Milestones in the history of thematic cartography, statistical graphics, and data visualization*

Michael Friendly

October 16, 2008

1 Introduction

The only new thing in the world is the history you don't know.

Harry S Truman, quoted by David McCulloch in *Truman*

The graphic portrayal of quantitative information has deep roots. These roots reach into histories of thematic cartography, statistical graphics, and data visualization, which are intertwined with each other. They also connect with the rise of statistical thinking up through the 19th century, and developments in technology into the 20th century. From above ground, we can see the current fruit; we must look below to see its pedigree and germination. There certainly *have* been many new things in the world of visualization; but unless you know its history, everything might seem novel.

A brief overview

The earliest seeds arose in geometric diagrams and in the making of maps to aid in navigation and exploration. By the 16th century, techniques and instruments for precise observation and measurement of physical quantities were well-developed— the beginnings of the husbandry of visualization. The 17th century saw great new growth in theory and the dawn of practice— the rise of analytic geometry, theories of errors of measurement, the birth of probability theory, and the beginnings of demographic statistics and "political arithmetic". Over the 18th and 19th centuries, numbers pertaining to people—social, moral, medical, and economic statistics began to be gathered in large and periodic series; moreover, the usefulness of these bodies of data for planning, for governmental response, and as a subject worth of study in its own right, began to be recognized.

This birth of statistical thinking was also accompanied by a rise in visual thinking: diagrams were used to illustrate mathematical proofs and functions; nomograms were developed to aid calculations; various graphic forms were invented to make the properties of empirical numbers– their trends, tendencies, and distributions— more easily communicated, or accessible to visual inspection. As well, the close relation of the numbers of the state (the origin of the word "statistics") and its geography gave rise to the visual representation of such data on maps, now called "thematic cartography".

Maps, diagrams and graphs have always been (and continue to be) hard to produce, still harder to publish. Initially they were hand drawn, piece-by-piece. Later they were etched on copper-plate and manually

*Dedicated to Arthur H. Robinson [1915–2004], who inspired and encouraged our interest; to Antoine de Falguerolles, who initiated it, and to *les Chevaliers des Album de Statistique Graphique*, who supported it with interest, enthusiasm, and resources. This work was supported by the National Sciences and Engineering Research Council of Canada, Grant OGP0138748.

colored. Still later, lithography and photo-etching, and most recently, computer software was used, but graphic-makers have always had to struggle with the limitations of available technology— and still do today. Some note-worthy places in the history of visualization must therefore be reserved for those who contributed to the technology.

Most recently, advances in statistical computation and graphic display have provided tools for visualization of data unthinkable only a half century ago. Similarly, advances in human-computer interaction have created completely new paradigms for exploring graphical information in a dynamic way, with flexible user control.

While most of the recent contributions listed here relate to the visual display of statistical data, there has also been considerable interplay with advances in information visualization more generally, particularly for the display of large networks, hierarchies, data bases, text, and so forth, where problems of very-large scale data present continuing challenges.

Varieties of data visualization

Information visualization is the broadest term that could be taken to subsume all the developments described here. At this level, almost anything, if sufficiently organized, is information of a sort. Tables, graphs, maps and even text, whether static or dynamic, provide some means to see what lies within, determine the answer to a question, find relations, and perhaps apprehend things which could not be seen so readily in other forms.

In this sense, information visualization takes us back to the earliest scratches of forms on rocks, to the development of *pictoria* as mnemonic devices in illuminated manuscripts, and to the earliest use of diagrams in the history of science and mathematics.

But, as used today, the term *information visualization* is generally applied to the visual representation of large-scale collections of non-numerical information, such as files and lines of code in software systems [66], library and bibliographic databases, networks of relations on the internet, and so forth. In this document we avoid both the earliest, and most of the latest uses in this sense.

Another present field, called *scientific visualization*, is also under-represented here, but for reasons of lack of expertise rather than interest. This area is primarily concerned with the visualization of 3-D+ phenomena (architectural, meterological, medical, biological, etc.), where the emphasis is on realistic renderings of volumes, surfaces, illumination sources, and so forth, perhaps with a dynamic (time) component. Finally, the areas of *visual design* and *information graphics* both draw on, and contribute to, the content presented here, but are also under-represented.

Instead, we focus on the slightly narrower domain of ***data visualization***, the science of visual representation of "data", defined as information which has been abstracted in some schematic form, including attributes or variables for the units of information. This topic could be taken to subsume the two main focii: statistical graphics, and thematic cartography.

Both of these are concerned with the visual representation of quantitative and categorical data, but driven by different representational goals. Cartographic visualization is primarily concerned with representation constrained to a spatial domain; statistical graphics applies to any domain in which graphical methods are employed in the service of statistical analysis. There is a lot of overlap, but more importantly, they share common historical themes of intellectual, scientific, and technological development.

In addition, cartography and statistical graphics share the common goals of visual representation for exploration and discovery. These range from the simple mapping of locations (land mass, rivers, terrain), to spatial distributions of geographic characteristics (species, disease, ecosystems), to the wide variety of graphic methods used to portray patterns, trends, and indications.

Milestones Project

> The past only exists insofar as it is present in the records of today. And what those records are is determined by what questions we ask.
>
> Wheeler [320, p. 24]

There are many historical accounts of developments within the fields of probability [116], statistics [226, 239, 273], astronomy [249], cartography [316], which relate to, *inter alia*, some of the important developments contributing to modern data visualization. There are other, more specialized accounts, which focus on the early history of graphic recording [137, 138], statistical graphs [91, 92, 257, 264, 286], fitting equations to empirical data [69], cartography [88, 162] and thematic mapping [253, 223], and so forth; Robinson [253, Ch. 2] presents an excellent overview of some of the important scientific, intellectual, and technical developments of the 15th–18th centuries leading to thematic cartography and statistical thinking.

But there are no accounts that span the entire development of visual thinking and the visual representation of data, and which collate the contributions of disparate disciplines. In as much as their histories are intertwined, so too should be any telling of the development of data visualization. Another reason for interweaving these accounts is that practitioners in these fields today tend to be highly specialized, and unaware of related developments in areas outside their domain, much less their history. Extending Wheeler [320], the records of history also exist insofar as they are collected, illustrated, and made coherent.

This listing is but an initial step in portraying the history of the visualization of data. We started with the developments listed by Beniger and Robyn [21] and incorporated additional listings from Hankins [121], Tufte [291, 292, 293], Heiser [132], and others (now too numerous to cite individually). In most cases, we cite original sources (where known) for the record; occasional secondary sources are included as well, where they appear to contribute to telling the story.

To convey a real sense of the accomplishments requires much more context— words, images, and, most usefully, interpretation. In this chronological listing, it has proved convenient to make divisions by epochs, and we provide some more detailed commentaries for each of these. The careful reader will be able to discern other themes, relations, and connections, not stated explicitly.

More importantly, we envisage this Milestones Project as the beginning of a contribution to historiography, on the subject of visualization. Some related publications are [79] and [87]. One goal is to provide a flexible, and useful multi-media resource, containing descriptions of events and developments, illustrative images, and links to related sources (web and in print) or more detailed commentaries. Another goal is to build a database which collects, catalogs, organizes, and illustrates these significant historical developments.

The present listing is simply chronological, but, as noted above, we provide some overview for each epoch. We have also begun coding the listings to be dynamically searchable by other criteria, for example by person, place, theme, content, and so forth. A parallel web version may be viewed on the Gallery of Data Visualization site at:

Milestones web site: http://www.math.yorku.ca/SCS/Gallery/milestone/

In the listings below, PIC: refers to a web link (URL) to a portrait, while IMG: and FIG: refer to graphic images (FIG for a larger copy of an IMG). To allow more extensive treatments, with commentaries on some people, events, or topics, we use TXT: to refer to a link to related text.

These links should be active in the `.pdf` and web versions of this document. As a result, the web URLs do not appear in a printed copy, and the many portraits and images we have collected are implicit, rather than shown inline.

2 Pre-17th Century: Early maps and diagrams

The earliest seeds of visualization arose in geometric diagrams, in tables of the positions of stars and other celestial bodies, and in the making of maps to aid in navigation and exploration. We list only a few of these here to provide some early context against which later developments can be viewed.

In the 16th century, techniques and instruments for precise observation and measurement of physical quantities were well-developed. As well, we see initial ideas for capturing images directly, and recording mathematical functions in tables. These early steps comprise the beginnings of the husbandry of visualization.

c. 6200 BC The oldest known map? (There are several claimants for this honor.)— Museum at Konya, Turkey.

IMG: Konya town map (280 x 160; 7K)
FIG: Konya town map (555 x 317; 24K)
TXT: Town map, with an errupting volcano (Hasan Daö?) and the Konya plain
TXT: An extended description of the most ancient maps

c. 550 BC The first world map? (No extant copies, but described in books II and IV of Herodotus' "Histories" [254]— Anaximander of Miletus (c.610BC–546BC), Turkey.
FIG: The first world map (325 x 326; 3K)
TXT: Anaximander biography

366–335 BC The first route map ("carte routière"), showing the whole of the Roman world, a map from Vienna, through Italy, to Carthage; painted on parchment, 34 cm. high, by 7 m. in length. (Named the table of Peutinger, after a 16th century German collector.)— Italy. 06/21/05:YL
FIG: Peutinger map (1251 x 833; 330k)
TXT: Peutinger map background
TXT: Peutinger map images

[The whole of the Roman world is reproduced on this painted parchment 34 centimetres in height and almost 7 metres in length. Although it is the most reproduced Roman chart, the Table of Peutinger does not make it possible to perceive the extent of the cartographic work undertaken by the Romans. Land conquerors, they had a utilitary vision of geography and their cartographic representations were related to the imperial conquests. Topographers accompanied the Roman armies in their campaigns in order to recognize the conquered grounds. Information collected was used for the military needs and the development of infrastructures such as the routes, but also to describe the routes. The table of Peutinger, named after the XVI century German collector to which it was offered, was a form of very widespread geographical description. If this chart does not bring topographic information, it gives indications of distances and size of the places, very practical information for the traveller. The North-South distances are represented on a smaller scale than the East-West distances, thus making it possible to the traveller to unfold or unroll the section which corresponded to its course.]

240 BC Calculation of the diameter of the earth by measuring noontime shadows at sites 800 km. apart— Eratosthenes (of Cyrene) (276BC–194BC), Libya. 06/24/05:YL
TXT: Eratosthenes biography
TXT: Eratosthenes of Cyrene

[Assuming the earth is a sphere, the measured angle between the sites is seven degrees and the circumference is about 50 times 800 km., or about 40,000 km.]

170 BC Invention of parchment. Parchment was superior to papyrus because it could be printed on both sides and folded.— Pergamon. 06/25/05:YL
TXT: History of parchment

134 BC Measurement of the year with great accuracy and building of the first comprehensive star chart with 850 stars and a luminosity, or brightness, scale; discovery of the precision of the equinoxes— Hipparchus (of Rhodes) (190–120BC), Turkey. 06/24/05:YL
TXT: Astronomy
TXT: Hipparchus the Astronomer
TXT: Hipparchus biography

[He seems to have been very impressed that either of two geometrically constructed hypotheses could 'save the appearance' of the path that a planet follows]

c. 105 Invention of paper, replacing (somewhat later) writing and other inscriptions on wood, cloth, stone, etc.—Tsai Lun, China 04/22/05
PIC: Tsai Lun portrait (180 x 180; 14K)
TXT: Tsai Lun, portrait and biography
TXT: Timeline of paper making

c. 150 Map projections of a spherical earth and use of latitude and longitude to characterize position (first display of longitude)— Claudius Ptolemy (c. 85–c. 165), Alexandria, Egypt.

PIC: Ptolemy, portrait from ca. 1400 (90 x 109; 9K)
FIG: Ptolemy's world map, republished in 1482 (640 x 496; 40K)
TXT: Ptolemy world map description, with images
TXT: The world according to Ptolemy
TXT: Ptolemy's world map, description and high-res image
TXT: Ptolemy history

c. 950 Earliest known attempt to show changing values graphically (positions of the sun, moon, and planets throughout the year)— Europe [91].
IMG: see [291, p. 28]
IMG: Planetary movements icon (222 x 124; 19K)
FIG: Planetary movements diagram (750 x 420; 92K)

c. 1280 Triangular diagrams of paired comparisons for electoral systems (how to elect a Pope or Mother Superior, when all the candidates are voting)— Ramon Llull (1235–1316), Spain [176].
PIC: Llull portrait (409 x 477; 69K)
TXT: Llull portraits
TXT: Llull's writings on electoral systems

1305 Mechanical diagrams of knowledge, as aids to reasoning (served as an inspiration to Leibnitz in the development of symbolic logic)— Ramon Llull (1235–1316), Spain.
FIG: Llull's tree of knowledge (329 x 467; 79K)
FIG: Llull's mechanical disks (518 x 354; 37K)

c. 1350 Proto-bar graph (of a theoretical function), and development of the logical relation between tabulating values, and graphing them (pre-dating Descartes). Oresme proposed the use of a graph for plotting a variable magnitude whose value depends on another, and, implicitly, the idea of a coordinate system— Nicole Oresme (Bishop of Lisieus) (1323–1382), France [217, 218]
PIC: Oresme portrait (268 x 326; 19K)
IMG: Oresme bar graph (225 x 117; 6K)
IMG: Page from Oresme (453 x 600; 19K)

1375 Catalan Atlas, an exquisitely beautiful visual cosmography, perpetual calendar, and thematic representation of the known world— Abraham Cresques (1325–1387), Majorca, Spain.
IMG: Carte de l'Europe, de l'Afrique du Nord et du Proche-Orient, BNF, ESP 30 (266 x 168; 48K)
IMG: Carte de l'Europe, de l'Afrique du Nord et du Proche-Orient, BNF, ESP 30 (747 x 508; 195K)
FIG: Catalan Atlas, detail: Europe, North Africa (747 x 508; 195K)
TXT: BNF description of Atlas catalan (BNF, ESP 30)
TXT: BNF listing of images from the Catalan Atlas
TXT: Detailed description of Catalan Atlas and Abraham Cresques (Henry-Davis)

c. 1450 Graphs of distance vs. speed, presumably of the theoretical relation — Nicolas of Cusa (1401–1464), Italy.
TXT: Cusa biography
TXT: Annotated links: Nicolas of Cusa on the Web

1453 Invention of moveable type printing press, and printing of the Mazarin bible (leads to a decline in the use of mixed text and graphics)— Johann Gutenberg (1387–1468), Germany.
PIC: Gutenberg portrait (124 x 114; 8K)
IMG: Gutenberg type sample (116 x 145; 5K)
FIG: Page from the Mazarin bible (375 x 952;196K)

c. 1500 Use of rectangular coordinates to analyze velocity of falling objects— Leonardo da Vinci (1452–1519), Florence, Italy [309].
PIC: da Vinci portrait (168 x 254; 10K)

TXT: biography of Leonardo da Vinci
IMG: The 'Arnovalley', the first known and dated work of Leonardo da Vinci (220 x 148; 13K)

1530 Theoretical description of how longitude may be determined using difference of times by a clock and the associated observed change in star positions (not implemented)— Regnier Gemma-Frisius (1508–1555), Leuven, Belgium [89].
PIC: Gemma Frisius portrait (90 x 109; 4K)
TXT: Frisius biography

1533 Description of how to determine mapping locations by triangulation, from similar triangles, and with use of angles w.r.t meridians— Regnier Gemma-Frisius (1508–1555), Leuven, Belgium [90].
PIC: Gemma Frisius at his desk surrounded by instruments and books (200 x 139; 30K) .
FIG: Image from Peter Apianius Cosmographia, edited by Gemma Frissius (383 x 503; 70K)
FIG: Gemma-Frisius Diagram of triangulation (272 x 400; 21K)
TXT: Frisius biography
TXT: Cosmographia web site

1545 The first published illustration of a camera obscura, used to record an eclipse of the sun, on January 24, 1544.— Regnier Gemma-Frisius (1508–1555), Leuven, Belgium [103].
IMG: Camera obscura (357 x 250; 40K)
FIG: Camera obscura (485 x 340; 90K)
TXT: Adventures in Cybersound: The Camera Obscura
TXT: Science, Optics and You - Timeline, 1000-1599

1550 Trigonometric tables (published 1596 posthumously)— Georg Joachim Rheticus (1514–1574), Germany.
TXT: Rheticus biography

1556 Development of a method to fix position and survey land using compass-bearing and distance. (Tartaglia is better known for discovering a method to solve cubic equations) — Niccolo Fontana Tartaglia (1499–1557), Italy [279].
PIC: Tartaglia portrait (268 x 326; 19K)
TXT: Tartaglia biography

1562 *Liber de Ludo Alaea*, a practical guide to gambling, containing the first systematic computation of probabilities; written in 1562, but not published until 1663.— Gerolamo Cardano (1501–1576), Italy [39, 55]. 06/25/05:YL
PIC: Gerolamo Cardano portrait (250 x 304; 24K)
TXT: Cardano (Galileo project)
TXT: Cardano biography

1569 Invention of cylindrical projection for portraying the globe on maps, to preserve straightness of rhumb lines— Gerardus Mercator (1512–1594), Belgium [258].
PIC: Mercator portrait (356 x 400; 34K)
FIG: Mercator's 1569 *Nova et Aucta Orbis Terrae* map (495 x 643; 145K)
TXT: Mercator biography, with related links
TXT: Mercator biography, with images

1570 The first modern atlas, *Teatrum Orbis Terrarum*— Abraham Ortelius (Ortel) (1527–1598), Antwerp, Belgium [219].
PIC: Ortelius portrait (160 x 217; 18K)
IMG: Map of the Netherlands, small (200 x 147; 32K)
FIG: Map of the Netherlands, medium (590 x 435; 255K)
FIG: Ortelius world map, from De Camp 1970 (700 x 874; 174K)
TXT: Overview of Ortelius and the Teatrum
TXT: Maps from Teatrum Orbis Terrarum

1572 Improvements in instruments for accurately measuring positions of stars and planets, providing the most accurate catalog on which later discoveries (e.g., Kepler's laws) would be based—Tycho Brahe (1546–1601), Denmark. 2/15/05

PIC: Tycho Brahe portrait (280 x 306; 27K)
FIG: Tycho Brahe's wall quadrant (290 x 450; 35K)
FIG: Parallax diagram (286 x 372; 31K)
TXT: Tycho Brahe "home page"
TXT: Galileo project summary of Brahe
TXT: Tycho Brahe biography

1581 Discovery of isosynchronous property of the pendulum (to be used for clocks and measurement)—Galileo Galilei (1564–1642), Italy.

TXT: Properties of the pendulum
TXT: Galileo's pendulum experiments

§2: 26 items

3 1600-1699: Measurement and theory

Among the most important problems of the 17th century were those concerned with physical measurement— of time, distance, and space— for astronomy, surveying, map making, navigation and territorial expansion. This century saw great new growth in theory and the dawn of practice— the rise of analytic geometry, theories of errors of measurement and estimation, the birth of probability theory, and the beginnings of demographic statistics and "political arithmetic".

By the end of this century, the necessary elements were at hand— some real data of significant interest, some theory to make sense of them, and a few ideas for their visual representation. Perhaps more importantly, one can see this century as giving rise to the beginnings of visual thinking.

early 1600s Tables of empirical data, published tables of numbers begin to appear. "Die Tabellen-Statistik," as a branch of statistics devoted to the numerical description of facts— Germany.

1603 Tables, and first world map showing lines of geomagnetism (isogons), used in work on finding longitude by means of magnetic variation. The tables give the world distribution of the variation, by latitude, along each of the meridians— Guillaume Le Nautonier (1557–1620), France [209, 181]. 2/15/05

PIC: Le Nautonier portrait (156 x 199; 56K)
TXT: Biographical sketch
FIG: Le Nautonier's geomagentic map (566 x 381; 93K)
FIG: Modern re-creation of the magnetic equator after Le Nautonier (888 x 459; 16K)

1603 The pantograph was invented for mechanically copying a figure on an enlarged or reduced scale—Christopher Scheiner (1575–1650), Italy.

PIC: Scheiner's portrait
FIG: Scheiner's pantograph (224 x 136; 4.5K)
TXT: Scheiner's sunspots, equatorial mount and pantograph

1610 The first astronomical pictures ever printed, from observations through a telescope, used to illustrate discoveries of craters on the moon, the 4 staelites of Jupiter and a vast number of stars never seen by unaided eyes— Galileo Galilei (1564–1642), Italy [95] 07/04/06:MF

FIG: Cover page from Sidereus Nuncius (500 x 672; 81K)
FIG: Page 9v: craters on the moon (226 x 366; 32K)
TXT: Works of Galileo: Starry Messenger

1614 Invention of logarithms, and the first published tables of logarithms— John Napier (1550–1617), Scotland [208].

PIC: Napier portrait (268 x 326; 9.6K)
FIG: Two pages from Napier's table of logarithms (1330 x 1014; 352K)
FIG: Diagram of spherical triangles from [208] (500 x 760; 42K)
TXT: Biography of Napier
TXT: Text of *A Description of the Admirable Table of Logarithms* (with images)

1617 First use of Frisius' method of trigonometric triangulation to produce locations of major cities in Holland; foundation of geodesy— Willebrord van Roijen Snell (Snellius) (1580–1626), Leiden, Netherlands [269].
PIC: Snellius portrait (200 x 257; 49K)
TXT: Snell, biographical sketch
[In 1621, Willibrord Snell, in *Cyclometricus*, discovered the law of refraction which says that the ratio of the sines of the angles of incidence and refraction is a constant and the index of refraction varies from one transparent substance to another. This law implies that the velocity of light in a medium is inversely proportional to its refractive index. Cyclometricus was published after Snell's death by Rene' Descartes.]

1620–1628 Invention of a mechanical device, containing a logarithmic scale of equal parts and trigonomic functions which, with the aid of a pair of calipers, could be used as a slide rule. This device, called "Gunter's scale," or the "gunter" by seamen, was soon replaced by a true slide rule, containing two parallel logarithmic scales— Edmund Gunter (1581–1626) and William Oughtred (1574–1660), England [10, 115].
TXT: Edmund Gunter - Biographical sketch
TXT: Edmund Gunter - Biography
TXT: William Oughtred - Biography
IMG: Gunter's log scale(398 x 39; 0.5K)
IMG: Oughtred's dual log scale (442 x 52; 1K)
FIG: Gunter's scale image (2200 x 176; 110K)

1623 The first known adding machine, a mechanical calculator called the "Calculating Clock." It could add and subtract up to six-digit numbers, based on the movement of six dented wheels geared through a "mutilated" wheel which with every full turn allowed the wheel located at the right to rotate 1/10th of a full turn—Wilhelm Schickard (1592–1635), Tubingen, Germany. 04/06/05
IMG: Schickard's calculating clock icon (133 x 114; 4.6K)
FIG: reproduction of Schickard's calculating clock (300 x 244; 34K)
TXT: Schickard biography
TXT: History of mechanical calculators - Part 1

1626 Visual representations used to chart the changes in sunspots over time. Also, the first known use of the idea of "small multiples" to show a series of images in a coherent display— Christopher Scheiner (1575–1650), Italy [259].
IMG: Scheiner sunspot image (135 x 150; 4K)
FIG: Apparatus for recording sunspots (600 x 320; 68K)
TXT: A brief history of sunspots
FIG: Sunspot plate from Scheiner's "Tres Epistolae" (650 x 505; 250K)

1632 Statistical analysis of observations on location of Tycho Brahe's star of 1572, based on idea that the most probable hypothesis is the one having the smallest (least absolute value) deviations— Galileo Galilei (1564–1642), Italy [96] [116, §10.3].
PIC: Galileo portrait (190 x 187; 4K)
TXT: Galileo biography

1637 Coordinate system reintroduced in mathematics, analytic geometry; relationship established between graphed line and equation—Pierre de Fermat (1601–1665) and René Descartes (1596–1650), France [59].
PIC: Descartes portrait (200 x 248; 18K)

TXT: Biographical sketch - Rene Descartes

TXT: Biographical sketch - Pierre de Fermat

[About 1629, Pierre de Fermat discovered that the equation $f(x, y) = 0$ represents a curve in the xy-plane. This is the fundamental principle of analytic geometry, and was first published by Descartes in 1637. He also formulated a method for determining the maximim and minimum values which give single solutions for problems which in general have two solutions. This procedure is "almost precisely that now given in the differential calculus"" "(Boyer 1949:156).]

1644 First visual representation of statistical data: variations in determination of longitude between Toledo and Rome— Michael F. van Langren (1600–1675), Spain [171].
IMG: Langren image (532 x 131; 11K)

1646 Invention of the first projection lantern (the magic lantern). [Images were painted on glass and projected on walls. Kirscher, a Jesuit priest, was the last recorded ordained priest openly to concern himself with optics. Henceforth, the art of projecting images was classified as an entertainment and curtailed.]— Athanasius Kirscher (1602–1680), Germany [160].
PIC: Althanasius Kircher portrait (180 x 220; 39K)
IMG: a Sturm Lantern, 1676 (100 x 120; 1K)
TXT: Jesuits and the Sciences, 1660–1719
TXT: Jesuits and the Sciences, 1660–1719

1654 Initial statements of the theory of probability— Blaise Pascal (1623–1662) and Pierre de Fermat (1601–1665), France.
PIC: Pascal portrait (200 x 229; 41K)
TXT: Pascal biography, extract from [13]

1654 The first large scale attempt at a scientific, economic survey (of the Irish estates confiscated by Oliver Cromwell), perhaps the first econometric study, leading to development of political arithmetic— William Petty (1623–1687), Ireland [230, 233].
PIC: William Petty portrait (200 x 240; 37K)
FIG: Map of William Petty's Down Survey (350 x 305; 26K)
TXT: Petty - Biographical profile, with links to works and resources
TXT: Political Arithmetick, by Sir William Petty

1657 First text on probability— Christiaan Huygens (1629–1695), Netherlands [145].
PIC: Huygens portrait (216 x 192; 9K)
TXT: Biographical blurb from [13]
TXT: English translation of De Ratiociniis in Ludo Aleae

1663 Automatic recording device (the weather clock) producing a moving graph of temperature and wind direction (in polar coordinates)— Christopher Wren (1632–1723), England [22, 327].
PIC: Wren portrait (210 x 290; 10K)
PIC: Wren portrait (268 x 326; 16K)
TXT: Wren catalog entry from the Galileo Project
TXT: Wren biography (St. Andrews)

1662 Founding of demographic statistics: Development of the idea that vital statistics (records of christenings and burials in London) could be used to construct life tables. The average life expectancy in London was 27 years, with 65% dying by age 16— John Graunt (1620–1674), England, [110, 275].
PIC: Graunt portrait (526 x 762; 75K)
IMG: Title page of Graunt's Bills of Mortality (309 x 387; 5K)
FIG: Mortality table, from [230] (1000 x 795; 237K)
TXT: Text of Graunt's "Observations on the Bills of Mortailty"

[Graunt's work of 1662 is often ascribed to Sir William Petty. The authorship question has been discussed by Wilcox [321], who concludes that although a portion of the work was by Petty, the majority is due to Graunt.]

