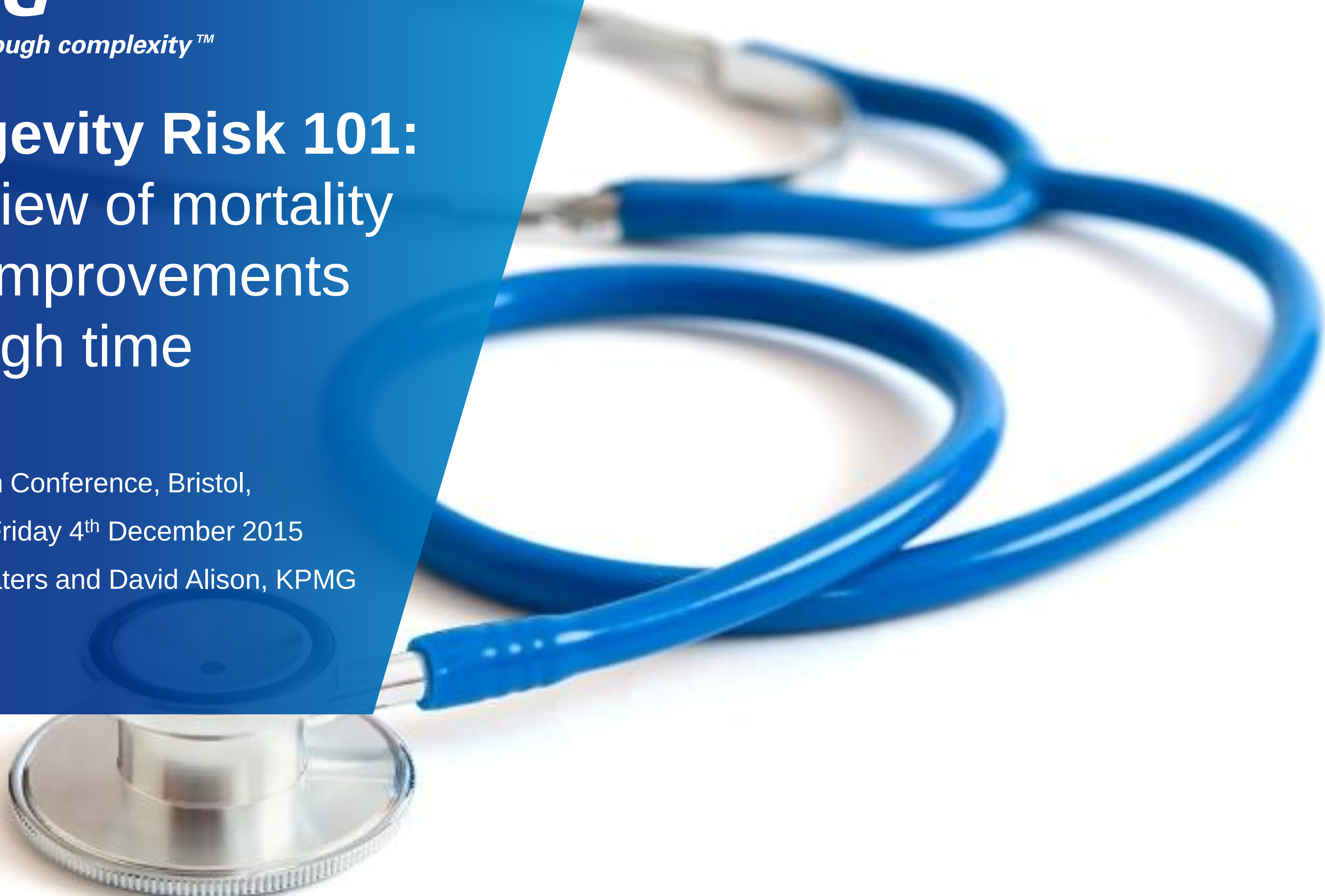
cutting through complexity™

Longevity Risk 101:
A review of mortality and improvements through time



Momentum Conference, Bristol,

11:30am, Friday 4th December 2015

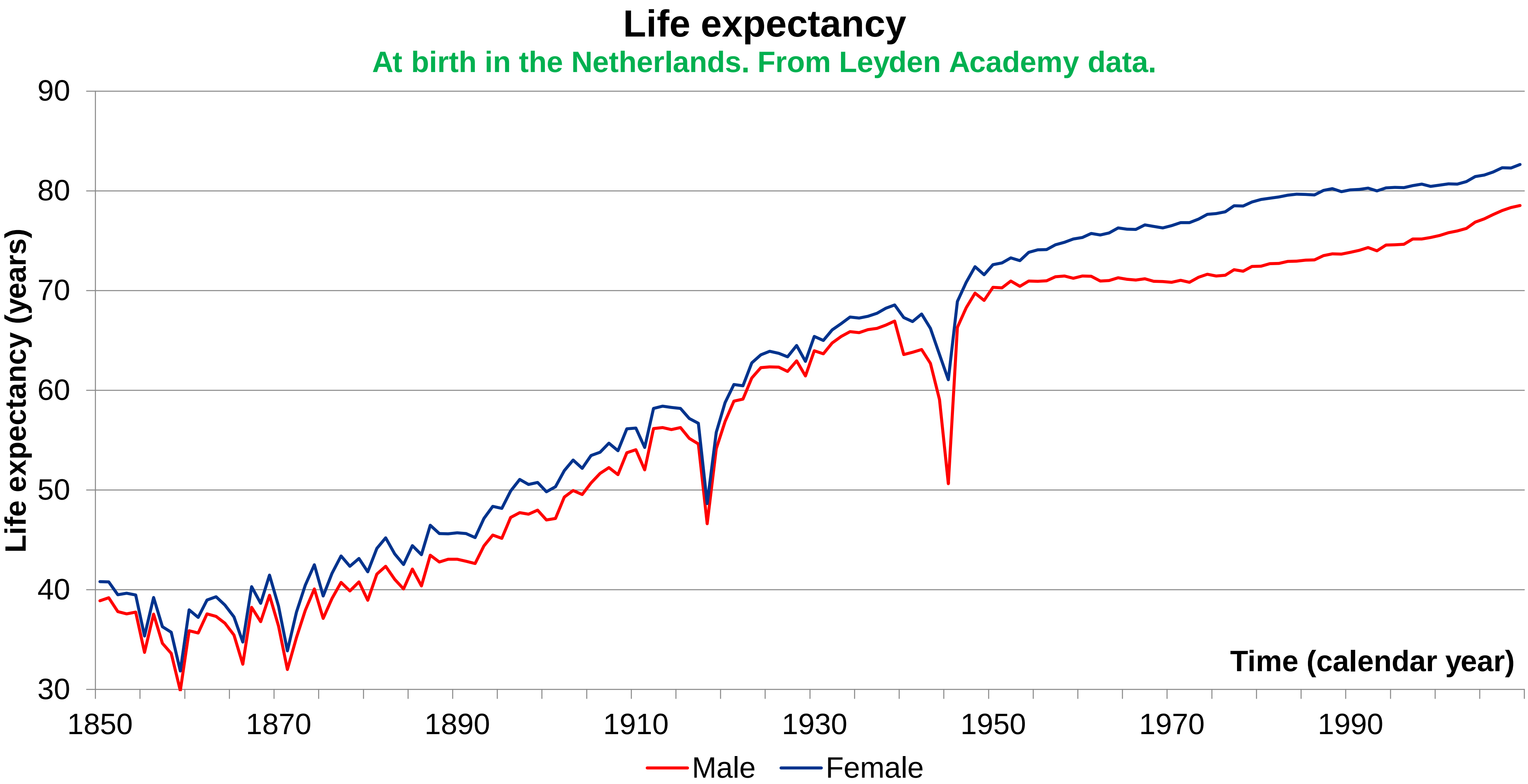
Joshua Waters and David Alison, KPMG

A review of mortality and improvements through time

1. Longevity experience around the world
2. Modelling longevity rates and improvements
3. The future of longevity
4. The regulatory view

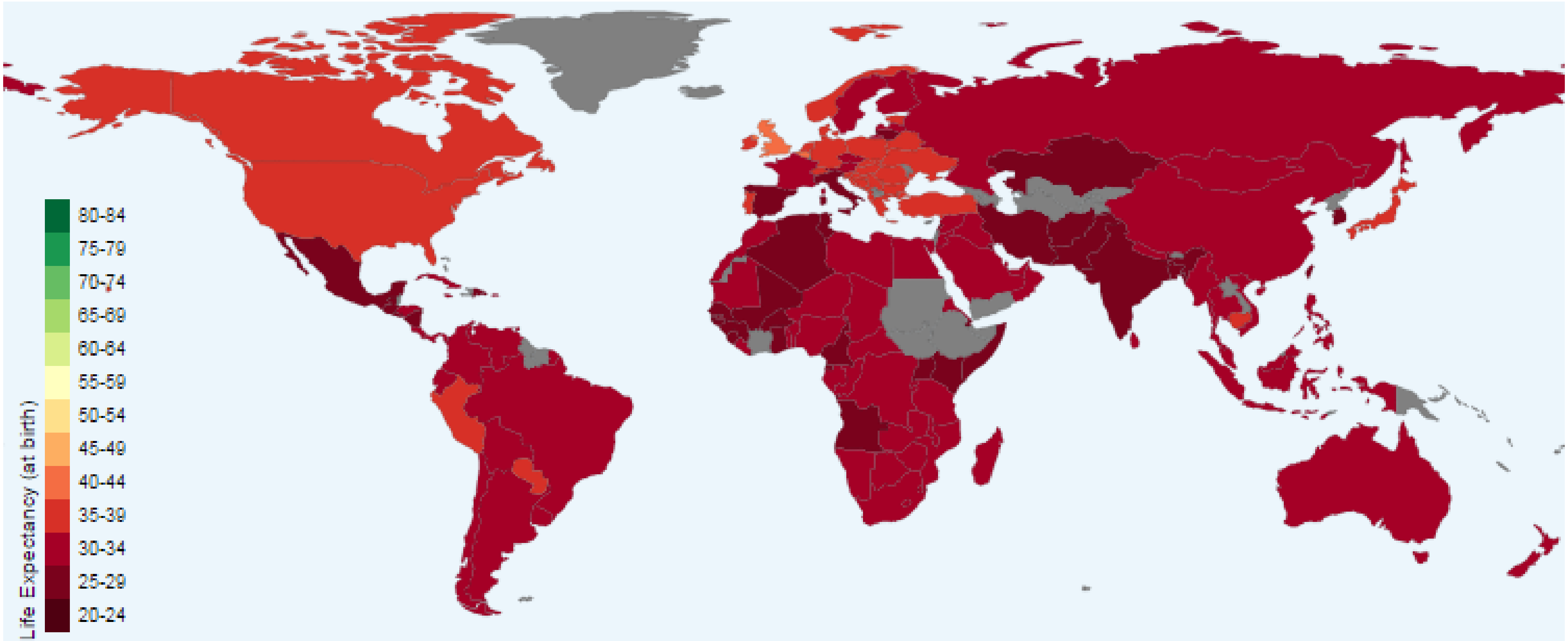
Longevity experience around the world

How has longevity changed over time?



