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Reckoning on Death and Chance with the Merchant's Rule

Mathematicks at that time, with us, were scarce looked upon as Academical Studies, but rather Mechanical; as the business of Traders, Merchants, Seamen, Carpenters, Surveyors of Lands, or the like, and perhaps some Almanack Makers in London. . . . For the Study of Mathematicks was at that time more cultivated in London than in the Universities.

John Wallis, seventeenth-century British mathematician, quoted in Taylor [1954] 1968, 4

In 1662, a London cloth merchant made several ingenious social comparisons that centuries later are considered the seeds of a science of quantitative observation. John Graunt's use of mathematics was not what we would call sophisticated; in fact he described it as the "Mathematiques of my Shop-Arithmetique" (Graunt [1662] 1975, 7). Graunt's mercantile analytical tools included comparison by division in the forms of ratios and percents, comparison by subtraction over time to follow increases and decreases, and the use of relative time frameworks to search for and predict seasonal and cyclical patterns. These arithmetic tools, socially distributed by merchants, became the basis for algorithms used in inductive studies from the seventeenth century onward. Although the data Graunt worked with were time series spanning twenty years, his chief arithmetic tool, the Rule of Three or the Merchant's Rule, is not usually associated with time series analysis. This comparison by division, however, is at the core of several types of data manipulation used in statistics, and I use it in this chapter to contrast the different contexts of quantitative reasoning.

The development from monetary to political to scientific arithmetic is the structure for this and all other chapters in Part I. We begin with an examination of Graunt's adaptation of his shop arithmetic into a policy tool applied to the bills of mortality. I then explore the leveling qualities of seventeenth-century urban labor markets and epidemics and their impact on political and statistical notions of population. In the last section of the chapter, I examine Karl Pearson's appropriation of Graunt's techniques and subject for his own scientific investigation into the age distribution of deaths.

The Merchant's Rule

The main tool of Graunt's mercantile-turned-political arithmetic was the Rule of Three. The Rule of Three is the simple arithmetic technique of using three knowns to solve for a fourth unknown factor in a ratio relationship. For example, solving for c in the expression

$$\frac{a}{b} = \frac{c}{d} \text{ or } a{:}b = c{:}d.$$

Graunt, for example, noted that from 1628 to 1662, 139,782 males and 130,866 females were christened. Using the Rule of Three, he simplified the gender comparisons by stating that there were fourteen men to every thirteen women. He carried this shop arithmetic into the realm of political arithmetic with the assertion that the value of the ratio served as proof that legislation against polygamy was consistent with the "*Law of Nature*" (Graunt [1662] 1975, 57–58).

In *Capitalism and Arithmetic: The New Math of the 15th Century*, Frank Swetz argues that for centuries the Rule of Three was the most esteemed mathematical technique in Europe. Swetz sees the Rule of Three as essential for all societies in which trade and exchange flourished. Although it can be traced to mathematical works from India and China as early as A.D. 250, its popularity and importance in Europe were due to its use in commercial practice, and it was often called the "Merchant's Rule" or the "Merchant's Key."[1] The earliest known printed mathematics books in the West are from late fifteenth-century Italy. These were texts for those engaged in commercial reckoning. The Rule of Three, *de regola del tre* or *la regula de le tre cose*, was the primary mathematical technique in these early texts and almost all of the illustrations given for the Rule of Three were of a mercantile nature.

In his book on *Painting and Experience in Fifteenth-Century Italy*, Michael Baxandall asserts the Rule of Three was such an important part of the training and work of merchants that they "played games and told jokes with it, bought luxurious books about it, and prided themselves on their prowess in it" (Baxandall 1988, 101). Baxandall reproduces several paintings that illustrate his premise that the universal commercial use of the Rule of Three, along with the technique of gauging volumes in the course of exchanging commodities, greatly influenced quattrocento Italian art. The commercial patron commanded art that visually played on the skills of comparing ratios and comparing volumes. Two centuries later, the merchant Graunt was flaunting his prowess with this rule and trying to persuade king and councilors of its effectiveness in simplifying comparisons of awkward quantities.

[1] A distinguishing name for the algorithm is still used in some countries. An Argentinean student explained to me that she determined comparative advantage in international trade problems by using the Rule of Three. This was the first time I had heard the expression outside of pre-twentieth-century tomes. Another student from Bulgaria also spoke of the comparative advantage calculation as the Rule of Three. The episodes brought to my mind that the entire logic of nineteenth-century comparative advantage problems in international trade and of twentieth-century exchange rate calculations in international finance is an exercise in the Rule of Three.

Although its popular origins were in commerce, the Merchant's Rule eventually became an important tool in the science of observation. Karl Pearson and Udny Yule, unlike John Graunt, were undoubtedly linked in their formal education and their research programs to the realm of science, mathematics, and statistical theory. One of the important vehicles for publishing their statistical research was the journal *Biometrika*. In a 1901 letter to Pearson, Yule suggested a quotation from Charles Darwin on quantitative methods as a motto for the new journal. Pearson agreed and used this passage, from Darwin's letter of May 23, 1855, in the first editorial of *Biometrika*: "I have no faith in anything short of actual measurement and the Rule of Three" (Darwin 1911, 411; Yule 1901b; Pearson 1901a, 4). The Rule of Three was the primary instrument of analysis in Graunt's seventeenth-century political arithmetic on the bills of mortality. By the nineteenth century, Darwin was far from alone in relying almost totally on the Rule of Three for quantitative analysis of observed natural and social phenomena.

The authors of the fifteenth-century Italian arithmetic books often used examples of the selling of cloth to illustrate the Rule of Three. It should, therefore, come as no surprise that a draper was to make the link between monetary and political arithmetic and introduce the Rule of Three to Charles II and his advisers for the purposes of quantitative decision making in public policy. In 1662, John Graunt's exhaustive and ingenious use of his "Shop-Arithmetique" ensured the unusual appointment of a cloth merchant to the newly formed Royal Society.[2] In his history of the Royal Society, Thomas Sprat used Graunt's appointment as an example of the king's, and thus the Royal Society's, regard for the "manual Arts" and "Mechanick Artists." In appointing Graunt as a charter member of the Royal Society, Charles II, according to Sprat, "gave this particular charge to His society, that if they found any more such Tradesmen, they should admit them all, without any more ado" (Sprat 1667, 67). It is no accident that the first foot in the door for the social sciences was that of a haberdasher.

Political Arithmetic with the Rule of Three

Why were the methods and conclusions of this merchant so well received by Charles II, his Privie Council, and the newly chartered Royal Society? In an essay on objectivity and authority, Ted Porter illustrated how statistics, in the realm of public policy, were used more to justify and rationalize than to discover and understand. Hereditary rulers who had absolute, unquestionable authority had no need for statistics (Porter 1991, 252). When Graunt presented his observations, the British royal family had only just come back into power following a civil war, the beheading of Charles I and Oliver Cromwell's rule (1649–1658). Charles II needed to reconstruct the crown's authority,

[2] A modern-day equivalent would be the election of a financial analyst on Wall Street to the National Academy of Science.

and Graunt in an obsequious way catered to that need. For example, one of Graunt's points was that 1660, the year of the restoration of throne, was a healthy and fruitful one and that, along with the evidence of health in 1648, "doth abundantly counterpoise the *Opinion* of those who think great *Plagues* come in with *King's* Reigns, because it happened so twice, *viz. Anno 1603* and 1625" (Graunt [1662] 1975, 51).

What had impressed Charles II was Graunt's skillful use of the Rule of Three to address such issues as population growth, age-specific mortality, the sustainability of a fighting army, the social futility of polygamy, the timing of plagues, and the age of the earth. Graunt noted the bills of mortality were made little use of other than to note weekly increases and decreases for general conversation, and in times of plague, "that so the rich might judge of the necessity of their removall, and Trades-men might conjecture what doings they were to have in their respective dealings" (Graunt [1662] 1975, 17). Graunt's achievement in bridging monetary and political arithmetic stemmed from his surmounting the boundaries of time in calculating ratios and making comparisons that could serve a state in justifying its actions and decrees. With over twenty years of data on cause of death and number of burials and christenings by sex, Graunt compared, through division and subtraction, one year, season, or parish with another, he calculated "mediums" to eliminate irregularities, and he reduced unwieldy raw proportions into percentages and other comprehensible forms. Graunt's calculations with the Merchant's Rule revealed the remarkable stability of some social mass phenomena over time and across parishes. Graunt's discovery of stable ratios has been recognized by many, but few have acknowledged Graunt's mercantile way of thinking and his insightful time series analysis.

In his ninety-page pamphlet, Graunt:

- reduced data from weekly bills from 1604–1660 into a few "Perspicuous Tables"
- examined inconsistencies, inaccuracies, biases, and limitations of data observed
- grouped observations into distinct categories, such as cause of death due to acute or to chronic diseases
- made comparisons between regions and over time
- calculated a life table
- patterned life cycles and seasonal variations of disease
- estimated the population, and death, birth, and growth rates for London

Three of the tables that Graunt constructed from the bills of mortality are reproduced in Tables 2.1 through 2.3. Most of Graunt's analysis on the data in the tables was comparison by division with the Rule of Three. The following passage, in which he compares the number of plague deaths with total deaths, illustrates his almost tortuous use of the Rule of Three:

Table 2.1 *Graunt's table of annual burials and christenings in London from 1604 to 1651. The first four columns of burials do not include deaths due to the plague, which are counted in the fifth data column. Graunt cautioned that from 1642 onward, the account of christenings was not an accurate recording of total births.*

The Table of Burials and Chriſtnings in London.