1666 First modern complete demographic census, a record of each individual by name of the 3215 inhabitants of New France— Jean Talon (1626–1694), Canada [108, p. 179],[154, p. xix].
TXT: Commentary on first Canadian census by Dan
TXT: The great intendant: A chronicle of Jean Talon in Canada (e-book)
TXT: Jean Talon biography from Statistics Canada
[E. H. Godfrey says that this is "a date prior to any modern census, whether European or American", see [108, p. 179]. The returns were fairly complete, giving data on population, sexes, families, conjugal condition, age, profession and trades, and they filled 154 pages. The original copy is now in the Archives of Paris, and a transcript in the Archives of Ottawa.]

1669 First graph of a continuous distribution function, a graph of Gaunt's life table, and a demonstration of how to find the median remaining lifetime for a person of given age— Christiaan Huygens (1629–1695), Netherlands [32]
IMG: see [116, Fig. 8.1.1].
IMG: Huygens graph (301 x 284; 1K)
TXT: Huygens - Biographical sketch
TXT: Complete works of Huygens
[Source: correspondence between Huygens and his brother Lodewijk.]

1671 First attempt to determine scientifically what should be the purchase price of annuities, using mortality tables— Jan de Witt (1625–1672), Netherlands [326].
PIC: de Witt portrait (82 x 109; 5K)
TXT: de Witt biography
TXT: Death and Statistics, including an account of de Witt's method

1686 Bivariate plot of a theoretical curve derived from observations (barometric pressure vs. altitude), graphical analysis based on empirical data— Edmond Halley (1656–1742), England [118].
PIC: Halley portrait (254 x 326; 21K)
FIG: Halley's graph of change in barometric pressure (914 x 773; 7K)

1686 First known weather map, showing prevailing winds on a geographical map of the Earth— Edmond Halley (1656–1742), England [117].
PIC: Halley portrait (254 x 326; 21K)
FIG: Halley's wind map, 1686 (512 x 196; 24K)
FIG: Halley's wind map, section 1 detail (739 x 627; 122K)
TXT: Halley - Biographical sketch

1687 Use of statistics for international comparisons, e.g., London vs. Rome and London vs. Paris, compared in people, housing, hospitals, etc.— William Petty (1623–1687), England [231, 232].
PIC: Petty portrait (137 x 194; 3K)

1693 First real mortality tables, containing the ages at death of a stable sample of individuals under stable conditions (from Breslau Bills of Mortality)— Edmond Halley (1656–1742), England [119].
TXT: Matthias Bohne edit of Halley 1693 paper

1693 First use of areas of rectangles to display probabilities of independent binary events— Edmond Halley (1656–1742), England [119].
IMG: Halley's diagram (356 x 237; 1K)
FIG: Halley 1893 2D diagram (284 x 232; 9.4K)
FIG: Halley 1893 3D diagram (461 x 450; 32K) §3: 26 items

4 1700-1799: New graphic forms

The 18th century witnessed, and participated in, the initial germination of the seeds of visualization which had been planted earlier. Map-makers began to try to show more than just geographical position on a map. As a results, new graphic forms (isolines and contours) were invented, and thematic mapping of physical quantities took root. Towards the end of this century, we see the first attempts at the thematic mapping of geologic, economic, and medical data.

Abstract graphs, and graphs of functions were introduced, along with the early beginnings of statistical theory (measurement error) and systematic collection of empirical data. As other (economic and political) data began to be collected, some novel visual forms were invented to portray them, so the data could "speak to the eyes".

As well, several technological innovations provided necessary nutrients. These facilitated the reproduction of data images (color printing, lithography), and other developments eased the task of creating them. Yet, most of these new graphic forms appeared in publications with limited circulation, unlikely to attract wide attention.

1701 Contour maps showing curves of equal value (an isogonic map, lines of equal magnetic declination for the world, possibly the first contour map of a data-based variable)— Edmond Halley (1656–1742), England [120, 282].
IMG: Halley isogonic map (400 x 468; 57K)
FIG: National maritime museum, Halley magnetic chart
TXT: Halley biography

1710 Invention of three-color printing— Jacob Cristoph Le Blon (1667–1741), Germany.
TXT: Le Blon biography
TXT: Origins of the art of colour reproduction
TXT: Color reproduction

1711 First test of statistical significance based on deviation between observed data and a null hypothesis (used to show that the guiding hand of a devine being could be discerned in the nearly constant ratio of male to female births in London over 1629–1710)— John Arbuthnot (1667–1735), England [7, 20].
PIC: Arbuthnot portrait (268 x 326; 14K)
TXT: Arbuthnot biography
FIG: Graph of the sex ratio from 1620–1710

1712 Literal line graph, inspired by observation of nature (section of hyperbola, formed by capillary action of colored water between two glass plates)— Francis Hauksbee (1666–1713), England [129].

1724 Abstract line graph (of barometric observations), not analyzed— Nicolaus Samuel Cruquius (1678–1758), Netherlands [54].

1727 Experiments paving the way to the development of photography: Images obtained by action of light on a mixture of chalk, nitric acid, and silver salts— Johann Heinrich Schulze (1687–1744), Germany.
PIC: Schultze portrait (132 x 181; 7K)
TXT: Schulze biographical blurb

1733 The normal distribution, derived as the limit of the binomial distribution— Abraham de Moivre (1667–1754), England [57, 58]. 03/18/07:MF
PIC: de Moivre portrait
TXT: Wikipedia: Normal distribution
TXT: Maty's (1755) biography of Abraham De Moivre

[The normal distribution was first introduced by de Moivre in an article in 1733 (reprinted in the second edition of his The Doctrine of Chances, 1738). Laplace [172] later extended this in his book Analytical Theory of Probabilities. A further generalization, to the central limit theorem occurred later.]

1736–1755 Development of the use of polar coordinates for the representation of functions. Newton's *Method of Fluxions* was written about 1671, but not published until 1736. Jacob Bernoulli published a derivation of the idea in 1691. [267, p. 324] attributes the development of polar coordinates to Fontana, with no date.— Isaac Newton (1643–1727), England, and Gregorio Fontana (1735–1803) and Jacob Bernoulli (1654–1705) [267, p. 324]. 06/10/05:MF

[1671 is probably too early; 1736–1755 would probably be more appropriate. There are earlier references to Hipparchus (190-120BC) regarding the use of polar coordinates in establishing stellar positions, and Abu Arrayhan Muhammad ibn Ahmad al-Biruni (1021) regarding the use of three rectangular coordinates to establish a point in space.]

1741 Beginnings of the study of population statistics (demography)— Johann Peter Süssmilch (1707–1767), Germany [131, 274].
TXT: French translation of "Die göttliche ordnung", 1741
IMG: Sussmilch portrait (191 x 264; 51K)
IMG: Image of a page from Sussmilch's book (421 x 341; 29K)

1748 First use of the term "statistik." The word "statistics" was first used by Zimmerman in 1787. (For the earlier use of "statist", "statista" and other terms, see [152].)— Gottfried Achenwall (1719–1772), Germany [2, 331]. 06/16/05:YL
TXT: Achenwall biography
TXT: Achenwall Wikipedia entry
[From [315, p. 32]]

1750–1755 Beginnings of the estimation of m unknown quantities from n emipirical equations (where $n > m$), taking account of the possibility of errors in the observations (later supplanted by the method of least squares)— Johanes Tobias Mayer (1723–1762), Germany and Rogerius Josephus Boscovich (1711–1787) [69, 185, 189].
TXT: Mayer biography
TXT: Boscovich biography
PIC: Boscovich, on the Croatian dinar

1752 Introduction of a notation which gives a name and address to every possible point in 3D space, (x, y, z).— Leonhard Euler (1707–1783), Switzerland [67]. 06/24/05:YL
TXT: De'couverte d'un nouveau principe de mecanique
TXT: Euler biography:
[To find the true place of the body at each instant, one only needs to locate it at the same time in respect to the three fixed planes, each perpendicular to the others [67][p. 89].]

1752 Contour map— Phillippe Buache (1700–1733), France [35].
IMG: Buache contour map icon (116 x 90; 2K)
FIG: Buache's 1770 *Carte physique ou Geographie naturelle de la France* (483 x 386; 58K)

1753 "Carte chronologique": An annotated timeline of history (from Creation) on a 54-foot scroll, including names and descriptive events, grouped thematically, with symbols denoting character (martyr, tyrant, heretic, noble, upright, etc.) and profession (painter, theologian, musician, monk, etc.)— Jacques Barbeu-Dubourg (1709–1779), France [70, 311] .
FIG: Dubourg scroll, closed (690 x 595; 65K)
FIG: Dubourg scroll, opened ((466 x 487; 72K)

1758–1772 Diagrams developed to represent color systems. In 1758, Mayer developed a system of constructing and naming many of the possible colours. Lambert extended this with a 3D pyramid indicating "depth" (saturation).— Johanes Tobias Mayer (1723–1762), Moses Harris (1731–1785) and Johann Heinrich Lambert (1728–1777), Germany [169, 190, 124]. 06/14/05:YL
FIG: Johann Heinrich Lambert's color pyramid, from [169] (771 x 582; 510k)
FIG: Tobias Mayer's colour pyramid, from [190] (195 x 184; 596k)
FIG: Moses Harris' prismatic colour mixture system, from[124] (228 x 264; 596k)
[Lambert wanted to extend the coverage of the system to include the concept of depth. He believed that the colour pyramid would be useful to textile merchants to decide if they stocked all the colours, and to dyers and printers as a source of inspiration.]

1760 Curve-fitting and interpolation from empirical data points— Johann Heinrich Lambert (1728–1777), Germany [167].

PIC: Lambert portrait (192 x 248; 20K)
TXT: Lambert biography

1763 Graph of the beta density— Thomas Bayes (1702–1761), England [15].
PIC: Bayes portrait (304 x 326; 47K)
IMG: Bayes' Graph of the beta density (294 x 334; 4K)
TXT: Essay towards solving a problem in the doctrine of chances
TXT: Bayes biography
TXT: Bayes biography by D. R. Bellhouse

1765 Theory of measurement error as deviations from regular graphed line. (Lambert made the observation that "a diagram does incomparably better service here than a table."[286, p. 204]— Johann Heinrich Lambert (1728–1777), Germany [168, Vol. 1, pp. 424–488].

1765 Historical timeline (life spans of 2,000 famous people, 1200 B.C. to 1750 A.D.), quantitative comparison by means of bars— Joseph Priestley (1733–1804), England [242].
PIC: Priestley portrait (216 x 192; 3K)
IMG: Priestley's specimen chart of biography (739 x 353; 69K)
TXT: Priestley biography

1767–1796 Repeated systematic application of graphical analysis (line graphs applied to empirical measurements) — Johann Heinrich Lambert (1728–1777), Germany.
FIG: Graph of evaporation of water vs. time (595 x 454; 30K)
FIG: Graph of rate of evaporation of water vs. temperature (254 x 337; 8.9K)
[Lambert was one of the first to use graphs to analyze experimental data, and to use graphical calculation, e.g., computing the slopes of curves to estimate rates of change.]

1776 Development of descriptive geometry, that leads to engineering drawing— Gaspard Monge (1746–1818), Beaune, France [280, 281]. 06/16/05:YL
PIC: Monge portrait (395 x 512; 85K)
FIG: Monge's system of multiple projections
TXT: Historical development of graphics
TXT: Monge's biography
[Monge's work, Descriptive geometry, was the first consciously formulated exposition of the science of orthographic projection and descriptive geometry. Sylvestre Lacriux discovered the principles of projection independently about the same time as Monge. Jean Pierre Hackette added new material to Monge's descriptive geometry and published a book on this subject in 1822.]

1778 Geological map (distribution of soils, minerals)— Johann Friedrich von Charpentier (1738–1805), Germany [41].
TXT: von Charpentier bio blurb (german)

1779 Graphical analysis of periodic variation (in soil temperature), and the first semi-graphic display combining tabular and graphical formats— Johann Heinrich Lambert (1728–1777), Germany [170, 121].
IMG: Lambert graphical table of temperatures (120 x 98; 9K)
FIG: Lambert graphical table of temperatures (570 x 456; 66K)
IMG: Lambert graph of solar warming vs. lattitude icon (120 x 95; 8K)
FIG: Lambert graph of solar warming vs. lattitude (754 x 579; 92K)

1782 Statistical map of production in Europe, possibly the first economic and thematic map (shows geographic distribution of 56 commodities produced in Europe)— August Friedrich Wilhelm Crome, Germany [49].
PIC: Crome portrait (552 x 584; 31K)
TXT: Wikipedia bio (German)

1782 First topographical map— Marcellin du Carla-Boniface, France [40].
IMG: du Carla-Boniface topographical map icon (90 x 120; 13K)
FIG: du Carla-Boniface map (447 x 597; 149K)

1782 Use of geometric, proportional figures (squares) to compare demographic quantities by superposition, an early "tableau graphique"— Charles de Fourcroy, France [76].
IMG: de Fourcroy's proportional squares (346 x 408; 38K)
IMG: de Fourcroy's proportional squares (600 x 709; 94K)
TXT: Description of de Fourcroy, from Palsky

1785 Superimposed squares to compare areas (of European states)— August Friedrich Wilhelm Crome, Germany [50, 214].
FIG: Crome's 1820 Verhaeltness Karte

1786 Bar chart, line graphs of economic data— William Playfair (1759–1823), England [237].
IMG: Playfair bar/line chart: price of wheat and wages (167 x 84; 8K)
FIG: Playfair bar/line chart: price of wheat and wages (504 x 267; 109K)
IMG: Playfair line graph: chart of national debt (70 x 120; 8K)
FIG: Playfair line graph: chart of national debt (390 x 669; 129K)

1787 Visualization of vibration patterns (by spreading a uniform layer of sand on a disk, and observing displacement when vibration is applied)— Ernest Florens Friedrich Chladni (1756–1827), Germany [45]. 06/16/05:YL
PIC: Chladni portrait
FIG: Chladni vibration patterns, from [45] (800 x 496; 158k)
TXT: Chladni biography
TXT: High frequency kink interaction
[Chladni is known as the father of acoustics; he also invented the euphonium.]

1794 Patenting and sale of printed graph paper, printed with a rectangular coordinate grid, attests to the growing use of Cartesian coordinates— Dr. Buxton, England

1795 Multi-number graphical calculation (proto-nomogram: contours applied to multiplication table, later rectified by Lalanne [165])— Louis Ézéchiel Pouchet (1748–1809), France [240].
IMG: Pouchet chart icon (120 x 115; 10K)
FIG: Pouchet's chart of the multiplication table (589 x 567; 111K)

1796 Automatic recording of bivariate data (pressure vs. volume in steam engine) "Watt Indicator," (invention kept secret until 1822)— James Watt (1736–1819) and John Southern, England.
PIC: James Watt portrait (180 x 249; 8.7K)
IMG: Watt Indicator icon (76 x 120; 9K)
FIG: Watt Indicator photo (892 x 1419; 177K)
FIG: Watt Indicator detail (328 x 336; 16K)
TXT: Watt biography
TXT: Wikipedia: Watt biography

1798 Invention of lithographic technique for printing of maps and diagrams ("At the time the effect of lithography ... was as great as has been the introduction [of the Xerox machine]" [253, p. 57]) (published in several translations, 1818–19)— Aloys Senefelder (1771–1834), Germany [262].
PIC: Senefelder portrait (200 x 248; 35K)
TXT: History of lithography and portrait
TXT: Senefelder biography

1798 First maps of the incidence of disease (yellow fever), using dots and circles to show individual occurrences in waterfront areas of New York— Valentine Seaman (1770–1817), USA [316, p. 103].
TXT: Origins of mortality mapping

FIG: Seaman's map (840 x 748; 53K)
TXT: Mapping disease: Seaman's maps §4: 34 items

5 1800-1849: Beginnings of modern data graphics

With the fertilization provided by the previous innovations of design and technique, the first half of the 19th century witnessed explosive growth in statistical graphics and thematic mapping, at a rate which would not be equalled until modern times.

In statistical graphics, all of the modern forms of data display were invented: bar and pie charts, histograms, line graphs and time-series plots, contour plots, and so forth. In thematic cartography, mapping progressed from single maps to comprehensive atlases, depicting data on a wide variety of topics (economic, social, moral, medical, physical, etc.), and introduced a wide range of novel forms of symbolism.

1800 Use of coordinate paper in published research (graph of barometric variations)— Luke Howard (1772–1864), England [139].
PIC: Luke Howard portrait (170 x 207; 13K)
TXT: Luke Howard biography
TXT: Luke Howard: The man who named clouds

1800 Idea for continuous log of automatically recorded time series graphs (of temperature and barometric pressure), also recording the maximum and minimum— Alexander Keith, England [159].

1801 Invention of the pie chart, and circle graph, used to show part-whole relations— William Playfair (1759–1823), England [238, 236, 271].
IMG: Playfair's 1805 *Statistical Representation of the U.S.A.* (265 x 286; 10K)
FIG: Playfair's 1805 *Statistical Representation of the U.S.A.* (612 x 689; 76K)
IMG: Playfair's diagram of population and taxes (474 x 336; 21K)
TXT: Oxford DNB article by Ian Spence (pdf)

1801 The first large-scale geological map of England and Wales, setting the pattern for geological cartography, and founding *stratigraphic geology*. Recently called (hyperbolically) "the map that changed the world" [325]. (Smith's map was first drawn in 1801, but the final version was not published until 1815.)— William Smith (1769–1839), England[268, 205].
PIC: William Smith portrait (99 x 169; 4K)
FIG: Smith's 1815 map (244 x 250; 22K)
FIG: Smith's map, in zoomable sections
TXT: William "Strata" Smith on the Web
TXT: William Smith, from "The Rocky Road to Modern Paleontology and Biology"
TXT: William Smith (1769-1839), "The Father of English Geology"
TXT: William Smith, history
TXT: Transcript of pages from Smith's 1816–1824 *Strata Identified By Organized Fossils*
[The first known geological map was produced by Christopher Packe in 1743, and depicts South England. Smith's map is impressive for its size (about 6 x 9 feet— printed as 15 separate copperplate engravings for a 5x3 grid), scope (all of England, Wales, and part of Scotland), beauty (elaborately hand-colored) and detail. More importantly, he was the first to discover that the strata of England were in a definite order and the first to show that their fossil contents were in the same order.]

1809 Methods of determining an orbit from at least three observations; presentation of the least squares method— Johann Carl Friedrich Gauss (1777–1855), Germany [102]. 06/24/05:YL
TXT: Gauss biography

1811 Charts using subdivided bar graphs, and superimposed squares, showing the relative size of Mexican territories and populations in the colonies — Alexander von Humboldt (1769–1859), Germany [142].
PIC: Humboldt portrait, young (761 x 945; 26K)

PIC: Humboldt portrait (200 x 254; 28K)
FIG: von Humboldt charts (578 x 768; 48K)
FIG: Cross-section diagram of the Chimborazo, 1805–07 (2155 x 1494; 259K)
TXT: Humboldt biography (French)
TXT: von Humboldt biography

1817 First graph of isotherms, showing mean temperature around the world by latitude and longitude. Recognizing that temperature depends more on latitude and altitude, a subscripted graph shows the direct relation of temperature on these two variables— Alexander von Humboldt (1769–1859), Germany [143].
IMG: von Humboldt isotherm icon (120 x 87; 6K)
FIG: von Humboldt isotherm (492 x 357; 60K)
FIG: von Humboldt isotherms from Berghaus' 1849 Atlas (768 x 577; 79K)
FIG: von Humboldt isotherms, Annals de Chemie et de physique, 1817 (937 x 744; 616K)

1819 Choropleth map with shadings from black to white (distribution and intensity of illiteracy in France), the first (unclassed) choropleth map, and perhaps the first modern statistical map. (This map dates from 1826 [61, Plate 1, vol. 2] according to Robinson [253, p. 232], rather than 1819 according to Funkhouser [92])— Baron Pierre Charles Dupin (1784–1873), France [60].
PIC: Dupin portrait (393 x 512; 35K)
PIC: Dupin portrait, with his map (600 x 707; 135K)
IMG: Dupin choropleth map of France (220 x 229; 34K)
FIG: Dupin choropleth map of France (1223 x 1270; 426K)
TXT: Dupin biography
[This entry is now deprecated.]

1820s An increasing number of scientific publications begin to contain graphs and diagrams which describe, but do not analyze, natural phenomena (magnetic variation, weather, tides, etc.)— Michael Faraday (1791–1867), England.
IMG: Faraday diagram of a magnet with lines of force (294 x 373; 13K)
TXT: Michael Faraday's Lines of Force, by Dan Denis
TXT: Faraday biography with portraits

1821 Ogive or cumulative frequency curve, inhabitants of Paris by age groupings (shows the number of inhabitants of Paris per 10,000 in 1817 who were of a given age or over. The name "ogive" is due to Galton.)— Jean Baptiste Joseph Fourier (1768–1830), France [77].
PIC: Fourier portrait (268 x 326; 15K)
IMG: Fourier ogive (750 x 456; 12K)
TXT: Fourier biography

1822 Mechanical device for calculating mathematical tables (the Difference Engine) [The beginnings of computing as we know it today. The Difference Engine was steam-powered, and the size of a locomotive.] — Charles Babbage (1791–1871), England.
PIC: Babbage portrait (280 x 340; 4K)
IMG: Babbage Difference Engine (440 x 437; 31K)
TXT: Babbage biography

1825 Gompertz curve, derived to describe expected mortality statistics for a population of organisms whose probability of death increases as a function of time— Benjamin Gompertz (1779–1865), England [109]. 06/16/05:YL
PIC: Gompertz portrait (200 x 241; 38K)
TXT: Gompertz biography
TXT: The Gompertz model
[Gompertz showed that the mortality rate increases in a geometric progression. Hence, when death rates are plotted on a logarithmic scale, a straight line known as the Gompertz function is obtained. The slope of the Gompertz function line indicates

the rate of actuarial ageing. The differences in longevity between species are the result primarily of differences in the rate of ageing and are therefore expressed in differences in slope of the Gompertz function.]

1826 Choropleth map with shadings from black to white (distribution and intensity of illiteracy in France), the first (unclassed) choropleth map, and perhaps the first modern statistical map— Baron Pierre Charles Dupin (1784–1873), France [60].
PIC: Dupin portrait (393 x 512; 35K)
FIG: Dupin choropleth map of literacy in France (909 x 953; 321K)
TXT: Dupin biography

1827 First successful photograph produced (an 8-hour exposure). [A type of asphalt (bitumen of Judea) was coated on metal plates. After exposure it was washed in solvents, the light areas were shown by the bitumen, dark areas by bare metal. Exposed to iodine, the plate darkened in the shadowed areas.]— Joseph Nicephore Niépce, France.
PIC: Niepce portrait (75 x 100; 2K)
IMG: Niepce photo, *Point de vue du Gras* (206 x 148; 2K)
TXT: Catalog of Niepce heliographies
TXT: University of Texas exhibition: The first photo

1828 Mortality curves drawn from empirical data (for Belgium and France)— Adolphe Quetelet (1796–1874), Belgium [243].
PIC: Quetelet portrait (268 x 326; 25K)
TXT: Quetelet biography
TXT: Quetelet biography
TXT: Quetelet web site

1829 Polar-area charts (predating those by Florence Nightingale [213]), showing frequency of events for cyclic phenomena— André-Michel Guerry (1802–1866), France [112]. 9/08/06:MF
FIG: Guerry barcharts and polar diagrams (3526 x 2402; 3114K)
FIG: Guerry's polar diagrams (814 x 626; 148K)
[The plate shows six polar diagrams for daily phenomena: direction of the wind in 8 sectors, births and deaths by hour of the day.]

1829 The first comparative choropleth thematic maps, showing crimes against persons and crimes against property in relation to level of instruction by departments in France— André-Michel Guerry (1802–1866) and Adriano Balbi (1782–1884), France [12, 113]. 1/08/20:MF
FIG: Balbi-Guerry maps (2080 x 2000; 654K)

1830–1835 Graphical analysis of natural phenomena begins to appear on a regular basis in scientific publications, particularly in England. For example, in 1832, Faraday proposes pictorial representation of electric and magnetic lines of force.— Michael Faraday (1791–1867), England
PIC: Faraday portrait (203 x 176; 14K)
FIG: Faraday's iron filing diagrammes, the earliest ever made (300 x 390; 46K)
TXT: Faraday biography
TXT: Faraday bio, with images

1830 First simple dot map of population by department, 1 dot = 10,000 people— Armand Joseph Frère de Montizon (1788–?), France [204].
IMG: see [253, Fig. 49]
FIG: Dot map of population of France, 1830 (360 x 238; 53K)

1832 Fitting a smoothed curve to a scatterplot, advocacy of graph paper and graphical methods as standard tools of science. ["The process by which I propose to accomplish this is one essentially graphical; by which term I understand not a mere substitution of geometrical construction and measurement for numerical calculation, but one which has for its object to perform that which no system of calculation can possibly do, by bringing in the aid of the eye and hand to guide the judgment, in a case where

judgment only, and not calculation, can be of any avail." (p. 178)] — John Frederick W. Herschel (1792–1871), England [134].[122]
PIC: Herschel portrait (160 x 238; 11K)
FIG: Herschel's graph of position vs time for γ; Virginis (745 x 686; 263K)
FIG: Derived double-orbit for γ Virginis (648 x 733; 205K) e
TXT: Herschel images
TXT: Herschel biography
[See [34] for some history of "squared paper."]

1833 The first comprehensive analysis of data on "moral statistics" (crimes, suicide, literacy, etc.) shown on thematic unclassed choropleth maps; bar charts (of crime, by age groupings and months)— André Michel Guerry (1802–1866), France [114].
TXT: Reference to English translation
FIG: Guerry's map of crimes against persons in France (1500 x 1595; 278K)
FIG: Guerry's map of crimes against property in France (1500 x 1603; 224K)
FIG: Guerry's map of "instruction" in France (1500 x 1556; 353K)
FIG: Guerry's map of suicides (1500 x 1592; 273K)

1833 Graphical rank lists, with lines showing shifts in rank order between categories (rank of types of crime from one age group to the next)— André Michel Guerry (1802–1866), France [114].

