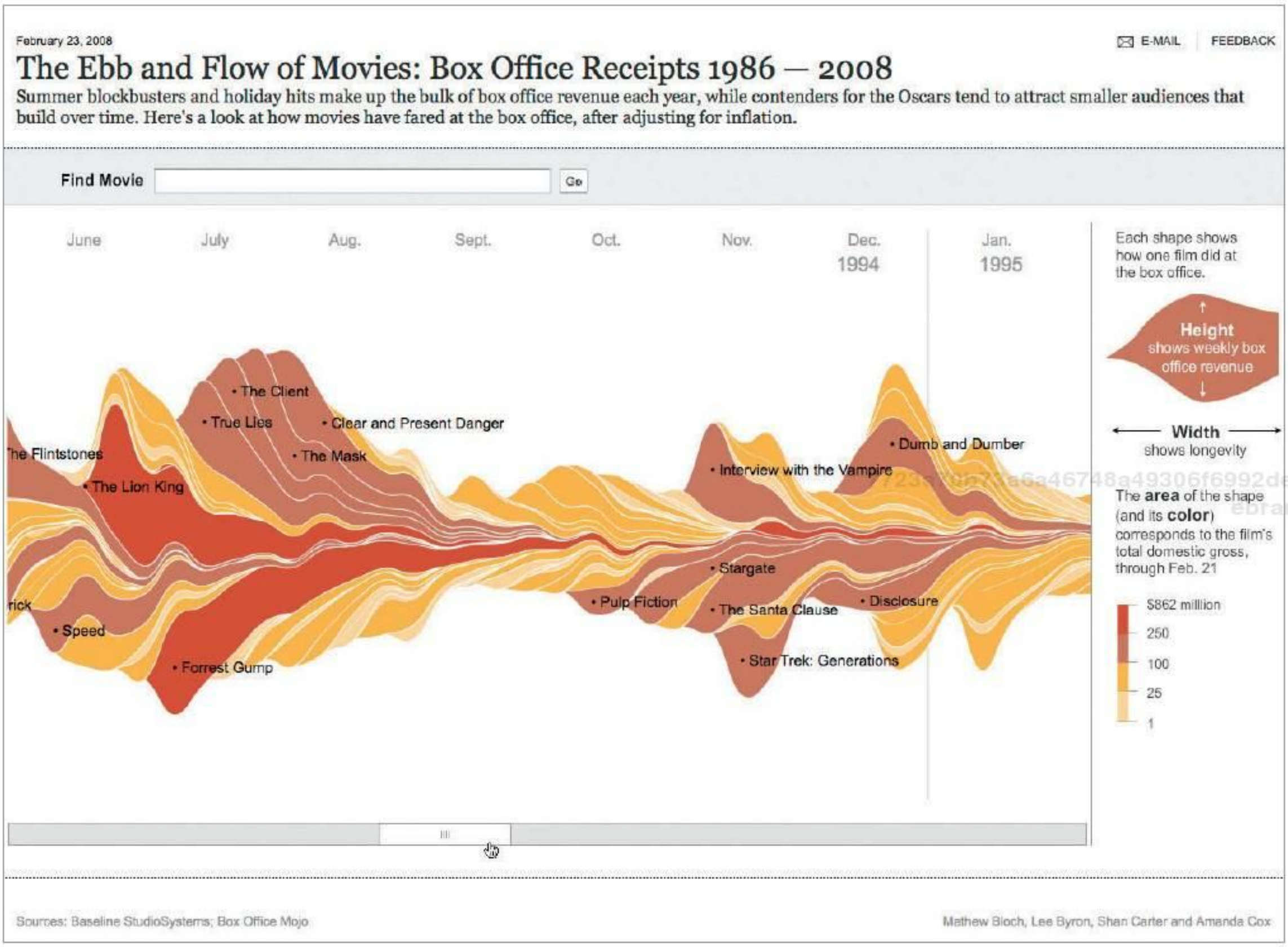

Matthew Bloch, Lee Byron, Shan Carter, and Amanda Cox (*New York Times*), U.S.: "The Ebb and Flow of Movies: Box Office Receipts 1986–2008," 2008.

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The visualization depicts box office revenues for 7,500 movies over twenty-one years. The "Ebb and Flow of Movies: Box Office Receipts 1986–2008" was published in February 2008 by the *New York Times* both on the printed version and online. It was designed by Mathew Bloch, Lee Byron, Shan Carter, and Amanda Cox. The visualization uses the *Streamgraph* method devised by Lee Byron, which arranges the layers in an organic stacked form. The method was inspired by *ThemeRiver*, a method devised by Havre and colleagues in 2000, a technique that creates a smooth interpolation from discrete data and generates a symmetrical layout of the layers centered around the horizontal axis, rather then stacked in one direction.[41]

Streamgraph also borrowed techniques from *NameVoyager* by Wattenberg, described on the previous page.

The graph reproduced here depicts the dichotomy between box office hits and Oscar nominations that was discussed in the original article. Time is represented horizontally from left to right. The height of each band of film represents the box office revenue per week, and the width its longevity. The area of the shape corresponds to the film's total domestic gross through February 21, 2008. The same is true of color, which has a four-color palette that ranges from pale yellow (low gross) to saturated orange (high gross).

Stacked graphs in general involve trade-offs, because the heights of individual layers add up to the overall height of the graph. With the purpose to spotlight stacked graphs as an interesting object of study, Byron and Wattenberg discuss several issues with the legibility of stacked area graphs with a fixed and varying baseline in the informative paper "Stacked Graphs—Geometry & Aesthetics."[42]

www.nytimes.com/interactive/2008/02/23/movies/20080223_REVENUE_GRAPHIC.html

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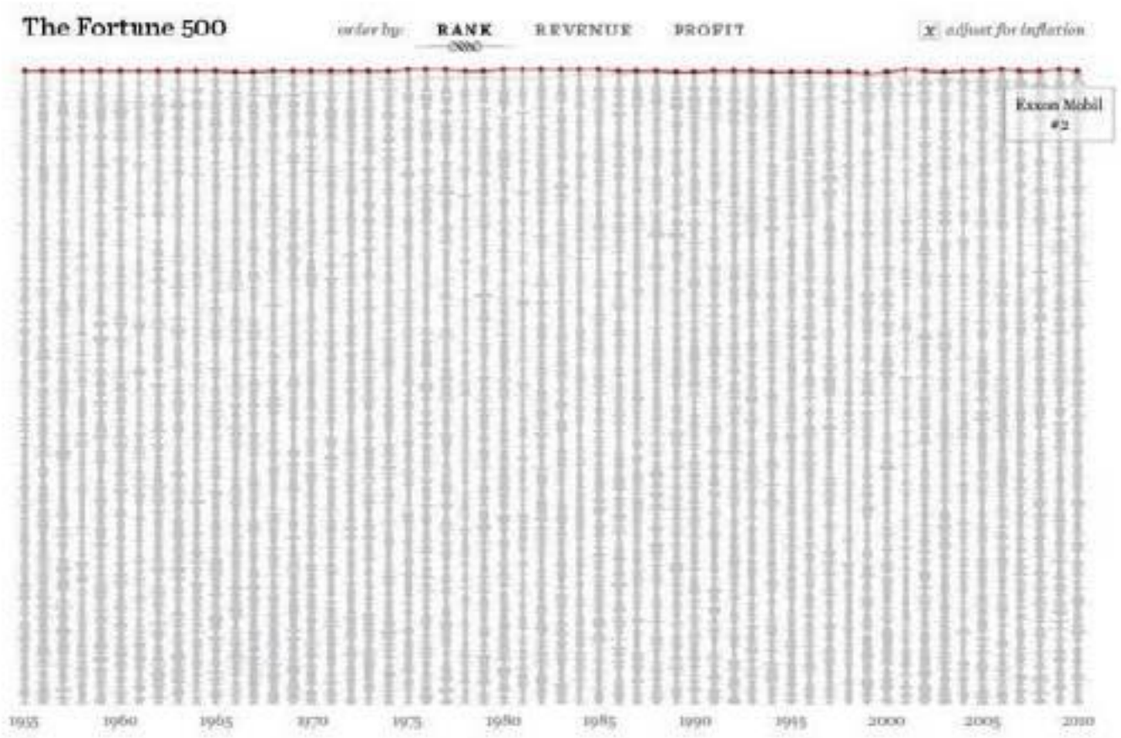