Anno Dom.	97 Pariſhes	16 Pariſhes	Out-Pariſhes	Buried in all	Beſides of the Plague	Chriſtned
1604	1518	2097	708	4323	896	5458
1605	2014	1974	960	5948	444	6504
1606	1941	2920	935	5796	2124	6614
1607	1879	2772	1019	5670	2352	6582
1608	2391	3218	1149	6758	2262	6845
1609	2494	3610	1441	7545	4240	6388
1610	2326	3791	1369	7486	1803	6785
1611	2152	3398	1166	6716	627	7014
	16715	24780	8747	50242	14752	52190
1612	2473	3843	1462	7778	64	6986
1613	2406	3679	1418	7503	16	6846
1614	2369	3504	1494	7367	22	7208
1615	2446	3791	1613	7850	37	7682
1616	2490	3876	1697	8063	9	7985
1617	2397	4109	1774	8280	6	7747
1618	2815	4715	2066	9596	18	7735
1619	2339	3857	1804	7999	9	8127
	19735	31374	13328	64436	171	60316
1620	2726	4819	2146	9691	21	7845
1621	2438	3759	1915	8112	11	8039
1622	2811	4217	2392	8943	16	7894
1623	3591	4721	2783	11095	17	7945
1624	3385	5919	2895	12199	11	8299
1625	5143	9819	3886	18848	35417	6983
1626	2150	3285	1965	7401	134	6701
1627	2325	3400	1988	7711	4	8408
	24569	39940	19970	84000	35631	62114

The Table of Burials, and Chriſtnings, in London.

Anno Dom.	97 Pariſhes.	16 Pariſhes	Out-Pariſhes.	Buried in all	Beſides of the Plague	Chriſtned
1628	2412	3311	2017	7740	3	8564
1629	2536	3991	2243	8771	0	9901
1630	2506	4101	2521	9237	1317	9315
1631	2459	3697	2132	8288	274	8524
1632	2704	4412	2411	9527	8	9584
1633	2378	3936	2078	8393	0	9997
1634	2937	4980	2982	10399	1	9855
1635	2742	4966	2943	10651	0	10034
	20694	33495	19327	73505	1603	75774
1636	2825	6924	3210	12959	10400	9522
1637	2288	4265	2128	8681	3082	9160
1638	3584	5926	3751	13261	363	10311
1639	2592	4344	2612	9548	314	10150
1640	2919	5156	3246	11321	1450	10850
1641	3248	5092	3427	11767	1375	10670
1642	3176	5245	3578	11999	1274	10370
1643	3395	5552	3269	12216	996	9410
	23987	42544	25221	91752	19244	80443
1644	2593	4274	2574	9441	1492	8104
1645	2524	4639	2445	9608	1871	7966
1646	2746	4872	2797	10415	2365	7163
1647	2672	4749	3041	10462	3597	7332
1648	2480	4288	2515	9283	611	6544
1649	2865	4714	2920	10499	67	5825
1650	2301	4138	2310	8749	15	5612
1651	2845	5002	2597	10804	23	6071
	21026	36676	21199	78896	10041	54617

Source: Graunt [1662] 1665, 174–175.

In the year 1592, and 1636 we finde the proportion of those dying of the *Plague* in the whole to be near alike, that is about 10 to 23. or 11 to 25. or as about two to five.

In the year 1625. we finde the *Plague* to bear unto the whole in proportion as 35 to 51. or 7 to 10. that is almost the triplicate of the former proportion, for the *Cube* of 7. being 343. and the *Cube* of 10. being 1000. the said 343. is not 2/5 of 1000.

In *Anno* 1603. the proportion of the *Plague* to the whole was as 30 to 37. viz. as 4. to 5. which is yet greater then that last of 7 to 20. For if the Year 1625. had been as great a *Plague*-Year as 1603. there must have died not onely 7 to 10. but 8 to 10. which in those great numbers makes a vast difference.

We must therefore conclude the Year 1603. to have been the greatest *Plague*-year of this age. (Graunt [1662] 1975, 45–46)

Table 2.2 *Graunt's table of burials and christenings by sex for London from 1629 to 1664. The distinction of sex was initiated in the London bills of mortality in 1629. Graunt took a subtotal at the year 1640, because he thought that after that year the accounts, particularly for christenings, were not exact. He asserted, however, that the neglect after 1640 affected both sexes equally, so comparisons with ratios or proportions would still be accurate.*

(180)

The TABLE of Males, and Females, *for* LONDON.

An.Dom.	Buried Males	Buried Females	Christened Males	Christened Females
1629	4668	4103	5218	4683
1630	5660	4894	4858	4457
1631	4549	4013	4422	4102
1632	4932	4603	4994	4590
1633	4369	4023	5158	4839
1634	5676	5224	5035	4820
1635	5548	5103	5106	4928
1636	12377	10982	4917	4605
	47779	43945	39708	37024
1637	6392	5371	4703	4457
1638	7168	6456	5359	4952
1639	5351	4511	5366	4784
1640	6761	6010	5518	5332
Total	73451	65293	60664	56549
1641	6872	6270	5470	5200
1642	7049	6224	5460	4910
1643	6842	6360	4793	4617
1644	5659	5274	4107	3997
1645	6014	5465	4047	3919
1646	6683	6097	3768	3395
1647	7313	6746	3796	3536
1648	5145	4749	3363	3181
	51577	47185	34804	32755

(181)

An.Dom.	Buried Males	Buried Females	Christened Males	Christened Females
1649	5454	5112	3079	2746
1650	4548	4216	2890	2722
1651	5680	5147	3231	2840
1652	6543	6026	3220	2908
1653	5416	4671	3196	2959
1654	6972	6275	3441	3179
1655	6027	5330	3655	3349
1656	73[illegible]	6556	3668	3382
	44005	41333	26380	24085
1657	6578	5856	3396	3289
1658	7936	7057	3157	3013
1659	7451	7305	3209	2781
1660	7960	7158	3724	3247
1661	10448	9287	4748	4107
1662	8623	7931	5216	4803
1663	8035	7321	5411	4881
1664	9369	8928	6041	5681
	66400	60843	34902	3180
Total	235427	214658	156750	14623

Source: Graunt [1662] 1665, 180–181.

Graunt's comparison by division resulted in various final forms that are summarized in Table 2.4. Proportions were Graunt's most common form of comparison, and the data set used for most of his proportions comprised annual observations on death due to different causes in London from 1629 to 1636 and from 1647 to 1659. Graunt calculated chance of death due to different causes by taking deaths due to one cause, summed over twenty years, and dividing that by total deaths summed over twenty years. With these proportions, Graunt constructed tables of notorious diseases and casualties so that "persons may the better understand the hazard they are in" (Graunt [1662] 1975, 31).[3] Graunt wrote that one of the chief goals of his analysis was "to

[3] Philip Kreager (1988) places Graunt's use of proportions in the context of the role of proportional checks in monitoring "accompts" in the typical bookkeeping practices of seventeenth-century London. Kreager also sees Graunt's inconsistencies in sums and his informal attitude toward totals as typical mercantile accounting.

Table 2.3 *Data from Graunt's "Table of Casualties" displaying the annual number of deaths in London by cause from 1647 to 1660 and from 1629 to 1636. Given the "Incapacity of a Sheet," Graunt limited his table to twenty-two years, omitting the years between 1636 and 1647 because "nothing Extraordinary" happened in those years. In many of his calculations, Graunt used the twenty-year (1629–1636 and 1647–1658) total for burials, which is in the next to last column. Given the incapacity of my sheet, I omitted six columns of subtotals of annual groupings and aggregated twenty-five causes of death that resulted in less than sixty-five burials in twenty years into a row labeled "sum of the others." I also appended the last column that recalculates the row totals and illustrates some printing or calculation errors in Graunt's totals.*

	1647	1648	1649	1650	1651	1652	1653	1654	1655	1656	1657	1658	1659	1660	1629	1630	1631	1632	1633	1634	1635	1636	In 20 Years	Corrected
Abortive and Stil-born	335	329	327	351	389	381	384	433	483	419	463	467	421	544	499	439	410	445	500	475	507	523	8559	8559
Aged	916	835	889	696	780	864	804	974	743	892	869	1176	909	1095	579	712	661	671	704	623	794	714	15759	15896
Ague and Fever	1260	884	751	970	1038	1212	1282	1317	689	875	999	1800	2303	2148	956	1091	1115	1108	953	1279	1622	2360	23784	23561
Apoplex, and Suddenly	69	74	64	74	106	111	118	86	92	102	113	138	91	67	85	95	37	79	82	97	104	34	1760	1760
Blasted	4	1			6	6			4		5	5	3	8	13	8	10	13	6	4		4	99	89
Bloody flux, Scouring and Flux	155	176	802	289	833	762	200	386	168	368	362	233	346	251	449	438	352	348	278	512	346	330	7818	7787
Burnt, and Scalded	3	6	10	5	11	8	5	7	10	5	7	4	6	6	3	10	7	5	1	3	12	3	125	125
Cancer, Gangrene and Fistula	26	29	31	19	31	53	36	37	73	31	24	35	63	52	20	14	23	28	27	30	24	30	609	621
Canker, Sore-mouth and Thrush	66	28	54	42	68	51	53	72	44	81	76	93	73	68	21	27	21	41	28	31	39	74	689	1010
Child-bed	161	106	114	117	206	213	158	192	177	201	236	225	226	194	150	157	112	171	132	143	163	230	3364	3364
Chrisomes, and Infants	1369	1254	1065	990	1237	1280	1050	1343	1089	1393	1162	1144	858	1123	2596	2378	2035	2268	2130	2315	2113	1895	32106	32106
Colick, and Wind	103	71	85	82	76	102	80	101	85	120	113	179	116	167	48	57					37	50	1389	1389
Cold, and Cough							41	36	21	58	30	31	33	24	10	58	51	55	45	54	50	57	598	597
Consumption, and Cough	2423	2200	2388	1988	2350	2410	2286	2868	2606	3184	2757	3610	2982	3414	1827	1910	1713	1797	1754	1955	2080	2477	44487	46583
Convulsion	684	491	530	493	569	653	606	828	702	1027	807	841	742	1031	52	87	18	241	221	386	418	709	9073	10363
Dropsie and Typany	185	434	421	508	444	556	617	704	660	706	631	931	646	872	235	252	279	280	266	250	329	389	9623	9077
Drowned	47	40	30	27	49	50	53	30	43	49	63	60	57	48	43	33	29	34	37	32	32	45	827	826
Executed	8	17	29	43	24	12	19	21	19	22	20	18	7	18	19	13	12	18	13	13	13	13	384	366
Flox, and small Pox	139	400	1190	184	525	1279	139	812	1294	823	835	409	1523	354	72	40	58	531	72	1354	293	127	10576	10576
Found dead in the Streets	6	6	9	8	7	9	14	4	3	4	9	11	2	6	18	33	20	6	13	8	24	24	243	236
French-Pox	18	29	15	18	21	20	20	20	29	23	25	53	51	31	17	12	12	12	7	17	12	22	392	402
Gout	9	5	12	9	7	7	5	6	8	7	8	13	14	2	2	5	3	4	4	5	7	8	134	134
Grief	12	13	16	7	17	14	11	17	10	13	10	12	13	4	18	20	22	11	14	17	5	20	279	279
Hanged, and made-away themselves	11	10	13	14	9	14	15	9	14	16	24	18	11	36	8	8	6	15		3	8	7	221	222
Jaundice	57	35	39	49	41	43	57	71	61	41	46	77	102	76	47	59	35	43	35	45	54	63	998	998