1833 First classed depiction of population density on a world map (using three broad classes in a dasymetric map)— George Julius Poulett Scrope (1797–1876), England [261].
TXT: Scrope biography
TXT: Wikipedia: Scrope biography

1833 Invention of the stereoscope, revealing the dependence of visual depth perception upon binocular vision, and allowing production of stereoscopic images— Charles Wheatstone (1802–1875), England. 06/25/05:YL
PIC: Charles Wheatstone portrait (225 x 260; 15K)
TXT: Stereoscopic photography
TXT: Wheatstone biography
TXT: Wheatstone uses paper tape to store data
[In 1857, Wheatstone also introduced the first application of paper tapes as a medium for the preparation, storage, and transmission of data.]

1836 First broad and general application of principles of graphic representation to national industrial and population data— Adolphe d' Angeville (1796–1856), France [6, 56]
FIG: Population of France, Carte 1 (946 x 1213; 226K)
FIG: Taille, Carte 5 (413 x 518; 85K)
TXT: Angeville biography

1836 Extensive data tabulation, time series, and mapping of prostitutes in Paris— Alexandre Jean Baptiste Parent-Duchatelet (1790–1836), France [225].
FIG: Duchatelet's map showing the origins of prostitutes in Paris (729 x 557; 178K)
FIG: Duchatelet's map showing the distribution of prostitutes in Paris (650 x 509; 153K)
TXT: English translation of *On prostitution in the city of Paris*

1837 First published flow maps, showing transportation by means of shaded lines, widths proportional to amount (passengers)— Henry Drury Harness (1804–1883), Ireland [123, 251].
IMG: see [253, Fig. 71]
PIC: Harness portrait (188 x 305; 35K)
FIG: Harness flow map of transportation of passengers in Ireland (1888 x 2923; 170K)

1838 Physical atlas of the distribution of plants, animals, climate, etc., one of the most extensive and detailed thematic atlases; most of the maps contained tables, graphs, pictorial profiles of distributions over altitude, and other visual accompanyments— Heinrich Berghaus (1797–1884), Germany [24].

IMG: Berghaus map icon (149 x 120; 12K)
TXT: Berghaus map, high-res
FIG: World map showing the tradewinds (768 x 577; 88K)
FIG: Charts showing temperature throughout the world (768 x 577; 80K)
FIG: Full colour "ideal" geologic cross-section (768 x 351; 55K)
TXT: Berghaus biography

1839 Development of the logistic curve, $y = k/(1 + Ce^{rt})$, to describe the growth of human populations— Pierre-François Verhulst (1804–1849), Belgium [245]. 06/16/05:YL
PIC: Verhulst portrait
TXT: Verhulst bio
TXT: Pierre-Francois Verhulst et la loi logistique de la population
[Verhulst showed that forces which tend to prevent a population growth grow in proportion to the ratio of the excess population to the total population. (reference from Funkhouser:1937, p.363 fn(46)]

1839 Invention of the first practical photographic process, using coated plates of metal and glass— Louis Jacques Mandé Daguerre (1787–1851), France. 06/25/05:YL
FIG: Daguerre, Parisian Boulevard (560 x 394; 48K)
TXT: The Daguerrian Society (with comprehensive links and images)
[The first daguerrotype of the disk of the Sun was obtained by two physicists in Paris in 1845 see [111, p. 54], and subsequent improvements in emulsion speeds had enormous repercussions for astronomy.]

1843 Contour map of a 3D table, temperature x hour x month (published in 1845)— Léon Lalanne (1811–1892), France [164].
IMG: Lalanne contour diagram (98 x 120; 10K)
FIG: Lalanne contour diagram (322 x 394; 79K)
TXT: Lalanne biography

1843 Use of polar coordinates in a graph(frequency of wind directions)— Léon Lalanne (1811–1892), France [164].
IMG: Lalanne windrose diagram (225 x 203; 24K)

1843 Ethnographic maps showing distribution of ethnic groups throughout the world— James Cowles Pritchard (1786–1848) and Alexander Keith Johnston (1804–1871), UK [241], [155]
PIC: James Cowles Prichard portrait (250 x 332; 16K)
FIG: Ethnographical map of Africa (440 x 512; 26K)
FIG: Ethnographical map of Europe (512 x 431; 33K)
FIG: Ethnographical map of Europe (384 x 267; 21K)
TXT: Pritchard biography
TXT: Johnston bio and portrait (pdf)
TXT: Johnston biography

1844 "Tableau-graphique" showing transportation of commercial traffic by variable-width (distance), divided bars (height $\sim$ amount), area $\sim$ cost of transport [An early form of the mosaic plot.]— Charles Joseph Minard (1781–1870), France [196]; see also: [56, 252].
IMG: Minard Tableau graphique (354 x 276; 20K)
TXT: Minard biography

1846 Logarithmic grid (the first log-log plot, as a nomogram for showing products from the factors)— Léon Lalanne (1811–1892), France [165].
IMG: Lalanne nomogram icon (120 x 118; 8K)
IMG: Lalanne nomogram image (221 x 206; 16K)
FIG: Lalanne's Universal Calculator (2317 x 2868; 529K)
TXT: l'Ecole des mines: Lalanne "compteur universel" and other calculating diagrams
[See also: Lalanne's ambitious *Universal Calculator* [163], combining logarithmic and trigonometric calculations (described by Tournès [288]).]

1846 Results of sampling from urns shown as symmetrical histograms, with limiting "curve of possibility" (later called the normal curve)— Adolphe Quetelet (1796–1874), Belgium [246].
FIG: Quetelet's graph of a binomial distribution, 999 trials (594 x 374; 34K)

§5: 36 items

6 1850–1899: Golden Age of data graphics

By the mid-1800s, all the conditions for the rapid growth of visualization had been established. Official state statistical offices were established thoughout Europe, in recognition of the growing importance of numerical information for social planning, industrialization, commerce, and transportation. Statistical theory, initiated by Gauss and Laplace, and extended to the social realm by Guerry [114] and Quetelet [244], provided the means to make sense of large bodies of data.

What started as the "Age of Enthusiasm" [223] in graphics and thematic cartography, may also be called the "Golden Age", with unparalleled beauty and many innovations.

1851 Map incorporating statistical diagrams: circles proportional to coal production (published in 1861)— Charles Joseph Minard (1781–1870), France [197].
FIG: Pie-map showing origin of meats consumed in Paris (341 x 349; 9.6K)

1852 Statistical graphics used in a lawsuit. (Reported by Ernst Engel at the 7th meetings of the International Statistical Congress, 1869, The Hague [92, p. 316])— Germany.

1853 First international statistics conference (organized by Quetelet)— International Statistical Institute Belgium [248].
TXT: ISI History
TXT: ISI historical biography
TXT: Quetelet biography

1855 Use of a dot map to display epidemiological data, leads to discovery of the source of a cholera epidemic— John Snow (1813–1858), England [270, 106].
PIC: Snow portrait (129 x 156; 11K)
IMG: Snow cholera map (160 x 143; 33K)
FIG: same, larger (700 x 671; 105K)
FIG: same, larger (764x852; 400K)
FIG: Cholera map (698 x 652; 510k)
TXT: John Snow UCLA web site, with zoomable images
TXT: John Snow MSU web site, online companion to a Snow biography

1857 Discussion of standardization and classification of graphical methods at the Third International Statistical Congress— Vienna, Austria [149].
TXT: The debate on the standardization of statistical maps and diagrams (1857-1901), Cybergeo, No. 85

1857 Exhibition display of graphs and cartograms. Third International Statistical Congress— Vienna, Austria [149].

1857 Polar area charts, known as "coxcombs" (used in a campaign to improve sanitary conditions of army)— Florence Nightingale (1820–1910), England [213].
PIC: Nightingale portrait (106 x 134; 6K)
IMG: re-creation of a coxcomb (148 x 154; 1K)
IMG: Nightingale coxcomb (398 x 263; 10K)
TXT: Florence Nightingale's Statistical Diagrams
TXT: JSE article: A Dialogue with Florence Nightingale
TXT: Florence Nightingale by I. Bernard Cohen

1861 The modern weather map, a chart showing area of similar air pressure and barometric changes by means of glyphs displayed on a map. These led to the discovery of the anti-cyclonic movement of wind around low-pressure areas— Francis Galton (1822–1911), UK [97, 98].
PIC: Portrait of Galton by Furse (198 x 200; 22K)
TXT: A comprehensive Galton web site, with many publications and images
TXT: Galton's 1861 "Meteorological charts", *Philosophical Magazine*
TXT: Galton's 1870 "Barometric predictions of weather", *Nature*
FIG: Galton's 1881 weather chart (470 x 593; 66K)

1861 Invention of the trichromatic process for making color photographs, by taking three monochrome images through red, green and blue filters— James Clerk Maxwell (1831–1879), England.
PIC: Portrait of Maxwell (200 x 196; 22K)
TXT: Maxwell biography
TXT: Maxwell biography

1863 Semilogarithmic grid (showing percentage changes in commodities)— William Stanley Jevons (1835–1882), England [150, 151].
PIC: Jevons portrait (268 x 326; 13K)
FIG: Graphical method, from [151] (401 x 284; 39K)
FIG: Quantitative induction, from [151] (400 x 673; 95K)
TXT: Jevons Home page, by Bert Mosselmans
TXT: Jevons biography
TXT: Jevons in Sidney and the logic piano
TXT: Comprehensive bibliography

1868 Statistical diagrams used in a school textbook— Émile Levasseur (1828–1911), France [173].
PIC: Levasseur portrait (404 x 543; 95K)
TXT: Link to bio blurb and texts

1869 Three-dimensional population surface or "stereogram," with axonometric projection to show curves of various "slices" (sometimes known as a "Zeuner diagram)"— Gustav Zeuner (1828–1907), Germany [330].
PIC: Zeuner portrait (180 x 261; 9.8K)
TXT: Wiklipedia: Zeuner biography

1869 Minard's flow map graphic of Napoleon's March on Moscow (called "the best graphic ever produced" by Tufte [291])— Charles Joseph Minard (1781–1870), France [198].
TXT: Web page for "Re-visions of Charles Joseph Minard"
IMG: Minard's March on Moscow graphic (569 x 273; 30K)

1869 The periodic table used to classify chemical elements according to their properties, and allowing the prediction of new elements that would be discovered later.— Dmitri Mendeleev (1834–1907), Russia.
06/16/05:YL
PIC: Mendeleev portrait (152 x 232; 13k)
PIC: Mendeleev portrait (152 x 232; 13k)
TXT: Mendeleev periodic table, and other pictorial representations
TXT: Mendeleev biography
[Mendeleev arranged all of the 63 elements, then known by their atomic weights, into groups possessing similar properties. Where a gap existed in the table, he predicted a new element would one day be found and deduced its properties. Three of those elements were found during his lifetime]

c. 1870 Election map of Paris, showing the breakdown of votes by parties—Leon Montigny, France [203].
01/19/07:MF
FIG: Montigny election map

1872 Congressional appropriation for graphical treatment of statistics— USA

1872 Use of statistical graphics by USA Government in census reports (cartograms of data from Ninth Census)— U.S. Bureau of the Census, USA [300].

1872 Classification of statistical graphical treatments by form, with consideration of appropriate uses of color, graphical elements, limitations of perception. At the 8th ISI meetings, St. Petersburg.— Hermann Schwabe (1830–1875), Germany [260, 44].

1872 Recording of motion (of a running horse) by means of a set of glass-plate cameras, triggered by strings— Eadweard Muybridge (1830–1904), USA.
IMG: Galloping Horse, 1878 (370 x 227; 20K)
FIG: Galloping Horse, 1878 (635 x 391; 44K)
TXT: UCR Museum of Photography, animated Muybridge Gallery
TXT: Eadweard Muybridge's photography of motion
TXT: Muybridge photos, with timeline and bio
TXT: Muybridge's zoopraxiscope
TXT: Complete history of cinematography

1873 Graphical methods applied to explain fundamental relations in thermodynamics; this includes diagrams of entropy vs. temperature (where work or heat is proportional to area), and the first use of trilinear coordinates (graphs of (x,y,z) where x+y+z=constant)— Josiah Willard Gibbs (1839–1903), USA [38, 104, 105].
PIC: Gibbs portrait (140 x 177; 6.3K)
TXT: Gibbs biography
FIG: Plot on trilinear graph paper by R. A. Fisher, ca. 1955 (540 x 425; 70K)
TXT: Gibbs, *Elementary principles in statistical mechanics*
TXT: Gibb's models

1873 First-known use of a semi-graphic table to display a data table by shading levels— Toussaint Loua (1824–1907), France [178]. 9/08/06:MF
TXT: Google Books: Atlas Statistique de la Population de Paris
FIG: Loua scalogram of 40 characteristics of 20 Paris districts (2422 x 1932; 1386K)
FIG: Loua scalogram, color version (1212 x 960; 318K)
FIG: Shaded map of Paris showing number of inhabitants per house (935 x 615; 77K)
[Loua used this as a graphic summary of 40 maps of Paris, each showing some feature of the population by arrondisement. This device was later used by Bertin [26], who also considered ways of reordering the rows and columns (the "reorderable matrix") to make the pattern of high/low values more apparent.]

1874 Age pyramid (bilateral histogram), bilateral frequency polygon, and the use of subdivided squares to show the division of population by two variables jointly (an early mosaic display) in the first true U.S. national statistical atlas— Francis Amasa Walker(Superintendent of U.S. Census) (1840–1897), USA [314].
TXT: History of US census atlases
TXT: Text of the Statistical Atlas of 1870
TXT: detailed Walker biography
PIC: Portrait (186 x 238; 7K)
PIC: Walker portrait (202 x 252; 52K)
IMG: Population pyramid (240 x 172; 10K)
IMG: Cover of the 1870 Statistical Atlas (113 x 150; 4K)
TXT: Detailed Walker biography

1874 Population contour map (population density shown by contours), the first statistical use of a contour map— Louis-Léger Vauthier (1815–1881), France [305].
PIC: Vauthier portrait (200 x 352; 13K)
IMG: Vauthier contour map (160 x 240; 4K)
FIG: Vauthier contour map (1405 x 2072; 767K)

FIG: Estuaire de la Seine en 1834 (650 x 315; 36K)
TXT: Wikipedia: Louis-Léger Vauthier

1874 Two-variable color map (showing the joint distribution of horses (red, vertical bars) and cattle (green, horizontal bars) in Bavaria, widths of bars $\sim$ animals/km^2)— Georg von Mayr (1841–1925), Germany [191, Fig. XIX]
IMG: see [312, p. 20].
PIC: von Mayr Portrait(223 x 248; 57k)

c. 1874 Galton's first semi-graphic scatterplot and correlation diagram, of head size and height, from his notebook on *Special Peculiarities*— Francis Galton (1822–1911), England.
FIG: Galton correlation diagram, from [136] (631 x 898; 569K)
TXT: Comprehensive Galton site: biography, papers, images

1875 Lexis diagram, showing relations among age, calendar time, and life spans of individuals simultaneously (but the paternity of this diagram is in dispute [304])— Wilhelm Lexis (1837–1914), Germany [175].
PIC: Lexis portrait (378 x 538; 55K)
IMG: Lexis diagram (468 x 468; 6K)
TXT: Illustrated description of the Lexis diagram
TXT: The Lexis diagram, a misnomer
TXT: Visualisation using Lexis pencils

1875 Galton's first illustration of the idea of correlation, using sizes of the seeds of mother and daughter plants— Francis Galton (1822–1911), England [227]. 06/21/05:YL
PIC: Galton portrait (268 x 326; 7k)
FIG: Galton's first correlation diagram
TXT: Comprehensive Galton website
[In 1875, Galton was interested in the inheritance of size in sweet-pea seeds, but appears to have tried with smaller seeds first, apparently that of cress. The isograms are represented by ink lines on the sheet of glass covering the little compartments which contain the ranked seeds of the daughter-plants.]

1877 First use of proportional, divided square in the modern (mosaic) form for data representation— Georg von Mayr (1841–1925), Germany [192, S. 80].
PIC: von Mayr portrait (351 x 448; 14K)
IMG: von Mayr's Area diagram (194 x 190; 3K)

1877 First use of polar diagrams and star plots for data representation— Georg von Mayr (1841–1925), Germany [192, S. 78][221].
IMG: von Mayr's polar diagram (181 x 181; 2K)

1877 Extensive statistical study of 24,500 children to improve school practice; early ideas of correlation and regression by quoting the "measure of stoutness", the ratio of annual increase in pounds weight to annual increase in inches height. Includes six charts, showing curvilinear regresions.— Henry Pickering Bowditch (1840–1911), Boston MA, USA [31],[315, p. 98–102] 06/21/05:YL
PIC: Bowditch portrait (325 x 435; 8.5k)
FIG: Early regression curves of height on weight for Boston schoolboys (507 x 514; 43K)
FIG: Early regression of heigh on weight for English schoolboys (500 x 504; 43K)
[Separate series of graphs showing the regression of height (or weight) on age and weight on height]

1878 First attempt to survey, describe, and illustrate available graphic methods for experimental data— Etienne-Jules Marey (1830–1904), France [183].
PIC: Marey portrait (79 x 131; 1K)
PIC: Marey portrait (210 x 302; 10K)
TXT: Google Books: La Méthode Graphique

TXT: Etienne Jules Marey - Movement in Light
TXT: Pioneers in Aeromodeling: E. J. Marey

1878 The term "graph" introduced, referring to diagrams showing analogies between the chemical bonds in molecules and graphical representations of mathematical invariants (also coined the term "matrix") — James Joseph Sylvester (1814–1897), UK [278].
IMG: Sylvester's diagram icon (85 x 120; 7K)
PIC: Sylvester portrait (339 x 335; 18K)
FIG: Sylvester's diagram image (421 x 594; 88K)
TXT: Sylvester biography
TXT: Wikipedia: Sylvester

1879 Stereogram (three-dimensional population pyramid) modeled on actual data (Swedish census, 1750–1875)— Luigi Perozzo, Italy [229].
IMG: Perozzo stereogram icon (160 x 195; 5K)
IMG: Perozzo stereogram image (613 x 727; 102K)
IMG: Perozzo ilustration of systems for 3D representation (392 x 625; 34K)

1879 Published instructions on how to use graph paper— William Stanley Jevons (1835–1882), England [151].
TXT: Biography

1879–1899 *Album de Statistique Graphique*, an annual series over 20 years, using all known graphic forms (map-based pies and stars, mosaic, line graphs, bar charts, and, of course, numerous flow maps) to depict data relevant to planning (railways, canals, ports, tramways, etc.) [This series, under the direction of Émile Cheysson, is regarded as the epitome of the "Golden Age of Statistical Graphics"]— Émile Cheysson (1836–1910) and Ministere de Traveaux Publics, France [199, 223].
PIC: Cheysson portrait (295 x 378; 12K)
TXT: Cheysson bio sketch

1880 Representation of logical propositions and relations diagrammatically. [Actually, Liebnitz and, to some degree, Euler had used such diagrams previously.]— John Venn (1834–1923), England [306, 307]
PIC: Venn portrait (268 x 326; 9K)
IMG: Venn diagram (174 x 139; 0.9K)
TXT: A survey of Venn diagrams
TXT: Venn biography
TXT: Create your own Venn diagram
TXT: Wikipedia page on Venn and similar diagrams

1882 Invention of precursor of motion-picture camera, recording a series of photographs to study fight of birds, running and walking— Etienne-Jules Marey (1830–1904), France [182].
TXT: Expo-Marey: Movement in Light
IMG: Somersault icon (161 x 44; 2K)
IMG: Somersault image sequence (612 x 46; 8K)

1882 Statistical reasoning employed to create a new system of bodily measurement, specifically for identifying criminals— Alphonse Bertillon (1853–1914), France.
PIC: Bertillon portrait (250 x 400; 24K)
TXT: Bertillon web site
PIC: Bertillon portrait (55 x 64; 3K)
IMG: Measuring the head with calipers (100 x 100; 5K)
FIG: Bertillon images (russian)
TXT: Science of criminal identification

1883 Patent issued on logarithmic paper (reported to the British Association for the Advancement of Science, in 1898). Also called "semi-log," "arith-log" paper and "ratio charts"— England.[92, p. 361] [308]
TXT: Graphing on log paper

1883–1885 Combination of many variables into multi-function nomograms, using 3D, juxtaposition of maps, parallel coordinate and hexagonal grids (L'Abaque Triomphe)— Charles Lallemand (1857–1938), France [166]. 06/21/05:YL
FIG: Lallemand's "L'Abaque Triomphe" (516 x 424; 250K)
TXT: Graphic representations in three dimensions
TXT: Lallemand biography and portrait
TXT: Detailed biography (French)
[Lallemand was director of the "Service de nivellement de la France," designed to establish the heights of locations, water levels and tides throughout France, taking geodetic measurement to the third dimension. He also served as Inspector General of Mines.]

1884 Pictogram, used to represent data by icons proportional to a number— Michael George Mulhall (1836–1900), England [207].
IMG: pictogram icon (220 x 135; 17K)
FIG: Mulhall pictogram image, railways (726 x 456; 58K)
FIG: Mulhall pictogram image, steam power (730 x 457; 52K)
FIG: Man, animal and machine pictogram (281 x 367; 66K)
TXT: Google booksd: Mulhall's Dictionary of Statistics

1884 Invention of the punched card for use in a machine to tabulate the USA Census (in 1890). Hollerith's company eventually became IBM— Herman Hollerith (1860–1929), USA.
PIC: Hollerith portrait (133 x 180; 4.7K)
IMG: Hollerith punched card machine: reader-sorter (374 x 300; 16K)
IMG: Hollerith punched card (270 x 117; 17K)
FIG: Hollerith tabulator machine for census bureau (474 x 402; 208K)
TXT: Comprehensive Hollerith biography
TXT: Wikipedia: Hollerith biography

1884 The first alignment diagrams, using sets of parallel axes, rather than axes at right angles; development of the essential ideas used in parallel coordinates plots. [Using the principle of duality from projective geometry, d'Ocagne [215] showed that a point on a graph with Cartesian coordinates transformed into a line on an alignment chart, that a line transformed into a point, and, finally, that a family of lines or a surface transformed into a single line [121].]— Maurice d' Ocagne (1862–1938), France [215, 216].
IMG: Traction of a locomotive in three coordinate systems (120 x 57; 5K)
FIG: Traction of a locomotive in three coordinate systems (703 x 335; 77K)
IMG: Diagram of parallel coordinates from [215, p. 6] (373 x 386; 13K)
TXT: Text of d'Ocagne's [215] book on parallel coordinates
TXT: D'Ocagne biography (French)

1884 A literary description of life in a two-dimensional world for people living in a 3D world. By analogy and extension, it suggests the possibile views of fourth and higher dimensions— Edwin A. Abbott (1838–1926), England [1].
PIC: Abbott portrait (84 x 110; 2K)
TXT: etext of Flatland
TXT: etext, with illustrations
TXT: Brief biography

1885 Normal correlation surface and regression, the idea that in a bivariate normal distribution, contours of equal frequency formed concentric ellipses, with the regression line connecting points of vertical tangents— Francis Galton (1822–1911), England [99].

PIC: Galton portrait (268 x 326; 7K)
IMG: Galton diagram of bivariate normal distribution (745 x 631; 56K)
TXT: Galton biography
TXT: Comprehensive Galton web site
TXT: Karl Pearson's biography of Galton, online

1885 Comprehensive review of all available statistical graphics presented to the Statistical Society of London, classified as figures, maps, and solids (3D), perhaps the first mature attempt at a systematic classification of graphical forms— Émile Levasseur (1828–1911), France [174]. 02/01/05
IMG: Area diagram comparing populations of countries to their colonies (402 x 662; 187K)
IMG: Circle diagram of Infant mortality by month in Brussels(368 x 407; 73K)
IMG: Population density in France in 1866 (266 x 287; 83K)
IMG: Four type of graphs illustrated by Levasseur (662 x 438; 123K)
TXT: Link to Levasseur's e-texts
TXT: Hi-res scan of Levasseur's La Statistique Graphique (15.6M)

1885 Graphic representation of a train schedule showing rate of travel along the route from Paris to Lyon. (The method is attributed to the French engineer Ibry)— Etienne-Jules Marey (1830–1904), France [184],[291, p. 31]. 06/21/05:YL
PIC: Marey portrait (210 x 302; 10K)
IMG: Train schedule graphic

1888 First anamorphic maps, using a deformation of spatial size to show a quantitative variable (e.g., the decrease in time to travel from Paris to various places in France over 200 years)— Émile Cheysson (1836–1910), France [223, Fig. 63-64]
PIC: Cheysson portrait (295 x 378; 12K)
TXT: Cheysson biography
TXT: Link to Cheysson's e-texts

1889 Street maps of London, showing poverty and wealth by color coding, transforming existing methods of social survey and poverty mapping towards the end of the nineteenth century— Charles Booth (1840–1916), London, UK [29, 30]. 01/25/06:MF
PIC: Booth portrait (235 x 221; 10K)
FIG: Portion of Booth's poverty map (500 x 309; 54K)
FIG: Booth's poverty map, larger (974 x 824; 429K)
TXT: Charles Booth: Mapping London's Poverty, 1885-1903
TXT: Charles Booth and poverty mapping in late nineteenth century London
TXT: Charles Booth Online Archive at LSE
TXT: Booth's 1889 London Poverty Map (digitized, zoomable)
[Charles Booth's work is a classic in several fields of social science, including sociology, urban studies, public administration, policy research, social surveys, demography and geography]

1892 Social data, diagrams, including regional survey, incorporated in museum— Patrick Geddes (1854–1932), Outlook Tower, Edinburgh, Scotland.
PIC: Geddes portrait (273 x 283; 71K)
TXT: Patrick Geddes Exhibition
TXT: Geddes biography
TXT: Outlook Tower as an anamorphosis of the world

1895 First movie, with the cinématographe, using the principle of intermittent movement of film (16 fps), but producing smooth projection (first public film screening on December 28, 1895 at the Cafe Grand)— Auguste Lumière and Louis Lumière, France.
PIC: Lumiere brothers portrait (109 x 127; 7K)
TXT: Lumiere Biography
FIG: Images: Auguste et Louis Lumière, le cinématographe Lumière

1896 Use of area rectangles on a map to display two variables and their product (population of arrondisements in Paris, percent foreigners; area = absolute number of foreigners)— Jacques Bertillon (1851–1922), France [25].
IMG: Bertillon map (479 x 352; 38K) ([223, Fig. 85])

1899 Idea for "log-square" paper, ruled so that normal probability curve appears as a straight line— Francis Galton (1822–1911), England [100]. §6: 53 items

7 1900–1949: Modern Dark Ages

If the early 1800s were the "golden age" of statistical graphics and thematic cartography, the early 1900s could be called the "modern dark ages" of visualization [85].

