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Sources and Methods of Historical Demography

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Preface

Historical demography is essentially the study of past populations. Its basic goals are twofold: to reconstruct demographic characteristics of past populations and to explain the causes and consequences of these characteristics.

Research in historical demography may be thought of as falling along a scale of increasing analytic breadth. At the scale's narrowest point, research is restricted solely to the documentation and description of classic demographic characteristics such as population size, geographical distribution, age structure, and change produced by births, deaths, and migration. At this end of the scale, demographic features are analyzed in their own right, with little or no regard for their possible relationships with nondemographic phenomena or specific historical settings. At the other end of the scale, the scope of historical demography is broadest. In contrast to the study of purely demographic phenomena in relative isolation from their temporal and social contexts, effort would be made to establish and analyze the causal links between a historical community's formal demographic properties and every important feature of the world in which its members lived. Obviously, most research lies between these two extremes.

A major goal of pioneering studies in historical demography since World War II has been essentially one of reconstruction. Knowledge about population size, settlement patterns, and household and family structures that this reconstructive research provided and will continue to provide forms the basis for work that attempts to explain the relationships between demographic phenomena and other facets of human life. To accomplish this latter goal, genetic, biological, socioeconomic, or other potentially relevant information may have to be drawn upon to understand why a historical population's demographic properties were as they were, as well as to understand the consequences these properties had for individuals, groups, and whole societies.

In recent years, historical demography has attracted to its ranks researchers from nearly every social science discipline. Moreover, work in population genetics, human biology, and nutrition has been seized upon by scholars who seek to describe and understand the demographic evolution of past human societies. Eagerness to incorporate findings, methods, and theoretical perspectives from a variety of disciplines seems boundless, making a simple description of historical demography difficult. It is as if the field itself has no firm boundaries but is constantly being enriched by the participation of researchers with a wide range of perspectives and skills.

That research is taking place simultaneously in a wide variety of seemingly disconnected disciplines makes the field appear fragmented. Rather than being a sign of immaturity or weakness, however, this multidisciplinary and increasingly interdisciplinary style of research is responsibile for the intellectual vitality and growth of historical demography.

Given the heterogeneous nature of historical demography and its growth in recent years, we believe there is need for a book that brings together diverse strands of research and at the same time expands methodological and theoretical perspectives in light of the strengths and weaknesses of major available source materials. *Sources and Methods of Historical Demography* is thus designed to inform the wide variety of researchers interested in historical population studies about the fundamental sources, methods, and approaches to explanatory modeling that appear to us most promising for describing, analyzing, and understanding demographic features of past societies. We have set out to accomplish this by drawing on the wealth of interesting research that has appeared in recent years, particularly since the publication of Louis Henry's *Manuel de démographie historique* (1967) and Thomas Hollingsworth's *Historical Demography* (1969). This book would have been impossible to write without the basic discussions of sources, empirical case studies, or introductions to methods of data collection and analysis that have appeared since that time.

The work is divided into five parts. The Introduction is designed to acquaint readers with the intellectual ancestry of historical demographic research, beginning in the seventeenth century. It is an effort to illuminate the origins of a broad, multifaceted field of inquiry that exemplified diversity from the start. Part II "Fundamental Source Materials," describes the most widely used categories of documents, analyzes some of their relative strengths, weaknesses or biases, and, wherever possible, offers techniques for adjusting for those biases. The emphasis here is on considerations of general interest to an international audience. In contrast to the approach of introductory texts on historical demographic sources for individual nations and specific time periods, we do not dwell at length on nation- and time-specific problems, since a discussion of these may be found in works cited in the text. Rather, the discussion is organized to bring out the structural similarities of sources by type. Broad categories of sources are considered one at a time, and techniques for integrating and studying information from different types of sources are considered in the remaining parts of the book. Illustrative material from different regions of the world is presented to distill the common problems that sources of a similar type may present.

Part III, "Methods of Population Reconstruction and Analysis of Historical Sources," offers readers an introduction to the logic of basic techniques for reconstructing and analyzing information from fundamental source materials. An exhaustive treatment of each method or analytic approach is impossible within the constraints of one book. Our hope is that this limited presentation will yield insights into the relative usefulness of the various techniques discussed and, importantly, stimulate readers to acquaint themselves with the fuller treatments cited in each chapter. The discussion of reconstructive and analytic methods is preparatory to a consideration of formal causal modeling. Whereas methods discussed in Part III help describe what happened in the past, the formulation of explanatory models may provide plausible answers to the question "Why?" In Part IV, "Causal Model Building and Hypothesis Testing: Major Themes," the full range of disciplines that have made major contributions to historical demography is tapped, and examples of empirical research are used to illustrate the argument. Part V, "Conclusion," argues the case for conducting historical demographic research with a broad, interdisciplinary ideal in mind.

The challenge of writing a book for the wide range of scholars interested in historical demography is a formidable one. These scholars are generally members of one of two groups: those whose academic backgrounds are primarily historical and, secondly, those whose training has been sociological or demographic in nature. Each group possesses complementary strengths. Historians will be less likely to require familiarization with historical demographic source materials. Sociologists, on the other hand, are more likely to be aware of specialized methods of demographic and social scientific research. The book is written with both audiences in mind.

Most of Parts I, II, and V should be readily intelligible to readers interested in learning about the origins and development of historical demography, its basic data sources, and its place in current research on human societies. However, in order to understand Parts III and IV, the discussion of methods and causal models, readers should already be familiar with a demography text and have some working knowledge of basic statistical methodology. We take the position not that relatively sophisticated methods are the only way to learn about the demographic characteristics of past populations but that they can, when used well, reward scholars for the long hours of data collection by helping them go beyond a descriptive level of understanding to approach larger theoretical questions. When data are sparse, unreliable, or scattered in time, the use of sophisticated methods or the construction of formal models may appear to be unwarranted. But until researchers make a reasonable effort to understand such techniques, they may be unaware of all their data might potentially reveal.

The use of quantitative techniques, which in many cases requires a computer, is at times blamed for social research that loses sight of the concrete experience of historical individuals or groups. This is, we believe, a valid concern. Quantitative methods and causal models often entail abstracting from the day-to-day world. If this is carried to an extreme where history is viewed only as the interaction of "processes," "structures," or "variables," our understanding of how demographic behavior has historically been linked to individuals' own notions and experience of their world would well become impoverished. The neglect of these latter features, moreover, may make it impossible to explain or understand demographic patterns. Therefore, it is vital that historical demographers maintain a sense of curiosity and concern about the living conditions and values of the individuals whose demographic experience is the primary focus of inquiry.

A final word about the limitations of the present work. *Sources and Methods of Historical Demography* is not designed to provide an elementary introduction to historical demography; nor does it pretend to discuss exhaustively any source, method, or approach to causal modeling. It is impossible at the same time both to reflect the diversity of the field and to treat each of its many facets in exhaustive detail, a limitation that we have sought to overcome by providing readers with extensive references and recommended readings to supplement the discussion of individual topics. The book is intended to inform and guide individual researchers in their choice of sources, methods, or approaches to causal modeling. Having chosen the lines of inquiry they wish to pursue, readers will have to move beyond the book to the more specialized and technical literature recommended.

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Acknowledgments

The idea for writing a book on the sources and methods of historical demography was stimulated by John Knodel, who several years ago expressed his view of the need for a general work that would contribute to the field of historical demographic research beyond the introductory level. We seized upon this idea and, in the course of writing *Sources and Methods of Historical Demography,* have benefited from the help of a number of people.

We particularly want to thank Daniel Scott Smith, Krishnan Namboodiri, and Charles Tilly for their careful, critical readings and helpful comments on an earlier draft of the manuscript. Dorit Carmelli read and made comments on a first version of the population genetics material. Maria Luiza Marcílio, Jean-Pierre Bardet, and Arthur P. Wolf helped us gain access to several of the works discussed in the text. Ray Wright and Ted Telford, of the Genealogical Society of Utah, provided vital assistance in securing reproductions of source materials that illustrate the book. Linda Burns, of the University of Utah Library, tracked down a number of the hard-to-find publications. Finally, we want to thank two friends and colleagues—Lee Bean and Mark Skolnick—for their support and encouragement of our collaborative work.

After hundreds of hours of discussion, animated debate, and final agreement on most matters, we have emerged convinced more than ever of the value of interdisciplinary collaboration. Having ventured beyond our respective disciplines of sociology and history, we alone are responsible for the use we have made of the rich variety of scholarship that characterizes our adopted field of historical demography.

1
A Genealogy of Historical Demography

Any genealogy of historical demography is sure to reflect the opinions of the genealogist at work. In the effort to illuminate significant contributions to the origins and development of historical demography, many names are bound to be ignored while the achievements of the best known are overemphasized. Identifying the originators of methodological, empirical, or theoretical breakthroughs made in historical demographic research is surely as difficult as tracing the discontinuous evolution of paradigms in the natural sciences, since, as Thomas Kuhn has argued, "any attempt to date the discovery must inevitably be arbitrary because discovering a new sort of phenomenon is necessarily a complex event, one which involves recognizing both *that* something is and *what* it is [1970:55]." However, there is value in retracing historical demographic work of the past and assessing its relation to more contemporary studies. Scholars now working in the field will find writers as early as the seventeenth century attempting to come to grips with some of the same substantive issues as are currently being debated. A glimpse into the past development of historical demographic research also reveals the same variety of approaches and concerns that continue to characterize this interdisciplinary field of inquiry.

The task of tracing the intellectual ancestry of historical demography demands some attempt to define the entity whose lineage is under consideration. Both Thomas Hollingsworth (1969:37) and Jacques Dupâquier (1974:9) have pointed to the descriptive aspects of historical demography—the concern to estimate or reconstruct the size and composition of populations in the past. Dupâquier argues that the techniques of historical demography "resemble those used by specialists on the Third World for the study of populations with incomplete records or suspect statistics."

However, historical demography as a field of research seeks to go beyond the description of populations of the past, a sheer estimation of size, quality, and change, to a discovery of the processes instrumental in forming, maintaining, or destroying them. As Marc Bloch has written: "The nature of our intelligence is such that it is stimulated far less by the will to know than by the will to understand, and, from this, it results that the only sciences which it admits to be authentic are those which succeed in establishing explanatory relationships between phenomena [1971:10]." At best, then, historical demographers will not only describe but also attempt to interpret and explain population processes.

Historical demography so defined can claim several sorts of ancestors. In this genealogy, we will discuss three principal kinds. First are the methodologists, those who seized upon available sources of data and who, through the application of mathematical reasoning, succeeded in creating models of population processes analogous to the paradigms, or exemplars, of the natural sciences (Kuhn, 1970:187). These are the researchers, many of them brilliant mathematicians, whom current demographers would very rightly claim as their own intellectual ancestors. Documenting scientific "progress" in this part of the lineage of historical demography is relatively straightforward and perhaps illustrative of the notion that "the recourse to mathematics, in one form or another has always been the simplest way to lend a style, form and scientific justification to positive knowledge about man [Foucault, 1966:362]." The second part of the lineage is composed of inquirers whose main concern was to analyze populations by estimating and describing their respective sizes, numbers, and characteristics. The origins of this tradition may be traced to the establishment of "Political Arithmetic" in seventeenth-century England. A third, and final, group, considered here as theorists, is dominated by the names of Thomas Robert Malthus, and, to a lesser extent, Karl Marx—students of society who were less interested in carrying out empirical research on population processes or modeling them mathematically but who sought to adduce high-level, explanatory theories of the relationships between population size and growth and natural or historical development.

Not surprisingly, some of the most interesting ancestors of historical demographic research were involved in all three pursuits. We see the empirical researcher, tiring of the thought that his analysis of one city or parish was relevant only to a single time or place, yielding to the temptation to claim from those findings the key to estimating the size of the population of whole kingdoms, or the world since Noah. This temptation was not limited to the Political Arithmeticians, though their fascination with ratios and multipliers often led them in this direction. As has been well demonstrated (Behar, 1976), the mathematicians who contributed to the development of life tables were also led to apply their mortality models, based often on data from one locality, to an understanding of mortality patterns throughout the world. The theorists, too, made their own claims for having discovered not only the existence but also the social implications of laws of population inherent in nature or history. Thus, the three categories of ancestors that are claimed here for historical demography should not be taken as mutually exclusive; nor should the fact that current scholars are still debating some of the issues that attracted the attention of researchers of the past detract from the latters' achievements. As chapters of Part II of this book will attempt to illustrate, sources available to early inquirers as well as ourselves are often unable, even with the most sophisticated methods, to yield definitive truths about past populations that are likely to satisfy future generations of historical demographers.

The Methodologists

The capacity to carry out meaningful investigations of demographic processes necessitates some sources of data. It is not, therefore, surprising that one of the most important ancestors of historical demography, John Graunt (1620–1674), should have lived in a kingdom whose capital city—London—regularly published weekly "Bills of Mortality" that gave its citizens an opportunity to see for themselves the number of christenings and burials occurring in their town (Hull, 1963–1964, 1:lxxx–xci). Graunt, whose work transformed the bills into sources for retrospective demographic research, was, in a time when population figures were regarded as valuable state secrets, puzzled by their publicity.

> There seems to be good reason, why the *Magistrate* should himself take notice of the numbers of *Burials*, and *Christnings*, viz. to see, whether the City increase or decrease in people; whether it increase proportionably with the rest of the Nation; whether it be grown big enough, or too big, etc. But why the same should be made known to the People, otherwise than to please them as with a curiosity, I see not [1975:27].

The magistrate's interest in matters of population was by this time taken for granted. Assessing taxes, raising armies, and provisioning large cities had long depended upon the capacity of ambitious monarchs to gauge at least approximately the numbers and wealth of their subjects. However, Graunt's work was not based entirely on public documents. His research on the published bills of mortality was supplemented by forays into the records of the parish clerks, whose company was responsible, at least since 1625, for printing the bills (Hull, 1963–1964, 1:lxxiii). From its beginning, the science of demography as practiced by Graunt had a decidedly retrospective aspect. He wished to procure a complete time series of the bills, demonstrating an awareness of the need for understanding current conditions as the product of past trends.

All of the characteristics of modern, empirical research are to be found in Graunt's *Natural and Political Observations Mentioned in a Following Index and Made Upon the Bills of Mortality* (1662): (*a*) a thorough attempt to trace the origins and history of the sources used (1975:19–20); (*b*) a detailed discussion of the limits of the area inhabited by the population referred to in the sources (1975:21–26); (*c*) a critical discussion of the methods by which the data for the bills were gathered; and (*d*) some suggestions on ways of improving them. However, the substance of Graunt's contribution to initiating historical demographic research lay in the methods he used, which revealed not only curious empirical findings but also an insight into the regularities observable in patterns of mortality.

Graunt's categorization of different types of mortality was a fundamental one. His distinction between "Epidemical" and "Chronical" diseases, the most important among the former being the plague, allowed him to distinguish throughout this work between causes of mortality that appeared to be regular and those that were merely accidental. The use of a large body of data was the precondition for his detection of certain regular relationships between levels of fertility (christenings) and mortality (burials). The "Table of Casualties" that he composed was based on 229,000 burials. Had Graunt been content to examine only the rural mortality that he discussed in Chapter 12 of the *Observations*, it is highly unlikely that he would have been able to draw the conclusions pointed to by an examination of the London bills. As Graunt noted in his passages about the "Country Bills," there was a much greater variability in the yearly mortality of one Hampshire parish than was evident in the bills for Greater London. His discovery of regular relationships between births and deaths during "normal" years was thus entirely dependent on his courageous use of such a mass of material as the London bills could offer.

Graunt defined "normal," "sickly," and "Plague" years by examining several relationships: (*a*) between the level of plague mortality and total mortality; (*b*) between one year's mortality and the mortality of adjacent years; and (*c*) between mortality and fertility. Each type of year was distinguished in quantitative terms from the others. A "sickly" year he defined as one "wherein the *Burials* exceed those, both of the precedent, and subsequent year, and not above 200 dying of the *Plague* [a figure that seems to have been determined arbitrarily], for such we call *Plague-Years*." The definition of "sickly" years could not rest merely on an excess of burials over christenings "because such excess of *Burials* may proceed from increase and access of People to the City onely [1975:50]."

In Graunt's work, there was a latent notion of a population system whose regular functioning was disrupted at intervals by catastrophic mortality. Epidemics affected not only the level of mortality but also its constituent causes. "Plague-Years" were defined as those with more than 200 deaths from the disease, as well as years in which the proportion of mortality attributable to epidemic causes rose multiplicatively over the "normal." Further, Graunt showed that "sickly" years, those defined as displaying higher levels of mortality than adjacent years, nearly always contained fewer than "normal" numbers of births, thus leading him to hypothesize "that the more sickly the years are, the less fecund, or fruitful of Children they also be [1975:50–51]." This latter finding was confirmed by the Hampshire parish records (1975:72–73).

Graunt's notion of the capacity of London's population to recover from periods of catastrophic mortality was, in retrospect, singularly sanguine: "Let the *Mortality* be what it will, the City repairs its loss of Inhabitants within two years [1975:50]." His conclusion, based on an awareness of the importance of migration as a contributing factor to London's growth, may have been empirically accurate—that is, the total number of inhabitants may have resumed preepidemic levels quite rapidly. However, the population affected would have recovered its previous age composition only with the passage of decades (LeBras, 1969; Livi-Bacci, 1978:63–91).

The issue of the London population's age composition was of keen interest to Graunt but led him into perhaps the least successful part of his work. Beginning in Chapter 7, "Of the Differences between Burials and Christnings," after he made a characteristically commonsensical observation of the obvious physical signs of London's increase belied by a mere comparison of burial and christening totals, Graunt's work began to falter. Attempts to calculate the size of London's or England's population from vital rates, the use of a high (eight) multiplier from house to total population, led him away from the more important insights of his work.

It was his design of a prototypical life table—one showing the number of survivors at different ages—that stimulated the most interest among Graunt's contemporaries and followers (see Table 1.1). The life table, as Ian Hacking (1975:109) has shown, was based on a nearly uniform risk of dying between age 6 and 76 and "results from first of all solving the equation $64(1-p)^7 = 1$, and then rounding off to the nearest integer . . . . That is, we assume 64 people alive at age 6, and only one at age 76, and solve for a constant chance p of dying in a decade." The empirical accuracy of Graunt's table was, in retrospect, less at issue than his suggestion of the regularity in age patterns of mortality. It was no doubt because of the possible existence of a mathematical regularity in mortality that later methodologists were drawn to the study of what had been viewed as an inevitable, but not necessarily predictable, phenomenon.

Table 1.1
John Graunt's "Life Table"

Age	Survivors
0	100
6	64
16	40
26	25
36	16
46	10
56	6
66	3
76	1

Source: Graunt, 1975.

Whereas Graunt's legacy to historical demography lies in his detection of regularities in the age pattern of mortality calculated from large amounts of data, the author believed his findings to have immediate and practical uses. Graunt lamented:

> That whereas the Art of Governing, and the true *Politiques*, is how to preserve the subject in *Peace*, and *Plenty* . . . men study onely that part of it, which teacheth how to supplant, and over-reach one another, and how, not by fair outrunning, but by tripping up each other's heels, to win the Prize [1975:78].

Graunt, the London merchant, was quite reasonably an advocate of magistrates occupying themselves with the kingdom's peace and plenty, and of "fair outrunning" in contradistinction to more aggressive means of achieving commercial or political goals.

It was in the final pages of the *Natural and Political Observations* that the work took on a tone characteristic of the Political Arithmeticians among whom Graunt is usually considered. The long-accepted idea that the Political Arithmetician William Petty, a friend of Graunt's, was actually the author of the *Natural and Political Observations* becomes most understandable when the conclusion of the essay is considered, since it diverged sharply from the tone and theoretical insights of the bulk of the work with its concern to generate ratios and multipliers linking vital rates to population size and composition. In the conclusion, Graunt (or perhaps even Petty) defended the usefulness of the work by pointing out the need for rulers to be well informed about a vast array of conditions, among others: "how many People there by of each Sex, State, Age, Religion, Trade, Rank, or Degree, etc. by the knowledge whereof Trade, and Government may be made more certain and Regular [1975:79]."

However, Graunt's contribution to the development of historical demography differed substantially from that of most of the Political Arithmeticians, who will be considered later in this chapter. In the body of his *Natural and Political Observations*, Graunt succeeded in going beyond the immediately useful task of attempting to estimate the size and/or composition of a population from numbers of vital events to the construction of a method of research and a conceptualization of regularities observable in the occurrence of those vital events—particularly mortality. His use of a mass of time series data on births and deaths and his effort to construct from them age patterns of mortality that echoed the regularities in causes of death in "normal" years formed the basis of his legacy both to methodologists of his time and to current demographers.

If we accept Kuhn's notion that "science" is distinguished by its capacity to experience "progress" and that one of the conditions of this progress is the existence of a community of researchers working with the same paradigms, then the legacy of Graunt's work and the process by which seventeenth- and eighteenth-century scholars exploited its implications become clearer. While Graunt's "fact-gathering" research displayed the randomness which Kuhn

(1970:15) argues is characteristic of the "preparadigmatic" days of any science; this was not the case with the scholarship of the able mathematicians who read and admired the *Natural and Political Observations*.

It was in Holland in particular that Graunt's essay had the most immediate and far-reaching effects. There, a group of mathematicians and actuaries, including Christiaan Huygens (1620–1699), John Dewitt (1625–1672), Grand Pensionary of the Netherlands, and Johan Hudde (1628–1704), Burgomaster of Amsterdam, were at work on the problem of calculating the value of the life annuities on which so many Dutch cities depended for their revenues during the wars with England and France (Hendriks, 1852–1853:257). The *Natural and Political Observations*, in fact, appeared during a time when there was a growing awareness of the relevance of the newly developing study of gaming to a variety of probability problems. As an insightful commentator has noted: "By the time [of Graunt] . . . problems about dicing and about mortality rate had been subsumed under one problem area [Hacking, 1975:109]." Seventeenth-century progress in the gathering, analysis, and explication of systematic age patterns of mortality was attributable in large measure to the attraction that probability puzzles of all kinds held for Europe's greatest mathematical minds, and to the perceived relevance of calculations of the probable outcomes of games of chance to the calculation of probabilities of death by age.

As Hacking (1975:92–93) has shown, Christiaan Huygens, in particular, was acquainted with the Pascal–Fermat correspondence and personally with the circle of mathematicians around Roannez and Méré. In 1669, he received a letter from his brother Lodewijk, who was reading Graunt, challenging Christiaan to calculate correctly the expectation of life of a newly conceived fetus from Graunt's table. Christiaan Huygens's solution resulted in the articulation of a fundamental distinction that had not occurred to his predecessors (nor to many who lived after him)—that between life expectancy and the average or median length of life. Huygens solved the puzzle through his proposition of "unequal chances." From Graunt's data, he calculated the expectation of life at conception by multiplying, for each age interval, the chances of living the whole interval by the number of survivors (for the first interval, for example, 64 times 6) and the chances of dying by the number who died (36 times 3—under the assumption that those dying had an equal chance of living one-half the interval). The sum of the two products for each interval was calculated, and then the total of the sums taken. Finally, Huygens divided this by the total number of chances (100) (Hacking, 1975:99–100). The result of his calculation was 18.22 years. What Huygens had created, though not with any obvious consciousness of the importance of his discovery, was the equivalent of what is now defined as the "L_x" column of the life table, the number of "person-years" lived in an age interval, which is still used as the basis for the calculation of life expectancy at different ages.

Huygens cautioned, however, that his figure for the expectation of life was not the one of greatest interest to the betting man or woman who wished to make a fair wager on the probable life of a newborn child—the age to which an individual had a 50% probability of surviving. This figure, from Graunt's data, was approximately 11 years (Hacking, 1975:100). Huygens wrote to his brother:

> The expectation or the value of the future age of a person and the age to which there is an equal probability that he will reach it or will not reach it, are two different things. The former is for the estimation of life annuities, the latter for that of bets [cited in Hendriks, 1899:387–388].

It was Huygens's colleagues, Hudde and Dewitt, who were faced with the practical problems of calculating actuarial tables for those Dutch citizens interested in purchasing life annuities by investing a fixed amount of money that would then be repaid with interest in annual installments until the end of their lives. The accurate estimation of the expectation of life at different ages, not only at birth, was thus of crucial interest to these Dutch researchers who were eager to aid their governments to profit from the sale of such annuities. Both Hudde and Dewitt had access to longitudinal records of individual annuitants that served as the empirical data for the calculation of life expectancy at different ages used in Dewitt's abridged life table presented in 1671 to the States General of Holland (Hendriks, 1852–1853:246). For reasons of the data themselves, which often bore misstatements of age at death, Hudde and Dewitt differed in their estimates of the mortality curve during adult years. However, through the efforts of the Dutch actuaries, the methodological model for correctly calculating the value of individual or joint annuities passed into "normal" science.

Perhaps the best-known life table research in the late seventeenth century was contained in Edmund Halley's (1656–1742) essay *An Estimate of the Degrees of the 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 upon Lives* (1693). The tone of Halley's essay contrasted sharply with the humility of Graunt's work and the methodological clarity of Dewitt's calculations. There was an air of complete self-assurance in the quality of his sources—the birth and death (by age) records of the Silesian city of Breslau during the 5 years 1687–1691, and the appropriateness of the town as a model or "Standard" (1942:4) from which to study the mortality of the human species.

Because of Halley's failure to illuminate crucial steps in his logic, some disagreement still remains on the exact route he followed in arriving at his famous life table reproduced in Table 1.2 (Greenwood, 1942:215–219; Halley, 1942:iii–vi; Dupâquier, 1976). Halley's belief in the appropriateness of Breslau as a model was based on an incipient notion of population stationarity, which, in the seventeenth and eighteenth centuries meant simply that a population under consideration was free of migration and neither growing nor declining (Behar, 1976:185). Halley was quite aware that Breslau did not conform exactly to this

Table 1.2
Edmund Halley's Life Table

Age Curt.	Persons	Age Curt.	Persons	Age Curt.	Persons	Age Curt.	Persons	Age Curt.	Persons	Age Curt.	Persons
1	1000	8	680	15	628	22	586	29	539	36	481
2	855	9	670	16	622	23	579	30	531	37	472
3	798	10	661	17	616	24	573	31	523	38	463
4	760	11	653	18	610	25	567	32	515	39	454
5	732	12	646	19	604	26	560	33	507	40	445
6	710	13	640	20	598	27	553	34	499	41	436
7	692	14	634	21	592	28	546	35	490	42	427
Age Curt.	Persons	Age Curt.	Persons	Age Curt.	Persons	Age Curt.	Persons	Age Curt.	Persons	Age Curt.	Persons
43	417	50	346	57	272	64	202	71	131	78	58
44	407	51	335	58	262	65	192	72	120	79	49
45	397	52	324	59	252	66	182	73	109	80	41
46	387	53	313	60	242	67	172	74	98	81	34
47	377	54	302	61	232	68	162	75	88	82	28
48	367	55	292	62	222	69	152	76	78	83	23
49	357	56	282	63	212	70	142	77	68	84	20

Age	Persons	Age	Persons
7	5547	56	2194
14	4584	63	1694
21	4270	70	1204
28	3964	77	692
35	3604	84	253
42	3178	100	107
49	2709	100	107
			34000

Source: Edmund Halley, "Degrees of Mortality of Mankind." (Ed.) Lowell J. Reed. Repr. of 1693 ed. (Baltimore, Johns Hopkins: 1942), p. 6. This table reproduces Halley's original format.

description, indicating that births in Breslau exceeded deaths by about 64 per year. However, he argued quite reasonably that this disturbing effect on his calculations would be small compared to the effects of migration on calculations drawn from cities such as London or Dublin (1942:3).

The radix of Halley's table was 1238 births—a source of much confusion—since some have believed that the figure of 1000 opposite the "Age Curt. [current] 1" was actually the number of births from which he began. Greenwood has convincingly argued and Halley (1942:4) in the text showed that he began with 1238 births—the "Age Curt." column referring not to the number of persons alive at an exact age but rather to a kind of mid-year population, which, under the assumption of stationarity, he took to be equivalent to the L_x or "person-years lived" column of the modern life table. The innovation of Halley was thus to use birth and death by age data, under the assumption of stationarity not only to calculate numbers of survivors at different ages but also to formulate a life table that indicated the actual age structure of Breslau's population or, more accurately, he believed, human populations in general.

The interests of his table were various, as Halley himself proclaimed. His table could be used for the calculation of probabilities of death by age, the value of life annuities, both individual and joint, and most importantly for the systematic estimation of age composition and population size of a whole community from good vital registration data, when the community had an equal number of births and deaths and was relatively free of migration.

Though the Breslau records appeared to Halley to be of high quality, he detected some anomalies in them, based on a comparison of them with other death-by-age data from Christ-Church Hospital. Whereas the Breslau mortality rate for persons ages 6–25 was approximately .01, it was suspiciously low for persons ages 14–17. His response to this anomaly was characteristic:

> And whereas in the 14, 15, 16, 17 *Years* there appear to die much fewer . . . yet that seems rather to be attributed to Chance, as are the other Irregularities in the Series of Ages, which would rectifie themselves, were the number of Years much more considerable, as 20 instead of 5 [1942:5].

In Halley's mind, the deviations of the Breslau data from what he was led by experience and an assumption of regularity to expect loomed not as "counter-instances" (Kuhn 1970:79–80) threatening his belief in the reality of predictable and regular age patterns of mortality but rather as accidental or contingent problems of the data themselves. This attitude and the dramatic flourishes of his text proclaimed Halley's own conviction that he was in fact in the midst of a genuine revolution in knowledge.

In retrospect, Halley's method of building his life table from death-by-age data had some unfortunate consequences, to the extent that it stimulated other researchers in the Old World (Jonckheere, 1965) and the New World (Vinovskis, 1971) to apply his method to the analysis of populations that deviated sharply from the condition of stationarity, thus leading to highly erroneous results.

In contrast, some of the best methodologists of the eighteenth century, including Antoine Deparcieux (1703–1768) and Pehr Wargentin (1717–1783), obviated this particular source of error either by deriving real "cohort" life tables from "closed" populations such as monks, nuns, subscribers to tontines, or, in the case of Wargentin, by working with empirical data on age structure gleaned from the eighteenth-century Swedish censuses.

The task of calculating life tables from age-at-death data on closed populations is, of course, less hazardous than the technique Halley employed. Deparcieux's well-known *Essai sur les probabilités de la durée de la vie humaine* (1746) was based essentially on good longitudinal data on the ages of death of such closed subpopulations. From them Deparcieux could calculate exactly the probabilities of death by age, discovering at the same time as Wargentin the notable differences between the mortality levels of men and women (1746:50). As Lazare Behar (1976:179) has shown, Deparcieux was the first noted methodologist to state in clear demographic terms the difference between median length of life and life expectancy at birth. Deparcieux was well aware that life tables constructed for relatively healthy, well-off subpopulations of *rentiers* or monks might not be the wisest standards from which to assess life expectancy for whole populations (1746:60–61, 70–71). It was this realization that prompted his interest in Wargentin's research, unique in the eighteenth century, since the latter had at his disposal not only the best nationwide vital registration data in the world but also some of the few national-level censuses that reported ages (Dupâquier, 1977). The charming bits of extant correspondence between the two men (Houdaille, 1967) demonstrate their mutual points of concern. Both had become aware of the problems of age misreporting—Wargentin from the age heaping apparent in the Swedish censuses and Deparcieux (citing Buffon), noting that it was unlikely for a population to show 46 people dying at age 49, 159 at age 50, and 63 at age 51, commenting that "Nature does not make such mistakes [1760:22]." Deparcieux concluded that good estimates of mortality by age should entail some combining of years of age into multiyear categories in order to mitigate the effects of people's tendency to round off reported ages.

The refinement of the theory and methods of life table construction in the eighteenth century (Behar, 1976) and the development of more clear-cut and restrictive notions of population stationarity in the nineteenth (Sauvy, 1976) were based on the pioneering work of a very few scholars. The legacy of such research in the twentieth-century work of Dublin and Lotka (1925;1949), Coale and Demeny (1966), and Ledermann (1969) is obvious.

Though formative work in this branch of historical demographic research tended to emphasize the systematic nature of mortality patterns and was based on a notion of population abstracted from the day-to-day lives of individuals, a number of methodologists were aware of the impact of societal conditions on the functioning of demographic processes. Near the end of his essay, Halley observed

> that the Growth and Encrease of Mankind is not so much stinted by anything in the Nature of the *Species*, as it is from the cautious difficulty most People make to adventure on the state of *Marriage*, from the prospect of the Trouble, and Charge of providing for a Family. Nor are the poorer sort of People herein to be blamed, since their difficulty of subsisting is occasion'd by the unequal Distribution of Possessions, all being necessarily fed from the Earth, of which yet so few are masters [1942:20].

Although considerations such as these were noted, they were to become focuses of primary attention in the works of the Political Arithmeticians of the seventeenth and eighteenth centuries.

Political Arithmetic

The tradition of social inquiry known as "Political Arithmetic," after its originator, William Petty (1623–1687), provides a second kind of ancestor for historical demography. Carried out under this name primarily in the seventeenth and eighteenth centuries, Political Arithmetic was characterized by its practitioners' firm belief in the ability of rulers and educated men to enhance their understanding of and control over the social world by the implementation of policies derived from the collection and analysis of quantified data about that world.

Although some of the scholars already discussed as "methodologists" were referred to by their contemporaries as "Political Arithmeticians," there are in retrospect several notable features that distinguish the contributions of one group from the other's. Whereas the methodologists were, in the main, quite excellent mathematicians concerned with regularities in demographic processes—mortality, in particular—this was not the case with Political Arithmeticians, as defined here. Political Arithmeticians such as Petty, the Maréchal de Vauban, Gregory King, or Moheau (Montyon) viewed questions of population in terms quite different from those used by the mathematically minded methodologists.

The methodologists constructed a model of the mortality process that could be divorced in its essentials from considerations of time and place. Political Arithmeticians, however, understood population processes as deeply imbedded within concrete sociohistorical settings. One of the contributions of Political Arithmeticians was in fact to emphasize the need for population data, particularly censuses, that would distinguish among the different categories of people who comprised the populations of kingdoms. Just as information about a country's agriculture in order to be useful to its governors had to include classifications of soil types, crops raised, livestock available, plows used, and climatic conditions, so too population information was useful to the extent that it delineated constituent elements: farmers, tradesmen, nobles, the unmarried, the rich, or the poor. Political Arithmeticians were, in general, concerned with population not in some abstract sense but with the characteristics of living, breathing inhabitants and their relationships to other productive resources of kingdoms. Gradually, from being part of the natural landscape along with the forests, croplands, and livestock, human inhabitants emerged in the studies of the Political Arithmeticians as a primary focus of their statistical investigations.

There was some generally shared notion among Political Arithmeticians about the way that population contributed to a kingdom's wealth, particularly through its members' productive activities. They believed that in studying population they were examining an aggregate of types of individuals with specific skills and, importantly, examining these aggregates in relation to the other resources at the inhabitants' disposal. The concrete relationships between population and resources were abstracted into numerical ones—usually expressed in terms of ratios. However, a number of the Political Arithmeticians had firsthand knowledge, at least as observers, of the conditions they hoped to convey in their figures. In the hands of the Political Arithmeticians, demographic investigation became an eminently social science.

Another broad distinction that might be drawn between the methodologists and the Political Arithmeticians was the circumscribed demographic interest of the former versus the universal, and often undiscriminating, curiosity of the latter. While the methodologists were engaged in a manageable if difficult kind of "puzzle-solving," the Political Arithmeticians were fascinated seemingly by all aspects of the social and economic life of which humans were a part. Furthermore, whereas the methodologists were engrossed in the study of the inevitable process of dying, the Political Arithmeticians were engaged in fact-finding that many of them believed would contribute to the regularization of that highly contingent art of statecraft. Between the mathematical modeling of regularities in mortality and the application of demographic information to statecraft lay the world of politics, within which some of the more eminent of these men, such as Petty, Vauban, or Montyon lived part or nearly all of their adult lives.

Finally, Political Arithmeticians employed a kind of analytic–descriptive mode of discourse that communicated information on population gleaned from quantified evidence, but not primarily through the language of mathematics. Their work, designed for the consumption of heads of state and educated men, was generally composed in everyday language.

In his work *Political Arithmetick*, published in 1690, Petty captured the spirit of the kind of inquiry he believed himself to be inaugurating with all the enthusiasm of the iconoclast:

> The Method I take . . . is not yet very usual; for instead of using only comparative and superlative Words, and intellectual Arguments, I have taken the course . . . to express my self in terms of *Number, Weight,* or *Measure;* to use only Arguments of Sense, and to consider only such Causes, as have visible Foundation in Nature; leaving those that depend upon the mutable Minds, Opinions, Appetites, and Passions of particular Men, to the Consideration of others [Hull, 1963–1964, 1:244].

The appetite of Petty and other Political Arithmeticians for facts and figures was gargantuan. The title page of Petty's own work (according to Hull, "probably supplied by Lord Shelburne") proclaimed the subjects addressed in it:

> The Extent and Value of Lands, People, Buildings; Husbandry, Manufactures, Commerce, Fishery, Artizans, Seamen, Soldiers; Public Revenues, Interest, Taxes, Superlucration, Registries, Banks; Valuation of Men, Increasing of Seamen, of Militia's, Harbours, Situation, Shipping, Power at Sea, etc. As the same relates to every Country in general, but more particularly to the Territories in His Majesty of *Great Britain,* and his Neighbours of *Holland, Zealand,* and *France.*

Although most of his published work could properly be understood as economic in focus, Petty was deeply intrigued by the contribution of population to the creation of national wealth and for this reason made valiant attempts to estimate the number of inhabitants of whole kingdoms and a number of European cities, in such works as *Two Essays in Political Arithmetick* (1687) and *Observations upon the Cities of London and Rome* (1687) (Hull, 1963–1964, 2:501–518). In his study *Observations upon the Dublin-Bills of Mortality* . . . (1683) (Hull, 1963–1964, 2:479–491), Petty had at his disposal short-term series of data on births and burials, lists summarizing the number of families and hearths for each parish of the city, and comparative birth and burial data for London. As in so many of his works, he was interested in comparative analysis, attempting to arrive at ratios expressing relationships, for example, between births and deaths that might be used in the analysis of the demographic profile of a number of cities. Finding that the average number of burials for 6 years in Dublin was $\frac{1}{12}$ the number in London, Petty estimated the size of the Irish capital at $\frac{1}{12}$ that of the English capital, cautioning, however, that births were a better source for inferring the population, "*Burials* being subject to more Contingencies and variety of Causes [Hull, 1963–1964, 2:482]". By calculating a ratio of the average number of births to burials in the two cities, a figure of $\frac{5}{8}$, the author believed he had found a standard for "normal" years that could fruitfully be compared with similar ratios from other cities in order to assess the health of the population (Hull, 1963–1964, 2:483).

Although Petty's labors were devoted to an assessment of the size or state of health of different populations from lists of hearths, hospital records, and particularly from records of christenings and burials in local bills of mortality, he voiced a frustration that later Political Arithmeticians would share over the limitations of the population data at their disposal:

> Without the Knowledge of the true *Number of People,* as a Principle, the whole scope and use of the keeping Bills of Births and Burials is impaired; wherefore by laborious Conjectures and Calculations to deduce the number of People from the Births and Burials, may be Ingenious, but very preposterous [Hull, 1963–1964, 2:485].

Petty's demonstration of London's preeminent place not only among the cities of Christendom but also those of the entire world, in his *Two Essays in Political Arithmetick concerning the People, Housing, Hospitals, etc. of London* (1687) (Hull, 1963–1964, 2:501–513), involved him in a dispute with French researchers, who were piqued by his calculation that London's population was larger than the populations of Paris and Rouen combined. In his *Political Arithmetick* Petty had averred "that a small Country and few People, may be equivalent in Wealth and Strength to a far greater People and Territory [Hull, 1963–1964, 1:249]," but his demonstration of the size and wealth of England's capital city had a gleeful tone, which made later Political Arithmeticians, such as Gregory King (Glass, 1965:162) suspicious of his predecessor's motives and skill as a calculator.

In an insightful work, Joyce Appleby has noted: "An indefatigable analyzer, Sir William Petty, tried to calculate the intrinsic value of all things [1978:81]." The value of the human inhabitants of a kingdom was no exception to this rule, though their value, in Petty's opinion, derived in large part from their extrinsic features, such as the work they did. In his *Treatise of Taxes and Contributions* (1662), Sir William had argued "that it was a mistake to believe 'that the greatness and glory of a Prince lies rather in the extent of his territory than in the number, art and industry of his people, well united and governed [cited in Strauss, 1954: 202].' " Petty was quite adept at estimating the "value of people" according to their labors, by determining the "Annual proceed of the Stock, or Wealth of the Nation," subtracting from it the estimated expenses of all Englishmen, yielding a figure that could then be divided by the relative earning potential of different types of people (Hull, 1963–1964, 1:105–108). The goal of all these calculations was to establish orders of magnitude and proportional relationships among the various factors of production to gather information that was useful in an immediate sense for purposes of governing.

Petty's belief in the relevance of accurate and detailed social data to the art of good government was echoed in the works of Vauban (1633–1707), whose writings included not only empirical research on various French populations but also designs for detailed censuses of the French kingdom, as well as the results of censuses he himself planned and executed in such cities as Valenciennes. His work was informed by the conviction that accurate, quantified information about inhabitants and their material resources could "serve as a basis for the effective fight against injustice [Vilquin, 1975:221]," especially, it would seem, in allocating the royal tax burden and calling the king's attention to areas in need of economic development. Although the value of census-type data to military governors of recently conquered areas of Louis XIV's kingdom was widely accepted at the time, Vauban argued for the general usefulness of accumulating detailed, comparative data on population. Both Eric Vilquin (1975) and Dupâquier (1979:47–50) have amply discussed the Maréchal's contributions to the design of census-taking as well as his interesting recommendations that the French monarch seek to adopt the kind of continuous, local population recording system reported to exist in China.

Vauban's *Description géographique de l'élection de Vézelay* (1696) (Boislisle, 1881, 1:738–749) captured the essence of a view of population shared by the seventeenth-century Political Arithmeticians. Beginning with a delineation of the location of the region under observation, a description of its areal size, political administration, soil, crop yields, houses, methods of cultivation, rivers, livestock, and woods, Vauban arrived at a description of the human population, in terms not only of its size and constituent parts (nobles, clergy, peasants) but also of the lower classes' physical capacities, mores and view of the world. Vauban scrutinized both the natural and social worlds here, seeing human habitants as mediators between the two.

Vauban's study concluded with long policy recommendations that his analysis of the region had stimulated. Since Vauban, like most of his educated contemporaries, believed and often repeated the dictum that "the greatness of Kings is measured by the number of [their] subjects [Vilquin, 1975: 255]," he was deeply concerned about the best means of increasing this valuable resource. For Vauban, however, this proposition, far from being a simple ideological reflex of a mercantilist bureaucrat, was confirmed by his personal observations of the ways that an inegalitarian taxation policy reinforced the poverty and underpopulation of many areas of rural France in the late seventeenth century. The proposition, furthermore, was not unqualified, either in the work of Vauban or Petty. Both Political Arithmeticians were conscious that a growing population led to increases in national wealth only if the members of the population were engaged in productive activities. Discussing the losses in national revenue occurring to England as the result of plague epidemics, Petty had written:

> If the Plague discerned well, between the well and the ill-affected to Peace and Obedience, or between the *Bees* and the *Drones*, the Fact would determine the Question: But if it destroy promiscuously, the Loss is proportionable to the Benefits we have by them that survive; for 'tis they that make *England* worth above 600 millions, as aforesaid: It being certain, That if one person only had escaped: the whole Territory, and all that is in it, had been worth but a livelihood for that one [*Verbum Sapienti*, 1664, in Hull, 1963–1964, 1: 110].

In other works, "William Petty made explicit his view that landlords were parasitical and tenants productive [Appleby, 1978:134]." Vauban, for his part proclaimed his contempt for the tax profiteers and other unproductive ne'er-do-wells who were sapping the French kingdom of its strength (Boislisle, 1881, 1: 744-745). Some of the strongest policy recommendations in his *Description* urged the systematic implementation of a policy of economic development within the *élection* of Vézelay. The king's policy would "render this area and all others where they were implemented more affluent, fertile and . . . populated, for the people being better nourished than they are would become more likely to marry, stronger, and capable of bearing and raising children--as well as less lazy [Boislisle, 1881, 1:744]."

Some of the earliest practitioners of Political Arithmetic, such as Petty and Vauban, were engaged primarily in the statistical description of populations in relation to their material resources and, in the case of Vauban, in the innovative design and execution of comparative and accurate enumerations. The most talented Political Arithmeticians who followed them attempted to infuse the pursuits of population description and estimation with the insights and techniques of such men as Graunt and the other methodologists. However, the mathematical skills of even the best, later Political Arithmeticians, such as Gregory King or Moheau (Montyon), did not equal those of the methodologists whom they so admired.

Though Glass (1965:167) has minimized Gregory King's (1648-1712) intellectual affiliation with Petty, the resemblance between some of their works is striking. King like Petty, had a "wide interest in political arithmetic for its own sake and for the sake of its relevance to public policy [Glass, 1965: 162]." He was doubtless a more disinterested arithmetician than Petty, one whose research (most of it unpublished during his lifetime) was much more focused than Petty's was on purely demographic subjects. King's estimates of the size and age composition of England and Wales were based on a rather unique set of national-level data composed of vital registration and individual enumeration information, generated by a 1694 law that taxed the registration of vital events and placed an annual levy on bachelors over age 25 and childless widowers (Glass, 1965:169). As a result of this tax, King had at his disposal both data on persons per house from a wide variety of areas in Britain and records of vital events, which he used as raw material for estimations of the kingdom's population.

However, King's researches were also informed by an admiration for the work of Graunt, whose legacy can be read in his interest in determining the age composition of the population as well as its size. Apparently as the result of private data gathering, King procured some local-level enumeration information containing ages, which he used (in smoothed form) to infer the relative weight of different age groups in the entire national population (Glass, 1965:180-181) as well as to compute a life table.

Interest in regional differences in population size, density, and crude birth rates was epitomized in the late eighteenth century work of the Baron de Montyon (1733-1820), who published his *Recherches et considérations sur la* *population de la France* under the name of his secretary, Moheau (Vincent, 1947-1948:57; Lecuir, 1979). Using the same variety of tax, birth and death, and enumeration records typical of King's work, Montyon went beyond the attempt to estimate the size, density and composition by age, marital status, sex, or occupation to a consideration of the causes for the decline or increase in population levels. These ranged from the physical or environmental (1912: 199-215) to investigations of the influence of occupation, custom, law, and government. His well-known discovery of the seasonality of births during the year (1912: 93-95) and his knowledge of the work of Halley, Deparcieux, Wargentin, and the other life table methodologists make his work on population stand out from that of the other Political Arithmeticians.

Montyon's knowledge of the regularities already detected in mortality patterns led him to investigate a number of propositions relating population variations to other social phenomena:

> It would be very desirable to see whether the years most abundant in agricultural production are similar in the production of human beings. There has been research into this subject, the number of births being compared to the price of grains—a moral proof of their scarcity. But no analogy between the fertility of the soil and that of women has been discovered [1912:90].

For a scholar who had discovered regular variations in the seasons of birth and conception, this failure to find any regular relationship between variations in grain prices and births was undoubtedly the source of some consternation.

The best of the Political Arithmeticians, such as Montyon, who turned their attention to inquiries into population, particularly fertility, were in fact working under much more difficult conditions than the methodologists. The detection of significant variations in fertility rates, for example, demanded much better data than they had at their disposal, or at least a method for reconstructing in detail the longitudinal history of the "units of production"—that is, couples—who produced the births. Cross-sectional views of fertility at the city or regional level could demonstrate that the populations of different areas were reproducing at different crude rates, and for reasons that Montyon and other, previous investigators, including Graunt, knew were related to the age composition of the population. However, the difficulties of accumulating information on the exact population size and structure of a wide variety of parishes or towns along with accurate records of births impeded progress toward the detection of significant regularities in fertility similar to those found to exist for mortality.

The Theorists

There is a kind of logic in passing from the explicitly mathematical paradigms of the methodologists of the seventeenth and eighteenth centuries, via the Political Arithmeticians, to the work of two theoreticians of the nineteenth century. The first of these, Thomas Robert Malthus (1766–1834), was undoubtedly the more important for his contemporaries. Karl Marx's (1818–1883) scattered statements on population, though far fewer in number than Malthus's, can be shown, however, to represent a systematic response to Malthusian theory and an important alternative model to his predecessor's.

Like the methodologists, Malthus was the creator of a paradigm of population, one based on a theory that undoubtedly changed the way a good many of his contemporaries viewed the world. It is quite obvious, however, that Malthus's theory of population functioned at an entirely different level of generality and meaning from the theory of mortality puzzled over and refined by the methodologists. In the first edition of his *Essay on the Principle of Population* (1798), Malthus believed that he was proclaiming a universal law of population that had functioned in all places and times. He articulated his theory with the same sense of discovery that we have seen reflected in the work of Halley. However, it is quite clear that Malthus's notion of population was not entirely, or even generally, an abstract one. Like the Political Arithmeticians, both Malthus and Marx conceptualized populations as aggregates of real people, with concrete occupations, values, and class affiliations that made a substantial difference in the regularity with which they, as individuals and members of social groups, "obeyed" the law they had discovered. Both Malthus's and Marx's theories of population, in contrast to the models of the mathematicians, are the kind of "constituent models" that Foucault has argued are characteristic of the "human sciences" (Foucalt, 1966:368—369). In these theoretical models, human beings, or populations are rooted in time and place, in the real world of work, custom, and language. Though in the first edition of his *Essay* Malthus implicitly undervalued the importance of historical development for shaping individual and group behavior, following editions, with their emphasis on the importance of the "preventive" checks to population growth took much greater note of the social, historical, and economic contexts in which his law of population functioned.

As many critics from William Hazlitt to Marx delighted in pointing out, the theory of population associated with Malthus's name was built on the work of many of his contemporaries (Albrecht, 1969). Malthus's "discovery" that population could increase beyond available means of subsistence and the "geometrical" increase of population had both been previously discussed (see, for example, Wallace, 1969). However, Malthus's contribution lay in his effort to go beyond discrete observations or hypotheses and gather together a number of propositions to formulate a general law inherent in "nature."

Malthus's theory, as expressed in the first edition of the *Essay*, may be simply stated—one of its sources of attraction. It was based, first, on two "postulata": "First, That food is necessary to the existence of man. Secondly, That the passion between the sexes is necessary and will remain nearly in its present state [Malthus, 1960: 8]." The fundamental deductions from these propositions were equally simple: "Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio [1960: 9]." Malthus concluded from his postulata and deductions, "That population does invariably increase where there are the means of subsistence . . . And that the superior power of population cannot be checked without producing misery or vice [1960:17]."

The innovativeness of Robert Malthus's theory lay in its underlying conception of society and the formulation of interrelationships between population growth and subsistence. A society's happiness or wealth was no longer positively associated with the size of its population, as some mercantilists had believed. Rather, society was viewed essentially as a set of different parts or classes whose interests and conditions often diverged radically from one another. The importance of delineating constituent groups in the population, which the Political Arithmeticians had pointed out, began to assume even greater significance for understanding demographic processes. Human inhabitants were conceived of not as members of a homogeneous "body politic" but as groups in civil society whose demographic behavior, particularly their fertility, formed the motor force of history.

One of the most important consequences of Malthus's theory was to shift attention away from the size or density of populations to the rate at which peoples increased or decreased. Fundamental, too, was his emphasis on the relation between processes of growth in supplies of people and supplies of food:

> The happiness of a country does not depend, absolutely, upon its poverty or its riches, upon its youth or its age, upon its being thinly or fully inhabited, but upon the rapidity with which it is increasing, upon the degree in which the yearly increase of food approaches to the yearly increase of an unrestricted population [1960:51].

Concern for rates of population increase or decrease had been expressed before, for example in nearly all of the literature surrounding the "Eighteenth-Century Population Controversy" (Glass, 1973). It could be argued, however, that these rates had been of interest primarily as a means of estimating total population size at two points in time in the absence of regular censuses of the population. Malthus, by contrast, shifted attention to the "moving part" of population as the characteristic most intrinsically worthy of study.

Malthus's mode of presentation in the first edition consisted primarily of the refutation of the ideas of his opponents—particularly William Godwin and the Marquis de Condorcet—whose beliefs in social equality or the perfectibility of man provided Malthus with his main sources of inspiration for composing the *Essay*. Malthus's criticism of his opponents' speculative arguments, his demand that "in philosophy . . . a just theory will always be confirmed by experiment [1960:7]," was a constant throughout the *Essay*. Yet it could be fairly argued that Malthus himself was singularly inattentive to the use of "experiment" in order to prove the most controversial deduction from his postulata, namely, the universal tendency of population to increase beyond its means of subsistence. Malthus's attention to the analysis of sources was notoriously lax, at least in the first edition. In later editions, six of them published during his own lifetime, he engaged in a kind of data "overkill" that makes them nearly unreadable. Strictly speaking, there was no explicit method or rule for data collection obvious in Malthus's essay. The components of his theory of population were suggested by certain empirical findings of his contemporaries and the rate of increase of the American population. Their association with a general law of population was deduced by an intuitive leap of the imagination based on a conviction that the world was regulated by universal laws.

However, to argue that Malthus did not prove his theory, particularly in the first edition, is to miss the expressed intention of his work. Malthus never claimed to be engaged in any proof of his basic propositions or deductions. In an appendix to the third edition (1807), he wrote:

> It has been said that I have written a quarto volume to prove that population increases in a geometrical and food in an arithmetical ratio, but this is not quite true. The first of these propositions I considered as proved the moment the American increase was related, and the second proposition as soon as it was enunciated. The chief object of my work was to inquire what effects these laws, which I considered in the first six pages, had produced and were likely to produce on society [cited in Ashley,1929:112–113].

Thus, Malthus quite rightly conceived his essay as a work illustrating, not proving, a universal theory of population growth whose veracity was a given.

One of the reasons that contemporaries had such difficulties with Malthus's theory, leaving aside for a moment the overwhelming importance of the political implications that many drew from it, was the diffuseness of the theory itself. At one level, certain of its basic propositions were entirely obvious truisms, the *Essay* as a whole, as Samuel T. Coleridge argued, so much "verbiage" written to prove an "axiomatic" proposition (cited in Albrecht, 1969:54). Malthus believed the basic facts leading to a discovery of his theory of the constant tendency of population to multiply beyond subsistence unless checked by vice and misery to be obvious "by what we daily see around us, by actual experience, by facts that come within the scope of every man's observation [1960:23]." On the other hand, Malthus argued that a comprehension of the law's operation demanded a penetration of mere appearances, an awareness that "in no state that we have yet known has the power of population been left to exert itself with perfect freedom [1960:11]." Rather immodestly, perhaps, Malthus several times alluded explicitly to Newton's articulation of the laws of motion and argued:

> To make the general theory just in application to the revolutions of these bodies, it was necessary to calculate accurately, the disturbing force of the sun upon the moon, and of the moon upon the earth, and till these disturbing forces were

> properly estimated, actual observations on the motions of these bodies, would have proved that the theory was not accurately true [1960:92].

Thus, on the one hand, the proposition that the level of subsistence ultimately regulated the possibilities of population increase appeared obvious, logical, and, in fact, trivial. However, a full appreciation of the universal *tendency* of population to outstrip its means of subsistence would be achieved only by looking beyond the short-term, or possibly accidental "oscillations" in population that could deceive "superficial observers" (1960:15). It was the teleological implications, not the temporary functioning of the law of population, that loomed as most important in Malthus's mind.

Malthus's notion of the different generative capacities of land and people was based on a categorical distinction. Throughout the *Essay,* Malthus distinguished between "animate" and "fixed" nature. Man, plants, and other animals were part of the first, and the land, part of the second. Land did not reproduce itself but was rather the medium through which members of the category "animate nature" supported their inherent propensity to increase. The parts of "animate nature" were demonstrably endowed with the possibility of reproducing themselves, and it was part of their definition to do so—at a geometrical rate. Members of "animate nature" were also capable of changing or mutating in degree, we might say, but not in kind. "Fixed nature" was similar in this latter respect. Land had the capability of being changed to support higher or lower rates of reproduction among "animate" beings, but its mutability also had limits—limits that, like the perfectibility of man, were perhaps indefinable but not indefinite (1960:61). The indefinite perfectibility of man or the indefinite possibilities of increasing crop yields would result in a logical absurdity—the destruction of those categories on which Malthus's whole argument was based. It was because of his belief in this basic categorical distinction between "animate"and "fixed" nature that Malthus paid very little attention to the subsistence side of the theory—that he spent so little effort in assessing the possibility of geometrical increases in land productivity that might take place. It was simply not in the nature of land to yield sufficient crops to offset projected increases in mouths to feed.

In the second and following editions of the *Essay,* Malthus modified some of his "harshest" conclusions, essentially by placing new emphasis on the special qualities that distinguished human beings from other kinds of animate beings, particularly their reason—an ability to refrain from reproduction before they and their fellows would be extinguished by the "positive checks" of famine or misery. The existence of this "preventive check" was, of course, referred to in the first edition but was associated there with the "vice and misery" that resulted from its implementation (1960:28). In later editions, "moral restraint"—that is, refraining from marriage and sexual intercourse, or abortion—was distinguished from vice (1960:160). Misery, induced by both man and nature, remained the exclusive "positive" check. This reformulation, the development of the idea of "moral restraint," and the operation of preventive checks in different societies, in fact, became the central focuses of Malthus's exposition. Once again, they were used as multiple illustrations of his population theory. Even with the important revisions of the later editions that illustrated the great importance of "preventive checks" in regulating the size and rate of increase of different populations, it was the statement of his population theory in the first edition that earned Malthus his notoriety.

It was also in this first edition that a penetration of empirical facts to a realization of the truth of the principle of population revealed a universe filled with grotesque ironies, where human motives and conditions led to their direct antitheses: benevolence to misery, equality to inequality, triumph over crises to the next crisis. One of his characteristic demonstrations of the effects of his universal law of population was to show the consequences of a primitive state of radical social equality à la Godwin. This situation was, Malthus argued, the most conducive to high rates of human reproduction. Unrestrained multiplication induced by the easy availability of resources would proceed apace, and at long last property, marriage, and inheritance would be invented. Inequality, transmitted by laws of inheritance, was the logical and inevitable result of an hypothesized state of equality (1960:74). Malthus sought to show that this law of population was the ultimate source of social inequality by projecting into the future of a hypothetical, Godwinian world.

In fact, of course, nowhere in his recitation of the functioning of the principle of population in history did Malthus conceive of any real, historical condition of social equality. His portrayal of the "rudest state of mankind, in which hunting is the principal occupation, and the only mode of acquiring food [the absence of foraging or "gathering" is instructive]" indicated an already stratified society: "I should compare the warriors in the prime of life with the gentlemen, and the women, children, and aged, with the lower classes of the community in civilized states [1960:19]." The essence of human society was analogous to that of "fixed nature." It was a medium through which human actions, both individual and aggregate, expressed their obedience to a universal law of nature that had ordained social inequality. The fundamental immutability of a basically inegalitarian human society, like that of "fixed nature," was clear.

However, it is not the bald assertions of the first edition of the *Essay* but rather the modifications in the second, concerning the adoption of "moral restraint" or at least restraint from marriage, that have been of most importance to historical demographic research. Malthus hypothesized an individual's adoption of "moral restraint" not merely on the basis of his or her level of income or standard of living but also on the individual's estimation of the degree and/or rate of decline that a failure to adopt it might entail. There was a notion that rational calculation was more characteristic of the upper than the lower classes, a notion solidified in second and later editions, in which an inverse correlation between the operation of preventive and positive checks on individual behavior was formalized (1960:322). The lower classes had been historically more likely to experience the ill effects of the positive check to population. Therefore, it was they who were least likely, either at the individual level or taken as a whole, to implement the preventive checks.

That scholars of population have been more fascinated with analyzing the comparative, historical importance of the positive and preventive checks to population than in examining Malthus's central proposition about the inevitable tendency of population to increase is not surprising, since this latter proposition is untestable as stated in the theory. Malthus's statement of a universal theory can never be tested, not only because data are lacking but also because of the ingenious methods that human societies have conspired to create for the control of their numbers. What Malthus conceived of as "disturbing influences" on the operation of his principle of population turns out to be human culture. The importance of demographic catastrophes brought on by epidemics, famines, or wars does not, in itself, confirm Malthus's principle as stated in the *Essay,* since these events often entail only "temporary" or "accidental" changes in the means or availability of subsistence resources, not a confirmation of population's universal tendency to increase beyond its means of subsistence.

Malthus's theory of population is, however, illuminating and provocative. Coming at a time when most of Western Europe had been free of catastrophic famine or epidemic for nearly a century, it posited the existence of a universe in which blind obedience to a demographic law established by God spelled inevitable disaster. The clear and logical links that Malthus consistently drew between individual and group behavior made his work intuitively acceptable, or at least comprehensible, to many. Though the usefulness of the theory to a number of nineteenth-century political leaders or policy makers lay in its status as a powerful, "scientific" explanation or justification of social inequality, its legacy to historical demography has been quite different.

Current scholars, debating the relative importance of "subsistence" crises or "homeostatic" mechanisms among human populations of the past are drawing on Malthus's own distinctions (see, for example, the debate between Dupâquier and Croix, 1975; Dupâquier, 1972). The concept of "natural fertility" (Henry, 1961; Knodel, 1977; Menken, 1978) as reproduction controlled *by* rather than consciously *within* marriage partakes of Malthus's notion of preventive checks on population. The documentation of quite different historical levels of marital fertility in the absence of parity-dependent fertility control has confirmed Malthus's realization, in later editions of the *Essay,* of the importance of examining the social and cultural dimensions of human fertility behavior.

Malthus was a student of the social world, particularly his own. Though he drew the analogy between Newton's discoveries and his principle of population, he was keenly aware that universal laws about human society were notoriously difficult to prove. By the time of the second edition of his *Essay,* he seems to have realized that the widespread presence of "preventive checks" indicated a much greater degree of human control over reproduction than he had postulated originally. Further, he was aware that his notion of the constant struggle between population and its means of subsistence, far from being abstract, tended always to resolve itself into the practical, political questions of *what* people, pressing against *whose* resources.

On these questions, as in most others related to population, Marx's contribution may be considered essentially as a response to the work of Malthus. Like Malthus, Marx was eager to relate population questions to concrete social phenomena, to discover regular relationships that may have existed between population growth and its means of support. Marx admired the emphasis that Malthus placed on the role of struggle and conflict in the social order. There are, in fact, striking similarities between their respective conceptions of the social world. Echoes of Malthus's universe filled with irony, conflict, and struggle are evident throughout the corpus of Marx's work. However, for Marx, historically meaningful struggles were waged not between human beings and "nature" but among historically specific groups of people. Both theorists saw population increase primarily as a "dependent variable," dependent on modifications in the means available to support human life. They diverged widely, however, in their estimation of the possibility of significant changes in the relationship between population and resources.

Marx's critique of Malthusian population theory led to several reformulations of the hypothesized relationships between population and its ability to feed itself. In the the *Grundrisse* (written 1857–1858), Marx introduced a critique that appeared in more developed form in the first volume of *Capital* (1867). The problem with Malthus's theory, for Marx, was that it was ahistorical — that it posited a law of population's relation to subsistence that failed to take into account the historicity of both man and his relation to nature:

> Malthus . . . abstracts from . . . specific historic laws of the movement of population, which are indeed the history of the nature of humanity, the *natural* laws, but natural laws of humanity, only at a specific historic development, with a development of the forces of production determined by humanity's own process of history [1974:606].

Marx did not question the possible existence of systematic relationships between increases in means of subsistence and increases in population but denied a universal, ahistorical relationship inherent in nature: "Every special historic mode of production has its own special laws of population, historically valid within its limits alone. An abstract law of population exists for plants and animals only, and only in so far as man has not interfered with them [1967:632]." Citing David Ricardo's critique of Malthus, Marx reformulated the postulated relationship between population and "means of subsistence" by considering the former in its relation to increases in the "means of employment," the more appropriate "independent variable" for an examination of population in a capitalist setting. Malthus's and Marx's conceptualization of population increases as the dependent variable should not be overstated. Both believed that there were important "feedback" effects of population increases on the subsistence–employment variable. However, both were essentially working with a model that saw population increase as a predictable "supply" response to increases in the subsistence–employment side of the equation.

The bulk of Marx's remarks on population centered on an analysis of population in a capitalist economy. His work was based on the tendency of the composition of capital to change progressively from an equal ratio between "constant" and "variable" capital to one in which the second was continuously diminishing in relation to the first. Certain implications of the rising ratio of constant to variable capital were postulated:

> Since the demand for labour is determined not by the amount of capital as a whole, but by its variable constituent alone, that demand falls progressively with the increase of the total capital, instead of, as previously assumed, rising in proportion to it. It falls relatively to the magnitude of the total capital, and at an accelerated rate, as this magnitude increases [1967:629].

It was not population but the process of capital accumulation itself that produced conditions in which an increasing number of people were considered "surplus." Marx made an analogy between the creation of surplus value by members of the proletariat and their creation of surplus children—both processes entailing an increase in the condition of exploitation.

Individual decisions by members of the working class to reproduce during periods of high employment were rational. Cyclic variations between "good times" and "hard times," however, made the sum of apparently rational decisions to reproduce become irrational at the aggregate level, at least in a capitalist context. Unlike Malthus, who by the time of the second edition of the *Essay* came to believe that individual and societal interests might be harmonized by the implementation of the preventive check by members of the working class, Marx viewed this as a historic impossibility within capitalist society.

From his basic postulates, Marx investigated the different kinds of surplus population, according to workers' relationship to the means of production. In this part of the argument Marx hypothesized different patterns of reproduction, mortality, and household size and composition for the diverse elements of the working class. Using average-age-at-death figures for an assessment of differential levels of longevity among various social classes—an unhappy use of demographic statistics—Marx postulated demographic patterns of the *employed* members of the proletariat:

> The absolute increase of this section of the proletariat must take place under conditions that shall swell their numbers, although the individual elements are used up rapidly. Hence, rapid renewal of the generations of labourers (this law does not hold for the other classes of the population). This social need is met by early marriages, a necessary consequence of the conditions in which the labourers

> of modern industry live, and by the premium that the exploitation of children sets on their production [1967:642].

Marx then investigated the condition of agricultural labor in a capitalist setting, arguing that decreasing levels of demand for agricultural labor encouraged agricultural laborers to seek employment in the manufacturing sector, either in rural areas or the city. The third category of the "relative surplus-population" was composed of casual laborers, often participants in "domestic industry": "It recruits itself constantly from the supernumerary forces of modern industry and agriculture, and specially from those decaying branches of industry where handicraft is yielding to manufacture, manufacture to machinery [1967:643]." This part of the modern working class was destined to grow continuously and to become an increasingly large part of the proletariat as a whole. For this group, "not only the number of births and deaths, but the absolute size of the families stand in inverse proportion to the height of wages, and therefore to the amount of means of subsistence of which the different categories of labourers dispose [1967:643]." The conclusion of these statements was to demonstrate that the adoption of "preventive checks" among the working class, the attempt to adjust numbers to available "means of employment," was inherently self-defeating since the "mechanism of capitalist production and accumulation constantly effects this adjustment" by creating "a relative surplus-population, or industrial reserve army [1967:644]."

The legacy of Marx's theory of the relation to population of "means of employment" is similar to the fate of Malthus's. Interest has focused on parts of the theory—particularly those in which Marx postulated demographic consequences from the transformation of a feudal into a capitalist economy. Building on the work of a number of scholars interested in assessing the socioeconomic effects of what has come to be called "protoindustrialization" (Mendels, 1972), historical demographers have examined postulated relationships between class (usually defined by occupation) and demographic behavior, historic changes in population composition during capitalist development, and the relationships between occupation and household composition (Anderson, 1971; Levine, 1977; Braun, 1978). Marx's notion that specific, historical modes of production have their own laws of population has received much less treatment.

The importance ascribed here to Malthus and Marx should not be taken to mean that there were no other developments in the field of population theory during their time. Mention should also be made of such investigators as Lambert Quetelet (1796–1874), whose work is more exemplary than either Malthus's or Marx's of the intersection of "methodological," "Political Arithmetic" and "theoretical" considerations. In his essay *On Man,* originally published in 1835, Quetelet demonstrated his command of probability theory (he was a student of Pierre Laplace's in Paris), acquaintance with the work of Malthus, and the Political Arithmetician's fascination for the collection of a vast array of data on the biological, demographic, and social propensities of man. His work, however, was not merely empirical but also reflected his firm conviction that the material world, of which man was an integral part, demonstrated discoverable laws: "It may be seen, in my work, that the course which I have adopted is that followed by the natural philosopher, in order to grasp the laws that regulate the material world. By the seizure of facts, I seek to rise to an appreciation of the causes whence they spring [1969:viii]." Though he shared Malthus's belief in a "natural" law of population, he also believed that "the laws which relate to the social body are not essentially invariable; they change with the nature of the causes producing them [1969:7]."

In Quetelet's work, we see the tradition of the Political Arithmeticians transformed into "social statistics" by the combined influences of a deepened concern for changing rates of various phenomena, and Quetelet's own high abilities to use probability theory to predict them. The nineteenth-century passion for the collection and analysis of social and "moral" statistics (Guerry, 1833; Perrot, 1977; Ozouf, 1977) was not necessarily based on any explicit theory of population and its relationship to means of subsistence or employment. However, like the earlier work of the Political Arithmeticians, it did have an impact on the formulation and implementation of social policy. These policies, to be sure, could often be traced to implicit views of population—the 1834 reform of the English Poor Law was largely infused with Malthusian deductions. However, it was the deductions and not the theory as a whole that usually provided guidance for action.

Thus, it is quite clear that the theory on which population mathematicians based their work and the theories of Malthus or Marx functioned in quite different ways. Population mathematics developed quite rapidly into a "scientific" endeavor as articulated by Kuhn, with a well-defined community of researchers all working on similar problems, rather removed from the political fray. Malthus's and Marx's theories, on the other hand, were highly public, available for consideration by the literate reader, their conceptions and deductions deeply enmeshed in problems of the times. Perhaps it will always be so for theories that attempt to relate population systematically to economic and/or social factors.

Current work into demographic transition "theory" (Beaver, 1975), which attempts to relate the adoption of family limitation techniques to a wide variety of individual and/or aggregate conditions, may be viewed as a kind of hybrid of Malthusian and Marxian propositions—many of them conflicting and/or difficult to test in the laboratory of the real world. Evidence that a "demographic transition" has occurred and is occurring in many parts of the world is not at issue—rather, its causes, means of diffusion and the units of analysis best suited to reveal its inner workings still remain to be fully illuminated.

The influence of the methodologists, Political Arithmeticians, and population theorists is detectable in a wide variety of current research in the field of historical demography. If we accept Kuhn's notion that "science" entails explicit paradigm formation and refinement, then the conclusion must be that current historical demography is in part such a science. However, it appears both likely and, to some, desirable that there remain room within its boundaries for those researchers whose interests lie with more exploratory, descriptive analysis than explicitly paradigmatic inquiries into populations of the past.

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II

FUNDAMENTAL SOURCE MATERIALS

This consideration of sources for prehistoric and historical demography makes no claim of exhaustiveness but is designed rather to inform readers about the most fundamental materials that have been used by researchers to reconstruct demographic patterns of the past. Since the 1969 publication of Thomas Hollingsworth's Historical Demography, *scholars from a variety of nations have devoted special attention to the discovery, description, and systematic critique of sources from their own archives. These efforts have made a more general discussion such as ours possible. Although the work of inventorying and assessing the quality of the sources of individual nations is vital, it is important to draw some broader, cross-national comparisons. Scholars working in different areas of the world have devised innovative ways of dealing with shortcomings in their sources—innovations that are of more than local interest. Furthermore, while generalizations about the completeness and reliability of different kinds of source materials are in constant need of qualification—as our text amply illustrates—the causes for lacunae and biases in them are often surprisingly similar across time and space.*

The goals of Part II, then, are several: to describe the different types of sources, to discuss the biases they may bear and possible means of correcting for such biases, and to refer, if sometimes only briefly, to the analytical issues toward which research on particular sources has been directed. With the exception of Chapter 2, greatest emphasis has been placed on nominative, individual-level sources of population data. Researchers working with these sources have the advantage of being able to aggregate their information in a number of interesting ways and, in many cases, of linking pieces of information on named individuals together from a variety of types of extant records. However, the use of non-nominative, aggregate materials is also considered, albeit less extensively, and the importance of aggregate techniques for evaluating the quality of sources pointed out.

It will be obvious to historians that a number of the sources fundamental to historical demography have long served as primary materials for studies in economic, social, religious, or cultural history. Generations of historians have contributed to an assessment of the strengths and weaknesses of individual sources for a variety of analytical endeavors. One of the virtues of historians as a group is their skepticism about the reliability of sources they use, even though they sometimes lack a knowledge of how to test systematically for different kinds of bias in quantitative data. This skepticism and a keen interest in the historical background of the organizations that produced the documents currently used as sources for historical demography have generally prevented them from viewing their documentary materials as a priori "data sets" from which believable demographic results may necessarily be drawn. In many cases, such an attitude is entirely warranted. The attention paid to the larger historical setting from which sources have come is a valuable and creative contribution to research on historical populations.

It is obvious that a familiarity with the social history of the communities from which sources derive is fundamental to historical demography. Curiosity about the concrete conditions of human social existence is central to understanding the results of historical demographic analysis quite simply because there is no theory from the science of demography, narrowly defined, that explains human demographic behavior at any time in history. Explanatory models, whether informal or formal, need other information on individuals or groups beyond the narrowly demographic in order to illuminate demographic findings. It is for this reason that historical demography as a field of inquiry has such close affinities with the pursuits of social history or historical sociology. Happily, sources for historical demography themselves often provide researchers with information on social, economic, or political conditions that may help in understanding the raw demographic information they bear.

2
Sources of Prehistoric Demography

The distinction between historical and prehistoric demography is based essentially on the differences between the periods in human history each studies and the source materials on which each relies. Historical demography depends on the availability of written sources, whereas prehistoric demography relies on the recovery and analysis of physical remains of human populations: their skeletons, the artifacts and buildings they have constructed, or the refuse of foodstuffs they have consumed. As one scholar has written:

> The expression "prehistoric demography" is somewhat misleading because the study that we have in mind is not necessarily prehistoric, nor is it strictly demography in the current conventional sense of the word. The essential objective is to find out as much as possible concerning the populations of extinct civilizations which are out of the reach of the usual historical sources [Cook, 1972:1].

In the study of societies for which both written and material sources are available, the interests and talents of prehistoric and historical demographers often overlap. Keith Hopkins's (1966) demographic work based on ancient Roman tombstone inscriptions, J. C. Russell's (1964) use of data on the number of plows in eleventh-century England gleaned from Domesday Book, as well as Kenneth Weiss's (1973) comparison of his model life tables formulated in part on the demographic experience of prehistoric populations with those of European medieval populations may be cited as examples (see also Acsádi and Nemeskéri, 1970:51). Though prehistoric and historical demography will doubtless continue to be based on sources that differ in form, there are enough similarities in the characteristics of the two fields' source materials to argue for the desirability of a closer dialogue between them.

Both prehistoric and historic sources are often very scanty, ill-preserved, and potentially unrepresentative of larger populations. To take an example, the underrepresentation of infant skeletal remains in many of the burial sites excavated by archaeologists is echoed in the underrepresentation of the same type of individuals in the vital registration and census records of a wide range of societies currently investigated by historical demographers. Moreover, populations of interest to prehistoric and historical demographers alike often have vague or ill-defined boundaries and are small enough to be highly vulnerable to the effects of migration and random variations in size over time.

This consideration of prehistoric demographic sources concentrates on the use of material remains of human populations used by archaeologists and paleodemographers to determine and explain demographic processes among hunting–gathering and horticulturalist societies of the distant past. We will give less attention to the interesting kinds of climatological and ecological data central to formulations of levels of "carrying capacity" or to eyewitness observers' reports of the size of indigenous populations at the time of contact with European populations. However, for reasons that should become clear, we will discuss some of the contributions of "demographic" anthropologists toward building theories that seek to explain population patterns documented by archaeologists and paleodemographers.

Censusing Prehistoric Populations from Material Remains

Man-made material remains of human settlements are the traditional sources of archaeological studies and can provide valuable insight into the size, social composition, and spatial distribution of human populations over time. The goal of using these remains is essentially to accomplish the task of the modern census-taker. The fundamental problem faced by prehistoric demographers using such sources has been well articulated by Albert J. Ammerman *et al.*:

> In modern census practice, the aim is to count all of those people living over a brief period of time or even ideally at a given point in time. In contrast, the archaeologist normally has to deal with material remains that from a census point of view have accumulated over a substantial time period. An estimate of the length of the period of accumulation as well as information on rates of accumulation are needed if useful statements are to be made about the number of objects in circulation (and, by extension, the number of people living) at a given point in time [1976:32].

Assessing the size and spatial density of settled human populations based on man-made remains depends on several fundamental procedures, including the evaluation of the physical extent of the settlement whose population is being counted, variations in density by zones or subregions within the area—for example, by determining the use to which different kinds of structures were put, and the length of time that different structures were in use. Variations in the size, density, or relative wealth of settled populations over time are of crucial interest, so that although estimates of population size are often very crude, it may be quite certain that the population in period *t* was larger or smaller than at time period $t + 100$ years or $t + 500$ years. One of the primary means of gauging the relative continuity of habitation or building use is through an examination of their contents, particularly ceramics, household utensils, and the like (Haviland, 1969:429; Blanton *et al.*, 1978: 29–30). Similarly, aggregate trends in population size may be gleaned from discontinuities in the internal, spatial distribution of inhabited sites within settlements—their nucleation or aggregation over time. Demographic relationships between settlements—particularly migration—may be potentially understood from the presence or absence of artifacts that can be demonstrated to have originated outside the settlement under study.

The successful establishment of the limits and zonal density of settled populations is a complex task, which increases in difficulty with the size and complexity of the population under study. Estimates of aggregate population size may change as new areas are uncovered and studied (Millon, 1976: 212), and the success of this strategy is obviously enhanced by achieving total coverage of the settlement site (Sanders *et al.*, 1979: 7) or creating a sampling design that unearths zones of habitation whose density and function are representative of the whole (Mueller, 1975).

In general, it is not one but a combination of indicators that is used by archaeologists to hypothesize aggregate population trends. Microlevel evidence, often from the household level, for example, may be combined with other evidence that points to an increasing or decreasing population or density to construct reasonable assessments of population size over time. The linchpin of this strategy is to create a credible "multiplier" that relates material objects to their users, much in the way early Political Arithmeticians tried to estimate population size from the counting of houses. In one of the most imaginative and oft-cited uses of this method, Christy Turner and Laurel Lofgren (1966) trace the population trends of the Kayental branch of the Anasazi Indians of the southwestern United States through the calculation of the ratio of the volume capacity of serving bowls and cooking jars used at the household level. The volume of the individual serving bowls was constant over the time period studied (A.D. 500–1900). However, they note a gradual increase in the presence and volume of the cooking jars used for food preparation for household members. Assuming a one-to-one relationship between the number of dwellers in each household and the number of individual-sized bowls, they argue that population growth and subsequent decline during a time of documented drought can be read in the number of individual servings provided by the cooking jars. An increase in the size of the cooking jars reflects, they argue, the increasing population of Anasazi households.

Turner's and Lofgren's research entails the use of a microlevel indicator of the density of human occupation at the household level itself, but more traditional (and familiar to historical demographers) is a calculation of the number of occupied dwelling units multiplied by an estimated number of dwellers per household. Information on household size is sometimes gleaned from current ethnographic information on the area under consideration (Culbert, 1974), a procedure whose accuracy obviously depends entirely on the degree to which occupied houses have contained the same number of individuals over time—an issue that may be almost impossible to resolve without the kind of accurately dated and intact utensils on which Turner and Lofgren base their argument. The tendency among archaeologists as well as historical demographers, not surprisingly, is to see household size as relatively constant over time in the absence of compelling evidence to the contrary, though in complex and socially stratified societies there will be various mean household sizes calculated for different kinds of dwellings, which are then weighted proportionally in the determination of total population size and its change over time.

Though the process of establishing plausible estimates of total population size may be carried out in many cases by using only highly aggregated data that bear a large margin of error (Blanton *et al.*, 1978: 30), the establishment of these totals is very often critical to a successful examination of a population's vital rates. This is simply because the population models on which much of paleodemography rests are predicated on assumptions about the relative growth or decline in total population over time. The exploration of population trends from rich collections of man-made remains requires a relatively sedentary society with more than a rudimentary array of tools, utensils, or dwellings that have the capacity of persisting intact over time—often through millenia. Hunting and gathering peoples, because they have historically been more mobile and less burdened with a rich material culture than, say, horticulturalists, are for this reason more difficult to study (Cohen, 1975). Our knowledge of the demography of people engaged in a hunting–gathering way of life—the most long-lived of all forms of human subsistence systems—thus requires a different kind of source, most particularly human skeletal remains.

The Study of Prehistoric Vital Rates: Paleodemography

It is in the systematic study of skeletal remains that archaeological research in prehistoric and protohistoric human communities converges most obviously with demographic analysis. The fundamental task of paleodemography is to describe and explain vital rates and the related age structure of early human populations. As several scholars have noted, the analysis of skeletal remains should ideally be integrated with a consideration of the inhumed population's ecological setting and cultural characteristics (Moore *et al.*, 1975:69). The realization of this ideal, however, often founders on a lack of evidence. Skeletons are frequently the only remains available for understanding the demographic patterns to which the living were subject. However, these remains themselves may bear evidence not only of narrowly defined demographic rates but also of causes of death, relative nutritional level (Haviland, 1967), biological kinship among different individuals in the collection (Spence, 1974), or the social status of the deceased (Blanton, 1974).

The difficult problem of accurately assessing the age and sex structure of inhumed populations, which lies at the basis of any successful work in paleodemography, has caused lively debates (Acsádi and Nemeskéri, 1970; Masset, 1973, 1977; Bocquet and Masset, 1977; Lovejoy *et al.*, 1977). Though the details of this important issue lie beyond the concerns of the present discussion, an article by two well-known practitioners in the field (Bocquet and Masset, 1977) suggests several points about the possibility of accurately "aging" human skeletal remains. The authors argue that the establishment of the exact age of death, by year, is least difficult for infants and children but becomes increasingly harder for the remains of adults. However, they also argue that is is generally possible to distinguish "adult" skeletons from the nonadult, defining the dividing line at 20 years of age. György Acsádi and János Nemeskéri's support for a multivariate approach to establishing the sex and age at death of individuals seems to have met with ready acceptance among paleodemographers (*Current Anthropology*, 1974). The establishment of the age and sex structure of inhumed populations, however, only initiates the difficult task of interpretation—of making demographic sense of what has been discovered.

Several features of collections of skeletal remains make this a challenging process. Perhaps the most consistent problematic feature, already alluded to, is the relative absence of infant and child remains in many collections. This characteristic has been ascribed to several factors: burial practices that dictated separate sites for the inhumation of infants and children—often very near or directly underneath house dwellings; the fact that infant remains, in particular, are often buried closer to the surface than those of adults making them vulnerable to disruption over time; and finally, the possibility that infant skeletal remains are subject to more rapid deterioration than those of adults (Cook, 1972: 5). For certain societies, burial sites may also be differentiated by sex (Randsborg, 1975: 140) or social status (Rathje, 1970). Therefore, skeletal remains may not be representative of the population that was alive at the time the individuals were buried, or the population that died during the same time that they were interred.

Questions of bias by age, sex, or, in some societies, social standing are of central importance to evaluating the quality and reliability of human skeletal remains as sources for paleodemography, since methods used to argue for the existence of vital rates and their related age structure depend on the relative acceptability of the assumption that the age pattern of mortality of the inhumed population is representative of the larger population of which it was once a part. Similarly, the size of the skeletal population is also important. Though, for reasons that will be explored, it is desirable for paleodemographic analysis to have access to a burial site that has received new remains over hundreds of years, not only at one point in time, this demand can also have the effect of reducing sample sizes for each period during which different groups of the inhumed population experienced death. Skeletal sample sizes have ranged from less than five to over a thousand, the larger ones tending to contain a wider variety of age groups. However, all of the potential biases within the data themselves have led some anthropologists as well as several demographers (Henry, 1957, 1959; Petersen, 1975) either to argue for extreme caution or to doubt whether any analyses based on such prehistoric data are worthy of confidence. The exasperated reply of one scholar to radical skepticism is understandable: "Must prehistoric demographers merely wait patiently until our populations develop writing and grow large enough so that we can turn their analysis over to the census bureaus, who will do it right? [Weiss, 1975b: 240]." Although some of the assumptions on which paleodemography is based may be unacceptable for certain populations at particular times and places, all source collections and the degree to which they deviate from these analytical assumptions are not equal. Simply put, some skeletal populations, particularly those that are relatively large and well preserved and that appear to include representatives of all age classes and both sexes are bound to be more reliable indicators of demographic conditions than small ones lacking heterogeneity by age. The degree of confidence placed in findings from different series is the fundamental issue, not, ideally, generalizations about the pursuit of paleodemographic studies as a whole.

As Acsádi and Nemeskéri have noted, "Data computed from a paleodemographic series, if unbiased, entirely represent the mortality conditions of the population buried in the cemetery [1974: 506]." The issue, then, is the relationship of the skeletal population's experience to that of the living population that was at one time at risk to have been buried with them. Once it is established how long the burial site was receiving human remains, the question is: Does the age pattern of mortality reflected in the skeletal sample accurately portray mortality conditions prevailing during that time? Several factors may militate against such an assumption. The first is the possibility of the incidence of a short period of "crisis mortality" during the time when the burial site was being used, whose "point effects" may distort the effort to assess "underlying" patterns of mortality by age (Armelagos and McCardle, 1975). As Weiss has written, "In skeletal deposits, once buried, a skeleton is always present. Therefore, a cemetery may contain the permanent residues of all demographic upsets, as well as its 'normal' deposits, and it may not reflect the underlying demographic patterns [1975a: 54]." Sporadic or one-time periods of crisis mortality among prehistoric as well as historic populations cause often-radical deviations from the mortality patterns of normal years, as observers as early as John Graunt well knew. These crises are oftentimes short in duration, so that it is difficult to estimate their exact temporal incidence.

In order to learn about underlying patterns of mortality from skeletal remains, paleodemographers have had increasing recourse to life table and stable or stationary population models. However, the incidence of short-lived demographic crises is one historical feature that may cause the age and sex structure of skeletal populations to deviate sharply from these models, and to render the task of determining underlying patterns of mortality nearly impossible.

A second source of deviation from models that assume stationarity is the existence of population growth itself. Acsádi and Nemeskéri argue that the assumption of stationarity needed to make their abridged life tables valid is in fact a modest and acceptable one for human populations of the Paleolithic and Neolithic. They argue, further, that the rejection of postulated stationarity and an acceptance of the possibility of small growth rates among inhumed populations of these periods will not severely invalidate interpretations of skeletal data based on such assumptions: "Population growth has very little influence on the mortality derived from the paleodemographic series where, because of high infant and child mortality, the expectation of life is short and where the period of observation is often as long as one to three centuries [1974: 505]."

Jean-Pierre Bocquet's and Claude Masset's (1977) article is also predicated on the usefulness of model life tables for prehistoric populations and concurs, in the main, with the judgments of Acsádi and Nemeskéri. Bocquet and Masset argue that high-quality skeletal series demonstrate certain internal consistencies by age grouping that may serve as the basis for calculating fundamental demographic indexes. Specifically, they argue, on the evidence of selected skeletal collections and a series of life tables derived from empirical data from both pre-twentieth- and twentieth-century populations that the ratio of individuals dead at ages 5–14 to those dying between age 20 and the end of the documented life span for a skeletal population may be used systematically to estimate infant mortality, child mortality, and life expectancy for the population that was at risk of dying, assuming stationarity. The authors control for the quality of the skeletal data by requiring that they demonstrate a ratio between deaths at ages 5–9 to those 10–14 that is equal to or more than 2. If the skeletal data meet this requirement, then the desired parameters may be estimated by working from a ratio of deaths at ages 5 to 14 to deaths at age 20 to the end of the life span. Like Acsádi and Nemeskéri, they argue that the assumption of stationarity is more hazardous for a study based on sources from a burial site used only during a short time. However, unlike Acsádi and Nemeskéri, they demonstrate the high standard errors of estimation to be expected when a stable population is growing (see also Ammerman *et al.*, 1976: 54). It should be noted, however, that Bocquet and Masset test the reliability of their estimators under the assumption of rates of growth as high as 2% a year—far beyond those accepted by Acsádi and Nemeskéri as realistic for populations of the Paleolithic and Neolithic.

The final assumption on which efforts at formulating model life tables for prehistoric populations are based is that the living population from which the skeletal remains are derived was free from the effects of in- and out-migration. It is a fundamental assumption of the tables, the vital rates, and age distributions they display. Compared with the problems already discussed, this particular conundrum may pale in significance. Paleodemography, in the opinion of its best practitioners, is an inexact science, and this final assumption may be relatively unimportant. However, it is mentioned here simply to point out the problem that the limits of the populations whose experience is studied from skeletal remains may often be vague, particularly if the populations were not composed of settled groups living in an area that has been completely excavated. Since hunting–gathering societies are characterized by relatively low population densities and members of the societies may live part of the year in small bands, too small to be understood as "populations" in the sense of intermarrying groups it is very often impossible to ascribe very definite spatial limits to the living population of which the skeletal individuals were once members. This problem, however, usually declines in relative significance when settled horticulturalists are under consideration, since the spatial limits of the excavated site themselves help define the population under consideration.

Mortality Patterns among Prehistoric Populations

One of the more interesting theoretical issues facing scholars seeking to interpret the demography of prehistorical and protohistorical societies on the basis of skeletal remains alone is the relative constancy of age patterns of human mortality through history. As is well known, the mortality pattern of historical societies gleaned from written sources such as parish registers or civil registration records resembles a U-shaped curve, or, more recently, a J-shaped curve, with the probabilities of dying being high in the first days and weeks of life and declining rapidly through childhood only to rise gradually with old age. The transition from a U-shaped to a J-shaped curve, part of what has been termed the "epidemiological transition" (Omran, 1971) is quite recent, entailing substantial reductions in infant mortality and a corresponding increase in the importance of degenerative disease as causes of death at high ages. By contrast, a number of skeletal samples reveal unexpectedly high probabilities of dying in childhood and young adulthood as well as infancy (Howell, 1976:34). These findings are unexpected if it is assumed that mortality of prehistoric, skeletal populations should display the same age patterns as larger and more recent national-level populations.

A number of researchers, among them Nancy Howell (1976:26) and Bocquet and Masset (1977), argue for a constancy in this pattern that is related to the unchanged nature of human biology and aging processes through time. Referring to Ansley Coale's and Paul Demeny's (1966) model life tables as "pan-human"

(1979: 79), Howell also argues (1976) that a rejection of the cultural "uniformitarian" position—which posits the constancy of age-related mortality patterns through human history—would simply make irrelevant stable–stationary theory and model life tables, which have become increasingly important to paleodemographic work. Thus, any significant deviation from age mortality patterns established for populations documented in written records should impugn the representativeness of the skeletal evidence, and not the uniformitarian hypothesis itself. Though nutritional, genetic, and pathology-related, as well as cultural, influences may have historically combined to produce different levels of demographic "performance," these considerations do not directly affect the acceptability of the uniformitarian hypothesis—since it is restricted to assumptions about mortality patterns and not about the levels themselves.

However, other scholars (Clarke, 1977) accept the possibility that both Paleolithic and more recent "precontact" hunting–gathering populations may have experienced age-specific patterns of mortality quite different from those of settled agricultural or industrial peoples. Though it is often extremely difficult to diagnose disease-linked causes of death from skeletal remains, research on infectious diseases does suggest that many of the more familiar and virulent among them require a critical-sized, interacting population for their transmission (McNeill, 1976:50–51). Armelagos and McCardle (1975:4–5), for example, argue that such diseases as measles and influenza require an interacting community of approximately 500,000 members to be maintained—many times greater than any documented community of hunter–gatherers. Zootic diseases endemic to animal populations and transmitted to humans in the form of sporadic epidemics are another source of prehistoric mortality in addition to deaths by violence. However, a great deal still remains to be known about the susceptibility of sparse and relatively isolated prehistoric populations to lethal diseases of a parasitical, infectious, or degenerative nature. Weiss concludes his discussion of life tables for anthropological populations thus:

> If primitives die so young, what is it that kills them? Aside from some known causes of mass mortality, such as alien diseases being introduced at first contact, very little is known about the normal causes of mortality. The same people reporting data which show evidence for high mortality also describe the relatively peaceful and disease-free nature of the people and their lives [1973:78].

One of the problems of using data from more current hunting–gathering societies in order to study prehistoric demography is that many of them had already become "contact" populations—that is, vulnerable to alien disease entities—by the time their mortality was investigated. This leads scholars such as C. Owen Lovejoy *et al.* (1977:293) to reject the value of much ethnographic evidence:

> Modern "anthropological" populations are virtually all contact societies and remain under the selective influence of a battery of novel pathogens. Skeletal

> series are for the most part remains of small and more isolated groups. It is possible that these two kinds of populations are showing mortality profiles reflective of distinctly different levels of early selection for immunological competence. If so, a major shift in the selective process in human evolution may not have received its due emphasis.

Both ethnographic and paleodemographic data often come from small-sized societies, where random fluctuations in even normal mortality are to be expected. Although the assumptions of the uniformitarian position make it possible to reconstruct prehistoric populations that display internal consistencies of age structure and demographic rates through the use of model life tables, there is a problem of circular reasoning. The goal of basic research is to study and explain *prehistoric* population patterns. However, empirical evidence from skeletal remains that contradicts documented, modern mortality patterns is often rendered suspect.

The challenge of the uniformitarian position is that it may stimulate paleodemographers to present enough counterexamples to argue forcefully for the position that prehistorical hunter–gatherers did in fact experience mortality patterns whose age distribution was significantly different from those of the more recent past. This will require not only large and representative samples of skeletal remains but also more refined techniques for determining age-related causes of death.

Population Growth in Prehistory

In another field of research on prehistorical and protohistorical population movements, recent scholars who take an evolutionary–ecological approach (see Chapter 19) to the question have challenged the "slow-growth" hypothesis on which much paleodemographic work has been based. In fact, one of the most important issues now being addressed by demographic anthropologists, archaeologists, and paleodemographers is whether constant population pressure or growth is the normal state of human beings as a historical species. The question is addressed in a variety of ways, using source materials in conjunction with conceptual models that in the main derive from the work of Malthus.

Several developments have served to focus the attention of scholars on this fascinating issue. Among other accomplishments, Ester Boserup's (1965) *The Conditions of Agricultural Growth* challenges the basic Malthusian assumption—expressed in both the first and subsequent editions of the *Essay*—that population growth is essentially a response to increases in agricultural production. Her work instead suggests that population pressure on food resources is, under conditions of relatively unsophisticated agricultural techniques, a creative force that itself may stimulate agricultural intensification and a rising productivity of acreage (Smith, 1972:12–13). Though relevant particularly to trends in current economic development, the model implicit in her work has been taken up as a challenging explanation for the adoption of agriculture by Upper Paleolithic hunter–gatherers. In its simplest guise, a derivation from the Boserup hypothesis isolates population pressure on food resources as the primary cause for the adoption of agriculture as a subsistence technique by hunting–gathering populations. An explanation for the adoption of agriculture by hunter–gatherers has appeared more problematic in recent years in large part because of a shift in many anthropologists' perception of the hunting–gathering, or gathering–hunting (Polgar, 1975: 2), way of life. In the past, when the life of these peoples was viewed by most as a living example of a Hobbesian state of nature where life was "solitary, poor, nasty, brutish and short," the adoption of agriculture could be understood as a socially rational way of leaving this undesirable state, providing, as it was thought to, a more secure and abundant food supply for all concerned. The sacrifice of a more egalitarian social life was viewed as a small sacrifice when the short- and long-term advantages of agriculture were taken into account.

However, hunter–gatherers are more currently viewed through a quite different paradigm, in large measure with the publication of Marshall Sahlins's *Stone Age Economics* (1972), which portrays both selected past and current hunter–gatherers as members of an original kind of "affluent society." Other ethnographic accounts (for example, Lee, 1979) have tended to support Sahlins's idea that hunter–gatherers may have had abundant leisure, a healthful diet based on a varied and secure food supply, and a generally agreeable existence when compared to many agriculturalists. Furthermore, Weiss has argued that the Neolithic Revolution "cannot be viewed as being a great demographic change with regard to the individual. Although the denser, more predictable food supply allowed a great many more individuals to live, it did *not* dramatically change their life expectancies. Longevity did not jump significantly until industrialization [1973: 50]." Even the question of more stable food supplies has been called into question.

However, the currently dominant view of hunting–gathering as a viable and attractive way of life—at least for those who survived infancy—is that the adoption of agriculture now has to be explained. The way of life it has historically supported is no longer viewed as a priori more desirable than hunting and gathering. Since the "pull" theory of the seductions of settled agriculture are no longer generally accepted, the theoretical stage has been set for an examination of the forces that may have *pushed* groups of human beings into this way of life. The notion of "population pressure" has found itself at the center of the debate about possible causes and not, as had formerly been the case, among the list of consequences of the widespread adoption of agriculture more than 10,000 years ago.

Though the argument that population pressure may have been the primary cause of the Neolithic Revolution is not the same as one that posits the relative constancy of human population pressure on resources throughout history, both ideas have been conceptually related in Mark Cohen's (1977) work. In an earlier (1975) article, Cohen had argued that a major reason for scholars' lack of awareness of a consistent growth of human populations in the period before the Neolithic Revolution was the difficulty of discovering and analyzing evidence among hunting–gathering populations that would point in this direction. In his 1977 work, he presents evidence that he believes supports the contention that "population pressure" on resources is the norm and not an occasional, sporadic phenomenon in human history. Evidence that points to a slow rate of population growth in prehistory (Carneiro and Hilse, 1966; Cowgill, 1975a, 1975b) is compatible with his "population pressure" model, when population pressure is defined as "*nothing more than an imbalance between a population, its choices of foods, and its work standards, which forces the population either to change its eating habits or to work harder (or which, if no adjustment is made, can lead to the exhaustion of certain resources)* [1977:50]."

One of the most pressing problems for a resolution of this issue is the definition of terms and the units of analysis and time frame used to test the hypothesis. *Population pressure* is a relative term, depending on the relationship between population size, growth rates, and their relation to changes in the food supply. As Philip Smith has observed, "In simpler societies at least, it is the number of people per square meal rather than square mile that must be recognized in the definition of population pressure [1972: 7]."

The way in which researchers have attempted to calculate the relationship between population and resources has generally been through the notion of "carrying capacity," defined by Sherburne Cook as "the maximum ability of an environment to produce subsistence at the level of culture provided by the inhabitants [1972: 25]." Ezra Zubrow, on the other hand, has argued that it is "*the maximum size of a population which can be maintained indefinitely within an area.* Since there is a tendency toward the maintenance of a state of balance, carrying capacity may be measured in terms of equilibrium [1975: 15]." Obviously, the adoption of this notion implies no one particular view of an innate or socially determined tendency of populations to grow but only the predictability of some equilibrium between population size, or growth, and the provision of adequate food.

However, as Cohen's work demonstrates, the hypothesis of constant (if sometimes slow) population growth and pressure, when combined with a notion of equilibrium, may transform population pressure into a primary cause of human sociohistoric development. Cohen has redefined "carrying capacity" in a way that obviates the necessity of believing that demographic catastrophe must actually be, or be perceived to be, imminent in order for a new population–resources equilibrium to be established. He writes, "Population pressure can be seen to motivate technological change in the food quest without ever threatening carrying capacity in the absolute sense, without ever reducing the human population to starvation and without threatening to break down the ecosystem [1975: 50]." Notions of "carrying capacity" are obviously central to any attempt to argue for the existence of population pressure or stress, and though the determination of an actual area's "carrying capacity" may be difficult, or even impossible (Hayden, 1975: 12), it has been found heuristically valuable for understanding the relationships among climatological, ecological, and demographic development over time, especially at the local or regional level. Cohen's argument (1977), by contrast, is designed to explain the spread of agricultural practices among hunting–gathering peoples who differed from one another in many other ways, at approximately the same point in history, without reference to a "diffusionist" model. His model is designed to explain global, not regional, history.

In an interesting critique of the "population pressure" model of human development, George Cowgill (1975a) has argued that certain "systemic" notions of the relationship between population and resources are overly abstract—that in them population is considered as an entity that is internally undifferentiated. He argues that in the face of population growth, different individuals, or socially identifiable groups of individuals, may react in varying ways and that certain, but not all, systemic approaches obscure this fact.

Bennet Bronson, on the other hand, emphasizes the need for using local or regional units of analysis in order to examine the population pressure hypothesis since "socioeconomic events do not (or did not until recently) happen on a worldwide scale. They take place instead within restricted blocks of area measuring at most a few hundred miles on a side, and have their roots in causes which operate within a similarly reduced frame [1975: 68]." On the basis of documentation that shows discontinuities in population growth at this level of analysis and a variety of other hypotheses that might explain the adoption of agriculture, as opposed to casual "cultivation" of food resources among hunter–gatherers, he opts for a multifaceted explanation of agriculture's adoption. He concludes:

> Population pressure is not the only possible explanation of farming. Nor does it invariably lead to farming . . . . High local densities must have occurred very early in man's history and with great frequency; only in a small percentage of post-Pleistocene cases can these have led to the adoption of large-scale food production. Thus, increase in population is neither necessary nor sufficient as an explanation. It is also among the most difficult of all data to recover archeologically, depending as it does on excavations on a tremendous scale and on datings of an improbable accuracy [1975: 75].

One of the most interesting results of renewed inquiry into population growth or pressure as a primary causal agent in human historical development has been a counterfocus on the ethnographically documentable countermeasures, besides technological innovation or the intensified search for food, that human populations have taken to adjust their numbers.

Ethnographic Evidence of Population Control in Prehistory

One of the more widely documented ways that recent hunter–gatherers and horticulturalists have consciously succeeded in regulating the size and composition of their populations is infanticide, sometimes selective by sex. However, Woodrow Denham (1974) argues that the importance of this phenomenon has been exaggerated in recent literature, observing that high rates of infant mortality from other causes, as well as the possibilities that many egalitarian societies offer for cooperative infant and child transport and care may have obviated the necessity of systematic infanticide. James Faris (1975) believes that it is essentially wrong to view infanticide as "numbers control" and sees it instead as a policy of "quality control" over the characteristics of children needed for group survival, citing evidence that it may be used primarily against malformed infants or twins, who are deemed unlikely to survive (see also Howell, 1979). Those anthropologists writing from a "sociobiological" perspective would agree with at least part of this argument, seeing infanticide as one means whereby individual parents might enhance their "reproductive success" through the killing of some infants, particularly if it is believed that without such action, the lives of other children may be threatened (Chagnon *et al.*, 1979: 294). However, they reject the idea that infanticide should be seen as a "population policy," enforced or sanctioned by groups for their survival, and instead view it purely as an individual-level strategy—a "family planning policy" (Acker and Townsend, 1975: 470).

However, ethnographic evidence has also pointed to the existence of practices that help prevent conception, though they are not necessarily designed to do so. Prolonged breast-feeding of infants, for periods as long as several years, has been demonstrated to suppress ovulation and thus conception for a length of time that may range from several months to years, depending on the nutritional level of the mother and the intensity of breast-feeding (Howell, 1979; Konner and Worthman, 1980). Increasing insight into practices that have the result of inhibiting family and population growth are of particular interest to those scholars who continue to believe that it is a slow, rather than a rapid, growth of human populations throughout history that demands explanation. Ethnographic investigation provides a unique opportunity to observe some of these practices in action, though the question remains whether they can be explained as normal or only occasional responses to short-term shifts in the population–resources relationship. As Cohen (1977: 48) and others have argued, current hunting–gathering populations may be a biased sample from which to study the functioning of certain population-control practices, since these peoples may be preselected for a certain technological conservatism and unusual success in maintaining numbers control. Just as "anthropological populations" of the more recent past can be demonstrated to be subject to different disease entities than hunter-gatherers or horticulturalists of more remote times, so it is argued that current hunter–gatherers may have evolved rather unique means of controlling their numbers.

