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# On the changing shape of the Australian mortality curve*

**J. H. Pollard**

*Nanyang Technological University, Singapore and Macquarie University, Sydney*

## Abstract

**Over the course of the twentieth century, mortality rates in Australia have shown substantial improvements at all ages. The improvements which have taken place at different ages, however, have not occurred at a uniform pace, and as a result, the shapes of the national mortality curves have varied over time. The most noticeable change for males has been the development of an 'accident hump' in the late teens and early twenties mid-century, the growth of this 'hump' in the 1960s and 1970s, and its sudden disappearance, or transformation into a 'bulge', in the late 1980s. This paper examines the reasons for the disappearance of the male 'accident hump', and the changes in mortality by cause which have occurred over the decade to 1992 and influenced the level and shape of the whole mortality curve both for males and for females. Extrapolating the trends observed for the various cause-specific mortality rates obtains projected life tables for Australian males and females in the year 2002.**

The Australian population has enjoyed remarkable improvements in mortality over the twentieth century. Expectation of life at birth for females rose from 59 years in the early years of the century to more than 80 years in 1992, and these improvements in longevity show no signs of abating. For males, the corresponding increase has been from 55 to 74. The improvements in mortality which have taken place have not occurred at a uniform pace in all age groups, and as a result, the mortality curve ($q_x$ plotted against age x) has undergone several important changes in shape. The increasing prominence of the so-called 'accident hump' at the younger adult ages for males (Figure 1), has been remarkable. A similar but less spectacular pattern for females emerged rather later (Figure 2).

But even more remarkable, perhaps, than the development of the male accident hump has been its sudden disappearance in the late 1980s (Figure 3), and its transformation to an 'accident bulge' not unlike that observed for the females a few years earlier. Random breath testing of drivers for alcohol was introduced in 1983, and there would appear to be a change in attitude among young adults concerning drink-driving. At the same time, compulsory use of seat-belts has been legislated, and there has been greater use and awareness of radar

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**Figure 1**
**Mortality q(x) curves of Australian males according to Australian Life Tables (Males) A1932-34, A1953-55, A1970-72 and the 1982 data.**

**Figure 2**
**Mortality q(x) curves of Australian females according to Australian Life Tables (Females) A1932-34, A1953-55, A1970-72 and the 1982 data.**

speed checks. The substantial decline in motor accident fatalities has also been widely publicized. An initial hunch, therefore, for the disappearance of the 'accident hump' would be the marked decline in motor vehicle deaths (1,408 and 658 for males and females respectively in 1992 compared with 2,492 and 872 in 1982), a large proportion of these being at the early adult ages, and the appearance of AIDS-related deaths which occur predominantly in the age range 25-40. The decline in the motor vehicle death rates at the early adult ages would drastically reduce the 'accident hump' and the rise in mortality in the late twenties and early thirties due to AIDS would convert the remaining 'hump' into a 'bulge'. In broad terms, the data support this hypothesis (Table 1). There are however changes in other causes of death which cloud the picture a little, and among these, the disturbing increase in suicides of males of all ages, from 1,318 in 1982 (a little over half the number of male road deaths that year) to 1,811 in 1992 (about 30 per cent higher than the number of road deaths) is particularly noteworthy. The sizes of the changes which have taken place are evident from Table 1. This paper examines the changes which occurred in Australian mortality, by cause, over the decade 1982-1992, and the effects these changes have had on the shape of the national life tables.

**Table 1**
**Australian males. Changes in cause-specific mortality rates per 100,000 between 1982 and 1992 and their effects on the all-causes mortality rate per 100,000 over that period[a].**

| | **Ages 15-19** | | **Ages 20-24** | | **Ages 25-29** | | **Ages 30-34** | |
|---|---|---|---|---|---|---|---|---|
| All cause rate in 1982 | | 128 | | 161 | | 142 | | 135 |
| Motor accid. 1982 | 67 | | 75 | | 49 | | 34 | |
| Motor accid. 1992 | 28 | | 34 | | 26 | | 20 | |
| Change | | -39 | | -41 | | -23 | | -14 |
| Suicide 1982 | 12 | | 27 | | 28 | | 21 | |
| Suicide 1992 | 19 | | 34 | | 32 | | 28 | |
| Change | | +7 | | +7 | | +4 | | +7 |
| AIDS flagged 1982 | 0 | | 0 | | 0 | | 0 | |
| AIDS flagged 1992 | 0 | | 2 | | 10 | | 17 | |
| Change | | +0 | | +2 | | +10 | | +17 |
| All other causes 1982 | 49 | | 59 | | 65 | | 80 | |
| All other causes 1992 | 36 | | 50 | | 60 | | 71 | |
| Change | | -13 | | -9 | | -5 | | -9 |
| All cause rate in 1992 | | 83 | | 120 | | 128 | | 136 |

[a] $100{,}000\ {}_5m_x$

**Figure 3**
**Mortality rates per 1000 for Australian males aged 18-38, according to the experiences of 1983, 1986, 1989 and 1992 (reproduced from Fabrizio, 1993)**

## The data

All the analyses for this article were performed using the World Health Organization mortality package LIFETIME, which requires deaths by cause in the age groups 0, 1, 2, 3, 4, 5-9, 10-14, 15-19, ..., 80-84, 85+. The same age groups are used for the mid-year population. The 1982 data in this format were kindly provided by WHO, although their original source was of course the Australian Bureau of Statistics (ABS). The 1992 deaths on the other hand were coded into the required form from the individual death records now made available by the Australian Bureau of Statistics, and the help of Mrs Jenny Wildgoose and the Cologne Life Reinsurance Company of Australia in this task is gratefully acknowledged. A major advantage of the individual deaths record is that AIDS deaths were flagged. AIDS deaths were virtually unknown in 1982, and were certainly not coded, and for the purpose of this paper, are assumed to be zero. Because of the age groupings used, there will be some minor differences between life table values produced by LIFETIME and those published annually by ABS, but these are of no consequence. The LIFETIME program in fact has a slight graduation effect, something which is absent from the annual tables produced by ABS. The cause-of-death codings used throughout have been the B codings under the Ninth Revision of the International Classification of Diseases. The Australian Life Tables, prepared by the Australian Government Actuary and published by ABS, are graduated tables based on deaths over three years around the time of a census. Three years of deaths are used to reduce the effects of statistical variation in the numbers of deaths and of other factors which are not believed to be annual events, such as influenza epidemics. The present analysis uses data from individual years and thus is subject to greater statistical variation. The higher mortality of females aged four in 1992 compared with males the same age, for example, is probably of this nature. The effect is reproduced in the abridged life tables which are reported later in this paper.