There were few graphical innovations, and, by the mid-1930s, the enthusiasm for visualization which characterized the late 1800s had been supplanted by the rise of quantification and formal, often statistical, models in the social sciences. Numbers, parameter estimates, and, especially, standard errors were precise. Pictures were— well, just pictures: pretty or evocative, perhaps, but incapable of stating a "fact" to three or more decimals. Or so it seemed to statisticians.

But it is equally fair to view this as a time of necessary dormancy, application, and popularization, rather than one of innovation. In this period statistical graphics became "main stream." Graphical methods entered textbooks [228, 107, 128, 222, 157], the curriculum [48, 317], and standard use in government [9], commerce [101, 263] and science.

In this period graphical methods were used, perhaps for the first time, to provide new insights, discoveries, and theories in astronomy, physics, biology, and other sciences. As well, experimental comparisons of the efficacy of various graphics forms were begun, e.g., [63], and a number of practical aids to graphing were developed. In the latter part of this period, new ideas and methods for multi-dimensional data in statistics and psychology would provide the impetus to look beyond the 2D plane.

Graphic innovation was also awaiting new ideas and technology: the development of the machinery of modern statistical methodology, and the advent of the computational power which would support the next wave of developments in data visualization.

1901 Attempt to formulate standards for graphical procedures at the International Statistical Congress; proposes that x,y scales be constructed so that the average behaviour corresponds to a curve of 45 degrees. Report not adopted, see [92, p. 321]; see also [141].— Jacques Bertillon (1851–1922) and Émile Cheysson (1836–1910) and M. Fontaine, Budapest, Hungary [141]. 06/16/05:YL
PIC: Cheysson portrait
TXT: Cheysson biography
TXT: Link to Cheysson's e-texts
[Some of the other recommendations also included cautious use of symbols and hieroglyphs, and sparing use of comparison by areas.]

1904 Use of the "butterfly diagram" to study the variation of sunspots over time, leading to the discovery that they were markedly reduced in frequency from 1645–1715 (the "Maunder minimum"). [Earlier work, started in 1843 by H. Schwabe, showed that sunspots exhibit an approximately twenty-two year cycle, with each eleven-year cycle of sunspots followed by a reversal of the direction of the sun's magnetic field]— Edward Walter Maunder (1851–1928), England
IMG: Maunder's butterfly diagram (250 x 150; 22K)
TXT: The butterfly diagram
TXT: The sunspot cycle

1905 Lorenz curve (cumulative distribution by rank order, to facilitate study of concentrations, income distribution)— Max Otto Lorenz (1880–1962), USA. [177].

TXT: Description of Lorenz Curve
IMG: Lorenz Curve (263 x 261; 6K)

c. 1910 Statistical diagrams begin to appear regularly in USA textbooks (graphs of temperature, population in texts of arithmetic, algebra)— USA

1910 Textbook in English devoted exclusively to statistical graphics— John Bailey Peddle, USA [228].

1911 First International Hygiene-Exhibition in Dresden, with 259 graphical-statistical figures of 35 national and international exhibitors and more than 5 million visitors. [Roesle also wrote publications which dealt with the structure of graphical-statistical displays [256].]— Emil Eugen Roesle (organizer) (1875–1962), Germany [255, 220].
PIC: Rosele portrait (283 x 417; 17K)
FIG: Trellis-like time series graphs of infant mortality (600 x 594; 116K)
FIG: Trellis-like time series graphs of tuberculosis (374 x 387; 33K)
FIG: 3D Histogram: *The course of death in Saxony* (891 x 643; 98K)

1911–1913 The Hertzsprung-Russell diagram, a log-log plot of luminosity as a function of temperature for stars, used to explain the changes as a star evolves. It provided an entirely new way to look at stars, and laid the groundwork for modern stellar physics and evolution, developed independently by— Ejnar Hertzsprung (1873–1967), Denmark [135] and Henry Norris Russell (1877–1957), USA. See [272] for a recent appraisal.
PIC: Russell portrait (439 x 638; 21K)
IMG: Hertzprung's first 1911 graphs (366 x 394; 23K)
IMG: early Hertzsprung-Russell diagram (689 x 546; 8K)
IMG: modern Hertzsprung-Russell diagram (283 x 335; 26K)
TXT: HR Diagram tutorial
TXT: Hertzsprung biography
TXT: Russell biography

1913 Arithmetic probability paper, ruled so that normal ogive appears as straight line— Allen Hazen (1869–1930), USA [130].
IMG: Probability paper (590 x 303; 8K)

1913 Parade of statistical graphics, May 17, 1913, including large graphs on horse-drawn floats, and a photograph with people arranged in a bell-shaped curve— Employees of New York City, New York, USA [33].
FIG: Photograph of the Parade of Statistical Graphics (504 x 407; 57K)
[According to Brinton [33], the graph that most impressed people was one showing the decline in death rate due to improvements in sanitation and nursing.]

1913 Discovery of the concept of atomic number, based largely on graphical analysis (a plot of serial numbers of the elements vs. square root of frequencies from X-ray spectra) The linear relations showed that the periodic table was explained by atomic number rather than, as had been supposed, atomic weight, and predicted the existence of several yet-undiscovered elements— Henry Gwyn Jeffreys Moseley (1887–1915), England [206].
TXT: Text of Moseley's article, with scanned graphs
IMG: Moseley graph image (345 x 543; 8K)
TXT: Henry Mosely biography
PIC: Moseley portrait (200 x 298; 14K)

1913–1914 College course in statistical graphic methods, "The Graphic Method" (possibly the first)— Martin F. P. Costelloe, Iowa State College, USA.[48]

1914 Published standards for graphical presentation (by representatives from several scientific societies) — American Society of Mechanical Engineers (Joint Committee), USA [156].

1914 Pictograms to represent a series of numbers by icons (combining concepts of the bar graph and pictogram of varying size)— Willard Cope Brinton, USA [33].
TXT: Google Books: Brinton's *Graphic Methods for Presenting Facts*
FIG: Comparative pictogram of copper production, Fig 25 (371 x 262; 19K)
FIG: Proportion of College Graduates, Fig 39 (526 x 537; 57K)
FIG: Ranks of states on educational features, Fig 33 (514 x 738; 112K)

1915 Creation of a standing committee on graphics— American Statistical Association, USA.

1915–1925 Beginnings of the development of modern statistical theory (sampling distributions (1915), randomization, likelihood (1921), small sample theory, exact distributions, analysis of variance (1925), etc.)— Ronald Aylmer Fisher (1890–1962), UK [72, 73].
PIC: R. A. Fisher portrait (268 x 326; 3K)
TXT: Fisher biography, with other links and portraits
TXT: Collected papers of R. A. Fisher [23]

1916 Correspondence course in graphical methods (20 lessons for $50, supplemented by a book of 100 specimen illustrations of bar, curve, and circle diagrams; entended title includes "There's an idea in every chart")— Frank Julian Warne (1874–1948), USA [317].

1917 Gantt chart, designed to show scheduled and actual progress of projects— Henry Laurence Gantt (1861–1919), Maryland, USA[101]. 06/16/05:YL
TXT: Gantt chart history
[As a mechanical engineer and management consultant, Gantt also designed the 'task and bonus' system of wage payment and developed methods of measuring worker efficiency and productivity.]

1918–1933 Annual college course in statistical graphical methods— E. P. Cubberly, Stanford University, USA.

1919 Social statistical chartbook, containing a variety of graphic and semi-graphic displays in a USA Government report. [The image below is a fine early example of a semi-graphic display, showing four variables simultaneously.]— Leonard Porter Ayres (1879–1946), USA [9].
FIG: American Divisions in France, WWI, from [291] (467 x 429; 5K)

1919 Use of ethnographic maps, showing the distribution of mixed nationalities, played an important role in redrawing national boundaries of Central Europe and the Balkans following World War I— Emmanuel de Martonne (1873–1955), France [224, 187, 188]. 09/03/08:MF
PIC: de Martonne portrait (1190 x 1762; 202K)
FIG: Distribution of nationalities in the the countries dominated by Roumanians (2925 x 1959; 1026K)
TXT: Wikipedia entry for De Martonne (French)
[De Martonne was a geographical expert and secretary of the Comité d'études, established by the French in 1915 to prepare guidelines for peace and the demarcation of boundaries. In this work, he had to develop ways to represent mixed distributions of different ethnic groups]

1920 Invention of the path diagram to show relations among a network of endogenous and exogenous variables forming a system of structural equations— Sewall Wright (1889–1988), USA [328].
PIC: Sewall Wright portrait (216 x 405; 15K)
FIG: Wright's first path diagram (682 x 563; 42K)
TXT: Sewall Wright Papers, from the American Philosophical Society
TXT: Biographical memoirs

1920–1926 Numerous textbooks on graphics, describing principles of graphical presentation of numerical information (published at a rate of about two each year), e.g.,— A. C. Haskell[128], Karl G. Karsten, USA [157], A. R. Palmer, England [222].

1923 Invention of the iconoscope television camera-tube— Vladimir Kosma Zworykin (1889–1982), Russia. 06/25/05:YL
PIC: Zworykin,portrait, with kinescope (200 x 218; 7.3K)
TXT: Zworykin biography and invention (with images)

1924 Museum of Social Statistical Graphics and the ISOTYPE system (International System of Typographic Picture Education)— Otto Neurath (Director) (1882–1945), Social and Economic Museum, Vienna, Austria [210, 211].
PIC: Neurath portrait - small (104 x 150; 4K)
PIC: Neurath portrait - large (363 x 502; 29K)
IMG: Neurath Isotype image (215 x 300; 14K)
FIG: Births and deaths in Germany, from [210] (699 x 551; 43K)
FIG: Infant mortality and social position in Vienna, from [210] (500 x 320; 46K)
FIG: Number of men living in Europe, from [210] (551 x 451; 62K)
FIG: Isotype figure (400 x 229; 276k)
TXT: Neurath biography
TXT: Wikipedia: Neurath biography

1925 Development of the control chart for statistical control of industrial processes— Walter A. Shewhart (1891–1967), USA[263].
PIC: Walter Shewhart portrait (82 x 109; 5K)
TXT: Collection of web sites on Shewhart

1926 Experimental test of statistical graphical forms (pie vs. subdivided bar charts)— Walter C. Eells, USA [63].
IMG: Experimental stimuli (415 x 316; 96K)

1927–1932 Spate of articles on experimental tests of statistical graphical forms— R. von Huhn [140], F. E. Croxton [51, 52, 53], J. N. Washburne [318], USA.
FIG: Graphical image used by Washburne: Income (653 x 1120; 116K)
FIG: Graphical image used by Washburne: Population of Florence (647 x 295; 35K)

1927–1934 The birth of psychometrics, including unidimensional scaling (the law of comparative judgment) and multiple factor analysis. This would give rise to visualizations in one or more dimensions of psychological constructs, like attitudes, preferences, and abilities.— Louis Leon Thurstone (1887-1955), Chicago, USA [283, 284]. 04/12/07:MF
PIC: Thurstone portrait (150 x 237; 9.8K)
FIG: Factorial diagram for study of radicalism and attitudes (500 x 398; 57K)
TXT: Wikipedia Thurstone biography
TXT: Thurstone, "Vectors of the Mind"

1928 Nomogram of chemical concentrations in blood, showing the relations among over 20 components— Lawrence Joseph Henderson (1878–1942), USA [133].
IMG: Henderson nomogram icon (120 x 59; 5K)
FIG: Henderson nomogram image (1305 x 642; 226K)
TXT: Henderson biography (pdf)

1928 Ideograph, a multivariate rectangular glyph, invented to display four variables and their relations (length and width of petals and sepals in iris flowers)—Edgar Anderson (1897–1969), USA [3, 161].
PIC: Portrait (150 x 200; 124k)
TXT: Brief biography

1929 Electroencephalograph invented, to record electrical signals from the brain via galvanometers that measure electrical signals from electrodes on the scalp. EEGs were printed on multiple-pen, strip-chart recorders, with each channel showing the the amplitude from a given electrode.— Hans Berger (1873–1941), Austria. 06/16/05:YL

PIC: Berger portrait (125 x 190; 9K)
FIG: EEG machine (300 x 238; 23K)
[In 1924, Berger made the first EEG recording in man and called it Electroenkephalogram. Berger was the first to describe the different brainwaves in the normal and abnormal brain. He also researched the nature of changes in EEG for brain diseases such as epilepsy.]

1930 Table of historical events drawn on logarithmic paper— Heinz Von Foerster (1911–2002),Austria. 06/16/05:YL
FIG: Table of historical events drawn on logarithmic paper
TXT: von Foerster biography
TXT: von Foerster interview and logarithmic timeline
TXT: Tabular representation of logarithic timeline
[von Foerster observed that the closer to the present, the more densely filled the paper was with historical events; conversely, the further you went back the thinner the table. Plotting the data using a logarithmic time scale allowed the history of time to be plotted on one table.]

1931 "Log Square" paper ($\log y, \log x$, for relations which are linear in log scales)— F. C. Martin and D. H. Leavens, USA [186].

1933 Standard statistical symbols (Neurath's Isotype method) established by government decree (for schools, public posters, etc.)— Soviet Union [210].

1933 Re-design of the routes of the London underground rail system to favor usability— Henry C. Beck (1903–1974), London, UK. 05/01/07:MF
PIC: Beck portrait (240 x 258; 20K)
FIG: Beck's initial underground map (450 x 308; 66K)
FIG: Modern London tube map following Beck
TXT: Wikipedia on Henry (Harry) Beck
TXT: Catalog of London Underground maps 1933-
[Beck, an engineering draughtsman, designed the map like an electrical circuit board, using only vertical, horizontal and 45 degree angled lines. He located stations according to available space. The resulting map was geographically inaccurate, but easier to use to determine how to get from point A to B. Beck's idea was soon copied by most subway (and bus) companies around the world.]

1935–1950 Lapse of interest in statistical graphics, as concern with formal, "precise", and numerical methods gained ascendancy (the modern "dark ages" of statistical graphics)[85].

1937 First modern review of the early history of statistical graphics— H. Gray Funkhouser (1898–1984), USA [92].

1939 Description of a memex, an associative information retrieval system which would help someone find information based in association and context rather than strict categorical indexing; conceptual creation of "hyperlink" and the "World Wide Web"— Vannevar Bush (1890–1974), USA. 06/25/05:YL
TXT: Bush biography (with links and images)
TXT: As We May Think (e-text):
[He foresaw this operating on an electric analog computer, which was completed in 1942. His description was published in the *Atlantic Monthly*, "As We May Think" July, 1945]

1944 Harvard's Mark I, the first digital computer, put in service. Officially known as the "IBM Automatic Sequence Controlled Calculator" (ASCC), the Mark I was 50 feet long and weighed about 5 tons.— Howard H. Aiken (1900–1973) and Grace Hopper (1906–1992), USA.
PIC: Howard Aiken portrait (200 x 278; 33K)
IMG: The "Mark I" IBM ASCC (240 x 144; 38K)
TXT: Aiken biography
TXT: Howard Aiken's Harvard Mark I
TXT: History of Computing: Harvard Mark I
[The first official record of the use of the word "bug" in the context of computing is associated with a relay-based Harvard Mark

II computer, which was in service at the Naval Weapons Center in Dahlgren, Virginia. On September 9th, 1945, a moth flew into one of the relays and jammed it. The offending moth was taped into the log book alongside the official report, which stated: "First actual case of a bug being found."]

1944 Development of an electro-mechanical machine to aid in the rotation of multidimensional factor analysis solutions to "simple structure." This allowed an analyst to carry out by direct manipulation of dials what one did by plotting pairs of factors, and hand calculation of the rotation matrices in earlier times [(work carried out under the Adjutant General for development of the Armed Forces General Classification Test) [289]]— Harry Harmon (1913–1976), USA .
PIC: Harry Harmon portrait (390 x 453; 82K) §7: 40 items

8 1950–1974: Re-birth of data visualization

Still under the influence of the formal and numerical zeitgeist from the mid-1930s on, data visualization began to rise from dormancy in the mid 1960s, spurred largely by three significant developments:

- In the USA, John W. Tukey, in a landmark paper, "The Future of Data Analysis" [294], issued a call for the recognition of data analysis as a legitimate branch of statistics distinct from mathematical statistics; shortly, he began the invention of a wide variety of new, simple, and effective graphic displays, under the rubric of "Exploratory Data Analysis" (EDA). Tukey's stature as a statistician and the scope of his informal, robust, and graphical approach to data analysis were as influential as his graphical innovations. Although not published until 1977, chapters from Tukey's EDA book [297] were widely circulated as they began to appear in 1970–1972, and began to make graphical data analysis both interesting and respectable again.
- In France, Jacques Bertin published the monumental *Semiologie Graphique* [26]. To some, this appeared to do for graphics what Mendeleev had done for the organization of the chemical elements, that is, to organize the visual and perceptual elements of graphics according to the features and relations in data.
- But the skills of hand-drawn maps and graphics had withered during the dormant "modern dark ages" of graphics (though every figure in Tukey's EDA [297] was, by intention, hand-drawn). Computer processing of data had begun, and offered the possibility to construct old and new graphic forms by computer programs. True high-resolution graphics were developed, but would take a while to enter common use.

By the end of this period significant intersections and collaborations would begin: (a) computer science research (software tools, C language, UNIX, etc.) at Bell Laboratories [16] and elsewhere would combine forces with (b) developments in data analysis (EDA, psychometrics, etc.) and (c) display and input technology (pen plotters, graphic terminals, digitizer tablets, the mouse, etc.). These developments would provide new paradigms, languages and software packages for expressing and implementing statistical and data graphics. In turn, they would lead to an explosive growth in new visualization methods and techniques.

Other themes begin to emerge, mostly as initial suggestions: (a) various visual representations of multivariate data; (b) animations of a statistical process; (c) perceptually-based theory (or just informed ideas) related to how graphic attributes and relations might be rendered to better convey the data to the eyes.

1957 Circular glyphs, with rays to represent multivariate data— Edgar Anderson, USA [4].
FIG: Use of metroglyphs in a graph (672 x 532; 48K)
FIG: Diagramming variables in more than 3 dimensions (571 x 275; 39K)

1957 Creation of Fortran, the Formula Translation language for the IBM 704 computer. This was the first high-level language for computing.— John Backus (1924–1998), USA. 06/25/05:YL

TXT: FORTRAN background

TXT: Backus biography and bibliography (with links and images)

1958 The "Phillips Curve," a scatterplot of inflation vs. unemployment over time shows a strong inverse relation, leading to important developments in macroeconomic theory— Alban William Housego Phillips (1914–1975), NZ [234].

FIG: The Phillips Curve (307 x 246; 4K)

FIG: The Phillips Curve (452 x 437; 19K)

TXT: Phillips biography

1962 Beginnings of modern dynamic statistical graphics (a 1 minute movie of the iterative process of finding a multidimensional scaling solution)— Joseph B. Kruskal (1929–), Bell Labs, USA.

PIC: Photo of Joseph Kruskal (197 x 248; 45K)

TXT: ASA Video Library blurb for video "Multidimensional Scaling", with sample frames

1965 Beginnings of EDA: improvements on histogram in analysis of counts, tail values (hanging rootogram)— John W. Tukey (1915–2000), USA [295].

PIC: Photo of John W. Tukey (151 x 219; 4K)

TXT: Biography, tributes, images, bibliography of JWT

TXT: Tukey biography

IMG: Hanging rootogram for the fit of a Poisson distribution (427 x 319; 3K)

1966 Triangular glyphs to represent simultaneously four variables, using sides and orientation— R. Pickett and B. W. White, USA [235]

mid 1960s Initial development of geographic information systems, combining spatially-referenced data, spatial models and map-based visualization. Example: Harvard Laboratory for Computer Graphics (and Spatial Analysis) develops SYMAP, producing isoline, choropleth and proximal maps on a line printer— Howard Fisher, USA [46, 287].

FIG: Early SYMAP image of Connecticut (763 x 768; 15K)

TXT: The GIS History Project

TXT: GIS Milestones

1967 Comprehensive theory of graphical symbols and modes of graphics representation— Jacques Bertin (1918–), France [26, 27]

PIC: Bertin portrait (156 x 240; 43K)

PIC: Bertin color portrait (180 x 223; 13K)

IMG: Bertin's seven visual variables (314 x 281; 9K)

IMG: The reorderable matrix (300 x 142; 2K)

TXT: 30 ans de semiologique graphique

TXT: Jacques Bertin, Semiologie Graphique web site

TXT: InfoVis interview with J. Bertin

[Among other things, Bertin introduced the idea of reordering qualitative variables in graphical displays to make relations more apparent— the reorderable matrix.]

1968 Systematic "graphical rational patterns" for statistical presentation— Roberto Bachi (1909–1995), Israel [11].

IMG: Bachi number patterns (371 x 253; 27K)

PIC: Bachi portrait (149 x 224; 251k)

1969 Graphical innovations for exploratory data analysis (stem-and-leaf, graphical lists, box-and-whisker plots, two-way and extended-fit plots, hanging and suspended rootograms)— John W. Tukey (1915–2000), USA [296].

IMG: Boxplot of leading digits of lottery numbers (640 x 495; 6K)

1969 Suggestion for displaying five variables by means of movements on a CRT— George Barnard, England [14]

1969 The first well-known *direct manipulation* interactive system in statistics: allowed users to interactively control a power transformation in realtime for probability plotting— E. B. Fowlkes, USA [78].

1971 Irregular polygon ("star plot") to represent multivariate data (with vertices at equally spaced intervals, distance from center proportional to the value of a variable) [but see Georg von Mayr in 1877 [192, S. 78] for first use]— J. H. Siegel, R. M. Goldwyn and Herman P. Friedman, USA [266]
FIG: Star plot of crime rates in US cities (504 x 505; 8K)
TXT: Star plot, description and example

1971 Proposal to use statistical graphics in social indicator reporting, particularly on television— Albert D. Biderman (1922–), USA [28].

1971 Development of the biplot, a method for visualizing both the observations and variables in a multivariate data set in a single display. Observations are typically represented by points, variables by vectors, such that the position of a point along a vector represents the data value— Ruben Gabriel (1929–2003), USA [94]. 10/20/05:MF
FIG: Biplot representation of blood chemistry data (511 x 483; 17K)
FIG: Biplot representation of ratings of automobiles (489 x 397; 5.8K)
TXT: Description of PCA and biplot

1972 Form of Fourier series to generate plots of multivariate data— David F. Andrews, Canada [5].
IMG: Fourier function plot image (217 x 222; 3K)

1973 Cartoons of human face to represent multivariate data— Herman Chernoff (1923–), USA [42].
PIC: Chernoff portrait (159 x 230; 24K)
IMG: Faces plot of automobile data, by origin (428 x 114; 3K)
TXT: Chernoff faces Java applet
TXT: Chernoff CV and portrait

1973 USA Government chartbook devoted exclusively to reporting social indicator statistics— Office of Management and Budget, USA [68].

1973–1976 Revival of statistical graphics innovation, use by U.S. Bureau of the Census— Vincent P. Barabba (1934–) (Director), USA.

1974 Color-coded bivariate matrix to represent two intervally measured variables in a single map (Urban Atlas series)[but see Georg von Mayr in 1874 [191, Fig. XIX] for first use]— U.S. Bureau of the Census, USA [301].
IMG: CDC map of incidence of stomach cancer (406 x 261; 60K)

1974 Comparative experimental test of histogram, hanging histogram and hanging rootogram— Howard Wainer, USA [310].

1974 Start of true interactive graphics in statistics; PRIM-9, the first system in statistics with 3-D data rotations provided dynamic tools for projecting, rotating, isolating and masking multidimensional data in up to nine dimensions— M. A. Fishkeller, Jerome H. Friedman and John W. Tukey (1915–2000), USA [74, 75]
PIC: Jerome Friedman portrait (935 x 965; 348K) §8: 22 items

9 1975–present: High-D data visualization

It is harder to provide a succinct overview of the most recent developments in data visualization, because they are so varied, have occurred at an accelerated pace, and across a wider range of disciplines. It is also more difficult to highlight the most significant developments (and because we have focused on the earlier history), so there are presently areas and events unrepresented here.

With this disclaimer, a few major themes stand out:

- the development of a variety of highly interactive computer systems and more importantly,
- new paradigms of direct manipulation for visual data analysis (linking, brushing, selection, focusing, etc.)
- new methods for visualizing high-dimensional data (grand tour, scatterplot matrix, parallel coordinates plot, etc.);
- the invention of new graphical techniques for discrete and categorical data (fourfold display, sieve diagram, mosaic plot, etc.), and analogous extensions of older ones (diagnostic plots for generalized linear models, mosaic matrices, etc.) and,
- the application of visualization methods to an ever-expanding array of substantive problems and data structures.

These developments in visualization methods and techniques arguably depended on advances in theoretical and technological infrastructure. Some of these are: (a) large-scale software engineering; (b) extensions of classical linear statistical modeling to wider domains; (c) vastly increased computer processing speed and capacity, allowing computationally intensive methods and access to massive data problems.

In turn, the combination of these themes and advances now provides some solutions for earlier problems.

1975 Weekly chartbook (eventually computer-generated) to brief U.S. President, Vice President on economic and social matters— Bureau of the Census and Office of Management and Budget (at request of Vice President Nelson Rockefeller), USA
TXT: Measuring 50 years of economic change

1975 "Four-Fold Circular Display" to represent 2 x 2 table— Stephen E. Fienberg, USA [71].
PIC: Stephen Fienberg portrait (368 x 368; 68K)
IMG: Fourfold display (258 x 254; 2K), from [81]
TXT: Friendly (1994) paper (.ps.gz format)
TXT: Fienberg CV and portrait

1975 Enhancement of scatterplot with plots of three moving statistics (midmean and lower and upper semimidmean)— William S. Cleveland and Beat Kleiner, USA [47]
PIC: Cleveland portrait (210 x 256; 31K)
IMG: USA 1970 Draft Lottery Data, with median and quartile traces (563 x 448; 8K)
TXT: Cleveland bio and papers

1975 Experiment showing random permutations of features used in Chernoff's faces affect error rate of classification by about 25 percent— Herman Chernoff (1923–) and M. H. Rizvi, USA [43].
TXT: Chernoff faces

1975 Experimental tests of statistical graphics vs tables, findings favoring latter— Andrew S. C. Ehrenberg, England [64, 65].
PIC: Ehrenberg portrait (270 x 211; 5.4K)
TXT: Summarising and presenting data- Rules for tables

1975 Scatterplot matrix, the idea of plotting all pairwise scatterplots for n variables in a tabular display— John Hartigan, USA [125]. 03/16/07:MF
PIC: Hartigan portrait (108 x 145; 21K)
IMG: Simple scatterplot matrix (248 x 248; 2.6K)
IMG: Enhanced scatterplot matrix (349 x 279; 5K)

1976 Monthly USA Government chartbook of economic and social trends (StatUS)— U.S. Bureau of the Census, USA [302]
TXT: US Bureau of Census home page

1977 "Cartesian rectangle" to represent 2 x 2 table, experimentally tested against other forms— Howard Wainer and Mark Reiser, USA [313]

1977 Ad Hoc Committee on Statistical Graphics, leading to the ASA Section on Statistical Graphics, later to the *Journal of Computational and Graphical Statistics*— American Statistical Association, USA

1978 Original invention of linked brushing (highlighting of observations selected in one display in another display of the same data), although in a manner different from how we see it in today's systems— Carol Newton, USA [212].