Ben Fry, U.S.: *"The Fortune 500,"* 2011.

Ben Fry created the online tool *The Fortune 500* in 2011. The series of interactive line graphs shows how the tool depicts the 500 companies on *Fortune* magazine's annual list of America's largest corporations. There are three ways in which one can compare the companies from 1955 to 2010: by Ranking, Revenue, and Profit, with the possibility to adjust for inflation. A log scale is used for plotting data in revenue and profit. Fry explains that the application was built with publicly available data found on Wikipedia. His intent was "to show how 84,000 data points could be easily viewed and navigated in an interactive piece."[43]

http://fathom.info/fortune500

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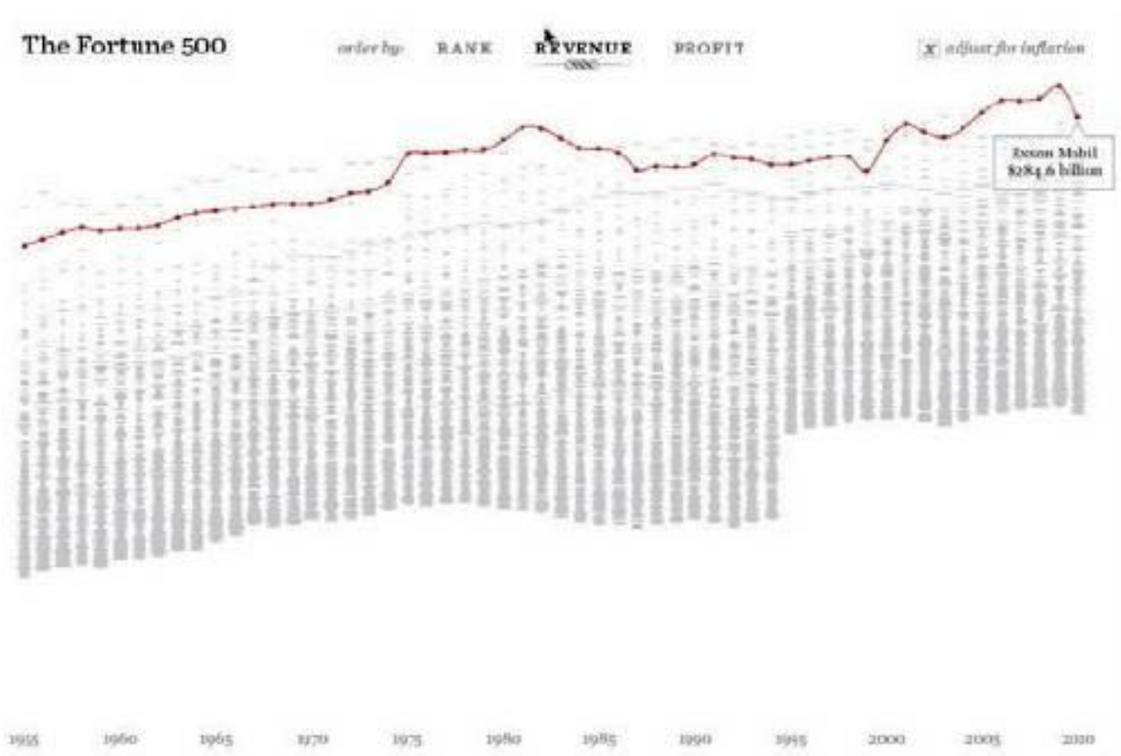