**Table 2**
**Crude mortality rates per 100,000, by cause. Australian males and females, 1982 and 1992.**

| Cause group | Males 1982 | Males 1992 | Females 1982 | Females 1992 |
|---|---|---|---|---|
| 1 Infect. dis. B1-B7 | 4 | 5 | 3 | 5 |
| 2 'Smoking' neopl. B8-B10 | 65 | 64 | 17 | 23 |
| 3 Breast cancer B11.3 | 0 | 0 | 26 | 28 |
| 4 All other neopl. B9 B11 -B17 excl. B11.3 | 124 | 146 | 100 | 109 |
| 5 Ischaemic heart dis. B27 | 250 | 196 | 177 | 164 |
| 6 Cerebrovascular dis. B29 | 74 | 56 | 110 | 81 |
| 7 Other circul. B25 B26 B28 and B30 | 68 | 59 | 82 | 72 |
| 8 Respiratory dis. B31-B32 | 77 | 68 | 41 | 47 |
| 9 Cirrhosis B34.7 | 12 | 9 | 5 | 3 |
| 10 Obstetrics B38-B41 | 0 | 0 | 0.33 | 0.10 |
| 11 Congen./perinatal B44- B45 | 15 | 11 | 12 | 8 |
| 12 Non-motor accid. B47-B53 excl. B47.1 | 25 | 19 | 12 | 11 |
| 13 Motor accid. B47.1 | 33 | 16 | 11 | 8 |
| 14 Suicide B54 | 17 | 21 | 6 | 5 |
| 15 Other violence B55-B56 | 3 | 4 | 1 | 2 |
| 16 AIDS flagged | 0 | 7 | 0 | 0.25 |
| 17 All other causes[a] | 68 | 77 | 74 | 91 |
| All causes | 835 | 759 | 677 | 656 |

[a] B18-B24, B33-B37 excluding B34.7, B42-B43, B46

**Table 3**
**Australian males and females. Changes in the crude mortality rates per 100,000 over the decade 1982 to 1992.**

| | |
|---|---|
| *Males:* | |
| CMR per 100,000 in 1982 | 835 |
| Effect of changed mortality | -203 |
| Effect of changed age structure | +127 |
| CMR per 100,000 in 1992 | 759 |
| *Females:* | |
| CMR per 100,000 in 1982 | 677 |
| Effect of changed mortality | -124 |
| Effect of changed age structure | +103 |
| CMR per 100,000 in 1992 | 656 |

## Crude mortality rates

Crude mortality rates per 100,000 for Australian males and females in 1982 and 1992 are exhibited in Table 2 for 17 selected causes of death (the causes are mutually exclusive and exhaustive) and for all causes combined. It is immediately apparent that over the decade a number of significant changes have taken place. Whilst ischaemic heart disease (IHD) remains the dominant killer for both sexes, its relative importance has continued to decline rapidly. So too has the importance of cerebrovascular disease, the second most important female killer and third most for males, and 'other circulatory diseases'. The changes which have taken place in motor vehicle mortality and suicide noted above are of course clearly reflected in the table. Changes in the contributions of other causes are also suggested by this table, but care must be exercised, since the effect of age structure changes can be significant, as is shown by the analyses in Table 3, based on the method of Kitagawa (1955). Male mortality from all causes, for example, has improved rather more than a direct comparison of crude rates in 1982 and 1992 would suggest: a proportionate fall of 203/835 or around 25 per cent (rather than 77/835) indicating an increase in life expectancy at the younger ages of almost three years. On the other hand the proportionate change in overall female mortality, based on the Kitagawa adjustment, is lower: a fall of 124/677 or around 18 per cent, indicating an improvement in life expectancy at the younger ages of around two years[1]. At long last the gulf between male and female life expectancy which has continued to widen for so many years now appears to be narrowing.

## Standardized mortality rates

To avoid the problems inherent in the study of crude mortality rates, caused by changing age structures, standardized mortality rates per 100,000 were computed for the same selected causes and for all causes combined. These are exhibited in Table 4. The standard population used was the Australian population of 1992, males and females combined. From this table, further interesting results emerge. Whereas males have enjoyed a substantial reduction in mortality from 'smoking' cancers and from respiratory diseases, female 'smoking' cancer mortality deteriorated over the decade and female respiratory disease mortality stagnated. Mortality from homicide and other violence, albeit a small proportion of total mortality, increased for females as well as for males. The ratios of the all-causes standardized mortality rates also reveal the sex differentials in life expectancy at the younger ages: about seven years in 1982 (1,138/637=1.8) and around six years in 1992 (887/521=1.7)[2].

[1] Under the Gompertz 'law' of mortality, which provides a good approximate representation of mortality beyond age 30 (where nowadays most deaths in a developed population occur), the force of mortality increases by around eight or nine per cent from one age to the next. So if mortality at all ages decreased by 25 per cent, the effect would be equivalent to treating all lives as being almost three years younger than in the original life table.

[2] See the Gompertz 'law' explanation in Footnote 1.

