Trends in scale and shape of survival curves

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Supplementary Table S1.

The graphical measurements of the characteristic life (α) from the survival curve at the age for $s(\alpha) = \exp(-1) \approx 0.367879$ (a standard deviation in measurements $\approx 3 \times 10^{-5}$). Data source: Swedish female life tables (period, 1 x 1) from the Human Mortality Database (http://www.mortality.org).

year	α (years)	year	α (years)	year	α (years)
1950	80.0525	1970	83.6787	1990	86.5397
1951	80.3035	1971	83.8454	1991	86.7595
1952	80.6391	1972	83.9854	1992	86.9433
1953	80.5884	1973	84.1579	1993	86.7934
1954	80.9887	1974	84.2919	1994	87.3893
1955	81.2295	1975	84.2641	1995	87.3779
1956	81.3343	1976	84.2969	1996	87.4592
1957	81.1717	1977	84.8430	1997	87.7033
1958	81.5393	1978	84.8745	1998	87.7737
1959	81.8789	1979	85.0024	1999	87.6986
1960	81.6369	1980	85.0665	2000	87.8836
1961	82.0544	1981	85.2333	2001	87.8933
1962	81.9802	1982	85.5888	2002	87.8657
1963	82.3428	1983	85.7992	2003	88.2213
1964	82.5337	1984	86.0353	2004	88.4649
1965	82.7467	1985	85.8699	2005	88.5502
1966	82.9233	1986	86.1312	2006	88.6732
1967	82.9847	1987	86.3034	2007	88.5896
1968	82.8098	1988	86.1488	2008	88.7732
1969	83.0654	1989	86.6936	2009	89.3028
				2010	89.3801

Supplementary Table S2.

The linear regression results of the death rate, $\ln(\mu(x)) = \ln(a) + bx$, and the survival plasticity, $\beta(x) = \beta_0 + \beta_1 x$, for the middle ages of 40–80 years (R^2 = the coefficient of determination). Data source: Swedish female death rates (period, 1 x 1) from the Human Mortality Database (http://www.mortality.org).

year	b	$\ln(a)$	R^2	β_1	β_0	R^2
1980	0.0953	-10.5540	0.9890	0.1119	0.3569	0.9950
1981	0.1000	-10.8960	0.9902	0.1112	0.5343	0.9965
1982	0.0985	-10.8190	0.9928	0.1084	0.6007	0.9967
1983	0.0969	-10.7570	0.9903	0.1142	0.2954	0.9955
1984	0.0973	-10.7990	0.9907	0.1096	0.5984	0.9964
1985	0.0995	-10.9390	0.9942	0.1132	0.3667	0.9968
1986	0.0975	-10.8310	0.9901	0.1121	0.4699	0.9946
1987	0.0967	-10.7850	0.9928	0.1103	0.5231	0.9953
1988	0.0954	-10.6820	0.9902	0.1105	0.5003	0.9956
1989	0.0952	-10.7390	0.9913	0.1126	0.4232	0.9947
1990	0.0969	-10.8300	0.9916	0.1118	0.4869	0.9936
1991	0.0958	-10.7680	0.9942	0.1087	0.6190	0.9935
1992	0.0966	-10.8320	0.9941	0.1019	1.0851	0.9956
1993	0.0990	-11.0090	0.9908	0.1092	0.7657	0.9949
1994	0.0947	-10.7690	0.9895	0.1070	0.8376	0.9868
1995	0.0967	-10.9010	0.9936	0.1043	1.0922	0.9909
1996	0.0983	-11.0170	0.9928	0.1029	1.1904	0.9916
1997	0.0987	-11.0820	0.9935	0.1050	1.1119	0.9943
1998	0.0972	-10.9930	0.9955	0.1054	1.1009	0.9914
1999	0.0959	-10.8980	0.9941	0.1056	1.1535	0.9893
2000	0.0987	-11.0930	0.9909	0.1017	1.3523	0.9829
2001	0.0990	-11.1280	0.9931	0.1032	1.3032	0.9868
2002	0.1003	-11.2300	0.9934	0.1060	1.1997	0.9900
2003	0.0993	-11.1920	0.9949	0.1052	1.2099	0.9908
2004	0.0996	-11.2380	0.9942	0.1038	1.2910	0.9911
2005	0.1002	-11.2780	0.9941	0.1000	1.5289	0.9859
2006	0.0999	-11.2930	0.9957	0.1057	1.2132	0.9905
2007	0.1007	-11.3480	0.9949	0.1073	1.2251	0.9907
2008	0.0988	-11.2530	0.9947	0.1083	1.1542	0.9861
2009	0.0990	-11.3140	0.9952	0.1052	1.3478	0.9902
2010	0.1045	-11.7070	0.9941	0.1062	1.3962	0.9943

Supplementary Table S3.

The graphical measurements of the characteristic life (α) from the survival curve at the age for $s(\alpha) = \exp(-1) \approx 0.367879$. Data source: (left column) Swedish female cohort life tables (1 x 1) for Fig. 3 and (right column) female period life tables (1 x 1) for Fig. 4 from selected wealthy countries: Japan, France, Switzerland, Australia, the USA, and the UK from the Human Mortality Database (http://www.mortality.org).