Table 2.3 *(cont.)*

	1647	1648	1649	1650	1651	1652	1653	1654	1655	1656	1657	1658	1659	1660	1629	1630	1631	1632	1633	1634	1635	1636	In 20 Years	Corrected
Jaw-faln	1	1			3			2	2		3	1			10	16	13	8	10	10	4	11	95	95
Impostume	75	61	65	59	80	105	79	90	92	122	80	134	105	96	58	76	73	74	50	62	73	130	1639	1638
Killed by several Accidents	27	57	39	94	47	45	57	58	52	43	52	47	55	47	54	55	47	46	49	41	51	60	1021	1021
King's Evil	27	26	22	19	22	20	26	26	27	24	23	28	28	54	16	25	18	38	35	20	20	69	537	531
Livergrown, Spleen, and Rickets	53	46	56	59	65	72	67	65	52	50	38	51	8	15	94	112	99	87	82	77	98	99	1421	1422
Lunatick	12	18	6	11	7	11	9	12	6	7	13	5	14	14	6	11	6	5	4	2	2	5	158	158
Meagrom	12	13		5	8	6	6	14	3	6	7	6	5	4			24					22	132	132
Measles	5	92	3	33	33	62	8	52	11	153	15	80	6	74	42	2	3	80	21	33	27	12	757	767
Murdered	3	2	7	5	4	3	3	3	9	6	5	7	70	20			3	7		6	5	8	86	86
Overlaid and starved at Nurse	25	22	36	28	28	29	30	36	58	53	44	50	46	43	4	10	13	7	8	14	10	14	529	519
Palsie	27	21	19	20	23	20	29	18	22	23	20	22	17	21	17	23	17	25	14	21	25	17	423	423
Plague	3597	611	67	15	23	16	6	16	9	6	4	14	36	14		1317	274	8		1		10400	16384	16384
Plague in the Guts				1		110	32		87	315	446		253	402									991	991
Pleurisie	30	26	13	20	23	19	17	23	10	9	17	16	12	10	26	24	26	36	21		45	24	415	425
Purples and Spotted Fever	145	47	43	65	54	60	75	89	56	52	56	126	368	146	32	58	58	38	24	125	245	397	1845	1845
Quinsie and Sore-throat	14	11	12	17	24	20	18	9	15	13	7	10	21	14	1	8	6	7	24	4	5	22	247	247
Rickets	150	224	216	190	260	329	229	372	347	458	317	476	441	521						14	49	50	3681	3681
Mother, rising of the Lights	150	92	115	120	134	138	135	178	166	212	203	228	210	249	44	72	99	98	60	84	72	104	2700	2504
Rupture	16	7	7	6	7	16	7	15	11	20	19	18	12	28	2	6	4	9	4	3	10	13	201	200
Scurvy	32	20	21	21	29	43	41	44	103	71	82	82	95	12	5	7	9		9		00	25	593	644
Sores, Ulcers, broken & bruised Limbs	15	17	17	16	26	32	25	32	23	34	40	47	61	48	23	24	20	48	19	19	22	29	504	528
Spleen	12	17					13	13		6	2	5	7	7									68	68
Stone and Strangury	45	42	29	28	50	41	44	38	49	57	72	69	22	30	35	39	58	50	58	49	33	45	937	931
Stopping of the Stomach	29	29	30	33	55	67	66	107	94	145	129	277	186	214								6	669	1067
Surfet	217	137	136	123	104	177	178	212	128	161	137	218	202	192	63	157	149	86	104	114	132	371	3094	3104
Teeth and Worms	767	597	540	598	709	905	691	1131	803	1198	878	1036	839	1008	440	506	335	470	432	454	539	1207	14236	14236
Tissick	62	47													8	12	14	34	23	15	27		242	242
Vomiting	1	6	3	7	4	6	3	14	7	27	16	19	8	10	1	4	1	1	2	5	6	3	136	136
Worms	147	107	105	65	85	86	53								19	31	28	27	19	28	27		830	827
Sum of the Others	23	27	41	40	22	23	23	29	40	21	27	29	77	97	18	20	20	26	33	13	28	31	601	534
Graunt's Total																							229250	
Recalculated Total																								232312

Source: Graunt [1662] 1665, foldout.

Table 2.4 *Final forms of Graunt's comparison by division:* $\frac{a}{b} = \frac{c}{d}$

Type	Numerical form	Example
Ratio	c & d are integers, small and close in value	14 males to 13 females
Rate of occurrence	c is equal to 1	1 in 32 die yearly in London
Proportion	c is equal to 1 or d is equal to 229,250 (total deaths) or c/d in simple form	Of total deaths, 1 of 1,500 "dies Lunatick," 51 of 229,250 starve
Percentage	d is equal to 100	7 percent die of old age

understand the Land, and the hands of the Territory to be governed, according to all their intrinsick, and accidental differences." He also admitted however, "That there is much pleasure in deducing so many abstruse, and unexpected inferences out of the poor despised Bills of *Mortality*" (Graunt [1662] 1975, 72).

Graunt's investigation led to several interesting conclusions:

- The practice by English women of maintaining a straight, horizontal posture during childbirth resulted in a higher maternal death rate than in countries where this was not the fashion (Graunt [1662] 1975, 43).
- Mental work, typical of businesses in London, produced "*Anxieties* of the minde," which hindered breeding compared with the "*corporal* Labour and Exercizes" of the country (56).
- Polygamy should not be allowed since the sex ratio at birth of males to females was greater than one, and where it is allowed "Wives can be no other then Servants" (13, 57–60).
- During the great plagues, one-fifth of the population of London died while two-fifths fled to the countryside; but the "City is fully re-peopled within two years"; the plague that began in 1603 lasted eight years, the one that began in 1636, twelve years, but the plague of 1625 lasted only one year (11, 47).
- Wars could easily be waged and colonies settled without destroying the due proportion of males to females (59).
- The population of England and Wales was 6,500,000, and the population of London represented one-fifteenth of the total (11, 54).
- The population of London doubled in 70 years compared with 280 years in the country parishes (12, 53–54).
- Not including great plagues, the death rate for London was 1 in 32, which was higher than that of the country, which was 1 in 50 (76).
- There are four children for every marriage (14).

- The world was not more than 5,610 years old, "which is the *age* of the world according to the *Scriptures*" (70).

Graunt's Epidemiology

The link between the shop arithmetic and the political arithmetic also comes out clearly in Graunt's analysis of seasonal and annual variations. In addition to his extensive use of the Merchant's Rule, Graunt employed comparison by subtraction, "medium" (average) annual values, and relative time frameworks to identify unhealthy years and seasons and to search for cyclical patterns in illness.[4] For example, Graunt labeled a year as "sickly" if the number of burials in that year was greater than the numbers in the previous year and the subsequent year.

Graunt's search for temporal patterns included a study of the progress of some diseases in absolute time. Graunt tried to determine whether rickets, a disease that appeared on the bills for the first time in 1634, was a new disease or merely a new name for an existing disease. Graunt concluded that the former was the case. He used the image of "backstarting" (what contemporary consumption theorists would call the "ratchet" effect) to visualize a typical temporal pattern of the annual progression in the mortality of a new disease such as rickets:

> Now, such backstartings seem to be universal in all things; for we do not onely see in the progressive motion of the wheels of *Watches*, and in the rowing of *Boats*, that there is a little starting, or jerking backwards between every step forwards, but also (if I am not much deceived) there appeared the like in the motion of the *Moon*, which in the long *Telescopes* at *Gresham-College* one may sensibly discern. (Graunt [1662] 1975, 39)

Using a relative-time framework, Graunt determined that, "the unhealthful Season is the *Autumn*" (Graunt [1662] 1975, 51). This was particularly true during epidemics of bubonic plague. The number of plague deaths generally peaked in late August or September. If mortality could be tracked on a weekly basis, then a marked increase in deaths in late summer would signal a visitation of pestilence.

The emerging urban markets in seventeenth-century London, in addition to providing Graunt the analytical tools, called forth the data for his observations. Throughout the seventeenth century, every week, in every parish of London, state-appointed searchers visited the homes of the recently deceased to determine the cause of death. The searchers, older women by decree, reported their findings to the parish clerks, and every Thursday, the numbers of parish christenings and burials and the causes of death were published and sent to those who had paid four shillings per year for the bills of mortality (a portion

[4] In Chapters 3 and 5, I examine in more detail the monetary algorithms of first differences and relative time frameworks respectively.

of the annual bill of mortality for 1665 is reproduced in Table 2.5). The subscribers included merchants anxious about the future of their trade and the wealthy, who could afford to leave town at the first hint of pestilence.