The different source materials available to prehistoric demographers have clearly influenced the kinds of approaches and explanatory models used to analyze findings. Excavations of settled communities over time have contributed primarily to the reconstruction of aggregate population size and change over time. Besides enhancing an understanding of material culture at different points in time, studies based on the distribution of moveable implements have shed further light on population density and social stratification as well as trade and migration links between societies. Paleodemographic studies, on the other hand, have begun to illuminate patterns of mortality among historic populations that have in many cases left only their own remains. Finally, ethnographic evidence has been used to try to understand possibly long-standing ways that individual couples or whole communities have historically tried to control their numbers.

Although it is clear that prehistoric and historical demography converge most clearly in the study of essentially prestatistical societies, such as early medieval Europe (Herlihy, 1972), the two pursuits, in general, bear a number of goals and thematic similarities that point toward the desirability of closer collaboration. Beyond the interest in reconstructing population movements in the past lie similar concerns for relationships between economic or technological change and demographic variations, the relative importance of "preventive" and "positive" checks on human population, and the growth and extinction of specific human communities.

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3
Parish Registers and Civil Registration Records

Parish register and civil registration records of vital events constitute some of the most widely used sources for historical demography. Since the pioneering work of Fleury and Henry in the 1950s, parish register records of baptisms, marriages and burials have assumed a privileged position as sources for understanding the demographic evolution of European societies and their colonies from the sixteenth to the early nineteenth centuries. The high value placed upon them is the result of two principal factors: their uniqueness as sources of continuous demographic information on individuals in the absence of regular censuses, and the fact that "family reconstitution" methods have shown the way to link the pieces of demographic information about individuals and families that they contain (see Chapter 8).

Parish register records of baptisms, marriages, and burials as well as civil registration records of births, marriages and deaths are highly appropriate for the study of the demographic history of individuals. Further, when the histories of a number of families can be aggregated into larger sets of time series data, they reveal some of the basic outlines of the demographic evolution of whole communities. As Charles Tilly has written,

> The handy thing about the demographic analysis of vital phenomena . . . is that it permits us to deal with the individual and the group at the same time: first, by specifying the logic by which the one is aggregated into the other; second, by permitting us to compare the experience of any particular individual with that of the population to which the individual belongs [1978:10].

Although the construction of sets of "linked" vital event records from individuals and families offers the opportunity to compare individual and group behavior, building such data bases is a tedious process, particularly when researchers are working alone and without a computer. It is no surprise, therefore, that most historical demographic studies based on parish registers have been limited to an examination of small communities typical of pre-industrial European society (for bibliographies, see Spagnoli, 1977; Smith, 1977).

However, studies of historical vital events have not been limited to the reconstruction of individual family histories from nominative information but have also included the collection and analysis of aggregate series of events that permit a less intensive but larger-scale study of regions or nations over time. Both approaches have their advantages (Leti, 1974). The painstaking task of linking individual, nominative information can illuminate the occurrence of vital events within a very concrete, local historical setting. The more aggregate approach yields important evidence for population growth or decline over time, insight into the incidence of demographic catastrophes such as famine, plague, or war, or less radical but nonetheless important shifts in the relationship among the three series of vital events for wide geographical areas.

Though parish register and more recent civil registration records are often structurally similar in manuscript form, containing information on named individuals at or near the time of vital events, there are several notable differences between them. The most obvious is a chronological one. Parish registers are characteristic of the protostatistical period in the history of Europe and its colonies and are used primarily to study the period from the sixteenth to the early nineteenth centuries, whereas civil registration records are, in general, the products of the nineteenth and twentieth centuries. Second, two of the vital events listed in parish registers—baptism and burial—are only surrogates for the events of birth and death, presenting special problems of interpretation. Third, parish register records of the three vital events may have begun at widely differing points in time, so that during early years of record keeping, particularly, exactly comparable series of baptisms, marriages, and burials may be unavailable (Corsini, 1974:651–654). Fourth, parish registers, in general, are more subject to lapses in recording or lost data for periods that may extend over months or even years for individual parishes.

Parish registers were originally sought out by historical demographers for their value as sources of nominative data for the analysis of family-level fertility behavior. In contrast, civil registration records have tended to be used more in the study of aggregate behavior, so that studies based on individual-level civil registration records are relatively few. In this discussion, therefore, we have followed the relative strengths of the literature on parish register and civil registration sources, emphasizing the use of the former for nominative analysis and the latter for aggregate study. After a brief glimpse into the history of parish registers and some discussion of the particular weaknesses they may bear, we examine methods for assessing the existence of underregistration or incomplete registration in series of vital event records.

As a rule, parish registers or civil registration sources used to build up a portrait of aggregate behavior from individual level records must be of higher quality than those used in aggregate studies that compare separate series of vital events over time. However, an assessment of the quality of any set of vital registration records usually begins with the examination of the separate series of events. We have made an effort here to incorporate techniques for assessing small as well as large series of vital registration data for possible biases. After discussing approaches to the assessment of aggregate data, we turn to two examples of ways that scholars have sought to correct for underregistration in the context of "family reconstitution" studies. This chapter then concludes with an examination of several of the many topics that have been illuminated by studies using parish register and civil registration sources, and some of the problems of interpretation they have raised.

The Development of Parish Registers

The general history of the development of parish registers is fairly well known. Though some medieval registers exist, continuous series most useful for demographic analysis date from mid- to late sixteenth century for Italy, England, and western France and from the seventeenth century for most of the rest of Europe. Their diffusion was associated with efforts by local clergymen to comply with directives issued by church and state leaders who wished to maintain records of the lives of various religious and secular officials, and, gradually, the population as a whole (Lé Mée, 1975; Fleury and Henry, 1976: 21–30; Bouchard and La Rose, 1976). Roger Mols (1954, 1: 78–83) traces the diffusion of parish registers from Italy and France in the sixteenth century, first to the southern Netherlands, England, and Switzerland and then eastward into central Europe. Though denying a monocausal relationship between the Reformation and the proliferation of parish registers in religiously heterogeneous central Europe, Mols concludes "that the appearance and success of the Reformation contributed to a more rapid diffusion of an institution which provided a simple method for supervising the population's religious adherence [1954, 1: 84]." Secular authorities were often deeply interested in the kinds of information contained in the registers and themselves played an important role in expanding and improving the quality of the information the registers contained. However, it was the churches that had the local personnel with the skills and legitimate authority to record the details of their communities' family lives (Mols, 1954, 1: 102).

The Contents of Parish Register Records on Individuals

Parish register entries of baptisms, marriages, and burials range from a terse notation of the event's occurrence to an elaborate description of the individuals and families affected by it. The following two examples, the first from an English burial register of 1729 and the second from a late eighteenth-century Brazilian baptism series for free, white infants, capture this diversity. In the first case, the registrar noted only: "Bury[e]d Hugh Cook a Stranger" (*Annales de Démographie Historique*, 1972:479). The second read:

> The thirteenth of December, 1790 in the parish of l'Exaltacão da Santa Cruz de Ubatuba, I baptized . . . Anna the legitimate daughter of Marianno José de Azevedo, born in the city of Ilha Grande, and of Anna Joaquina da Conceição, born in this parish; granddaughter on the paternal side of Manoel Fernandes de Oliveira and Maria de Ozevedo, both born in the city of Ilha Grande; and on the maternal side, of Captain José Peres de Gusmão, born in the city of Parati and Maria Madelena de Jesus born in this parish. The godparents were Vicente Antonio de Jesus and his wife Felicia Maria. I have registered such the same day, month and year as indicated above. [Signed] the priest, Joaquim Martins de Aguiar [Marcílio, 1974:43].

These examples reflect two extremes along a spectrum of information on individuals and families contained in parish registers.

The ideal parish register record would include, for baptisms, the date of birth as well as baptism, and not only the name of the infant (with some notation of whether the child was legitimate or illegitimate) but also parents' names, including an indication of the mother's maiden name. If the study envisaged is designed to relate socioeconomic to demographic experience, occupational information on parents is invaluable. The ideal marriage record would include the names and ages of the partners, previous marital status (whether single or widowed) and if previously married, to whom, plus information on occupations and witnesses. Burial records, generally the least extensive in information of the three types of records, should ideally contain age at death and the marital status of the deceased, date of death as well as burial, and names of surviving kin. Signature of all parties to vital events and their witnesses, as well as of the registrar himself, provide additional data for the study of literacy in the past and indications about changes in the registration personnel. In reality, of course, historical demographers have had to settle for less than these ideals.

Any general discussion of the contents of parish register records founders on their wide variability by time and place. The wealth of data in Scandinavian and French Canadian registers as early as the late seventeenth century has been well documented (Backer, 1947; Gille, 1949–1950; Johansen *et al.*, 1972; Thestrup, 1972; Imhof, 1976:47; Roy and Charbonneau, 1976). The French registers for the northern parts of the country became extremely informative by the 1740s. The English registers, long a subject of intensive study by demographic historians, suffer, like the registers of all countries affected by English law, from a lack of information on mothers' maiden names on the baptismal records of children—a deficiency that increases the difficulty of identifying females unambiguously and linking their vital events. The English parish registers are not unique in this respect, however, as Hungarian and

Bohemian registers followed the same practice (Henry, 1972a:618). The growing interest in parish registers as sources for historical demography has resulted in an increasing number of publications that describe in detail the specific contents of these materials in many areas of the world for the various periods for which the registers are available (Marcílio, 1970; Comitato Italiano per lo Studio della Demografia Storica, 1974; Centro Latinoamericano de Demografía, 1975; Flinn, 1977; Bruneel, 1977; Wrigley and Schofield, 1981). In general, the extensiveness of information on individuals contained in parish registers has tended to increase over time, with the best records in this respect dating usually from the eighteenth and early nineteenth centuries.[1]

The extensiveness of information on individuals, however, is only one determinant of the value of parish registers for historical demographers. Information they contain, no matter how extensive, may be relatively valueless for the study of historical communities if it is not accurate, or if it refers only to small or unrepresentative segments of the parish population whose events the registrar was supposed to record. The extensiveness and accuracy of information in the registers have historically been affected by three primary factors: the concern of church and state leaders to communicate and enforce rules for the keeping of records; the actual skills of the local registrar himself; and a wide variety of circumstances in a community's history and geography that affected the registrar's or inhabitants' ability to record vital events at the approximate time of their occurrence. Each of these subjects requires some discussion.

In recent years, there has been a great deal of attention devoted to the legislation that governed the keeping of parish registers in various countries, information that is available in a number of the works cited here. Increases in the amount of biographical information on individuals and their families contained in parish registers do not appear to have followed a linear process of growth. Rather, the history of the registers of individual countries' records was marked by successive legislative interventions of church and state authorities that qualitatively altered the kinds of information available. For example, French state legislation of 1667 indicated the inclusion of the signature of witnesses to vital events, information on the specific relationships between bride, groom and witnesses in the marriage records, and the age and residences of the spouses. Lord Hardwicke's Act of 1753 in England, which introduced the use of forms on which marriage acts were to be completed, required the recording of signatures of the spouses and information on their "settlements" (Eversley, 1965:412–413). Legislation such as this, which usually took several years to pass into general usage, often led to transformations of the source materials. Although attention to general promulgations of Roman Catholic,

1. One easily available source of information about the contents and accessibility of parish registers throughout the world is the series of "Genealogical Research Papers" published by the Church of Jesus Christ of Latter-Day Saints for individual countries. They are available from the Genealogical Society of Utah, 50 East North Temple, Salt Lake City, Utah 84150.

Protestant, or secular authorities in different regions is fundamental, it is also true that wide variations in conformity to legislation also existed. For example, Louis Henry and Jacques Houdaille (1979:425–426) have noted that the French clergy, though conforming to church legislation that required ages on burial records, often failed to include ages of marriage partners demanded by state authorities. Conformity to directives from religious authorities was not necessarily greater than conformity to secular legislation. Actual practices proceeded according to customary usages whose logic often remains obscure.

An evaluation of the extensiveness of information available in the different records must thus go below the national to the very local level, to consider the skills of individual record keepers, the ultimate mediators of the kind of information that was actually recorded on a consistent basis. As Claude Bruneel (1977:23) has noted, there was frequently a radical discrepancy between the ambitious goals of legislation and the actual practice at the "grass-roots" level. The skills of individual registrars varied widely. An assessment of this feature may entail at first only informal methods of evaluation—for example, of the neatness, regularity, and legibility of the registrar's handwriting. Dupâquier (1972:85) has argued that the methods of recruitment to the French clergy under the ancien régime led to a higher concentration of proficient registrars in the larger, populous villages and *bourgs* of seventeenth-century France than in smaller settlements, a finding that may be a reasonable generalization for a wider variety of times and places. Raymond Roy and Hubert Charbonneau (1976:94–96) in their intensive studies of the French Canadian registers have noted significant variations in the proficiency of registrars by clerics' religious order. Notable lapses in the quality of the recording often occurred when a registrar who had lived for a long time in the community was replaced with a newcomer (Drake, 1974:55).

Historical Conditions Affecting the Quality of Parish Register Information

The extensiveness and accuracy of the information in parish register records have been most directly mediated by concrete historical conditions that affected the possibilities of registration at or near the time of the events themselves. This set of problems is related more directly to the circumstances of the inhabitants than to those of the registrar. Certain of these population-related problems are most obvious in the parish registers of New World "frontier" populations or in areas of Europe that were sparsely settled. In newly settled areas, inhabitants were often scattered over wide areas whose parish and/or administrative boundaries were constantly changing. Whereas the area covered by studies of the French parishes such as Crulai (Gautier and Henry, 1958) extended to some 20 square kilometers, a number of Latin American parishes, such as the one studied by Nicolás Sánchez-Albornoz (1967:65), covered thousands of square kilometers.

Several results may have occurred. In order to accommodate the growth and shift of populations, church or secular authorities may have changed the boundaries of parishes—resulting in temporary inflations or deflations in the number of vital events within individual record-keeping areas. As Maria Luiza Marcílio (1970:69) has noted, this may lead unwary scholars to conclude, falsely, that radical changes in the number of vital events recorded within a parish imply demographic shifts when they may result only from alterations in registration boundaries.

In frontier societies, problems of transportation radically affected the capacity of inhabitants, no matter how religiously observant, to abide by the time limits during which events were supposed to be reported to the registrar (Charbonneau, 1975:74–77). In many areas of Latin America, residence near the parish church was highly correlated with ethnicity—individuals of Hispanic or creole descent tending to live nearer the place of registration than Native American populations (Sánchez-Albornoz, 1967:66). Closer proximity, in principle, leads to more accurate registration simply because the events will be recorded more quickly after they occur. In areas of dispersed or sparse settlement, the clergy's strategy was usually to make periodic visits to outlying populations to baptize or marry, or to solemnize burials that had occurred months previously. Although this offered members of the clergy the opportunity to have a role in registering vital events, the long lag between visits tended to result in the underregistration of baptisms because of child deaths shortly after birth, or the artificial "bunching" of vital events in the registers for those periods when the visits took place.

Problems caused by geography, transportation, or changes in the boundaries of record-keeping units are not restricted to frontier populations, however. The growth of population in English parishes in the late eighteenth and early nineteenth centuries and the consequent establishment of new chapelries designated to take over some record-keeping responsibilities provide the same kind of challenges to those using the English registers (Drake, 1974:56).

The existence of separate registers for different religious, racial, or status groups does not, in principle, present special problems of interpretation if the registers for all groups comprising the population can be assembled. In fact, however, heterogeneity in legal (free/slave) or religious status has been shown to confound attempts to gain an understanding of the historical demographic behavior of whole communities. The Roman Catholic parish registers for the unfree populations of the New World generally contain much less complete information than those for free populations. The existence of non-Anglican populations in England, which increased in size at the end of the eighteenth century, presents particular problems of interpretation (Wrigley and Schofield, 1981:89–96). The problem is not simply that Dissenters failed to participate in the registration of their vital events at the parish church but, more importantly, that they may have done so only intermittently—registering some births but not others. As Henry has written:

> Before the institution of civil vital registration, registration did not cover the whole population compulsorily. Members of certain religious faiths could escape it in law or in fact. This type of non-registration is not very difficult to deal with when the fraction of the population which escapes vital registration is small and well defined. It is much more annoying when a dissident group is registered in a partial and episodic manner [1968:63].

Of course, inconsistent or delayed registration of vital events was not the preserve of dissenting communities alone but could also stem from a gradual decline of general religious observance among the "orthodox" as well (Berry and Schofield, 1971).

Assessing the Quality of Small Sets of Vital Registration Records

Although designed for use with Anglican parish registers in the period 1528–1837, Michael Drake's (1974: 47–63) method of assessing the quality of relatively small sets of vital registration records has a wider and more general applicability. His strategy for judging the completeness of the records is a particularly convenient and logical way to subject yearly totals of the three vital events occurring at the parish (or combined parishes) level to systematic examination. His recommendation of working on a population with at least 100 vital events a year—approximately 25–65 baptisms, the same number of burials, and 5–10 marriages—is designed to dissuade researchers from working on parishes where there are so few events per year that real, temporary lapses in registration will be undetectable. In studies that are designed to cover long periods of time, he suggests subjecting a sample of years (for example, every fifth one) to particular scrutiny.

The procedure begins with attention to establishing the real de facto limits of the registration area across time, and proceeds with the identification of months in which registration appears to have lapsed as well as a possible identification of causes for those lapses (change in personnel, catastrophic mortality that may have carried off the registrar or a significant portion of the population). Drake recommends the use of interpolation to correct for short lapses in registration by reference to the same month totals of surrounding years. A "rough and ready" way of detecting systematic underregistration of the different kinds of vital events is simply to establish ratios among them. For example, he argues that the ratio of baptisms to marriages within rather short (several years) periods of time should be within the range of four or five to one in conformity with the documented fertility of women in western European, preindustrial communities.

Ratios of baptisms to marriages as high as seven or eight to one might suggest some underregistration of marriages if in fact the baptism figures are themselves worthy of confidence.

Another simple method of detecting incomplete registration in aggregate series of baptism records is directed toward a very specific problem—the possible underregistration of female births (Herlihy, 1977:137). The calculation of the sex ratio at baptism, the ratio of male to female baptisms, should be approximately 1.05. There are no absolute rules here, but any sex ratio over 1.10 may be sufficient to call into serious question the completeness of the registration of female births, if such a ratio lasts over a period of years. Massimo Livi-Bacci (1968b:232), for example, has used the decline of the sex ratio at birth from 1.10 to 1.05 to argue for the growing completeness of birth registration in Spain during the twentieth century. In cases where the interval between birth and baptism is known to be relatively lengthy—more than a week or two—baptism registers should demonstrate ratios even closer to 1.00 because of the rate of infant mortality that is higher among male than female children.

The assessment of the completeness of registration from the comparative study of the separate series from one or several parishes offers the possibility of determining, for example, whether ratios of the different vital events to one another differ radically from those found in other, comparable parishes already studied. However, in the case of parishes that yield only a small number of vital events a year, it is important to remember that what appears to be a significant fluctuation—marriages increasing 50% from 5 to 10 a year—may be purely random (Lee, 1977: 338–347). These "small numbers" problems are endemic to studies based on only one small locality and can be remedied only by the inclusion of a larger number of parishes in the area or the extension of the study to a longer period of time. Otherwise, the researcher risks spending a great deal of time trying to explain variations in vital rates that are purely and simply the result of chance. As Giuseppe Leti (1974: 97) has noted, "Results are subject to error which is relatively smaller as the output of research is increased."

Assessing the Quality of Large Sets of Vital Event Records

In cases where research is designed to study the demographic evolution over time of record-keeping units larger than a single parish, those in which vital events numbered in the hundreds or thousands yearly, researchers will in theory have an easier time identifying significant variations in the number of vital events in need of explanation. One of the problems is then to decide whether variations in the number of registered events from one year to the next were apparent or real—whether the variation occurred as the result of shifts in the boundaries of the record-keeping unit, laws governing registration, the administration of the laws, or were the product of real changes in demographic behavior.

In his work on the birth registration records of Massachusetts in the nineteenth century, Robert Gutman (1956) has outlined a set of straightforward, practical approaches to identifying and, in some cases, correcting for fluctuations in the number of aggregate vital events registered that were primarily the product of changes in the registration system, and not in demographic trends. His three basic approaches are generally designed to help researchers isolate the probable cause of notable variations in the number of registered events by systematically rejecting other, less probable explanations. Gutman labels his methods "documentary," "expectation," and "comparative." The "documentary," method entails gathering written opinions of informed contemporaries about the relative accuracy and completeness of vital registration at the time that the events of interest were recorded, a kind of evidence most likely to be available only for recent records. The "expectation" method entails the formulation of a reasonable expectation of whether the number of vital events—in this case, births—should have been rising or declining during the period under study, based on contemporary data on economic conditions, marriages, and migration. The "comparative" method is based on the collection of information on the trend in vital events in adjacent districts, to see whether neighboring areas demonstrated variations similar to those under study.

Periods that Gutman chose for particular examination include those during which birth registration rules changed; those in which there were no changes in rules, but where there was a 10% increase in births registered from one year to the next; and several longer periods of growth in the number of registered births. His application of the "expectation" method to the birth records of the period encompassing the first major change in the birth registration law of Massachusetts (1844) was based on the notion that if real changes in demographic behavior (excluding changes in migration) accounted for a part or all of a large increase in births registered during a short period of time, then one might reasonably expect to find a systematic and positive relationship between increases in registered births and increases in registered marriages within subregions (in this case, counties) of the entire registration district. In other words, counties with proportionally high increases in the number of registered births should also show correspondingly high increases in the number of marriages registered in the few years before the increase in registered births. On the other hand, in years in which increases in the number of registered births were mainly the product of changes in the registration laws or their administration, there should be a very low correlation between increases in registered births and registered marriages. In order to test this proposition for years in which short-term increases in the number of registered births took place, Gutman ranked individual counties by their proportional increases in births and marriages and calculated the rank order correlation coefficient. His results showed that for years in which there were changes in laws or their administration, correlation coefficients linking increases in the two events were extremely low. In a number of the other kinds of years targeted for study, for which increases in marriages appeared a plausible explanation for increases in registered births, the coefficients were much higher.

Such a technique obviously rests on several assumptions—the most important being that the quality of marriage registration is not improving at the same time as birth registration. If this were the case, it would be possible to establish a high rank order correlation coefficient between the two sets of increases, but one that would nevertheless be the product of changes in rules and not real behavior. There are other, more sophisticated ways of assessing and correcting for the underregistration of births from aggregate data, particularly when census data are available. One strategy recommended by Gutman (1956:71) entails comparing the number of recorded births to the number of young children listed in cotemporaneous censuses, corrected for rates of infant mortality and net migration. More recently, a wide repertoire of techniques for correcting aggregate level series of vital event records has been outlined by E. A. Wrigley and Roger Schofield (1981: Part 1).

Estimating and Correcting for the Underregistration of Vital Events

Systematic ways of correcting for the underregistration of vital events in parish registers, particularly births, have evolved from family reconstitution studies, and more specifically from the difficulties of using registers whose quality is far from ideal. For areas that possess other nominative records in addition to the registers—for example, fiscal documents, censuses, or probate records, the existence of individuals whose vital events have been lost or were not registered can sometimes be discovered with a degree of accuracy (Charbonneau, 1975: 82–83). These additional records can also be employed to check on the accuracy of information given in the registers (Thestrup, 1972). However, the methods of correcting for the lacunae in registration that will be discussed here do not require other records beyond those found in the parish registers. They are, however, based on a prior linkage of individual records, using family reconstitution methods (see Chapter 8).

The first approach, developed by Henry (1972a), has been used up to the present in studies based on French and French-Canadian parish registers (Charbonneau, 1975). It rests on a clear typology of the different causes for the failure of certain births to appear in the baptismal registers (see Figure 3.1).

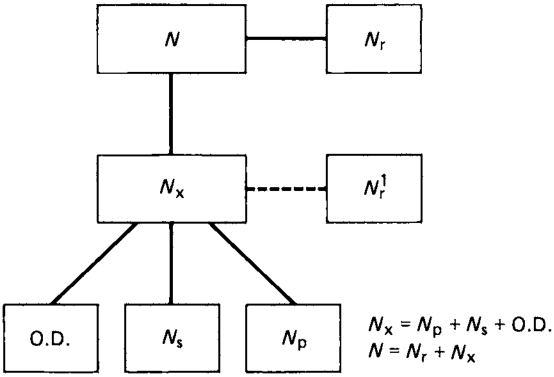

Figure 3.1. *Types of births used in family reconstitution. (Adapted from Charbonneau, 1975.)*

Births fall into two general types: those that appear as baptisms in the parish register (N_r) and those that do not appear in the register (N_x). Among births not appearing in the register, there are those whose existence can be discovered from other records (N_r^1) such as marriage records, burials, or nominative censuses. However, in most cases, where there are few other records with which to compare the registers, the number in this category will be miniscule. The other types of births for which there are no baptism records must be systematically estimated. "Accidentally" unregistered or "lost" births (N_p) are those that do not appear in the baptism register purely as the result of problems in the record-keeping or record-preservation process: loss of pages in the registers, temporary absence of the recorder, or illegible pages in the register. This type of underregistration of baptisms is not the result of any selective bias. The estimation of the number of baptisms lost for these reasons proceeds from a calculation, by decade, of the proportion marrying among those people in the parish whose baptisms do appear in the register such that:

$$N_p = M_p(N_r/M_r), \tag{3.1}$$

where N_p equals the number of "lost" births; M_p, the number of marriages corresponding to people with "lost" baptism records; N_r, the number of registered baptisms; and M_r, the number of marriages corresponding to N_r. This formula rests on the assumption that the proportion marrying of people whose baptisms were "accidentally" omitted from the register was similar to the proportion marrying of those whose baptisms do appear in the register.

The second category of births not appearing in the baptism register (O.D.) is comprised of children whose baptisms were never registered as the result of death shortly after birth. This group (*ondoyés décédés*) is defined as those who died less than 3 days after birth, primarily as a result of their obviously frail condition, and many of whom received a kind of "private" baptism at the hands of midwives who delivered them. A number of stillbirths are believed to be included in this category as well. Henry has estimated this group at approximately 3% of registered baptisms in France of the ancien régime. Notations about these children are often found in burial records, and their actual number has been calculated in one study (Charbonneau, 1975: 79–81) by increasing the number found in the burial records by a factor that would make their total equal to 3% of registered baptisms. The appearance of mentions of this kind of infant death in the burial records may also be an indicator of the conscientiousness of the recorder.

The third type of births not appearing in the baptism registers, whose numbers can be calculated, consists of children who died more than 3 days after birth, but before registration of birth could take place (N_s). This is, of course, a category that will increase in size as the birth-baptism interval is lengthened. In order to estimate the size of this selective source of underregistration, researchers must have some idea of the average length of the birth-baptism interval, gleaned usually from baptism acts that indicate birth as well as baptism date, and also of the level and pattern of infant mortality likely to have prevailed in the area. With these data, the number of births unregistered as the result of a selective criterion—infant mortality—may be determined, and the size of the N_s group calculated.

Another method of compensating for the underregistration of births, which has been successfully used with the English parish registers, entails the invention of "dummy" birth dates for children whose existence is known only from the burial records (Wrigley, 1977). When the identity of the parents of the dead infant can be assessed with relative confidence, and there are clear reasons for assigning a birth to a particular couple with a suspiciously long interval between two registered baptisms, the creation of these "dummy" birth dates may help remedy the deficiencies of birth registration. There is some possibility, as Wrigley acknowledges, that such a procedure may tend to overestimate infant mortality—particularly its endogenous component (usually taken as equal to the number of infant deaths in the first month of life)—since older children whose burials appear in the record may be wrongly assumed to have died shortly after birth. The absence of age-at-death information in the English burial records before the early nineteenth century is an exacerbating problem to that of underregistration. However, since the burial records appear to be more complete than the baptismal records for the late eighteenth and early nineteenth centuries, there is no inherent reason not to employ them for this purpose. Wrigley also demonstrates how the comparison of baptism and burial records for specific infants may be used to form some idea of the proportion of infants who died before reaching age 1 (1977:290–293).

In general, Henry's method for systematically estimating the number of births that do not appear in baptismal records is most useful in cases where the marriage records are very good, where the average birth-baptism interval is known with some confidence, and where the lacunae in the registers—losses of pages, illegibility—do not extend over long periods. The "dummy" birth date method, on the other hand, may be useful when burial series are more complete than baptisms.

The problem of the underregistration or misregistration of births is not peculiar to parish registers. Civil registration records of births are also likely to contain ambiguities, though the extent and exact causes of missing birth data have yet to be systematically evaluated. Certain nations—for example, Norway—were very careful in the directions given to registrars for the correct listing of live births and stillbirths (Drake, 1969:14). However, in some countries, problems persisted. Etienne Van de Walle (1974:47–49) and Roland Pressat (1972:86) have pointed to the continuous problem of the inclusion of stillbirths in different civil registration series for the nineteenth and twentieth centuries in France, and it is likely that such problems existed elsewhere (Glass, 1973b).

Vital Registration Records and Historical Demography

The use of aggregated series of baptism, marriage, and burial records to study the historical demographic development of entire countries has a long past. In the absence of regular, countrywide censuses, these series of vital event records provided some of the best empirical evidence that could be brought to bear on the "population controversy" of the eighteenth century (Glass, 1973a), which centered on the relative size and growth of different European populations. In recent years, the design and carrying out of an investigation of the parish registers and civil registration records for a sample of French communes, carried out under the auspices of the Institut National d'Etudes Démographiques (I.N.E.D.) for the period 1670–1830 and of a sample of 404 English parishes from 1541–1871 by the Cambridge Group for the History of Population and Social Structure (Wrigley and Schofield, 1981) stand out as the most systematic efforts to use these sources (see also Henry, 1978; Henry and Houdaille, 1978, 1979). The formulation of the sampling procedure for the I.N.E.D. project met with an early challenge (Baehrel, 1960). Nonetheless, the study has provided a wealth of data on the country as a whole, leading to some revisions of previous understanding of eighteenth-century growth trends, in particular (Dupâquier, 1976). The more recent Cambridge Group study, besides reconstructing the aggregate demographic history of England over more than three centuries, is of high methodological interest. The authors' formulation of a long-term model of English population growth, which they term a "fertility-dominated low-pressure system" (Wrigley and Schofield, 1981:451) provides a stimulating alternative to the crisis model of preindustrial European population history articulated by such scholars as Pierre Goubert (1973:36–38).

Despite the growth of large, coordinated research projects in France, French Canada, and England, interest in local-historic demographic monographs that incorporate demographic perspectives has continued (Macfarlane *et al.*, 1977), in part because of the feasibility of such research for individual researchers working alone. A number of scholars (Schofield, 1972; Dupâquier, 1972; Leti, 1974) have long voiced a desire that scholars select parishes for monographic consideration on the basis of scientific criteria: considerations of the economic or social representativeness of the parish in its region, for example, in order to avoid the arbitrariness that often dictated the selection of parishes for examination in the earliest days of family reconstitution studies.

Dupâquier (1972) has outlined the dual problems of "representativeness" raised by parish studies based on the linking of nominative data. The first is whether the reconstruction of the demographic history of any individual parish has implications broader than the limits of the parish itself, and, secondly, whether the proportion of the population whose fertility, nuptiality, and mortality history can actually be reconstituted through parish register sources can be construed as representative even of the locality. The latter issue, discussed by Schofield (1972), Hollingsworth (1972), and Athos Bellettini (1972), centers on whether there has been a systematic bias introduced into family reconstitution studies by the fact that they are comprised in the main of couples who remained within the record-keeping area under study for the duration of their marriages. The demographic history of migrants from parishes, either those who left temporarily or permanently sometime after birth often may not be reconstructed because of insufficient information on them. If migration was systematically related to demographic behavior (fertility, in particular) as some scholars believe, then the underrepresentation of migrants in family reconstitution studies may seriously bias our understanding of the historical demography of preindustrial Europe. In an effort to address this possible source of bias, David Levine (1977:168–170) has shown that the fertility of migrant women whom he was able to locate with the help of nineteenth-century census lists did not differ significantly from that of women who remained within the parish of birth. However, in order to convince the skeptics who believe that migration may be systematically related to demographic behavior, the number of such demonstrations will have to be multiplied.

One of the most promising strategies for capturing the demographic histories of individuals and families in the period covered by the parish registers is the adoption of a regional perspective. This method entails identifying an area that has an ecological, socioeconomic or cultural identity and carrying out demographic analysis within it. In order to cope with the larger number of individuals whose demographic histories are to be reconstructed, Dupâquier (1972) has argued for the reconstitution of the demographic history of a sample of couples, chosen by the first letter of the husband's last name. To the extent that regions can be defined so as to facilitate the tracing of migrants across the boundaries of very small record-keeping units, this perspective appears extremely promising (Imhof, 1979). The difficulty is that communities' regional affiliations may vary according to whether the definition of region is based on economic, geographic–ecological, cultural, or demographic criteria. The region in which a community dwells, demographically speaking, may differ from the limits of the economic region of which it is a part.

Beyond their usefulness for the study of vital rates, parish register and civil registration records of individuals have been used imaginatively to reconstruct some of the more important social, ideational, biological, and cultural patterns of past societies. The use of individual-level marriage records from both parish registers and civil registration sources has been particularly revealing of social networks in the past. Researchers have been able to reconstruct patterns of occupational and/or social class endogamy from the employment information that more recent marriage records often bear (Tilly, 1964: 88–90; Charbonneau, 1970; Sewell, 1974; Foster, 1974; Levine, 1977). In her study of one French commune from the eighteenth to the twentieth centuries, Martine Segalen (1972) was able to document the gradual formation of an industrial population within a largely agrarian setting. Weavers within the commune under study became an increasingly distinctive part of the population, being characterized by high rates of intermarriage among themselves and relative exclusion from nuptial alliances with the majority of the peasant population. Comparisons between the occupations of bride and groom at the time of marriage may be enhanced by cross-generational analysis, entailing the comparison of occupations of groom, his father, and father-in-law. Where occupations of witnesses as well as spouses and parents are recorded, the possibility exists for analyzing networks of friendship within which the marriage occurred. Marriage records that indicate the bride's and groom's place of residence at the time of marriage may also contribute to our understanding of the spatial limits of local marriage networks in the past—a topic of interest to researchers seeking to determine the limits of one important kind of ecological area for intensive historical demographic analysis (Johnston and Perry, 1972).

Aggregate series of marriage records have been used creatively for the study of patterns of conformity to religious usages, particularly among Roman Catholic populations. In their study of the marriage records for the city of Rouen at the end of the ancien régime, for example, J. P. Bardet and J. M. Gouesse (1978) were able to use patterns of marriage during the year to show the effects of French revolutionary "dechristianization" policy in causing significant deviations from the church's strictures on marriage during Lent and Advent. They saw a partial return to older patterns of conformity with the coming of the Napoleonic empire, but at lower levels than those characteristic of the area at the end of the eighteenth century.

The seasonal dimension of all three vital events in the past has been of keen interest, and the causes have been debated since some of the earliest parish monographs. The apparent conformity of rates of conception to the agricultural calendars of a number of societies (Léridon, 1973) has been hypothetically related to differential labor demands and their effects on rates of sexual intercourse and, most recently, to the relationship between female fecundity and variations in food supplies (Le Roy Ladurie, 1975; Frisch, 1978; Trussell, 1978).

The use of signature data on vital records has led to the growth of studies on levels of literacy in preindustrial society. The capacity to sign one's name to records has been increasingly used as a surrogate for the ability to read and/or write—though there is still debate on the validity of measurement that such evidence provides (Schofield, 1968, 1973; Stone, 1969; Sanderson, 1972; Furet and Sachs, 1974; Houdaille, 1977; Cressy, 1977).

Future use of individual-level civil registration records, particularly the linking of nominative information contained in them to census records, will no doubt confront researchers with some of the same problems raised by the use of nominative data from parish registers. An appreciation of the range of problems and ingenious solutions devised to correct for some of the weaknesses of these older sources of vital registration information is likely to contribute dramatically to the ability of researchers to evaluate and adjust for some of the same biases in more modern series of civil registration records.

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4
Enumerations and Censuses

In order to discuss the variety of population counts available to historical demographers, several definitions must be recalled. In general, the term *census* is reserved for a written enumeration of all individuals inhabiting a well-defined area or one nation, also referred to as a "general census." An enumeration, on the other hand, "is any operation which is designed to yield a population total. It differs from a simple count in that a list is generally prepared [United Nations, 1958: 12]." Before the nineteenth century, when national censuses of individuals were taken with increasing regularity, the term *enumeration* is generally more appropriate for describing the kinds of population counts available. The need for a wide variety of land surveys, tax lists, or similar documents historically led to the compilation of lists of individuals or households that may be used for historical demographic analysis. However, in most cases, these enumerations were not designed with demographic goals in mind.

Enumerations in the Past

In their most ambitious form, pre-nineteenth-century enumerations were implemented in order to establish a range of politically and economically useful information about significant groups of individuals within a well-defined region. Not all individuals inhabiting the area were included in such enumerations since, depending on the specific goals of the population count, not all individuals were worthy of interest. One well-known English document of the eleventh century illustrates the monarch's concern for establishing quantitative relationships between specific types of individuals and their resources. In it, enumerators were to indicate

> the name of the manor, who held it in the time of King Edward, who holds it now, how many hides are there, how many plough-teams in demesne and how many are held by the tenants, how many villeins, how many cottars, how many slaves, how many free men, how many sokemen, how much wood, how much meadow, how much pasture, how many mills, how many fisheries, how much has been added or taken away, how much the whole was worth then and how much now, how much each freeman or sokeman had there or has [cited in Finn, 1973: 2].

Some of the most detailed, later population enumerations reflected this same desire to assess the number of particular kinds of individuals within a concrete social–geographic context, demonstrating relationships between population and resources. However, elaborate or detailed information gathering within large territories illustrated in Domesday Book constituted an exceptional enterprise.

Most early enumeration-type materials tended to cover much smaller areas or regions, reflecting even the most powerful rulers' inability to control vast territories and subject them to intensive statistical scrutiny with much regularity. Great empires, such as the Chinese or the Ottoman, instituted sophisticated and often regular systems of enumerating the total population or significant population groups, but such systems were usually functional only in small parts of the territories or lacked the kind of detail about households or individuals needed to make more than very approximate estimates of total population size (Barkan, 1957; Durand, 1960; Cartier and Will, 1971; M. A. Cook, 1972: 112–113).

The historical development of the practice of counting large numbers of people has been well documented in Hecht (1977: 21–81). Such activities were closely related to the growth of city–states, kingdoms, or empires whose leaders needed to extract labor or other kinds of wealth—for example, money or sons—from their subjects in order to survive or expand. Local enumerations that contained information on the relation between population size and resources were often needed to avert starvation and/or violence in crisis situations where the balance between food and people was becoming perilously low. In these latter instances, enumerations of *bouches à nourrir* (literally, mouths to feed) might be extraordinarily inclusive, counting not only the wealthy or the taxpayers but also every man, woman, and child who would need to be fed (Bautier, 1959: 255–256).

The prerequisites for carrying out an enumeration of the total population or of special target groups within it included the felt need on the part of the ruler for such information as an enumeration could yield; personnel who could carry out such a count and establish the results in a meaningful way; and a population that would not resist being included in the count. The last requirement was fulfilled historically in a number of ways. In cases where people were convinced that they would not suffer material loss, or at least no more material loss than their neighbors, there was little problem. In other documented instances, however, leaders had to use incentives for cooperation ranging from blackmail and denunciation to terror. Instructions for a Chinese enumeration of 1370 ordered:

> Each householder is to be given an official blank with a half-seal on each stub which can be detached from the original. Since the military forces of this region are no longer going out on campaigns they are to be sent to every district and department to make a census of the households and to check the duplicate returns. Those households whose tallies agree will be treated as subjects in good standing; if not, the family will be placed on the list of those liable for military service. If, in their search the military come across minor officials who have suppressed the facts, those officials are to be decapitated. Any common people who hide from the census will be punished according to law and will be drafted into the army [cited in Durand, 1960: 214].

The fifteenth-century Florentines were characteristically wilier, and one would think, more effective in their execution of the *Catasto* of 1427. Those who anonymously denounced their fellow citizens who tried to avoid being included in the tax count, or who underestimated their wealth, were compensated for their trouble by receiving a portion of the recovered wealth (Herlihy and Klapisch-Zuber, 1978: 71–72).

Jacques Dupâquier (1969; 1979: 100) and Georges Frêche (1971) have argued that French records of the *taille personnelle*, an important source of population counts in the northern parts of the country under the ancien régime, may have been quite accurate because of the manner in which the tax was allocated and collected. Since the absence of names resulted in a heavier burden for other taxpayers in the community, collective pressure could be counted on to yield rather complete enumerations of those subject to it. (For the evolution of different kinds of taxation systems, see Arnould, 1956: 85–120). Such examples of the ways that people were historically urged to include themselves in population enumerations should remind us that orderly cooperation with enumerators is a historically learned experience, one that tended to be learned more rapidly when people felt secure that the expropriation of their scarce resources would not be the price of cooperation. In the absence of this belief, pressure, force, or both were necessary.

Hearths and Households in Early Enumerations

The most basic unit of enumeration for most of recorded history has been the hearth, house, or family. If the number of individuals per hearth or family is reasonably consistent across regions or constituent groups within a population, the number of hearths can be multiplied by some constant to yield a reasonable total. This kind of operation lay at the heart of the work of Political Arithmeticians and in some cases remains the only means of estimating the size and density of many historical populations. In 1771, Arthur Young, an advocate of regular, detailed censuses of individuals bemoaned the quality of inferences about total population made from data on hearths: "The calculations drawn up from the number of houses are, in all probability fallacious: that they are mere *guesses* we well know; for by what rule is the number of souls *per* house to be determined? How is the medium to be found out between the palace, and the cot? [cited in Glass, 1973: 5]."

The establishment of such a medium, or mean, has been most recently identified with the work of the Cambridge Group for the History of Population and Social Structure (Laslett and Wall, 1972). Most notable have been findings pointing to the general lack of historical variability in mean household size across a wide variety of time and cultures. Although the question of what constitutes significant deviations from documented mean household sizes is still debated (Bradley and Mendels, 1978), inquiries into the characteristics of households are of interest not only because of their importance as the basic residential and labor units of most historical societies but also for the inferences about total population size that may be used when data on household size and composition are available. While the thrust of the Laslett and Wall volume has been to downplay the overall significance of variations in mean household size for historical communites, other research has concentrated on systematic variations in household size and composition among constituent groups in past societies.

In a meticulous examination of the post-Conquest and later colonial population enumerations of Mexico, Sherburne Cook and Woodrow Borah (1971, 1: 119–200) have documented the evolution of definitions of basic population units used by enumerators. They found, for example, a tendency for clerical enumerators to focus on the "natural" family of man, woman, and children for purposes of counting in parish censuses, whereas enumerations carried out by secular officials focused on residential units (1971, 1: 135–136). Indians were the most likely of all racial–ethnic groups to be enumerated in their "natural" family groupings. The authors also discovered systematic regional variations in the way families or household groupings were reported. These differences, as the authors demonstrate, may be used productively to refine estimates of communities' population from partial data on households or families alone. Their conclusion that "the way in which the family was conceived as being constructed is a significant factor when the family size is calculated by dividing total population by the stated number of families" emerged from attempts to refine the "multiplier" that should be used to infer population size from data on number of married males, families, or hearths in different communities (1971, 1:177).

Because of the lack of information on the individuals comprising hearths or households in the medieval or early modern world, historical demographers have had to seek out information that could be used to make probabilistic judgments about the size and composition of these basic enumeration units. In one study, J.C. Russell (1965: 89) argued that a determination of the number of female-headed households in an enumerated population could give some insight into the type and size of households at any one time. If the proportion of households headed by females (especially widows) was large (say 10% of the total), then one might conclude that older persons were not generally expected to coreside with their married children, and households could be predicted to be small and nuclear. In contrast, if there were few households headed by such individuals, we might infer that they were expected to coreside and that households would be more complex and their mean size larger. This idea is intuitively appealing (La Démographie Médiévale, 1972: 105–106) but has been criticized for the short-term variations to which such an index of household size and composition may be subject. More recent work (Herlihy and Klapisch-Zuber, 1978: 211; Dupâquier, 1969: 90) has shown that household size and composition were extremely vulnerable to change during demographic crisis. Far from being good indicators of *general* social rules about household formation or family "organization" (Bradley and Mendels, 1978: 381), ratios of female-headed to total hearths may be radically affected by short-term conditions. Dupâquier (1969) has gone so far as to argue that these households should be eliminated from consideration in trying to estimate the size of hearths and changes in them over time (Derouet, 1980).

The Use of "One-Time" Enumerations

Using enumeration data that give information on the actual composition of households or hearths by sex or broadly drawn age statuses to study historical societies is most difficult when only one document, relatively lost in time, is available. In dealing with a single population enumeration, researchers have at their disposal only a snapshot of one moment in the working-out of the processes of fertility, mortality, and migration. An enumeration, particularly of a small population, that is isolated in time from other, comparable documents may simply be a very biased "sample" of the historical experience of the population it documents, especially, as was often the case, when such enumerations were taken in times of impending or recently past social stress. Populations enumerated at such times would be highly unlikely to display the kind of normal age or sex distributions found within modern, national population or stable population models. Thus, scholars whose data come from small populations enumerated at only one moment in time may have little reason to draw strong inferences from their sources. In many cases, it will be impossible to gauge whether decidedly "abnormal" (in relation to modern census findings) relationships between age or sex groups revealed in such enumerations were the result of short-term "period" effects, long-standing conditions, or biases in the data themselves.

A good illustration of this dilemma is Emily Coleman's (1974) study of the well-know *Polyptyque* of the holdings of the Abbey of Saint Germain in the early ninth century (see also Reinhard *et al.*, 1968: 61–62, for a discussion of this source). Inhabitants of the abbey's lands were enumerated by landholdings, households, and villages. Characteristically, no ages were given, but for adults and a majority of children, sex and marital status could be determined. Systematic correlations between size of household, landholdings, and household heads' social status were found, as well as a sex ratio that deviated consistently from those found among modern populations, though more at the household or village level than within the whole. The high sex ratios were in need of explanation. As the author states, "Each historian must decide on the explanation or set of explanations that seems the most likely" (1974: 325).

The explanation Coleman decided on was that systematic female infanticide was being practiced within the population under study. In the absence of direct evidence of this practice, the explanation seems to be a "strong" one, though perhaps no more indefensible than a conclusion that females were systematically underregistered, or that males were more likely to remain or migrate to the abbey's lands than the females—since there was no direct evidence of any of these phenomena. The lack of age data and of locale-specific corraborating evidence quite simply precludes firm conclusions from the evidence available. In his own work, Russell (1958: 14–17) showed the wide variability in sex ratios gleaned from medieval enumerations of rural and urban populations and hypothesized that balanced sex ratios were more typical of larger enumeration units (for example, those used in the English poll tax lists of 1377) and that cities normally showed a predominance of women in their populations "unless influenced by some unusual circumstance [1958: 16]."

The presence of age information may be used to help illuminate unusual findings by facilitating the identification of those groups among which sex ratios are most skewed. The accuracy of age reporting need not be necessarily high in order to identify which broadly defined age groups appear most inconsistent with the whole pyramid, or where possible biases are creeping into the data. In his study of one enumeration for the French city of Reims in 1422, Pierre Desportes (1966) had at his disposal complete returns on individuals for 2 of 13 parishes, which together comprised more than one-third of the total population that had been counted during a 4-to-5 day period by household visitations. One of the 2 parishes, Saint Pierre, contained data on the age of each individual. Though all inhabitants were apparently happy to state their ages to the enumerator, the biases in reported ages were clear.

A simple calculation permits an examination and cross-time, cross-national comparisons of this perennial problem in census type data. Whipple's index (Shryock and Siegel, 1973, 1: 205–206) indicates the tendency of persons to round their actual ages to those ending in zero or 5, historically found to be points of attraction for age "heaping." The index is calculated by summing the number of individuals (usually separately for both sexes) at ages 25, 30, 35, 40, 45, 50, 55, and 60 multiplying the total by 5, dividing the result by the number of individuals ages 23 to 62 inclusive, and multiplying by 100. When there is no preference for ages ending in zero or 5, the index will equal 100.

From the figures given in Desportes (1966: 47), the index for his parish of 1311 persons who indicated their ages was a whopping 239.9 for males and 254.3 for females. This is extremely large by modern standards (the comparable figure for the city of York, England, in the census of 1851, for example, was 120.4 for household heads and 129.0 for their wives) (Alan Armstrong, 1974: 36–37). Desportes noted the attraction of even-numbered ages among both men and women (1966: 496). In the fifteenth century, Florentines avoided the reporting of ages ending in 1, 3, 7, and 9 (Herlihy and Klapisch-Zuber, 1978: 367). The rich data on wealth in the Florentine *Catasto* enabled the latter authors to show that age reporting was more accurate among men than women, among urban than rural people, and among the rich than the poor (1978: 368).

The value of these age data, therefore, does not lie in their accuracy at the individual level, but taken in the aggregate they may suggest the relative importance of documented social practices, such as the differential sending of female rather than male children to wet nurses, age- or sex-selective processes of migration, or even the development of different groups' attitudes toward aging. By gathering together age data into 5-year groups around the "heaped" ages, or by applying a computer program (i.e., United States Bureau of the Census, 1976: 487–498) designed to "smooth" the data, researchers may also see from the corrected age pyramid the tendency of their population to grow or decline. Knowledge of the specific conditions in which the enumeration was taken—how long it took, what the particular incentives for age misreporting might have been, the possible incidence of recent age-selective mortality crisis—is indispensable for making sense of an age pyramid of an "unstable" population. Even with faulty age data, however, scholars have the possibility of studying or making reasonable inferences about the vital processes that their one-time enumeration population was experiencing.

An Example of a Regular Series of Early Enumeration Data: The Stati d'Anime

Turning from a situation in which only occasional, or isolated, enumerations of populations are available to one where fairly regular counts are still extant permits more detailed analysis of the accuracy of individual population counts and the processes of change within the population covered. Though often sporadic and incomplete, Italy's series of *stati d'anime* (lists of souls) provide an illustration of one of the earliest examples of regular enumerations where the recorder was interested not only in hearths or households but also in individuals.

The *stati d'anime*, by definition, were lists of individual communicants, the earliest records being mere lists of souls without indication of family or household affiliation. Though sporadic ecclesiastical enumerations exist for individual localities throughout Europe in the early modern period (see, for example, Lions and Lachiver, 1967), Italy's series of *stati d'anime* appear to be among the earliest regular enumerations of individuals available for historical demographic analysis (Comitato Italiano per lo Studio della Demografia Storica, 1974, 1: 2–236).

Series of these parish-level enumerations date generally from the seventeenth century, with a few survivals from before 1600 (Bellettini, 1974: 4). Carlo Corsini (1974: 85) has argued that from their inception, they had both pastoral and administrative purposes. The increasingly detailed and complete information on individuals and households available from the seventeenth to the late eighteenth centuries may be largely ascribed to the growing interest of local, secular authorities in the kind of information contained in the *stati d'anime*. Although the earliest books were essentially nominative lists of individuals eligible for communion—that is, adult Christians in good standing—the presence of a meticulous priest at the parish level or of a demanding bishop at the diocesan level might result in documents that presented lists not only of names but also of individuals arranged by households with clear indications of the relationship of household members to its head. The radically differing dates at which series of *stati d'anime* began to appear in different localities, even within the same region, demonstrate the difficulties encountered by Roman Catholic authorities in trying to enforce regulations such as Pope Paul V's 1614 "*Rituale Romanum*," which, in theory at least, imposed the keeping and form of these yearly enumeration books on the local head parish priest. Increasing numbers of series of *stati d'anime* began to appear after this directive but often coincided with the appointment of new parish priests, pastoral visits by the bishop, or after natural disasters—events that demanded specific information on the number of inhabitants (Bellettini, 1974: 20; Corsini, 1974: 93–94). Such events might also be occasions for the updating of registers in cases where a lax priest had failed to maintain them in regular fashion.

By the eighteenth century, regular series of summaries ("*ristretti*") of total population at the parish or diocesan level, organized by sex and eligibility for communion, began to appear, though they are often marred by their compilers' tendency to round off totals or to change summary categories of individuals from year to year. The *stati d'anime*, like the parish registers, are much better for keeping a count of the geographically stable elements of local populations, though in some areas, particularly those characterized by seasonal-work migrations, the priest often gave quite detailed information on the temporary absences of household members and the causes for them (Corsini, 1974: 110–115, on the area of Valdibure, near Pistoia, in the eighteenth century).

The manner in which the Italian *stati d'anime* were compiled is the subject of some debate, and practices no doubt varied widely by region and the personal level of skill and commitment of the individual priest. In certain places (for example, Naples and Perugia), priests appear to have visited individual houses for enumeration purposes and for an annual pastoral blessing during the period before Easter communion, when the *stati d'anime* were generally drawn up (Comitato Italiano per lo Studio della Demografia Storica, 1974, 1: 203). In other cases, it has been hypothesized that these enumerations were merely routine updatings of information from previous years' books, and not in-person counts of parish inhabitants. Livi-Bacci, for example, has argued that most parish priests probably made only "mental" excursions through the parish at the time when the enumeration was supposed to take place (Comitato Italiano per lo Studio della Demographia Storica, 1974, 1: 204). Inaccuracies, particularly repetitions of age errors in series of *stati d'anime* for specific localities, can be determined through a comparison of nominative data with individual information contained in the parish registers of baptisms, marriages, or burials. When it is determined, for example, that an erroneous age for an individual has been inscribed in one enumeration and repeatedly updated from year to year, there is reason to question whether the priest had in fact been carrying out face-to-face enumerations of his parishioners (Bellettini, 1974: 16).

One of the most important sources of incompleteness, particularly before the later eighteenth century, is the underenumeration of children who were not yet eligible for communion. Children and others not admitted to the sacrament might often be listed only in summary tables. Other omissions, of non-Christians or the excommunicated, are less numerically important. Various kinds of occupational information, usually most complete for heads of households, began to become more abundant with the later eighteenth century. Earlier volumes appear to have given information only on the social status of local notables: nobles, lawyers or landowners (Bellettini, 1974: 17). Even when the occupational data became more extensive, especially with the Napoleonic occupation, they often reflected the "casual" nature of much employment especially in the urban areas—where people's occupation changed often. Despite their many lacunae, the Italian *stati d'anime* are among the few series of continuous documents on local and regional populations that give information on household composition for the seventeenth and eighteenth centuries in Roman Catholic Europe. Their most promising usage, for regions where records have been relatively well preserved, is in conjunction with regional family reconstitution projects that go beyond the purely local limits imposed by parish-level documents on small and varying populations (Schifini d'Andrea, 1971).

Assessing the Accuracy of Enumeration Data

The use of several consecutive enumerations to assess the size of local or regional populations offers whole new possibilities for historical demographic research, permitting the documentation of changes in population size, structure, and settlement patterns over time. When more than one enumeration of a whole population are available for the same community or set of communities, several simple tests of comparability between or among the documents may be carried out. These tests are based on assumptions that will be more or less acceptable depending on the actual conditions prevailing at the time that the enumerations took place.

Jean-Noël Biraben (1961) has outlined one method of assessing the comparative accuracy of enumerations in cases where data are available at two points in time for subunits comprising the area under study. The strategy is simply to calculate the correlation coefficients between the population figures for subunits at the two different dates. In certain cases, the researcher will have reason to accept the accuracy of at least one of the enumerations. In such cases, if the correlation coefficients determined are near 1, then the historical demographer concludes that the second count, whose value is under examination, is reliable. In instances in which the value of both counts is unknown, high coefficients of correlation are presumed to demonstrate the accuracy of both. If they are low, then either one or both of the counts is presumed to be inaccurate, but it will be impossible to judge which one. In his work, Biraben was attempting to assess the quality of enumeration data for the area of Reims, France, in 1773 by comparing them with totals for the same area in the census of 1806, generally believed to be fairly reliable. The kind of test he proposes rests on several assumptions: that there were no radical shifts in the way population was distributed among the subunits of the area in the years intervening between the two counts; that there are sufficient subunits to make the results meaningful (Biraben was working with 182 communes); and that the data being compared were gathered along the same criteria—that is, within the same units of observation (1961: 728).

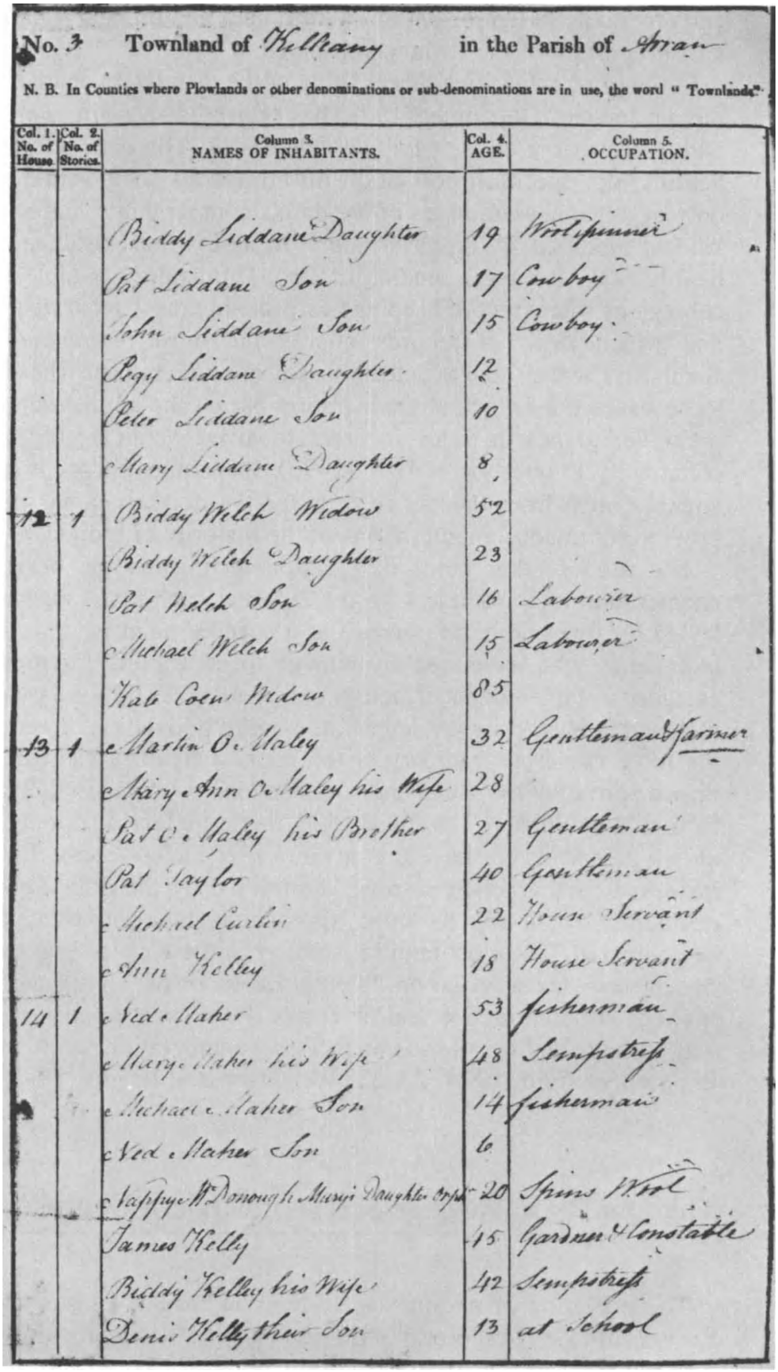
The logic of such a method is extended in a study by Sasha Weitman, Gilbert Shapiro, and John Markoff (1976), who sought to arrive at a best estimate of the French population and the relative importance of different regions at the end of the eighteenth century. Although most of the population estimates available from contemporary evidence were based on vital registration sources and not on enumeration data, their technique, like Biraben's, is extremely useful for the comparative evaluation of population totals drawn from more than one enumeration. Since information on the specific sources and methods used to establish the 20 sets of figures available to them was in many cases slim, there seemed little a priori reason to accept any one with entire confidence. Their strategy, therefore, was to calculate coefficients of correlation for the extant totals, and then to reduce the resulting matrix to its essential relationships with the use of factor analysis (see Chapter 11). Besides observing rewardingly high coefficients of correlation among the counts gleaned from a variety of sources, the authors were able to show that only two factors in their solution, corresponding to figures based on birth data and on hearth data, explained the vast proportion of the variance observed.

In the most exhaustive recent study of the population enumerations of a large region, Jacques Dupâquier (1979) has subjected his sources of local population data to a variety of tests for possible biases. His data offered only totals of hearths, not specific information on household composition, thus permitting only aggregate assessments of the data's comparability and accuracy. Using a kind of modified "Whipple's index" to assess the existence of "heaping" of hearth totals at integers ending in zero, Dupâquier was able to identify those subregions where record keeping was probably most accurate (1979: 113–140) and which kinds of records offered the most promise of completeness. Similarily, he was able to detect those population returns whose totals appeared to be based not on actual enumeration but on the application of a "constant" multiplier to hearth totals in order to arrive at an aggregate figure for the community in question (1979: 92–93). Dupâquier's work is based on regular counts drawn from the tax records for the northern areas of France, which provide continuous enumerations of the majority of individual taxpayers.

The use of other kinds of taxation records as the basis for population enumeration often founders on the fact that such taxes were only occasional, levied for one particular purpose at a specific point in time, and only among individuals who were wealthy enough to contribute. Exemptions of specific categories of individuals or households from taxes (in the case of the *taille*, this included nobles, clergy members, the entire population of certain cities), or of the more numerous category of the poor, sometimes yielded lists that gave a biased portrait of the social order. Exceptionally "democratic" taxes, such as the British "Lay Subsidy" of 1524–1525, that were levied not only on land but also on goods and wages have the advantage of inclusiveness. But their value for historical demographers is often diminished by the difficulty of finding other enumeration data from the same, approximate time with which their results may be compared. The most familiar strategy in these cases is to use other kinds of documents—taxes levied on different bases, or parish register records—to see whether population size and/or composition corresponded in any systematic way with the findings of socially inclusive enumeration records widely dispersed in time (Spufford, 1974: 23–37; Wrightson and Levine, 1979: 32–36).

The Quality of Regular Series of Modern Censuses

The evolution of nationwide systems of regular census-taking in much of Europe and the New World in the nineteenth century provides source materials for analysis that, in general, present qualitatively different possibilities and

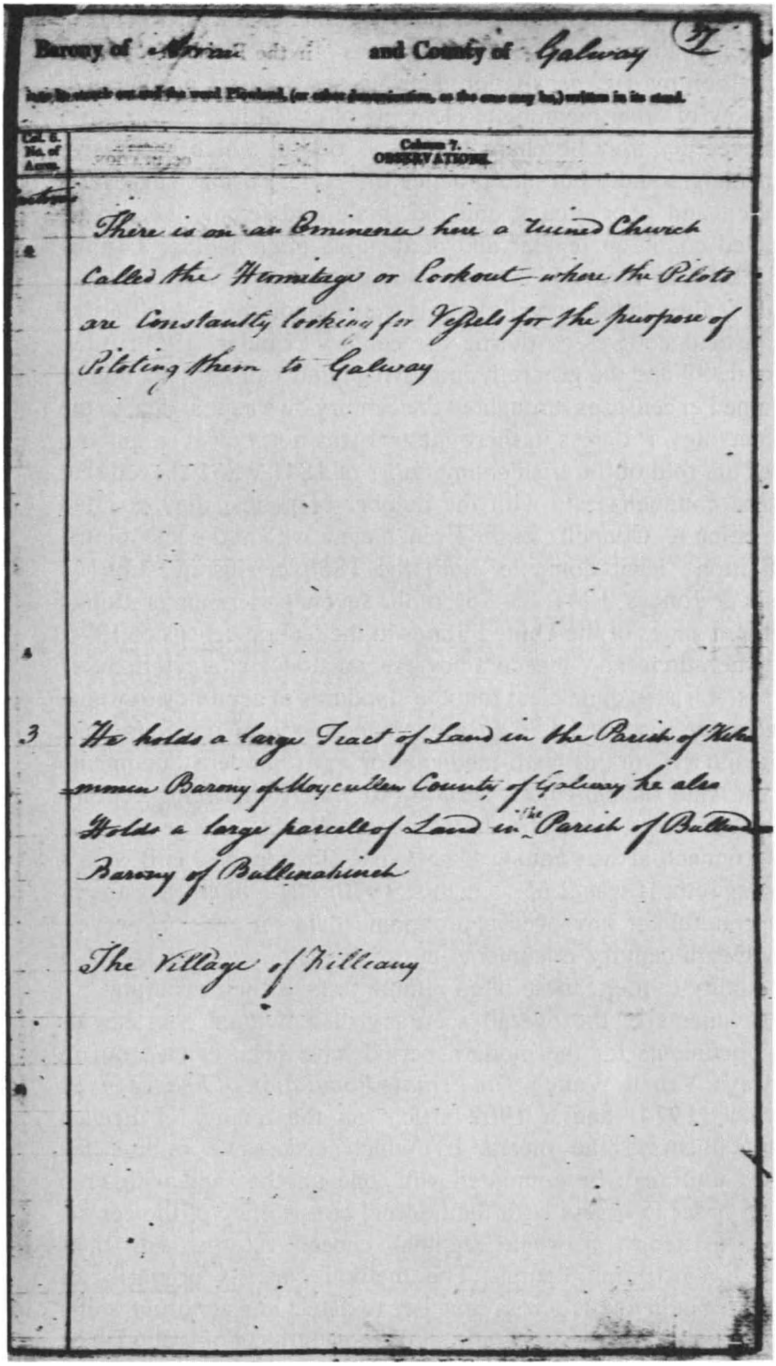


No. 3 Townland of Kilkeany in the Parish of Arran

N. B. In Counties where Plowlands or other denominations or sub-denominations are in use, the word "Townlands"

Col. 1. No. of House	Col. 2. No. of Stories.	Column 3. NAMES OF INHABITANTS.	Col. 4. AGE.	Column 5. OCCUPATION.
		Biddy Liddane Daughter	19	Wool spinner
		Pat Liddane Son	17	Cow boy
		John Liddane Son	15	Cowboy
		Pegy Liddane Daughter	12	
		Peter Liddane Son	10	
		Mary Liddane Daughter	8	
12	1	Biddy Welch Widow	52	
		Biddy Welch Daughter	23	
		Pat Welch Son	16	Labourer
		Michael Welch Son	15	Labourer
		Kate Coen Widow	85	
13	1	Martin O Maley	32	Gentleman and farmer
		Mary Ann O Maley his Wife	28	
		Pat O Maley his Brother	27	Gentleman
		Pat Taylor	40	Gentleman
		Michael Curlin	22	House Servant
		Ann Kelley	18	House Servant
14	1	Ned Maher	53	fisherman
		Mary Maher his Wife	48	Sempstress
		Michael Maher Son	14	fisherman
		Ned Maher Son	6	
		Nappy McDonough Mary's Daughter Orph	20	Spins Wool
		James Kelly	45	Gardner & Constable
		Biddy Kelley his Wife	42	Sempstress
		Denis Kelly their Son	13	at School

Figure 4.1. *Census of Ireland (1821). Courtesy of the Public Record Office, Dublin.*



Barony of Arran and County of Galway (37)

... struck out and the word Ploughland, (or other denomination, as the case may be,) written in its stead.

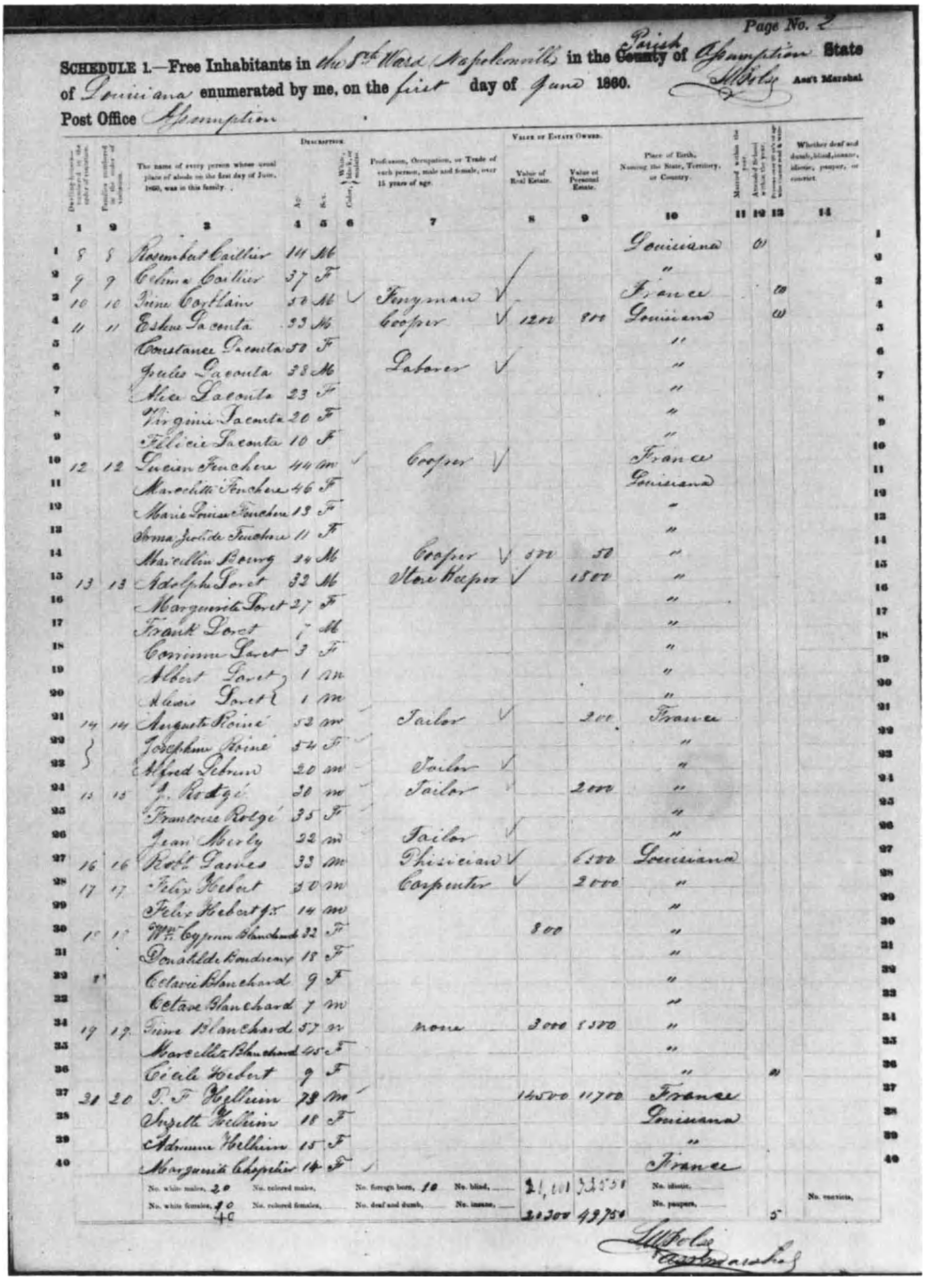
Col. 6. No. of Acres.	Column 7. OBSERVATIONS.
	There is on an Eminence here a ruined Church Called the Hermitage or Lookout where the Pilots are Constantly looking for Vessels for the purpose of Piloting them to Galway
3	He holds a large Tract of Land in the Parish of Kilcummen Barony of Moycullen County of Galway he also Holds a large parcell of Land in the Parish of Ballin... Barony of Ballinahinch
	The Village of Killeany

Figure 4.1. *(continued)*

problems for historical demographic analysis than documents of earlier periods. The possibilities include the reconstruction of patterns of settlement, household and family composition by age, occupation distributions, indirect measures of fertility, and a variety of other meaningful elements of social life.

The nineteenth century may be characterized as one in which successive national governments gradually put into practice the rather curious suggestion that all people, rich and poor, young and old, male and female, should be subjected to detailed counts at regular and predictable intervals (see Figures 4.1, 4.2, and 4.3). Such an idea, which had its advocates long before this time, was translated into reality and its specific details were elaborated in a variety of international, statistical congresses during the century (Linder, 1959: 332–333). The level of detail and the generally improving quality of individual-level information contained in censuses throughout the century owe a great deal to the success of such meetings. Progress in these matters was not, however, smooth and linear. Stories are told of the Irish enumerators of 1841 who believed that their pay would be commensurate with the number of people they counted (Drake, 1969: 2, citing K. Connell); of the French clerk who at the last minute inserted the definition "legal domicile" into the 1836 census question on residence (Moreau de Jonnès, 1847: 75–76); of the severe underenumeration of the war-torn southern states of the United States in the federal census of 1870. Though underenumerations and inaccuracies are no doubt characteristic of "modern" censuses, it is also quite clear that the standards of accuracy to which these data are held are also higher than for enumerations of previous eras. Historical demographers working with medieval or early modern documents may wonder at the kind of meticulous scrutiny to which nineteenth-century documents are sometimes put—concern that, for example, the average absolute years' deviations from actual ages among 41–50-year-olds reported in Boston's 1880 federal census returns was 2.65 (Knights, 1970: 82)—when they themselves would be grateful for any even approximate data on ages. However, many of the nineteenth-century documents currently being studied are of a sufficiently high quality to merit these often minute tests of their accuracy.

Systematic assessments of the overall accuracy of individual censuses or series of census documents for the modern period have been carried out in several different ways. Van de Walle's *The Female Population of France in the Nineteenth Century* (1974) and a 1969 article on the quality of French demographic data illustrate the means by which successive returns for subnational census units can be compared with one another and with vital registration data in order to assess both the internal consistency of the census series and the consistency between regional census returns and their corresponding vital registration figures. The method consists primarily in tracing birth cohorts of individuals across censuses to detect any abnormal shifts in their size. In the absence of large or erratic shifts in patterns of migration in or out of the census unit, the size of the cohort, traced from birth through death, should show gradual, systematic diminution. Use of the birth and death data for


Page No. 2

SCHEDULE 1.—Free Inhabitants in the 5th Ward Napoleonville in the Parish of Assumption State of Louisiana enumerated by me, on the first day of June 1860. [illegible] Ass't Marshal.

Post Office Assumption

1	2	3	4	5	6	7	8	9	10	11	12	13	14
8	8	Rosembert Caillier	14	M					Louisiana				
9	9	Celima Caillier	37	F					"				
10	10	Pierre Carlhian	50	M		Ferryman			France				
11	11	Esthin Laconte	33	M		Cooper	1200	800	Louisiana				
		Constance Laconte	50	F					"				
		Jules Laconte	38	M		Laborer			"				
		Alice Laconte	23	F					"				
		Virginie Laconte	20	F					"				
		Felicie Laconte	10	F					"				
12	12	Lucien Fenchere	44	M		Cooper			France				
		Marcellite Fenchere	46	F					Louisiana				
		Marie Louise Fenchere	13	F					"				
		Ilma Julide Fenchere	11	F					"				
		Marcellin Bourg	24	M		Cooper	500	50	"				
13	13	Adolphe Loret	32	M		Store Keeper		1500	"				
		Marguerite Loret	27	F					"				
		Frank Loret	7	M					"				
		Corinne Loret	3	F					"				
		Albert Loret	1	M					"				
		Alexis Loret	1	M					"				
14	14	Auguste Roiné	52	M		Tailor		200	France				
		Josephine Roiné	54	F					"				
		Alfred Lebrun	20	M		Tailor			"				
15	15	J. Rodgé	30	M		Tailor		2000	"				
		Francoise Rodgé	35	F					"				
		Jean Merly	22	M		Tailor			"				
16	16	Robt. Dames	33	M		Physician		6500	Louisiana				
17	17	Felix Hebert	30	M		Carpenter		2000	"				
		Felix Hebert Jr.	14	M					"				
18	18	Wd. Cyprien Blanchard	32	F			800		"				
		Donalilde Boudreaux	18	F					"				
		Octavie Blanchard	9	F					"				
		Octave Blanchard	7	M					"				
19	19	Pierre Blanchard	57	M		none	3000	5500	"				
		Marcellite Blanchard	45	F					"				
		Cécile Hebert	9	F					"				
21	20	P. F. Helluin	73	M			14500	11700	France				
		Sophie Helluin	18	F					Louisiana				
		Adrienne Helluin	15	F					"				
		Marguerite Chopin	14	F					France				

No. white males, 20 No. colored males, No. foreign born, 10 No. blind, No. idiotic, No. convicts,
No. white females, 20 No. colored females, No. deaf and dumb, No. insane, No. paupers,

Figure 4.2. *Federal census of the United States (1860).*

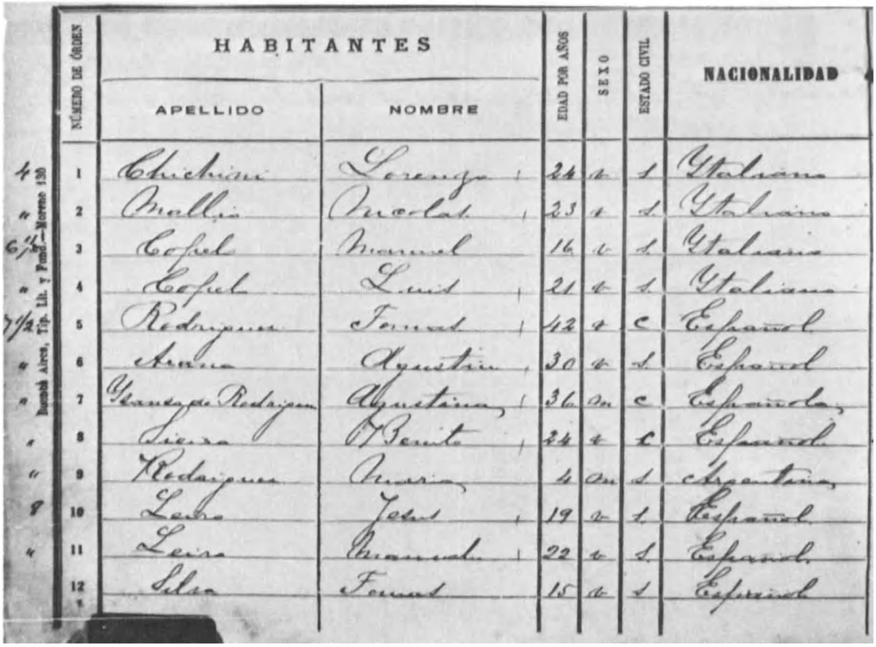
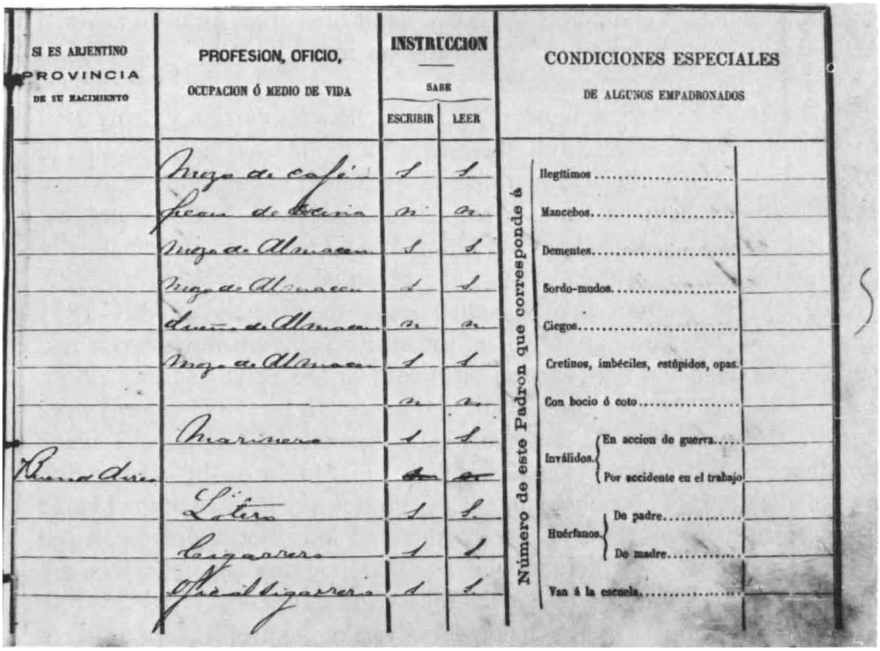


Figure 4.3. *Census of Argentina (1869). Courtesy of the Archivo General de la Nación, Buenos Aires.*

the same administrative units or for an entire nation (Wrigley and Schofield, 1981) permits an assessment of the level of total population predictable from one census to the next, and a means of correcting for deficiencies in the census-taking procedure. Other volumes in the Princeton Office of Population Research's "European Fertility Project," for example, John Knodel's work on Germany (1974: 23–25), have also addressed the quality of regional-level census data in the nineteenth and twentieth centuries. The use of the "balance equation" method for assessing the accuracy of census returns, by van de Walle for French *départements* or Sundbärg (discussed in Hofsten and Lundström, 1976: 159–167) for the whole Swedish population, is much more appropriate for larger population units than individual cities or towns, where migration flows whose size and composition are often difficult to determine may have historically effected important and/or erratic changes in the size and relative importance of local age cohorts over time.

One of the difficulties of testing the completeness or coverage of local censuses is that they tend to be the most historically inclusive of nineteenth-century population documents. Other records, such as city directories or tax records, are usually measured against census returns to estimate their own inclusiveness for precisely this reason. At the national level, vital registration


SI ES ARJENTINO PROVINCIA DE SU NACIMIENTO

PROFESION, OFICIO, OCUPACION Ó MEDIO DE VIDA

INSTRUCCION — SABE — ESCRIBIR | LEER

CONDICIONES ESPECIALES DE ALGUNOS EMPADRONADOS

Número de este Padron que corresponde á

Ilegítimos

Mancebos

Dementes

Sordo-mudos

Ciegos

Cretinos, imbéciles, estúpidos, opas

Con bocio ó coto

Inválidos: En accion de guerra; Por accidente en el trabajo

Huérfanos: De padre; De madre

Van á la escuela

Figure 4.3. *(continued)*

may rival or in some instances outstrip the censuses in terms of completeness. For example, it may have been more difficult for an individual to escape inclusion in vital registration records at the time of birth, marriage, or death than to avoid inclusion in the census, especially if the population of the place where the individual resided was very large, and if residence there was for only a brief period of time. However, modern census manuscripts, in general, are probably more inclusive and socially representative than, for example, marriage records simply because the latter records demanded not only presence in a place but also an act that potentially bore the bias of age, class, or ethnicity. Another obvious factor is that being born, being married, or dying in a particular place does not necessarily mean that the individual in question resided there, so that taking the experience of an individual registering a vital event in a particular place as representative of the life course of residents may sometimes be quite misleading. Ideally, one would wish to combine and check on the completeness and accuracy of information on individuals in censuses by comparing it to vital registration records for the same persons. This has been done for rather small communities such as Colyton, England (Wrigley, 1975), where the author wished to determine the accuracy of information given by individuals to the census takers on their place of birth and the inclusiveness of the vital registration information. The task of comparing these two kinds of sources for accuracy and completeness, by linking nominative records on individuals is however, too time-consuming for large communities.

Of the nineteenth-century manuscript census schedules currently being used for historical demographic research, the greatest attention has been devoted to those returns that offer the widest range of information on individuals and relationships among them, particularly at the household level. The enumerators' books for the English censuses of 1851 and 1861 have been systematically described and assessed for their quality and potential biases (Wrigley, 1972; Lawton, 1978). The destruction of the schedules for the censuses of 1801–1831 (Drake, 1972: 31), the lower quality of information on relationship of household members to the head, on age, and on birthplace of the 1841 census (Tillott, 1972: 82), and only recently lifted restricted access to the 1871 returns have combined to focus attention on these particular documents, examples of which are reproduced in W. A. Armstrong (1978: 71–81). Similarly, the introduction of explicit indications of household members' relationship to head in the United States federal census of 1880 has made this and later documents preferred sources. Descriptions of the contents of individual nations' past censuses are contained in a wide variety of publications (for example, Wright, 1900; Biraben, 1963; McCaa, 1978). A detailed analysis of the problems of different nations' individual census returns is obviously impossible within the confines of the present discussion. Rather, what we have attempted to capture here are several data-related and conceptual problems in the use of modern manuscript census schedules that are apt to be of more than local interest.

The Definition and Boundaries of Census Units

An illustration of the problem of shifting boundaries of the basic census unit is provided in P. M. Tillott's (1972) discussion of the British censuses of 1851 and 1861, which were based on the enumeration of named individuals by household. Characteristically, the most unambiguous cases for enumerators were male-headed, two-generational, nuclear households that occupied the entire space of one building or "house." Difficulties crept in when census takers, attempting to follow often ambiguous instructions, tried to enumerate correctly other individuals who inhabited the same building as a clearly designated "occupier" (1972: 90) but who had a relationship to him that was closer than that between landlord and tenant—people such as boarders or lodgers (Modell and Haraven, 1973; Laslett, 1977: 45–46). In the 1851 British census there was no mention of handing out separate census schedules to lodgers. Single lodgers were simply designated as such within households. The problem of delineating "household boundaries" arose when there were clusters or families of lodgers dependent upon a household head or occupier. In the 1851 census, the head of a "lodging" family was likely to be designated as the head of a new household within the same building, even though his or her own family was actually coresiding with the family of the primary occupier (Tillott, 1972: 97).

For the taking of the 1861 census, however, separate schedules were left with the heads of "lodger" groups, but instead of them being designated as heads of separate households, they were listed as "lodgers" in relationship to the head of a primary household within the same building. One of the results of such a change in practice is that it is misleading to compare the number of boarders and lodgers in the two censuses (Tillott, 1972: 105). Sorting out the shifting definitions of household boundaries, and studying the size and characteristics of these units at one or more points in time, is of interest not only for researchers concerned with typologies of households, such as the one presented in Laslett and Wall (1972: 31; see also Chapter 8) but also for an understanding of individual-level experiences.

Though, characteristically, individuals studied from census manuscripts have been understood primarily in terms of their relationship to their household's head, that is, as spouse, child, or parent, individual experience at the household level may be best understood as imbedded in a rich variety of relationships—for example, the child who is both the child of a lodger and by extension a dependent of a household head. Lutz Berkner's (1975: 734) remark that "family structure is not a thing, it is a set of relationships," is appropriate to the household as well. Community-level variables, such as "mean household size," attempt to summarize these sets of relationships, to characterize the household units that are comprised of certain clusters of relationships among individuals. The way that data on household boundaries are understood must obviously derive from the research questions asked. At the most aggregate level, "mean household size" can provide insight into the nature of basic census units. Researchers interested in going below this unit to a study of individual experience, might however, be more interested in asking, for example, What proportion of designated groups (children, workers, the middle class) lived in households of particular kinds at the time of the census? At an even more intensive level of examination of individual experience, they might wish to gather information on all household-level relationships (not just to household head) that individuals experienced, for example, as children of a head, brother or sister to a sibling, grandchild, and so on. Such analyses risk becoming extraordinarily complicated but will contribute to our understanding of the variety of relationships within the household.

Relationships among Individuals within Households

The disentangling and elucidation of relationships between individuals in census manuscript households is often difficult simply because an explicit description of them was not asked as part of the census itself. This is the case with all United States federal censuses before 1880. To be sure, even in premodern enumerations containing data on individuals, the order in which household members were listed, even without explicit designations of individual relationships, was not usually capricious. Heads of households were usually named and listed first, followed by spouses and children (if present), and only then such persons as collateral kin, employees, boarders, and lodgers. A wide variety of orders in which household members were indicated is obviously possible, depending upon the views of kinship statuses in particular societies. A study written in conjunction with the Philadelphia Social History Project (1976) demonstrates the way in which relatively high-quality census data on individuals used in comparison with information from an adjacent period can be employed to deduce relationships between household members when explicit information was not given (Miller, 1972). The logic and method of this study illustrate a means for working with census manuscripts that contain individual-level information, such as name, age, marital status, and occupation, but no explicit designation of relationships among individuals comprising the households.

Buffington Miller began with a sample of individuals (in this case, black Americans residing in households headed by blacks) from the manuscripts of the United States federal census of 1880 in which relationships to the household head were indicated. Initially, individual information, including sex, age, name, households (i.e., female, of a particular age distribution, with same name listing), was recorded (1972: 18). He then established a range of possible values that each of the variables of name, sex, and age could have. The name and sex variables were easily dichotomized: Either individuals had the same name as the household head or they did not; individuals were either female or male. Raw data on age (1–99) were included. It was then possible to tabulate the characteristics, for example, of individuals who were listed as wives of heads of households (i.e., female, of a particular age distribution, with same name characteristics as head, and so on). However, given that even the 1880 United States federal manuscripts did not include marital status, certain confusions could arise. Not all women listed after the household head who were of an age characteristic of wives and who shared the same name as the head were in fact wives. As the author notes,

> It is easy enough to tabulate the ages, etc. of all persons given a particular relationship and then say that persons of the given relationship generally fall into a certain age range . . . . But that is not to say that a person within that age range is likely to have the given relationship to the head of the household [1972: 27].

What was needed was a calculation of the statistical probabilities that individuals with certain characteristics were in fact in a particular relationship to the household head.

Results of this procedure suggested that the inference rules devised correctly predicted an individual's relationship to household head with varying degrees of accuracy when compared to the actual document. For example, correct identification of wives was possible in 97.4% of the cases, whereas only 60% of individuals who were actually sons of heads but who had a different name could be predicted as such. (It should be noted that there were 2234 sons in the sample who shared the same name as the head of the household and that they could be correctly identified in 96% of the cases, whereas there were only 173 sons who did not share the same name as the household head).

Having developed and tested rules for inference-making from the 1880 manuscripts, Miller could then go back to earlier censuses that lacked information on relationships among individuals and make reasonable judgments about them. For certain statuses, a 60% success rate may be unacceptable, and finer inference rules may have to be developed. However, the method and its logic are innovative and may be of tremendous usefulness for researchers dealing with household-level census data. Miller's effort rested on the existence of the 1880 census and on the assumptions (1972: 75) that neither age at marriage nor the age at which women began to bear children changed drastically between 1850 and 1880. In situations of rapid social change, such assumptions may be hazardous, but they can often be tested, for example, using vital registration data. If there are no censuses close in time to the one that is to be studied indicating the kind of information Miller used from the 1880 United States manuscripts, then there is no clear way to assess the predictive accuracy of the rules developed. However, even in such cases, when census manuscripts give information on age, name, marital status, occupation, and the like, different hypotheses about the age range between husbands and wives can be developed, and results from different sets of inference rules can be tested to get a least an approximate insight into patterns of household composition and the human relationships on which they were based.

Most modern censuses indicate a range of information on individuals as well as the rules given to enumerators for the order in which certain kinds of individuals were to be listed. Miller simply took partial data on individuals and attempted to predict systematically the probable relationships between them. Other valuable methods for inferring patterns of household composition from modern census data indicating numbers of households and aggregate information on the sex, age, or marital status of the population have been reviewed by W. L. Parish and M. Schwartz (1972) and Thomas Burch (1980).

Occupational Data from Census Records and the Analysis of Social Structure

Ambiguities in information about individuals or households gleaned from modern census manuscripts do not result purely from changing definitions of census units or missing information. It is quite apparent, too, that the constancy of certain category names, particularly occupational titles, may conceal the facts of basic transformations in local or regional economies and shifting significance of the job labels ascribed to individuals. The longer the period studied, and the more rapid the currents of socioeconomic transformation, the less comparable job titles will be over time. This obvious fact has been widely discussed, particularly among the large numbers of scholars interested in the study of occupational or social mobility—either within a generation or across generations (see Thernstrom, 1973: 220–261, for a discussion of this literature).

Many scholars would probably agree with the importance attributed by one observer to the occupational experience of an individual: It "indicates, with some degree of accuracy . . . the kind of associates he will have . . . the kind of clothes he will wear . . . the kind of house he will live in . . . the kind of food he will eat," and "the cultural level of his family" (cited in Conk, 1978: 118). Male occupational titles have been used widely as basic distinguishing characteristics of individuals, which, when used in conjunction with wage, income, or wealth data (usually of an aggregate kind), serve as the basis for describing the realities of systems of social stratification and individuals' passage from one socioeconomic group to another.

These subjects are of interest to Marxist and non-Marxist scholars alike, though the two groups differ greatly in their conceptualizations of the nature and causes of inequality, as well as the relationship between occupation and social class formations. The problem of using occupational data from census manuscripts to examine social structure is, however, similar for both types of scholars. In order to assess the possible importance of "class" or "socioeconomic status" in determining demographic behavior, household composition, or residential patterns of groups of individuals, researchers must construct some kind of classification system that gathers together empirical information on occupation, wealth, or income into several basic categories that reflect the structure of social inequality. Such a classification must be made prior to the analysis of possible relationships between occupational or class status, on the one hand, and demographic behavior or household types associated with the different groups. Marxist historians, such as Edward Thompson, have rejected typologies of socioeconomic groupings which ignore the historical and political dimensions of social class formations (1963: 9–12). Writing from a different perspective, Stephan Thernstrom, in his *Poverty and Progress* (1964: 225–239), has criticized Lloyd Warner's "ahistorical method of conceptualizing and observing social class [1964: 235]." Census information on occupation may be helpful for documenting broad, sectoral changes in local economies over time. However, it is insufficient by itself for understanding the individual or group experiences of occupation or the way in which different occupations should be aggregated in order to study the possible relationships between socioeconomic and demographic conditions.

Census manuscripts are likely to underestimate levels of employment among married women and children, whose wages were historically important components of household economies and determinants of living standards. Furthermore, they may fail to capture the "casual" nature of much employment, and levels of unemployment in general (see Sennett, 1970: 241–243; Thernstrom, 1973: 300, on the use of unemployment information from the United States federal censuses). Published summaries of employment categories that accompany individual censuses may leave a great deal to be desired for social historians or historical demographers interested in relating occupational data to the socioeconomic system as a whole. Margo Conk (1978: 116) has offered such an example, from the United States federal census of 1940, in which a gas station proprietor shared a place in the same occupational category with the president of Standard Oil Company. These and similar kinds of examples could be used to demonstrate that much of the work of grouping occupational titles into meaningful categories will have to be done by individual researchers themselves. Once a body of literature has begun to be published using a specific classificatory scheme, for example, (W. A. Armstrong, 1972: 191–310), other scholars may follow suit in order to make the results of their research comparable. It is quite possible, however, that given the regional specificity of economies in the nineteenth century, classification schemes that fail to take into account local wealth distributions, unemployment levels, or political development may sacrifice a good bit of historical reality in the effort to achieve comparability of analytical categories.

One of the more interesting results of research using census data on the occupations of individuals has been the attention paid to changes in occupation or socioeconomic status through individuals' life cycles. Census records on identifiable individuals can be used, usually in conjunction with city directories, to trace the longitudinal history of sample individuals in order to investigate characteristic career patterns or rates of social and/or geographical mobility through time. Although individual case studies vary, they have tended to be based on techniques that begin with a sample of heads of households or employed males at one point in time drawn from the census manuscripts that contain information such as age, nativity status (i.e., foreign or native born), occupation, or specific place of residence (for intraurban studies of physical mobility, such as Chudacoff, 1972), then attempt to see how many of these original individuals can be traced as living and working in the same place usually a decade later, using the city directories.

The research goals and nature of the sources used, as well as the fact that males are more likely to be employed than females, have dictated the study groups chosen. Those working with pre-1850 federal United States manuscripts are forced to study household heads because these individuals were the only persons whose names were actually recorded. Thernstrom (1973: 222), reviewing a number of geographical-mobility studies, demonstrates the general comparability of persistence ratios (the proportion of the original sample) in United States cities over 10-year periods throughout the nineteenth and into the twentieth centuries. Nearly one-half of the studies cited in Thernstrom (1973: 222) for the period 1800–1890 traced the mobility of men who were already household heads at the time the study began, a fact that has elicited some criticism (Knights, 1971: 10).

In studies of both geographical and occupational mobility, however, considerations of the age dimension are singularly lacking. That is, the occupational or geographical mobility of individuals (adult males, household heads, employed males) is generally studied by using aggregates of men in different occupational or socioeconomic groups with little regard for their age when they entered observation. The age structure of different subgroups within samples is sometimes given (Hopkins, 1968), but, excluding studies in which attrition by death is considered (Kirk and Kirk, 1973–1974) often in only summary fashion, there has been insufficient attention to the possible demographic causes of either occupational or geographical mobility. Occupation, nativity, and occupation of fathers have been used as predictors of geographical or occupational mobility, but rarely are considerations such as the age structures of occupational groups, differences between ethnic groups' age structures, or changes in the age structures of these groups considered as possible determinants of mobility patterns. This is not to say that age is the best predictor of the propensity to rise or fall in the occupational scale, or to stay or leave a place of residence—occupation, race, and nativity status may be the most important attributes of an individual in understanding or merely predicting his or her life course through time. Thernstrom's critique (1973: 336–337, note 7) of studies that fail to incorporate age data into the delineation of wealth groups—in other words, to distinguish between the cross-sectional characteristic of an aggregate group at one point in time and the propensity of some of that group's members (particularly the young) to rise out of it in the course of their lives—might be extended to much of the mobility literature in general.

Although age may be found to be a much less powerful predictor of geographical mobility than characteristics already investigated, there seems little reason not to explore this dimension. Increasing or decreasing rates of different kinds of mobility, social or occupational, may be in some measure the result of the fact that the age structure of different sample groups (heads of household, for example) tended to shift through time. (For a critique of one analysis that gave a great deal of emphasis to the age dimension of wealth holding, see Pessen, 1979). As Thernstrom points out, the dynamic of age needs to be reinjected into studies that attempt to build longitudinal information out of what are essentially cross-sectional data.

Census Data and the Study of Fertility

One of the ways in which age distributions of different study groups may be incorporated into investigations of their behavior from census manuscripts on households is illustrated in Tamara Hareven's and Maris Vinovskis's (1978) study of fertility ratios. The ratio of children, ages 0–5, to 1000 married women, aged 20–49 with husbands present, is used as an indicator of current marital fertility at the household level. As the authors note, such an index is affected by a number of factors, including child mortality, child-rearing practices (including the possibility of children being raised outside their parents' home), and, importantly, the age structure of the group of married women on whom the index is based. For example, if it is found that the child–woman ratio of native-born women at one point in time is lower than that for a group of foreign-born women, this may be the result of the fact that the age distribution of native-born women is simply weighted more heavily toward women in the older age categories. (It may also be the result of the differentials between child mortality and child-rearing practices). If these latter kinds of variables can be controlled for, and ethnic or regional variations in mortality patterns or child-rearing practices investigated to determine their relative weight, then the child–woman ratio, as constructed by Hareven and Vinovskis, offers the possibility of investigating current marital fertility across selected subgroups within a census population.

This index is far from being perfect. However the construction of a "completed fertility ratio"—"the number of children the average women can expect to have during her lifetime if current fertility were to persist throughout her reproductive years [1978: 94]"—is perhaps less trustworthy, particularly in a period of demographic change, unless the age groups of women in different ethnic categories were equally affected by the forces that may have caused them to alter their fertility. Even though the age distribution of different groups of mothers is standardized, if the youngest cohorts of, say, native-born women began to change their fertility behavior at the time of a census, this effect would not radically influence the current child–woman ratio established from one census. However, if they persisted in their fertility-reduction behavior during the course of their reproductive lives, their completed family size might deviate sharply from the predicted "completed fertility ratio." The use of the child–woman ratio seems most warranted when researchers are interested in a relatively short period surrounding the taking of a census and have good information on the kinds of social influences that may have affected mortality and household formation during the period studied.

Enumerations and censuses are some of the most socially inclusive of all documents available for historical demographic analysis. Their requirements for inclusion of individuals—physical presence—were often minimal. Their propensity to undercount the poorest, or mobile, members of a community has not been a historical constant, particularly if the counts were designed in part to assess the number of those individuals with legitimate claims on the community's financial resources.

Another great strength of census-type materials is their appropriateness for the analysis of general conditions prevailing at a specific point in time. The desire to create a longitudinal portrait of individuals' lives from census manuscripts is understandable, particularly for the study of societies that lack good vital registration records. However, the tracing of specific individuals across censuses too often founders on the phenomenon of migration. One of the ablest researchers using nineteenth-century census documents has voiced an extremely pessimistic note on this issue: "If a significant section of the population moves out of the community under study and cannot be traced, then any analysis derived only from data of those who remain, however technically sophisticated it may be, is worthless [Anderson, 1979: 78]." Though more inclusive than many of the sources used previously to examine popular life in the past, censuses, too, have their weaknesses. Studying relationships among family, household and work, for example, requires combining census-type materials with other sources of information on the individuals or groups whose lives were recorded at one or more points in time in enumeration or census documents.

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5
Genealogies and Population Registers

Genealogies and population registers are two kinds of sources valued particularly for their usefulness in studying the history of individuals, families, or entire communities across long periods of time. In this chapter, we will first discuss the use of genealogies in general terms and then describe several complex types of genealogies. We then turn to population registers, sources that incorporate some of the characteristics of both genealogies and censuses. They are considered here because of their unique value for the longitudinal analysis of spatially defined, genealogical-type populations.

The formulation of oral or written genealogies is one of the most pervasive ways that individuals or entire communities of human beings have sought to define themselves by welding historical links with other, named individuals who came before them. Unlike other sources for historical demography, genealogies have apparently existed in nearly all types of societies, from hunting–gathering to modern industrial. As one scholar has reminded us, "Every real community, like every real society, is a process in time [Edmund Leach, cited in Hackenberg, 1973: 310]." What might be termed a "genealogical imperative"—a human desire to invent, describe, or clarify links to ancestors— is one measure of the importance of this time dimension for human beings' efforts at self-definition. Edward Gibbon captured this spirit eloquently:

> A lively desire of knowing and of recording our ancestors so generally prevails that it must depend on the influence of some common principle in the minds of men. We seem to have lived in the persons of our forefathers; it is the labor and reward of vanity to extend the term of this ideal longevity. Our imagination is always active to enlarge the narrow circle in which nature has confined us. Fifty or a hundred years may be allotted to an individual; but we stretch forward beyond death with such hopes as religion and philosophy will suggest, and we fill up the silent vacancy that precedes our birth by associating ourselves to the authors of our existence [cited in Kent, 1977: ii].

Genealogies have no existence apart from a desire for historical affiliation and must be formulated by living individuals or communities. The compilation of a genealogy may be not only the expression of an already-existing sense of community with ancestors or other members of one's lineage but may also serve to enhance conscious affinity or concrete bonds based on common descent (Meskill, 1970: 141).

The current relative lack of attention to genealogies as sources for historical demographic studies may be the result of several factors. First is the great deal of work recently focused on the importance of household composition, or the residential aspect of family life. Although social definitions of lineage and rules of descendance are extraordinarily important for understanding patterns of property inheritance (Le Roy Ladurie, 1976; Goody, *et al.*, 1976; Lamaison, 1979), concern for documenting the nuclear or extended composition of households has tended to direct attention away from sources, such as genealogies, that are inappropriate for the study of coresidence. Secondly, though large collections of genealogies of ordinary people in modern societies do exist (Henripin, 1954; Charbonneau and Roy, 1976; Skolnick *et al.*, 1978; Mineau *et al.*, 1979), written genealogies have historically tended to be limited to the privileged, affluent, or powerful members of society. The current concern of social historians to study the lives of the majority or masses of people in societies, both ancient and modern, has led them to more socially inclusive kinds of source materials. While it is important to be aware of some of the limitations of genealogies as sources for historical demographic studies, it is also appropriate to signal some of their special strengths.

In general, the usefulness of genealogies lies in their longitudinal expanse through time, often within societies for which there are no other sources of demographic information. Genealogies ideally give us information on named individuals as they passed through the vital events of their lives, revealing links between individuals and generations that were both biological and social. For population geneticists, well-kept genealogies can provide one of the primary sources for the study of the hereditary dimensions of certain diseases (Chaventré, 1976). For social anthropologists or ethnographers, genealogies may be valuable for the insight they offer into the existence of marriage rules and the degree to which such rules are actually obeyed (Yengoyan, 1970: 88) or for purposes of comparison with other demographic data (Morrill and Dyke, 1980). In general, written genealogies provide already-reconstituted families, or couples, thus obviating the time-consuming task of linking events to individuals and individuals to one another.

