Demographic, Economic and Financial Perspectives 2003-2030

Seminar organized by the Quebec Pension Plan in cooperation with the Actuarial Science Chair of Laval University and the Quebec Actuarial Club

September 25-26, 2003

Mortality in Quebec: Past Changes, Trends and Outlook

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*The author wishes to thank Laurie Paquette and Carolyne Alix, demographics master's students, for their contribution.

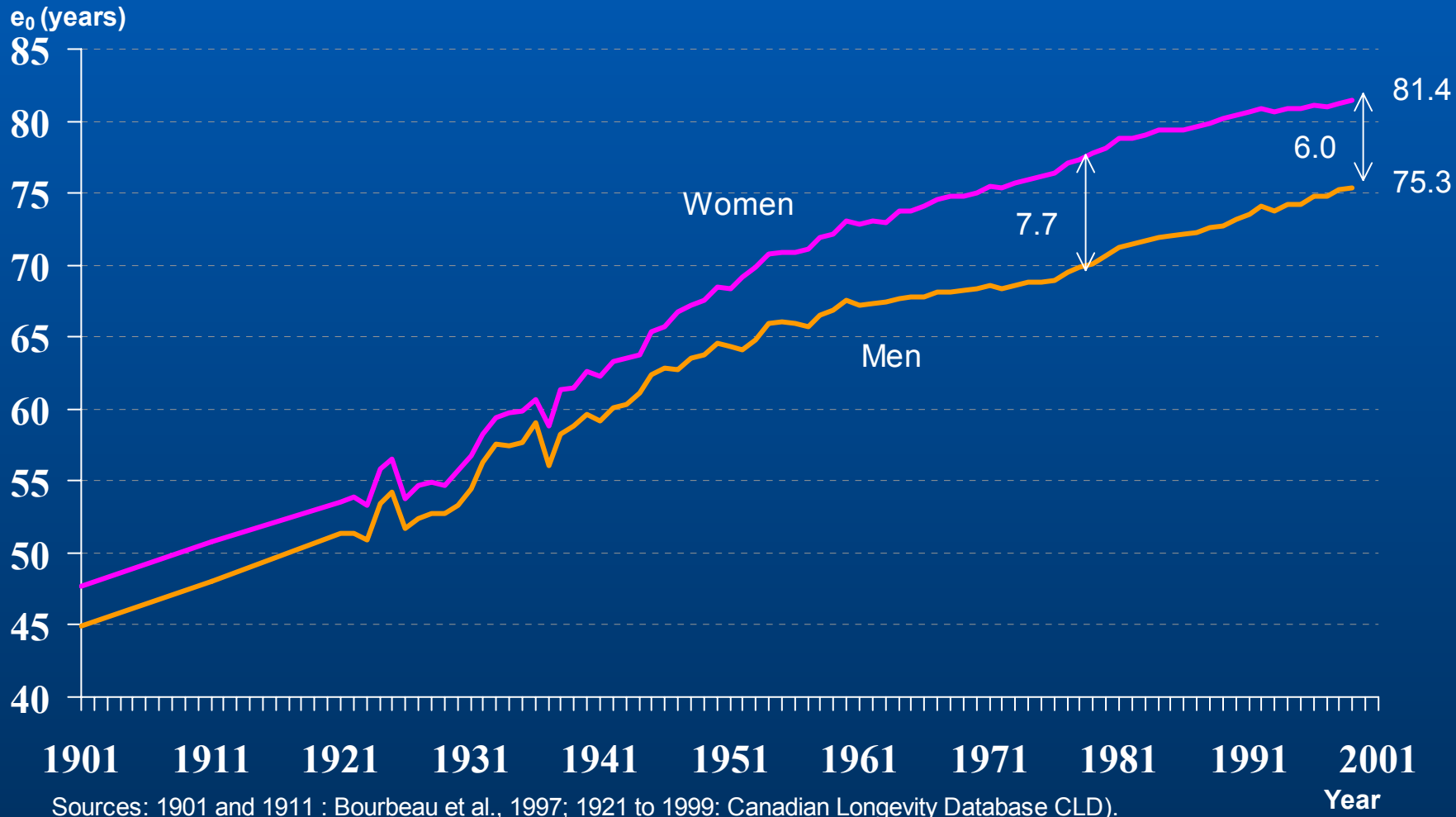
Presentation Outline

- Mortality in Quebec in the XXth century: main trends
- Changes in mortality from age 60
- Mortality at very old ages: data quality and change assumptions
- Mortality projections: some possibilities

Mortality in Quebec in the XXth Century: Main Trends

- Remarkable advances in life expectancy at birth
- An improvement in quantity and qualify of life?

Life expectancy at birth (e_0) by sex, Quebec, 1901-1999



Sources: 1901 and 1911 : Bourbeau et al., 1997; 1921 to 1999: Canadian Longevity Database CLD).

International comparison of life expectancy at birth in 1999

Men		Women	
Iceland	77.7 years	Japan	84.0 years
Japan	77.1 years	Switzerland	82.5 years
Sweden	77.1 years	France	82.4 years
Switzerland	76.8 years	Spain	82.1 years
Canada	76.3 years	Sweden	81.9 years
Italy*	75.7 years	Italy*	81.8 years
Norway	75.6 years	Canada	81.7 years
Greece	75.5 years	Iceland	81.5 years
Quebec	**75.3 years**	**Quebec**	**81.4 years**
France	74.9 years	Greece	80.6 years
United States	73.9 years	United States	79.4 years

Source: INED, 2003; Statistics Canada, 2002. * Year 1998

Total life expectancy in good health at birth by sex, Quebec, 1978-1979 to 1998

		1978-1979	1986	1987	1992-1993	1998
Life expectancy at birth (years)	**Male**					
	Total	69.7	72.0	72.2	73.6	74.6
	In good health	60.4	62.4	63.9	65.9	65.4
	In poor health	**9.3**	**9.5**	**8.3**	**7.7**	**9.2**
	Female					
	Total	77.6	79.5	79.7	80.8	81.1
	In good health	63.1	66.3	68.5	69.3	68.1
	In poor health	**14.5**	**13.1**	**11.2**	**11.5**	**13.0**

Sources: 1978-1979: Dillard, 1983 ; 1986: Wilkins, 1991 ; 1987 to 1998: Pageau et al., 2001.

Total life expectancy in good health at age 65 by sex, Quebec, 1978-1979 to 1998

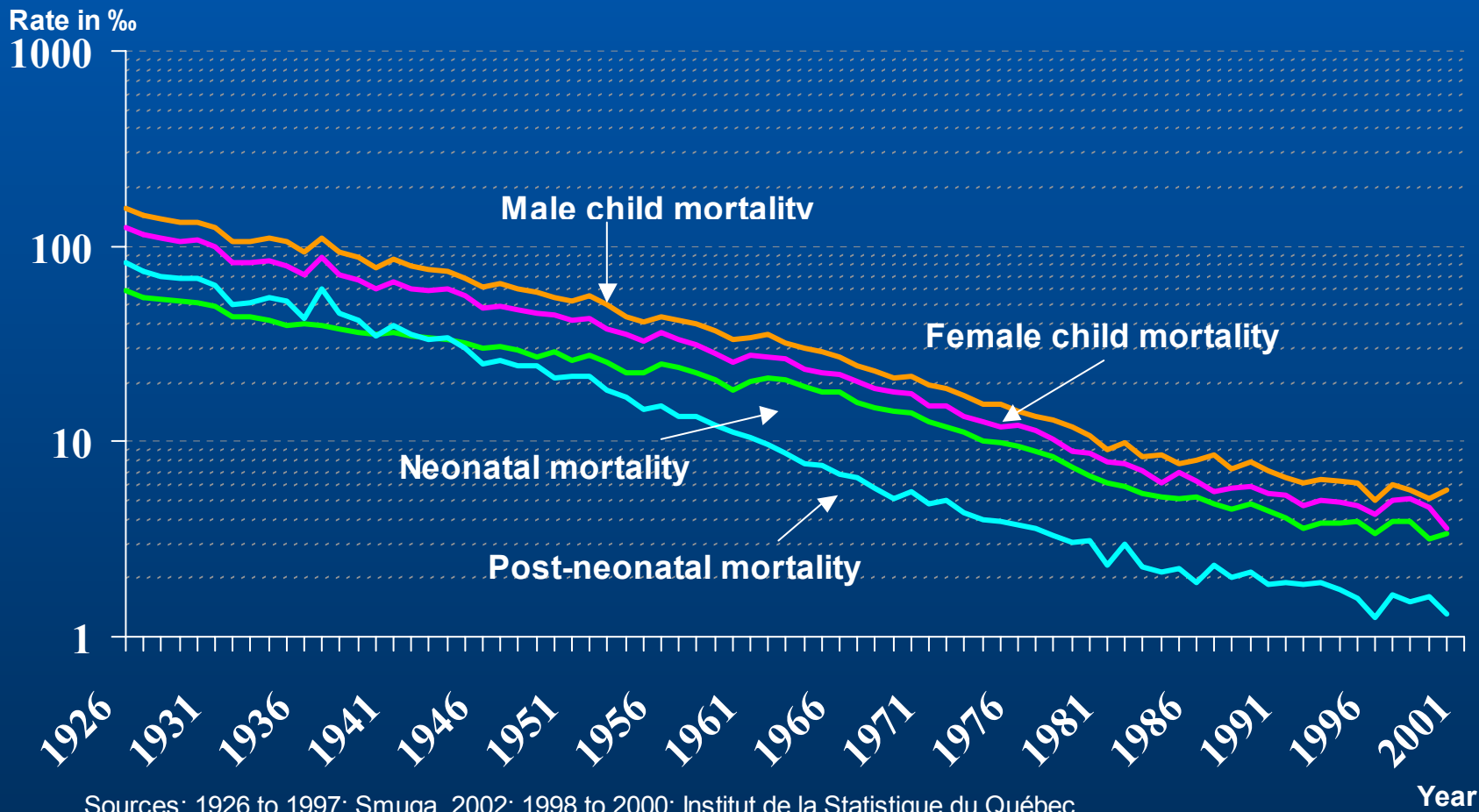
		1978-1979	1986	1987	1992-1993	1998
Life expectancy at age 65 (years)	**Male**					
	Total	..	14.1	14.3	15.1	15.5
	In good health	..	8.6	10.6	11.3	10.7
	In poor health	**..**	**5.5**	**3.7**	**3.8**	**4.8**
	Female					
	Total	..	18.9	19.0	19.8	19.8
	In good health	..	10.2	13.0	13.3	13.2
	In poor health	**..**	**8.7**	**6.0**	**6.5**	**6.6**

Note: .. = data not available.
Sources: 1978-1979: Dillard, 1983 ; 1986: Wilkins, 1991 ; 1987 to 1998: Pageau et al., 2001.

Mortality in Quebec in the XXth Century: Main Trends

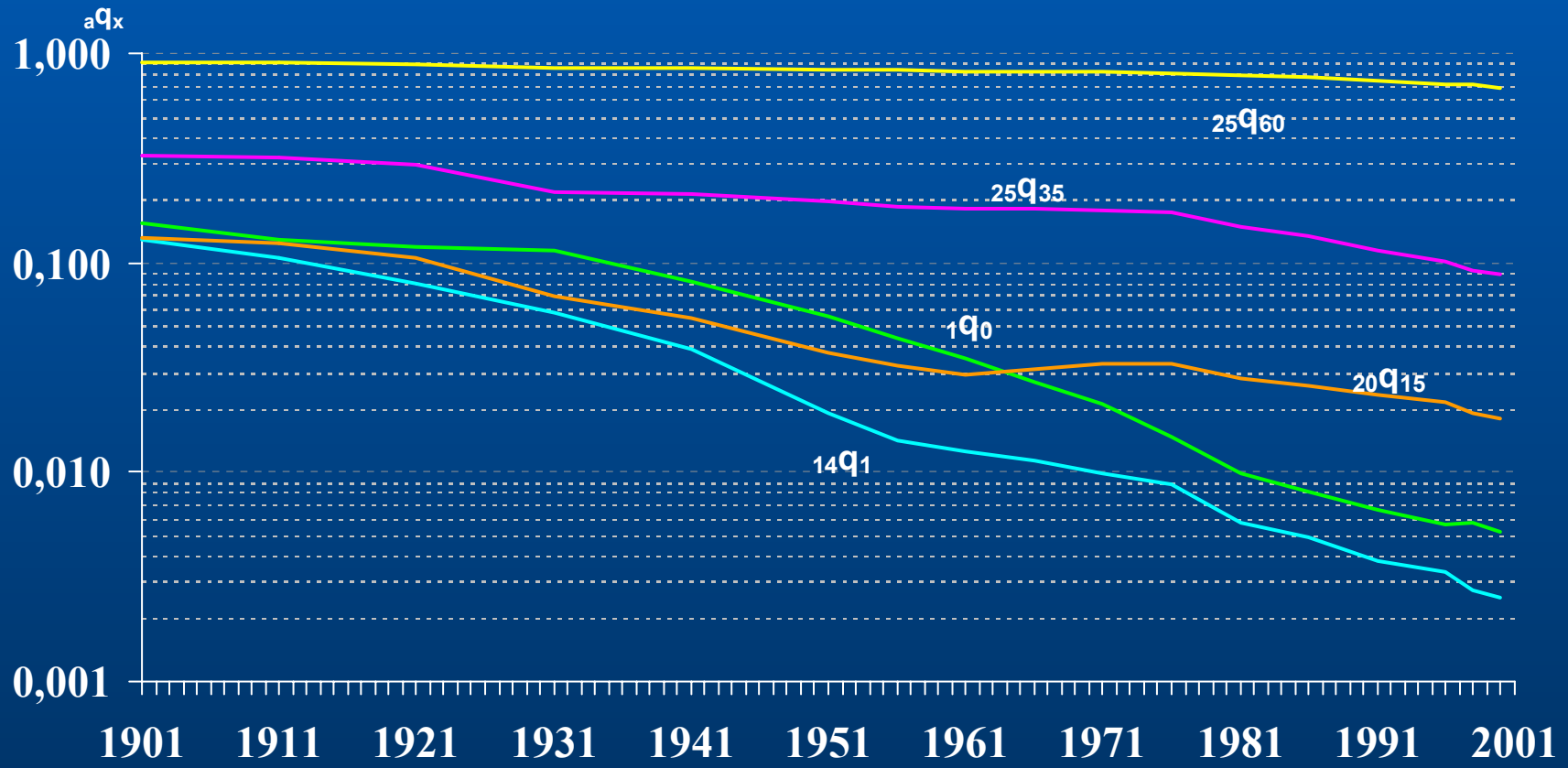
- Spectacular decline in child mortality
- Uneven drop in mortality at other ages

Infant, neonatal and post-neonatal mortality rates by sex, Quebec, 1926-2000



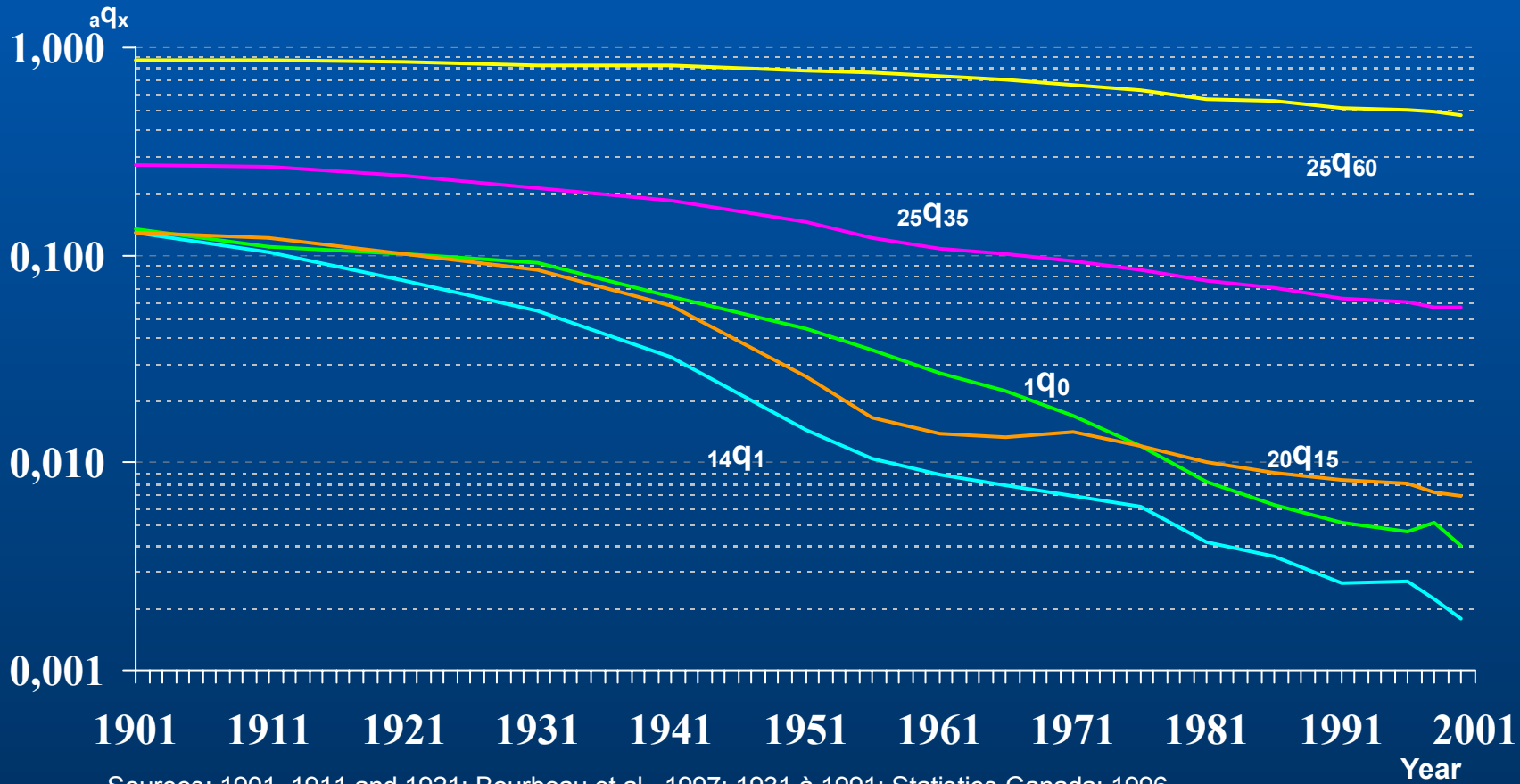
Sources: 1926 to 1997: Smuga, 2002; 1998 to 2000: Institut de la Statistique du Québec.

