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A "New" General Theory of Population Ageing

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The main theories of population ageing based on recent data on human longevity, life expectancy, morbidity changes, disability trends and fall in mortality show co-existing contradictory tendencies in disability and functioning. These contradictions reflect differences in geographic, cultural, socio-economic, political and medical contexts, for instance:

- an increase in the survival rates of sick persons which would explain the expansion of morbidity and/or disability that is now taking place in Taiwan,
- control of the progression of chronic diseases which would explain the subtle equilibrium between the fall in mortality and the increase in disability currently observed in the U.K.,
- an improvement in the health status and health behaviours of the new cohorts of old people which would explain the reduction in morbidity and/or disability now found in France, Switzerland and the U.S.

Obviously, all of these co-exist, and future trend scenarios, namely the expansion or reduction in morbidity and/or disability, depend on their respective weighting leading to the need to anticipate the progressive but unavoidable emergence of very old and frail populations (which would explain a new increase in morbidity and/or disability).

In this context, the proposed new theory of the ageing population is based on a cyclical movement, where, first, sicker people survive into old age and disability rises, then the number of years lived with disability decreases as new cohorts of healthier people enter old age but finally, the number of years lived with disability rises again, when the average age of death rises so much that many people spent their last years at an advanced age burdened by multiple chronic diseases and frailty.

This theory needs to be confirmed by a worldwide harmonization of functional decline measurements and a periodic "international ageing survey" to monitor global ageing by means of a sample of carefully selected countries.

1. Introduction

All conceptual health population models date back to the 1970s or 1980s or even earlier, namely demographic change (Notestein, 1945), epidemiological change (Omran, 1971), and rectangularization of the survival curve and reduction in morbidity (Fries, 1980). In fact, these models shared the same framework:

(a) previously, mortality and fecundity were high, deaths were mainly due to infectious diseases or accidental trauma, and the population was young;
(b) subsequently, mortality and fecundity were lower but stable, and death was due to degenerative or age-related causes. The population was old but life expectancy was

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supposed to be limited to 85 years with a small dispersion of individual life spans around this mean value. This limited life expectancy associated with the control of the morbidity risk factors, would explain a rectangular survival curve for the whole population with reduced morbidity (Fries, 1980).

In this framework, the probabilities of survival above the age of 90 were low and little attention was given to changes in age structure or to changes in functional health status. In a recent systematic review of disability trends during the 1980s and 1990s, Freedman and colleagues showed that older North Americans suffered a decline in physical functional abilities (difficulties lifting and carrying a bag of roughly 10lb, climbing stairs and walking a quarter of a mile) and observed conflicting evidence of an increase in basic 'activities of daily living' disability ('ADL': bathing, mobility, toileting, dressing, transfers from bed to chair, feeding) (Freedman, Aykan and Martin, 2002). At the same time, Robine and colleagues collected evidence that ADL disability is clearly worsening among the older people in Europe (Robine, Romieu and Michel, 2002), especially in the U.K., where the decline in the inability to carry out activities of daily living was substantial over the period from 1976 to 1994 (Grundy, 1997).

These apparently contradictory trends in functioning and disability, which gave rise to numerous interesting health theories (Notestein, 1945; Omran, 1971; Strehler, 1975; Gruenberg, 1977; Fries, 1980; Manton, 1982), demand a new and wider conceptual approach which will be first justified and then developed in the present paper.

2. Basis of the classical theories of population ageing

2.1 Increase in life expectancy

It can no longer be doubted that the ongoing increase in life expectancy at birth in low mortality countries (Oeppen and Vaupel, 2002; White, 2002) is due to the decrease in mortality at more advanced ages (Vaupel, Carey and Christensen, 1998), even if the exact causes of this fall in mortality among the oldest are not yet clear. In Switzerland for instance:

- At the beginning of the 1970s, life expectancy at birth was 70.1 years for males and 76.2 years for females; 5.1 per cent of males and 11.3 per cent of females survived to age 90 in the mortality conditions of 1968-1973.
- Twenty years later, in 1990, life expectancy at birth was 74.0 years for males and 80.8 years for females; 10.1 per cent of males and 25.1 per cent of females survived to age 90 in the mortality conditions of 1988-1993.
- In 2001, life expectancy at birth was 77.2 years for males and 82.8 for females (Heiniger and Wanders, 2002).