**Table 4**
**Standardized[a] mortality rates per 100,000, by cause. Australian males and females, 1982 and 1992.**

| Cause group | Males 1982 | Males 1992 | Females 1982 | Females 1992 |
|---|---|---|---|---|
| 1 Infect. dis. B1-B7 | 5 | 6 | 3 | 4 |
| 2 'Smoking' neopl. B8-B10 | 81 | 71 | 17 | 20 |
| 3 Breast cancer B11.3 | 0 | 0 | 26 | 25 |
| 4 All other neopl. B9 B11-B17 excl. B11.3 | 164 | 169 | 98 | 94 |
| 5 Ischaemic heart dis. B27 | 344 | 233 | 166 | 125 |
| 6 Cerebrovascular dis. B29 | 115 | 70 | 100 | 59 |
| 7 Other circul. B25 B26 B28 and B30 | 105 | 73 | 73 | 52 |
| 8 Respiratory dis. B31-B32 | 117 | 84 | 37 | 37 |
| 9 Cirrhosis B34.7 | 13 | 10 | 5 | 3 |
| 10 Obstetrics B38-B41 | 0 | 0 | 0.32 | 0.10 |
| 11 Congen./perinatal B44-B45 | 14 | 10 | 12 | 8 |
| 12 Non-motor accid. B47-B53 excl. B47.1 | 29 | 21 | 12 | 8 |
| 13 Motor accid. B47.1 | 33 | 17 | 11 | 8 |
| 14 Suicide B54 | 19 | 21 | 6 | 5 |
| 15 Other violence B55-B56 | 3 | 4 | 1 | 2 |
| 16 AIDS flagged | 0 | 7 | 0 | 0.25 |
| 17 All other causes[b] | 96 | 93 | 70 | 70 |
| All causes | 1138 | 887 | 637 | 521 |

[a]The Australian female population 1992 was used as standard. [b]B18-B24, B33-B37 excluding B34.7, B42-B43, B46

## Australian life tables in 1982 and 1992

Abridged life tables for Australian males and females in 1982 and 1992 are presented in Tables 5 and 6. Full life tables were also computed using LIFETIME, but for the sake of conciseness are not reproduced here. As was noted above, the observed female mortality rate at age four in 1992 was higher than the corresponding male rate. The most likely explanation is statistical variation, particularly as the observed numbers of deaths are so small. The aberration is reflected in the life tables, which suggest slightly higher female mortality near age four in 1992. Fortunately, the effect of such statistical error on life expectancy and other important measures is insignificant. The abridged tables indicate that mortality rates at all ages under the 1992 table are lighter than those under the 1982 table, for both sexes. In the early thirties, for males, however, the differences between the 1992 rates and the 1982 rates are small. AIDS deaths in 1992, which were virtually non-existent in 1982, are probably a significant factor contributing to this feature. The full male life table for 1992 provided by LIFETIME gives mortality rates at ages 32 and 33 which are higher than the same rates in

1982. Table 5 reveals that life expectancy at birth for males improved 3.32 years over the decade, compared with 2.28 years for females (Table 6), resulting in a narrowing of the sex differential in life expectancy at birth from 7.03 to 5.99 years, results which I anticipated in my earlier examination of the Kitagawa-adjusted crude mortality rates and the standardized mortality rates.

**Table 5**
**Abridged life tables for Australian males, 1982 and 1992 and projected for 2002**

| Age | 1982 experience | | | 1992 experience | | | 2002 (projected) | | |
|---|---|---|---|---|---|---|---|---|---|
| x | $^{1}x$ | $10^{5}q\,x$ | $^{oe}x$ | $^{1}x$ | $10^{5}q\,x$ | $^{oe}x$ | $^{1}x$ | $10^{5}q\,x$ | $^{oe}x$ |
| 0 | 100000 | 1159 | 71.16 | 100000 | 794 | 74.48 | 100000 | 622 | 76.83 |
| 1 | 98841 | 107 | 70.99 | 99206 | 61 | 74.08 | 99378 | 54 | 76.30 |
| 2 | 98736 | 69 | 70.07 | 99146 | 48 | 73.12 | 99324 | 37 | 75.34 |
| 3 | 98668 | 54 | 69.12 | 99098 | 34 | 72.16 | 99287 | 26 | 74.37 |
| 4 | 98614 | 45 | 68.15 | 99065 | 24 | 71.18 | 99261 | 20 | 73.39 |
| 5 | 98570 | 40 | 67.18 | 99041 | 20 | 70.20 | 99242 | 17 | 72.41 |
| 10 | 98387 | 37 | 62.30 | 98943 | 20 | 65.26 | 99164 | 15 | 67.46 |
| 15 | 98167 | 78 | 57.44 | 98823 | 46 | 60.34 | 99069 | 37 | 62.52 |
| 20 | 97542 | 170 | 52.79 | 98413 | 118 | 55.58 | 98742 | 98 | 57.72 |
| 25 | 96760 | 148 | 48.19 | 97826 | 125 | 50.90 | 98243 | 108 | 53.00 |
| 30 | 96076 | 134 | 43.52 | 97201 | 132 | 46.21 | 97693 | 117 | 48.28 |
| 35 | 95430 | 146 | 38.80 | 96542 | 142 | 41.51 | 97106 | 126 | 43.56 |
| 40 | 94654 | 205 | 34.09 | 95814 | 176 | 36.80 | 96454 | 155 | 38.84 |
| 45 | 93466 | 351 | 29.49 | 94845 | 253 | 32.15 | 95606 | 219 | 34.16 |
| 50 | 91396 | 606 | 25.10 | 93408 | 408 | 27.60 | 94359 | 348 | 29.58 |
| 55 | 88006 | 1019 | 20.96 | 91048 | 693 | 23.25 | 92338 | 584 | 25.16 |
| 60 | 82609 | 1659 | 17.16 | 87154 | 1199 | 19.17 | 89015 | 1000 | 21.00 |
| 65 | 74641 | 2668 | 13.71 | 80792 | 2023 | 15.47 | 83594 | 1671 | 17.19 |
| 70 | 63226 | 4263 | 10.71 | 71255 | 3257 | 12.18 | 75412 | 2663 | 13.77 |
| 75 | 48534 | 6718 | 8.17 | 58166 | 5306 | 9.33 | 63971 | 4281 | 10.76 |
| 80 | 31875 | 10232 | 6.12 | 48949 | 6761 | 8.27 | 48949 | 6761 | 8.27 |
| 85 | 16743 | 15263 | 4.47 | 24432 | 12696 | 5.25 | 32192 | 10100 | 6.27 |