1978 *S*, a language and environment for statistical computation and graphics. *S* (later sold as a commercial package, *S-Plus*; more recently, a public-domain implementation, *R* is widely available), would become a *lingua franca* for statistical computation and graphics— Richard A. Becker and John M. Chambers, Bell Labs, USA [18, 17, 16].
PIC: Richard Becker portrait (200 x 300; 39K)
IMG: Boxplot of the NJ Pick-it Lottery (160 x 124; 28K)
TXT: A Brief History of S (Postscript)
TXT: The R Project for Statistical Computing

1979 Geographic correlation diagram, showing the bivariate relation between two spatially referenced variables using vectors to represent geographic covariation— Mark Monmonier, USA [200]
PIC: Monmonier portrait
TXT: Monmonier bio

1981 Mosaic display to represent frequencies in a multiway contingency table— John Hartigan and Beat Kleiner, USA [126, 127]. See also:[84].
IMG: Mosaic display á la Hartigan and Kleiner (339 x 366; 3K)
FIG: Hartigan & Kleiner 5-way mosaic of TV ratings (629 x 663; 105K)
TXT: A Brief History of the Mosaic Display (pdf)

1981 Fisheye view: an idea to provide focus and greater detail in areas of interest of a large amount of information, while retaining the surrounding context in much less detail— George W. Furnas, USA [93].
IMG: Fisheye view of central Washington, D.C. (207 x 207; 14K)
FIG: Fisheye view of central Washington, D.C. (512 x 512; 63K)
FIG: Fisheye view of central Washington, D.C. (512 x 512; 63K)
TXT: Nonlinear magnification home page[many references and links]
TXT: Furnas home page
TXT: Generalised fisheye views paper (pdf)

1981 The "draftsman display" for three-variables (leading soon to the "scatterplot matrix") and initial ideas for conditional plots and sectioning (leading later to "coplots" and "trellis displays")— John W. Tukey (1915–2000) and Paul A. Tukey, Bell Labs, USA[299].

1982 Another early version of brushing, invented independently of Newton, together with a system for 3-D rotations of data— John A. McDonald, USA [193].

1982 Visibiltiy Base Map, a map of the United States where areas are adjusted to provide a readily readable platform for area symbols for smaller states, such as Delaware and Rhode Island, with compensating reductions in the size of larger states— Mark Monmonier, USA [202].
PIC: Mark Monmonier portrait (140 x 202; 3.9K)
FIG: US Visibility Map (531 x 335; 5K)

1982 The USA Today color weather map begins an era of color information graphics in newspapers. Shortly, colorful visual graphics become widespread.— George Rorick, USA. 05/01/07:MF
PIC: George Rorick portrait (197 x 208; 8.8K)
IMG: Weather map icon (196 x 319; 23K)
FIG: Weather map image (357 x 578; 77K)
TXT: The Colorful Origins of USA Today
[Rorick used a combination of color, maps, tables, symbols and annotation to transform often dull and incomprehensible information into something more interesting and accessible]

1983 Sieve diagram, for representing frequencies in a two-way contingency table— Hans Riedwyl (1935–) and Michel Schüpbach, Switzerland [250]
PIC: Riedwyl portrait (118 x 160; 14K)
IMG: Sieve diagram image (179 x 170; 2K)
TXT: Riedwyl bio and portrait
TXT: Sieve diagrams applet

1983 Esthetics and information integrity for graphics defined and illustrated (some concepts: "data-ink ratio", "lie factor")— Edward Tufte (1942–), USA [291, 292, 293]
PIC: Tufte portrait (190 x 218; 8.4K)
TXT: Graphics and web design according to Tufte's principles

1985 Grand tour, for viewing high-dimensional data sets via a structured progression of 2D projections— Daniel Asimov, USA [8].
TXT: Technical report, *The grand tour via geodesic interpolation of 2-frames* (pdf)

1985 Parallel coordinates plots for high-dimensional data— Alfred Inselberg, USA [146, 147, 148].
PIC: AlInselberg portrait (1110 x 785; 95K)
TXT: Parallel coordinates– How it happened
TXT: Parallel coordinates visualisation applet
TXT: Java applet, allowing direct manipulation: The Parallel Coordinate Explorer
IMG: Representation of a six dimensional point in parallel coordinates (282 x 174; 2K)
FIG: Representation multivariate data in parallel coordinates (455 x 339; 9K)

1986 Automatic design of graphical presentations of relational data using a computational extention of Bertin's semiology of graphics— Jock Mackinlay, Palo Alto, USA [179, 180]. 07/15/08:JM
PIC: Mackinlay portrait (100 x 120; 5.6K)
FIG: APT generated graphic, 4 variables in a scatterplot (466 x 559; 582K)
TXT: ACM Transactions on Graphics article

1987 Interactive statistical graphics, systematized: allowing brushing, linking, other forms of interaction— Richard A. Becker and William S. Cleveland, USA [19].
FIG: Figure 14 from "Brushing scatterplots" showing interactive labeling of brushed points (681 x 566; 76K)
TXT: ASA Video Library blurb for video "Dynamic Displays of Data"
TXT: Becker bio and portrait

1988 First inclusion of grand tours in an interactive system that also has linked brushing, linked identification, visual inference from graphics, interactive scaling of plots, etc.— Andreas Buja, Daniel Asimov, Catherine Hurley and John A. McDonald, USA [36].
PIC: Andreas Buja portrait (663 x 887; 51K)
TXT: XGobi - multivariate visualization
TXT: Buja home page
TXT: Hurley home page

1988 Interactive graphics for multiple time series with direct manipulation (zoom, rescale, overlaying, etc.)— Antony Unwin and Graham Wills, UK [303].

IMG: DiamondFast image, overlaid time series, aligned and rescaled interactively (344 x 97; 19K), lynx trapping data
TXT: Unwin home page

1989 Statistical graphics interactively linked to map displays— Graham Wills, J. Haslett, Antony Unwin and P. Craig, UK [324]; Mark Monmonier, USA [201]
IMG: REGARD image: largest annual oil flows into EU, 1977–1990 (476 x 359; 30K)

1989 Use of "nested dimensions" (related to trellis and mosaic displays) for the visualization of multidimensional data. Continuous variables are binned, and variables are allocated to the horizontal and vertical dimensions in a nested fashion— Ted Mihalisin, USA [194, 195].
FIG: TempleMVV image: 4 response variables vs. age, sex, education (912 x 585; 290K)
FIG: TempleMVV image: 4-way association (913 x 586; 527K)

1990 Lisp-Stat, an object-oriented environment for statistical computing and dynamic graphics— Luke Tierney, USA [285].
TXT: Lisp-Stat information
PIC: Luke Tierney portrait (198 x 302; 33K)
TXT: Tierney home page

1990 Grand tours combined with multivariate analysis— Catherine Hurley and Andreas Buja, USA [144]

1990 Textured dot strips to display empirical distributions— Paul A. Tukey and John W. Tukey (1915–2000), USA [298].

1990 Lexis pencil: display of multivariate data in the context of life-history— M. Keiding, UK [158]
IMG: Lexis pencil image (394 x 300; 39K)
FIG: Animated 3D lexis pencil, from Brian Francis (360 x 270; 135K)
TXT: Bertin, lexis, and the graphical representation of event histories

1990 Statistical theory and methods for parallel coordinates plots— Edward Wegman, USA [319].
PIC: Ed Wegman portrait (176 x 219; 11K)
FIG: Representation multivariate data in parallel coordinates (455 x 339; 9K)

1991 Mosaic display developed as a visual analysis tool for log-linear models (beginning general methods for visualizing categorical data)— Michael Friendly (1945–), Canada [86, 82].
TXT: Tutorial description of mosaic displays
TXT: Brief history of the mosaic display
IMG: Two-way mosaic of hair color and eye color (329 x 299; 4K)
IMG: Three-way mosaic of hair color, eye color, and sex (329 x 299; 4K)

1991 Treemaps, for space-constrained visualization of hierarchies, using nested rectangles (size proportional to some numerical measure of the node)— Ben Shneiderman (1947–), USA [265, 153].
PIC: Ben Shneiderman portrait (110 x 150; 5.9K)
FIG: TreeViz image of files on the HCIL server (636 x 429; 14K)
TXT: Treemaps description and images
TXT: Treemap homepage
TXT: Wikipedia: Ben Shneiderman biography

1991–1996 A spate of development and public distribution of highly interactive systems for data analysis and visualization, e.g., XGobi, ViSta— Deborah Swayne, Di Cook, Andreas Buja [276, 37, 277], Forrest Young (1940–2006) [329], USA.
PIC: Debbie Swayne portrait (200 x 370; 14K)
IMG: XGobi screen shot (901 x 682; 29K)
TXT: ViSta - The Visual Statistics System
TXT: XGobi and XGVis homepage

1992 Beginnings of the general extension of graphical methods to categorical (frequency) data— Michael Friendly (1945–), Canada [80, 83].

1994 Table lens: Focus and context technique for viewing large tables; user can expand rows or columns to see the details, while keeping surrounding context— Ramana Rao and Stuart K. Card, Xerox Parc, USA [247].
IMG: Table lens screen shot (600 x 459; 58K)
TXT: The Table Lens: Merging Graphical ... (CHI, 1994) paaper
TXT: ACM SigChi paper: Exploring Large Tables with the Table Lens, Rao and Card
TXT: Interactive table lens demonstrations, from InXight
TXT: Information visualization and the next generation workspace (pdf)

1996 Cartographic Data Visualiser: a map visualization toolkit with graphical tools for viewing data, including a wide range of mapping options for exploratory spatial data analysis— Jason Dykes, UK [62].
PIC: Jason Dykes portrait (120 x 160; 4.1K)
TXT: CDV paper
IMG: CDV screen shot (432 x 300; 38K)
TXT: Dykes home page

1999 *Grammar of Graphics*: A comprehensive systematization of grammatical rules for data and graphs and graph algebras within an object-oriented, computational framework— Leland Wilkinson (1944–), USA [322, 323].
PIC: Lee Wilkinson portrait (204 x 277; 5.7K)
FIG: Contour plot of death rate vs. birth rate (575 x 575; 24K)
FIG: 3D Contour map, Fig 8-11 (511 x 453; 48K)
FIG: Minard's March on Moscow graphic (561 x 267; 22K)
TXT: Wilkinson home page

2004 Sparklines: "data-intense, design-simple, word-sized graphics," designed to show graphic information inline with text and tables — Edward Tufte (1942–), USA [290]. 1/22/07:MF
IMG: Sparkline of the US deficit, 1983–2003 (62 x 16; 0.1K)
IMG: Sparkline graphic for 4 stocks (80 x 20; 0.8K)
TXT: Sparkline entry from Wikipedia
TXT: Tufte's explanation of sparklines §9: 41 items

10 Related resources and web links

There are many other useful collections of historical information related to the milestones detailed here. We list below a few of the more useful ones encountered so far.

History of science

- Major Scientific & Medical Discoveries, Inventions & Events 1650-1800: A simple, but useful timeline.
- Eighteenth-Century Resources – Science and Mathematics: part of a larger collection of Eighteenth-Century history resources.
- Media history timeline pages: an illustrated chronology of media developments, with links to related timelines.
- Science timeline: A detailed listing of important developments in the history of science, mathematics, and philosophy of science from the dawn of civilization, by David Lee.

- An Historical Timeline of Computer Graphics and Animation
- Timeline of knowledge representation: From a slightly quirky artificial intelligence perspective, the site lists hundreds of developments across many fields.
- GEsource thematic timeline of maps Part of a hub of internet resources related to geography and environmental studies.
- intute: Timelines of science, engineering and technology A large collection of timelines of notable events from prehistoric times to the present, broken down into separate subject areas and themes.

History of cartography

- Henry Davis: Cartographic Images Home Page: Time charts of cartography, with a large collection of map images and descriptions, from ancient to late 19th century.
- The History of Cartography: An on-going project at the University of Wisconsin, producing a six-volume set, covering prehistoric and ancient cartography, through the 20th century.
- Historical Map Web Sites: A large list of links to historical maps on the web.
- Web Articles on the History of Cartography: Early maps, and the resources and activities associated with them, form the subject of over 100 'pages' on this site. All the worthwhile information about old maps can be found here, directly or indirectly.
- Map History / History of Cartography: All the worthwhile information about early, old, antique and antiquarian maps can be found here, or from here. The 100 pages of this site offer comment and guidance, and many, many links - selected for relevance and quality. Maintained by Tony Campbell, Map Librarian (retired), British Library, London.
- History and Milestones of GIS: A detailed timeline of history of maps and developments in GIS, from pre-200 AD to present.
- GiS TiMELINE, from the Centre for Advanced Spatial Analysis: An interactive, visual overview of key historical events in the development and growth of Geographical Information Systems from their conception in the 1960's to the present day.
- Places and Spaces, an exhibit on "cartography of the physical and abstract," uses illustrations of cartographic maps, concept maps and domain maps to explain how aspects of visual perception, data analysis, spatial layout and other aspects combine to create a visualization of spatially-referenced information.

History of probability and statistics

- The History of Mathematicians Archive: A large collection of biographical sketches of mathematicians and statisticians, with alphabetical and chronological indexes, and quite a few portraits.
- Materials for the history of statistics, University of York: A collection of portraits, biographies, original works, and images.
- UCLA History of Statistics pages: A collection of original articles and images from the history of statistics.
- History of Statistics Timeline: Dan Denis' collation of significant events in the history of statistics.
- Figures from the History of Probability and Statistics A chronological listing from 1650–present, with portraits and many links.

Information visualization

- Our Gallery of Data Visualization has a section on Historical Milestones, as well as many examples of the best and worst of statistical graphics.
- Keith Andrews' Information Visualization lecture notes provide many examples of recent advances in this field.
- The Numerical Aerospace Simulation maintains the comprehensive Annotated scientific visualization web site bibliography.
- InfoVis.net is an eclectic, bilingual (English, Spanish) web site on Information Visualization with a weekly newsletter by Juan C. Dürstfeler from UPF in Barcelona.
- Les fonds anciens de la bibliothèque de l'Ecole des mines de Paris has mounted a lovely exposition, Les graphiques scientifiques: prolégomènes à leur usage et à leur histoire of some of the history and usage of scientific graphics, under the direction of M. Henri Vérine. Several images linked here appear through the courtesy of Marie-Noelle Maisonneuve.

278 items

Milestones content totals: 278 items, 338 text links, 423 images, 331 bib refs.

11 Catgeory cross references

The milestones items have been classified into hierarchical categories as an aid to researchers wishing to examine this material by thematic groups. The categories of **Content** (Section 11.1) relate to the substance or subject matter of the milestone or innovation— what is was *about*. Some of the main category headings are Astronomy, Commerce, Education, and Social science. The categories of **Form** (Section 11.2) relate to the graphic or technological details of the milestone item— what it *consisted of*. Some of the main categories used here are graphic types or elements: Chart, Curve, Diagram, etc. The entries in the listing are the item keys, in the form *yearName*, from the chronlogical listing.

In this version of the cross-reference, a given item can appear at several levels in the hierarchy, representing broader or narrower categories.

11.1 Content C1

Astronomy 240BCEratosthenes, 134BCHipparchus, 950Unknown, 1375Cresques, 1530Gemma-Frisius, 1545Gemma-Frisius, 1572Brahe, 1626Scheiner, 1632Galilei, 1809Gauss, 1904Maunder, 1911Hertzsprung.

> **Cosmography** 134BCHipparchus, 1375Cresques, 1530Gemma-Frisius, 1545Gemma-Frisius, 1572Brahe, 1632Galilei, 1911Hertzsprung. C11

> **Planetary movement** 240BCEratosthenes, 950Unknown, 1809Gauss. C13

> **Sunspot** 1626Scheiner, 1904Maunder. C15

Calculation 1550Rheticus, 1663Cardano, 1600sUnknown, 1614Napier, 1623Schickard, 1637Fermat, 1654Pascal, 1693aHalley, 1736Newton, 1750Mayer, 1760Lambert, 1765Lambert, 1767Lambert, 1795Pouchet, 1822Babbage, 1832Herschel, 1846Lalanne, 1846Quetelet, 1884Hollerith, 1885Galton, 1914Brinton, 1920Wright, 1944Harmon, 1957Anderson, 1965Tukey, 1966Pickett, 1969Tukey, 1969Fowlkes, 1972Andrews, 1974Wainer, 1975Ehrenberg, 1977Wainer, 1981Hartigan, 1981Tukey, 1983Riedwyl, 1987Becker, 1990Tukey, 1990Wegman, 1991Friendly, 1991Shneiderman, 1992Friendly, 1999Wilkinson. C2

> **Geodesy** > **Rhumb line** 1569Mercator. C726

> **Temperature** 1663Wren, 1779Lambert, 1800Keith, 1817Humboldt, 1843Lalanne, 1873Gibbs, 1910Unknown, 1911Hertzsprung. C73

> **Topography** 6200BCUnknown, 550BCMiletus, 1782Carla-Boniface. C74

> **Weather** 1663Wren, 1686aHalley, 1820sFaraday, 1830Faraday, 1843aLalanne, 1861Galton, 1975Cleveland, 1975Chernoff. C75

Social science 1280Llull, 1662Graunt, 1666Talon, 1669Huygens, 1671Witt, 1687Petty, 1693Halley, 1711Arbuthnot, 1741Sussmilch, 1753Barbeu-Dubourg, 1765Priestley, 1782Fourcroy, 1798Seaman, 1811Humboldt, 1819Dupin, 1821Fourier, 1825Gompertz, 1828Quetelet, 1830Montizon, 1833Guerry, 1833aGuerry, 1833Scrope, 1836Angeville, 1836Parent-Duchatelet, 1839Verhulst, 1843Pritchard, 1852Unknown, 1855Snow, 1857Nightingale, 1869Zeuner, 1869Minard, 1872USCensus, 1874Walker, 1874Vauthier, 1874Galton, 1875Lexis, 1877Bowditch, 1879Perozzo, 1882Bertillon, 1884Mulhall, 1884Hollerith, 1884Abbott, 1885Levasseur, 1892Geddes, 1896Bertillon, 1910Unknown, 1911Roesle, 1913City, 1917Gantt, 1919Ayres, 1924Neurath, 1927Huhn, 1929Berger, 1930vonFoerster, 1969Tukey, 1971Siegel, 1971Biderman, 1972Andrews, 1973Chernoff, 1973USBudget, 1974USCensus, 1975Census, 1975Fienberg, 1976USCensus, 1978Becker, 1990Keiding. C8

> **Annuity** 1671Witt, 1741Sussmilch. C81

> **Demographics** 1662Graunt, 1666Talon, 1687Petty, 1782Fourcroy, 1821Fourier, 1872USCensus, 1874Walker, 1874Galton, 1875Lexis, 1879Perozzo, 1882Bertillon, 1884Hollerith, 1885Levasseur, 1919Ayres, 1924Neurath, 1973USBudget. C82

> **Epidemiology** 1798Seaman, 1855Snow, 1911Roesle, 1973USBudget. C83

> **Health** 1798Seaman, 1855Snow, 1857Nightingale, 1877Bowditch, 1911Roesle. C84

> **Literacy** 1819Dupin, 1973USBudget. C85

> **Medical** 1855Snow, 1973USBudget. C86

> **Military** 1857Nightingale, 1869Minard, 1919Ayres. C87

> **Military** > **Infirmity** 1857Nightingale. C871

> **Moral Statistics** 1833Guerry, 1833aGuerry, 1833Scrope, 1836Parent-Duchatelet, 1843Pritchard, 1882Bertillon, 1971Siegel, 1973USBudget. C88

> **Moral Statistics** > **Crime** 1833Guerry, 1833aGuerry, 1882Bertillon, 1971Siegel. C881

> **Moral Statistics** > **Law** 1833Guerry. C882

> **Moral Statistics** > **Prostitution** 1833Guerry, 1836Parent-Duchatelet. C883

> **Moral Statistics** > **Suicide** 1833Guerry. C884

> **Mortality** 1662Graunt, 1666Talon, 1669Huygens, 1671Witt, 1687Petty, 1693Halley, 1711Arbuthnot, 1825Gompertz, 1828Quetelet, 1875Lexis, 1885Levasseur, 1911Roesle, 1924Neurath. C89

> **Politics** 1280Llull, 1753Barbeu-Dubourg, 1929Berger. C8A

> **Population** 1662Graunt, 1666Talon, 1687Petty, 1741Sussmilch, 1811Humboldt, 1821Fourier, 1830Montizon, 1836Angeville, 1839Verhulst, 1869Zeuner, 1872USCensus, 1874Walker, 1874Vauthier, 1879Perozzo, 1885Levasseur, 1896Bertillon, 1910Unknown, 1913City, 1919Ayres, 1924Neurath, 1927Huhn. C8B

Technology 170BCparchment, 105Lun, 1453Gutenberg, 1500Vinci, 1545Gemma-Frisius, 1556Tartaglia, 1572Brahe, 1581Galilei, 1603Scheiner, 1617Snell, 1620Gunter, 1623Schickard, 1646Kirscher, 1663Wren, 1686Halley, 1710Blon, 1727Schulze, 1750Mayer, 1776Monge, 1787Chladni, 1794Buxton, 1796Watt, 1798Senefelder, 1800Howard, 1800Keith, 1822Babbage, 1827Niepce, 1833Wheatstone, 1839Daguerre, 1861Maxwell, 1872Muybridge, 1879Jevons, 1883Unknown, 1884Hollerith, 1895Lumieres, 1899Galton, 1913Hazen, 1923Zworykin, 1929Berger, 1931Martin, 1939Bush, 1944Aiken, 1944Harmon, 1957Backus, 1962Kruskal, 1960sFisher, 1969Barnard, 1969Fowlkes, 1971Biderman, 1974Fishkeller, 1978Becker, 1985Asimov, 1985Inselberg, 1988Buja, 1988Unwin, 1989Wills, 1989Mihalisin, 1990Tierney, 1990Hurley, 1991Swayne, 1994Rao, 1996Dykes, 1999Wilkinson. C9

> **Computing** 1822Babbage, 1939Bush, 1944Aiken, 1944Harmon, 1957Backus, 1969Fowlkes, 1974Fishkeller, 1978Becker, 1991Swayne, 1994Rao, 1996Dykes, 1999Wilkinson. C91

> **Material** 170BCparchment, 105Lun, 1879Jevons, 1883Unknown, 1899Galton, 1913Hazen, 1931Martin. C93

> **Measurement** 1556Tartaglia, 1572Brahe, 1581Galilei, 1617Snell, 1620Gunter, 1686Halley, 1750Mayer, 1884Hollerith. C94

> **Motion** 1450Cusa, 1500Vinci, 1787Chladni, 1872Muybridge. C95

> **Photography** 1727Schulze, 1827Niepce, 1839Daguerre, 1861Maxwell, 1882Marey. C96

> **Printing** 1453Gutenberg, 1710Blon, 1798Senefelder, 1960sFisher. C97

> **Production** 1453Gutenberg, 1710Blon, 1833Wheatstone. C98

> **Projection** 1646Kirscher, 1776Monge, 1882Marey, 1895Lumieres, 1923Zworykin, 1962Kruskal, 1960sFisher, 1969Barnard, 1985Asimov, 1985Inselberg, 1988Buja, 1988Unwin, 1989Wills, 1989Mihalisin, 1990Tierney, 1990Hurley, 1991Swayne, 1994Rao, 1996Dykes. C99

> **Recording** 1545Gemma-Frisius, 1663Wren, 1794Buxton, 1796Watt, 1800Howard, 1800Keith, 1833Wheatstone, 1872Muybridge, 1879Jevons, 1882Marey, 1929Berger, 1974Fishkeller. C9A

> **Reproduction/Copying** 1453Gutenberg, 1603Scheiner, 1710Blon. C9B

Travel 1837Harness, 1844Minard, 1879Cheysson, 1885Marey, 1888Cheysson. CA

> **Ferry** 1879Cheysson, 1885Marey. CA1

> **Rail** 1879Cheysson, 1885Marey, 1888Cheysson. CA2

> **Road** 1879Cheysson. CA3

11.2 Form F1

Apparatus 170BCparchment, 105Lun, 1453Gutenberg, 1545Gemma-Frisius, 1581Galilei, 1603Scheiner, 1623Schickard, 1646Kirscher, 1663Wren, 1822Babbage, 1827Niepce, 1833Wheatstone, 1839Daguerre, 1872Muybridge, 1882Marey, 1882Bertillon, 1884Hollerith, 1895Lumieres, 1899Galton, 1923Zworykin, 1929Berger, 1939Bush, 1944Aiken, 1944Harmon, 1957Backus, 1960sFisher, 1971Biderman. F2

Chart 134BCHipparchus, 1857Nightingale, 1917Gantt, 1925Shewhart, 1969Tukey, 1975Census, 1975Ehrenberg, 1976USCensus, 1978Becker. F21

> **Box plot** 1969Tukey, 1975Census, 1976USCensus, 1978Becker.