Types of Genealogies

Though any genealogy documents the vital events occurring to members of a common lineage, there are several special types of complex genealogies that incorporate information on a number of lineages selected according to various criteria. One type of complex genealogy might be termed a "corporate" genealogy—one that contains information on a number of lineages whose members shared a similar social position, hereditary office, or political status. Into this category we would place the sources of Henry's work on the Genevan bourgeoisie (1956), Hollingsworth (1964) on the British peerage, or R. Burr Litchfield (1969) on the patrician families of Florence. A second type includes the German village or local genealogies (*Ortssippenbücher, Dorfsippenbücher*) which contain demographic information on the members of different lineages whose vital events occurred within a common territory. The spatial, as well as longitudinal, dimension of these latter sources make them extremely valuable for historical demographic analysis (Houdaille, 1970a, 1970b; Knodel and Shorter, 1976).

Some General Problems of Genealogical Sources

Genealogies are usually one step further removed from the occurrence of the vital events they document than are parish registers or civil registration records. Henry (1956: x) has thus referred to them as "intermediary" documents. The compilation of a genealogy often occurs decades or hundreds of years after the events they record, and may entail the passage of either oral or written information through the memories or hands of many individuals. Resulting as they do from the human desire to clarify or establish links with the past, genealogies may contain a great deal of wishful thinking or downright falsification. This is especially the case where the rewards to be expected from the establishment of certain links were high, and where there are no other sources of information against which the accuracy of the genealogy may be checked. When entry into political office or honorific societies, or eligibility for inheritance were the inspirations for originating genealogical inquiries, suspicion about the accuracy of the results may be aroused. Human vanity or greed may, of course, work in the opposite direction. Whole categories of scoundrels may have been systematically eliminated from certain family genealogies. In the case of the Ming/Qing Chinese genealogies used by Stevan Harrell (1981), for example, this group included, among others, sons who did not marry, illegitimate sons, and men who became monks. Each family or society has had its own notion of those ancestors or collateral kin whose existence is best forgotten, though undoubtedly genealogists vary widely in the level of censorship they have imposed on their sources (Adams and Kasakoff, 1980).

For historical demographers, omissions of all kinds will in general pose more problems than fictitious links. As Henry has noted (1956:16–17), this is in part a result of the fact that genealogists and historical demographers often have different goals. Although family members or genealogists who compiled source materials have generally been concerned to attach specific people to their historic roots, historical demographers wish to begin from well-documented ancestors and trace, as far as possible, *all* the descendants of the ancestors in question. The omission or underrepresentation of other groups besides "scoundrels" is a problem endemic to genealogies. Genealogies were often designed to emphasize not only the glorious aspects of a lineage's past but also its durability through time. Consequently, members who contributed little to the group's duration were likely to be missing or underrepresented. This category might include individuals who did not reach maturity and those who survived but had no children, or who had children who themselves died at young ages or failed to reproduce. In other words, the likelihood of being included in a genealogy is positively correlated with the number of direct descendants the individual produced. Though currently we tend to think of a "normal" life cycle as the passage from birth to young adulthood, to marriage, childbearing, and death, recent scholarship has shown that in the past such a life course was not necessarily the norm (see Tables 5.1 and 5.2).

Thus, it is quite likely that all but the most complete genealogies will tend to be biased toward the most fertile couples, those whose children experienced the lowest rates of infant and child mortality and the highest rates of nuptiality. Looking at the reproductive and survival behavior of the most genetically "fit" people will not bias the results of population-genetics research based on genealogies but will certainly bias upward rates of survival, marriage, or growth if the experience of those who survived to maturity, married, and had surviving children is generalized without qualification to an entire cohort, region, or nation as a whole.

With the notable exception of the German *Ortssippenbücher*, nearly all genealogies studied in the published literature contain more complete information on males than on females. Women are usually "imports" into the genealogy of a male-based lineage. Thus, we tend to know more about females as wives or mothers than as daughters. In certain instances, such as the commoner husbands of daughters of British peers (Hollingsworth, 1964: 73), it was the males who were the "imports," and information on their births and ages of marriage or death is less complete than that for the women they married, who were "born into" the genealogy. Concerned as they often were with the

Table 5.1
Life Course of One Hundred Hypothetical Rural Women, Ancien Régime France

Event	Number of women experiencing event
Birth	100
Survival to age 1	75–80
Survival to age 25	50–60
Marriage	40
Childbirth	35

Source: Dupâquier, 1974.

Table 5.2
Life Course of One Hundred Native-Born Massachusetts Women, by Cohort of Birth

	Number of women experiencing event, by cohort				
Event	1830	1850	1870	1890	1920
Birth	100	100	100	100	100
Survival to age 20	64	69	69	74	89
Marriage	52	54	51	56	79
Childbirth within marriage	42	44	40	44	70

Source: Adapted from Uhlenberg, 1969. For a critique of the mortality estimates on which this is based, see Vinovskis, 1978.

persistence of family names through time, genealogies that were created within societies where women changed their names at the time of marriage, or where children were routinely given their father's surname alone, do tend to devote less attention to female descendants of females. As one genealogist explained, "He 'had nowhere attempted to trace the descendants of female lines because that would have greatly added to the bulk of the work without much increasing its interest' [cited in Bosworth, 1978: 179]."

Assessing the Quality of Genealogical Sources

As Hollingsworth (1964: 8) has written, genealogical data lend themselves quite naturally to cohort analysis (Glenn, 1977). The evaluation of the quality of genealogical data, in fact, usually begins from the assignment of individuals to cohorts—groups that experienced the same vital event, usually birth or marriage, at approximately the same point in time. The way cohorts are defined depends most obviously on the number of individual records available and often on the completeness of information on individuals' vital events. With very large data sets, cohorts may be only 10 years in length, or even less, since there are adequate cases to derive meaningful results for each. The more narrowly the cohorts are defined, however, the greater are the problems of assigning individuals to them. For example, if the dates of marriage for a large proportion of individuals in the genealogical population can be estimated only to within 10 or 15 years, it makes little sense to try to establish marriage cohorts of 25 years in length for the analysis of a phenomenon for which data are not very accurate. Thus, cohorts of 50 years or even more may have to be used if there is a small number of cases and/or the dates of vital events are known only approximately.

When there is substantial variation in the number of events recorded for different periods of time covered by the genealogy, there is a temptation to construct cohorts of varying lengths in order to equalize the number of cases analyzed for each. One of the problems with this strategy, however, is that it may tend to give more relative weight to short-term "period" effects for the shorter cohorts, as illustrated in Figure 5.1. For example, the construction of a marriage cohort of 1670–1680 from hypothetical data illustrated in Figure 5.1, whose characteristics are then compared to those of 50-year cohorts,will tend to overemphasize the importance of the short-term conditions (e.g., recovery from a crisis, the return of soldiers from a war) that led to an abnormally high number of marriages during this short-term period. Arguing for the comparison of cohorts of equal length is not to deny the frequent, historical importance of short-term conditions to a specific cohort's life experience but is only to urge that the larger picture of the genealogy members' experience be sought out first, with the size of cohorts held constant, before breaking them down (when possible) into more narrowly defined groups. The shorter the length of the cohort interval, the easier it is to isolate the timing of possible changes in demographic behavior. However, the quantity and qualities of the data often preclude any but the broadest definition.

Evaluating the quality of genealogies of any type for historical demographic analysis usually entails considerations of the plausibility of demographic patterns they reflect and, where possible, a comparison of at least a sample of the genealogical records with the sources from which the genealogy was compiled. In a most systematic critique, John Knodel and Edward Shorter (1976) have carried out both "internal" and "external" checks on the quality of a sample of the German *Ortssippenbücher* they studied, which were drawn primarily from the regions of Baden and Hesse. Their "internal checks" entailed an examination both of the local parish registers from which the *Ortssippenbücher* had been compiled and of the data contained in the books themselves. They found that the German parish registers contained some notable lapses of recording of 10 years or more but that these "gaps" tended to diminish to insignificance after 1750–1800. Information on individuals available from the parish registers, however, was as extensive, if not more extensive, than individual data in the French parish registers for the same period.

In order to assess the plausibility of the demographic data contained in the *Ortssippenbücher* themselves, they compared several indicators to the results of parish reconstitution studies and to German data from a later period. Since infant deaths and illegitimate births are among the most likely of vital events to be missing from genealogies, they devoted special attention to these phenomena. One of their tests for the completeness of data on infant deaths was to calculate the proportion of all infant deaths occurring in the first month of life, in order to compare their findings with comparable, later figures. Second, they found confirmation in the genealogical data of their expectation that rates of infant mortality would be higher among illegitimate than legitimate children. Other tests included a comparison of illegitimacy ratios for selected villages with later regional data, calculations of rates of childlessness among couples

Figure 5.1. *Series of marriages per year from a hypothetical genealogy.*

indicated in the *Ortssippenbücher*, and the comparison of birth intervals with findings from other studies.

Knodel and Shorter then undertook several "external" checks on the quality of the transcription process and on the way in which the original genealogist had "reconstituted" families from the parish registers. Working on a sample of villages and individual families, the authors were able to show a conscientious transcription of all types of vital events on the part of the compiler and a very small degree of discrepancy between the family reconstitution work of the compiler and their own, independent reconstitution. Disagreements on this score often stemmed from ambiguities in the raw, parish register data themselves.

In many cases, external checks on the accuracy and completeness of the vital events indicated in genealogies will be impossible, since it was the absence of vital registration records that initially led to the choice of genealogical sources in the first place. In these cases, only "internal" checks on the completeness and reliability of the data are possible.

Dealing with Partial or Incomplete Data on Individuals

The availability of only partial or approximate data on the occurrence or timing of vital events among individuals is one of the pervasive problems of working with genealogical sources. Exact dates (day, month, year) of vital events may be missing, or individuals with relatively precise data on birth and death, for example, may be missing information on the birth dates of their children. If all those whose data are partial or only approximate are eliminated from consideration, the number of cases available for study may be sharply reduced. Furthermore, if there was a systematic relationship between the demographic experience of various subgroups within the genealogical population and the relative completeness of their records, then excluding individuals with only partial information may bias the results of the analysis. For example, if there was a positive correlation between having only an approximate date of birth recorded and dying as a child—a not unreasonable association to hypothesize—then eliminating from the analysis of mortality all those who have only exact birth and death dates would seriously bias downward estimates of the level of child mortality and of mortality in general (Henry, 1956: 143).

Certain studies based primarily on genealogical sources have been supplemented with other information that may help researchers to narrow the range of years during which the vital event in question may be estimated to have occurred. Mentions of persons still alive at a date after their last mention in the genealogical records, may, for example, serve as the basis for making more refined estimates of dates of death (Henry, 1956: 145).

An extensive and varied repertoire of efforts to correct for the incompleteness of vital-event data for individuals of a genealogical population has been included in Hollingsworth's work on the British peerage (1964: apps. 1–3, 8). More recently, G. P. Mineau *et al.*, (1979: 432) have carried out estimates of marriage dates for those women in their genealogical population who lacked marriage dates by "setting the approximate age of marriage equal to the age at birth of the first child minus the average interval between marriage and first birth," calculated from the experience of those cohort members for whom age at marriage and age at birth of the first child were available. Estimations of dates of birth for children whose data were incomplete were made on the basis of a knowledge of the length of birth intervals. In extremely large populations, there may be no reason to expect the introduction of biases using such strategies if the proportion of genealogy members lacking complete data is relatively small. The smaller the population and the larger the proportion of individuals with very incomplete information, the greater is the possibility of producing biased results if the experience of those with incomplete information deviated significantly from that of the individuals whose data are complete.

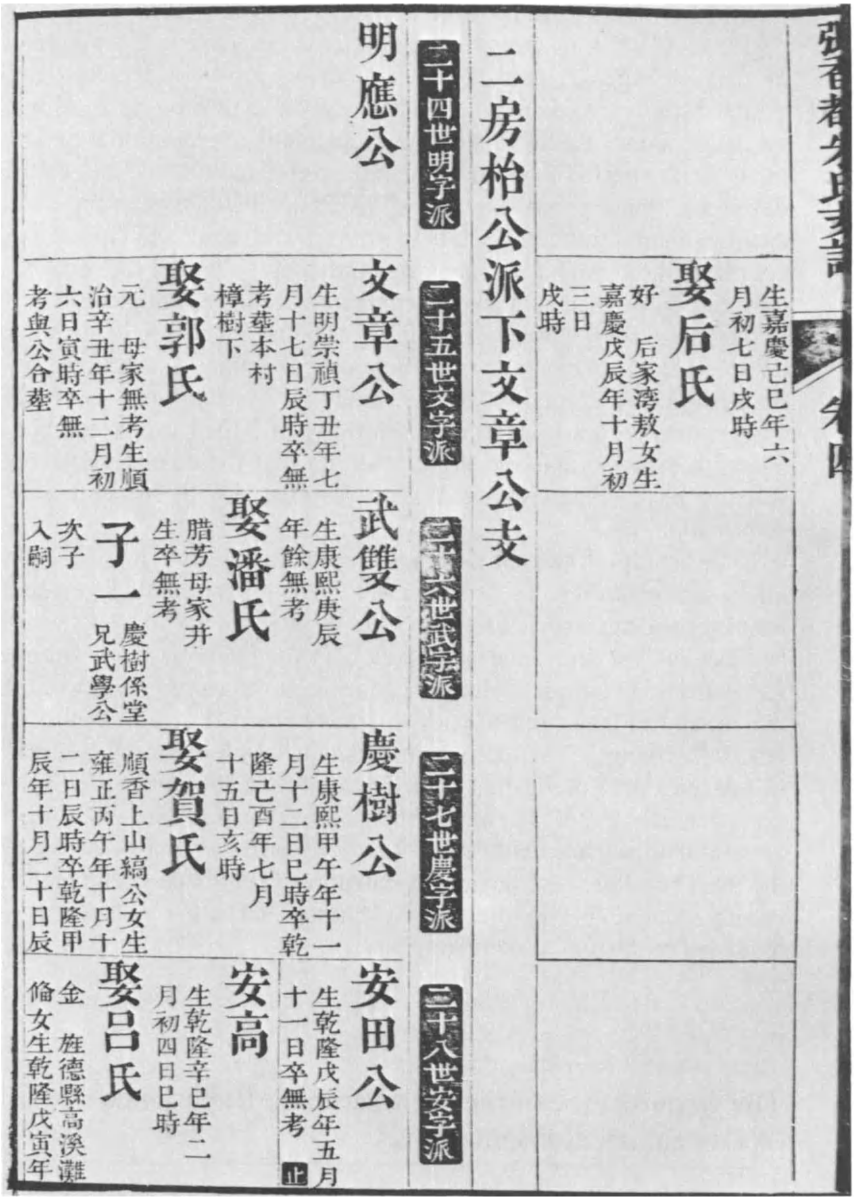
Modern European and North American genealogies contain relatively complete information on vital events, compared with many of the Asian sources that are beginning to be used for historical demographic purposes (see Figure 5.2). Chinese genealogies, from the Sung to the Qing dynasties, are often extraordinary in their longitudinal expanse, with some lineages under observation for 500 years or more. Characteristically, the quality of the information improves over time. However, these sources are often impossible to exploit using standard demographic techniques. Lineages may very often be traced through the male line alone, and in most instances they lack data on the birth dates of women marrying into the lineage as well as birth dates of female children. Male and female children are usually listed separately, so that only birth order by each sex alone can be calculated. Data on dates of marriage are frequently missing, so that it is impossible to assess rates of fertility by women's age.

Harrell (1981), in studying the relationships between the wealth of segments of Chinese lineages and their tendency to grow or decline, has sought to establish period measures of relative growth over time by looking at the data on males alone. Rather than simply calculating generational rates of replacement for the period from the sixteenth to the mid-nineteenth centuries, he has devised a "male population index" (MPI), which assesses the relative size of each segment at different points in time. Harrell begins to calculate his MPI by counting the number of men demonstrably alive at a certain date from information on their vital events contained in the genealogical record, and adds to this figure the life table probabilities of being alive at that date for men lacking complete data. Those men migrating away from the geographical origins of the lineages are excluded from the analysis. Assumptions on which such a measurement rests include the uniformity of biases in the compilation of the genealogies over time and the probability that the chance of survival for men missing death dates was the same as that for those men with complete information.

In her study of several Taiwanese genealogies covering the eighteenth and nineteenth centuries, Ts'ui-Jung Liu (1978) has attempted to calculate age at marriage and age-specific fertility rates through the use of a proxy variable—age at birth of first son—and estimates of birth intervals from European parish reconstitution studies. Unlike the genealogies explored by Harrell, Liu's data, like many European genealogies, did make mention of individuals of the lineage who "died young," so that rough estimates of child mortality could be made. Given the nature of the data in the Chinese genealogies already explored, which are so much better for males than females, strategies entailing the use of generational replacement rates for males, and/or *their* fertility by age, may be the most sensible—the obvious disadvantage being that such results will not be readily comparable to the fertility findings for other non-Asian populations analyzed by historical demographers.

The Significance of the Demographic Experience of Genealogical Populations

One of the potential problems of interpreting the demographic results of the analysis of genealogical populations is that the characteristic(s) that originally defined the population under observation may tend to be diluted over time. This is particularly the case with very complete sources whose compilers have succeeded in tracing descendants of a lineage over wide territories.



二房柏公派下文章公支

二十四世明字派

明應公

二十五世文字派

文章公

生明崇禎丁丑年七月十七日辰時卒無考葬本村樟樹下

娶郭氏

元　母家無考生順治辛丑年十二月初六日寅時卒無考與公合葬

二十六世武字派

武雙公

生康熙庚辰年餘無考

娶潘氏

腊芳母家并生卒無考

子一

慶樹係堂兄武學公次子入嗣

二十七世慶字派

慶樹公

生康熙甲午年十一月十二日巳時卒乾隆己酉年七月十五日亥時

娶賀氏

順香上山縞公女生雍正丙午年十月十二日辰時卒乾隆甲辰年十月二十日辰

二十八世安字派

安田公

生乾隆戊辰年五月十一日卒無考 止

安高

生乾隆辛巳年二月初四日巳時

娶呂氏

金　旌德縣高溪灘倫女生乾隆戊寅年

生嘉慶己巳年六月初七日戌時

娶后氏

好　后家湾敖女生嘉慶戊辰年十月初三日戌時

Figure 5.2. *Chinese clan genealogy, Sung Dynasty (960–1278 A.D.).*

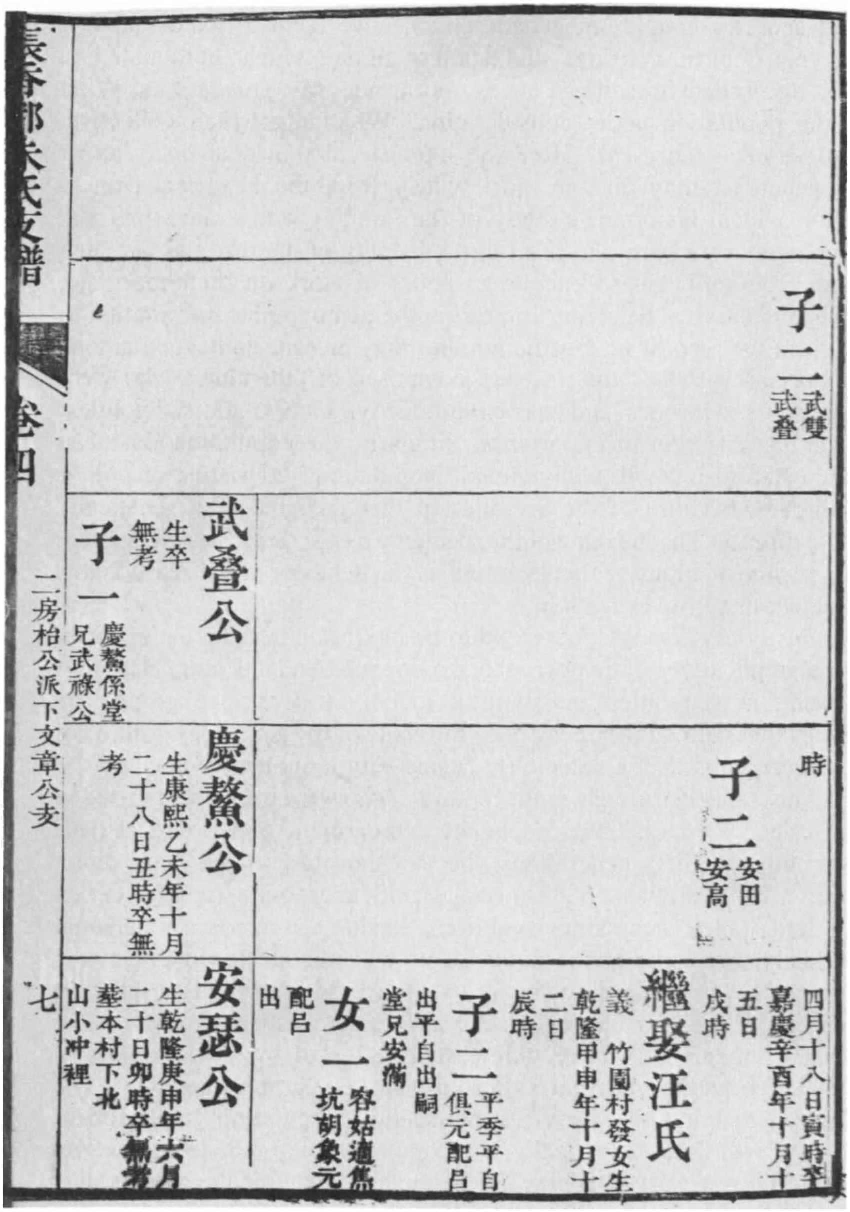


Figure 5.2. *(continued)*

An example may clarify this point. Assume that from a number of completely documented ancestor couples in generation one, we have in hand the day, month, and year of birth, marriage, and death of all individuals, both male and female, who descended from those ancestors through five generations. What exactly is the population under consideration? What might their collective, historical experience represent? Here the interests of the local historian or population geneticist may diverge most widely from the historical demographer's. For a local historian, a study of the families whose ancestors and some descendants were born and lived in the locality of interest and did such and such may be sufficient to encourage hours of work on their marriage, reproductive, and survival behavior. Interest in the demographic information to be gleaned from the records of specific families may be especially keen among political historians if those families were composed of individuals who were heirs or pretenders to thrones, and whose reproductive success affected political events of the highest order of importance. Similarly, the population geneticist may be interested in a small, well-defined "population" consisting of one or several pedigrees, because of the presence in that pedigree of a genetically transmissible disease. The meaning of that pedigree's experience is well defined: It is the experience of a lineage that exemplifies the behavior of a disease that is itself the subject under investigation.

However, historical demographers tend to be interested in the broader social and historical implications of demographic experience. And it is quite clear that even beginning in generation one with a socially well-defined group, the characteristics that defined the ancestors—the roots of the genealogy—may not define the descendants. If the researcher begins with a number of ancestors—say, Swedish peasants in the eighteenth century—who were born and married in one circumscribed area, and then traces the demographic experience of their descendants through five generations, he or she may come into direct confrontation with a problem of historical significance quite rapidly. Given systems of inheritance, economic conditions, health conditions, or personal taste, it is likely that some of the descendants will migrate to other regions; migrate to small towns, to large towns, or to the United States; adopt different occupations; and so on. If the lineage itself survives across many generations, it is likely that its members will be differentially affected by a whole host of historical experiences that may have affected their demographic behavior. The characteristic(s) that initially served to define the "population" will tend to become diluted with time. Genetically, the population may remain distinctive, but socially and historically, this may not be the case. Among the descendants of Racine discussed by Houdaille (1971:953), for example, were a traveling salesman, several professors, and a rural gendarme, where once there had been only hauts-bourgeois and nobles. This is hardly surprising. One need not hypothesize the existence of a wide-open "rags-to-riches" society to see that the descendants of common ancestors may share little but genetic inheritance. Scholars working with large, corporate genealogies, where a socially distinct title or status was passed on from generation to generation, may not be bothered by such a question of significance, since the original characteristic defining the population under observation is held constant through time. Similarly, the exclusion of descendants lost to migration reinforces the spatial dimension of the analysis, facilitating the examination of the independent effect of other characteristics on demographic behavior.

Population Registers

Population registers combine some of the characteristics of both genealogies and censuses. Like censuses, they contain information on a spatially defined population at risk to experience vital events. However, at the same time they document the occurrence of those events to named individuals and families. Of the two kinds of population registers to be discussed here, both give information on individuals by households. A record containing data on household members served as the basis; and the occurrence of a vital event to any household member was either systematically noted by the recorder or, in some cases, must be inferred from changes in household membership or annotations in the register. Thus, these registers provide a longitudinal picture of individual, household, and community experience through time.

Among population registers, there appear to be two main types. The first includes population registers such as the *shūmon aratamē chō* of Tokugawa, Japan (c. 1600–1868), which are more like yearly censuses from which the occurrence of vital events may in many cases have to be inferred. The second type, composed of European registers, was designed actually to register the occurrence of vital events to each member of the household at the time that the event took place (see Figures 5.3 and 5.4). Scholars working with the Tokugawa records often have no way to gauge the quality or completeness of vital event registration in the *shūmon aratamē chō* records by comparing them with other sources and must assess the quality of the data by checking for internal consistency. Exceptions to this rule, however, have been demonstrated. Thomas Smith *et al.* (1977: 15, 18) have shown the usefulness of vital event registers and registers of servants in checking and supplementing information in the *shūmon aratamē chō*. Susan Hanley and Kozo Yamamura (1977: 146–151) have used a variety of feudal domain and tax records to check at least the aggregate population figures given by local *shūmon aratamē chō* listings. However, scholars working on the European registers appear to have some advantage over their colleagues working with such Asian records. All of the European registers so far studied have existed in societies that had parish registers or civil registration records with which data in the population registers might be checked, by the same methods used by Knodel and Shorter (1976) for the German *Ortssippenbücher*.

Figure 5.3. *Japanese Shūmon-chō, late eighteenth century.*

The Japanese population registers, whose name literally means 'Registers of the Investigation of Religious Sects' (Robert J. Smith, 1972: 431), were, as the name implies, designed in large part to help document religious affiliation during a period when the Japanese central government was attempting to eradicate Christianity from the land. Originating in the early to mid-seventeenth century, they became nationwide by about 1670 (Hayami, 1969: 619). The households of Japanese commoners, who comprised over 90% of the total population, were obliged each year to declare their (Buddhist) temple affiliation to local secular officials and/or temple priests who were ordered to keep records of these declarations and often to swear to the accuracy of the information contained in them. The exact contents and the timing of the adoption of this system of population registration varied by region. However, in general, the kinds of information contained in the *shūmon aratamē chō* consist of: the names, ages, and relationships of household members to the head, certain "personal categories" such as servants, and annotations on the incidence of in- or out-migration. In many cases, widows and married women are listed only by the name of their husbands (Thomas Smith *et al.*, 1977: 16; Hanley and Yamamura, 1977: 42). Like the *Ortssippenbücher*, many *shūmon aratamē chō* give additional information on the community under observation. Those registers examined by Hanley and Yamamura (1977: 42), for example, contain information on the amount of land held by the village, the number of houses, and total population of human beings and animals.

The basic unit of observation was the household, and records were kept for villages within feudal domains or within small administrative units of larger cities. However, several scholars have pointed out certain points of ambiguity on this score. Individual villages may have been dependencies of more than one domain—resulting in the dispersal of their records. Even within individual households, adult members could be affiliated with different temples, so that in order to study the whole population of a particular rural or urban community, records from a number of temples must be pieced together (Hayami and Uchida, 1972: 474). Though in principle, the *shūmon aratamē chō* were updated yearly, all series studied so far contain gaps, only some of which may be compensated for with the consultation of other records. Hanley (1968: 623) has argued that the *shūmon aratamē chō* were higher in quality during their earliest period of existence, declining in completeness gradually with the success of the anti-Christian campaign that had originally inspired their implementation.

Among the second type of population register, the earliest and best-known are the Swedish *husförhörslängd*, translated as 'General Parish Register' (Eriksson and Rogers, 1973: 60), 'Church Examination Registers' (Demografiska Databasen, n.d.: 1), or 'Catechetical Examination Record.' This type of document also had its origins in the seventeenth century, in the struggle to enforce Lutheran orthodoxy. They were originally designed to test adults' knowledge of the Lutheran catechism but gradually from the late seventeenth to early eighteenth centuries came to include children and to give a wide range of demographically interesting information on all members of Swedish households. By the eighteenth century, when the form of the registers had become more standardized throughout the country, this information included: names of all members of the households of each parish, relationships of household members to heads, dates and places of each individual's birth, records of inoculations, levels of catechetical mastery and communion, dates of marriage, whether the person was widowed or not, the parish of in- or out-migration, and comments about physical disabilities and reprehensible mores, including drunkenness and adultery as well as higher crimes (Eriksson and Rogers, 1973; Kälvemark, 1979: 223–226). Extracts from these registers served as the bases for Swedish censuses, which were taken every 3 years in the late eighteenth century and every 5 years from 1800 to 1860 (Demografiska Databasen, n.d.: 2).

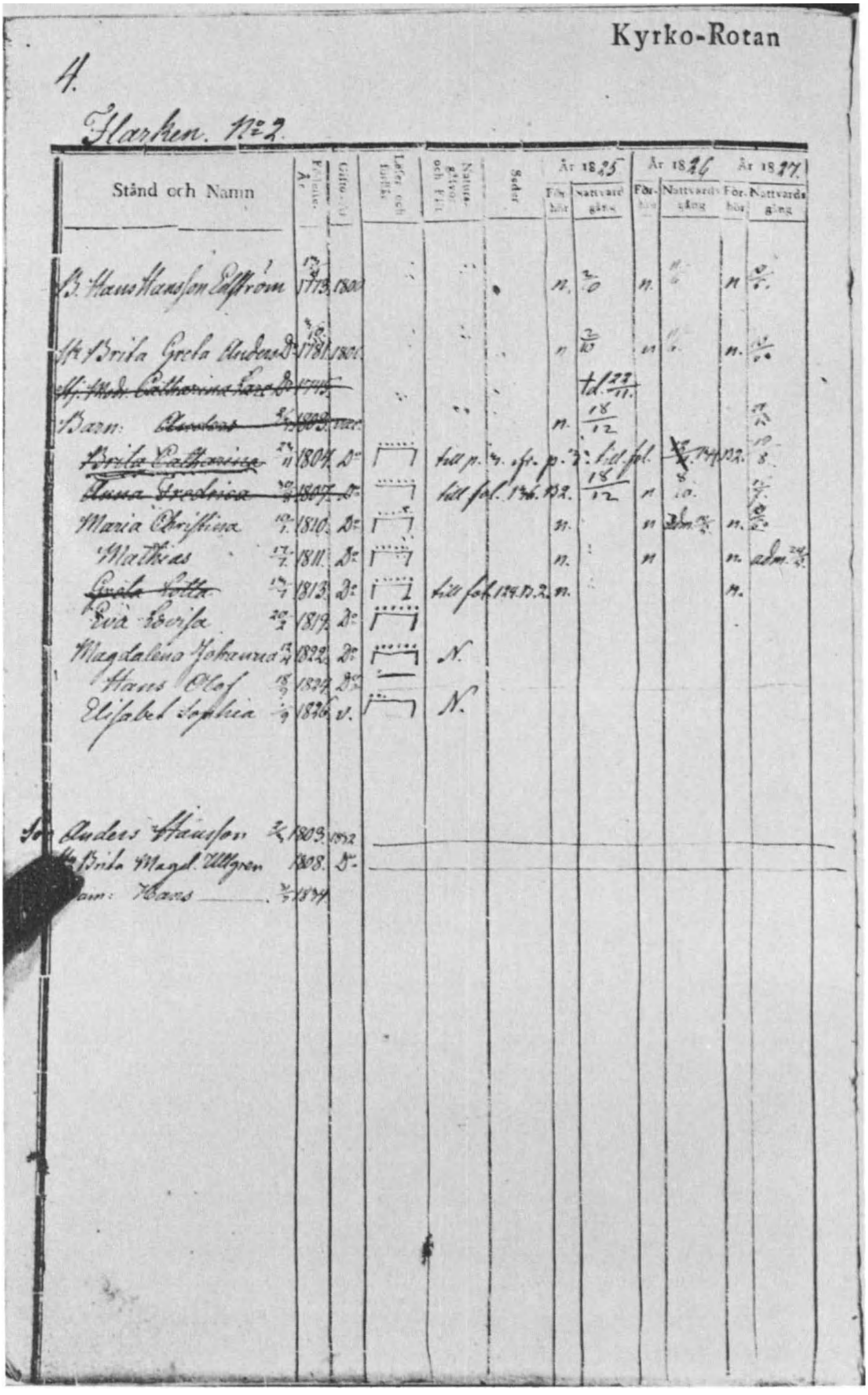


Figure 5.4. *Nineteenth-century Swedish förhöslängd register. Courtesy of Landsarkivet i Härnösand.*

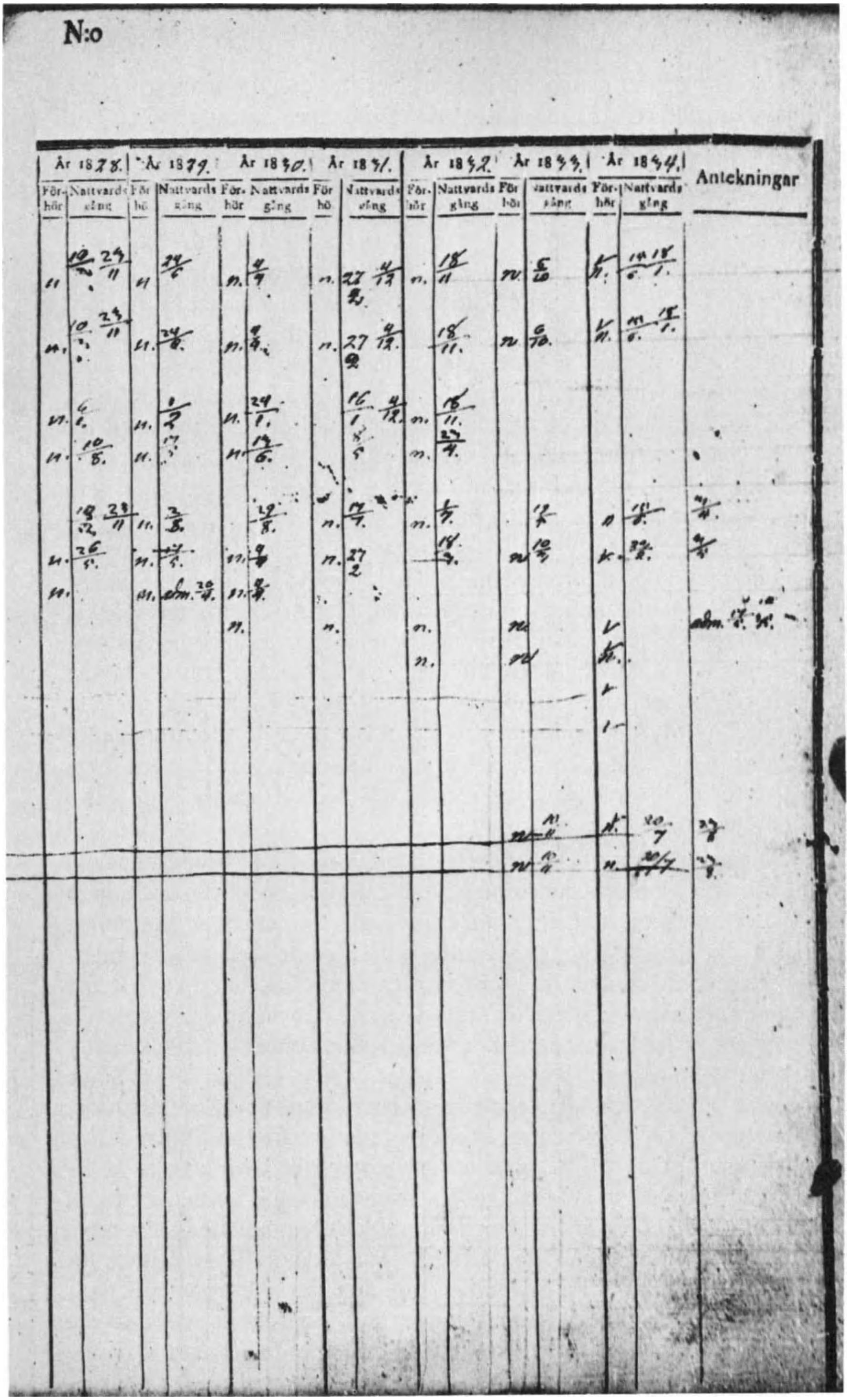


Figure 5.4 *(continued)*

During the course of the nineteenth century, as the quality of the Swedish registers improved, different European governments, such as the Belgian and Dutch, adopted a system of population registers (Belgian *Registres de population* or *Burgerlijke Bevolking Registers*; Dutch *Bevolkings Registers*) more of the Swedish than of the Japanese type (van de Walle, 1976; Gutmann and van de Walle, 1978). The goal of these registers was to record the existence of households within entire communities and the occurrence of vital events to household members at the same time that the event was recorded in the civil registration registers. Thus, a birth, for example, would appear both in the register of births for the particular commune or locality and in the record of the individual household of which the child was a member. The Belgian government hoped that the implementation of such a system would obviate the need for special, regular censuses (Gutmann and van de Walle, 1978: 123). However, these hopes went unrealized, and it is, in fact, the existence of censuses with which the registers can be updated that makes the population register sources more valuable. The early (early-to-mid nineteenth century) Belgian registers contain basic information on the composition of households, including the names of members, ages, and information on occupation, place of birth, and marital status. Later, printed forms came into use, and more information on households was added, including an individual's relationship to the head of household and dates of birth (Gutmann and van de Walle, 1978: 124). In the Brabant commune studied by Myron Gutmann and Etienne van de Walle, the quality and completeness of the vital event registration in the population registers seem to have deteriorated after the late 1860s, though it is unclear whether this was a local or national trend.

Both the Belgian and Japanese population registers have been shown to present rather similar problems concerning the population under observation in the registers. Both tend to confuse actual with legal residence, so that some individuals actually present but not legally domiciled tended to be under-reported, whereas individuals who were legally domiciled but had left the community continued to be registered. Unlike Gogol's "Dead Souls," however, individuals who continued to be counted in the registers appear to have actually left as the result of migration, not death (Gogol, 1961: Chaps. 2–3). Since population registers are potentially excellent sources for the study of migration, it is worthwhile going into some detail about this particular kind of bias.

In examining the quality of the population registers for their village of La Hulpe, Gutmann and van de Walle (1978) discovered that certain kinds of migrants actually residing in the commune but not legally domiciled there were more likely to be omitted from the registers than others. They found, for example, that when couples or entire families migrated into the commune, their existence was much more likely to be noted—a new household added to the register—than was the case with lone migrants. This resulted in part from the fact that a couple or family was more likely to experience a vital event within the new place of residence. The authors also showed that among the vital events of birth, marriage, and death, the occurrence of a birth or marriage among migrants was more likely than a death to precipitate the registration of migrants new to the commune. Thus, a young couple migrating into a village might not be registered until the wife gave birth to a child. Though the registrar of the commune was supposed to record acts of migration at the time they took place, in fact there were often lapses in time before these events were noted in the register. A comparison with the registers of vital events showed that a small number of births, deaths, or marriages also went unrecorded. The probability of migrants appearing in the European population registers, or in the *shūmon aratamē chō* for that matter, increased directly with the duration of residence and the occurrence of vital events to the migrants.

The problem of distinguishing between actual and only legal residents in the *shūmon aratamē chō* is exacerbated by the fact that entries concerning the occurrence of vital events to individuals in the registers were often written on pieces of paper separate from the registers, which were then attached to them. Over the years, many of these "emendations" have been lost (Thomas Smith *et al.*, 1977: 19). In addition, certain forms of "illegal" and only temporary migration—especially of workers—appear to have been systematically under-registered. Those Japanese workers who left their legal residence without notifying the village headman, or who remained in their place of in-migration for less than 1 year between two dates of register updating, were undercounted (Hanley and Yamamura, 1977: 177–253). It is often difficult to know whether individuals who disappeared from the household from 1 year to the next actually migrated, died, or simply were not counted. As Robert J. Smith's (1972) article on the use of urban *shūmon aratamē chō* records has shown, this is a particularly difficult problem in the case of single-member households. The entire household may simply disappear from one register to the next with no explanation. This problem of unexplained absences or disappearances is obviously compounded when there are lacunae in adjacent years of the registers. Thomas Smith *et al.*'s (1977) strategy in these instances was to make different assumptions about the disappearances of individuals from the registers—resulting in varying estimates of mortality and migration.

Both the Belgian and Swedish population registers permit the detailed study of migration, though in both cases intercommunity migration is better documented than intracommunity movements. The registers permit researchers to isolate the timing of migration in the lives of individuals to much higher degrees of accuracy than is possible using even regular census data. The value of the Swedish *husförhörslängd* for the study of this subject is exemplified in Eriksson and Rogers (1973). In their study of the parish of Uppsala-Nås, they found that between 1881 and 1885, there was a net in-migration of 25 individuals into a parish where a total of 945 people resided during the 5-year period. However, they were also able to calculate that this net migration of 25 persons was the result of 855 individual acts of in- and out-migration during the period studied. Besides documenting the use of the Swedish general parish registers, they show that migration and interparish movements may be conceptualized in different ways, yielding varying rates of migration and totals of "population at risk." Though the Belgian registers may not be as complete as the Swedish in their coverage of migration, a consultation of census and civil registration records permits researchers to isolate the kind of migrants (young, individual, and probably temporary) who are least likely to appear in the registers (Gutmann and van de Walle, 1978: 133–134).

The underregistration of infants in the European registers may also be adjusted for by a consultation of the birth and death records. Stillbirths and the birth of children who died at very young ages are far more likely, in general, to appear in the vital event series than in the population registers. Problems in this regard are much more serious for users of the *shūmon aratamē chō*. There, the system of record keeping resulted in a radical undercounting of infants. Since the registers were updated only once a year, children who were born and died in the interim were very likely never to be registered. The Japanese system of age counting (which ascribes age 1 to newborns) functioned such that all children born in the same lunar year bore the same numerical age until the next lunar year, when all turned age 2 (Thomas Smith *et al.*, 1977: 18–20). Children were thus likely to appear for the first time in the *shūmon aratamē chō* when they were age 2 under the Japanese system of age counting. Infant mortality rates gleaned from the use of the *shūmon aratamē chō* are thus very low compared with European preindustrial populations. Hanley and Yamamura (1977: 213–224), for example, indicate rates of 0–32.75 per thousand for the three villages they studied. These lacunae in the Japanese registers make many of them inappropriate for the study of infant mortality and suggest the strategies of interpolation and comparison to model life table curves (Thomas Smith *et al.*, 1977: 161–162).

Although population registers of both Europe and Asia offer a number of lacunae in the population they cover, their value stems from the amount of already-linked information about individuals and households they contain, which permits the reconstruction of individual longitudinal experience in the context of particular family or household types or village-level economies. Population registers thus offer the possibility of examining demographic changes at the individual, household, and community levels while providing particularly good data on the phenomenon of migration. Futher, when used in conjunction with vital registration and census records, they allow one to construct relatively complete series of individual, longitudinal biographies in which the *timing* of vital events can also be calculated with greater accuracy than is possible with other types of sources. Their usefulness for reconstructing the commonalities and diversities in the timing of important life cycle events is one of their additional strengths (Watkins and McCarthy, 1980).

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6
Organizational and Institutional Records

Nearly all series of written records on individuals or groups used as sources for historical demography can be considered as organizational records, in the formal sense of the term. With the exception of family records kept by private individuals, most sources of historical population data were created and maintained by formal organizations for their own use. Unlike records that were intended to include entire resident populations or all individuals experiencing vital events, however, the organizational and institutional sources to be discussed here usually provide information only on specific subgroups within a general population. Simply put, requirements for entry into organizational or institutional population records have historically been more restrictive than those for entering, for example, census or vital registration records.

Organizational records come from a wide variety of historical agencies: charitable and poor-relief organizations, the courts, notaries and lawyers, and the police. "Institutional" records, in this discussion, are a special kind of organizational records, collected by establishments that Erving Goffman has defined as "total institutions" such as monasteries, workhouses, asylums, or prisons (1961: 4–12). They are distinguished from other formal organizations by the fact that they historically have been composed of resident populations usually segregated from the outside.

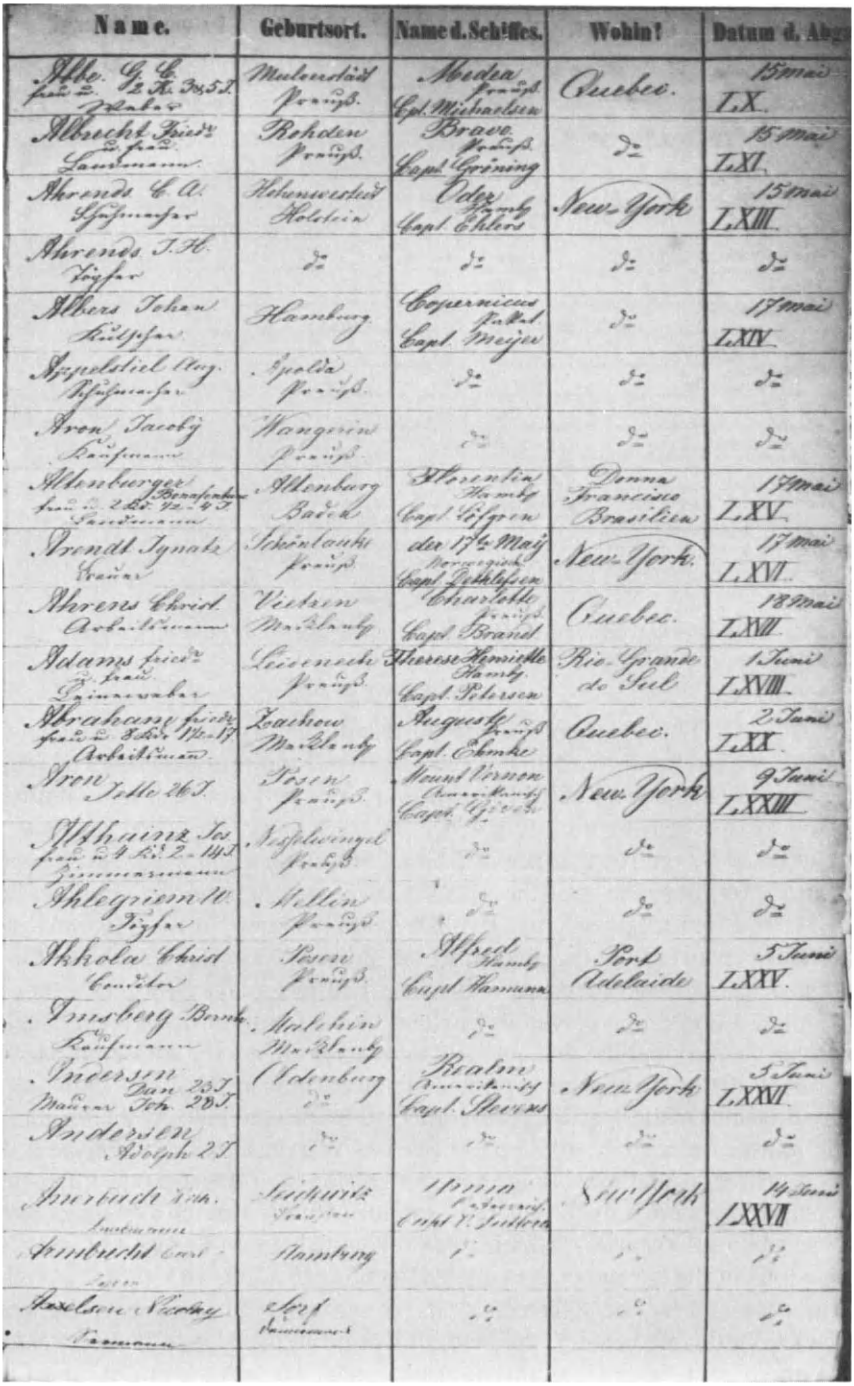
In theory, organizational or institutional populations may be composed of individuals whose only shared characteristic consisted of being observed and recorded at one point in time by a historical agency with which they came into contact. Members of organizational populations, in particular, may never have dwelt near one another, like census populations, or experienced a vital event at approximately the same time, like members of the same birth or marriage cohort studied from vital registration records. They may thus appear to be "populations" in only the most abstract sense, as mere aggregates of people with few or no shared qualities. In fact, however, organizational populations in many cases tend to be selective for age, social class, or sex, reflecting the particular activities of the record-keeping organization itself. Groups of the poor enumerated by outdoor relief agencies (Webb, 1966) or international migrants recorded by immigration or naturalization authorities (Hvidt, 1975) tend to share more attributes than the one that determined their presence in the organizational source (see Figures 6.1 and 6.2).

Marriage Contracts

Among the more valuable organizational sources available for historical demographic research are marriage contracts and wills. These records are of interest primarily because of their close connection with the vital events of marriage and death and the social and financial information on individuals and families that can be gleaned from them. The drafting and/or carrying out of the clauses of these documents have in general necessitated the intervention of legal personnel—notaries, lawyers, or probate authorities. The largest number of published studies available using marriage contracts for social historical research come from societies where the tradition of Roman or written law and the notary's place within it were strongest. By constrast, wills appear to be a more universal kind of source, offering insight not only into questions of wealth and property transmission but also into relations between family members and the size of families in the past. Both marriage contracts and wills may be used as complements to vital registration records, or in cases where the latter are lacking, as surrogates for them. They may also be fruitfully used in combination with other nominative records for purposes of verification and linkage (Poisson, 1974: 53). In one of the most interesting studies of eighteenth-century urban social structure, the author chose to work from marriage contracts rather than from the available parish register records of marriage because of the contracts' rich biographical information on the new spouses (Garden, 1970: 71).

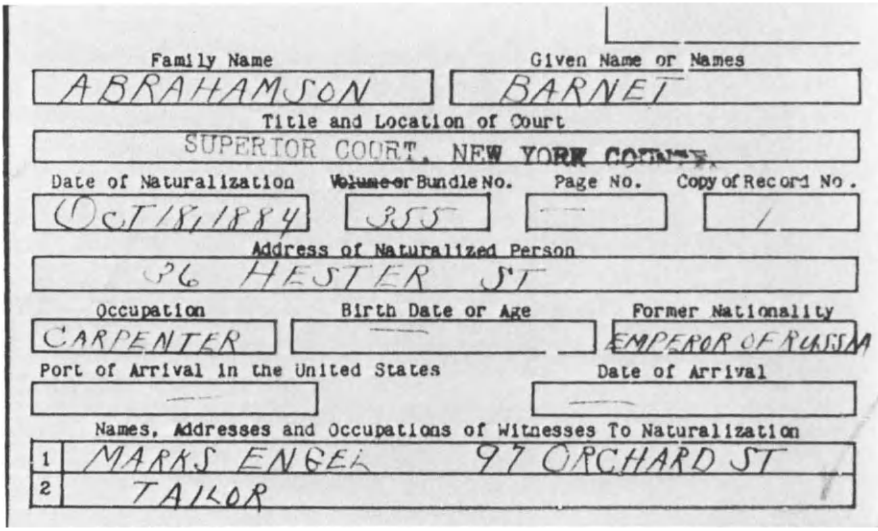
The growing body of research on marriage contracts not surprisingly comes from societies where the practice of making out written documents of this kind was a widespread custom—particularly France, Italy, Spain, and Spanish America. It is through the survival of notarial collections and series of governmentally required extracts from them that we have the largest sets of information on individuals from marriage contracts.

According to one commentator, the first recorded mention of the notary's presence in medieval England appeared in a thirteenth-century document, and was characteristically related to the drawing up of a marriage contract. The notary, probably an Italian, was charged with drafting a contract for the marriage, in 1258, between Isabel de Clare, daughter of the earl of Gloucester and Hertford, and the marquess of Montferrat, which took place in Lyon (Cheney,



Name.	Geburtsort.	Name d. Schiffes.	Wohin?	Datum d. Abg.
Albe G. C. [illegible]	[illegible] Preuß.	Medea Preuß. Cpt. Michaelsen	Quebec.	15 Mai LX.
Albrecht Friedr. m. Frau Landmann	Rohden Preuß.	Bravo Preuß. Capt. Gröning	do	15 Mai LXI.
Ahrends C. A. Schuhmacher	Hohenwestedt Holstein	Oder Hamb. Capt. Ehlers	New-York	15 Mai LXIII.
Ahrends J. H. Tischler	do	do	do	do
Albers Johann [illegible]	Hamburg	Copernicus [illegible] Capt. Meyer	do	17 Mai LXIV.
Appelstiel Aug. Schuhmacher	[illegible] Preuß.	do	do	do
Aron Jacoby Kaufmann	Wangerin Preuß.	do	do	do
Altenburger [illegible]	Altenburg Baden	Florentin Hamb. Capt. Löfgren	Donna Francisca Brasilien	17 Mai LXV.
Arendt Ignatz Brauer	Schönlanke Preuß.	den 17ten Maij Norwegisch Capt. Dethlefsen	New-York.	17 Mai LXVI.
Ahrens Christ. Arbeitsmann	Vietzen Meklenburg	Charlotte Preuß. Capt. Brandt	Quebec.	18 Mai LXVII.
Adams Friedr. m. Frau [illegible]	[illegible] Preuß.	Therese Henriette Hamb. Capt. Petersen	Rio Grande do Sul	1 Juni LXVIII.
Abraham Friedr. [illegible] Arbeitsmann	Zachow Meklenburg	Auguste Preuß. Capt. Ehmke	Quebec.	2 Juni LXX.
Aron Jette [illegible]	Posen Preuß.	Mount Vernon Amerikanisch Capt. Green	New York	9 Juni LXXIII.
Althainz Jos. [illegible] Zimmermann	[illegible] Preuß.	do	do	do
Ahlegriem W. Tischler	Mellin Preuß.	do	do	do
[illegible] Christ. Conditor	Posen Preuß.	Alfred Hamb. Capt. Hamann	Port Adelaide	5 Juni LXXV.
[illegible] Bernh. Kaufmann	Malchin Meklenburg	do	do	do
Andersen [illegible]	Oldenburg do	Realm Amerikanisch Capt. Stevens	New York	5 Juni LXXVI.
Andersen Adolph [illegible]	do	do	do	do
Auerbach [illegible]	[illegible]	Emma [illegible]	New York	14 Juni LXXVII.
[illegible] Carl [illegible]	Hamburg	do	do	do
Axelsen Nicolay [illegible]	[illegible]	do	do	do

Figure 6.1. *Nineteenth-century German emigration register: The Hamburg Passenger Lists. Courtesy of the Staatsarchiv, Hamburg.*



Family Name: ABRAHAMSON
Given Name or Names: BARNET
Title and Location of Court: SUPERIOR COURT, NEW YORK COUNTY
Date of Naturalization: OCT/18/1884
Volume or Bundle No.: 355
Page No.: —
Copy of Record No.: 1
Address of Naturalized Person: 96 HESTER ST
Occupation: CARPENTER
Birth Date or Age: —
Former Nationality: EMPEROR OF RUSSIA
Port of Arrival in the United States: —
Date of Arrival: —
Names, Addresses and Occupations of Witnesses To Naturalization
1 MARKS ENGEL 97 ORCHARD ST
2 TAILOR

Figure 6.2. *Nineteenth-century United States naturalization record. Courtesy of the County Clerk, New York County.*

1972: 14–15). Though from the late thirteenth century the notary became a figure recognized for his work in both ecclesiastical courts and administration as well as the royal chancery of the English king, he never gained the same status in England as that held by his counterparts in other parts of Europe which were more affected by the renaissance of Roman law studies and practices. Cheney (1972: 52, 69) observes that the notary's work was opposed by common law lawyers and unrecognized by English common law itself. He was not historically involved in the legalizing of property transfers such as those contained in marriage contracts and wills. The role played by the notary in Roman law Europe was played in England by the family solicitor—the Anglo-American "notary public" having little to do with the notary whose practice in wide areas of the European continent involved him in the most intimate of family financial matters as they were affected by private law. At the beginning of the fourteenth century, Philippe le Bel was responsible for establishing the French system regulating notaries and recognizing their quasi-public character. His legislation is cited as formative in establishing the French system of royal and seigneurial notaries, which was extended into France's Canadian possessions in the seventeenth century (Vachon, 1962: 9, 16).

The development of different kinds of property arrangements between spouses from the medieval to the modern European world is intimately related to the nature and existence of marriage contracts. Though the intricacies of the subjects of inheritance and marriage laws are beyond the scope of this discussion, a few generalizations about the development of property relations between spouses may be made. The existence of notarial marriage contracts is most typical of areas where custom and law dictated that married women retain rights separate from their husbands' to specific kinds of property they brought into the marriage or acquired after it. High ratios of contracts to marriages performed in a locality were characteristic of areas where custom or law simply demanded that the contracts be made and/or areas in which the spouses or the parties drawing up the contract had some choice over the kind of property relations they wished to establish.

The systems of property relationships between spouses in the European past ranged on a spectrum between those of absolute community property, in which both spouses' property held at the time of marriage and accumulated during its course was under the control of both jointly, to rigid separation of property rights between spouses. One general characteristic of community property systems is that both spouses in theory enjoy the right to will property to designated heirs. Systems without community property can be further divided into those where husbands have control over all the property and the system of marriage portions, or dowries, in which the wife may maintain some legal control over certain properties. Between the two extremes of absolute community and absolute separation lay several hybrid systems that allowed spouses to specify which of their possessions would be held separately and which held jointly after marriage. One of the purposes of the marriage contract, historically, was to indicate clearly into which category the possessions of husband and wife fell.

Systems of community property have historically been most characteristic of urban areas of northern Europe, parts of Holland, Germany, and Switzerland, and selected towns of northern France, such as Tournai and Arras (Brissaud, 1912: 812–823). However, the lower classes of Portugal and Sicily lived under a system of absolute community property. The best-known systems of separate property rights are the English common law tradition and the dowry system of Mediterranean Europe and Spanish America. Under the English common law, in theory at least, women experienced "civil death" at the time of their marriage, with all of their property rights passing to their husbands—at least until a law of 1882 (Brissaud, 1912: 784). A woman's right to property reappeared at the dissolution of the union—for example, at the time of the husband's death—in the form of the customary dower's right to one-third of the property, or, beginning in the sixteenth century in a "jointure" or sort of widow's pension whose size would usually be determined at the time of the marriage (Stone, 1965:642). Recourse to establishing trusts for daughters that were administered by third parties could allow fathers of daughters to have some property preserved for them that was beyond their husbands' control. However, this strategy appears to have been limited to the wealthiest of social groups and was not a generalized practice.

The system of dowries was typical of much of southern France, Italy, and Spain, as well as Spanish America. Though one of the logical foundations of the strict dowry system was to provide a newly married couple with a sum of money or goods that could not be freely or easily disposed of by either spouse, the tendency historically was toward an easing in the system—allowing the husband or wife to dissipate the dowry under certain circumstances. Dowries existed in several of the "hybrid" property systems referred to above. In southwestern France and Navarre, for example, dowries existed alongside joint ownership of certain kinds of property that the couple acquired after marriage. The customary law of community property in "moveables and acquisitions," characteristic of the Paris area and many regions north of it, allowed spouses to acquire property jointly after marriage but also provided for the maintenance of clear and separate rights over property held before marriage, and for the possibility of a dowry for the wife. It is this Parisian system that became known as the customary law of France regulating property relations between spouses.

The regional dimension of marriage property practices was a strong one. The inheritance laws of Normandy, allowing as they did very little leeway in the willing of property to female children, and the widespread practice there of concluding marital property agreements privately, without a notary present, make the small number of marriage contracts extant for the latter part of the ancien régime nearly worthless for social historical or historical demographic purposes (J.-C. Perrot, 1961: 95–97). The English system of property settlements both at the time and after marriage took place was quite different from practices typical in areas of written law.

In those societies living under Roman law, the dowry or marriage portion was in theory designed to accomplish several things, depending upon the social milieu. In rural areas, the dowry might consist simply of the moveable household goods that the wife brought to the marriage and that, through clauses of the marriage contract, she was entitled to will to her own daughters. In urban, working-class communities, the wife's dowry would most likely consist of cash saved from her earnings during a number of years (Garden, 1970: 69–70). At the upper end of the social scale, large dowries raised by the father of the bride might be used to find desirable husbands (Chojnacki, 1975: 571–575). In theory, the dowry was given by the father of a bride to her as a stable, income-earning kind of property for her and her husband. However, in certain societies ruled by the strict dowry system, new historical conditions could lead to adaptations of the practice. For example, in colonial Peru, newly wealthy men could often make advantageous marriages with respectable creole and Spanish women whose only failing was relative poverty by endowing the women themselves (Lockhardt, 1968: 155–156). Asunción Lavrin and Edith Couturier (1979: 284–285) have reminded us that one of the goals of the dowry was to avoid the return of a daughter to the household of her parents in the event of her husband's death, serving the same kind of function as the English "jointure," dower's right, or the "*augment*" described by Geneviève Laribière (1967: 346) as characteristic of fourteenth- and fifteenth-century Toulouse marriage contracts.

The kinds of information on individuals found in European marriage contracts from the fifteenth to the nineteenth centuries seem to be remarkably similar, though becoming more complete over time. Generally, marriage contracts available in notarial collections include the names of the future bride and groom, whether they were single or widowed at the time of marriage, whether they were minors, some information about the nature of the property they were bringing to the marriage, and the kind of property arrangments under which it would be regulated. Precise age information is usually lacking, although some exceptionally informative series, such as those for Bordeaux in the latter part of the eighteenth century, do exist (Dravasa, 1963: 968–978). Information on the domiciles and occupations of parents of the future spouses is less often complete, even in some of the more recent contracts (Chaline, 1970: 257; Garden, 1970: 67). Signatures of the bride, groom, parents, and witnesses may also be contained in the contracts.

The nature and specificity of the wealth information contained in marriage contracts vary primarily by the type of property arrangements made and the historical period. Good information on the wealth holdings of both bride and groom is most likely to be contained in contracts establishing some dowry rights for the woman, or in those combining partial community and partially separate rights for bride and groom. Contracts establishing completely separate property for bride and groom detail only the property holdings of the wife, thus making them incomparable to the other types of contracts (Daumard and Furet, 1959: 679). Most of northern France, with the exception of Normandy, practiced some form of community property, whereas most of the south tended toward some form of strict dowry system. Work on Latin American marriage contracts has emphasized the importance of dowries in the marriage of colonial, urban women—particularly the Hispanic women, who were the ones most likely to marry under the Spanish dowry system imported in the New World (Lockhardt, 1968: 270; Lavrin and Couturier, 1979: 281). The kind of property relations established between the future spouses in the marriage contract would be affected by customary practices in the region where they were marrying, so that couples were not always entirely free to dispose of their property in any way they or their families wished. As Maurice Garden (1970: 72) has shown for eighteenth-century Lyon, couples who had their contracts drawn up in that city but who planned to live elsewhere frequently established property relations between themselves that were customary in the area where they intended to live. However, Etienne Dravasa (1963: 979) noted that migrants to citites often chose the customary arrangements of the place where they were born.

The use of French marriage contracts for the study of wealth distribution is discussed critically in the works of Daumard (1958, 1963) Tirat (1963), and Poussou (1964). Generally speaking, the problems of gaining a knowledge of wealth distribution from these documents result from several factors. Couples are observed at only one point in their married life cycle, thus making it nearly impossible to study the effects of aging on wealth. The wealth of different families may be difficult to compare, since differential mortality and fertility may mean that certain parents had more children to establish, thereby affecting the size of dowries or other wealth given to the young couple.

The question of wealth information in marriage contracts raises one of the more important issues concerning possible biases in this type of record. Common sense might suggest that only those with a good deal of property would bother to go through the formality and expense of using a notary for drawing up a contract. This commonsense notion has some basis in fact for the nineteenth century but must be qualified for particular areas and times in the more distant past. For example, for early eighteenth-century Bordeaux, Dravasa (1963: 984) found that notarial marriage contracts came essentially from the lower classes, whereas the bourgeoisie, he hypothesizes, drew up their contracts privately among themselves. The latter practice had existed for centuries in Normandy, arousing the central government to attempt to repress it with a series of laws at the end of the seventeenth century (Vilar-Berrogain, 1958: 51–52; J.-C. Perrot, 1961). In many cities of southern France, the drawing up of a marriage contract by the notary was a customary procedure designed to specify the legal status of the couple's different kinds of property, no matter how little there was of it. Widows, in particular, who were likely to remarry under the system of strictly separated property rights, wished to have the goods accumulated during their first marriage remain under their own control. Jacques Lafon (1972: 29), working on fifteenth- and sixteenth-century Bordeaux, found that rather vague information on the occupation of the groom-to-be in marriage contracts there was positively correlated with small dowries, leading him to conclude that quite humble people were in fact included in these records.

Research on the practice of drafting marriage contracts with the legal services of the notary in France has revealed that a high percentage of marriages carried out in particular times and places entailed such contracts (see Table 6.1). The results in Table 6.1, and all studies of urban notarial records, contain marriage contracts drawn up by the notary for couples not actually resident in the city where he practiced, though it is often difficult to estimate this number with precision. However, the proportion is thought to be small, since couples are generally believed to have sought out the services of the notary of the bride's family, implying that in general couples did not venture far from home for their contract (Daumard and Furet, 1959: 76; Chaline, 1970: 255).

Several studies of nineteenth-century French marriage contracts, résumés of which are contained in series of the *Archives de l'Enregistrement* (Daumard, 1958), have emphasized a general decline in their use, and the increasing upper-class bias that they bear as one moves closer and closer to the present. Jean-Pierre Chaline (1970), working on the Norman city of Rouen, shows how couples there gradually adopted the dowry system provided for in the Napoleonic code after the Revolution as the system closest to their old customary law. The uses of the contract and dowry were common practices at the beginning of the nineteenth century. Gradually, however, an increasing

Table 6.1
Number of Marriage Contracts for One Hundred Marriages Celebrated in Selected French Cities and France, Eighteenth to Twentieth Centuries

Place	Period	Contracts as percentage of marriages celebrated
Dijon	1730	65
	1753	71
	1760	74
Lyon	1730–1787	95
Toulouse	1700–1800	93
Bordeaux	1700–1800	53–72
Paris[a]	1730	68
	1750	69
	1787	68
	1799–1800[b]	60
Rouen	1818–20	43
	1859–60	24
	1886–87	22
	1901–1910	17
	1913	17
France	1913–1949	20[c]

Sources: Daumard and Furet, 1959; Dravasa, 1963; Chaline, 1970; Lafon, 1972.
[a]Records of some notaries are missing from all Paris figures.
[b]Year VIII, September 1799–September 1800.
[c]Mean of figures for 1913, 1919–1921, 1945–1949.

proportion of couples marrying failed to use their option of a marriage contract. Thus, in the course of the century, the practice of making a marriage contract was one of the characteristics that came to distinguish Rouen's urban middle class, sometimes of recent rural origins, from the city's workers (Chaline, 1970: 247).

In general, researchers have not found it misleading to infer that the vast majority of intended marriages documented in contracts were actually carried out. Garden (1970: 214) found a very small number of cases of contracts nullified, changed, and the like, but this appears to have been a very marginal phenomenon. Using marriage contracts as surrogates for marriage records can result in an increase in the number of couples whose fertility histories may be included in parish reconstitution studies. M. Robine (1974), working on a village in the south of France with an excellent set of notarial marriage contracts dating from the seventeenth to the nineteenth centuries attempted to derive the theoretical distribution of delays between the drawing up of marriage contracts and marriages for the different centuries under consideration. By estimating this delay, he could invent a marriage date for couples lacking a marriage record and incorporate their fertility history in the study of the village's development by linking the births of their children to the estimated date of marriage. The distribution on which the study rests was composed of cases where both the date of contract signing and date of marriage were known. The empirical distribution of the time intervals tended to follow a log-normal law. Robine's study is based on an extremely small number of contracts for one particular locality and assumes that the distribution of delays between contract and marriage is the same for cases with full and partial documentation. However, his method offers some hope for studying the demographic evolution of places with good series of marriage contracts but partially missing marriage records.

Beyond their usefulness in helping determine the timing of marriage in cases where complete sets of marriage records are unavailable, marriage contracts have also been used simply for the verification of information contained in marriage and other vital event records and, importantly, for the study of migration—particularly female migration from rural to urban areas in the past. This is possible given background data on bride and groom contained in many contracts and where information on the domiciles of parents of the spouses is included in the contracts (Daumard and Furet, 1959: 76).

Studies based on marriage contracts have revealed the variety of information on people that is contained in them, and their value for understanding the family milieu and financial conditions in which marriages in the past took place. Collections already studied, both for Latin America and Europe, are overwhelmingly urban, some of their analysts taking a longitudinal perspective (Dravasa, 1963) on time series of marriage contracts and others (Daumard and Furet, 1959; Chaline, 1970) taking cross sections of contracts made in one or several adjacent years. Lafon (1972: 16–17) sees the formulation of the marriage contract in fifteenth/sixteenth-century Bordeaux as an affair of the extended family of which the marrying couple was only a part. For eighteenth-century Lyon, on the other hand, Garden finds a mention of parents as the sources of the marrying couple's wealth in only 20% of the contracts studied (Garden, 1964: 58). In his tale "The Marriage Contract," Balzac (1965: 392) represented the notaries for the betrothed couple as "matrimonial condottieri," each doing battle for his respective client in trying to formulate an advantageous contract. That series of marriage contracts exist for periods antedating the development of vital registration systems means that they are of especial value to historians of the medieval and early modern periods. However, as research on more contemporary history has shown, they in many cases offer a unique source of data on the background, wealth, family connections, and future property arrangements of couples in modern society as well.

Wills

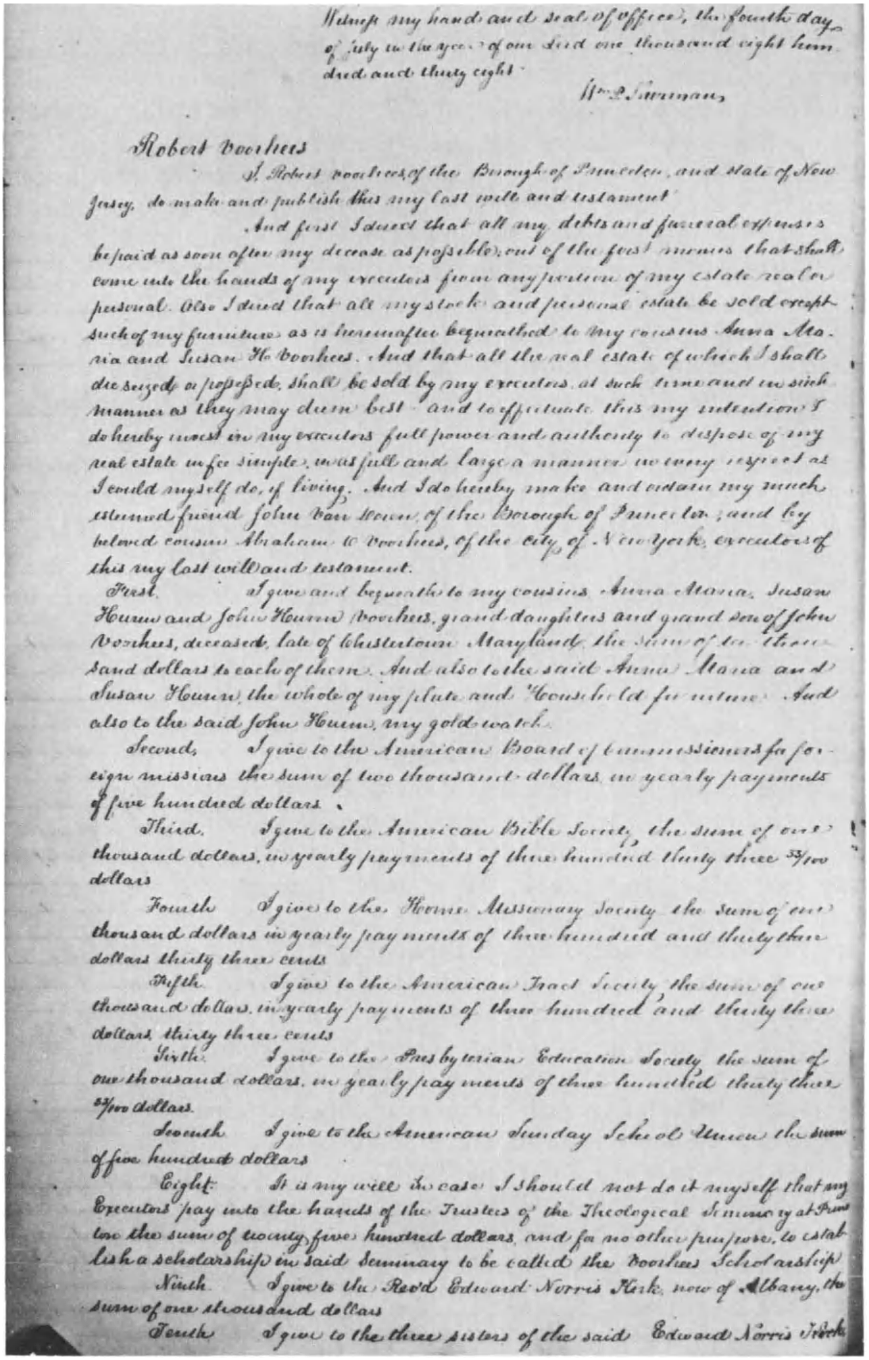
Like marriage contracts, wills and will inventories have been most recently used as sources for the study of wealth holding, its transmission through generations, and general relationship to patterns of social inequality (see Figure

6.3). This research, developed particularly in France and the United States, has been valuable for historical demographic work primarily for the information it gives on the characteristics of the will-making populations of different societies. In modern societies with civil registration records, the age and wealth characteristics of the will-making population may be compared with those of the population as a whole, or the adult population, in order to assess the kinds and degree of bias that a study of the will-makers would introduce if findings from a study of them were generalized to the population as a whole (Daumard *et al.*, 1973; Main, 1974, 1977; Smith, 1975; Ball, 1976; Nash, 1976; Warden, 1976). Further, the wording of wills, as well as the information they give on patterns of legacy among kin networks, have recently and creatively been used to investigate affective and financial relationships among family members in the past (Keyssar, 1974; Chojnacki, 1975) and the religious "*mentalité*" of will-makers (Chaunu, 1978). The study of literacy from wills has been carried out in a fashion similar to that used for the investigation of this same phenomenon and its relation to social structure using parish register materials (Lockridge, 1979).

The most explicitly demographic use of wills, however, has been for the investigation of aggregate and individual-level demographic trends in medieval and early modern Europe, including the study of mortality crises, family size, and various indexes of generational replacement. In addition, they have been used as supporting evidence for trends suggested by time series of parish register baptisms, marriages, and burials.

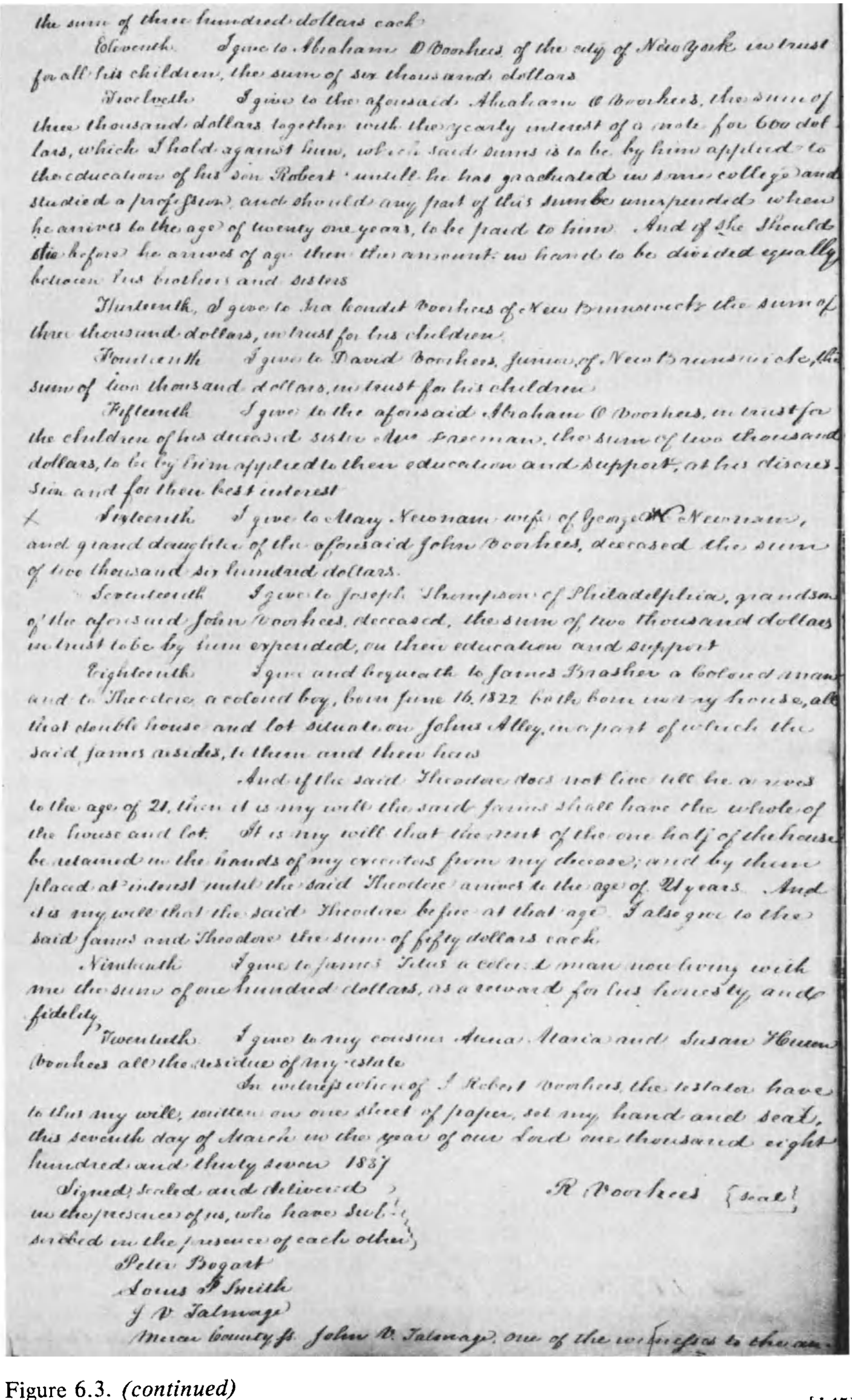
To the extent that infant and child deaths accounted for a substantial proportion of yearly deaths in preindustrial societies, will-making populations may be considered to be a priori unrepresentative of the population dying in any one year. However, since in the absence of parish registers it is nearly impossible to gather good information on exact ages at death, most historians have turned their attention more to the question of the representativeness of the will-making population for the adult population dying. In other words, the question they have asked is not how similar was the will-making population to the population dying in 1 or a series of years but rather how similar to the group of adults who died were those who made wills. As Robert Gottfried (1978: 22–23) has pointed out, there may be important differences among the types of wills that have come down to us in written form. In his own work, he found that whereas adult men and women in fifteenth-century East Anglia were equally likely to have the possibility of making wills of their own, only a small minority of the women actually had their wills registered or probated. Women were thus underrepresented in the population whose wills went through the procedures necessary for inclusion in archival collections.

The general wisdom emerging from studies of populations whose wills have survived is that they tend to be wealthier and older and to contain a higher proportion of males than either the adult population dying or the adult population still alive. In fact, unusually great wealth and age are sometimes taken to be the direct causes for an individual's decision to have a will drawn up.


Witness my hand and seal of office, the fourth day
of July in the year of our Lord one thousand eight hun-
dred and thirty eight
Wm. P. [illegible]

Robert Voorhees
I, Robert Voorhees, of the Borough of Princeton, and State of New
Jersey, do make and publish this my last will and testament
And first I direct that all my debts and funeral expenses
be paid as soon after my decease as possible, out of the first monies that shall
come into the hands of my executors from any portion of my estate real or
personal. Also I direct that all my stock and personal estate be sold except
such of my furniture as is hereinafter bequeathed to my cousins Anna Ma-
ria and Susan H. Voorhees. And that all the real estate of which I shall
die seized or possessed, shall be sold by my executors at such time and in such
manner as they may deem best and to effectuate this my intention I
do hereby invest in my executors full power and authority to dispose of my
real estate in fee simple, in as full and large a manner in every respect as
I could myself do, if living. And I do hereby make and ordain my much
esteemed friend John Van Doren, of the Borough of Princeton; and my
beloved cousin Abraham W. Voorhees, of the City of New York, executors of
this my last will and testament.
First. I give and bequeath to my cousins Anna Maria, Susan
Hunn and John Hunn Voorhees, grand daughters and grand son of John
Voorhees, deceased, late of Chestertown Maryland, the sum of ten thou-
sand dollars to each of them. And also to the said Anna Maria and
Susan Hunn, the whole of my plate and household furniture. And
also to the said John Hunn, my gold watch.
Second, I give to the American Board of Commissioners for for-
eign missions the sum of two thousand dollars in yearly payments
of five hundred dollars.
Third. I give to the American Bible Society the sum of one
thousand dollars, in yearly payments of three hundred thirty three 33/100
dollars
Fourth I give to the Home Missionary Society the sum of one
thousand dollars in yearly payments of three hundred and thirty three
dollars thirty three cents
Fifth I give to the American Tract Society the sum of one
thousand dollars in yearly payments of three hundred and thirty three
dollars, thirty three cents
Sixth I give to the Presbyterian Education Society the sum of
one thousand dollars, in yearly payments of three hundred thirty three
33/100 dollars.
Seventh I give to the American Sunday School Union the sum
of five hundred dollars
Eight It is my will in case I should not do it myself that my
Executors pay into the hands of the Trustees of the Theological Seminary at Prince-
ton the sum of twenty five hundred dollars, and for no other purpose, to estab-
lish a scholarship in said Seminary to be called the Voorhees Scholarship
Ninth I give to the Rev'd Edward Norris Kirk, now of Albany, the
sum of one thousand dollars
Tenth I give to the three sisters of the said Edward Norris Kirk

Figure 6.3. *Nineteenth-century will, United States. Mercer County Courthouse, New Jersey.*


the sum of three hundred dollars each

Eleventh I give to Abraham O Voorhees of the city of New York in trust for all his children, the sum of six thousand dollars

Twelveth I give to the aforesaid Abraham O Voorhees, the sum of three thousand dollars together with the yearly interest of a note for 600 dollars, which I hold against him, which said sums is to be by him applied to the education of his son Robert until he has graduated in some college and studied a profession, and should any part of this sum be unexpended when he arrives to the age of twenty one years, to be paid to him. And if he should die before he arrives of age then the amount in hand to be divided equally between his brothers and sisters

Thirteenth, I give to Ira Condit Voorhees of New Brunswick the sum of three thousand dollars, in trust for his children

Fourteenth I give to David Voorhees, junior, of New Brunswick, the sum of two thousand dollars, in trust for his children

Fifteenth I give to the aforesaid Abraham O Voorhees, in trust for the children of his deceased sister Mrs Freeman, the sum of two thousand dollars, to be by him applied to their education and support, at his discretion and for their best interest

× Sixteenth I give to Mary Newman wife of George H Newman, and grand daughter of the aforesaid John Voorhees, deceased the sum of two thousand six hundred dollars.

Seventeenth I give to Joseph Thompson of Philadelphia, grandson of the aforesaid John Voorhees, deceased, the sum of two thousand dollars in trust to be by him expended, on their education and support

Eighteenth I give and bequeath to James Brasher a colored man and to Theodore a colored boy, born June 16, 1822 both born in my house, all that double house and lot situate on Johns Alley, in a part of which the said James resides, to them and their heirs

And if the said Theodore does not live till he arrives to the age of 21, then it is my will the said James shall have the whole of the house and lot. It is my will that the rent of the one half of the house be retained in the hands of my executors from my decease; and by them placed at interest until the said Theodore arrives to the age of 21 years. And it is my will that the said Theodore before at that age. I also give to the said James and Theodore the sum of fifty dollars each.

Nineteenth I give to James Titus a colored man now living with me the sum of one hundred dollars, as a reward for his honesty and fidelity

Twentieth I give to my cousins Anna Maria and Susan Heron Voorhees all the residue of my estate

In witness whereof I Robert Voorhees, the testator have to this my will, written on one sheet of paper, set my hand and seal, this seventh day of March in the year of our Lord one thousand eight hundred and thirty seven 1837

Signed, sealed and delivered in the presence of us, who have subscribed in the presence of each other

R Voorhees {seal}

Peter Bogart
Louis P Smith
J V Talmage

Mercer County ss John V. Talmage, one of the witnesses to the an-

Figure 6.3. *(continued)*

However, in medieval Europe, the practice of will-making may have been relatively uncorrelated with great wealth or social standing since the practice of leaving an oral or written will was incumbent on all Christians in order to encourage pious donations to religious institutions (Sheehan, 1963: 258). In her work on sixteenth-century Cambridgeshire, Margaret Spufford (1976: 170–171) has argued that the existence of dependent children, rather than unusual wealth or standing in the community, was the primary determinant of an individual's propensity to leave a written will.

Clearly, who left wills and why are important questions to be answered before these documents can be used for demographic purposes. Local variations in customs—for example, between the New England and Middle Atlantic states of colonial America—have been shown to cause different proportions of adults leaving wills or will inventories (Jones, 1972: 116). As one scholar working with these kinds of sources has written, "[Probate records] are a much better source for the analysis of change over time within a small area than for the study of the differences between regions and classes [Smith, 1975: 106]."

In medieval and early modern Europe, variations in mortality patterns between "normal" and "crisis" years may have led to rather important short-term shifts in the composition of the will-making population. In his work on East Anglia, Gottfried found that with the coming of a demographic crisis—usually an outbreak of the plague—the time between the drawing up and probate of wills contracted sharply and rates of intestacy increased (1978: 25). The latter may well have resulted from the fact that younger people, who were less likely than the old to have drawn up their wills, were caught off guard by the crisis and had little opportunity to draw up a will before their sudden deaths. On the other hand, Richard Emery (1967: 618), in his study of the plague in fourteenth-century Perpignan, found that there were probably adequate facilities for composing one's will even during periods of mortality crises. The fact remains, however, that recurrent pandemics of plague or other epidemics would probably carry off with them an adult, will-making population that was younger than the population dying in a "normal" year. Smith's argument for the use of probate documents over time in a rather circumscribed area seems particularly well taken for the distant past. The possibility of radical fluctuations in the age composition of the dying population, which, as we shall see, has important effects on the number and characteristics of heirs mentioned in the wills, suggests the preferability of constructing longitudinal studies of these documents rather than cross-sectional investigations that may select unrepresentative years for examination.

It is for the aggregate study of mortality trends that wills appear to be the least subject to a whole range of misinterpretations and biases. As long as the researcher can be reasonably sure that he or she is dealing with complete series of wills for a well-defined region over a period of at least 50 years or so, there is a possibility of using them as surrogate burial records or bills of mortality (Hollingsworth, 1969: 145–148) to gain an insight into the outlines of a community's mortality patterns. The opportunity of examining the seasonality of death is often hindered by the difficulty of calculating the exact timing of death during the year. In his work, Gottfried simply took the mean time between the drawing up of the document and the time it was registered, in an effort to estimate the "season" of death, rather than the exact date or month (1978: 24).

The fascination with wills as sources for historical demography, however, lies also with the possibilities of going below the aggregate level to the investigation of two or more generations of a family at one point in time, for an assessment of family size and/or the capacity of family groups or whole social classes to renew themselves. It is in the use of wills for these kinds of analyses that the evidence in them may be subject to most misinterpretation. Because of the tendency of so many inheritance systems to dictate the passage of landed property through wills to the male line rather than the female, the appearance of named female children in wills is not commensurate with their actual representation within the population. In many systems, female children received moveable property during the lifetime of their parents, so that they may have been ineligible to inherit. This was the case, for example, in fourteenth- and fifteenth-century Périgueux studied by Arlette Higounet-Nadal (1978: 286), where married daughters who had received property had no further claims to an inheritance (see also Yver, 1966). In a provocative piece, Monique Zerner (1979: 567) has shown that female children were more represented than males as inheritors of property in wills made by women, whereas the reverse was true for wills of men. However, as the author notes, her study is based on a tiny sample of wills where random variations may have played a large part. Nearly all series of European and American wills used up to now as sources for social history or historical demography contain a minority made up by women.

It is in many cases imprudent to include women's wills in a study that is designed to look at possible changes in the size of generations or families over time. In the study of this important but difficult subject, the researcher wishes to hold as many circumstances constant as possible. If it is generally true, as Gottfried reports (1978: 25), that female children were more likely to be mentioned in wills during times of crisis mortality, when males were less sure of the survival of male heirs, this is still an artifact of a short-term (if sometimes endemic) condition. If findings about changes in family size or generational size are based on these short-term increases in the mention of female descendants, the results risk being incomparable to those for "normal" times. In societies where females were generally highly underrepresented in wills, it is best to base the analysis on male heirs of males.

The kind of questions explored by comparing the number of male will-makers to the number of their inheriting sons relate generally to the tendency of a population to increase or decrease. That is, the numbers of heirs mentioned in men's wills are taken as indexes that the general population from which the subpopulation of will-makers is drawn is itself changing in size over time. In order to have confidence in such a use of the wills as sources for the study of this subject, a number of other explanations for the increase or decrease in the average number of named male heirs among a will-making population should be explored and rejected. In studies based on wills composed and probated over long periods of time, say a hundred years or more, significant changes in the average number of sons named in their fathers' wills may be the result of modifications in inheritance practices—from unequal to more equal distribution of goods, or its reverse—a stricter adoption of inheritance practices favoring one child over the rest. Changes in social composition of the will-making population may also have an effect. If the proportion of will-makers practicing distinctive kinds of inheritance rules changes, then the average number of sons per father may change also. To take a hypothetical example, if an increasing proportion of wills in a particular town is made by tradesmen who practiced equal distribution of property among their sons, then even if all demographic rates remain unchanged, the *average* number of sons per father mentioned in the wills will increase over time.

With inheritance customs and the compositional dimension of the will-making population held constant, increases in the average number of sons mentioned may indicate a growing rate of generational replacement over time. Age information on the will-makers themselves, however, is indispensable for helping to isolate the causes for an apparent increase in the size of generations. A secular increase in male life expectancy at older ages, for example, will tend to effect an increase in the age at which men made out their wills and, all else being equal, result in a larger number of sons being named. This increase in life expectancy may imply a larger family size, but not necessarily.

Explaining the causes for real increases in the average number of sons per will, excluding those already mentioned, is extremely difficult, if not impossible, without corroborating evidence from other sources. A secular drop in male age at marriage, with male age-specific fertility rates held constant, could result in the birth of a larger number of sons to whom property could be left. Similarly, changes in male age-specific fertility, holding age at marriage constant, could result in the same finding. The only way to control for these variables is to have some data on males' ages at marriage, their fertility, or both over time. A variety of changes in mortality patterns may be at work at any one time, leaving their various effects on the ratio of fathers to sons indicated in wills. Infant mortality among males may decline, ensuring the survivability of more sons to adulthood. The main problem with the use of wills to assess family size is that the size of the generations is observed at only one point in time and, in many cases, without information on the ages of the members of the two (or even three) generations involved (Higounet-Nadal, 1978: 286).

The relevance of the study of the replacement ratio of sons to fathers among the will-makers and their heirs to the general population must also be assessed. In other words, does the will-making population of married men leaving sons stand in the same relation to the general population of adults across time? Is there any reason to believe that the proportion marrying is becoming smaller? If so, then changes in the apparent family size of the men leaving sons may have little to do with the tendency of the wider population to grow or shrink. Other kinds of evidence—tax lists, parish registers, series of baptisms, marriages, and burials—may provide much firmer evidence than wills about the tendency of general populations to grow or decline. Wills may, at best, provide some confirmatory evidence of such a trend (Dyer, 1973).

The Historical Demography of Institutional Populations

One of the distinctions made between organizational and institutional sources for historical demography was that in many cases organizational sources recorded individuals at only one point in time. On the other hand, institutional records, which in most cases refer to actual resident, inmate populations—whether slaves, soldiers, or prisoners—may contain continuous administrative observations about the inmates' "careers"[1] in the institution as well as information on the entries and exits of individuals into and out of the population under study.

The clear boundaries of institutional populations and the continuous nature of the observation under which they were held, are, of course, two reasons why some of the most interesting, early demographic methodologists made use of their records. The populations of monasteries and convents, the original and pervasive "total institutions" of the medieval period, provided Deparcieux with some of the raw data from which he studied mortality patterns in a rigorously controlled setting (1746: tables 8–12). This kind of use of institutional records continues (Arretx *et al.*, 1976).

One of the most difficult problems in using institutional or organizational records for historical demographic research is that the qualifications for entering the populations they document may change abruptly—or gradually over time. These changes may radically affect the number and/or kind of individuals being recorded in a year or set of years, and ultimately the composition of the population itself. For example, a short-term condition of high bread prices in a preindustrial town may have led not only to a higher incidence of "food riots" during a number of months but also to a greater tendency of local police to make arrests and for courts to imprison those committing petty crimes (Deyon, 1975: 81). In periods when the definition of crimes is undergoing change, long-term series of arrest and imprisonment records will reflect not only some constant behavioral phenomenon but also a whole range of administrative decisions,

1. See Goffman, 1961: 127. *Careers* here is used in Goffman's first sense of the word as "any social strand of any person's course through life" and "such changes over time as are basic and common to the members of a social category."

political conditions, and public opinion, which are difficult to control for. Both short- and long-term shifts in the "recruitment rules" for organizational and institutional populations will introduce biases into the admission and dismissal rates and changes into the composition of the population that may be subject to possible misinterpretation. For example, if the population of an institution is found to change over time in its overall demographic characteristics, such as age, wealth, or education, such variations *could* be the result of changes in the general population, which are faithfully mirrored in the characteristics of the institutional population. If we find that prison populations are becoming older, poorer, and less literate over time, this may be because the population from which they are drawn is also becoming older, poorer, and less literate.

However, findings about the changed characteristics of the prison population may also be attributable to changes in the law or its enforcement—that there were fewer arrests, fewer convictions, lighter sentences, earlier releases (or a combination of these) for individuals committing similar offenses in time $t + 20$ years than in time t. The admission of fewer young offenders would cause the prison population to "age." If the period under consideration is one of generally improving living and educational conditions, then the prison population will tend to appear gradually less wealthy and less well educated than the rest of society, simply because it is made up of a disproportionate number of old people.

This problem of interpretation is illustrated in V.A.C. Gattrell and T. B. Hadden's (1972: 379–385) work on the prison population of England during the nineteenth century. They were able to document the simultaneous decline of literacy among prisoners, a growth in the proportion who had previous arrest records, and a rising proportion of prisoners, both male and female, in the oldest age (30-plus) category. They concluded that these characteristics pointed to a shift in the characteristics of the subpopulation from which prisoners were recruited: "That proportionately more offenders later in the century come from a hardened and perhaps experienced criminal class than was the case in earlier decades [1972: 385]." Yet their data on the declining severity of punishments during the course of the century (1972: 382) might also suggest the conclusion that the prison population as a whole was becoming increasingly dominated by those arrested at earlier periods in the century. Important compositional changes in institutional populations can be effected by alterations in rules of admission and exit not only over the short term but over the long term as well.

Using data on institutional populations to make inferences about the populations from which they were recruited must therefore incorporate considerations of the effects of time. Successive examinations of the characteristics of individuals *entering* institutional populations are required to control for compositional changes that altered admission requirements alone may bring to them. Consideration must also be given to possible changes in the spatial limits of the populations from which inmates are recruited. This problem is illustrated in Figure 6.4. Although at time t, a hypothetical institutional population may be

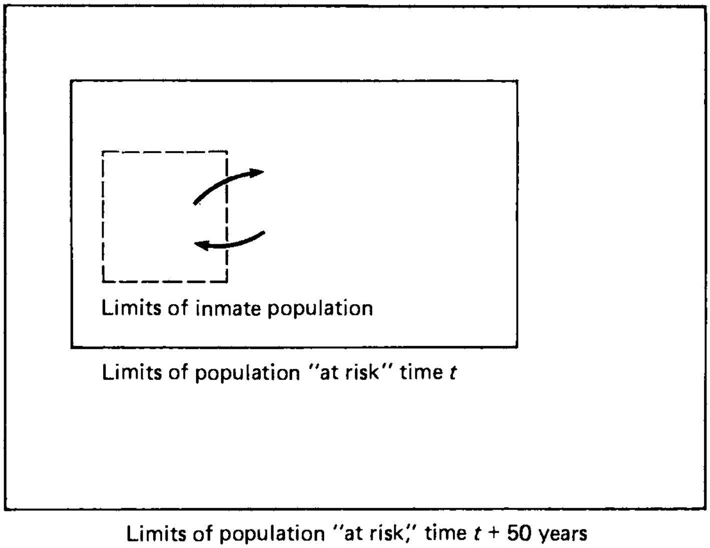


Figure 6.4. *The relationship of the institutional population to the population "at risk."*

recruited essentially from among residents of a small, circumscribed locality, the historical tendency (time $t + 50$ years) may be for the spatial limits of the population from which it is drawn to expand. Compositional changes in the institutional population may in such a situation occur simply because the size and composition of the population "at risk" to enter the institution have changed.

A creative use of organizational/institutional data for historical demographic purposes is illustrated in Lorne Tepperman's (1975) investigation of the demographic determinants of the career mobility patterns of officers within a small, elite military corps during a period of 150 years. The population under observation displays some of the characteristics of both organizational and institutional groups, as defined here. Like an institutional population, Tepperman's officers were under observation for the duration of their careers in the military. However, like many organizational populations, the officers were not in continuous residence under the same roof. With individual-level data on age at the time of entry into the corps, promotions, and leaving—by retirement or death—the author was able to isolate the relationships between individual advancement and the demographic structure of the group, under the assumptions of various rates of growth, decline, and structural reorganization of its age hierarchy. Although the focus of the author's interest is on individual upward mobility through a hierarchical organization, the perspectives he introduces are equally relevant to the study of institutional populations where "advancement" was unimportant.

Since Tepperman's officer population was under observation during the whole of each member's career, the author is able to calculate a life table showing the amount of time individuals spent at each rank. Promotion was essentially age-dependent, but Tepperman shows that the rate at which advancement took place was dependent on a number of features of the officer population as a whole—particularly its growth rate, patterns of retirement, and stability of its rank hierarchy. The primary sociodemographic condition impinging on the population of the organization from the larger society was war.

Other work on the recent historical development of institutions, in particular, "total institutions," has also sought to investigate the relationship between general, sociodemographic conditions and the lives of institutional populations. The growth of urban society in nineteenth-century America, the growing proportion of migrants or foreign immigrants in local populations, and increasingly distinct divisions among social classes have been identified as background factors helping to explain not only the "discovery" but also the persistence of "total institutions" (Rothman, 1971: 57–58, 183, 240). In late eighteenth century England, short-term demographic shifts brought about by young men returning from or departing for wars were echoed by changes in the size of prison populations (Ignatieff, 1978: 46, 82).

In other studies, shifts in the composition of institutional populations according to age, ethnic, or social-class characteristics have been shown to be crucial factors in determining the actual goals that institutions set for themselves. Compositional changes in institutional populations may have contributed to the transformation of institutions whose original goals were viewed as basically therapeutic into "holding tanks" for whole categoires of the socially undesirable or politically feared. For example, the concentration of the impoverished or foreign born within nineteenth-century prisons and asylums was, David Rothman argues, a key to the transformation of reformatories into essentially "custodial" institutions (1971: 283–290). In nineteenth-century Massachusetts, asylum administrators feared a growing proportion of elderly inmates in their institutions as a threat to the therapeutic goals that had been set for their agencies (Rosenkrantz and Vinovskis, 1978:104,114). Other demographic phenomena, such as mortality crises within total institutions, historically provided occasions for inquests and/or a wholesale reexamination of the policies of incarceration (Ignatieff, 1978: 176).

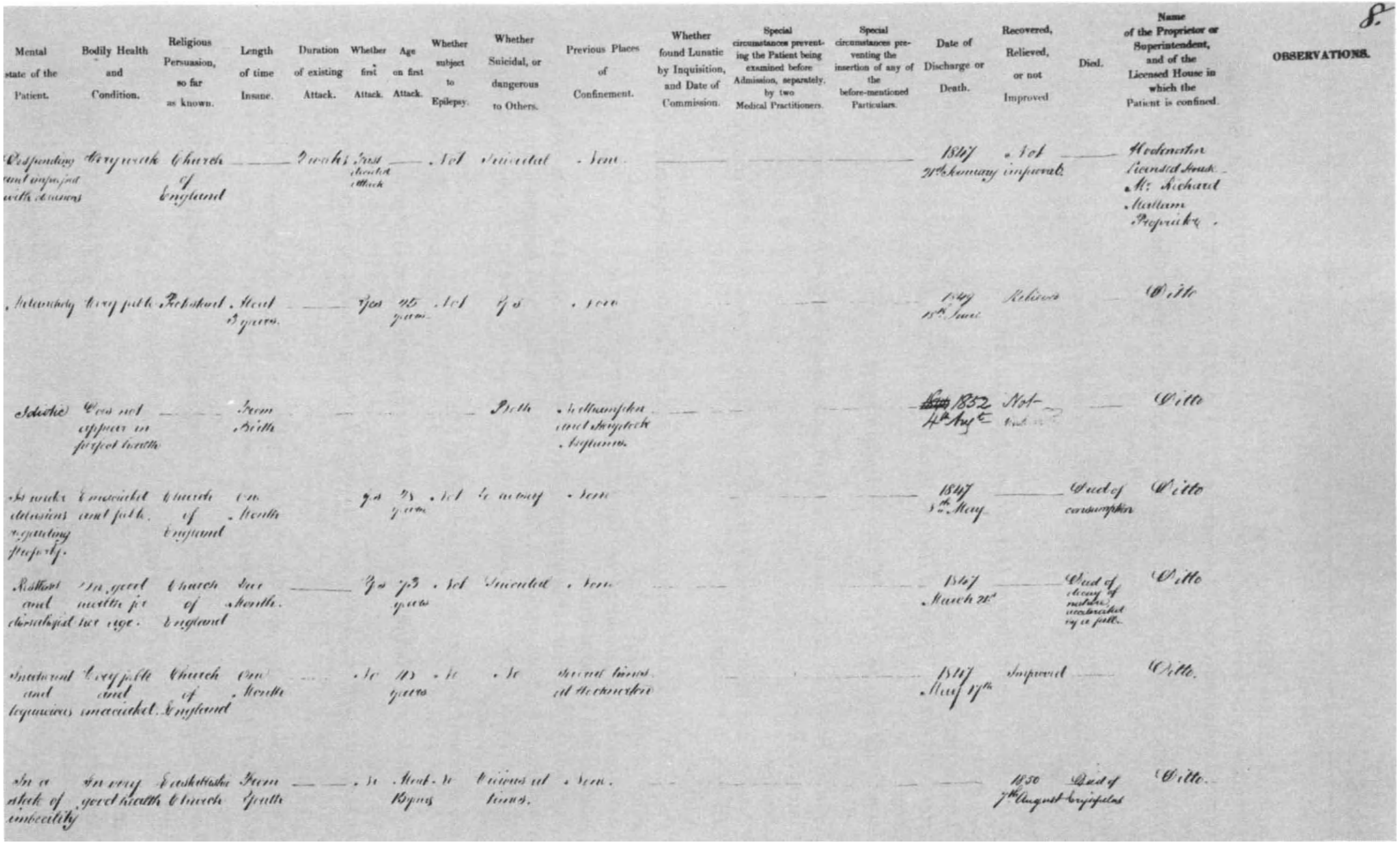
The demographic life of institutional populations, however, has remained relatively unexplored in its details. The lack of good, individual-level data indicating age, occupation, or family background of inmates at the time of admission or exit may be cited as one explanation of this. As Rothman (1971: 131) has written, aggregate statistics provided by various institutions were often biased in order to enhance the agencies' reputation as successful vehicles of individual or social reform. However, although data on common prisoners or asylum or workhouse inmates may fall short of the quality of sources documenting more elite institutional populations, it is also true, in principle, that many modern total institutions were established with the ideal of maintaining a regime of statistical as well as physical surveillance over their inmates (see Figure 6.5). Thus, an examination of the age or social composition of institutional populations over time, changes in the nature of the population dwelling within them, possible shifts in the length of incarceration, or attributed causes of death may not only contribute to an understanding of these demographic microcosms but also shed further light on possible causes for successive views of such agencies as vehicles of social reform or control (Walton, 1979; Tyor and Zainaldin, 1979).