Great Plagues

Graunt applied his "shop-arithmetique" to numbers gleaned from the searchers' data, which had been tabulated on a weekly basis from as early as 1532.[5] These parish bills, regularly posted to monitor the course of plagues, were products of a modern way of perceiving and accounting the human creatures that inhabited the British Isles. The bubonic plagues were mass phenomena, and visitations brought home the numerical equivalence of the dead, whether they were rich or poor while they lived.[6] The breakdown of the sense of the individual was vividly described in Daniel Defoe's account of the mass burial pits in which thousands of corpses were put during the 1665 London plague:[7]

> The Cart had in it sixteen or seventeen Bodies; some were wrapt up in Linen Sheets, some in Rugs, some a little other than naked, or so loose, that what Covering they had fell from them in the shooting out of the Cart, and they fell quite naked among the rest; but the Matter was not much to them, or the Indecency much to any one else, seeing they were all dead, and were huddled together into the common Grave of Mankind, as we may call it, for here no Difference made, but Poor and Rich went together, there was no other way of Burials. . . .
>
> It was reported by way of Scandle upon the Buriers that if any Corpse was delivered to them decently wound up, as we call'd it then, in a Winding Sheet Ty'd over the Head and Feet, which some did, and which was generally of good Linen; I say, it was reported, that the Buriers were so wicked as to strip them in the Cart and carry them quite naked to the Ground. (Defoe [1722] 1968, 69–70)

Thomas Dekker's description of mass burial during the 1603 visitation in London is similar:

[5] Charles Hull (1899, lxxx–xci) draws on many historical sources to try to determine the dates and forms of the earliest bills of mortality. The fire of 1666 apparently destroyed all sets of London bills before 1658, but Graunt's tables, John Bell's *London's Remembrancer*, and assorted manuscripts enable a reconstruction of some of the earlier years. The distinction of births and deaths by sex and the designation of cause of death were introduced in the London bills in 1629. Graunt therefore chose that year as the start of his data analysis. Following suggestions by Graunt and William Petty, the London bills eventually included number of marriages and age of death.

[6] As one can see in Table 2.3, the leveling qualities of the London bills of mortality are also evident in the number of executions. For the year 1649, King Charles I and commoners are presumably added together to calculate the total of 29 deaths.

[7] Although Defoe's account was published in 1722 as an eyewitness account of a London saddler in 1665, historians doubt that Defoe was more than four years of age during that year of the plague. The narrative was supposedly based on a journal of H.F., which, as James Sutherland points out in his introduction to *The Journal*, are the initials of Daniel Defoe's uncle. Unlike in his other works, Defoe makes extensive use of data and documentation in *The Journal*, and it is very possible that Graunt's observations (from later editions) or John Bell's *London's Remembrancer* was one among the sources Defoe used.

Table 2.5 *A portion of a London bill of mortality for the plague year of 1665. This was a year-end bill that totaled deaths by cause for the entire year. Not included in this reproduction are the total deaths by Parish.*

1665.

A General BILL for this preſent Year,

Ending the 19th Day of December 1665.

According to the Report made to the King s moſt excellent Majeſty,

By the Company of Pariſh Clerks of LONDON, &c.

DISEASES and CASUALTIES.

ABortive and Stillborn	617	Executed	21	Overlaid and Starved	45
Aged	1545	Flox and Small Pox	655	Palſy	30
Ague and Fever	5257	Found dead in the Streets, Fields, &c.	20	Plague	68596
Apoplexy and Suddenly	116	French Pox	86	Planet	6
Bedrid	10	Frighted	23	Pluriſy	15
Blaſted	5	Gout and Sciatica	27	Poiſoned	1
Bleeding	16	Grief	46	Quinſy	35
Bloody Flux, Scowring, and Flux	185	Griping in the Guts	1288	Rickets	557
Burnt and Scalded	8	Hang'd and made away themſelves	7	Riſing of the Lights	397
Calenture	3	Headmouldſhot and Mouldfallen	14	Rupture	34
Cancer, Gangrene, and Fiſtula	56	Jaundies	110	Scurvy	105
Canker and Thruſh	111	Impoſthume	227	Shingles and Swine Pox	2
Childbed	625	Kill'd by ſeveral Accidents	46	Sores, Ulcers, broken and bruiſed Limbs	82
Chriſomes and Infants	1258	King's Evil	86	Spleen	14
Cold and Cough	68	Leproſy	2	Spotted Fever and Purples	1929
Colick and Wind	134	Lethargy	14	Stopping of the Stomach	332
Conſumption and Tiſſick	4808	Livergrown	20	Stone and Strangury	98
Convulſion and Mother	2036	Megrims and Head-ach	12	Surfeit	1251
Diſtracted	5	Meaſles	7	Teeth and Worms	2614
Dropſy and Tympany	1478	Murdered and Shot	9	Vomiting	51
Drowned	50			Wen	1

CHRISTENED	Males	5114	BURIED	Males	48569	Of the Plague 68596
	Females	4853		Females	48737	
	In all	9967		In all	97306	

Increaſed in the Burials in the 130 Pariſhes and at the Peſt-houſe this Year 79009.
Increaſed of the Plague in the 130 Pariſhes and at the Peſt-houſe this Year 68590

Source: A Collection of the Yearly Bills of Mortality from 1657 to 1758 Inclusive [1758] 1759.

> All ceremonial due to them was taken away, they were launched ten in one heap, twenty in another, the gallant and the beggar together, the husband saw his wife and his deadly enemy whom he hated within a pair of sheets. What rotten stenches and contagious damps would strike up into thy nostrils. (From Dekker's *Seven Deadly Sins of London*, 1606, quoted in Creighton [1891] 1965, 482)

Plague epidemics definitely qualify for the label of mass phenomena, and the weekly mortality during plague years was structured through time in a symmetrical, formal pattern. Graunt and his contemporaries saw this pattern in comparisons of weekly mortality tables. In all major and minor plague years in London in the seventeenth century the peak mortality was in the last weeks of August and the first weeks of September. Linked with the seasonal pattern, there was also a change in the typical symptoms of the disease during the course of an epidemic. The changing severity of the symptoms was one of the determining causes of the seasonal symmetry in the mortality curve. The symptoms at the prime of the life of the visitation were very different from those experienced at the birth and death of the epidemic. Creighton quotes William Boghurst, an apothecary who treated hundreds of cases of the plague in 1665:

> It fell not very thick upon old people till about the middle or slake of the disease, and most in the decreases and declining of the disease. . . . In summer about one-half that were sick, died; but towards winter, three of four lived. (Boghurst quoted in Creighton [1891] 1965, 675)

Defoe also remarked on the change of the rate of mortality of those infected:

> few people that were touch'd with it in its height about *August* and *September*, escap'd; And, which is very particular, contrary to its ordinary Operation in *June* and *July*, and the beginning of *August*, when, as I have observ'd many were infected, and continued so many Days, and then went off, after having had the Poison in the Blood a long time; but not on the contrary, most of the People who were taken during the two last Weeks in *August*, and in the three first Weeks in *September*, generally died in two or three Days at farthest, and many the very same Day they were taken. (Defoe [1722] 1968, 191–192).

Indeed, Defoe mentions rumors of a specific turning point in the mortality: the peak was apparently one September morning when 3,000 died in London between the hours of one and three o'clock in the morning.

An indication that the disease had lost its fatal strength was when the swellings (the buboes) in the lymph nodes discharged pus (suppurated). This was much more common in those who were smitten after the early autumn peak of the epidemic. Hardened buboes characterized the more fatal form of the disease that was common around the August–September peak. Creighton did not publish graphs of seasonal variation in his nineteenth-century study of the history of epidemics in Britain, but his description of the temporal change in the bubonic symptoms evokes a visual image of the seasonal

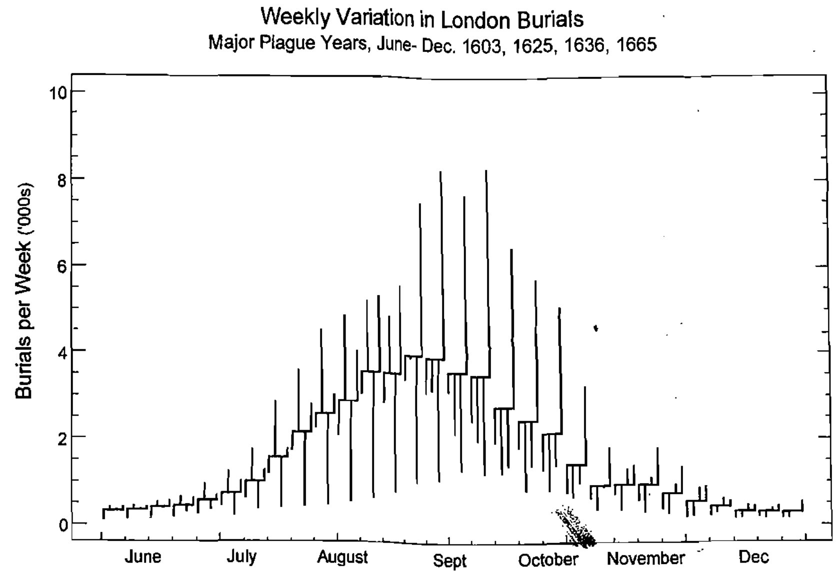

Figure 2.1 This plot is based on data in the fifth edition of Graunt's *Observations* ([1662] [1676] 1899). The height of a horizontal line measures the number of deaths for that week averaged over four plague years.

epidemic "curve" or "law" that must have entered into the minds of those like Creighton and Graunt who constructed tables of the weekly deaths from the bills of mortality:

> an epidemic of plague declined as a whole in malignity towards the end, so that the buboes suppurated, and three out of four, or three out of five, patients recovered. If that were the case in the descent of the curve, why should there not have been something corresponding in the ascent? (Creighton [1891] 1965, 655)

Graunt in the seventeenth century, Defoe in the eighteenth century, and even Creighton in the nineteenth century worked with tables to get a sense of the process of plague mortality. I have taken the liberty of using some of the raw material Graunt worked with to construct graphs that will give those of us less attuned to tabular reasoning a sense of the temporal patterns of epidemics of bubonic plague. If one plots typical seasonal variation of deaths per week in seventeenth-century London during plague years, one constructs a bell curve with a peak in mortality in early autumn (see Figures 2.1, 2.2). There is no similar seasonal ordering patterns of mortality in the nonplague years of the sixteenth or eighteenth century, even in cases of other epidemics (see Figures 2.3, 2.4,). There was no periodic pattern to the appearance of plagues in London that would enable one to predict which year would be a plague year. Once a plague arrived, however, it took on an incredible weekly

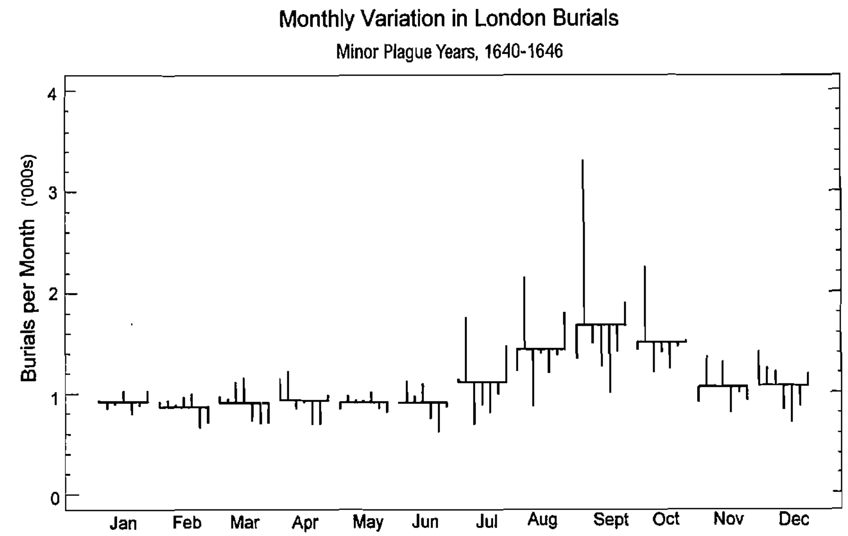

Figure 2.2 This plot is based on data in J. Bell 1665. The height of a horizontal line measures the number of deaths for that month averaged over seven years.

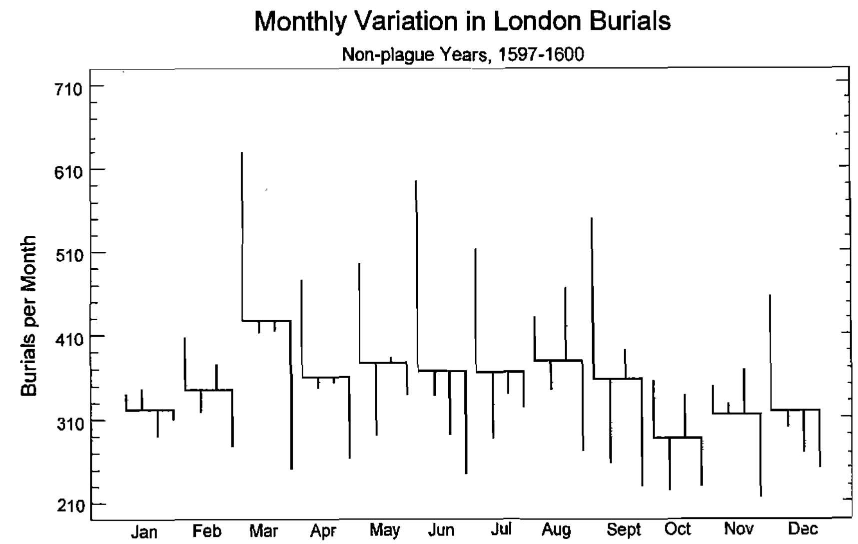

Figure 2.3 Plot based on data from Hull [1899] 1986.

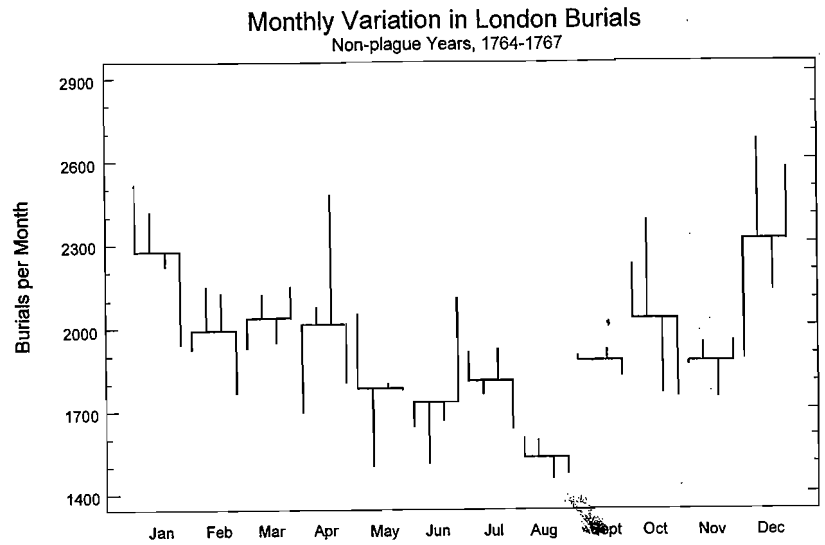

Figure 2.4 Plot based on data in Heberden [1801] 1973.

pattern in late August: first exponential growth, a turning point, then rapid decline.[8]

The parish clerks, responding to decrees by the lord mayor and financed by the merchants and the rich, tracked the mortality pattern week to week in the form of tables of absolute counts (deaths or deaths due to the plague in the past week). Unfortunately, few of the weekly bills survived the great fire of London in 1666, but from data in Graunt's fifth edition of *Observations* (1676), Bell's *London's Remembrancer* (1665), W. Heberden ([1801] 1973), and manuscripts that Hull (1899, 426–428) investigated, it is possible to construct graphs of seasonal variation. The graphs used in Figures 2.1–2.4 group weekly (in the case of Figure 2.1) or monthly data (in the case of Figures 2.2–2.4) in a relative time framework of an annual cycle. For Figure 2.1, the horizontal axis orders the weekly data from the first week in June until the last week in December; for Figures 2.2–2.4, the months go from January to December.

What follows is a description of Figure 2.1, but a substitution of the word "month" for "week" will adapt the description to the other three figures. The vertical axis measures deaths per week in London parishes. The height of the

[8] I did not come across any reference to this historical seasonal pattern in the accounts I read of the outbreak of bubonic and pneumonic plague in India in the fall of 1994. There were reports in late August of a visitation of bubonic plague in the Maharashtra State in western India. By late September, thousands of cases of bubonic and pneumonic plague had been reported in neighboring states, particularly in the city of Surat in the state of Gujurat. By late October, public health officials were saying they had the epidemic under control. Even in the great epidemic of 1665, mortality was "under control" by the end of October in London. A historical awareness of previous trackings of the predictable seasonal pattern of the plague would have aided health workers, reporters, and medical journalists covering this recent outbreak. Some scientists are using an awareness of the seasonal pattern of the Ebola virus to determine which animal carriers would be consistent with a November peak in human mortality.

horizontal line for each week measures the number of deaths for that week averaged over the four great plague years. The height of the end of a vertical line perpendicular to a horizontal line plots the number of deaths in that week for a specific year, and the length and direction of the vertical line indicates each year's deviation from the average for that week.

Figure 2.1 illustrates the weekly variation in total deaths for the years of major plague visitations in London, 1603, 1625, 1636, 1665. One can see the peak of average mortality in the fourteenth week after the beginning of June, which would be the last week in August or first week in September. The average number of deaths for the four great plagues years for that week was 4,000. One can see by the upward reaching vertical lines on the far right of each horizontal bar that the deaths in 1665 were above average for almost every week and greater than any of the preceding years. In the first week in September 1665, parish clerks in London recorded 8,252 deaths.[9]

Even for minor plague years in the seventeenth century, in which total annual plague deaths were 3,000 or less, and in which diseases such as typhus (spotted fever) claimed more lives, the remarkable seasonal pattern persists. This is true for weekly and monthly variation. Figure 2.2 plots the variation in deaths per month over an entire year for the years of relatively minor pestilence from 1640 to 1646. The symmetrical pattern centered around a peak of deaths in September is not evident in the monthly variation plotted from the bills of mortality recording deaths from 1597 to 1600 (Figure 2.3). Likewise the seasonal pattern of mortality for 1764–1767 (Figure 2.4), with declining deaths as the summer proceeds and a peak of monthly mortality in early winter, is remarkably different from that in the preceding two centuries.[10]

The weekly, numerical tracking of the ascent and descent of the curve and the sudden, indiscriminate elimination of over a sixth of the urban population no doubt helped to lay the seeds for a statistical way of thinking. In seventeenth-century London, a person could be just a corpse and a corpse could be a number. As Graunt illustrated, the numbers could be manipulated to quantify population and the rate of change in population. The acknowledgment of equivalence and the summation of many individuals led to a recognition of social mass phenomena. The whole was different from the sum of the parts and displayed a stability and certainty in stark contrast to the attributes of individual constituents. Populations could thus be characterized by summary parameters and analytical images.