> **Alignment diagram** 1884Ocagne. F51

> **Area diagram** 1693aHalley, 1877Mayr, 1885Levasseur, 1896Bertillon. F52

> **Area diagram** > **Area rectangle** 1693aHalley, 1896Bertillon. F521

> **Butterfly diagram** 1904Maunder. F53

> **Chladni diagram** 1787Chladni. F55

> **Colour diagram** 1758Mayer. F56

> **Correlation diagram** 1874Galton, 1875Galton, 1979Monmonier. F57

> **Glyph** 1533Gemma-Frisius, 1928Anderson, 1957Anderson, 1966Pickett. F59

> **Glyph** > **Circular glyph** 1957Anderson. F591

> **Glyph** > **Multivariate rectangular glyph** 1928Anderson. F593

> **Glyph** > **Triangular glyph** 1533Gemma-Frisius, 1966Pickett. F594

> **Hertzsprung-Russell diagram** 1911Hertzsprung. F5A

> **International System of Typographic Picture Education** (See: Isotype) 1924Neurath, 1933Unknown. F5B

> **Isotype** 1924Neurath, 1933Unknown. F5C

> **Lexis diagram** 1875Lexis. F5D

> **Lexis pencil** 1875Lexis, 1990Keiding. F5E

> **Mechanical diagram** 1305Llull. F5F

> **Nomogram** 1795Pouchet, 1846Lalanne, 1885Lallemand, 1928Henderson. F5G

> **Nomogram** > **Multifunction nomogram** 1885Lallemand. F5G3

> **Path diagram** 1920Wright. F5H

> **Polar diagram** 1877aMayr. F5J

> **Proportional** 1782Fourcroy, 1851Minard, 1877Mayr. F5K

> **Proportional** > **Proportional circle** 1851Minard. F5K1

> **Proportional** > **Proportional divided square** 1877Mayr. F5K2

> **Rectangle** 1977Wainer, 1983Riedwyl, 1991Shneiderman. F5L

> **Square** 1782Fourcroy, 1785Crome, 1811Humboldt, 1874Walker, 1877Mayr. F5N

> **Square** > **Superimposed square** 1782Fourcroy, 1785Crome, 1811Humboldt. F5N1

> **Stereogram** 1869Zeuner, 1879Perozzo. F5O

> **Textured dot strip diagram** 1990Tukey. F5P

> **Treemap** 1991Shneiderman. F5Q

> **Triangular diagram** 1280Llull. F5R

> **Historical** > **Historical committee** 1872USCongress, 1872USCensus, 1914Engineers, 1915Association, 1973Barabba. F822

> **Historical** > **Historical conference** 1853ISI, 1857ISI, 1857aISI, 1872Schwabe, 1911Roesle. F823

> **Historical** > **Historical group** 1885Levasseur, 1901ISI, 1924Neurath, 1977Association. F825

> **Historical** > **Historical group** > **International Statistical Institute** 1901ISI. F8251

> **Historical** > **Historical test** 1727Schulze, 1975Ehrenberg. F827

> **Time line** (See: Timeline) 1753Barbeu-Dubourg, 1765Priestley. F83

> **Timeline** 1753Barbeu-Dubourg, 1765Priestley. F84

Line 1765Lambert, 1885Galton, 1913Hazen, 1975Ehrenberg. F9

> **Line between two points** 1885Galton. F9A

> **Tangent line** 1885Galton. F9K

Map 6200BCUnknown, 550BCMiletus, 335BCPeutinger, 150Ptolemy, 1375Cresques, 1556Tartaglia, 1569Mercator, 1570Ortelius, 1603Nautonier, 1654Petty, 1686aHalley, 1701Halley, 1752Buache, 1778Charpentier, 1782Crome, 1782Carla-Boniface, 1798Senefelder, 1798Seaman, 1801Smith, 1817Humboldt, 1819Dupin, 1830Montizon, 1833Guerry, 1833Scrope, 1836Angeville, 1836Parent-Duchatelet, 1837Harness, 1838Berghaus, 1843Lalanne, 1843Pritchard, 1851Minard, 1855Snow, 1857aISI, 1861Galton, 1869Minard, 1872USCensus, 1874Vauthier, 1874Mayr, 1879Cheysson, 1885Lallemand, 1888Cheysson, 1960sFisher, 1982Monmonier, 1989Wills, 1996Dykes. FB

> **Atlas** 335BCPeutinger, 1375Cresques, 1570Ortelius, 1838Berghaus. FB1

> **Projection** 150Ptolemy, 1569Mercator. FB3

> **Projection** > **Cylindrical projection** 1569Mercator. FB32

> **Scope** 550BCMiletus, 335BCPeutinger, 1375Cresques, 1603Nautonier, 1654Petty, 1686aHalley, 1752Buache, 1782Crome, 1833Scrope, 1837Harness, 1843Pritchard, 1874Mayr, 1982Monmonier. FB4

> **Scope** > **Continent** 1782Crome. FB41

> **Scope** > **Country** 335BCPeutinger, 1837Harness, 1874Mayr, 1982Monmonier. FB42

> **Scope** > **Town** 6200BCUnknown. FB44

> **Scope** > **World** 550BCMiletus, 1375Cresques, 1603Nautonier, 1686aHalley, 1752Buache, 1833Scrope, 1843Pritchard. FB45

> **Thematic map** 1375Cresques, 1603Nautonier, 1701Halley, 1752Buache, 1782Crome, 1782Carla-Boniface, 1798Seaman, 1801Smith, 1817Humboldt, 1819Dupin, 1830Montizon, 1833Guerry, 1833Scrope, 1836Parent-Duchatelet, 1837Harness, 1843Lalanne, 1855Snow, 1857aISI, 1861Galton, 1869Minard, 1872USCensus, 1874Vauthier, 1874Mayr, 1879Cheysson, 1888Cheysson, 1960sFisher, 1982Monmonier. FB5

> **Thematic map** > **Anamorphic map** 1888Cheysson. FB51

> **Thematic map** > **Chloropleth** 1798Seaman, 1819Dupin, 1833Guerry, 1857aISI, 1872USCensus, 1960sFisher. FB52

FB521

> **Thematic map** > **Chloropleth** > **Cartogram** 1819Dupin, 1857aISI, 1872USCensus.

FB53

> **Thematic map** > **Dasymetric map** 1833Scrope.

FB54

> **Thematic map** > **Dot map** 1830Montizon, 1855Snow.

FB55

> **Thematic map** > **Flow map** 1837Harness, 1869Minard, 1879Cheysson.

FB57

> **Thematic map** > **Isarithmic map** 1701Halley, 1752Buache, 1817Humboldt, 1843Lalanne, 1874Vauthier.

FB571

> **Thematic map** > **Isarithmic map** > **Contour map** (See: Isograph) 1701Halley, 1752Buache, 1843Lalanne, 1874Vauthier.

FB572

> **Thematic map** > **Isarithmic map** > **Isogram** (See: Isograph) 1701Halley, 1752Buache, 1843Lalanne, 1874Vauthier.

FB573

> **Thematic map** > **Isarithmic map** > **Isograph** 1701Halley, 1752Buache, 1817Humboldt, 1843Lalanne, 1874Vauthier.

FB574

> **Thematic map** > **Isarithmic map** > **Isopleth** 1817Humboldt, 1874Vauthier.

FB59

> **Thematic map** > **Proportional Symbol** 1861Galton.

FB5B

> **Thematic map** > **Two-variable map** 1874Mayr.

FB5C

> **Thematic map** > **Visibility base map** 1982Monmonier.

FC

Mathematics 240BCEratosthenes, 1533Gemma-Frisius, 1550Rheticus, 1663Cardano, 1600sUnknown, 1614Napier, 1617Snell, 1620Gunter, 1632Galilei, 1637Fermat, 1654Pascal, 1657Huygens, 1669Huygens, 1687Petty, 1693aHalley, 1711Arbuthnot, 1741Sussmilch, 1748Achenwall, 1750Mayer, 1763Bayes, 1765Lambert, 1776Monge, 1809Gauss, 1825Gompertz, 1846Lalanne, 1875Galton, 1878Sylvester, 1884Ocagne, 1885Galton, 1913Moseley, 1915Fisher, 1944Harmon, 1965Tukey, 1969Tukey, 1969Fowlkes, 1974USCensus, 1979Monmonier, 1985Asimov.

FC2

> **Atomic number** 1913Moseley.

FC6

> **Geometry** 240BCEratosthenes, 1637Fermat, 1776Monge, 1884Ocagne.

FC61

> **Geometry** > **Analytic Geometry** 1637Fermat.

FC62

> **Geometry** > **Descriptive Geometry** 240BCEratosthenes, 1776Monge.

FC7

> **Matrix** 1878Sylvester, 1974USCensus.

FC8

> **Statistics** 1533Gemma-Frisius, 1663Cardano, 1600sUnknown, 1614Napier, 1617Snell, 1620Gunter, 1632Galilei, 1654Pascal, 1657Huygens, 1669Huygens, 1687Petty, 1693aHalley, 1711Arbuthnot, 1741Sussmilch, 1748Achenwall, 1750Mayer, 1763Bayes, 1765Lambert, 1809Gauss, 1825Gompertz, 1846Lalanne, 1875Galton, 1877Bowditch, 1885Galton, 1915Fisher, 1944Harmon, 1965Tukey, 1969Tukey, 1969Fowlkes, 1979Monmonier, 1985Asimov.

FC83

> **Statistics** > **Quantitative statistics** 1663Cardano, 1614Napier, 1620Gunter, 1654Pascal, 1657Huygens, 1669Huygens, 1693aHalley, 1711Arbuthnot, 1750Mayer, 1765Lambert, 1809Gauss, 1825Gompertz, 1846Lalanne, 1875Galton, 1877Bowditch, 1885Galton, 1915Fisher, 1969Fowlkes, 1975Cleveland.

FC831

> **Statistics** > **Quantitative statistics** > **Beta density** 1763Bayes.

> **Bivariate plot** 1686Halley. FF1

> **Chernoff face** (See: Face plot) 1973Chernoff, 1975Chernoff. FF2

> **Conditional plot** 1981Tukey. FF3

> **Coplot** 1981Tukey. FF4

> **Face plot** 1973Chernoff, 1975Chernoff. FF6

> **Fourier function plot** 1972Andrews. FF7

> **Frequency polygon** 1874Walker. FF8

> **Irregular polygon** (See: Star plot) 1971Siegel. FF9

> **Log-log plot** 1846Lalanne, 1911Hertzsprung. FFA

> **Logarithmic plot** (See: Log-log plot) 1846Lalanne, 1911Hertzsprung. FFB

> **Mosaic display** (See: Mosaic plot) 1844Minard, 1874Walker, 1879Cheysson, 1989Mihalisin, 1991Friendly. FFC

> **Mosaic plot** 1844Minard, 1874Walker, 1879Cheysson, 1989Mihalisin, 1991Friendly. FFD

> **Parallel coordinates plot** 1884Ocagne, 1990Wegman. FFE

> **Star plot** 1877aMayr, 1971Siegel. FFF

> **Stem-leaf plot** 1767Lambert, 1969Tukey. FFG

> **Trellis display** 1981Tukey, 1989Mihalisin. FFH

Table 1450Cusa, 1550Rheticus, 1600sUnknown, 1603Nautonier, 1614Napier, 1662Graunt, 1666Talon, 1669Huygens, 1671Witt, 1686Halley, 1693Halley, 1760Lambert, 1765Lambert, 1779Lambert, 1795Pouchet, 1822Babbage, 1828Quetelet, 1833aGuerry, 1836Parent-Duchatelet, 1838Berghaus, 1843Lalanne, 1869Mendeleev, 1913Moseley, 1930vonFoerster, 1975Fienberg, 1975Ehrenberg, 1977Wainer, 1983Riedwyl, 1994Rao, 1996Dykes. FG

> **2 x 2 table** 1975Fienberg, 1977Wainer. FG1

> **Contingency table** 1983Riedwyl. FG2

> **Empirical data table** 1600sUnknown. FG4

> **Logarithmic table** 1614Napier. FG5

> **Mathematical table** 1822Babbage. FG6

> **Multiplication table** 1795Pouchet. FG7

> **Periodic table** 1869Mendeleev, 1913Moseley. FG8

> **Trigonometric table** 1550Rheticus. FG9

> **Bivariate data** 1450Cusa, 1686Halley, 1796Watt, 1896Bertillon, 1975Fienberg, 1979Monmonier. FGB

> **Categorical data** 1983Riedwyl, 1991Friendly, 1992Friendly. FGC

> **Empirical data** 1600sUnknown, 1686Halley, 1760Lambert, 1767Lambert, 1828Quetelet. FGE

> **Multivariate data** 1928Anderson, 1957Anderson, 1966Pickett, 1969Barnard, 1971Siegel, 1972Andrews, 1973Chernoff, 1985Asimov, 1985Inselberg, 1987Becker, 1988Buja, 1989Mihalisin, 1990Hurley, 1990Keiding, 1990Wegman. FGG

> **Ordinal data** 1833aGuerry. FGI

> **Time series data** 1450Cusa, 1836Parent-Duchatelet, 1988Unwin. FGK

Visual 1626Scheiner, 1644Langren, 1710Blon, 1752Euler, 1758Mayer, 1787Chladni, 1843Lalanne, 1861Maxwell, 1869Zeuner, 1874Mayr, 1879Perozzo, 1919Ayres, 1960sFisher, 1974USCensus, 1974Fishkeller, 1978Newton, 1982McDonald, 1982Monmonier, 1983Tufte, 1985Asimov, 1987Becker, 1988Buja, 1988Unwin, 1989Wills, 1989Mihalisin, 1990Tierney, 1990Hurley, 1991Friendly, 1991Swayne, 1994Rao. FH

> **Colour** 1710Blon, 1758Mayer, 1819Dupin, 1861Maxwell, 1874Mayr, 1974USCensus, 1981Furnas. FH1

> **Colour** > **Black and white** 1819Dupin. FH11

> **Colour** > **Colour** 1758Mayer, 1874Mayr, 1974USCensus, 1981Furnas. FH12

> **Colour** > **Trichromatic process** 1710Blon, 1861Maxwell. FH13

> **Display** 1626Scheiner, 1919Ayres, 1981Tukey, 1983Tufte. FH2

> **Display** > **Data-ink ratio** 1983Tufte. FH21

> **Display** > **Lie Factor** 1983Tufte. FH23

> **Display** > **Semi-graphic display** 1919Ayres. FH25

> **Display** > **Small multiples** 1626Scheiner. FH26

> **Dynamic** 1962Kruskal, 1990Tierney. FH3

> **Interactive** 1969Fowlkes, 1974Fishkeller, 1978Newton, 1982McDonald, 1987Becker, 1988Buja, 1988Unwin, 1989Wills, 1990Hurley, 1991Swayne, 1994Rao. FH4

> **Interactive** > **Brushing** 1978Newton, 1982McDonald, 1987Becker, 1988Buja. FH41

> **Interactive** > **Linking** 1978Newton, 1987Becker, 1988Buja. FH42

> **Orientation** 1752Euler, 1758Mayer, 1843Lalanne, 1869Zeuner, 1879Perozzo, 1974Fishkeller, 1982McDonald, 1982Monmonier, 1985Asimov, 1989Mihalisin. FH5

> **Orientation** > **1-D** 1982Monmonier. FH51

> **Orientation** > **2-D** 1758Mayer, 1985Asimov, 1991Friendly. FH52

> **Orientation** > **3-D** 1752Euler, 1758Mayer, 1843Lalanne, 1869Zeuner, 1879Perozzo, 1974Fishkeller, 1982McDonald. FH53

References

A few items in this reference list are identified by shelfmarks or call numbers in the following libraries: BL: British Library, London; BNF: Bibliothèque Nationale de France, Paris (Tolbiac); ENPC: École Nationale des Ponts et Chaussées, Paris; LC: Library of Congress; SBB: Staatsbibliothek zu Berlin.

[1] Abbott, Edwin A. (1884). *Flatland: A Romance of Many Dimensions*. Cutchogue, NY: Buccaneer Books. (1976 reprint of the 1884 edition). 25

[2] Achenwall, Gottfried (1749). *Staatsverfassung der heutigen vornehmsten europäischen Reiche und Völker im Grundrisse*. n.p. 12

[3] Anderson, Edgar (1928). The problem of species in the northern blue flags, iris versicolor l. and iris virginica l. *Annals of the Missouri Botanical Garden*, *13*:241–313. 30

[4] Anderson, Edgar (1957). A semigraphical method for the analysis of complex problems. *Proceedings of the National Academy of Sciences*, *13*(3):923–927. Reprinted in *Technometrics*, 2:387–391 (August 1960). 32

[5] Andrews, David F. (1972). Plots of high dimensional data. *Biometrics*, *28*:125–136. 34

[6] d'Angeville, Adolphe (1836). *Essai sur la Statistique de la Population française*. Bourg-en-Bresse: F. Doufour. (Reprinted: Paris, Maison des Sciences de l'Homme, vol. VI. Mouton, Paris-La Haye, 1969.). 18

[7] Arbuthnot, John (1710). An argument for devine providence, taken from the constant regularity observ'd in the births of both sexes. *Philosophical Transactions*, *27*:186–190. Published in 1711. 11

[8] Asimov, D. (1985). Grand tour. *SIAM Journal of Scientific and Statistical Computing*, *6*(1):128–143. 37

[9] Ayres, Leonard Porter (1919). *The War with Germany, A Statistical Summary*. Washington, D.C.: U.S. Government Printing Office. ISBN 040511852X. Commonly known as the *Ayres report*; reprinted: Arno Press, NY, 1979. 27, 29

[10] Babcock, B. E. (1994). Some notes on the history and use of Gunter's scale. *Journal of the Oughtred Society*, *3*:14–20. 8

[11] Bachi, Roberto (1968). *Graphical Rational Patterns, A New Approach to Graphical Presentation of Statistics*. Jerusalem: Israel Universities Press. 33

[12] Balbi, Adriano and Guerry, André-Michel (1829). Statistique comparée de l'état de l'instruction et du nombre des crimes dans les divers arrondissements des académies et des cours royales de France. Jules Renouard, Paris. BL:Tab.597.b.(38); BNF: Ge C 9014 . 17

[13] Ball, W. W. Rouse (1908). *A Short Account of the History of Mathematics*. London: Macmillan & Co., 4th edn. (re-published in 1960, N.Y.: Dover). 9

[14] Barnard, George (1969). Summary remarks. In N. L. Johnson and Jr. H. Smith, eds., *New Developments in Survey Sampling*, pp. 696–711. New York: Wiley-Interscience. 34

[15] Bayes, Thomas (1763). Essay towards solving a problem in the doctrine of chances. *Philosophical Transactions*, *53*:370–418. URL `http://www.jstor.org/cgi-bin/jstor/viewitem/02607085/ap000041/00a00520/0`. 13

[16] Becker, Richard A. (1994). A brief history of S. In P. Dirschedl and R. Ostermann, eds., *Computational Statistics*, pp. 81–110. Heidelberg: Physica Verlag. 32, 36

[17] Becker, Richard A. and Chambers, J. M. (1984). *An Interactive Environment for Data Analysis and Graphics*. Bellmont, CA: Wadsworth. ISBN 053403313-X. 36

[18] Becker, Richard A. and Chambers, John M. (1978). 's': A language and system for data analysis. Tech. rep., Bell Laboratories. (described version 2 of S). 36

[19] Becker, Richard A. and Cleveland, William S. (1987). Brushing scatterplots. *Technometrics*, *29*:127–142. 37

[20] Bellhouse, D. R. (1989). A manuscript on chance written by John Arbuthnot. *International Statistical Review*, *57*(3):249–259. 11

[21] Beniger, J. R. and Robyn, D. L. (1978). Quantitative graphics in statistics: A brief history. *The American Statistician*, *32*:1–11. 3

[22] Bennett, J. A. (1982). *The Mathematical Science of Christopher Wren*. Cambridge, UK: Cambridge University Press. 9

[23] Bennett, J. H., ed. (1989). *Statistical Inference and Analysis : Selected Correspondence of R. A. Fisher*. Oxford, UK: Oxford University Press. 29

[24] Berghaus, Heinrich (1838). *Physikalischer Atlas*. Gotha: Justus Perthes. 2 vols., published 1845–48. 18

[25] Bertillon, Jacques (1896). Fréquence des étrangers à Paris en 1891. In *Cours élementaire de statistique administrative*. Paris: Societé d'éditions scientifiques. (map). 27

[26] Bertin, Jacques (1967). *Sémiologie Graphique: Les diagrammes, les réseaux, les cartes*. Paris: Gauthier-Villars. 22, 32, 33

[27] Bertin, Jacques (1983). *Semiology of Graphics*. Madison, WI: University of Wisconsin Press. (trans. W. Berg). 33

[28] Biderman, Albert D. (1971). Kinostatistics for social indicators. *Educational Broadcasting Review*, *5*:13–19. 34

[29] Booth, Charles (1889). *Charles Booth's descriptive map of London poverty 1889 by Charles Booth; introduction by David A. Reeder.* London: London Topographical Society, 1984. BL: Maps 182.c.1 Facsimile of maps published in Labour and Life of the People, Appendix to vol. II, 1891. 26

[30] Booth, Charles (1889). *Labour and Life of the People*. London: Macmillan and Co. (2 volumes, plus maps under separate cover; expanded to 17 volumes in 1902 edition). 26

[31] Bowditch, Henry Pickering (1877). The growth of children. Tech. Rep. 8, Board of Health of Massachusetts. Reprinted in "Papers on Anthropometry", Boston, 1894. 23

[32] Boyer, Carl B. (1947). Note on an early graph of statistical data (huygens 1669). *Isis*, *37*(3/4):148–149. ISSN 0021-1753. URL `http://www.jstor.org/view/00211753/ap010065/01a00060/0`. 10

[33] Brinton, Willard C. (1914). *Graphic Methods for Presenting Facts*. New York: The Engineering Magazine Company. ISBN 0405135041. Xi, 371 p. : ill. ; 24 cm.; reprinted: Arno Press, NY, 1980. 28, 29

[34] Brock, William H. and Price, Michael H. (1980). Squared paper in the nineteenth century: Instrument of science and engineering, and symbol of reform in mathematical education. *Educational Studies in Mathematics*, *11*(4):365–381. ISSN 0013-1954. 18

[35] Buache, Phillippe (1752). Essai de géographie physique. *Mémoires de L'Académie Royale des Sciences*, pp. 399–416. BNF: Ge.FF-8816-8822. 12

[36] Buja, Andreas, Asimov, Daniel, Hurley, Catherine and McDonald, John A. (1988). Elements of a viewing pipeline for data analysis. In William S. Cleveland and M. E. McGill, eds., *Dynamic Graphics for Statistics*. Pacific Grove, CA: Brooks/Cole. 37

[37] Buja, Andreas, Cook, Di and Swayne, Deborah F. (1996). Interactive high-dimensional data visualization. *Journal of Computational and Graphical Statistics*, *5*(1):78–99. URL http://www.research.att.com/~andreas/xgobi/papers/xgobi96.pdf. 38

[38] Bumstead, H. A., ed. (1961). *The Scientific Papers of J. Willard Gibbs*. New York: Dover Publications, Inc. (an unabridged republication of the work originally published by Longmans, Green and Company in 1906). 22, 59

[39] Cardano, Gerolamo (1663). *Liber de Ludo Alaea*. Milan: n.p. Trans. Sidney Henry Gould, 1961, New York: Holt, Rinehart & Winston. 6

[40] du Carla-Boniface, Marcellin (1782). Expression des nivellements; ou, méthode nouvelle pour marquer sur les cartes terrestres et marines les hauteurs et les configurations du terrain. URL http://ucpj.uchicago.edu/Isis/journal/demo/v000n000/000000/000000.fg15.html. In François de Dainville, "From the Depths to the Heights," translated by Arthur H. Robinson, *Surveying and Mapping*, 1970, 30:389–403, on page 396. 14

[41] von Charpentier, Johann F. W. T. (1778). *Mineralogische Geographie Der Chursachsischen Lande*. Leipzig: Crusius. 13

[42] Chernoff, Herman (1973). The use of faces to represent points in k-dimensional space graphically. *Journal of the American Statistical Association*, *68*:361–368. 34

[43] Chernoff, Herman and Rizvi, M. H. (1975). Effect on classification error of random permutations of features in representing multivariate data by faces. *Journal of the American Statistical Association*, *70*:548–554. 35

[44] Cheysson, Émile (1878). Les méthodes de statistique graphique à l'exposition universelle de 1878. *Journal de la Société de Statistique de Paris*, *12*:323–333. URL http://www.lsp.ups-tlse.fr/Fp/Falguerolles/FACSIMILE/cheysson.pdf. 22

[45] Chladni, Ernest Florens Friedrich (1787). *Entdeckungen uber die Theorie des Klanges*. Leipzig: Bey Weidmanns Erben und Reich. 14

[46] Chrisman, N. (1988). The risks of software innovation: A case study of the harvard lab. *The American Cartographer*, *15*(3):291–300. 33

[47] Cleveland, William S. and Kleiner, Beat (1975). A graphical technique for enhancing scatterpiots with moving statistics. In *Proceedings of the Annual Meeting*. Atlanta, GA: American Statistical Association. 35

[48] Costelloe, Martin F. P. (1915). Graphic methods and the presentation of this subject to first year college students. *Nebraska Blue Print*. 27, 28

[49] Crome, August F. W. (1782). *Producten-Karte von Europa*. Dessau: (self published). 13

[50] Crome, August F. W. (1785). *Über die Grösse and Bevölkerung der Sämtlichen Europäschen Staaten*. Leipzig: Weygand. 14

[51] Croxton, F. E. (1927). Further studies in the graphic use of circles and bars. *Journal of the American Statistical Association*, *22*:36–39. 30

[52] Croxton, F. E. and Stein, H. (1932). Graphic comparisons by bars, squares, circles and cubes. *Journal of the American Statistical Association*, *27*:54–60. 30

[53] Croxton, F. E. and Stryker, R. E. (1927). Bar charts versus circle diagrams. *Journal of the American Statistical Association*, *22*:473–482. 30

[54] Cruquius, Nicolaus Samuel (1724). Observationes accuratae captae ... circa mediam barometri altitudinem, mediam thermometri elevationem, tum et hydrometri varietatem mediam, etc. *Philosophical Transactions*, pp. 4–7. 11

[55] Dahlke, Richard, Fakler, Robert A. and Morash, Ronald P. (1989). A sketch of the history of probability theory. *Mathematics Education*, *4*:218–232. 6

[56] Dainville, François de (1970). Les bases d'une cartographie industrielle de l'europe au xix^e siècle. Tech. Rep. 540, Centre National de la Recherch Scientifique, Lyon. Colloques Internationaux du C.N.R.S. 18, 19

[57] De Moivre, Abraham (1733). Approximatio ad summam terminorum binomii a $(a + b)^n$ in seriem expansi. Reproduced in Archibald, 1926. 11

[58] De Moivre, Abraham (1738). *The Doctrine of Chances*. London: Woodfall, 2nd edn. 3rd ed. online at http://www.ibiblio.org/chance/. 11

[59] Descartes, Réne (1637). La géométrie. In *Discours de la Méthode*. Paris: Essellier. (Appendix). 8

