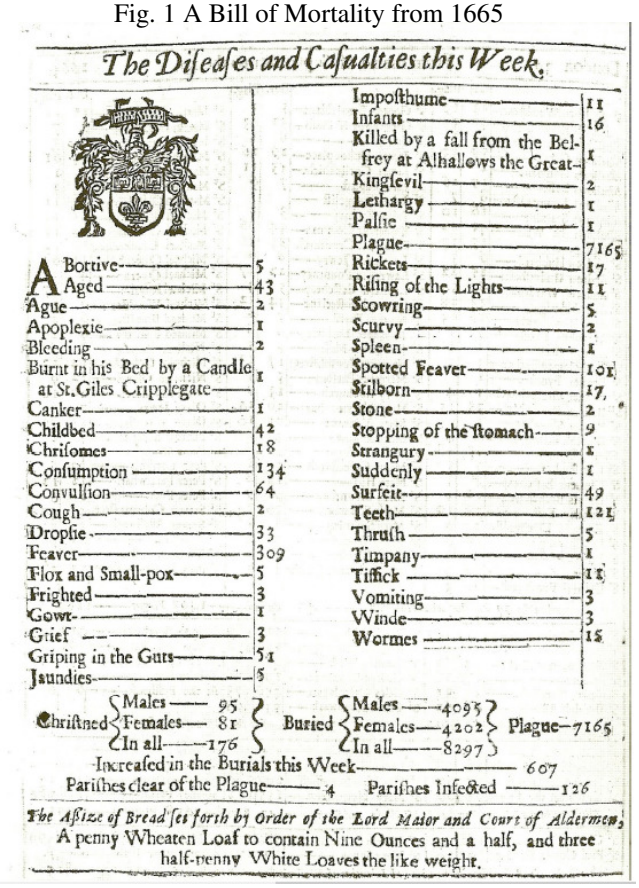
History of Statistics 1

The Bills of Mortality, and the Beginning of Statistics. John Graunt (1620 –1674)

From ancient times people have counted stuff: money, cattle, taxpayers and soldiers, to name a few. It is impossible to pick a date to mark the beginning of "statistics," as used in this general sense. For our purposes it is reasonable to choose a time when the use of numerical information became noticeably similar to current approaches.

Beginning in the middle 1500s, during the reign of Henry VIII, parish registrars in England began to keep records of all weddings, christenings and burials for all parishioners in the Church of England. The records were used especially to keep track of deaths caused by epidemics of bubonic plague. Beginning in 1603 such lists – called *bills* - were regularly printed for the public. By 1625 the enterprise was well established with a dedicated printing press under the offices of the Archbishop of Canterbury. These ***bills of mortality*** were published weekly. As you can see in Figure 1, they include some strange causes of death.*

Fig. 1 A Bill of Mortality from 1665



The Diſeaſes and Caſualties this Week.

Abortive	5	Impoſthume	11
Aged	43	Infants	16
Ague	2	Killed by a fall from the Belfrey at Alhallows the Great	1
Apoplexie	1	Kingſevil	2
Bleeding	2	Lethargy	1
Burnt in his Bed by a Candle at St. Giles Cripplegate	1	Palſie	1
Canker	1	Plague	7165
Childbed	42	Rickets	17
Chriſomes	18	Riſing of the Lights	11
Conſumption	134	Scowring	5
Convulſion	64	Scurvy	2
Cough	2	Spleen	1
Dropſie	33	Spotted Feaver	101
Feaver	309	Stilborn	17
Flox and Small-pox	5	Stone	2
Frighted	3	Stopping of the ſtomach	9
Gowt	1	Strangury	1
Grief	3	Suddenly	1
Griping in the Guts	51	Surfeit	49
Jaundies	5	Teeth	121
		Thruſh	5
		Timpany	1
		Tiſſick	11
		Vomiting	3
		Winde	3
		Wormes	15

Chriſtned { Males — 95, Females — 81, In all — 176 } Buried { Males — 4093, Females — 4202, In all — 8297 } Plague — 7165