Population

The significance to statistical theory of Graunt's observations on the bills of mortality stems from three important insights: the applicability of mercantile arithmetic to a social and political science of observation; the importance of

[9] There were more people living in London in 1665 compared with the other years, but even the proportionate mortality appears to be higher in 1665. Based on estimates of London population by Charles Creighton ([1891] 1965, 660) and the number of deaths recorded in the bills of mortality, 17 percent of the population died in 1603, 16 percent died in 1625, and 21 percent died in 1665.

[10] The high autumn mortality in the seventeenth century might have been as much a background cause of the relatively high frequency of bubonic plague epidemics as an effect of the epidemics.

population to the state; and the stability of social proportions and ratios over time and across parishes. Population is a key concept in the logic of statistical method. The act of defining a population is premised with the assumptions of an equivalence of individual constituents, of an order and relationship binding the constituents, and of a manifestation of the whole.[11] The historical context in which these assumptions were first relevant to nation-states is also the context in which statistics had its origins.

Equivalence of all inhabitants, like equivalence of outcomes in a game of chance, is a relatively modern notion. For example, Karl Marx in volume one of *Capital* argued that Aristotle failed to fully understand the economic relationship of value in exchange because his ideas were the product of a slave society where equivalence between laborers had no meaning (Marx [1867] 1976, 152).[12] Rigid social inequality bound in a system of tradition prohibited notions of equivalent exchange values and of population in feudal as well as slave societies.

Geoffrey Kay and J. Mott (1982) argue that, in Britain at least, the feudal order was replaced by the order of equivalence, which gave rise to the notion of population. Kay and Mott point out that the Doomsday Book of the eleventh century did not count people, but instead, listed fiscal units to which groups of people of varying status were attached and emphasized the extent and use of property rather than the number of people. The counting of John Graunt and William Petty six centuries later assumed political and fiscal equivalence of citizens and their labor as a source of value.[13]

By the seventeenth century, commodity exchange in London was becoming what Marx would describe as a "very Eden of the innate rights of man" (Marx [1867] 1976, 280). The sphere of circulation of commodities between people appeared to be an exclusive realm of freedom and equality, and within this sphere what counted was not the specific nature of concrete labor, but simply abstract labor time embodied in goods produced for exchange. With the market's reduction of the essence of all value to human labor in the abstract, and with the political creation of an "order of equivalence," a population way of thinking became a necessity for the state. Joseph Schumpeter described this dawn of the era of equivalence: "A numerous and increasing population was the most important *symptom* of wealth, it was the chief *cause* of wealth; it *was* wealth itself – the greatest asset for any nation to have. Utterances of this

11 For example, in the course of explaining the "science of means" in his article on the "Method of Statistics" for the *Jubilee Volume of the Royal Statistical Society*, Ysidro Edgeworth commented, "The term 'Means' of course implies the correlative conception: members of a class, or terms of a 'Series' (in Mr. Venn's phrase) of which the mean is to be taken: 'Massenerscheinungen' in the language of Professor Lexis" (Edgeworth 1885, 182).

12 In Marx's words: "However, Aristotle himself was unable to extract this fact, that, in the form of commodity-values, all labour is expressed as equal human labor and therefore as labour of equal quality, by inspection from the form of value, because Greek society was founded on the labour of slaves, hence had as its natural basis the inequality of men and of their labour-powers. The secret of the expression of value, namely the equality and equivalence of all kinds of labour because and in so far as they are human labour in general could not be deciphered until the concept of human equality had already acquired the permanence of a fixed popular opinion" (Marx [1867] 1976, 151–152).

13 William Petty not only equated one person to another but even land and people through calculation of the monetary value of each. He considered the latter equation the most important consideration in "political oeconomies" because it was a condition for allocation of the proportionate and thus fair share of the tax burden (see Hull 1899, lxxi).

kind were so numerous as to render quotations superfluous" (Schumpeter 1954, 251).

In his observations on the bills of mortality, Graunt noted that "Princes are not only Powerfull but Rich, according to the number of their People (Hands being the Father, as Lands are the Mother, and Womb of Wealth)" (Graunt [1662] 1975, 61).[14] Eighteenth-century philosophers considered population one of the most important social issues, and by the end of the nineteenth century the concept of population was an integral part of statistical theory. John Graunt's observations inspired Johann Peter Sussmilch's work on population. That in turn inspired Thomas Malthus, and the latter was a source of inspiration to Charles Darwin.[15] The "Divine Order" that became Sussmilch's theme was initiated in Graunt's revelation of the stability of the ratios he calculated over time. Graunt's declaration of stability, in phenomena as diverse as the ratio of male to female births or the proportion of accidental deaths to total deaths, meshed well with the goal of the scholars of the Enlightenment to find uniformity amid variety and order amid chaos.

Graunt's Statistical Structure in Time: The Life Table

Graunt's confidence in the stability of the ratios that he had constructed spanning twenty years of data is evident in his construction of the first life table. This statistical structure in relative time is now a staple in actuarial practice. The relative time is the human life cycle marked by decades of age. Examining the numbers dying by each cause over twenty years, Graunt estimated how many deaths were those of infants, and how many were elderly. For these decades of the life cycle and the ones interpolated in between, Graunt determined out of 100 live births how many died at each decade, and therefore what percentage was alive above each age.

Graunt calculated that in twenty years 71,124 people, out of a total death count of 229,250, died of causes that he surmised affected only children. His next step was to use the Merchant's Rule to put this into a proportional form that readers could easily grasp: "that is to say, that about ⅓ of the whole died of those diseases, which we guess did all light upon children under four or five Years old" (Graunt [1662] 1975, 29–30). Graunt guessed that one-half of deaths due to certain other causes (e.g., small-pox) were also children under six and concluded that "thirty six *per centum* of all quick conceptions, died before six years old" (Graunt [1662] 1975, 30).[16]

Graunt estimated that 1 in 15 of all deaths, 7 percent, were attributed to old age by the searchers, and concluded that "if in any other Country more

14 Although Graunt spoke of the people of a land, Philip Kreager (1988) points out that he never actually used the word "population."

15 James Bonar ([1929] 1966) discussed the links between Graunt and Sussmilch.

16 The Rule of Three was an act of commerce and percent was an act of finance. If money had been borrowed or lent then the phrase "per cent" or "per centum" was in the vocabulary. "Per cent" was a type of proportion, an offspring of the "Rule of Three"; it was a statement of the rate of interest (for word origins see the *Oxford English Dictionary*, 2nd ed., 1989, vol. 11, 1031). It was in the life-table construction, when he wanted a common denominator for each decade of life, that Graunt reduced proportions to percents. Although Graunt used first differences and expressed some proportions in the form of percents, he never combined the comparison by subtraction with comparison by division in a

Table 2.6 *The first life table, constructed by John Graunt.*

Viz. Of an hun-	The third *De-*
dred there dies with-	*cad*---------9
in the firſt ſix	The fourth---6
years ————36	The next——4
The next ten years,	The next-----3
or *Decad*-————24	The next-----2
The ſecond *Decad*-15	The next-----1

Source: Graunt [1662] 1665, 125.

then seven of the 100 live beyond 70, such Country is to be esteemed more healthfull then this of our City" (Graunt [1662] 1975, 3[illegible]). Graunt interpolated percents between the extremes of infancy and old age and crudely estimated the number of deaths for each decade of life for a cohort of 100 live births.[17] Graunt's life table is reproduced in Table 2.6. True to his aim of *political* arithmetic, Graunt's first use of the life table was to estimate the number of fighting men from London the king could rely on for future wars. From his table, Graunt calculated that 34 percent of all males were between the ages of sixteen and fifty-six; he translated that into approximately 70,000 men of fighting age in London proper.

In a footnote in his 1899 edited version of Graunt's observations, Charles Hull lists Edouard Mallet's estimates of relative frequency of death by age based on recordings of age of death in Geneva from 1601 to 1700. Mallet's data showed 42.6 percent of all deaths were of those aged six or less, and 5.8 percent of those who died were over seventy-six years of age. Neither Graunt nor Mallet constructed graphs from their tables, but Figure 2.5 graphically compares Graunt's estimates of the relative frequency of age of death to those of Mallet's. The former, being an arithmetical interpolation between the two end-point ages, is obviously a smoother graduation, but the images are similar.

Graunt's work inspired not only the construction of life tables (e.g., by Edmund Halley), but also the inclusion of age of death in the London bills of mortality. In 1758, Corbyn Morris summarized death by age based on the London bills for various years in the eighteenth century. Figure 2.6 illustrates the stark contrast between the age distribution of deaths in London in 1728–30 and in the United States in 1991.[18] What is striking in the plots of Graunt's,

calculation of a *percent change. Percent change,* as opposed to just *percent*, was not a common monetary algorithm until the nineteenth century. When Graunt examined growth or change over time he used expressions such as "doubled" or "encreased from one to four."

[17] Karl Pearson (1978) and Anders Hald (1990), among others, discuss Graunt's interpolation in the construction of a life table.

[18] With both Figures 2.5 and 2.6, one must keep in mind that the age distribution of the population influenced the age distribution of death and vice versa.

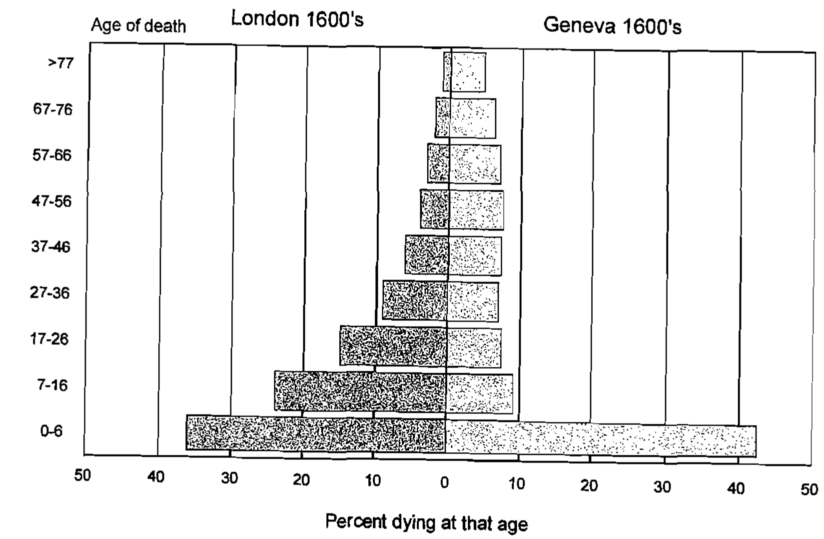

Figure 2.5 Age distribution of death in seventeenth-century London and Geneva. *Source:* Graunt ([1662] [1676] 1899).