[60] Dupin, Charles (1826). *Carte figurative de l'instruction populaire de la France*. Jobard. BNF: Ge C 6588 (Funkhouser (1937, p. 300) incorrectly dates this as 1819). 16, 17

[61] Dupin, Charles (1827). *Forces productives et commerciales de la France*. Bachelier. 16

[62] Dykes, J. A. (1996). Dynamic maps for spatial science, a unified approach to cartographic visualization. In D. Parker, ed., *Innovations in GIS 3*, pp. 177–187. London: Taylor & Francis. 39

[63] Eells, W. C. (1926). The relative merits of circles and bars for representing component parts. *Journal of the American Statistical Association*, *21*:119–132. URL http://www.jstor.org/cgi-bin/jstor/viewitem/01621459/di985710/98p04715/0. 27, 30

[64] Ehrenberg, A. S. C. (1975). Numerical information processing project, London Graduate School of Business Studies. Unpublished personal communication. 35

[65] Ehrenberg, A.S.C (1977). The rudiments of numeracy. *Journal of the Royal Statistical Society, Series A*, *140*:277–297. 35

[66] Eick, S. G. (1994). Graphically displaying text. *Journal of Computational and Graphical Statistics*, *3*:127–142. 2

[67] Euler, Leonhard (1752). Decouverte d'un nouveau principe de mecanique. *Mémoires de l'académie des sciences de Berlin*, *6*:185–217. 12

[68] Executive Office of the President, Office of Management and Budget (1973). *Social Indicators 1973*. Washington, D.C.: U.S. Government Printing Office. 34

[69] Farebrother, R. W. (1999). *Fitting Linear Relationships: A History of the Calculus of Observations 1750–1900*. New York: Springer. ISBN 0-387-98598-0. 3, 12

[70] Ferguson, S. (1991). The 1753 carte chronographique of Jacques Barbeu-Dubourg. *Princeton University Library Chronicle*, *52*:190–230. 12

[71] Fienberg, Stephen E. (1975). Perspective Canada as a social report. Tech. rep., Department of Applied Statistics, University of Minnesota. Unpublished paper. 35

[72] Fisher, Ronald Alymer (1915). Frequency distribution of the values of the correlation coefficient in samples from an indefinitely large population. *Biometrika*, *10*:507–521. URL http://www.library.adelaide.edu.au/digitised/fisher/4.pdf. 29

[73] Fisher, Ronald Alymer (1915). Theory of statistical estimation. *Proceedings of the Cambridge Philosophical Society*, *22*:700–725. URL http://www.library.adelaide.edu.au/digitised/fisher/42.pdf. 29

[74] Fishkeller, M. A., Friedman, J. H. and Tukey, John Wilder (1974). PRIM-9: An interactive multidimensional data display and analysis system. Tech. Rep. SLAC-PUB-1408, Stanford Linear Accelerator Center, Stanford, CA. 34

[75] Fishkeller, M. A., Friedman, J. H. and Tukey, John Wilder (1974). PRIM-9, an interactive multidimensional data display and analysis system. In *Proceedings of the Pacific ACM Regional Conference*. 34

[76] Fourcroy, Charles de (1782). *Essai d'une table poléométrique, ou amusement d'un amateur de plans sur la grandeur de quelques villes*. Paris: Dupain-Triel. 14

[77] Fourier, Jean Baptiste Joseph (1821). Notions generales, sur la population. *Recherches Statistiques sur la Ville de Paris et le Departement de la Seine*, *1*:1–70. 16

[78] Fowlkes, E. B. (1969). User's manual for a system for interactive probability plotting on Graphic-2. Tech. rep., Bell Laboratories. 34

[79] Friendly, M. (2007). A brief history of data visualization. In C. Chen, Wolfgang Härdle and Antony Unwin, eds., *Handbook of Computational Statistics: Data Visualization*, vol. III, chap. 1, pp. 1–34. Heidelberg: Springer-Verlag. ISBN 978-3-540-32825-4. 3

[80] Friendly, Michael (1992). Graphical methods for categorical data. *Proceedings of the SAS User's Group International Conference*, *17*:1367–1373. 39

[81] Friendly, Michael (1994). A fourfold display for 2 by 2 by K tables. Tech. Rep. 217, York University, Psychology Dept. URL http://hotspur.psych.yorku.ca/ftp/papers/4fold.ps.gz. 35

[82] Friendly, Michael (1994). Mosaic displays for multi-way contingency tables. *Journal of the American Statistical Association*, *89*:190–200. 38

[83] Friendly, Michael (2000). *Visualizing Categorical Data*. Cary, NC: SAS Institute. ISBN 1-58025-660-0. 39

[84] Friendly, Michael (2002). A brief history of the mosaic display. *Journal of Computational and Graphical Statistics*, *11*(1):89–107. URL http://www.math.yorku.ca/SCS/Papers/moshist.pdf. 36

[85] Friendly, Michael and Denis, Dan (2000). The roots and branches of statistical graphics. *Journal de la Société Française de Statistique*, *141*(4):51–60. (published in 2001). 27, 31

[86] Friendly, Michael and Fox, John (1991). Interpreting higher order interactions in loglinear analysis: A picture is worth 1000 words. Tech. rep., Institute for Social Research, York University, Toronto, CA. 38

[87] Friendly, Michael and Palsky, Gilles (2007). Visualizing nature and society. In James R. Ackerman and Robert W. Karrow, eds., *Maps: Finding Our Place in the World*, pp. 205–251. Chicago, IL: University of Chicago Press. 3

[88] Friis, H. R. (1974). Statistical cartography in the United States prior to 1870 and the role of Joseph C. G. Kennedy and the U.S. Census Office. *American Cartographer*, *1*:131–157. 3

[89] Frisius, R. Gemma (1530). Principiis astronomiae cosmographicae. 6

[90] Frisius, R. Gemma (1533). Libellus de locorum describendorum ratione. Antwerp. 6

[91] Funkhouser, H. Gray (1936). A note on a tenth century graph. *Osiris*, *1*:260–262. URL http://tinyurl.com/2czmqc. 3, 5

[92] Funkhouser, H. Gray (1937). Historical development of the graphical representation of statistical data. *Osiris*, *3*(1):269–405. URL http://tinyurl.com/32ema9. Reprinted Brugge, Belgium: St. Catherine Press, 1937. 3, 16, 20, 25, 27, 31

[93] Furnas, George W. (1981). The fisheye view: A new look at structured files. Tech. Rep. Technical Memorandum 81-11221-9, Bell Labs. URL http://www.si.umich.edu/~furnas/POSTSCRIPTS/FisheyeOriginalTM.ps. 36

[94] Gabriel, K. Rubin (1971). The biplot graphic display of matrices with application to principal components analysis. *Biometrics*, *58*(3):453–467. 34

[95] Galelei, Galileo (1610). *Sidereus Nuncius [The Starry Messenger]*. Venice, Italy: (n.p.). URL http://imgbase-scd-ulp.u-strasbg.fr/displayimage.php?album=47&pos=0. 7

[96] Galilei, Galileo (1632). *Dialogo sopra i due massimi sistemi del mondo, Tolemaico, e Copernicano (Dialog concerning the Two Chief World Systems— Ptolemaic and Copernican)*. Pisa: n.p. (English translation by S. Drake, 1953 (2nd ed., 1967), Berkeley, CA: Univ. California Press). 8

[97] Galton, Francis (1861). Meteorological charts. *Philosophical Magazine*, *22*:34–35. URL http://www.mugu.com/galton/essays/galton-1861-charts.pdf. 21

[98] Galton, Francis (1870). Barometric predictions of weather. *Nature*, *2*:501–503. URL http://www.mugu.com/galton/essays/galton-barometric-predictions.pdf. 21

[99] Galton, Francis (1886). Regression towards mediocrity in hereditary stature. *Journal of the Anthropological Institute*, *15*:246–263. URL http://www.jstor.org/cgi-bin/jstor/viewitem/09595295/dm995266/99p0374f/0. 25

[100] Galton, Francis (1899). A geometric determination of the median value of a system of normal variants from two of its centiles. *Nature*, *16*:102–104. 27

[101] Gantt, Henry L. (1919). *Organizing for work*. New York: Harcourt, Brace & Rowe. 27, 29

[102] Gauss, Johann Carl Friedrich (1809). *Theoria motus corporum coelestium in sectionibus conicis solem ambientum*. Hamburg: n.p. 15

[103] Gemma-Frisius, Reinerus (1545). *De Radio Astronomica et Geometrica*. Louvain: (n.p.). 6

[104] Gibbs, Josiah Willard (1873). Graphical methods in the thermodynamics of fluids. *Transactions of the Connecticut Academy of Arts and Sciences*, *2*:309–342. Reprinted in [38]. 22

[105] Gibbs, Josiah Willard (1873). A method of geometrical representation of the thermodynamic properties of substances by means of surfaces. *Transactions of the Connecticut Academy of Arts and Sciences*, *2*:382–404. Reprinted in [38]. 22

[106] Gilbert, E. W. (1958). Pioneer maps of health and disease in England. *Geographical Journal*, *124*:172–183. 20

[107] Gilman, S. (1917). Graphic charts for the business man. Chicago. 27

[108] Godfrey, Ernest H. (1918). History and development of statistics in Canada. In John Koren, ed., *History of Statistics, their Development and Progress in Many Countries*, pp. 179–198. New York: Macmillan. 10

[109] Gompertz, Benjamin (1825). On the nature of the functions expressive of the law of human mortality, and on a new mode of determining the value of life contingencies. *Philosophical Transactions*, *115*:513–585. 16

[110] Graunt, John (1662). *Natural and Political Observations Mentioned in a Following Index and Made Upon the Bills of Mortality*. London: Martin, Allestry, and Dicas. 9

[111] Gribbin, John and Gribbin, Mary (2000). *Stardust: Supernovae and Life: The Cosmic Connection*. New Haven: Yale University Press. 19

[112] Guerry, André-Michel (1829). Tableau des variations météorologique comparées aux phénomènes physiologiques, d'aprés les observations faites à l'obervatoire royal, et les recherches statistique les plus récentes. *Annales d'Hygiène Publique et de Médecine Légale*, *1*:228–. 17

[113] Guerry, André-Michel (1832). *Statistique comparée de l'état de l'instruction et du nombre des crimes*. Paris: Everat. URL ftp://ftp.bnf.fr/010/N0104035_PDF_1_13.pdf. 17

[114] Guerry, André-Michel (1833). *Essai sur la statistique morale de la France*. Paris: Crochard. ISBN 0-7734-7045-X. English translation: Hugh P. Whitt and Victor W. Reinking, Lewiston, N.Y. : Edwin Mellen Press, 2002. 18, 20

[115] Gunter, Edmund (1624). Description and use of the sector, the crosse-staffe and other instruments. 8

[116] Hald, A. (1990). *A History of Probability and Statistics and their Application before 1750*. New York: John Wiley and Sons. 3, 8, 10

[117] Halley, Edmund (1686). An historical account of the trade winds, and monsoons, observable in the seas between and near the tropicks, with an attempt to assign the phisical cause of the said wind. *Philosophical Transactions*, *16*:153–168. URL http://www.jstor.org/view/02607085/ap000004/00a00260/0. 10

[118] Halley, Edmund (1686). On the height of the mercury in the barometer at different elevations above the surface of the earth, and on the rising and falling of the mercury on the change of weather. *Philosophical Transactions*, *16*:104–115. 10

[119] Halley, Edmund (1693). An estimate of the degrees of mortality of mankind, drawn from curious tables of the births and funerals at the city of Breslaw, with an attempt to ascertain the price of annuities on lives. *Philosophical Transactions*, *17*:596–610. URL http://www.pierre-marteau.com/editions/1693-mortality.html. 10

[120] Halley, Edmund (1701). The description and uses of a new, and correct sea-chart of the whole world, shewing variations of the compass. London. 11

[121] Hankins, Thomas L. (1999). Blood, dirt, and nomograms: A particular history of graphs. *Isis*, *90*:50–80. 3, 13, 25

[122] Hankins, Thomas L. (2006). A "large and graceful sinuosity": John Herschel's graphical method. *Isis*, *97*:605–633. URL http://www.journals.uchicago.edu/cgi-bin/resolve?id=doi:10.1086/509946. 18

[123] Harness, Henry D. (1838). *Atlas to Accompany the Second Report of the Railway Commissioners, Ireland*. Dublin: H.M.S.O. (a) Map showing the relative number of passengers in different directions by regular public conveyances, 80 x 64 cm; (b) map showing the relative quantities of traffic in different directions, 80 x 64 cm; (c) map showing by varieties of shading the comparative density of the population, 80 x 64 cm. 18

[124] Harris, Moses (1766). *The natural system of colours*, chap. Prismatic color mixture system. Licester-Fields: Laidler. 12

[125] Hartigan, John A. (1975). Printer graphics for clustering. *Journal of Statistical Computing and Simulation*, *4*:187–213. 35

[126] Hartigan, John A. and Kleiner, Beat (1981). Mosaics for contingency tables. In W. F. Eddy, ed., *Computer Science and Statistics: Proceedings of the 13th Symposium on the Interface*, pp. 268–273. New York, NY: Springer-Verlag. 36

[127] Hartigan, John A. and Kleiner, Beat (1984). A mosaic of television ratings. *The American Statistician*, *38*:32–35. 36

[128] Haskell, A. C. (1919). *How to Make and Use Graphic Charts*. New York: Codex. 27, 29

[129] Hauksbee, Francis (1712). Account of the experiment on the ascent of water between two glass planes in an hyperbolick figure. *Philosophical Transactions*, *27*:539–540. (Read to Royal Society 13 Nov., 1712. 11

[130] Hazen, Allen (1914). Storage to be provided in impounding reservoirs for municipal water supply. *Transactions of the American Society of Civil Engineers*, *77*:1529–1669. Read December 17, 1913. 28

[131] Hecht, Jacqueline (1987). Johann Peter Sussmilch: a German prophet in foreign countries. *Population Studies*, *41*(1):31–58. URL `http://www.jstor.org/cgi-bin/jstor/viewitem/00324728/di980794/98p03643/0`. 12

[132] Heiser, Willem J. (2000). Early roots of statistical modelling. In J. Blasius, J. Hox, E. de Leeuw and P. Schmidt, eds., *Social Science Methodology in the New Millenium: Proceedings of the Fifth International Conference on Logic and Methodology*. Amsterdam: TT-Publikaties. 3

[133] Henderson, Lawrence J. (1928). *Blood: A Study in General Physiology*. New Haven, CT: Yale University Press. 30

[134] Herschel, John F. W. (1833). On the investigation of the orbits of revolving double stars. *Memoirs of the Royal Astronomical Society*, *5*:171–222. 18

[135] Hertzsprung, Elnar (1911). Publikationen des astrophysikalischen observatorium zu Potsdam. Num. 63. 28

[136] Hilts, V. L. (1975). *A Guide to Francis Galton's English Men of Science*, vol. 65. Philadelphia, PA: American Philosophical Society. 23

[137] Hoff, Hebbel E. and Geddes, L. A. (1959). Graphic recording before Carl Ludwig: An historical summary. *Archives Internationales d'Histoire des Sciences*, *12*:3–25. 3

[138] Hoff, Hebbel E. and Geddes, L. A. (1962). The beginnings of graphic recording. *Isis*, *53*:287–324. Pt. 3. 3

[139] Howard, Luke (1800). On a periodical variation of the barometer, apparently due to the influence of the sun and moon on the atmosphere. *Philosophical Magazine*, *7*:355–363. 15

[140] von Huhn, R. (1927). A discussion of the Eells' experiment. *Journal of the American Statistical Association*, *22*:31–36. URL `http://www.jstor.org/cgi-bin/jstor/viewitem/01621459/di985714/98p05477/0`. 30

[141] von Huhn, R. (1931). A trigonometrical method for computing the scales of statistical charts to improve visualization. *Journal of the American Statistical Association*, *26*:319–324. 27

[142] von Humboldt, Alexander (1811). *Atlas Géographique et Physique du Royaume de la Nouvelle-Espagne*. Paris: F. Schoell. 15

[143] von Humboldt, Alexander (1817). Sur les lignes isothermes. *Annales de Chimie et de Physique*, *5*:102–112. 16

[144] Hurley, Catherine and Buja, Andreas (1990). Analyzing high-dimensional data with motion graphics. *SIAM Journal on Scientific and Statistical Computing*, *11*(6):1193–1211. 38

[145] Huygens, Christiaan (1657). De ratiociniis in ludo aleae. In F. van Schooten, ed., *Exercitationum mathematicarum libri quinque*. Amsterdam: Elsevirii. URL http://www.stat.ucla.edu/history/huygens.pdf. Reprinted in *Oeuvres Complétes*, Société Hollandais des Sciences, Nijhoff, La Haye, Vol. 14 (1920). 9

[146] Inselberg, A. (1985). The plane with parallel coordinates. *The Visual Computer*, *1*:69–91. 37

[147] Inselberg, Alfred (1989). Discovering multi-dimensional structure using parallel coordinates. In *Proc. Amer. Stat. Assoc, Sec. on Stat.Graphics*, pp. 1–16. American Statistical Association. ISBN 0-8186-2083-8 (PAPER). 37

[148] Inselberg, Alfred and Dimsdale, Bernard (1990). Parallel coordinates: a tool for visualizing multi-dimensional geometry. In *VIS '90: Proceedings of the 1st conference on Visualization '90*, pp. 361–378. Los Alamitos, CA, USA: IEEE Computer Society Press. ISBN 0-8186-2083-8 (PAPER). 37

[149] International Statistical Congress (1858). Emploi de la cartographic et de la méthode graphique en général pour les besoins spéciaux de la statistique. In *Proceedings*, pp. 192–197. Vienna. 3rd Session, August 31-September 5, 1857. 20

[150] Jevons, William Stanley (1863). A serious fall in the value of gold ascertained, and its social effects set fourth. London. 21

[151] Jevons, William Stanley ([1879] 1958). Graphical method. In *Principles of Science: A Treatise on Logic and Scientific Method*, pp. 492–496. New York: Dover, 3rd edn. First ed.: 1874; page numbers from 3rd Ed. Dover reprint (1958). 21, 24

[152] John, V. (1883). Statistik - eine etymologisch skizze. *Journal of the Statistical Society of London*, *46*(4):656–679. 12

[153] Johnson, Brian and Shneiderman, Ben (1991). Treemaps: A space-filling approach to the visualization of hierarchical information structures. In *Proc. of the 2nd International IEEE Visualization Conference*, pp. 284–291. San Diego, CA. 38

[154] Johnson, N. L. and Kotz, S., eds. (1997). *Leading Personalities in Statistical Science*. New York: John Wiley and Sons. 10

[155] Johnston, Alexander Keith (1843). *The National Atlas of Historical, Commercial, and Political Geography*. London: William Blackwood and Sons. 19

[156] Joint Committee on Standards for Graphic Presentation (1914). Preliminary report published for the purpose of inviting suggestions for the benefit of the committee. *Publications of the American Statistical Association*, *14*(112):790–797. URL http://www.jstor.org/cgi-bin/jstor/viewitem/15225437/di985667/98p0252o/0. 28

[157] Karsten, K. G. (1925). *Charts and Graphs. An Introduction to Graphic Methods in the Control and and Analysis of Statistics*. New York: Prentice Hall. 27, 29

[158] Keiding, M. (1990). Statistical inference in the lexis diagram. *Philosophical transactions of the Royal Society of London, series A*, *332*:487–509. 38

[159] Keith, Alexander (1800). Description of a thermometer, which marks the greatest degree of heat and cold from one time of observation to another, and may also register its own height at every instant. *Journal of Natural Philosophy, Chemistry and the Arts*, *3*:266–268. Reprinted in Fulford, Tim (ed.) 2002, Romanticism and Science, 1773-1833, Routledge. ISBN:0415219523, pp. 95-101. 15

[160] Kirscher, Athanasius (1646). *Ars Magna Lucis et Umbrae*. Germany: (n.p.). 9

[161] Kleinman, Kim (2002). How graphical innovations assisted Edgar Anderson's discoveries in evolutionary biology. *Chance*, *15*(3):17–21. 30

[162] Kruskal, William (1977). Visions of maps and graphs. In *Proceedings of the International Symposium on Computer- Assisted Cartography, Auto-Carto II*, pp. 27–36. 1975. 3

[163] Lalanne, Léon (1844). *Abaque, ou Compteur univsersel, donnant á vue á moins de 1/200 près les résultats de tous les calculs d'arithmétique, de geometrie et de mécanique practique*. Paris: Carilan-Goery et Dalmont. 19

[164] Lalanne, Léon (1845). Appendice sur la representation graphique des tableaux météorologiques et des lois naturelles en général. In L. F. Kaemtz, ed., *Cours Complet de Météorologie*, pp. 1–35. Paulin. Translated and annotated by C. Martins. 19

[165] Lalanne, Léon (1846). Mémoire sur les tables graphiques et sur la géométrie anamorphique appliquées a diverses questions qui se rattachent a l'art de l'ingénieur. *Annales des Ponts et Chausées, 2e series*, *11*:1–69. Read 1843. 14, 19

[166] Lallemand, Charles (1885). *Les abaques hexagonaux: Nouvelle méthode générale de calcul graphique, avec de nombreux exemples d'application*. Paris: Ministère des travaux publics, Comité du nivellement général de la France. 25

[167] Lambert, Johann Heinrich (1760). *Photometria sive de mensura et gradibus luminis colorum et umbrae*. Augustae Vindelicorum: Vidvae Eberhardi Klett. 12

[168] Lambert, Johann Heinrich (1765). Theorie der zuverlässigkeit. In *Beyträge zum Gebrauche der Mathematik and Deren Anwendungen*, vol. 1, pp. 424–488. Berlin: Verlage des Buchladens der Realschule. 13

[169] Lambert, Johann Heinrich (1772). *Beschreibung einer mit dem Calauschen Wachse ausgemalten Farbenpyramide*. Berlin: n.p. 12

[170] Lambert, Johann Heinrich (1779). Pyrometrie; oder, vom maasse des feuers und der wärme mit acht kupfertafeln. Berlin. URL http://imgbase-scd-ulp.u-strasbg.fr/displayimage.php?album=83&pos=0. 13

[171] van Langren, Michael Florent (1644). La Verdadera Longitud por Mar y Tierra. BL: 716.i.6. 9

[172] Laplace, Pierre Simon (1812). *Théorie analytique des probabilités*. Paris: Courcier. 11

[173] Levasseur, Émile (1868). *La France, Avec Ses Colonies*. Paris: Librarie Charles Delagrave. 21

[174] Levasseur, Émile (1885). La statistique graphique. *Journal of the Statistical Society of London*, *50?*:218–250. 26

[175] Lexis, Wilhelm (1875). Einleitung in der theorie der bevölkerungsstatistik. 23

[176] LLull, Ramon (1274–1283). Artifitium electionis personarum. Biblioteca Apostolica Vaticana, Cod. Vat. lat. 9332, f. 11r-12v. 5

[177] Lorenz, M. O. (1905). Methods of measuring the concentration of wealth. *Publications of the American Statisical Association*, *9*:209–219. URL http://www.jstor.org/cgi-bin/jstor/viewitem/15225437/di985625/98p06356/0. 27

[178] Loua, Toussaint (1873). *Atlas statistique de la population de Paris*. Paris: J. Dejey. 22

[179] Mackinlay, Jock D. (1986). Automating the design of graphical presentations of relational information. *ACM Transactions on Graphics*, *5*(2):110–141. ISSN 0730-0301. doi:http://doi.acm.org/10.1145/22949.22950. 37

[180] Mackinlay, Jock D. (1987). *Automatic design of graphical presentations*. Ph.D. thesis, Stanford University, Stanford, CA, USA. 37

[181] Mandea, Mioara and Mayaud, Pierre-Noël (2004). Guillaume le nautonier, un precurseur dans l'histoire du géomagnétisme magnetism. *Revue d'Histoire des Sciences*, *57*(1):161–174. 7

[182] Marey, Etienne-Jules (1873). *La Machine Animale, Locomotion Terestre et Aérienne*. Paris: Baillière. 24

[183] Marey, Etienne-Jules (1878). *La Méthode Graphique dans les Sciences Expérimentales et Principalement en Physiologie et en Médecine*. Paris: G. Masson. 23

[184] Marey, Etienne-Jules (1885). *La méthode graphique*. Paris. 26

[185] Marie, C. and Boscovich, J. T. (1755). *De Litteraria Expeditione per Pontificiam Ditionem*. Rome: N. and M. Palearini. French translation by Fr. Hugon, M. Tillard, Paris, 1770. 12

[186] Martin, F. C. and Leavens, D. H. (1931). A new grid for fitting a normal probability curve to a given frequency distribution. *Journal of the American Statistical Association*, *26*:178–183. 31

[187] de Martonne, Emmanuel (1919). Répartition de nationalities dans les pays oú dominant les roumains. In *Travaux du Comité d'études, tome II, Questions européennes, Atlas*. Paris: Service Géographique de l'Armée. 1:1,000,000; plate 14. 29

[188] de Martonne, Emmanuel (1920). Essai de carte ethnographique des pays roumains. *Annales de Géographie*, *29*:81–98. Map in Plate IV. 29

[189] Mayer, Johannes Tobias (1750). Abhandlung über die umwälzung des Monds und seine Axe. *Kosmographische Nachrichten un Sammlungen*, *1*:52–183. English translation of pages 146–159 by Trenkler (1986). 12

[190] Mayer, Jophannes Tobias (1758). *De affinitate colorum commentatio*, chap. Farbendreieck. n.p. Edited by Lichtenberg, 1775. 12

[191] Mayr, Georg von (1874). *Gutachten Über die Anwendung der Graphischen und Geographischen Methoden in der Statistik*. (n.p.). 23, 34

[192] Mayr, Georg von (1877). *Die Gesetzmäßigkeit im Gesellschaftsleben*. Oldenbourg. 23, 34

[193] McDonald, John A. (1982). *Interactive Graphics for Data Analysis*. Ph.D. thesis, Stanford University. 36

[194] Mihalisin, Ted, Gawlinski, E., Timlin, J. and Schwegler, J. (1989). Multi-dimensional graphing in two dimensional spaces. *Scientific Computing and Automation*, *6*:15–20. 38

[195] Mihalisin, Ted, Schwegler, J. and Timlin, J. (1992). Hierarchical multivariate visualization. In H. J. Newton, ed., *Computing Science and Statistics: Proceedings of the 24th Symposium on the Interface*, vol. 24, pp. 141–149. 38

[196] Minard, Charles Joseph (1844). Tableaux figuratifs de la circulation de quelques chemins de fer. lith. (n.s.). ENPC: 5860/C351, 5299/C307. 19