In Japan, in 2001, life expectancy at birth reached 78.1 years for males and 84.9 years for females: 18.2 per cent of males and 40.1 per cent of females survived to age 90 in the mortality conditions of 2001 (Ministry of Health and Welfare, 2001).

When it was realized in the 1980s that mortality was falling at more advanced ages, the initial explanation was linked to the medical care or medical progress that enabled people to live longer. Today, both the probability of becoming a centenarian and the future consequences in terms of health status of this likely population remain unknown.

2.2 Healthy active life expectancy (HALE) measurements

As early as 1984, the World Health Organization (WHO) proposed a general model of health transitions making it possible to evaluate the consequences of the increase in survival on health status. This model, which consisted of extending the notion of life expectancy to morbidity and disability, made it possible to calculate not only life expectancy but also disease-free life expectancy and disability-free life expectancy (WHO, 1984).

Then the setting up of chronological series on the prevalence of chronic diseases and disability in the population and the calculation of "healthy active life expectancies" enabled the consequences of the fall in mortality among the oldest old to be monitored. These chronological series helped the WHO experts to identify three different possible scenarios geographically:

- "a pandemic of chronic diseases and disabilities", corresponding to the pessimistic theories of Gruenberg (1980) and Kramer (1980); for example, Fuchs (1984) wondered whether people escaped death from heart disease only to live with poor health;
- "a rectangularization of the survival curve", followed by a reduction in morbidity and disability at the last ages of life, corresponding to the optimistic theory of Fries (1980), the disease-free and disability-free curves coming nearer to the total survival curve;
- "a dynamic equilibrium", proposed by K.G. Manton (1982) who contrasted the fears of Gruenberg and Kramer with the optimism of Fries and proposed an alternative scenario in which the increased prevalence of chronic diseases was counterbalanced by a decrease in the severity of the same diseases.

These three theories have to be completed by two other possible scenarios:

- "a lengthening of the biological life duration", corresponding to Strehler's theories (1975), with a parallel shift of the three curves to the right, illustrating a profound change in biological ageing; and
- the case of relative independence in the evolution of the three curves, the interventions being liable, for example, to postpone the onset of diseases or reduce their disabling consequences.

In this context a few years later, an International Network on Health Expectancy and the Disability Process (http://www.prw.le.ac.uk/reves/) (in French REVES, Réseau d'Espérance de Vie en Santé) was created to facilitate international collaboration in calculating health expectancy (Robine, Romieu and Michel, 2002). Today, calculations have been done for more than 50 countries and time series are available in almost all low mortality countries, in Europe (Perenboom, Van Oyen and Mutafova, 2002), North America (Lamb, 2002), Asia (Saito, Qiao and Jitapunkul, 2002) and Australia as well as New Zealand (Davis, Mathers and Graham, 2002). These calculations cover a 40-year period, from 1958 to 1998, and can be used to compare changes in life expectancy, disease-free life expectancy and disability-free life expectancy (all levels of disability combined) and "severe" disability-free life expectancy. Together these multiple, repeated and harmonized calculations showed:

(a) there had been a universal and regular increase in life expectancy at age 65 in the low mortality countries since 1970;
(b) the same was not true for disability-free life expectancy which appeared to be stagnating; the gains in life expectancy were years with disability (whatever the disability level);

(c) on the other hand "severe" disability-free life expectancy paralleled the increase in life expectancy in all the countries in which data were available, namely, Australia,[1] Canada, France, Japan, the U.K. and the U.S. This probably meant that if the years gained in life expectancy were years of life with disability, they were not with severe disability (Robine, Romieu and Cambois, 1999).

2.3 Conflicting trends in disability and functioning

Many time series studies, performed during the last two decades, on the prevalence of various health conditions showed either convergent or contradictory results.