## The change in life expectancy at birth

The approximate sizes of the improvements in life expectancy at birth were evident from the changes in standardized mortality rates reported in the fourth section, where the major contributing causes were also identified in general terms. Precise details of the contributions of the selected causes within selected age ranges to these improvements in life expectancy are readily obtained using the decomposition method of Pollard (1982, 1988) included in the LIFETIME package. The results are shown as Tables 7 and 8 for males and females respectively. In the case of the males (Table 7), we see for example that improvement in ischaemic heart disease mortality contributed more than 40 per cent of the increase in life expectancy at birth (1.34 years out of 3.32) and that IHD mortality improvement between 50

**Table 6**
**Abridged life tables for Australian females, 1982 and 1992 and projected for 2002**

| Age | 1982 experience | | | 1992 experience | | | 2002 (projected) | | |
|---|---|---|---|---|---|---|---|---|---|
| x | $^{1}x$ | $10^{5}q\,x$ | $^{oe}x$ | $^{1}x$ | $10^{5}q\,x$ | $^{oe}x$ | $^{1}x$ | $10^{5}q\,x$ | $^{oe}x$ |
| 0 | 100000 | 908 | 78.19 | 100000 | 601 | 80.47 | 100000 | 474 | 82.11 |
| 1 | 99092 | 91 | 77.90 | 99399 | 61 | 79.95 | 99526 | 48 | 81.50 |
| 2 | 99001 | 55 | 76.97 | 99339 | 35 | 79.00 | 99478 | 32 | 80.54 |
| 3 | 98946 | 35 | 76.01 | 99304 | 27 | 78.03 | 99446 | 24 | 79.57 |
| 4 | 98912 | 24 | 75.04 | 99277 | 25 | 77.05 | 99422 | 21 | 78.59 |
| 5 | 98888 | 21 | 74.06 | 99253 | 22 | 76.07 | 99401 | 19 | 77.60 |
| 10 | 98795 | 18 | 69.12 | 99167 | 14 | 71.13 | 99327 | 12 | 72.66 |
| 15 | 98694 | 30 | 64.19 | 99091 | 23 | 66.19 | 99261 | 20 | 67.70 |
| 20 | 98489 | 47 | 59.32 | 98924 | 43 | 61.29 | 99122 | 37 | 62.80 |
| 25 | 98258 | 50 | 54.45 | 98712 | 43 | 56.42 | 98940 | 37 | 57.91 |
| 30 | 98000 | 54 | 49.59 | 98494 | 50 | 51.54 | 98745 | 45 | 53.02 |
| 35 | 97721 | 70 | 44.72 | 98218 | 66 | 46.68 | 98495 | 59 | 48.14 |
| 40 | 97303 | 118 | 39.91 | 97850 | 95 | 41.84 | 98162 | 86 | 43.30 |
| 45 | 96582 | 202 | 35.18 | 97293 | 150 | 37.07 | 97650 | 138 | 38.51 |
| 50 | 95377 | 339 | 30.59 | 96398 | 250 | 32.39 | 96819 | 231 | 33.82 |
| 55 | 93417 | 530 | 26.18 | 94913 | 408 | 27.85 | 95446 | 374 | 29.27 |
| 60 | 90504 | 825 | 21.94 | 92592 | 642 | 23.48 | 93313 | 585 | 24.87 |
| 65 | 86049 | 1317 | 17.93 | 89039 | 1030 | 19.31 | 90054 | 928 | 20.68 |
| 70 | 79375 | 2104 | 14.22 | 83512 | 1728 | 15.41 | 85048 | 1523 | 16.74 |
| 75 | 69582 | 3558 | 10.85 | 74824 | 2990 | 11.89 | 77294 | 2564 | 13.15 |
| 80 | 55255 | 6213 | 7.97 | 61682 | 5246 | 8.86 | 65673 | 4364 | 10.01 |
| 85 | 36828 | 10474 | 5.68 | 43851 | 8864 | 6.41 | 49700 | 7218 | 7.39 |

and 70 years of age alone contributed almost 25 per cent (0.75 years). Circulatory disease mortality improvement as a whole contributed almost two-thirds of the total increase. A gain of more than a quarter of a year of life came as a result of motor accident mortality reduction in the age range 15-29 with almost as much again gained from motor accident mortality reduction at all other ages. The advent of AIDS on the other hand reduced life expectancy by a sixth of a year, predominantly as result of deaths in the age range 30-49. Decreased mortality from 'smoking' cancers added a seventh of a year of life. The female analysis is shown in Table 8. Improved IHD mortality produced a third of the increase in life expectancy (0.74 years out of 2.29). Reduced mortality from circulatory diseases as a whole produced two-thirds of the gain (1.51 years). Other causes had relatively minor effect. Increased 'smoking' cancers mortality at the older ages had the effect of reducing life expectancy by 0.05 years, whilst improved motor accident mortality increased life expectancy by a seventh of a year.

**Table 7**
**Contributions of mortality changes by age and cause[a] to the change in life expectancy at birth of Australian males between 1982 and 1992. The contributions shown are hundredths of a year of life[b].**

| Cause | Age group |
|---|---|

| group | 0 | 1-4 | 5-14 | 15-29 | 30-49 | 50-69 | 70+ | All ages |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | -1 | 0 |
| 2 | 0 | 0 | 0 | 0 | 2 | 8 | 4 | 14 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 1 | 1 | 5 | 0 | -4 | 4 |
| 5 | 0 | 0 | 0 | 0 | 15 | 75 | 43 | 134 |
| 6 | 0 | 0 | 0 | 1 | 2 | 16 | 22 | 41 |
| 7 | 0 | 0 | 0 | 1 | 3 | 9 | 15 | 28 |
| 8 | 0 | 1 | 1 | 1 | 2 | 10 | 16 | 32 |
| 9 | 0 | 0 | 0 | 0 | 2 | 3 | 1 | 6 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 17 | 1 | 0 | 0 | 0 | 0 | 0 | 18 |
| 12 | 0 | 2 | 2 | 4 | 4 | 3 | 1 | 18 |
| 13 | 0 | 2 | 5 | 27 | 7 | 4 | 1 | 47 |
| 14 | 0 | 0 | 0 | -4 | -3 | 0 | 0 | -8 |
| 15 | 0 | 0 | 1 | -1 | -1 | -1 | 0 | -1 |
| 16 | 0 | 0 | 0 | -3 | -11 | -2 | 0 | -17 |
| 17 | 8 | 1 | 1 | -2 | 0 | 6 | 0 | 15 |
| All causes | 27 | 8 | 12 | 26 | 28 | 132 | 99 | 332 |

[a]For a description of each cause group, see for example Table 2. [b]Because of rounding, row and column sums may not tally exactly with the totals shown.