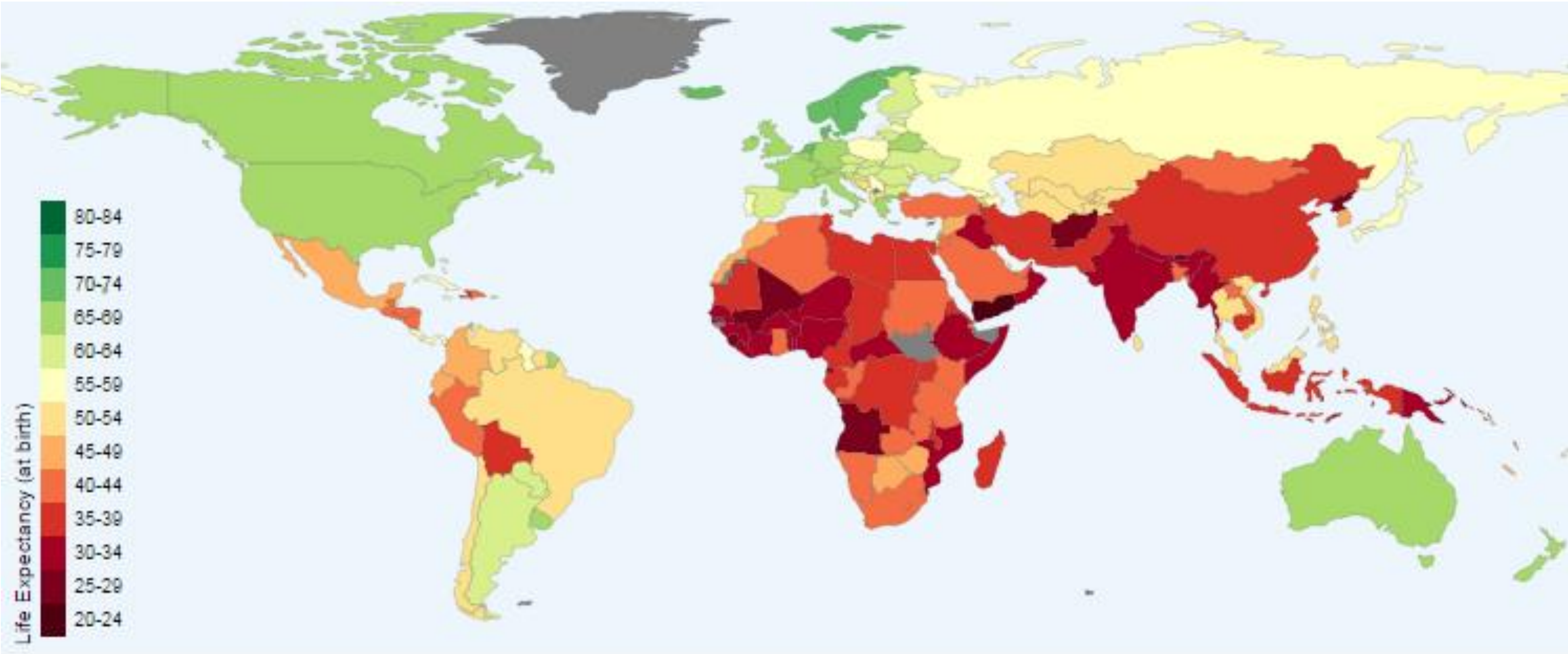
How has longevity changed around the world?

1800



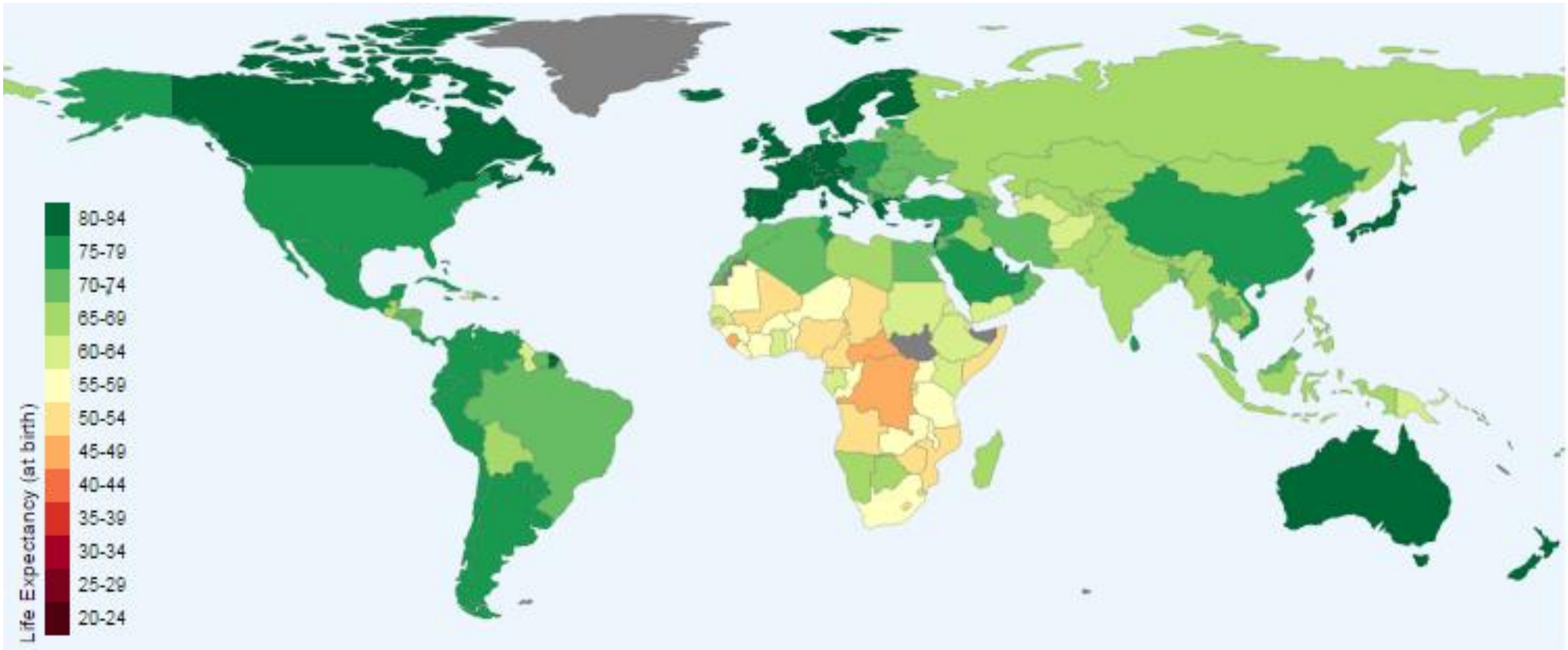
How has longevity changed around the world?