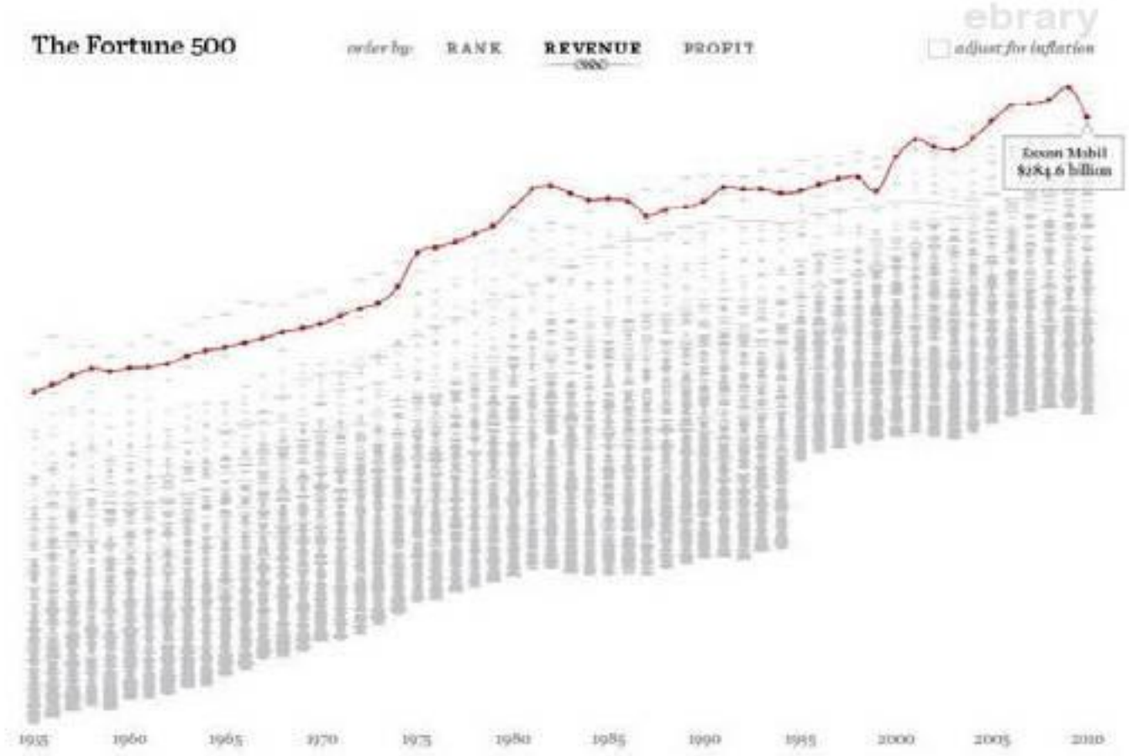

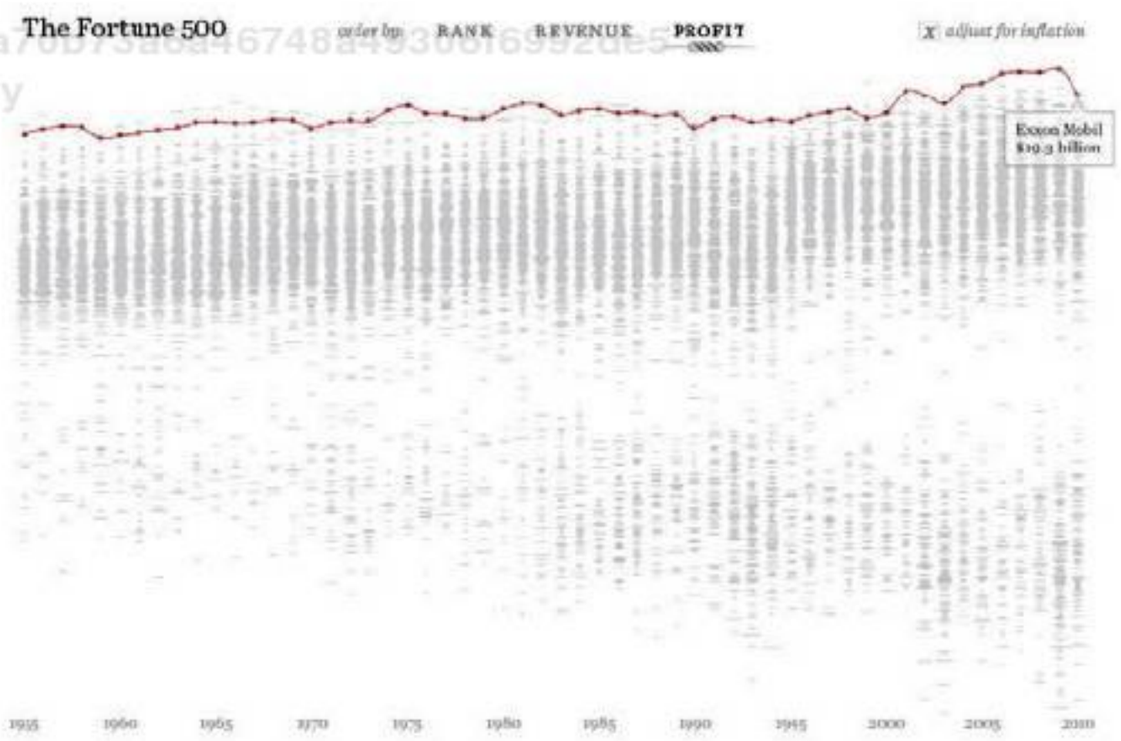

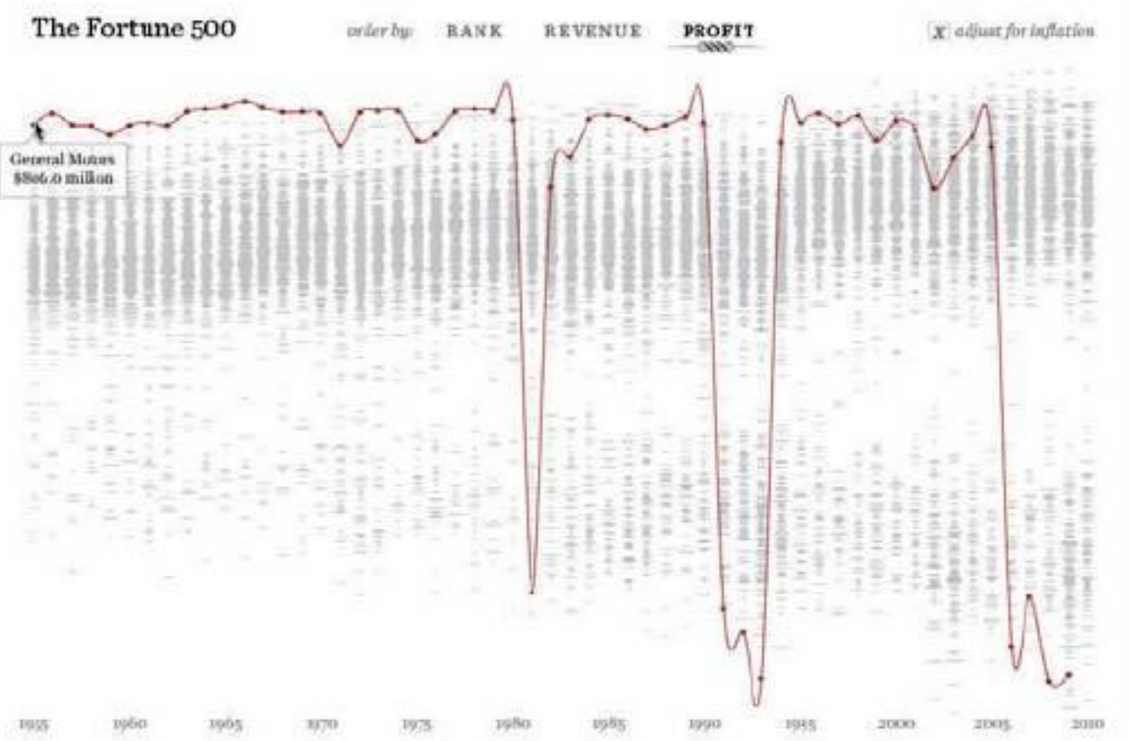

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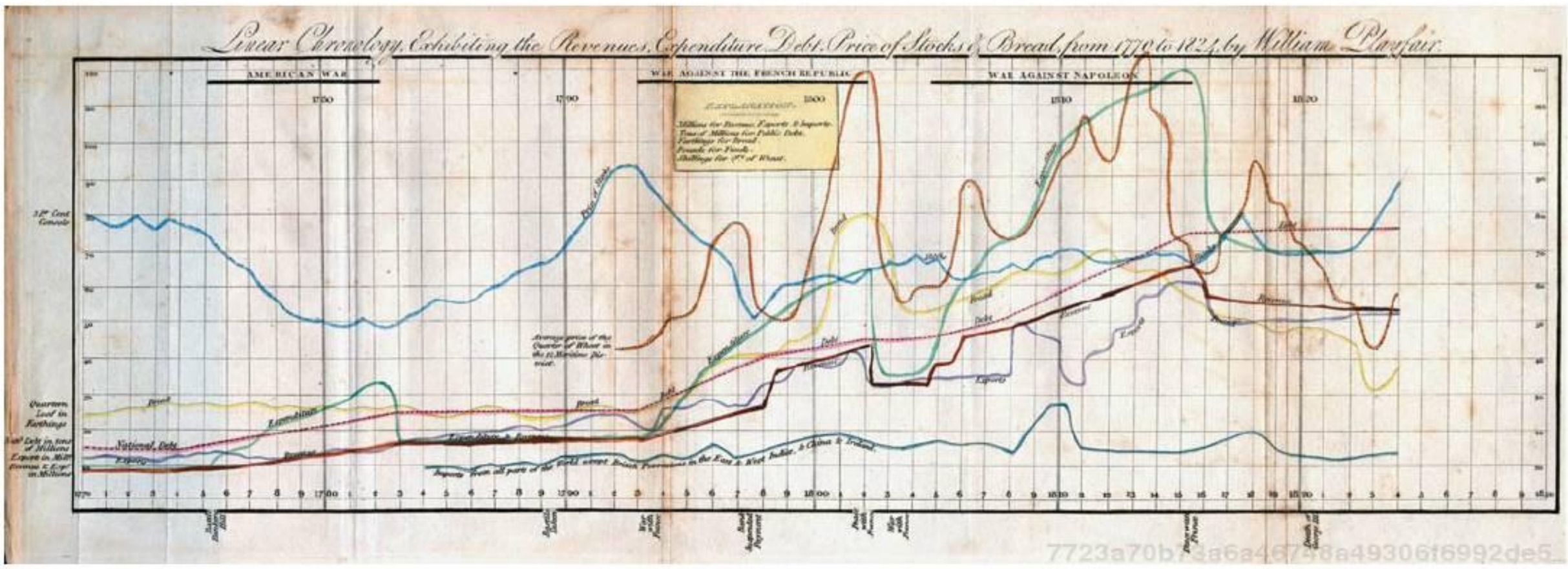
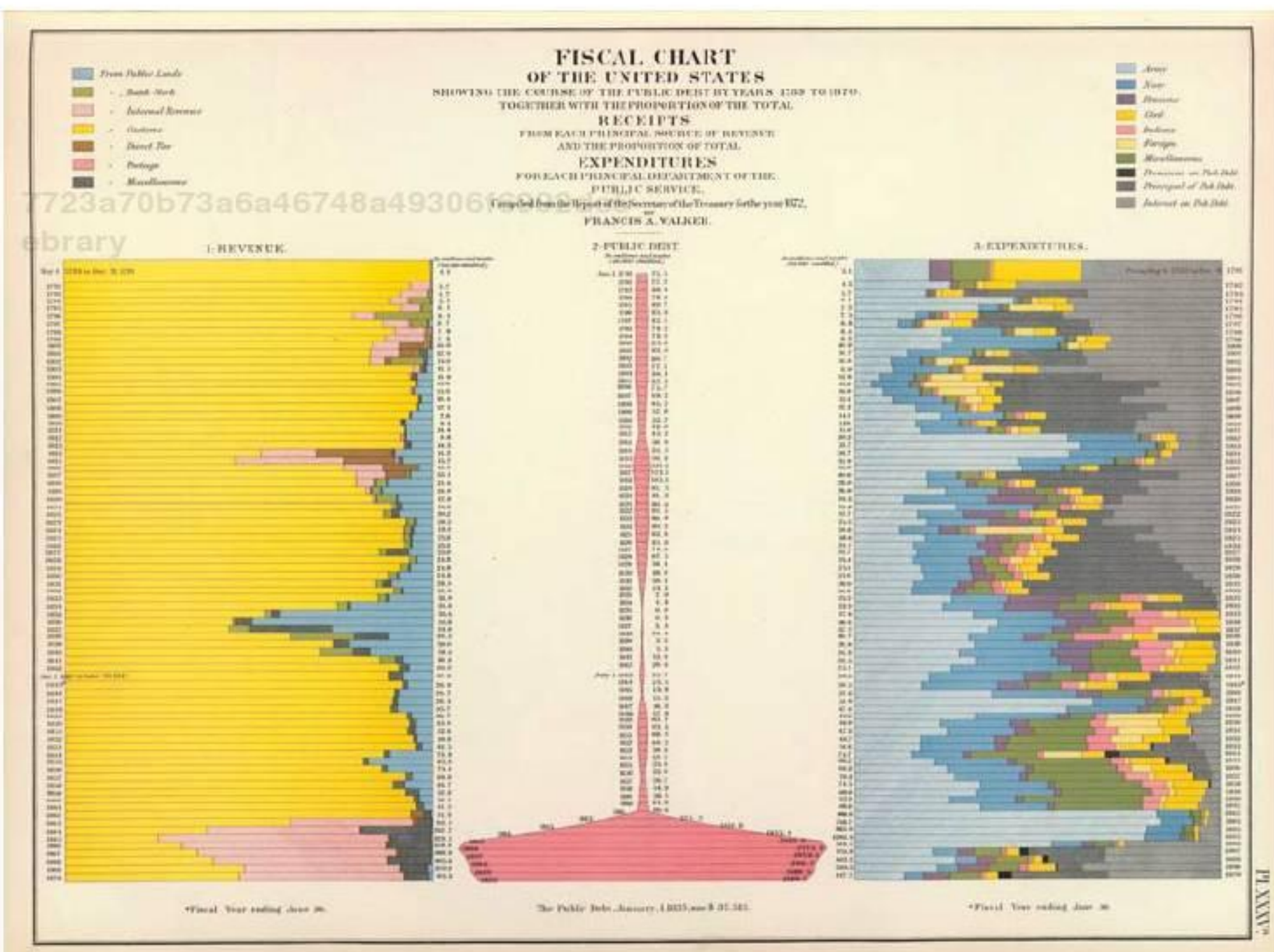


William Playfair devised "Linear Chronology, Exhibiting the Revenues, Expenditure, Debt, Price of Stocks & Bread, from 1770 to 1824" for reproduction in the *Chronology of Public Events and Remarkable Occurrences within the Last Fifty Years; or from 1774 to 1824.* Delaney explains, "This volume was intended to be a perpetual publication, adding a year on at the end while removing one from the beginning, so that it would continually present a record of the last fifty years. Here, Playfair's popular time line has been extrapolated beyond his death (1823) for another year."[44] Color encodes categorical data, for example, red for revenue, green for expenditure, yellow for bread, and so on. Note the addition of main historical events to the year marks on the horizontal axis at the bottom.



Francis A. Walker (1840–1897) compiled this fiscal chart of the United States showing the course of the public debt over years. It covers a period from 1789 to 1870 and is represented in a vertical scale, with earliest dates at the top. It includes 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. It was published in 1874 in the *Statistical Atlas of the United States,* based on the results of the ninth census (1870).

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Shan Carter, Amanda Cox, Kevin Quealy, and Amy Schoenfeld (*New York Times*), U.S.: "How Different Groups Spend Their Day," 2008.

When data are portrayed linearly, hourly trends are not easily perceived, because it is impossible to compare events occurring at the same periods. For that we need to aggregate values, as in this example from the *New York Times*' "How Different Groups Spend Their Day." The interactive visualization depicts data as a stack area graph of activities performed (as percentages) by different demographic groups over the course of a day. Color encodes the different activities, such as sleeping, eating, socializing, etc.