Probability of death by age group, male, Quebec, 1901 to 2000



Sources: 1901, 1911 and 1921: Bourbeau et al., 1997; 1931 to 1991: Statistics Canada; 1996, 1998 and 2000: Institut de la Statistique du Québec.

Probability of death by age group, female, Quebec, 1901-2000

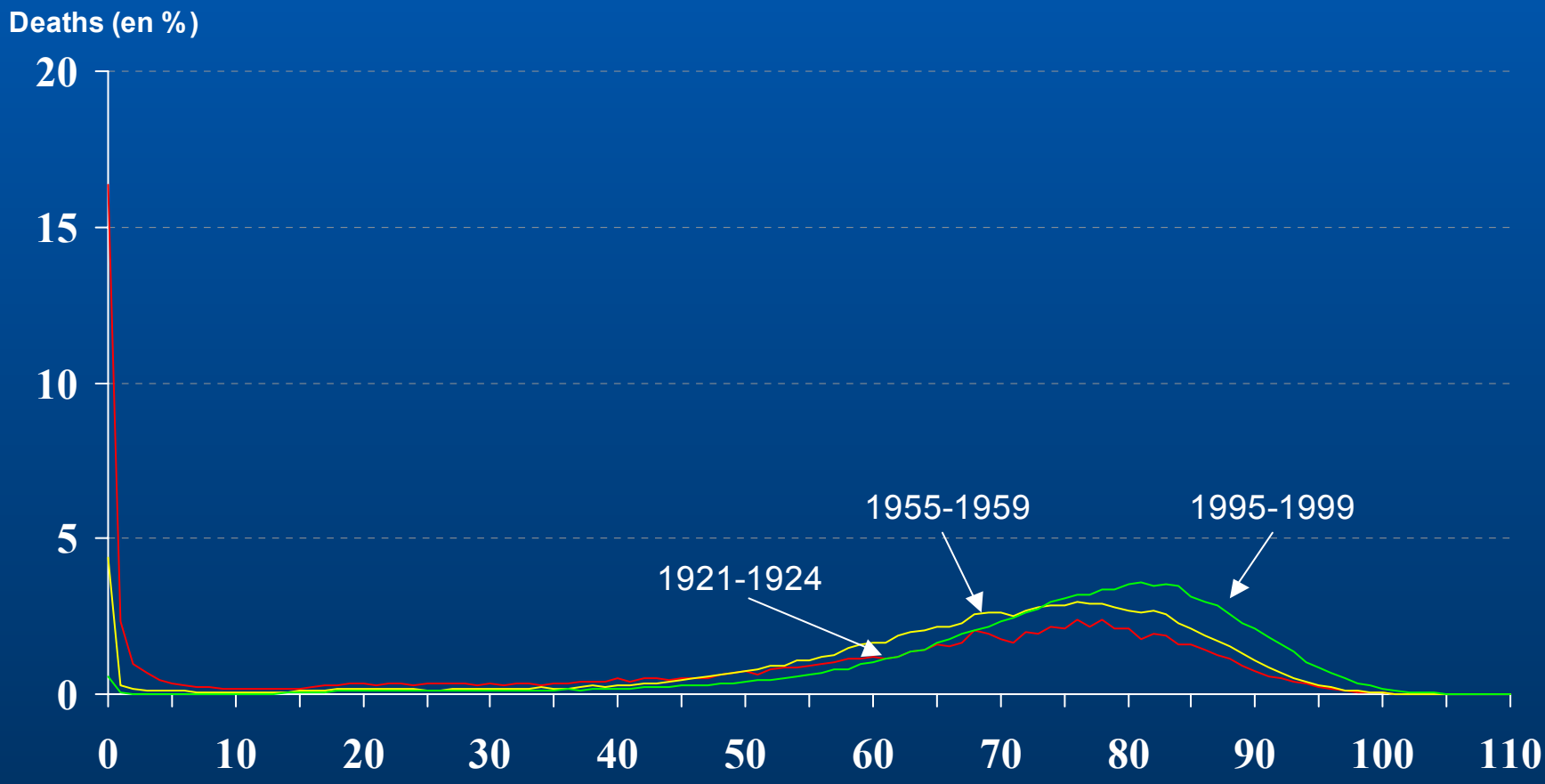


Sources: 1901, 1911 and 1921: Bourbeau et al., 1997; 1931 à 1991: Statistics Canada; 1996, 1998 and 2000: Institut de la Statistique du Québec.

Mortality in Quebec in the XXth Century: Main Trends

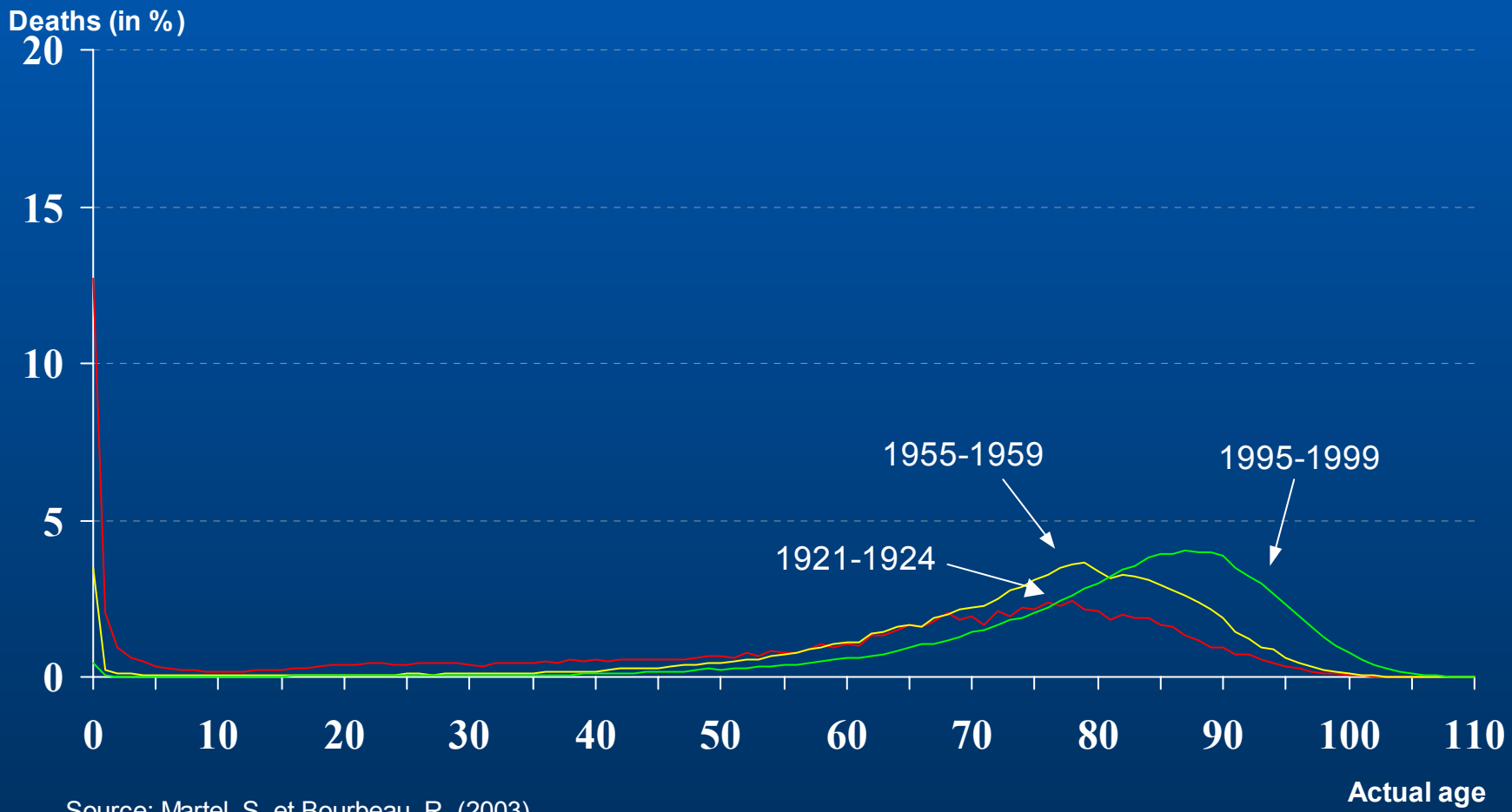
- Greater concentration of deaths at certain ages (compression of mortality)
- Increased rectangularization of the survival curve

Death curves by age, male, Quebec, 1921-1924, 1955-1959 and 1995-1999



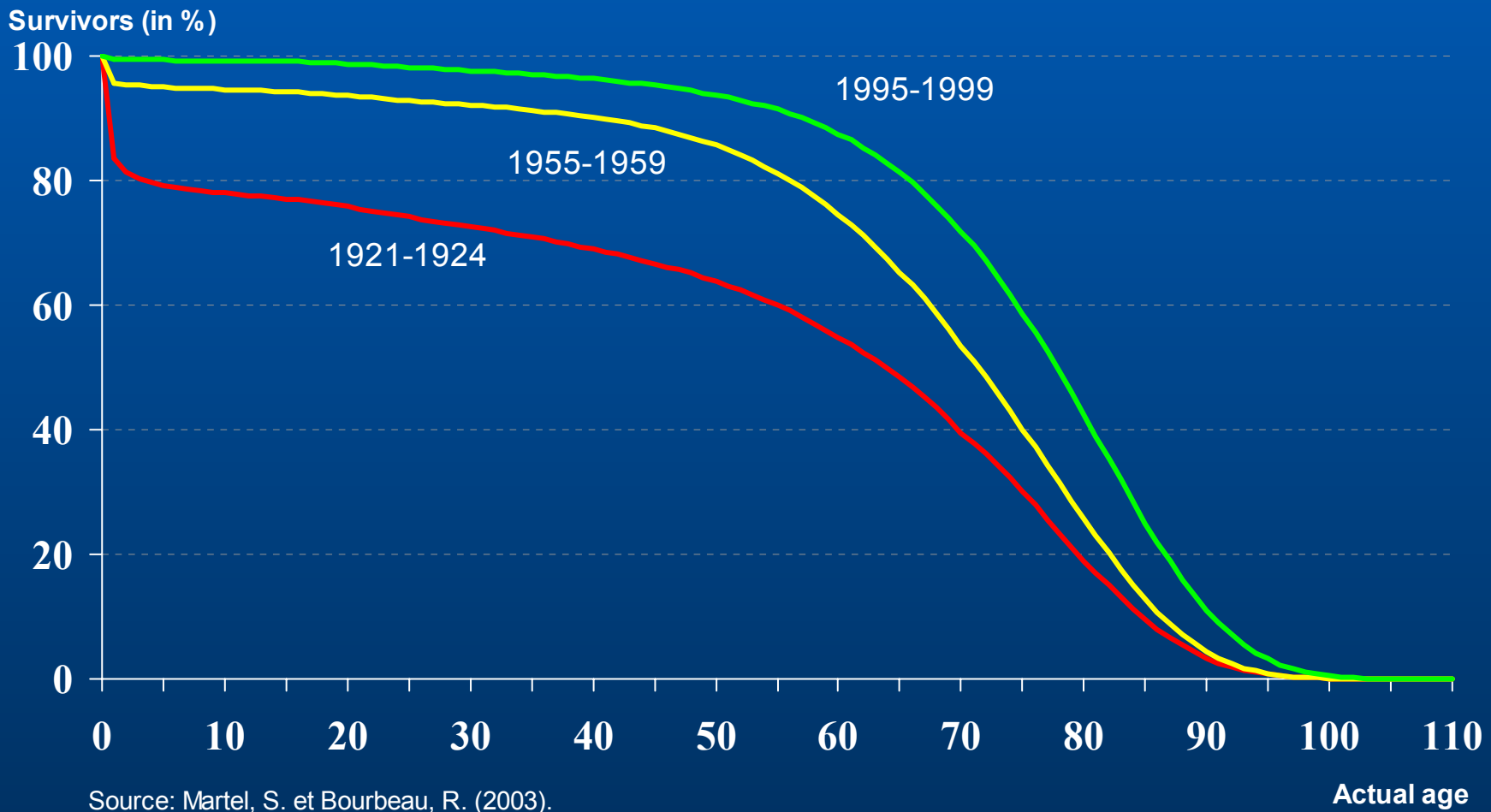
Source: Martel, S. et Bourbeau, R. (2003).

Death curves by age, female, Quebec, 1921-1924, 1955-1959 and 1995-1999



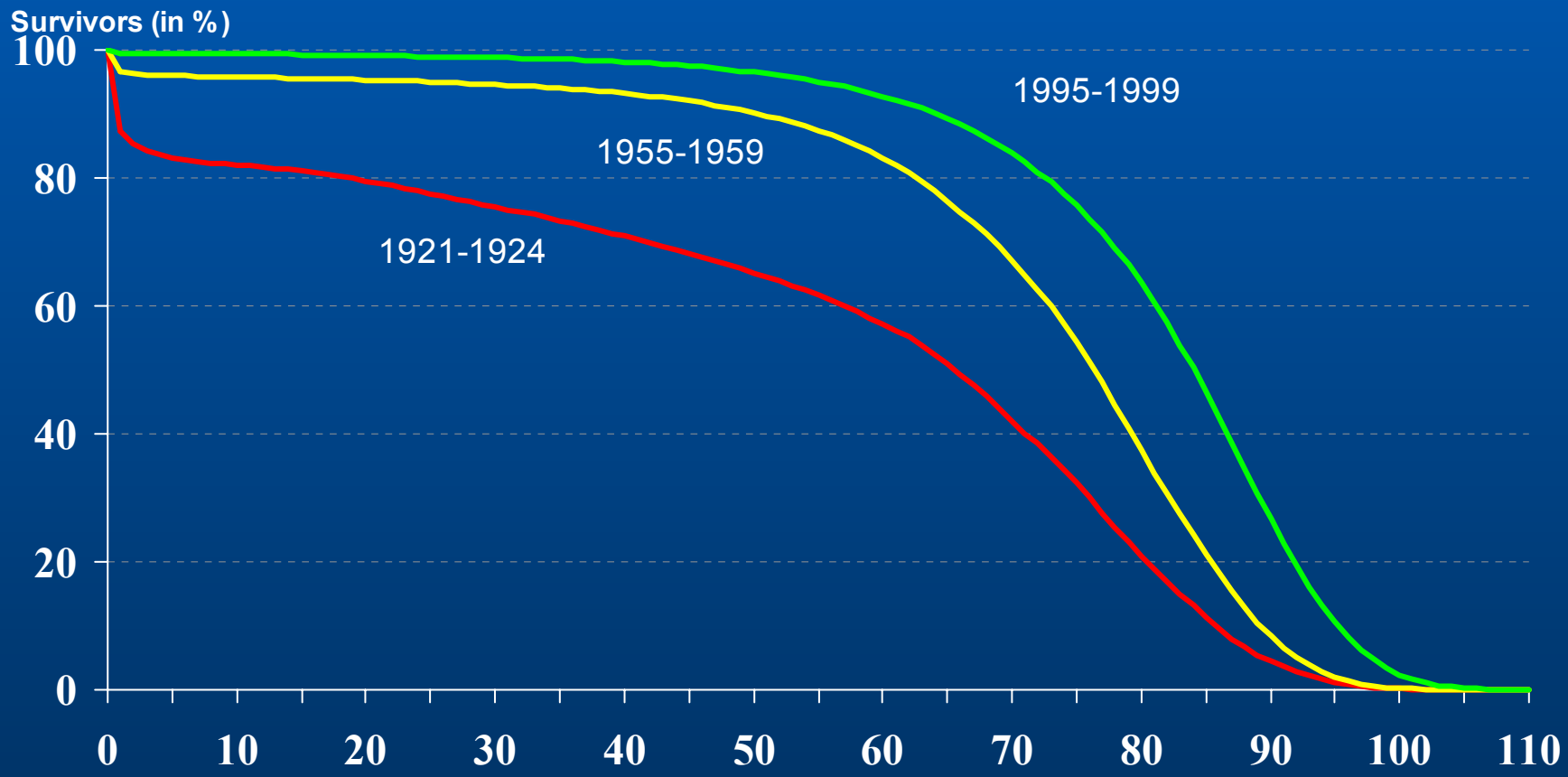
Source: Martel, S. et Bourbeau, R. (2003).