## The differential in life expectancy at birth

The method used to study the change in life expectancy at birth of a population can also be used to analyse sex differentials in life expectancy, and in particular sex differentials in life expectancy at birth (Tables 9 and 10). From the first of these tables, we see that the major causes producing the sex differential in life expectancy at birth were, in descending order of magnitude: ischaemic heart disease contributing 2.38 years (almost three times the contribution of its next rival), 'smoking' neoplasms (0.85 years), respiratory diseases (0.80 years), all other neoplasms excluding breast cancer (0.77 years), and motor vehicle accidents (0.63 years). Whilst IHD maintained its number one position in 1992, its contribution fell dramatically to 1.69 years (Table 10). All other neoplasms (excluding breast cancer) moved up into second position with a much increased value of 1.04 years, whilst 'smoking' neoplasms, with a marginally lower contribution than in 1982 (0.81 years), dropped to third position. Like 'smoking' cancers, respiratory diseases suffered a fall in contribution as well as a step down in rank, to fourth position. The contribution of motor accident mortality to the sex differential fell to less than half of its 1982 value, with the result that this cause was ranked 7 in 1992, behind suicide and non-motor accidents. Breast cancer reduced the differential in life expectancy at birth by almost half a year of life in 1982 and in 1992. Whilst prostate cancer has not been separated out in this analysis, a calculation with the 1982 data using the same subroutine revealed that 0.27 years (virtually all in the 70+ age group) of the 0.77 years contributed to the sex differential by all other cancers other than breast cancer could be attributed to this particular male neoplasm.

**Table 8**
**Contributions of mortality changes by age and cause[a] to the change in life expectancy at birth of Australian females between 1982 and 1992. The contributions shown are hundredths of a year of life[b].**

| Cause group | Age group 0 | 1-4 | 5-14 | 15-29 | 30-49 | 50-69 | 70+ | All ages |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | -1 | 1 |
| 2 | 0 | 0 | 0 | 0 | 1 | -1 | -5 | -5 |
| 3 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| 4 | 0 | 0 | 0 | 0 | 2 | 8 | -2 | 10 |
| 5 | 0 | 0 | 0 | 0 | 5 | 33 | 36 | 74 |
| 6 | 0 | 0 | 0 | 0 | 3 | 16 | 46 | 65 |
| 7 | 0 | 0 | 0 | 0 | 2 | 5 | 26 | 32 |
| 8 | 1 | 0 | 0 | 0 | 2 | 0 | -1 | 2 |
| 9 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 5 |
| 10 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 11 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 18 |
| 12 | 0 | 2 | 1 | 0 | 0 | 1 | 3 | 6 |
| 13 | 1 | 2 | 2 | 5 | 2 | 2 | 1 | 13 |
| 14 | 0 | 0 | 0 | -1 | 1 | 2 | 0 | 2 |
| 15 | 0 | 0 | 0 | -1 | 0 | 0 | 0 | -2 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1 |
| 17 | 4 | 0 | 0 | 0 | 1 | 5 | -5 | 6 |
| All causes | 25 | 5 | 2 | 6 | 20 | 75 | 97 | 229 |

[a]For a description of each cause group, see for example Table 2. [b]Because of rounding, row and column totals may not tally exactly with the totals shown.

## Australian life tables 2002

It is interesting to conjecture what the Australian life tables would look like in 2002 if the trends in cause of death which were observed over the decade to 1992 were to continue into the new millennium. Whilst this approach is essentially a form of extrapolation, such an approach to mortality projection has proved as successful as any and better than most other methods (Pollard 1987). From Table 4, it is immediately apparent that the standardized mortality rates for the three circulatory diseases groups fell substantially between 1982 and 1992 for both sexes, but particularly the males. For most cancers, on the other hand, mortality remained stagnant, with only minor changes in the standardized mortality rates.

**Table 9**
**Contributions of mortality differentials by age and cause[a] to the sex differential in life expectancy at birth in Australia in 1982. The contributions shown are hundredths of a year of life[b].**

| Cause group | Age group 0 | 1-4 | 5-14 | 15-29 | 30-49 | 50-69 | 70+ | All ages |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 |
| 2 | 0 | 0 | 0 | 0 | 5 | 47 | 32 | 85 |
| 3 | 0 | 0 | 0 | 0 | -12 | -22 | -8 | -43 |
| 4 | 0 | 0 | 1 | 3 | 4 | 28 | 41 | 77 |
| 5 | 0 | 0 | 0 | 1 | 26 | 125 | 85 | 238 |
| 6 | 0 | 0 | 0 | 0 | 1 | 10 | 8 | 19 |
| 7 | 0 | 0 | 0 | 1 | 4 | 18 | 16 | 39 |
| 8 | 0 | 0 | 1 | 1 | 1 | 22 | 54 | 80 |
| 9 | 0 | 0 | 0 | 0 | 4 | 9 | 2 | 15 |
| 10 | 0 | 0 | 0 | -1 | 0 | 0 | 0 | -1 |
| 11 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| 12 | 0 | 2 | 3 | 15 | 14 | 7 | 2 | 43 |
| 13 | 0 | 1 | 5 | 38 | 13 | 4 | 2 | 63 |
| 14 | 0 | 0 | 1 | 13 | 9 | 4 | 2 | 29 |
| 15 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 5 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 8 | 1 | 1 | 3 | 5 | 9 | 13 | 40 |
| All causes | 19 | 5 | 14 | 76 | 76 | 263 | 251 | 703 |

[a]For a description of each cause group, see for example Table 2. [b]Because of rounding, row and column sums may not tally exactly with the totals shown.