1950

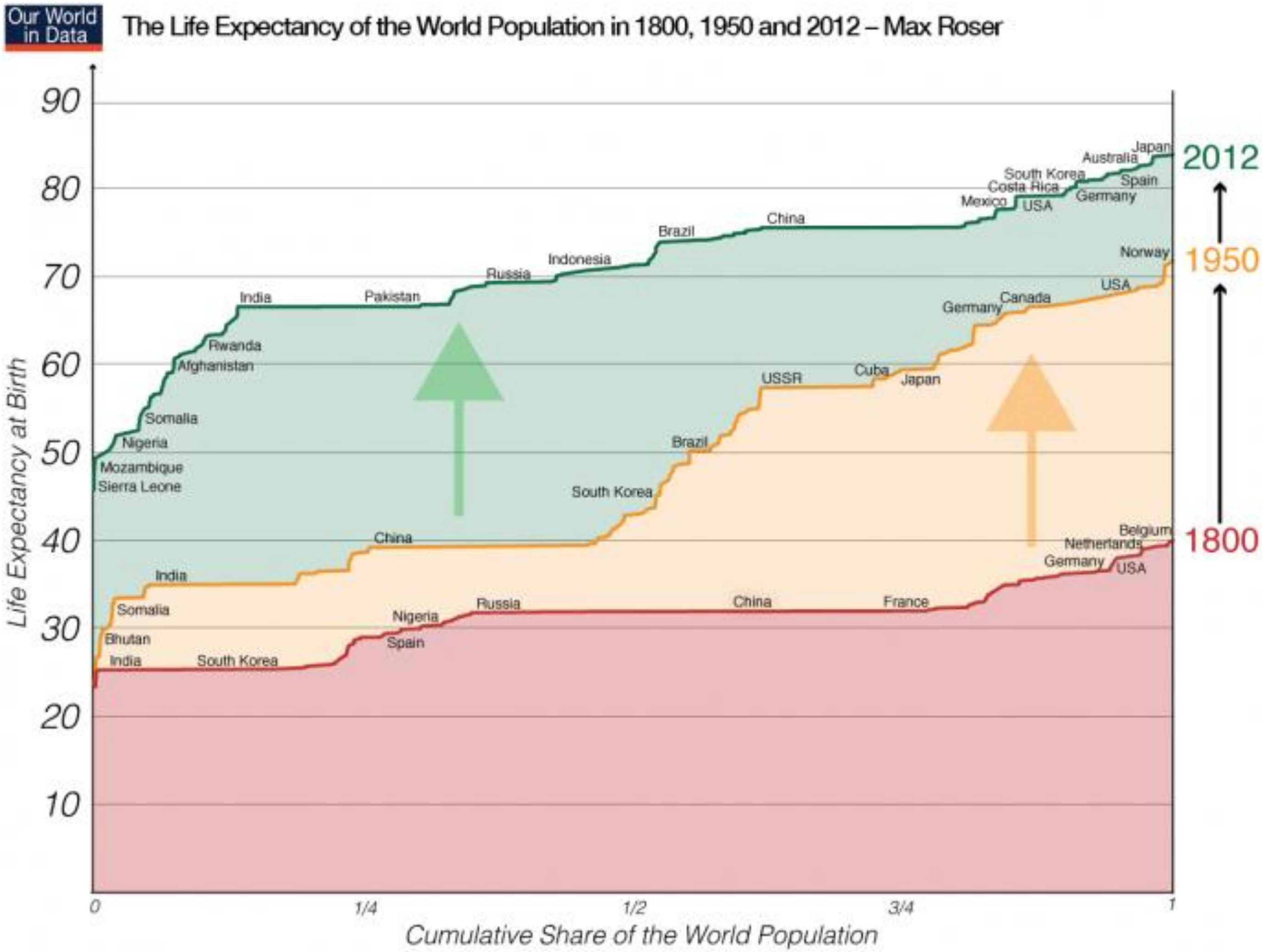


How has longevity changed around the world?

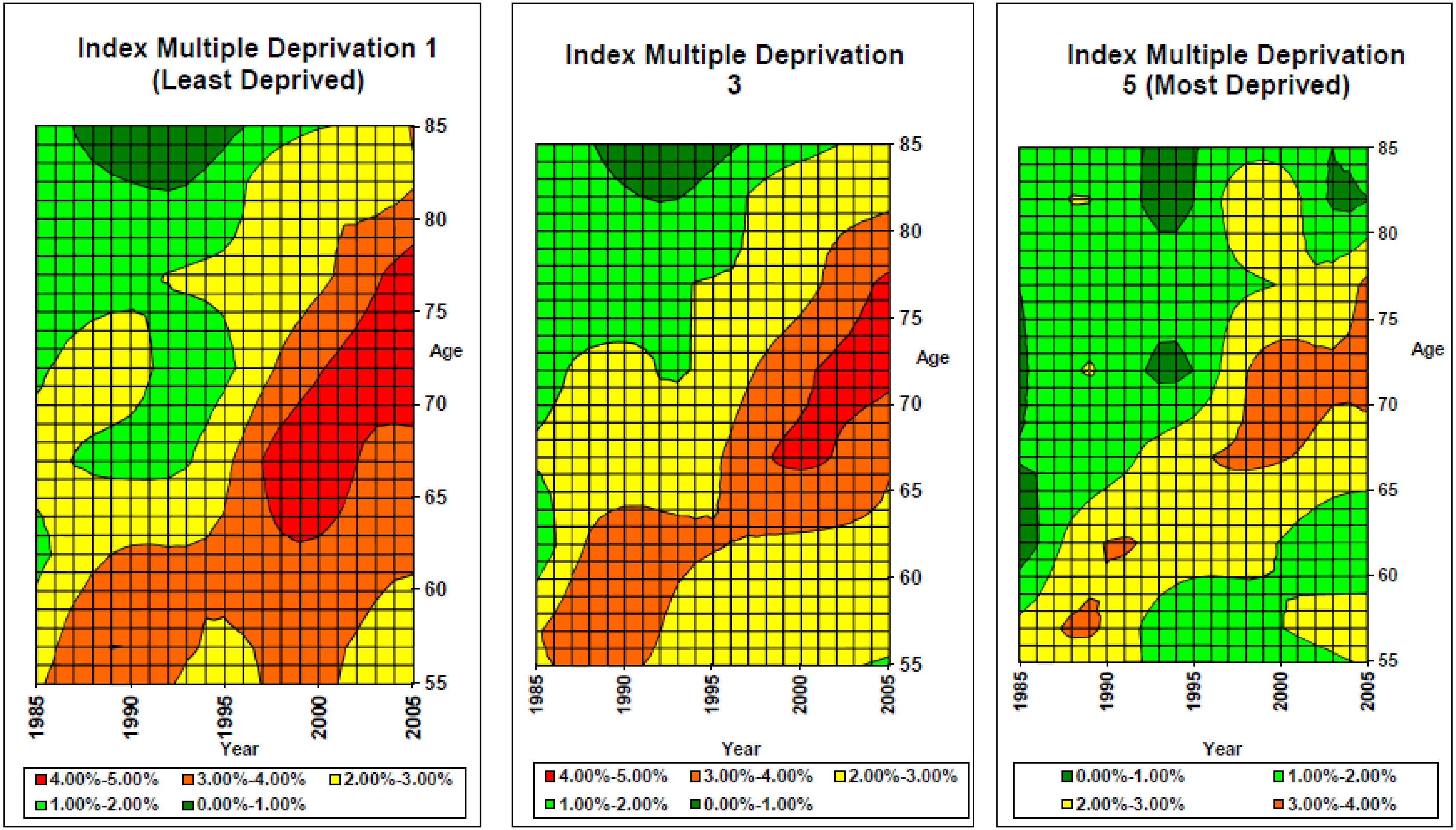
2011



How has longevity changed around the world?



How has longevity changed by age and income level?



Mortality improvement of people in IMD quintiles in England & Wales

Demographic changes affecting mortality

Environmental	Medical	Lifestyle
Access to clean drinking water	Vaccines	Smoking habits
Improved sanitation	Surgical anaesthetic	Drinking
National Health Service	Antibiotics	Physical exercise
Changes in pollution	Changes in heart surgery	Improvement to diets
Decrease in crime rate	Radiological imaging	
Improved efficiency in using natural resources	Organ transplants	
	Increased ability to identify symptoms	

Individual factors affecting mortality

1st tier factors

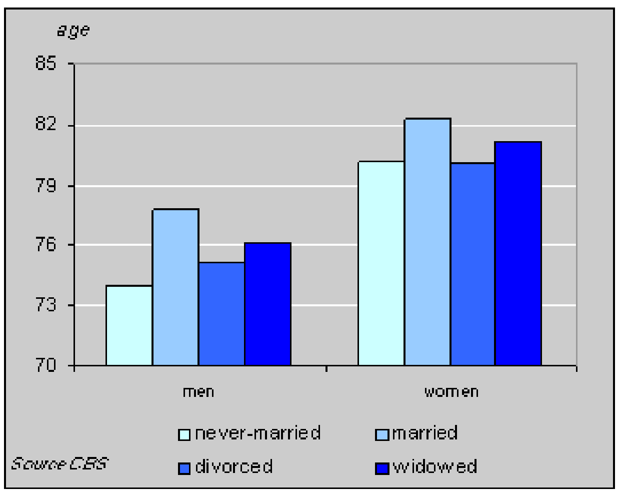
- Age
- Gender
- Medical condition
- Genetic factors

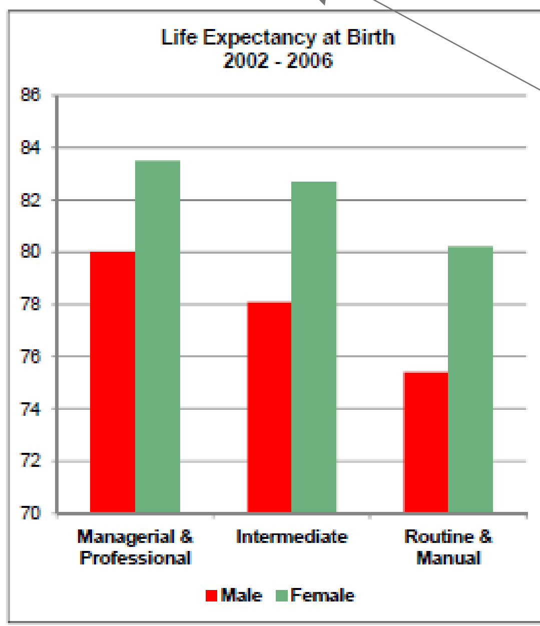
Socio-economic

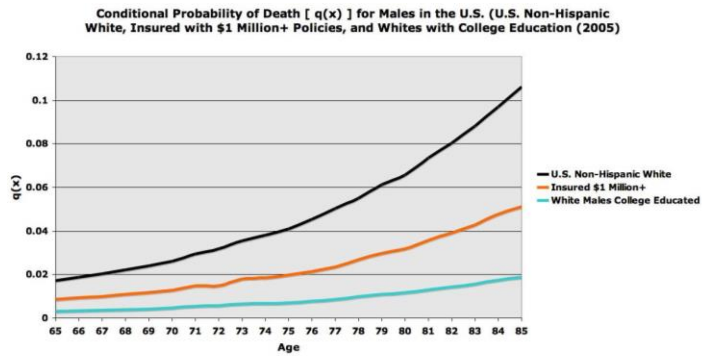
- Marital status
- Occupation
- Income
- Education