Prevalence of chronic diseases

A clear increase in the prevalence of chronic diseases was noticed in low mortality countries such as England (Kelly and Baker, 2000) or Finland (Aromaa, Koskinen and Huttunen, 1999). Probably this result was linked to change in social, political and economic factors and also in societal attitudes, earlier diagnosis and better behaviours and treatments of chronic conditions.

Moreover, it is now well established that morbidity and functioning have to be clearly distinguished. The main consequent problem is to use reliable and consensual tools to measure the various degrees of disability and to interpret their changes over time correctly (Robine and Michel, 2004 and comments). As this is not yet the case, it is necessary to present the recorded/published data, specifying each of the measurements carried out and the exact period of the survey.

Functional limitations

A significant decrease was noted in:

- the U.S. (difficulties lifting and carrying a bag of roughly 10lb, climbing stairs and walking a quarter of a mile) in the 1980s and 1990s suggesting an improvement in physical vigour (Freedman and Martin, 1998, 1999, 2000);
- France for the items "climbing stairs and walking 500-1000 meters", within the 1988-1998 period and for the 75-84 years age group (Peres and Barberger-Gateau, 2001).

At the opposite extreme, an increase in specific functional limitations was significant in:

- Australia for "loss of sight, loss of hearing, incomplete use of arms or fingers, incomplete use of feet and legs, need for help or supervision because of a mental illness or condition" during the period 1981-1998 (Davis, Mathers and Graham, 2002);
- Great Britain for several functions limitations between the 1985 and the 1996/97 surveys (Grundy, Ahlburg and Ali, 1999);
- New Zealand for "problems climbing stairs" during the period 1981-1992 (Davis, Mathers and Graham, 2002);
- Quebec, Canada for "seeing, hearing and walking difficulties" during the period 1986-1998 (Saucier and Lafontaine, 2001);

[1] For the most recent period 1993-1998 "severe" disability-free life expectancy decreases in Australia.

- Taiwan for "climbing and walking difficulties" during the period 1993-1999 (Zimmer, Martin and Chang, 2002).

Finally, no change in physical functional limitations was found in:

- the Netherlands for the 55-84 age group during the period 1992-1998 (Portrait and Alessie, 2002);
- the U.S. for "blindness or hearing impairments" among older people between 1984 and 1995 (Desai, Pratt and Lentzner, 2001).

Mild disability and IADL difficulties

A significant decline in mild disability in older people was actually noticed in only two countries:

- France, when measuring "being hampered in daily life" during the period 1981-1991 (Robine and Mormiche, 1994) (see Figure 1) or when measuring the ADL and IADL restrictions among people aged 75-84, during the 1988-1998 period (Peres and Barbenger-Gateau, 2001);
- the U.S. when estimating the IADL restrictions in the 65+ age group (Manton, Corder and Stallard, 1993, 1997; Freedman and Soldo, 1994; Waidmann, Bound and Schoenbaum, 1995; Crimmins, Saito and Reynolds, 1997; Waidmann and Liu, 2000; Manton and Gu, 2001; Liao, McGee and Cao, 2001).

In both countries trends towards more educated elderly cohorts could partially explain the decline in disability (Preston, 1992; Freedman and Martin, 1999) among other explanations (Cutler, 2001; Costa, 2002). These trends could also be explained by an

