Attempts at Prediction and the Theory They Stimulated

The tools needed for population projections, age-specific fertility and mortality rates, were in existence by the early part of the 19th century. They remained unused almost to the 20th. Edwin Cannan's (1895) article, which begins this chapter, both established life table rates as the necessary base for competent projections and demonstrated that if care were taken the rates could reasonably be adjusted in anticipation of future changes.

Independently of Cannan's work and later contributions by A. L. Bowley (1924, 1926), P. K. Whelpton (1936) also developed component population projections. Whelpton in his projections for the United States divided total population into ethnic groupings recognized by the census, handling each separately, and considered immigration as an independent component; apart from fertility he followed procedures he and W.S. Thompson had previously worked out (Whelpton 1928; Thompson and Whelpton 1933). The estimates were almost immediately overtaken by events, a war that was not widely expected in 1936 and a postwar baby boom not expected even when it hit. Yet for the few years that the future was orderly it accorded with Whelpton's calculations, and the clear logic of separating age groups has never since been at issue. We include Whelpton's 1936 article as paper 23. Methods it has replaced are discussed by Cannan and also in chapter 4.

The use of matrices in population projections was first suggested by Harro Bernardelli (1941), paper 24, who noted from the sizes of Burmese birth cohorts that birth peaks occurred at intervals of a generation and that these might carry important economic and social implications, a question examined more recently by Richard Easterlin (1966) for its possible relationship to Kuznets cycles. From a projection matrix formed by holding fertility and mortality constant Bernardelli isolated the characteristic roots of the net maternity function for the discrete case, identifying the dominant root as the intrinsic growth rate of the population and relating the other roots to oscillations in the birth rate. By mischance, Bernardelli utilized a matrix concentrating fertility into a single age category. This gives rise to the exceptional result, which he took to be a general case and drew several spurious conclusions from, that oscillations in the birth rate and hence in the age structure might be maintained or amplified over time rather than becoming damped.

In a paper that followed Bernardelli's address by three months, E.G. Lewis (1942) presented a better but still essentially preliminary exploration of the

projection matrix, which we include here as paper 25. This is followed by P. H. Leslie's (1945) definitive article: Leslie develops the use of matrices fully, with attention to the several types of information they make accessible and their relationship to the earlier theory developed by Lotka. The present widespread use of projection matrices is an extension of his work. A generalized inverse for the Leslie matrix to permit limited backward projection is given by Greville and Keyfitz (1974). We follow Leslie's article with an extension due to Leon Tabah (1968), in which he shows how matrices may be applied to migration and labor force projections as well as to overall population change. The method is also explained in Rogers (1968, pp. 6—15).

From the development of the projection matrix we turn to the concepts of strong and weak ergodicity, whose initial proofs were developed through matrix formulation but which otherwise are a continuation of the discussion in chapter 2. Paper 28 extracts from Alvaro Lopez (1961) a statement of ergodicity. The concluding article by Beresford Parlett (1970) compactly summarizes matrix development of ergodicity and general stable population theory.

The reader might return from Parlett to the opening article of the chapter to appreciate the impressive achievements in discrete stable theory and determination of characteristic roots and vectors that have followed from Cannan's introduction of simple but correct principles for population projection.