Country	calendar year	α (years)	Country	calendar year	α (years)
Sweden	1870	73.4190	**Japan**	1980	84.8082
(cohort)	1871	73.4630	**(period)**	1985	86.4097
	1872	73.1804		1990	87.5975
	1873	73.0854		1995	88.6653
	1874	72.8293		2000	90.4676
	1875	73.1137	**France**	1980	85.2641
	1876	73.4639	**(period)**	1985	86.0157
	1877	73.9806		1990	87.4475
	1878	74.4143		1995	88.3434
	1879	74.7990		2000	89.0090
	1880	74.9574	**Switzerland**	1980	85.3064
	1881	75.2238	**(period)**	1985	86.4250
	1882	75.2355		1990	86.9817
	1883	75.7363		1995	87.9358
	1884	76.1390		2000	88.5698
	1885	76.2851	**Australia**	1980	84.9866
	1886	76.5915	**(period)**	1985	85.2625
	1887	76.9657		1990	86.5231
	1888	77.2315		1995	87.4262
	1889	77.4440		2000	88.5184
	1890	77.6506	**USA**	1980	85.1661
	1891	78.1672	**(period)**	1985	85.6220
	1892	78.7910		1990	86.2846
	1893	79.0562		1995	86.4446
	1894	79.3368		2000	86.6584
	1895	79.4349	**UK**	1980	83.4746
	1896	79.8486	**(period)**	1985	83.9928
	1897	80.0487		1990	85.0045
	1898	80.3385		1995	85.4905
	1899	80.6981		2000	86.4482
	1900	81.1434			

Supplementary Figure S1.

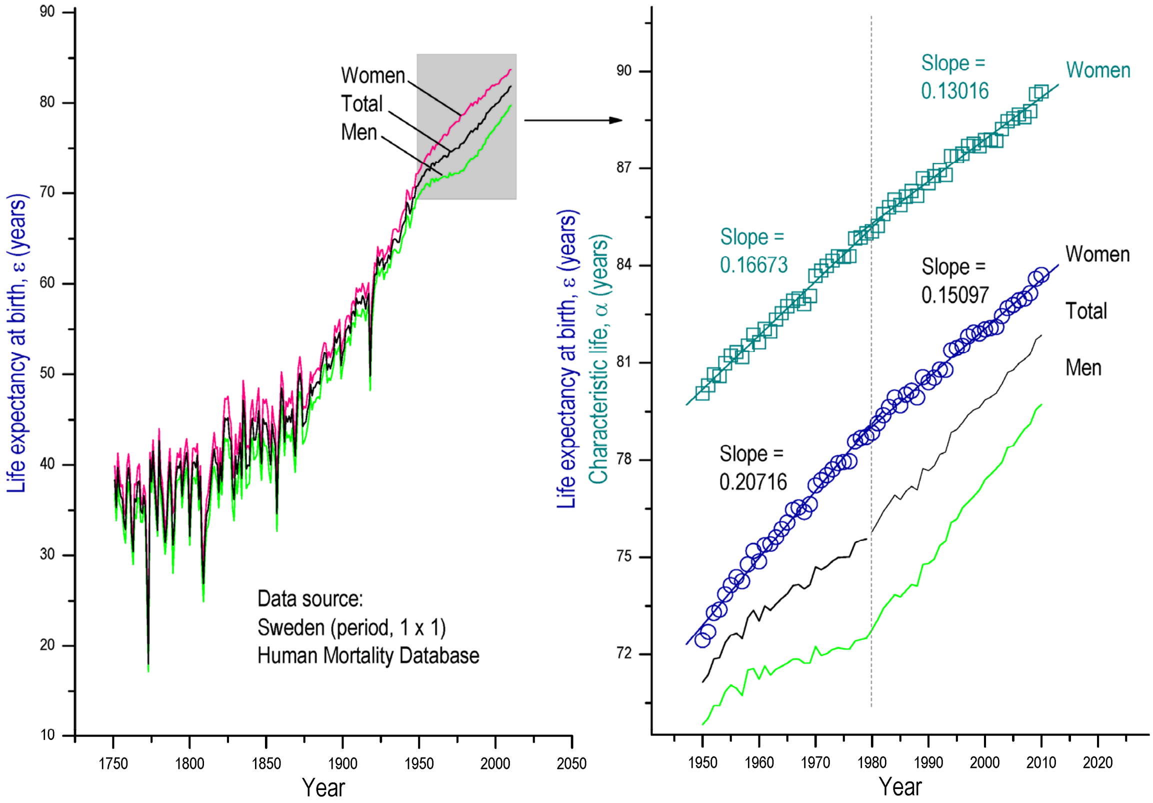

Figure S1. A comparison between the characteristic life (α) in Fig. 1c and Supplementary Table 1 (our method) and the life expectancy at birth (ε) (general method). The life expectancy at birth is the average number of years that a newborn is expected to live. The data for the life expectancy at birth (period, 1 x 1) for Swedish women (circles), for men, and for total (men and women) were taken from the Human Mortality Database (http://www.mortality.org). The similar trends in the historic trends between α (squares) and ε (circles) for women suggest the usefulness of the characteristic life as an indicator of lifespan evolution (scale effect in survival curves). The slope decrease at 1980 is found at both cases of α (0.16673→0.13016) and ε (0.20716→0.15097) for women. The apparent acceleration in total (men and women) at 1980 is attributed to the acceleration of the life expectancy for men.