Increaſed in the Burials this Week — 607

Pariſhes clear of the Plague — 4 Pariſhes Infected — 126

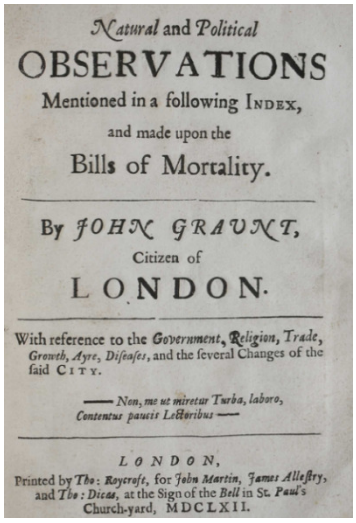
The Aſſize of Bread ſet forth by Order of the Lord Major and Court of Aldermen;
A penny Wheaten Loaf to contain Nine Ounces and a half, and three half-penny White Loaves the like weight.

In about 1660 **John Graunt**, a respected businessman in London, began to analyze the whole collection of bills. In 1662 he published a small book, ***Natural and Political Observations on the Bills of Mortality*** based on about 70 years of data. As you can see from the first words of the preface to the book, he thought that the information in the bills was good for more than just gossip or quick business opportunities. As a result, he is considered a founder of two fields that make heavy use of statistics, ***demography*** (descriptions of populations) and ***epidemiology*** (study of diseases in populations).

From the preface:

Having been born, and bred in the City of London, and having always observed, that most of them who constantly took in the weekly Bills of *Mortality*, made little other use of them, then to look at the foot, how the Burials increased, or decreased; And, among the *Casualties*, what had happened rare, and extraordinary in the week currant: so as they might take the same as a *Text* to talk upon, in the next Company; and withall, in the *Plague-time*, how the *Sickness* increased, or decreased, that so the *Rich* might judge of the necessity of their removall, and *Trades-men* might conjecture what doings they were like to have in their respective dealings:

Now, I thought that the Wisdom of our City had certainly designed the laudable practice of takeing, and distributing these Accompts, for other, and greater uses then those above-mentioned, or at least, that some other uses might be made of them:



Natural and *Political*
OBSERVATIONS
Mentioned in a following INDEX,
and made upon the
Bills of Mortality.

By JOHN GRAUNT,
Citizen of
LONDON.

With reference to the *Government*, *Religion*, *Trade*, *Growth*, *Ayre*, *Diſeaſes*, and the ſeveral Changes of the ſaid CITY.

—— Non, me ut miretur Turba, laboro,
Contentus paucis Lectoribus ——

LONDON,
Printed by *Tho: Roycroft*, for *John Martin*, *James Allestry*, and *Tho: Dicas*, at the Sign of the *Bell* in St. *Paul's* Church-yard, MDCLXII.

CAPTAIN JOHN GRAUNT

As an aside, the issue of *cause* of death has always been tricky. If a patient today with severe heart disease contracts pneumonia and dies, what is the cause of death? Heart disease or pneumonia? Who decides? Today it is the function of a doctor to submit an official death certificate with the cause identified. In Graunt's time the people who decided cause of death were "Searchers," who were older women with no medical training but who had learned by long experience. The box on the right is Graunt's description of the procedure.

> When anyone dies, then, either by tolling, or by ringing of a Bell, or by bespeaking of a Grave of the *Sexton*, the same is known to the *Searchers*, corresponding with the said *Sexton*. The Searchers hereupon (who are antient Matrons, sworn to their office) repair to the place, where the dead Corps lies, and by view of the same, and by other enquiries, they examine by what *Disease*, or *Casualty* the corps died. Hereupon they make their Report to the *Parish-Clerk*, and he, every *Tuesday* night, carries in an Accompt of all the *Burials*, and *Christnings*, hapning that Week, to the *Clerk* of the *Hall*. On *Wednesday* the general Accompt is made up, and Printed, and on *Thursdays* published and dispersed to the several Families, who will pay four shillings *per Annum* for them".