Lifestyle

- Smoking
- Drinking
- Physical exercise
- Diet







Modelling longevity rates and improvements

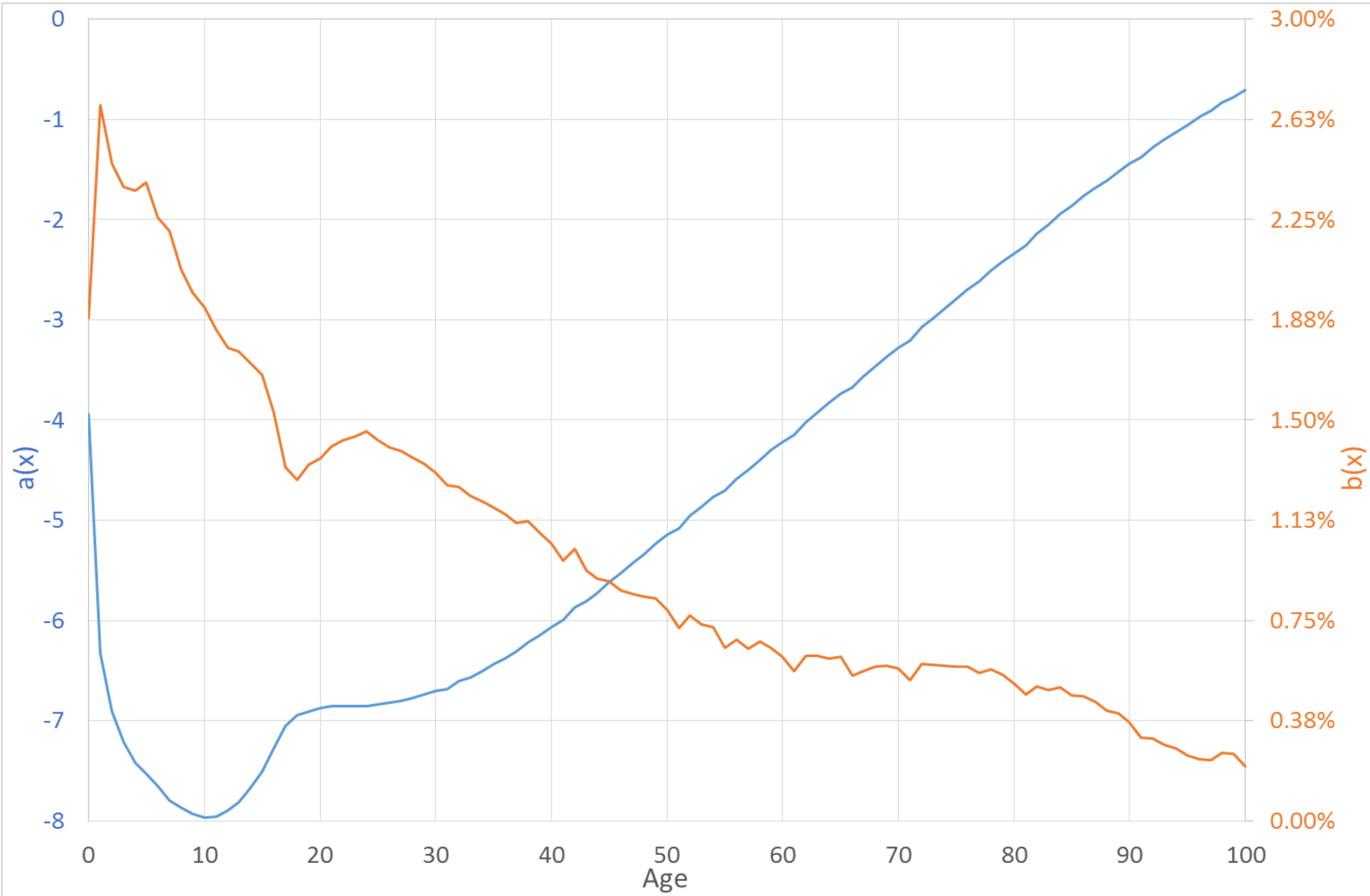
How can we model historic mortality improvements?

Too many dimensions for ages 60 to 100. Need a dimension reduction technique that fits the historic data. Then we can project forward.

	Lee Carter	**Cairns Blake Dowd**
Year	1992	2006
Focus	Whole lifetime	Retirement
Formula	$\log q_{x,t} = \alpha_x + \beta_x \kappa_t + error$	$\text{logit}\, q_{x,t} = A_t + (x - \bar{x}) B_t + error$

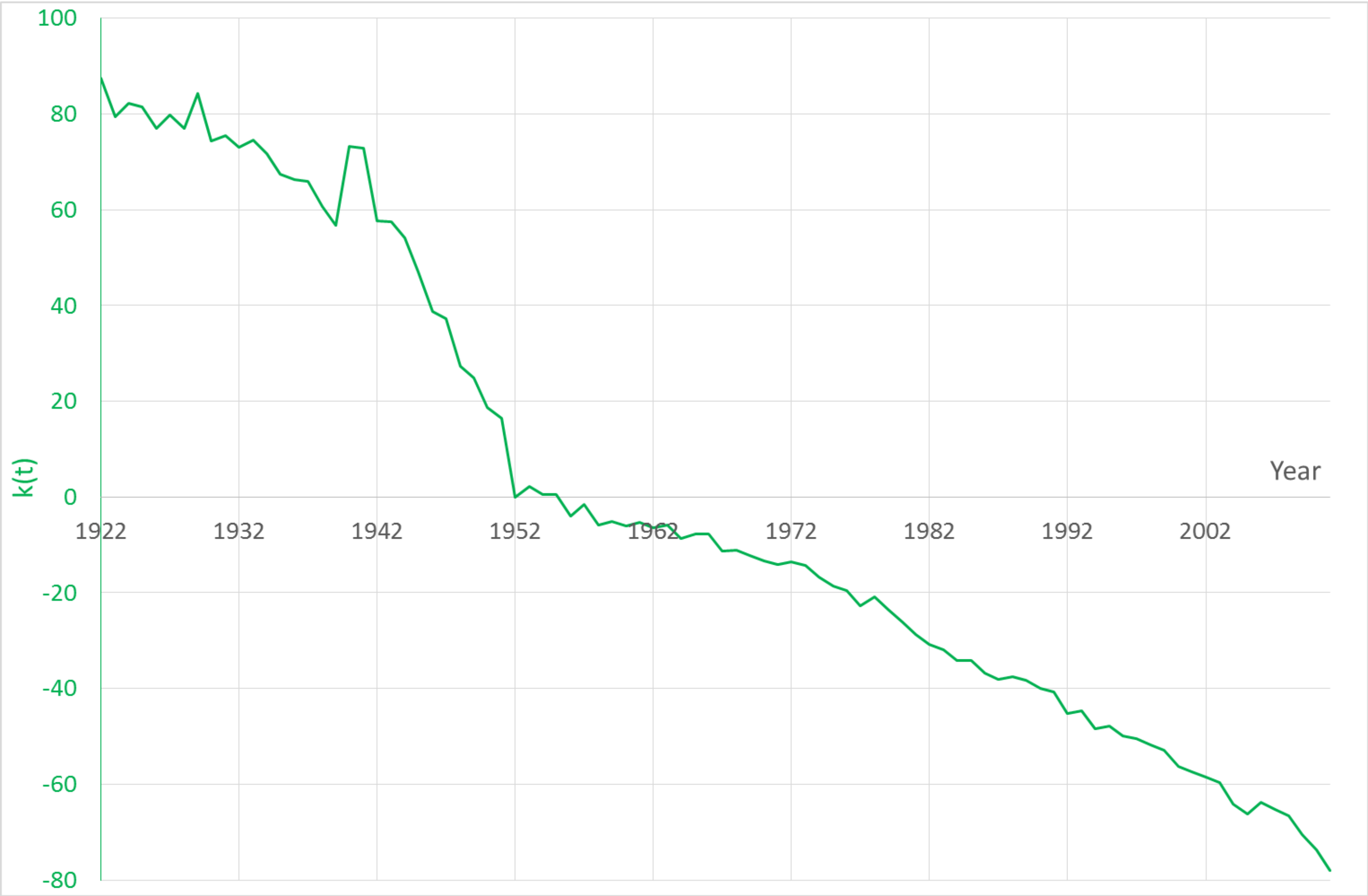
Lee Carter (1992)

$$\log q_{x,t} = \alpha_x + \beta_x \kappa_t + error$$



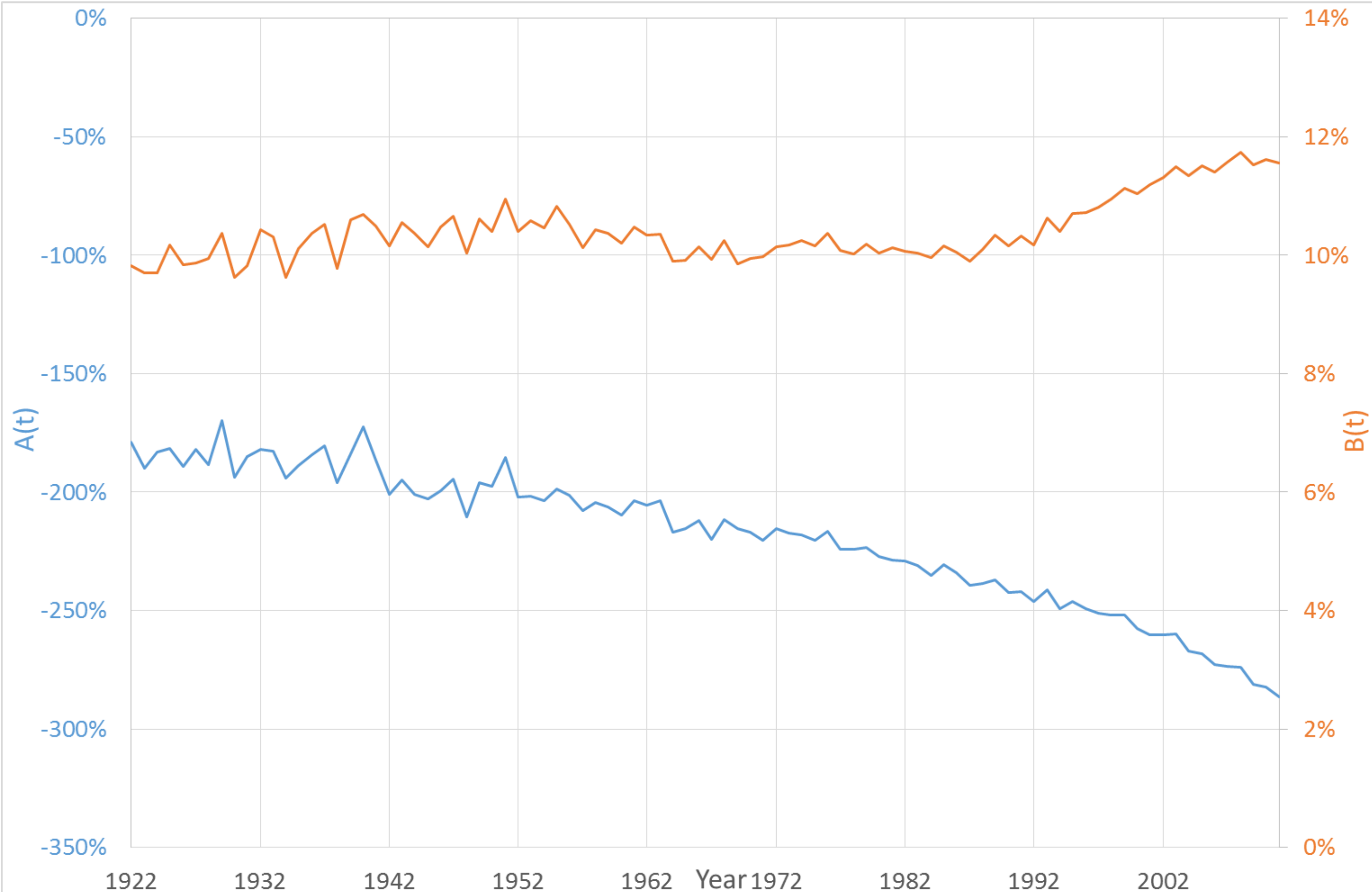
Lee Carter (1992)

$$\log q_{x,t} = \alpha_x + \beta_x \kappa_t + error$$



Cairns Blake Dowd (2006)

$$\text{logit}\, q_{x,t} = A_t + (x - \bar{x})B_t + error$$



How can we model historic mortality improvements?