**Table 10**
**Contributions of mortality differentials by age and cause[a] to the sex differential in life expectancy at birth in Australia in 1992. The contributions shown are hundredths of a year of life[b].**

| Cause group | Age group 0 | 1-4 | 5-14 | 15-29 | 30-49 | 50-69 | 70+ | All ages |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 4 |
| 2 | 0 | 0 | 0 | 0 | 4 | 44 | 33 | 81 |
| 3 | 0 | 0 | 0 | 0 | -13 | -24 | -11 | -48 |
| 4 | 0 | 0 | 0 | 2 | 1 | 39 | 63 | 104 |
| 5 | 0 | 0 | 0 | 1 | 16 | 79 | 74 | 169 |
| 6 | 0 | 0 | 0 | 0 | 1 | 6 | 8 | 15 |
| 7 | 0 | 0 | 0 | 0 | 3 | 14 | 14 | 30 |
| 8 | 1 | 0 | 0 | 0 | 1 | 12 | 46 | 59 |
| 9 | 0 | 0 | 0 | 0 | 4 | 9 | 1 | 14 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| 12 | 0 | 1 | 2 | 11 | 9 | 5 | 2 | 31 |
| 13 | 0 | 1 | 2 | 15 | 8 | 2 | 1 | 27 |
| 14 | 0 | 0 | 0 | 18 | 15 | 7 | 2 | 42 |
| 15 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 4 |
| 16 | 0 | 0 | 0 | 3 | 13 | 2 | 0 | 18 |
| 17 | 3 | 1 | 0 | 5 | 6 | 8 | 15 | 38 |
| All causes | 15 | 1 | 4 | 57 | 68 | 204 | 250 | 599 |

[a]For a description of each cause group, see for example Table 2. [b]Because of rounding, row and column sums may not tally exactly with the totals shown.

'Smoking' cancers showed some evidence of change with an appreciable decline in male mortality and a substantial increase in female mortality. The ratio of the 1992 standardized rate to the 1982 standardized rate is shown in Table 11 for each of selected causes with the exception of AIDS. It was assumed that the 1992 mortality rates by age and cause should be adjusted with these ratios to project the 2002 mortality rates by age and cause. The ratios of

the standardized rates by cause in 2002 to those in 1992 would then replicate those shown in Table 11. Whilst it could be difficult to maintain the rates of improvement which have been sustained in the recent past, over the next decade, there is little evidence that the pace of change is slackening, and the temptation to make more conservative assumptions was resisted. AIDS-flagged deaths posed a problem. Development of the disease in the community has not been as devastating as originally feared, and its effect on the 1992 life table was relatively minor. For projection purposes, therefore, it was assumed that the age-specific mortality rates for AIDS-flagged deaths would remain unchanged. Life tables and multiple decrement tables under the adjusted mortality regime are readily computed using the Cause Elimination/Reduction/Modification routine of LIFETIME, and the projected abridged life tables for 2002 are shown in Tables 5 and 6 alongside those which pertain to 1982 and 1992. Graphs of the projected $q_x$ curves based on the full projected 2002 life tables are included in Figures 4 and 5, with the corresponding 1982 and 1992 curves. In the case of the males (Figure 4), the 'accident hump', so clearly evident in 1982, and transformed to an 'accident bulge' in 1992, is still very evident as a 'bulge' in 2002. The 1992 and 2002 values shown for ages 18, 19, 20 and 21 need to be treated with some scepticism, due to the five-year data grouping in LIFETIME and the algorithm used over this particular age range, which is specifically designed not to graduate out an 'accident hump'. The true values over the age range 18-21 for 1992 and 2002 are probably a little lower than those depicted, and the graphed age 19 value in 1982 is probably exaggerated slightly. Despite these minor shortcomings, the overall picture is very clear. In the case of the females, the 'bulge' remaining in 2002 is still clearly evident, albeit on a much smaller scale than that of the males. The cautionary note in respect of ages 18-21, given in respect of the male curves, also applies. It would seem that the $q_x$ curve projected for the year 2002 is almost completely flat from about 18 to 24. The probabilities of ultimately dying of the selected causes for the 1982, 1992 and projected 2002 life tables are listed in Table 12. Under the mortality projected for 2002, males are equally likely to die from IHD and 'all other neoplasms', and these two causes together account for almost 50 per cent of deaths. The proportions expected to die from the other major killers ('smoking' neoplasms, cerebrovascular disease, other circulatory disease, and respiratory diseases) are of much lower magnitude. Owing to the marked improvements in mortality projected for some of the major killers, the proportion of males likely to die from 'all other causes' will be much higher than in 1992 or 1982. If deaths from breast cancer are included with 'all other neoplasms', the picture for the females is not dissimilar. Fewer are expected to die from 'smoking' cancers, compared with the males, but rather more from cerebrovascular disease and 'other circulatory diseases'.