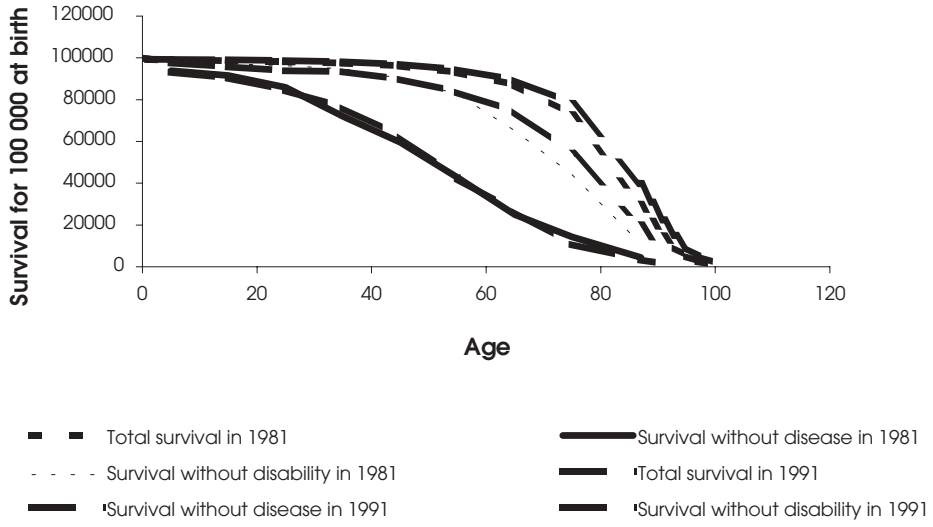

Figure 1: Total survival and survival without disease or disability, female, France, 1981 and 1991 (WHO model, 1984)

Source: Robine and Mormiche (1994).

improvement in cognitive functioning (Freedman, Aykan and Martin, 2001; Freedman, Martin and Schoeni, 2002). Furthermore, in both countries decline in institutional use was observed (Manton and Gu, 2001; Delbes and Gaymu, 2001). However, if a clear decline in use of institutions before the age of 90 years was observed in France, the rate of institutionalization among 90-year-olds and over has significantly increased since 1975 due to ageing of this open-ended age group (Delbes and Gaymu, 2001), and in the U.S. the proportion of people living in nursing homes and demonstrating a high level of disability was shown as lower in 1997 when compared to figures relating to the same in 1985 (Sahyoun, Pratt and Lentzner, 2001).

Finland probably offered a third example of clear decline in disability since the 1980s (Martelin, 2002).

But mild disability seemed increasing in all the other countries such as Australia, Canada and the U.K.

Severe disability /ADL difficulties

Severe disability, measured through ADL difficulties among older persons or the bedridden and housebound, appeared to decline in:

- the U.K. during the 1976-1994 period (Grundy, 1997),
- France for females during the 1988-1998 period (Peres and Barberger-Gateau, 2001),
- Finland, during the 1986-1994 period (Aromaa, Koskinen and Huttunen, 1999), and
- Switzerland, during the 1979-1994 period (Lalive d'Epinay, Bickel and Maystre, 2000),

to stagnate in:

- the U.S. for persons aged 70 and over, most of the decline in disability involving routine activity needs (IADL) but not personal care needs (ADL) (Waidmann, Bound and Schoenbaum, 1995; Schoeni, Freedman and Wallace, 2001; Liao, McGee and Cao, 2001), and
- the Netherlands (Portrait and Alessie, 2002),

and to increase in:

- Australia, where severe disability substantially increased during the period 1993-1998,
- and perhaps in Japan, where the inability to perform at least one ADL increased from 1992 to 1998 (Saito, 2001).

Perceived health

It is now acknowledged that perceived health can follow a trend other than disability (Crimmins, 1996; Spiers, Jagger and Clarke, 1996). Especially it was feared or expected that perceived health would deteriorate even if functional status improved. However, several recent studies showed an improvement in the perceived health of older people (Aromaa, Koskinen and Huttunen, 1999; Lalive d'Epinay, Bickel and Maystre, 2000). In Austria, for example, life expectancy in good perceived health at age 65 increased for females from 3.5 years in 1978 to 8.3 years in 1998 (Doblhammer and Kytir, 2001).[2]

The main problem linked to these contradictory results is not their explanation but the

[2] Based on the health ratings "very good" and "good".

need for a better understanding of their dynamic, in order to be able to anticipate the future needs of the ageing population at both a local and international level.

3. Towards a general theory of population ageing

J.-M. Robine was the first to ask whether a general theory would make it possible to reconcile the various theories on the evolution of health status – "pandemic of morbidity/disability", "dynamic equilibrium", and "morbidity/disability compression" – which would only be the different stages of a single transition (Robine, 1992). More recently, Zimmer *et al.* tried to reconcile American and Taiwanese results on physical functional limitations by asking again whether the expansion and reduction of morbidity scenarios would be both correct but corresponding to different stages of the same transition (Zimmer, Martin and Chang, 2002). A recent study in the U.S. showed through disability-free life expectancy calculations from 1970 to 1990, that reduction of morbidity began among those of higher educational status whereas those of lower status were still experiencing increasing morbidity (Crimmins and Saito, 2001) underlining again the need for a general theory of population ageing and disability transition.