Death curves by age, male, Quebec, 1921-1924, 1955-1959 and 1995-1999



Source: Martel, S. et Bourbeau, R. (2003).

Death curves by age, female, Quebec, 1921-1924, 1955-1959 et 1995-1999

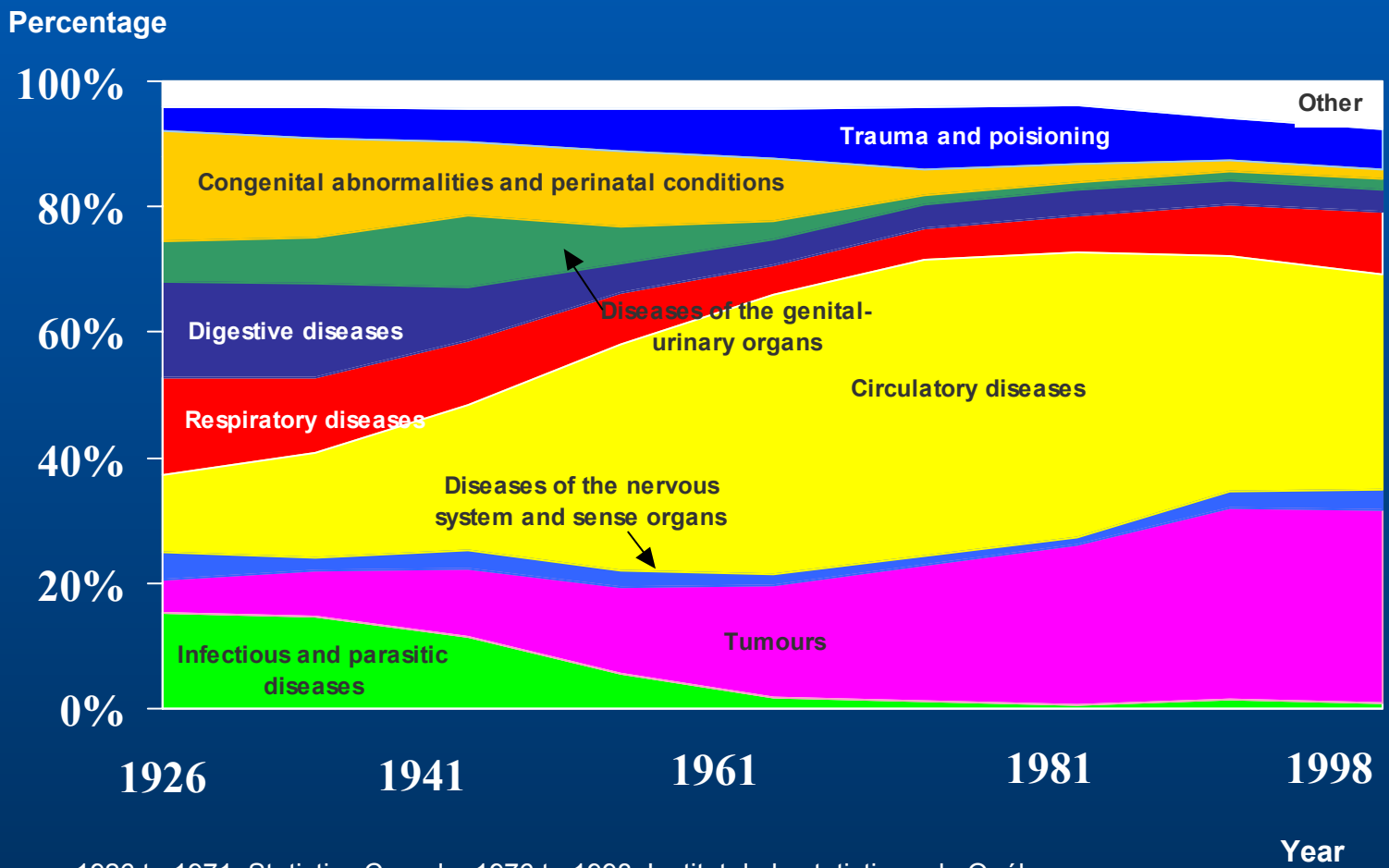


Source: Martel, S. et Bourbeau, R. (2003).

Mortality in Quebec in the XXth Century: Main Trends

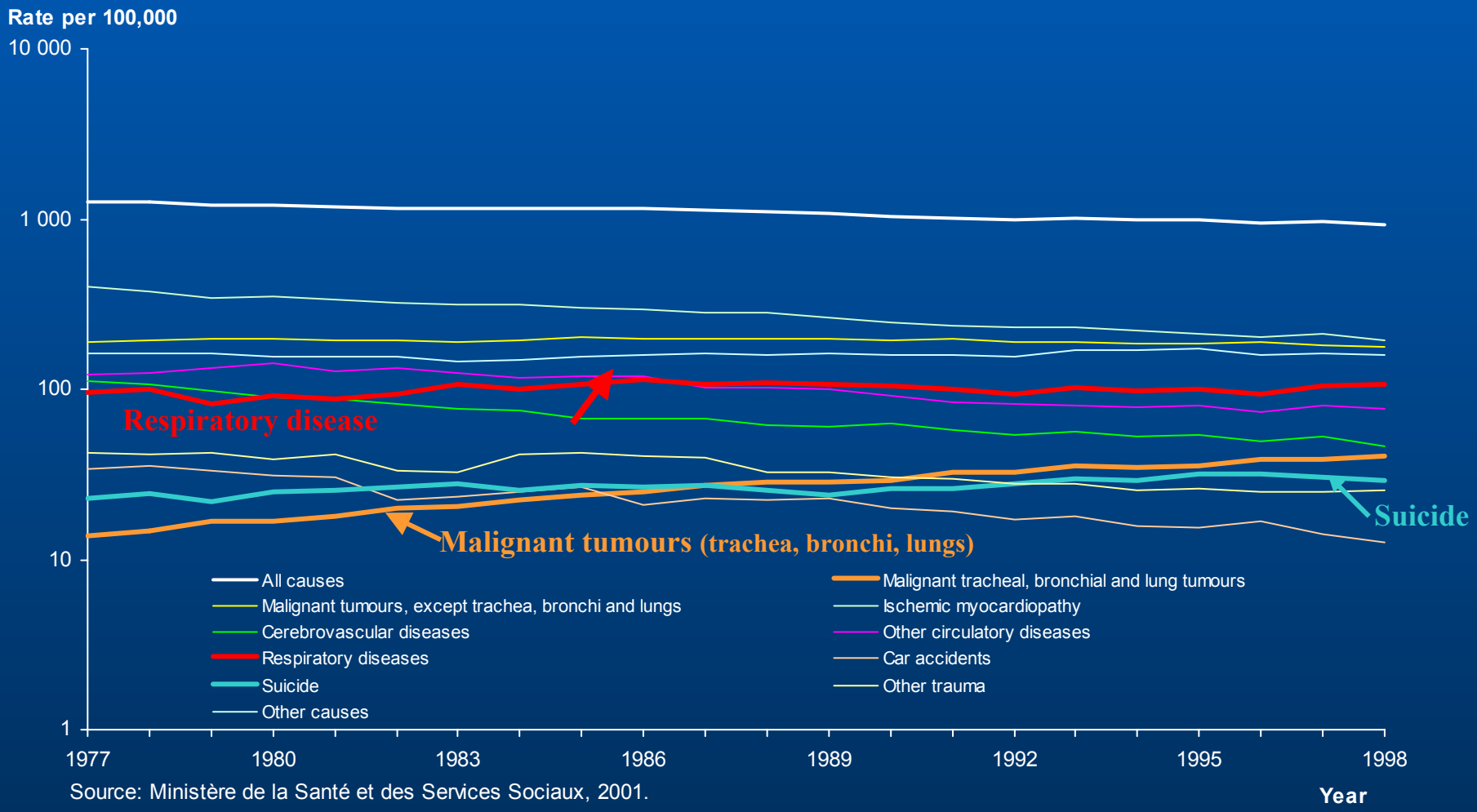
- Change in distribution of deaths by cause (epidemiologic transition)
- Some causes of death on the increase:
  - –Malignant tumours: trachea, bronchi, lungs (women especially)
  - –Respiratory diseases
  - –Suicide

Distribution of deaths by cause, both sexes, Quebec, 1926-1998



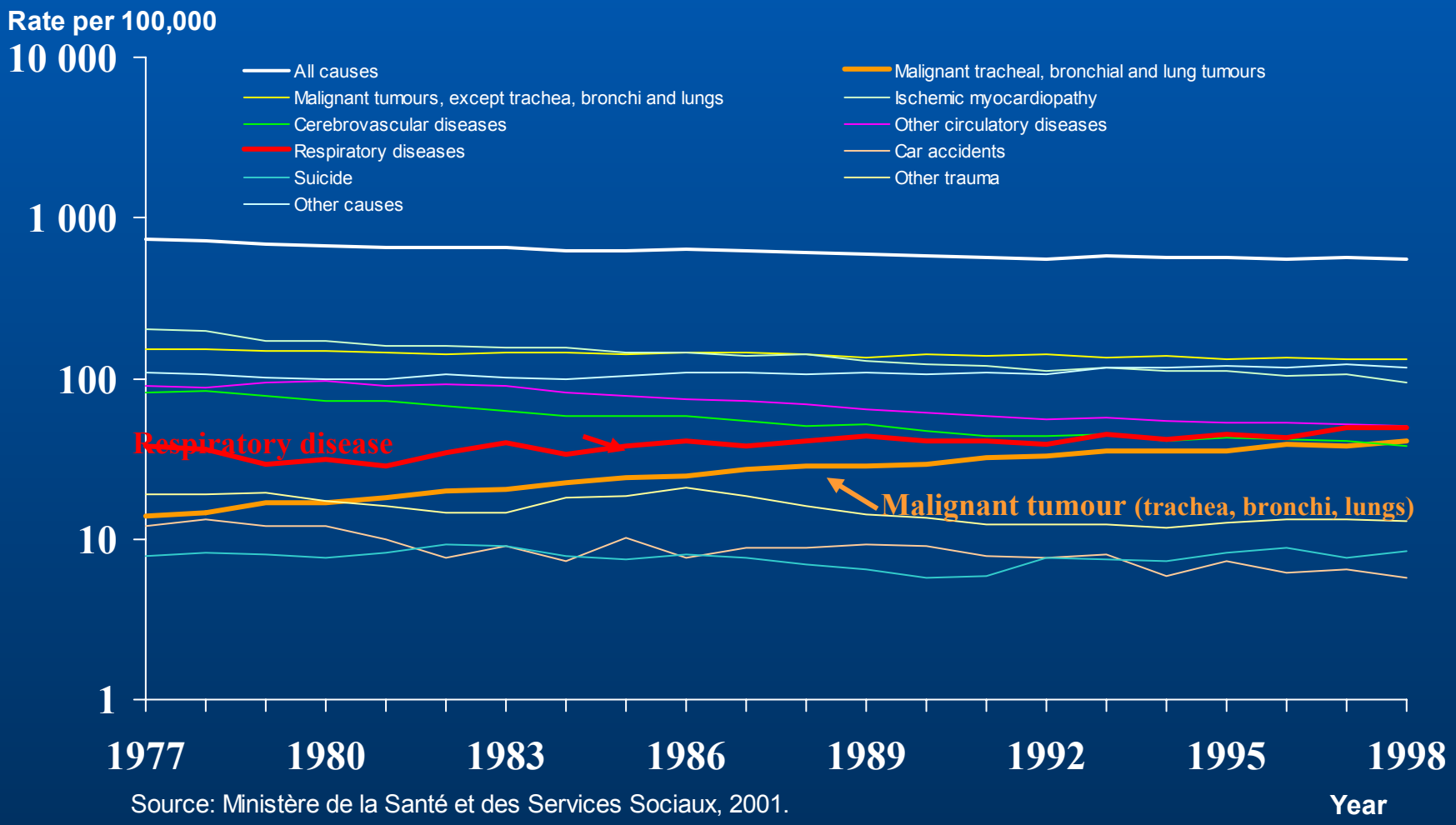
Sources: 1926 to 1971: Statistics Canada; 1976 to 1998: Institut de la statistique du Québec.

Adjusted mortality rate by cause of death, male, Quebec, 1977 to 1998



Source: Ministère de la Santé et des Services Sociaux, 2001.

Adjusted mortality rate by cause of death, female, Quebec, 1977 to 1998



Source: Ministère de la Santé et des Services Sociaux, 2001.

Contribution (in %) of age groups to gains in life expectancy at birth, both sexes, Quebec, 1921-1924 to 1995-1999

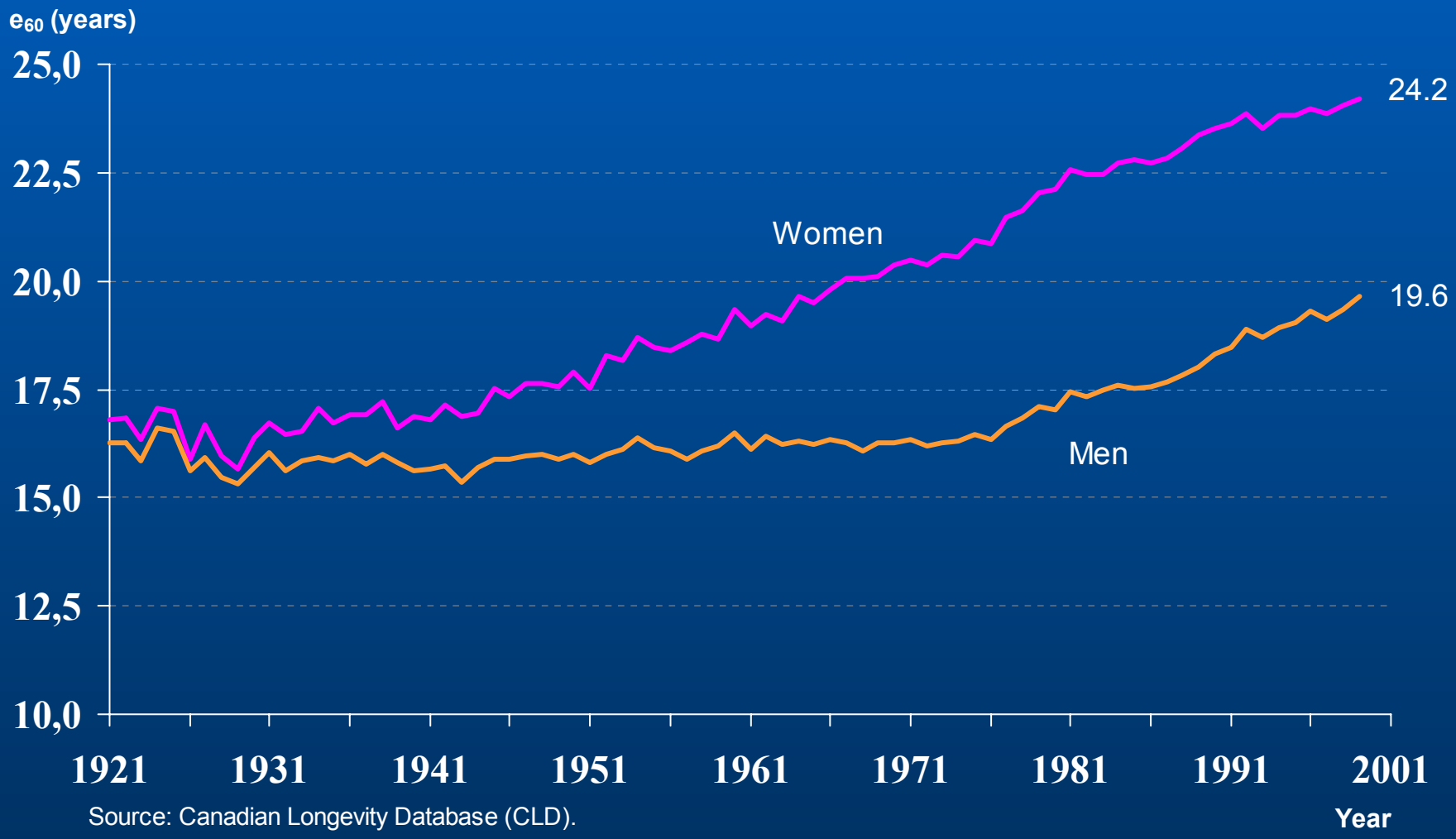
Age group	Period					
	1921-1924 to 1960-1964		1960-1964 to 1995-1999		1921-1924 to 1995-1999	
	Gain	Percentage	Gain	Percentage	Gain	Percentage
0-1 year	8.35	**48.4**	1.93	24.4	10.99	**43.7**
1-14 years	3.77	**21.9**	0.54	6.8	4.56	**18.1**
15-34 years	2.53	14.7	0.37	4.7	3.12	12.4
35-64 years	2.03	11.8	2.51	31.8	4.17	16.6
65-84 years	0.54	3.1	2.28	**28.8**	2.13	8.5
85 years +	0.01	0.1	0.28	**3.5**	0.17	0.7
Total	17.23	100.0	7.91	100.0	**25.14**	100.0

Source: Canadian Longevity Database (CLD).