When the goal is to visualize trends in people's routines, the period we deal with is the twenty-four-hour cycle of the day. We know a day starts at 00:00 and ends at 23:59. But structuring data around this temporal convention usually interrupts certain patterns. To avoid this issue, for example, this visualization starts at 4:00 AM instead of at 00:00, because it focuses on daily activities. The result is an effective use of space, in which the most relevant data fall into the center of the visualization, with sleeping times divided into the sides. To avoid this problem, it is often recommended to closely examine the data because they provide good indications of the most appropriate time stamps to start and end the time series.

www.nytimes.com/interactive/2009/07/31/business/20080801-metrics-graphic.html

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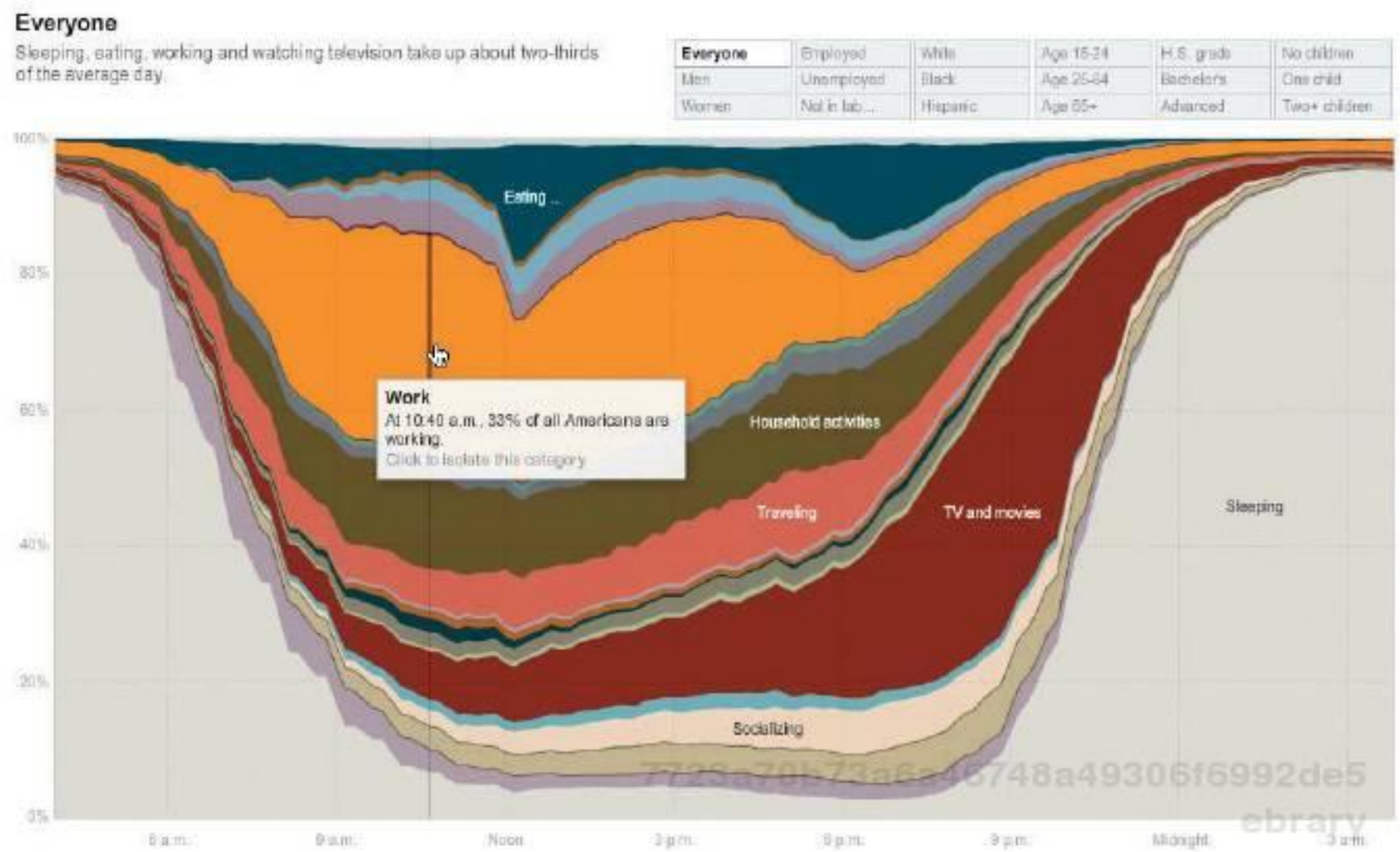