In 2004, J.-M. Robine and J.-P. Michel proposed a new theory of the ageing population (Robine and Michel, 2004), which was widely discussed in the same journal by 13 well-known demographers, epidemiologists, gerontologists and geriatricians. Among them, J. Guralnick said that there may be a cyclical movement, where, first, sicker people survive into old age and disability rises, then the number of years lived with disability decreases as new cohorts of healthier people enter old age, but finally, the number of years lived with disability rises again when the average age of death goes so high that many people spent their last years at an advanced old age burdened by multiple chronic diseases and frailty (see Figure 2).

This trend would explain an increase in the survival rates of sick persons corresponding to a new expansion in morbidity. In the first phase of the epidemiological transition, described by A. Omran (Omran, 1971), modern economic developments resulted in a fall in infant mortality due to increased food availability, a decline in infectious diseases and improvement in hygiene. All this progress brought about a significant decrease in infant mortality (since great improvements in standards of living were not needed to obtain this infant mortality reduction). Then a greater number of new born carried out a "normal" life (Kannisto, 2001). In a second phase, modern economic developments contributed to a lengthening of the "normal" lifespan by reducing the mortality of older people. The fall of mortality among older people, which started shortly after World War II in the low mortality countries (Robine, 2001) often raises very disturbing and interesting questions. Generally it is explained by the considerable improvement in living conditions of old people after World War II, including the availability of health and medical services. When mortality in older people began to fall, under the impact of economic, medical and technical progress, it concerned initially a population in bad health in comparison with the current population of the same age today. The fall of mortality then increases the prevalence of chronic diseases and disability by at first increasing the survival rates of sick persons. From now on, sick persons have greater chances of survival. It is the scenario of morbidity expansion which may have occurred in the U.S. in the 1960s or 1970s (Gruenberg, 1977) and which perhaps is currently occurring in Taiwan (Zimmer, Martin and Chang, 2002).

Control of the progression of chronic diseases would explain a subtle equilibrium between the fall in mortality and the increase in disability. Gradually, medical progress could slow down the progression of chronic diseases involving a kind of equilibrium with

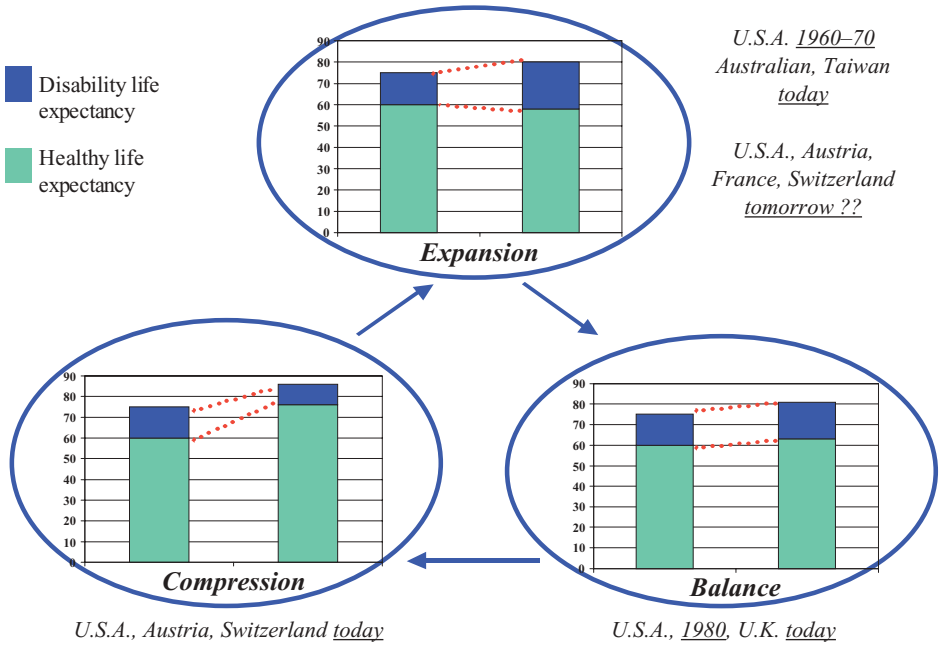

Figure 2: Synthesis of a new ageing theory population

Source: authors.

decline in mortality (Manton, 1982). It is the cardiovascular revolution (Meslé and Vallin, 2000) which could explain the turning points in disability trends that some scholars believe they have detected in the U.S. in the 1980s (Freedman and Soldo, 1994; Crimmins and Ingegneri, 1991).