Changes in mortality from age 60

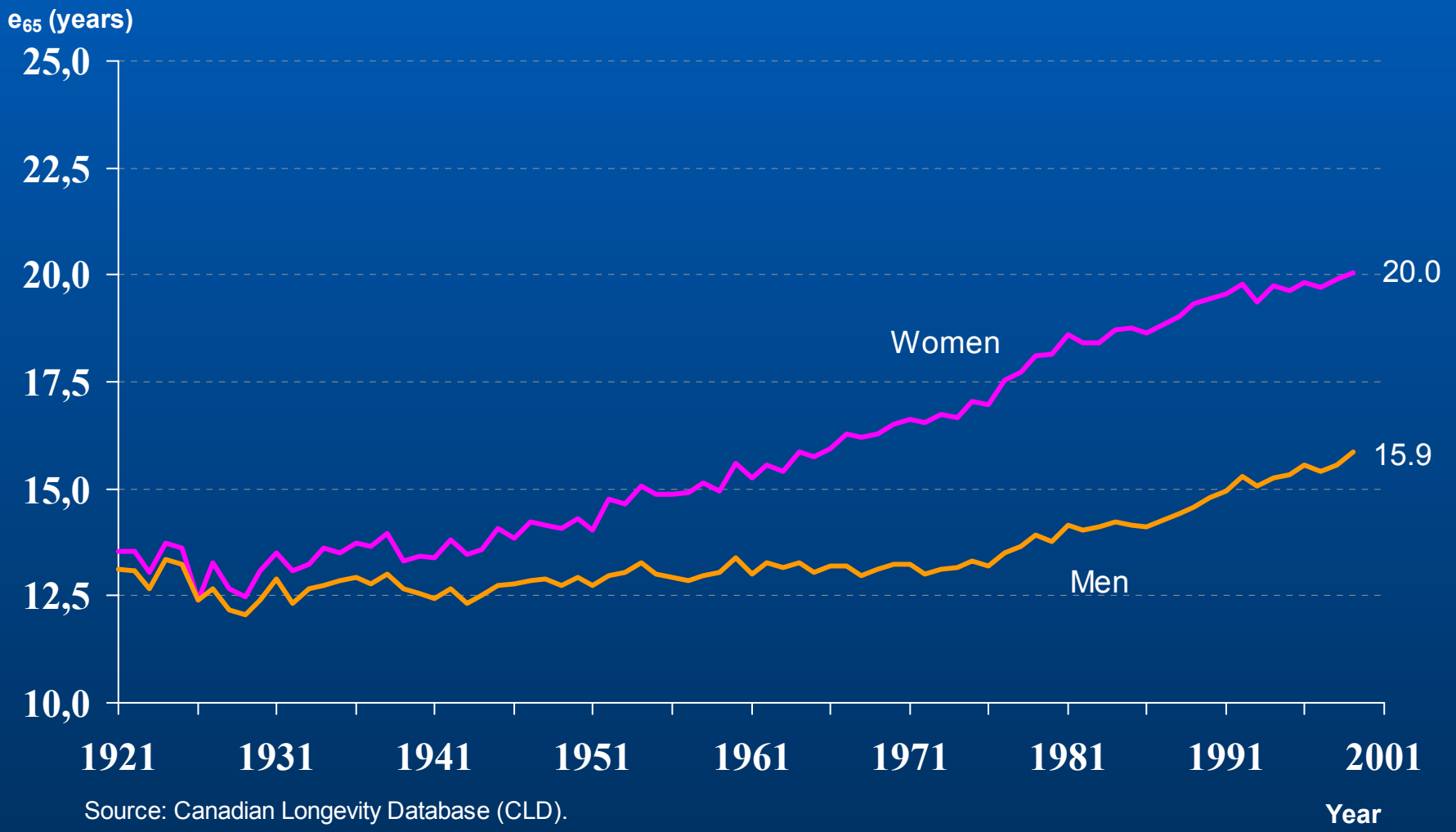
- More recent progress
- Decline in gap between sexes

Life expectancy at age 60 (e_{60}) by sex, Quebec, 1921-1999



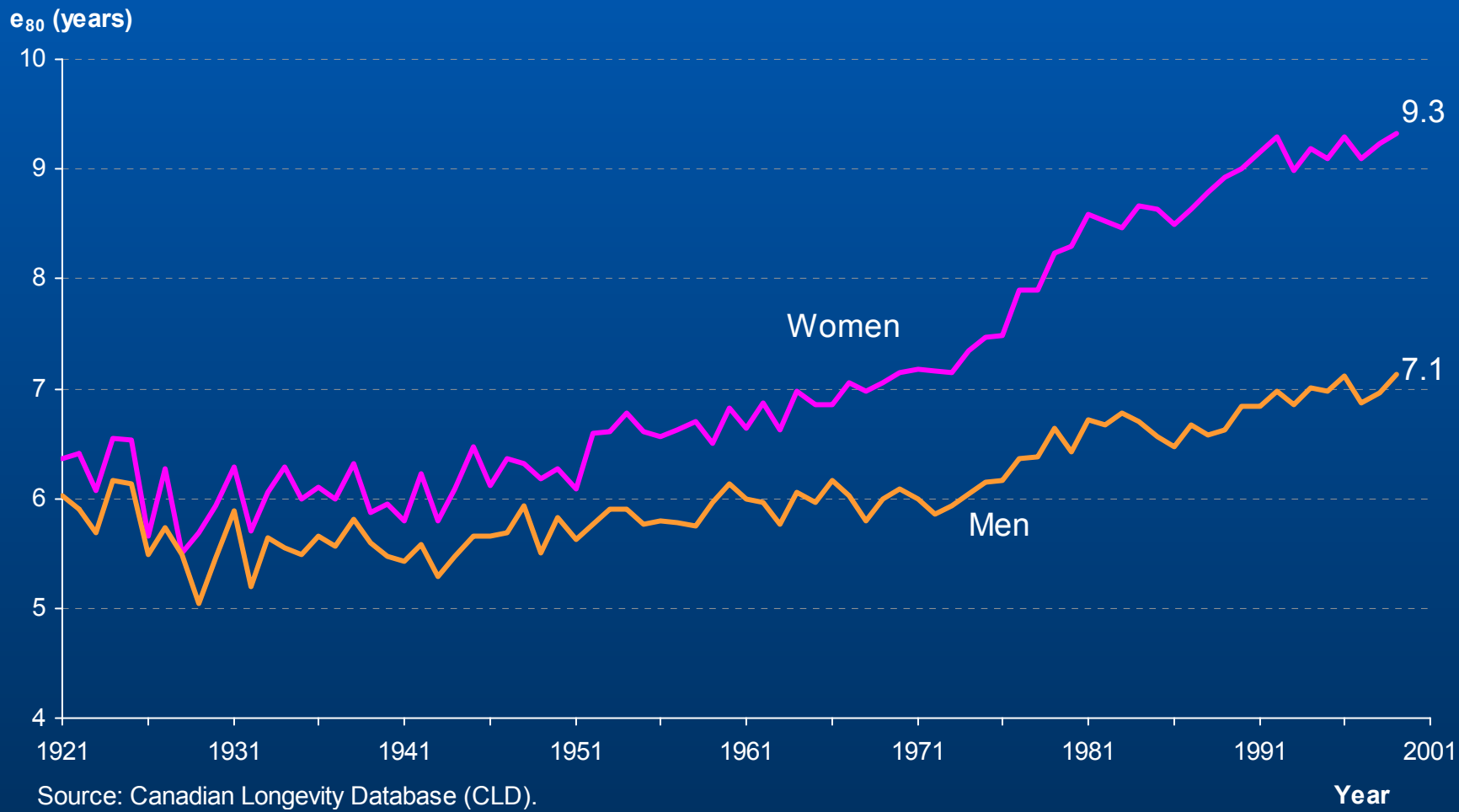
Source: Canadian Longevity Database (CLD).

Life expectancy at age 65 (e_{65}) by sex, Quebec, 1921-1999

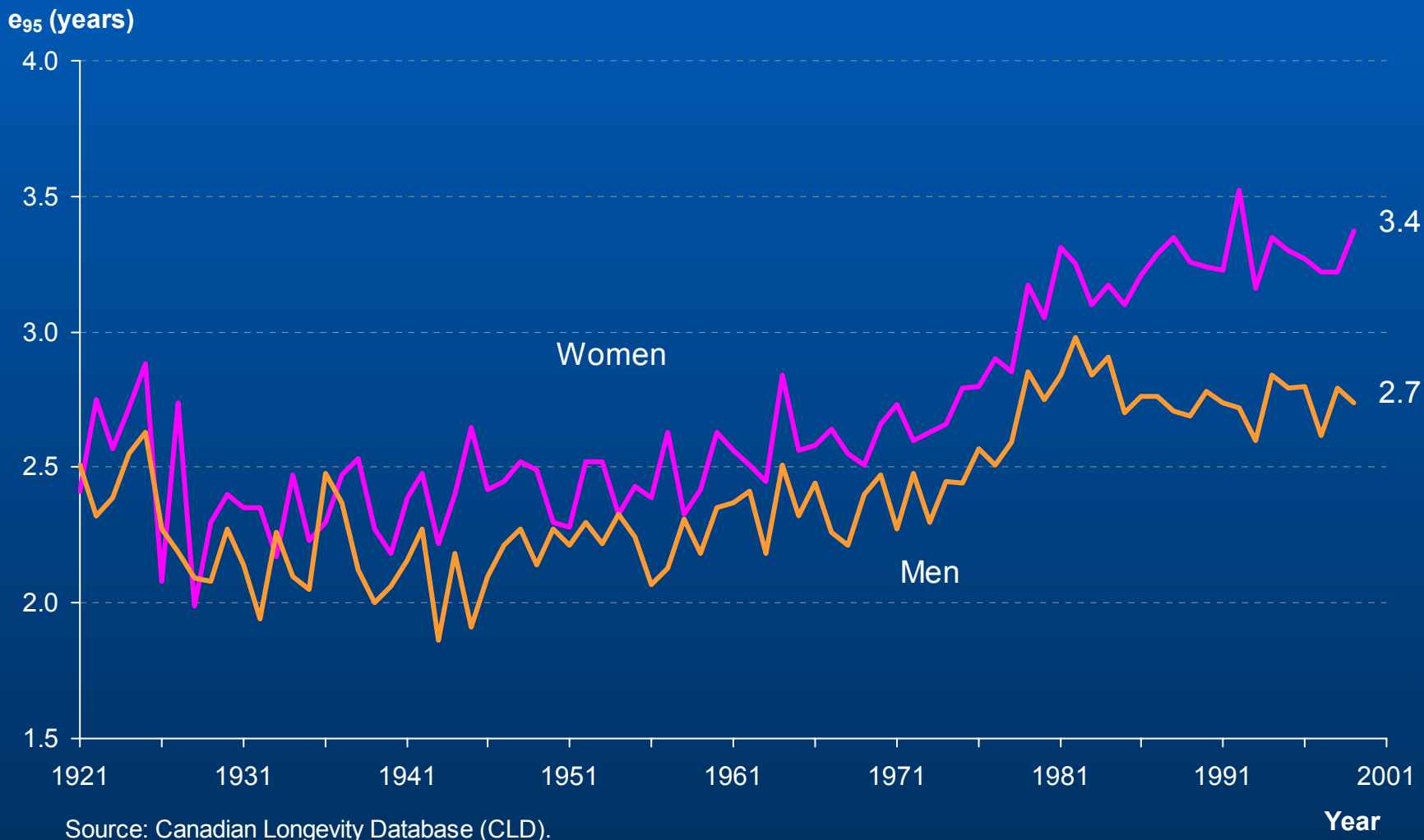


Source: Canadian Longevity Database (CLD).