The variety of organizational and institutional sources available for historical demograhic analysis is nearly limitless. Though such records are obviously indispensable for scholars studying periods before the implementation of more regular and inclusive sources such as civil registration or census records, they are important, too, for an understanding of the populations of more modern societies. One of the conclusions of the discussion of marriage contracts and wills was that in some societies they became less socially inclusive with the passage of time. Though often particularistic, however, some organizational and institutional sources provide a one-time or long-term portrait of social groups missing from even the most all-inclusive sources of historical demographic information. Writing of the geographically mobile urban poor of the eighteenth century, Pierre Deyon has observed:

> It is not always easy to evaluate the number of . . . proletarians and marginal people, a large proportion of whom escape the censuses whose archives now inform the historian. Most of the time, they pay no taxes, have neither reason nor the means to come before the notary on the occasion of marriage or a will. It is most often by comparison that we note their absence or discover their mute presence. The obscure among the obscure, they are identifiable only in court or hospital registers [1975: 51].

Institutional sources, in particular, can help capture that part of a society's population that is rarely introduced into demographic consideration. As Goffman has reminded us: "Total institutions are . . . incompatible with another crucial element of our society, the family [1961: 11]." Inmates born, residing, and/or dying in such institutions—from foundling homes to prisons, monasteries, or workhouses—were, in some important ways, removed from the mainstream of their societies, either temporarily or permanently. Their fates may have had little effect on aggregate level demographic development. However, a consideration of the groups from which inmates were recruited, their own institutional "careers," and their rates of entering and leaving such institutions provides a richer understanding not only of institutional subgroups within historical populations but also of those populations themselves.

Date of last previous Admission (if any)	Number in order of Admission	Date of Admission	Christian and Surname, at length	Age	Sex, and Class. Private. M.	Private. F.	Pauper. M	Pauper. F	Condition, as to Marriage. Married.	Single.	Widowed.	Condition of Life, and previous Occupation	Previous Place of Abode	County, Union, or Parish to which Chargeable	By whose Authority sent	Dates of Medical Certificates, and by whom signed
	49	1846. 17th November	Maria Davis	41		F.			M.			Assisted her husband	Great Tew	—	Thomas Davis, Great Tew, Patients(?) husband	16th November 1846 – John Faulkner(?), Chipping Norton, Surgeon; and 17th November, John Cleveland(?), Chipping Norton.
	50	23rd November	Sarah Westbury	28				F.		S.		Occasionally in field work	—		Charles Davenport, Officiating Clergyman of the Parish of Welford(?), Gloucestershire; and Robert Ward(?), Relieving Officer of Stratford Union	22nd November 1846 – Frederick Pritchard(?), Stratford on Avon, Surgeon and Apothecary
	51	15th December	Mary Ann Gilkes	25				F.		S.					Edwd Woodall(?), Mayor of the Borough of Warwick; and Wm Perry(?), Relieving Officer	14th December 1846 – J. C. Sapte(?), Surgn St Warwick, Surgeon
	52	15th December	Jane Evans	23				F.		S.		Servant			H. C. Wise, Justice of the Peace for the County of Warwick; and J. J. Harwood(?), Relieving Officer	12th December 1846 – Joseph Waters(?), Warwick, Apothecary.
	53	15th December	Ann Rudge	73				F.			W.	Housekeeper			H. C. Wise, Justice of the Peace of the County of Warwick; and J. J. Harwood(?), Relieving Officer	12th December 1846 – Joseph Waters(?), Warwick, Apothecary.
	54	25th December	Rebecca Hunt	68				F.	M.			Charwoman			S. Wykeham Martin(?), Officiating Clergyman of the Parish of Charlecote; and John Garrard(?), Overseer(?) of Charlecote	22nd December 1846 – Ed. Greaves(?), Middleton Cheney, Surgeon.
	55	1847. 5th January	Ann Harris	56				F.		S.		Labourer's Daughter	—		Francis Bedford(?) Leonard, Officiating Clergyman of the Parish of Evenley(?); and William Gillett, Relieving Officer of Brackley Union	4th January 1847 – John Cowie(?), Brackley, Surgeon.



Mental state of the Patient.	Bodily Health and Condition.	Religious Persuasion, so far as known.	Length of time Insane.	Duration of existing Attack.	Whether first Attack.	Age on first Attack.	Whether subject to Epilepsy.	Whether Suicidal, or dangerous to Others.	Previous Places of Confinement.	Whether found Lunatic by Inquisition, and Date of Commission.	Special circumstances preventing the Patient being examined before Admission, separately, by two Medical Practitioners.	Special circumstances preventing the insertion of any of the before-mentioned Particulars.	Date of Discharge or Death.	Recovered, Relieved, or not Improved	Died.	Name of the Proprietor or Superintendent, and of the Licensed House in which the Patient is confined.	OBSERVATIONS.

Figure 6.5. *Mid-nineteenth-century English asylum register. Courtesy of the Oxfordshire County Record Office, Oxford.*

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III

METHODS OF POPULATION RECONSTRUCTION AND ANALYSIS OF HISTORICAL SOURCES

Following our discussion of the basic types of source materials used by historical demographers, we now turn to important types of methodological issues and approaches to source analysis. The third part of the book is divided into three major sections. The first, concerning the selection and linkage of archival records, includes Chapters 7 through 9: "Record Linkage and the Study of Historical Communities as Relational Systems," "Family Reconstitution and Household Structure Analysis," and "Sampling in Historical Research." The second section focuses on descriptive analysis and the search for "deep structures" and consists of Chapters 10 through 12: "Lexis Diagrams and Formal Demographic Indexes," "Factor Analysis," and "Nonmetric Multidimensional Scaling and Cluster Analysis." Finally, Part III concludes with a consideration of approaches to causal model building in Chapters 13 through 15: "Regression and Time Series Modeling," "Log-Linear Modeling," and "Computer Simulation of Historical Processes."

These three major sections are logically related. The first lays a foundation for treating historical demography as an interdisciplinary science. Here we argue that demographic phenomena cannot be fully understood in isolation from their social historical contexts or apart from their relationships with nondemographic variables. Methodologically, this implies that a variety of archival source materials need to be linked together in some fashion to highlight the interrelationships essential for interpreting the causes and consequences of historical demographic processes.

Family reconstitution, a special form of record linkage peculiar to historical demography, is discussed and contrasted with the analysis of household structure. Despite their obvious value, these two traditional analytical approaches yield results that leave unanswered scores of interesting questions, such as: What accounts for differences in reproductive life cycles? What types of couples practice birth control? When and why do they do so? Why are there *a variety of different household structures? Do population growth and increasing density stimulate social and cultural revolutions? How do marriage customs and beliefs specific to different social classes affect the nature of sexuality and family life? To answer these sorts of questions requires moving beyond purely demographic data and adopting a wide variety of methodological techniques.*

Finally, in this first section, we address the subject of sampling in historical research. When studied with individual-level records, the relatively large populations encountered in regional and urban historical demographic research will inevitably require the adoption of sampling designs to keep projects within realistic cost and data processing constraints. The formulation of a sampling design can be best understood as an attempt to select optimally *the minimum amount of information required to answer a set of substantive questions with satisfactory statistical assurances. A faulty sampling design can obviously cripple an entire research project; therefore, designs must be chosen with extreme care.*

The second section of Part III discusses the more important and frequently used formal demographic techniques, such as the Lexis diagram, life and cohort tables, and descriptive indexes. These are potentially valuable procedures, but they have more than occasionally been abused by those who failed to allow substantive issues to guide their application and interpretation. Scientific investigation inevitably seeks to probe beneath the descriptive level of surface realities in the hope of discovering very simple, fundamental structural relationships. The existence and study of such "deep structures" may render intelligible aspects of demographic history that would otherwise remain a confusing mass of seemingly disconnected details. Thus, historical demographers need to consider seriously the advantages of exploratory and confirmatory data reduction techniques such as factor analysis and nonmetric multidimensional scaling as a second stage of research following the use of more elementary descriptive methods.

The last section logically extends the descriptive and data reduction techniques of the preceding two sections to consider causal model building procedures. The strategy of presentation in this part of the book has been to carry the reader in a deliberate, step-by-step manner toward the goal of constructing formal, explanatory models for demographic history. Studies that comfortably terminate at purely descriptive or at data reduction stages are of necessity incomplete as long as more profound explanatory options remain open to exploration. We begin with a discussion of regression analysis, considering its prospects and problems. Extreme structuralist arguments notwithstanding, history is inherently temporal in nature. Accordingly, considerable space is devoted to Box-Jenkins time series techniques and the modeling of longitudinal data. Next, the reader is introduced to log-linear modeling, a relatively new and powerful approach to causal analysis carrying relatively few statistical constraints. It can be used with qualitative, cate-

gorical data and thus permits a historical demographer to construct causal models in a manner not otherwise possible with the interval-level data requirements of regression analysis. Finally, we conclude Part III with an exposition of computer simulation model-building techniques. Simulation model outputs can be matched with known historical data as a means of validating a model and thus, implicitly, the understanding of causal demographic processes.

In summary, we present the reader with three rank-ordered levels of methods: descriptive, data reduction, and causal. The descriptive approach logically precedes the data reduction stage, with both of these being presupposed by formal causal modeling methods.

7
Record Linkage and the Study of Historical Communities as Relational Systems

Once the physical sciences arrived at a common understanding of their basic concepts and dimensions (space, time, temperature, energy, etc.), progress has repeatedly occurred through single discoveries of new relationships (Cattell, 1978: xiii). Classic examples include Lavoisier's noting a change in weight after an object was burned, Boyle's measurements on the pressure and volume of a gas, and Becquerel's discovery that photographic films fogged near radium. However human societies appear so complex, relative to "clinical level." physical realities that comparable bivariate discoveries are very unlikely. The most important future advances in historical demography will most likely hinge upon the use of methods linking a variety of archival materials, revealing small to moderate effects, expressed in quite complex relationships.

Examples of recent work that address these new theoretical perspectives include Mark Skolnick *et al.*'s (1978) summary of research projects using automatic family reconstitution techniques and Charles Stephenson's (1980) discussion of historical census record linkage to noncensus records such as city directories, tax lists, and vital statistics files. These efforts at the synthesis of source materials and the discovery of relational patterns within total historical systems are also at the heart of the "*Annales*" enterprise (Revel, 1979). The originality and main reason for the effectiveness of the *Annales* school derives from its strategic character in creating a rallying point for the social sciences and legitimizing the scientific study of history (Burguière, 1979). Historical demographers wishing to share in the spirit of the *Annales* research program must gain familiarity with the philosophy and methodology of record-linkage systems and the justification for their applications in empirical research. The following section provides the reader with an introduction to these perspectives and argues strongly for their increased adoption.

Important Concepts for the Systems Theorist

Historical communities are not mere chaotic aggregations of people and may be treated as possessing varying degrees of social organization, with system-like properties. A system can be defined mathematically as a set of simultaneous differential equations such that a change in any one variable within the set is a function of all the other variables found in the set. Conversely, change of any one variable will lead to change in all the other variables and of the set of variables as a whole. Long-term mortality declines, for example, have been shown in many historical situations to produce effects throughout a society. Although a systems conception of a historical community may at first appear overly abstract and foreign, it captures the essential characteristics of the fundamental assumptions upon which a social science approach to history may be grounded. Here, demographic, social, economic, genetic, or cultural facets of communities are presumed to be related such that a pattern of change in any one of these facets, which might in principle be expressed as an equation, will eventually be reflected and appear as a patterned response in others. This conception of human communities carries with it the extremely important presupposition that no one characteristic can be adequately understood in isolation. Thus, a formal demographer might be able to chart with considerable precision a phenomenon such as age-specific marital fertility rates, but the more comprehensive task of the historical demographer, as we envisage it, would be left incomplete were research simply to terminate at a descriptive level. An answer to the question What happened? demographically to a historical community is important and necessary for research, but it is only preliminary to the more interesting causal questions of How and why did this happen?

Adopting a perspective that allows us to view historical communities as "systems" can aid in clarifying the scientific role of historical demography. More than anything else, this role entails the investigation of causal interrelationships between the demographic characteristics of historical communities and their other features. Although demographic phenomena constitute historical demography's investigative core, causal interrelationships with the social, economic, genetic, and cultural sectors of historical communities cannot be ignored. The growth or decline in the size of a population in competition for limited resources, the extent to which the demographic existence of a community depends upon and/or influences other characteristics, and the extent to which patterns of demographic change mirror patterns of change in a community as a whole are all research issues that suggest a systems approach to history. This approach presumes that demographic phenomena are not accidental or purely chancelike but instead follow systematic, interactive patterns that can be identified and understood in a causal sense.

The abstract concepts associated with formal systems theory are derived from a variety of different fields, one of the most important of which is cybernetics.

From cybernetics come concepts such as "stability," the "black box," and the notion of a "structural constraint." Demographers, following Alfred Lotka's (1939) formulations, are familiar with the concept of stability. A population that is experiencing unchanging fertility and age-specific mortality will eventually arrive at an invariant age distribution and growth rate. Lotka defined this limiting case as a stable population. This narrow conception of stability might easily be broadened to encompass any social demographic process that tends toward a state of equilibrium, invariance, or oscillation within fixed limits. Although historical populations may rarely if ever actually reach stable states, the concept of stability serves as a fruitful theoretical concept to study observed population dynamics. Louis Henry (1976: 216–228) shows how Lotka's theory of a stable population stimulated research on nuptiality and migration. Other extensions and elaborations of the concept of stability are clearly possible and await historical demographers interested in constructing theories of population dynamics.

Social demographic exchanges between populations are evident throughout history, implying that such populations must be studied as "open systems." A closed population, on the other hand, is a population that may legitimately be studied in relatively complete isolation. Henry makes the rather startling statement that "in the present state of demography, it is impossible to study open phenomena as such [1976: 161]." A closed state assumes that exchanges that may take place between a population under study and other populations do not affect the probability of events under analysis in the study population.

The "black box" approach derived from cybernetics is designed to study open systems and consequently may prove to be of considerable theoretical value in coping with the problem noted by Henry. A "black box" approach to historical communities that are not closed systems might begin with deliberate ignorance of social demographic structure within a study community. Only the exchanges with other communities (the inputs and outputs of the study community) would be studied over time. Attempts would then be made to infer the nature of the study community's social demographic structure on the basis of relationships discovered in the patterns of exchange with other communities. It is clear, however, that this method of analysis must be supplemented since it can be shown that any given behavior of a "black box" can be produced by an infinitely large number of causal networks (Lilienfield, 1978: 42).

Despite this serious drawback and ignorance of the cybernetic literature dealing with "black box" methodology, historians frequently use analogous forms of this methodology. Even the most cursory survey of recent social historical research shows repeated use of inferences from purely behavioral data to social psychological and attitudinal matters. The analogy with a "black box" approach arises from the fact that the behavioral exchanges between individuals and groups with their environments form the basis for constructing models of their otherwise unknown interior motives, values, and aspirations. Exploratory factor analysis, a method commonly used in the social sciences and to be discussed later, is another example of a "black box" approach. Here, a set of external indicators or variables is used to try to infer the existence of an unobserved factor structure. The point is that historical demographers frequently encounter situations in which inferences regarding unrecorded phenomena will have to be made. Cybernetic theory and its associated "black box" methodology may prove helpful in stimulating the development of innovative solutions to what might otherwise appear to constitute hopeless barriers to understanding population dynamics.

A third cybernetic concept—"structural constraint"—is implicit in any study of nonrandom demographic phenomena. A population without any social, economic, or genetic constraints on its behavior would be completely chaotic and unpredictable. Socialization of children and the transmission of culture would be nearly impossible under conditions of a randomly changing environment. Departures from randomness found in populations are products of structural constraints. Age at marriage, inheritance laws, economic conditions, trade regulations, or nutrition, are examples of structural constraints that may affect completed family size.

Available evidence strongly suggests that demographic behavior is never completely deterministic or completely random. Change in a historical population inevitably possesses a probabilistic or stochastic character. The transition matrix in Figure 7.1 describes a purely deterministic situation. Here, *X* always changes to become *Z*, *Y* remains invariant, and *Z* always becomes *X*. Figure 7.2 is a matrix of transition probabilities. The ultimate concern of cybernetic theory is to study and understand the type of probabilistic processes found in transition matrices similar to Figure 7.2.

Figure 7.2 presents a more complex set of circumstances than Figure 7.1. *X* no longer always changes to become *Z*, but it does 70% of the time. *X* remains unchanged in 20% of the cases in which it appears and becomes *Y* in 10% of the cases. *X*, *Y*, and *Z* might represent three subpopulations of females, and the matrix of transition probabilities refers to the chances of marriage with males having the same characteristic(s) used to define the three female subpopulations. Religious affiliation, for example, might be chosen as a salient characteristic to subdivide a female population. Thus, if *X* represented Roman Catholics, *Y* Jews, and *Z* Protestants, the matrix of transition probabilities would be read as saying that the odds of a female Roman Catholic marrying a male Roman Catholic are 1 in 5, of marrying a Jewish male, 1 in 10, and of marrying a Protestant, 7 in 10.

Although this simple system of three female populations is deterministic in the sense that the probabilities are invariant, individual females marry only with specific probabilities and are therefore not unequivocally determined to select a marriage partner with a particular religious affiliation. Entropy, a cybernetic concept that measures the variability found in a phenomenon, would be at a maximum for Roman Catholic females if the likelihoods of these women

	X	Y	Z
X	0	0	1
Y	0	1	0
Z	1	0	0

Figure 7.1. *A nonprobabilistic transition matrix.*

marrying a Roman Catholic, Jewish, or Protestant male were equal. If the probability of marrying males of one of the three religious denominations were 100%, the entropy for this selection process would be said to be zero since no variation in marriage patterns would be present.

Regulation in Historical Demographic Systems

Historical communities often continue to exist over time only because they have developed regulatory mechanisms to ensure their survival. What survives over the long term are not specific individuals but regulatory patterns of behavior that they pass from generation to generation. These patterns give cultural identity to a community. A cybernetic approach to the temporal persistence of a community would seek answers to questions such as: What general principles govern the overall survival of the community? What concrete regulatory mechanisms actually account for its demographic survival? Is age at marriage an important element in the regulatory mechanism? How important is it relative to other factors? Does its importance change over time? Why?

E. A. Wrigley (1969: 15) has proposed a simple negative feedback system in which an increase in fertility produces changes that tend to keep a community's population size close to its original level. Figure 7.3 reproduces the essentials of Wrigley's model. The model starts with a positive change in fertility, which leads to an increase in total food consumption. Given a fixed food supply, this

	X	Y	Z
X	.2	.1	.7
Y	.1	.8	.1
Z	.2	.2	.6

Figure 7.2. *A probabilistic transition matrix.*

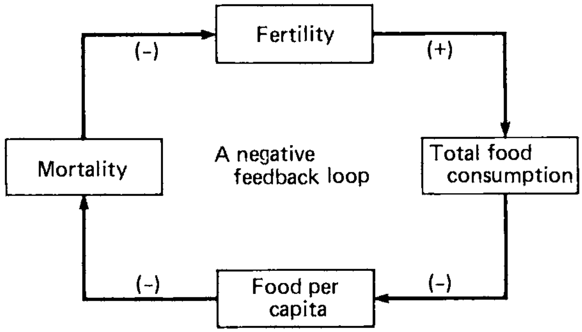

Figure 7.3. *A simple model of a homeostatic demographic system. (Adapted from Wrigley, 1969: 15.)*

produces a drop in the food available to the population. The decrease in food per capita causes a rise in mortality, which in turn increases the proportion of marriages interrupted by the death of one or both partners before the end of the wife's fecund period. The end result is to offset the original fertility rise. The stability of such a hypothetical community may thus be interpreted as the maintenance of essential traits, perhaps population size, within acceptable limits. Adaptation, as opposed to fundamental structural change, is behavior that maintains stability and preserves some sense of identity. This distinction can be very important in evaluating the nature and causal character of change in a society. Adaptive change that serves to maintain a society's fundamental structural relationships must be interpreted differently from change resulting in irreversible alterations in those relationships.

Network Analysis

If we ask ourselves just what it is that gives a historical community a distinctive identity and allows us to approach it analytically as a system possessing regulatory mechanisms, it seems clear that it is the existence of socially constructed networks that overlap and interlock with one another. Although the nature and degree of saliency of specific types of networks (e.g., kinship, economic, organizational) will vary over time and across different stages of cultural and technological development, the causal reconstruction of a community's networks, with special attention given to demographic phenomena, is a fundamental research goal of the historical demographer.

Assuming that theoretical and important substantive issues have led us to study a particular community and time period, we ask, How are the networks present in this community to be causally reconstructed? First, an informed decision must be made regarding the geographical boundaries most appropriate for including the essential networks that give a community its identity. This may prove to be a relatively simple task in the case of an isolated village. However, considerable pretesting may be required when studying a cluster of closely spaced villages which may have to be treated together as a group. The geographical boundaries of a community may also change over time. Consequently, a longitudinal study of a community may require that initial social and economic boundaries be monitored and revised when necessary.

The next logical stage of research would be to create a reasonably complete inventory of primary and secondary source materials. The source materials selected for research purposes must be scrutinized carefully to determine their reliability and comparability over time. This may require long, painstaking detective work, especially when drawing upon multiple sources. To encounter reliability problems is the rule rather than the exception in most historical research.

Having gained an overview of one's source materials and an informed feel for the extent of their reliability over time, a decision must be made either to proceed, making adjustments to correct deficiencies in the sources where necessary and possible, or to turn to another community in the hope of discovering more reliable and complete sources. This is often a difficult decision, especially in instances of only moderately reliable data. A "patch and mend" approach requiring considerable ingenuity may prove to be the sole alternative to abandoning a particular line of empirical research.

Keith Wrightson's and David Levine's (1979) study of an agricultural English village, Terling, from 1525 to 1700, offers an example of historical research with a strong demographic component built upon an elaborate inventory of different types of source materials. These included the parish register of Terling, the wills of the villagers, manorial and estate records, parish account books, taxation records, the records of Quarter Sessions and Assizes, the records of ecclesiastical courts, contemporary printed books, and other locally and centrally kept records.

If whatever problems the available records pose are not insurmountable in terms of a project's research goals, salient aspects of each type of source material should be computerized in a manner that maximizes the chances of establishing valid links between appropriate individuals listed on the records. The amount of additional information found on the records that might also be considered for computerization will ordinarily prove to be a function of a researcher's budget, available time, and the substantive considerations guiding the research project. Where practical, then, the most essential information contained within each type of record or source should be transformed into a corresponding computer file.

If, for example, the principal demographic source for a community is a parish register; baptism, burial, and marriage files should be created and linked together to reconstitute families. Under somewhat more modern, nineteenth-century circumstances, censuses and vital registration records may replace parish registers as basic demographic sources requiring computer linkage. Use of the Terling parish register allowed Wrightson and Levine (1979) to determine demographic structures, such as annual totals of baptisms, burials, and marriages; age at first marriage for men and women; the relationship between age at first mariage and the ultimate number of children a woman bore; age-specific fertility, duration-specific fertility, birth intervals by birth rank, all by wife's age at marriage; infant and child mortality rates by age of mother; life expectancies for men and women at different ages; and the impact of changing fertility, mortality, and illegitimacy on the net rate of replacement. Analysis of these demographic structures showed, in the case of Terling, that age at marriage and fertility, not mortality, were the prime agents of demographic control.

Once the demographic records of the individual inhabitants of a community are computerized and linked together, it becomes possible not only to create a series of indexes and measures of demographic structures and patterns of change but also to investigate kinship networks. An approach to recreating kinship networks would be to trace intermarriages between families in a manner built upon a web of preexisting networks resulting from past intermarriages. Another, perhaps more fruitful, line of research, when initially working with a demographic data base drawn from parish registers, would be to link a household-type census (if available) to the data base. Generally speaking, most researchers would probably like to be able to examine kinship links within, as well as between, households. Detailed household censuses, however, are not commonly found prior to the nineteenth century. Most English villages, for example, have no census-type listing of their inhabitants during the sixteenth and seventeenth centuries. Wrightson and Levine (1979), however, were able to reconstruct and analyze the network of kinship linkages between households in Terling in 1671, using the hearth tax listing of the village for that year. The kin of each household on this list were manually traced to their respective family reconstitution forms, as well as to a name index, based on every other available record of the village for the period 1524–1700, which was already coded to indicate connections between individuals. The kin of each householder could then be traced back for two generations and then forward to the date of the tax listing. This procedure is equivalent to tracing the kin of each married couple. Excluding the possibility of error and misleading changes in the spelling of names, the absence of kin links may reflect the extent of population migration over time.

Comparative measures for kin linkages can be established. Taking links between households formed by parents and children or through siblings (first-order kinship links), measurements of both absolute and relative kinship density are possible. In the first case, the absolute number of kin links of the average householder or conjugal family is determined. The second measurement entails calculating the proportion of kin links observed relative to the total number of possible kin links. Other types of measures may also be created to aid in the statistical analysis of kinship networks.

Linking other types of nominative source materials, such as probate records, into a kinship network may provide answers to a number of possibly important questions: How do variations in social position affect the likelihood of having kin among other households? To what extent do kinship links cross or remain within particular social categories? What is the nature of these links? Which sections of the community were linked by them? Why do some links cross social categories while others do not? How do differences in economic structures and demographic rates across communities affect the answers given to these questions?

The research strategy we have proposed up to this point should be evident. Briefly, a computer (or manually) linked demographic data base is first established. Other relevant source materials are then linked into this data base gradually to build up multiple overlapping networks. The range of research questions and problems that can be answered with these reconstructed networks is limited only by the content of the original records and the ingenuity of the investigator. Introspective evidence, such as diaries and personal letters, would also be linked to the demographic data base to yield additional biographical information about their authors and to aid in discovering the social psychological characteristics of a community. Emmanuel Le Roy Ladurie's (1978) skillful utilization of the detailed inquisition register of Jacques Fournier to shed light on the marriages, death, childhood, religion, and other social and demographic phenomena in the fourteenth-century French village of Montaillou is of considerable methodological interest. It lucidly demonstrates how personal, introspective evidence can be drawn upon to recreate the social mentalities and culture of a community. In the absence of information of this nature, causal interpretations of many historical demographic phenomena may be futile.

Although such scholars as Le Roy Ladurie and Wrightson and Levine largely restrict themselves to relatively small villages and link records manually, the growth of historical demography as a discipline can be expected to make computerized regional studies more and more feasible. Evidence of migration in and out of a community—the source of extracommunity links—provides a logical starting point for branching out into historical analyses with regional, national, and international scope. Whenever possible, findings from the study of a single community should be integrated into and contrasted with existing findings for the region surrounding it and its national context. Unless this is done, the validity and completeness of interpretation of the core demographic data base may be suspect and of questionable quality.

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8
Family Reconstitution and Household Structure Analysis

Louis Henry's *Anciennes familles Genevoises* (1956) and his coauthored study of the French parish of Crulai (1958) with Etienne Gautier were milestones in the development of historical demography. They demonstrated how a method of record linkage, family reconstitution (described more recently by Fleury and Henry, 1976) could be used for scientific purposes to recover demographic histories at individual and group levels. The Geneva and Crulai analyses led to a proliferation of similar mainly descriptive studies (e.g., Lachiver, 1969; Charbonneau, 1970; Houdaille, 1971; Thestrup, 1972). Across the Channel, less than a decade later, the publication of *Household and Family in Past Time* (Laslett and Wall,1972) demonstrated the feasibility of comparative studies on the size and structure of domestic groups by presenting results covering the last 3 centuries for English, French, Serbian, Japanese, and colonial North American populations.

Historical demography now began increasingly to view the family and/or household as a fundamental unit of analysis. The reconstruction of vital rates and their documentation as time series still remains an important task, but a more interesting and basic research effort turned toward identifying the different types of demographic dynamics found in families and households that give rise to aggregate rates. With individual- and group-level data available in the form of kinship and domestic networks, an entirely new range of research questions was considered.

The Logic of Automatic Family Reconstitution

The typical parish reconstitution study covers about a 100-year period and utilizes the church registers of a preindustrial village of a thousand or so inhabitants, linking entries in the marriage registers to those in the baptism and burial registers, thus reconstituting families onto a "family sheet." If desired, aggregate statistics are then drawn up from the "family sheets" to describe particular aspects of the demographic history of a village. Studies of single villages often demonstrate the importance of local migration between neighboring villages in a region. Since fully reconstituted families are made up only of nonmigrant couples (at least, individuals who have not migrated since the time of their marriage) and their children, it is possible that a relatively large number of single individuals and migrant married couples may be excluded from a family reconstitution study. This problem raises serious questions about the representativeness of reconstitution findings relative to the entire range of demographic behavior present in a village or parish (see p. 71). One way of coping with this problem, by tracing the movements of local migrants, is to attempt to reconstitute a series of villages or parishes that comprise an ecological region. This might take the form of a small town surrounded by a number of agricultural villages or a set of villages isolated by natural boundaries such as mountains, rivers, or seacoasts. However, the traditional, manual approach to record linkage becomes unrealistic when considering the reconstitution of regional or urban populations.

Since a computer can be programmed to execute virtually any set of rules that might guide manual reconstruction techniques, automatic or computerized approaches are beginning to grow in popularity. A general overview of the state of the art appears in Skolnick *et al.* (1978). Several different record-linking techniques are in use: births to deaths, baptisms to marriages, reconstitution by couple recognition, simultaneous individual and family reconstitution, sequential individual reconstitution, and linking across reconstituted families. Here we shall describe the couple recognition scheme used by the Research Program in Historical Demography at the University of Montreal, since it provides a relatively clear introduction to an area of sophisticated methodology that has increasingly become the domain of highly skilled computer scientists.

The fundamental types of linkage situations involved in family reconstitution are depicted in Figure 8.1. Note that there are five distinct operations that refer entirely to a given married couple: (1) the births of their children; (2) the deaths of their children; (3) the marriages of their children; (4) remarriage of one or both of the parent couple; and (5) the deaths of the parental partners. Operations 6 and 7 link events relating to each child and complete the family reconstitution process. The principal features of this process, as implemented by the Montreal Group, appear in three stages in Figures 8.2, 8.3, and 8.4.

In Figure 8.2, we see that the flow diagram begins with the collection of the nominative vital records to be linked and then moves to the transcription of names into their Henry code. This code is designed to aid in coping with variations in spelling and misspellings of names by forming a compressed "name," which usually contains the first letter of an individual's name and the next two consonants. Another code, the Russell-soundex code, described in

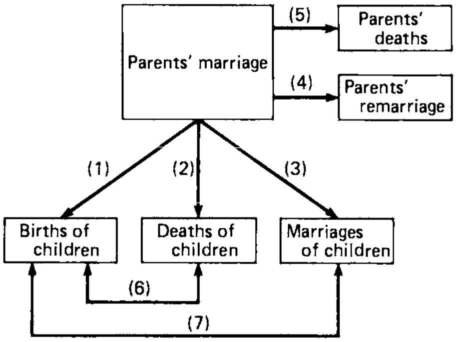

Figure 8.1. *The seven distinct types of linkage operations, centered around a married couple, which are required for family reconstitution. (Adapted from Beauchamp* et al., *1977: 377.)*

Skolnick *et al.* (1978: 16–17), is more commonly used with English names. Neither coding system can completely eliminate spelling problems. Modifications in the Henry and Russell-soundex systems for name structures other than those of French or English origin, may increase the efficiency of such systems, since neither has truly universal applications. Finally, a set of linkage weights, using H. B. Newcombe's (1967) procedures, are computed on the basis of name-match and mismatch probabilities. Flow graphs of algorithms comparing first names and comparing family names and nicknames appear in Betrand Desjardins *et al.* (1977: 76–77). A fundamental principle in establishing weights is that matches between relatively uncommon names are seen as more likely to be

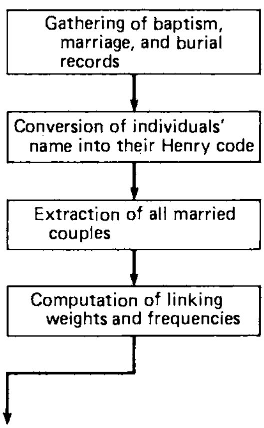

Figure 8.2. *Coding, extraction, and weighting procedures. (Adapted from Beauchamp* et al., *1977: 379.)*

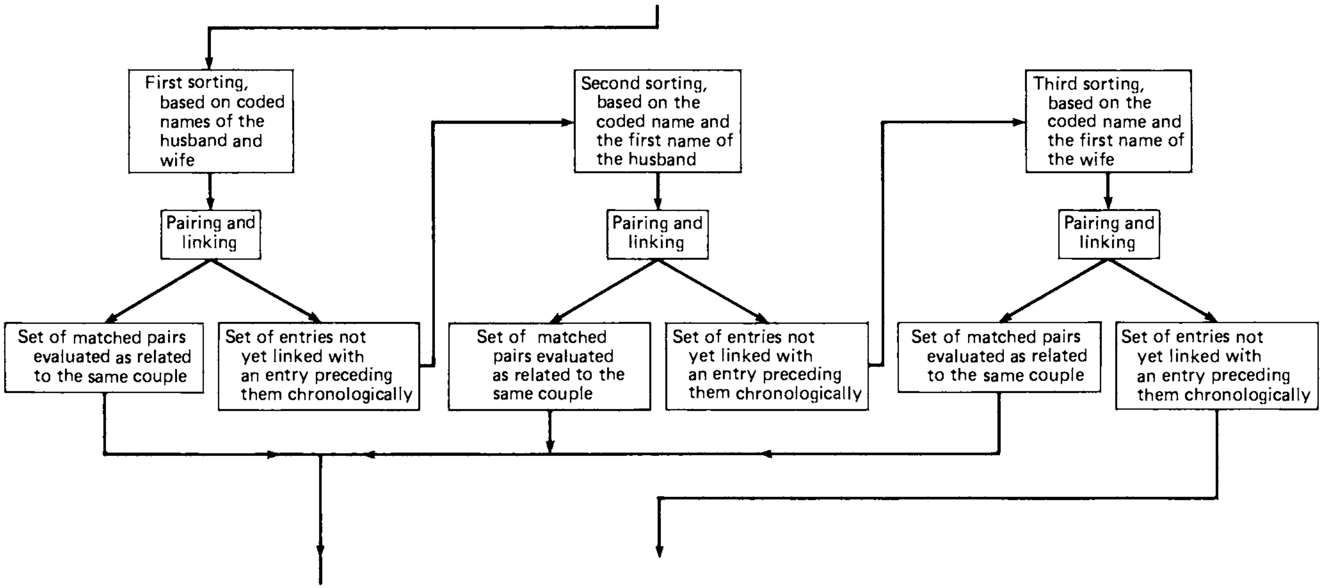

Figure 8.3. *Sorting, pairing, and linking procedures. (Adapted from Beauchamp* et al., *1977: 379.)*

valid than those between very common names, such as Smith or Jones, where the probability of a mismatch might be relatively high.

Sorting, pairing, and linking procedures form the next stage of data processing. They are represented in Figure 8.3. The data are sorted into subsets containing entries with a minimum of two nominative elements in common, out of the four identifying a couple (their first and last names). This simplifies the pairing procedures. Most of the matched entries show up in the first sort. The remaining sorts pick up pairings associated with name changes and misspellings that could not be dealt with by the Henry code. If a preliminary sort of the data base were not undertaken, it would have been necessary to form all possible pairs of names taken two at a time with a great loss in efficiency and computer time. If other information is available to identify a couple, a more elaborate sorting routine could be developed. Pairing and linking are now carried out within each sorted subset. The principle underlying the pairing procedure is to pair each nominative entry successively to chronologically preceding entries. The succession is terminated when the entry is accepted as paired according to a certain probability criterion. The acceptance or nonacceptance of pairs is based on a weighting system of agreement or disagreement probabilities (Newcombe, 1967) in the linkage step.

Finally, Figure 8.4 shows the few remaining steps in the reconstitution process. These merely entail codification and printing of the results of the pairing and linking procedures. The Montreal Group reports that the application of the approach just outlined permitted them to reduce the number of possible pairs in their data base from 670,000,000 to 210,000, with 98% of the desired groupings being formed automatically, with an accuracy of 97%. These impressive results demonstrate that very large, historical demographic data

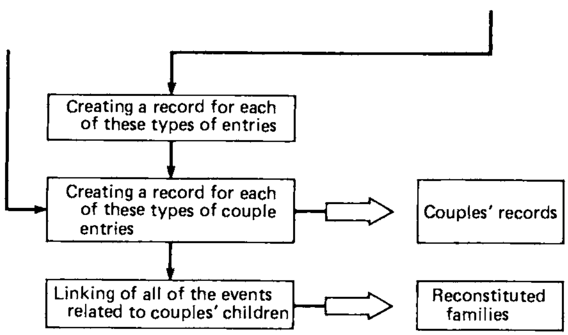

Figure 8.4. *Codification and printing of the linkage results derived from the flowgraph shown in Figure 8.3. (Adapted from Beauchamp* et al., *1977: 379.)*

bases can be created for regional and/or urban populations and can be successfully reconstituted with automatic techniques.

Calculating Demographic Rates from Family Reconstitution Data

At least three methods of computing population totals, age distributions, and vital rates from a family reconstitution study have been proposed. In Gautier's and Henry's (1958) Crulai study, it was presumed that the parish's population size and age structure remained constant between 1675 and 1750. Age-specific net out-migration and age-specific mortality schedules were drawn up, allowing a population total and age distribution to be computed. A second method, proposed by Ronald Lee (1974), assumes a closed population and uses a single population count for forward and reverse projections to obtain longitudinal estimates of population totals, age structures, and vital rates. A third method, suggested by Allan Sharlin (1978), drops the requirement in Henry's approach of having a stationary population as well as Lee's assumption of a closed population but requires information on age at death for the entire population. Sharlin raises the important question "How can the given set of demographic measures from a family reconstitution, which record the experience of a varying subgroup of the population and which may or may not accurately express what happened to that population as a whole, be used in order to estimate additional measures accurately for the entire population [1978: 512]."

Sharlin's method assumes that the age-specific mortality rates found in a family reconstitution study are correct for the population as a whole. Thus, the method stands or falls on whether age-specific mortality schedules are the same for natives and in-migrants. He computes $P_i = D_i/m_i$, where P_i is the number of persons in the ith age group in the population and D_i is the number of deaths in the entire population in the ith age group. The number of deaths, D_i can be computed only if the burial registers record deaths of migrants and list age at death for everyone. Data of this nature are recorded in many Continental parish burial registers from the seventeenth century on but age at death is not recorded in English records until the nineteenth century. Finally, m_i is the age-specific mortality in the reconstituted families for the ith age group. Summation over the P_i yields the total population. Certain vital "rates" for the entire population can also be obtained. These include the crude birth and death rate, the general fertility rate, and the general marital fertility rate (if marital status is known). With this additional information, the Coale (1969) I_f, I_g, and I_m descriptive indexes can be computed.

Family reconstitution studies for regional and urban populations hold out great promise for creating the type of large-scale, longitudinal data bases required for detailed, sophisticated causal modeling and rigorous testing of substantive theories of human behavior, social organization, and cultural change within varying historical contexts.

The Structure of Coresident Domestic Groups

Two of the principal systems of classification of coresident domestic groups (households) are those of Louis Henry (1967: 44–46) and Peter Laslett and Richard Wall (1972: 28–32). The major difference between the two systems is that whereas Henry classifies domestic groups by their heads, usually the first person listed on a household enumeration record or census, Laslett classifies these groups on the basis of the type of familial unit present. Laslett and Wall illustrate how the two systems would lead to different results:

> Henry classifies a widowed person coming first in the list of names for a household, that is the *household* head, as constituting a *family* head, whether or not there are accompanying children, and therefore as creating a multiple household where in our system there would simply be an upwardly extended one. Widowed persons coming later in a household are taken by Henry as dependent, and so not as constituting heads of families. This difference must be borne in mind when reading contributions (printed here) from the Continent of Europe, where Henry's system has been in use [1972: 33; emphasis in the original].

Although comparative studies would probably benefit from the adoption of a uniform system of household classification, varying research interests and historical contexts may require and justify the use of specialized classification systems. Table 8.1 presents the system developed by the Cambridge Group for the History of Population and Social Structure. The typology found in Table 8.1 presumes that a household has been defined as:

> all those who appear in the list [i.e., a census-type document] grouped together, or in any way clearly separated from groups of others before and after. Occasionally the compiler has made what appears to be subdivisions, to indicate more than one household sharing the same set of premises. In such cases the term *household* designates the larger group. A household is also to be designated as the inhabitants of a *dwelling*, and the houseful as the inhabitants of a set of *premises* [Laslett and Wall, 1972: 86; emphasis in the original].

Census-type documents may indicate boundaries and list the relationship of each member to the head of the household (see pp. 98–99). On the other hand, neither the boundaries nor the relationships may be stated. In the latter cases, inference rules must be established to reconstruct as much structural information as possible using clues such as the order of individuals on a list, their marital statuses, ages, or any other biographical data available.

Table 8.1
A Typology of Coresident Domestic Groups Proposed by the Cambridge Groups for the History of Population and Social Structure

Type[a]	Variations
1. Solitaries	a. Widowed b. Single, or of unknown marital status
2. No family	a. Coresident siblings b. Coresident relatives of other kinds c. Persons not evidently related
3. Simple family households	a. Married couples alone b. Married couples with child(ren) c. Widowers with child(ren) d. Widows with child(ren)
4. Extended family households	a. Extended upwards b. Extended downwards c. Extended laterally d. Combinations of 4a–4c
5. Multiple family households	a. Secondary unit(s) UP b. Secondary unit(s) DOWN c. Units all on one level d. *Frérèches* e. Other multiple families
6. Indeterminate	
7. Stem families	5b 5b + 5a 5b + 5a + 4a
8. *Frérèches*, alternative definitions	5d 5d + 5c 5d + 5c + 4c 5d + 5c + 4c + 2a

Source: Laslett and Wall, 1972: 31.
[a]Each type may be further divided into those with and without servants.

The Cambridge Group has formulated a fairly comprehensive set of definitions and inference rules for use with English records (Laslett and Wall, 1972: 86–89). Their framework can serve as a convenient benchmark against which alternative definitions and inference rules can be tailored to meet the characteristics of census-type records that deviate in important ways from English listings, where age and other ancillary data are rarely available until the nineteenth century. A married couple, a widow or widower, a child, a servant, or resident kin in a household can be defined as such when (*a*) they are stated to be so by the compiler or person who in the past drew up the listing; (*b*) can be shown to be so on the basis of external evidence such as a parish register or family reconstitution results; or (*c*) can be presumed to be so on the basis of certain inference rules. The Cambridge Group's inference rules regarding marital status, offspring (children who live in the households of their own parent(s), stepparent(s), or grandparent(s) and are themselves unmarried), and kinship are as follows:

1. *Presumptions about marital status:*
   a) Those may be *presumed married* who are of opposite sex, appear first and second in the household and have the same surname. This presumption is strengthened if those following the first two have the same surname and/or are described as children. Those may also be *presumed married* who appear later in the household, i.e., not first and second, but who have the same surname and are followed in the household by those who have the same surname and/or are described as children.
   b) An individual may be *presumed widowed* who is
      i) described as either mother or father of the head or other member of the household (a spouse not being present) or
      ii) the head of a household containing either or both a married couple and children (so described) with the same surname or with no surname given.

   It will be seen that deserted wives or husbands are regarded as widowed and even those living separately from their spouses, or with their spouses temporarily absent.
   c) An individual may be *presumed single* who is
      i) described as a child, son, daughter, nephew, niece, sojourner, servant, apprentice, journeyman, bastard, unless there is evidence to the contrary
      ii) living with what is described as his or her bastard child or bastard with the same surname (and not described as married)
      iii) living in a household in which the only relative is a sibling.
2. *Presumptions about offspring:*
   An individual may be *presumed offspring* who is listed immediately after a married couple, a presumed married couple, a widowed person or a presumed widowed person and has the same surname or is listed without a surname.
3. *Presumptions about Kinship:*
   a) An individual may be *presumed a grandchild* who is described in the list as the offspring of a parent(s) whose own (presumed) parent(s) head(s) the household.
   b) An individual may be presumed a parent of the preceding generation who is described as widowed in a household headed by a man or woman of the same surname.
   c) Members of a household with the same surname may be presumed kin. This final statement is perhaps the most arbitrary of all, since many surnames in English, such as Smith, are very unreliable as indicators of kinship. Almost no affinal relationships can be recovered by use of this principle, since the wife's surname is also known so seldom [Laslett and Wall, 1972: 88–89; emphasis in the original.]

After a classification and inference system has been created, household heads, marital units, related individuals and others are coded according to the system using nominative census-like lists. A typical household structure analysis (see Laslett and Wall, 1972: *passim*) entails computing the proportions of different household types. Although information of this sort is of considerable value, great care must be exercised in the interpretation of such findings. Extended family households (i.e., marital units living together with one or more relatives other than offspring), for example, are "not static in composition, but go through developmental cycles in which the combination of kin and marital units are constantly changing so that the proportion of households with two or more related couples at a given point in time depends on the demographic, economic, and cultural variations which affect the timing of marriage and the duration of coresidence" (Berkner, 1977: 159). Interpreting the proportion of extended households, therefore, is not as straightforward as it may appear. The standard presentation of proportion of household types is quite limited.

Lutz Berkner (1977) suggests alternative methods of counting household types, each of which offers a different perspective to assist in interpreting simple proportions. An application of these methods appears in Berkner and Shaffer (1978). In addition to finding the number of households of a particular type as a proportion of all households, Berkner proposes that the number of marital units in a particular type of household be computed as a proportion of all marital units. Let us say that we had a list of 50 one-marital-unit (nuclear family) households and 50 two-marital-unit (joint family) households. Using the standard method of proportions, we would report that 50% of the households were composed of nuclear families. If marital units were used, however, we would report that only 33% of the marital units were in nuclear family households. Differences in the results obtained from the two methods are a function of the prevailing proportions of household types. If only 25% of the households are joint (i.e., two marital units living together that are connected by kinship or marriage), then 50% of the marital units are in joint households.

Another approach to studying household structure is to calculate the proportion of the entire population located in different household types. Proportions computed in this manner are highly sensitive to the number of children in a population and their distribution within households. In households with stem or joint organization, the number of children present will peak at the midpoint of the family cycle, which occurs after about 15 years of marriage. Berkner (1977: 162) argues that the largest number of children per marital units will coincide with the nuclear phases of stem and joint households.

The two major weaknesses in the approach to household structure often attributed to the Cambridge Group by its critics are, first, that the likelihood of a marital unit experience in different structural settings is confused with the probability of different household types. The previous example showed that although only 25% of households might be joint, 50% of all marital units were experiencing life within a joint household structure. Thus, although the odds of a household being joint were only 1 in 4, the odds of a marital unit being in a joint household were even. Although this distinction may seem obvious, a reading of the household structure literature in the early 1970s suggests otherwise. The second weakness is that household structure analysis based on a single slice of cross-sectional data often founders on methodological problems that arise when attempts are made to interpret structural characteristics observed at a single point in time, which are caused by a host of poorly understood and undocumented dynamic processes. As sensitivity to the often insurmountable methodological problems and limitations posed by cross-sectional analyses increases, we can expect to see greater efforts directed toward the reconstruction of dynamic and life-cycle processes (Plakans, 1979: 92–93).

Dynamic Studies of Household Structure and Family Life Cycles

Several recent works illustrate the multidisciplinary shift from static, cross-sectional to time-dependent, dynamic studies of household structure. These include analyses by a demographer using Belgian population registers (van de Walle, 1976); anthropologists using a series of French censuses (Segalen, 1977), Japanese household registers (Smith, 1978) and a wide variety of longitudinal Swiss sources (Netting, 1979); and, finally, two historians (Chudacoff and Hareven, 1979), using United States census samples collected at three time points.

Selecting a population register for a commune of Walloon Brabant, La Hulpe, covering the 20-year period from 1847 to 1866, Etienne van de Walle (1976) is able to construct a set of matrices of transition probabilities from one household type to another. A key concept used by van de Walle is that of the "person-year" (the number of years spent by persons in certain states or categories such as an age group, a specific marital status, or type of household). The population of La Hulpe accumulated 37,162 generalized person-years between 1847 and 1866. Van de Walle reports an age distribution in 5-year categories spent in five different household types. He computes a measure of the proportions of different types by weighting frequency of household type by duration. The importance of each type is determined by calculating the number of person-years lived in a household type by individuals, and their proportion of the total number of person-years lived in La Hulpe. Probabilities of transition from one household to another, say from A to B, are obtained by dividing the number of transitions from type A to type B by the amount of time spent in type A. The probability or risk of disruption of a particular type of household, then, is equal to the total number of their transitions to other types (including total disappearances), divided by their total duration. Van de Walle then disaggregates this probability into separate risks of transition to each of the other types, as well as of becoming extinct. Transition probabilities from simple to complex types ("upward" transitions) and from complex to simple types ("downward transitions) may thus be computed. Finally, he determines transition rates by age.

Van de Walle raises substantive questions that might be answered with this type of dynamic household data: "Does the use of contraception appear first in extended or multiple families living in small houses—keeping, of course, age and marital status constant? Or is it possible that high fertility breaks up the complex families, by compelling the most fecund couple to settle on their own? Who are the migrants when the families split up? Older ones? Cadets? Married daughters or married sons? Who succeeds the household head when he dies? (1976: 92–93)."

Martine Segalen's (1977) study of households of a Breton village, Saint-Jean-Trolimon, is based on census lists gathered, with few exceptions, every 5 years from 1836 to 1975. By employing a large number of cross-sectional census measurements with relatively short time intervals between them, she attempts to overcome the bias problems inherent in cross-sectional data. Using Laslett's classificatory system (despite some debate over its merit), she constructs a model by observing how individual households that persist over a minimum of 25 years, or six census lists, are established, change, or disappear. Laslett's classification categories are used as a variable to characterize the formation and dissolution phases of the household during its cycle.

Japanese household registers of the Tokugawa period, for commoners in two wards of the town of Tēnnoji, run in a broken series from 1757 to 1856. Of the yearly registers, 36 survive and have been analyzed by Robert Smith (1978). He develops a set of nine "family forms" and tries to confirm the existence of a previously discovered developmental cycle: a three-generation stem family with a midgeneration head, to a two-generation conjugal family, to a two-generation stem family with a senior head, and finally back to the original type. Only 40 of the 1095 families that appear in the registers are actually traced over time. The results are somewhat inconclusive, partially because of missing data. However, future research with Japanese household registers may be able to investigate issues such as the life cycles of males and females, how mortality affects family structure, the role of adoption, and the amount of time individuals spend in families of different composition (see p. 127).

Along similar lines, Robert Netting (1979), has undertaken the study of one nineteenth-century Swiss village, Torbel, using censuses, church registries, civil records of vital statistics, and a genealogy book containing most of the village's families from the late seventeenth to the early twentieth centuries. Some of the descriptive tables generated by Netting include, for each of five censuses (1829, 1837, 1850, 1870, and 1880), the number of members per household; the resident kin types (lineal, near collateral, other collateral, affine, and distant) related through both men and women; relationships through males and females of kin in households; kin relationships of servants and nonservants to household core groups; and household types, using Laslett's standard typology. Netting uses marriage cohorts of 25 years to compute mean age at marriage by sex and 25-year death cohorts to find mean age at death by sex.

The final example deals with family dissolution and life course transitions into old age. The data for this study by Howard Chudacoff and Tamara Hareven (1979) consist of individual-level census samples from Providence, Rhode Island, for the years 1865, 1880, and 1900. The sample was drawn in a manner that permits individuals to be reaggregated into families, households, ethnic and racial groups, age and occupational categories, and other types of groupings. The authors focus on four types of transitions: exit from the labor force; entry into the "empty nest"; onset of widowhood; and loss of household headship. They begin their analysis by tabulating age-specific rates for each transition. Changes in the distribtuion of these rates are compared over time, and since no significant shifts are found in the transition patterns, the three census samples are aggregated into one data set. Each type of transition's characteristics are then described.

Research based on source materials containing data on households and families requires careful, historically grounded conceptualization which may entail combining cross-sectional and longitudinal perspectives. Great opportunities exist for more creative use of descriptive statistical techniques (for example, see Tukey, 1977; Mosteller and Tukey, 1977). Historical household and family studies are entering an era of increased theoretical sophistication and statistical rigor, placing sometimes severe but legitimate demands for change upon traditional modes of historical inquiry (Laslett, 1977: 1–11).

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9
Sampling in Historical Research

Samples are used to represent some larger group or "target" population. Examples of so-called target populations might include the entire Dutch population between 1840 and 1850, or only married females living in a large city such as Amsterdam. Precise definitions of target populations as well as their individual elements, or primary sampling units (PSUs), are quite important. Skillful sampling can prove to be both a tool of data analysis and a highly efficient method of answering theoretical questions in cases where studying total populations would be too costly or time-consuming.

The use of sampling techniques in recent historical demographic research has taken a variety of forms. Individual parish reconstitution studies carried out in isolation of one another, which were characteristic of the early period of development of historical demography, are being superseded by projects involving parishes as primary sampling units within a target population of all parishes located in a given society. Louis Henry and Jacques Houdaille (1978), for instance, use a sample of French parishes to analyze changes in the proportion of never-married individuals during the eighteenth and early nineteenth centuries. The authors show that earlier monographs dealing with individual French parishes could not adequately study the proportion of never-marrieds because this calculation is affected not only by marriage rates but also by migration. Thus, the population of France as a whole needed to be studied. To do so would be virtually impossible without being able to rely upon a sample of parishes.

Sampling is one of the most powerful of research strategies available to the historical demographer. It can also be one of the riskiest, as demonstrated by the heated controversies that surrounded Stephan Thernstrom's (1973) *The Other Bostonians: Poverty and Progress in the American Metropolis, 1880–1970* and Robert Fogel and Stanley Engerman's (1974) *Time on the Cross: The Economics of American Negro Slavery.* Debates centered upon the representativeness of the samples used in Thernstrom's work (Alcorn and Knights, 1975; Thernstrom, 1975), and on Fogel and Engerman's failure to specify the sampling designs used to simplify the task of analyzing the mass of quantitative data available. Herbert Gutman's (1975) *Slavery and the Numbers Game* presents a comprehensive critique of sampling applications found in *Time on the Cross*. In other studies, Herbert Gutman and Richard Sutch (1976a, 1976b, 1976c) show that the samples in *Time on the Cross* were often unrepresentative, biased, and too small to support the book's generalizations about the demographic experience of American slaves.

Knowledge of how to design proper sampling procedures can open up vast areas of demographic data closed to earlier generations of scholars who believed either that complete population enumerations were always necessary or considered sampling too complicated to warrant consideration. Census schedules, one of the most important sources of data for many historical demographers, typically contain such a formidable array of information that scholars without knowledge of sampling techniques may rapidly be overwhelmed. However, census schedules are usually broken down into enumeration districts. These relatively small spatial units of analysis are valuable for studying geographical patterns within a city or an entire region and for making the task of locating an individual easier than it might otherwise be. However, they can also be utilized with relative ease to draw a random sample (see, for example, Perlmann, 1979).

The mysterious atmosphere surrounding sampling needs to be dispelled if significant progress it to be expected in the analysis of urban-, regional-, and societal-level populations of the past. The historical demographer who does not know how to sample has lost sight of one of the most valuable of available research methods. While we shall discuss some types of samples most likely to be used by historical demographers, additional texts should be consulted to amplify our treatment in the event that the use of sampling is being contemplated in a research project (see, for example, Raj, 1972; Sudman, 1976; Jessen, 1978). For the non-mathematically inclined, Bill Williams's *A Sampler on Sampling* (1978) is an excellent supplement to the discussion that follows.

Simple Random, Systematic, and Cluster Sampling

Samples are simply subsets of larger populations. The fundamental strategy is to select properly a relatively small amount of data that can reveal the properties of the parent population. The resulting savings in labor and costs can be immense. At the start, it is of critical importance to have a clear conception of the population to be sampled. Is it a population of individuals, households, streets, or geographical units? Seymour Sudman suggests that the following criteria be kept in mind when evaluating the design of a sample:

1. How well can the data be generalized?
2. How complete is the discussion of the sample and its limitations?
3. Is the use of a special population necessary to test a theory or is a special population used only for convenience?
4. Is the sample size adequate for the analysis reported?
5. How well was the sample design carried out?
6. How well were the limited resources used [1976: 46]?

An elegant article that implicitly addresses all of these criteria is Melvyn Hammarberg's (1971) "Designing a Sample from Incomplete Historical Lists." Stephan Thernstrom's (1964) *Poverty and Progress: Social Mobility in a Nineteenth Century City* provides an interesting example of the difficulties encountered when sampling a population at different points in time. The reader will find it instructive to examine both of these studies, keeping Sudman's six criteria in mind.

A simple random sample is the easiest to understand of all sampling types. It may be defined as a sample in which each element (for example, an individual on a census list or parish register) is equally likely to be selected and is done so independently of all other elements. A table of random numbers might be used, for example, to draw a simple random sample of numbered individual items from sources such as pages of a large census manuscript or vital events register. An interesting property of a simple random sample is that a simple random sample of a simple random sample is also a simple random sample.

While simple random samples are preferable, systematic random samples are often easier to extract. To draw a systematic random sample, a sampling interval and a random starting point are required. If a census list is to be systematically sampled, a sampling interval could be set equal to the ratio of the number of individuals in the desired sample size to the number in the total census population. Thus, if we want to sample 1000 persons from a list of 10,000, we would choose every tenth person from the list. The principal danger with systematic sampling arises from the possible presence of periodicities in the lists to be sampled that might coincide with the sampling interval (Schofield, 1972.) For example, if the sampling interval was such that individuals residing at the ends of streets in a city were preferentially selected, bias might enter if their socioeconomic characteristics differed in some significant way from persons found elsewhere at potentially less favorable street locations. Once a sampling interval has been chosen, the first element in the sample is chosen by selecting a number at random from the sampling interval. In the sample above, this would be a number from 1 to 10.

Cluster sampling is often used instead of simple random sampling or systematic sampling to make data collection less time-consuming and more efficient. This is achieved by taking account of the fact that the elements of a population are usually located in relatively small spatial clusters such as counties or *départements*, baronies, communes, parishes, households, and so on. Deciding how to cluster a population is a critical decision. Sudman suggests that use of any given kind of clustering should depend on the following factors:

1. The clusters must be well-defined. Every element of the population must belong to one and only one cluster.
2. The number of population elements in each cluster must be known, or there must be available at least a reasonable estimate.
3. Clusters must be sufficiently small so that cost savings are possible—otherwise the point of clustering is lost.
4. Clusters should be chosen so as to minimize the increase in sampling error caused by clustering [1976: 70].

Because clustering lowers the number of independent observations, "sampling error" or variability from one sample to another will increase as a factor of the size and homogeneity of the clusters. The extent of sampling error can usually be computed by procedures discussed in standard sampling texts and should always be reported along with any published results.

Michael Anderson's (1971) *Family Structure in Nineteenth Century Lancashire* studies the extent, strength, and function of family and kinship ties for individuals residing in Lancashire cotton towns, particularly Preston. The 1851 population of Preston numbered about 69,542 persons, 70% of whom were migrants. His procedure was to take a 1-in-10 (cluster) sample of all occupied private residences and quasi-institutions listed in the censuses under study. Persons residing in institutions were sampled on the basis of 1 inmate in 10 for use when data on the whole population were required. In actuality, persons living in 1700 houses, about 15% of Preston's houses, were cluster sampled from the censuses of 1841, 1851, and 1861. The representativeness of his sample was checked by comparison with the distribution of the Preston population by birthplace, age, and sex found in published, aggregate census tables. Anderson found that in all cases the distributions were within a 5% tolerance limit. In addition, two comparison samples were drawn from nearby villages. They were to be used for comparison with Preston's migrants and were sampled on the basis of the distribution in the Preston sample of the birthplaces of all heads of households born within 30 miles of Preston in villages with an 1851 population of 5000 or less. Consequently, the number of houses sampled from the villages was proportional to the number of migrants in the Preston sample born in each village. A table of random numbers was used to select 781 houses from "agricultural villages" and 913 from "other villages."

Michael Ornstein and Gordon Darroch (1978) have proposed a general cluster sampling strategy for national studies of geographic and social mobility that is similar to a technique used a decade ago by Jacques Dupâquier (1968). Their approach requires only nominative records of the entire population for two points in time. The method proposed uses a type of cluster sampling and is completely general. It may be applied to any kind of data that meet the minimum criteria just mentioned. With two nominative enumerations of a population, a sample drawn from the first enumeration can be linked to the second by using a "letter sample." All persons whose surnames begin with a randomly selected letter, such as *W*, could be coded from both enumeration lists. Every person who appears on the two lists then can be subject to linking. Changes in surnames, death, out-migration from the study region, spelling errors, or underenumeration, obviously reduce the number of potential links that can be made over the time interval separating the two lists.

A letter sample contains 26 possible clusters, one for each letter of the alphabet. Cluster sampling can yield larger errors than simple random sampling if a salient property of the population being sampled is not randomly distributed over the clusters. For multiethnic populations, it will probably prove to be the case that the first letter of individuals' surnames will be associated nonrandomly with certain ethnic groups. Ornstein and Darroch, for example, found that in nineteenth-century Canada, a disproportionately large number of Scots had surnames beginning with the letter *M* while those of French origin were overrepresented with surnames beginning with *L*. Since there is almost always an unequal distribution of surnames beginning with different letters of the alphabet, sample size will be differentially affected by the letter(s) selected for the sample. Ornstein and Darroch suggest that this problem might be overcome by coding names using the Russell-soundex code. They show that instead of 26 clusters of surnames, the Russell-soundex code would produce 192 subclusters. These subclusters could then be recombined to obtain a new set of clusters of approximately equal size. A probability procedure, such as simple random sampling, could then be used to draw a final sample of clusters. Ornstein and Darroch estimate that it is necessary to sample about twice as many persons as one can expect to link over a 20-year period for nineteenth-century Canada.

Stratified and Multistage Sampling

When interest centers on the comparison of subgroups in a population, stratified sampling is often the most efficient procedure. The optimal sample is one in which the sample size of all subgroups is equal, since this minimizes the standard error of the difference. Thus, if we stratified a population into three groups, the first of which constituted 60% of the population, the second 30% and third 10%, the sampling rate for the third stratum would be six times the rate for the first stratum. Similarly, the sampling rate for the second stratum would be twice that for the first stratum.

Multistage samples are samples that require final sample selection to take several steps. Such samples are often used when complete lists of the entire population are not available or would be prohibitively expensive to acquire. Sudman has outlined an example of a multistage sample, one which entails sampling differing sizes of clusters with probabilities proportionate to size:

> 1. The PSUs or clusters are arranged in the desired order to obtain possible benefits from stratification, that is, sorted by region, race, economic, and other variables . . .
> 2. The size measure for each PSU or cluster is obtained from U.S. census data or other sources.
> 3. The size measures are cumulatively summed over clusters.
> 4. The sampling interval is determined as the total cumulative sum of the size measures divided by m, the number of clusters desired.
> 5. A random start is selected, and the selection numbers are found as r, $r + s$, $r + 2s$, $r + 3s$, . . . , $r + (m - 1)s$, where r is the random start and s is the sampling interval.
> 6. A cluster is selected if the selection number falls into its sequence of numbers; that is, the selection number is greater than the cumulative sum of all previous clusters, but less than or equal to the cumulative sum including the designated cluster [1976: 134].

Sampling with probability proportionate to size, as described earlier, corrects for variations in cluster sizes and yields an approximately optimal sample from a statistical viewpoint.

John Foster's (1974) *Class Struggle and the Industrial Revolution: Early Industrial Capitalism in Three English Towns*, made use of town directories supplemented by 1851 census schedules to draw a stratified sample of the bourgeoisie in Oldham, Northampton, and Shields. His approach was to sample individuals from all occupations and social groups most likely to have some stake in the "system." Strata were composed of employers of all sizes, merchants and tradesmen (excluding small shopkeepers), members of the established professions, and magistrates, guardians, and councillors. Important occupations with too few persons to permit sampling, such as coal mine owners, hat manufactures, and engineers in Oldham, were completely enumerated. A one-in-two, and in Northampton a three-in-four, sample was taken alphabetically. This resulted in a selection of 341 persons in Oldham, 200 in Northampton, and 293 in Shields.

A far more complicated stratified sampling design developed for a project on the demography and social history of old age in America has been outlined by Daniel Scott Smith (1978). United States counties were selected as the primary sampling unit (PSU). Published census data for 1880 and 1900, in machine-readable form, for 2800 counties were used to stratify the counties for selection in an 1880 national sample, a sample of the older black population in the South in 1880, and a nonurban 1900 sample. This was done using factor analysis, scales created by factor scores, manual mapping, and other techniques.

The probability of a county falling into the sample was kept proportionate to its population size. By systematically selecting a PSU from rural clusters of counties within states, the full range of economic and demographic features of a census region were represented. One disadvantage of this systematic stratification sampling approach, however, is that it makes it difficult to compute sample variance and sampling errors.

Following the first-stage selection of the PSUs, a procedure had to be developed for sampling within PSUs. A systematic sampling strategy was adopted in which every N-th census manuscript page was chosen, with every person on those pages in the target age group (over 65) coded. The 55–64-year-old age group was coded off pages which were two pages forward from those chosen in the sample for the over 65 group. Smith convincingly describes the advantages of this approach:

> Instead of having our 3,000 persons over age 65 being chosen randomly throughout the whole country (impossible), or systematically on an individual level (requiring the examination of 75,000 census lines on 1839 reels of film), they are located on about 750 pages of film in 100 primary sampling units, 35 cities and the nonurban areas of 56 counties, within previously stratified regions. This approach provides a reasonable approximation of a national sample of the noninstitutionalized older population [1978: 71–71].

To evaluate the representativeness of the sample, its characteristics (percentage male, age composition, conjugal condition, percentage foreign born, percentage illegitimate, and tenure of homes) for those 55–64 and 65 and over were compared with published census figures for 1900. However, since the census included the institutionalized population and the sample does not, the two are not precisely comparable.

Sample Size

One of the most difficult problems to resolve is the proper size of the sample to be drawn. If the width of the statistical confidence interval and probability level desired can be specified, however, an exact formula exists to compute the appropriate sample size (see Raj, 1972: 34, 59). Although most historical demographic studies that use sampling draw samples large enough to facilitate study of the total population, the size of subgroups of interest within the sample may prove to be too small. For example, if an adequately sized, systematic sample of heads of households was drawn from a census list, this would provide no guarantee that if we were to subdivide the heads by social class, the number of heads left in the resulting subgroups would be sufficient to conduct a statistically significant analysis of those subgroups. Sudman suggests that as a general rule "the sample should be large enough so that there are 100 or more units in each category of the major breakdowns and a minimum of 20 to 50 in the minor breakdowns [1976: 30]."

There is no magic sample size or sampling design that will automatically yield optimal results in every historical demographic research project. However, the examples cited in this chapter illustrate the broad range of options used in sampling historical populations.

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10
Lexis Diagrams and Formal Demographic Indexes

The construction and use of demographic indexes within a cohort perspective can serve as one of the most powerful, descriptive methods of documenting critical changes in a population over time. For example, in the last of a series of four papers analyzing marital fertility between the end of the seventeenth and the beginning of the nineteenth centuries in four major regions of France, Louis Henry (1978) uses six marriage cohorts to study the fertility of all couples, sterility and childlessness, the age of the mother at the birth of her last child, premarital conceptions, and the transition from a system of presumed natural fertility to one characterized by the voluntary limitation of births.

The reconstruction of time series of raw demographic data or rearrangement of previously aggregated data are necessary steps prior to the creation of cohort diagrams and the construction of demographic indexes. Monique Maksud's and Alfred Nizard's (1977) compilation of statistics on foundlings and filiation in France in the nineteenth and twentieth centuries is a good example of this type of preliminary data manipulation. Their results show that during the first half of the nineteenth century, about 40% of illegitimate children were abandoned. This declined to 18% in 1910, 13% in 1925, and 4% in the 1950s. Whereas the infant mortality of illegitimate children was almost twice that of the legitimate children in 1850, it is currently about 60% higher. Time series data of this and of a similar nature suggest that the application of cohort techniques and the building of indexes may reveal additional insights into the phenomenon of illegitimacy.

Use of sample data and ingeniously designed demographic indexes can lead to substantial revisions in our understanding of historical processes. Danièle Rebaudo (1979), employing mortality data from a sample of 50 French villages for 1670 to 1740, for instance, computes a "crisis index" proposed earlier by Jacques Dupâquier. The results contradict the pessimistic analyses usually made regarding the period at the end of Louis XIV's reign, indicating that a reinterpretation of that period's demography is in order.

Cohort analysis with demographic data can also be creatively designed to explain theoretical anomalies. The completed fertility rate of nonwhites born after the Civil War in the United States was considerably higher than that of the white rate. The gap declined over time until rates for both racial groups during the Great Depression were nearly equal. However, the gap increased afterward. This is rather puzzling, since theories concerning minority-group fertility in unassimilated populations would predict a higher completed fertility rate and a less rapid decrease for nonwhites than for whites. To investigate this apparent anomaly, Phillips Cutright and Edward Shorter (1979) examine *involuntary* controls on fertility. They document black and white fertility and health conditions for female birth cohorts from 1867 through 1935. Using parity-specific progression ratios (the probability that women who have ever borne a child will by age X have borne another child), their cohort analysis shows that in contrast to changes in white fertility, changes in black fertility have largely been due to changes in the health of black women. The Cutright and Shorter article is a fine example of how a demographic index such as the parity-progression ratio can be used within a cohort analysis framework to discover major historical trends.

One of the most promising historical demographic applications of cohort analysis lies in making the family life cycle a framework for organizing critical life events. An individual can be said to follow a "trajectory" as life progresses along a path following marriage. Criticisms of the use of the family life cycle as a theoretical concept and as a stratification scheme for studying change have emphasized the need to consider the potentially great variation in the timing of critical events from family to family (Nock, 1979). Responding to this criticism, Graham Spanier and Paul Glick (1980) assess differentials in life-cycle events for several important demographic variables by presenting life-cycle progressions by birth cohorts of American women born in the first half of this century, classified by race, educational attainment, and number of times married. Earlier life-cycle analyses had generally displayed median ages, whereas the Spanier and Glick study reports mean ages in order to facilitate the computation of standard deviations of ages at reaching successive family life cycle stages and in making comparisons of those ages across racial and educational groups. One of the most important relationships discovered is that the substantial differences between blacks and whites in life-cycle events tend to be minimized among women at the upper educational level. The authors argue that this suggests that if the general educational attainment level of black women reaches that of white women, many historical, racially based demographic differences may disappear.

These, and a number of other studies illustrate the value of conceptualizing demographic phenomena in a dynamic manner by linking processes and events to the movement of cohorts or subcohorts within a population. This perspective is critical if one hopes to capture a sense of historical change and learn how effects diffuse between different segments of a population.

Lexis Diagrams

Virtually all formal demographic measurements of collective histories can be conceptualized in reference to what is known as a Lexis diagram, named after the German demographer Wilhelm Lexis. This type of diagram allows one to locate events in time for a group of individuals, or cohorts, who possess some common temporal characteristic(s). Examples of cohorts include all woman born in Geneva in 1750 (a birth cohort), all couples who married in Paris in 1800 (a marriage cohort), or all persons beginning textile mill work in Manchester in 1855 (a labor force cohort). A cohort's demographic experiences can be pinpointed in time by measuring the calendar period (or date) and the duration over time since the origin of the cohort. For example, one could locate in a Lexis diagram 40-year-olds who died during the calendar year 1740, for female birth cohorts of 1699 and 1700.

A typical Lexis diagram appears in Figure 10.1. The lowest horizontal line (the abscissa) marks calendar periods (i.e., the years 1800–1810). The first verticle line on the left (the ordinate) marks the time elapsed (here, time in years since birth). The diagonal lines, or "lifelines," identify different cohorts' passage through history. Let us assume that the Lexis diagram in Figure 10.1 is for female birth cohorts. Entry into the diagram occurs for females born between the years 1800 and 1810. The cohort in the diagram labeled Cohort One contains females who were born during the first calendar period, the year 1800. Females who were born on the first day of the year, point A on the diagram, will be 1 year older at the beginning of the year 1801, point F. The tip of the "lifeline" of females in this birth cohort will be located at point B (January 1, 1801). Additional diagonals, 364 more, could in principle be sketched to represent the "lifelines" corresponding to all possible female birthdays during the year 1800. In actual practice, however, the only diagonals used in Lexis diagrams are those marking the earliest calendar period entry of individuals in each cohort. The area blocked off by the letters ABCDEF includes the 1800 female birth cohort for the first 2 years of its life (1800–1802).

Now let us assume that we are interested in studying female child mortality. All deaths taking place at a given age would be located on the same horizontal line in a Lexis diagram. Deaths on a given calendar date would be located on the same vertical line, and the deaths of female children with the same birthday would be located on the same diagonal "lifeline." Squares, such as square H in Figure 10.1, include the deaths of two birth cohorts of female children of a given age in a given calendar year. Parallelograms, such as parallelogram J, include

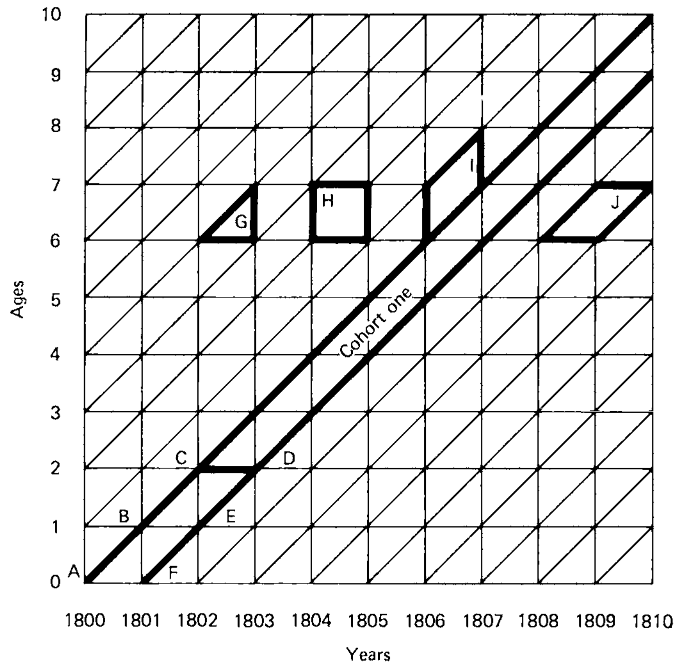


Figure 10.1. *A Lexis diagram for the study of demographic phenomena related to cohorts. (Adapted from Henry, 1976: 46.)*

deaths at a given age in completed years for females of a given cohort. On the other hand, parallelograms such as parallelogram I include deaths during a given calendar year of a given birth cohort. Finally, triangles such as triangle G include females of a given birth cohort and age who die during a given calendar year.

Cohort and Period Indexes: Methodological Problems

Formal demographic analysis is most often concerned with the development and measurement of descriptive indexes (see, for example, Coale, 1969). Since all of the common demographic indexes, such as the crude birth rate, the age specific marital fertility rate, and the parity progression ratio, are defined and described in virtually every demography textbook, we shall discuss only a few indexes to illustrate some fundamental ideas. Readers interested in a full catalogue of descriptive indexes should consult standard texts (e.g., Shryock, Siegel, *et al.*, 1976; Wunsch and Termote, 1978).

Although they are gradually becoming less common, many historical demographic studies have implicitly employed a research strategy that entails data collection, computation of descriptive indexes, and conclusions based on interpretations of index values. However, this is an approach that is incomplete and easily may lead to misleading results. This is not to say that formal demographic indexes, such as the M and m indexes (Coale and Trussel, 1974) used in studies of natural fertility in historical populations, are necessarily to be avoided. The point is that descriptive indexes in and of themselves often create gross oversimplifications of complex historical realities. The use of such indexes should never become an end point of research but rather should be viewed as preparatory to the construction of comprehensive causal models.

Louis Henry (1976: 45) suggests some rules for selecting indexes to measure demographic phenomena. His rules may be illustrated in the following applied example. Assume that we have selected a group (cohort) of all individuals having experienced an event E_1 during a given year. Let us stay that E_1 corresponds to the birth of a sample of Dutch females in the year 1830 and that we are investigating another event E_2, the first marriages of this group of females. Two indexes that might be computed for this type of longitudinal, cohort phenomenon would be the proportion of the group who experience E_2, and the distribution of the time intervals between E_1 and E_2. Thus, we would measure the proportion of Dutch women, born in 1830, who married once, before death, as well as the distribution in yearly intervals between birth and first marriage.

Superficially, these indexes might not appear problematic. However, let us consider some of the difficulties that Henry (1976: 47–51) alludes to, which might confound a naive "index approach" to a historical analysis of nuptiality. First marriages are evitable, nonrenewable events. They require two individuals of different sexes and are consequently affected by the relative numbers of males and females available (at risk) and the relationship of their respective age distributions to cultural norms regarding nuptiality. The relative numbers of males and females and their age distributions are in turn related to historical factors, such as the birth rate, in which both sexes are almost equally affected, and migration and mortality, in which one sex may be more affected than the other. Henry observes that formal demographic analysis "aims at eliminating these disturbing influences so as to reach a fundamental understanding of nuptiality, independent of structure. Up to now this aim has not been achieved and, for lack of the means to do better, nuptiality continues to be treated as if it were related to each sex separately [1976: 47]." When confronted with similar problems, historical demographers should seriously consider the problematic nature of attempting to study nuptiality behavior in the absence of contextual information. They should ask themselves: What does it mean to study a demographic phenomenon, such as nuptiality, "independent of structure" (i.e., historical context)? Is this an illusory research goal? If not, what would be the relative causal value of such information in comparison to information regarding the structural, historical determinants of the phenomenon?

Cohort analysis can be affected by membership attrition resulting from out-migration and mortality. An attempt sometimes used to eliminate the effect of out-migrants on cohort nuptiality is to substitute their nuptiality experience elsewhere for what would have happened if they had not migrated. This solution is almost sure to be flawed if the determinants of nuptiality at the migrants' point of origin are different than at their point of destination when marriage takes place (see Solberg, 1978: 156). Mortality affects cohort nuptiality through the premature deaths of the persons in the single population at risk of first marriage. To eliminate these influences, it would be necessary to know what the marriage patterns of those who died would have been had they lived. To cope with this problem, it is sometimes assumed that single persons who died at a specific age would have married in the same way as those singles who survived beyond that age. Henry shows that this hypothesis is unlikely to be true for a population as a whole. He argues,

> Let's imagine that there are only two classes, class A with a high mortality and low definitive probability of remaining single and class B with a low mortality and a high definitive probability of remaining single, and that in each class the above hypothesis is true; it will not be true for the whole [population] since at each age class A would be comparatively larger without mortality than it is with it [1976: 49].

Futhermore, it is unlikely that the hypothesis would even be confirmed within a class because certain illnesses lower the probability of marriage and raise the probability of death. Despite all these warnings, let us look at some typical indexes and their relation to Lexis diagrams.

The Probability of First Marriages

We shall now demonstrate how one might begin to design a first-marriage probability index. The probability of nonrenewable events E_1, such as first marriages, is computed as the ratio of the number of events E_1 occurring between two age categories, say A_1 and A_{i+1}, to the number of cohort members who have reached age A_i but have not experienced event E_1. If we assume that migration effects are negligible and that there is no mortality, then the probability, n_a, of marrying between year A_i and A_{i+1} is given by Eq. (10.1) below:

$$n_a = M_a/S_a, \qquad (10.1)$$

where M_a is the number of first marriages between ages A_1 and A_{i+1} of single persons, and S_a is the number of single persons of a generation at exact age a.

Figure 10.2 illustrates how Eq. (10.1) may be related to a Lexis diagram. If

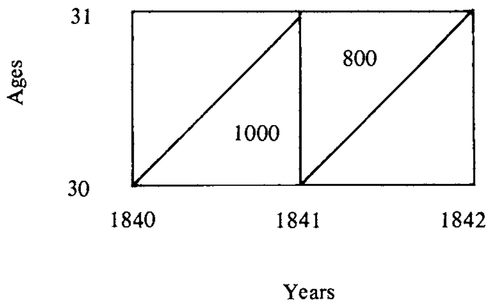


Figure 10.2. *An abbreviated Lexis diagram showing a hypothetical number of first marriages of single persons for the birth cohort of 1810 at age 30.*

we assume that the number of single persons in the 1810 generation depicted in Figure 10.2 is 20,000 as of the first day of the year 1841, and that migration and deaths can be neglected, then:

$$M_{30} = 1000 + 800 = 1800 \quad (10.2)$$

$$S_{30} = 20{,}000 + 1000 = 21{,}000 \quad (10.3)$$

$$n_{30} = M_{30}/S_{30} = 1800/21{,}000 = 0.0857,$$
or approximately 86 per thousand. (10.4)

Other related indexes that might be computed include the probability of remaining single for all years A_i, the mean, median, and modal ages at first marriage, and the standard deviation around the mean age at first marriage. Analogous indexes can be constructed to describe divorce, remarriage, and widowhood. To the extent that migration and deaths cannot be neglected, these indexes will provide misleading information. There is no need to report standard demographic indexes if their assumptions are not appropriate to particular historical contexts.

Fertility Rates in Marriage Cohorts

If we make the assumptions that migration effects can be ignored and that fertility can be treated as a renewable event, a fertility rate index for year x (i.e., between exact age a and exact age $a + 1$) would equal:

$$f_x = N_x/\bar{P}_x, \quad (10.5)$$

where N_x is the number of births between the x and $(x + 1)$th anniversary of a marriage cohort and $\bar{P}_x$, equal to $(P_x + P_{x+1})/2$, is the average number of members of the cohort over duration x.

Using Figure 10.3 as a guide, let us calculate the overall fertility rate at age 30 for women born in 1810. Those women between their thirtieth and thirty-first birthdays had some 3000 births in 1840 and 2800 in 1841. If we take the size of the 1810 generation on the first day of the year 1841 (say, 30,000 women) as the average of women reaching age 30 and age 31, then:

$$f_{30} = N_{30}/\bar{P}_{30} = (3000 + 2800)/30{,}000$$

$$= 0.193, \text{ or } 193 \text{ per thousand.} \qquad (10.6)$$

The same computational procedure would be duplicated successively if one wanted the overall fertility at age 30 for a series of different generations, say those extending from 1820 to 1870.

Other fertility indexes that are often computed in formal demographic studies include the net fertility rate, the total fertility rate, the gross reproduction rate, the child–woman ratio, the parity progression ratio (Curtin *et al.*, 1979), the interval between marriage and the first birth, and age at birth of the last child. Insofar as these indexes confound the effect of fertility with mortality and migration effects, their application may prove to be of questionable value.

Probabilities of Dying: The Life Table

Mortality rates and probabilities of dying suffer from many of the same problems cited for nuptiality and fertility indexes. For instance, Henry (1976: 135) maintains that no study of mortality can be done without taking age into

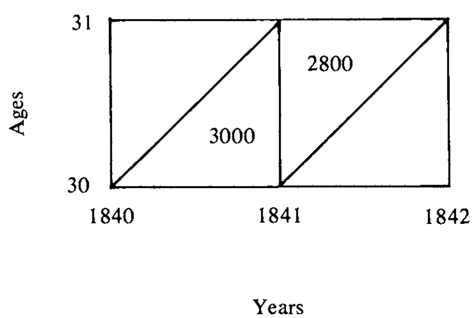


Figure 10.3. *An abbreviated Lexis diagram showing a hypothetical number of births for the 1810 birth cohort of women at age 30.*

account. The crude death rate (the ratio of yearly deaths to total population) is thus another index of dubious value. Life tables display age differentials, but their construction with historical data is often a formidable task (see, for example, Samuel Preston's and Etienne van de Walle's [1978] life table analysis of female mortality in three nineteenth-century French *départements*). The life table for a population for a restricted interval of time, say, 1840–1844 is made up of the set of probabilities of dying at different ages and is known as a period life table. An additional three indexes, derived from the probabilities of dying, are usually included in life tables: the number of survivors, life table deaths, and the expectation of life at different ages.

To illustrate the basic technique involved in computing probabilities of dying, consider Figure 10.4 and Eq. (10.7), adapted from Henry (1976: 143). More complex approximation procedures usually represent some variation on the technique presented in the following discussion. To compute the probability q_a of females (or males) dying at a particular age, say age 31, certain fundamental information must be available. The Lexis diagram in Figure 10.4 lists hypothetical female deaths in those cells necessary to compute q_{31}. In addition, we need to know the number of females alive in the 1810 and 1809 cohorts on the last day of the year 1840. Let us say that these figures are 3000 and 2800, respectively. The probability of dying at age 31 is then:

$$\begin{aligned} q_{31} &= [(109 + 100) + (102 + 104)]/[(2800 + 109) + (3000 - 101)] \\ &= 0.0714, \text{ or } 7.14 \text{ per thousand} \end{aligned} \tag{10.7}$$

The numerator of Eq. (10.7) has two main terms within the outer parentheses. The first is the number of female deaths at age 31 for the cohort of 1809 during the years 1840 and 1841. The second term is the number of female deaths at age

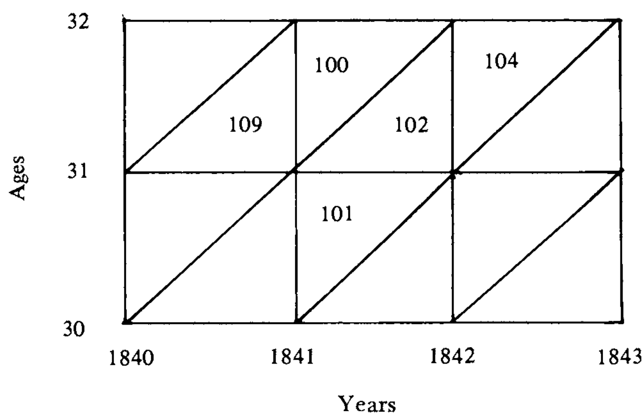


Figure 10.4. *An abbreviated Lexis diagram with hypothetical female death data.*

31 for the 1810 cohort between 1841 and 1842. The denominator of Eq. (10.7) is also broken into two parts. The first is the number of females in the 1809 cohort who reach age 31 and the second is the number of females in the 1810 cohort who reach age 31. The reader should study Eq. (10.7) in terms of the Lexis diagram in Figure 10.4 until the logic underlying the computation of q_{31} is clear.

Life tables are usually constructed on a period basis covering a short interval of time. It is possible, however, to construct cohort life tables for well-documented populations with minimal migration. Assuming that all deaths are recorded, we can construct tables of deaths by age for each sex. If we begin by adding the deaths from the bottom of the tables up to any particular age, we obtain the number of survivors prior to passing through that age. The probability of dying at any age, q_a, would be computed as the ratio of deaths of females (or males) at age a to the number of female (or male) survivors at the beginning of age a.

In addition to period and cohort life tables for specific populations, a variety of efforts have been put into constructing "model" life tables that yield approximate, overall patterns of mortality (Coale and Demeny, 1966; Ledermann, 1969). Model life tables are applied in circumstances where incomplete or defective data rule out attempts to construct actual life tables. Most model life tables are, however, based on data for contemporary populations in economically developed countries. Historical populations may well possess different mortality patterns. Michael Haines (1979), for example, found that one of the most commonly used model life tables, the Coale and Demeny West Model, did not adequately depict the changing shape of mortality in the United States over the period from 1850 to 1910. Haines used William Brass's (1971) two-parameter system and available life tables from northern, industrial states to construct a valuable but limited model life table. Basia Zaba (1979) has expanded Brass's system to include four parameters: one, governing the level of mortality, one governing the relationship between mortality in youth and adult life, one governing infant mortality, and one governing mortality patterns at extreme ages (over 70). Model life table systems that provide good approxi-

Table 10.1
A Cohort Table Containing Hypothetical Data in Which Change Is Due Entirely to Age Effects

	Year			
Age	1830	1840	1850	1860
20–29	20	20	20	20
30–39	30	30	30	30
40–49	40	40	40	40
50–59	50	50	50	50

Source: Adapted from Glenn, 1977: 49.

mations to historical mortality schedules may require even more parameters than Zaba's four-parameter system. Whether this proves to be the case or not, multiparameter life table systems, such as the Brass and Zaba systems, are likely to be of greater utility to historical demographers than the older Coale and Demeny (1966) "family" of model tables because they permit more historical information to be used in the design of the tables.

Interpreting Cohort Tables: Methodological Problems

Although the construction of Lexis diagrams and tables to describe cohort experiences may require considerable ingenuity (see, for example, Preston and van de Walle, 1978), the interpretation of the resulting diagrams and tables may prove even more challenging. Norval D. Glenn (1976; 1977) has summarized the major difficulties posed by the valid interpretation of cohort data. Responses to Glenn's rather pessimistic conclusions have been made by William Mason *et al.* (1976), David Knoke and Michael Hout (1976), and Stephen Fienberg and William Mason (1978). The reader should consult this literature before undertaking serious research with cohort data.

To shed some light on the major points of debate regarding the possibility of arriving at valid interpretations of cohort data, consider Tables 10.1, 10.2, and 10.3, which illustrate "pure" age, period, and cohort effects. These three tables are in standard cohort table form. That is to say, in their intervals the widths between dates are the same as the intervals between age cohorts. Having constructed a cohort table, one should approach it with at least some hypotheses in mind to aid in identifying potential patterns of variation. The patterns in Tables 10.1, 10.2, and 10.3 are fairly obvious because of the "pure" nature of the effects present. Tables derived from actual historical data can be expected to contain combinations of these three effects and consequently be much more difficult to interpret. Nonetheless, it is instructive to see what cohort tables would look like if "pure" effects were present.

Table 10.2
A Cohort Table Containing Hypothetical Data in Which Change is Due Entirely to Period Effects

	Year			
Age	1830	1840	1850	1860
20–29	20	30	40	50
30–39	20	30	40	50
40–49	20	30	40	50
50–59	20	30	40	50

Source: Adapted from Glenn, 1977: 51.

Table 10.3
A Cohort Table Containing Hypothetical Data in Which Change Is Due Entirely to Cohort Effects

	Year			
Age	1830	1840	1850	1860
20–29	50	60	70	80
30–39	40	50	60	70
40–49	30	40	50	60
50–59	20	30	40	50

Source: Adapted from Glenn, 1977: 50.

In Table 10.1, we find "pure" age effects. Note that the columns for each period (year) have the same pattern of linear, monotonic variation, although there is no variation across the rows. The essential properties required for a "pure" age effect are that the cross-sectional data for each period have the same pattern whereas the data at each age level remain trendless. Table 10.2 illustrates "pure" period effects. Here, there is no age variation at any period, whereas the variation from each period to another is the same at each age level and in each cohort. Finally, Table 10.3 contains "pure" cohort effects. Note that there is no variation along the cohort diagonals and that the direction of the variation as age increases is the opposite of the variation found as one moves from early to later periods at each age level.

The three fundamental effects (age, period, and cohort) give rise to an "identification" problem in cohort tables. If an equation is unidentified, an infinite number of possible structures could produce the same relationships between observed variables (Hanushek and Jackson, 1977: 255). No matter how a cohort table is considered, two of the three effects are confounded with each other. For example, age and period effects are confounded in each cohort diagonal. Similarly, age and cohort effects are confounded in each column, and cohort and period effects are confounded in each row. Thus, it may be impossible to "identify" the extent to which each effect influences the numerical data in a cohort table. Within cohort tables, age is a perfect function of cohort membership and period of time, cohort membership is a perfect function of age and period, and period is a perfect function of age and cohort membership.

This implies that

> in any kind of statistical analysis designed to estimate the effects of a number of independent variables on a dependent variable—age, cohort, and period cannot all three be entered as independent variables, although any two can. However, when two are used as independent variables, the estimate of the effects of each is "contaminated" by the confounding of its effects with those of the third variable [Glenn, 1977: 13].

When statistical techniques alone are not sufficient to provide a choice between causal alternatives, a researcher must draw upon theory and additional empirical evidence from outside the cohort table or else analyze the data by means other than cohort analysis. Identification problems are characteristic of results produced by many formal demographic methods. When human history is even moderately complex, formal demographic findings may prove impossible to interpret validly unless supplemented by insights and data that extend beyond the purely demographic realm.

Migration and Multiregional Analysis

Migration and nuptiality, unlike fertility and mortality, are "open" phenomena since they both establish connections between two populations. Nuptiality connects those of marriageable men and women, whereas migration connects a population of origin to a population of destination. Unfortunately, given the present state of demography, it is extremely difficult to study open phenomena as such (Henry, 1976: 161). In almost every instance, migration is analyzed as a "closed" phenomenon by assuming that whatever changes migration causes in the populations of origin and destination, these changes do not offset the probability of migration in whichever population is being investigated.

Nathan Keyfitz begins his *Introduction to the Mathematics of Population* with the statement that the "life table . . . is . . . a population model, covering . . . a cohort or group of people born at the same moment, *closed to migration*, and followed through successive ages until they die . . . . We are incapable of thinking of population change and mortality from any other starting point [1977: 3, italics added]." Many formal demographers, such as Keyfitz, largely ignore migration because a closed population (one that loses no members through emigration or receives no new ones through immigration) is so much easier to model mathematically. Despite a number of simplifying advantages, closed population models may often be of only heuristic interest and have relatively limited applicability in empirical historical demographic research. Thus, it is generally inappropriate for historical demographers to use a life-table approach, closed to migration, as a starting point of analysis.

In contrast, the concept of "accounting," based on the fundamental demographic balance equation containing birth, death, and migration data (see, for example, Henry 1976: 163) offers a more secure, although complicated framework from which to consider building population models. Migration must not be treated merely as an "unfortunate" perturbation in mathematical demographic models, since "one of the most impressive and consistent findings of the historical demographers has been the high level of local mobility among preindustrial European people [Tilly, 1978: 63]."

The principles underlying an "accounting" approach to population systems have been developed in considerable mathematical detail by P. H. Rees and A. G. Wilson (1977) and Andrei Rogers (1975). We shall summarize the Rees–Wilson accounting framework and suggest how it may be applied to historical analyses involving multiregional migration. Accounting in a demographic context entails tracing the life histories of population units: individuals, groups, or other entities. To discuss procedures in a concise manner requires that we develop some notation conventions.

A "state" index i that runs $1, 2, \ldots, S$ will be used so that we can speak of a unit in a population as being in a state i out of S possible states. To introduce time, a "time" index j that also runs $1, 2, \ldots, T$ will be used. Thus P_{ij} will be defined as a population unit in state i at time j. A complete account of all population unit states and times, P_{ij}, may be represented in the matrix form depicted in Figure 10.5. Each row of the matrix in Figure 10.5 describes what happened from time t to time T to a given population unit (say, females aged 20–24) who were intially in the state specified by their row index. The row sum is the total initial population in state i.

To introduce a bit of empirical complexity, let us redefine P_{ij} somewhat to allow us to represent symbolically the 16 basic types of historical demographic events that may occur over a given time interval. Assume that we are studying a historical period ranging from an initial time t to a final time T. The subscripts of P ($i = 1,2,\ldots, N$ and $j = 1,2,\ldots, N$) will represent initial and final regional locations of persons between t and T. If $i = j$, P_{ii} describes persons who resided in region i at time t and are still there at time T. If $i \neq j$, P_{ij} describes persons who initially resided in region i but then migrated to region j by time T. Since people will be born and die during the t to T time interval, we want also to represent them. Persons born in region i between t and T will be symbolized as $b(i)$ and who die in region j between t and T as $d(j)$. Then, $P_{b(i)j}$ would describe those persons who were born in region i between t and T and migrated to region j by time T. Thus, $P_{b(i)d(j)}$ denotes persons born in region i between t and T who migrate and die in region j before time T. This notation can now be used to set up the population accounting matrix in Figure 10.6. The accounting equations for any region i in the accounting matrix may be obtained by taking the appropriate row and/or column sums. For example, those who are alive at time t

$$\begin{matrix} P_{11} & P_{12} & \cdots & P_{1T} \\ P_{21} & P_{22} & \cdots & P_{2T} \\ \vdots & \vdots & & \vdots \\ P_{S1} & P_{S2} & \cdots & P_{ST} \end{matrix}$$

Figure 10.5. *A matrix specifying the life history of a hypothetical population unit.*

$$\left[\begin{array}{cccc|cccc} P_{11} & P_{12} & \cdots & P_{1N} & P_{1d(1)} & P_{1d(2)} & \cdots & P_{1d(N)} \\ P_{21} & P_{22} & \cdots & P_{2N} & P_{2d(1)} & P_{2d(2)} & \cdots & P_{2d(N)} \\ \vdots & \vdots & & \vdots & \vdots & \vdots & & \vdots \\ P_{N1} & P_{N2} & \cdots & P_{NN} & P_{Nd(1)} & P_{Nd(2)} & \cdots & P_{Nd(N)} \\ \hline P_{b(1)1} & P_{b(1)2} & \cdots & P_{b(1)N} & P_{b(1)d(1)} & P_{b(1)d(2)} & \cdots & P_{b(1)d(N)} \\ P_{b(2)1} & P_{b(2)2} & \cdots & P_{b(2)N} & P_{b(2)d(1)} & P_{b(2)d(2)} & \cdots & P_{b(2)d(N)} \\ \vdots & \vdots & & \vdots & \vdots & \vdots & & \vdots \\ P_{b(N)1} & P_{b(N)2} & \cdots & P_{b(N)N} & P_{b(N)d(1)} & P_{b(N)d(2)} & \cdots & P_{b(N)d(N)} \end{array}\right]$$

Figure 10.6. *A multiregional accounting of migrations, births, and deaths over a historical time period from time t to T.*

in region i and either die in region i between t and T or are alive in i at T are given by the sum of all terms in the first row of the matrix in Figure 10.6.

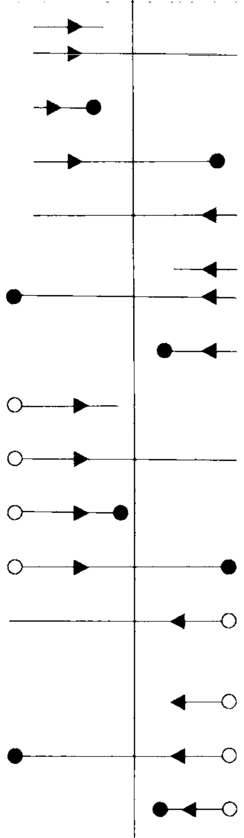
In order to simplify Figure 10.6's matrix and express P_{ij} as a matrix equation, we shall define P as a $2N \times 2N$ matrix with P_{ij} ($i = 1, 2 \ldots, 2N$ and $j = 1, 2 \ldots, 2N$) as its (ij)th element. The birth states will be denoted as $i = b(i)$ and death states $j = d(j)$, where both i and j may run $N + 1, N + 2, \ldots, 2N$. Further let us assume that we have a two-region system with region i as the study region and region R as the rest of the world. These regions form a closed system. We can now write P as:

$$P = \left[\begin{array}{cc|cc} P_{ii} & P_{iR} & P_{id(i)} & P_{id(R)} \\ P_{Ri} & P_{RR} & P_{Rd(i)} & P_{Rd(R)} \\ \hline P_{b(i)i} & P_{b(i)R} & P_{b(i)d(i)} & P_{b(i)d(R)} \\ P_{b(R)i} & P_{b(R)R} & P_{b(R)d(i)} & P_{b(R)d(R)} \end{array}\right] \qquad (10.8)$$

Note that Eq. (10.8) contains 16 cells in its matrix. Verbal and graphical definitions explaining each of these cells appear in Table 10.4. These 16 cells or possible states represent a mutually exclusive set of historical demographic alternatives. Figure 10.7 shows how they can be represented in terms of a multiregional Lexis diagram. A closed demographic accounts table for a two-region system can also be constructed (see Table 10.5).

The various figures and tables just presented represent a conceptually valid framework for multiregional population analysis. They establish conditions that enable a historical demographer to build models that are relatively faithful to the fundamental idea of a population as a system undergoing exchange through migration with other populations. A far more detailed mathematical presentation of accounting techniques with worked examples appears in Rees and Wilson (1977). The principal features that make their accounting approach attractive are several. With this approach it is possible to define in a general way

Table 10.4
The Sixteen Basic Types of Demographic Events That Can Be Exhibited in a Two-Region System in a Historical Time Period



Region i	Region R	Symbol	Definition
		P_{ii}	Persons who survive in region i over the time period
		P_{iR}	Persons who migrate and survive over the time period, migrating from region i to region R
		$P_{id(i)}$	Persons present in region i at time t who die in region i at some time during the period
		$P_{id(R)}$	Persons present in region i at time t who migrate to region R and die during the time period
		P_{Ri}	Persons who migrate and survive over the time period, migrating from region R to region i
		P_{RR}	Persons who survive in region R over the time period
		$P_{Rd(i)}$	Persons present in region R at time t who migrate to region i and die there during the time period
		$P_{Rd(R)}$	Persons present in region R at time t who die in region R at some time during the period
		$P_{b(i)i}$	Persons born in region i in the time period who survive in region i
		$P_{b(i)R}$	Persons born in region i in the time period who migrate and survive in region R
		$P_{b(i)d(i)}$	Persons born in region i in the time period who die in region i during the period
		$P_{b(i)d(R)}$	Persons born in region i in the time period who migrate to region R and die there during the period
		$P_{b(R)i}$	Persons born in region R in the time period who migrate to region i and survive there during the period
		$P_{b(R)R}$	Persons born in region R in the time period who survive to the end of the period in region R
		$P_{b(R)d(i)}$	Persons born in region R in the time period who migrate to region i and die there
		$P_{b(R)d(R)}$	Persons born in region R in the time period and who die there

Source: Adapted from Rees and Wilson, 1977: 21–22; ○ = birth; ● = death —◀— = migration.

for N regions and R age groups, all possible demographic states and the historical transitions between them; second, it offers an illuminating way of viewing Lexis diagrams and understanding the accounting basis of traditional life tables; and, finally, accounting tables and their equations provide a foundation for causal modeling in time-dependent multiregional contexts. Virtually all historical demographic research is multiregional because even if a single population is the object of the study, there is always the rest of the world, as a second region, with which that population will interact in varying degrees.