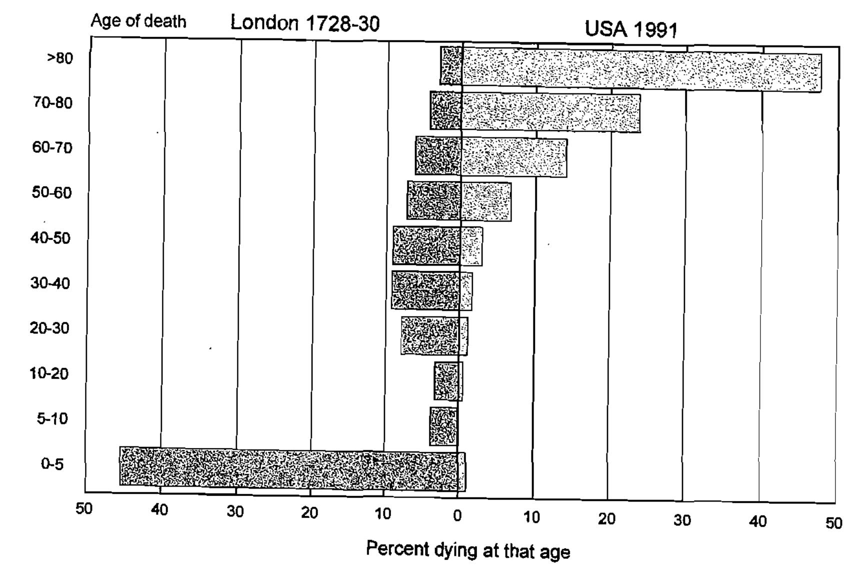

Figure 2.6 Age distribution of death in eighteenth-century London and twentieth-century USA. *Source:* Morris [1758] 1759, U.S. National Center for Health Statistics 1995.

Mallet's, and Morris's data is the high level of child mortality. Even in the U.S. data, the first few years of life appear more precarious than those that immediately follow.

Graunt's observations on the bills of mortality earned him membership in the Royal Society and posthumous fame as the "father of statistics." Graunt's original contribution to the construction of life tables is well recognized as is his observation that year after year, parish after parish, there were more males born than females (Graunt reduced the ratio for London to fourteen males to every thirteen females). Even his observation that "Physicians *have two* Women *Patients to one* Man, *and yet more Men die then Women*" (Graunt [1662] 1975, 12) is still referred to in the popular press of the late twentieth century.

Karl Pearson and others have seen Graunt's main contribution to statistics as the implicit recognition of the stability of statistical ratios over time and space (Pearson 1978, 30). For example, Graunt noted with "Chronical" diseases, such as consumption (tuberculosis), suicide, and even in the case of some types of accidents, such as drowning, over the years the deaths due to particular casualties bore a constant proportion to the whole number of burials.

Although Graunt's contribution in the area of stable ratios is well recognized, far less attention has been paid to the link between Graunt's arithmetic and his occupation. Only a merchant would have analyzed the data from the bills of mortality in the way that Graunt did, and it was merchants, anxious to predict the future course of their trade, who paid the four shillings for the results of the work of the searchers and parish clerks on the bills of mortality. Also, out of past experience or wishful thinking, merchants had confidence in the overall stability of the numbers they worked with through thick and thin markets. Graunt not only demonstrated the stability of ratios, but he also hoped that his analysis would lead to even greater commercial and social stability. He argued that careful quantification of "the People" would engender "the knowledge wherof Trade, and Government may be made more certain, and Regular" (Graunt [1662] 1975, 79). The merchants' desire for, and confidence in, stability proved instrumental in Graunt's calculation of ratios spanning two decades and in later nineteenth-century commercial practice that fed into the construction and modeling of stationary time series.

Graunt was a retailer and his shop arithmetic consisted of using comparison by division to simplify relationships, using comparison by subtraction to determine the temporal patterns of illness and mortality, calculating "mediums" (averages) over time to eliminate irregularities, presenting the data in the form of spread-sheet-style tables, and reorganizing the values into relative time frameworks for comparisons between seasons and between ages.[19] In adapting his shop arithmetic to political arithmetic, Graunt expanded the time horizon, addressed issues of policy, and used his analytical tools to persuade and justify. In their reckoning of the chance of death, nineteenth-century

[19] While replicating Graunt's work, I realized that the obvious choice of software was not a statistical package, but rather a spreadsheet program, which is more associated with financiers and retailers than with scientists or econometricians. The formulas commonly used with spreadsheet software are very similar to Graunt's shop arithmetic. I also noticed in my spreadsheet replication that Graunt had made several errors, some quite significant, in his arithmetic.

scientists and applied mathematicians built on the monetary and political layers, but embellished the storytelling with symbols embedded in equations and laws embodied in smoothed curves. Karl Pearson's work on the age distribution of the chance of death serves as an excellent illustration of how the shop-*cum*-political arithmetic of Graunt was modified for the purposes of scientific investigation and the development of a mathematical theory of statistics.

Pearson's Statistical Structures in Time: Mortality Curves

> To the Royal Society
> which fostered the many lines of inquiry set in train by John Graunt through his 1662 publication, *Natural and Political Observations on the London Bills of Mortality*

Thus read the dedication of Egon Pearson's edition of his father's lectures on the history of statistics (Pearson 1978). Karl Pearson was one of many Royal Society fellows who was inspired by Graunt's political (shop) arithmetic, and Graunt was one of the major actors in Pearson's history.

In his essay "The Chances of Death," Pearson addressed a question similar to that of Graunt's: Out of a cohort of 1,000 people born alive at the same time, how many die at each age? In contrast to the table that Graunt constructed, Pearson answered with a mortality curve (Figure 2.7). The graph included the frequency of death by age plotted from data collected from 1871 to 1880 by the registrar-general.[20] Pearson decomposed the curve connecting the data points into five smooth curves mapped out from mathematical functions of chance frequency distributions centered on the ages of 72, 42, 23, and 3 years and 1 month before birth.

Pearson's essay was an argument for adopting a modern, more mature notion of chance and death. The medieval notion of chance was that of chaotic, random incident; the modern notion of chance was that of mathematical law and geometric order. Similarly, the medieval metaphor of death was the random action of the "dance of death."[21] In contrast with the medieval image of the dance of death, Pearson saw death as "a marksman with a certain skewness of aim and a certain precision of weapon" (Pearson 1897, 25). To metaphorically explain his decomposition of a mortality curve into five chance distributions, Pearson had his wife paint his stochastic view of the chances of death as that of five marksmen of death aiming their deadly weapons at humans traveling over the bridge of life (Figure 2.8).[22] To compare his view of death – that is, a regiment of marksmen maintaining law and order in mass

[20] In London in 1824, the state took over from the church the regular publication of mortality data.

[21] The image of the "dance of death" may have had a more orderly, deterministic flavor in the Middle Ages than Pearson gives credit for. Historian Mary Hill Cole pointed out to me that medieval dances were often very defined, formal, and scripted rituals.

[22] In his essay Pearson mentions that he had asked two artists to draw his image of the bridge of life. The one trained in "the modern impressionist school" failed, but his wife "reared among the creations of Holbein, Flaxman, and Blake" came closer to realizing his image. Karl Pearson's rough sketch and Maria Sharpe Pearson's prints and large painting of the bridge of life are in the Pearson Papers at The Library, University College, London.

PLATE IV.

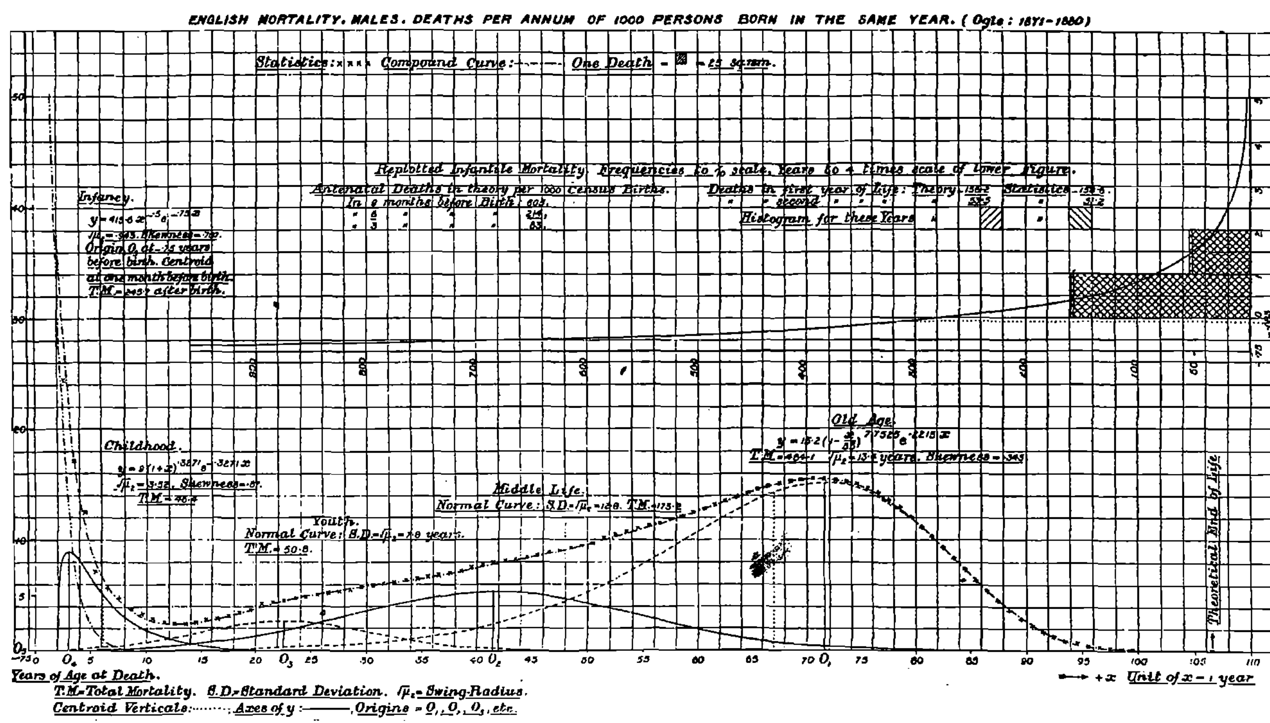

Figure 2.7 Pearson's plot of the age distribution of death in England 1871–1880 (curve with x's), broken down into five component chance distributions. *Source:* Pearson 1897, plate IV.