Life expectancy at age 80 (e_{80}) by sex, Quebec, 1921-1999

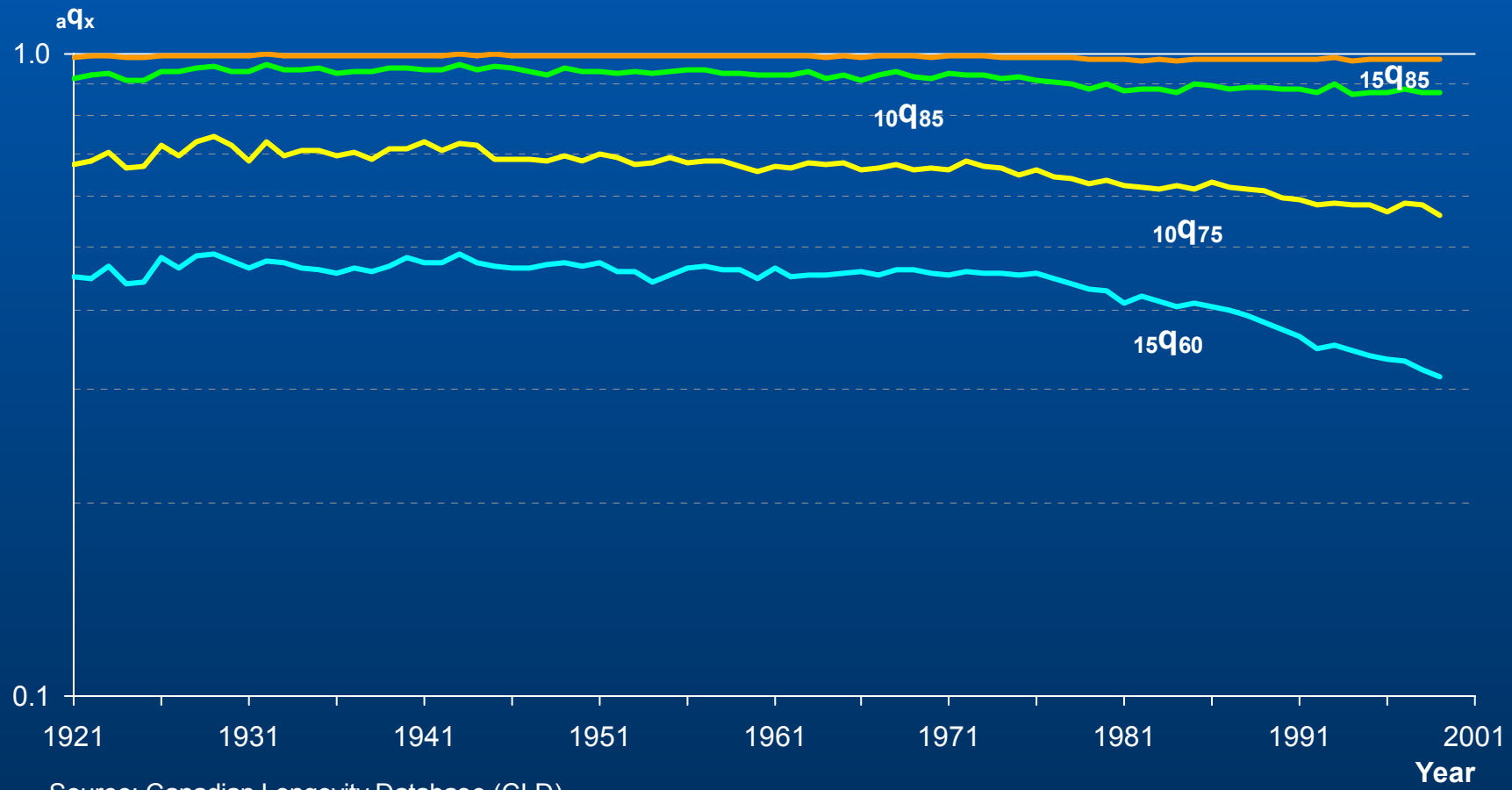


Life expectancy at age 95 (e_{95}) by sex, Quebec, 1921-1999



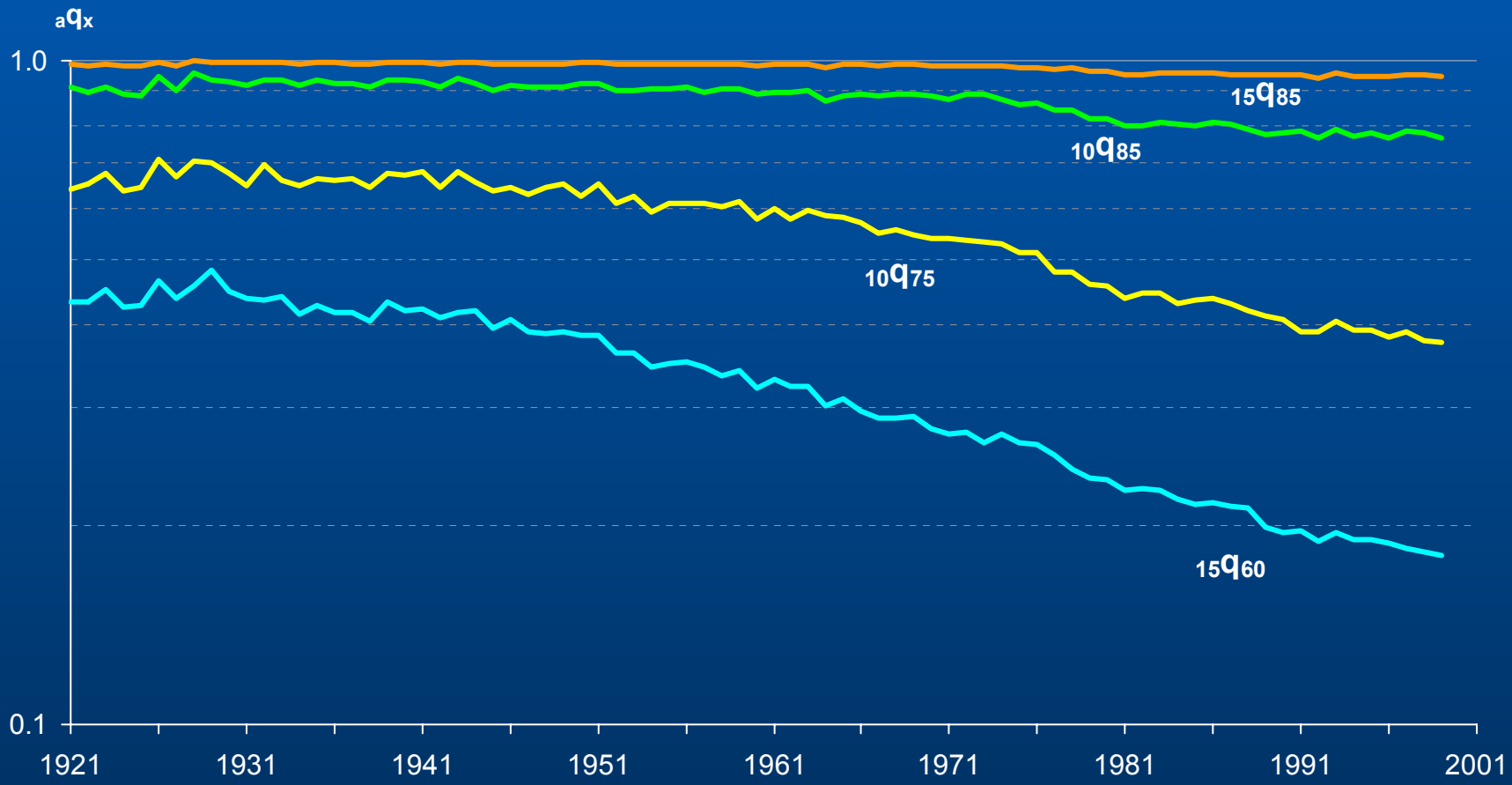
Source: Canadian Longevity Database (CLD).

Probability of death by age group, male, Quebec, 1921 to 1999



Source: Canadian Longevity Database (CLD).

Probability of death by age group, female, Quebec, 1921 to 1999

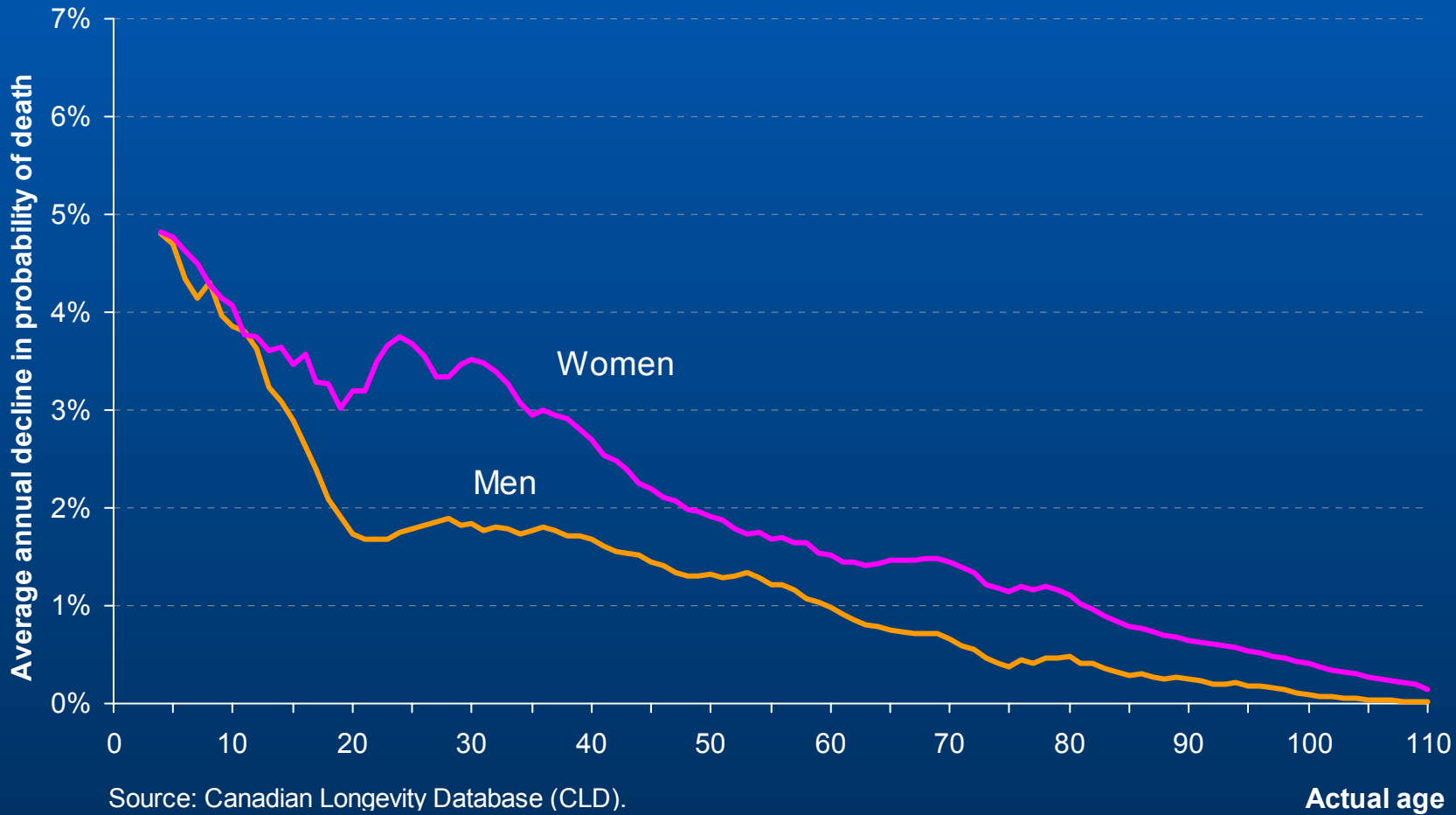


Source: Canadian Longevity Database (CLD).

Changes in mortality after age 60

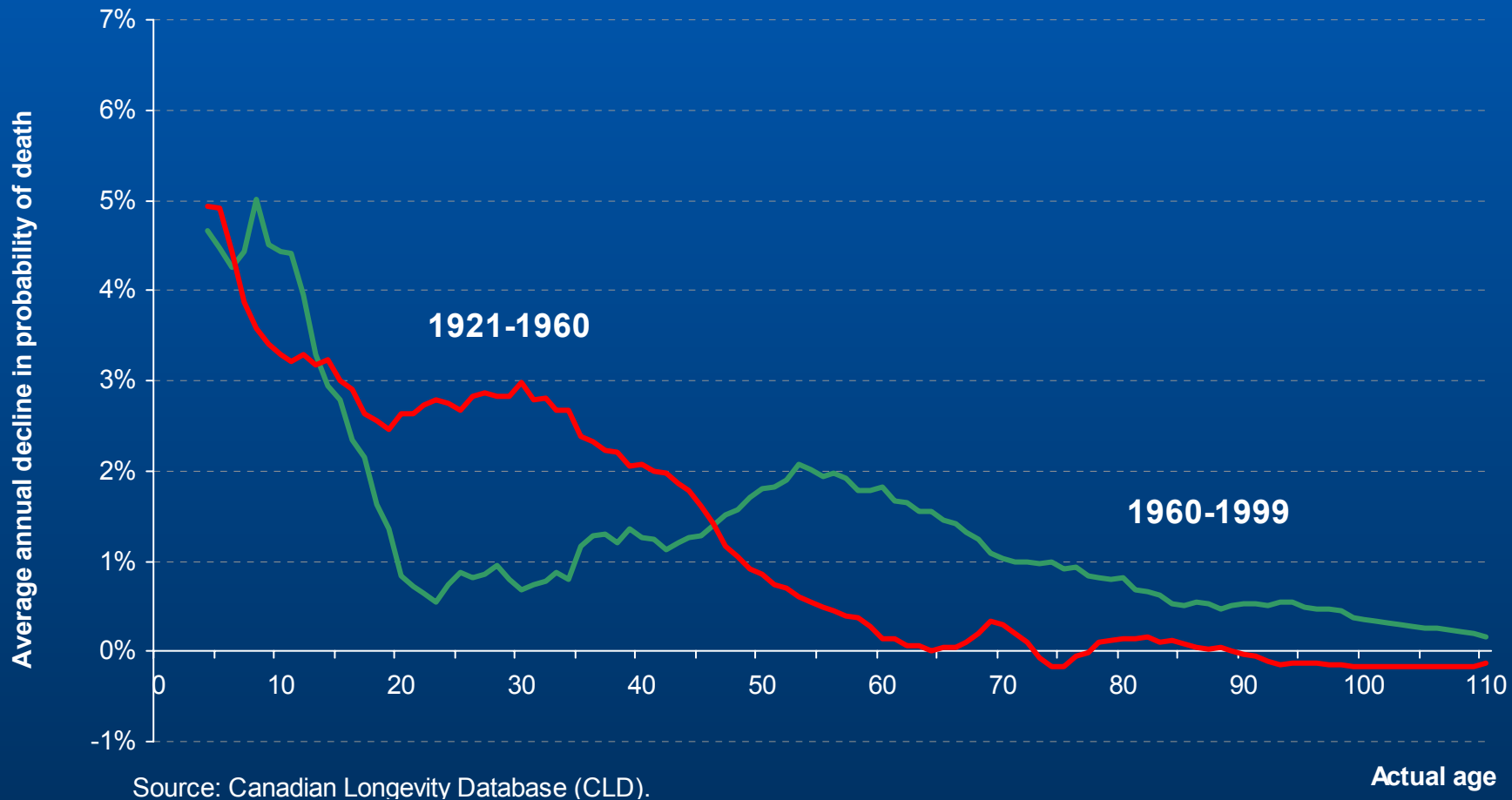
- Average annual decline:
  - long term (1921-1999)
  - medium term (40 years)
  - short term (20 years)

Average annual decline in probability of death, by age and sex, Quebec, 1921 to 1999



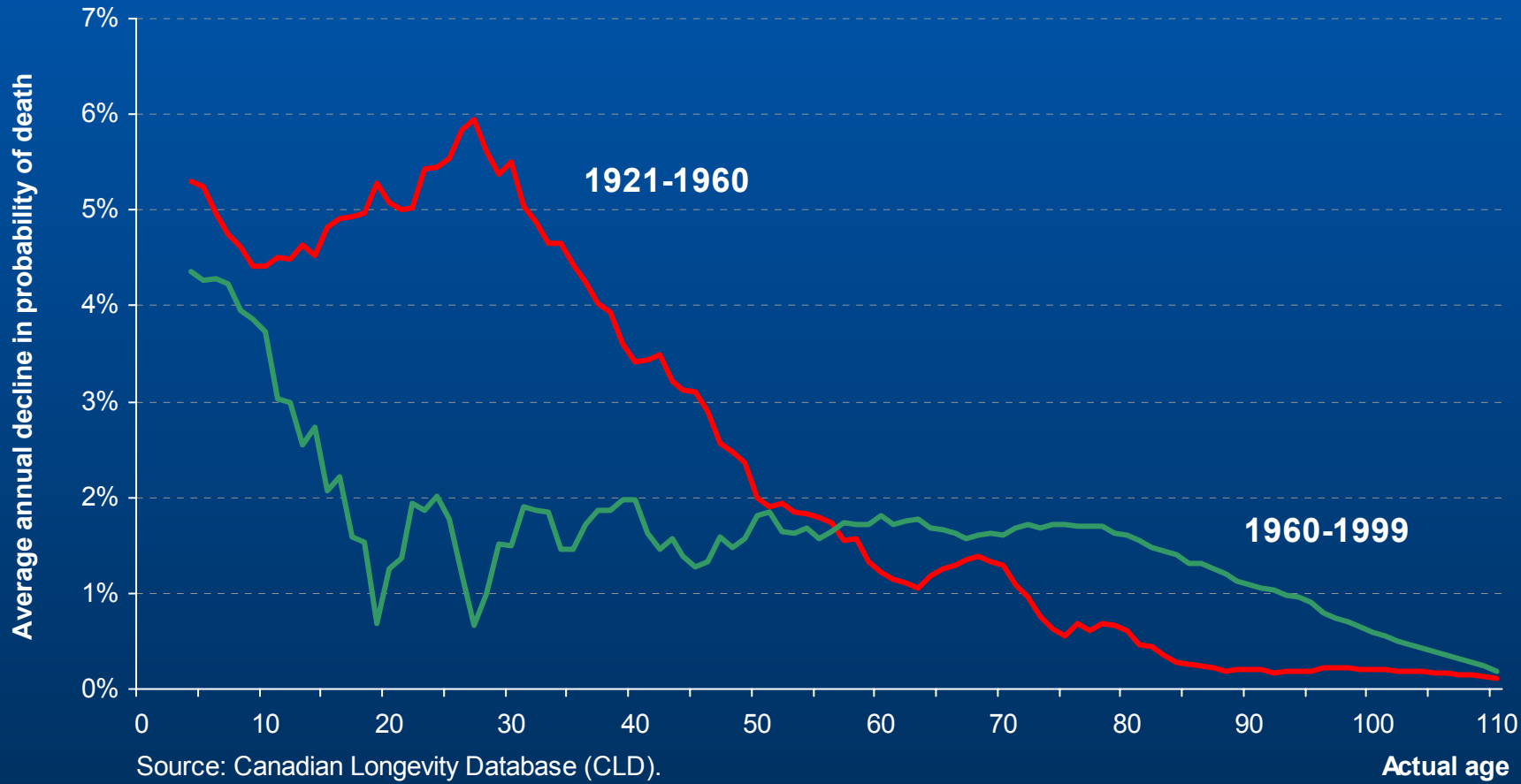
Source: Canadian Longevity Database (CLD).

Average annual decline in probability of death, male, Quebec, 1921-1960 and 1960-1999



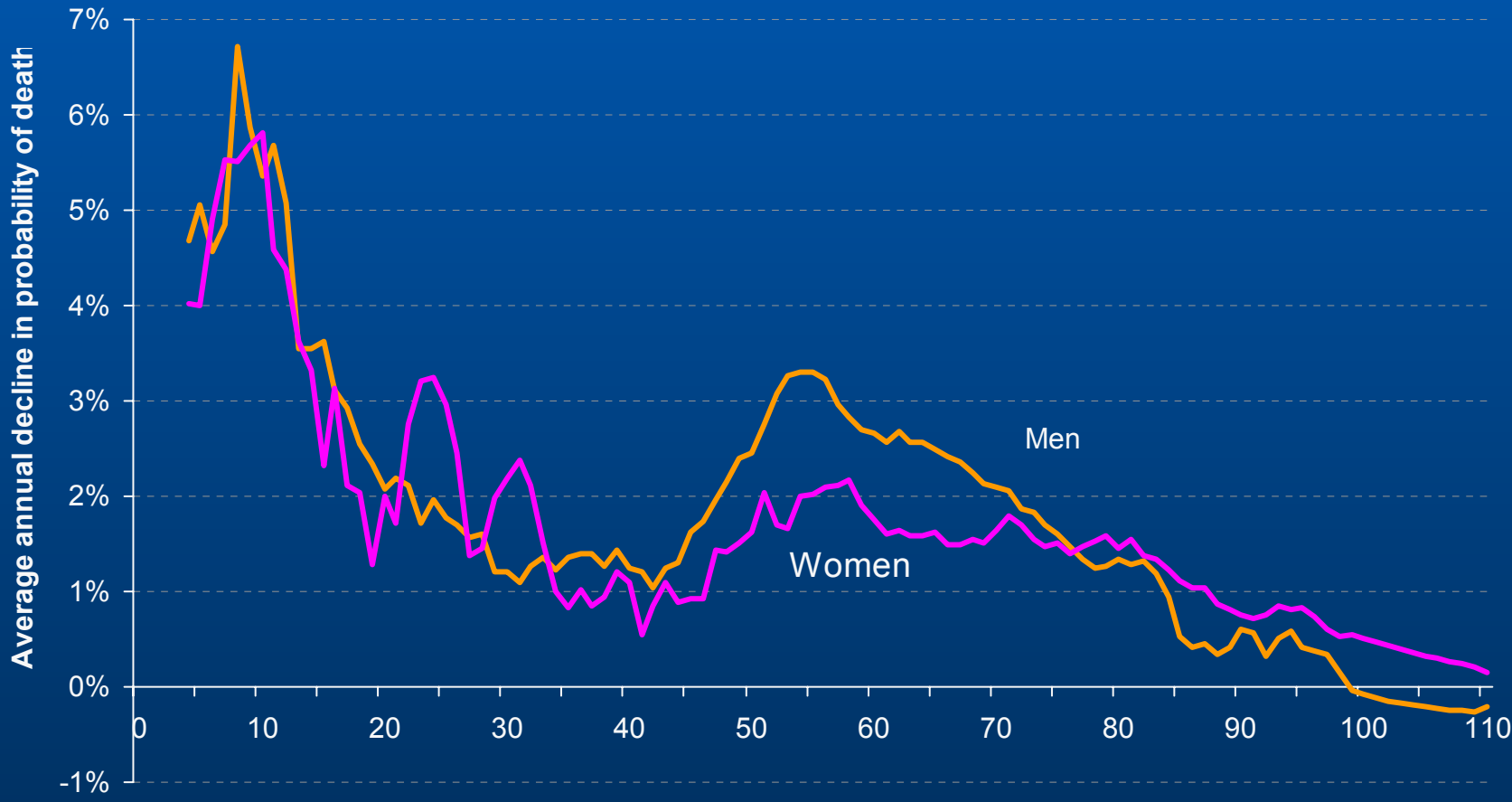
Source: Canadian Longevity Database (CLD).