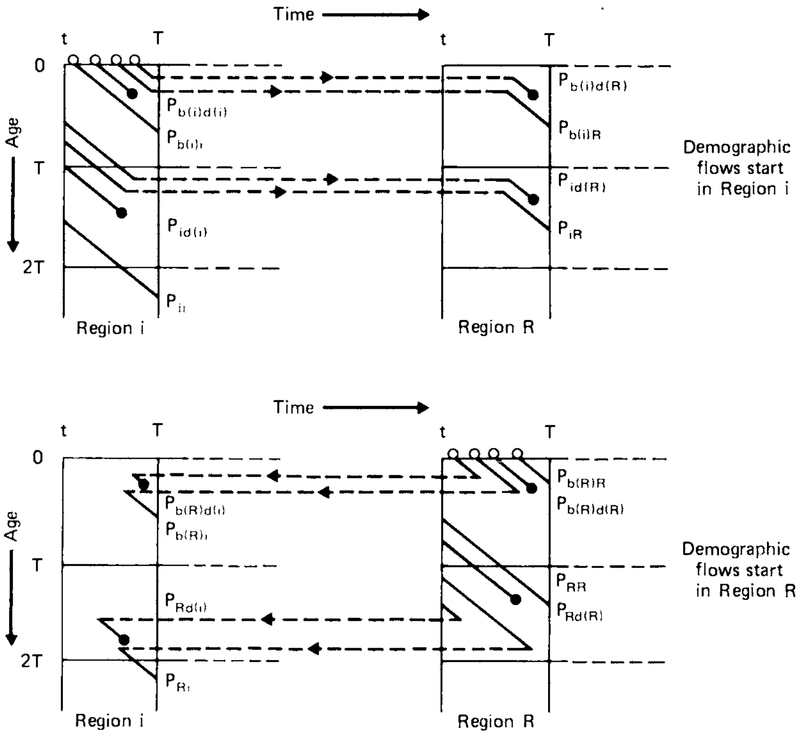


Figure 10.7. *Sixteen basic demographic flows represented in a two-region Lexis diagram. (Adapted from Rees and Wilson, 1977: 219.)*

Computer Programs

The International Statistical Programs Center of the United States Bureau of the Census has compiled FORTRAN listings of a number of computer programs that may be applied to historical demographic data (U.S. Bureau of the Census, 1976). The names and purposes of some of the more pertinent programs for computing specific indexes, rates, and life tables are indicated here:

1. IRDID compares the age distribution of two populations by calculating the Index of Relative Difference and the Index of Dissimilarity.
2. RVFWD obtains an estimate of the underenumeration of age group 0–4 in a population census, under the assumption that fertility has remained constant during the past 10–15 years.

Table 10.5
A Closed Demographic Accounts Table Corresponding to the Representations in Equation 10.8, Table 10.4, and Figure 10.7

State at time T		State at time t			
		Birth in		Initial states	
		Region R	Region i	Region R	Region i
Death in	Region R[a]	$P_{b(R)d(R)}$	$P_{b(i)d(R)}$	$P_{Rd(R)}$	$P_{id(R)}$
	Region i	$P_{b(R)d(i)}$	$P_{b(i)d(i)}$	$P_{Rd(i)}$	$P_{id(i)}$
Survival in	Region R	$P_{b(R)R}$	$P_{b(i)R}$	P_{RR}	P_{iR}
	Region i	$P_{b(R)i}$	$P_{b(i)i}$	P_{Ri}	P_{ii}

Source: Adapted from Rees and Wilson, 1977: 152.
[a]Region R might be conceptualized as "the rest of the world" relative to region i.

3. BRASF estimates 5-year age-specific fertility rates from information on the average number of children ever born per woman and a set or pattern of age-specific fertility rates.
4. NRSFR calculates age-specific fertility rates, given a pattern of fertility rates, a life table, the net reproduction rate, and the proportion of female births to total births.
5. BLT calculates a Coale–Demeny regional life table for both sexes combined, given a life expectancy at birth for both sexes combined, a region (north, south, east, west) of the model life tables, and the sex ratio at birth.
6. BRASM estimates the level of infant and child mortality, based on tabulations of the average number of children ever born and the average number of children surviving, by age of mother.
7. ELT calculates an abridged life table from age-specific mortality rates of the probabilities of dying between exact ages a and $a + 5$.
8. MLT calculates a regional model life table corresponding to a given life expectancy at birth, sex and region using Coale–Demeny regression coefficients.
9. INTSP estimates a stable population distribution and the life table pertaining to such a population, given the intrinsic growth rate and another stable population parameter.

In addition, the BMDP series of computer programs (Dixon, 1981: 555–594) includes procedures that can estimate the survival (time-to-response) distribution of individuals (say, time from birth to marriage) who have been observed over varying periods of time. Survival curves can be reported for an entire population or for subsets of a population. For example, separate estimates might be desired for different social classes. The equality of the survival curves or distributions for different social classes can be tested by two nonparametric rank tests. There is also the option of analyzing survival data for which the time-to-response is influenced by other measured variables. These explanatory variables, or covariates, might represent either inherent differences among persons in a population (i.e., age or sex) or constitute a set of external socioeconomic factors. The analysis is based on the Cox proportional hazards regression model which presumes that survival rates may be modeled as log-linear functions of their covariates.

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11
Factor Analysis

Factor analysis carries us into a realm of searching for "deep structures" lying beneath the surface characteristics of historical data. In social science, the term *structure* is applied in two different ways. Contemporary structural-functionalists use structure primarily as a descriptive term referring to a pattern of social relationships. In this context, the term *function* refers to how such patterns actually operate as systems (see Giddens, 1979: 9–95). The other usage appears among structuralists who interpret structure as having a more fundamental, explanatory role. Structural analysis is presumed to penetrate below the level of surface or phenomenological appearances. The term *deep structure* is an expression indicating that the word structure is being employed in the general manner found in the body of literature associated with structuralism (see Sebag, 1964). Structuralism replaces the division between structure and function by one between "code" and "message." If the correlations between variables in a historical demographic study are understood as representing surface or message level information, factor analysis may be interpreted as a methodology which may permit us to uncover the code that gives rise to surface level correlations.

Factor analysis, which facilitates the search for deep structures is "the furthest logical development and reigning queen of the correlational methods, goes further and is capable of revealing patterns and structures responsible for the observed single correlation connections [Cattell, 1978: 4]." As such, it may aid immensely in finding the underlying historical dimensions of greatest theoretical significance.

If such discoveries are generally agreed to be one of the major goals of the scientific enterprise, why are not applications of factor analysis more common in historical demography? At least three reasons may be adduced. First, the theoretical frameworks informing most research do not seem to call for use of methods designed to discover "deep structures." They are, in fact, excessively phenomenological in character. Second, few researchers in the field have academic training and practical experience in working with factor analysis. It appears a bit mysterious as a method but is actually quite simple once mastery of elementary correlational techniques has been achieved. We suspect that more widespread knowledge and use of factor analysis will have a salutary effect on types of theory construction oriented toward conceptualizing historical processes in terms of "deep structures." This seems to have happened in psychology, where the first important applications of factor analysis took place. Third, there are certain data requirements for the use of factor analysis. Generally speaking, all that is required is a correlation matrix containing a good number more variables than anticipated factors or underlying dimensions. This is often not a very stringent requirement by social science standards.

A research situation often encountered in historical demography is one in which a single dependent variable and a small number of independent variables are to be studied using multiple regression. As the number of variables grows, however, multiple regression becomes conceptually and statistically less attractive, with one order of complexity represented by the original variables being replaced by statistical complexities that may do little to increase understanding of the data. Faced with the problem of discovering the patterns among 40 or more variables, factor analysis may become a viable alternative to multiple regression analysis as a data reduction technique. A major drawback, however, is that the ability to distinguish explicitly between the dependent and independent variables is now lost. If a multiple regression approach cannot be given up, factor analysis may still be helpful as a preliminary step to regression analysis by identifying those variables most likely to be usefully included in a regression equation (Bennett and Bowers, 1977: 146–147).

Suppose that in addition to the presence of a large number of variables, these variables could be divided into a set that is fertility-related (such as age at marriage or parity) and a set that are social and economic (such as occupation or religion) and that the social and economic variables are considered as independent and the fertility-related variables as dependent. Both sets of variables might be factor analyzed separately and multiple regression then used to study relationships between the factors. This strategy still presents difficulties, however, if more than one dependent factor must be taken into consideration. Further, the factors produced from the set of social and economic variables may not be the optimal composite to account for the variance of the fertility-related variables. Both of these problems can be dealt with by employing canonical discriminant analysis (see Dixon, 1981: 500–537).

An Overview

Factor analysis is a data-reduction technique that uses a matrix of correlation coefficients to determine whether "some underlying pattern of relationships exists such that the data may be 'rearranged' or 'reduced' to a smaller set of *factors* or *components* that may be taken as source variables accounting for the observed interrelations in the data [Jae-On Kim, 1975: 469]." Similarities exist between factor analysis and multiple regression. The fundamental equation for multiple regression is:

$$Y = B_1X_1 + B_2X_2 + \cdots + B_nX_n, \tag{11.1}$$

where Y is the dependent variable in standardized form, the X_n are independent variables in standardized form, and the B_n are regression coefficients whose weights or sizes determine the relative importance of the independent variables. If the regression coefficients are known in advance, the scores an entity has on each independent variable can be used to predict the score on the dependent variable (see Dixon, 1981: 235–344). For an interesting application of multiple regression analysis, see B. W. Higman's (1976) attempt to test the combined effect of various economic, ecological, and distance variables on the density of the early nineteenth-century Jamaican slave population.

The basic equation for factor analysis takes the following form:

$$Z_{jk} = A_{1j}F_{1k} + A_{2j}F_{2k} + \cdots + A_{ij}F_{ik} + A_{sj}S_{sk}, \tag{11.2}$$

where Z_{jk} is the standardized score of entity k on variable j, A_{ij} is the factor loading (or correlation) of variable j on factor i in standardized form, A_{sj} is the factor loading of variable j on a specific factor, and S_{sk} is the factor score of entity k on a specific factor. Specific factors are what the variable Z measures that it does not measure in common with any of the other variables. In a principal-components analysis, the proportion of variance due to specific factors is neglected and the $A_{sj}S_{sk}$ term is eliminated. In such a situation, an entity's score on any variable (analogous to the dependent variable in multiple regression) can be predicted from a knowledge of the factor loadings (analogous to regression coefficients) and the entity's scores on the common factors (analogous to independent variables). The aims of the two models are somewhat different. Whereas factor analysis assumes interdependence of variables, multiple regression analysis assumes that one variable is dependent upon all the other variables (Bennett and Bowers, 1977: 146).

Perhaps the best known application of factor analysis to demographic data was carried out by Sully Ledermann and Jean Breas (1959). As their data base, they took 157 life tables covering the first half of this century for some 50 countries which were used in the construction of the United Nations's model life tables. Thirty-eight coefficients were derived from each table, the male and female death rates for each of 18 age groups and the expectation of life at birth for each sex. This yielded 38 times 157, or 5966, coefficients that varied over time and space under the causal influence of what was hoped would prove to be a handful of factors. Jean Bourgeois-Pichat has shown that the Ledermann and Breas factor analysis was a very progressive methodological move because although "life tables are very useful in analyzing sex-age-specific variations in mortality, they are obviously no more than a first step [1963: 152]."

Lederman and Breas identify three factors that account for most of the probability of death dispersion in the 157 life tables. The first factor accounts for almost three-quarters of the probability of the dispersion. Except for cases of low and high mortality, the first factor clearly reproduces a model life table based on the same expectation of life at birth for both sexes. It operates for all ages and sexes, clearly sets off developed from underdeveloped countries, and seems to reflect historical changes in health conditions. The second factor has the following properties:

> (*a*) Its effect may operate in either direction; it may, in relation to the first component, represent either excess or reduced mortality. It may therefore be considered either good or bad;
> (*b*) The effect of the second component varies greatly with age. It is primarily a mortality of adults and of persons approaching old age, but it is also a mortality of children over one year of age;
> (*c*) The effect on children is opposite to the effect on adults and old people. It is as though man acquires a relative excess mortality as he learns to prevent the death of his children;
> (*d*) In adult years and old age, men are more susceptible than women to the effects of the second component. When this component produces an excess mortality, men are affected more than women, and when there is a reduced mortality the advantage is with the men rather than the women;
> (*e*) The opposite is observed in children, boys being less affected than girls [Bourgeois-Pichat, 1963: 160].

The historical causes of this second factor are likely to be a set of interrelated variables whose effects change over time and are not necessarily the same for both sexes and for all age groups. Opposite effects are in fact observed for adult versus child mortality. The nature of these variables and their interrelationships has yet to be discovered.

The properties of the third factor have been described as follows:

> (*a*) Its effect on the first component, like the effect of the second component, can operate in either direction. In other words, the third component may bring about an increase or decrease in the mortality due to the first component;
> (*b*) Its effects are most marked at the extremities of the life span;
> (*c*) Its effects on children operate in the same direction as its effects on the aged, whereas the effects of the second component operated in opposite directions;
> (*d*) Women at all ages are more sensitive than men to third-component mortality. It will be remembered with regard to the second component that there, too, females were more sensitive than males so far as children were concerned but that the opposite was true in the case of adults [Bourgeois-Pichat, 1963: 164].

Whatever variables are responsible for this third factor, it has almost no influence on the determination of death rates for individuals between the ages of 5 and 65 years.

There is a wide variety of possible uses for factor analysis in historical demography. First, it may be employed as an exploratory technique to discover unanticipated patterns among variables that could lead to valuable qualitative or quantitative distinctions. For example, factor analysis might be used to establish that rural and urban dimensions serve to differentiate a set of fertility-related variables better than any other dimensions that might have been present in the data. Second, if it had been hypothesized in advance that rural and urban dimensions should prove to be important in distinguishing between the original set of variables, then factor analysis might be used to test this hypothesis. Under such circumstances, factor analysis would be said to have been used in a confirmatory, as opposed to an exploratory, manner. Finally, factor analysis might be used as a measuring device to create scales for the investigation of other sets of similar data. For instance, factor analyzing a set of administrative areas might lead to the formulation of an urbanization scale that would enable a researcher to make inferences about the extent of urbanization present in administrative areas.

Factor analysis is most often applied in contexts involving a "two-mode" data matrix in which the first mode, formed by the rows of the matrix, represents "entities" with the second mode made up of variables that form the matrix's columns (see, for example, Furet and Sachs, 1974). The row entities could be "individuals" (persons, groups, administrative units, etc.), "variables" (migration indexes, marriage rates, etc.), or "occasions" (months, years, 10-year intervals, etc.). If all possible permutations of "individuals," "variables," and "occasions" are considered, six different factor analytic techniques can be distinguished (cf. Gorsuch, 1974: 277): Individuals are factored and variables (occasions) are used to compute indexes of association when all the data are based on one occasion (variable). Second, variables are factored and individuals (occasions) are used to compute indexes of association when all the data are based on one occasion (individual). The remaining two possibilities are that occasions are factored and variables (individuals) are used to compute indexes of association when all the data are based on one individual (variable).

If occasions (e.g., years) are being factored and the mode across which indexes of association are computed is either individuals (e.g., administrative areas) measured on a single variable (e.g., a mortality index), or variables for a single individual (e.g., an administrative area), the result will be to identify environments or situations, respectively. When variables, based on measurements of individuals or occasions, are factored, traits (factors are assumed to generalize across time) or states (analysis is across time) are sought. Finally, factor analysis of individuals' values across different occasions, or on different variables, attempts to identify types of individuals.

"Three-mode" factor analysis is also possible (Tucker, 1966). We could, for instance, allow one mode to be occasions, another variables, and the third individuals. A specific example might be a set of nineteenth-century British administrative areas (individuals), measured on a number of demographic indexes (variables), at 10-year intervals (occasions). Examples of three-mode factor analysis are rare and typically appear in psychological research literature (Gorsuch, 1974: 283–291).

Stages in Factor Analyzing Historical Demographic Data

The factor analytic model is based upon the assumption that the observed covariation within a set of variables is due in a causal sense to one or more unobserved, underlying factors. If there is no theoretical reason to believe this to be the case, then some other approach rather than factor analysis should be applied. As an illustrative example, let us presume that we have drawn a random sample of heads of households from a source such as a nineteenth-century French census. In addition, we have also obtained extensive socioeconomic measurements on these individuals from other sources. We assume that the observed covariation of these measurements (variables) can be accounted for in terms of two factors, one primarily demographic in character and the other economic. As a general, statistical rule of thumb, at least four times as many variables are required for each anticipated factor. Measurements on each variable should be obtained from at least 50 sampled entities (here, household heads). If these minimum data requirements cannot be met, use of factor analysis is likely to yield unsatisfactory statistical results.

Having gathered sufficient data, normal procedure would now entail input of the raw data matrix into a computer program such as those found in the SPSS, BMDP, OSIRIS, and SAS package programs to produce either a correlation or covariance matrix. Unless comparison of factor structures between groups is planned, use of a correlation matrix is recommended (Kim and Mueller, 1976). Different procedures are required if one intends to perform exploratory versus confirmatory factor analysis. We shall treat the exploratory case first and in doing so follow the flowchart in Figure 11.1.

Exploratory Factor Analysis

The two most common approaches for extracting the underlying factors from a correlation matrix are the least-squares and maximum-likelihood methods. Generally speaking, these methods will produce fairly comparable results. The least-squares approach extracts a set of factors that according to the least-squares principle minimizes the squared differences between the observed correlations and those that can be reproduced by the factors. The maximum-likelihood approach assumes that the raw data matrix is a sample from a

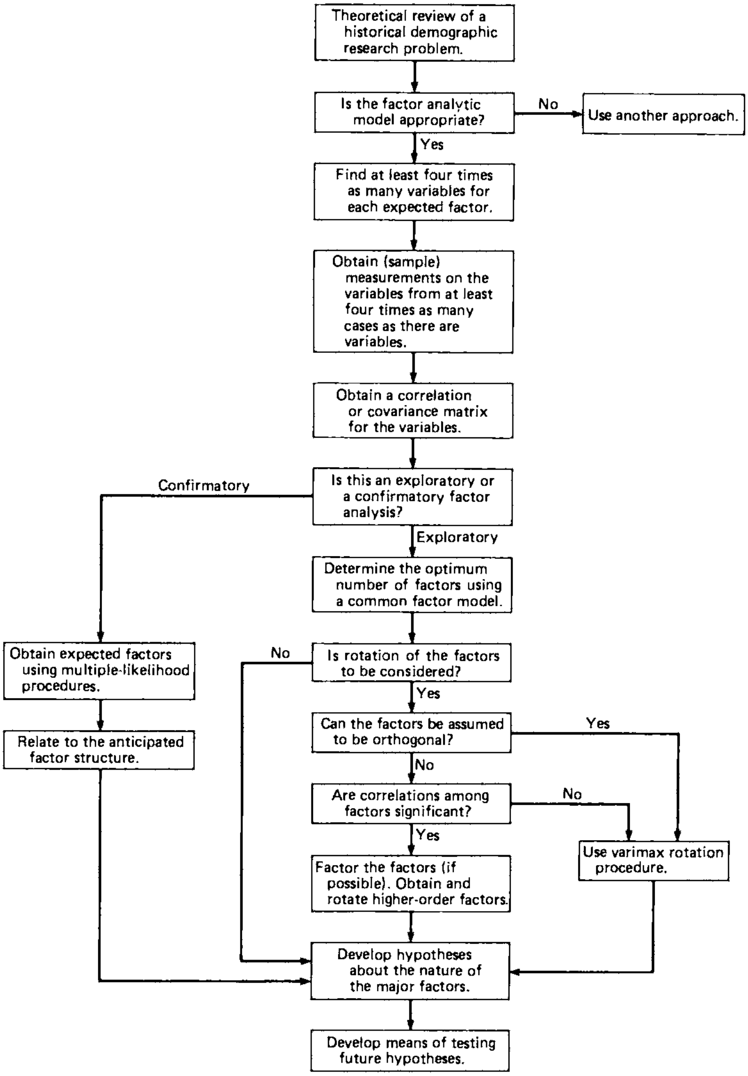

Figure 11.1. *Flowchart of recommended stages to be followed in using factor analysis. (Adapted from Richard L. Gorsuch,* Factor Analysis *(Philadelphia: W. B. Saunders) 1974, pp. 330–331. © 1974 by W. B. Saunders Company.)*

multivariate normal population. One of the criteria in common use to finalize a maximum-likelihood solution is to arrange the factors in a manner that maximizes the determinant of the residual matrix found by subtraction of the observed correlation matrix from the correlation matrix that the factors can reproduce. Since the observed correlations between a set of variables can be perfectly reproduced by using as many factors as there are variables, exploratory factor analysis entails finding the smallest number of factors that, according to some criterion, can best reproduce the observed correlations. A number of different statistical criteria are provided by factor analytic computer programs to aid in determining if a satisfactory solution has been achieved.

Once the number of factors and the communalities (the squared multiple correlations of the variables with the factors extracted) of each variable has been determined, "rotation" methods need to be considered in searching for the best interpretable solution. A common technique used in exploratory factor analysis is to instruct one's computer program to carry out a "varimax" rotation. This has the effect of maximizing the variance of the squared "loadings" (or correlations) of the variables on each factor. The reason the varimax method may aid in the interpretation of the factor structure is because it tends to produce a solution with a few variables with high loadings on each factor whereas the remaining variables have low or zero loadings. In this way the most salient features of each factor are emphasized. Most factor analysis programs are also capable of performing "oblique" rotations by relaxing the constraint that the factors be uncorrelated or orthogonal (i.e., set at right angles to one another). If factors turn out be orthogonal under an oblique rotation option, their orthogonality can be presumed to be genuine and not merely an artifact of one's computer program. If an oblique solution is found (where the factors are at right angles), however, it may provide grounds for considering the existence of higher-order factorial causation, which can account for the correlations between the oblique factors (see Dixon, 1981: 480–489). Under certain but rare circumstances it may be possible to factor analyze a correlation matrix of factors. However, such solutions are almost never encountered in actual research.

Exploratory factor analysis is guided by guesses, hunches, and a good deal of luck. Even if one eventually turns to another approach, use of factor analysis can often serve as an extremely valuable way of acquiring familiarity with the characteristics of a set of data that were otherwise hidden from view. Exploratory factor analysis may be quite valuable as a theory building technique. Whenever possible a researcher should seek to press beyond a final solution by posing and, it is hoped, answering questions such as: Why was the solution so simple (complex)? Why were some factors so much more important than others? What would happen if I tried to replicate this factor structure with another population or even with the same population at a different time? Do my findings challenge or confirm those derived by others using qualitative approaches to the same research problem?

Confirmatory Factor Analysis

In contrast to exploratory factor analysis, where little or no advance knowledge exists regarding the possible properties underlying a correlation or covariance structure, the confirmatory approach explicitly requires formulation of hypotheses regarding an expected factor structure. The specificity of the hypotheses may vary considerably. The number of factors, whether they are orthogonal or oblique, and the size of the factor loadings for individual variables may all be specified. Sörbom and Jöreskog's (1976) confirmatory factor analysis computer program permits solution parameters to be fixed in advance of a computer run in a manner that permits one to match the constraints of almost any hypothesized factor structure. The program is then run to test how closely the empirical covariance structure can be reproduced by the hypothesized factor structure. This computer program can also yield factor analysis solutions that can be interpreted in a "path analytic" or causal sense. An example of this type of solution might entail hypothesizing the presence of two factors, each of which accounts for the observed covariation of two distinct sets of variables, say demographic and economic variables, with one factor (the demographic one) being the cause of the other factor.

Confirmatory factor analysis can be extended from the study of a single population to compare hypothesized factor structures across populations. An example of this more complicated application might entail hypothesizing for a given set of demographic, social, and economic variables that factor structures for rural nineteenth-century American populations would be very similar in certain respects to urban populations but otherwise radically different. To test a hypothesis of this sort, parameters believed to be similar for rural and urban populations would be set equal, and the remaining parameters would be specified to fit the hypothesized unique characteristics of each population. The Sörbom–Jöreskog (1976) program will then produce results that would amount to a test of this possibly complex set of subhypotheses.

Comparison of Factor Structures over Time

In this discussion of confirmatory factor analysis, we considered applying such an approach to a data set in which a group of variables was measured across two different populations. The research question posed entailed investigating similarities and differences between the two populations. The study of a single population over time is comparable. In a longitudinal analysis, the second population, rather than being an entirely different population, is simply the first population measured at a different time. As long as the data are available, it is possible in principle to compare a population's factor structure at any given point in time with its structure at any other time.

A variation on this approach involves using canonical analysis (Levine, 1977). Let us assume that we have obtained measurements on a number of variables across a set of units of observation in a population at a specific point in time. For a later point in time, we repeat these measurements. Using a computer program to carry out canonical analysis, we can determine the extent to which knowledge of the structural relationships between the variables at time one allows us to predict them at time two. An interesting application of this form of analysis might be to use points in time that bracket some catastrophic event such as a famine, plague, or war to determine if fundamental structural change has taken place in a population.

Discriminant analysis (Bennentt and Bowers, 1977: 95–177) may be applied to a population measured at two or more points in time on the same set of variables in an effort to pinpoint which variable(s) is responsible for differentiating the populations from each other if they differ over time. Discriminant analysis weighs and combines variables in a linear fashion, creating one or more "discriminant functions," in order to maximize the statistical independence of populations. It can be used to determine the degree to which assumed discriminating variables (for example, religious or occupational status) actually serve to discriminate the populations under study. If we had a set of historical populations, say villages, which differed in their levels of overall fertility, discriminant analysis might be used to determine the degree to which this difference could be explained by religious and/or occupational status variables. When significant discrimination occurs, a set of classification functions can be constructed that may then be used to classify new cases whose population membership, in a structural sense, is unknown (see Dixon, 1981: 519–537). The ability to classify populations on the basis of the statistical properties of the structural relationships between their variables might be applied in circumstances where it is possible to construct an evolutionary typology with distinct stages of growth. An analysis of the development of the Industrial Revolution in European countries, with England's stages of growth as a benchmark, might be approached from the perspective of discriminant analysis.

Factor analysis, canonical analysis, and discriminant analysis are closely related techniques, but each offers something distinct in terms of illuminating the structural relationships found in populations. The principal goal of each technique is to search for and identify a "deep structure" hidden within the empirically observed relationships between relatively large sets of variables.

Indeterminacy in Factor Analytic Solutions

The issue of factor indeterminacy and its significance for research has stimulated revived interest (Steiger, 1979). Briefly, the problem of factor indeterminacy arises from the fact that although every linear causal system has a covariance structure associated with it, other possible linear causal systems may give rise to an identical, observed covariance structure. Consequently, in the absence of additional information, one cannot with certainty infer the actual linear causal system responsible for an empirical covariance structure. Purely exploratory factor analysis can therefore prove extremely risky.

Three types of factor indeterminacy need to be considered (Kim and Mueller, 1978: 34–46). The first stems from the fact that given a set of factor axes derived from a correlational or covariance structure, they may be rotated to any orientation in the factor space. Rotating the axes changes the factor loadings of the variables for each factor. Which orientation most closely conforms to the real linear causal system? There are no abstract mathematical or statistical criteria that can provide an automatic answer. The only way this problem can be resolved is to draw upon additional information such as prior research findings, theory, even "intuition." Factor analytic rotations can often turn out to be like puzzles whose solutions can depend as much on an informed but essentially lucky hunch as on anything else.

The second type of factor indeterminacy poses the problem of choosing the number of factors to be accepted in a final solution (cf. Gorsuch, 1974: 130–160). A decision in this matter would be quite easy if one or two factors were found to account for virtually all of the variance in a set of data. Intermediate cases are common, however, and require the exclusion of factors from a final solution. Comprehensive knowledge regarding one's data may often help in justifying the exclusion of minor factors. The relative contributions of various factors (i.e., their "eigenvalues") may yield important information. Let us assume, for example, that we uncover a three-factor solution. The first, dominant factor has demographic variables loading very highly on it, the second factor has environmental variables associated with it, and the third, a relatively weak factor, is associated with economic variables. This solution would suggest that the most salient features of a causal system under analysis are demographic and environmental rather than economic. One might proceed further even to exclude the economic factor from a final solution. A finding of this nature might have significant theoretical implications in the event previous historical interpretations had emphasized the role of economic phenomena as causal agents.

The third and final issue is perhaps the most fundamental. As mentioned earlier, the factor analytic model assumes that the correlation or covariation between variables in a data set is due to the existence of a relatively small set of underlying, unobserved causes. If this is not really the case, a researcher could easily end up identifying an entirely spurious causal model. The real model might involve some of the variables in the data set being the causes of the remaining variables. And it is this fact that gives rise to the observed covariation between the variables. Once again, the only way this problem can be attacked is to be able to make informed assumptions about the real causal structure. Unfortunately, it is impossible to devise a purely empirical test to establish the legitimacy of assuming that a factor analytic causal model underlies a set of data. The most we can do is to build a theoretical case for the legitimacy of the model and then test to see if a plausible solution emerges.

Giving factors conceptual and theoretical meaning and identifying their causes can be expected to carry the historical demographer into an investigation of social, economic, cultural, and environmental variables. As the Ledermann and Breas example cited earlier well demonstrates, the data reduction achieved by factor analysis may be only a starting point for more detailed causal analysis.

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12 Nonmetric Multidimensional Scaling and Cluster Analysis

Nonmetric ("qualitative") multidimensional scaling and cluster analysis may be viewed as analogous types of factor analysis insofar as they permit us to uncover fundamental dimensions or clustering patterns otherwise hidden in complex sets of data. A particular advantage that they hold over factor analysis is that they can be applied to ordinal (rank-ordered) or even nominal-level data without serious fears of violating their statistical assumptions. This could prove to be a tremendously important analytical asset under circumstances where only qualitative, fragmentary, or fuzzy data restrict measurement to ordinal or nominal (presence/absence) levels.

Nonmetric multidimensional scaling is a method exceptionally well suited to describing structures, their principles of organization, and their change within historical social systems. Every individual in a community has a set of social positions that may be characterized categorically in terms of group membership and demographic attributes, such as sex, age, religious affiliation, ethnic origin, migrant status, or occupation. An individual's set of social positions provides a type of "location" in a community with respect to other community members. A social structure may be defined as a persisting pattern of social relationships among social positions. A social relationship is any direct or indirect linkage between persons as characterized by their social positions. The absence of a relationship may be as theoretically important as its presence.

Historical demographic structures such as intermarriage patterns may be conceptualized as containing their own logic and constraints. Aspects of Marxist theory, for instance, anticipate certain structural priorities, with specific types of relationship structures being more fundamental and formative than others. Relationships among social positions in a population are unlikely to be formed randomly but rather derive in part from some principle of differentiation among positions. This principle of organization of the social structure may be interpreted as a "distance-generating mechanism arranging the relative proximities of positions for every social relationship. The nature of the mechanism will, of course, differ from one type of relationship to another [Laumann and Pappi, 1976: 8]." For a set of examples with real data, the reader is urged to consult Vivien Brodsky's (1977) analysis of marriage allegations from London between the years 1583 and 1618, marriage allegations from Canterbury between the years 1618 and 1642, and apprenticeship records from London companies. Although all three sources introduce bias by excluding the poorer members of English society, the methodological aspects of Brodsky's paper are very clear and instructive.

Nonmetric multidimensional scaling and cluster-analysis techniques can be employed with demographic data to take the rather intuitive notion of a social network and make it far more attractive as a theoretical topic. A social network may be defined in general as a set of persons or groups linked by a set of social relationships of a particular type. In a population of 20,000 there are about 400 million possible pairwise relationships between the individuals who comprise the population. Since it is quite unrealistic to work with so many relationships simultaneously, aggregates of individuals sharing a particular attribute, such as social class, may be used as the "nodes" of the network under investigation. The question is then how to infer the presence of links between "nodes" such as social classes. Edward Laumann and Franz Pappi have proposed the following procedure:

> One solution is to relax the notion of a concrete social relationship, such as friendship, work partners, or marriage, into a stochastic relationship. That is, one can consider the "relationship" between two nodes consisting of complex entities as being indicated by the differential likelihood that their constituent elements have the relationship in question with one another. For example, members of the Protestant working class (PWC) node may be more likely to marry members of the Protestant middle class (PMC) than members of the Catholic working class (CWC) node. Other things being equal, we might want to argue that the PWC node is more closely related to the PMC node than to the CWC node. Once the concept of social relationship in a network is broadened in such a fashion, there are a number of ways of measuring the relative presence or absence of relationships between nodes [1976: 19].

Nonmetric multidimensional scaling and cluster analysis, like factor analysis, are general strategies for systematically describing the "deep structure" of demographic networks. They make it possible for the historical demographer to describe the macrostructure of a community's population subsystem in terms of the differential likelihood of the formation of specified relationships, such as marriage, among social positions.

Historical demographers are often faced with complex classification decisions (for example, household types or occupational groupings). Analogous measurement problems exist for other scientists, particularly those working in the fields of biometrics and psychometrics (see, for example, Gregson, 1975). Recent methodological advances in psychometrics can readily be adapted for use in historical demography by using similarity–dissimilarity measurements as empirical counterparts of logical class membership by inclusion or exclusion. This entails creating statistical decision-making procedures for partitioning aggregates of individuals, groups, or other entities. Unfortunately, there are as yet virtually no published applications of nonmetric multidimensional scaling to historical demographic research problems. Worked examples from a variety of survey research data sets appear in Susan S. Shiffman, M. Lance Reynolds, and Forrest W. Young's *Introduction to Multidimensional Scaling* (1981). The authors also include two chapters on how to interpret MDS results.

Creating Proximity Measures

Just as factor analysis uses a correlation or covariance matrix as input, nonmetric multidimensional scaling (MDS) begins with a matrix of similarity or "proximity" measures among individuals, groups, or other entities. The output from an MDS program, similar in certain respects to factor analysis, is a maplike spatial configuration of points where greater distances between points imply less similarity. The MDS configurations are presumed to reflect the "deep structure" present in the data and often make the data easier to comprehend (Kruskal and Wish, 1978: 7).

There are numerous ways of obtaining sets of proximity measures with historical demographic data. The amount of interaction of any kind between individuals, groups, or other entities can serve as a measure of their "proximity." Kinship links between households in small villages, for instance, might be used as proximity measures in an MDS analysis to search for demographic patterns among the villages.

Let us assume that that the symmetric matrix (with the upper half deleted) in Table 12.1 contains a set of hypothetical proximity measures derived from historical intermarriages between persons residing in a group of 10 villages (V01 to V10). These proximity measures are hypothetical in nature and are intended to reflect the degree of intermarriage between the inhabitants of pairs of villages. The numerical values reported in Table 12.1 may be interpreted as intermarriage "distances" between pairs of villages. A high numerical value implies a large distance and consequently a relatively low degree of intermarriage. The fact that the proximity measure between V10 and V08 is 12.1 and between V10 and V07 is 1.0 requires that V10 and V08 be much farther apart in a MDS intermarriage space than V10 and V07. Inspection of the MDS solution in Figure 12.1 confirms this.

The strategy to be used to obtain proximity measures should be clear. The only constraint to be kept in mind at this point is that MDS computer programs are normally unable to process very large matrices. Trying to work with more than 70 variables or points at a time can be unrealistic.

Table 12.1
Hypothetical Proximity Measures in Lower-Triangular Matrix Form for a Group of Ten Villages (V01 to V10)

Villages	V01	V02	V03	V04	V05	V06	V07	V08	V09	V10
V01	0									
V02	3.0	0								
V03	6.0	4.5	0							
V04	3.5	4.6	4.5	0						
V05	9.5	8.5	4.1	6.3	0					
V06	3.0	5.8	8.3	4.9	11.6	0				
V07	3.7	3.5	8.1	7.1	12.2	5.5	0			
V08	10.6	9.4	4.7	8.2	1.7	12.8	12.6	0		
V09	11.0	8.7	5.1	9.5	4.7	14.1	12.0	3.4	0	
V10	2.5	2.8	7.5	6.1	11.9	4.6	1.0	12.1	11.6	0

From Nonmetric to Metric Information

One of the novel features associated with nonmetric versions of MDS is that it is possible to begin with ordinal (nonmetric) data and arrive at precise metric solutions. Hence, if we are studying average migration rates between villages in an ecologically defined region, we would not need to know exact numerical rates for each pair of villages but only whether values for each pair of villages were greater than, approximately equal to, or less than those for the other pairs. As

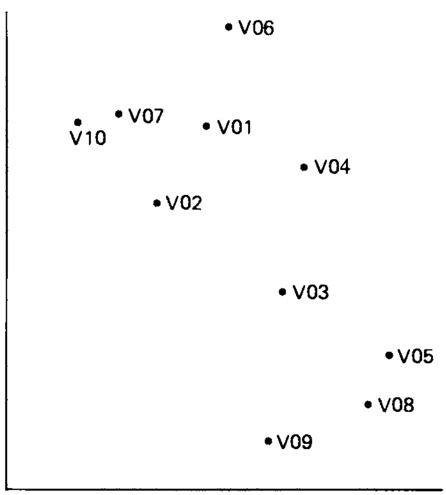

Figure 12.1. *A MDS, two-dimensional solution for the hypothetical village proximity measures in Table 12.1.*

information of this nature is added to a symmetric matrix of villages by villages, we impose more and more nonmetric contraints on the matrix. This has the effect of requiring the villages as points in the MDS space to satisfy so many nonmetric inequalities that their interpoint distances can produce a unique, metric solution that does not violate any of the inequalities.

This characteristic makes nonmetric MDS very attractive for historical demographers working with fragmentary and incomplete data sets which are capable of yielding no more than rank-ordered or ordinal-level information. As long as orderable differences between individuals, groups, or other entities can be obtained from source materials, a metric representation of them may be produced with a nonmetric MDS computer program that will be nearly the same as if precise metric data were available from the start!

The Dimensionality of MDS Spaces

MDS computer programs are generally designed to allow the user to apply various criteria to select a minimum-dimensionality space and avoid spurious (local minimum) solutions. Ideally, one seeks to embed data into a space with a minimum of residual error variance or "stress" (see Kruskal and Wish, 1978: 48–56). Ideally, the space arrived at will have very few dimensions. Otherwise, it may be conceptually impossible to understand the solution.

Let us return to Figure 12.1. Unlike factor analysis, MDS does not create spatial coordinates that may be given a substantive interpretation. With MDS, a researcher has to discover coordinates by using additional information about the points found in the solution's spatial configuration. Assuming that the two-dimensional solution in Figure 12.1 yields an acceptably low "stress" value, we would begin to search for some sort of patterns in the configuration. Figure 12.2 shows two dimensions sketched into Figure 12.1's configuration. These dimensions represent the hypothetical situation in which we have found that the villages at the lower end of Dimension One (V08 and V05) are rural and that as we move along the dimension they become increasingly proindustrial. Thus, we call Dimension One a protoindustrialization dimension. Let us say that we have also found that villages at the lower end of Dimension Two (V09 and V10) are predominantly Protestant and that as one moves along this dimension Roman Catholics form an increasingly large majority of the populations of the villages. We call Dimension Two a religiòn dimension. The conclusion to be drawn, if this were more than just a hypothetical data set, is that the "deep structure" of the intermarriage patterns for the villages in this region is made up of two fundamental dimensions: one involving protoindustrialization and the other religious affiliation. Additional research should now be directed toward an explanation, possibly with a causal model incorporating additional village data,

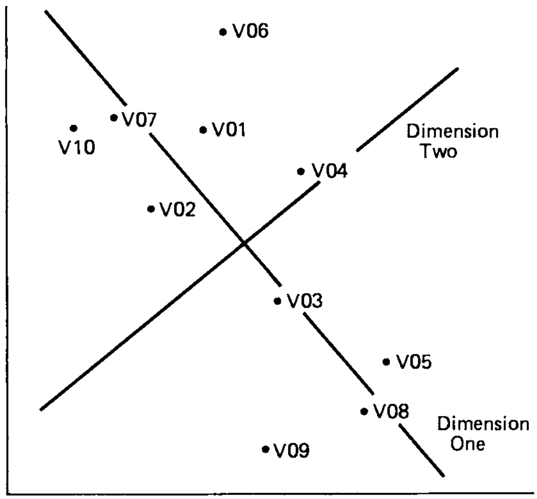

Figure 12.2. *Hypothetical dimensions sketched into the MDS configuration found in Figure 12.1.*

for the fact that only these two dimensions and no others seem so salient in regard to intermarriage patterns.

If we want a statistical demonstration of the validity of the dimensions we believe we have identified in a MDS configuration, we can use linear multiple regression (see Kruskal and Wish, 1978: 36). In the case of the preceding example, degree of protoindustrialization would be made a dependent variable and regressed over the coordinates of Dimension One. The coordinates of this dimension are the independent variables in the regression. A multiple correlation coefficient of 0.9 or better would indicate that a valid dimension has been identified. If the coefficient is not statistically significant at the 0.01 level, however, an alternative interpretation of the MDS configuration should be sought.

One of the best nonmetric MDS computer programs currently available, ALSCAL (Takane and Young, 1977), can carry out individual differences (or three-way) multidimensional scaling in addition to the two-way scaling discussed earlier. ALSCAL can accept data with missing observations, defined at either the nominal, ordinal, interval, or ratio level of measurement. It optimizes the fit of a configurational model directly to the data by an alternating least-squares procedure that works well even in the presence of moderate measurement error.

An example of the type of historical demographic data suitable for individual-differences analysis would be a set of proximity matrices derived from individuals, groups, or other entities, each constructed in the same manner for a set of different villages within an ecologically defined region. ALSCAL, when operating in its individual-differences mode, would then permit a researcher to discover differences in configurational structures between individual villages. Alternatively, we might construct a set of proximity matrices on variables for a single village at different points in time. Organizing data this way might help to pinpoint the nature of historical, structural change in a village during a theoretically interesting period of time such as a famine or a fertility transition.

Cluster Patterns in Multidimensional Scaling Spaces

In addition to attempting to discover dimensional interpretations of MDS configurations, clusters of points in regions of a MDS space may also yield valuable information, particularly when the individuals, groups, or other entities under analysis tend to be made up of polar opposites that would appear only at the ends of dimensions with no intermediate cases falling along the remainder of the dimensions. As an aid in the identification of clusters in a two-dimensional MDS space, the original matrix of proximities used as input to the MDS computer program also can be run through a cluster analysis program (see Dixon, 1981: 447–478 for available computer programs). Without a substantive theory to evaluate resulting clusters, cluster analysis solutions cannot be falsified (the clusters are true by definition) and can only suggest a testable theory (Baird and Noma, 1978: 225). A variety of cluster analysis programs is in use, each of which emphasizes certain properties of a proximities matrix at the expense of others (Sattath and Tversky, 1977). Conflicts between cluster structure solutions, resulting from the application of different but mathematically sound computer programs, might be used to discover alternative interpretations of the same data.

To illustrate how one might proceed to combine MDS and cluster analysis, let us assume that we have obtained the MDS configuration depicted in Figure 12.3. Let us also assume that the configuration was derived from hypothetical proximity data for average migration rates between eight villages in an ecologically defined region. If the same matrix of proximities used to obtain the MDS configuration in Figure 12.3 is run through a hierarchical clustering program, we would obtain the tree (or dendrogram) found in Figure 12.4. This tree diagram provides a number of hints regarding the proper interpretation of the MDS solution. In Figure 12.5, we superimpose the clustering results from Figure 12.4 on the MDS configuration of Figure 12.3 by sketching in a series of nested contours, corresponding to the subclusters or branches of the tree diagram.

Note that there are two main clusters in Figure 12.5. In searching for a substantive interpretation of these clusters, we might find that all the villages in the left-hand cluster (V01, V02, V03, and V07) are protoindustrial in nature,

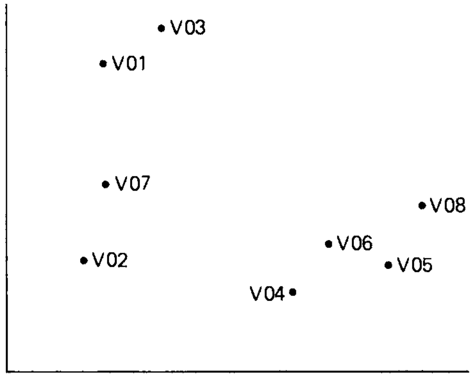

Figure 12.3. *A two-dimensional MDS solution based on hypothetical migration data for eight villages.*

with the two subclusters containing predominantly Roman Catholic (V01 and V03 and Protestant (V02 and V07) villages. Alternatively, we might find that the large right-hand cluster (V04, V05, V06, and V08) contains villages tied to a more traditional rural economy, with the smallest subcluster (V04 and V05) having predominantly Protestant villages, V06 being a village of mixed religious affiliation, and V08 being a predominantly Roman Catholic village. Thus, we would conclude that types of economic activity and religious affiliation appear as central features of the "deep structure" underlying our hypothetical village migration patterns.

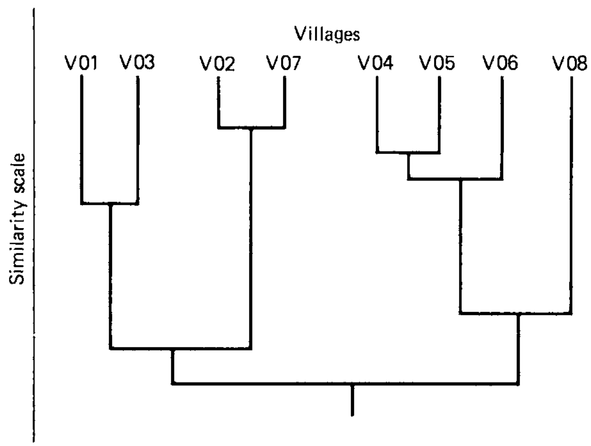

Figure 12.4. *A hierarchical clustering solution for the same village migration data used for the MDS solution shown in Figure 12.3.*

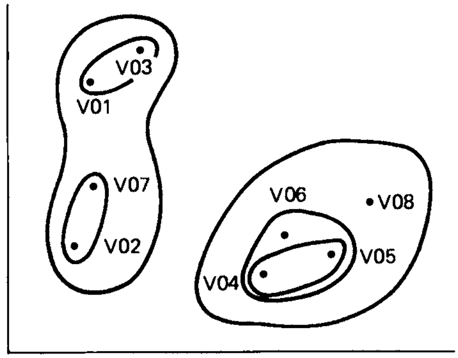

Figure 12.5. *Superposition of the hierarchical clustering solution in Figure 12.4 over the MDS solution in Figure 12.3. Contours are sketched in by hand to aid in visual interpretation.*

A danger exists, however, in trying to interpret clusters in two-dimensional MDS configurations when "stress" (or goodness-of-fit) criteria call for a higher-dimensionality solution. We can always obtain a perfect goodness-of-fit in a MDS solution by using as many dimensions as we have points. The strategy to follow, however, is to achieve an acceptable goodness-of-fit by having to rely on as few dimensions as possible. In our example with 10 villages a two-dimensional solution was achieved, but we might have had to face a ten-dimensional solution. Points that should be pulled apart, and would be in a valid three-dimensional solution, for instance, might appear close together in a high stress two-dimensional solution. A method of checking for this problem, proposed by Joseph Kruskal and Myron Wish (1978: 46), is to draw a line between every pair of points whose proximity exceeds some threshold value (indicating strong proximity, as determined from the original data). If long, haphazardly crossing lines are found in the two-dimensional MDS configuration, they indicate the presence of large residuals in the two-dimensional space itself or misleading point superposition effects arising from the presence of salient higher dimensions. A general rule of thumb is that points in clusters in two-dimensional MDS configurations should be closely connected with one another, and weakly connected, if at all, with points outside their respective clusters.

An example of how nonmetric multidimensional scaling or cluster analysis might be used with nominal-level (presence/absence) data, is provided by the demographically oriented content analysis work carried out by Herman Lantz *et al.* (1968, 1973, 1975). Lantz and his colleagues have investigated attitudes toward American family patterns during the periods 1741–1794, 1794–1825, and 1825–1850 through content analysis of the important magazines of each period. They devote special attention to power patterns between husband and wife, romantic love, motivations for marriage, and advocated and actual sanctions on persons involved in premarital and extramarital relationships.

Lantz *et al.*'s handling of literary sources as data may be subject to the same kinds of criticisms leveled against any type of content analysis of source materials over a long time interval. We shall concern ourselves not so much with the validity of their research design but rather with the abstract character of their binary, multidimensional data. Our heuristic discussion will also extend to consider hypothetical conditions not found in the data available to them. For the period 1825–1850, all issues of 47 of the most important magazines containing content applicable to their study were examined, and the tables of contents of 5334 issues systematically searched for those depicting male–female relationships. When titles were not informative enough, the first pages of articles were read. Articles that were finally selected were read in their entirety, and appropriate tabulations were made if they contained information on any of the variables being coded. Reliability was maintained by applying criteria for classification in a consistent manner.

Power relationships between males and females were conceptualized and categorized as follows:

> Power was defined as the ability of one individual to dominate another or others, to coerce and control them, obtain obedience, interfere with their freedom, and compel their action in particular ways. Power was coded as being exerted overtly by the male, overtly by the female, or by males and females cooperatively. Existent and advocated discussions of power were encoded in one of five categories, general discussions of power, that is, explicit discussions of power that did not pertain to a particular form of behavior; power over morality, that is, power over sexual, gambling, or drinking behaviors; power in courtship; power in the handling of finances; and power in certain other situations like child rearing and minor decision making [1975: 24].

"Romantic love" was defined by using five nominal categories: idealization of the loved one; the one and only; love at first sight; love wins over all; and glorification of personal emotions. The sexual norms of the period were defined in relation to the sanctions imposed upon premarital or extramarital relations: punishment, ostracism, and sympathy. Motivations for marriage were placed into three categories: happiness, wealth, and status.

The results of Lantz *et al.*'s content analysis can be arranged to yield binary, conditional, multiway data matrices. Dimensions underlying such matrices may be investigated with ALSCOMB3 (Sands and Young, 1980), a nonmetric multidimensional scaling program. A variety of analyses might be attempted by introducing "conditions" such as whether the variables in the magazines dealt with fictional or nonfictional matters or whether the focus was primarily on the male or the female side of relationships. If the available data made it possible to project different time periods into a multidimensional space, we might find that they were ordered or scaled along a dimension that corresponded to a measure of increasing industrialization. This would suggest that demographically related attitude changes between men and women reflected in the magazine content of successive time periods were produced by variables related to the rate of industrial growth. These ideas are speculative and are intended only to suggest how highly qualitative, nominal-level data of historical demographic interest might be creatively utilized in a quantitative manner to explore important theoretical issues.

Returning to our earlier discussion of network analysis at the beginning of this chapter, let us consider another possible application of nonmetric multidimensional scaling and cluster analysis. Assume that we are studying a historical city such as Geneva (see Henry, 1956, for a description of the Genevan bourgeoisie) and wish to represent *both* elite members and other population subgroups of Genevan society in the same multidimensional space such that the relative distances among persons and groups will reflect the "relative proximity" of each member of the elite to each of the other subgroups. To estimate the proximities of members of the elite to one another, of members of the other population subgroups to one another, and of the elite to the population subgroups, we might consider the possibilities of using intergenerational marriage data or whatever measures of interclass relationships that might be found.

Let us assume that we have identified 30 key members of the Genevan elite and that we have been able to subdivide the rest of the population of Geneva into eight social subgroups. The nonmetric multidimensional scaling input matrix of proximities to study the structure of the relationship between the elite and the other subgroups is depicted in Figure 12.6. One might select a method of computing proximities from those discussed by Gregson (1975: 45–57). Note that three quite different sets of demographic information have been

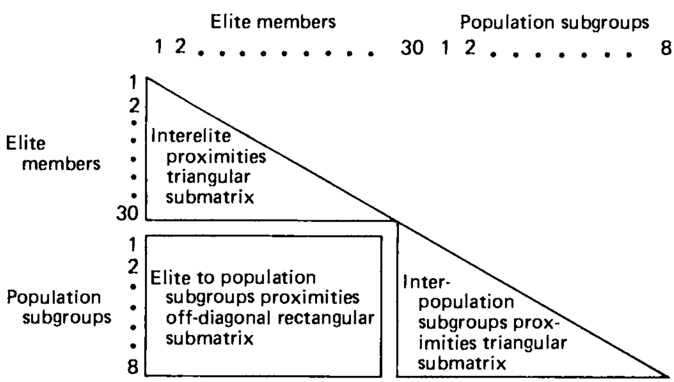

Figure 12.6. *A hypothetical nonmetric multidimensional scaling input matrix to study elite–population subgroup relationships. Adapted from Laumann and Pappi (1976: 223.)*

introduced into a single system of analysis. This matrix and its proximities would be fitted to the best possible dimensional solution. An interpretation of the solution chosen might be based upon prior knowledge of the principles structuring the Genevan community and its population subgroups as a whole, the principles organizing the Genevan elite structure, and the principles peculiar to the relationship between the elite and other groups in the population. Following the theoretical or conceptual identification of the dimensions in the scaling space, an attempt would be made to construct a theory accounting for the relative distances of elite members from each of the other population subgroups. A final test might entail the development of a causal model to test a theory put forward to explain the historical structure of Genevan society.

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13 Regression and Time Series Modeling

The preceding methodology chapters dealt primarily with the arrangement and linkage of source materials, and with descriptive and data-reduction methods. We now turn to methods that are more directly related to formal causal model building. A causal model may be most simply defined as a set of assumptions about how certain historical data were generated. In this sense, qualitatively oriented historians are engaged in causal model building quite a bit of the time. Here, however, we introduce the reader to statistical rather than impressionistic methods to assess the fit of a causal model to historical data. We wish to make causal inferences that can be evaluated *statistically*.

While causal analysis of varying degrees seems to be an essential ingredient in the everyday life of scholars, it often becomes a controversial issue when applied to historical demographic research (Laslett, 1980). However, causal modeling should stand alongside archival source identification and evaluation, descriptive analysis, data reduction and theory construction as an integral part of the investigation of past populations.

Regression Analysis: Preliminary Considerations

Regression analysis is one of the most extensively used methods of determining relationships among quantitative variables. A functional relationship among a set of variables may be expressed as an equation connecting an estimated dependent variable Y' with one or more independent variables, X_1, $X_2, \ldots, X_n$, as follows:

$$Y' = B_0 + B_1X_1 + B_2X_2 + \cdots + B_nX_n, \qquad (13.1)$$

where B_0 is the Y intercept and B_1, $B_2, \ldots, B_n$ are defined as regression coefficients and are determined from the data. If only a single independent variable is present, the equation is called a simple regression equation. In a simple regression equation the (unstandardized) regression coefficient B_1 indicates the expected change in Y following a change of one unit in X_1. In a multiple regression equation, B_1 indicates the expected change in Y with a one-unit change in X_1 when X_2 and whatever remaining independent variables may be present in the equation are held constant or controlled (see Dixon, 1981: 235–288). A multiple regression problem may involve trying to predict or explain the age-adjusted mortality rates in different eighteenth-century French parishes (the dependent variable) by a series of environmental and socioeconomic factors (the independent variables). Differences between the actual or observed age-adjusted mortality rates (Y) and those estimated (Y') by the regression equation are called residuals. Regression analysis is designed to minimize the sum of the squared residuals.

Common Problems Encountered in Regression Analysis

Despite the common and widespread use of regression analysis with demographic data, it is a technique that cannot be employed without paying considerable attention to the characteristics of one's data. Since independent variables in a multiple regression equation are often measured in different units, such as years or completed family size, all variables should be standardized by setting their standard deviations equal to unity in order to be able to compare the relative effects of the independent variables on the dependent variable. When standardized variables are used in a regression equation, the coefficients are referred to as standardized regression coefficients or beta weights. Standardization also has the effect of setting B_0, the Y intercept, equal to zero. If there are serious violations of the basic assumptions underlying linear regression (e.g., metricity, linearity, constancy of error variance, lack of heteroscedasticity, absence of outliers, and uncorrelated errors), the inferential statistics reported by most computerized regression programs may be meaningless.

If sample data, such as a random sample extracted from the 1851 English census was being used, inferential statistics could be calculated to determine the statistical significance of the observed linear association between variables derived from the census. One way of judging the predictive accuracy and the strength of the linear association between dependent and independent variables is to form a ratio of the explained variation in Y to the total variation in Y. This ratio is usually symbolized as R^2 and called the coefficient of determination. Its square root is the Pearson product-moment correlation between variables Y and X_1 for a simple regression equation, whereas in the case of the multiple regression equation it is the correlation between Y and its estimate, Y'.

Outliers are extreme data points with relatively large residuals. That is, their values are poorly predicted by the regression. To detect and gauge the effects of the outliers in a simple regression equation, one can plot Y against X_1 and look for the presence of extreme data values. In most applied situations, there will be some outliers but the effect of their presence may be hard to judge. Therefore, one should proceed to carry out the desired regression. The adequacy of the model arrived at can then be tested, apart from reported inferential statistics, by constructing several graphs. First, standardized residuals should be created by dividing each residual by the standard deviation of the residuals. The standardized residuals should then be plotted against Y' and X_1 to see if the linearity assumption is justified. An acceptable plot would show the residuals to be randomly distributed about their zero point with no extreme values. Regression coefficients and associated statistics are quite sensitive to outliers. A few extreme data points can dominate the results of a regression equation.

If it appears that there are outliers that may have seriously biased the regression results, the data points producing the residual outliers should be removed from the data and the regression equation's parameters reestimated. The outliers may be the result of measurement error or perhaps point to some important phenomenon that does not typify the rest of the data.

If nonlinearity is present, it can often be identified by plotting the data. A variety of transformations exist that can be employed to linearize data (Cohen and Cohen, 1975: 242–264). Nonlinear regression techniques are also available (Dixon, 1981: 289–344). Further, transformations may be used to make the error variance constant for all observations. This type of invariance, homoscedasticity, is a basic assumption of the linear regression model. When unequal error variances appear, the standard deviation of the residuals for an independent variable tends to become greater as that variable's magnitude increases in size. Approaches for detecting this potentially serious problem, assessing its effects on the regression analysis, and selecting transformations for removing heteroscedasticity from data are discussed in Chatterjee and Price (1977: 38–50, 102–116) and in Hanushek and Jackson (1977: 141–163).

The interpretation of a regression coefficient as indicating the change in a dependent variable when a corresponding independent variable is increased by one unit and all other independent variables are held constant may be invalidated if there are strong linear relationships between the independent variables. If there are no linear relatonships among the independent variables in a regression equation, they are described as being orthogonal. *Multicollinearity* is a term that refers to nonorthogonal or collinear data. The independent variables in almost all empirical regression models are not totally orthogonal. A certain degree of multicollinearity is unavoidable and may not seriously bias regression results. Chatterjee and Price (1977: 155–156) suggest that an indicator of multicollinearity is the presence of unstable regression coefficients. Coefficients are said to be unstable if they undergo large changes when a variable is added or removed from the regression equation, or when a data point is dropped. Presuming that the residual plots show that the regression equation has been adequately specified, other indicators of instability are if the algebraic signs of the coefficients turn out to be the opposite of what was expected or if the coefficients associated with key variables possess large standard errors.

Since any attempt to identify the presence of multicollinearity is based upon the structure of the correlations among the independent variables and since every linear regression model can be transformed into a set of orthogonal independent variables, it is possible to derive what is known as a principal-components method of detecting multicollinearity. This method requires that the independent variables first be standardized by subtracting the average value of the observations from each observation and then dividing by the standard deviation of the observations. If these standardized variables are orthogonal, their matrix of variances and covariances will have ones along the diagonal and zeroes in all of the off-diagonal cells. Having standardized the independent variables, they should now be transformed to principal components. Chatterjee and Price (1977: 172–173) describe a matrix algebra procedure to accomplish this. The diagonal of the covariance matrix of the principal components is now examined. If the diagonal cells are all equal to unity, the original independent variables are orthogonal. If any of the diagonal cells are zero, or near zero, multicollinearity is present. This method will not eliminate multicollinearity, but it can indicate which coefficients are estimable and the degree of dependency that exists among the independent variables. Principal components and ridge regression can be employed to obtain more precision in the estimated coefficients when a significant amount of multicollinearity is detected (see Chatterjee and Price, 1977: 167–172, 175–192, for a discussion of these rarely used methods). Ridge regression may also be applied to discover the presence of multicollinearity and to eliminate it by discarding the appropriate variable(s).

In a recent application of regression analysis to historical demographic data, N. F. R. Crafts (1978) tests H. J. Habakkuk's (1971) hypothesis that there should be a significant, negative relationship between urbanization and age at marriage. The approach adopted by Crafts is to extract aggregate marriage data for 41 counties from the 1861 census of England and Wales, in combination with standardized nuptiality curves developed by Ansley J. Coale (1971), to produce estimates of average age at first marriage. A simple regression equation is then set up with average age at first marriage (A) as the dependent variable and an index of urbanization (U) as the independent variable. Crafts's results,

$$A = 25.248 - 0.016U, \qquad (13.2)$$

show a small negative regression coefficient. The urbanization index accounts for only 18% ($R^2 = 0.18$) of the variation in A. Crafts states that his inability to specify, measure, and include other important independent variables can be expected to have biased the estimated coefficient. Nonetheless, he argues that the results suggest that urbanization, for the period of time considered, probably did not lower the age at marriage significantly enough to be of major importance in affecting population growth.

A sophisticated application of multiple regression techniques that more explicitly introduces time as a factor appears in Toni Richards's "Fertility Decline in Germany: An Econometric Appraisal" (1977). She reanalyzes John Knodel's (1974) data for Germany over the period 1880–1910 in order to test hypotheses about the "demographic transition." Multivariate time series cross-sectional models are developed to determine, for the time interval considered, whether industrialization is the main explanatory variable of fertility decline in Germany. Following Steven Beaver's (1975) suggestion that cross-sectional and time series effects should be separated when studying the "demographic transition," Richards first allows her independent variables to account for as much of the variance in the dependent variable, marital fertility, as they can and then explores partitions of the residual variance in terms of cross-sectional and temporal variation according to a procedure described by G. S. Maddala (1971).

At least four different models of the demographic transition have been proposed: the structural change model, the rationality model, the diffusion model, and the threshold model. Richards considers only the first two models and tries to determine which is more successful in accounting for the German fertility decline. The structural change model is the traditional explanation of the demographic transition. This model assumes that the structural relationships between fertility and key socioeconomic variables remain unchanged. Thus, fertility changes because the levels of the independent socioeconomic variables change. If the structural relationships between fertility and its socioeconomic determinants changed over time this could not be explained by the structural change model and would represent an "innovation." It is a bit confusing that the so-called structural change model assumes no change in the structural relationships between variables. The second model, the rationality model, focuses on the importance of normative changes accompanying industrialization and urbanization. Although the same variables are used as in the structural change model, this model permits the relationships between fertility and certain independent socioeconomic variables to change. Specifically, it predicts that these relationships will grow stronger over time.

Richards's data are those collected by Knodel from German censuses for 71 administrative areas (the units of analysis) at five time periods: 1880, 1885, 1890, 1900. 1910. The regression model estimated is

$$Y_{it} = B_0 + B_1 X_{1_{it}} + \cdots + B_k X_{k_{it}} + e_{it} \qquad (13.3)$$

$$i = 1, \ldots, N; \qquad t = 1, \ldots, T,$$

where N is the number of administrative areas in each cross section and T is the number of time points; Y_{it} is marital fertility in area i, in year t; X_k are the independent variables; and e_{it} is the error component including period effects, the effect of each administrative area, interactions between these effects, and the component peculiar to each observation. The dependent variable is Coale's (1969) marital fertility index (I_g), which measures the marital fertility of each administrative area relative to Hutterite fertility. Two groups of independent variables are employed. The first group provides measures of social and economic structure. They include the proportion of population living in rural areas (R), dependent upon secondary industry (S), dependent upon tertiary industry (T), and Catholic (C). The variables R, T, and S turn out to be collinear, with S and T together able to account for 84% of the variance in R. Richards consequently experiments by including and excluding R but finds that it had little influence on the analysis. The second group of variables, more demographic in nature, are Coale's (1969) index of the proportion married (I_m), the infant mortality rate (m_0), and the net migration rate (M). In estimating the regression model, contemporaneous values of C, R, and I_m were used, but 5-year-old values of S and T, 2-year-old values of m_0, and the value of M chosen was that for the 5-year period immediately preceding the date used for I_g. Values of S, T, m_0, and M were lagged to reflect the timing of their presumed causal influences upon I_g. Their lag periods, however, were largely determined by the availability of data.

The first model treated by Richards assesses the effect of the independent variables on fertility without paying attention to possible regional and/or period differences. The portion of variance in I_g explained by the pooled independent variables is 54%. A second model assesses the importance of cultural differences by allowing each administrative area (cross-sectional observation) to have its own intercept, thus removing the region-specific, period independent effect and leaving only variance due to temporal factors. The explained variance R^2 now increases from .54 to .95, showing that most of the unexplained variance in the first model was cross-sectional. A third model evaluates the extent to which temporal change can be explained by estimating period effects directly, with and without considering regional differences. Here Richards finds that the dynamic characteristics of the "demographic transition" within regions cannot be accounted for by structural change alone. The addition of period dummy variables, representing temporal differences, does not significantly increase the proportion of variance explained by taking into account regional differences alone. These findings illustrate the potentially critical need to employ relatively sophisticated statistical methods to judge the importance of different components of the variance found in a dependent variable such as I_g. Less sophisticated bivariate techniques might have led an investigator to conclude that structural change alone could explain the German fertility decline and therefore that changing levels of the independent variables were completely responsible for the decline.

Regression with Nominal Variables

Nominal level variables can be used in regression equations, even though they are unordered and have no unit of measurement. Such variables are often termed "dummy variables." Richards (1977: 545–548), for instance, used period dummy variables to represent temporal differences. Dummy variables are created by taking each category of a nominal variable as a distinct variable and determining for each case whether it is present or absent from the categories. This results in the creation of a dichotomous or dummy variable with possible metric values of 0 or 1 that may be handled as an interval-level variable in regression analysis.

Certain nineteenth-century French censuses list religious affiliation. Working with this type of data, the religion categories of Jew, Roman Catholic, Protestant, and Other could be created and conceptualized as four dichotomous variables with each person listed in such censuses as having a score of 1 or 0 on each variable. A Jew, for example, would be assigned a 1 on the dummy variable for Jews and a 0 on all the other variables.

Because the value of any given dichotomous variable in a set of dichotomous variables, created from the categories of a nominal variable such as religion, can be ascertained from the other members of the set when entered into a regression equation, a proper solution of the equation requires that one of the dichotomous variables not be used. The excluded dichotomous variable becomes a reference category against which the effects of the other dichotomous variables can be ascertained and interpreted. Table 13.1 shows scores for each dichotomous religion variable, with Other as the reference category. The appropriate regression equation, based on Table 13.1, would be:

$$Y = B_0 + B_1R_1 + B_2R_2 + B_3R_3. \tag{13.4}$$

The expected Y value (the mean) for Jews is $B_0 + B_1R_1$ and for Others would be B_0. Hence the regression coefficient B_1 can be interpreted as the difference in

Table 13.1
Example of Scores for Dichotomized Categories of the Nominal Variable Religion

	Dichotomized variables		
Categories	R_1	R_2	R_3
Jew	1	0	0
Roman Catholic	0	1	0
Protestant	0	0	1
Other	0	0	0

the predicted value of Y for individuals who were classified as Jews in comparison to those classified as Others. The difference between two regression coefficients, such as B_2 and B_3, measures the difference in the predicted value of Y between Roman Catholics and Protestants.

Regression with dichotomized categories of a nominal variable is equivalent to a one-way analysis of variance (Iverson and Norpoth, 1976). A research problem might involve studying the effect of religion on completed family size using civil registration data for different religious groups found in a given geographical region. Assuming that heads of families could be classified as Jews, Roman Catholics, Protestants, and Others, a possible first step would be to create dichotomous variables to represent the categories of the religion variable (see Kim and Kohout, 1975: 375, to see how this might be done using SPSS). This procedure could then readily be extended to cover cases involving two or more nominal variables. If the birthplaces of persons were also known for this example, a new variable, migration status, could be added, such that

$$Y = B_0 + B_1R_1 + B_2R_2 + B_3R_3 + B_4M_1, \tag{13.5}$$

where M_1 represents the variable migrant status. This results in the creation of a joint reference category, made up of nonmigrant Others. The values calculated for the regression coefficients B_1, B_2, and B_3 measure the linear effects of the categories of the religion variable when the effect of migrant status is controlled. The value of B_4, on the other hand, measures the linear effect of migrant status, the expected difference between migrants and nonmigrants, upon completed family size when differences across religion categories are controlled.

To perform a full analysis of variance (see Dixon, 1981:345–436), dichotomous versions of the categories of the nominal variables need to be created to produce a "saturated" model that includes all possible interaction terms:

$$\begin{aligned} Y = B_0 + B_1R_1 + B_2R_2 + B_3R_3 + B_4M_1 \\ + B_5R_1M_1 + B_6R_2M_1 + B_7R_3M_1. \end{aligned} \tag{13.6}$$

An analysis of covariance (Wildt and Ahtola, 1978) also can be carried out with nominal variables and metric predictor variables. To illustrate this type of analysis, we shall add a new metric variable to the original regression model, social class (S). It is assumed that we have been able to create an interval-level social-class scale such that persons with particular occupations may be assigned an index number. The saturated model would be:

$$\begin{aligned} Y = B_0 + B_1R_1 + B_2R_2 + B_3R_3 + B_4S \\ + B_5R_1S + B_6R_2S + B_7R_3S. \end{aligned} \tag{13.7}$$

We shall now adapt the approach outlined earlier to show how dummy variables can be used with time series data. Suppose we wished to test a regression model relating mortality rates (M_t) to food prices (F_t):

$$M_t = B_0 + B_1 F_t + U_t, \qquad (13.8)$$

where M_t is the number of deaths per 1000 persons in the tth period, F_t is a food price index in the tth period, and U_t is the error component or residual term in the tth period. In addition, let us assume the existence of a seasonal effect on mortality rates that is determined on a quarterly basis by food prices. We may then define a set of dummy variables for F_t to express the presumed existence of the seasonal effect:

$$F_{1t} = \begin{cases} 1, & \text{if the } t\text{th period is a first quarter} \\ 0, & \text{otherwise} \end{cases}$$
$$F_{2t} = \begin{cases} 1, & \text{if the } t\text{th period is a second quarter} \\ 0, & \text{otherwise} \end{cases} \qquad (13.9)$$
$$F_{3t} = \begin{cases} 1, & \text{if the } t\text{th period is a third quarter} \\ 0, & \text{otherwise} \end{cases}$$

Possible results, if this scheme were applied to historical data for an agrarian region, might be that instead of a four-season effect there are only two seasons affecting mortality rates and that these relate to the times of planting and harvesting.

The presence of structural change and the stability of regression coefficients over time can also be studied with dummy variables (see Chatterjee and Price, 1977: 96–100). Both intertemporal and interspatial comparisons can be made. Let us choose a model that specifies that literacy rates (Y) in nineteeth-century French administrative areas can be predicted by knowing per capita income (X_1), the proportion of the population under 18 years of age (X_2), and the proportion of population residing in urban areas (X_3). We might study the effects of regional characteristics on the regression results by applying the model to distinct ecological areas, using dummy variables, and test the stability of the literacy relationship (found with the pooled data) with respect to the ecologically defined space.

If the data were available on these four variables for French administrative areas at several points in time, such as 1860, 1870, and 1880, and the same regression equation could be specified for each time period, then the stability of the literacy relationship could be determined by measuring the variation in the estimated regression coefficients over time. To carry out this kind of analysis, the data would be pooled to create a set of observations that would equal the product of the number of administrative units and the number of time periods, and dummy variables defined as follows:

$$T_{1t} = \begin{cases} 1, & \text{if the } i\text{th observation was from 1860} \\ 0, & \text{otherwise} \end{cases}$$
$$T_{2t} = \begin{cases} 1, & \text{if the } i\text{th observation was from 1870} \\ 0, & \text{otherwise} \end{cases} \qquad (13.10)$$

The full model in its dummy variable formulation would then be written as

$$\begin{aligned} Y = B_0 &+ B_1X_1 + B_2X_2 + B_3X_3 + B_4T_1 \\ &+ B_5T_2 + B_6T_1X_1 + B_7T_1X_2 + B_8T_1X_3 \\ &+ B_9T_2X_1 + B_{10}T_2X_2 + B_{11}T_2X_3 + U. \end{aligned} \qquad (13.11)$$

A variety of different tests may be carried out with this equation. For example, if we want to determine if the regression system for these French administrative areas was invariant over time, we would look to see if $B_4 = B_5 = B_6 = B_7 = B_8 = B_9 = B_{10} = B_{11} = 0$.

Regression analysis is often employed to evaluate noncausal hypotheses. Numerous studies of historical American communities, for instance, have shown that status decentralization tends to be the dominant pattern for large communities undergoing population growth and geographical expansion. These findings are often referred to as the Burgess zonation hypothesis (Burgess, 1925), a descriptive rather than causal hypothesis. Others, most notably Gideon Sjoberg (1960), have proposed an inverse zonal hypothesis for preindustrial communities in which the dominant spatial pattern is one of status centralization. Under the Burgess hypothesis the social class or status of individuals should increase or be positively related to their distance from a city's center. Sjoberg's hypothesis for preindustrial cities predicts just the opposite. Regression analysis can be used to evaluate these different hypotheses.

Using the Russian census of 1897 as baseline data, Walter Abbott (1974) takes data from 18 police districts to test the inverse zonal hypothesis in terms of the spatial structure of Moscow. Areal characteristics are organized into infraecological, socioeconomic, and disorganizational dimensions. Infraecological measures for each police district include mean distance in miles from the city center (the Kremlin), population density, and the percentage change of areal population from 1871 to 1897. Data on estates, literacy, occupation, and educational attainment are used to examine the distributional pattern of socioeconomic status. Four ecological measures are used to indicate patterns of social disorganization: the sex ratio, percentage with physical defects and mental disorders, the percentage of the population 17 years and above that is divorced, and the percentage of infant survival. The regression analysis test of the inverse zonal hypothesis entails taking each of the variables just mentioned as a dependent variable and the distances of police districts from the Kremlin as the independent variable. The signs of the resulting regression coefficients are then used to evaluate the hypothesis. For example, there should be a general inverse relation between status and increasing distance from the Kremlin. If this is the case, the sign of regression coefficients would be negative. Abbott's findings confirm the inverse zonal hypothesis and demonstrate that the pattern found in late nineteenth-century Moscow was quite different from that predicted by Burgess for expanding American cities. Abbott also claims that an inverse zonal urban structure characterizes historical European cities such as Budapest, Rome, and Stockholm as well as important cities in Latin America, Asia, and Africa.

Abbott's study of the spatial demographic structure of 1897 Moscow uses regression analysis to confirm predicted relations between variables. The percentage of infant survival, for example, was predicted to decrease with distance from the Kremlin. However, historical demographers should be concerned not only with predicting phenomena but also with explaining them. Why did infant mortality in 1897 Moscow increase with distance from the city center? When can regression coefficients be interpreted as causal parameters? If certain assumptions are met, then reverse causation must be ruled out by theory or logic (see Kenny, 1979: 96–109). Accurate measurement of variables must be assured. This is often relatively easy with certain demographic variables such as sex and place of residence. And there must be no common causes, or third variables. Spurious relationships arise when the apparent association between two variables is a result only of both being caused by a third variable. Potential common causes may be measured, but it is logically impossible to conclude that all third variables have been excluded as long as the correlation coefficient between variables is less than one. Finally, if variables are measured cross-sectionally at one point in time, it must be assumed that the influences of causes have been fully transmitted.

Time Series: Preliminary Considerations

Although regression analysis as well as some methods discussed in earlier chapters can be used with longitudinal data, they were primarily developed to analyze cross-sectional data. Methods directly designed for time series data are generally less well understood and are applied with relative infrequency. This is due in part to the disdain with which many American sociologists have regarded historical analysis, a disdain that ironically may prove to have been one of the most important barriers to sociology's efforts to become a scientific discipline.

A distinction is often made between time series analysis and panel analysis. In the former, data on a single entity are gathered for a relatively large number of time points, whereas in the latter, data are gathered on many entities at usually no more than five time points. Regression techniques can be used to study cross-lagged panel data (Kenny, 1979: 227–249). Log-linear models may be applied to panel data and are discussed in the next chapter. Here, however, we shall be concerned with time series analysis rather than panel analysis. Readers with an interest in panel analysis are advised to consult Ronald Kessler's and David Greenberg's *Linear Panel Analysis: Models of Quantitative Change* (1981).

Time series analysis is designed to detect patterns that may exist in the historical changes undergone by a single variable or to identify the relationships between two or more variables such as food prices, mortality rates, and fertility rates. The four fundamental patterns found in demographic time series are horizontal, trend, seasonal, and cyclical. The first pattern characterizes a time series with no systematic tendency to depart from its mean value. The population size of a region that maintains itself in close equilibrium to an invariant environment would display a horizontal pattern. A series is said to have a trend if it possesses a consistent tendency either to increase or decrease over time. Seasonal time series vary according to some seasonal characteristic(s), such as certain days of the week, certain months, or harvest times (see, for example, Henry, 1976: 36–42). A cyclical pattern is similar to a seasonal pattern but repeats itself in cycles with a period of a year or longer (see Congdon, 1980; Smith, 1981).

Although one might expect historical demographers to have developed sophisticated methods for studying time series, this has not been the case. With few exceptions (for example, Lee, 1975), historical demographers have failed to create their own methods or adapt techniques formulated by econometricians and others. Time series methodology follows two major paths: (*a*) spectral analysis (Jenkins and Watts, 1968), which is concerned with splitting a time series into different frequency components; and (*b*) ARMA (autoregressive, moving average) techniques (Box and Jenkins, 1976), which use regression procedures to derive models of stationary time series with maximum simplicity and the minimum number of parameters consonant with representational adequacy.

Spectral analysis describes a time series in terms of sine and cosine waves of different frequencies. Many of the basic concepts and methods found in spectral analysis are analogous to those in Box–Jenkins ARMA procedures (see Dixon, 1981: 595–603). The most important forms of information derived from spectral analysis come from the Fourier analysis not of the time series itself but of the autocovariance and cross-covariance functions (the numerators of the autocorrelation and cross-correlation functions used in Box–Jenkins methods). Box–Jenkins methods do encounter difficulty when feedback occurs between series. This is because "the autocorrelation remaining in the presumed outcome series can obscure the real causal parameter [Cook and Campbell, 1979: 335]." This difficulty is passed over into spectral analysis to create inferential ambiguity. The reason why attention is drawn to the pass-over effects to spectral analysis of problems encountered with Box–Jenkins methods is to caution the reader about assuming that the shortcomings of one approach can be overcome by turning to the other. A more detailed discussion of spectral analysis appears in Ronald Lee (1977) and Wilfrid Dixon (1981: 604–638). Jorde and Harpending (1976) apply cross-spectral analysis to study the frequency response of the birth rates of four historical populations to variability in rainfall.

Whether spectral analysis is superior to Box–Jenkins ARMA techniques is somewhat of a moot issue since they can be conceptualized as mathematically translatable. We prefer ARMA techniques, however, since they seem to offer an explicit model-building methodology with clear advantages. They can aid a historical demographer to create models that may yield critical information regarding the nature of the system generating a demographic series, represent dynamic relations between series, show how variables produce change in a dependent variable, and predict future values of a series. Finally, because ARMA techniques are based on regression-like models, they offer most scholars an easier entry point into the highly complicated world of mathematical and statistical time series modeling.

Time series data are indispensable for the study of many demographic effects. For example, Jacques Houdaille (1978) uses a sample of French vital registration data to study the seasonal and regional fluctuations of marriages before, during, and after the French Revolution (see page 72). In eighteenth-century France few marriages were celebrated during Lent and Advent. This effect faded during the period of religious persecution associated with the revolution, only to rise again to somewhat lower than original levels. The seasonal timing of marriages thus appears to serve as an indicator of French religious practice. In another study, Eric Vilquin (1977) employs Belgian demographic statistics for the years 1841 to 1850 which contain detailed information on infant deaths by month of registration of death and by age in months of the deceased infant, to study the cumulative influence of age at death and season of death. January–February and August show up as periods of excess mortality. Thus, infants born in March or July are subject to excess mortality at the most sensitive stage of biological growth. Those born in October, however, pass through the periods of excess mortality when they are least vulnerable.

Demographic projections and forecasts are often constructed from extrapolations of existing time series. If one stays within the past, however, it is possible to compare the differences between observed and expected population values, and thus evaluate the quality of forecasting techniques. An example of this strategy appears in an extrapolation study of the total population of the *départements* and towns in France from 1821 to 1975. The authors of this study, Louis Henry and Hector Gutierrez (1977), extrapolate the intercensal rate of growth, comparing the ratios of two successive quinquenniums and decenniums to measure the central value and dispersion of the second period from each value of the rate for the first period. They discuss the risks involved in short-term forecasting and show how historical data can be used to elucidate methodological uncertainties found in the analysis of contemporary data and forecasts.

The autoregressive, moving average (ARMA) models to be discussed later are perhaps the most sophisticated and valuable of currently available time series modeling and forecasting techniques. John McDonald (1979), for example, uses the ARMA model building process to analyze the Australian 1921–1975 total live births time series. A one-way causal transfer function model (see Dixon, 1981: 650–656) is also employed to see if total births can be better modeled by including information on the number of females in reproductive age groups as well as information on past births. Calculations suggest that the 15–39-year-old female age group series does not help to explain births once the pattern of past births has been allowed for.

Since ARMA techniques are based upon the general linear model (Horton, 1978), we shall preface the formal treatment of these techniques with a discussion of important regression concepts and statistical pitfalls characteristic of the general linear model. Following these prefatory remarks, an overview of ARMA techniques and intervention hypothesis testing will be presented in sufficient detail to enable the reader to judge their applicability to specific problems and sets of data. Our treatment is not exhaustive, and consultation of the recommended readings is essential.

Autocorrelation Analysis

Autocorrelation is one of the most important concepts in time series analysis. An autocorrelation coefficient is analogous to a product-moment correlation coefficient except that rather than measuring the degree of linear association between two variables, suçh as nuptiality and fertility rates, it measures the degree of correlation of values of a single variable with those of other values of the same variable that occur at different time lags. For example, a single variable, a fertility rate X_t can be taken and a second variable X_{t-3} formed from it, which is lagged by three time periods, and the correlation (autocorrelation) between the two calculated. The resulting coefficient shows the degree to which the fertility rate X_t is related to its value X_{t-3} years previously. If the autocorrelations for all of the possible time lags for a variable are near to zero, it may normally be assumed that the variable is behaving in a random manner.

Autocorrelation coefficients r_k are computed at different time lags k with the following formula:

$$r_k = \sum_{t=1}^{n-k} (X_t - \bar{X})(X_{t+k} - \bar{X}) \Big/ \sum_{t=1}^{n} (X_t - \bar{X})^2, \qquad (13.12)$$

where x_t is the value of variable X at time t, $\bar{X}$ is the mean of all the X values, k is the time lag, and n is the number of observations in the series.

Trends

Trends in series can often be removed by "differencing" the series one or two times. This is accomplished in the case of a first difference by merely subtracting from every value in a series the value immediately preceding it in order. Thus, the first value is subtracted from the second, the second from the third, and so on. A second difference of a series then repeats this procedure on the series resulting from taking first differences. One of the major reasons for differencing a series with a trend, a nonstationary series, to transform it into a stationary series is that many time series methods can be applied only to series without trends.

A variety of tests are available to learn if differencing has yielded a stationary series. If the original series has a trend, a graph of its autocorrelation coefficients will also show a trend. The differenced series, if rendered stationary, will have its autocorrelation coefficients randomly scattered around a zero value line. Another test entails comparing the mean of the first half of a presumed stationary series with that of the second half. If the series is stationary, the two means should be nearly equal. A third test that may be used entails comparing the coefficients of variation for each level of differencing. The level yielding the smallest coefficient will have the series closest to stationarity.

Randomness in Time Series

Before attempting to draw any inferences from a set of time series data, it is prudent to learn if the series is random. To determine if the observations in a series are randomly ordered, an estimate of the standard error, which assumes randomness, may be calculated. This estimate is equal to $1/\sqrt{n}$, where n is the number of observations. If the autocorrelations for a series fall within plus or minus two of these standard errors, the original data can be presumed to be random. Alternatively, a chi-square can be computed for the autocorrelation coefficients of a series, and if it is smaller than the tabulated value at a 95% confidence limit, the empirical observations are random.

A test for randomness is one of the first that ought to be carried out with time series data. If a series is completely random, there would be little point in attempting to analyze it with a view toward constructing a model of its characteristics. The degree of randomness in a series reflects the lack of systematic variations among the causal factors which give rise to the series. It might be instructive to compare the extent of randomness in different series such as birth, marriage, and mortality rates within a single administrative area and then to compare these findings to those for other areas with different social and economic characteristics.

Moving Averages

A method of "moving averages" is often employed to eliminate trend and seasonality from time series by averaging adjacent values. It can also serve as a means of removing randomness from a series. The expression *moving* refers to the fact that this procedure entails "moving" ahead observation by observation, dropping the oldest observation as each new observation is added.

If we assume that a time series X_t is composed of three additive components: trend (T_t), cycle (C_t), and randomness (R_t), then

$$X_t = T_t + C_t + R_t. \tag{13.13}$$

To eliminate R_t using the method of moving averages, we would take a certain number of successive observations, say every three, find their averages, subtract these averages from their corresponding sets' middle observations, and form a new series of subtracted averages. If this method has been successful, the new series would have all its values close to zero. Should this not occur, experimentation with different-sized sets of observations must be conducted, say, taking every five instead of every three successive observations.

Assuming that R_t has been eliminated from X_t by the method of moving averages and that we define M_t to be a new series made up of the successive averages used in the process to remove R_t; then M_t will equal the sum of T_t and C_t. Subtracting M_t from the original equation (13.13) for X_t yields a new series X_t equal to R_t, which is purely random. This demonstrates how the method of moving averages can be used to remove nonstationarity from a series. It is also important to note that if the number of successive observations used in calculating a moving average is set equal to the series' seasonality, or the period of its cycle, the seasonality or cycle will disappear.

The Univariate Box–Jenkins Approach to Modeling a Time Series

Having considered some of the basic concepts of time series analysis, we shall now turn to a discussion of a very efficient, general method of modeling, using autoregressive (AR) and moving average (MA) processes, developed by Box and Jenkins (1976). Their approach is derived from Wold's (1938) theorem that any time series X_t can be conceptualized as a combination of an autoregressive expression,

$$\phi_1 X_{t-1} + \phi_2 X_{t-2} + \cdots + \phi_p X_{t-p} + e_t, \tag{13.14}$$

and a moving average expression,

$$e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \cdots - \theta_q e_{t-q}. \tag{13.15}$$

Thus, X_t can be written as the sum of two very different types of expressions. The AR expression, similar in form to a regression equation, states that the values of X_t can be reconstructed on the basis of a linear combination of past values. The p subscript can be varied to obtain the best possible fit to the observed values of X_t. The optimal value assigned p is defined as the "degree" of the AR process. The last term, e_t, represents the error left in the resulting AR model (i.e., the difference between the observed values of X_t and those produced by parametrization of the AR model). The moving average (MA) representation for X_t assumes that the values of X_t can be reproduced by past values of model errors for different lag periods. The q parameter is varied to obtain the best possible results.

The Box–Jenkins approach entails combining the AR and MA expressions into a single equation, set equal to X_t. This is defined as a mixed autoregressive-moving average (ARMA) model. The strategy underlying this modeling approach is to specify the best possible AR model, take the remaining unsuccessfully modeled component of the variance (i.e., the error), and attempt to represent whatever patterns it contains in the MA part of the equation. Ideally, the error component in the final ARMA model for X_t should be completely random. ARMA time series models are very general and accurate, have no linear estimation constraints, and can be fitted to any stationary time series.

Three research stages that show the steps required to apply the Box–Jenkins approach can be described. To carry out the initial stage, it is necessary to determine if the data have a trend and/or are seasonal–cyclic using the tests described earlier. If the data are nonstationary, they need to be differenced to obtain a stationary series.

If the data have no randomness (an unrealistic assumption), the exact ARMA (p,q) model could be found by studying the patterns produced by the autocorrelation and partial autocorrelation coefficients. Standard texts on Box–Jenkins procedures (e.g., Makridakis and Wheelwright, 1978) should be consulted for graphs of coefficient patterns that indicate the appropriate p and q values to be selected. Partial autocorrelation coefficients, analogous to partial correlation coefficients, show the strength of the relationship that exists between particular values of a series and various lagged values of the same series. Partial autocorrelations may be calculated for every time lag by removing the effect of all other time lags on the lag in question and on the original time series. All historical series will inevitably possess some randomness, however, and this will affect the values of the autocorrelation and partial autocorrelation coefficients, possibly resulting in misidentification of the optimal model. If this should occur, the mistaken identity will probably appear when the adequacy of the model is tested against the original data. If the degree of fit between the model and the empirical series is unsatisfactory, alternative values for p and q should be tried.

After having chosen tentative values for p and q, the ϕ and θ parameters must be estimated. A Box–Jenkins computer program (Makridakis and Wheelwright, 1978: xi; Dixon, 1981: 639–649) will compute these parameters using recur-

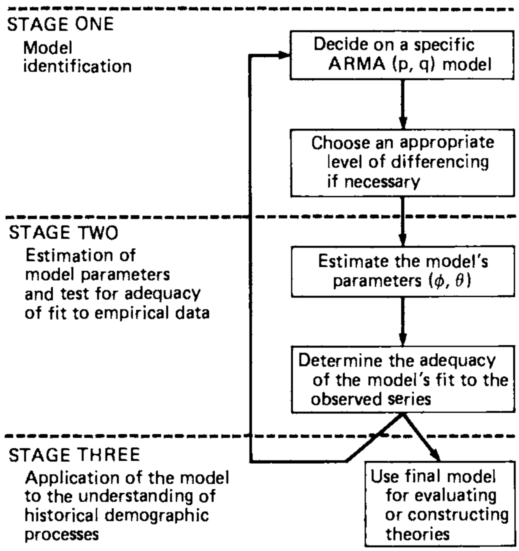

Figure 13.1. *An outline of the stages to be followed in applying Box-Jenkins time series methodology. (Adapted from Makridakis and Wheelwright, 1978: 246.)*

sive, nonlinear, maximum-likelihood estimation procedures. After estimating all of a model's parameters, one may evaluate the adequacy of the model by seeing if the residual differences between the observed data and those produced by the model are random. This is done by determining if the autocorrelations of the residuals e_t in the final model are significantly different from zero.

If the model is acceptable, substantive interpretations may be given to the sizes of its various parameters. For example, lags of 5–30 years might appear stronger than any of the other possible lags, with the coefficient for the 30-year lag much larger than that for the 5-year lag. If the series under investigation entailed birth data, the 30-year lag might prove to be due to the succession of generations, with the shorter lag related to climate–harvest fluctuations.

The Multivariate Box–Jenkins Approach to Modeling a Time Series

Until fairly recently, Box–Jenkins computer programs were restricted to univariate analysis. This represented a major barrier to parametric model building in the time domain, forcing investigators to turn to cross-spectral analysis in order to study the interrelationships between series. However, a computer program, MULTBJ (Makridakis and Wheelwright, 1978) extends the Box–Jenkins univariate (ARMA) procedures to multivariate (MARMA) situations. Thus, one series (an independent variable, such as food prices) can be used to attempt to account for another series (a dependent variable, such as an infant mortality rate), combining time series and causal inference approaches in a single modeling technique.

A two-variable MARMA model can be expressed as follows:

$$
\begin{aligned}
Y_t = {} & \phi_1' Y_{t-1} + \phi_2' Y_{t-2} + \cdots + \phi_r' Y_{t-r} + \phi_0 X_{t-b} \\
& - \phi_1 X_{t-b-1} - \cdots - \phi_s X_{t-b-s} + \theta_1' e_{t-1} + \theta_2' e_{t-2} \\
& + \cdots + \theta_p' e_{t-p} + e_t' - \theta_1 e_{t-1}' - \theta_2 e_{t-2}' - \cdots - \theta_q e_{t-q}',
\end{aligned}
\tag{13.16}
$$

where Y_t is the dependent variable, $Y_{t-1}, \ldots, Y_{t-r}$ are past values of Y_t, X is the independent variable, r is the number of terms which include Y, s is the number of terms, plus one, which include X, b is the period length or time lags X leads Y, p is the number of terms included in the autoregressive part of the residual section of the model, and q is the number of terms included in the moving average part of the residual section of the model.

To initiate analysis in the MARMA case, the independent and dependent variables must be subjected to "prewhitening." This entails the elimination of all nonrandomness or patterns *within* both series, leaving only patterns existing *between* the X and Y series. To accomplish this, one simply finds a univariate ARMA model for the independent and dependent variables, that leaves behind the desired set of random residuals for each variable. The residuals for these variables, call them X_{Rt} and Y_{Rt}, that have little or no within-series variation in them, are then studied in relation to each other to discover the nature of the presumed causal covariation between the original X_t and Y_t series. One might, for example, use a MARMA approach to look for possible lagged relationships between food prices and nuptiality rates and later see how this latter rate might covary with fertility rates. For an analogous procedure restricted to two variables, see the treatment of bivariate spectral analysis in Dixon (1981: 608–612).

Cross autocorrelations may be calculated to find the strength of the relationship between two time series for different time lags. They would be calculated by applying the following formula:

$$
r_{XY}(k) = \sum_{t=1}^{n-k} (X_t - \bar{X})(Y_{t+k} - \bar{Y}) \Big/ \sum_{t=1}^{n} (X_t - \bar{X})^2 \left(\sum_{t=1}^{n} (Y_t - \bar{Y})^2 \right)^{1/2},
\tag{13.17}
$$

where X is the dependent variable, Y is the independent variable, k is the number of lags between X_t and Y_{t+k}, and n is the number of observations in the series.

Intervention Hypothesis Testing

Historical demographers often direct their attention to studying the temporal effects of critical historical events such as famines, plagues, wars, or rebellions. We shall refer to such events as "interventions" and show how they may be modeled statistically (see Dixon, 1981: 646–649).

First, let us consider the different types of effects that may follow in the wake of an intervention:

1. A sharp discontinuity may occur at the time of the intervention. A rising birth rate might drop precipitously following a revolution and then begin rising at a later time. This would produce a change in the level or intercept of a time series because the level of the series drops and preintervention and post-intervention slopes would show different intercepts when extrapolated back to a common point in time in the past.
2. The slope or trend of a series can change after an intervention. A birth rate might rise only half as fast following a revolution as it was rising prior to that event.
3. Variances around the mean values in a series may change after an intervention. Attitudes toward reproductive behavior might become heterogeneous following a revolution and show up as larger variations around the mean birth rate when rates for different administrative regions, differentially affected by the revolution, are averaged.
4. Seasonal patterns can change. Revolutions can alter cultural practices dominating the seasonal timing of an event, such as marriage, which would in turn affect the seasonality of births for newly married couples.
5. An intervention can produce a continuous effect that persists over time. The change in the level of the birth rate following a revolution might remain invariant. Alternatively, an intervention can produce an effect that fails to remain present and fades as time progresses.
6. An intervention can generate either an instantaneous or a delayed effect. In the latter case, the effect may be causally confounded with events more proximate in time. Some demographic delays are relatively easy to predict. Biological constraints dictate that there be at least a 9-month lag in any birth rate change triggered by a social upheaval.

All of these effects can be characterized as falling along one of three dimensions: *the indicators* of the intervention (the level, slope, variance, and pattern of seasonality); *the permanence* of the intervention (a continuous or discontinuous effect); and *the timing* of the effects (instantaneous or delayed) (see Cook and Campbell, 1979: 209, and McDowall *et al.*, 1980).

Looking back for a moment at Figure 13.1, we can add a new, fourth stage, termed "intervention hypothesis testing," which is based on the Box–Jenkins

(1976) transfer function approach. Before discussing this approach, however, it should be pointed out that if the number of observations in the time series under investigation is not greater than 50, other techniques will have to be tried. If the unsystematic variations (or error component) in consecutive observations are correlated, multiple analysis of variance (MANOVA) (Bock 1975: 447–489) or repeated measures analysis of variance (ANOVA) with a degree of freedom correction (Geisser and Greenhouse, 1958) may be utilized to estimate an intervention effect. Since it is likely that error components in demographic time series will be correlated, application of ordinary least squares (OLS) regression to determine the effect of an intervention will lead to biased estimates of the standard deviations of the series' parameters. The t-statistic typically used to evaluate the significance of change in a time series will then be biased upwards, making an intervention appear to have had a greater historical effect than actually took place.

After fitting an ARMA model to a stationary time series, we can ask if the addition of an intervention component would add significantly to the model's ability to reproduce the observed series. This is equivalent to asking the question whether an intervention, such as a revolution, produces a statistically significant effect in a series at a certain point in history. Adapting Leslie McCain's and Richard McCleary's (1979) treatment of transfer function models, we shall discuss the three types of intervention effects most likely to be encountered by historical demographers: an abrupt, constant change; a gradual, constant change; and an abrupt, temporary change in a series.

An abrupt, constant intervention model may be expressed as follows:

$$X_t = wI_t + \text{an ARMA } (p, q) \text{ model}, \qquad (13.18)$$

where w is a parameter that measures the magnitude of an intervention effect. The independent variable I_t represents the intervention at time t. It is a step function that is set equal to 0 before the intervention and equal to 1 thereafter. Since w measures the magnitude of the shift in the level of the series, an intervention hypothesis test entails evaluating the statistical significance of w.

A gradual, consistent intervention model can be created by adding another term to the preceding model:

$$X_t = dX_{t-1} + wI_t + \text{an ARMA } (p, q) \text{ model}, \qquad (13.19)$$

where d is a parameter that is estimated from the series. The intervention hypothesis test for this type of model involves testing the statistical significance of both d and w. Under this model, a gradual change in the level of the series begins at the time of the intervention, with the final change in level equal to the ratio $w/(1 - d)$. The rate of historical change due to the intervention is $d^n w$, where n is the nth point in time after the intervention. The parameter d will always have a value less than 1. The larger d is, the more gradual will be the change in the level of the series. In other words, the closer d is to 0, the more abrupt will be the intervention effect. In the limit as d approaches 0, Eq. (13.19) becomes Eq. (13.18).

Finally, let us consider an abrupt, temporary intervention effect. This can be expressed by Eq. (13.19) except that I_t will now be defined as a "pulse function." To do this, we set the value of I_t equal to 0 before the intervention, equal to 1 at the time of the intervention, and equal to 0 afterward. This model abruptly raises the level of a series by an amount w. The new level of the series then decays over time at a rate d until it reaches its original level.

Visual inspection of a time series may be sufficient to indicate which if any of the three intervention models applies. A list of more complicated combinations of these basic effects appears in Box and Tiao (1975). By starting with Eq. (13.19) and defining I_t as a pulse function, it is not necessary to make an a priori choice between abrupt or gradual patterns of intervention. The strategy would be as follows:

> If the estimated value of d is relatively small, the analysis stops. But if the estimated value of d is relatively large, say $d = .9$ or larger, the analyst will take this as evidence of a permanent effect. The analysis is then replicated, using equation [13.19] but with I_t defined as a step function. Again, if the estimated value of d is relatively large, the analysis stops. But if the estimated value of d is relatively small, say $d = .1$ or smaller, the analyst takes this as evidence that the effect is both permanent and abrupt. The analysis is then replicated with equation [13.18]. Using this logic, the analyst need never make an a priori choice among models of impact [McCain and McCleary, 1979: 266].

The type of time series studied in Jacques Houdaille's (1978) article on the seasonality of marriages before, during, and after the French Revolution seems to capture a major intervention effect very similar to the kind under discussion and suggests that his data would in principle lend themselves to fruitful analysis with ARMA intervention modeling techniques. The French Revolution may be interpreted as a historical intervention with a multitude of effects, one of which was religious in character. During the period prior to the French Revolution, very few marriages were celebrated in March and December since Lent and Advent fell within these months. Houdaille's sample vital registration data show that this practice greatly declined during the religious persecutions of the revolution. Later, the practice reappeared, although it did not reach pre-intervention levels. Thus, the intervention model seems to conform to Eq. (13.19), where I_t is defined as a pulse function, producing an abrupt, temporary intervention effect. A simple modification could be introduced to take into account the lack of complete restoration of the series to preintervention levels.

Houdaille's data is disaggregated so that eight regions and three different sizes of towns may be studied independently. In principle, it would be possible to build separate ARMA-intervention models for each of these demographic data sets to study the differential religious effects of the French Revolution and thus perhaps open up an entirely new range of research questions.

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14 Log-Linear Modeling

Log-linear modeling is one of the more recently developed areas of social science methodology for analyzing categorical data and offers an attractive statistical framework for the historical demographer concerned with the construction of causal models based on these kinds of data. Although log-linear modeling has a quite complicated statistical apparatus associated with it, practical applications require primarily a knowledge of essential concepts, review of applied examples (say, Duncan 1979; Hauser, 1978) to get a concrete sense of its capabilities, and access to relevant computer programs such as ECTA.

In a 1979 study, Otis Duncan uses an expanded version of the famous 1949 British cross-classification table of respondents' occupations to illustrate how multiplicative structural models can respond to a variety of intriguing research questions associated with social mobility. Since a variety of historical demographic sources, such as nominative censuses or marriage records implicitly contain occupational mobility data, cross-classification tables similar in form to the one analyzed by Duncan can be constructed and studied using a comparable modeling approach.

Log-linear modeling is a methodological technique that enables historical demographers to analyze causally sets of data previously examined by earlier researchers who used less powerful and noncausal computational procedures. It opens up tremendous possibilities for future research by permitting an investigator to examine potential causal relations with qualitative, categorical data in a manner denied to a prior generation of historical demographers. It is a technique of the future.

The social demographic data encountered in historical sources often exist in the form of unordered categories such as sex, religion, marital status, occupation, place of birth, or cause of death. This kind of information, known as nominal data, is purely discrete in nature and does not permit one to consider possible comparative gradations. For example, in a concrete historical setting, a person was either born in Paris in 1789 or not; similarly, a person was either a Calvinist or not. In other words, this type of data does not convey gradated, quantitative information such as how far from the geographical center of Paris a Parisian was born or how consistent the behavior and attitudes of a Calvinist in seventeenth-century Geneva may have been with Calvinist religious ideals. Sophisticated analysis of nominal data in multivariate situations is generally not found in historical demographic research literature. To be sure, cross-classifications of nominal data are reported (e.g., migrant status versus religious affiliation). But attempts to push further to analyze cross-classifications of nominal variables in terms of explanatory models are very few.

The Organization of Categorical Data

Nominal data, based on classification systems with rules that designate the categories or classes to which individuals are to be assigned, represent the simplest form of categorical data. Historical source materials of demographic interest usually result from the application of classification schemata to populations. Such schemata need to be critically evaluated prior to formal analysis and explanatory modeling to learn if they are truly appropriate ways of measuring the phenomena in question. An occupational classification system, for instance, may be too abbreviated to capture the real degree of heterogeneity and nature of work in a population. Occupations associated with professional activity might be listed in considerable detail but agricultural laborers, who often constitute the majority of a population and whose work activity is no less specialized than that of professionals, might wrongly be aggregated into a single occupational category.

Under some circumstances, logically or empirically deficient classification systems may be improved by ingenious transformations of the data. Nonetheless the magnitude of differences within the original categories found in primary sources will always remain lost to view whenever additional information from complementary sources is absent.

Whenever possible, potential causal relationships between variables should be taken into consideration as early as possible, distinguishing between dependent and independent variables. In cross-classifying a dependent and an independent variable, each of which have two categories, a "two-dimensional" table results. The general form of an $I \times J \times K$, three-dimensional table is presented in Table 14.1. If a distinction can be made between dependent and independent variables, a table of this nature would ordinarily be arranged so that the independent variable appears as the column variable, X, and the dependent variable, Y, is the row variable; Z is the "layer" or "control" variable. The

Table 14.1

A Hypothetical Three-Dimensional Table, $I \times J \times K$, Demonstrating an Appropriate Manner of Organizing the Categorical Relationships between a Dependent (Y), an Independent (X), and a Control Variable (Z)

Variable		1	2	...	J	Totals
		X at the first level of control variable Z $(k = 1)$				
	1	f_{111}	f_{121}		f_{1J1}	$\sum_{j=1}^{J} f_{1j1}$
Y	2	f_{211}	f_{221}		f_{2J1}	$\sum_{j=1}^{J} f_{2j1}$
	⋮		⋮		⋮	
	I	f_{I11}	f_{I21}		f_{IJ1}	$\sum_{j=1}^{J} f_{Ij1}$
Totals		$\sum_{i=1}^{I} f_{i11}$	$\sum_{i=1}^{I} f_{i21}$		$\sum_{i=1}^{I} f_{iJ1}$	$\sum_{i=1}^{I} \sum_{j=1}^{J} f_{ij1}$
		X at the second level of control variable Z $(k = 2)$				
	1	f_{112}	f_{122}		f_{1J2}	$\sum_{j=1}^{J} f_{1j2}$
Y	2	f_{212}	f_{222}		f_{2J2}	$\sum_{j=1}^{J} f_{2j2}$
	⋮		⋮		⋮	
	I	f_{I12}	f_{I22}		f_{IJ2}	$\sum_{j=1}^{J} f_{Ij2}$
Totals		$\sum_{i=1}^{I} f_{i12}$	$\sum_{i=1}^{I} f_{i22}$		$\sum_{i=1}^{I} f_{iJ2}$	$\sum_{i=1}^{I} \sum_{j=1}^{J} f_{ij2}$
		X at the Kth level of control variable Z				
	1	f_{11K}	f_{12K}		f_{1JK}	$\sum_{j=1}^{J} f_{1jK}$
Y	2	f_{21K}	f_{22K}		f_{2JK}	$\sum_{j=1}^{J} f_{2jK}$
	⋮		⋮		⋮	
	I	f_{I1K}	f_{I2K}		f_{IJK}	$\sum_{j=1}^{J} f_{IjK}$
Totals		$\sum_{i=1}^{I} f_{ijk}$	$\sum_{i=1}^{I} f_{i2K}$		$\sum_{i=1}^{I} f_{iJK}$	$\sum_{i=1}^{I} \sum_{j=1}^{J} f_{ijK}$

number of observations or cases in each cell of a given row or column at a given level may be symbolized as f_{ijk}. For example, f_{123} refers to the frequency of observations in the cell formed by the first row and the second column at the third level.