Too many dimensions for ages 60 to 100. Need a dimension reduction technique that fits the historic data. Then we can project forward.

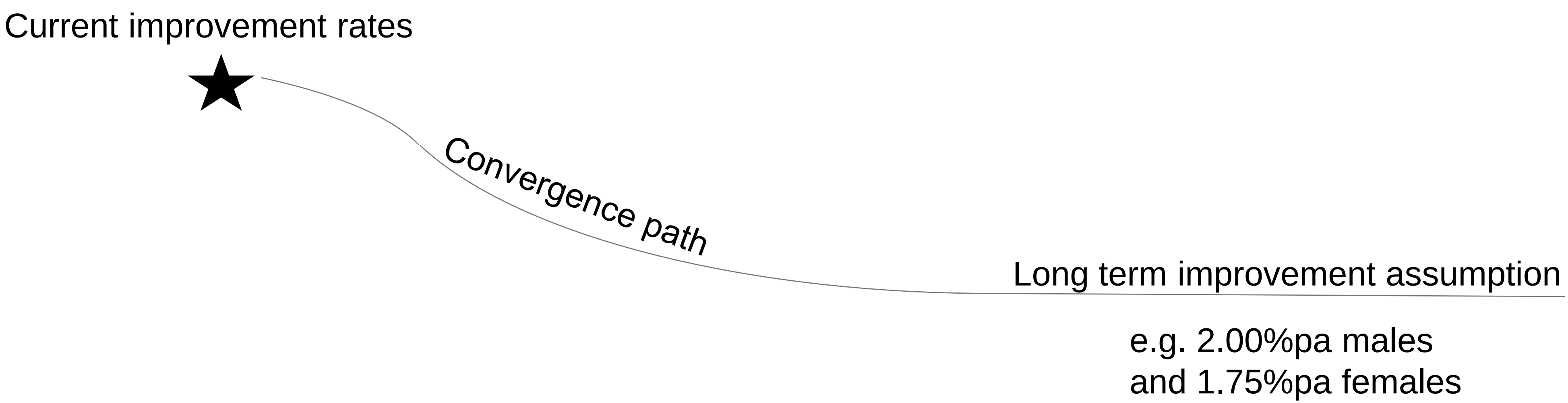
	Lee Carter	**Cairns Blake Dowd**
Year	1992	2006
Focus	Whole lifetime	Retirement
Additive term	Base mortality curve	Level of mortality through time
Time dependent term	Fully parameterised	Intuitive form
Parameters	≈ 300	≈ 200
Strengths	Captures infant mortality	Better fit in retirement
Weaknesses	Doesn’t tell you how to project forwards	
Transformation	Logarithm, $\log q$	$logit\ q \ := \log(q) - \log(1-q)$
Formula	$\log q_{x,t} = \alpha_x + \beta_x \kappa_t + error$	$\operatorname{logit} q_{x,t} = A_t + (x - \bar{x}) B_t + error$

How can we project forward future mortality improvements?

The past is no guide to the future. We need a way of informing expert judgement.

	CMI Model	Cause of Death	Cause of Improvements
Approach	Overall improvements	Split by disease e.g. cancer	Split by driver e.g. exercise

CMI Model


Current improvement rates
Convergence path
Long term improvement assumption
e.g. 2.00%pa males
and 1.75%pa females

Cause of Death Model

Reduce dimensions using Principal components analysis, Lee Carter model or age standardised mortality rates

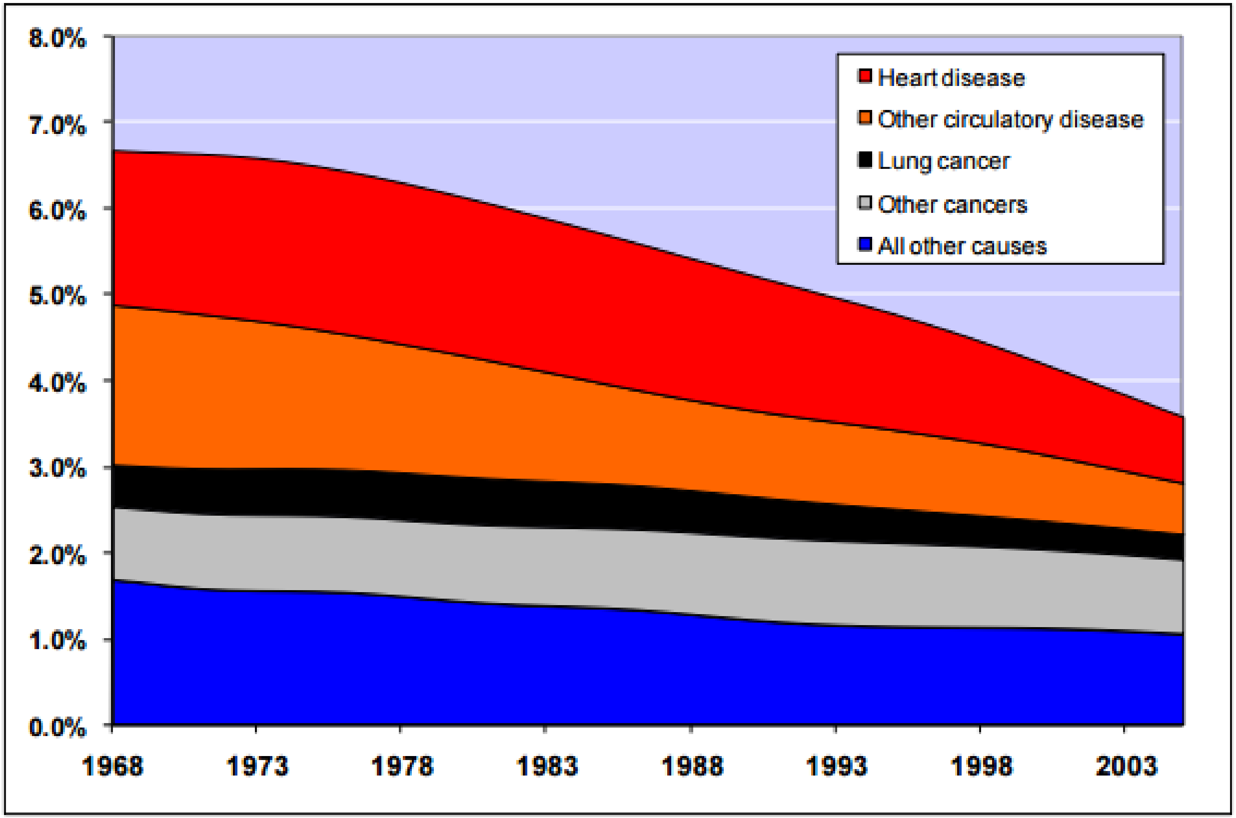
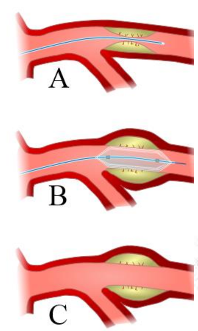
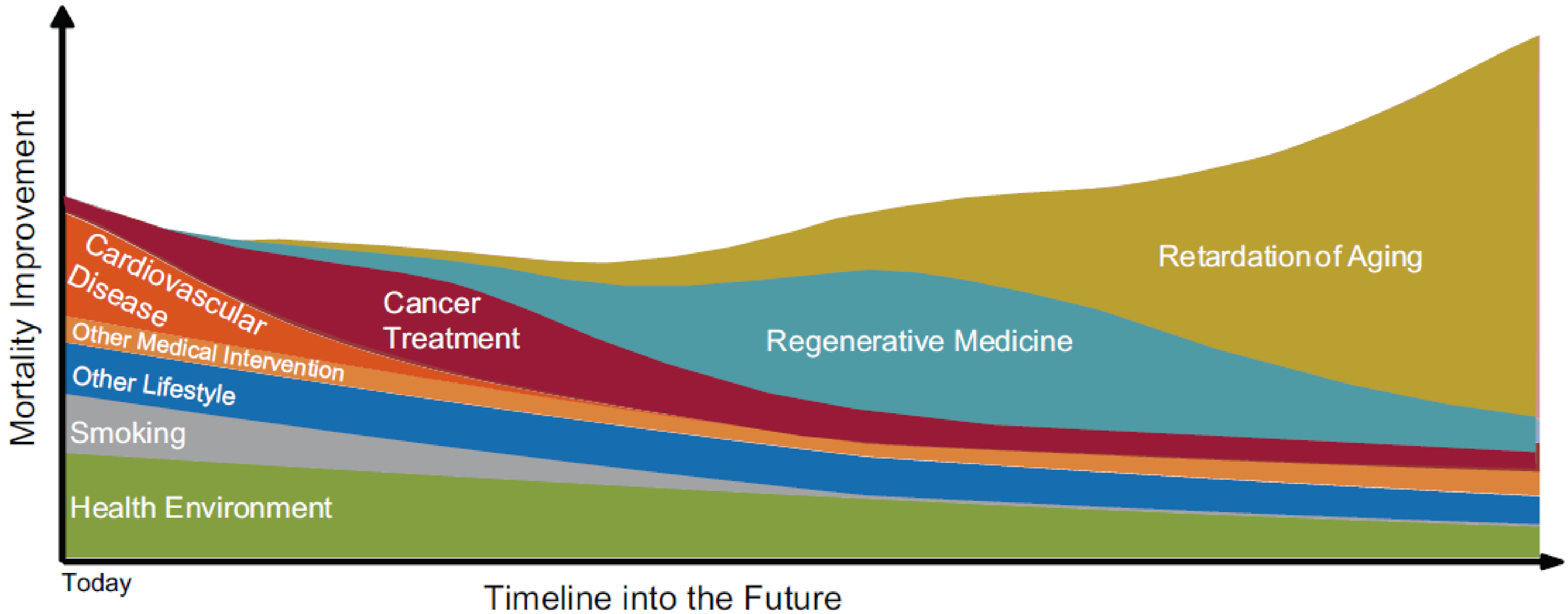