Average annual decline in probability of death, female, Quebec, 1921-1960 and 1960-1999



Source: Canadian Longevity Database (CLD).

Average annual decline in probability of death by age and sex, Quebec, 1980 to 1999



Source: Canadian Longevity Database (CLD).

Contribution (in %) of age groups to gains in life expectancy at age 65, male, Quebec, 1960-1964 to 1995-1999

Age group	Period					
	1960-1964 to 1980-1984		1980-1984 to 1995-1999		1960-1964 to 1995-1999	
	Gain	Percentage	Gain	Percentage	Gain	Percentage
65-69 years	0.21	25.08	0.57	**38.51**	0.80	**34.32**
70-74 years	0.18	21.72	0.46	**31.41**	0.65	**28.03**
75-79 years	0.17	20.63	0.29	19.77	0.46	19.81
80-84 years	0.13	14.85	0.12	8.36	0.24	10.34
85-89 years	0.11	12.93	0.03	1.76	0.13	5.67
90 years +	0.04	4.79	0.003	0.20	0.04	1.83
Total	0.85	100.0	1.48	100.0	**2.32**	100.00

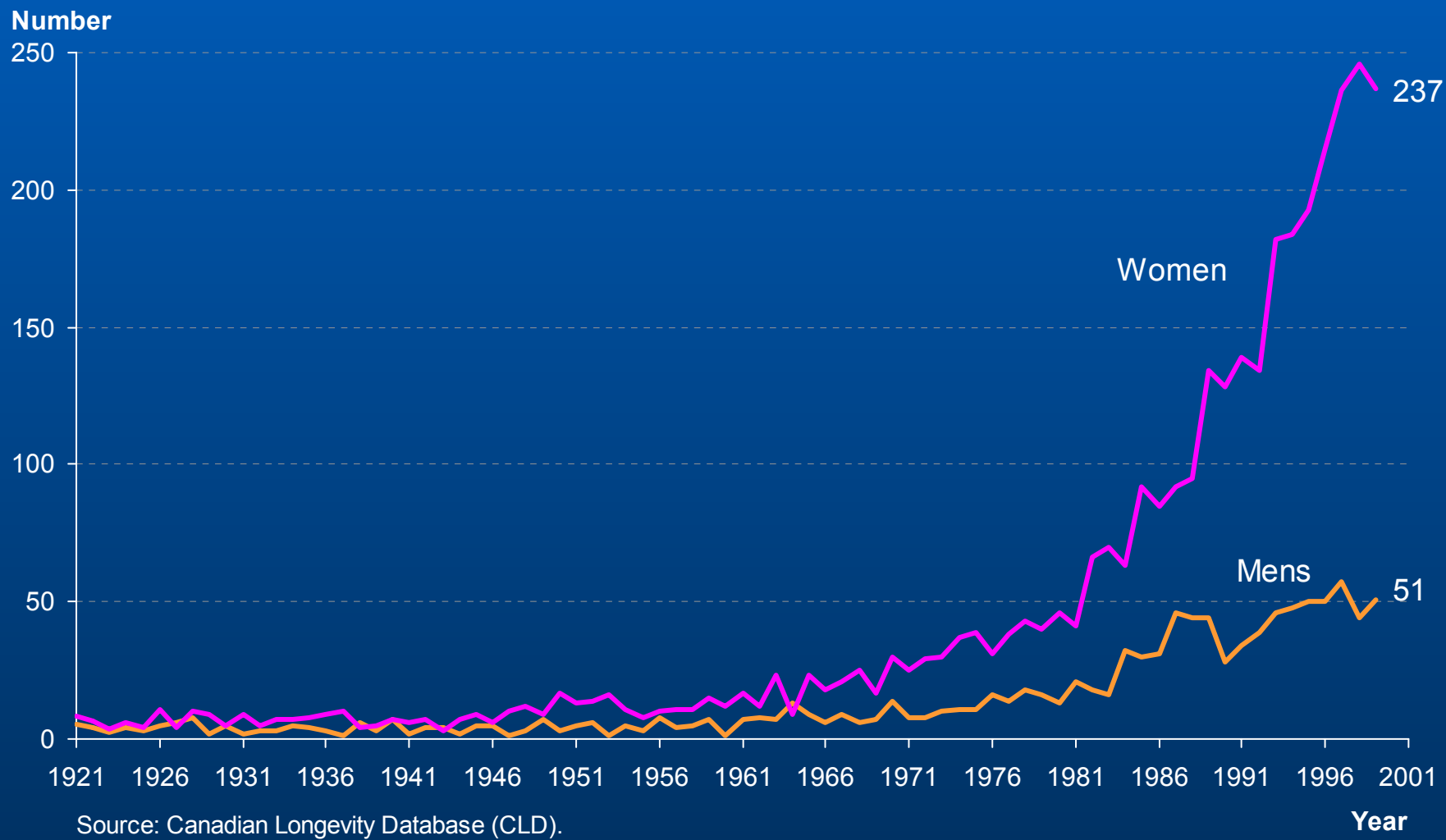
Contribution (in %) of age groups to gains in life expectancy at age 65, female, Quebec, 1960-1964 to 1995-1999

Age group	Period					
	1960-1964 to 1980-1984		1980-1984 to 1995-1999		1960-1964 to 1995-1999	
	Gain	Percentage	Gain	Percentage	Gain	Percentage
65-69 years	0.59	19.99	0.29	21.33	0.91	21.33
70-74 years	0.70	23.79	0.29	21.61	1.02	23.98
75-79 years	0.73	25.08	0.31	23.17	1.06	24.83
80-84 years	0.52	17.66	0.28	**20.49**	0.76	17.80
85-89 years	0.29	9.85	0.12	**8.93**	0.38	8.85
90 years +	0.11	3.63	0.06	**4.48**	0.14	3.21
Total	2.93	100.0	1.35	100.0	**4.27**	100.00

Mortality in very old age: data quality and change assumptions

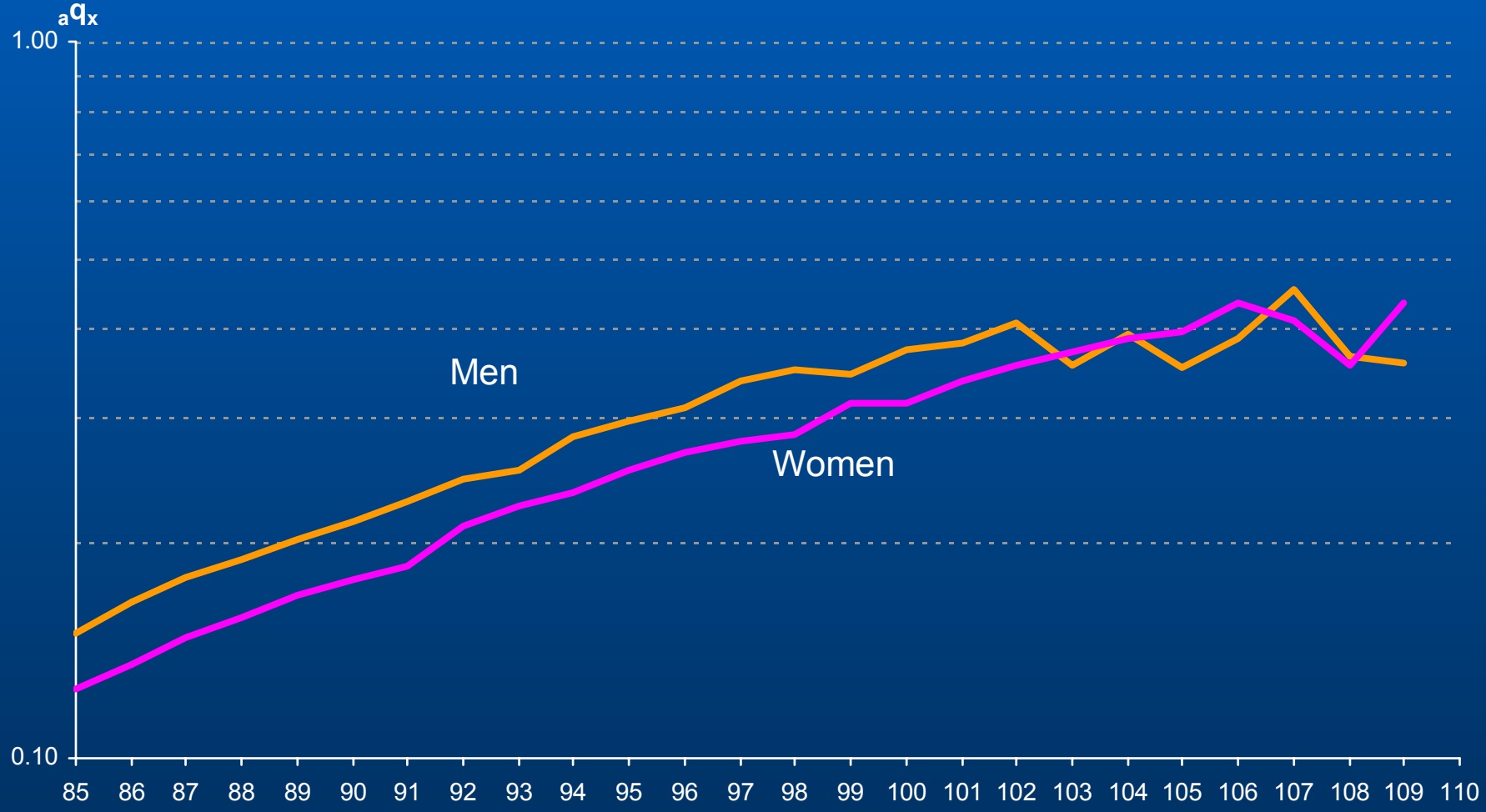
- Explosive growth in number of centenarians
- Measurement problem
  - data quality (age exaggeration)
  - small numbers (population sizes and deaths)
- Selecting a model:
  exponential, logistic, quadratic...

Centenarian deaths by sex, Quebec, 1921-1999



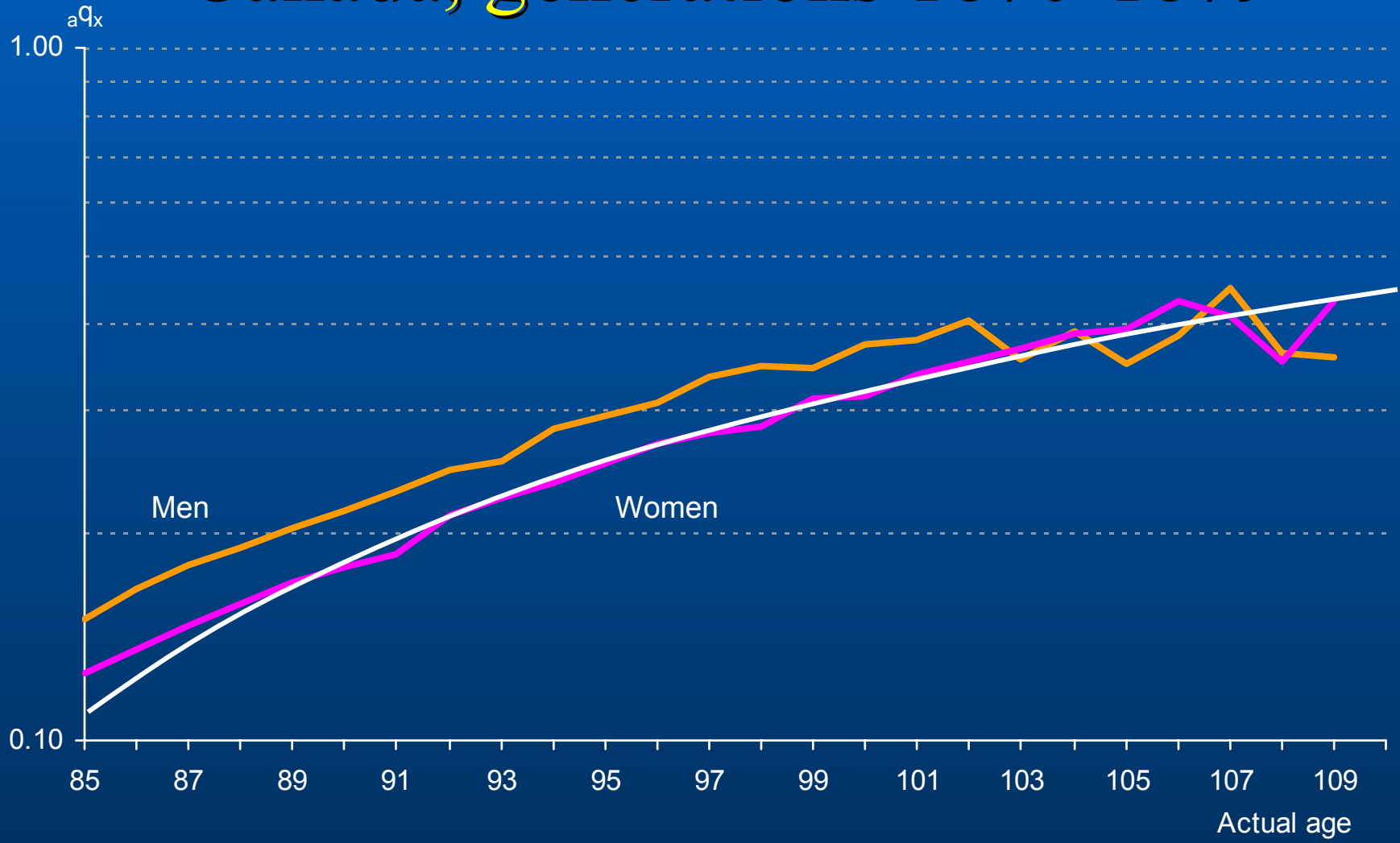
Source: Canadian Longevity Database (CLD).