The totals at the margins found at the right-hand side and bottom of each level's table are the sums of the frequencies in the rows and columns respectively. The total number of observations in each table is given by the double summation shown in their lower right-hand corners. Higher dimensional tables may be produced by extending the basic framework of a three-dimensional table.

The Odds Ratio

Once a cross-classification table has been created, questions arise regarding the nature and strength of the relationships between the table's variables. A wide variety of measures of statistical association exist and are routinely generated by computer program packages such as SPSS (Nie *et al.*, 1975) and BMDP (Dixon, 1981). Here, we shall consider the odds ratio, a measure of association between variables whose statistical properties are well understood and that is employed in the categorical, multivariate technique known as log-linear analysis (Goodman, 1978).

Table 14.2 presents hypothetical data for dichotomous variables, migrant status (migrant/nonmigrant) and social class (working class/nonworking class). The frequencies appearing in Table 14.2 indicate that the two variables are associated with each other, but we would like to express the degree of their relationship in a precise manner. Comparing the odds of being a member of the working class is one way of making a statistical, rather than an impressionistic, statement about the variables' extent of association. For migrants, the odds are 1000 to 100 or 10 to 1 of being a member of the working class. If migrant status had no relationship to social class, we should expect to find that the odds of being a member of the working class are approximately the same for migrants and nonmigrants. In our hypothetical example, the odds of being a nonmigrant member of the working class are 500 to 400 or 1.25 to 1. To compare the odds, we can calculate their ratio:

$$\text{Odds Ratio} = O_r = (f_{11}/f_{21})/(f_{12}/f_{22}) = (1000/100)/(500/400) = 10/1.25 = 8.0 \qquad (14.1)$$

If the odds for both categories of migrant status were equal, their ratio would be 1.0, indicating the absence of a statistical relationship with social class.

The odds ratio, O_r, is not a symmetric measure of association because if two tables have the same degree of association but in opposite directions, they will

Table 14.2
Relationship between Migrant Status and Social Class Based on Hypothetical Data

	X: migrant status		
Y: social class	Migrant	Nonmigrant	Totals
Working class	1000	500	1500
Nonworking class	100	400	500
Totals	1100	900	2000

not have the same odds ratios. This property of O_r can be removed by taking the natural logarithm of O_r to create a new measure, O_r^* known as the log odds, which ranges in size from plus to minus infinity, with zero indicating no relationship between the variables in question.

One of the most useful properties of the odds ratio and its logarithm is that they are unaffected by row and column multiplications. This means that it is legitimate to compare relationships in tables derived from different-sized populations. For example, if the nature of the association between migrant status and social class was similar in four different nineteenth-century German villages, the odds ratios and their logarithms would also be similar for each village (apart from the effects of possible sampling errors), regardless of differences in the marginal distributions of the tables for each village.

Generalization of the odds ratio and its logarithm from a 2×2 table to larger $I \times J$ tables presents no serious problems since such $I \times J$ tables are composed merely of subsets of 2×2 tables. An odds ratio can be calculated for each subtable. This approach permits detailed analysis of relationships in every part of a table, and since "simultaneous" confidence intervals can be calculated for odds ratios (cf. Goodman, 1969), all of the subhypotheses of interest related to a table can be evaluated.

The analysis of nominal data can be extended from bivariate to multivariate situations involving three or more variables. For example, after having established that a significant relationship exists between migrant status and social class in a particular region or administrative unit of a society, such as a barony or *département*, it might be of interest to learn if the strength of this relationship is independent of geographical location. If comparable data were available for a number of regions, region would be conceptualized as a control variable with each region representing a level of the control variable. Let us assume that we have two regions, one industrialized and the other nonindustrialized, and a contingency or cross-classification table showing the relationship between migrant status and social class for each region. If the strength of the association is significantly different between the tables and thus varies from one level of the control variable to the other, we would infer that an interaction effect is present between the variable "region" and the relationship between the variables "migrant status" and "social class." The presence of such interaction effects may be quite important and may serve as focal points for continued research.

When examining relationships between variables within a level of a control variable, analysis should be guided whenever possible by causal models (see Heise, 1975, for a discussion of procedures required to construct causal models). Suppose that we wanted to construct and evaluate a causal model explaining variations in the relative sizes of social classes and that we evaluate three models. The first model, direct causation, assumes that changes in migrant status directly affect relative social class sizes or the proportions of individuals in social class categories. A second model might argue that the first model of direct causation is spurious and that changes in migrant status have no direct effect upon the proportions of individuals in different social class categories because both of these population characteristics are caused by the presence or absence of industrialization in a region. A third possible model, a developmental-sequence model, might predict that changes in migration would lead to changes in the extent of industrialization, which would in turn change social class composition. Both the second and third models presume that historical evidence exists for establishing that industrialization temporally preceded change in social class composition. If controlling for region (given industrialized and nonindustrialized regions) does not eliminate whatever relationship is found to exist between migrant status and social class over time, we can rule out

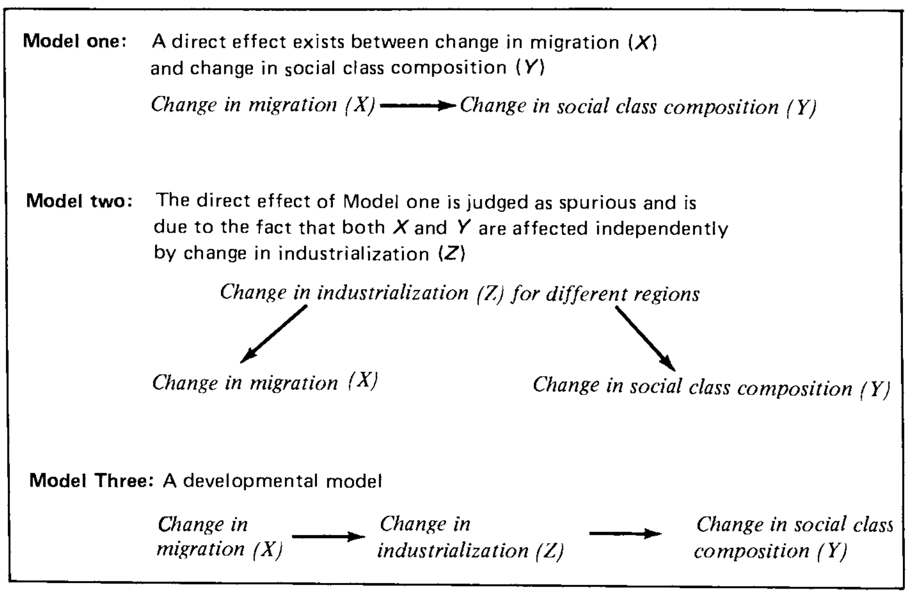

Figure 14.1. *A set of three possible causal models, associating change in migration (X), social class composition (Y), and industrialization (Z).*

models two and three. Although we cannot establish the actual nature of the historical causality associated with change in social class composition at this point, we can at least disconfirm two possible causal models by demonstrating that they are inconsistent with the data.

Studying relationships within different levels of a dichotomous, control variable may be fairly easy in situations such as those described earlier, but sophisticated computerized procedures are required to cope with the complex interaction patterns typically found in large multivariate cross-classification tables.

Log-Linear Models

A relatively new statistical modeling technique, log-linear analysis (Goodman, 1978), can provide the historical demographer or social historian with an extremely useful and statistically powerful methodology for causal model building. Log-linear analysis begins with a set of observed frequencies (as might be obtained from a nineteenth-century Belgian population register or French census) grouped into categories and cross-classified. The cell probabilities (or some function of them) derived from cross-classification tables are the unit of analysis, not the individual values that would typically be employed in other statistical techniques such as regression analysis.

An $I \times J \times K$ cross-classification of population characteristics can have a probability P_{ijk} assigned to each cell of the resulting table. For instance, p_{213} would be the probability that an individual is in the second category of the first variable, the first category of the second variable, and the third category of the third variable. Any member of the set of probabilities p_{ijk}, or function of them, may be used as a dependent variable in log-linear analysis.

H. T. Reynolds (1977: 57–58) suggests five steps in developing a satisfactory log-linear model. First, propose a model on theoretical grounds that might account for the observed frequencies. This is equivalent to making a statement about the distributions and interrelationships between the variables in a cross-classification table and requires some sort of prior information about the variables that can serve to guide in constructing the model. Second, derive a set of expectations that should occur if a hypothesized model is statistically significant. If a model predicted that there ought to be no relationship between individuals' migrant status and social class (i.e., they are mutually independent), a computer program could be used to estimate what a sample cross-classification of a given size would look like if these variables were independent. A third step entails comparing the expected frequencies under a given hypothesized model with the empirically observed frequencies and then deciding on the basis of some statistical criterion whether or not the model adequately accounts for the absence or presence of relationships found in the data. Fourth, if the fit of the model to the data is unacceptable, a new model should be proposed and evaluated. On the other hand, if a good fit is achieved, a fifth step entails estimating the parameters of the model and attempting to translate their signs and numerical values into substantive statements.

In order to simplify the notation required to discuss log-linear models, we shall consider a two-way, $I \times J$ table rather than a higher dimensional table. The primary goal of log-linear analysis is to arrive at a model of one's data with probabilities p_{ij} of an individual being found in the ith row and jth column of a cross-classification table. Alternatively, it is possible to compare the expected frequencies F_{ij} under a given model with the observed frequencies f_{ij}. The natural logarithm L_{ij} of the expected frequencies may also be used since each can be easily transformed into the other.

If the variables X (migrant status) and Y (social class) are independent and an individual is equally likely to fall into the categories of each variable, a cross-classification table for such a population would have approximately the same P_{ij}, F_{ij}, or L_{ij} values in each cell. This is known as the "no effects" model. A second model containing only "row effects" would postulate that the categories of the row variable Y are not equiprobable (e.g., an individual is more likely to belong to the working class than not). Under this second model, X and Y are still statistically independent, however, and the categories of the column variable are equiprobable. Migrant status and social class are unrelated, and an individual is as likely to be a migrant as a nonmigrant. In terms of the natural logarithm L_{ij} of the expected frequencies, the no effects model can be expressed as

$$L_{ij} = 0 \tag{14.2}$$

and the row effects model as

$$L_{ij} = \theta + \lambda_i^Y, \tag{14.3}$$

where θ and λ are the model's parameters. In each model, θ is a grand mean, defined as the average of all of the logarithms of the cell frequencies. In the system of notation for the log-linear parameters, the λs, a superscript designates the variable associated with an effect—in the case of Eq. (14.3), the effect is Y. A subscript indicates that the effects are a set of parameters corresponding to each category of a variable (e.g., working class and nonworking class). Thus, λ_i^Y symbolizes the ith effect for variable Y.

A slightly more complicated model, the independence model, has row and column effects along with the grand mean, θ. In this situation,

$$L_{ij} = \theta + \lambda_i^Y + \lambda_j^X, \tag{14.4}$$

where λ_i^Y and λ_j^X are the "main effects" of the model and are defined as departures from the grand mean. The equation for calculating the row effect is simply

$$\lambda_i^Y = \left[\left(\sum_{j=1}^{J} L_{ij} \right) / J \right] - \theta, \tag{14.5}$$

and for the column effect, the equation is

$$\lambda_j^X = \left[\left(\sum_{i=1}^{I} L_{ij} \right) / I \right] - \theta. \qquad (14.6)$$

The introduction of parameters such as these in a log-linear model indicates the presence of nonequiprobability, but since they have no underlying metric scale, any formal interpretation of their absolute numerical values is problematic. On the other hand, insight into the meaning of the size of these parameters can be gained from the fact that they can be summed to yield the predicted value of the logarithm of the expected frequency of any cell in a cross-classification table. The antilogarithm of these values yields the estimated frequencies F_{ij}, which can be compared with the observed frequencies f_{ij}.

Having considered the no effects, row effect, and row and column effects models, the next logical step is to consider a model that predicts a relationship between Y and X:

$$L_{ij} = \theta + \lambda_i^Y + \lambda_j^X + \lambda_{ij}^{YX}. \qquad (14.7)$$

In the case of a 2×2 table, this is a "saturated" or a full effects model because it has as many independent parameters as there are cells in the table. Saturated models always produce expected frequencies equal to observed frequencies, since all of the possible effects present in a table are included in such models.

The interaction parameters in Eq. (14.7) are defined as follows:

$$\lambda_{ij}^{YX} = L_{ij} - \left(\sum_{j=1}^{J} L_{ij} \right) / J - \left(\sum_{i=1}^{I} L_{ij} \right) / I + \left(\sum_{j=1}^{J} \sum_{i=1}^{I} L_{ij} \right) / JI. \qquad (14.8)$$

If interaction parameters must be present in a model in order to make it statistically significant, they will indicate which variables are related to one another. However, the magnitudes of the interaction parameters cannot be given an exact statistical interpretation except one specifying that if an interaction parameter is close to zero, the relationship is weak, and if quite large in magnitude, the relationship is strong. Once an acceptable log-linear model has been discovered, other less statistically problematic measures of association can be used if required.

Log-linear models are usually hierarchical. This means that the superscripts of any interaction parameters in a model require that the model have λ parameters corresponding to all subsets of the superscripts. Thus, if a model had an interaction term λ^{YXZ}, it must also have the terms λ^Y, λ^X, λ^Z, λ^{YX}, λ^{YZ}, and λ^{XZ}, since these are the subsets of the YXZ superscript. Given an $I \times J \times K$, three-variable table, the mutual independence model, analogous to the two-variable independence model discussed earlier, can be expressed as

$$L_{ijk} = \theta + \lambda_i^Y + \lambda_j^X + \lambda_k^Z. \qquad (14.9)$$

In terms of the previous example regarding migrant status (X), social class (Y), and geographical region (Z), the model in Eq. (14.9) implies that the ratio of working-class to non-working-class individuals will be equal in each column of the table and that there is no relationship between region and social class composition or between region and migrant status.

Suppose, however, that it is important to test the hypothesis that social class and migrant status were associated but that neither was associated with region. The log-linear model in this situation would be

$$L_{ijk} = \theta + \lambda_i^Y + \lambda_j^X + \lambda_k^Z + \lambda_{ij}^{YX}. \quad (14.10)$$

If, in addition, migrant status is believed to be related to region, the model would appear as follows:

$$L_{ijk} = \theta + \lambda_i^Y + \lambda_j^X + \lambda_k^Z + \lambda_{ij}^{YX} + \lambda_{jk}^{XZ}. \quad (14.11)$$

This model states that the only two variables without any direct relationship are social class and geographical region. There is, of course, a spurious relationship between the two because they are both associated with migrant status. As a causal system with no other causally significant variables present, it might be argued that a change in migrant status would result in changes in both social class composition and the degree of industrialization present in a region. The covariance of social class composition and presence of industrialization in a region would then be shown to be spurious thus revealing that these variables are independent of each other since when one controls for migrant status, the relationship between social class composition and region disappears.

The next level of complexity entails postulating that every variable in the cross-classification table is significantly related to every other variable:

$$L_{ijk} = \theta + \lambda_i^Y + \lambda_j^X + \lambda_k^Z + \lambda_{ij}^{YX} + \lambda_{jk}^{XZ} + \lambda_{ik}^{YZ}. \quad (14.12)$$

This log-linear model implies that if any of the three variables is controlled or held constant, the relationship between the remaining two will not be eliminated. Finally, the saturated model, containing a three-way interaction, is:

$$L_{ijk} = \theta + \lambda_i^Y + \lambda_j^X + \lambda_k^Z + \lambda_{ij}^{YX} + \lambda_{jk}^{XZ} + \lambda_{ik}^{YZ} + \lambda_{ijk}^{YXZ}. \quad (14.13)$$

The three-way interaction term in Eq. (14.13) implies that all three variables are associated with one another. In terms of our example, this might mean that the relationship between social class composition and migrant status would have to be specified for each type of geographical region. More concretely, if individuals in an industrialized region behaved differently because of as-yet-unspecified historical factors different from those found in a nonindustrialized region, the preceding model anticipates that migration status would affect social class composition in a different manner in each region.

Tests for equiprobability, mutual independence, conditional independence, and interactions of various types can be carried out for tables with more than three variables, although the number of possible models to consider expands rapidly with each additional variable. With four variables there are 27 possible models to take into account. By eliminating parameters from the saturated model and preserving a statistically significant reduced model, one can exclude improbable causal relations in a stepwise manner (see Dixon, 1981: 143–206).

Illustrative Example

Let us suppose than an application of family reconstitution techniques together with additional record linkage to other supplementary data sources makes it possible to arrive at the cross-classified data presented in Table 14.3. Given a table of this nature, log-linear analysis permits us to ask a number of potentially interesting, causal questions: To what extent does the presence of industrialization in a region (*R*), social class membership (*S*), and migration status (*M*) directly affect completed family size (*F*)? How do region, social class, migration, and completed family size affect or interact with one another?

Figure 14.2, a "path diagram," graphically depicts the relevant causal relationships to be explored (see Goodman, 1978: 173–229). The double-headed arrows between variables *R*, *M*, *S*, and *F* can represent two distinct types of effects. In the case of *R* and *M*, for example, the double-headed arrow may refer either to their mutual relationship or to the conjoint effects of *R* on *M* and of *M* on *R*. In the first instance, the association between *R* and *M* would be

Table 14.3
Cross-Classification of Seven Hundred Fourteen Hypothetical Families with Respect to Four Dichotomous Variables[a]

			Completed fertility (*F*)	
Region (*R*)	Social class (*S*)	Migration (*M*)	*FA*	*FB*
RA	*SA*	*MA*	84	40
		MB	14	16
	SB	*MA*	23	44
		MB	8	26
RB	*SA*	*MA*	38	32
		MB	24	47
	SB	*MA*	56	49
		MB	79	134

Note: With respect to "region," *RA* denotes the presence of industrialization and *RB* a relative lack of industrialization. With respect to "social class," *SA* denotes working-class affiliation and *SB* non-working-class affiliation. With respect to "migration," *MA* denotes migrants and *MB* nonmigrants. With respect to "completed fertility," *FA* denotes the presence of a "natural fertility" birth schedule and *FB* the presence of some form of family limitation.

[a]Variables are geographical region (*R*), social class composition (*S*), migration status (*M*), and completed fertility (*F*).

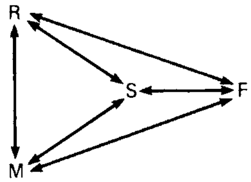

Figure 14.2. *A path diagram for the system of all possible two-way effects between* R, M, S, *and* F, *applied to Table 14.3.*

attributed to unknown causes not identified in the path diagram, as well as the possible conjoint effects of R on M and M on R. If a variable such as the presence of industrialization in a region (R) were to be conceptualized as temporally prior to a migratory influx, then a single-headed arrow would have been drawn from R to M. Under this historical interpretation of the data, we would postulate that the observed level of R (presence/nonpresence of industrialization) would affect the odds regarding the observed level of M (migrant/nonmigrant status) for families. However, there would be no feedback, or return effect, of migration upon industrialization.

When variables are presumed to affect one another, a double-headed arrow in a path diagram implies that the observed level of one categorical variable is believed to affect the observed level of another categorical variable and vice versa. For example, a positive or amplifying feedback loop might reasonably be presumed to exist between industrialization and migration such that as migration into a region increases and expands the labor force, industrialization spreads, and simultaneously as industrialization grows, more and more migrants are attracted into the region.

A recommended strategy to follow once one has designed a cross-classification table containing the relevant categorical variables is to look first at the size and statistical significance of all effects possibly present in the table, that is, to consider the "saturated model." Log-linear results for the saturated model for the four-way table (*RMSF*) are presented in Tables 14.4–14.7. Since Table 14.3 involves a cross-classification of four categorical variables, two-, three-,

Table 14.4
Results for Table 14.3 of Fitting Log-Linear Models of Progressively Higher Order

k–categorical variables	Degrees of freedom	Likelihood ratio chi-square (G^2)	Probability
0 (mean)	15	302.42	.0000
1	11	216.80	.0000
2	5	16.18	.0063
3	1	.07	.7976

Table 14.5
Tests for Table 14.3 to Determine If Interactions between Categorical Variables of a Given Order k Are Zero

k–categorical variables	Degrees of freedom	Likelihood ratio chi-square (G^2)	Probability
1	4	85.61	.0000
2	6	200.62	.0000
3	4	16.12	.0029
4	1	.07	.7976

and four-way interactions may be present and must be considered if an adequate model of causal relationships is to be developed.

Tables 14.4 and 14.5 list results for two different types of tests for the presence of statistically significant interactions for the four possible orders. Test results in Table 14.4 were derived to evaluate the statistical significance of all interactions of order $k + 1$ and higher. When $k = 2$, the log-linear model that is fitted to the cross-classified data in Table 14.3 is the full second-order model, made up of all possible two-way effects, and corresponds diagrammatically to the path model in Figure 14.2. If the likelihood ratio chi-square (G^2) for $k = 2$ was not significant, then we could conclude that all higher three-way and four-way interactions were approximately zero.

Test results in Table 14.5, on the other hand, were derived by measuring the statistical significance of the difference between fits of models of progressively

Table 14.6
Tests for Table 14.3 of the Partial Associations of the Categorical Variables R, M, S, F

Effect	Likelihood ratio chi-square (G^2)	Probability
F	5.33	.0210
M	.45	.5029
S	21.40	.0000
R	58.43	.0000
FM	17.89	.0000
FS	7.63	.0057
FR	.16	.6861
MS	13.55	.0002
MR	65.17	.0000
SR	34.40	.0000
FMS	.45	.5030
FMR	.03	.8653
FSR	12.82	.0003
MSR	.20	.6571
FMSR	.07	.7976

Table 14.7
Tests for Table 14.3 of Marginal Associations of the Categorical Variables R, M, S, F

Effect	Likelihood ratio chi-square (G^2)	Probability
FM	25.83	.0000
FS	14.78	.0001
FR	3.86	.0495
MS	42.33	.0000
MR	90.50	.0000
SR	58.94	.0000
FMS	3.20	.0736
FMR	.20	.6542
FSR	14.90	.0001
MSR	.01	.9565

higher orders (i.e., between a model of order $k - 1$ and a model of order k). Both Tables 14.4 and 14.5 show that the third-order interaction is statistically significant, but that the four-way interaction (*FMSR*) is nonsignificant. We now have strong evidence that our final model will probably have to include at least one of the four possible three-way interactions (*FMS, FMR, FSR, MSR*). To determine which two-way and three-way effects need to be included in our final model, there are two tests to screen effects. The rationale for employing two different tests is that the statistical significance of a specific effect, say λ^{MR}, may be contingent upon the other effects present in the model. Thus, different types of tests may be required to judge the relative significance of individual effects (see Brown, 1976, for a full discussion). The results presented in Tables 14.6 and 14.7 involve tests of partial and marginal association, respectively, for the categorical variables found in Table 14.3.

To test whether or not the partial association of k-categorical variables is zero, a comparison is made between the fit of two hierarchical models to determine if a significant difference exists between them. The first hierarchical model is designed to contain all possible effects of order k, whereas the second is a reduced model with a specific k-categorical variable interaction removed. Returning to Table 14.3, let us go through the steps to be followed to test the statistical significance of the partial association between the categorical variables migration status (*M*) and region (*R*). A log-linear model with all of the two-way effects (*FM, FS, FR, MS, MR, SR*) would be fitted to the data in Table 14.3. Then λ^{MR} is dropped and the reduced model (*FM, FS, FR, MS, SR*) fitted. The statistical significance of the difference between these tests of fit is a test of the significance of the λ^{MR} effect. Table 14.6 shows that all of the two-way effects, with the exception of λ^{FR}, are significant.

A second test available looks at the marginal association of k-categorical variables to determine if a specific interaction is zero in the marginal subtable formed by the variables in question. Thus, the statistical significance of the association between migration status (M) and region (R) is determined by extracting from Table 14.3 the two-way subtable indexed by M and R and testing for the significance of the two-way interaction between them.

The tests of marginal association in Table 14.7 should be compared with the tests of partial association in Table 14.6. Both tests show that the three-way effect λ^{FSR} is significant and that the three-way effects λ^{FMR} and λ^{MSR} are not significant. There is some disagreement between the tests in regard to λ^{FMS}, but it does not appear to be sufficiently large to warrant including this effect in a final model. With the exception of λ^{FR}, both tests unambiguously find all of the two-way effects to be significant. We might try to exclude λ^{FR} from a final model, but since we have already decided to include λ^{FSR}, that is not possible, since a hierarchical model requires that all lower-order effects whose categorical variables are subsets of a higher-order effect must also be included. Since λ^{FSR} is significant, λ^{FS}, λ^{FR}, λ^{SR}, λ^{F}, λ^{S}, λ^{R}, and θ are automatically included in any model containing λ^{FSR}.

We are now in a position to choose a model to fit the data found in Table 14.3. Results presented in Tables 14.4 through 14.7 suggest that the best and possibly most parsimonious model is (*FM*, *MS*, *MR*, *FSR*), which includes all of the main effects, two-way interactions, and one of the four possible three-way interactions. This model's fit (likelihood ratio chi-square = 0.77, probability = 0.9426) is highly nonsignificant, and therefore the fitted or expected frequencies generated under its hypothesized relationships come very close to reproducing the observed frequencies in Table 14.3. To learn if an even more parsimonious but less powerful model can be accepted, we could delete effects from a model in a stepwise fashion and then test each reduced model. Residuals, standardized

Table 14.8
Standardized Residuals Resulting from the Application of the Log-Linear Model (FM, MS, MR, FSR) *to Table 14.3*[a]

			Completed fertility (F)	
Region (R)	Social class (S)	Migration (M)	FA	FB
RA	*SA*	*MA*	.026	−.251
		MB	−.063	.423
	SB	*MA*	−.110	.295
		MB	.192	−.362
RB	*SA*	*MA*	.282	−.056
		MB	−.335	.047
	SB	*MA*	−.186	.004
		MB	.160	−.002

[a]Standardized residuals are calculated by taking the difference between observed and fitted frequencies and dividing by the square root of the fitted frequencies.

residuals, and Freeman–Tukey deviates may also be obtained if desired (see Dixon 1981: 143–206). The standardized residuals for the model (*FM*, *MS*, *MR*, *FSR*) appear in Table 14.8. As expected, they are quite small. In cases where a good fit has not been achieved, inspection of a model's residuals may reveal a pattern(s) of nonfit that can assist in interpreting or redesigning a model.

The standardized log-linear parameters (lambdas) may be used to estimate the relative sizes of effects in a path diagram. Figure 14.3 is a modification of Figure 14.2, displaying the standardized lambdas. It also attempts to diagram the three-way effect, *FSR*. Figure 14.3 provides interesting information about the relationships between the categorical variables, but it is not entirely satisfactory. We would like to be able to determine if any of the double-headed arrows can be reduced to single-headed arrows, implying unidirectional causality. To justify such reductions would require that the data available in Table 14.3 be supplemented with additional historical information.

Consider the double-headed arrow between migration status (*M*) and completed family size (*F*). This arrow might suggest the presence of relationships such as the following: (*a*) some couples migrate shortly after being married, and their status as migrants affects their completed family size during the reproductive period at their point of destination in a manner different from that of nonmigrant couples; and (*b*) other couples in the same population migrate late in their marriage, having achieved a threshold family size, after which they have few or no additional children. Under condition (*a*), migratory experience affects completed family size, whereas under condition (*b*) it is a threshold family size that results in the decision to migrate. If either condition *a* or *b* was shown to be negligible on the basis of supplementary historical evidence, then a single-headed arrow would be drawn from (*M*) to (*F*), instead of a double-headed arrow.

The three-way effect, *FSR*, in Figure 14.3, is ambiguous, and it would be helpful to break apart the effect in order to understand its structure. The tack we

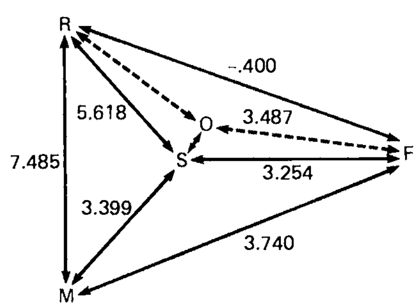

Figure 14.3. *A log-linear path diagram, using standardized lambda parameters, for the model* (FM, MS, MR, FSR) *based on Table 14.3.The dotted lines symbolize the three-way effect,* FSR

Table 14.9

Tests for the Upper (RA) *Half of Table 14.3 of the Partial Associations of the Categorical Variables* M, S, F

Effect	Likelihood ratio chi-square (G^2)	Probability
F	.03	.8521
M	65.05	.0000
S	10.92	.0009
FM	5.33	.0210
FS	23.01	.0000
MS	2.87	.0904
FMS	.34	.5577

Table 14.10

Tests for the Lower (RB) *Half of Table 14.3 of the Partial Associations of the Categorical Variables* M, S, F

Effect	Likelihood ratio chi-square (G^2)	Probability
F	9.16	.0025
M	25.90	.0000
S	69.42	.0000
FM	13.32	.0003
FS	.07	.7881
MS	11.25	.0008
FMS	.17	.6795

Table 14.11

Tests for the Upper (RA) *Half of Table 14.3 of the Marginal Associations of the Categorical Variables* M, S, F

Effect	Likelihood ratio chi-square (G^2)	Probability
FM	8.87	.0029
FS	26.56	.0000
MS	6.41	.0114

Table 14.12
Tests for the Lower (RB) *Half of Table 14.3 of the Marginal Associations of the Categorical Variables* M, S, F

Effect	Likelihood ratio chi-square (G^2)	Probability
FM	13.34	.0003
FS	.10	.7548
MS	11.28	.0008

will follow entails stratifying Table 14.3 by region (a reasonable hunch) and examining separate models for each type of region (industrialized/nonindustrialized). This is an exploratory test to determine if we can obtain two models that have interpretable two-way effects. Tables 14.9 through 14.12 present results for each model, showing that our hunch to stratify by region has yielded an interpretable basis for understanding the three-way effect, *FSR*.

Although partial and marginal association tests for category *RA*, industrialized region(s), show all three two-way effects (*FM*, *FS*, *MS*) to be significant, the same tests for *RB*, nonindustrialized region(s), show only effects *FM* and *MS* to be significant. This suggests that the three-way effect *FSR* arises in the general model presented in Figure 14.3 because at the first level of *R*, *RA*, a significant interaction exists between social class composition (*S*) and completed family size (*F*), whereas at the second level *RB*, only a weak, nonsignificant effect exists between *F* and *S*. Log-linear path diagrams for both models appear in Figure 14.4.

The preceding methodological introduction and worked example touch on the major features of log-linear analysis likely to be of interest to a historical demographer. Our treatment is far from being exhaustive. The reference materials cited at the end of this chapter should be consulted in detail prior to

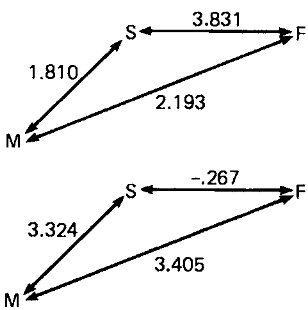

Figure 14.4. *Log-linear path diagrams, using standardized lambda parameters, for the model (*FM, MS, SF*) under condition* RA *(upper panel) and under condition* RB *(lower panel), based on Table 14.3.*

research applications in order to ensure that computer analysis with Leo Goodman's ECTA or other available programs is properly executed and correctly interpreted. A log-linear novice may find that confidence in the use of this method is most quickly gained by constructing a hypothetical data set whose structural properties are easily understood and then studying log-linear results for it.

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15
Computer Simulation of Historical Processes

It is not an exaggeration to claim that the basic principles of simulation are implicit in many traditional, qualitative historical studies. The guiding ideas behind simulation are certainly not contemporary creations. What is new, however, is the development of computer languages that enable scholars to translate conceptual simulations of historical processes into sets of equations whose implications can be studied with a computer. Simulation with a computer is simply a more rigorous, controlled, and powerful extension of dealing with age-old questions of the type "What must it have been like in the past if such and such happened?

Since the demographic histories of past societies become more complex as the size of populations increases (Biraben, 1979), any method of gaining insight into such complexity should be welcome. Computer simulation techniques merely expand mental capacities to enable us to consider simultaneously the interactions of large numbers of variables over time. Computer simulation models and experiments run on models, such as sensitivity analyses, are only as good as the ideas that go into their formulation. The models themselves are by no means an escape from the intellectual requirements upon which the great historical studies of the past have been grounded.

Although computer simulation has rarely been made use of by historical demographers, it can prove indispensable as a method for evaluating the plausibility of theoretical models, studying phenomena under data-deficient conditions, and observing the structural effects of differing degrees of random variation. The logic of computer simulation methodology is fairly simple to understand. Programming a simulation model to run on a computer requires some expertise, but should not be considered as falling outside the range of the tools of the historical demographer.

Developing a Model to Simulate

A very useful habit to acquire when theorizing is to sketch causal diagrams that capture the basic outlines of one's ideas. Figure 15.1 illustrates a demographically based model that hypothesizes a system of causal relationships between a society's population and its economic and social structure. Virtually any complex theory of demographic phenomena can be reformulated as a multiloop model. Such models can serve a number of important purposes. They make explicit the structural assumptions of a theory that might otherwise be obscured or ambiguous if left in verbal form, and demonstrate how interacting feedback loops may account for observed historical change.

Causal loop diagrams are constructed by identifying pairwise relationships between the variables used in a theory. If a change in a variable is hypothesized to have no significant direct effect on another variable, an arrow is not drawn between the variables. In Figure 15.1, for example, there is no arrow directly connecting the variable mortality to the variable age at marriage. Mortality is shown, however to have a direct effect on population size. Population size has a direct effect on real income per capita, which in turn has a direct effect on age at marriage. Thus, translating this part of the causal diagram into words, we can say that although the effect of mortality on age at marriage is not direct, there is an indirect effect mediated through population size and real income per capita. The arrows between these four variables all have negative signs placed alongside them. This draws attention to the additional hypotheses that changes in variables at the tips of the arrows are in the opposite direction to the changes in the variables at the other ends of the arrows. An *increase* in mortality, for instance, is hypothesized to produce a *decrease* in population size. Similarly, a *decrease* in population size yields an *increase* in real income per capita, which in turn leads to a *decrease* in age at marriage.

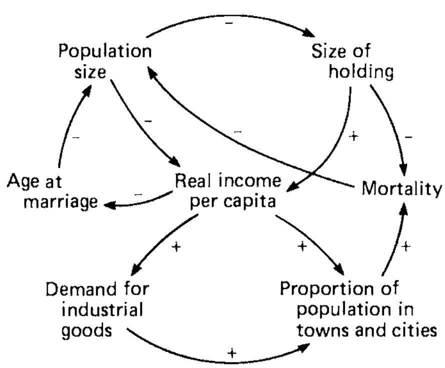

Figure 15.1 *A causal loop model of relationships between demographic, social, and economic change. (Adapted from Wrigley, 1969: 109).*

Positive and Negative Feedback Structures

Closed paths, beginning and ending with the same variable, are called feedback loops because they "feed an effect" back to a cause that originally helped produce that effect. Two types of feedback loops are possible: positive and negative. In the case of a positive loop, a variable "feeds back" on itself to increase its existing behavior. In Figure 15.2, the variables population size and births form a positive loop. As the number of births per year increases, population size grows and causes additional births, and so on.

Negative feedback works to keep a system in equilibrium. Instead of reinforcing the same type of change in a variable as occurs under conditions of positive feedback, a negative loop acts to oppose change in a variable. Figure 15.3 builds a negative feedback loop into the simple model found in Figure 15.2. If the positive feedback of Figure 15.2 was left unmodified, population size would grow infinitely large. This is, of course, quite unrealistic, since constraints of some type always intervene to restrict the historical growth of a population. Therefore, to construct a realistic model of population growth (or decline) requires that we theorize about or discover the existence of negative feedback structures that interact with the positive loop tending to produce unlimited population growth. Figure 15.3 shows one such negative loop. Here we have taken a step in constructing a potentially more realistic model by introducing the variable of density as an ecological constraint on population growth. In tracing the negative loop, beginning with the variable of population, we see that as population size increases, so does density, but as density increases, fertility *decreases*. As fertility decreases, births decrease, and finally population decreases to close the negative loop. This is a classic instance of a control system.

Our model will now be complicated a bit further (see Figure 15.4) by adding two additional negative feedback loops that take into account mortality effects arising from population density. Feedback loops, such as those depicted in Figure 15.4 regulate all dynamic, demographically based systems as these systems pass back and forth through stages of instability, growth, decay, and equilibrium. Instead of theorizing in terms of unidirectional causality, a feedback approach forces a historical demographer to consider explicitly the role of causal networks of relationships between variables.

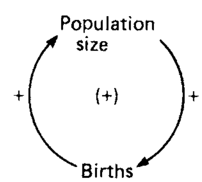

Figure 15.2. *Example of a positive feedback loop.*

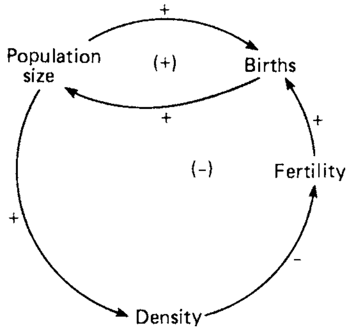

Figure 15.3. *Example of interlocked positive and negative feedback loops.*

Choosing a Simulation Language

We are now ready to turn from causal loop diagramming to formal simulation techniques. A wide variety of approaches to simulation exists. Kenneth Wachter *et al.* (1978), for instance, have utilized the SOCSIM microsimulation program (Hammel *et al.*, 1976) to study relationships between demographic processes and household structure. The SOCSIM program, however, does not offer the user a full range of simulation capabilities. Wachter *et al.* (1978: 16) candidly point out a very serious oversimplification in SOCSIM's demography—the absence of any provision for migration. Evidence indicates that migration rates in preindustrial communities were relatively high (see, for example, Laslett,

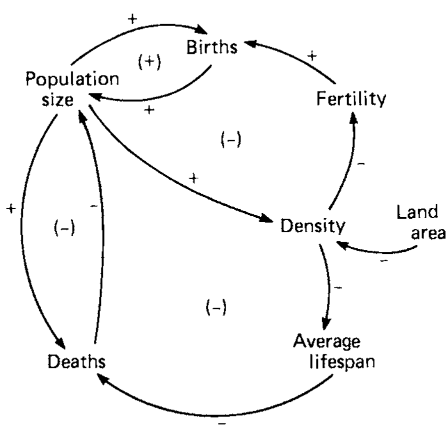

Figure 15.4. *An ecological causal model, showing population growth under regulation. (Adapted from* Study Notes in System Dynamics *by Michael R. Goodman by permission of The MIT Press, Cambridge, Massachusetts, p. 145. Copyright © 1974 Wright-Allen Press, Inc.)*

1977: chap. 1). The simulated populations used in SOCSIM are not only closed to migration but also homogeneous, requiring that the same demographic rates and household-formation rules apply to every individual equally regardless of class, occupation, tenant status, religion, or any other characteristic. SOCSIM has some utility as a heuristic simulation program. However, it is desirable that historical demographers make an effort to learn a simulation language in order not to be limited by the constraints of packaged programs such as SOCSIM.

One easily comprehensible simulation language is DYNAMO (Goodman, 1974). Simulation equations written in DYNAMO language can be translated into FORTRAN, BASIC, or other computer languages with a modest effort if necessary and run on the new breed of relatively inexpensive, personal microcomputers (see, for example, Anderson, 1977: 241–243). Because DYNAMO is a very easy language to learn, affording a one-to-one relationship between computer equations and causal model diagrams, it offers an excellent point of entry to simulation techniques for individuals unskilled in computer programming.

Causal Models in DYNAMO Format

Feedback loops are the elementary building blocks of all complex demographically based historical systems. The structure of these systems may be conceptualized as concatenations of feedback loops. One of the major research tasks of the historical demographer is to identify the population-related aspects of such loops and then learn how these demographic loops are causally concatenated with, for example, social and economic loops. Together, these loops produce what a simulator may consider to be the aggregate aspects of history.

DYNAMO flow diagrams incorporate a number of special symbols whose purposes must be understood in order to translate the causal loop diagrams we have worked with up to this point into a DYNAMO format. First of all, DYNAMO flow diagrams use only two types of variables: level variables, which are produced by integration or summation processes and act as the "memory" of a system's past behavior, and rate variables, which control system changes. Causal paths within DYNAMO flow diagrams are made up of alternating level and rate variables. If historical time was to stop, only the existing values of the level variables would appear as observables. Unlike level variables, which have no substructure, rate variables have four components: (*a*) a stabilizing goal state; (*b*) an existing variable state; (*c*) an expression describing the numerical gap between (*a*) and (*b*); and (*d*) an expression describing how system activity is contingent upon this gap. Complicated rate equations may be uncoupled into sets of auxiliary equations to achieve greater conceptual clarity and to meet concrete theoretical specifications. Cloudlike figures are used in DYNAMO diagrams to symbolize the inputs and outputs of a system that are not formally included in a model. Parameters are represented by short straight lines. Material flows (e.g., people, money, goods, etc.) are depicted by solid arrows and informational flow (i.e., level states used in the rate equations) by dashed arrows. Rates are symbolized by valvelike figures, rate auxiliaries by circles, and levels by rectangles.

A simple example of a population and net birth rate (births per year minus deaths per year) will be used to illustrate how to create a DYNAMO flow diagram. Figure 15.5 depicts the positive feedback loop that captures the essential characteristics of historical population change. In Figure 15.6, we translate Figure 15.5 into DYNAMO format, and in Figure 15.7, we identify the symbols used in Figure 15.6. With a bit of practice, it is easy to write down simulation equations directly from a DYNAMO flow diagram. Parameters and initial level variable magnitudes are set independently of the flow diagram. The simulation equations for Figure 15.6 are as follows:

$$\text{POP}.K = \text{POP}.J + (DT)\,(\text{NBR}.JK) \tag{15.1}$$
$$\text{POP} = 1000 \tag{15.2}$$
$$\text{NBR}.JK = \text{NGF*POP}.K \tag{15.3}$$
$$\text{NGF} = .01. \tag{15.4}$$

If one has access to a computer facility with a DYNAMO compiler, these equations can be entered and the model simulated with ease. If not, it is a relatively simple matter to translate a small set of equations into another computer language and run it on a programmable hand calculator or microcomputer. Translating Eq. (15.1) into words, we have, the level (i.e., size) of the population at time K (POP.K) is equal to the level at an earlier time J (POP.J) plus the product of the time interval (DT) between times J and K and the net birth rate (NBR.JK) for the time interval J to K. Equation (15.2) sets the initial level of the population at 1000 persons. The net birth rate (NBRJK) for the time interval J to K is calculated in Eq. (15.3) and is equal to the product of the net growth factor (NGF) and the level of the population at time K. Finally, Eq. (15.4) sets the value of the net growth factor at 1.0% per year.

This simple system of equations produces exponential population growth and

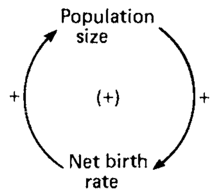

Figure 15.5. *The first-order positive feedback loop which accounts for the basic nature of historical population growth.*

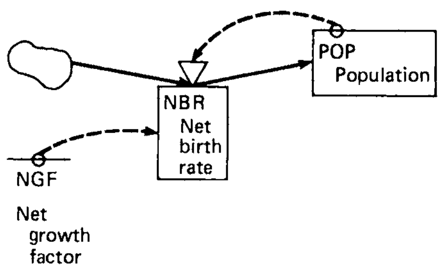

Figure 15.6. *A DYNAMO flow diagram representation of Figure 15.5.*

can easily be simulated over time by integrating or summing the calculations for the equations through as many time intervals (*DT*) as desired. One would begin by substituting the initial population level (1000 individuals) from Eq. (15.2) and the net growth factor (1.0%) from Eq. (15.4) into Eq. (15.3) to obtain a value for the net birth rate (NBR.*JK*). We can now solve Eq. (15.1) for the population level at time *K*: POP.*J* is 1000, NBR.*JK* is 10, and *DT*, the time interval between *J* and *K*, is one year. This process would normally be repeated, replacing the initial population level with its new value. Note that since the net birth rate is proportional to the population level, it grows each year along with the size of the population. Growth in a positive feedback system of this type can be measured by a time constant *T* defined in this context as the reciprocal of the net growth factor (1/NGF). It can be shown that the time required for an exponentially growing variable, such as POP.*K*, to double in size is equal to approximately 70% of the time constant, *T*. In our example, the initial population of 1000 individuals would double in about 70 years.

To demonstrate how easy it is to build simulation models of historical processes, let us consider two additional models: an epidemic model and a migration model. Figure 15.8 is a causal model of the growth of an epidemic. The model is translated into a DYNAMO flow diagram in Figure 15.9. Note that the diagram includes an auxiliary symbol, the circle. As mentioned earlier,

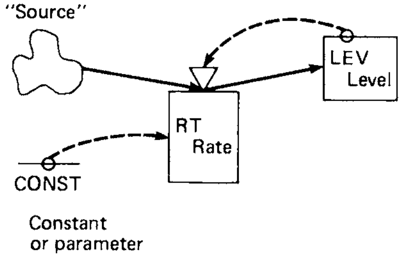

Figure 15.7. *A DYNAMO flow diagram, identifying the basic symbolic elements used in DYNAMO models.*

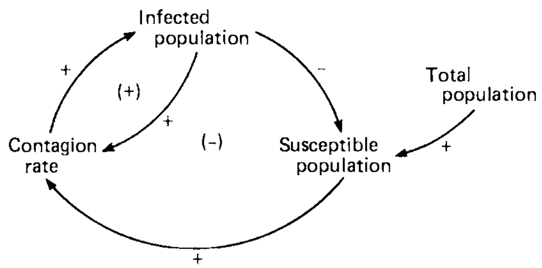

Figure 15.8. *A causal loop diagram of the spread of an epidemic in a population. (Adapted from* Study Notes in System Dynamics *by Michael R. Goodman by permission of The MIT Press, Cambridge, Massachusetts, p. 85. Copyright © 1974 Wright-Allen Press, Inc.)*

auxiliary equations are used to help clarify the factors involved in complex rates. In this case, we have chosen to have a separate equation for the susceptible population rather than to build it into the equation for the contagion rate. The full set of equations for our epidemic model follows:

$$\text{IP}.K = \text{IP}.J + (DT)\,(\text{CR}.JK) \qquad (15.5)$$
$$\text{IP} = 10 \qquad (15.6)$$
$$\text{CR}.KL = \text{IPC*NCF*IP}.K\text{*SP}.K \qquad (15.7)$$
$$\text{IPC} = .1 \qquad (15.8)$$
$$\text{NCF} = .02 \qquad (15.9)$$
$$\text{SP}.K = P - \text{IP}.K \qquad (15.10)$$
$$P = 1000 \qquad (15.11)$$

This model's simulation output illustrates the sigmoidal or S-shaped growth of an infected population. There are two loops in the model. One is the positive

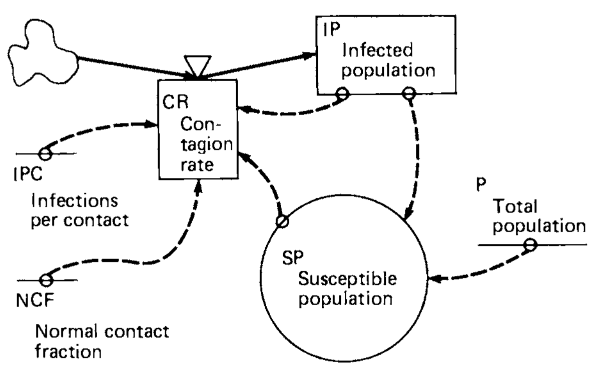

Figure 15.9. *A DYNAMO flow diagram representation of Figure 15.8.*

feedback loop in which the contagion rate adds more and more people over time to the infected population. The other is a negative feedback loop, which takes into consideration the finiteness of the susceptible population. As the infected population grows in size, the susceptible population must decrease as long as the total population is kept invariant. The epidemic ends, under the conditions specified in this simple model, when the entire population becomes infected. At this point, there is no longer any susceptible population (SP), and the contagion rate (CR) thus drops to zero.

The contagion rate (CR) is based on the probability of infections arising from contact between individuals, which are assumed to occur randomly in a closed environment. The product of the size of the infected population (IP) and the susceptible population (SP) is established as the number of possible contacts per day. The percentage of actual contacts per day, defined as NCF, is set at 2.0. The reader is advised to carry out a simulation of this model with a hand calculator to demonstrate that it produces sigmoidal growth of the infected population.

Our final example is an elementary migration model. The causal loop diagram appears in Figure 15.10 and is translated into DYNAMO notation in Figure 15.11. The population level (POP.*K*) is increased by the in-migration rate (IMR) and is lowered by the out-migration rate (OMR) and the net death rate (NDR). The equations for this model follow:

$$\text{POP}.K = \text{POP}.J + (DT)\,(\text{IMR}.JK\text{-OMR}.JK\text{-NDR}.JK) \quad (15.12)$$
$$\text{POP} = \text{POP}I \quad (15.13)$$
$$\text{POP}I = 1000 \quad (15.14)$$
$$\text{IMR}.KL = \text{NIM}*\text{POP}.K \quad (15.15)$$
$$\text{NIM} = .145 \quad (15.16)$$
$$\text{OMR}.LK = \text{NDM}*\text{POP}.K \quad (15.17)$$
$$\text{NOM} = .02 \quad (15.18)$$
$$\text{NDR}.KL = \text{POP}.K*\text{DRF} \quad (15.19)$$
$$\text{DRF} = .025. \quad (15.20)$$

With an in-migration rate of 14.5% per year, a normal out-migration rate of 2.0% per year, and a net death rate of 2.5% per year, a net population growth of

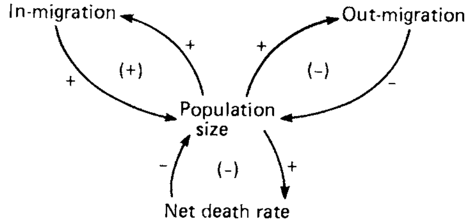

Figure 15.10. *A causal loop diagram of a simple migration model. (Adapted from* Study Notes in System Dynamics *by Michael R. Goodman by permission of The MIT Press, Cambridge, Massachusetts, p. 322. Copyright © 1974 Wright-Allen Press, Inc.)*

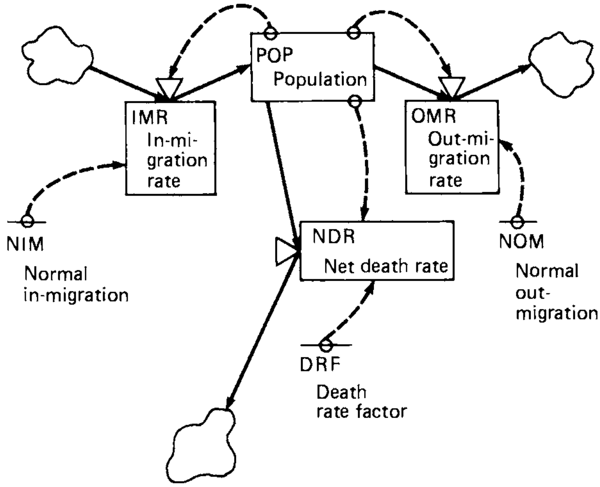

Figure 15.11. *A DYNAMO flow diagram representation of Figure 15.10.*

10.0% occurs each year. Thus, the population will double in about 7 years.

All these simulation models are oversimplifications of actual historical processes. Using the modeling principles we have outlined, however, we can construct much more complicated simulation models incorporating additional causal features. There is virtually no limit to the degree of sophistication that can be built into DYNAMO models. Once a plausible simulation model has been constructed to fit a particular research problem and historical context, the results generated by the model can be compared with known historical data. If the fit is satisfactory, a researcher may be able to lay claim to a certain degree of validity for the processes embodied in the simulation model. On the other hand, if a large discrepancy arises, the model will have to be revised by building in neglected causal factors, modifying the existing structure and parametric assumptions of the model, or some combination of both.

Simulating Randomness in Causal Models

The models discussed so far have not explicitly incorporated any random variation. Randomness is to be expected in historical data, and the effects of random variation can be incorporated into DYNAMO models as well as into those DYNAMO models translated into other computer languages, such as FORTRAN and BASIC. This may be accomplished by making use of the random-number generator facility available in almost all computers. The effect one desires is to add controlled amounts of random variation or "noise" to certain variables' values during a simulation. A historical demographer must be able to distinguish matters of general validity from incidental patterns resulting from mere chance, since most historical realities undoubtedly lie somewhere between pure chance and absolute determinism. Careful consideration must always be given to their probable location along this spectrum.

Wachter *et al.* (1978) devote a good deal of time describing the results of using SOCSIM to investigate the effects and possible extent of random variation present in preindustrial English household formation. They conclude that stem families, which some historians have identified as an important phase in the life cycles of preindustrial Europeans, may be nothing more than a loosely connected set of associated relationships, arising possibly as a mere coincidence of circumstances.

Being able to judge accurately the degree and manner in which randomness affects demographic phenomena in different historical contexts is of obvious importance. Identifying genuine randomness, however, may prove exceedingly difficult. What appears as random variation may be nothing more than an artifact of a historical demographer's unawareness of the existence of complex causal relationships. For example, let us make the reasonable assumptions that a typical village in a society under investigation has four well-defined social classes that vary considerably in size and have very different rules of household formation. It is also true of our hypothetical village that young married couples in two of the four social classes are much more likely to out-migrate. If we build a simulation model to study household formation that ignores social class distinctions, migration, and the interaction between these two factors (as would be the case with Wachter *et al.*'s (1978) SOCSIM model which excludes consideration of such variables), we might easily be led by the logic of the simulation model to attribute higher rates of "random variation" to history than are justified. The reason for this is straightforward. A simplistic simulation model is likely to explain only a small amount of historical variation. If researchers are unaware of flaws in the model, they may quite reasonably claim that the unexplained variation is purely random in nature. If a more sophisticated and accurate simulation model was constructed, however, more historical variation would most likely be accounted for, thus demonstrating that what was previously considered to be random in nature was really systematic variation. Our inability to understand the apparent vagaries of history should not lead us too quickly to relegate them to the realm of unintelligible randomness.

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IV

CAUSAL MODEL BUILDING AND HYPOTHESIS TESTING: MAJOR THEMES

Historical demographers are confronted with particularly difficult intellectual endeavors. The complexities and subtleties of demographic phenomena and their interrelationships with natural and social environments often cannot be deciphered without adoption of an interdisciplinary research perspective. Widely differing theoretical and methodological approaches must typically be drawn upon to reconstruct and understand the populations of the past.

The historical demographer must ultimately face the issue of "numbers." Demographic data by their very nature tend to be quantitative and require the use of statistical methodology. This is not a reductionist position, however, since historical demography is obviously far more comprehensive than merely the processing of numerical data. We are beginning to learn, nonetheless, that many theoretical debates, historical hypotheses, and substantive puzzles may never be validly resolved without recourse to carefully designed, quasi-experimental quantitative research designs. This is, of course, easier said than done. Qualitative and quantitative perspectives toward the subject matter of interest to historical demographers should not be considered as mutually exclusive. Some mixture of the two is implicit in all research. The relative strengths and weaknesses of each perspective must be assessed in terms of the nature of the anticipated research and available source materials. Thus, it becomes a question of optimally *integrating theory, source materials, and research methodology.*

Having passed from demographic sources to research methods, we ought to stop for a moment to consider some of the major obstacles to achieving the type of synthesis just noted. Hubert M. Blalock (1979a) has codified a rather comprehensive set of problems posing barriers to the integration of conceptualization and measurement in the social sciences, at least nine of which are relevant to formulating an optimal research relationship between his-

torical demographic source materials and the types of analytical methodology and causal modeling to be discussed in Part IV.

1. *Historical phenomena may be so complex that adequate demographic theories will require 20, 30, or even more variables in order to capture important causal relationships. This could place impossible demands on what can be learned empirically from surviving archival sources.*
2. *Historical change can at times be so rapid in comparison to the timing of observations derived from source materials, such as decennial censuses, that temporal sequences may be lost from view and their effects misinterpreted.*
3. *Models of historical demographic processes may require the incorporation of numerous nonrecursive relations or feedback loops in which variables mutually affect one another. Such relations can easily turn into statistical nightmares.*
4. *Intercorrelation of key theoretical variables can lead to a statistical effect known as multicollinearity in which statistical estimates are biased. The use of very large population samples and precise measurement of variable values would be required to address this problem.*
5. *The individuals in a population and the historical social systems that they create are likely to be nonhomogeneous with respect to statistical analysis because population subgroups will have to be identified and studied separately.*
6. *Historical groups, events, and geographical settings often have rather vague or fuzzy boundaries. Causal and statistical analysis will accordingly suffer if we are uncertain about what our source materials are really measuring.*
7. *Aggregation of demographic data may not adequately take into account ecological or contextual differences between populations. This will affect the testing of theories as well as attempts to link social psychological to structural theories or vice versa.*
8. *Because of the scarcity or unreliability of documents, it may often be necessary to establish less than suitable correspondence between theoretical constructs and empirical data.*
9. *Historical demographers will always be plagued by missing data either because of the spotty character of archival records or because theoretically important types of information were never preserved or even recorded.*

These nine problems suggest in practice that historical demographic theories, such as demographic transition theory, and their associated research may rarely prove to be general enough to achieve the interdisciplinary character required to incorporate all of the salient variables required to produce completely satisfying causal explanations. They may also fail to be simultaneously specific enough to generate falsifiable hypotheses. Some trade-

offs between generality and specificity will ordinarily be required. The sacrifices and gains involved in such trade-offs demand careful consideration.

Perhaps the most serious obstacle to an integration of theory and research in historical demography stems more from deficiencies in data collection from potential archival source materials than from data analysis. Failure to carry out a complete inventory of source materials and to use their contents creatively to operationalize theoretical constructs may render any subsequent analysis, no matter how sophisticated, nothing more than an arbitrary exercise in numerical manipulation.

A long-term goal to which historical demographers need to give high priority entails linking structural studies in which groups of individuals, aggregated on the basis of some criterion, are the unit of analysis to microlevel studies in which unaggregated individuals are treated as the unit of analysis. A related goal would be to integrate studies carried out using different levels of aggregation (for example, Irish county to baronial levels).

A number of influential historical demographic studies have been built around the use of highly aggregated data. For example, Princeton University's Office of Population Research's European Fertility Project studies incorporate geographical subdivision level statistics as their analytical centerpieces. This can produce serious interpretation problems. If the criterion for population aggregation has little or no relevant theoretical significance, statistical findings and demographic indexes may be of only marginal utility in probing beneath purely descriptive levels to reconstruct causal processes. Demographic data, aggregated into territorial units typically found in published censuses, are often unlikely to form meaningful subpopulation groupings for more than a handful of variables. If the territorial units created for administrative purposes do not reflect homogeneity in regard to phenomena such as nuptiality or marital fertility, it may be difficult to link demographic index values for such units to the social processes that gave rise to them (see, for example, the use of province-level data in Ansley J. Coale et al.'s Human Fertility in Russia Since the Nineteenth Century *(1979) to create macrolevel demographic indexes).*

The use of demographic data, aggregated by administrative criteria for purposes other than those of theoretical interest to the historical demographer, may confound effort to unravel causal interrelationships by tempting researchers to bypass important theoretical issues in favor of analytical simplicity. Practical trade-offs between theoretical requirements and the most immediately attractive analytical options will always pose a dilemma (Blalock, 1979b).

Having considered basic sources and methods of interest to historical demographers, we now turn in Part IV *to what is often the most difficult task of research, the integration of theory and empirical findings through causal modeling. Part* IV *is divided into two interrelated sections. The first consists of Chapter 16, "Theory Construction and the Nature of Scientific Explanation." The second section, focusing on multidisciplinary research in historical* *demography, includes Chapters 17 through 20: "Population Genetics Models"; "Biometric Models"; "Evolutionary-Ecological Models"; and "Socioeconomic Models."*

In the first section, we discuss key aspects of theory construction, validity issues, quasi-experimental research designs, and drawing causal inferences. Failure to be sensitive to the issues raised by these philosophical topics can unwittingly lead to an invalid integration of theory and empirical research that jeopardizes painstaking data collection and analysis. Since historical demography finds ready application in a variety of different disciplines, the second section draws attention to the multidisciplinary dimensions within which historical demographers conduct research. Numerous examples drawn from four major fields of investigation are discussed to illustrate recent attempts to integrate theory and empirical research within explanatory or causal frameworks.

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16
Theory Construction and the Nature of Scientific Explanation

Historians often seem concerned more with the description of past events than with the discovery of causal models that might explain those events (Hempel, 1965: 231). Similarly, formal demographers are usually more interested in ascertaining patterns rather than in explaining them, especially in cases where it is difficult to account for them solely in terms of internal demographic factors (Smith, 1977: 1–2).

Charles Tilly (1978: 17) has suggested three reasons that may explain why research in historical demography has tended to be far more descriptive than analytical: The questions that drew many investigators into the field were largely descriptive, the data for dealing with several variables simultaneously were difficult to acquire, and a major part of the empirical work was done by scholars who were not accustomed to using formal modeling techniques. All of these factors are now changing. Causal rather than descriptive questions are being posed, computerization of demographic data has become easier and less expensive, and graduate training programs are educating increasing numbers of quantitatively skilled researchers. None of these changes necessarily guarantees that the quality of research will improve. They do, however, open new, unexplored possibilities for research that were typically not available to earlier generations of scholars.

The Nature of Scientific Hypotheses

Scientific hypotheses are statements that are capable of being confirmed or disconfirmed with suitable empirical evidence. They have the following form: Whenever an event of kind *C* occurs at a certain location and time in history, another event of kind *E* will or is very likely to occur at a certain location and time that is related to the properties associated with the occurrence of the first event. Although C and E are used to suggest "cause" and "effect," the events included in a hypothesis need not be causally related.

The purpose of using hypotheses in historical demography is to relate demographic and other events in patterns that lead to explanations and predictions. An event E is "explained" when its causes or determining factors have been satisfactorily identified. A scientific explanation of a historical event involves a set of initial and boundary conditions $C_1, C_2, \ldots, C_n$ for the occurrence of event E. These determining conditions are then built into one or more hypotheses upon which the explanation is grounded. The hypotheses state that whenever events of the kind $C_1, C_2, \ldots C_n$ take place, an event of the kind to be explained will occur. The difference between explanation and prediction is only pragmatic in character. In explanation, we know that a final event of kind E has taken place, and we seek to discover its determining conditions. In prediction, however, the determining conditions are given, but the final event of kind E is unknown. If a historical event of kind E can be derived from a set of determining conditions and hypotheses included in an explanation, then the event in principle could have been predicted historically, before it actually took place, using the same determining conditions and hypotheses.

Historians often neglect to make explicit the hypotheses that they nevertheless implicitly presuppose to underlie the explanations they offer. In such instances, it is instructive to attempt to reconstruct their hypotheses. Hempel (1965: 236–237) cites as an example the statement that the Dust Bowl farmers migrated to California "because" long-term drought and sandstorms threatened their survival and "because" California appeared to offer a far more favorable environment. This historical explanation of migration rests upon the unstated general hypothesis that populations will tend to migrate to regions with less adverse environments. Historical explanations always implicitly assume the existence of general hypotheses that interrelate the properties of individuals, groups, or other entities to one another.

Explanation Sketches

Until far more empirical research, theory construction, and testing is undertaken in historical demography, the explanatory analysis of events will remain at the level of what may be termed *explanation sketches*. These sketches would typically include informed, probabilistic guesses with respect to the relevant determining conditions for an event, and a set of testable hypotheses. Such sketches, of course, need to be filled in, through further research and hypothesis testing, until they begin to achieve the status of satisfactory explanations.

Even if a historical demographer maintains that his or her research is restricted to "pure description" of past events without any reference to causality or explanatory patterns, Hempel (1965: 243) has persuasively argued that historical researchers cannot avoid using general hypotheses. Since the primary object of historical demographic research is past demographic events, the acquisition of descriptive knowledge requires, at a bare minimum, use of indirect methods, which in turn entail general hypotheses linking present data to past events, which are forever inaccessible to direct examination. Attempts to separate "descriptive analysis" from "hypothetical generalization and theory construction" in empirical research are largely unjustified and pointless. The two cannot be separated in the process of acquiring knowledge. It is likewise unjustified to create artificially rigid boundaries around the development of demography based on historical data. The demographer, as well as anyone else interested in historical inquiry, will of necessity have to make extensive use of general hypotheses derived from fields traditionally distinguished from either demography or history. This is one of the key features of what Hempel (1965: 243) refers to as the methodological unity of empirical science.

Models of Scientific Explanation

To answer the question Why? rather than only the question What? is a major objective of empirical science. Although this claim is not entirely unproblematic, many more differences of opinion exist regarding the function and fundamental characteristics of scientific explanation. The deductive–nomological or D–N model of explanation proposed by Hempel (1965) is generally considered to represent the archetypal structure of scientific explanation. The D–N model may be considered to be a deductive argument that answers the question Why did an event of kind E occur? by demonstrating that it resulted from certain circumstances $C_1, C_2, \ldots, C_n$, in accordance with certain general hypotheses $H_1, H_2, \ldots, H_m$. The logical structure of the D–N model is such that it argues that given the events and hypotheses in question (the explans), an event of kind E (the explanandum) *was expected to* occur. According to Hempel, this type of explanation enables us to *understand why* an event of kind E took place.

An explanation of an event involves identifying what "caused" it. In the simplest case of a statement of causal connection, we affirm a causal hypothesis when saying that whenever an event of kind C occurs, then there also occurs a corresponding event of kind E. The D–N model as just described is deterministic in nature. No mention was made of probabilities. However, most explanatory models in historical demography can be expected to be statistical in nature, not purely deterministic. Historical demographers inhabit a probabilistic world. A statistical explanation is an explanation that makes essential use of at least one general hypothesis of statistical form. There are two logically different types of such explanations. A deductive–statistical or D–S explanation that makes use of the mathematical theory of statistical probability to compute or deduce derivative probabilities (found in the explanandum) from other probabilities (found in the explans) that either have been found to be the case empirically or are hypothetically assumed to be true. The other type of explanation is an inductive–statistical or I–S explanation. It usually has the following form: The statistical probability of a kind of event E occurring when two factors A and B are present is very high. And A and B are present in a particular instance. Therefore, in this particular instance, it is very likely that E will take place. In contrast to the D–N and D–S models of explanation, the explans in the I–S model, which consists of a statistical hypothesis and a historical instance of the copresence of two factors, implies the explanandum statement regarding E not with deductive certitude but with only high probability.

The ambiguity of I–S explanations that confer high probability on certain events arises from the fact that there will often exist at least a few empirical cases for which an alternative argument of the same probabilistic form will confer high probability on the nonoccurrence of the same event or outcome. This is a problem inherent in all probabilistic arguments. The application of inductive logic calls for a *requirement of total evidence* if problems of explanatory ambiguity are to be completely resolved. Using partial evidence is justified only if the explanation's conclusion will have the same probability as if total evidence were available. The degree to which the requirement of total evidence should be applied to I–S models in historical demography will depend on the ability of the researcher to obtain the narrowest possible reference class to which the total information assigns the case or cases of empirical interest. For example, the probability of a rise in the mortality rate of a particular preindustrial village would be construed as the statistical probability that the kind of event considered (a rise in the mortality rate) has within the narrowest available reference class to which the village belongs (for example, an eighteenth-century English village in the county of Lancashire) and for which there is reliable statistical evidence available. The narrower the reference class, the less extensive are the requirements of total evidence.

It should be obvious to the reader that unlimited requirements for total evidence, if strictly enforced, would often nullify the possibility of obtaining significant statistical explanations. If we let K_t be the set of all scientific statements asserted or accepted by historical demography at time t, K_t represents the total sum of scientific knowledge at that time. Hempel (1965: 400) has proposed a requirement of "maximal specificity," whose purpose is to mitigate the problem of epistemic ambiguity in I–S models. It provides a measure of the extent to which the requirement of total evidence applies to I–S models. Using this requirement when constructing or evaluating an I–S model in historical demography would entail taking into consideration the full extent of information provided by K_t that is of potential *explanatory* relevance to any explanandum event E. The epistemic relativity of I–S models in historical demography would therefore be seen as a function of a given knowledge situation K_t. This is an unpleasant but inescapable problem facing the development of every science using I–S models.

Explanation Closure

Historians often study what they consider to be unique, individual events. But if human history is conceived of as a temporal succession of entirely unique events, efforts to formulate general hypotheses are likely to be pointless. Adoption of a "uniqueness of events" viewpoint almost certainly guarantees that historical research will remain descriptive–analytic. Overemphasizing the uniqueness of historical events limits the possibility of explaining them because it precludes understanding these phenomena as particular instances of given *kinds* of events. Thus, even though events such as the Irish famines of the mid-nineteenth century were unique, unrepeatable events in regard to their temporal location, they still can be fruitfully and scientifically studied by a historical demographer as particular instances of a given *kind* of event, a famine. This approach enables a researcher to respect the concreteness of a specific historical event without being so blinded by its concreteness as to exclude the possibility of constructing an explanation sketch in which the event is treated as a member of a set of events with important similarities.

The professional socialization of historians and the academic organization of history as a discipline often work hand in hand to preclude ready acceptance of a scientific approach to the analysis of events. Historians frequently describe themselves as eighteenth-century German historians, fourteenth-century Italian historians, or historians of the French Revolution rather than as historians of kinds of events such as famines, revolutions, or "demographic transitions." The latter kind of historians would study similar types of events regardless of their geographical or temporal location and would in principle be a far stronger research position to construct explanation sketches.

Scientific explanations of individual occurrences of concern to historical demographers are not possible unless such occurrences are at least implicitly subsumable by deductive or inductive means under general hypotheses or theoretical principles. But all empirical phenomena in historical demography are not necessarily scientifically explainable. This is due in large measure to the available level of theoretical knowledge K_t. At every stage of development of historical demography as a field, certain facts will remain unexplainable because there is no "deeper" or more comprehensive theory available to incorporate them into analytic models.

Explanation in Historical Research

Analysis of historical studies demonstrates that the following types of explanation occur: (*a*) explanation by description (descriptive); (*b*) explanation by pointing to the origin of a given phenomenon (genetic); (*c*) explanation by indication of a phenomenon's place in a given structure (structural); (*d*) explanation by offering a definition of a phenomenon (definitional); and (*e*) explanation by indicating a cause (causal) (Topolski, 1976: 536). If a historical demographer asks how fertility is related to land availability, for instance, an acceptable answer might entail nothing more than a simple description of the facts involved. A simple descriptive explanation is an answer to a "what" question. Genetic explanations, on the other hand, answer questions of the form How did it occur that . . . ? The successive historical stages of development of the relationship between fertility and land availability would be traced out in detail. Whereas a genetic explanation is the answer to a "developmental how" question, a structural (or functional) explanation answers questions about the role of a given phenomenon within some comprehensive structure. Looking at land availability as one among the many structural relationships affecting fertility might lead to a structural explanation. Definitional explanations answer What (who) is that? and certain types of restricted Why? questions. What is natural fertility? Why are the Hutterites described as a natural fertility population? One gives answers to these kinds of questions by formulating a definition or some direct consequence of a definition. Only causal explanations, however, are true explanations in a strict sense. They alone, in contrast to the four previous types of "explanations," lead a historical demographer beyond a simple description of events and explicitly link empirical research findings with general hypotheses and scientific theories.

In order to understand the nature of causal analysis in historical demography, we need to introduce a distinction between "source-based" and "non-source-based" knowledge (Topolski, 1976: 386–427). Historical sources include all information about human life in the past and the ways in which such information has been transmitted. Non-source-based knowledge includes the initial knowledge with which a historical demographer begins his or her research, formulates research problems, and develops methods of solving them. Thus, progress in our understanding of past human populations requires not only creating more sophisticated and refined methods for decoding source-based knowledge but also increasing sensitivity to and overcoming the conceptual limitations and hidden biases present in non-source-based knowledge. Historical demographic research takes place on two dialectically related levels, one empirical, the other theoretical.

The critical role of non-source-based knowledge can best be seen when we consider the various stages in a research project and simultaneously compare it with the role of source-based knowledge. Source materials are of course absolutely essential to historical demographic research. At the same time, however, sources and source-based knowledge in and of themselves are only two among many key components in a research project. Figure 16.1 illustrates how the all-important choice of an area of research and the posing of questions (the problematic) are arrived at by drawing upon non-source-based knowledge. Both of these decisions entail selection criteria that are related to a given system of values that in turn is a function of the knowledge possessed by an investigator. Different personal value systems can be expected to carry with them congruent selection criteria and result in a restricted range of possible research questions (Bourdieu, 1977: 1–29).

Source-based knowledge assumes its greatest importance during the "face establishing" stage shown in Figure 16.1. But, even here, the reliability of source materials can ordinarily be determined only through comparison with facts and patterns found outside the materials at hand. Non-source-based knowledge again assumes critical importance at the "causal explanations" stage. To arrive at causal explanations, we need to relate historical, empirical findings to general hypotheses derived from theoretical, non-source-based knowledge.

Causal Inferences from Historical Statistics

Theoretical advances in historical demography clearly cannot be restricted to deterministic or exceptionless generalizations of the form "if X, then always Y." Theories in historical demography are most likely to appear in the form of testable, *statistical* generalizations. Since single counterexamples are not

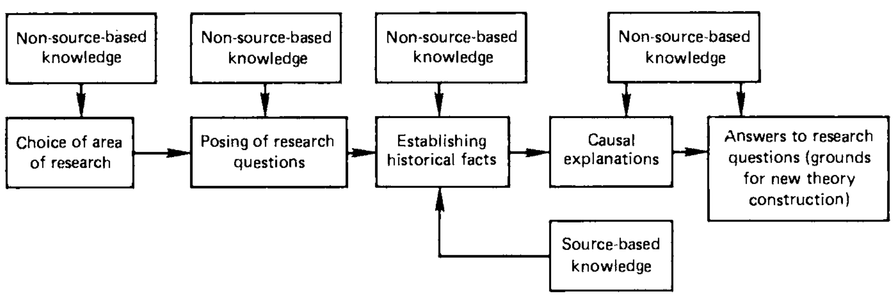


Figure 16.1. *The role of source-based and non-source-based knowledge in developing causal explanations within a research project. (Adapted from Topolski, 1976: 418.)*

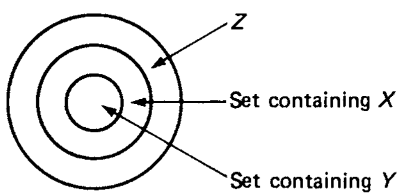
sufficient to disconfirm statistical hypotheses, methodological problems arise regarding the type of significance test required to reject confidently or accept such hypotheses. Although correlations between variables may be shown to be statistically significant, this obviously does not offer conclusive evidence of causality. Barometric readings can be highly correlated with and useful in predicting weather patterns, but barometric instruments do not cause the weather. A historical factor that serves as a reliable predictor of a type of demographic change may likewise prove irrelevant in a causal explanation of that change. Predictor variables can provide important clues for understanding a phenomenon, but this does not guarantee them any privileged status as explanatory or causal variables. Prediction must never be confused with explanation. The discovery of reliable predictor variables represents an early stage in the quest for scientific answers to Why? questions.

David Papineau (1978) has written one of the best accounts of how the leap is made from statistical premises to conclusions about deterministic causal relationships. Following his approach, we shall discuss the conditions under which conclusions about causes may be inferred from historical statistics. First, we shall consider the manner in which the presence of causality can be demonstrated to exist in situations involving exceptionless generalizations. An event is a *sufficient* condition for another if whenever the first event is observed, the second is also observed. An event is a *necessary* condition for another event if the latter event never occurs without the former event having taken place. Thus, a provisional attempt at a definition of causality might be embodied in the principle that one event is a cause of another if it is a sufficient condition for it. Harvest failure, for instance, is usually sufficient for a rise in mortality rates in preindustrial societies. Knowledge of a sufficient condition for an event, along with a generalization containing the sufficient condition, allows us to deduce the expected appearance of the event.

If we subject to closer scrutiny the notion that for one event to cause another it must be a sufficient condition of it, we can easily find events which are caused by prior events that are not, however, sufficient conditions for them. A poor harvest may well cause a rise in a preindustrial village's mortality rate, although mortality rates do not always rise in response to poor harvest conditions. To resolve this interpretative difficulty, we might require causes to be necessary for their effects, but then it is obvious that a harvest failure does not have to be a necessary condition for a rise in mortality. An epidemic or a war can also produce abnormally high mortality rates regardless of harvest conditions. Another way of attempting to meet the objection we have raised is to conceptualize causes not in a unitary sense but as involving the simultaneous presence of a variety of factors, whose coexistence is sufficient for the effect under investigation (see, for example, Gutmann, 1980). A harvest failure in and of itself may not be sufficient for a significant rise in mortality. But a harvest failure along with the lack of any food reserves and the impossibility of importing food, when jointly present, are likely to constitute a sufficient condition for abnormally high mortality rates. The harvest failure in this case is only one of a set of factors that *together* led to a rise in mortality. If large food reserves were available, and additional food supplies were imported with relative ease, it is unlikely that a direct causal relation would be perceived to exist between the harvest failure and the rise in the mortality rate.

When a set of conditions is jointly sufficient for an event, each condition may be termed a "cause," with the total set of conditions being described as the "full cause." A cause is therefore whatever is necessary for the factors present to be sufficient for an effect. A "full cause" of an event is a minimally sufficient set of conditions that are jointly sufficient for an effect. If any one of the conditions of a minimally sufficient set is not present, we would not observe an effect. If a harvest failure did not take place, for example, the lack of food reserves and the impossibility of importing food would not suffice to produce a rise in mortality.

If a cause is defined as one among a set of factors jointly and minimally sufficient for an effect, we still encounter some conceptual problems. Our definition of a cause includes no explicit provision for distinguishing the irrelevant side effects of the cause of an event from intermediate causes that follow from an initial cause and then themselves produce the effect under study. Is *Y* (an absence of food reserves) a side effect of *X* (a harvest failure) causing *Z* (abnormally high mortality rates), or is *Y* part of a minimally sufficient set for *Z*? To know if *Y* is a real cause of *Z*, *Y* must be part of a minimally sufficient set of factors for *Z*. Also, it is necessary that there are no other factors which can "eclipse" *Y* as a cause of *Z*. The "no-eclipsing" requirement states that there is no *X* satisifying the Venn diagram:



Y is a direct cause of *Z* if it is part of a minimally sufficient condition for *Z*, and there are no other factors eclipsing *Y* as a cause of *Z*. There are some awkward problems with applying the "no-eclipsing" requirement as a means of distinguishing genuine causes from spurious ones. [If the reader wishes to pursue these problems, Papineau (1978: 58–60) should be consulted.] This can be called an "eclipsing" requirement since the issue involves ruling out situations in which one cause may be "eclipsing" another. Causes are uneclipsed sufficient conditions.

If two events are statistically related, the first might occur without the second following it. The conceptualization of the nature of the causality present in statistical relationships runs somewhat counter to commonsense, deterministic notions of the linkage between a cause and its effect. The spread of an epidemic in a historical population might be interpreted as resulting from contact between infected and susceptible subgroups. Although we might be able to study the spread of an epidemic, we would ordinarily be unable to identify the set of factors, together with physical proximity or contact, that determined *particular* individuals to become infected. This is in contrast to the previous example of a harvest failure where we knew the other factors that together with the failure would *inevitably* result in a rise in mortality. In a statistical situation, we do not know the minimally sufficient set of factors required for an infection. All we may know is that contact between susceptible and infected persons increases the probability of the disease spreading.

A conclusion that might be drawn from these remarks is that all causal explanations have to do is demonstrate how the probability of an effect is related to prior factors. A deterministic cause would then represent the limiting case where the probability of the effect is 100%. However, we may be able to take a step further and demonstrate that statistical relationships can provide indirect evidence for deciding that one event is part of a sufficient condition for another event even though we do not know the reason why.

Suppose, for example, that we want to explain "natural fertility" as an event Z. If Z and some other event Y are statistically associated, Z will be more likely to occur in the presence of Y. Thus, if it is found that natural fertility is more likely to be present in predominantly Roman Catholic, Y, populations, we might claim that people have a natural fertility reproductive history because they are Roman Catholics. This conclusion could be erroneous, however, if one or more facts are confounding the statistical relationship between Y and Z. For instance, social class membership X might be the actual cause of Z, with Y being an irrelevant side effect of X. But if Y is not related to any causes of Z, it can be demonstrated that if the probability of Z is higher in the presence of Y than in its absence, this can be true if and only if Y is a direct cause of Z.

This logic is quite simple. Assuming that Y is a direct cause of Z, then Z will occur whenever other causes of Z are present or the factors that jointly suffice with Y to cause Z are present. If Y is not a direct cause of Z, Y's presence will not increase the probability of Z taking place. To test this, however, we would have to determine that Y does not occur more (less) often in the presence of the other direct causes of Z since this would show (fail to show) a statistical relationship between Y and Z, although Y was not (was) a direct cause of Z. If Y is related to other causes of Z, "spurious" associations can be detected by considering categories of the unit of analysis (e.g., the social class of individuals) that are similar in respect to any other causes of Z with which Y is related. If Y still makes Z more probable within these categories, we can conclude that it is likely to be a direct cause of Z. Otherwise, Y only appears to be a cause because of its associations with Z's actual causes. The logic behind the procedure just outlined is to "control" for the factors that might confound a causal interpretation of the relationship between Y and Z. Causes are thus sufficient conditions that are not eclipsed by any other prior factors associated with an effect, after we have controlled for those factors. The principle of *uneclipsed sufficiency* is the key to conceptualizing the type of causality present within statistical relationships. Such relationships imply causality when there are no confounding influences, or when they are present, they have been "controlled." It is "only because causes are specifically *uneclipsed* conditions that we can take absence of statistical association to show an absence of causation [Papineau, 1978: 63]."

Nonexperimental Causal Inference and Structural Models

Structural models are a blend of mathematics and theory (Kenny, 1979: 22). The translation of a theory into equations is termed *specification*, since the theory "specifies" the form of the equations. If a theory is incorrectly specified, it is said to contain one or more *specification errors.* A structural model contains variables and parameters. Although variables vary across the individuals or other entities whose behavior is causally specified in a model, parameters refer to the entire population. Completed family size, for example, may be used as a variable. With the family as the unit of analysis, each family will have a specific completed size that will vary from 0 to perhaps as high as 15 or more children. The mean and variance of the sizes of the families included in this hypothetical example are parameters. Parameters in structural models are called *structural parameters* or "path coefficients" (if all the variables are standardized), and each is multiplied by a variable. The sums of specific parameter and variable products, a *structural equation*, equals an *effect variable*.

Let us assume that the unit of analysis in a fertility research project is a geographical–administrative area, such as a Belgian arrondissement or an Irish barony, and that our theoretical approach leads us to believe that nuptiality (N_i) is causally influenced by industrialization–urbanization (I_i) and secularization (S_i). For arrondissement or barony i, the specification of this aspect of our theory as a structural equation becomes

$$N_i = aI_i + bS_i. \qquad (16.1)$$

In Eq. (16.1), N, I, and S are variables, whereas a and b are causal parameters. Conventions for writing structural equations call for placing the effect or endogenous variable (here, N) on the left side and the causes or exogenous variables (I, S) on the right. Note that structural equations are more than just mathematical statements. They express theoretical relationships as well. Suppose Eq. (16.1) was recast into the following equivalent mathematical form:

$$-bS_i = -N_i + aI_i. \qquad (16.2)$$

It should be easy to see that Eq. (16.2) makes no theoretical sense.

The present state of substantive theory in historical demography is such that it is very unlikely that a variable of such potential complexity as nuptiality could be completely specified with measurable variables. To take account of this problem, a special variable or "disturbance term" representing the theoretically unspecified causes of endogoneous variables is introduced into structural equations and is usually symbolized by the letter U. Equation (16.1) would thus be rewritten as:

$$N_i = aI_i + bS_i + cU. \tag{16.3}$$

When working with a set of structural equations, it is often assumed that the disturbance terms are uncorrelated with one another and with the purely exogenous variables. Intractable statistical complications may arise if this assumption does not hold.

Structural models may be either hierarchical or nonhierarchical. A hierarchical model's structural equations can be written in a manner in which the effect variables never reappear as causes within the set of equations describing the model. If this cannot be done, the model is nonhierarchical and contains direct or indirect feedback loops. In direct feedback, X causes Y and Y causes X. For example, population size and the net birth rate form a direct, positive feedback loop: An increase in population size (X) results in an increase in the net birth rate (Y), and this in turn results in an increase in population size. An indirect feedback loop contains an "indirect" causal link. For example, W causes X, X causes Y, Y causes Z, and Z causes W. A concrete example would involve the situation in which an increase in fertility (W) leads to an increase in a population's total food consumption (X). This causes a decline in the food available per capita (Y), which leads in turn to an increase in mortality (Z). Increasing mortality (Z) then lowers fertility (W) to close an indirect, negative feedback loop. The central concern in most structural modeling textbooks (see Duncan, 1975; Heise, 1975; Kenny, 1979) is with hierarchical models, since the statistical theory underlying such models is better understood.

The major goal of structural modeling is to determine the values of the causal parameters. Kenny (1979: 33) suggests a four-stage process for determining these parameters: (a) measure as many variables of the theoretical model as possible; (b) compute the correlations between measured variables; (c) derive the formulas for correlations using the "first law of path analysis"; and (d) solve for the causal parameters. The first two steps are in principle quite straightforward. The third step entails a procedure not previously discussed. In a hierarchical, standardized structural model the correlation between any two variables, derived by covariance algebra, is given by the first law of path analysis:

$$r_{YX} = \sum_i p_{YX_i} r_{X_iZ}, \tag{16.4}$$

where p_{YX_i} is the cause parameter connecting X_i to Y, r_{X_iZ} is the correlation between X_i and Z, and the set of X_i variables represents all of Y's causes. The last step (d) may be the most problematic since it may not be possible to solve for the causal parameters from the correlations. An *identification* problem may arise.

Econometricians use the term *identification* to refer to the number of correlations between measured variables. The minimum condition of identification is that the number of causal parameters in a model be less than or equal to the number of correlations between the measured variables. An *overidentified* structural model has fewer parameters than correlations. In this case, there will be more than one way to estimate a causal parameter. A *just-identified* model has an equal number of parameters and correlations. An *underidentified* model has fewer correlations than parameters. An infinite number of values can satisfy a set of underidentified equations. Procedures for assessing the identification status of a model are given in Kenny (1979: 35).

If a model proves to be overidentified, a causal parameter can be expressed as two or more functions of the correlations. To cope with this difficulty, overidentifying restrictions may be imposed as null hypotheses and then tested. For example, the different functions of correlation could be set equal to one another. In the event that a model is underidentified, various strategies, if justified by substantive theory, can be utilized to transform it into an overidentified or just-identified model. These include measuring more variables, reducing the number of parameters by assuming that one or more of them are effectively zero, setting two or more parameters equal to one another, and so forth. Finally, even though a set of equations is in principle identified, the denominator of an expression used to estimate a causal parameter in the model may be zero or very close to zero, precluding a solution. This may be described as "empirical underidentification," and there may be no strategy available to eliminate it. One situation that may produce empirical underidentification would be if the exogenous variables were highly intercorrelated. This gives rise to the phenomenon of "multicollinearity" and can result in such extremely large standard errors for causal parameters that their interpretation will be largely meaningless.

In conclusion, we can summarize the stages of nonexperimental causal inference, within a structural modeling setting, as follows:

1. Draw up a set of structural equations using a substantive theory or group of associated hypotheses.
2. Determine the identification status of the model, and take remedial steps if necessary and possible.
3. Estimate the correlations (covariances) between the measured variables, and from these correlations (covariances) estimate the model's causal parameters. Test any overidentifying restrictions.

Historical demographers with specific research questions or hypotheses must decide whether or not the research design and source(s) they intend to utilize are adequate: Is the research design sensitive enough to measure covariation between the variables of interest? Do the sources contain sufficient evidence to infer the strength of the covariations between the presumed cause and effect? The creation of a research design for use with a particular source or set of source materials requires estimating how much "statistical power" is available to detect an hypothesized effect, given certain variances and sample sizes. If the approximate magnitude of the expected effect and range of variation in the data can be estimated, appropriate samples sizes can be determined using formulas supplied in sampling texts. To test whether a presumed cause and effect covary, one would compare the extent of covariation and randomness found in the sample data to an a priori risk of being wrong in judging that they covary. The risk is usually chosen to be a 5% probability level. Practical applications of this level, and Type I and Type II errors, are discussed in most elementary statistical texts.

In addition to assessing whether covariation can be inferred, an issue of statistical significance, one needs to make magnitude estimates of the amount of covariation because they are less contingent upon sample size. Relatively weak effects will show up as statistically significant if sample sizes are very large. Whenever possible, historical demographic findings should be reported in terms of both statistical significance and the amount of covariation, bounded by confidence intervals. Such findings would be reported in the following form: "The independent variable ______ caused a statistically significant increase (decrease) in the dependent variable ______. The effect in 95% of the cases was an increase (decrease) in the dependent variable of between ______ and ______ per given time period." The use of bounded magnitude estimates avoids interpretative problems posed by the reporting of speciously precise point estimates such as: "The average increase (decrease) in the dependent variable ______ was ______ per given time period." When working with small samples, a historical demographer should always report the magnitude of the effect that *could have been detected* given the sample sizes, the variances found in the analysis, and the probability level (usually 5%).

Problems in Drawing Valid Causal Inferences in Historical Demography

Four major questions appear in most historical demographic research of a causal nature:

1. Is there a relationship between a given demographic variable and another variable? This is a problem of statistical conclusion validity.
2. If there is a relationship, is it plausibly causal, or would it have occurred regardless of the presence of the independent variable under study? This is the issue of internal validity.
3. If the relationship is plausibly causal, to what extent can we make generalizations about high-order constructs (for example, to the existence of autoregulatory mechanisms, or to a pattern between fertility and social mobility) from historically specific empirical findings? This entails the problem of determining the construct validity of causes and/or effects.

4. Given that there is a plausible causal relationship between a certain construct A (say, fertility) and a construct B (say, social mobility), how generalizable is this relationship across persons, socioeconomic conditions, and time? This poses a problem of external validity.

These four types of validity have been analyzed thoroughly by Thomas Cook and Donald Campbell (1979: 39–136). The following discussion of validity issues and research designs is an adaptation of their argument to the specific concerns of historical demographers. Readers are urged to consult the Cook and Campbell text itself for a complete discussion of these issues.

Problems of Statistical Conclusion Validity

The most important problems of statistical conclusion validity, discussed by Cook and Campbell, which historical demographers are likely to encounter in attempting to draw valid inferences regarding covariation between variables include:

1. "*Low statistical power.* The likelihood of making an incorrect no-difference conclusion (Type II error) increases when sample sizes are small and α is set low [Cook and Campbell, 1979: 42]."

2. "*Violated assumptions of statistical tests.*" Standard statistical texts should always be consulted to learn about the assumptions of a statistical test and how they may or may not be met with the type of data under analysis.

3. "*The error rate problem.*" The possibility of incorrectly concluding that two variables covary (Type I error) "increases when multiple comparisons of mean differences are possible [Cook and Campbell, 1979: 42]" and there is no way of determining the proportion of the comparisons that will be significantly different by chance (Tukey, 1977).

4. *Unreliability.* Variables whose "meanings" are unstable are said to have low reliability and cannot be expected always to reflect changes accurately. The reporting of religious status in a census, for example, may often not be a reliable measure of actual religious commitment.

5. *The reliability of the effects of an independent variable.* The absence of a standardized effect of an independent variable upon persons, as well as from occasion to occasion, will lower the probability of discovering valid differences between people and across time periods (Boruch and Gomez, 1977).

6. "*Random irrelevancies.*" Variables in a historical context other than the independent variable under study will normally affect a dependent variable. If contexts cannot be chosen that minimize extraneous sources of variation in the dependent variable, these sources should be measured for the groups being compared and their measurements introduced into the statistical analysis.

7. *"Random heterogeneity" of individuals.* The historical persons included in groups being compared may differ significantly on the variables that are

correlated with the principal dependent variable. This may be dealt with by trying to select more homogeneous subpopulations.

If these problems of statistical conclusion validity can be satisfactorily resolved and it has been determined that a pair of variables covary, we would next want to ascertain if they are *causally* related and whether the direction of causality is primarily from one to the other, or vice versa. Knowledge of a historical sequence, *A* then *B*, is often essential where a measure of change in a dependent variable *B*, is hypothesized to be related to an independent variable *A*. The possibility of a third-variable effect, *A* then *C* then *B*, is a major problem since ignorance of *C* might lead to the false conclusion that *A* causes *B* directly. Third-variable effects are likely to constitute the most serious impediment to establishing the internal validity of a historical demographic study.

Problems of Internal Validity

In addition to third-variable effects, there are other kinds of effects that may detract from the internal validity of an historical demographic research project. These include (Cook and Campbell, 1979: 51–54):

1. *"History."* The internal validity of a study can be jeopardized if an unaccounted for, influential event, such as an epidemic, occurs between measurements at two points in time (say, two censuses) and "contaminates" the effect of an independent variable on the dependent variable of interest. It is clearly not possible to isolate a historical population from "contaminating" causal events. We can only note their occurrence and adjust for their consequences as best as we can.
2. *"Maturation."* Observed demographic effects may not be due to what we think they are but rather to the fact that the study population is simply aging or maturing in some fashion.
3. *"Testing."* An effect may arise from the nature of a demographic recording process. The adulterous status of a child, for instance, might be concealed from a parish priest (as well as from a wife's husband) as he fills out a baptismal register.
4. *"Instrumentation."* Changes in the classification procedures and significance of occupational and other terms from one time period to another, as found in a census, may threaten the internal validity of a study.
5. *"Selection."* Different groups may be differentially affected by events. If this was unanticipated, it might confound the interpretation of the effect of the independent variable.
6. *"Mortality."* Individuals may drop out of a population because of death or

migration, making the composition of the population different at the end of a demographic analysis from what it was at the start.

7. *"Interactions with Selection."* History, maturation, and instrumentation can interact with selection to produce effects that may be spuriously attributed to an independent variable. A history–selection interaction would be produced if the ecological settings of the historical populations included in a study were such that each experienced a unique local history, which in turn differentially influenced the dependent variable of research interest.

8. *"Ambiguity about the Direction of a Causal Influence."* Historical demographic studies that rely only on cross-sectional data where temporal precedence is ambiguous may be unable to infer confidently the direction of causal influence.

9. *"Diffusion."* Assumed differences between populations may not be present because of unanticipated contact between them. Infants taken from their urban mothers to be cared for by rural wet nurses, for instance, might invalidate census-based, urban–rural, child–woman ratios.

In estimating the internal validity of a hypothetical causal relationship, the historical demographer should proceed deductively, systematically trying empirically to rule out these problems. Eliminating them will enable a qualified, but rather confident, conclusion to be drawn regarding the plausibility of a causal relationship.

The Problem of Construct Validity

Construct validity refers to the appropriateness with which entities are named. Occupational categories, rural–urban distinctions, presumed causes and effects, ecological settings, and so forth, all might be described in terms of one or more referent constructs. For construct validity to exist, one's research constructs must correspond to what is actually being measured. A variety of problems may combine to weaken the construct validity of causal relationships (Cook and Campbell, 1979: 64–70):

1. *Inadequate definition of a construct.* The construct "social class," for instance, might be so loosely conceptualized that the assignment of individuals in a population with particular occupations to this category becomes difficult. A historical, social-class-based study of fertility might then lack construct validity because of uncertainty over whether those assigned to the "social class," based on their occupations as recorded in a census manuscript, should in fact be placed there.

2. *Lack of multiple measures.* Whenever possible, multiple indicators of

cause and effect constructs should be used to exclude the possibility that what are presumed to be irrelevant variables are not producing the effect(s) under consideration.

3. *"Confounding Constructs and Levels of Constructs."* This problem emerges when a cause X and effect Y do not vary linearly over the entire range of X. Effects of a famine X upon fertility Y may appear only when X reaches a certain threshold intensity. To control for this problem, it might be necessary to measure the relationship between X and Y at different levels of X before one can make confident generalizations about the causal nature of their relationship.

The Problem of External Validity

A fourth type of validity—external validity—is typically addressed in two stages (Cook and Campbell, 1979: 73–80). First, the historical demographer must define a target population(s), an ecological setting(s), and a time period(s). Second, representative samples must be drawn that are designed as well as possible to correspond to the targeted population(s). To be able to *generalize* across populations presumes that one has been already able to generalize *to* each target population from a sample. A variety of problems exist that may challenge external validity, all of which inevitably involve tests of statistical interactions. An interaction between fertility and social class, for instance, would preclude generalizing about fertility-related phenomena *across* social classes. At least two kinds of important interactions can be specified: interaction between the independent variable and different categories of persons within a population or between populations; and interaction between the independent variable and different ecological settings. To ensure external validity, one should follow random sampling for representativeness, as well as sampling for heterogeneity of populations, historical time periods, and ecological settings.

Statistical conclusion validity and internal validity are related to one another (Cook and Campbell, 1979: 80–81). Both are concerned with the possibility of drawing false conclusions regarding causal hypotheses. Statistical conclusion validity is concerned with *random* variation in data that may conceal true differences and with the proper application of statistical tests. Internal validity, on the other hand, focuses upon problems arising from factors that *systematically* bias mean values and thus obscure true differences *between* populations, historical periods, and ecological settings. Construct validity and external validity focus primarily upon the contingencies determining a causal relationship and how they affect possibilities for generalizing *across* populations, historical periods, and ecological settings. These four types of validity should be kept in mind during the planning, execution, and final analytical stages of research.

Research Designs with Historical Data

Can experimentation be carried out with historical demographic data? In an expanded sense of the term *experimentation*, the answer is yes. Experiments in scientific research are usually formalized as causal propositions and tested by deliberate manipulation of an independent variable. The language of experimental design literature refers to the possible causes of a phenomenon, the independent variables, as "treatments." The possible effects, or dependent variables, are termed "outcomes." At a minimum, an experiment includes an independent variable, a dependent variable, and a source of comparison that facilitates inference about the nature of the causal relationship between the independent and dependent variables.

Randomized experiments create comparisons by randomly assigning individuals, or social groups, found in a population to situations in which they would either be exposed to the influence of an independent variable or not. In a formal scientific experiment, individuals are *randomly* assigned to groups to create "equivalent" study and control groups. For two such groups to be "equivalent," they need not have identical sample means on variables measured at the time prior to the event under study. Two groups would be "equivalent" if after repeated random assignment (continued until the sample sizes in each group became extremely large), they had identical means, variances, and so forth on all salient variables prior to the occurrence of a historical event whose effects we wish to study. We shall refer to the time immediately prior to such an event as the "pre-event" period. The "post-event" period describes the situation immediately following an event under investigation. The term *equivalence* is to be interpreted within the context of sampling theory. It refers to an identity of *expected* or "population" values, not sample values.

Quasi-experiments, on the other hand, do not use random assignment as a means of comparison. Cook and Campbell (1979: 6) show that the type of comparisons used in quasi-experiments to infer change by an independent variable depend on the presence of nonequivalent groups that differ from one another in many ways other than the presence of the independent variable whose effect(s) is being studied. Nonequivalent groups therefore have different *expected* values on at least one salient variable. Even though historical groups might appear to be equivalent because pre-event measurements revealed few differences between certain variables, this is no firm guarantee (even if the expected values of these unmeasured variables were identical) that the groups are equivalent. Other unmeasured variables whose values differ significantly from one another may have an important influence upon the post-event value of the dependent variable under study.

Since selection differences arising from historical, nonrandom assignment of individuals to groups might have yielded significant post-event differences between a study and a control group regardless of the influence of the independent variable under investigation, it is always necessary to "control" or adjust one's analysis to take this into account. Otherwise, it is not possible to interpret validly the consequences of historical causal processes. A variety of statistical methods exist to cope with this problem (see, for example, the treatment of inferential statistics in Loether and McTavish, 1980). However, no single method is preferable under all research conditions. Charles Reichardt in the Cook and Campbell text argues as follows:

> Any procedure for the analysis of the nonequivalent group designs can be biased under different circumstances. That is, no analysis technique exists that can be blindly applied to all sets of data with foolproof results. Rather, the analysis must be carefully tailored to fit each research situation. Second, this tailoring cannot be done in an automated and thoughtless fashion. While there are several logical frameworks (or rationales) to guide the researcher in tailoring the analysis to fit the specific research setting, a great deal of knowledge and thought on the part of the researcher is still required [1979: 150].

The task confronting a historical demographer who was attempting to interpret the results of a quasi-experiment would be to separate the effects of an independent variable from those of the initial noncomparability between the average units (for example, individuals or households) in each group. To separate these effects requires identifying and in some way dealing with the threats to valid causal inference that *random* assignment of the influences of the independent variable to a group would have eliminated. A nonequivalent group design is a type of quasi-experiment in which the changes in a group to which an independent variable has been applied by "historical processes" are evaluated against those of a comparison group. The process of history may be viewed in a certain sense as creating quasi-experimental designs whenever individuals are partitioned into nonequivalent groups that are affected by different independent variables.

Quasi-Experimental Research Designs with Nonequivalent Groups

Any explanatory statement in historical demographic analysis can ultimately be traced back to some type of implicit control group design. The validity of explanatory claims can therefore be assessed in terms of the adequacy of the control group designs upon which they are based. Adapting the discussion of Cook and Campbell (1979: 95–133), we shall consider three commonly used designs that may prevent a research project from confidently evaluating causal hypotheses, because they do not foreclose the possibility of alternative hypotheses explaining the same data pattern. Research findings derived from these three designs are *generally* although not invariably uninterpretable (Cook and Campbell, 1979: 96). Since a fairly significant proportion of historical research is implicitly built around these flawed designs, serious questions may be raised regarding the validity of our knowledge of many aspects of past populations. In discussing nonequivalent control group designs, we shall use a variation of the Cook and Campbell (1979: 95) notational system: X stands for the application of an independent variable to the dependent variable under study, O stands for an observation or measurement of the dependent variable, and subscripts 1 through n indicate a sequential order of applying independent variables ($X_1, \ldots, X_n$) or of measurements ($O_1, \ldots, O_n$). A dashed line between groups symbolizes that they were not randomly formed. A wavy line between nonequivalent groups indicates that they are cohorts or groups that follow each other together over time.