John Graunt was not a professional scholar. He was a tradesman, a haberdasher, involved in London society and politics. He was a learned man with friends in the newly formed Royal Society, which is where he distributed the first copies of his book in January, 1662. About a month later he was given membership in the Society. He never published anything else. The originality in his *Observations* was phenomenal. The new deep perception that Graunt presented was the value of ***population level*** analysis. Healers had always thought about causes of illness and death in individuals, but no one before him had studied *community-wide patterns of mortality over time*. For example,

> **Among the several Casualties some bear a constant proportion unto the whole number of Burials; such are Chronical diseases, and the diseases, whereunto the City is most subject.**

Here is an appreciation of Graunt's achievements by epidemiologist Kenneth Rothman in the medical journal *Lancet* (January 1996).

> **With this book Graunt added more to human knowledge than most of us can reasonably aspire to in a full career. Graunt was the first to report, and to document, that more boys than girls are born. *He presented one of the first life tables.* He reported the first time-trends for many diseases, taking into account changes in population size. He described new diseases, and noted others that seemed to increase over time only because of changes in classification. He offered the first reasoned estimate of the population of London, demonstrating its rapid growth and showing that most of the growth came from immigration. He proffered epidemiological evidence refuting the theory that the plague spreads by contagion. (He also refuted the notion that plague epidemics are coincident with the reign of a new king.) He showed that the large population decreases in plague years were offset by large increases in births in subsequent years. He showed that physicians have twice as many female as male patients, but that more males than females die. He produced the first hard evidence about the frequencies of various causes of death. And, presaging our present-day paranoia, he tried to allay unwarranted anxiety about risks that were feared far out of proportion to their likelihood of occurrence.** (page 37)

Graunt was clearly an original thinker. From other sources we see that he was also a popular and good-natured person. It is interesting to note how his lack of higher education made him quite defensive (or maybe "modest" is a better word) about his book. The last part of his preface is a gem of wit and humility:

> **How far I have succeeded in the Premisses, I now offer to the World's censure. Who, I hope, will not expect from me, not professing Letters, things demonstrated with the same certainty, wherewith Learned men determine in their *Scholes*; but will take it well, that I should offer at a new thing, and could forbear presuming to meddle where any of the Learned Pens have ever touched before, and that I have taken the pains, and been at the charge, of setting out those *Tables,* whereby all men may both correct my *Positions*, and raise others of their own: For herein I have, like a silly Schole-boy, coming to say my Lesson to the World (that Peevish, and Tetchie Master) brought a bundle of Rods wherewith to be whipt, for every mistake I have committed.**

Life Tables

The previous quotation from Rothman states that Graunt is credited with producing one of the first ***life tables***. The basic function of a life table is to give the expected remaining years (on average, of course) for people of a given age. Life tables are a fundamental tool of the insurance industry and of public health officials. In the US the Center for Disease Control (CDC) publishes life tables for every state and for various population subgroups. The tables are based on the vital statistics (births and deaths) reported by doctors.

Graunt produced his table based on the births and deaths he saw in 70 years' worth of records published in the bills of mortality. He had to make some simplifying assumptions about the likelihood of death for different age groups and he lacked sufficient data to do this very accurately, but he established the basic rules for constructing such tables.

Here is an illustration from Chapter 1 of Graunt's book. The list on the left gives the number who died in each decade. The list on the right gives the number who are still alive. ("Quick conceptions" means "live births".)

9. Whereas we have found, that of 100 quick Conceptions about 36 of them die before they be six years old, and that perhaps but one surviveth 76, we, having seven *Decads* between six and 76, we sought six mean proportional numbers between 64, the remainder, living at six years, and the one, which survives 76, and finde, that the numbers following are practically near enough to the truth; for men do not die in exact Proportions, nor in Fractions: from whence arises this Table following.