Probability of death by age and sex, Canada, generations 1870-1879



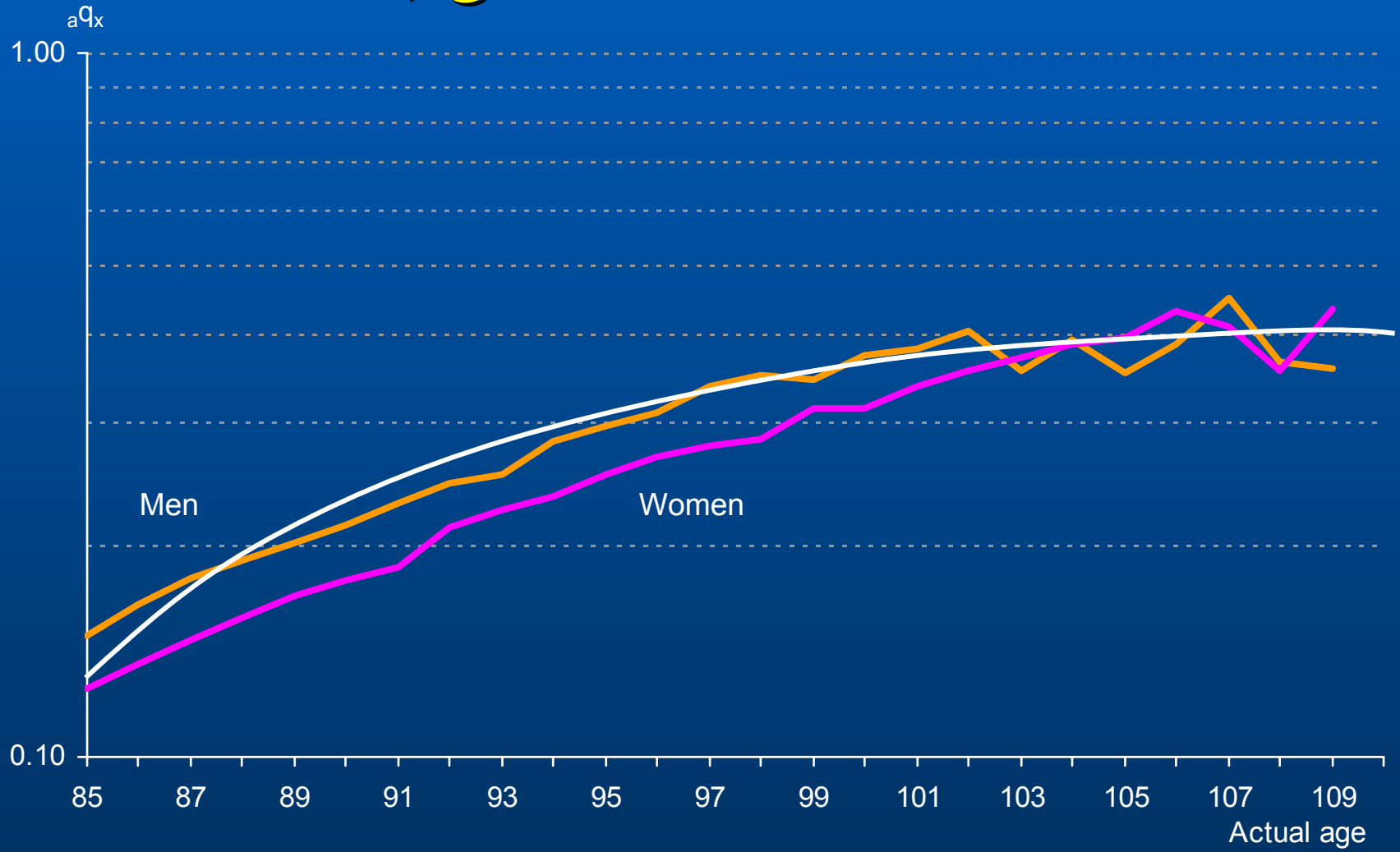
Source: Bourbeau et Desjardins, 2002

Probability of death by age and sex, Canada, generations 1870-1879



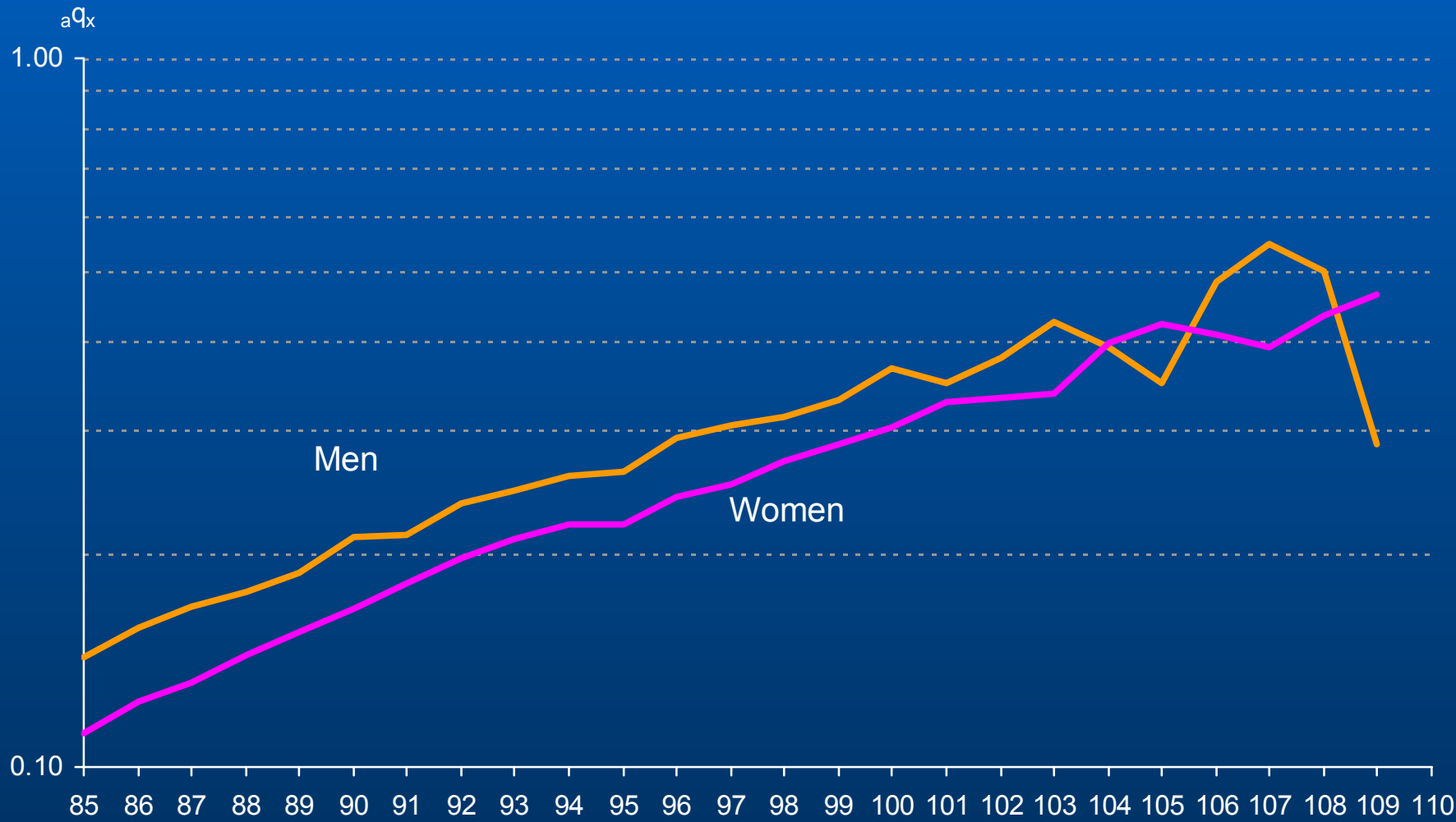
Source: Bourbeau et Desjardins, 2002

Probability of death by age and sex, Canada, generations 1870-1879



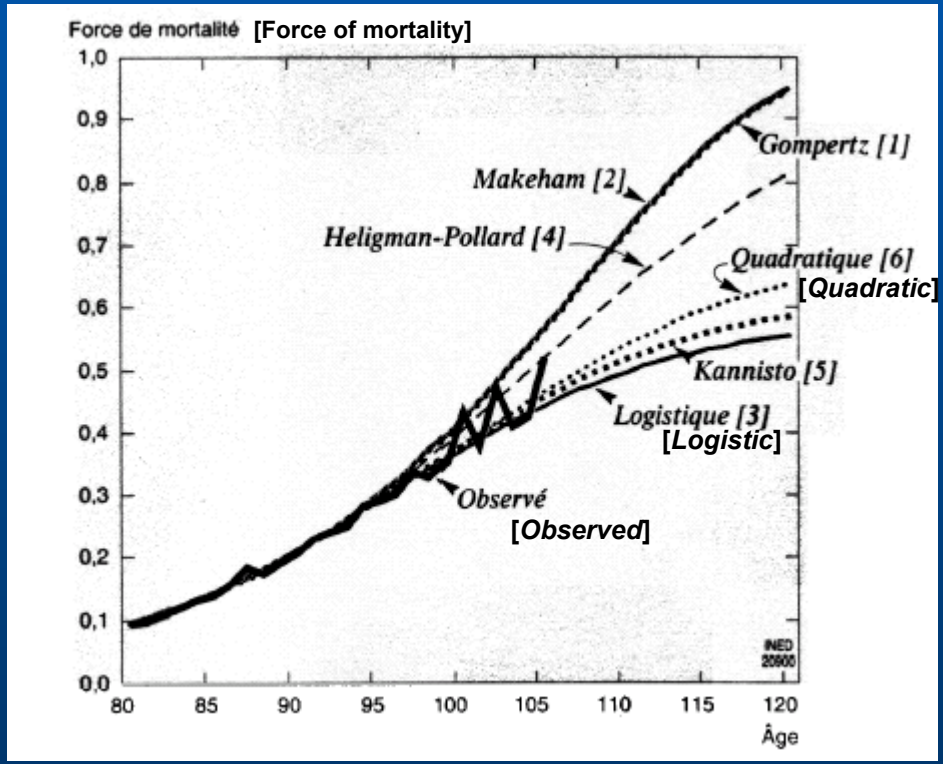
Source: Bourbeau et Desjardins, 2002

Probability of death by age and sex, Canada, generations 1880-1884



Source: Bourbeau et Desjardins, 2002

Comparison of actual probability of death and probabilities obtained from various models, over age 80, France, female generation 1875



Source: Caselli, Vallin and Wunsch, 2001, page 201.

Mortality at very old ages: data quality and change assumptions

- Evaluation of data quality in Quebec: very good results
- North American mortality profile?: lower mortality at old ages

Sample Description

1985-1999 Centenarian deaths in Quebec
3,031

Born in Quebec
2,280

Other
751

French Canadian
2,039

English names (Protestants)
241

Sample:

Percentage	Age	N
100%	107+	41
50%	106	17
25%	105	21
10%	102-104	63
5%	100-101	67
Total:	**209 Cases (41 M, 168 F)**	

Source: Bourbeau et Desjardins, 2002

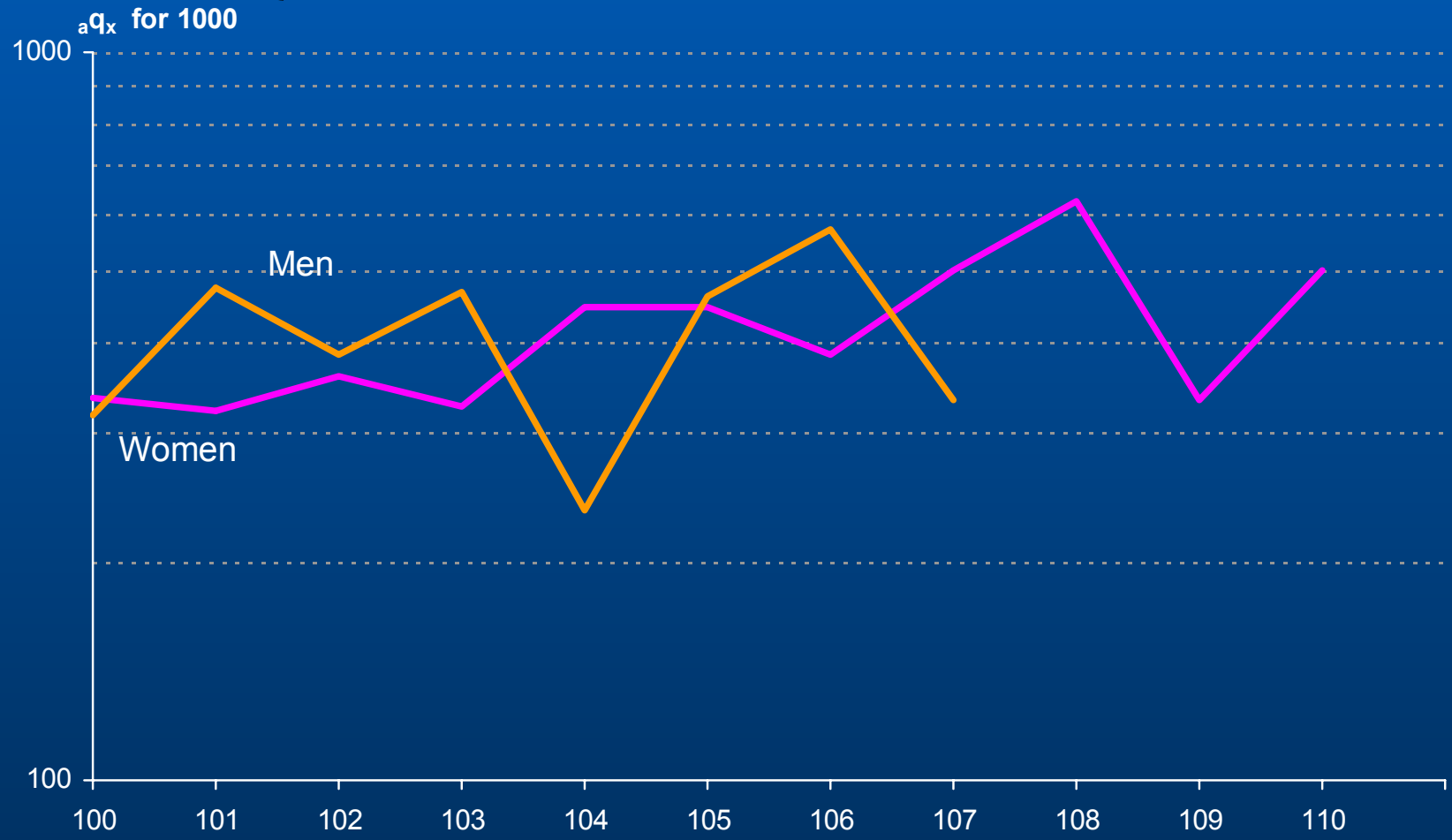
Validation of results

- 158 baptisms corresponding or found in censuses
- 18 cases of direct evidence with overlap
- 25 cases of indirect evidence (incorrect age selection highly unlikely)
- 4 errors (all at 107+ ; 3 of the 4 were age exaggerations)
- 4 without information

209

Source: Bourbeau et Desjardins, 2002

Probability of death by age and sex of centenarians born in Quebec, Quebec, cohorts 1885-1889



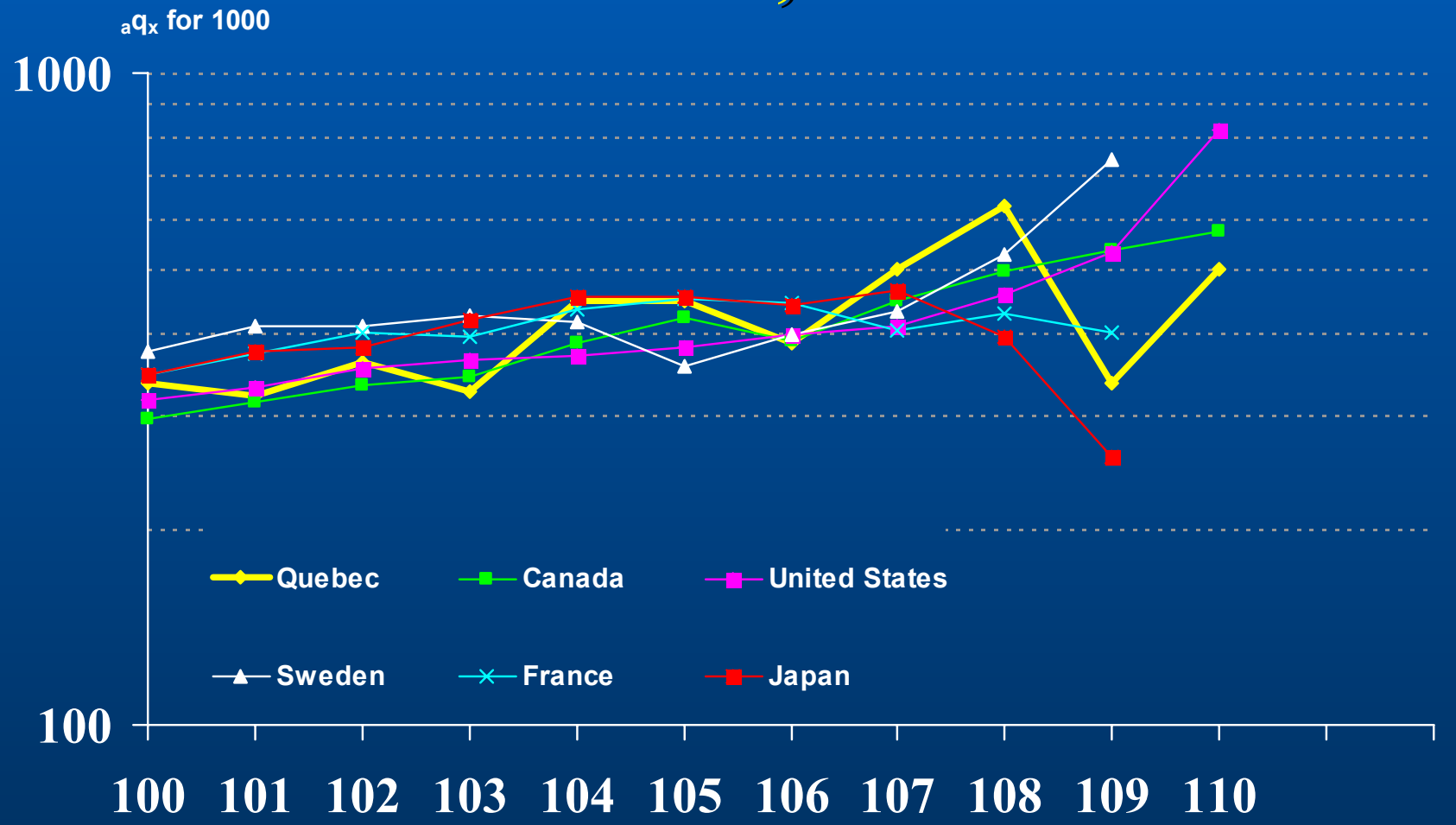
Source: Bourbeau et Desjardins, 2000

North American mortality profile?