Figure A1: Age-standardised mortality rates for males in England & Wales aged 60-89, 1968-2005, by constituent cause

Cause of Improvements Model

	Children	Working age population	Retired population
Developing countries			
More developed countries			 

Cause of Improvements Model



Source: http://riskinc.com/Publications/Longevity_Risk_brochure.pdf

How can we project forward future mortality improvements?

The past is no guide to the future. We need a way of informing expert judgement.

	CMI Model	Cause of Death	Cause of Improvements
Approach	Overall improvements	Split by disease e.g. cancer	Split by driver e.g. exercise
Assumptions	• Long term improvements rate	• Future improvements in each cause	• Future path of drivers
	• Convergence path	• Interdependency between causes	• Impact of drivers on mortality
Strengths	Low data requirements Quicker to build	Easier to justify expert judgements	Allows for interdependency
Weaknesses	Difficult to validate expert judgements	Higher number of expert judgements	Difficult to validate expert judgements

How can we underwrite annuities?

Historical data

- Public, own data, reinsurer
- Curve fitting, generalised linear model

Underwriting

- Smoker status, postcode, BMI, medical conditions, education
- Medical exam, questionnaire

Important notes
Please describe as much information about your health as possible before signing this form. All questions asked are relevant, and by providing full and accurate information you will allow an insurer to provide as accurate a quotation as possible. The amount of your annuity income will be based on the medical information supplied. However an insurer may also seek to obtain independent verification of this information from your doctor. If it is subsequently found that the questions were not answered accurately and with reasonable care, then that could result in your income being reduced or your policy being cancelled.

Enhanced Pension Annuity Quotation Request Form

You/Dependant to complete sections 1+2
Financial Adviser to complete sections 3+4

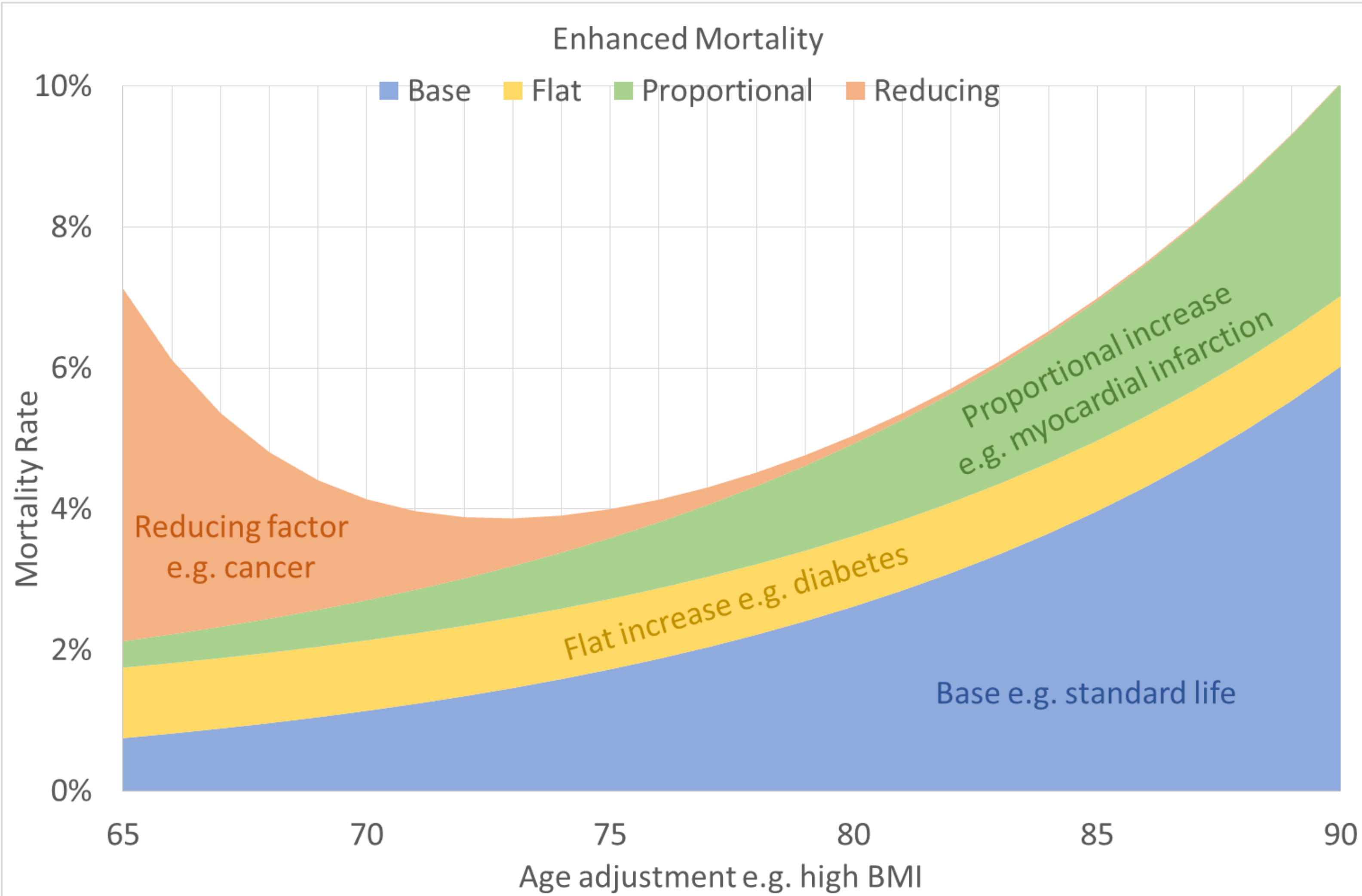
AVIVA · Canada Life · FriendsLife · justretirement · Legal & General · LV= · mgmadvantage · partnership · PRUDENTIAL

For more information visit www.commonquotation.co.uk
(this includes details on how to complete this Quotation Request Form).

Other considerations

- Anti-selection from enhanced annuities
- Seasonality effects

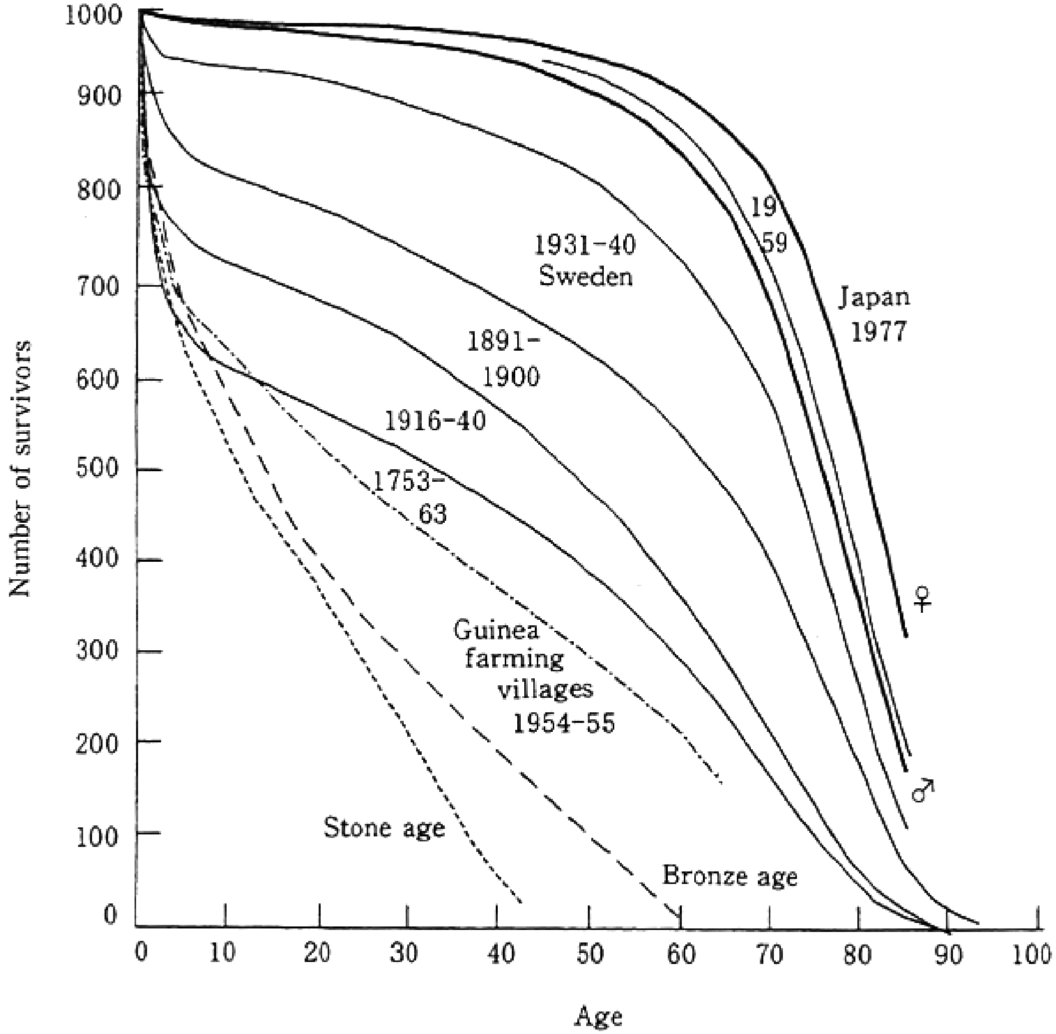
How can we model enhanced mortality?