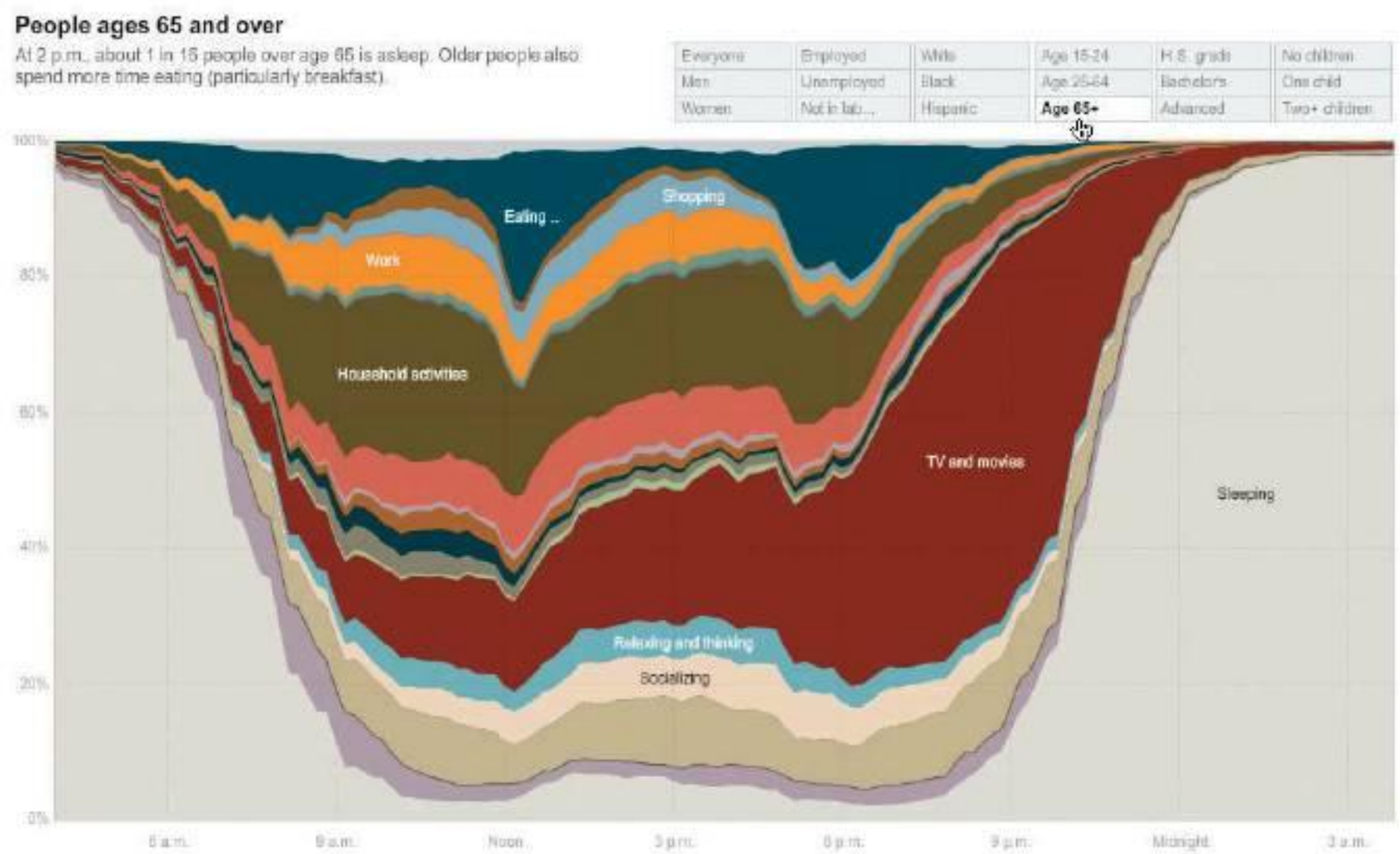

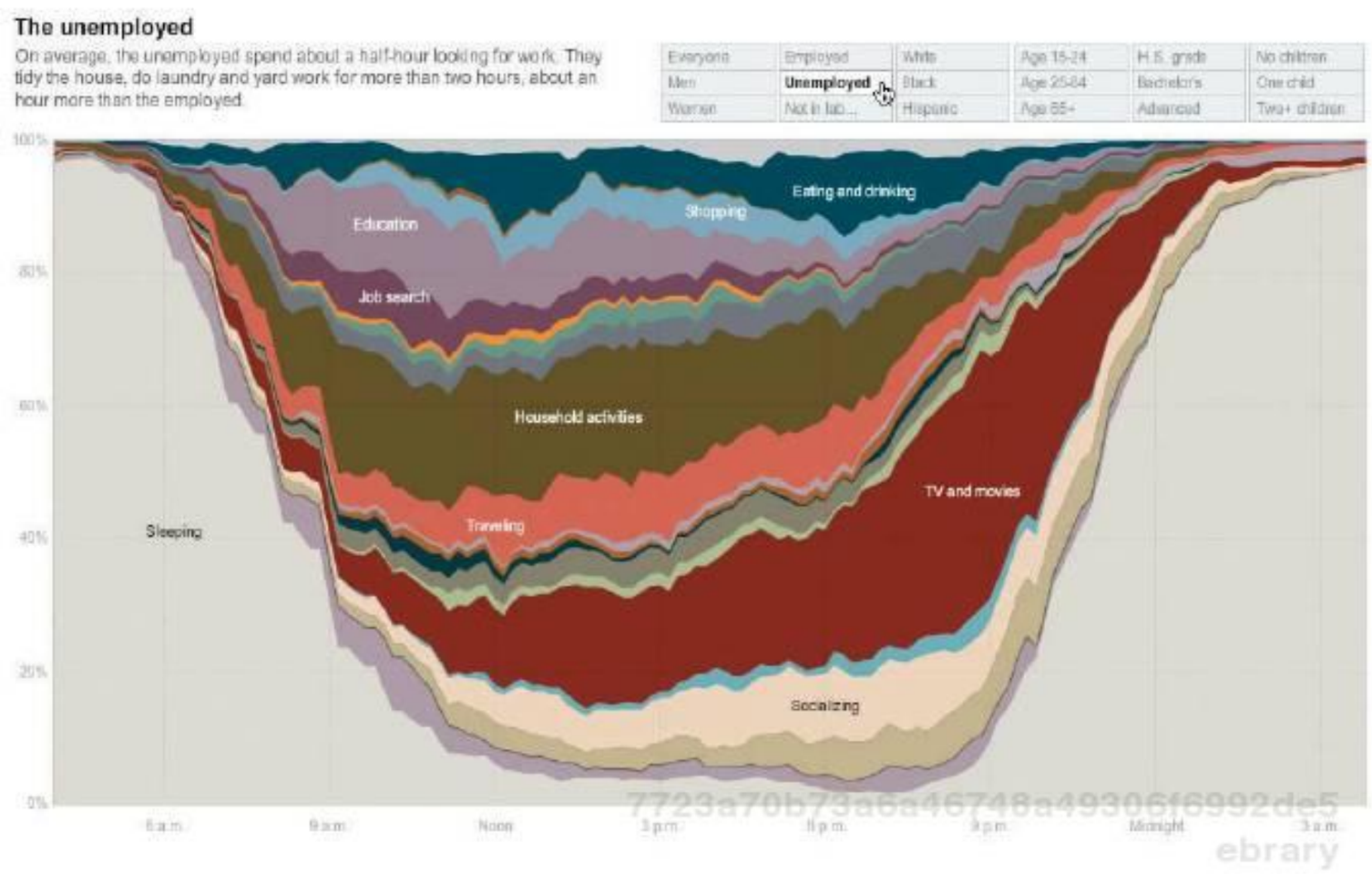

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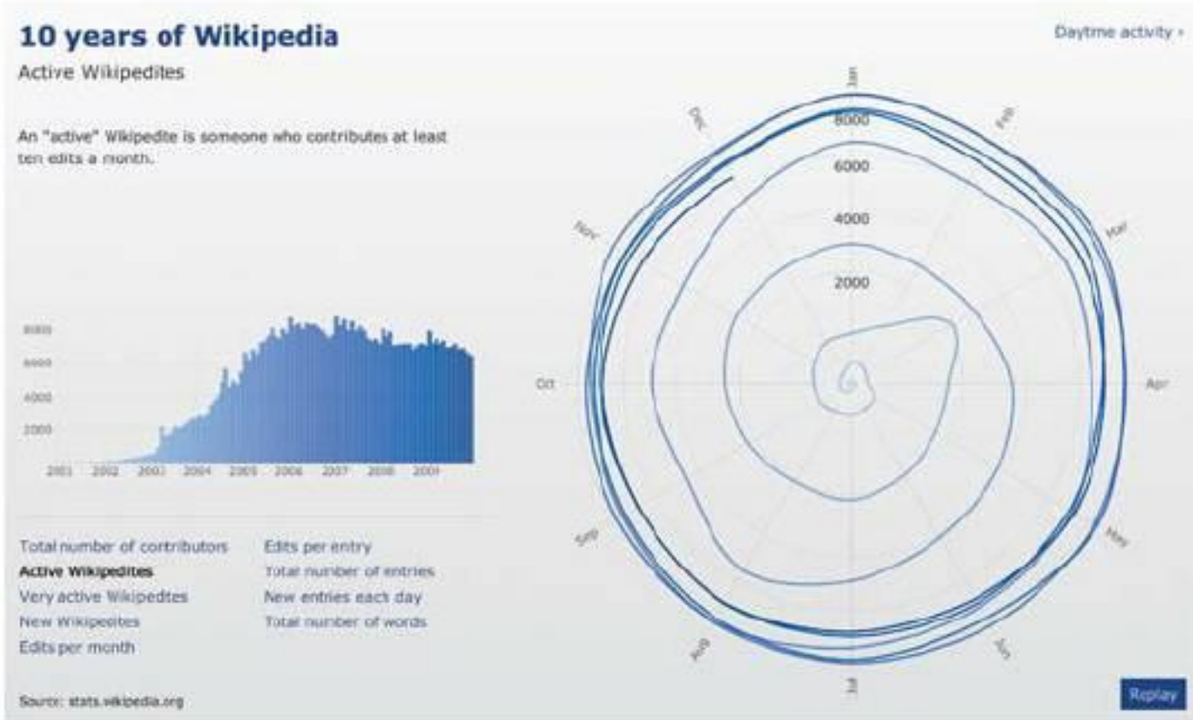