Figure 2.8 Maria Sharpe Pearson's etching of the Bridge of Life. Each marksman represents a component curve on Figure 2.7. *Source:* Pearson 1897, frontispiece.

PLATE II.

GROSS-BASEL.

Figure 2.9 Fifteenth-century images of the "Dance of Death" at the church at Gross-Basel. *Source:* Pearson 1897, plate II.

phenomena – with the medieval image, Pearson reproduced examples of the older notion of the "dance of death." These reproductions included fifteenth-century images from a cemetery in Gross-Basel (Figure 2.9) and sixteenth-century prints of Holbein.

Pearson's marksmen aimed their weapons at the mode years of the five frequency distributions. The type of weapon gave a sense of the maximum mortality in the mode year and the standard deviation of the distribution. For example, the weapon of the mortality of childhood was centered on the third year of life, more people died at this mode than at the mode of youth or middle-age mortality, and the standard deviation of childhood mortality was less than any other except that of infancy. The precision and deadliness of the marksman of childhood was thus conveyed with the weapon of a "maxim gun." In middle-age mortality, centered on the forty-second year of life, the fire of the marksmen is "slow and scattered, and his curve of destruction a very flat-topped one. His work might by typified by a blunderbus as compared with the rifle-fire of old age death" (Pearson 1897, 31).

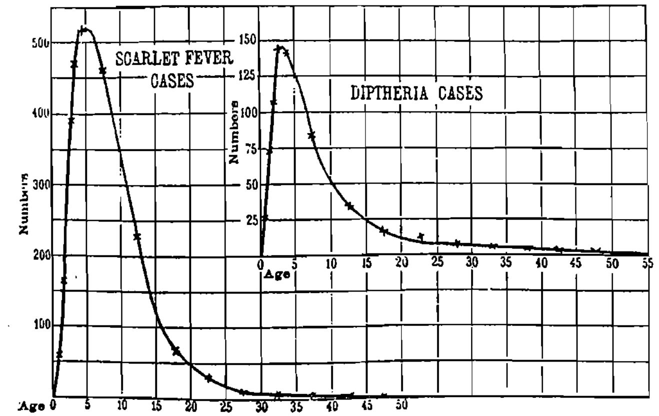

Figure 2.10 Pearson's plots of the frequency of illness by age. *Source:* Pearson 1897, 33.

Table 2.7 *Properties of Pearson's mortality curves in "The Chances of Death"*

	Mode in years of age	Standard deviation in years	Skewness	Total mortality out of 1,000	Weapon of death in "Bridge of Life"
Infancy	−0.08	.94	0.71	245.7	Bones of ancestry
Childhood	3	3.52	0.87	46.4	Maxim gun
Youth	23	7.8	0	50.8	Bow and arrow
Middle age	42	12.8	0	173.2	Blunderbus
Old age	72	13.4	0.34	484.1	Rifle

It is obvious from the overlapping component frequency curves in Figure 2.7 that a person dying at age fifteen could have been struck by either the marksman of childhood, middle age, or youth, though most likely that of youth. Pearson did not fully explain how this translated into reality, but he linked the five distributions to different causes. He plotted the age distribution for cases of various illnesses including enteric fever, scarlet fever, and diphtheria. The latter two are obviously childhood killers; they are rarely the cause of death in the first year of life (infancy) and relatively few people catch or die of these diseases after the age of 10 (see Pearson's graph reproduced in Figure 2.10).

Pearson reasoned that the laws of frequency, deduced from coin tossing and dice throwing, were the laws of all large numbers, including the age distribution of the frequency of death. The five law curves he saw in operation for age-determined mortality were frequency distributions that could be described with equations (noted on Figure 2.7) from which values for a mode, mean, standard deviation, coefficient of skewness, maximum mortality in mode year, and total mortality covered by entire distribution could be determined (see Table 2.7). The skewed distribution of old age gave a theoretical limit to life that would not exist if the distribution were a normal one. Although only the curves for youth and middle age were strictly bell curves, all five curves were chance distributions.

The most interesting curve – and marksman of death – is that of infancy. For one thing, Pearson's equation for infantile mortality predicts the deaths before birth of 605 fetuses for every 1,000 live births, with most of these occurring within the first three months of conception.[23] Pearson had not intended to go into this antenatal region, but the only equation that would fit the postnatal data took him there. The second striking feature of Pearson's analysis of infant mortality was his linking it to heredity. Pearson's commitment to the eugenic cause is blatant in his choice of a human skull as the weapon to typify the human encounter on the bridge of life with the most deadly marksmen of all, the marksmen for fetuses and infants. Pearson lay the blame for the "unremitting destructiveness" of infantile and fetal mortality with "bad parentage": "The marksman Death strikes down the young life with the bones of its ancestry" (Pearson 1897, 36). This choice is inconsistent not only with the visual metaphors of the other marksmen, but also with Pearson's literal analysis of causes of death at other ages. Pearson was unable to perceive ways for reducing infant mortality other than state control of who should be allowed to prosper and multiply.[24]

With regards to the issue of biological evolution and the "numerical measures of the processes described by Darwin," Pearson saw his work on the age distribution of mortality as helping to "localise the time and manner of selection" (Pearson 1897, 41). Pearson's main theme, however, was illustrating the scientific reconstruction of the notion of chance. As Pearson saw it, "Our conception of chance is one of law and order in large numbers; it is not that idea of chaotic incidence which vexed the medieval mind" (Pearson 1897, 15). The data and hypothetical curves of mortality (Figure 2.7) drawn by Karl Pearson and the print of the "Bridge of Life" (Figure 2.8) etched by Maria Sharpe Pearson are both images of Pearson's vision of "law and order in large numbers." They are the visions of an applied mathematician schooled in geometry and the leisurely arts of gambling and archery; the visions of a well-to-do, white, male, British professional schooled in the fine arts; the visions of a eugenist schooled in the Darwinian theory of evolution.

[23] Note that the comparison by division of 605 fetuses with 1,000 live births is a ratio. The postnatal deaths at each age compared with 1,000 live births are proportions.

[24] In Chapter 7 there are more details on the link between the eugenics movement and the development of statistical theory, including Pearson's admiration of Adolph Hitler's "experiment." Suffice to say here, the dramatic decrease in the infant mortality rate over the past century has not been due to a state-controlled change in the gene pool. In 1994 only 6 out of 1,000 infants died in Britain compared with the 152 deaths out of 1,000 infants Pearson recorded for the 1870s. That decline is due to changes in the environment in which the unborn and the newly born are nurtured – changes that stem from popular awareness of nutrition and hygiene, new medicines, a higher standard of living, and a more equitable distribution of prenatal and postnatal health care. The policy prescriptions implied by Pearson's naming of the cause as bad ancestry would have been much less effective and caused far more strife than the adopted public health policies that have emphasized nurture rather than nature.

Pearson, with his mortality curve decomposed into mathematical laws associated with games of chance and target practice, and Graunt, with his percent table of an age distribution of deaths, constructed statistical structures in time. Pearson's five distributions are parallel to time, and his conception of the chances of death resembles a moving average. The chance of dying at age fifteen is like a weighted average of the chance of dying at the ages of three, twenty-three, and forty-two. The structures in time of Graunt and Pearson do not, however, describe any process of change through time. The structures are not, for example, tales of the development of a typical individual, as Adolphe Quetelet's structures in relative time were (see Chapter 5). Although those whose deaths are recorded are at different ages of the life cycle, the data are taken at one moment in time and the laws depicted are out of time. Graunt's table and Pearson's curve are means for static comparisons; one can compare the chance of death at age twenty with the chance of death at age fifty. Similarly, Graunt's and Pearson's structures in time are descriptions of societies. Individuals are unlikely to identify with the age-specific chances of death unless they forsake a subjective notion of probability for a frequency approach. To the individual, a disorderly "dance of death" might still be a more appropriate image of the fatal moment.

To Graunt's shop arithmetic, Pearson and other applied mathematicians added the academic regalia of laws: smooth lines, uniform shapes, and algebraic equations. Empirical paths plotted through ages were decomposed into age-specific functions in relative time. Summary parameters economized on information, and the formal laws were generalized to and from other mass phenomena. Death and chance could be reckoned not only with the Merchant's Rule and tabular "accompts" but also with equations and geometry. Roots for the mathematical structuring of temporal statistics, however, lie with the *Mechanick Artists*, demanding discipline and control of commercial processes, tracking the course of future demand, and reckoning on the accumulation of their capital.