The first design, the one-group post-event-only design, is diagrammed following (Cook and Campbell, 1979: 96). We use the expression *event* to refer to the period of influence of some independent variable, X.

$$X \qquad O$$

In experimental design literature, this is called a "treatment." The design entails observing the units of analysis (i.e., individuals) in a population who have experienced the influence of an independent variable X only at a time following this event. The fundamental flaw in the design arises from the absence of pre-event observations. Without such observations, it is impossible to conclude easily that changes in the population are due to the independent variable. A second flaw is the absence of a control group that did not experience the influence of the independent variable. These two flaws may be overcome to a certain degree by skillful use of contextual control information to make up for the lack of formal pre-event and control group measurements. Scholarly effort in historical, one-setting, one-time-period case studies "should be redistributed so as to provide explicit evidence about conditions prior to the presumed cause and about contemporary conditions in social settings without the treatment that are similar to the setting in which the case study is taking place [Cook and Campbell, 1979: 96–97]."

A second research design that is a variation on the traditional case study is the post-event-only design with nonequivalent groups (Cook and Campbell, 1979: 98). As the following diagram illustrates, the only difference is the addition of a control group that does not experience the influence of the

$$X \qquad O$$

- - - - - - - - - - -

$$\qquad O$$

independent variable. Again, the basic flaw in this design is the absence of pre-event observations. Without such observations, it is not easy to determine if post-event differences between the groups are due to the influence of the independent variable of interest or merely to selection differences between the two groups (i.e., that an effect may arise from the differences between the kinds of people in the two groups). "The plausibility of selection differences in research with nonequivalent groups usually renders the design uninterpretable [Cook and Campbell, 1979: 98–99]." A strategy sometimes used to cope with this problem is to identify available pre-event measurements for variables such as age, sex, social class, and place of birth, which ought to correlate with, and thus in a sense can be used as surrogate clues to estimate, the unmeasured pre-event values of the dependent variable.

A third design, the one-group pre-event, post-event design, is frequently used in historical studies (Cook and Campbell, 1979: 99). Since this design is so prevalent, we shall introduce a hypothetical example to illustrate the problem it poses for drawing valid causal inferences.

$$O_1 \quad X \quad O_2$$

Assume that economic conditions X are altered in a historical community and that this change is hypothesized to lead to a significantly observable O_2 increase in fertility over the pre-event O_1 level. If the post-event level is found to be reliably higher, this evidence might indicate the existence of a causal relationship between economic and demographic variables. Alternatively, however, other historical events, unrelated to economic change, might have occurred in the interval between O_1 and O_2 that affected fertility. A historical demographer would have to use a theory or general historical evidence to show that such events were implausible. If their plausibility cannot be ruled out, then they would have to be demonstrated empirically not to have taken place. Statistical regression effects may also flaw this design. Fertility might be low in a given period because of random factors such as climatic conditions that in turn affect harvest yields. Under relatively stable conditions, fertility will likely increase in the next period of time as it regresses toward the grand mean of a fertility trend. A regression artifact will occur if causally unrelated economic conditions change and are unwittingly measured just as fertility concomitantly increases as a result of random fluctuations. In addition to the random fluctuations in fertility levels that produce the kind of statistical regression effects that can trick a researcher into making invalid causal inferences, systematic fluctuations also may be present. If fertility is systematically on the increase independently of changes in our economic variable X, then post-event increases in fertility over pre-event levels could lead to spurious causal inferences regarding the influence of X upon fertility. The plausibility and/or existence of statistical regression and systematic trend effects must be ruled out in order to validate causal inferences based upon a one-group, pre-event, post-event design.

We now turn to some "generally interpretable nonequivalent control group designs [Cook and Campbell, 1979: 103]" that are qualitatively different from the preceding three "generally uninterpretable" designs, insofar as they make it easier to rule out more barriers to the validity of causal inferences. Since each of the designs possesses unique features, an ideal would be to combine them creatively within a single study, thus excluding as many threats to internal validity as possible.

The uninfluenced control group design with pre-event and post-event observations underlies most social science research.

O_1	X	O
O_1		O_2

Following the logic of the Cook and Campbell (1979: 103–112) treatment of this design, we shall discuss it in terms of group differences in pre-event dependent variable increases. Five different historical outcomes will be illustrated (see Figure 16.2). The first outcome will be used to exemplify the most common threat to the internal validity of a historical demographic study.

A wholly independent "selection–maturation" effect could result in an Outcome 1 pattern if persons in the study group were, say, wealthier on the average and were simply using their economic status to respond more rapidly than the control group to the characteristics of a historical setting. Here, each

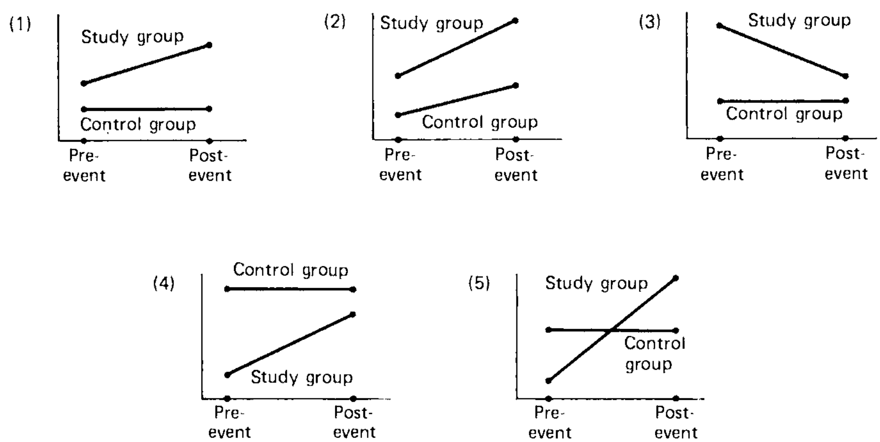


Figure 16.2. *Five possible outcomes of the uninfluenced control group design with pre-event and post-event measurements. (Adapted from Figures 3.1, 3.2, 3.3, 3.4, and 3.5 in Thomas D. Cook and Donald T. Campbell:* Quasi-Experimentation: Design and Analysis Issues for Field Settings. *Copyright © 1979 by Houghton Mifflin Company. Used by permission.*

group's mean value on the dependent variable regresses to a different population baseline because one group is, say, on the average wealthier than the other. "Selection" and "history" can interact by themselves to produce a "local history" effect to create an Outcome 1 pattern. In this case, events other than the independent variable affect the study group but not the control group, or vice versa.

Outcome 2's pattern (see Figure 16.2) could be produced by a systematic "selection–maturation" interaction in which the nonequivalent groups were already growing at different average rates in the same general direction, prior to the presumed influence of the independent variable X. Cook and Campbell (1979: 106–107) suggest looking for clues that may indicate if nonequivalent groups are maturing at different rates over time. If the group mean differences are a function of biased social aggregation or selection, then it is likely that *within-group* variances measured at the post-event will be larger than at the pre-event. Alternatively, differential average growth rates are likely to be present if a plot of pre-event observations against a suspected maturational variable (for example, number of years married) for both groups separately shows that the regression lines differ in their linear slope.

Outcome 3 of Figure 16.2, although subject to the problems discussed earlier, might involve a "catch up" effect in which the control group has *already* experienced the effect of the independent variable that the study group is only now experiencing. Outcome 4 is of interest because it excludes the possibility of differential linear growth in which a higher-level, pre-event group is growing at a faster rate than the lower-level, pre-event group. Finally, Outcome 5's pattern of switching mean differences makes a statistical regression explanation more unlikely. Since the interpretability of the no-influence control group design depends, at least in part, on the outcome pattern, a researcher may wish to consider in advance which of the five outcomes in Figure 16.2 is most likely to occur and the potential risks it carries for yielding only equivocal demographic interpretations.

The uninfluenced control group with proxy pre-event measurements is the same as the pre-event, post-event design with nonequivalent groups except that proxy measurements (A) are used at the time of the pre-event because direct measurements of the demographic phenomenon (B) under study are not

O_{A1}	X	O_{B2}
O_{A1}		O_{B2}

available. For this design to succeed, the proxy variable A evaluated at the time of the pre-event must be highly correlated with the unmeasurable dependent variable B (Cook and Campbell, 1979: 112–115).

The uninfluenced control group design with separate pre-event and post-event samples is depicted following (Cook and Campbell, 1979: 115–117). It is a variation of the basic pre-event, post-event design with nonequivalent groups. Different samples are drawn to make up the groups at each time point.

O	X	O
O		O

The dashed vertical line symbolizes that all of the same individuals are not necessarily being measured across time. This may be a difficult design to implement. Cook and Campbell (1979: 117) observe that without independent evidence of the comparability of pre-event and post-event samples, the design is nearly worthless for inferring causality associated with an independent variable X since the simplest form of selection might offer a plausible alternative causal interpretation.

The uninfluenced control group design with pre-event measurements at more than one time interval simply adds on one or more pre-event measurements (Cook and Campbell, 1979: 117–118). The addition of a second pre-event provides an opportunity to detect the presence of selection–maturation effects.

O_1 O_2	X	O_3
O_1 O_2		O_3

For example, this design might allow one to run a check to determine if the nonequivalent groups were changing at different rates *before* the independent variable's influence enters history.

The nonequivalent dependent variables design (Cook and Campbell, 1979: 118–120) is one of the least interpretable of quasi-experimental designs but can prove quite helpful in strengthening causal inferences if used in conjunction with other designs:

O_{1A}	X	O_{2A}
O_{1B}		O_{2B}

In the diagram for this design, A and B symbolize different measurements from the *same* group of individuals. The strategy involved here is to measure a group on two different variables, one of which is the dependent variable of interest A and which is expected to change under the influence of the independent variable X. The other variable B is *not expected* to change. Thus, this design would fit historical demographic situations in which differential change is predicted. Cook and Campbell (1979: 119) point out, however, that findings derived from the design would only be interpretable if variables A and B were conceptually similar and would be affected by most of the plausible alternative causal explanations of the observed effect, other than the independent variable X.

The removed independent variable influence with pre-event and post-event measurements design may be employed in the absence of a control group (Cook and Campbell, 1979: 120–123). Four waves of data collection are required. A simple one group, pre-event, post-event design is incorporated in the first two waves O_1 and O_2. The historical period from O_3 to O_4,

$$O_1 \quad X \quad O_2 \quad O_3 \quad \bar{X} \; O_4$$

during which the influence of X has been removed (symbolized as $\bar{X}$), serves as a no-influence control for the previous O_1 to O_2 time interval. If this design worked as anticipated, X would cause the dependent variable of interest to change in a certain direction between O_1 and O_2 but then *reverse* its direction of change when X's influence is removed between O_3 and O_4.

The repeated independent variable influence design can be used with a single population subject to repeated but transient effects of an independent variable (Cook and Campbell, 1979: 123–124). The most easily interpretable pattern

$$O_1 \quad X \quad O_2 \quad \bar{X} \quad O_3 \quad X \quad O_4$$

arising from this design would be if a change in the dependent variable of interest between O_1 and O_2 and between O_3 and O_4 was in the same direction, with a reversal of direction between O_2 and O_3.

"Cohort designs" are attractive for causal analysis if a good deal of comparability of background characteristics may be presumed to exist between cohorts that are not influenced by an independent variable. Cook and Campbell (1979: 127) note that the use of cohort designs to unconfound the effects of age (i.e., growing older), cohort membership (i.e., being married within a given time span), and a period of history (i.e., the events occurring between any two time intervals) can encounter very serious inferential pitfalls. "History" and "selection" effects are the most likely "threats" to the internal validity of a cohort design. The simplest cohort design, which follows, is intended to determine if the two cohorts differ as a result of X influencing the later cohort

$$\begin{array}{lll} \hline O_1 & & \\ \hline & X & O_2 \\ \hline \end{array}$$

(Cook and Campbell, 1979: 128–132). To strengthen the internal validity of this cohort design, one might consider partitioning it, such that members of the later cohort can be identified who will experience different degrees of influence, X_1 and X_2, from the independent variable X.

$$\begin{array}{lll} \hline O_1 & & \\ \hline & X_1 & O_2 \\ \hline O_1 & & \\ \hline & X_2 & O_2 \\ \hline \end{array}$$

If the influence of the independent variable cannot be presumed to differ within a cohort, a design of the following form might be utilized.

$$\begin{array}{lllll} \hline O_1 & O_2 & & & \\ \hline & & O_3 & X & O_4 \\ \hline \end{array}$$

Here, O_1 and O_2 are pre-event measurements on the dependent variable of interest for an earlier "control" cohort, with O_3 and O_4 representing measurements for a later cohort measured at later time intervals. A series of control cohort years with dependent variable measurements will lower the probability of a "history effect" being misinterpreted as due to the independent variable X. A three-cohort design can significantly render a history effect implausible if certain patterns are observed. Consider the three-cohort design that follows. A history effect can confidently be ruled out if measurements on the dependent

$$\begin{array}{llllll} \hline X & O_1 & & & & \\ \hline & & O_2 & X & O_3 & \\ \hline & & & & & O_4 \\ \hline \end{array}$$

variable of interest have higher values at O_3 than at O_2, at O_1 than at O_2, and at O_3 than at O_4, for respective cohorts. This design tries to establish the absence of a history effect by requiring such an effect to be operative at *two different times* to account for the fact that the value of the dependent variable is greater at O_1 than at O_2, and also greater at O_3 than at O_4. This particular design also renders selection effects less plausible since the values of the dependent variable are based on *the same individuals* at O_2 and O_3. Cook and Campbell comment that the major drawback with this design is that its interpretability is contingent upon "a complex pattern of outcomes in which three contrasts are all statistically reliable in similar ways. Since two of these contrasts involve O_2, a chance elevation of measurement values at O_2 would have disastrous implications. This implies that the design should only be used with reliable measures and large samples [1979: 133]."

The most important point to be noted in considering all of these possible nonequivalent group designs is one of research strategy. Possible threats to the internal validity and causal interpretability of a study should be made as explicit as possible before data collection from archival sources begins. Every effort should be made to find measurements for all salient variables in order to match research results as closely as possible with patterns of relationships that logically exclude threats to valid causal inference. This will require creative and ingenious linking of many of the different types of source materials and methods discussed in this book. The availability and content of source materials, together with the nature of the research design selected, will ordinarily narrow the range of potentially useful methods. Any choice among methods should therefore be grounded upon a prior consideration of substantive matters. The historical demographer should understand the logic behind the causal analysis of source materials with nonequivalent group designs and thus view specific methods such as factor analysis or nonmetric multidimensional scaling as options for the application of this logic to actual research.

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17
Population Genetics Models

Although any attempt at an overall reconstruction of the human populations that have spread out over the globe during the last 200,000 years is probably out of the question (Langaney, 1979), advances in the study of genetically transmitted characteristics make it possible to define rigorously the genetic structure of a population. Biological properties of populations are contingent upon three parameters: their ancestral genetic stock and contributions from neighboring populations, genetic drift (chance), and natural selection. Use of these parameters permits partial reconstruction of the genetic and demographic history of a population. Jean Bernard and Jacques Ruffié (1979) have shown that genetic reconstructions turn out to reflect events known from conventional history. They cite examples from the Mediterranean area, Western Europe, Africa, the Far East, and South America to show how great historical events, such as the Neolithic Revolution, have left their traces upon the genetic structure of populations.

Three historical demographic studies based upon genetic research illustrate this relatively new venture: Laurent Degos *et al.* (1977) use the polymorphism properties of the HLA tissue incompatibility system to discriminate between human populations. The concept of genetic distance leads to the reconstruction of phylogenic trees. Linkage imbalances detected in such trees then provide clues to study the history of the great migrations.

Jacqueline Bourgoin-Vin Tien Khang (1978) has used the parish and civil registers of four Pyrenean villages to compile complete genealogies from 1740 to 1973. The resulting computer files allow her to use the pattern of marriages to study village endogamy, the exchange of mates, and the relations between exogamy and kinship. Transformations of the genetic inheritance of the villages are analyzed by computing the probabilities of the origin of genes to depict gene flow and "gene turnover." Inbreeding is estimated directly from the genealogical pedigrees and compared with results based on "apparent inbreeding" using ecclesiastical marriage dispensation registers and "isonomy" (the frequency of marriages between people with the same surnames).

Finally, Alain Bideau *et al.* (1979) carry out a fascinating study of the Rendu–Osler disease, a rare genetic disease caused by a gene mutation transmitted by autosomic domination. For any person affected by the disease, one of the parents will also be affected, and it is thus possible to trace the genealogical transmission of the disease. Families afflicted by Rendu-Osler disease were located in the French village of Chèzery. Historical demographic and genetic data were then used to retrace the history of affected families back for several centuries to common infected ancestors, thus leading to a causal understanding of the present epidemiological profile of the Rendu-Osler disease. Other hereditary diseases may be studied similarly, demonstrating how historical demographic findings can shed light upon present and future medical problems of persons alive today, as well as those yet to be born.

The rediscovery of the Moravian monk Gregor Mendel's laws of heredity in the early twentieth century marked the beginnings of genetics as a science. Although chromosomes, genes, and DNA are now entities whose characteristics even have become part of popular culture, the science of population genetics is not well known; nor are its research goals obvious. Here, we intend to offer a brief overview of some of the most important theoretical concepts used in population genetics and to suggest how this particular research approach can make unique contributions to the understanding of historical demographic phenomena. Our treatment will rely heavily upon the theoretical works of Albert Jacquard (1974, 1978), and of L. L. Cavalli-Sforza and W. F. Bodmer (1971) and will cite examples of applied research.

The Historical Perspective of Population Genetics

Sexual reproduction, from a genetic viewpoint, involves the transmission of the two factors ("genes"), one each from the male and the female parent. Half of the biological information contained in a living individual is derived from each parent. A population may therefore be thought of not as a group of individuals but rather as a group of genes carried by individuals. A population possesses a "gene pool" whose properties can in principle be measured at any point in time and compared with those of earlier generations. Thus, the biological evolution of a population becomes a history of the genes of its members.

Studying the history of genes rather than the genetic histories of individuals can lead to relatively simple results. Compare the two representations of the same case history in Figure 17.1. Genetic transmission through human sexual reproduction is inherently uncertain. Half of the genes of each parent are transmitted to their offspring in a probabilistic biological process governed by

Mendelian segregation laws. The possible outcomes or results of such a process can be predicted in principle, but only a probability can be assigned to each.

Genetic Structure

Every human population possesses a distribution of groups of genes or "alleles," $a_1, a_2, \ldots, a_n$, that can occupy a specific "locus." The locus is the position where each gene is found on each of the two sets of chromosomes received from one's parents. An individual's "genotype" is determined by the pair of genes at a locus. Thus if n alleles can occupy a locus, there are $[n(n+1)/2]$ possible genotypes. If the genes present at every locus for all N members of a population could be determined, the frequency of each of the genotypes and of each of the alleles could be calculated. In practice, such gene frequency measurements are impossible, and one must place reliance upon certain hypotheses to determine the probabilities P_{ij} that an individual selected at

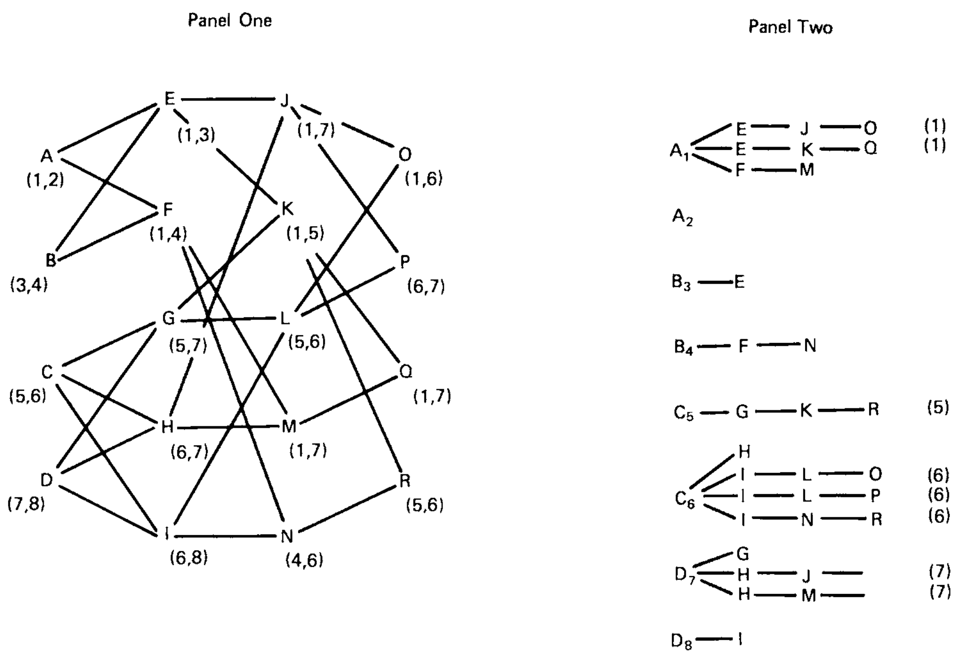

Figure 17.1 *Panel One shows the genetic histories of 18 interrelated individuals. Panel Two is the same case histories but is based on the genes the individuals carry at a given locus. (Adapted from Jacquard* et al., *1978: 17.)*

random from a population will have the genotype $(a_i a_j)$ and the probability P_i that a gene selected from a locus under investigation will represent the allele a_i. The genotypic probability structure of a population S is equal to the $[n(n + 1)/2]$ possible values of P_{ij}. The genic probability structure of a population s is equal to the n possible values of P_i. Jacquard *et al.* (1978: 26) define the problematic or research objective of population genetics as the determination of the changes in population structures S and s over generations as well as the relationship between their structures at any selected point in time. Phenotypes are observed characteristics that arise from the interplay of a genotype and its environment.

Hardy–Weinberg Equilibrium

A reference model frequently used to study empirical populations is based on a set of six assumptions or conditions that specify a certain simplifying population equilibrium. If these conditions are met, then the 1908 law of Hardy–Weinberg applies. The law states that genotypic frequencies produced by a system of random marriage (or mating) will be constant and contingent only upon the gene frequencies of the initial generation.

The assumptions associated with the Hardy–Weinberg law are as follows: First, the unit of time is a "generation." An individual is said to be a member of generation g if his or her parents belong to generation $g-1$. Since parents may not always be members of the same generation (for example, an uncle may marry his niece), the first simplifying assumption requires that parents always belong to the same generation. The presence of immigrants in a population requires knowledge of such features as their populations of origin, their genetic structures, and so forth. The second assumption, not surprisingly, assumes no in-migration. Mutations are rare, and since they give rise to new genes, they complicate the study of genetic transmission. A third assumption, therefore, excludes the possibility of mutations at study loci in the chromosome. A fourth assumption requires that a gene at a study locus have no selective advantage. An example of a gene with a selective advantage would be one that favored the survival of offspring and would thus tend to spread in future generations of a population. If these four assumptions are approximately true in a human population, the genic probability structure of any given generation will be the same as that of an initial historical generation.

A fifth assumption of "panmixia," designed to make the genic structure of the parents independent, requires that father and mother are not chosen on the basis of a gene or trait corresponding to the study locus. If this assumption is valid, we can relate the probability of having a genotype $(a_i a_j)$ to the probability of discovering genes a_i and a_j in a previous generation. To determine the actual distribution of these genotypes, it is necessary to study relatively large populations. In a small population, certain genes, a_i, whose transmission probabilities are initially low may disappear over time. Thus, it is necessary to utilize the law of large numbers, which states that the frequency of an event approaches the probability of that event as the number of "trials" n grow in size. The event in this case is the conception of offspring with genotype $(a_i a_j)$. Thus, the final hypothesis for the Hardy–Weinberg law, the "infinite size" condition, states that the size of the population N must be so large that $1/N$ can be treated as if it were zero.

Although the theoretical equilibrium model underlying the Hardy–Weinberg law has been shown to be a good approximation of a number of actual human populations, care must be exercised in judging the appropriateness of its assumptions when studying historical populations that are small in size and in which immigration may be quite important. In the absence of selection, mutation, and changes in gene frequencies due to sampling error in small populations, the Hardy–Weinberg law requires a population's genetic variation to remain virtually unchanged throughout history (Roughgarden, 1979: 25).

Kinship and Identity Coefficients

Individuals in historical populations are linked together through a variety of social, economic, cultural, and biological factors. Although every individual has 2^g ancestors back to the gth generation, every gene has exactly one ancestral gene. When measuring genetic links between pairs of individuals, we can start with the condition of genetic identity and then consider deviations from this condition. If two individuals have at a locus genes that are copies of the prenatal gene, these genes are said to be "identical." If no mutation has taken place in the study locus, these genes also constitute the same allele. Until very recently, there was no way of determining if one gene was identical to another. Measurements of the degree of genetic relatedness between individuals had to be derived from genealogy-based probabilities.

Since each individual has received at a given locus one paternal and one maternal gene, nine possible relationships can exist between the genes of the two persons, A and B:

1. The four genes of A and B are identical.
2. The two genes of A are identical and the two genes of B are identical, but there is no kinship link between A and B.
3. The two genes of A are identical and match one of B's genes.
4. The two genes of A are identical, but the two genes of B are not identical either to each other or to A's.
5. The two genes of B are identical and match one of A's genes.

6. The two genes of B are identical, but the two genes of A are not identical either to each other or to B's.
7. Each of the two genes of one person is identical to a single gene of the other person.
8. A single gene of one person is identical to a single gene of the other person, but the remaining genes are not identical; nor do they match the other two.
9. There is no genetic identity at all.

Probabilities, termed "coefficients of identity," may be assigned to each of the nine relationships. To compute the nine coefficients of identity of A and B requires knowledge of their genealogies and the possible types of transmission of the four genes possessed by A and B at the study locus. Also, if we know the genotypic probability structure of a person A, we can calculate the structure of a blood relative B. This requires knowledge of the genealogy that links A to B and the genetic structure of their population of origin. The "coefficient of kinship," ϕ, of two individuals is the probability that at a given locus, a gene randomly selected from these individuals will be identical.

Genetic Drift in Small Populations

One of the six assumptions legitimating application of the Hardy–Weinberg law is that the size of the population must be extremely large, in fact, infinite. Since the historical demographer interested in genetic issues is unlikely to obtain data for huge populations, it would appear at first that the Hardy–Weinberg law cannot be utilized. Since only half of a person's genetic composition is transmitted to each offspring, there is some probability that as much as half of the composition will not be transmitted and will thus be lost forever to a population. At an aggregate population level, the amount of untransmitted genetic composition depends on the distribution of individuals with regard to their number of offspring. Thus, the distribution of family alleles, the genic structure of a small population, might not be affected by the loss of a gene. Another gene might be duplicated that has the same allele. If we consider the transmission of different alleles rather than of the genes of an individual, the intergenerational transmission of the genetic structure of a population comes into focus. In a finite population of size N at every generation where P_i is the frequency of an allele a_i, the probability that a gene representing this allele is transmitted to the next generation is also P_i. Since P_i is a probability, the original frequency P_i will vary somewhat from generation to generation. This is a type of change to which no specific cause is assigned and is defined as *genetic drift*. Drift will eventually lead to a homozygote population defined as the case in which each of the two genes received by an individual at a given locus performs the same functions. Decreasing population size is positively associated with increasing genetic drift.

The coefficient of inbreeding for an individual is a probability that can be derived only from the genealogical information available for that individual. The evolution of the genetic composition of a population can be studied if the genealogies have been reconstructed. The most distant ancestors in a population's genealogies are known as the "founders." Genealogic distances between two individuals or two groups of individuals, such as two different generations, may be determined by calculating the difference in their probability of origin. For example, the Jicaque Indians of Honduras, a population founded approximately 100 years ago by several individuals, have lived in isolation until very recently. Jacquard *et al.* (1978: 81–83) have calculated the probabilities of origin for five successive generations. Their genetic structure is shown to have changed rapidly as a result of differences in fertility and infant mortality among couples. Immigration occurs after the fourth generation, accelerating genetic evolution.

Selection

Individuals in a population can in principle be rated according to their capacities to transmit their genetic composition. These differences may lead ultimately to significant changes in the genetic structure of a population. Several studies by historical demographers have provided statistical evidence regarding the distribution of families in regard to the number of "successful" offspring. "Success" in this context refers to those offspring who reach reproductive age and who will in turn transmit genes to the next generation. Jacquard *et al.* (1978: 1009) draw upon results from Louis Henry's study of the bourgeoisie of Geneva to demonstrate the selection effects produced by the adoption of birth control in the eighteenth century. Looking at Table 17.1, we find that the mean number of births decreased by 47% between the two time periods. As a result of improved health conditions, the mean number of successful offspring dropped by only 26% over the same time interval. Contraceptive practices accounted for the increased uniformity in family size. The variance of the number of

Table 17.1
Fecundity and Selection among the Families of the Genevan Bourgeoisie

Time period (birth of husband)	Total births: Mean N	Total births: Variance V	Successful offspring: Mean N_u	Successful offspring: Variance V_u	Index of opportunity for selection $I=V_u/N_u^2$
1600–1650	5.5	20.1	3.1	7.0	0.73
1750–1800	2.9	4.3	2.3	2.6	0.49

Source: Jacquard *et al.*, 1978: 109.

successful offspring drops by 63%. The accompanying decrease in the index of opportunity for selection shows that the context within which selection processes took place was narrowed by almost one-third. The same magnitude of transitions can be expected to be found whenever a population changes from a situation in which excess births are balanced by high infant mortality to another condition in which low infant mortality is balanced by decreasing the number of births.

Selection of marriage partners is generally not random in human populations. A variety of ever-changing cultural systems have existed throughout history that serve to set criteria for mate selection. The genetic consequences of these systems may prove quite important in modifying the relationship between the genic and genotypic structures of a population at a given point in time or even in producing a significant change in the genetic structure of a population. An extreme example would be a population in which only brother–sister marriages are allowed. Within four generations, half of all initially different genetic loci would become homozygous.

Historical populations have rarely been completely isolated from one another. Genetic exchange with nearby populations is quite typical and inevitably results in some modifications in a host population's genetic structure. The significance of the modifications will depend upon the degree of immigration and the differences in genetic structure between host and sending populations. The black population of the United States has been in contact with a white population for approximately 10 generations. It has been estimated (Jacquard *et al.* 1978: 128) that the black population has received a gene contribution from the white population of about 3% per generation. This can be shown to have led to a change in the black population such that at present 27% of its genes are derived from the white population. A coefficient of kinship between two populations such as United States blacks and whites is analogous to the coefficient of kinship between two individuals. In principle, the estimation of this coefficient should begin with the genealogies of the two populations and work upward to their common ancestors. Since such lineages of ancestry are often difficult if not impossible to reconstruct, the estimation procedure is carried out indirectly using hypotheses concerning the historical isolation of the populations under study.

Research Examples

The Kel Kummer Tuareg of Mali are an extremely endogamous nomadic population. Their matrimonial system allows a noblewoman to marry below her rank, but the children of the marriage become members of their father's group and are not allowed to marry a noble. Men of noble rank almost always marry noblewomen. If a man does marry below his rank, however, his children cannot marry within the tribe. The French ethnologist, A. Chaventré (1972) spent 15 years reconstructing the complete genealogy of the 2420 members of the Kel Kummer tribe back to its seventeenth-century founders. This genealogy shows the lines along which genes were transmitted from one generation to the next over a time interval of 3 centuries. Jacquard (1974: 513–552) has calculated the probabilities of origin of the population's genes from different founders. He found that the group of the 15 most important founders contributes 80% of the genes in the contemporary Kel Kummer. The next 10 founders contribute 8%, and the remaining 131 founders less than .5%. Biologically, this demonstrates that the genes in the Kel Kummer tribe are essentially descended from only 25 founders and thus that the tribe represents a true genetic isolate. Calculating genetic "distances" between generations shows that although immigrants are integrated into the tribe from time to time, the marriage customs are such that their children must seek partners from other tribes. Thus, immigrant or "foreign" genes are present within the population only for relatively short time periods.

A second example of genetic research within a historical and demographic framework is an analysis by Dorit Carmelli and L. L. Cavalli-Sforza (1979) of 12 Jewish and 20 non-Jewish populations living in four geographical areas. Previous research confirmed that in any society in which a Jewish minority has resided for several generations, the Jews resemble to a certain degree the non-Jewish majority in respect to skin pigmentation, eye color, and blood types. However, Jewish communities often differ considerably from one another with respect to such traits. Carmelli and Cavalli-Sforza posed three research questions:

1. Can Jewish communities be allocated to their known historical origin in the Near East using character measures derived from contemporary Jews?
2. Are different character measures equally useful for allocation?
3. Is it possible to use available data on gene frequencies for different Jewish groups, and for the people with whom they were in contact, to estimate migration rates, the "original" gene frequencies, and the amount of random genetic drift of historical Jewish communities (often of small size)?

To answer these questions, Carmelli and Cavalli-Sforza obtained four blood markers from members of 12 Jewish communities, sampled mostly in Israel, and 20 non-Jewish populations who inhabited the same geographical areas occupied by the Jews in the Diaspora. They used two statistical techniques to estimate the genetic origins of the Jews and the degree of historical admixture with other populations. First, they applied discriminant analysis in order to learn how best to discriminate among non-Jewish populations. Clusters were defined on a geographical basis. Portuguese, Spanish, Italian, Yugoslavian, and Greek populations, for example, were assigned to a South Europe cluster. The other three clusters were Central and Eastern Europe, the Near East, and North Africa. The research strategy undertaken was to build a discriminant function that maximized the differences between the clusters. Next, the locations of individual Jewish populations in the discriminant space were measured to see if they: (*a*) appeared in the Near East cluster, where they most probably came from originally; (*b*) were found in the clusters with the populations with whom they lived until recently; or (*c*) showed up somewhere else. Case (*a*) corresponds to a test of the hypothesis that the Near East origin of the Jews is still genetically evident despite intermarriage and genetic drift. If case (*b*) is true, the original ethnic characteristics of the Jewish groups would be shown to have disappeared largely because of drift, selection, and admixture through marriage. Case (*c*) is a residual situation that if true would suggest that the history of drift, selection, and admixture is too complex to allow the reconstruction of the origins of the Jews by discriminant analysis.

The main feature of the solution in a two-dimensional space defined by the first two canonical variates (which account for 96% of the intergroup variances) is a significant dispersion of all Jewish populations. Despite the dispersion, the centroid of the Jewish populations is closest to the Near East cluster. The scatter of the Jewish populations in the discriminant space can be interpreted as resulting from immigration and genetic drift. Historical migration effects were estimated on the basis of the gene frequencies of the "gene donors" who were assigned to be those of the present non-Jewish groups in an area. The original Jewish gene frequencies were jointly estimated from the data for all Jewish groups. Cumulative migration rates were determined for each Jewish population using maximum likelihood techniques. An estimation of the effects of genetic drift was attempted after having taken into account migration effects. The results show drift to be the major factor producing the scatter of Jewish gene frequencies in the discriminant space.

The systematic study of the genetic basis of social demographic behavior is receiving widespread attention as a result of the vigorous debate over the controversial claims made by sociobiologists about the scope and adequacy of genetically grounded models (see Caplan, 1978). Sociobiologists have argued that genetic research will enable us to understand historical demographic patterns of behavior in ways not otherwise possible. Critics of this approach, on the other hand, argue that genetic reductionism will fail because "genotypes never account for all the variations in behavioral phenotypes" (Harris, 1980: 121). In response to this criticism sociobiologists are attempting to formulate more sophisticated theoretical models which focus attention on historical, social demographic data (see, for example, Lumsden and Wilson, 1981).

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18
Biometric Models

Our knowledge of the biological character and range of variation of the biometric properties of human populations can obviously be greatly expanded by drawing upon as-yet-unanalyzed historical demographic data. Mathematical relationships discovered to be present in contemporary populations may attain a more confident generalized status if found to hold in historical populations as well. Hervé Le Bras's (1976) study of the neglected link between mortality levels and the life span, for instance, might be replicated with data reaching further back into the past. Le Bras shows that the so-called mortality laws of Gompertz and Makeham are not really laws in a narrow sense since log-normal and gamma distributions can also be fitted to mortality data. He shows in addition that Gumbel's paradox, that life tables with higher levels of mortality lead to more individuals surviving to old age, is consistent with the convergence of the Gompertz "lines" found in many life tables. Mathematical, biometric modeling of this sort can be anticipated to become more prevalent in historical demography along with the increasing availability of large data bases. It is, however, a rarefied realm of research that few may enter with ease and confidence.

The three following mortality studies are more typical of biometric explorations undertaken with historical demographic data. Catherine Rollet and Agnès Souriac (1974) use French administrative records for the period 1890–1910 to study the feeding practices and mortality of infants within the first year of birth. They superimpose infant mortality patterns upon a geographical map of France showing areas where animal milk and human milk were respectively used. Regional differences in feeding practices were related to employment opportunities and the geographical distribution of dairy farming. Rollet and Souriac find infant mortality to be particularly high in regions using animal milk in the period before pasteurization. Regions where late weaning was practiced also had high infant mortality.

Louis Henry and Jean Hurault (1979) have analyzed the mortality of the populations of European stock in French Guiana between 1700 and 1763, using parochial records and a census. Their results demonstrate the deleterious health effects of a humid equatorial climate. Another study, Dominique Tabutin's (1978) analysis of data for Sweden, France, England and Wales, and Belgium, shows that female excess mortality *rose* during the nineteenth century, particularly for adolescents. It was not until 1939 that this effect ceased in France. She argues that the existence and growth of excess female mortality at certain ages was apparently due in large part to sex-selective infectious diseases.

These mortality studies illustrate the wide variety of biologically related topics under investigation by historical demographers. The future integration of findings from these types of historical studies will permit a more profound understanding of the biological properties and adaptive capacities of human populations in varying environments.

We shall consider biometrics from the point of view of the relationship between human biological characteristics and demographic behavior. As mortality prior to and during the reproductive life span declines in the modern world, fertility becomes more and more important as a determinant of population growth and structure. Biometric models have accordingly focused more upon the causes of changes in birth rates in recent history rather than those of mortality, even though the two are clearly interlocked before and during demographic transitions (McKeown, 1976: 18–43; Preston, 1978). A major purpose of biometric models has been to describe aspects of fertility behavior by means of mathematical functions whose parameters may vary among populations (Menken, 1975: 52). Other purposes include predicting or forecasting fertility–mortality from a model viewed as theory, as well as studying the magnitude of change induced by historical alterations in the biological determinants of fertility–mortality. Socioeconomic, ecological, and other types of variables, mediated through biological variables, are normally excluded from formal biometric models. The examples of models that follow illustrate major biometric research themes that have entailed the use of historical demographic data.

A General Analytical Framework

Human reproduction involves complex interactions between biological, health, and behavioral factors, the importance of each of which may vary considerably within differing historical, economic, and ecological contexts. Figure 18.1 attempts to capture the life-cycle aspects of health and behavioral factors that appear most immediately to affect the three basic biological

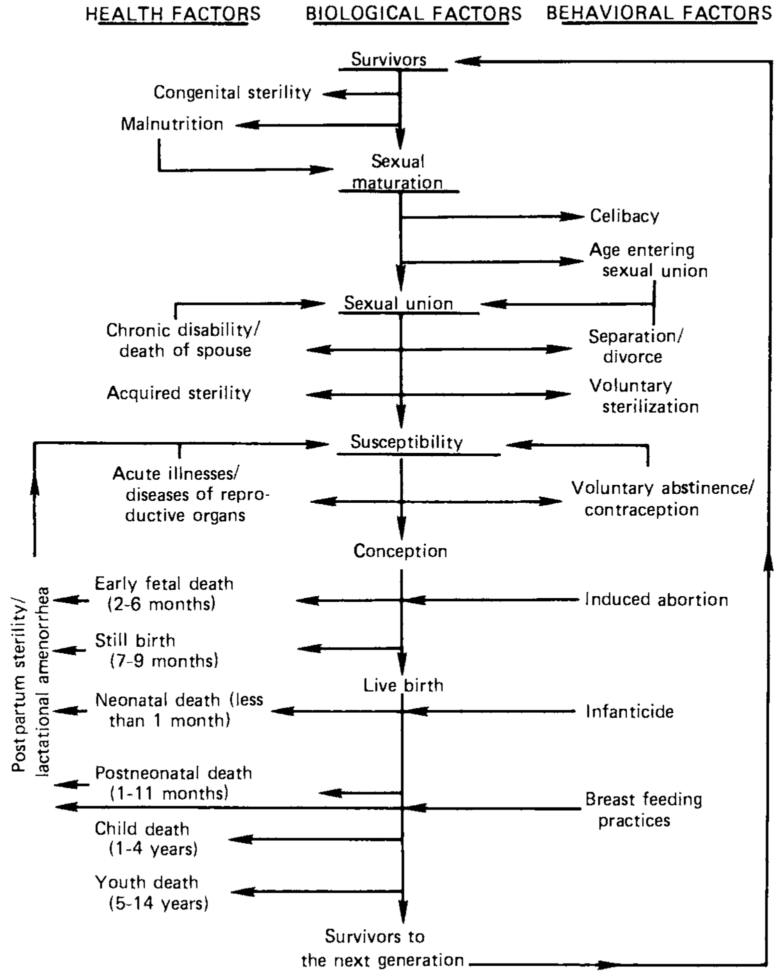

Figure 18.1. *A general analytical framework showing the interaction of factors which affect human reproduction. (Adapted from Mosley, 1978: 6.)*

mechanisms regulating live birth rates: (*a*) exposure to intercourse; (*b*) exposure to conception; and (*c*) successful gestation.

The biological states through which a woman must pass to have surviving offspring are represented by the vertical line in Figure 18.1. Sexual maturation and sexual union are responsible for establishing a woman's reproductive life span. The susceptible interval exposes a woman to the risk of pregnancy until conception. A successful gestation period issues in a live birth, a potential survivor to the next generation. Following the termination of a pregnancy, every woman enters a period of postpartum sterility and/or lactational amenorrhea interval, returning once again to a state of susceptibility. This series of steps constitutes one complete reproductive cycle.

Birth Intervals and the Duration of the Nonsusceptible Period

Louis Henry (1972: 80–89) has proposed a model to demonsrate how fertility rates measured over a given time period, z, are related to birth intervals. Let us assume that a woman has two or more births over interval z and that z is subdivided into two types of intervals, as shown in Figure 18.2. The straddling interval contains two fractions, prior and posterior to the beginning or end of z. The interior intervals occur entirely within the time frame defined by z. If n is the number of births during interval z, then

$$z = s + d_1 + d_2 + \cdots + d_{n-1} + r. \qquad (18.1)$$

The fertility rate f for interval p, of k women, nearly all of whom conceive at least once during z and who subsequently give birth some time after the end of z to at least one child, may be written as,

$$f = \sum n_i / [k\bar{s} + \bar{d}\sum_i (n_i - 1) + k\bar{r}], \qquad (18.2)$$

where n_i is the number of children born during interval z by woman i, and $\bar{s}$, $\bar{d}$, and $\bar{r}$ are the mean values of s, d, and r. If we assume that this function is independent of the woman's age, the distribution of an interval between conceptions will be unchanged. The mean duration of prior and posterior fractions will be identical. Thus, interval z can be conceptualized as being made up of n_i intervals of which there are $n_i - 1$ interior intervals and one straddling interval. The inverse of the fertility rate given in Eq. (18.2) now turns out to be equal to the mean value of the n_i intervals. If $\bar{y}$ is the mean of the straddling intervals, it can be shown that

$$1/f = [\bar{y}k/2 + \bar{d} \sum_i (n_i - 1) + \bar{y}k/2] / \sum_i n_i. \qquad (18.3)$$

In words, Eq. (18.3) states that the inverse of the fertility rate is equal to the weighted mean of the intervals beginning or ending with interval z, such that the interior intervals have twice the weight of the straddling interval. Henry states the result as follows: "The fertility rate of women subsequently fertile is equal to the inverse of the mean of all intervals beginning or ending within this period; in that mean, the interior intervals intervene twice, once at the beginning and once at the end [1972: 83]." Given the previous assumptions, this result should apply to heterogeneous populations as long as there is a 5- or 10-year period of life existing on either side of interval z.

Henry illustrates the relationship he has derived between fertility rates and birth intervals with historical, "natural fertility" data for families in Geneva in

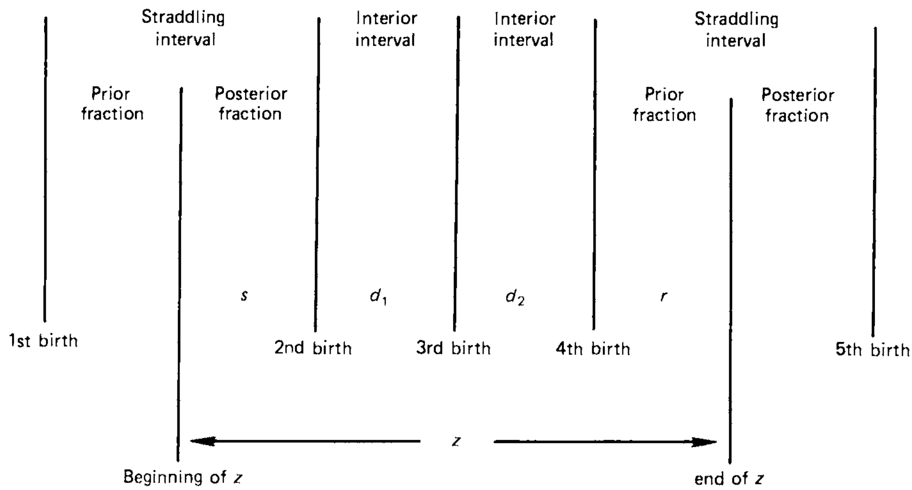

Figure 18.2. *Straddling and interior intervals for a hypothetical woman with three births within the period z. (Adapted from Henry, 1972: 80.)*

which the husband was born before 1600, and for the population of Crulai using marriages dating from 1674 to 1742. Table 18.1 shows the fractions of intervals in months at different female age levels. Note that at age 20, the prior fraction is *larger* than the posterior fraction, whereas at age 25 the two fractions are almost identical in size. At age 30, the prior fraction is *smaller* than the posterior. This relation remains the same for Crulai at age 35 but reverses itself in Geneva. Finally, at age 40, the prior fraction is *larger* than the posterior for both

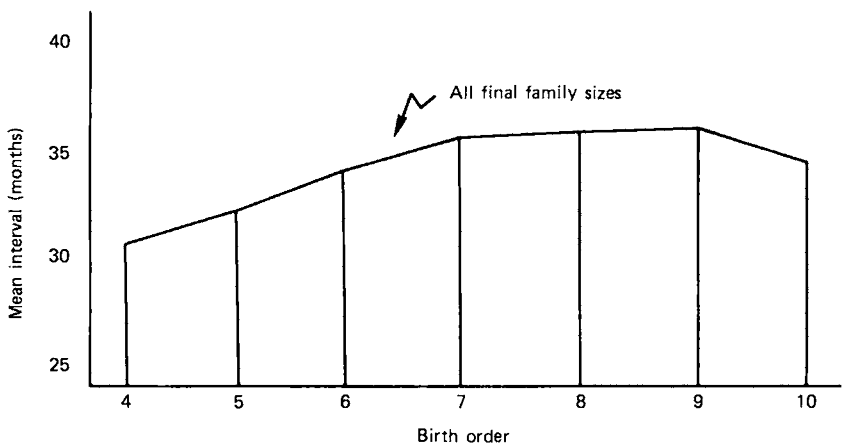

Figure 18.3. *Birth intervals and final size of families. (Adapted from* Human Fertility: The Basic Components *by Henri Léridon by permission of The University of Chicago Press. Copyright © 1977.)*

Table 18.1

Prior and Posterior Interval Fractions (in Months) for Women from Historical Geneva and Crulai

	Age of women (in years)									
	20		25		30		35		40	
	Prior	Posterior	Prior	Posterior	Prior	Posterior	Prior	Posterior	Prior	Posterior
Geneva										
(husband born before 1600)	14.3	12.7	14.2	13.3	15.2	16.6	18.2	14.2	28.4	14.8
Number of observations	8		22		27		23		13	
Crulai										
(marriages of 1674–1742)	13.5	11.5	13.3	13.1	13.7	15.6	15.8	17.0	18.7	16.3
Number of observations	12		61		90		75		47	

Source: Henry, 1972: 86.

Table 18.2

Interior and Straddling Intervals (in Months) between Births for Female Age Groups 25–29 and 30–34, for Historical Geneva and Crulai

	Intervals							
	25–29 years				30–34 years			
	Straddling 25 years	Interior	Straddling 30 years	Weighted mean	Straddling 30 years	Interior	Straddling 35 years	Weighted mean
Geneva								
Mean of the intervals	26.9	24.8	31.8	26.8	31.8	27.3	31.8	29.7
Number of intervals	21	27	21	48	23	21	23	44
Crulai								
Mean of the intervals	27.2	23.0	30.6	25.4	29.6	25.9	33.0	28.5
Number of intervals	51	73	51	124	65	70	65	135

Source: Henry, 1972: 87.

populations. How does Henry interpret these findings? First of all, at age 20, the number of observations is very small, and the differences between fractions may be due to chance or the fact that the duration of the nonsusceptible period varies progressively with age. The equality of fractions found at age 25 suggests that fecundability, duration of the nonsusceptible period, and frequency of abortions and stillbirths vary only slightly with age. Beyond age 30, however, a decline takes place in the number of women subsequently fertile. This is shown by the fact that the prior fraction is smaller than the posterior for Crulai. This effect does not show up in Geneva. Random variation and the small number of observations in Geneva may mask the effect. On the other hand, its absence might be significant and prove to be related to factors present in Geneva that are not present in a rural area such as Crulai. At age 40, the mean of the posterior fraction must fall below that of the prior fraction because of the onset of definitive sterility. This effect is confirmed for both populations.

To test his biometric model by showing that the fertility rate and the inverse of the weighted mean interval are approximately equal, Henry considers women in the age groups 25–29 and 30–34 years. Table 18.2 lists the sizes of the interior and straddling intervals between births for these two age groups. Using the data presented in Table 18.2, the fertility rate of women subsequently fertile can be computed by dividing the number of births by five times the number of women. The inverse of the weighted mean intervals can also be computed with Eq. (18.2). The results are given in Table 18.3 and show relatively close agreement. Henry accounts for the small discrepancies between the two measures by arguing that the conditions for his model are not completely fulfilled: The time since marriage is not long enough for early oscillations in behavior to disappear, and fecundability, duration of the nonsusceptible period, and frequency of abortions and stillbirths begin to vary with age after age 30.

Table 18.3
Observed Fertility Rates Compared with Henry's Model Using the Inverse of the Weighted Mean Interval, for Females, Aged 25–29 and 30–34, in Historical Geneva and Crulai

	Age of women (in years)	
	25–29	30–34
Geneva		
Observed rate	.457	.383
Rate from model	.448	.404
Crulai		
Observed rate	.486	.416
Rate from model	.472	.421

Source: Henry, 1972: 88.

Every conception initiates a nonsusceptible period in a woman. A variety of factors determine the length of this period: delay in the reappearance of ovulation due to prolonged breast-feeding, a prohibition against sexual intercourse during lactation, the type of outcome of a pregnancy, or a woman's age and parity. Direct measurements of the nonsusceptible period would require a series of longitudinal physical measurements and interviews of a sample of women. Obtaining valid measurements of this nature might be quite difficult, and results would not necessarily be applicable to patterns of "natural fertility" in historical populations. Thus, Henry (1972: 119) believes that indirect measurements may be preferable, using available historical data on intervals between live births. Because of limitations in the aggregate data, Henry had to assume that these intervals were equivalent to the intervals between live-born children. Each interval has two time segments: the postconception nonsusceptible period and the subsequent delay in the conception of a live-born child.

Henry's research strategy is as follows: First, he takes the mean interval between marriage and the first live birth (excluding possible cases involving bridal pregnancies) in a "natural fertility" population and uses it as an estimate of the mean delay between marriage and the conception of a live-born child. For females aged 20–29 years, fecundability seems to remain at a relatively constant plateau level. Thus, if the mean delay in the conception of a live-born child following marriage can be assumed to be approximately equal to the conception delay that occurs after a nonsusceptible period, the mean postpartum nonsusceptible period can be estimated by subtracting the mean interval between marriage and the birth of the first child from the mean interval between consecutive births within marriage. For the 81 women married at ages 20–29 in Crulai in 1674–1742 who conceived their first child after marriage and had at least two live-born children in succession, Henry found that the mean interval between marriage and the first birth was 16.2 months and that between the first and second births it was 26.5 months. The first postpartum nonsusceptible period is thus about 10 months. Jean Ganiage's (1963: 148) data for 79 women marrying at ages 20–29 in Mesnil-Theribus in 1740–1779 show that the first mean nonsusceptible period for women who had at least four births was 16.6 months and that between the first and second births was 20.2 months.

Henry (1972: 124–154) has proposed another indirect approach to estimating the duration of the nonsusceptible period. To begin with, he assumes that the simplest of all conditions holds: a homogeneous group of women with constant fecundability and period of nonsusceptibility, with sufficient time for reproduction to allow conception delays to have their expected values. Oscillations in fertility that take place shortly after marriage are assumed to disappear. Conceptions, rather than births, are considered. The mean conception delay for a susceptible woman is symbolized by c, the duration of the nonsusceptible period as g, fecundability by p (note that p will equal $1/c$), and the characteristic interval, i, defined to be equal to $g + c$.

The thirtieth birthday of every woman in this homogeneous group will occur between conceptions, if the time on each side of this date is long enough to permit at least one conception. This interval can be conceptualized as a straddling interval with two half-intervals. There is a prior fraction that extends from the conception immediately preceding the thirtieth birthday and a posterior fraction lying between that date and the date of the next conception. Fertility will be constant and equal to $1/(g + c)$. Over a period of time g, extending from $t - g$ to t, the expected number of conceptions will be $g/(g + c)$. This implies that there are $c/(g + c)$ women whose last conception prior to time t also occurred before time $t - g$. These women have an expected interval between this conception and their next conception equal to $g + 2c$, whereas the remaining women have an interval of $g + c$. The expected value of the straddling interval will then be given by

$$\begin{aligned} D &= (g + 2c)\,[c/(g + c)] + (g + c)\,[g/(g + c)] \\ &= g + c + c^2/(g + c) \\ &= i + c^2/i. \end{aligned} \tag{18.4}$$

Since the logic of this argument is a bit elusive, let us look at the matter in somewhat greater detail. Because we have assumed that the fundamental functions of fertility (fecundability, duration of the nonsusceptible period, frequency of abortion and stillbirth) are approximately invariant with respect to age, the expected value of the prior fraction will equal that of the posterior fraction. The prior fraction for the $g/(g + c)$ women who conceived in the time period from $t - g$ to t will have a mean length of $g/2$. But for the $c/(g + c)$ women who conceived before time $t - g$, this interval will have a mean length of $g + u$, where u is the mean interval between the end of the nonsusceptible period and time t. Taking into account both groups of women, the prior fraction extending over the period from the last conception to time t will have a mean length of $[c(g + u) + g(g/2)]/(g + c)$. Furthermore the $c/(g + c)$ women who conceived before $t - g$ are now susceptible at time t. Because their fecundability p is constant, the mean duration until next conception will equal the mean conception delay c. However the mean time between t and the next conception for the $g/(g + c)$ women is $g/2 + c$. The posterior fraction, the interval from t to the next conception, taking into account both groups of women, will have a mean duration of $(c^2 + g^2/2 + gc)/(g + c)$. Since we have assumed that the prior and posterior fractions have equal length, we can set the two expressions just derived equal to each other, demonstrating that $u = c$. Consequently, for the $c/(g + c)$ women whose last conception is before t, the expected interval between this conception and the next is $g + u + c$ or $g + 2c$, the result mentioned earlier. Table 18.4 summarizes the expressions derived or discussed up to this point.

The inverse of Eq. (18.2) can be set equal to the characteristic interval i. This provides a means of estimating i with a weighted average of straddling and

Table 18.4
Summary of Expressions Used to Study the Duration of a Woman's Nonsusceptible Period

	Women who conceived between t-g and t	Women who conceived before t-g	All women
Expected proportion	$g/(g+c)$	$c/(c+g)$	1
Mean prior fraction from the last conception to t	$g/2$	$g+u=g+c$	$[c(g+u)+g(g/2)]/(g+c)$
Mean posterior fraction from t to the next conception	$g/2+c$	c	$[c(c)+g(g/2+c)]/(g+c)$
Straddling interval	$g+c$	$g+2c$	$g+c+c^2/(g+c)$

interior intervals. When fecundability c and duration of nonsusceptibility g vary with age, a characteristic interval is no longer present. We know that either c and/or g will vary with a woman's age. To take this into account, Henry introduces the concept of a "reference interval," Y, which is a weighted mean of intervals beginning or ending within a select age interval. A reference interval at 27.5 years, for example, might be computed as the weighted mean of intervals beginning and/or ending between a woman's twenty-fifth and thirtieth birthdays, with the weights for the interior being twice those for straddling intervals.

Table 18.5 presents data from Ganiage (1963: 143–146) for 19 women from the villages of Mesnil-Theribus, Marcheroux, and Beaumont-les-Nonains in the *dèpartement* of the Oise, who were married between 1740 and 1799 and who had their first child before age 25. Using the inverse of Eq. (18.2) and adding on a factor of 0.5 to account for the fact that the data in Table 18.5 are given in elapsed months, the reference interval for the first couple at age 25–29 is

$$Y = [22 + 2(22) + 2(16) + 17]/6 + 0.5 = 19.7. \qquad (18.5)$$

This calculation would be repeated for all 19 couples and averaged to obtain the mean reference interval at age 27.5. Table 18.6 presents Henry's calculations, for the same three villages, of the straddling intervals at their limits and the reference interval for age groups 25–29, 30–34, and 35–39. In Table 18.7, similar calculations appear for age groups 27.5–32.4 and 32.5–37.4. Inspection of these results shows that change in the mean intervals with age is *linear*. Results for Crulai marriages between 1674 and 1742 are reported in Table 18.8.

To obtain a lower limit or minimum possible value for g, g_m, regression estimates of D and Y can be obtained to insert into the following equation:

$$g_m = Y - [(D - Y)Y]^{1/2}. \qquad (18.6)$$

Table 18.5
Birth Intervals for a Sample of Married Women Giving Birth before Age 25 and Whose Last Birth Occurs between Ages 40 and 49, from Three Historical Villages of the Ile-de-France

Identification number	Intervals (in months)[a]						
	Straddling age 25	Interior	Straddling age 30	Interior	Straddling age 35	Interior	Straddling age 40
1	22	22,16	17	20,18	18	20,18	21
2	23	12,15,15	19	30	32	–	55
3	19	35	23	30	19	24,15	22
4	22	12,13,22	12	21,10,14	14	12,22,17	12
5	18	18,19	20	23,22	21	23	21
6	24	32	28	18,21	19	16,23	39
7	13	14,13,14	13	13,16,16	43	–	39
8	22	28,24	19	26,11	26	–	40
9	18	21,19	20	40	39	–	35
10	19	18,17	24	25	27	–	63
11	31	20	30	20,22	29	19	23
12	22	22,24	17	24,23	24	27	18
13	22	23,31	32	24	23	27	24
14	13	22,15	23	–	53	16,31	27
15	25	30	25	19,25	39	24	21
16	15	21,22	36	–	35	38	62
17	23	35	24	24	47	22	66
18	25	32	29	28	30	24	34
19	20	29	69	–	41	–	50

[a]The straddling intervals were derived by Henry (1972: 130) from the work of Ganiage (1963: 143–146).

Table 18.6

Straddling and Reference Intervals for Different Female Age Groups, for Three Historical Villages of the Ile-de-France

	Age of women								
Interval	25	27.5	30	30	32.5	35	35	37.5	40
Straddling	22.0		26.4	25.9		32.2	30.3		37.7
Reference		23.8				27.2			31.5
Number of women		28			58			49	

Source: Henry, 1972: 131.

Table 18.7

Straddling and Reference Intervals for Different Female Age Groups, for Three Historical Villages of the Ile-de-France

	Age of women					
Interval	27.5	30	32.5	32.5	35	37.5
Straddling	24.6		30.2	28.5		33.3
Reference		25.8			28.9	
Number of women		38			49	

Source: Henry, 1972: 132.

Table 18.8

Straddling and Reference Intervals for Different Female Age Groups, for Historical Crulai

	Age of women					
Interval	25	27.5	30	30	32.5	35
Straddling	27.2		30.6	29.6		33.0
Reference		27.1			30.1	
Number of women		51			65	

Source: Henry, 1972: 137.

This equation can be obtained by starting with the defining equation for the characteristic interval ($i = g + c$), the expected value of the straddling interval D, derived earlier, to set $g = i - [(D - i)i]^{1/2}$, and then substituting the reference interval Y in place of i. Henry shows how even lower limits for g_m can be estimated by adopting hypotheses other than one requiring the nonsusceptible period to be invariant. Values computed for g_m, presented in Table 18.9 show that nonsusceptible periods are relatively long because they have to be greater than the lower limit g_m values and that g_m increases with a woman's age. Henry puts forward an interesting explanation based on nursing practices to account for the increase in g_m with age. Historical medical data are required to arrive at a completely satisfying explanation. Other perspectives on the calculation of birth interval lengths for the study of family limitation are discussed in Knodel (1981).

Natural Fertility

The first extensive investigations with biometric models of data from populations reproducing "naturally," without intentionally limiting births, were undertaken by Louis Henry (see, for example, Henry, 1972: 1–25). Natural fertility is often defined as the fertility of couples who make no parity-dependent effort to limit births. Although historical populations have been found under conditions approaching natural fertility, in most instances of applied research the concept of natural fertility serves primarily as a hypothetical fertility against which actual fertility may be compared to appraise the effectiveness of various methods of fertility regulation.

Reliable demographic data for historical populations that generally avoid use of all methods of birth control may be obtained from parish registers, genealogies, and various vital registration systems. Although marital customs such as age at marriage, conditions for remarriage after widowhood, and types of marriage obviously affect fertility levels, they are excluded from biometric models as social rather than biological birth control variables. Thus, fertility

Table 18.9
Lower Limits for g_m and Reference Intervals for Women at Different Ages in Marriages between 1740 and 1779, for Three Historical Villages of the Ile-de-France

Interval	Age of women				
(in months)	27.5	30	32.5	35	37.5
g_m	19.0	19.7	20.1	20.7	21.5
Y	23.6	25.5	27.3	29.1	31.0

Source: Henry, 1972: 132.

rates may vary considerably from one approximately natural fertility population to another. Table 18.10 presents a summary of marital fertility rates in a wide variety of populations not practicing birth control.

The great dispersion of results in Table 18.10 is of considerable interest. Henri Léridon (1977), who assembled these data from different studies, shows that sizes of completed families and age-specific fertility rates can vary by as much as 100%. In addition to differences in fertility levels, the fertility schedules (rates across the ages of women) are quite dissimilar. From a biometric viewpoint, the overall levels of the rates are determined by the degree of fecundability and the duration of the nonsusceptible period. The evolution of the rates with age (fertility schedules) are determined by increases in sterility with age. This could be accompanied with a form of birth limitation that becomes more effectively applied as family size increases.

As we saw in the previous section, the mean duration of successive birth intervals is related to the fertility rate. If we plot birth intervals by order of birth in a quasi–natural fertility population of completed families (i.e., families in which the women are at least 45 years old and their marriages have not yet been broken by divorce or widowhood), it is likely that a curve similar in shape to that in Figure 18.3 would result. Note that a plateau is reached, followed by slight decline. This appears somewhat counterintuitive, for we might expect to find that successive intervals between births increase since fertility rates decrease as women age. Léridon (1977: 112–113) shows that this paradox may be resolved if mean birth intervals are recomputed for each completed family size. The expected lengthening of the final one or two intervals is then observed for each different family size. Léridon (1967) has gathered findings for 450 eighteenth-century completed French families that have at least five children. Average age at marriage for the wives in this sample was about 25 years. A sketch of Léridon's aggregated data shows birth intervals classified by rank and final family size. Note that the curves in Figure 18.4 are tiered and that the last birth interval increases by 6 to 7 months *regardless* of the completed family size. Readers interested in the subject of natural fertility are strongly urged to consult *Natural Fertility: Patterns and Determinants of Natural Fertility*, a work edited by Henri Léridon and Jane Menken (1979). Many of the methodological techniques treated here are applied throughout their volume.

Given the differences and similarities between populations presumed to be living in conditions of natural or quasi-natural fertility, what methods of modeling are available to describe and analyze this type of fertility? One approach would be to apply mathematical models that attempt to capture the functional relationships underlying aggregate reproductive event histories (see, for example, Sheps and Menken, 1973). However, a common drawback to formal mathematical demographic models is that solutions in closed form or even numerical approximations often require making too many simplifying assumptions about the real world. Even if one can find functional relationships that achieve a respectable fit to observed data, they may be of little use in trying to understand the causal processes at work. Curve-fitting exercises may at times

Table 18.10
Age-Specific Marital Fertility Rates for a Variety of Historical Populations Living under Conditions of Quasi-Natural Fertility

	Age-specific marital fertility rates (per 1000)							Mean number of children
Historical populations	15–19	20–24	25–29	30–34	35–39	40–44	45–49	(completed families, women married at age 20)
Canada (marriages 1700–1730)	493	509	495	484	410	231	30	10.8
Hutterites, United States (marriages 1921–1930)	–	550	502	447	406	222	61	10.9
Amish, United States (women born 1900–1920)	83	365	462	251	221	82	14	7.0
Geneva (bourgeoisie; husbands born before 1600)	264	389	362	327	275	123	19	7.5
Geneva (bourgeoisie; husbands born 1600–1649)	419	525	485	429	287	141	16	9.4
Norway (years 1871–1875)	433	426	393	332	281	166	40	8.2
Sweden (marriages 1841–1900)	–	319	332	279	226	122	12	6.4
Anhausen, Germany (marriages 1692–1799)	–	472	496	450	355	173	37	9.9
Colyton, England (marriages 1560–1629)	412	467	403	369	302	174	18	8.7

Northwest France (marriages 1670–1769)	317	447	426	380	293	150	1o	8.5
Southwest France (marriages 1720–1769)	275	404	363	343	260	146	22	7.7
Boulay, France (marriages before 1780)	433	480	452	391	341	183	27	9.4
Bilhères d'Ossau, France (marriages 1740–1779)	198	414	400	353	319	165	13	8.3
Crulai, France (marriages 1674–1742)	324	428	431	359	319	119	10	8.3
Ile-de-France, France (marriages 1740–1779)	461	527	515	448	368	144	21	10.1
Sotteville, France (marriages 1760–1790)	–	491	440	429	297	125	10	9.0
Thézels Saint-Sernin, France (marriages 1700–1791)	208	385	335	290	242	67	0	6.6
Tourouvre, France (marriages 1665–1714)	236	412	425	378	330	164	11	8.6

Source: Adapted from ***Human Fertility: The Basic Components*** by Henri Léridon by permission of The University of Chicago Press. Copyright © 1977.

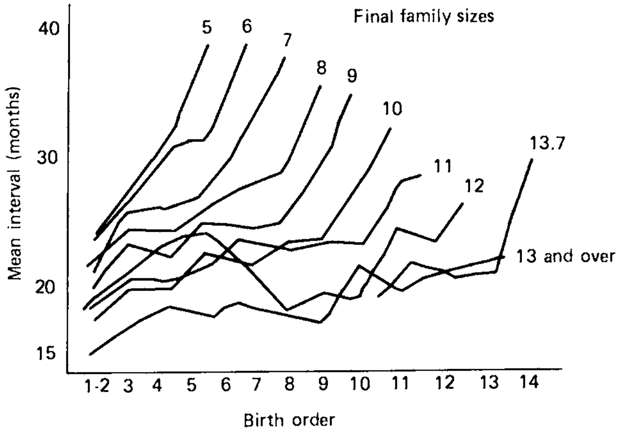

Figure 18.4. *Birth intervals, by order and final size of family for historical France. (Adapted from* Human Fertility: The Basic Components *by Henri Léridon by permission of The University of Chicago Press. Copyright © 1977.)*

lead to insights, but their utility is quickly exhausted when faced with fundamental causal questions. Simulation models represent an alternative approach. Macrosimulation models are made up of a set of deterministic equations that contain probabilities that can change over time and that describe the likelihoods of transitions between the reproductive states of being pregnant, amenorrheic, fecundable, and sterile. Microsimulation models, on the other hand, recreate hypothetical reproductive histories of women one at a time, using in part a random-number generator. Final results are then aggregated. Dyke and MacCluer's *Computer Simulation in Human Population Studies* (1974) contains a variety of examples of both macrosimulation and microsimulation models.

A macromodel of the reproductive process based on systems-analysis methodology has been proposed by John Bongaarts (1977). The computer program (REPMOD) used to simulate the model is written in FORTRAN for a minicomputer. The relationships between the inputs and outputs of his reproductive model are depicted in Figure 18.5. The seven model inputs are usually considered to be the most immediate determinants of fertility. Three levels of interaction are specified in the model. At the first level of interaction, four variables that can vary with age and parity combine to determine the birth interval distribution. At the second level, duration-specific birth rates or family building patterns are determined by a sequence of birth intervals that are affected by variables (5) and (6). Finally, the third level issues in the fertility patterns of an entire birth cohort. This cohort's fertility history is an aggregation of the family duration-specific birth rates of all the different first-marriage cohorts. The sizes of these cohorts are determined by entering into the model a distribution of first marriages by age. Thus, three kinds of output may be

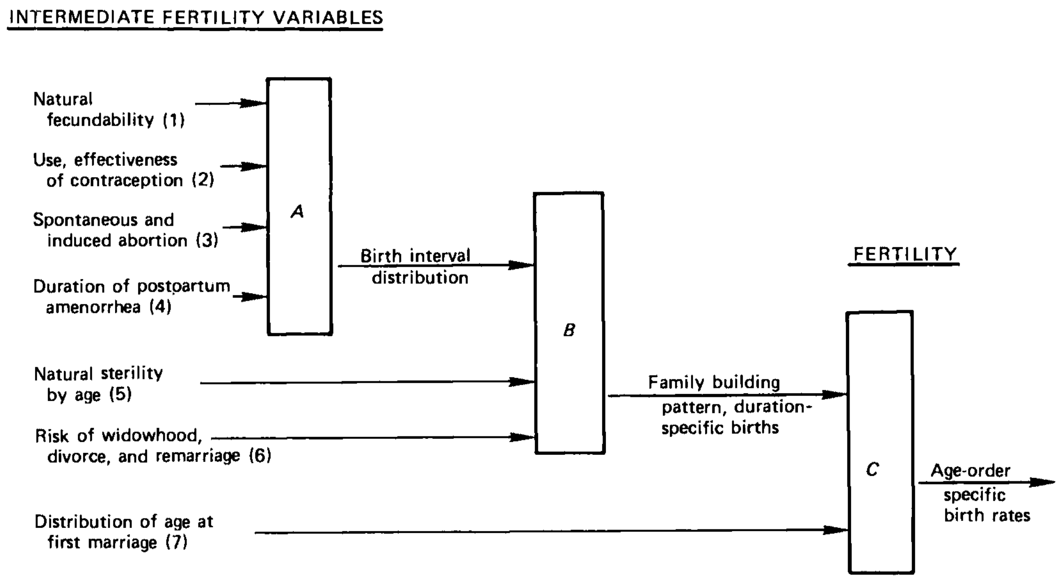

Figure 18.5. *An input-output diagram of a reproductive model proposed by Bongaarts (1977: 61).*

obtained from the simulations: the age-specific or age-order-specific birth rates of a birth cohort; birth interval distributions; and duration-specific or duration-order-specific birth rates.

The causal modeling strategy followed by Bongaarts is to begin with the simplest set of assumptions:

1. The reproductive behavior of all women is identical.
2. There is no deliberate birth control.
3. Fecundability, risk of spontaneous abortion, and mean duration of postpartum infecundability remain invariant.
4. Marriages remain intact.

These assumptions may later be weakened to produce more realistic versions of the model. A marriage model proposed by Coale and McNeil is used to provide the first-marriage distribution. It describes the proportion of the birth cohort leaving the unmarried state by age. An observed first-marriage distribution could also be used. The "waiting time" distribution in the fecundable state is represented by a geometric distribution. This time between the beginning of a pregnancy and a live birth is assumed to be 9 months. The "waiting time" in the postpartum infecundable state is assumed to be a Pascal distribution. The "waiting time" from conception to the end of the postabortion amenorrhea interval in the event of a spontaneous abortion is taken to be a geometric distribution with a fixed parameter of 0.40. The incidence of sterility with age is based on a pattern estimated by Henry. All of these waiting-time distributions are then used to derive the differential equations that make up the basic version of the simulation model.

Variations in the basic version of the model are possible. With regard to fecundability, it is possible to create a set of homogeneous subcohorts whose fecundabilities differ according to a prespecified fecundability distribution. Each subcohort can be simulated separately and a weighted average taken of their outputs to determine the overall reproductive behavior of the entire birth cohort. Finally, limitation practices can be introduced in a similar manner, employing separate simulations for subgroups of women following different contraception practices and then computing a weighted average. Variations with age in natural fecundability, risk of spontaneous abortion, and the mean postpartum infecundable period can all be altered to fit historical conditions. A model male life table is used to estimate the risk of widowhood by age. Other model modifications are also possible.

To test the adequacy of his model, Bongaarts attempts to fit its output to data taken from eighteenth-century Canadian genealogies compiled by C. Tanquay in the late nineteenth century from censuses and parish registers. Excluding genealogies with missing data and those containing marriages disrupted by death or divorce before the end of a wife's reproductive period (age 45), Bongaarts obtained the complete reproductive histories of 512 marriages that took place between 1700 and 1750. It may be reasonably assumed that this is a sample from an approximately natural fertility population.

Model options and values of the input variables have to be chosen. How does Bongaarts go about this task? First, fecundability is assumed to be heterogeneous. Three equal-sized subcohorts with fecundabilities set, respectively, at 50%, 100%, and 150% of the mean value at all ages are used. This distribution was chosen because it closely approximates those identified in three other approximately natural fertility historical populations. The model's standard age pattern was employed in an unmodified form for all of the input variables with the exception of the distribution of age at marriage, where the observed pattern was used. The fecundability parameter was taken from a previous study. The mean risk of spontaneous abortion was estimated to be 0.24. The mean duration of the postpartum infecundable period was determined to be 9.6 months by constraining the total fertility rate output by the model to equal that of the data (6.46 children). The mean postpartum infecundable period was adjusted to a value that ensured the best fit of the model to the data. Since all of the input assumptions and parametric adjustments fall within plausible ranges, the model can be evaluated with a fair degree of confidence and realism by using chi-square tests to compare simulated distributions with observed distributions.

Age-specific birth rates for single-year age groups, the parity distribution at age 50, age-order-specific birth rates for single-year age groups, and annual and monthly duration-specific birth rates are found to correspond quite well. This suggests that despite our lack of knowledge regarding the minute details of the reproductive process, the assumptions and hypotheses incorporated in Bongaarts's model appear to be fairly accurate. A model of this type could be used to evaluate hypothetical historical outcomes resulting from changes in factors such as the mean age at first marriage, mortality rates, breast-feeding practices (affecting the duration of postpartum amenorrhea), or various family limitation options. The consequences of deviations from approximately natural fertility conditions within different historical contexts could therefore be studied under quasi-experimental circumstances.

The Relationships between Changes in Fertility and Mortality

The degree to which changes in mortality effect changes in fertility is of considerable theoretical and empirical interest since the balance of these forces (in the absence of migration) determines the rate of population growth or decline (Preston, 1978: 1). As noted earlier, effects determining birth intervals become translated into fertility rates.

Various models have been proposed to demonstrate the manner in which internal effects due to variations in infant mortality can determine total fertility rates (TFR). A model proposed by Preston (1978: 8) views the TFR of a woman as the ratio of the length in months of her reproductive period to the mean number of months between births. This model is as follows:

$$\text{TFR} = N/[W + S_0 + IMR(S_1) + (1 - IMR)(S_2) + K(W + S_3)] \tag{18.7}$$

where the interbirth interval in the denominator has several components. The terms in Eq. (18.7) are defined as follows: N is the length of a woman's reproductive life; W is the average waiting time until pregnancy for a susceptible woman; S_0 is the duration of sterility during a pregnancy that issues in a live birth; S_1 is the duration of sterility following a live birth that results in an infant death; S_2 is the duration of sterility following a live birth that results in a surviving infant; S_3 is the duration of sterility during and following a pregnancy that terminates in a fetal death; IMR is the infant mortality rate; and K is equal to the odds that a pregnancy will result in a live birth rather than a fetal death.

John Knodel's (1978) review of evidence from individual level data on the effect of infant and child mortality on fertility in historical European populations is a fine example of ingenious inferences drawn from data that at first appear opaque to the questions he poses. Some of the questions are

1. Do the results of contemporary studies of the influence of breast-feeding on postpartum sterility indicate that the differences in birth interval sizes found in preindustrial populations can be attributed to the physiological effect of infant mortality alone?
2. How large a reduction in fertility would result from the physiological effect of infant mortality alone if infant mortality levels dropped sharply?
3. Can family history data be used to show that infant mortality affects the size of birth intervals independently of physiological effects?

In response to the first question, Knodel concludes that all studies that work with direct evidence on lactation postpartum amenorrhea show that breast-feeding prolongs the duration of postpartum sterility, but that variations in the size of this effect are so substantial as to preclude the possibility of identifying the extent of the impact of lactation alone on fecundability. It appears necessary to take into account other factors affecting this relationship, such as the nutritional level or the average age of death of infants before their first birthday.

The physiological effect of a large reduction in infant mortality upon the average birth interval can be estimated. To demonstrate how to do this, Knodel sets up a hypothetical situation in which two cohorts of women marry at the same age and cease childbearing at the same age. If in the first cohort 25% of children die before age 1, and in the second cohort 5% die before age 1, the proportionate difference in the number of second or higher-order births between the two cohorts will only be about 7%. Since each cohort has the same number of first births, the difference in the total number of births would be even less. If infant mortality was higher than the 25% assumed in this example, the practice of prolonged breast-feeding would tend to lower the effect of a reduction in infant mortality.

Knodel responds to the third question by showing that available family history data reveal a general pattern: The interval between a second and third birth is *shorter* if the first child dies in infancy rather than survives. This effect is *independent* of the physiological effect of breast-feeding and suggests that infant mortality affects the length of birth intervals in a unique manner. That this effect is observed in what may be presumed to be approximately natural fertility populations indicates that there might have been some attempt to control the timing of births. A tentative implication of Knodel's review of historical evidence on the relationship between infant mortality and fertility is that "once family limitation is introduced into a population and starts to spread, couples who have unfavorable experiences with child mortality will be more resistant than couples with favorable experience to practice birth control [1978: 43]." Note that Knodel's biometric approach does not entail construction of formal mathematical models. He tries to achieve conceptual understanding of reproductive processes and isolate relatively easily observed effects with tabular data.

That sharp drops in European mortality and fertility rates took place in many areas during the nineteenth and early twentieth centuries, often within the relatively short time span of two generations, has suggested that the drop in mortality rates is causally related to the fertility transition (Davis, 1963). The Princeton European Fertility Project, initiated about a decade ago, was designed to employ aggregate-based data to describe the decline in fertility in each of more than 700 European provinces, using a set of uniform indexes. Poul Matthiessen and James McCann (1978) draw upon a number of the Princeton Project studies to assess the status of arguments relating the fertility transition to mortality reductions. These include the following issues: Did the decline in infant and child mortality systematically precede the decline in fertility? Could pretransition Europe be legitimately characterized as having a steady-state balance between mortality and fertility? Is there any real correlation in the amounts of change in mortality and fertility? In responding to these questions, Matthiessen and McCann reach a general conclusion:

> The relevant information in the national reports of the Princeton project do not point to any general, positive association of the vital forces in the years preceding the demographic transition. In the absence of such an equilibrium, any causal connection must be understood in terms of events and relations more or less specific to the period of transition, for example, the diffusion of contraception and the general process of modernization [1978: 67].

These sentiments are echoed in another review of the Princeton Project by Michael Haines: "We now perhaps realize more firmly that the transition is really a collection of variant patterns of fertility and nuptiality changes and that the relationships between demographic and socio-economic variables are not constant or even very predictable in shape and magnitude [1978: 169]." Thus results from the Princeton Project seem to suggest that a purely biometric model, linking fertility and mortality, would be unlikely to have very much explanatory significance.

If a causal model can be constructed to account for the purely biometric aspects of the association between infant–child mortality and fertility, relevant statistical correlations must be processed in a manner that remove spurious and "nuisance" effects produced by other variables. William Brass and J. C. Barrett (1978) discuss the difficulties inherent in such an endeavor. They propose a microanalytic simulation approach that aids in the resolution of some of the more important problems. A variety of factors may confound surface effects presumed to link infant–child mortality and fertility. Under certain historical conditions, a feedback loop may exist between the two variables. Although it seems more likely that lowered infant–child mortality leads to lowered fertility, a weaker but statistically significant reverse effect might also be present. Nonvolitional influences arise from the nutritional level and health of women, as well as from periods of postpartum infertility. Volitional effects may include factors such as the frequency of intercourse, cultural norms regarding ideal family size, and periodic separation of spouses under circumstances of seasonal migratory labor.

Aggregate studies of infant–child mortality and fertility typically use groups of families. But if these families are socioeconomically heterogeneous, distinctive interaction patterns for socioeconomic subgroups are likely to be jumbled together, rendering less meaningful the interpretations of overall indexes such as those employed in the Princeton Project. A cross-sectional investigation of family aggregates at a given time and/or serially over time is a possible approach. Here infant–child mortality would ordinarily be used as an explanatory variable in a regression analysis of fertility. Although temporal considerations may permit some inferences to be drawn regarding the directionality of effects, autocorrelation present in serial cross-sectional analyses and the probable influence of other important factors make this approach appear promising. Use of time series for a set of geographically distinct aggregates, all of which are subject to similar socioeconomic causes but with variations in the strength and timing of the impacts of those causes, would be a more fruitful research strategy to tease apart subtle influences.

Since changes in marriage patterns seem to be relatively unrelated to factors such as infant–child mortality that influence family size, age-standardized marital fertility should be used rather than cruder fertility measures, unless there is little variation in age and marriage patterns. The Princeton Project uses indirect standardization based on the marital rates of twentieth-century Hutterites. Cohort rather than time-period measures might be considered since the influence of early childhood mortality would appear in the subsequent activity of the cohorts of women who experience an infant death during their ages of highest fertility. But socioeconomic influences might have a different time lag, and variations in female response times might conjointly obscure the biometric nature of any infant–child mortality effect.

This is clearly a very complex research problem. No definitive study exists. To investigate the possible impacts of various biases upon a biometric analysis of infant–child mortality and fertility relationships, Brass and Barrett (1978: 228–233) developed a Monte Carlo simulation model to generate female reproductive histories that have no volitional family limitation present. Their analysis points to the importance of what appear to be "chance artifacts" when the number of births per woman varies for a fixed exposure to risk of pregnancy and when infant–child mortality is examined in relation to mean family size. The model is quite limited, however, since nonvolitional, physiological, and socioeconomic factors are ignored. Future microanalytic simulation models can be expected to include these factors as aids in the interpretation of purely biometric interactions between infant–child mortality and fertility.

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19
Evolutionary–Ecological Models

Theories of social evolution have fascinated scholars since the time of Heraclitus and Aristotle to Compte, Marx, and contemporaries such as Gerhard Lenski (1975), Robert Nisbet (1970), Charles Tilly (1975), and Immanuel Wallerstein (1974). The concept of directional social change has remained one of the most enduring and debated in the history of human thought.

Immanuel Wallerstein's *The Modern World-System: Capitalist Agriculture and the Origins of the European World-Economy in the Sixteenth Century* (1974) offers convincing evidence of the seriousness and sophistication with which social scientists are returning to the macrolevel study of historical phenomena. Wallerstein is quite explicit in making the claim that "the only road to nomothetic propositions is through the historically concrete [1974: 391]." The old political units of the nation–state are set aside in favor of an ecologically differentiated division of labor containing three main zones: core, semiperiphery, and periphery. The zones are integrated by an international economic system designed to reward disproportionately the core with surplus commodities and financial resources. The evolution of early modern Europe is thus accounted for by an ecological–evolutionary model in which international domination plays a decisive part.

Despite flaws pointed out by his critics (Janowitz, 1977; Skocpol, 1977; Thirsk, 1977), Wallerstein's efforts are pioneering in character and richly controversial. Grand evolutionary models such as Wallerstein's are intellectually exciting material. They need to be taken much more seriously by historical demographers, particularly those working with relatively small, geographically circumscribed problems where a sense of the scale and influence of global historical trends tends to be lost. The vast majority of evolutionary–ecological models constructed by historical demographers may not match the same degree of temporal and spatial scope found in Wallerstein. Nonetheless, there is a sense in which historical demographers should be quite sympathetic to the overall theoretical and empirical goals of scholars such as Wallerstein. Historical demographers can make significant theoretical contributions towards confirming or disconfirming Wallerstein-like models. In so doing, they will be moving toward the type of synthesis characteristic of the *Annales* school, discussed in Chapter 21. The premises and foundations of many theories of social evolution and change invariably include population processes as a key variable. Thus, a choice among existing theories may have profound implications for the type and style of research undertaken by a historical demographer, the nature of the hypotheses tested, and global interpretations of population histories.

Evolutionary Theory

Six major premises seem to capture the most influential features of evolutionary theory (Nisbet, 1970: 166–188). First, *change is natural.* Structure is structure-in-change. Statics and dynamics are inseparable in the actual observation of historical populations. A basic research objective is, therefore, to uncover the causal roots of ongoing change. Obstructions to growth or social development are abnormal historical phenomena. Second, *change is directional.* It takes place as a succession of differences in time within a persisting identity. Theories of social evolution are primarily concerned with capturing the nature of that identity. Auguste Compte's law of three stages, Georg Friedrich Hegel's view of the spirit of freedom, Karl Marx's analysis of the direction of social–historical evolution, Alexis de Tocqueville's treatment of the inexorable progress of equality, Sir Henry Maine's concept of the transition from status to legal contract, Herbert Spencer's notion of the process of increasing heterogeneity, Lewis Henry Morgan's stages of savagery, barbarism, and civilization and Emile Durkheim's notion of the shift from mechanical to organic solidarity—all represent attempts to uncover universal patterns of social evolution. Third, *change is immanent.* In Baron Gottfried Leibniz's view "each created being is pregnant with its future state, and that it naturally follows a certain course if nothing hinders it [1898: 44]." Social evolutionists are most often concerned with the discovery of the determinants of change that are immanent in the structure of societies under investigation. For Marx, "No social order ever disappears before all the productive forces for which there is room in it have been developed, the new, higher relations of production never appear before the material conditions of their existence have matured in the womb of the old society [1904: 13]."

Four, *change is continuous.* The idea of continuity, involving logical gradations of steps within a single series is one of the most fundamental in Western thought. Charles Darwin's theory of natural selection is grounded in this conception of change: "As natural selection acts solely by accumulating slight, successive, favorable variations, it can produce no great or sudden modifications; it can act only by short and slow steps. Hence the canon of *Natura non Facit Saltum*, which every fresh addition to our knowledge tends to confirm, is in this theory intelligible [1936: 361]." Five, *change is necessary*. If social evolution is directional, immanent, and continuous, it logically follows that it is necessary. Hegel writes that development is a property of things that "presents itself not as an exclusively dependent one, subject to external changes, but as one which expands itself in virtue of an internal, unchangeable principle [1896: 57]." Darwin also saw necessity in evolution: "Each creature tends to become more and more improved in relation to its conditions. This improvement inevitably leads to the gradual advancement of the greater number of living beings throughout the world [1936: 93]." Six, *change proceeds from uniform causes*. The principle of uniformism is derived in part from the eighteenth-century theory of natural history. The premise that nature must be consistent and uniform was a prime factor in the attack of nineteenth-century agnosticism on Christian fundamentalism. The theology of creation in Christianity was viewed as a "catastrophic" thing of the past and therefore to be doubted. This notion dovetailed nicely with Darwin's argument that natural selection, a single uniform process, could explain biological evolution. The present contains the processes of the past. Kant, Hegel, and Marx all found conflict internal to societies to be the uniform cause of their development. Kant expressed this idea as follows: "The means employed by Nature to bring about the development of all the capacities of men is their antagonism in society, so as this is, in the end, the cause of a lawful order among men [1963: 15]."

These six conceptions of change are fundamental to most theories of social evolution. Nisbet's basic thesis in *Social Change and History* (1970) is that the application of evolutionary theory to social phenomena is based on the metaphor of growth and analogies between the life cycles of the organic world and those of human societies. He concludes that the contemporary theory of neo-evolutionism is "singularly without merit when it comes to our understanding of the nature of change, the conditions under which change takes place, and the effects of change upon social behavior [1970: 270]. He challenges each of the six previous premises by arguing the following:

1. Fixity, not change, is natural.
2. Directionality in change is inescapably subjective.
3. Changes resulting from self-contained sources in societies are usually small and frequently cancel themselves out over the course of time.
4. There is no historical evidence that macrochanges in time are the cumulative results of small-scale, linear microchanges.
5. There is no necessity in any pattern of change if our attention is fixed on the social behavior of human beings in time and place.
6. To make uniform processes serve as the principal causes of social change in time will prove to be at least as futile as such processes are today deemed to be in geology and biology.

Perhaps the best rejoinder to Nisbet and other antievolutionists appears in Gerhard Lenski (1976). He argues that Nisbet makes almost no reference to empirical research in archaeology where evolutionism is a dominant paradigm that rests neither on growth metaphors nor on organismic analogies. Lenski agrees that the hypothesized patterns of growth and development found in evolutionary theory have historical exceptions. For example, Mayan civilization, far from evolving, simply disappeared. Neo-evolutionary theorists make an important distinction between specific and general evolution (Sahlins and Service, 1960). Although specific evolution is concerned with individual cases such as the Maya, general evolution deals with the *frequency distribution* of different groups or societies. To disconfirm a hypothesis such as the directionality of increasing population size on the level of general evolution, requires that there be no trend with respect to the central tendencies or the upper limit of frequency distributions. As Lenski points out, we should call a halt to the practice of citing individual deviant cases as disproof of propositions about large populations or social entities. The existence of a few couples with no children would not in itself serve as adequate evidence for disproving the existence of a natural fertility regime in a context of several hundred marriage partners.

Lenski responds to Nisbet's antievolutionist premises in the following way. Is fixity more normal than change? Social change has been more evident at certain times in human history than others. This is not merely a random phenomenon. Historical evidence seems to suggest that the rate of social change has been steadily increasing since the beginnings of human societies. Nisbet's notion of fixity best describes human societies for the Lower and Middle Paleolithic. Is long-range directionality an illusion? Obviously, unpatterned events arise in human history in response to unpredictable contingencies. Evolutionists, however, claim that history is not all "noise" but that "signal" (i.e., meaningful information) is also present.

Is there a single master trend underlying most if not all of the trends observed in the record provided at this moment by archaeology and historical demography? Lenski answers in the affirmative, arguing that growth in the amount of technological information has historically been the dominant factor permitting populations to manipulate and transform their environments. There are, of course, documented cases of societies in which societal and technological evolution do not appear related. However, these cases do not alter the fundamental shape of the frequency distributions associated with the trend toward increasing growth in technological information.

Is social change immanent, or is it due to external forces? This is one of Nisbet's false dichotomies. Evolutionists often chart a middle ground between pure immanence and pure environmentalism. Is social change really noncumulative? Nisbet's view that there is no historical evidence that macrochanges in time are the cumulative results of small-scale, linear microchanges would seem to be erroneous. The growth of population and the growth of the division of labor contradict his position. Allegedly noncumulative patterns of change, even of the scope of the fourteenth-century Black Death that decimated many European populations, turn out to be short-run deviations in long-term trends. Is change devoid of necessity? Most contemporary evolutionists use probabilistic rather than deterministic formulations. Evolutionary theory is designed to offer probabilistic answers to questions regarding fundamental trends in human history. It deals with the behavior of aggregates, not individual units. Is uniformitarianism passé? Catastrophism, as an alternative extreme view of change, sees human history as the product of a series of random catastrophic events, such as plagues, famines, and floods. Contemporary evolutionary theory steers between uniformitarianism and catastrophism, adopting a perspective of "emergentism." This theoretical approach argues that uniform processes operate over long periods of history, but that the working out of these processes may lead to the emergence of new subprocesses that may ultimately take precedence over earlier subprocesses (see Lumsden and Wilson, 1981: 343–364).

Is the new evolutionism really *not* new? Lenski points to four important differences between the older and the newer evolutionism. First, the new evolutionism rests on a far wider and more reliable foundation of archaeological and historical demographic facts. Second, whereas the older, nineteenth-century versions of evolutionism often identified "progress" with moral progress, contemporary theorists use the term *progress* to refer to directional trends and to define social evolution as growth in the amount of symbolically coded information and its consequences. Third, earlier eclectic and racialist explanations have yielded to materialist explanations. Lenski maintains that the majority of the newer evolutionists explain the basic trends and patterns of human history by reference to some combination of the following: "(*a*) the human genetic heritage, (*b*) the technologies our species have fashioned to enhance this heritage, (*c*) the biophysical environment, and (*d*) intersocietal selection in the form of military and economic warfare [1975: 147]." Finally, contemporary theorists tend to formulate their theories in probabilistic, not deterministic, forms. In taking the signal-to-noise problem seriously, "period" historians must beware of denying the existence of signals whose presence may be obscured by their choice of time frame. Evolutionists, on the other hand, need to acknowledge the existence of "noise" in human history and resist the dangers of carelessly extrapolating theoretical principles at the level of general evolution to the level of specific evolution.

Sociobiological Theory

The fundamental premise of sociobiological theory is that "no species, ours included, possesses a purpose beyond the imperative created by its genetic history [Wilson, 1978: 2]." If the phenomena of historical demography could be "biologicized" within the framework of sociobiology, they would each be weighted for their adaptive significance and then related to the basic principles of population genetics. The prolegomenon of sociobiological theory is laid out in Figure 19.1. Edward O. Wilson describes the future outline and direction of population research from a sociobiological perspective as follows:

> The evolution of social behavior can be fully comprehended only through an understanding, first, of demography, which yields the vital information concerning population growth and age structure, and second, of the genetic structure of the populations, which tells us what we need to know about effective population size in the genetic sense, the coefficients of relationships within the societies, and the amounts of gene flow between them. The principal goal of a general theory of sociobiology should be an ability to predict features of social organization from a knowledge of these population parameters combined with information on the behavioral constraints imposed by the genetic constitution of the species. It will be a chief task of evolutionary ecology, in turn, to derive the population parameters from a knowledge of the evolutionary history of the species and of the environment in which the most recent segment of that history unfolded. The most important feature of the prolegomenon, then, is the sequential relation between evolutionary studies, ecology, population biology, and sociobiology [1975: 5–6. Reprinted by permission from Edward O. Wilson, *Sociobiology: The New Synthesis* (Cambridge, Mass.: Harvard University Press, 1975. Copyright © 1975.].

Although many of the theoretical linkages that Wilson identifies are real and establish a variety of new directions for interdisciplinary research in historical demography, several of his speculative pronouncements appear premature, possibly obscuring the outlines of an emerging synthesis of these fields (see Quadagno, 1979).

Ecological Theory

The field of ecology analyzes three levels of organization:

1. The ecology of *individuals* investigates the methods whereby individuals survive, acquire resources, and interact with their environment.
2. The ecology of *populations* focuses upon the growth of populations and competition between populations for environmental resources.
3. The ecology of *communities* is concerned with how a collection of populations or subgroups coexist in their environment as an ecosystem.

A key research question involves the discovery of conditions under which ecosystems will have similar patterns of organization. Evolutionary ecology represents a synthesis of evolutionary theory with ecological research on historical population–environment interactions.

A fundamental equation in population ecology describes population growth as an explosive phenomenon:

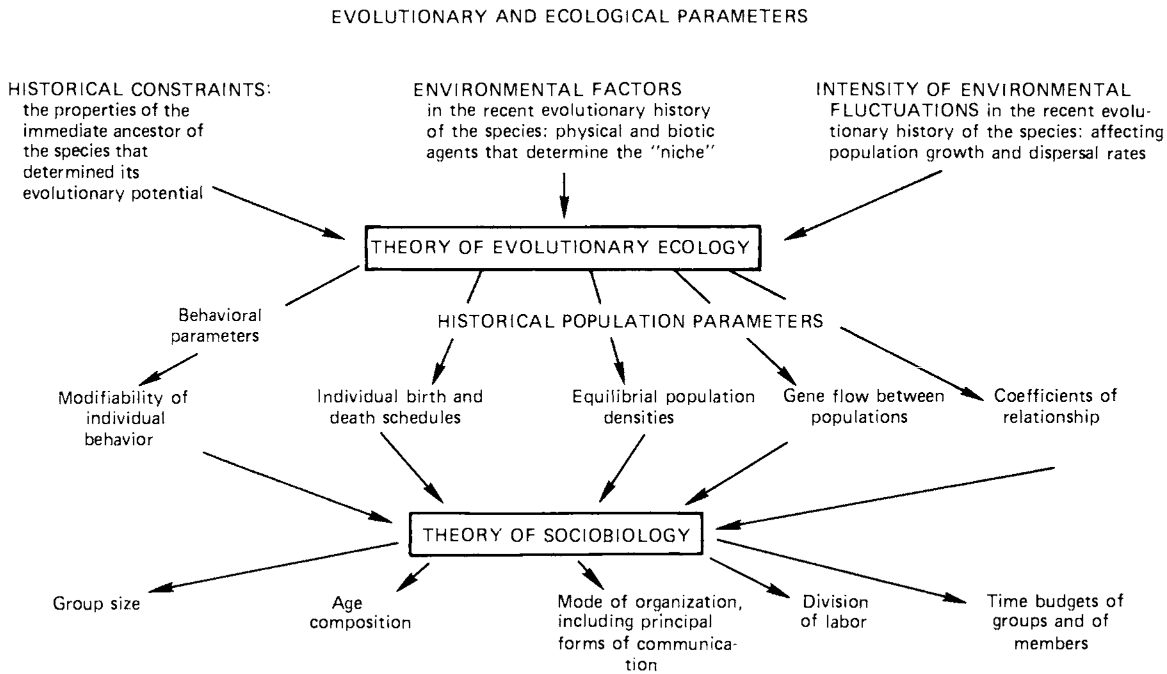

Figure 19.1. *The connections between evolutionary, ecological, and historical population parameters. (Adapted from Edward O. Wilson,* Sociobiology: The New Synthesis *(Cambridge, Mass.: Harvard University Press, 1975), p. 5. Copyright © 1975. Reprinted by permission.)*

$$dN(t)/dt = \begin{pmatrix} \text{an individual's contribution} \\ \text{to population growth} \end{pmatrix} N(t), \qquad (19.1)$$

where $N(t)$ is a population's size at time t; dN/dt is the rate at which its size is changing as expressed in the notation of differential calculus. In words, Eq. (19.1) says that the growth rate of a population is equal to the product of an individual's contribution and the number of individuals. Let us assume that an individual's contribution is equal to a constant r, the intrinsic rate of increase, and that we substitute r into Eq. (19.1). This differential equation can be solved if we can find a function whose slope at each point equals the product of r and the value at that point. To do so involves "integrating" the equation. The solution is

$$N(t) = e^{rt}N(0). \qquad (19.2)$$

This equation tells us that the population size at time t can be determined by raising e to the rtth power and multiplying that value by the initial population size at $t = 0$, $N(0)$. Equation (19.2) will exhibit exponential growth. The "speed" at which population growth occurs will increase with increasing population size.

Since all human populations are in principle capable of exponential growth, a central concern of the ecological approach is to construct causal theories that explain why exponential growth does *not* occur within certain historical–environmental settings. The causal factors included in an ecological model may be density independent, density dependent, or some combination of both. Density-independent factors are unrelated to existing population size. They might include certain types of diseases (see, for example, Lilienfeld, 1976) or environmental fluctuations such as periodic droughts. Examples of density-dependent factors include the direct effects of resource depletion, leading to increased mortality, as well as indirect effects producing territorial expansion in the search for new resources.

Since historical populations can be expected to have a variety of density-independent and density-dependent factors affecting them, they will require specially tailored models. The logistic equation is the simplest model incorporating density-dependent population growth. We shall first describe this model and then consider its limitations. Although a variety of functions might be used to describe a density-dependent process, let us assume that an individual's contribution to population growth is a linear function of population size, N:

$$\begin{pmatrix} \text{an individual's contribution} \\ \text{to population size} \end{pmatrix} = r - (r/K)N, \qquad (19.3)$$

where the y intercept is r, the intrinsic rate of growth and the slope is $-r/K$, where K is an as-yet-unnamed parameter. Substituting Eq. (19.3) into Eq. (19.1) yields:

$$dN(t)/dt = [r - (r/K)N(t)]N(t)$$
$$= [1 - N(t)/K]N(t). \qquad (19.4)$$

This is known as the logistic equation and states that the fertility of an individual decreases as a linear function of population size. Integrating Eq. (19.4) gives:

$$N(t) = K/[1 + (K/N(0) - 1)]e^{-rt}, \qquad (19.5)$$

where K can now be interpreted as an equilibrium population size parameter, defined as "the carrying capacity." It may also be interpreted as the "amount of renewable resources in the environment in units of the number of organisms these resources can support [Roughgarden, 1979: 305]. Looking at Eq. (19.5), we can see that as N approaches K, the growth rate approaches zero. When $N = K$, the growth rate is zero and the population size remains invariant. If N approaches zero, Eq. (19.5) approaches the form of Eq. (19.2), and the population growth rate is almost entirely determined by r. Unlike exponential growth, logistic or S-curve growth levels off at a value equal to the carrying capacity K, of the environment.

We use the expressions K- and r-selection to denote whether density-dependent or density-independent factors determine the outcome of population size. For example, r-selection would characterize a population subject to recurrent catastrophes in its environment, such that it is never able to achieve its equilibrium value. Thus, it is in principle possible to study the level of density-independent mortality in a population's environment and draw inferences regarding the probable sizes of its r and K parameters.

Models that introduce a carrying-capacity factor, limiting the size at which a population can be indefinitely supported by its environment, are often described as Malthusian models. William Petersen (1975), however, has argued that they would be more appropriately labeled Darwinian since Malthus's views were somewhat inconsistent over time and because the theoretical concept of a carrying capacity is quite clearly described in Darwin's theory of natural selection. The idea of a carrying capacity for a population is derived from the notion that organisms can exist only within a limited range of physical conditions with access to at least a minimum amount of energy and critical materials (Hardesty, 1977: 196).

The central problem in trying to estimate carrying capacities for historical populations is that single limiting factors, such as the total land available to feed a population, may be extremely complex and difficult to measure (see pp. 50–51). Available land will be a function of human technology and habitat and vary considerably from one geographical area to another. Furthermore, in societies with important degrees of social inequity, particular individuals or subgroups will have unequal access to products of the land. The institutional organization of a society may be a critical factor. Robert Adams (1965), for example, has shown how the carrying capacity, population size oscillations, and maintenance of irrigation networks in the Lower Diyala Basin in Iraq are all related to the political instability resulting from dynastic changes. Differing land tenure customs can also affect carrying capacities in areas with otherwise identical technologies and habitats. Estimates of carrying capacities must include the degree of integration of the economy of a local area under study into regional, national, and international market systems (see, for example, Wallerstein, 1974). The static concept of a carrying capacity as found in logistic population growth models is clearly an oversimplification of historical realities.

When the ecological notion of a carrying capacity is placed into an evolutionary context, conditions are suitable to construct "population pressure" models. Robert Carneiro (1970), for example, uses a population pressure model to explain the origins of Mesopotamian and Mesoamerican societies. The basic argument underlying pressure models is that when a population's size places "pressure" on resources, the population will attempt to change its relationships to its environment in a manner so that a greater population density can be supported (Glasgow, 1978: 40). R. G. Wilkinson (1973) has developed a population pressure theory containing a series of different stages. First, the stability of an existing ecological system is upset by population growth and environmental change. Technological and social innovations arise to relieve stress, but poverty increases. This leads to a second stage of innovations that results in elaborate economic development. To support this theory, Wilkinson considers English demographic history from the twelfth century to the present. He analyzes the three periods of most acute population pressure, around 1300, 1600, and the late eighteenth century, to find that events in each instance appear to follow the expected theoretical patterns.