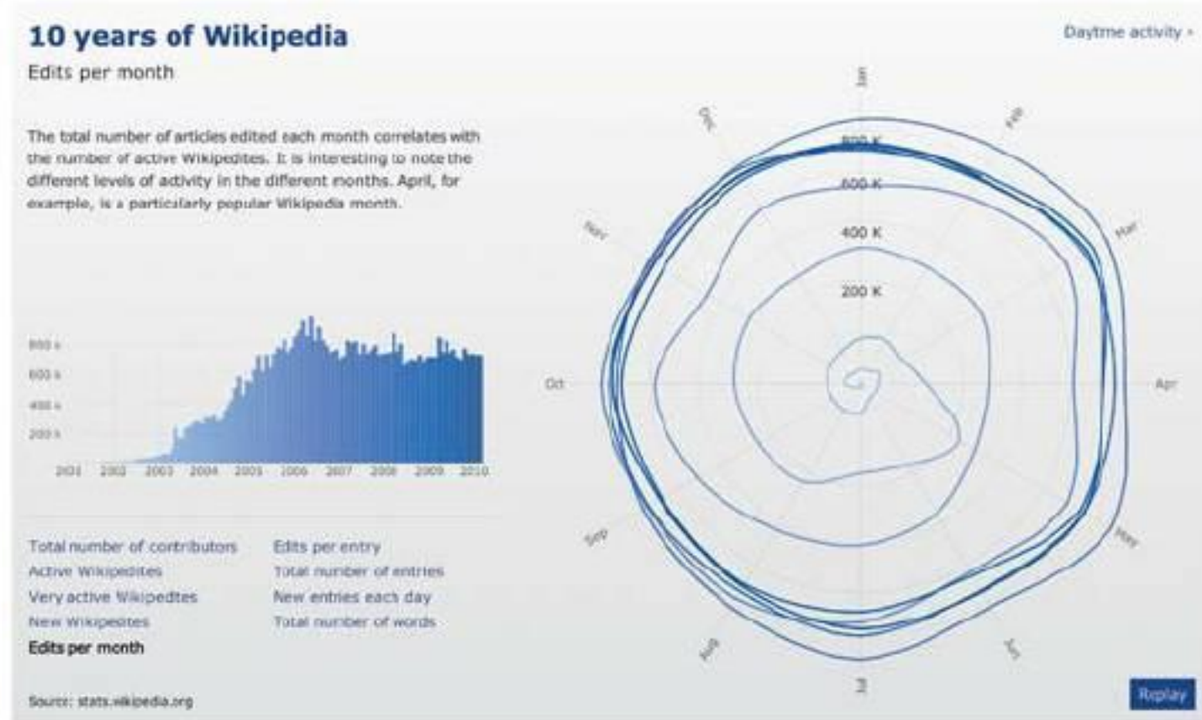

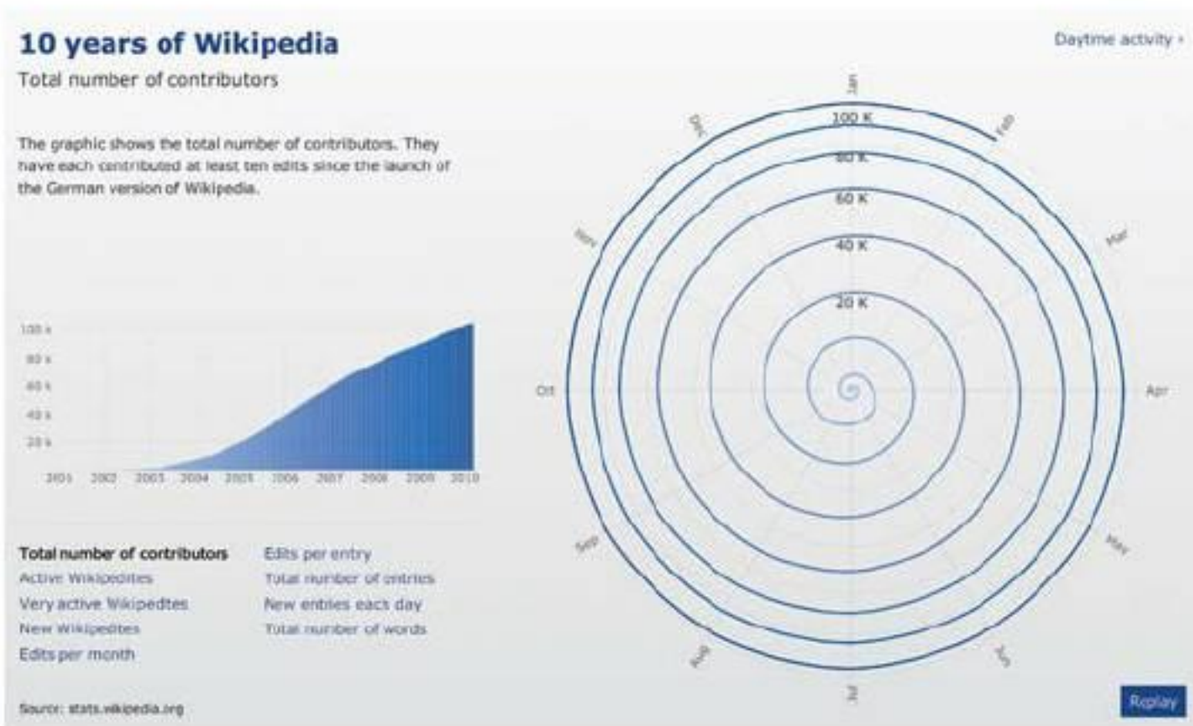

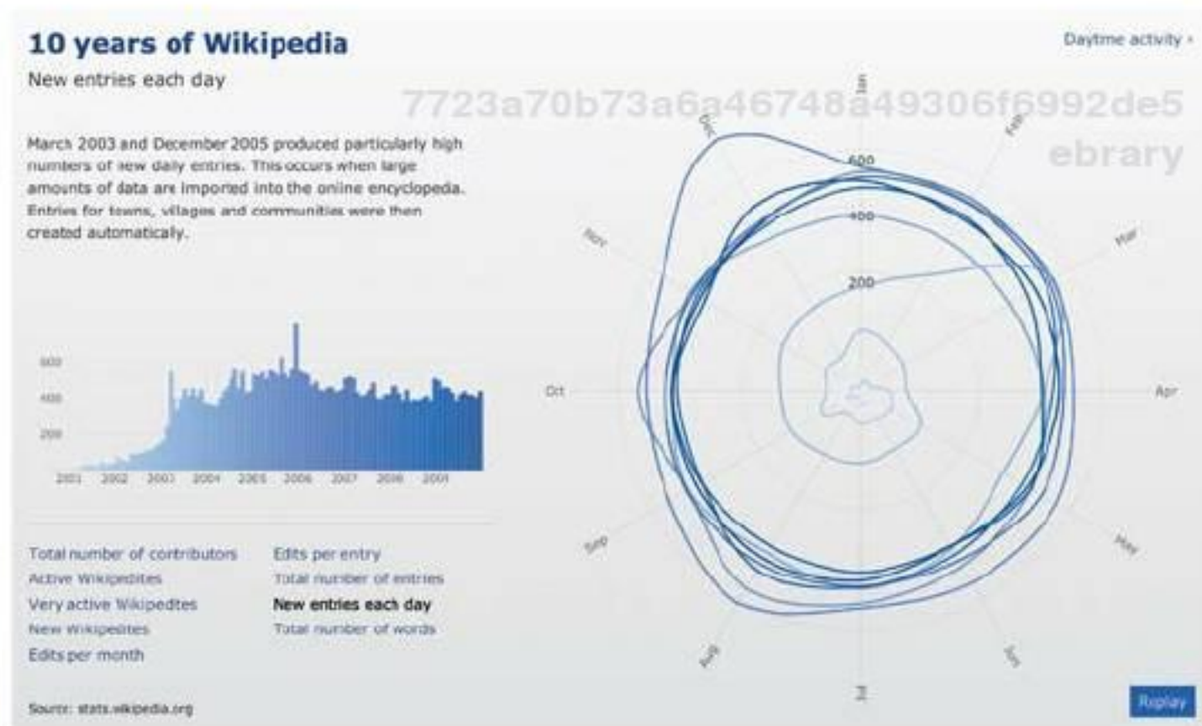

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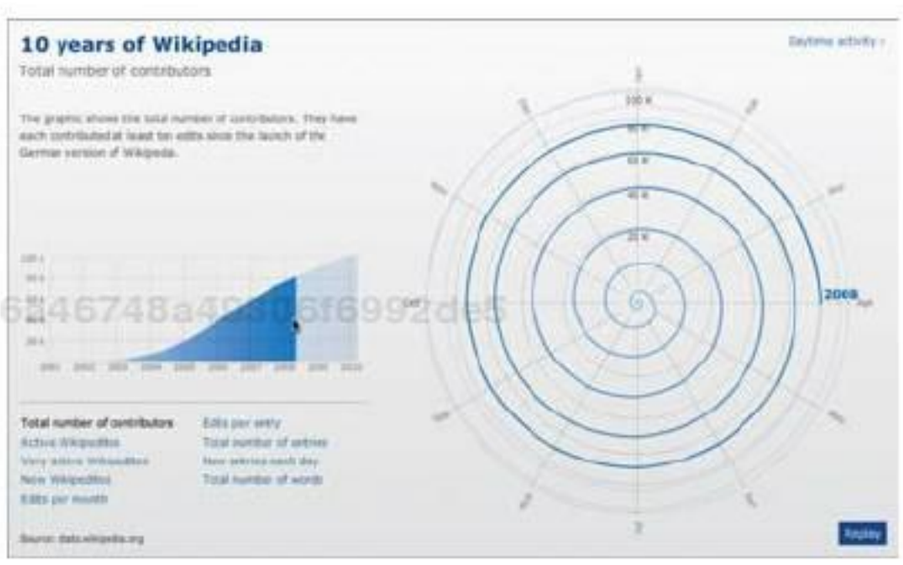

Gregor Aisch, Germany: "10 Years of Wikipedia," 2011.

Circular or spiral structures are often used when the goal is to show a continuous timescale, as well as to reveal periodic data. Spirals are best at depicting continuous data over many cycles, similar to several concentric circles. Different from linear time series, which depict data by aggregating values, in spirals we can represent individual amounts per temporal unit. In this visualization depicting "10 Years of Wikipedia," Gregor Aisch used a polar line chart to reveal the periodical growth patterns of a few selected metrics in relation to the daily