- **Comparison with some countries (use of the same method for deceased generations)**
  - **Sweden, Cohorts 1886-1890**
  - **Canada, Period 1991-1994**
  - **France, Period 1991-1995**
  - **Japan, Period 1991-1995**
  - **United States, Period 1991-1992**

Source: Bourbeau et Desjardins, 2000

Probability of death by age of centenarians for Quebec and some countries, female



Source: Bourbeau et Desjardins, 2000

Life expectancy at age 100 and probability of survival between ages 100 and 105 by sex, Quebec and some countries

Country	Cohort or period	Men		Women	
		e_{100}	${}_5p_{100}$	e_{100}	${}_5p_{100}$
Quebec	Cohort 1885-1889	**2.05**	0.0897	**2.34**	0.1078
Canada	Period 1991-1994	**2.24**	0.1030	**2.53**	0.1312
United States (Whites)	Period 1991-1992	2.14	0.0922	2.38	0.1195
Sweden	Cohort 1886-1890	1.69	0.0443	1.98	0.0742
France	Period 1991-1995	1.88	0.0571	2.12	0.0849
Japan	Period 1991-1995	1.84	0.0572	2.11	0.0811

Source: Bourbeau et Desjardins, 2000

Mortality projections: some suggestions

- Current practices in Quebec
- Role of assumptions
- Longitudinal contribution

Institut de la statistique du Québec ISQ - 3 scenarios

- Reference: Trended decline based on changes over past 25 years (1971-1996) in mortality to 2041.
- Weak: Trended decline in mortality until 2011 and constant mortality thereafter.
- Constant: Constant mortality from 1996 onward.

ISQ amended (Bourbeau et al., 2002)

- Futuristic scenario in which e_0 = 100 years for the generation born in 2001.

Statistics Canada method

(modified version of Lee and Carter model)

Assumptions for 2026 calendar year:

- **High assumption**: life expectancy **80.6 years** for men and **84.8 years** for women in 2026 (difference of 4.2 years)
- **Medium assumption**: life expectancy **79.2 years** for men and **83.8 years** for women in 2026 (difference of 4.6 years).
- **Low assumption**: life expectancy **77.7 years** for men and **82.8 years** for women in 2026 (difference of 5.1 years).
- For each of these assumptions, Statistics Canada has interpolated life expectancies for the years between 1996 and 2026, assuming that gains will occur more quickly early in the period.
- Mortality rate projections were generated based on those life expectancies projected by sex, using the parametric model developed by Lee and Carter (1992).

Quebec Pension Plan (2000)

- Continuous reduction in mortality rates for the entire projection period (SSA)
- Variable reduction by age, sex and year
- Slower reduction than observed between 1966 and 1998
- Life expectancy gap closing between men and women

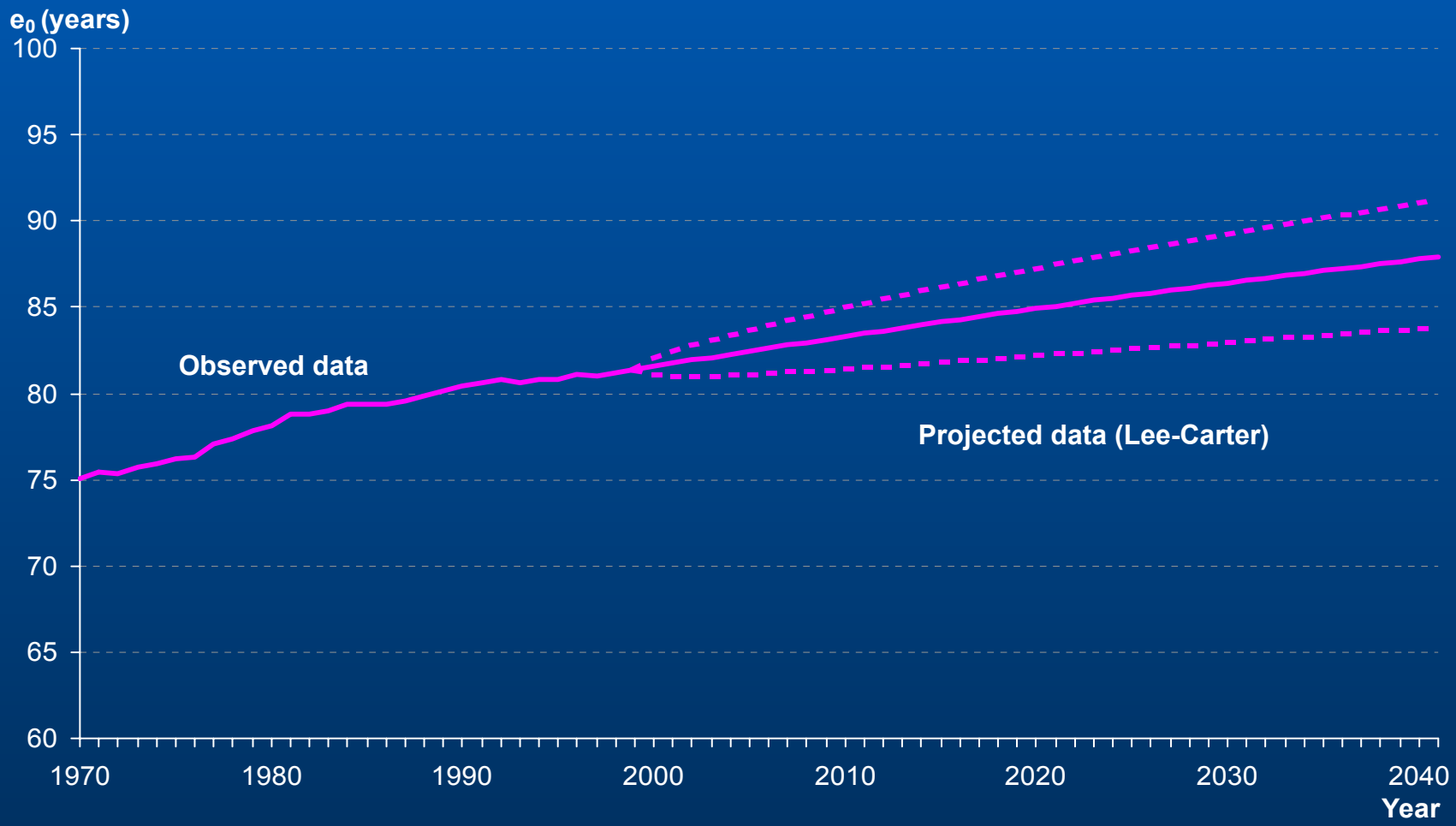
Lee and Carter model (1992)

$$\ln(m_{x,t}) = a_x + b_x k_t + \varepsilon$$

$m_{x,t}$ = mortality rate at age x and time t
a_x = average mortality profile by age
b_x = rate of change of mortality rate at each age
k_t = parameter of mortality level at time t
ε = model residual

- Age and time components are determined on the basis of a 30-year period (t) (1970-1999) for the female sex in Quebec.
- Projection of indicator k_t is made over a 50-year period (2000-2050), which makes it possible to project mortality rates and life expectancies for half of the XXIth century.

Life expectancy at birth (e_0) with confidence interval of 95%, female, Quebec, 1970-2041



Source: Paquette L. et Bourbeau, R. (in preparation)

Life expectancy at birth (e_0) by sex, Quebec, 2001 to 2041

Year	ISQ (R)		ISQ amended		Statistics Canada (M)		Lee Carter	
	M	W	M	W	M	W	M	W
2001	75.60	81.82	75.60	81.82	75.70	82.10	…	81.75
2011	77.24	83.15	79.06	84.37			…	83.48
2021	78.80	**84.42**	82.36	**86.78**	79.20*	**83.80***	…	**85.07**
2031	80.29	85.61	85.50	89.08			…	86.55
2041	81.72	**86.75**	88.52	**91.26**			…	**87.92**

*: Year 2026.

Life expectancy at birth (e_0) by sex, Quebec, 2001 to 2041

Year	ISQ (R)		ISQ amended		QPP		Lee Carter	
	M	W	M	W	M	W	M	W
2001	75.60	81.82	75.60	81.82	75.7	81.4	…	81.75
2011	77.24	83.15	79.06	84.37			…	83.48
2021	78.80	**84.42**	82.36	**86.78**	78.4*	**83.1***	…	**85.07**
2031	80.29	85.61	85.50	89.08			…	86.55
2041	81.72	**86.75**	88.52	**91.26**	80.2†	**84.5 †**	…	**87.92**

*: Year 2025; †: Year 2050

Life expectancy at age 60 (e_{60}) by sex, Quebec, 2001 to 2041

Year	ISQ (R)		ISQ amended		QPP		Lee Carter	
	M	F	M	F	M	F	M	F
2001	20.05	24.57	20.05	24.57	19.7	24.2	…	24.45
2011	21.20	25.57	22.59	26.57	…	…	…	25.70
2021	22.32	**26.54**	25.13	**28.54**	21.6*	**25.4***	…	**26.91**
2031	23.42	27.48	27.68	30.47	…	…	…	28.08
2041	24.50	**28.39**	30.22	**32.37**	22.9 †	**26.5 †**	…	**29.20**

*: Year 2025; †: Year 2050 ; ... = data unavailable.

Life expectancy at age 80 (e_{80}) by sex, Quebec, 2001 to 2041

Year	ISQ (R)		ISQ amended		QPP		Lee Carter	
	M	F	M	F	M	F	M	F
2001	7.50	9.52	7.50	9.52	7.1	9.3	…	9.65
2011	8.03	10.05	8.92	10.76	…	…	…	10.38
2021	8.56	**10.59**	10.47	**12.06**	8.1*	**9.9***	…	**11.10**
2031	9.11	11.13	12.12	13.41	…	…	…	11.81
2041	9.67	**11.68**	13.88	**14.81**	8.7 †	**10.6 †**	…	**12.51**

*: Year 2025; †: Year 2050 ; ... = data unavailable.

Survivors per 100,000 births at age 60 by sex, Quebec, 2001 to 2041

Year	ISQ (R)		ISQ amended		Lee Carter	
	M	W	M	W	M	W
2001	87,878	93,255	87,878	93,255	…	93,221
2011	89,577	94,236	91,040	94,879	…	94,454
2021	91,070	**95,076**	93,422	**96,109**	…	**95,449**
2031	92,326	95,790	95,159	97,055	…	96,257
2041	93,393	**96,400**	96,443	**97,762**	…	**96,916**

... = data unavailable.

Survivors per 100,000 births at age 80 years by sex, Quebec, 2001 to 2041

Year	ISQ (R)		ISQ amended		Lee Carter	
	M	W	M	W	M	W
2001	45,421	65,832	45,421	65,832	…	65,074
2011	50,639	69,646	56,034	72,598	…	69,740
2021	55,583	**73,149**	65,315	**78,253**	…	**73,891**
2031	60,256	76,309	73,104	82,874	…	77,551
2041	64,619	**79,150**	79,431	**86,592**	…	**80,756**

... = data unavailable.

Life expectancy at age 60 (e_{60}) according to current tables and generation tables, male, Quebec (ISQ reference scenario)

Generations	Men	Year	Men	Difference (Generation-Year)
1941	21.69	2001	20.05	1.64
1951	22.90	2011	21.20	1.7
1961	24.09	2021	22.32	1.77
1971	**25.27**	**2031**	**23.42**	**1.85**
1981	26.38	2041	24.50	1.88

Life expectancy at age 60 (e_{60}) according to current tables and generation tables, female, Quebec (ISQ reference scenario)

Generations	Women	Year	Women	Difference (Generation-Year)
1941	26.31	2001	24.57	1.74
1951	27.34	2011	25.57	1.77
1961	28.33	2021	26.54	1.79
1971	**29.31**	**2031**	**27.48**	**1.83**
1981	30.24	2041	28.39	1.85

Conclusions

- Remarkable advances in survival in Quebec
- Significant changes in mortality level and profile
- Issues at old ages: compression or expansion of morbidity (mortality); limit on human life
- Mortality at very old ages: data quality and changes in assumptions

Conclusions (cont'd)

- Considerations for projections
- Average life has increased and is continuing to do so
- Tendency to underestimate gains. Reality has always exceeded past perspectives (Oeppen and Vaupel, 2002, Science, May 2002)
- Maximum age at death has also risen (validated data) (Wilmoth et al., Science, Sept. 2000)
- Increasing numbers of centenarians and supercentenarians.

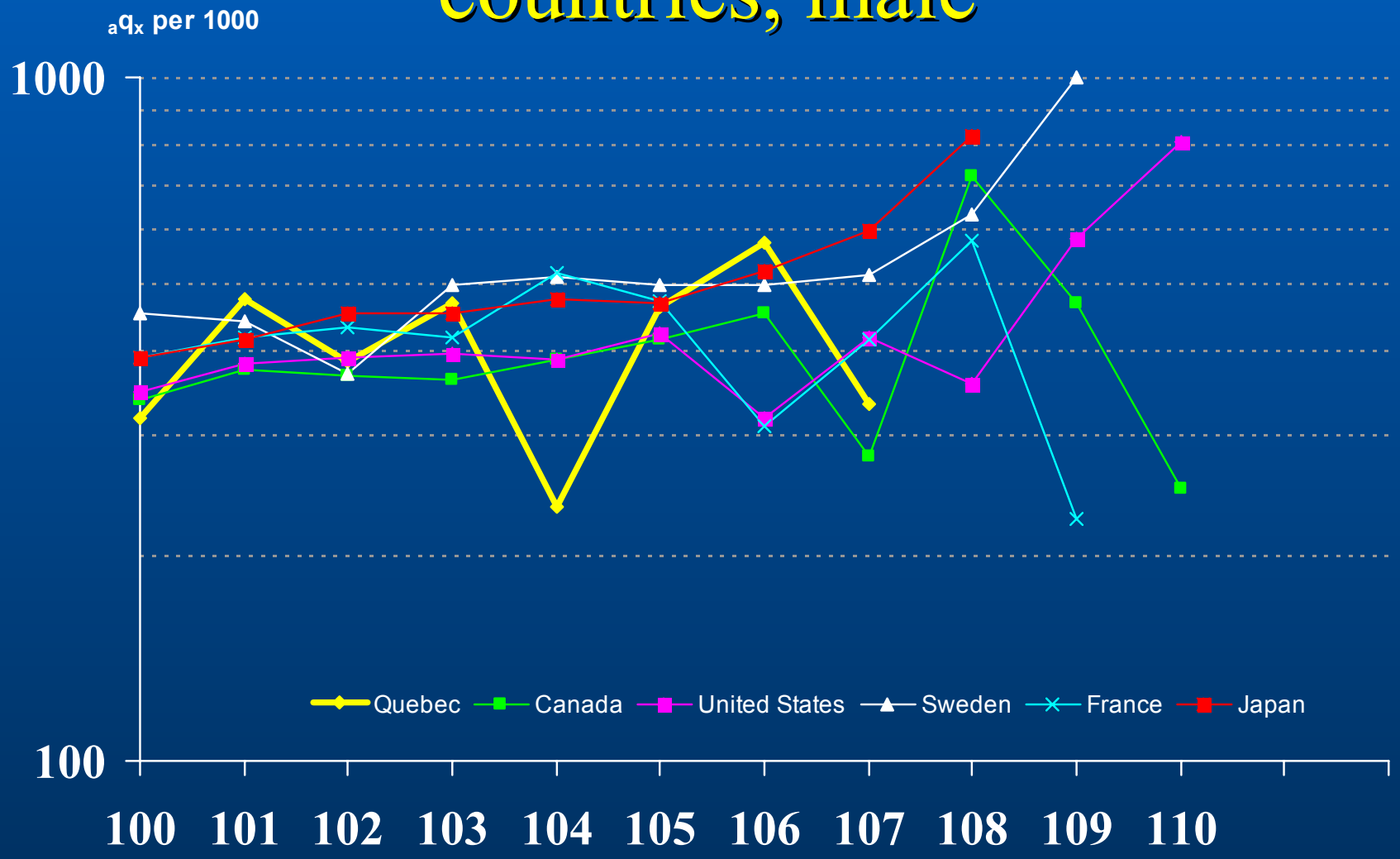
Conclusions (cont'd)

- Assumptions and their effects on results (number of survivors - beneficiaries) and number of years to live (benefit period)
- Trends over past 20 or 30 years
- Importance of longitudinal approach
- Continue data improvement efforts (validation)

At the wellspring of longevity: Jeanne Calment (1875-1997), the Doyenne of Humanity

Researcher at work in his laboratory: Arles Cemetery, France, May 2003.

Probability of death by age of centenarians for Quebec and some countries, male



Source: Bourbeau et Desjardins, 2000