**Table 11**
**Australian males and females. Ratio of standardized mortality rate in 1992 to that pertaining to 1982, by cause**

| Cause group | Males | Females |
|---|---|---|
| 1 Infect. dis. B1-B7 | 1.21 | 1.14 |
| 2 'Smoking' neopl. B8-B10 | .088 | 1.22 |
| 3 Breast cancer B11.3 | 1.00 | 0.97 |
| 4 All other neopl. B9 B11-B17 excl. B11.3 | 1.03 | 0.97 |
| 5 Ischaemic heart dis. B27 | 0.68 | 0.75 |
| 6 Cerebrovascular dis. B29 | 0.61 | 0.59 |
| 7 Other circul. B25 B26 B28 and B30 | 0.69 | 0.71 |
| 8 Respiratory dis. B31-B32 | 0.72 | 0.99 |
| 9 Cirrhosis B34.7 | 0.74 | 0.64 |
| 10 Obstetrics B38-B41 | 1.00 | 0.31 |
| 11 Congen./perinatal B44-B45 | 0.73 | 0.72 |
| 12 Non-motor accid. B47-B53 excl. B47.1 | 0.72 | 0.73 |
| 13 Motor accid. B47.1 | 0.50 | 0.65 |
| 14 Suicide B54 | 1.13 | 0.85 |
| 15 Other violence B55-B56 | 1.21 | 1.49 |
| 16 AIDS flagged[a] | - | - |
| 17 All other causes[b] | 0.96 | 1.00 |

[a]Ratio is infinite. See text. [b]B18-B24, B33-B37 excluding B34.7, B42-B43, B46

**Table 12**
**Probability of ultimately dying from a particular cause. Australian males and females, 1982, 1992, and projected 2002.**

| Cause group | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | 1982 | 1992 | 2002 | 1982 | 1992 | 2002 |
| 1 | .004 | .007 | .011 | .004 | .009 | .007 |
| 2 | .073 | .077 | .077 | .020 | .038 | .028 |
| 3 | .000 | .000 | .000 | .032 | .036 | .034 |
| 4 | .146 | .189 | .236 | .130 | .160 | .145 |
| 5 | .309 | .272 | .233 | .213 | .247 | .268 |
| 6 | .103 | .085 | .069 | .181 | .103 | .139 |
| 7 | .094 | .088 | .080 | .139 | .110 | .123 |
| 8 | .105 | .102 | .095 | .063 | .086 | .072 |
| 9 | .011 | .009 | .007 | .005 | .003 | .004 |
| 10 [a] | .000 | .000 | .000 | $.0^{3}2$ | $.0^{4}2$ | $.0^{4}7$ |
| 11 | .010 | .007 | .005 | .008 | .004 | .006 |
| 12 | .022 | .019 | .016 | .018 | .014 | .015 |
| 13 | .023 | .012 | .006 | .010 | .004 | .007 |
| 14 | .014 | .016 | .019 | .005 | .004 | .005 |
| 15 | .002 | .003 | .004 | .001 | .003 | .002 |
| 16[b] | .000 | .005 | .005 | .000 | $.0^{3}2$ | $.0^{3}2$ |
| 17 [c] | .084 | .108 | .136 | .110 | .177 | .144 |
| All causes | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |

[a]The female entries are respectively .0002, .00007 and .00002 [b]The female entries are respectively .000, .0002 and .0002. [c]B18-B24, B33-B37 excluding B34.7, B42-B43, B46.

**Figure 4**
**Mortality q(x) curves of Australian males according to Australian Life Tables (Males) A1932-34, A1953-55, A1970-72, the national experiences of 1982 and 1992, and the projected table for 2002.**

**Figure 5**
**Mortality q(x) curves of Australian females according to Australian Life Tables (Females) A1932-34, A1953-55, A1970-72, the national experiences of 1982 and 1992, and the projected table for 2002.**

## The life expectancy of cohorts

National life tables are always cross-sectional in that they summarize the mortality of the population at a given epoch, by attained age; a single mortality rate is recorded from each cohort, the rate corresponding to the attained age of the cohort, and these rates from all the cohorts are combined in the cross-sectional life table. Since no life will ever be subject to the mortality of a cross-sectional table, such a table must be regarded as an artificial device, albeit useful. To a 70-year old's question: 'What is my life expectancy?', the most recent cross-

sectional table can at best provide an imprecise answer. In a situation of continually improving mortality, the cross-sectional table will provide a lower bound for his or her life expectancy, but that is all. Over the decade 1982 to 1992 and for some years earlier, Australian males and females at the higher ages (over 60, say) have experienced age-specific mortality rates which have improved on average about two per cent per annum (even slightly more for the males 60-80). A male aged 70 in 1992, therefore, would expect to live slightly longer than the 12.18 years quoted for 1992, but probably less than the projected 2002 life expectancy figure for a 70-year old (13.77). On the assumption that mortality at all relevant ages will continue to improve by two per cent per annum, it is possible to produce a special projected life table for the cohort of lives who were aged 70 in 1992, but this is a rather tedious procedure, and separate projected cohort life tables need to be constructed for each cohort. Approximate calculations, however, are readily performed to answer the above question, using a formula based on the Gompertz 'law' of mortality. The results, even for populations not strictly of the Gompertz type, are quite accurate. Where the Gompertz 'law' $\mu_x = B\, e^{kx}$ is applicable to the cross-sectional table, the cohort force of mortality at age x ($x \geq 70$) for a life aged 70 in the base cross-sectional table, having force of mortality $\mu_{70}$ at that time is given by $\mu_{70} = \exp[(k-0.02)(x-70)]$, on the assumption that the force of mortality at all ages will continue to decline continuously at two per cent per annum. The cohort mortality is also of the Gompertz form, but with exponential parameter $k'=k-0.02$. The accurate approximate method for estimating the cohort expectation of life is based on the exact derivative formula $de^o_x/dk = [1 - (\mu_x + k)\, e^o_x]/k^2$ (1) which is easily derived using the approach of Pollard (1993). Various methods can be used to determine the Gompertz parameter k when the cross-sectional life table is not strictly of the Gompertz form. The simplest is to note that k is equal to the force of mortality $\mu_m$ at the mode of the curve of deaths (Pollard 1991). To select k in practice therefore, all one has to do is find the age y at which the deaths column $d_y$ is a maximum, and set $\mu_m$ equal to $(\mu_y + \mu_{y+1})/2$. The expectation of life for a person who is aged x at the date of the cross-sectional table, but who will be subject to cohort mortality which is continuously improving at two per cent per annum is given by the accurate approximation $e^o_x$ (cohort) $= e^o_x - 0.02\,[1 - (\mu_x + \mu_m)\, e^o_x]/\mu_m^2$ . (2) This formula, whilst based on the Gompertz 'law', only involves functions which are available in any life table. In situations where the rate of improvement is 100r per cent per annum, the number 0.02 is simply replaced by the fraction r. Cohort life expectancies for lives in the age range 60 to 90 are shown in Table 13, alongside the cross-sectional source data. As might be expected, the life expectancy of the cohorts around age 60 in 1992 are higher than the projected cross- sectional life expectancies for those ages in 2002, and the converse is true for the older 1992 cohorts.