Viz. of 100 there dies within the first six years	36
The next ten years, or *Decad*	24
The second *Decad*	15
The third *Decad*	09
The fourth	6
The next	4
The next	3
The next	2
The next	1

10. From whence it follows, that of the said 100 conceived there remains alive at six years end 64.

At Sixteen years end	40
At Twenty six	25
At Tirty six	16
At Fourty six	10
At Fifty six	6
At Sixty six	3
At Seventy six	1
At Eighty	0

Put into a more modern format and converted to proportions it would look like this:

Graunt's life table in modern format

Age interval	Number of deaths in interval	Number alive the start of the interval	Proportion of deaths in interval	Proportion alive the start of the interval
0-6	36	100	.36	1.00
7-16	24	64	.24	.64
17-26	15	40	.15	.40
27-36	9	25	.09	.25
37-46	6	16	.06	.16
47-56	4	10	.04	.10
57-66	3	6	.03	.06
67-76	2	3	.02	.03
77-86	1	1	.01	.01

A life table from the CDC today looks like the next one. You can see it grew from Graunt's ideas. This image shows just the first few rows. The frequency columns in the CDC life tables assume there were 100,000 people to start.

National Vital Statistics Report, Volume 60, Number 9, September 14, 2012

Table VT-1. Life table for the total population: Vermont, 1999-2001

[All life table calculations were carried out using floating point precision, allowing for fractional deaths and fractional years of life lived. Thus, users of the decennial life tables are cautioned that the life table calculations are based on additional significant digits than shown and back-calculation using the rounded numbers cannot be expected to reproduce the exact published results. See Technical Notes.]

Age	Probability of dying between ages *x* to *x + 1*	Number surviving to age x	Number dying between ages x *to x + 1*	Person-years lived between ages *x to x + 1*	Total number of person-years lived above age *x*	Expectation of life at age *x*
X to x+1	q_x	l_x	d_x	L_x	T_x	e_x
0-1	0.00344	100,000	344	99,828	7,824,089	78.24
1-2	0.00114	99,656	113	99,599	7,724,261	77.51
2-3	0.00052	99,542	52	99,516	7,624,662	76.60
3-4	0.00029	99,490	29	99,475	7,525,146	75.64
4-5	0.00018	99,461	18	99,452	7,425,671	74.66
5-6	0.00016	99,443	16	99,435	7,326,219	73.67

Exercises

1. See the Vermont life tables at http://www.cdc.gov/nchs/data/dvs/lewk4_vermont.pdf. Use the appropriate one to determine the average length of time people your age and gender have left to live. What does that tell you about yourself? What is the value of this information if it's not about any particular person?

2. (Fake data). Let's assume there is some short-lived organism, say a bug or a plant that yields these data.

Age interval *x* to *x*+1 (years)	l_x Number alive at start of age interval	T_x Total number of *years* still to be contributed by organisms alive at the start of this age group	$e_x = T_x / l_x$ Expectation of life at age x
0-1	100		
1-2	90		
2-3	60	85	
3-4	20	25	1.25
4-5	5	5	1.00
5-6	0	0	

Study the patterns in the table and fill in the five missing cells. Hint: The T_x column is easiest to understand from the bottom up. From your completed table: What is the average life expectancy *at birth* of these organisms? If one of them makes it to age 3, how much longer can it expect to live?
A graph of l_x against x is called a survivorship curve. Plot those six dots and connect them by a smooth curve. Interpret what you see. Why isn't the graph a straight line?

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*For translation into modern disease names see http://www.edstephan.org/Graunt/diseases.html

Sources:

David, F. N. *Games Gods and Gambling,* Charles Griffin & Co., 1962
Graunt, John, *Natural and Political Observations Made upon the Bills of Mortality, 1662,*
You can find a copy of the first edition at http://www.edstephan.org/Graunt/graunt.html. This web site has much to show about John Graunt and about 17th century London.
Rothman, Kenneth, "Lessons from John Graunt", *Lancet,* Jan 6, 1996.
Sutherland, Ian. "John Graunt: A Tercentenary Tribute". *Journal of the Royal Statistical Society. Series A (general)* 126 (4), 1963.
Vermont Life Table: cdc.gov/nchs/data/dvs/lewk4_vermont.pdf
Image of Graunt. http://www.york.ac.uk/depts/maths/histstat/people/graunt.gif