Supplementary Figure S2.

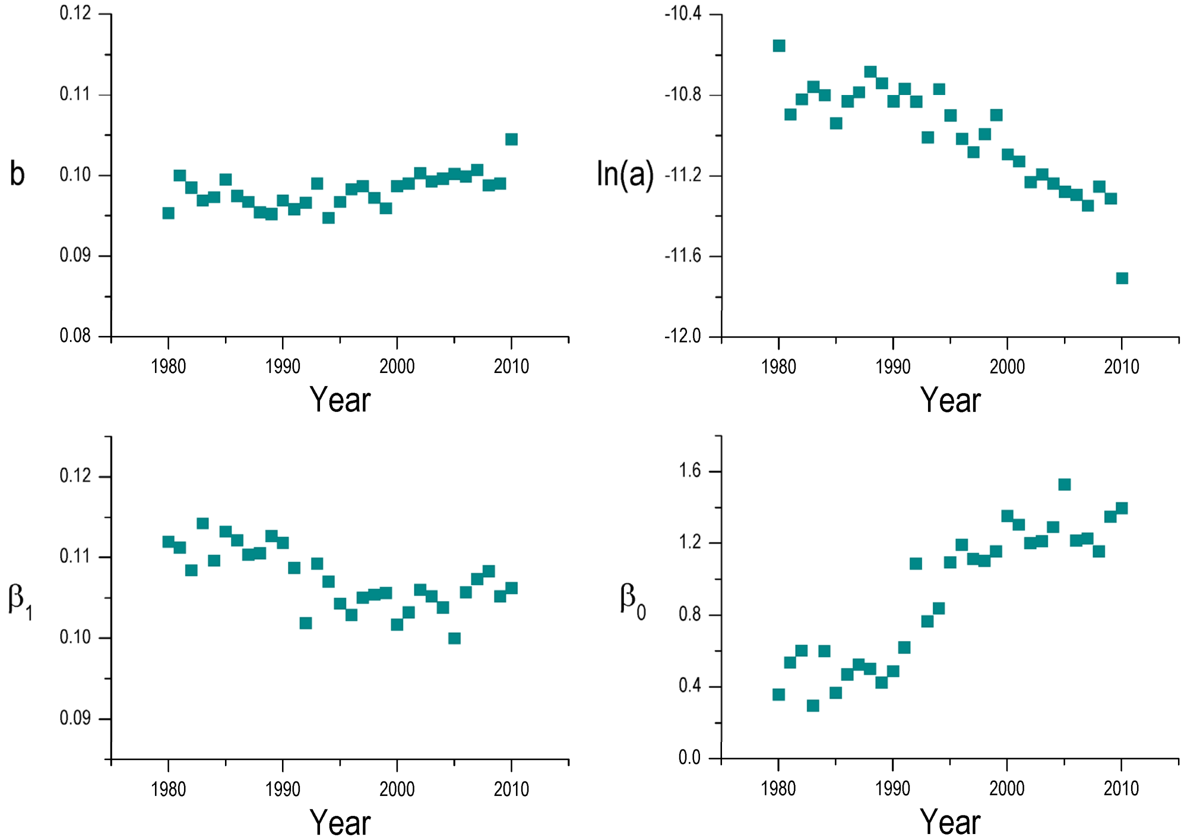

Figure S2. The historic trends of the parameters: b and $\ln(a)$ from the death rates, $\ln(\mu(x)) = \ln(a) + bx$ (linear fits in Fig. 2b), and β_1 and β_0 from the survival plasticity, $\beta(x) = \beta_0 + \beta_1 x$ (linear fits in Fig. 2d). Interestingly, the absolute values for the intercepts, $\ln(a)$ and β_0, gradually increase with calendar year, while the slopes, b and β_1, are almost invariant. This is a reason for the negative linear correlation between the parameters.

Additional Discussion.

Complex relationships between life and death processes could be relevant to many biological and non-biological factors involved in human survival and in the dynamics of aging. Possible factors are listed as follows.

I. Survival instinct can increase complexity between life and death rates in biological survival games [1,2].
II. Life can be maintained by exchanging matter, energy, and information from surroundings [3,4] and by coping with genetic and environmental fluctuation [5].
III. To cope with hostile environmental conditions, biological capability such as physiological complexity would be essential [6].
IV. Intelligence would be favorable to select optimum strategies for health and survival: smart individuals may have better survival chance against harsh exigencies and unpredictable changes of daily life [7,8].
V. Cooperation or competition of individuals with neighbors may improve flexibility in survival strategies: better strategies between cooperation and competition should be properly selected in survival games [9–12].
VI. Altruism may be an important strategy for survival of an entire population [13–15].

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