[197] Minard, Charles Joseph (1861). *Des Tableaux Graphiques et des Cartes Figuratives*. Paris: E. Thunot et Cie. ENPC: 3386/C161; BNF: V-16168. 20

[198] Minard, Charles Joseph (1869). Carte figurative des pertes successives en hommes de l'armée qu'Annibal conduisit d'Espagne en Italie en traversant les Gaules (selon Polybe). Carte figurative des pertes successives en hommes de l'armée française dans la campagne de Russie, 1812–1813. lith. (624 x 207, 624 x 245). URL http://www.math.yorku.ca/SCS/Gallery/images/minard/orig.gif. ENPC: Fol 10975, 10974/C612. 21

[199] Ministère des Travaux Publics (1879–1899). *Album de Statistique Graphique*. Paris: Imprimerie Nationale. É. Cheysson, director. 24

[200] Monmonier, Mark (1989). An alternative isomorphism for mapping correlation. *International Yearbook of Cartography*, *19*:77–89. 36

[201] Monmonier, Mark (1989). Geographic brushing: Enhancing exploratory analysis of the scatterplot matrix. *Geographical Analysis*, *21*(1):81–84. 38

[202] Monmonier, Mark and Schnell, George (1983). *The Study of Population: Elements, Patterns, Processes*. Columbus, OH: Charles E. Merrill. 36

[203] Montigny, Léon (n.d.). *Les élections parisiennes de mai et juin 1869, application de la géométrie à la statistique*. Imprimerie Monrocq, 3 rue Suger, Paris: Lanée. 21

[204] Frère de Montizon, Armand Joseph (1830). Carte philosophique figurant la population de la France. BNF. 17

[205] Morton, John L. (1992). *Strata: How William Smith drew the First map of the Earth in 1801 and inspired the Science of Geology*. Stroud, England: Tempus Publishing. ISBN 0 7524 1992. URL http://freespace.virgin.net/hgf.c/stop.htm. 15

[206] Moseley, Henry (1913). The high frequency spectra of the elements. *Philosophical Magazine*, *26*:1024–1034. (Part II, 27:1914, pp. 703–). 28

[207] Mulhall, Michael George (1884). *Dictionary of Statistics*. London: G. Routledge. URL http://books.google.com/books?id=vnbXZIGW5RsC. 25

[208] Napier, John (1614). Mirifici logarithorum canonis descriptio. (English translation, *A Description of the Admirable Table of Logarithms*, published in 1616 by Edward Wright, London: Nicholas Okes). 7, 8

[209] de Nautonier, Guillaume (1602–1604). *Mecometrie de l'eymant, c'est a dire la maniere de mesurer les longitudes par le moyen de l'eymant*. Paris: R. Colomies. BL: 533.k.9; BNF: RES-V-432. 7

[210] Neurath, Otto (1973). From Vienna method to Isotype. In M. Neurath and R. S. Cohen, eds., *Empiricism and Sociology*, pp. 214–248. Dordrecht, NL: Reidel. (papers written 1925-45). 30, 31

[211] Neurath, Otto (1991). *Gesammelte Bildpaedagogische Schriften*. Vienna: Verlag Hoelder-Pichler-Tempsky. ISBN 3209008639. Rudolf Haller and Robin Kinross (eds.). 30

[212] Newton, Carol M. (1978). Graphics: From alpha to omega in data analysis. In P. C. C. Wang, ed., *Graphical Representation of Multivariate Data*. New York, NY: Academic Press. Proc. of the Symp. on Graphical Representation of Multivariate Data, Naval Postgraduate School, Monterey CA, Feb 24, 1978. 36

[213] Nightingale, Florence (1857). *Mortality of the British Army*. London: Harrison and Sons. 17, 20

[214] Nikolow, Sybilla (2001). A.f.w. crome's measurements of the strength of the state: Statistical representations in central europe around 1800. In J.L. Klein and M.S. Morgan, eds., *The Age of Economic Measurement*. Raleigh, NC: Duke University Press. 14

[215] d'Ocagne, Maurice (1885). *Coordonnées Parallèles et Axiales: Méthode de transformation géométrique et procédé nouveau de calcul graphique déduits de la considération des coordonnées parallèlles*. Paris: Gauthier-Villars. URL `http://historical.library.cornell.edu/cgi-bin/cul.math/docviewer?did=00620001&seq=3`. 25

[216] d'Ocagne, Maurice (1899). *Traité de nomographie: Théorie des Abaques, Applications Pratiques*. Paris: Gauthier-Villars. 25

[217] Oresme, Nicole (1482). Tractatus de latitudinibus formarum. Padova. BL: IA 3Q024. 5

[218] Oresme, Nicole (1968). *Nicole Oresme and the Medieval Geometry of Qualities and Motions: A Treatise on the Uniformity and Difformity Known as* Tractatus de Configrationibus Qualitatum et Motuum. Madison WI: University of Wisconsin Press. Tr.: M. Clagget. 5

[219] Ortelius, Abraham (1570). *Theatrum Orbis Terrarum*. Antwerp: Coppenium Diesth. URL `http://www.uba.uva.nl/en/collections/maps/ortelius/overview.html`. 53 maps in coperplate, 41 x 29 cm. 6

[220] Ostermann, R. (2001). Emil Eugen Roesle - grafikpionier im bereich der medizinstatistik und epidemiologie. *Informatik, Biometrie und Epidemiologie in Medizin und Biologie*, *244*. 28

[221] Ostermann, Rüdiger (1999). Georg von Mayrs beiträge zur statistichen graphik. *Algemeines Statistiches Archiv*, *83*(3):350–362. ISSN 0002-6018. 23

[222] Palmer, A. R. (1921). *The Use of Graphs in Commerce and Industry*. London, U.K.: (n.p.). 27, 29

[223] Palsky, G. (1996). *Des Chiffres et des Cartes: Naissance et développement de la cartographie quantitative française au XIX^{e} siècle*. Paris: Comité des Travaux Historiques et Scientifiques (CTHS). ISBN 2-7355-0336-3. 3, 20, 24, 26, 27

[224] Palsky, Gilles (2002). Emmanuel de Martonne and the ethnographical cartography of Central Europe. *Imago Mundi*, *54*:111–119. URL `http://www.jstor.org/stable/1151508`. 29

[225] Parent-Duchâtelet, Alexandre Jean Baptiste (1836). *De la prostitution dans la ville de Paris*. Bruxelles: Dumont. URL `http://www.library.dal.ca/kellogg/Cogswell_Library_1864/search/330.htm`. 18

[226] Pearson, Egon S., ed. (1978). *The History of Statistics in the 17th and 18th Centuries Against the Changing Background of Intellectual, Scientific and Religeous Thought*. London: Griffin & Co. Ltd. ISBN 85264 250 4. Lectures by Karl Pearson given at University College London during the academic sessions 1921–1933. 3

[227] Pearson, Karl (1914–1930). *The life, letters and labours of Francis Galton*. Cambridge: University Press. 23

[228] Peddle, John B. (1910). *The Construction of Graphical Charts*. New York: McGraw-Hill. 27, 28

[229] Perozzo, Luigi (1880). Della rappresentazione graphica di una collettività di individui nella successione del tempo. *Annali di Statistica*, *12*:1–16. BL: S.22. 24

[230] Petty, William (1665). *The Economic Writings of Sir William Petty: Together with the Observations upon the Bills of Mortality*. Cambridge: The University Press. C. H. Hall (ed.) (more probably by Captain John Graunt). 9

[231] Petty, William (1687). *Observations upon the Cities of London and Rome*. London: H. Mortlock and F. Lloyd. Tries to show that, though Rome at the birth of Christ was the greatest city of the world, London at the coronation of James II was nearly six times as great as Rome. 10

[232] Petty, William (1687). *Two Essays in Political Arithmetick, Concerning the People, Housing Hospitals &c. of London and Paris*. London: H. Mortlock and F. Lloyd. Tries to show that London has more people and housing than Paris and Rouen put together; more people die in hospitals in Paris than in London. 10

[233] Petty, William (1690). *Political Arithmetick*. London: Robert Clavel, 3rd edn. URL http://www.marxists.org/reference/subject/economics/petty/. 9

[234] Phillips, Alban W. H. (1958). The relation between unemployment and the rate of change of money wage rates in the United Kingdom, 1861-1957. *Economica, New Series*, *25*(2):283–299. 33

[235] Pickett, R. and White, B. W. (1966). Constructing data pictures. In *Proceedings of the 7th National Symposium of the Society for Information Display*, pp. 75–81. 33

[236] Playfair, W. (1805). *A Statistical Account of the United States of America by D. F. Donnant*. London: J. Whiting. William Playfair, Trans. 15

[237] Playfair, William (1786). *Commercial and Political Atlas: Representing, by Copper-Plate Charts, the Progress of the Commerce, Revenues, Expenditure, and Debts of England, during the Whole of the Eighteenth Century*. London: Corry. URL http://ucpj.uchicago.edu/Isis/journal/demo/v000n000/000000/000000.fg4.html. Re-published in Wainer, H. and Spence, I. (eds.), *The Commercial and Political Atlas and Statistical Breviary*, 2005, Cambridge University Press, ISBN 0-521-85554-3. 14

[238] Playfair, William (1801). *Statistical Breviary; Shewing, on a Principle Entirely New, the Resources of Every State and Kingdom in Europe*. London: Wallis. Re-published in Wainer, H. and Spence, I. (eds.), *The Commercial and Political Atlas and Statistical Breviary*, 2005, Cambridge University Press, ISBN 0-521-85554-3. 15

[239] Porter, T. M. (1986). *The Rise of Statistical Thinking 1820–1900*. Princeton, NJ: Princeton University Press. 3

[240] Pouchet, Louis Ézéchiel (1795). Arithmétique linéaire. In *Echelle Graphique des Nouveaux Poids, Mesures et Monnaies de la République Française*. Rouen: Seyer. (Appendix). 14

[241] Prichard, James Cowles (1843). *Researches Into the Physical History of Man*. London: Houlston & Stoneman. 19

[242] Priestley, Joseph (1765). *A Chart of Biography*. London: (n.p.). BL: 611.I.19. 13

[243] Quetelet, Adolphe (1828). *Instructions Populaires sur le Calcul des Probabilités*. Brussels: M. Hayez. 17

[244] Quetelet, Adolphe (1831). *Recherches sur le penchant au crime aux différents âges*. Brussels: Hayez. English translation by Sawyer F. Sylvester. Cincinnati, OH: Anderson Publishing Company, 1984. 20

[245] Quetelet, Adolphe (1838). Notice sur la loi que la population suit dans son accroissement. *Corrrespondence mathématique et physique*, *10*:113–121. 19

[246] Quetelet, Adolphe (1846). *Lettres sur la Théorie des Probabilités, Appliquée aux Sciences Morales et Politiques*. Brussels: M. Hayez. 20

[247] Rao, Ramaana and Card, Stuart K. (1994). The table lens: Merging graphical and symbolic representations in an interactive focus+context visualization for tabular information. In *Proc. CHI'94*, pp. 318–322. Boston, Massachusetts: ACM. URL http://www.ramanarao.com/papers/tablelens-chi94.pdf. 39

[248] Ravenstein, Ernest G. (1875). Statistics at the Paris geographical congress. *Journal of the Statistical Society of London*, *38*:422–429. URL http://www.jstor.org/cgi-bin/jstor/viewitem/09595341/di992600/99p0003j/0. 20

[249] Riddell, R. C. (1980). Parameter disposition in pre-Newtonain planetary theories. *Archives Hist. Exact Sci.*, *23*:87–157. 3

[250] Riedwyl, Hans and Schüpbach, Michel (1983). Siebdiagramme: Graphische darstellung von kontingenztafeln. Tech. Rep. 12, Institute for Mathematical Statistics, University of Bern, Bern, Switzerland. 37

[251] Robinson, Arthur H. (1955). The 1837 maps of Henry Drury Harness. *Geographical Journal*, *121*:440–450. URL http://tinyurl.com/ys8eds. 18

[252] Robinson, Arthur H. (1967). The thematic maps of Charles Joseph Minard. *Imago Mundi*, *21*:95–108. 19

[253] Robinson, Arthur H. (1982). *Early Thematic Mapping in the History of Cartography*. Chicago: University of Chicago Press. ISBN 0-226-72285-6. 3, 14, 16, 17, 18

[254] Robinson, J. M. (1968). *An Introduction to Early Greek Philosophy*. New York: Houghton Mifflin. 4

[255] Roesle, Emil Eugen (1911). *Sonderkatalog für die Gruppe Statistik der wissenschaftlichen Abteilung der Internationalen Hygiene-Ausstellung*. Dresden, Germany: Verlag der Internationelen Hygiene-Ausstellung. (15 colored reproductions of posters from the exhibition). 28

[256] Roesle, Emil Eugen (1913). Graphische-statistische darstellungen, ihre technik, methodik und wissenschaftliche bedeutung. *Archiv für soziale Hygiene*, *8*:369–406. 28

[257] Royston, E. (1970). Studies in the history of probability and statistics, III. a note on the history of the graphical presentation of data. *Biometrika*, *43*:241–247. Pts. 3 and 4 (December 1956); reprinted In *Studies in the History Of Statistics and Probability Theory*, eds. E. S. Pearson and M. G. Kendall, London: Griffin. 3

[258] van Rupelmonde, Gerard Mercator (1569). Nova et aucta orbis terrae descriptio ad usum navigantum emendate accomodata. 6

[259] Scheiner, Christophe (1626–1630). *Rosa Ursina sive Sol ex Admirando Facularum & Macularum Suarum Phoenomeno Varius*. Bracciano, Italy: Andream Phaeum. BL: 532.l.6. 8

[260] Schwabe, Hermann (1872). Theorie der graphischen darstellungen. In P. Séménov, ed., *Proceedings of the International Statistical Congress*, 8th Session, Pt. 1, pp. 61–73. St. Petersburg: Trenké & Fusnot. 22

[261] Scrope, George P. (1833). *Principles of Political Economy, Deduced from the Natural Laws of Social Welfare, and Applied to the Present State of Britain*. Longmans. 18

[262] Senefelder, Aloys (1819). *A Complete Course of Lithography: Containing Clear and Explicit Instructions...* London: Ackermann. (English translation). 14

[263] Shewhart, Walter A. (1931). *Economic control of quality of manufactured product*. Milwaukee, WI: American Society for Quality Control. 27, 30

[264] Shields, M. C. (1937). The early history of graphs in physical literature. *American Journal of Physics*, *5*(2):68–71. doi:doi:10.1119/1.1991176. 3

[265] Shneiderman, Ben (1991). Tree visualization with treemaps: A 2-D space-filling approach. Tech. Rep. TR 91-03, University of Maryland, HCIL. (Published in *ACM Transactions on Graphics*, vol. 11(1): 92–99, 1992). 38

[266] Siegel, J. H., Goldwyn, R. M. and Friedman, H. P. (1971). Pattern and process of the evolution of human septic shock. *Surgery*, *70*:232–245. 34

[267] Smith, David Eugene (1925). *History of Mathematics, vol. II*. Boston: Ginn and Co. 11

[268] Smith, William (1815). *A delineation of the strata of England and Wales, with part of Scotland; exhibiting the collieries and mines, the marshes and fenlands originally overflowed by the sea, and the varieties of soil according to the substrata, illustrated by the most descriptive names*. London: John Cary. BL: Maps 1180.(19). 15

[269] Snell, Willebrord van Roijen (Snellius) (1617). Eratosthenes batavus. 8

[270] Snow, John (1855). *On the Mode of Communication of Cholera*. London: (n.p.), 2nd edn. 20

[271] Spence, Ian (2005). No humble pie: The origins and usage of a statistical chart. *Journal of Educational and Behavioral Statistics*, *30*(4):353–368. 15

[272] Spence, Ian and Garrison, R. F. (1993). A remarkable scatterplot. *The American Statistician*, *47*(1):12–19. 28

[273] Stigler, S. M. (1986). *The History of Statistics: The Measurement of Uncertainty before 1900*. Cambridge, MA: Harvard University Press. 3

[274] Süssmilch, Johann Peter (1741). *Die göttliche Ordnung in den Veränderungen des menschlichen Geschlechts, aus der Geburt, Tod, und Fortpflantzung*. Germany: n.p. URL `http://www.ined.fr/publicat/collections/classiques/Ordivin.htm`. (published in French translation as *L'ordre divin. dans les changements de l'espèce humaine, démontré par la naissance, la mort et la propagation de celle-ci*, trans: Jean-Marc Rohrbasser, Paris: INED, 1998, ISBN 2-7332-1019-X). 12

[275] Sutherland, I. (1963). John Graunt: A tercentenary tribute. *Journal of the Royal Statistical Society, Series A*, *126*:537–556. URL `http://www.jstor.org/cgi-bin/jstor/viewitem/00359238/di992967/99p11214/0`. 9

[276] Swayne, Deborah F., Cook, Di and Buja, Andreas (1992). XGobi: Interactive dynamic graphics in the X Window System with a link to S. In *Proceedings of the 1991 American Statistical Association Meetings*, pp. ??–?? American Statistical Association. 38

[277] Swayne, Deborah F., Cook, Di and Buja, Andreas (1998). XGobi: Interactive dynamic data visualization in the X Window System. *Journal of Computational and Graphical Statistics*, *7*(1):113–130. 38

[278] Sylvester, James Joseph (1878). On an application of the new atomic theory to the graphical representation of the invariants and covariants of binary quantics, with three appendices. *American Journal of Mathematics*, *1*:64–128. URL `http://ucpj.uchicago.edu/Isis/journal/demo/v000n000/000000/000000.fg3.html`. 24

[279] Tartaglia, Niccolo Fontana (1556). *General Trattato di Numeri et Misure*. Venice: Vinegia. BL: 531.n.7-9; 47.e.4. 6

[280] Taton, R. (1950). *Gaspard Monge*. Basel. 13

[281] Taton, René (1951). *L'oeuvre scientifique de Monge*. Paris: Presses universitaires de France. 13

[282] Thrower, N. J. W., ed. (1981). *The Three Voyages of Edmond Halley in the* Paramore *1698 - 1701*. London: Hakluyt Society. ISBN 0 904 180 02. 2nd series, vol 156-157 (2 vols). 11

[283] Thurstone, Louis Leon (1927). A law of comparative judgement. *Psychological Review*, *34*:278–286. 30

[284] Thurstone, Louis Leon (1934). The vectors of the mind. *Psychological Review*, *41*:1–32. URL http://psychclassics.yorku.ca/Thurstone/. Presidential address to American Psychological Association, 1933; published as a book in 1935 by University of Chicago Press. 30

[285] Tierney, Luke (1990). *LISP-STAT: An Object-Oriented Environment for Statistical Computing and Dynamic Graphics*. New York: John Wiley and Sons. ISBN 0-471-50916-7. 38

[286] Tilling, Laura (1975). Early experimental graphs. *British Journal for the History of Science*, *8*:193–213. 3, 13

[287] Tomlinson, R. and Petchenik, B., eds. (1988). *Reflections on a Revolution: The Transition from Analogue to Digital Representations of Space, 1958-1988*, vol. 15 (3). *The American Cartographer*. (Special issue). 33

[288] Tournés, D. (2000). Pour une histoire du calcul graphique. *Revue d'Histoire des Mathématiques*, *6*(1):127–161. 19

[289] Tucker, Ledyard (2002). Personal communication. 32

[290] Tufte, Edward (2006). *Beautiful Evidence*. Cheshire, CT: Graphics Press. ISBN 0-9613921-7-7. 39

[291] Tufte, Edward R. (1983). *The Visual Display of Quantitative Information*. Cheshire, CT: Graphics Press. 3, 5, 21, 26, 29, 37

[292] Tufte, Edward R. (1990). *Envisioning Information*. Cheshire, CT: Graphics Press. 3, 37

[293] Tufte, Edward R. (1997). *Visual Explanations*. Cheshire, CT: Graphics Press. ISBN 0-9613921-2-6. 3, 37

[294] Tukey, John Wilder (1962). The future of data analysis. *Annals of Mathematical Statistics*, *33*:1–67 and 81. 32

[295] Tukey, John Wilder (1965). The future of processes of data analysis. In *Proceedings of the Tenth Conference on the Design of Experiment in Army Research Development and Testing*, pp. 691–729. Durham, NC: U.S. Army Research Office. ARO-D Report 65-3. 33

[296] Tukey, John Wilder (1972). Some graphic and semigraphic displays. In T. A. Bancroft, ed., *Statistical Papers in Honor of George W. Snedecor*, pp. 293–316. Ames, IA: Iowa State University Press. Presented at the Annual Meeting of the American Statistical Association, August 1969. 33

[297] Tukey, John Wilder (1977). *Exploratory Data Analysis*. Reading, MA: Addison-Wesley. Chapters from what would become this book were circulated privately 1971–75. 32

[298] Tukey, John Wilder and Tukey, Paul A. (1990). Strips displaying empirical distributions: I. Textured dot strips. Tech. rep., Bellcore. 38

[299] Tukey, Paul A. and Tukey, John Wilder (1981). Graphical display of data sets in 3 or more dimensions. In V. Barnett, ed., *Interpreting Multivariate Data*. Chichester, U.K.: Wiley and Sons. 36

[300] U. S. Bureau of the Census (1872). *Statistics of Wealth and Public Indebtedness*. Washington, D.C.: U.S. Government Printing Office. 22

[301] U. S. Bureau of the Census (1974). *Urban Atlas*. Washington, D.C.: U.S. Government Printing Office. Series GE-80. 34

[302] U. S. Bureau of the Census (1976). *StatUS*. Washington, D.C.: U.S. Government Printing Office. 36

[303] Unwin, Antony R. and Wills, Graham (1988). Eyeballing time series. In *Proceedings of the 1988 ASA Statistical Computing Section*, pp. 263–268. American Statistical Association. 37

[304] Vandeschrick, Christophe (2001). The Lexis diagram, a misnomer. *Demographic Research*, *4*(3):97–124. URL http://www.demographic-research.org/Volumes/Vol4/3/4-3.pdf. 23

[305] Vauthier, L. L. (1874). Note sur une carte statistique figurant la répartition de la population de Paris. *Comptes Rendus des Séances de L'Académie des Sciences*, *78*:264–267. ENPC: 11176 C612. 22

[306] Venn, John (1880). On the diagrammatic and mechanical representation of propositions and reasonings. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, *9*:1–18. 24

[307] Venn, John (1881). *Symbolic Logic*. London: MacMillan. 24

[308] Vincent, J. H. (1898). On the use of logarithmic coordinates. In *Report of the sixty-eighth meeting of the British Association for the Advancement of Science*. Bristol. 25

[309] da Vinci, Leonardo (1500). *Notebooks*, vol. M, Verso 40. Paris: Manuscripts of the Institute of France. (c. 1500). 5

[310] Wainer, Howard (1974). The suspended rootogram and other visual displays: An empirical validation. *American Statistician*, *28*:143–145. 34

[311] Wainer, Howard (1998). The graphical inventions of Dubourg and Ferguson: Two precursors to William Playfair. *Chance*, *11*(4):39–41. 12

[312] Wainer, Howard (2000). *Visual Revelations: Graphical Tales of Fate and Deception from Napoleon Bonaparte to Ross Perot*. Hillsdale, NJ: Lawrence Erlbaum and Associates. 23

[313] Wainer, Howard and Reiser, M. (1976). Assessing the efficacy of visual displays. In *Proceedings of the Social Statistics Section*, vol. 19, pp. 89–92. American Statistical Association. Part 1. 36

[314] Walker, Francis A. (1874). *Statistical Atlas of the United States, Based on the Results of Ninth Census, 1870, with Contributions from Many Eminent Men of Science and Several Departments of the [Federal] Government*. New York: Julius Bien. 22

[315] Walker, Helen M. (1929). *Studies in the History of the Statistical Method*. Baltimore, MD: Williams & Wilkinson Co. 12, 23

[316] Wallis, Helen M. and Robinson, Arthur H. (1987). *Cartographical Innovations: An International Handbook of Mapping Terms to 1900*. Tring, Herts: Map Collector Publications. ISBN 0-906430-04-6. 3, 14

[317] Warne, Frank J. (1916). *Warne's Book of Charts, A Special Feature of Warne's Elementary Course in Chartography*. Washington, D.C.: F. J. Warne. 3 p. l., 106 charts. 31 x 41 cm. 27, 29

[318] Washburne, J. N. (1927). An experimental study of various graphic, tabular and textual methods of presenting quantitative material. *Journal of Educational Psychology*, *18*:361–376, 465–476. 30

[319] Wegman, Edward J. (1990). Hyperdimensional data analysis using parallel coordinates. *Journal of the American Statistical Association*, *85*(411):664–675. 38

[320] Wheeler, John Archibald (1982). Bohr, Einstein, and the strange lesson of the quantum. In R. Q. Elvee, ed., *Mind in Nature*. San Francisco: Harper and Row. 2, 3

[321] Wilcox, W. F. (1937). The founder of statistics. *Revue de l'institute international de statistique*, *V*:321–328. 9

[322] Wilkinson, Leland (1999). *The Grammar of Graphics*. New York: Springer. ISBN 0-387-98774-6. 39

[323] Wilkinson, Leland (2005). *The Grammar of Graphics*. New York: Springer, 2nd edn. ISBN 0-387-24544-8. 39

[324] Wills, Graham, Haslett, J., Unwin, Antony R. and Craig, P. (1989). Dynamic interactive graphics for spatially referenced data. In F. Faulbaum, ed., *Fortschritte der Statistik-Software 2*, pp. 278–287. Stuttgart: Gustav Fischer Verlag. 38

[325] Winchester, Simon (2001). *The Map That Changed the World: William Smith and the Birth of Modern Geology*. New York: Harper Collins. 15

[326] de Witt, Jan (1671). *The Worth of Life Annuities Compared to Redemption Bonds*. Leiden: n.p. 10

[327] Wren, Christopher (1750). *Parentalia: Or, Memoirs of the Family of the Wrens*. London: T. Osborn and R. Dodsley. 9

[328] Wright, Sewall (1920). The relative importance of heredity and environment in determining the piebald pattern of guinea-pigs. *Proceedings of the National Academy of Sciences*, *6*:320–332. 29

[329] Young, Forrest W. (1994). ViSta: The visual statistics system. Tech. Rep. RM 94-1, L.L. Thurstone Psychometric Laboratory, UNC. 38

[330] Zeuner, Gustav (1869). Abhandlungen aus der mathematischen statistik. Leipzig. BL: 8529.f.12. 21

[331] Zimmerman, E. A. W. (1787). *Political Survey of the Present State of Europe*. London. 12

Index