An improvement in the health status and health behaviours of the new cohorts of old people would explain the compression of morbidity. Progressively with the arrival of new cohorts, the health of the elderly population improves. There are many arguments in favour of this: a better adult life, a better educational level (Preston, 1992) and better health practices (Cutler, 2001; Costa, 2002; Allaire, Lavalley and Evans, 1999). All that could lead to a phase of reduction in morbidity, a phase which is seen today in Austria, France and the U.S. (Freedman, Aykan and Martin, 2002; Crimmins and Ingegneri, 1991). However, progress continues, in particular in the buildings and services provided for the oldest old. The fall in mortality leads from now on to the emergence of extremely old populations like that of the super-centenarians and to the emergence of frail populations.

An emergence of the very old and frail populations would explain a new expansion in morbidity. Frailty is a biological syndrome of decreased physiological reserves and resistance to stressors causing vulnerability to adverse outcomes (Fried, Tangen and Walston, 2001). The exhaustion of reserves, seen as redundancy, can explain a mortality deceleration in later life (Gavrilov and Gavrilova, 2001, 2003). Frailty does not equal disability. A person with a disability can be robust and live in the community, independently or not, but without specific health and mortality risks, while frailty entails an increased risk of disability (Chin, Dekker and Feskens, 1999) and death (Cohen, Harris and Pieper, 2003;

Fried, Tangen and Walson, 2001). The concept of frailty is not new. What is new is the emergence of frail persons. Previously frail persons were dying too fast to constitute significant numbers (Gavrilov and Gavrilova, 2001, 2003). While there is still no operational definition of frailty, frailty appears in gerontology as a fourth dimension to individual health status. It is conceptually different from age, co-morbidity and disability even if it is statistically associated with these other three dimensions. Frailty is the loss of the ability to cope with daily stress, whatever the stress (social events, passage of seasons, minor diseases) and whatever the cause (loss of reserves or loss of the ability to mobilize and use them). At the extreme, frail persons cease to be able to resist environmental hazards (the 2003 West European summer heat wave, for example) or resist them extremely weakly (Gavrilov and Gavrilova, 2003).

However, the combination of the absence of clear life-threatening diseases and a protective environment (confinement within the family, the development of modern nursing homes and the provision of essential nursing services such as meals) explain firstly, the accumulation of frail persons among the oldest old and secondly, the mortality plateaus observed today at age 110 and over (Robine and Vaupel, 2002). The causes of death for the oldest old are poorly understood and their death certificates contain mainly imprecise causes of death (Michel, Pautex and Zekry, 2002). In this context, a general theory of population ageing should integrate the emergence of the very old and frail population.

These new phenomena bring us back to the starting point, i.e. to an increase in morbidity. Would this be the scenario currently seen in Australia (Davis, Mathers and Graham, 2002)?

4. Conclusion

Into this necessarily simplistic picture of population ageing, we have introduced four successive elements, which might constitute the basis of a new general theory of population ageing:

- an increase in the survival rates of sick persons which would explain the expansion in morbidity,
- a control of the progression of chronic diseases which would explain a subtle equilibrium between the fall in mortality and the increase in disability,
- an improvement in the health status and health behaviours of the new cohorts of old people which would explain the compression of morbidity, and eventually
- the emergence of very old and frail populations which would explain a new expansion in morbidity.

Obviously, all these elements co-exist today and future scenarios – expansion or compression of disability – will have to be validated by setting up (a) universal measurements of the functional decline which one can combine with mortality data through time and across the world, and (b) a periodic International Ageing Survey to monitor the global ageing through a sample of carefully selected countries.

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