activity curves of the top 100 editors. The interactive visualization was developed by Gregor Aisch with Marcus Bösch and Stellen Leidel (editors) for the *Deutsche Welle* at the occasion of the encyclopedia's anniversary in 2011.

There are few antecedents to the circular schema, such as Nightingale's rose chart and the star and polar diagrams (see page 92, 94, 95).

http://visualdata.dw.de/en/wikipedia

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Meirelles, Isabel. Design for Information : An Introduction to the Histories, Theories, and Best Practices Behind Effective Information Visualizations. Osceola, WI, USA: Rockport Publishers, 2013. ProQuest ebrary. Web. 26 April 2016.
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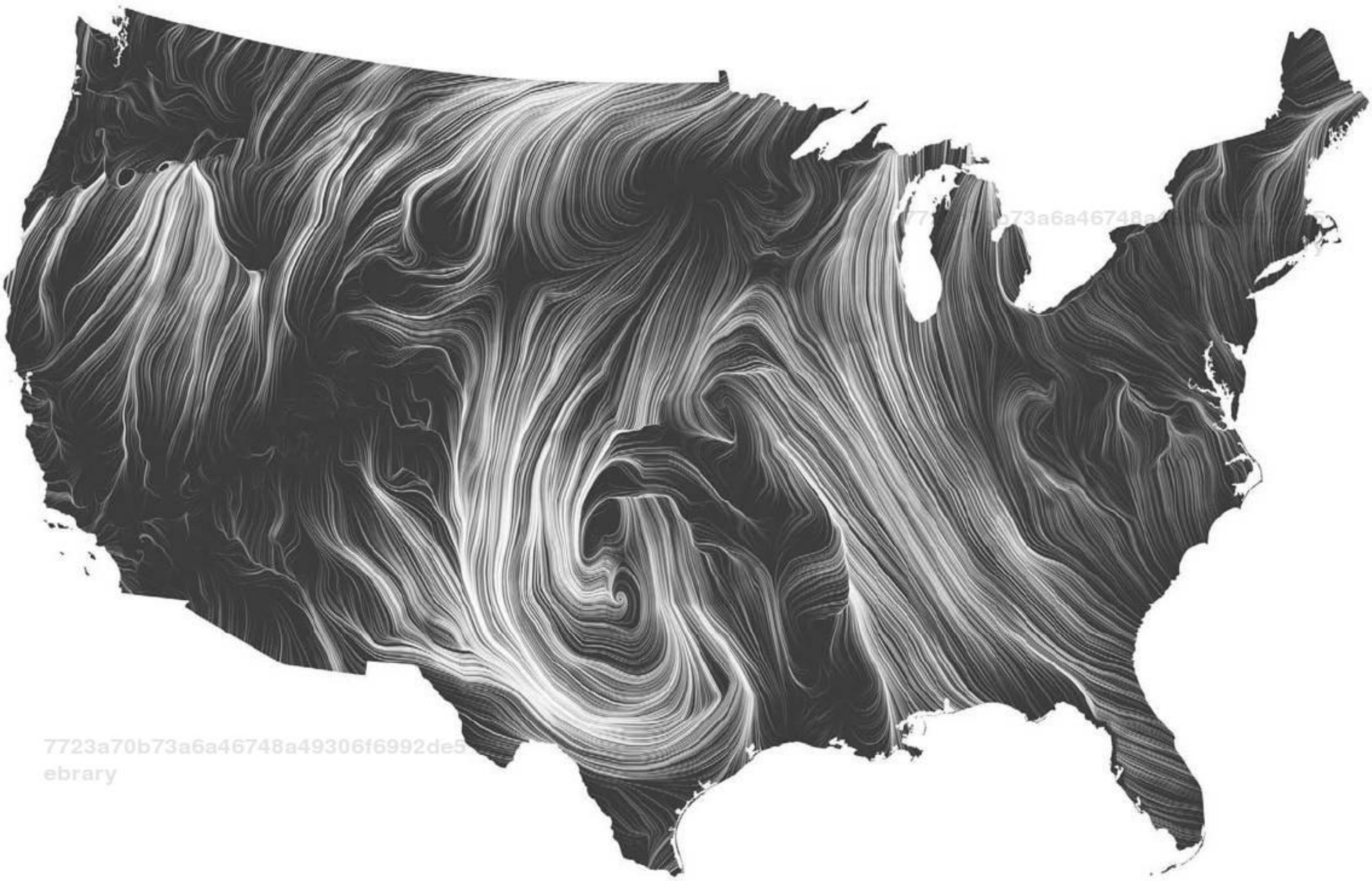

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