**Table 13**
**Cross-sectional force of mortality and life expectancy, and projected cohort life expectancy for lives aged x in 1992 (x=60, ..., 90)**

| Age | Males | | | Females | | |
|---|---|---|---|---|---|---|
| x | Cross-sectional | | Cohort | Cross-sectional | | Cohort |
| | $\mu_x$ | $e^o_x$ | $e^o_x$ | $\mu_x$ | $e^o_x$ | $e^o_x$ |
| 60 | .01139 | 19.17 | 21.51 | .00616 | 23.48 | 26.43 |
| 61 | .01275 | 18.39 | 20.59 | .00674 | 22.63 | 25.43 |
| 62 | .01427 | 17.64 | 19.72 | .00738 | 21.79 | 24.44 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 63 | .01588 | 16.90 | 18.85 | .00810 | 20.95 | 23.45 |
| 64 | .01756 | 16.17 | 18.00 | .00894 | 20.13 | 22.49 |
| 65 | .01943 | 15.47 | 17.18 | .00986 | 19.31 | 21.53 |
| 66 | .02148 | 14.77 | 16.36 | .01087 | 18.51 | 20.60 |
| 67 | .02377 | 14.10 | 15.59 | .01199 | 17.71 | 19.66 |
| 68 | .02619 | 13.45 | 14.84 | .01329 | 16.93 | 18.76 |
| 69 | .02877 | 12.81 | 14.09 | .01481 | 16.17 | 17.88 |
| 70 | .03159 | 12.18 | 13.36 | .01650 | 15.41 | 17.00 |
| 71 | .03469 | 11.58 | 12.67 | .01839 | 14.67 | 16.14 |
| 72 | .03809 | 10.99 | 11.99 | .02049 | 13.95 | 15.31 |
| 73 | .04204 | 10.41 | 11.33 | .02288 | 13.25 | 14.51 |
| 74 | .04664 | 9.86 | 10.71 | .02562 | 12.56 | 13.72 |
| 75 | .05174 | 9.33 | 10.12 | .02868 | 11.89 | 12.96 |
| 76 | .05740 | 8.83 | 9.57 | .03211 | 11.24 | 12.22 |
| 77 | .06367 | 8.35 | 9.04 | .03594 | 10.61 | 11.50 |
| 78 | .07021 | 7.89 | 8.53 | .04030 | 10.01 | 10.83 |
| 79 | .07696 | 7.46 | 8.06 | .04526 | 9.42 | 10.17 |
| 80 | .08436 | 7.04 | 7.59 | .05082 | 8.86 | 9.54 |
| 81 | .09246 | 6.64 | 7.15 | .05707 | 8.32 | 8.95 |
| 82 | .10135 | 6.27 | 6.76 | .06409 | 7.81 | 8.39 |
| 83 | .11056 | 5.91 | 6.36 | .07154 | 7.32 | 7.84 |
| 84 | .12001 | 5.57 | 5.96 | .07938 | 6.86 | 7.33 |
| 85 | .13028 | 5.25 | 5.63 | .08808 | 6.41 | 6.83 |
| 86 | .14142 | 4.94 | 5.29 | .09773 | 5.99 | 6.37 |
| 87 | .15362 | 4.65 | 4.97 | .10843 | 5.58 | 5.92 |
| 88 | .16665 | 4.37 | 4.66 | .12031 | 5.20 | 5.50 |
| 89 | .18091 | 4.10 | 4.37 | .13350 | 4.83 | 5.10 |
| 90 | .19638 | 3.85 | 4.10 | .14812 | 4.49 | 4.73 |

*Note.* For males, $\mu_m = 0.08841$; for females, $\mu_m = 0.10308$.

## Conclusion

Over the century to 1992, expectation of life at birth for Australian males rose from 49.13 years (Moors and Day 1901) to 74.48, an average improvement of a quarter of a year per annum. For females, the corresponding change in life expectancy was from 52.13 years to 80.47, an improvement over the century of about 0.28 years of life per annum. Improvements in mortality have not taken place uniformly over the span of life nor over time. Over the first 60 to 70 years, much of the improvement in life expectancy at birth was the result of reduction in infant and child mortality. Mortality at these ages is now at such a low level that any further contribution to improvement in life expectancy at birth will be trivial. Most of the increase in expectation of life over recent decades has been the result of mortality reduction at the older ages, from 50 onwards (Pollard 1982), and the continuous annual increase has still been remarkable: about 0.23 years of life per annum for females and about 0.33 for males over the decade 1982-1992. Because improvements in mortality have not occurred at a uniform pace in all age groups, the Australian mortality curves have undergone important changes in shape, the most obvious one being the appearance of a distinct ‘accident hump’ near age 20 and its even more rapid disappearance. The same phenomenon has been observed in the United States of America (Kranczer 1995) and elsewhere, and the explanation appears to be the same: decreased accident mortality in the early twenties and increased mortality due to AIDS around

age 30. Any projection of future mortality is an extrapolation of that observed in the recent past, and a projection in which major causes of death are extrapolated separately appears to be less prone to error than those which simply extrapolate age-specific mortality in aggregate. With rapid improvements in mortality from certain major killers, there is always the temptation to adopt more conservative assumptions for the future. Those who have adopted such conservative assumptions in the past, however, have usually been proved too cautious by time. When mortality rates from major causes are projected separately, some will be proved to have been too low and some too high. To a certain extent therefore, projection errors for the separate causes will counteract each other. The mortality projected for Australia in 2002 envisages an expectation of life at birth of 76.83 for males and 82.11 for females. The 'accident hump', so prominent for the latter part of the twentieth century and which reduced to a 'bulge' around 1990, is expected to decline even further.

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