The future of longevity

History of survival

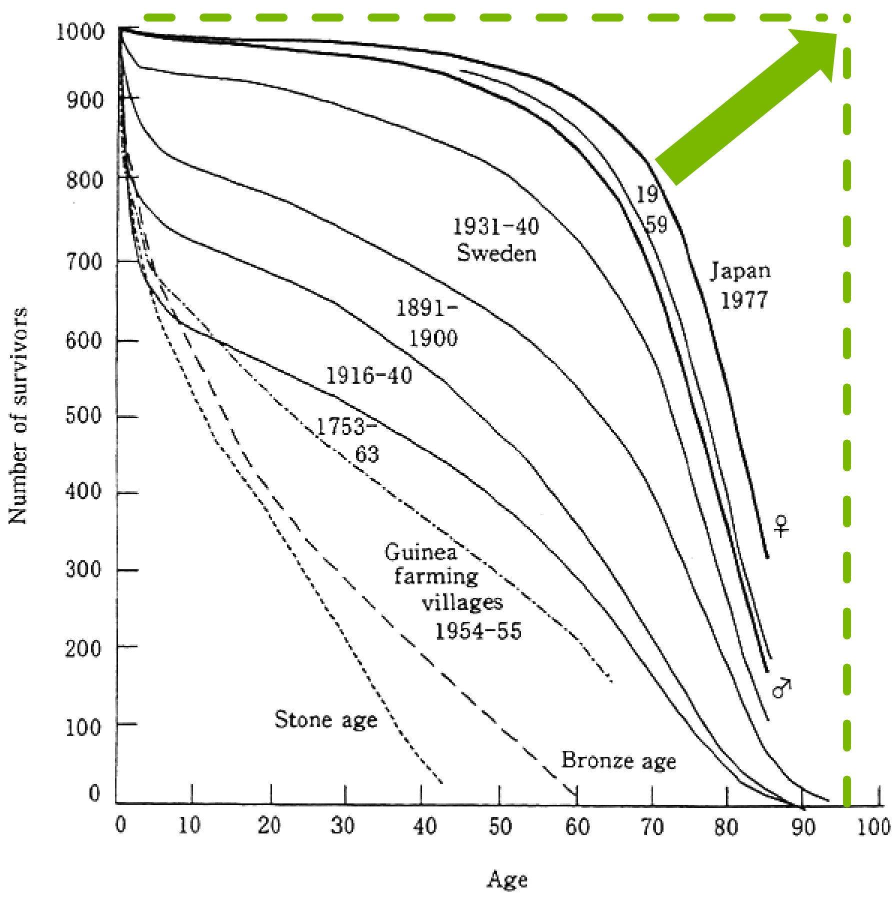
Survival Curve for Number of Survivors Per 1,000 Births

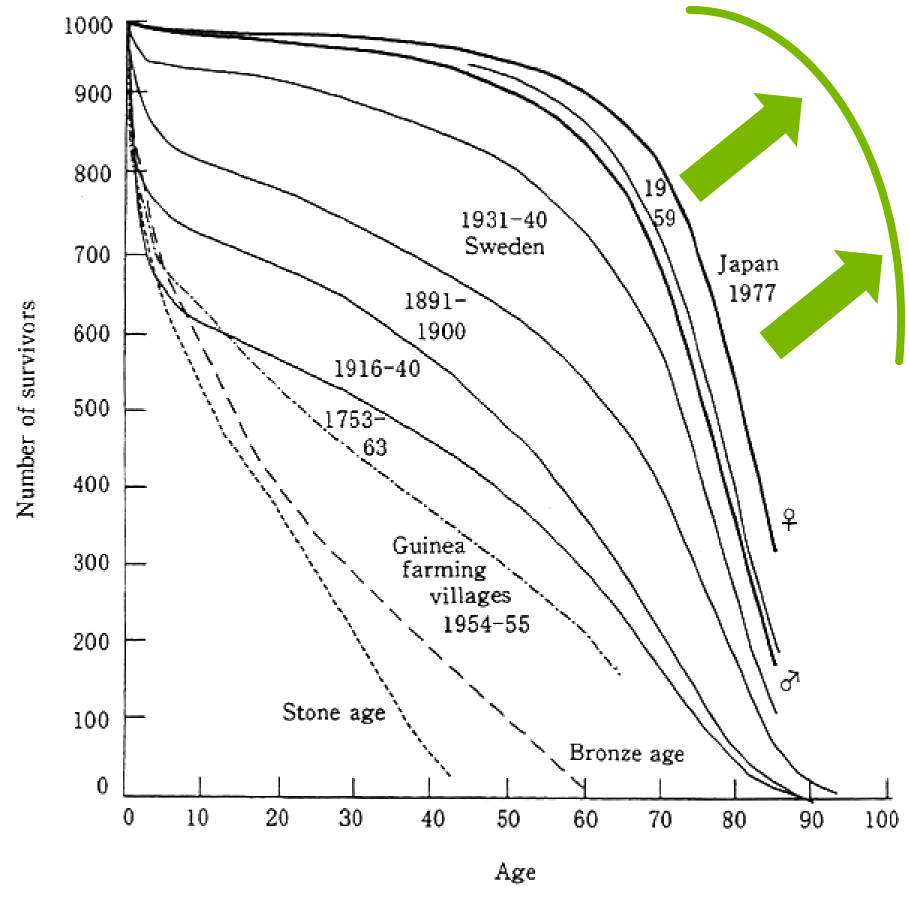


What next?

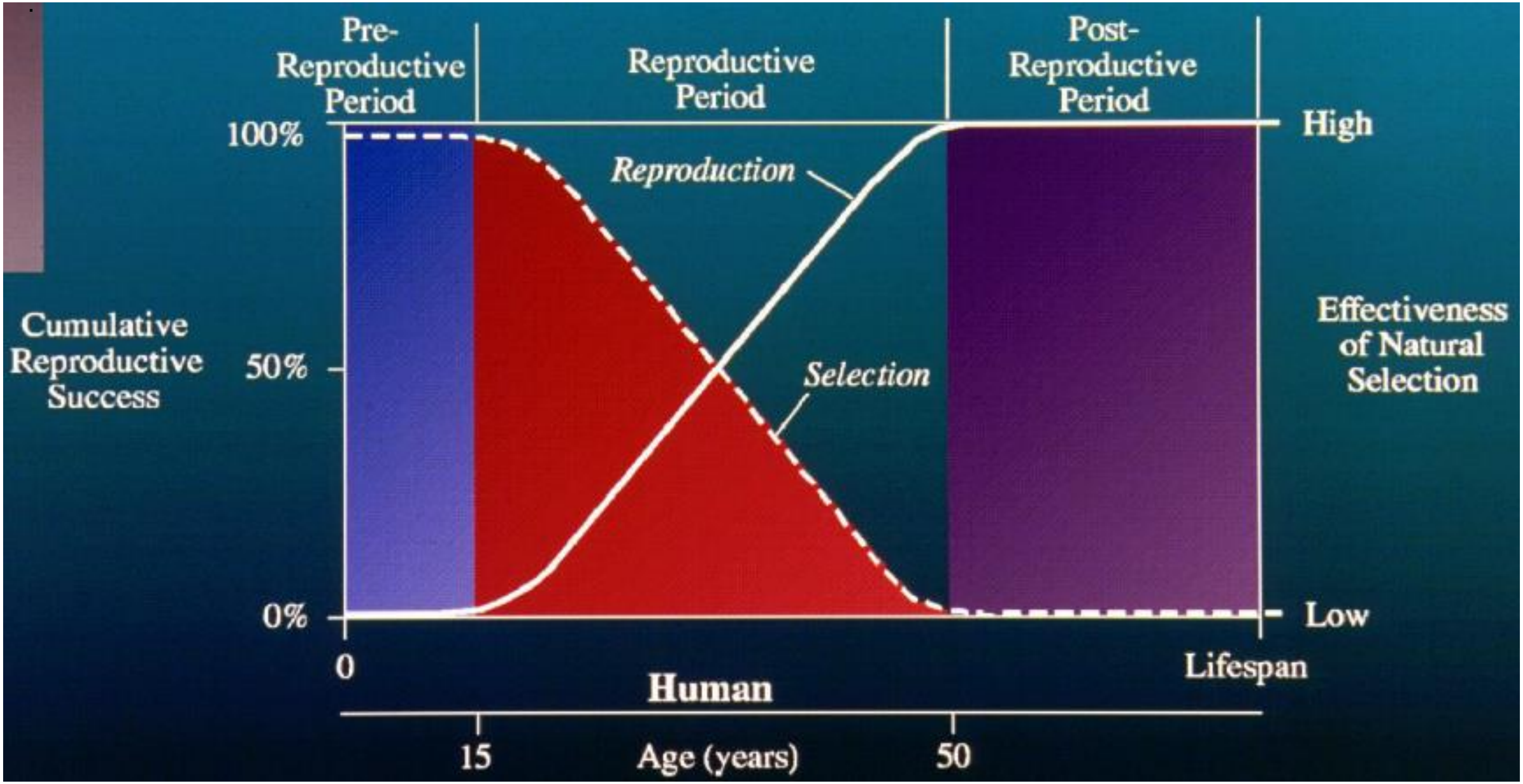
Source:
https://www.env.go.jp/en/wpaper/1995/eae240000000000.html

Rectangularisation or Methuselah?