The Concept of Stability

Stability is another important concept in ecology, which is illustrated in the Leslie model (Keyfitz, 1977). Let us assume that we are able to census a population every 10 years and that its age structure is divided into 10-year classes. Assume also that age-specific mortality data are available in the form of age-specific conditional probabilities of survival. If x is the age class index (which runs from 0 to w), P_x will be defined as the proportion of individuals alive in age class x who survive over the time interval between the censuses. Using 10-year intervals implies that if t is 1740, then $t + 1$ is 1750, and $t + 2$ is 1760, and so on. If $n_{x,t}$ is defined as the number of individuals in age class x at time t, then

$$n_{x+1,t+1} = P_x n_{x,t}, \qquad (19.6)$$

where $x = 0, 1, \ldots, w - 1$. Equation (19.6) states that a proportion of individuals in age class x at time t survive to enter class $x + 1$ at time $t + 1$. Note, however, that this expression does not allow us to predict the number of individuals in the youngest age class at $t + 1$. Fertility data must be introduced to obtain this quantity. If we can determine the average number of offspring born to a woman of age x who survives until the next census, F_x, the number of individuals in the youngest class at time $t + 1$ will equal the sum of the children for women of all ages:

$$n_{0,t+1} = F_0 n_{0,t} + F_1 n_{1,t} + \cdots + F_w n_{w,t}. \tag{19.7}$$

Equations (19.6) and (19.7) provide a model to predict a population's age structure over time. If these equations are iterated over a long enough historical interval, it can be shown that,

$$n_{x,t+1} \doteq \lambda n_x, \tag{19.8}$$

where λ is a parameter that does not depend on x. Equation (19.8) states that the *proportion* of the total population in each age class remains unchanged. In other words, the population's age distribution reaches an equilibrium. This is known as a *stable age distribution*, and it is determined entirely by the values of P_x and F_x. Since each age class increases by a factor of λ with each iteration in a stable age distribution, the total population size will also increase by the same factor. Thus,

$$N_{t+1} \doteq \lambda N_t, \tag{19.9}$$

and henceforth the total population size over time will be given by

$$N_t \doteq \lambda e^t N_0. \tag{19.10}$$

But since we already know that N_t equals $e^{rt}N_0$, we can define λ to be equal to e^r. This interesting result demonstrates that a population enters a period of exponential growth only *after* it achieves a stable age distribution. Prior to this point, the initial age distribution is a determinant of population size, but afterward population growth can be predicted solely from age-specific mortality and fertility data. This finding is known as the Leslie model. Note that it contains no density-dependent factors. Yet, we know historically that human populations simply do not increase indefinitely without some type of density-dependent mechanism asserting itself. Historical demographers need population dynamic models that incorporate both ecological density dependence and age structure. But even rather simple mathematical models of this type rapidly lead into a conceptual and computational terra incognita (Guckenheimer *et al.*, 1977; Roughgarden, 1979: 345).

Randomness in Ecological Settings

Two different causes of random population fluctuations can be distinguished (May, 1973). "Demographic stochasticity" is said to be present if population size fluctuates because the number of offspring only *on average* replace adults who die. "Environmental stochasticity" occurs when fluctuations take place in the parameters that describe a population's environment. A model incorporating both types of stochasticity appears in Keiding (1975). Stochastic processes can sometimes be approximated by diffusion processes, and there are currently two methods (the Ito and the Stratonovitch) of computing a population dynamic model with a diffusion equation (see Roughgarden, 1979: 379–391). Both methods transform the logistic equation to allow stochasticity to be introduced. Analysis of a diffusion equation allows one to determine the statistical distribution of population sizes (if it exists) and whether and how fast populations are tending to extinction due to environmental fluctuations. Three situations involving the logistic equation are of interest: (*a*) only *r* fluctuates; (*b*) only *K* fluctuates; and (*c*) both fluctuate together.

In many historical instances, it appears that a population's variability is affected by environmental autocorrelation and is to that extent predictable. Roughgarden (1979: 391–408) shows how population dynamic models may be constructed for a first-order, autoregressive, carrying-capacity process. He derives a number of interesting mathematical relationships between a population's ability to "track" fluctuating resources and the predictability of its environment. Variations in the spatial correlations or the "patchiness" of a population in a fluctuating environment may also be studied by extending a stochastic population growth model to include spatial variation. This results in a "dispersal" model. Roughgarden (1979: 405–407) shows that the qualitative effect of decreasing *r* in such a model is to cause shorter and less distinct "patches" of population abundance. The model shows that "patchiness" in a population's spatial distribution is an inevitable outcome of dispersal in a stochastic environment, *regardless* of whether the environment itself possesses patchiness. This mathematically derived result may account for the presence of patchiness in the spatial distributions of historical populations when no other explanation seems viable.

Synthesizing Evolutionary and Ecological Theories

Due to the vast vistas of time considered and its empirical tradition, archaeology stands out as the discipline that has most thoroughly incorporated an explicit evolutionary–ecological perspective. The sources of demographic information and the analytical sequence of demographic investigation in archaeology are depicted in Figure 19.2. Although demographic archaeology is only in its first stages of development, it has provided information

> on the life expectancy of prehistoric populations, rates of population growth during the Paleolithic and the Neolithic, maternal mortality, average local and regional size of hunting–gathering populations, levels of population density under various economic conditions . . . [and] exploded the myth that pre-historic man was always on the verge of extinction and has provided a realistic estimate of the true magnitude of the 'rapid' rate of population increase following the adoption of agriculture [Hassan, 1978: 88].

The theoretical significance accorded an ecological perspective in developmental historical analysis of populations is also evident in many of the works of authors associated with the French *Annales* school. Fernand Braudel's *The Mediterranean and the Mediterranean World in the Age of Philip II* (1976), for example, is structured almost entirely around the dialectic of environment and time.

Research Examples

An important effort to utilize an ecological perspective to study historical hunter–gatherer populations appears in Michael A. Jochim's *Hunter–Gatherer Subsistence and Settlement: A Predictive Model* (1976). The purposes of Jochim's model are to operationalize expectations about how hunter–gatherer populations would use a given environment, compare these expectations to empirical patterns, and to formulate predictions that will allow the model to be applied to various classes of archaeological source materials. The human ecological approach in Jochim's study gives primary consideration to resource-exploitive activities and their implications for settlement patterns and demographic structures. The three subsystems of resource use, site placement, and demographic arrangement are interrelated to give the greatest independence and causative priority to resource-use time scheduling.

Jochim shows how the goals of the resource-use scheduling subsystem are the objectives, found in available ethnographic evidence, guiding a hunter–gatherer population's resource procurement. A primary goal of such a population's economic activities is to provide for its food needs. Consideration of risk minimization in part determines the importance of different resources and activities, as well as site locations. Some degree of suprafamilial population aggregation (about 25 persons) also appears necessary to reduce the work expenditure required for survival to acceptable levels. Exploitation of the natural environment to provide subsistence can be expected to be a primary determinant of the duration and placement of settlements.

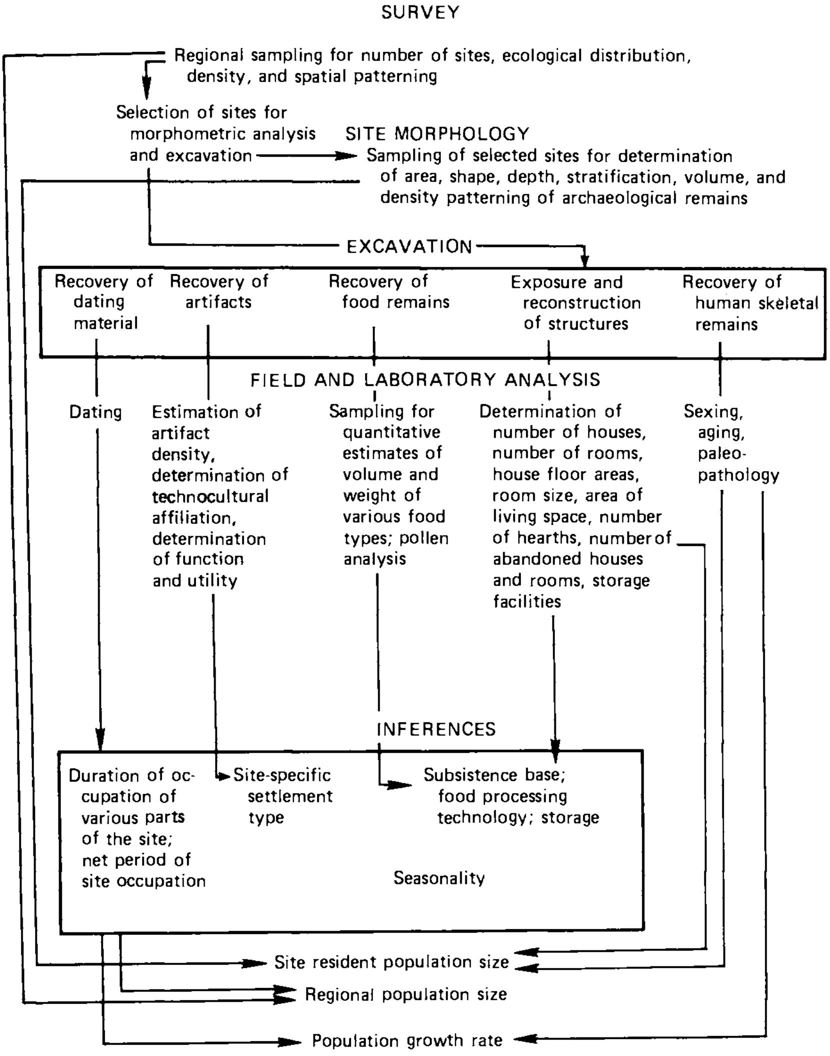

Figure 19.2. *Archaeological sources of demographic data and methods of historical demographic analysis. (Adapted from Hassan, 1978: 89.)*

Besides proximity to resources, settlement decisions of a hunter–gatherer population may be affected by the availability of shelter from the weather, texture and dryness of the ground surface, and a concern for a view of game animals and other migrating hunter–gatherer populations. Thus, the form of settlement patterns can be expected to be adapted to the spatial and temporal resource distributions found in an inhabited area. Jochim (1976: 70) maintains that the objectives governing the size of a hunter–gatherer population would include (*a*) provision of sufficient food to feed everyone; (*b*) resource procurement at low cost; (*c*) resource procurement with high security; (*d*) ensurance of reproductive viability; and (*e*) provision of sufficient social interaction.

Jochim applies his predictive model to Mesolithic hunter–gatherer populations of southwestern Germany. Two main concentrations of sites have been discovered: one consisting of more than 80 individual sites along the former shores of Federsee Lake and the other including a series of caves and shelter sites along the upper Danube, within 40 kilometers of the Federsee sites. A historical chronology for this region has been reconstructed using a microlithic typology, supported by radiocarbon and palynological data.

The main categories of food resources believed to be important include red deer, roe deer, wild boar, beaver, fish, birds, plants, and various smaller game species. Jochim estimates the weights of each type of animal resource, giving consideration to age and sex differences and changes in weight that may have occurred since Mesolithic times. Animal densities are much harder to reconstruct. Due to the vast differences between modern and prehistoric vegetational environments, only rough estimates of densities can be made. Group size and mobility of the different animal species are drawn from recent evidence. Final estimates are shown in Table 19.1. Table 19.2 documents the expected dietary importance of various food resources. The availability and body weights of these food resources vary during the year because of the rutting period, pregnancies, and summer–winter weather changes. Table 19.3 shows expected proportional resource contributions to the monthly diets of southwestern German Mesolithic populations. Aggregation of results from Table 19.3 yields the series of economic resources shown in Table 19.4.

If the major determinant of site location is resource distribution, the structure of economic seasons reconstructed in Table 19.4 should be of some importance in predicting Mesolithic site locations. They might be located closest to the least mobile resources—plants and fish. Since fish may be utilized during all of the

Table 19.1
Estimated Food Resource Attributes for Southwest German Mesolithic Hunter–Gatherer Populations

Resource	Weight (kg)	Group size	Density (animals per km^2)	Mobility (km per day)
Red deer	217.0	13.0	4.0	1.5
Roe deer	34.0	2.5	12.0	1.2
Boar	135.0	13.5	12.0	1.4
Beaver	20.0	5.0	.65	1.0
Fish	1.0	3.0	98.0	.05
Small game	3.6	2.0	103.0	.20

Source: Jochim, 1976: 107.

Table 19.2
Expected Dietary Importance of Food Resources for Southwest German Mesolithic Hunter–Gatherer Populations

Resource	Percentage of yearly diet
Red deer	26
Roe deer	3
Boar	22
Beaver	1
Fish	13
Small game	13
Birds	2
Plants	20

Source: Jochim, 1976: 108.

year's seasons, base camps would be likely to be situated near bodies of water with abundant fish. For the months of January through March, the narrow upper Danube Valley in the Alb is the area producing an overlap of the four most important animal resources. This region also provides the greatest relative shelter and has the least snow cover. In the summer months of June through August, however, there is no zone of overlap of animal resources, and the resource exploitation zones for summer and winter territories do not overlap either. Jochim's analysis of seasonal variations in resource distributions leads him to conclude that the Mesolithic settlement system included at least two base camps during the year, with perhaps two others for the intermediate fall and spring seasons.

Table 19.3
Predicted Resource Contributions to the Monthly Diets of Southwest German Mesolithic Hunter–Gatherer Populations

	Month											
Resource	J	F	M	A	M	J	J	A	S	O	N	D
Red deer	.47	.43	.47	.20	.12	.11	.17	.19	.27	.25	.20	.24
Roe deer	.05	.04	.05	.04	.02	.02	.02	.02	.02	.02	.02	.04
Boar	.31	.27	.27	.11	.11	.14	.16	.17	.18	.20	.36	.36
Beaver	.02	.02	.02	.02	–	–	–	–	–	–	–	.02
Fish	.02	.04	.05	.13	.40	.22	.20	.20	.22	.05	.04	.04
Birds	–	–	.06	.06	–	–	–	–	–	.06	.06	–
Plants	–	–	–	.30	.30	.30	.30	.30	.30	.30	.30	–
Small game	.11	.18	.07	.12	.05	.18	.13	.10	.01	.10	.01	.16

Source: Jochim, 1976: 115.

Table 19.4
Predicted Economic Seasons for Southwest German Hunter–Gatherer Populations

Seasonal clusters (months)					
JFM	A	M	JJA	SO	ND
Red deer	Plants	Fish	Plants	Plants	Boar
Boar	Deer	Plants	Fish	Deer	Deer
Small game	Fish	Deer	Deer	Boar	Plants
			Boar	Fish	

Source: Jochim, 1976: 116.

The carrying capacity of Jochim's study region is defined as the size of its seasonal coresident hunter–gatherer populations, their choices of resource use, and the spatial settings of these resources. To compute the carrying capacity for a particular human population, calculations such as the following are made: If a typical red deer weighs 217 kilograms (kg), it will have a caloric content of approximately 2000 kilocalories (kcal) per kg, and given that only 50% of the deer can be eaten, it will make 217,000 kcal potentially available to human hunters if distributed equally. Assuming a density of four red deer per square kilometer (km), 868,000 kcal are available per square km. Since red deer are presumed to constitute 26% of a southwest German hunter–gatherer population's diet during Mesolithic times, the total diet will be 868,000/0.26 or 3,338,462 kcal. If each hunter–gatherer required on average 730,000 kcal per year, this diet can support 4.57 hunter–gatherers per square km if 100% of the deer are killed and eaten. But if 20% are killed, only 0.91 hunter–gatherers per square km can be supported. Calculations for other resources appear in Table 19.5. Since Jochim's German study region is about 6700 square km in area, the upper limit to the hunter–gatherer populations would be 871 individuals. Additional assumptions and calculations lead Jochim to estimate that individual

Table 19.5
Supportable Hunter–Gatherer Population Sizes per Square Kilometer Based on Different Food Resources and Harvest Success

Resource	100% harvest	20% harvest
Red deer	4.57	.91
Roe deer	18.63	3.73
Boar	28.24	5.65
Beaver	4.99	1.00
Fish	.67	.13
Small game	4.22	.84

Source: Jochim, 1976: 134.

hunter–gatherer populations in the summer would range in size from 54 to 108 individuals. During the winter these populations would disperse into groups of 17–33 individuals. They would use a system of as many as four base camps throughout the year.

Looking at the archaeological findings from the Mesolithic sites stretching along the Danube in the western Alb, around the former shores of Federsee Lake, along the lower Danube, its tributaries, and on the heights of the eastern Alb, significant but puzzling differences appear. But when they are examined in the light of Jochim's ecological model, a coherent pattern emerges on the basis of the probable functional roles of the various sites as elements of a demographic, subsistence-settlement network.

William T. Sanders *et al.*'s *The Basin of Mexico: Ecological Processes in the Evolution of a Civilization* (1979) is a second example of current historical demographic research that uses archaeological estimation techniques. Sanders *et al.* have spent over a dozen years developing map-making procedures to create settlement-pattern maps to study processes of ecological adaptation and socio-political evolution in Mexico. Given reasonably good site conditions and proper excavation strategies and techniques, archaeologists "can provide almost as much data on the demographic characteristics of a prehistoric population as the ethnographer can for a contemporary one [Sanders *et al.*, 1979: 34]."

The basic control provided by their archaeological estimates is population data from post-Conquest sixteenth-century civil tax censuses and ecclesiastical registers. During the period from 1560 to 1610, taxes had to be paid at a rate of one-half peso per year per taxpayer. Censuses were generally drawn up on the basis of taxes collected from eligible taxpayers. Hence, use of these records requires estimating the total population from the sample of actual taxpayers. Estimation procedures were considerably aided by the fact that several total population censuses existed for a number of individual communities in the region. Civil and ecclesiastical censuses were used together to evaluate their respective reliabilities. On the basis of the combined use of these censuses, the population history of the basin showed a marked decline over the entire period from 1519 to 1610. The 1560 population was found to be very close to the rural population between 1900 and 1940 for the same region. An estimate of the absolute carrying capacity of the basin, based on contemporary practices and productivity, correcting for changes in both parameters, turns out to be very similar to the 1519 population estimate based on the censuses.

Next, Sanders *et al.* divided up the history of the basin into equal time units and computed the total residential area of all the settlement sites occupied during each period of time. With such findings, it is in principle possible to create a set of ratios between each of the earlier phases and the later Aztec period. The earlier population sizes could be calculated as a particular fraction of the known population size for the Conquest period. Thus, if there were a dozen Aztec-period sites totaling 100 hectares in a survey area and an earlier Middle-Formation site of 5 hectares, the Middle-Formation population would be estimated to be one-twentieth that of the Aztec population. However, in cases where surface domestic architecture was preserved, the density of remains was found to differ greatly, implying that population density might vary considerably from site to site.

Assuming that artifact densities on residential sites are correlated with house densities, Sanders *et al.* created a scale to estimate population densities. To convert estimates of surface occupation into population size, they assumed that the correspondences between surface density and population, found in contemporary rural villages and during the Aztec period, also correspond to pre-Aztec communities:

> *Scanty-to-light occupation.* Typical of the "compact rancheria" settlement type. Population numbers 200–500 persons per square kilometer (2–5 persons per hectare).
> *Light-to-scanty or light occupation.* Equivalent to the "scattered village" settlement type. Population levels characteristically run about 500–1000 persons per square kilometer (5–10 persons per hectare).
> *Light-to-moderate occupation.* Closely resembling the "compact low-density village" settlement type. Population densities are typically about 1000–2500 per square kilometer (10–25 persons per hectare).
> *Moderate occupation.* Associated with the "compact high-density village" settlement type. Population densities are generally 2500–5000 persons per square kilometer (25–50 persons per hectare).
> *Moderate-to-heavy or heavy occupation.* Typical of the upper range in population density found in the compact high-density village settlement type. Modal population density is about 5000–10,000 persons per square kilometer (50–100 persons per hectare) [1979: 39].

This approach has some clear limitations. For example, it is very difficult to estimate sherd densities for a particular time period in a multicomponent site occupied over several time periods. In addition, estimates of sherd density were based only on subjective visual inspection of the general surface. Other problems, complicating the drawing of inferences regarding population densities from sherd densities, include differential treatment of the ground surface by modern cultivators, differential erosion and alluviation, and the possibility of temporal or seasonal site occupation.

A Late Formative site at Loma Torremote near Cuautitlan was excavated in 1974. The historical population in Loma Torremote resided in walled house compounds with an approximate area of 500 square meters. The compounds included houses, a patio, and a garden area. The dead of all ages and both sexes were buried within the compound. House floors were rebuilt every 15–20 years, and food was stored in underground pits. Sanders *et al.* reconstructed household sizes for each of the levels of a house compound from the burial data. These estimates were then compared to estimates based on house floor areas. Both of these estimates were then checked against artifact consumption ratios and food storage pit usages. A crude mortality rate (CMR) was derived from skeletal samples taken from data reported by Vaillant in the 1930s, based on excavations in El Arbolillo, Zacatenco, and Ticoman. A CMR of 40.29 deaths per 1000 inhabitants per year was found.

At Loma Torremote, individuals were buried directly under house floors, in defunct pits in the patios or in pits near the houses. Sixteen burials were uncovered in three partially excavated compounds for Atlamica phase households. The total number of expected burials in each compound, ΣB_e, was calculated as:

$$\Sigma B_e = b_{ex}(\Sigma b_s)/b_{s_{ex}}, \tag{19.11}$$

where b_{ex} is the total number of excavated burials, Σb_s is the percentage of the total compound space that represents potential burial space, and $b_{s_{ex}}$ is the percentage of burial space excavated. The number of expected deaths, ΣB_M, assuming a constant CMR (as derived from Vaillant's skeletal samples), is given by

$$\Sigma B_M = (\text{CMR})\,(P_x)(T), \tag{19.12}$$

where P_x is a hypothetical population of any size, and T is the study's time interval. A population estimate P for an individual household would be computed as follows:

$$P = \Sigma B_e(P_x)/\mid \Sigma B_M \mid . \tag{19.13}$$

Although the frequency distribution of burials showed little variability in mean population size between households (approximately 5–6 persons), the roofed-over space for the same households varied considerably. Assuming that each household was continuously occupied during the Atlamica Phase, with 5–6 persons per household, a density range of 80–114 persons per hectare would have existed. Since the area covered by Formative household units was approximately 25 hectares, an estimate of the total population for Loma Torremote is 2000–2800 persons.

Settlement sites were classified in a typology using the criteria of site size (derived from measurements of 1:15,000 air photographs), occupational densities (based on field observations), architectural complexities (the number of different kinds of mounds and their spatial arrangement), and location relative to other contemporary sites. The typology included the following categories: supraregional centers, provincial centers, regional centers, large and small nucleated villages, large and small dispersed villages, hamlets, Tezoyuca hilltop centers, large and small ceremonial precincts, salt-making stations, quarries, royal retreats, and indeterminant sites. The greatest weakness of this typology is that site function is not controlled in any systematic manner. Thus, some of the relatively small "villages" and "hamlets" may only have been temporal, seasonal, or even nonresidential in nature. Settlement localities were plotted on a Basin of Mexico map. Major ecological zones were defined to demonstrate settlement-pattern–environmental type correlations.

Having presented a rather detailed description of the settlement history of the

Basin of Mexico over a period of 3000 years, Sanders *et al.* develop a multilineal theoretical paradigm. Their strategy is to propose three lawlike generalizations believed to govern evolutionary development and then to discuss some of the feedback effects of the social system on the operation of these laws. The first law, that of biotic potential, states that humans have the potential to increase constantly in numbers. A second law of least effort postulates that when a set of alternatives for action is available, the option that produces the greatest gain for the least effort will be selected. The third law states that the course of action that produces the minimal risk will be chosen over all other solutions. To test the usefulness of the first two of these generalizations to the problem of the social evolution of the Basin of Mexico, Sanders *et al.* adopt a population pressure model (Logan and Sanders, 1976: 31–178), based on work by Ester Boserup (1965). Their model is as follows:

I. Population growth depends on certain favorable combinations of three factors:
   A. Fertility
   B. Mortality
   C. Migration
II. If interaction of factors in I leads to population increase and subsistence stress, the group may respond by:
   A. Physical and social fission
   B. Increase in food production per unit of space by intensifying use of available resources or by exploiting newly incorporated or newly developed resources within the same physical space
III. II–A will be eliminated as a response and II–B will occur if:
   A. Environment is circumscribed and desirable resettlement locales are either occupied or nonexistent
   B. Environmental factors permit II–B
IV. If II–B does occur, this will then stimulate:
   A. Sedentary residence
   B. Differential access to both agricultural and nonagricultural resources, first within settlements and then between settlements
   C. Intrasocietal and intersocietal competition
V. If IV–A, IV–B, and IV–C occur, then the following processses will result:
   A. Occupational specialization in nonagricultural activities
   B. Further intensification of agriculture, including specialization in agriculture in the first stages of the process
   C. Increase in economic exchange networks and the development or elaboration of managerial institutions
   D. Rank differentiation and, ultimately, class stratification
   E. Political linearization, or the emergence of more numerous, increasingly complex political controls
VI. The rate of development of II–B, IV, and V is affected by:
   A. Population size and rate of growth
   B. Size of the circumscribed region
   C. Resource variability within the circumscribed region
   D. Technological base of production and military spheres of culture
   E. Comparable events and processes occurring in the nearby geographical areas

VII. The stability of, or decline in, cultural complexity will occur when:
  A. Factors in I result in a stable or diminishing population
  B. II–A is operative
  C. III–B does not permit II–B
  D. Circumscribed areas are excessively small or isolated [1979: 370].

To test this model, Sanders *et al.* estimate the carrying capacities for the various regions of the basin in terms of different agricultural systems by applying William Allan's (1965) method of using cultivation, land use, and arable land factors. The settlement survey, the reconstruction of population levels based on it, and direct evidence of the agricultural techniques indicate that population growth, concentrations of populations in large settlements, intensification of agriculture, and the increasing significance of low-level groups in the sociopolitical system are all interrelated during the First Intermediate One-Three time period. Revolutionary events of the First Intermediate Four Phase, subsequent developments in Phase Five and the Middle Horizon, and the shift into the Late Horizon appear to require a more complex evolutionary–ecological model.

A prominent human ecologist, Amos Hawley (1973: 1198), argues that there is no direct relationship between a population and its environment. Forms of social organization intervene between them, so that adaptation is necessarily accomplished through social organization. Consequently, the critical relationship is between social organization and environment. For example, it appears that in the process of technological evolution, a point is reached at which productivity becomes independent of the size of the labor force. Hawley (1973: 1199) speculates that this may be why Simon Kuznets found no more than negligible correlations between population growth and economic growth in the histories of developed societies. The interrelationships between evolutionary and ecological processes are not yet clearly understood. Several more decades of empirical research may be required before theoretical models can be accepted with great confidence. This is not to argue against theory construction but only to caution against underestimating the complexities involved in creating valid causal models of centuries-long civilizational processes.

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20
Socioeconomic Models

It is a necessary but not a sufficient task for the historical demographer to reconstruct the population statistics of past societies and social groups. To understand historical demographic events usually requires analysis that brings out their socioeconomic causal significance. This, in turn, requires the creation of an analytic framework—a theory of socioeconomic and demographic relationships. To the extent that the present is determined by the working out of past processes, such a framework should have some degree of relevance for the understanding of man's current activity as well as that in the past (Kemp, 1978: 4). Historical demography need not be an antiquarian exercise. The socioeconomic and demographic conditions required for the continuing existence of mankind in the face of environmental and adaptational problems may well be clarified by the study of these conditions in the past.

The behavior patterns of historical populations which have existed in different socioeconomic circumstances may be conceptualized as a series of "natural experiments," some of which failed, resulting in extinction, and others which were more or less successful depending upon the importance one attaches to various evaluative criteria. There exist a variety of approaches to the study of demographic phenomena within socioeconomic contexts, entailing research strategies for understanding two different aspects of human life: the behavioral and the mental.

These two aspects may be studied from a dual perspective: first, from the perspective of the members of the population themselves, as revealed in diaries, personal journals, descriptive accounts by contemporaries or inquisitorial records (see, for example, Le Roy Ladurie, 1978; and Cipolla, 1979); second, from the perspective of the outsider, the historical demographer. Scientific analyses are possible in both cases. In the first instance, concepts and distinctions meaningful and appropriate to the population's members are employed, whereas in the second instance, concepts and distinctions meaningful to the historical demographer are utilized. If criteria of empirical replicability and testability are met, either perspective may lead to valid knowledge of mental and behavioral events, although the accounts rendered in each case may be quite different from one another. When conducting research from the point of view of the members of a past population, the strategy is to try to acquire a knowledge of their categories and rules, so as to be able to think vicariously as a member. On the other hand, the application of categories and rules from the data language of science may entail the measurement and juxtaposition of events that members might have considered to be irrelevant. The existence of such divergences are an object of research in themselves.

In this chapter, we discuss several general approaches to the problem of how socioeconomic information on past societies may be used systematically with demographic data to shed light on social development. Having considered such general approaches, we turn to a number of recent works that provide innovative insights into the relationships between socioeconomic development and demographic processes within specific historical societies.

A Framework for Demographic Model Building within Historical Socioeconomic Contexts

The structure of socioeconomic systems is ultimately based upon human genetic, biological, and ecological constraints, and on the distinction between thought and behavior. Every society, every social group, must satisfy certain minimal requirements in order to survive. The major behavioral categories, together with some examples of socioeconomic phenomena that fall within each domain found in human societies, have been conveniently summarized by Marvin Harris:

> *Mode of Production:* The technology and the practices employed for expanding or limiting basic subsistence production, especially the production of food and other forms of energy, given the restrictions and opportunities provided by a specific technology interacting with a specific habitat.
> Technology of subsistence
> Techno-environment relationships
> Ecosystems
> Work patterns
>
> *Mode of Reproduction*: The technology and the practices employed for expanding, limiting, and maintaining population size.
> Demography
> Mating patterns
> Fertility, natality, mortality
> Nurture of infants
> Medical control of demographic patterns
> Contraception, abortion, infanticide

Domestic Economy: The organization of reproduction and basic production, exchange, and consumption within camps, houses, apartments, or other domestic settings.
Family Structure
Domestic division of labor
Domestic socialization, enculturation, education
Age and sex roles
Domestic discipline, hierarchies, sanctions
Political Economy: The organization or reproduction, production, exchange, and consumption within and between bands, villages, chiefdoms, states, and empires.
Political organization, factions, clubs, associations, corporations
Division of labor, taxation, tribute
Political socialization, enculturation, education
Class, caste, urban, rural hierarchies
Discipline, police/military control
War
Behavioral Superstructure:
Art, music, dance, literature, advertising
Rituals
Sports, games, hobbies
Science [1979: 52–53]

This scheme can be simplified by grouping together the modes of production and reproduction and referring to them as the infrastructure. Domestic and political economies may also be combined and termed structure. Thus, the behavioral components of socioeconomic systems include an infrastructure, a structure, and a superstructure. Paralleling these behavioral components, a set of mental components can be identified as follows.

Behavioral Components	*Mental Components*
Infrastructure	Ethnobotany, ethnozoology, subsistence lore, magic, religion, taboos
Structure	Kinship, political ideology, ethnic and national ideologies, magic, religion, taboos
Superstructure	Symbols, myths, aesthetic standards and philosophies, epistemologies, ideologies, magic, religion, taboos [Harris, 1979: 53–54].

Karl Marx's *A Contribution to the Critique of Political Economy* called for a strategy to guide the development of social theory in these terms: "The mode of production in material life determines the general character of the social, political, and spiritual processes of life. It is not the consciousness of men that determines their existence, but on the contrary, their social existence determines their consciousness [1970: 21]." Harris (1979: 55) remarks that this principle was equivalent in its time, 1859, to the formulation of the principle of natural selection by Alfred Wallace and Charles Darwin. However, the ambiguities in the expression "the mode of production" and the neglect of a demographic "mode of reproduction" requires that certain elements of Marx's work be reformulated.

A cultural materialist version of Marx's principle is as follows: The behavioral modes of production and reproduction probabilistically determine the behavioral domestic and political economy, which in turn probabilistically determine behavioral and mental superstructures. Harris (1979: 56) refers to this as the principle of infrastructural determinism. While such an approach, positing a unidirectional causal relationship between infrastructural to structural to superstructural variables may fail to illuminate the demographic development of many societies, Harris's principle of infrastructural determinism may be quite valuable for a historical demographer because it offers a set of strategic priorities for formulating and testing theories and causal models of demographic and socioeconomic phenomena.

This strategy calls for giving causal priority to infrastructural variables. If specification of causal models with such variables proves unsatisfying, structural variables would be tested for causal primacy. Variables in the behavioral superstructure would be a third choice. Granting causal primacy to the mental superstructure would represent a model of ultimate recourse, after the failure of behavioral models. This approach does not rule out various possibilities that mental, superstructural components can exercise significant causal influences on socioeconomic systems. It only foregoes consideration of those possibilities until the fullest possible exploration of the determining effects of the behavioral infrastructure has taken place.

Why should we assume that priority be given to production- and reproduction-related variables? In response to this important theoretical question, we shall present a modified summary of Harris's (1979) position. It represents a far-reaching synthesis of decades of debate over the primacy of behavioral versus mental factors. First, it seems plausible to begin constructing causal models in historical demography that incorporate lawlike regularities found in the natural world. We know that human beings, like all other organisms, expend energy to acquire energy and in many instances tend to produce offspring at a rate greater than their ability to obtain energy for them. Thus, humans throughout history have had to seek an equilibrium between reproduction, production, and consumption of energy. Although providing means to vary productive rates, technological innovation is subject to a set of physical, chemical, biological, and ecological laws that limit its rate of change, direction, and degree of control in specific environmental contexts. The infrastructure of a human society stands out as the principal mediator between social organization and nature—a boundary, to paraphrase Harris, across which physical, chemical, biological, and ecological restraints on human behavior interact with the principal socioeconomic activities designed to overcome, adapt to, or modify those restraints. The ordering of causal priorities from behavioral infrastructure, to structure, and finally to mental superstructure parallels the distance of these respective components from the social organizational–nature relationship. In searching for causal patterns that account for the maximum amount of historical variation in socioeconomic systems, Harris argues that the priority for theory building should logically begin with those sectors that are under the greatest direct constraints of natural laws.

The Cultural Materialist Reformulation of Marx

Although the principle of infrastructural determinism under discussion here owes a great deal to Marx's original formulations, many of his key theoretical concepts are either incomplete or ambiguous. Rather than trying to puzzle out what Marx might have meant to say or would have said if he had lived longer, it seems more fruitful to push forward along some of the general lines proposed by Harris (1979) and reformulate Marx's theoretical approach where necessary.

The infrastructure, just discussed, is designed to contain a parsimonious number of variables but also those presumed to be most important in causally influencing a society's socioeconomic system. Note that, following Harris, we have treated the classic Marxist concept of the "relations of production" or "ownership of the means of production" as an organizational aspect of structure and not as part of the infrastructure. This presumes that the evolution of the ownership of the means of production can be best understood as a dependent variable influenced by the evolution of demographic, technological, ecological, and subsistence economy factors. Exchange patterns, including trade, markets, employment, and financial transactions are viewed as structural and mental superstructure components.

Marx explained changes in the modes of production by drawing upon the Hegelian notion that structures—in this case, socioeconomic structures—evolve because they contain internal contradictions that are their own seeds of change. Specifically, the forces and relations of production contradict each other and this conflict leads to "higher" relations of production that increasingly realize the potential of the means of production by reducing conditions of scarcity. However, this model may be too limited to explain adequately the historical expansion of productive forces. Demographic factors, a mode of reproduction, are required to complement Marx's approach. It is no accident that social evolution has generally been accompanied by accelerated population growth, increased productivity, and rising energy expenditures made possible by improved technology. Why did these factors increase concomitantly? Harris argues that Marx never raised this question because he believed that population growth was simply inevitable under certain conditions. Marx's failure to devote sufficient attention to what we have called the mode of reproduction may have been due to his extreme distaste for Malthus (see pp. 27–29). Marx's antipathy toward Malthus is likely to have prevented him from seeing the utility of incorporating demographic and ecological variables as more important causal factors in his theory of societal evolution.

Some contemporary Marxist scholars, recognizing certain conceptual inadequacies in Marx's work, have frequently turned to French structuralism as a source of ideas (Sebag, 1964). Since structuralism may be considered "the most important surviving European representation of the cultural idealist tradition [Harris, 1979: 165]," this appears to be a rather strange wedding of theoretical perspectives. French structuralism, a research strategy developed largely by Claude Lévi-Strauss (1963, 1976), is a set of principles for finding binary oppositions in the collective social mind, a panhuman, neurologically grounded unconscious mental dialectic. Structuralist explanations often consist in demonstrating how the surface content of the mind can be accounted for in terms of a hidden, deep structure. For example, Lévi-Strauss's *The Elementary Structures of Kinship* (1969) proposes to construct a general theory of the surface forms of kinship and marriage systems by showing them to be manifestations, at a deeper level, of an exchange system in which groups of men exchange women with other groups of men, who reciprocate in kind. Kinship and marriage systems are thus reduced to an ahistorical binary opposition of mine–yours, seeking resolution. Harris (1979: 185–186) points out that this approach fails to explain why weakly stratified societies such as the Kachun and Purum practice asymmetrical hypergyny (superordinates give wives to subordinates), why more highly stratified societies found in India and feudal Europe practice asymmetrical hypogyny (superordinates take wives from subordinates), or why in advance stratified societies endogamous marriage systems exist with no exchange present.

How *are* productive and reproductive modes interrelated? What types of positive and negative feedback processes exist between the infrastructure, structure, and superstructures of a society? These are central questions that draw upon principles of Marxism, structuralism, cultural materialism, ecology, and social psychology.

Structured Social Inequality

Variations in the degree of social inequality throughout human history are considerable. Figure 20.1 presents a very approximate graphic summary. The unequal distribution of goods within populations has been a persistent theme among social analysts stretching from Plato, Aristotle, Confucius, John of Salisbury, Ibn Khaldun, Hobbes, Locke, Rousseau, Marx, Weber, Durkheim, Michels, and Pareto to more modern thinkers too numerous to list. Gerhard and Jean Lenski (1974: chap. 5) classify historical societies according to their basic mode of subsistence, identifying principal types:

	1 Simple hunting–gathering societies	
	2 Advanced hunting–gathering societies	
Fishing societies	3 Simple horticultural societies	Simple herding societies
	4 Advanced horticultural societies	
Maritime societies	5 Simple agrarian societies	Advanced herding societies
	6 Advanced agrarian societies	
	7 Industrial societies	

Although empirical evidence regarding the historical processes whereby these types of societies emerged and the nature of their structured social inequality is often quite limited, some common factors can be identified:

> The development of these civilizations was connected with (1) technological innovations that made possible the production and accumulation of surplus; (2) ecological and demographic trends resulting in the developing of denser population clusters and centers—be they economic (urban), ritual (temple) or political; (3) the invention of writing; and (4) increasing international contact. These four factors gave rise to the features that distinguish early civilizations from primitive societies:
> 1. growing internal structural differentiation;
> 2. growing differentiation and rationalization within the symbolic sphere;
> 3. intensification of interrelationships between societies and of intersocietal differentation;
> 4. distinctiveness of centers vis-à-vis the periphery [Eisenstadt, 1978: 54].

What types of structural differentation, social hierarchies, and inequalities are found in societies with differing subsistence and/or technology? To what degree are these factors influenced by demographic variables? Does the causal salience of specific demographic variables vary from one societal type to another? If so, why? Figure 20.2 illustrates how social classes in agrarian societies, for example, are not merely a set of superimposed layers; rather, they overlap and cover a range of the distributive spectrum of power and prestige. The breakdown of class domination, successful revolutionary conflict, and radical structural change are issues of considerable theoretical importance

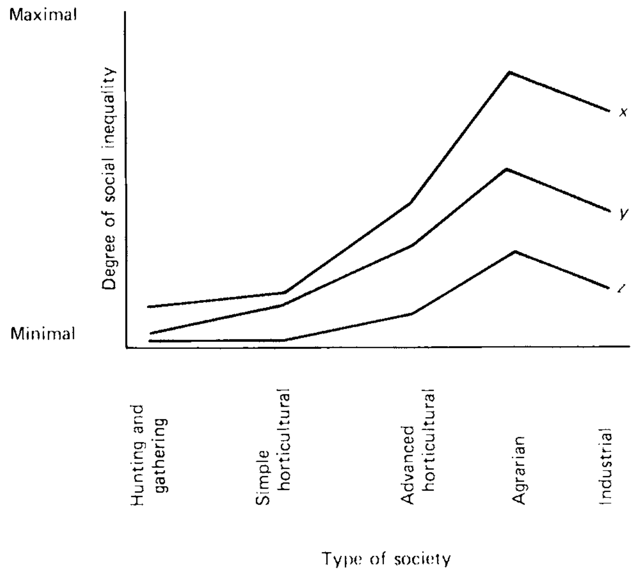

Figure 20.1. *The degree of social inequality found in different types of societies. (Adapted from Lenski, 1966: 437).* x = *upper limit of range;* y = *median;* z = *lower limit of range.*

(Eisenstadt, 1978: 19–46). Yet, it is disappointing that there seems to be rather little scholarly attention directed toward exploring direct demographic causes and contributions to social revolutions. Although exceptions exist, many excellent historical analyses of monumental social changes typically focus on structural and superstructural phenomena (Eisenstadt, 1978: 4–8), to the neglect of possible demographic factors.

Theda Skocpol's *States and Social Revolution: A Comparative Analysis of France, Russia, and China* (1979), for instance, largely ignores the possible causal significance of demographic factors. Her conclusion, that the social–revolutionary transformations that occurred in France in 1789, Russia in 1917, and China in 1911 were possible in each case only because peasant and urban-working-class revolt took place simultaneously with state administrative–military breakdown, comes from a kind of analysis familiar to political historians. A counterinterpretation might readily argue that both of the elements identified by Skocpol are *only effects* of the interplay of more fundamental infrastructural factors involving the modes of production and reproduction in these societies, and that Skocpol is trying to explain radical social transformations from a structural rather than an infrastructural perspective.

The same could be said of Jerome Blum's *The End of the Old Order in Rural Europe* (1978) that analyzes the transition from a society of orders to a class society during the eighteenth and nineteenth centuries. This was a period of unprecedented demographic change, with the 100 or so million people living in

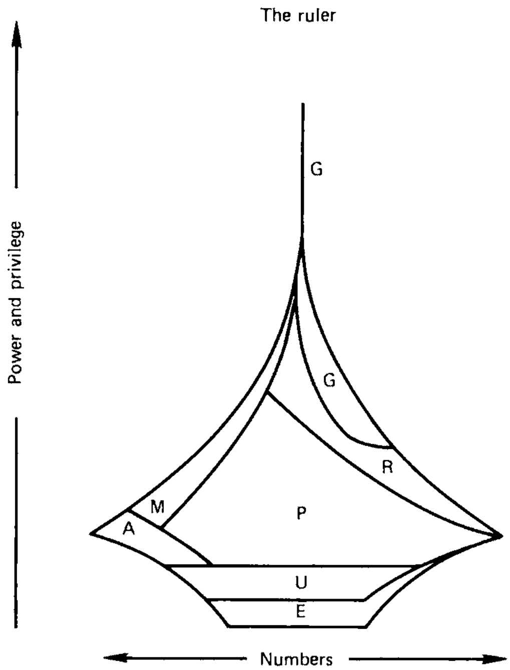

Figure 20.2. *A hypothetical graphic representation of the relationships between classes in agrarian societies. (Adapted from Lenski, 1966: 284.) A = artisans; E = expendables; G = governing class; M = merchants; R = retainers and priests; U = unclean and degraded.*

servile lands in the last quarter of the eighteenth century increasing to nearly 300 million by the first decade of the twentieth century. A historical demographer might speculate that demographic growth was an important causal factor leading to the emancipation of Europe's peasantry. However, the freeing of the peasantry from their bonds of servility in Savoy, Denmark, France, Germany, Switzerland, the Austrian monarchy, Poland, the Baltic lands, Romania, and Russia is dealt with by Blum with little regard for possible demographic causes. Nonetheless, Blum has written an important work that provides historical demographers with a panoramic framework within which to organize data and conduct comparative research on the demographic determinants of the timing of the transition from a hierarchy of orders to a new kind of social and demographic arrangement—the class society.

Works in comparative sociological history, such as Skocpol's or Blum's that lack a demographic foundation can provide convenient, incomplete frameworks for historical demographers to expand, restructure theoretically, and possibly refute. Perhaps historical demographic factors will at some later date be shown to have been irrelevant to the French, Russian, and Chinese revolutions or the emancipation of Europe's peasantry. But this can be accepted only by taking the demographic characteristics of these populations into consideration.

In contrast to Skocpol and Blum, Barrington Moore, in his *Injustice: The Social Bases of Obedience and Revolt* (1978) makes a serious attempt to utilize historical demographic data to understand the historical development of German popular and lower-class conceptions of injustice, in general, and National Socialism in particular. In Moore's words, "I found invaluable the German census reports, supplemented by those of the factory inspection service, neither of which so far as I know has yet been the object of critical scrutiny and interpretation [1978: xv]." In his view, the creation of modern capitalist society in Western Europe marked the replacement of one set of principles of social inequality for another. In pre-1848 Germany, the guild system, a series of local monopolies forming part of the old order of Estates, was the most important form of social organization in the daily lives of townspeople and city dwellers. The guild system, however, could succeed only in a relatively static demographic regime. Moore shows how German population growth produced critical consequences for the guild system:

> The number of journeymen was rising and doing so most rapidly in the most modern areas, such as the city of Berlin. In the kingdom of Prussia as a whole, between 1816 and 1843 the ratio of masters to journeymen and apprentices combined dropped from 100:56 to 100:76. By 1846 the ratio for Berlin had reached 100:205. The change meant a reduction in the opportunity for journeymen and apprentices to become masters in Berlin and other large industrial centers. The top of the ladder of advancement was beginning to disappear and with it the purpose of much hard work [1978: 133].

Thus, the increase in population and the gradual intrusion of capitalism resulted in the appearance of large numbers of people in the towns and countryside whom traditional social institutions could not absorb.

This problem became more and more acute in the years just before the 1848 revolution. In the first half of the nineteenth century a "surplus" population emerged in German society. It was, as Moore (1978: 135) describes, surplus to a particular stage of historical evolution. In the area that would eventually become the German Empire in 1871, the population rose by over one-third, from about 25 million in 1816 to more than 34 million in 1845. This led to severe suffering, whose impact varied with different ecological settings and social structures. There was less and less room at the bottom of the social ladder as population size and the number of proletarians rapidly increased. These conditions of population pressure did not change significantly until German industrialization became a dominant force after the founding of the empire in 1871. Moore observes that "one could say that industrialization solved the problem of the proletariat rather than created it [1978: 135]."

Moore's *Injustice: The Social Bases of Obedience and Revolt* is a superb example of a demographically grounded approach to social historical topics of considerable human concern. This study is particularly noteworthy in documenting the strain that changing demographic variables placed on the guild system, the appearance of the proletariat, the behavior and attitudes of German workers in the revolution of 1848, the changing size and composition of the industrial work force, and relations between elites and the masses of workers.

Later on in his work, Moore uses 1935 Nazi party statistics and official census reports to identify the social-class backgrounds of party members (see 1978: table 13). Who were the Nazis? How did they come to power? These are questions that Moore partially and skillfully answers with the help of historical demographic data. He shows how demographic transformations and structured social inequality led to a moral rejection of misery, causing people to embrace new forms of behavior in efforts to resist and change their social order. Tragically, these efforts spilled over into cruelty, aggression, and fascism. Moore's analysis demonstrates the potentially great causal significance of demographic data for exploring one of the key social questions of history—Why do people at the bottom of the social order with little or no property, income, education, power, authority, or prestige so often remain silent victims of their societies, and why at other times do they revolt?

Historical Demographic Perspectives on Social Mobility and Inequality

Perhaps no research topic has occupied contemporary American sociologists more than social mobility. The process of stratification when viewed as a dynamic phenomenon involving occupational incumbencies necessarily focuses on the mechanisms through which the socioeconomic statuses of one generation are tied to those of the next. The study of social mobility is thus inherently historical. It logically calls for the construction of theories of class and status inequalities. Since occupational and/or wealth data are often recorded in demographic census-type records, at least in the nineteenth century, social mobility becomes a research topic conveniently available to historical demographers. Initial conditions affecting the occupational inheritance of successive cohorts in a historical population include such typical demographic variables as place of birth, family size, and parity within the family. Geographical mobility, marriage, and child-rearing practices are of importance later in the life cycle.

One of the most recent and methodologically sophisticated studies, Robert Hauser and David Featherman's *The Process of Stratification: Trends and Analyses*, has found that "little, if any, change has taken place in intergenerational mobility in the U.S. in the last 30 to 40 years that cannot be attributed to shifts in the occupational distributions of successive cohorts [1977:

xxiii]." Expressed differently, this implies that the associations between occupations of origin (the father's) and destination (the son's) do not change over time. This apparent invariance in the endogenous association of social origins and destinations is undoubtedly affected by historical, institutional arrangements within the family, the socialization of youth, and the labor market. Hauser and Featherman's "negative" findings regarding the extent of social mobility challenge the popular notion of America as a land of opportunity where the possibilities of upward occupational mobility have more than just marginal probabilities. It is puzzling that the socioeconomic changes that have taken place in America over the last 40 years, documented in studies such as Thomas Espenshade's and William Serow's *The Economic Consequences of Slowing Population Growth* (1978), Peter Lindert's *Fertility and Scarcity in America* (1978), and Julian Simon's *The Economics of Population Growth* (1977), do not show up as being translated into statistically significant intergenerational mobility effects. It is entirely possible, despite the relatively vast commitment of research funds to allow sociologists to analyze social mobility in the United States, that inappropriate measures have been applied to the wrong questions.

The possibility that misleading and artificial questions have guided recent social mobility research has been examined by Allan Sharlin (1979). Criticizing Michael Katz's manual–nonmanual system of occupational classification to provide a set of rankings to measure upward and downward mobility in nineteenth-century Canada, he proposes that "in both historical and contemporary cases what is needed is not simply a more refined occupational scheme but a different wäy of looking at occupational structure altogether [1979: 340]." In attempting to offer another perspective, Sharlin investigates the situation of small shopkeepers in the occupational structure of mid-nineteenth century Frankfurt am Main. In doing so, he provides a context for the interpretation of mobility rates and proposes a common but clearly partial solution to respond to the technical question of occupational classification and to the theoretical question of how properly to interpret mobility rates.

The license petition records of the Frankfurt *Rechnei-Amt* (finance office) are first used to determine the general condition of the shopkeepers and their position relative to other occupational groups. A sample of real estate tax records showing the rent paid on living quarters by heads of households in different occupational classes provided corroborating evidence for drawing a sharp distinction between merchants and shopkeepers. Using what appear to be Frankfurt society's own categories, Sharlin finds that small shopkeepers fall near the bottom of the social order. Classification of shopkeepers as "white collar" workers would clearly be misleading. Although historical demographers are unable to interview members of past populations to determine occupational status rankings, sources may be available that are functionally similar to Sharlin's license petitions and real estate tax records and that permit some degree of reconstruction of the power and prestige of various statuses.

The differences between shopkeepers and merchants suggested by qualitative data would indicate that relatively little movement should occur between these occupational classes. To confirm this, Sharlin analyzes marriage registers from 1846 to 1851. Although marriage registers are not a representative sample of an entire population, they offer information on the occupation of the groom, his father, and his father-in-law. Comparing father's and son's occupation at marriage allows some limited analysis of occupational mobility. Comparison of the groom's occupation and the father-in-law's occupation offers evidence of social interaction between occupational classes.

A variety of methodological issues arise in the analysis of social mobility (see, for example, Duncan, 1966). If we use simple percentages along rows or columns in a table of occupational classifications to compute mobility, differences between tables may be due *either* to different occupational distributions or to truly different patterns of mobility. To control for distributional differences to make meaningful comparisons between tables possible, Edward Deming's (1964) procedure can be used to double-standardize a table proportionately over both rows and columns so that they each sum to 100. The larger a double-standardized value is between two occupational classes, the greater is the movement from one to the other. Alternatively, Leo Goodman's (1969) method of computing odds ratios may be used. Odds ratios range from 1.0, implying purely random interaction between two occupational classes, to larger values with no defined upper limit. An odds ratio in a social mobility table may be interpreted as the probability of movement into one of two occupational classes for individuals originating in either class.

Sharlin subdivides occupations into six major classes: merchants, professionals, artisans, shopkeepers, clerks, and nonguild workers. A sample of his findings appears in Tables 20.1 and 20.2. An analysis of these tables shows that there is a lack of transitivity across the occupational hierarchy. Ignoring the case of clerks who were partly trainees for higher positions, shopkeepers turn out to be intergenerationally closer to the other occupational classes than they are to one another. Thus, although in terms of a vertical ranking schema, based on presumed wealth, shopkeepers are in the poorer occupational classes, the strength of linkages to the other classes do not conform to the same rankings. This demonstrates the importance of using multiple sources to understand mobility through a study of the entire historical, socioeconomic context in which it occurs.

An understanding of the determinants of socioeconomic inequality, using a variety of historical demographic data is also illustrated in Harvey Graff's *The Literacy Myth: Literary and Social Structure in the Nineteenth-Century City* (1979) which investigates two important issues in modern social theory: the relation between schooling and success and the relative salience of achievement over ascription. Drawing primarily upon linked census and tax assessment records, Graff examines the lives and livelihoods of illiterate and literate men and women in three cities: Hamilton, Kingston, and London. He uses several types of record linkage: census to tax assessment lists (1861, 1870–1871–

Table 20.1

Double-Standardized Values Showing Intergenerational Mobility and/or Inheritance in Frankfurt am Main, 1846–1851

	Son's occupation							
			Artisans					
Father's occupation	Merchants	Professionals	Food	Building	Transportable Goods	Shopkeepers	Clerks	Nonguild workers
Merchants	48.5	15.7	.0	2.9	8.9	7.0	13.0	3.9
Professionals	12.8	46.5	.0	10.0	7.1	12.2	7.5	3.9
Artisans								
Food	1.1	1.4	79.2	.0	3.3	6.9	6.6	1.5
Building	1.1	3.5	.0	66.9	7.2	7.4	6.9	7.1
Transportable goods	6.1	4.2	4.8	9.2	37.6	19.7	12.2	6.3
Shopkeepers	14.1	8.9	6.9	3.3	19.4	20.0	14.8	12.7
Clerks	14.0	18.0	.0	.0	6.3	16.1	19.9	25.7
Nonguild workers	2.3	1.8	9.1	7.8	10.3	10.6	19.0	39.0

Source: Reprinted from "From the study of social mobility to the study of society." by Allan Sharlin, in *American Journal of Sociology*, 1979, 85, 2: 352, by permission of The University of Chicago Press. Copyright © 1979.

Note: Father's and son's occupations are their occupations at the time of the son's marriage. To the extent that age is a factor in mobility, Sharlin's results are biased. Father's and son's occupations would have to measured so that, for example, father's occupation at age 40 is compared with son's occupation at age 40.

Table 20.2

Double-Standardized Values Comparing Groom's Occupation with Father-in-Law's Occupation in Frankfurt-am-Main, 1846–1851.

Father-in-law's occupation	Groom's occupation: Merchants	Professionals	Artisans: Food	Building	Transportable Goods	Shopkeepers	Clerks	Nonguild workers
Merchants	42.2	32.5	1.8	1.9	8.5	4.3	6.3	2.5
Professionals	16.2	36.8	2.5	11.1	9.3	8.6	12.0	3.5
Artisans								
Food	3.5	3.8	59.7	.0	17.5	11.7	.0	3.7
Building	4.8	4.1	.0	24.7	13.2	15.6	18.9	18.7
Transportable goods	7.7	7.3	9.0	14.5	19.8	15.2	15.6	11.0
Shopkeepers	13.6	7.9	10.3	6.8	11.4	20.2	19.6	10.2
Clerks	7.1	4.5	14.0	31.1	9.7	13.7	.0	19.8
Nonguild workers	4.9	3.3	2.7	9.8	10.4	10.7	27.6	30.6

Source: Reprinted from "From the study of social mobility to the study of society," by Allan Sharlin, in *American Journal of Sociology*, 1979, 85, 2: 354, by permission of The University of Chicago Press. Copyright © 1979.

Note: Father-in-law's and groom's occupations are their occupations at the time of the groom's marriage. An alternative and perhaps better measure of social interaction would have been to compare the groom's father's occupation with the father-in-law's occupation.

1872), decennial census to tax assessment lists (1861–1871), and four-way census to tax assessment lists (1861–1871). The census-to-tax assessment linkage of literate persons was accomplished through the use of a semiautomated system developed by the Canadian Social History Project. Linkage to other sources was carried out manually. Systematic patterns of inequality and stratification, reconstructed from census records and including origins, class, sex, race, and age, are shown to be relatively unaltered by literacy. Graff attacks the myth underlying the promise of education in the nineteenth century by showing with demographic data that even as late as the second third of the century literacy was not a significant requirement for social and economic advancement or for the intergenerational mobility of children. Historical demographic data are skillfully utilized to confront systematically traditional assumptions and theories that assert that industrialization, economic progress, and literacy were directly related to one another. Graff comments that theories supportive of that older view need revision since they "hold little systematic evidence when examined carefully [1979: xix]."

Graff's basic research strategy is to pinpoint all of the critical socioeconomic, demographic connections that tied literacy to the social structure and to processes of social inequality. In this way he is able to demonstrate that the facts of social reality contrast strikingly with social perceptions and with widely accepted social theories. Literacy turns out not as an independent or dominating factor; rather, it "interacted with ethnicity, age, occupation, wealth, adjustment, and family organization, reinforcing and mediating the primary social processes that ordered the population, rather than determining their influences [1979: 56]."

Socioeconomic Models with Demographic Data

One of the best recent examples of the use of socioeconomic and demographic data within an explicit, causal modeling framework is Ron Lesthaeghe's (1977) study of the Belgian fertility decline amidst nineteenth-century socioeconomic change. Lesthaeghe's work is the fourth in the Princeton Office of Population Research's study of the historical decline of fertility within the provinces of various European countries. It is the first, however, that explicitly utilizes formal causal modeling techniques that take socioeconomic variables into account.

In the middle of the nineteenth century, Belgium was characterized by high mortality and uncontrolled marital fertility, late and nonuniversal marriage, and negligible illegitimate fertility. These "Malthusian" aspects of the population existed until 1870, after which signs of a genuine demographic transition appeared, marked by an earlier age at marriage, a rise in illegitimate fertility, and control of marital fertility. However, the country was divided, both linguistically and economically, with French-speaking Walloons residing in the south in an area dominated by heavy industry and mining, and the Flemish-speaking population in the north relying on agriculture and cottage industries.

Lesthaeghe's analyses are, in general, based on census and vital registration data for arrondissements containing between 50,000 and 500,000 persons. Results are therefore evidence of relationships at the aggregate rather than the individual level. The series of nuptiality and fertility indexes used starts in 1846 with the first national census.

After examining zero-order correlations between a number of presumed independent variables and measures of fertility, Lesthaeghe concludes that several relationships in Flanders were different from those in Wallonia. To determine further if separate causal models should be constructed for the two subpopulations, an analysis of covariance is carried out on the marital fertility index, I_g. This index relates the annual number of legitimate live births in a study population to the number of legitimate live births that would occur to married women in each age group of the childbearing age span, if they were subject to natural (Hutterite) fertility. Using an analysis of covariance permits one to inspect the difference between the two means of I_g for Flanders and Wallonia, controlling for the effects of select independent variables: nuptiality, industrialization, literacy, urbanization, infant mortality, and secularization.

Nuptiality is operationalized as the index of proportion married, I_m. It summarizes the nuptiality pattern within the childbearing age span and its effect on overall fertility by comparing the number of children married women would bear if they were subject to natural (Hutterite) fertility to the number of children all women, married or not, would bear under the same circumstances. In 1856, the province of East Flanders had one of the lowest levels of I_m ever observed, 0.303. Industrialization is measured negatively as the percentage of the male active population working in agriculture. Literacy is measured as the percentage of the population aged 15–55 that can read and write. Urbanization is computed as the percentage of the population living in communities with more than 10,000 inhabitants. Infant mortality is operationalized as the number of deaths before age 1 per 1000 live births. Finally, secularization, a mental superstructure variable, computed only for the year 1910, is calculated using as a proxy measure the percentage of non-Catholic votes in the 1919 election. Results of the covariance analysis show that the difference in levels of marital fertility between the two language regions cannot be attributed to differences in nuptiality, industrialization, literacy, urbanization, or infant mortality. Some other variable must be responsible for the Flemish–Walloon differences in I_g. Secularization seems to be that variable. The introduction of the secularization variable into the covariance analysis reduces to zero the difference between the mean levels of I_g in Flanders and Wallonia. Unfortunately, because of the choice of indicator for secularization, tests of this effect are carried out only for the year 1910, and not the other time periods of 1880, 1890, and 1900. The industrialization, literacy, and urbanization covariates are measures of socioeconomic structure, whereas nuptiality and infant mortality covariates measure demographic structure. Secularization, on the other hand, seems to measure a difference in *mentalité*, a mental superstructure phenomenon. The less traditional mentality in Wallonia apparently led to the earlier drop in marital fertility. This is a somewhat unexpected result and runs counter to the presumed hierarchy of causal priorities previously suggested.

Since the covariance analysis shows that most of the independent variables have different effects in the two language regions, separate causal models are required. Language homogeneity is introduced as a new variable and is measured by the ratio of the population aged 15 and older that speaks only the language of the area (Flemish in Flanders, French in Wallonia) to the total population aged 15 and older. In an initial path model, feedback loops were introduced between marital fertility and illegitimate fertility, and between nuptiality and illegitimate fertility. To achieve mathematical identification in the model, a decision was made to drop the effect of illegitimate fertility on marital fertility. This effect is believed to be almost negligible anyway. To eliminate multicollinearity problems, the relation between illegitimate fertility and nuptiality was eliminated. The final path model for both regions is depicted in Figure 20.3. Relevant structural coefficients are presented in Table 20.3. Lesthaeghe's justification for using a causal inference technique (i.e., path analysis) is worth citing:

> We are going to deal with what is statistically known as causal inference. This term is rather misleading since, using non-experimental data, no statistical procedure is capable of proving or disapproving that a relationship is solely asymmetric or causal. In many instances, however, one is willing to accept that a relationship is asymmetric on the basis of theoretical (and not on the basis of purely statistical) considerations. Phrased slightly differently, results from regression analysis can be given a causal interpretation only when one is willing to accept the existence of a theoretical causal model on a priori grounds. In the following sections, we felt that such grounds existed and that we would somewhat underinterpret our results if we were to continue to treat them solely as mere indicators of associations rather than asymmetric effects [1977: 152].

Now let us examine the patterns of structural coefficients in Table 20.3. First, we see that the higher the degree of industrialization–urbanization and secularization, the lower the level of I_g in both regions. The degree of language homogeneity in Flanders is associated with higher levels of I_g, whereas in Wallonia the signs of the coefficients are reversed. Although individual-level fertility data would be needed to confirm it, these findings suggest that the French-speaking minority in Flanders may be the first to control marital fertility. Both literacy and infant mortality have negligible effects on I_g. In fact, because of the role of the Belgian Roman Catholic church in organizing primary education in the nineteenth century, the degree of literacy in an arrondissement could be a better indicator of traditionalism than of modernization. Degree of

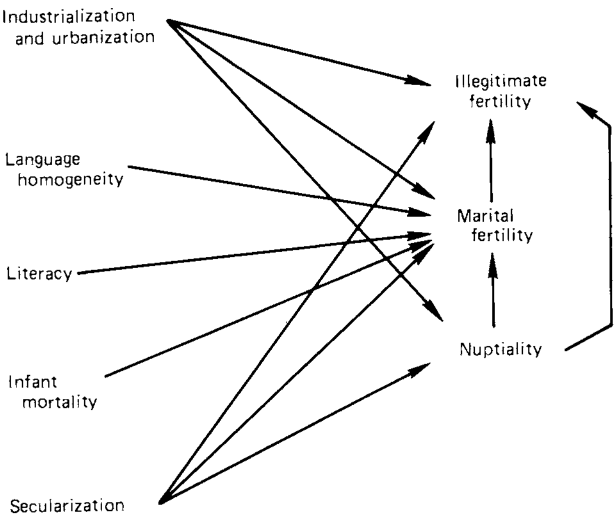

Figure 20.3. *A causal model showing hypothesized relationships between social indicators and demographic variables. (Adapted from Ron J. Lesthaeghe,* The Decline of Belgian Fertility, 1800–1970. *Copyright © 1977 by Princeton University Press. Figure 6.3, p. 211, adapted by permission of Princeton University Press.)*

literacy is generally negatively correlated with measures of social change in Belgium. Nuptiality has a negative effect on I_g in both regions, the effect being greater in Wallonia. This tentatively suggests that a decrease in the mean age at marriage occurs first and the resulting increase in the length of the reproductive span enhances the probability of adopting birth control. Other statistical evidence, however, suggests that in Flanders, nuptiality and marital fertility are causally independent.

From studies of seventeenth- and eighteenth-century French villages, Jacques Dupâquier (1972) proposed three Malthusian rules: (*a*) no conceptions outside wedlock; (*b*) no sharing of one dwelling by more than one couple; and (*c*) no marriage without "establishment" (i.e., the availability of an independent means of living). Thus, deviations from the Malthusian marriage pattern—rules (*a*) and (*b*)—should be accompanied by a positive association between nuptiality intensity and illegitimate fertility. Although Lesthaeghe finds a strong positive correlation between these two factors in both subpopulations, the index of illegitimate fertility is statistically dependent on nuptiality intensity. Interpretation of the strength of the association between the two is therefore problematic.

Socioeconomic models that posit relationships between demographic behavior, social structures and belief systems have in most instances used economic or infrastructural variables as the independent or causal determinants of demographic conditions. However, it is noteworthy that, as in the Lesthaeghe

Table 20.3
Structural Coefficients for the Causal Model Depicted in Figure 20.3, Flanders and Wallonia, 1880–1910.

		Structural coefficients					
		Flanders			Wallonia		
Social indicator	Date	Illegitimate fertility	Nuptiality	Marital fertility	Illegitimate fertility	Nuptiality	Marital fertility
Industrialization and urbanization	1880	.466[s]	.665[s]	−.241	.544[s]	.645[s]	−.245
	1890	.435[s]	.674[s]	−.312	.496[s]	.721[s]	−.218
	1900	.343	.772[s]	−.322	.465[s]	.722[s]	−.388
	1910	.465[s]	.665[s]	−.159	.024	.511	−.162
Language homogeneity	1880			.418[s]			−.113
	1890			.527[s]			−.207
	1900			.487[s]			.071
	1910			.303			−.197
Literacy	1880			−.161			−.050
	1890			−.207			−.133
	1900			−.067			.015
	1910			.126			−.143

Infant mortality	1880			.428^{s}			.172
	1890			.218			.083
	1900			.118			.336
	1910			−.038			.042
Secularization	1910	.212	.131	−.489^{s}	.889^{s}	.228	−.637^{s}
Nuptiality	1880	.243		−.348	.342		−.524
	1890	.251		−.120	.473		−.637^{s}
	1900	.416		−.256	.421		−.569^{s}
	1910	.313		−.112	.351		−.303
Marital fertility	1880	−.409^{s}			.025		
	1890	−.350^{s}			.144		
	1900	−.230			.058		
	1910	.052			.413		

Source: Adapted from Ron J. Lesthaeghe, *The Decline of Belgian Fertility, 1800–1970.* Copyright © 1977 by Princeton University Press. Table 6.3, p. 213 adapted by permission of Princeton University Press.

Note: A superscript "s" (^{s}) following a number indicates a statistically significant value.

example, secularization, more of a *mentalité* or superstructural variable, was the most powerful predictor of the Belgian fertility decline. The construction and testing of socioeconomic models does not require the acceptance of the primacy of social or economic conditions in determining demographic behavior. Rather, as we have suggested, demographic processes themselves may be found increasingly to lie at the foundation of major political and social events in human societies.

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21 Historical Demography and "Total History"

The focus of historical demographic inquiry is by definition the study of population processes. However, it is clear that an understanding of the causes and consequences of these processes can occur on many levels and from a wide variety of perspectives. No one set of sources, analytical techniques or causal models is likely to help answer the large number of research questions brought to the study of historical demography by scholars from the different disciplines. What is needed, we have argued, is the integration of the skills of sensitive source criticism with increasingly sophisticated techniques of data analysis and the capacity to go beyond narrow demographic analysis to the construction of explanatory sketches or models. In the final chapter, we draw together some of the continuous strands of our argument about what historical demography can be by laying out what seems to us to be one particularly successful conceptual approach to the multidisciplinary pursuit of knowledge about past populations in all their complexity.

There is an obvious affinity between the increasingly multidisciplinary character of historical demography and the goal of "total history" usually identified with the work of historians of the "*Annales*" school of research (Braudel, Trevor-Roper and Hexter, 1972; Furet and LeGoff, 1973; Chaunu, 1973, Iggers, 1974; Stoianovich, 1976; Forster, 1978; Kinser, 1981). At the most basic level, this affinity can be identified as one of focus. *Annalistes* such as Pierre Goubert (1960; 1969), Emmanuel Le Roy Ladurie (1974a; 1978) or Fernand Braudel (1975; 1976) have not only reconstructed and described the demographic characteristics of the local or regional communities they have studied but have also pointed toward the occasional or long-term importance of demographic processes in determining other facets of social life. Although it would be an error to argue that the investigators of this "school" are demographic determinists, there is little doubt that many of their works indicate a conviction that population size, structure, density, and tendency to grow or decline are inextricable features of "material life."

In his *Capitalism and Material Life, 1400–1800*, for example, Braudel (1975) shows that population size was itself as much cause as consequence of the material progress following in the wake of the disintegration of an international *ancien régime* and a crucial indicator of decisive relationships among human groups. The demographic ebb and flow of the *ancien régime*, later followed by high growth rates, makes almost all other causal factors appear secondary. It is for this reason that Braudel's starting point is demographic: "We have used numbers [i.e., population size] to give a first glimpse of the different destinies of the world between the fifteenth and eighteenth centuries. Men were divided into great masses as unevenly equipped to deal with their material life as the different groups within a given society [1975: 65]." He identifies the central characteristic of the *ancien régime* as its capacity for short-term demographic revival in the face of "very high infant mortality, famine, chronic undernourishment and virulent epidemics." Even technology is viewed as "always a product of numbers [1975: 55]." In fact, Braudel comes very close to a position of historical demographic determinism in asserting that "the world is divided and organized according to the force of numbers which give each living mass its individual significance and fixes its level of culture and efficiency, its biological (and economic) rhythm of growth, and its pathological destiny [1975: 54]." Thus, Braudel places historical demographic factors at the very center of the stage of human destinies.

In contrast to Marx's explicit notions of human history determined primarily by successive transformations in the means and organization of modes of production—transformations that might be echoed in large-scale demographic change as well as historically specific forms of class struggles—recent work of the *Annalistes* has offered a different conceptualization of the relationship between the demographic and economic dimensions of human history. First, whereas the demographic and economic activities of human communities over time are distinguished for purposes of separate reconstruction and analysis, there is a tendency among *Annalistes* to approach the demographic structure of human groups as an intergral, defining feature of different systems of material life. At the concrete level, the size, density, and spatial distribution of historical populations, as well as their experience of vital demographic processes, are not easily abstracted from productive activities. Thus, although separate series of economic and demographic data may be constructed for the examination of many societies over time, these features are the two, equally important, constituent elements of which "material" life is formed.

Secondly, in the work of *Annaliste* historians, basic demographic features of societies do not appear to be necessarily or universally determined by economic ones. For example, the demographic catastrophes that so markedly shaped the preindustrial world of continental Europe from the fourteenth to the eighteenth centuries were the product of a chain of causation beginning with bad weather and leading to harvest failures, scarcity, high prices, disease and death (Goubert, 1969: 38). Braudel (1975: 53) refers to the "biological" aspects of the demographic *ancien régime*. And although both Goubert and Le Roy Ladurie (1974b) show that the incidence and gravity of such crises were mediated by social and political forces, they indicate their belief that the fundamental causes of such catastrophes were for many centuries beyond the ability of human communities to control.

Much of the demographically oriented work of the *Annalistes* has been focused on the European world from the late Middle Ages to the end of the eighteenth century. And although the identification of the "European Marriage Patterns" that took shape sometime during these centuries was most brilliantly carried out in the work of Hajnal (1969), it is in great measure among French scholars—not all of them *Annalistes*, to be sure—that the existence and functioning of such a system have been explored. It might plausibly be argued that the *Annalistes* have been most successful in relating the existence of an "*ancien régime démographique* characterized by high age at marriage, relatively high proportions unmarried, and periodic demographic crises to a wide range of other historical phenomena, including attitudes towards death, family limitation and dietary habits [Kinser, 1981: 104]."

Not only have researchers within the *Annales* school paid special attention to the demographic characteristics of historical communities. They have also led in the integration of biological, ecological, and climatological factors into historical studies. Several explanations for these interests might be hypothesized. First, from its inception, one of the main focuses of *Annales* research, illustrated in the work of Marc Bloch (1968), has been on rural history. Bloch directed his attention to the origins and evolution of lasting features of the French countryside. Although more recent regional studies have expanded on the importance of geographical and cultural variety among the regions discussed by Bloch, there has been a wide and continuously reinforced impression of a generalized stability in the French rural world from the fifteenth to the eighteenth centuries. This stability in means of cultivation of the soil, crop yields, and techniques of production is echoed in the longevity of basic characteristics of the demographic system also identified as an integral feature of what Le Roy Ladurie (1974b) has termed "*l'histoire immobile.*"

The identification of such long-term stability illustrated in the work of Bloch and others might be argued as a cause of the *Annalistes'* willingness, even eagerness to explore the possible relevance or causal importance of phenomena not usually studied by historians accustomed to the investigation of the lives of one or several generations. Given the need to explain the relative constancy of fundamental material features of the French rural world, *Annales* historians reasonably turned to the examination of phenomena whose own influence was relatively unchanging—soil types or climate, for example. It is no surprise to read, in the first line of Le Roy Ladurie's *Histoire du climat depuis l'an mil*: "It was agrarian history which led me, by an imperceptible and natural transition, to the history of climate [1967: 7]."

Thus, at the same time that demographic characteristics and processes have been assigned an equal status with "economic" ones as determinants of fundamental material life, there was among *Annaliste* historians a legacy of openness to the notion that circumstances not subject to human control might help account for the basic stability of a rural world that one of their masters had reconstructed, in its essentials, very early on. In contrast to the English rural world of the early modern period, already subject to the transformational influence of commercial agriculturalists, the French rural world appeared determined by long-term forces not entirely subject to the will of its inhabitants, whether seigneurs or peasants. As Le Roy Ladurie has noted, "The English kingdom, where *The World We Have Lost* was defined for the first time, was probably of all occidental countries the one where this world was the least typical and stable [1974: 673]." (See Macfarlane, 1978, for a vigorous defense of such a view.)

Once articulated, the model of an essentially stable material life prepared *Annales* historians studying the early modern period, in particular, to accept the appropriateness, indeed the necessity, of seeking possible causal explanations in conditions or processes that human collectivities only gradually learned to control with any success. The detection and illumination of such long-standing patterns, of course, required the analysis of masses of "serial" data for which the *Annalistes* are known (Chaunu, 1978).

Another facet of *Annales*-style research that has made it such a rich contributor to the creation of a multidisciplinary approach to historical demography is its rejection of history as a primarily story-telling field of inquiry. Characteristically, the most vigorous articulation of this position was voiced by Lucien Febvre (1953: 114–118). His critique of story-telling history ("*histoire historisante*") constituted a denunciation of one of the principal tasks of historians, broadly defined, through the ages: the re-creation and explication of incidents or events in order to satisfy idle curiosity, edify by teaching the actions of great men, or to reinforce systems of values or bonds of community among listeners (in nonliterate societies) or readers (in those with writing).

The rejection of story-telling history does not mean that the narrative of events is missing from the writings of *Annales* historians, since in many cases stories provide the raw material from which historical explanations are formulated. The difference lies in the way that stories or events are constituted as sources. In order to be selected or constituted as data, stories or events should exemplify meaningful historical trends already identified or hinted at in previous work, or appear—often at some intuitive level—to have the possibility of illuminating large historical problems. For example, in his work *The Royal Touch*, Bloch, referring to the magical ability to heal scrofula ascribed to English and French monarchs, noted:

> The problem confronting us now is a double one. The royal miracle stands out above all as the expression of a certain concept of supreme political power. From this point of view, to explain it would be to link it with the whole body of ideas and beliefs of which it was one of the most characteristic expressions. Moreover, does not all scientific "explanation" rely on the principle of bringing a particular case within the compass of some more general phenomenon [1973: 28]?

Furet and LeGoff have articulated as well as anyone this essential, distinguishing feature of *Annales* research.

> Non-eventful history rejects narrative—at least the literary type—to the extent that it first defines problems. Living on its borrowings from contemporary social sciences—demography, geography, sociology, etc., it has renewed our historical curiosity by specifying it. Its first act is to decompose the different levels of historical reality in order to retain only several or one, describing them as systematically as possible—that is, in isolation. This is why it constitutes historical "facts" which are doubly different from those of eventful history. [The facts of non-eventful history] are usually alien to the classical realm of large political changes, and defined not by their unique character, but by their comparative value to those which precede and succeed them. [Such a] fact is a phenomenon selected and constructed as a function of its repetitive character and its comparability across an expanse of given time [1973: 231–232].

Another essential characteristic of the *Annales*-style approach to the writing of "total history," of which historical demographic inquiry has been an integral part, is thus to identify as most potentially meaningful those phenomena that reoccur with some regularity across large expanses of time.

There is no consistent theory of historical causality manifest among the different scholars writing from an *Annales* approach, but there is rather a method of constituting factual material, a concern for observing the object of study, whether a community, region, or indicator of commercial activity, across as long a time as reason permits. Not all monographs are as time and space encompassing as Braudel's *The Mediterranean and the Mediterranean World of Philip II* (1976), wrongly identified as the one best exemplification of an approach whose strength lies in its heterodoxy. Studies of shorter time periods and cross-sectional approaches are also undertaken, but they are explicitly informed by their authors' awareness of the long-term features or characteristics of the society whose experience they are examining over the short term, and with special attention to key variables such as the conditions of material life or collective belief systems. Thus, it is hardly surprising, given the *Annales* school's ideal of observing documentary material over the long term, that scholars of this ilk seek explanations in institutions and patterns of belief, as well as biological or ecological conditions whose impact transcends the lives of one or several generations.

It may be objected that a style of research that places such high value on the analysis of human collectivities (Kinser, 1981: 67) and seeks to explain large-scale transformations, not the short-term alterations in human conditions, must necessarily degenerate into the portrayal of a human past in which groups of individuals or unique individuals are seen primarily as objects of aggregate processes over which they have little or no control, whether such forces be material or ideational. The factors that appear of greatest significance in reconstructing and explaining large-scale historical development may not be identical to those that appear best to explain individual or small-group reaction to short-term conditions that are, after all, the measure of the human life span. If practitioners of "total history" did nothing but document and explain the forces that constrain human actions, an understanding of the historically specific might well be lost.

However, this argument might reasonably be countered by the proposition that the identification of long-standing demographic, social, or biological conditions in human societies is a necessary precondition for the identification of the historically unusual or unique. Unless scholars have some awareness of the long-standing, repeated responses of human communities to conditions caused by the forces of nature, or other human beings, they will be unable to identify a novel resolution—perhaps a sign of historical change—to familiar dilemmas. Furthermore, it appears that an understanding of continuous features of the material or ideational circumstances of entire societies, or constituent groups within them, may lead to a more realistic understanding of the ways that individuals were "grounded" in their age. Although the introduction of ecological or biological factors into an understanding of human demographic conditions might appear to reinforce the portrait of an overly determined past, this result necessarily depends on the way in which the relationship between human beings and their natural world is understood.

Marx, for one, believed that the investigation of this relationship provided the starting point for the understanding of human historical development. In a well-known passage from the *German Ideology* (1967: 409), he noted:

> The first premise of all human history . . . is the existence of living human individuals . . . . The first fact to be established, then, is the physical organization of these individuals and their consequent relationship to the rest of nature. Of course, we cannot discuss here the physical nature of man or the natural conditions in which man finds himself—geological, orohydrographic, climatic, and others. These relationships affect not only the original and natural organization of men, especially as to race, but also his entire further development or non-development up to the present. All historiography must proceed from these natural bases and their modifications in the course of history through the actions of men [1967: 409].

One of the advantages of a "total history" approach to the study of historical demographic development is that it identifies different levels of human historical existence—biological, ecological, economic, demographic, or political—and attempts to assess varying causal relationships among these humanly conditioned dimensions of existence in order to understand both constancy and change in the past.

One of the critics of the notion of "total history" has characterized its pursuit as:

> one that seeks to reconstitute the overall form of a civilization, the principle—material or spiritual—of a society, the significance common to all the phenomena of a period, the law that accounts for their cohesion—what is called metaphorically the "face" of a period. Such a project is linked to two or three

> hypotheses; it is supposed that between all the events of a well-defined spatio-temporal area, between all the phenomena of which traces have been found, it must be possible to establish a system of homogeneous relations: a network of causality that makes it possible to derive each of them, relations of analogy that show how they symbolize one another, or how they all express one and the same central core; it is also supposed that one and the same form of historicity operates upon economic structures, social institutions and customs, the inertia of mental attitudes, technological practice, political behavior, and subjects them all to the same type of transformation; lastly, it is supposed that history itself may be articulated into great units—stages or phases—which contain within themselves their own principle of cohesion [Foucault, 1976: 9–10].

Such a characterization, if true, would imply a belief in the existence of some one hidden or quasi-magical principle of which the different dimensions of historical life are mere predicates. However, in both their method of constituting facts and seeking to explain stability and change, practitioners of the "total history" approach, on the contrary, appear to be extremely eager to reconstruct and explain characteristics of historical human societies not by reference to single principles or features but by concentrating on the causal impact of different dimensions of human experience on *one another*. This is, in fact, one of the rationales for first distinguishing among and reconstructing these aspects of existence in isolation from one another.

As three concluding illustrations may demonstrate, the integration of historical demographic studies into the pursuit of "total history" may contribute greatly to the understanding of individuals, communities, and whole societies of the past. There are different barriers to its realization for scholars from the variety of disciplines that have contributed to the development of historical demography. Problems may arise from the weaknesses of basic source materials, from a division of labor among the different disciplines that resist an inherently multidisciplinary pursuit, or the lack of familiarity with methods that might enhance the possibilities for causal explanation.

From the beginning of his work *The Family Life of Ralph Josselin*, Alan Macfarlane expresses a fear of the neglect of individual-level data in the study of human societies of the past:

> The search for answers to new questions usually coincides with the discovery of new sources of information. The recent shift of interest from political and constitutional to economic and social history has been accompanied by the increased utilization of the vast deposits of local records scattered throughout Europe and North America. The major intellectual advances in the next few years will be made by combining the problems suggested by the social sciences, particularly sociology and social anthropology, with the documents stored in regional archives. Yet there are a number of dangers inherent in this exciting synthesis. One of these is the tendency for individuals and their attitudes to be overlooked in the search for statistical facts. Another bias is toward the material and outward aspects of human life, the physical conditions of the past. The fundamental problems of attitudes and assumptions, of the mental life of people living long ago, are ignored because local records are peculiarly silent—except indirectly—about large sectors of past thought [1970: 3].

Although such a neglect of "mental life" either of individuals or groups could not be held against the *Annalistes*, who hold Febvre's (1942) study of Rabelais or Bloch's (1973) portrait of the ideological reinforcements of royal power in such high esteem, Macfarlane's remarks address a problem to which scholars interested in exploring the world of historical individuals are particularly sensitive. His work, which in many ways exemplifies the techniques of "total history," is therefore doubly valuable, since it illustrates how this approach can illuminate both an individual life and the larger society in which Ralph Josselin lived.

Like Bloch, in the passage quoted previously, Macfarlane is interested not only in the possibly unique features of Josselin's material and mental world but also in the way in which his life studied in its variety of dimensions might help us understand seventeenth-century England, or societies like that of seventeenth-century England. He writes, "The number of first-class diaries increases very markedly in the eighteenth and, especially, the nineteenth centuries and it should be possible to make a series of biographical studies of individuals who illustrate the change of attitudes during these centuries [1970: 9]." However, even Macfarlane's use of one primary source, Josselin's own diary, is informed by a wide knowledge of seventeenth-century England and a variety of societies that in some ways resemble the material or ideational world that Josselin inhabited and made sense of for himself.

The delineation of the separate spheres of Josselin's life is carried out in a typical "total history" approach. Since Macfarlane is studying the life of one particular individual, those political conditions of seventeenth-century England that shaped Josselin's ability to earn a living, as well as his interpretation of the meaning of his life's events, are the starting point for the author's reconstruction of the time and place in which Josselin lived. The financial activities of the clergyman, land ownership, and the processes of gaining and spending income are reconstructed, thus "grounding" Josselin, in very concrete ways, in English rural society. Part 2, "The Life-Cycle," documents the occurrence of vital events in Josselin's life, explores the meaning of passages from different age statuses, the rituals of courtship and marriage—not only for Josselin but also for other seventeenth-century Englishmen. In Part 3, we see Josselin in relation to his kin, acquaintances, and friends, with a reconstruction of social networks in time and space. The final part, "The Mental World," entails the effort to reconstruct not only Josselin's reactions to discrete events of conditions of his life but also to understand the way different attitudes expressed by the clergyman in his diary might represent the coherent responses of an inhabitant of the reconstructed material, political, and cultural world already documented to concrete circumstances of that world.

Many of Josselin's attitudes, in fact, appear similar to those expressed by individuals widely separated in time and place from seventeenth-century England. We learn that in Josselin's mind "the world of phenomena was seen as purposeful and comprehensible [1970: 193]" and that in this, as in his understanding of the cause of human suffering, Josselin may have expressed an attitude found in many societies that are perhaps rarely thought of as meaningfully comparable to seventeenth-century England (1970: 194). Macfarlane's sensitive and artful reconstruction of the totality of Ralph Josselin's world ends with the author's statement of the way that individual-level information might be brought to bear on what we have characterized as "total history":

> Further problems, far too complex for discussion in this context, await the historian who tries to relate Josselin's mental structure to his social and physical background, to see for example, whether his religious beliefs were "appropriate" in his cultural surroundings. Yet it does not seem too optimistic to predict that if other sources are as adequate as the one Diary investigated in the preceding pages, it should one day be possible to discover the ways in which the mental, social and economic structures of the pre-industrial period were linked. In such an endeavor we will need not merely the painstaking demographic and economic analysis of the new schools of social and local history, but also the awareness of comparative material, and the constant pressure to investigate new and basic problems which can only be acquired through a detailed study of anthropological and sociological literature [1970: 196].

Although information from one diary is inadequate for the reconstruction of the "total history" of seventeenth-century England, Macfarlane's comparative perspectives are much broader than this. Insight into Josselin's responses to the human experience of vital events, networks of kin, neighbors, and politics finds rich illumination in the comparison of a seventeenth-century clergyman's life with the experience of those individuals inhabiting societies that are chronologically or spatially removed from Josselin's parish of Earls Colne.

The reconstruction of the "total history" of an entire community is illustrated in Emmanuel Le Roy Ladurie's *Montaillou: The Promised Land of Error* (1978). The Montaillou of the fourteenth century was a small parish near the Pyrennees in southern France with a local population of 200–250 persons. Le Roy Ladurie's primary source is the Inquisitorial Register of Jacques Fournier, bishop of Pamiers in Ariège (later to be Pope Benedict XII at Avignon), dating from 1318 to 1325. This register supplied the depositions of 25 accused heretics of the Albigensian persuasion and of witnesses residing in Montaillou. Each deposition typically covered 15 or more of the large folio pages in the register.

In Le Roy Ladurie's imagery, Montaillou is only a drop in the ocean that, thanks to the microscope created by the Fournier register, allows us to see the protozoa swimming about in it. Le Roy Ladurie's analysis of this mountain-dwelling microsociety brings us very close to an understanding of forces governing everyday life in small-scale peasant communities. *Montaillou* is divided into two parts. The first part deals with the "ecology" of the village, while the second part is an "archaeology," tracing relationships referring to body language and sexuality, marriage, the life cycle, social relationships, and the culturally perceived dimensions of the spiritual world. It is a complex study, interlocking different layers of demographic, sociological, and social psychological realities.

At the beginning of *Montaillou*, we find an ecological description of the village, perched on a hillside in the shadow of its grand château, surrounded by a checkerboard of small plots of land. Crop cultivation, the division of labor by age and sex, the relation of population size and emigration to food supplies, disease, the distribution of political power, the manorial system, and the relative absence of class struggle are all sketched in succession. Since the inhabitants of the village belonged to local peasant families, Le Roy Ladurie temporarily abandons the issue of social stratification to consider the peasant family, embodied in the 40 or so houses of the village.

Many passages in the Fournier register show the importance of the household or *domus*, as a unifying factor in socioeconomic life. In fact, the register permits the partial reconstruction of the interior of a typical house, as well as the population structure and genealogical links of the *domus*:

> Montaillou contained some truncated nuclear families (widows living alone, or with one child), some nuclear couples with children, some couples with several children and one parent (a widowed grandfather, or, more often, grandmother) and some groups of brothers, sometimes together with an elderly mother, sometimes with both parents, in which only one of the brothers would be married (the other brothers and sisters, even if they were grown up, would remain unmarried all the time the group continued to live together). The purely nuclear family was perhaps the most common, but it did not have a local monopoly.
>
> Family structure, in fact, varied chronologically. The same family was successively extended, then nuclear, then extended, and so on [1978: 47]
>
> Another version of the fully extended family was the multi-fraternal group. This included two brothers, or a brother and sister, with their respective spouses. They lived in a group of four, together with their children (there is no instance of this arrangement in Montaillou itself, though I have come across several true *frérèches*—sibling groups—in other localities in upper Ariège at the period which which we are concerned). Finally, the *domus* cannot be understood without its genealogical links, which connected it with other related, living *domus* through consanguinity (*parentela*). These bounds also linked the *domus* with the past, under the auspices of the lineage (*genus*) of the family, which was the *domus* looked at against the background of the past four generations at the most [1978: 48–49. This quotation and the following quotation cited to Ladurie (1978) are reprinted from *Montaillou: The Promised Land of Error* by Emmanuel Le Roy Ladurie, by permission of the publishers, Scolar Press and George Braziller, Inc. Copyright English translation, 1978 by Scolar Press. First published in French by Editions Gallimard © 1975, translated by Barbara Bray.]

The *domus* was the center, a network of demographic, friendship, and neighborhood links.

Without land registers it is difficult to arrive at a statistical estimate of the wealth distribution in Montaillou. The relative range from the most opulent to the poorest probably represented a difference of 50 to 1. These differences were usually expressed in terms of ownership of land or sheep, with illegitimate male children and children who were not heirs experiencing downward social mobility to become heads of a poor *domus*. The Clergue family and their houses dominated the village. The Fournier records show that there were at least 22 persons with the name Clergue, about twice as many as the next most frequently mentioned name. The Clergues of Montaillou exercised their influence through wealth, family connections, heresy, and power. Pierre Clergue, the village priest, controlled the spiritual realm, and Bernard Clergue, the *bayle* (bailiff), saw that tenants paid their rents and other manorial dues for the comte de Foix, lord of the village. The Clergues served as mediators between village society and the larger society that surrounded it.

The second part of *Montaillou* is perhaps the most fascinating. Here, Le Roy Ladurie takes us on a tour of peasant sexuality and illicit sexual relationships. We are presented with detailed descriptions of the decisional world of affairs, liaisons, and concubinage that underlies the demographic statistics of births, marriages, and infant deaths. The Fournier register describes a dozen authenticated mistresses of Pierre Clergue. His most important affair was with Beatrice de Planissoles, wife of the *châtelain*. The lovers used contraceptive precautions of dubious value. Beatrice describes Pierre's magic herb, amulet, or pessary in these words:

> When Pierre Clergue wanted to know me carnally, he used to wear this herb wrapped up in a piece of linen, about an ounce long and wide, or about the size of the first joint of my little finger. And he had a long cord which he used to put round my neck while we made love; and this thing or herb at the end of the cord used to hang down between my breasts, as far as the opening of my stomach [*sic*]. When the priest wanted to get up and leave the bed, I would take the thing from around my neck and give it back to him. It might happen that he wanted to know me carnally twice or more in a single night; in that case the priest would ask me, before uniting his body with mine, "Where is the herb?"
>
> I was easily able to find it because of the cord around my neck; I would put the "herb" in his hand and then he himself would place it at the opening of my stomach, still with the cord between my breasts. And that was how he used to unite himself with me carnally, and not otherwise [1978: 173].

The register shows that a minimum of 10% of the 50 or so couples in Montaillou, around 1300–1320, were "living in sin."

Despite these irregularities, which also included homosexual networks, marriage and local endogamy were the rule. Statistics derived from the register show that about 80% (43 couples) of the natives of Montaillou married within the parish. Why did people marry? Was it for love, or was the troubadour tradition correct that this passion existed only outside marriage? It is difficult to say. Many marriages were arranged by family or friends, and women appeared to regard real love as belonging outside legal marriage. That males typically married women much younger than themselves, in a time when people died relatively early in life, meant that women often went through two or even three marriages.

The peasant world of Montaillou was quite misogynous, with physical coercion by husbands a frequent means of responding to conflict. However, the register reports only two cases of marital separation out of some 50 couples. Over the period from 1280 to 1324 covered by the register, Le Roy Ladurie estimates a legitimate fertility rate of 4.5 births per family. Although the register does not contain any formal statistics on mortality, the partial data relating to the Cathar ceremony, the *consolamentum*, administered to believers on their deathbeds, yields a proportion of eight "young" to seven "old." The register suggests that exodus rather than starvation followed food shortages. It also provides evidence of epidemics and the classification of illnesses.

Le Roy Ladurie shows us how an obscure source, a fourteenth-century Latin register, makes it possible to reconstruct a "total history" of the demographic, biological, ecological, and socioeconomic levels of French peasant life and how they interpenetrated one another. In Le Roy Ladurie, we see the historian reaching out toward a demographically grounded, interdisciplinary, and quantitative style of research.

Although individual- or community-level data permit the reconstruction of the concreteness of daily life and human interaction shaped by demographic events, belief systems, or forms of land distribution and cultivation, it is in the study of long-term demographic change that the need to construct formal explanatory models becomes most explicit.

Livi-Bacci's *A History of Italian Fertility during the Last Two Centuries* (1977) investigates the aggregate aspects of historical demographic change in Italy. While Italy has a pattern of change quite similar in a number of important respects to other European populations, the decline of Italian fertility took place almost a century after that of France, a few decades after those of other western European countries, but a few decades before other southern European populations, such as the Spanish and Portuguese. His investigation starts systematically from the time of Napoleonic hegemony and extends up to the early 1960s.

While a comprehensive demographic history of Italy during the first part of the nineteenth century still awaits its author, Livi-Bacci draws upon a wide spectrum of secondary sources to give a brief survey of premodern fertility levels in five Italian villages for which nominative reconstitution has been undertaken. The average hypothetical number of children per woman marrying at age 20 or 25 is found to be one-fifth to one-third lower than the Hutterite natural fertility standard, with no evidence of voluntary control of fertility. Average family size ranged between five and six children. Birth rates of the Italian *dipartimenti* during Napoleonic times (1807–1813) are traced in scattered official publications and archival materials. For the 24 *dipartimenti* within the Kingdom of Italy, the birth rate was 39.2 per thousand in 1810–1812. The geography of natality during the 1830s is reconstructed for 78 provinces, showing that more than half had a birth rate between 35 and 40 per thousand. This was quite similar to the earlier Napoleonic period. But the paucity and imperfection of available statistical data generally prevent use of fertility measures more detailed than the crude birth rate or the general fertility rate.

Livi-Bacci investigates the fertility of two small, relatively homogeneous groups, Jews and aristocrats. The urban Jewish population's birth rate began to decline almost 100 years before that of the Italian population as a whole. Livi-Bacci speculates that Jews may have adopted neo-Malthusian habits as a result of feeling the physical pressure of a limited environment. Recent studies on the fertility of the aristocracy in Florence and Lombardy document a clear trend toward lowered fertility and family size by the second part of the eighteenth century. It is interesting that what appears to be voluntary control of fertility within marriage found its earliest acceptance among an oppressed religious minority and a privileged social elite.

Secular trends in fertility and nuptiality are computed from the 10 official censuses for the post-unification period (1861–1961), using the indirect standardization indexes proposed by Ansley Coale. At the national level, the fertility transition began at the end of the nineteenth century, lasting about 60 years, but the transition had quite different regional time spans. Livi-Bacci infers the possible "existence of a 'diffusion' pattern, according to which an increasing proportion of the population is led to reduce family size [1977: 109]."

Having computed indexes of overall fertility (I_f), marital fertility (I_g), illegitimate fertility (I_h), and the proportion married (I_m), for each census by region, Livi-Bacci is quick to observe that the Coale indexes do not give a complete picture. His comments on the index of marital fertility, for example, deserve attention:

> The index of marital fertility, for instance, may be the same in two groups of women, one with a very low, the other with a very high, age at marriage. The ratio of their actual fertility performance within their married life to the Hutterite standard would, in both cases, be the same. But the number of children per woman, or per marriage, would be very different. For example, the I_g of Albania was .696 in 1955; and that of Ireland was .612 in 1960–1962, or 12 percent less; however, the birth rate of the latter country (21.2) was half the birth rate of the former (41.7). Similar differences would also be found in the number of children per woman [1977: 86. This quotation and following quotations cited to Livi-Bacci (1977) are from Massimo Livi-Bacci, *A History of Italian Fertility during the Last Two Centuries*. Copyright © 1977 by Princeton University Press. Excerpts reprinted by permission of Princeton University Press.]

This quotation clearly illustrates that calculations of the Coale indexes are only a starting point for a thoroughgoing causal analysis. The index of proportion married, for example, may be a function of at least six different factors: the mean age at marriage; the proportion remaining single; the frequency of separation and divorce; the level of mortality; the frequency of remarriage of the widowed and divorced; and the sex ratio. Regional differentials in an index such as I_m may be due to different combinations of factors. Likewise, values of I_m for two or more regions may be numerically equal, but for entirely different reasons. Being quite sensitive to the methodological difficulties thus posed, Livi-Bacci devotes the remaining half of his work to the integration of his demographic findings with biological, ecological, and socioeconomic factors in a genuine but admittedly incomplete approximation of a "total history."

Since it is often assumed that neo-Malthusian behavior will occur first in urban populations in which social mobility, the standard of living, and the extent of education are normally higher than elsewhere, Livi-Bacci begins his explanatory analysis of the Italian fertility decline by testing the validity of this general urban–rural hypothesis. His research strategy is as follows:

> (1) Ascertaining whether the fertility decline actually started in the urban areas, and whether it was more rapid in the urban, than in the rural, population
> (2) Ensuring that the [fertility] decline is related to the diffusion of voluntary birth control methods, and not to the effects of external factors such as sex composition, postponement of marriage, and so forth
> (3) Examining the structural characteristics peculiar to urban populations that may affect (at least indirectly) the level of fertility, but whose exact impact cannot be appreciated with the traditional tools of demographic analysis [1977: 110].

The distinction between the urban and the rural population is based on the assumption that the population sizes of *communi* (small administrative units of residence) are directly correlated with the degree of urbanization. Livi-Bacci defines three classes of *communi*: mainly rural, semirural, and mainly urban. He computes general and marital fertility rates for each commune class by region, using published data from the censuses of 1871, 1901, 1931, and 1951. A special 1931 census report on fertility is also employed to study urban–rural differentials in greater detail.

Since statistics on families according to personal wealth and number of surviving children may, under certain conditions, be used to estimate differential fertility, Livi-Bacci surveys a variety of previous studies and sources to complement his own analyses. The *Catasto* of Florence of 1427 was a tax inventory of the wealth of the population of the city, listing for every family the name, age, sex, marital status, and relationship of each individual to the head of the family. Data of this nature allow one to compute the mean number of surviving children in households for age groups of married men or women in different wealth categories. However, statistics of this nature may be affected by at least four interacting factors: age-specific fertility; infant and child mortality; age at marriage; and the age and rate of exit of children from the household due to marriage or emigration.

Thus, although analysis of the *Catasto* shows that a relatively higher number of surviving children appear in every age group for married women in rich families, "it is impossible, in the absence of an evaluation of the level of mortality and of the age at marriage to say whether differential fertility existed between families of different wealth; if they did exist, it is likely that the wealthier families also had higher fertility [Livi-Bacci, 1977: 220]." Despite this serious caveat, and with only similarly ambiguous findings from other available studies, Livi-Bacci provisionally accepts as a fact that until the beginning of the nineteenth century, a direct relationship existed between the number of surviving children and socioeconomic level. He then theorizes that because the motivation for curtailing family size was related to the economic, psychological, and physical pressure children exert on couples, family limitation can be expected to appear first among richer families who had a higher number of surviving children (primarily due to differential mortality and possibly differences in age at marriage). Thus, what had been a traditional, positive relationship between the number of surviving children and socioeconomic status reversed itself as time went on, leaving poorer families with more children. Livi-Bacci anticipates that in the future, the level of fertility will return to the "logical" equilibrium of the fifteenth-century pattern.

Since in a population in which contraception is not widespread biological factors may be a key determinant of variability in fertility differentials, Livi-Bacci draws together existing information regarding the ages of puberty and menopause, the diffusion and duration of breastfeeding, and sterility. He argues that prolonged breast-feeding may have been an important factor in keeping the predecline fertility of the Italian population below the predecline fertility of non-Mediterranean European populations.

Livi-Bacci concludes that additional aggregate-level research will be unlikely to alter the general picture of fertility decline that he has reconstructed. Acknowledging the limitations of aggregate-level, formal demographic analysis, Livi-Bacci ends his work by pointing future researchers in the direction of "total history":

> . . . Two different [non-aggregate level] approaches do merit attention.
>
> With the first approach, at the micro-level, the characteristics of fertility decline could be followed for selected groups of the population. For instance, the comparative evolution of fertility and nuptiality in the agricultural classes, according to the type of land-ownership system and in connection with the analysis of the structure of the family and of the response to changing economic conditions, could prove extremely productive. This type of approach, however, could be followed only on a small scale, and on the basis of data collection from nominative records.
>
> On the other hand, a satisfactory interpretation of the factors of fertility decline cannot be done without a careful reconstitution of the *histoire des mentalités*. The gradual acceptance of fertility control has to be explained in the light of the general evolution of the attitudes of the population. Modifications of religious feelings and of the prevailing morale, changes in the relations between men and women and parents and children, and the development of a political conscience and the formation of a class conscience among the rural, urban, industrial, and middle classes are some of the many important elements necessary for the reconstitution of the general cultural climate generating the changes of attitudes on procreation.

> The first approach is the demographer's task. But he cannot ignore the second, unless he is resigned to accepting a purely deterministic interpretation of demographic trends [1977: 289–290].

Although the skills of the social anthropologist, historian, and formal demographer illustrated in the preceding examples, will doubtless continue to remain distinctive, it is through the balanced combination of their points of view that historical demography can most obviously contribute to the pursuit of a "total history" perspective. The multidisciplinary capacities that Hollingsworth (1969: 11) prescribed for the ideal historical demographer can rarely, if ever, be mastered by one individual. However, as much of this book has attempted to illustrate, historical demography is one of the fields of inquiry among the human sciences most likely to benefit from the trend toward interdisciplinary research. E. A. Wrigley's comments of over a decade ago regarding historical demography are still quite relevant: "Perhaps indeed the most fascinating time of all in the development of a subject comes when its possibilities have grown plain but only a fraction of the source material has been sifted and the techniques and unifying concepts are still at the state of rapid change and improvement [1969: 29]." The formulation of a research design specifying how historical demographic sources and statistical methods are best combined to fulfill theoretical requirements is typically a creative act. The present book can carry the historical demographer only so far. A theoretically informed, scholarly ingenuity must ultimately take over to blend knowledge of sources with technical expertise.

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