Rectangularisation – Life expectancy is reaching a limit



Source: Theories of Longevity – Robert L. Brown, PhD

Rectangularisation – Life expectancy is reaching a limit

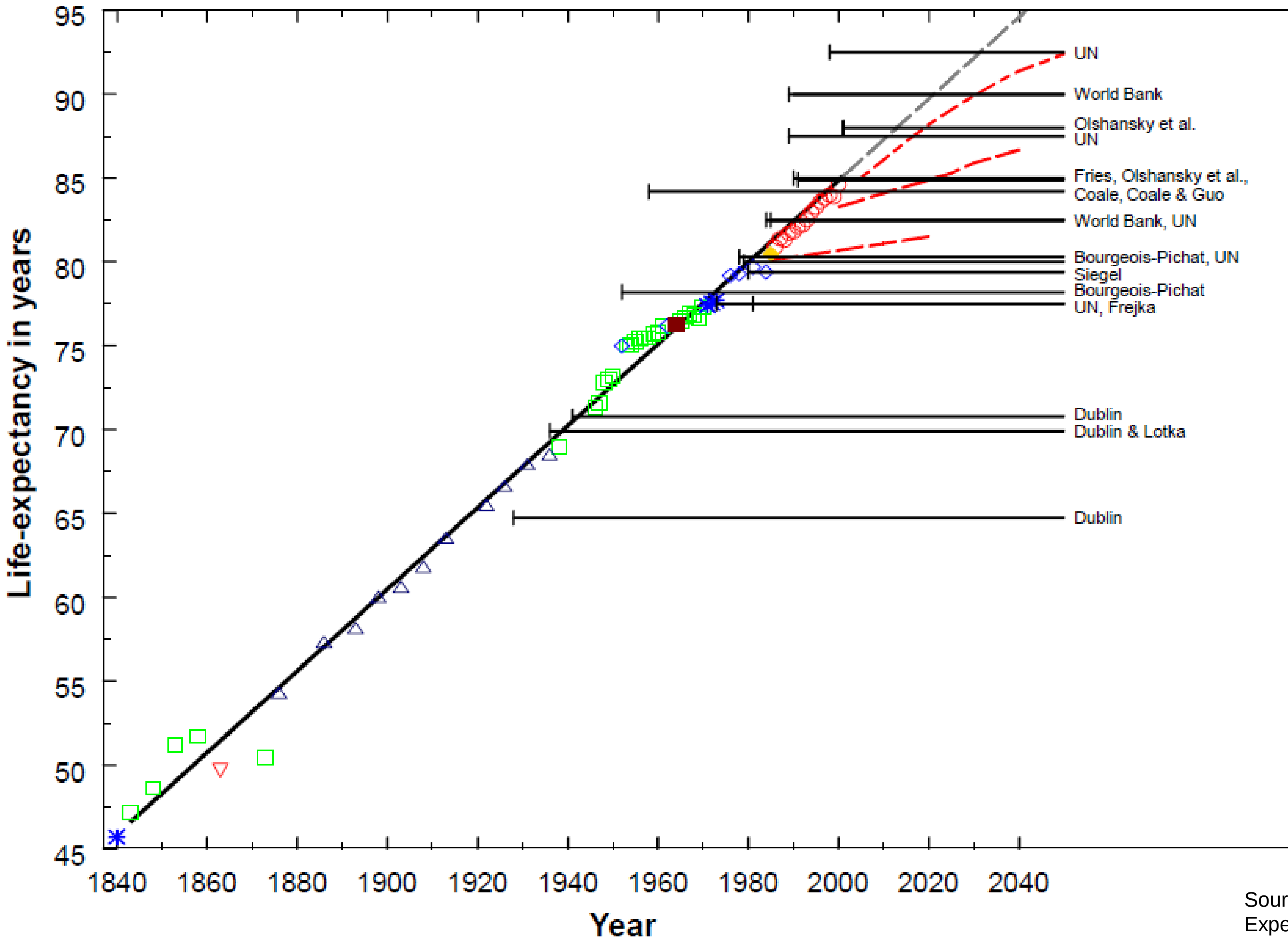
Improvements have focussed mainly on the heart

Largest progress in raising life expectancy relates to infants.

No strong evidence that max age is increasing

Current causes of death only impact so much

Methuselah – Life expectancy and maximum life span will continue to grow



Source: Broken Limits to Life Expectancy – Oeppen and Vaupel

Methuselah – Life expectancy and maximum life span will continue to grow

Even experts can be wrong

Natural selection can conquer senescence

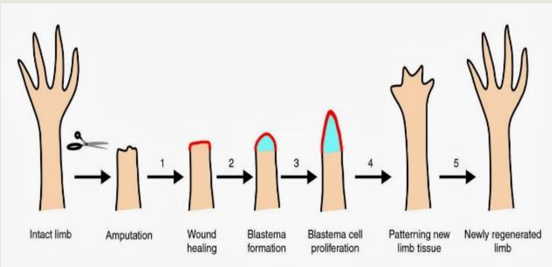
Studies reveal aging can be surprisingly elastic

Not just life span, but health can also be preserved

Genetic engineering, nano-technologies have all contributed to significant successes

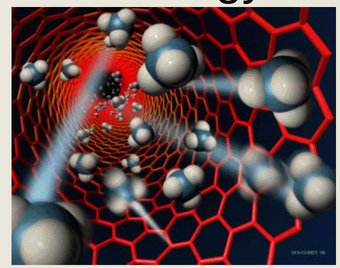
The Future Will Be Different from the Past

Advancements in Medical Technology

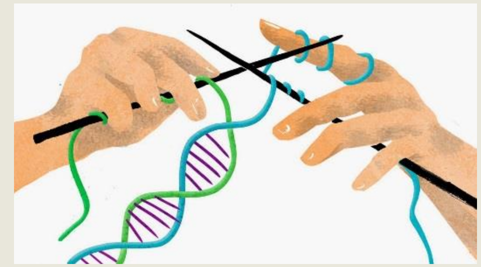


Regenerating and rejuvenating tissue

Slowing the rate of aging



Nanotechnologies



Replacing deleterious genes

Shifting focus from the past

 Country 

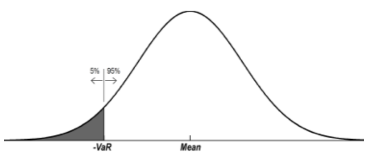
 Causes 

 Ages 

PRA treatment of mortality

Quantitative Indicators

The PRA has split longevity risk into two sub-risks: base mis-estimation risk and future improvement risk:



Base mis-estimation

Actual mortality experience differs from the best estimate mortality assumption

No QI as each firm's exposure is unique

Future improvement

Actual future improvements differ from best estimate future improvements assumption

Less heterogeneous and therefore the PRA have derived a QI for future improvement risk

How much could the best estimate future improvement assumption change over one-year?

Data Risk

Simulating an additional year of data and recalibrating the trend risk model accordingly.

Event Risk

The impact of new information emerging which is not captured by historical data. The PRA has equated this with changing a trend risk model

Comments from the PRA approach

1-year VaR

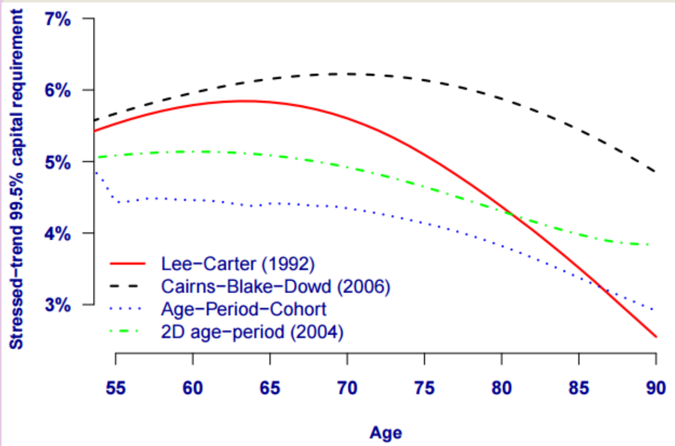
- PRA is focussed on a 1-year VaR
- Whereas a catastrophe can occur in an instant, longevity risk takes decades to unfold
- Mortality shocks are easy to spot. Longevity shocks much less so, since you can only detect a trend change several years after it has already started.
- Longevity risk not a natural fit to “1:200 over one year” approach and a run-off may be a more appropriate way to view this risk.
- How do you find a multi-year run-off scenario equivalent to a 1:200 event over one year?

No Cause-of-Death

- PRA does not consider cause-of-death modelling a robust model
- None of the models are “cause of death” models due to their greater complexity, data requirements and the need for a greater level of expert judgement to be exercised.
- Concerned that the correlations between causes of death were not easily measured and would not be stable over time

Model Risk

- The PRA itself works with: “four commonly used families of stochastic longevity risk models”
- The best way to deal with model risk is to not rely on a single model.
- Different models produce different capital requirements



Source: A Value-at-risk framework for longevity trend risk - S. J. Richards, I. D. Currie and G. P. Ritchie

This doesn’t stop firms from using these approaches, but the challenge then is to demonstrate consistency with the one-year calibration standard.

How does this compare to the true nature of longevity risk?

Richards Risk Behaviours*	Comments	Assessment against QIs
Basis risk	Uncertainty in the assumptions drawn from "external" experience	Portfolio specific – no QIs proposed
Idiosyncratic risk	Case of unusually light mortality experience from random individual variation.	
Mis-estimation risk	Statistical error in the calibration of the mortality basis to past experience	
Model risk	It is impossible to know if the selected projection model is correct.	Covered by PRA "event risk"
Volatility	Case of unusually light mortality experience from seasonal or environmental variation	Covered by PRA "data risk", but question is whether this is a <u>*permanent*</u> or <u>*temporary*</u> increase to life expectancy
Trend risk	Even if the model is correct and there is no basis risk, an adverse trend may result by chance which is nevertheless fully consistent with the chosen model.	**Has this truly been covered by PRA's VaR approach?**

*A VALUE-AT-RISK FRAMEWORK FOR LONGEVITY TREND RISK – S. J. Richards et al.

Other risks potentially not considered

- Underwriting risk – uncertainty in the assumptions from the specific information by the individual
- Catastrophe risk – a "catastrophic shift" in mortality rates

Summary and questions…

Experience around the world

Modelling longevity

The future of mortality

View of the regulator

Thank you!