The Actuarial Profession
making financial sense of the future

Peter Banthorpe and Douglas Anderson

Using health scenarios to understand long-term mortality trends

6 November 2012

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Synopsis

Considerable uncertainty exists in long-term mortality trends. Pricing and reserving bases commonly assume a rapid deceleration in current rates of improvement. But what assumptions on population health and medical developments justify these assumptions?

This session will first present a summary of previous and current work in the field by actuaries, medics and epidemiologists. We will then host a debate to discuss:

- the audience's view of the best approaches for further research
- the appetite for an actuarial working party to advance research in this area.

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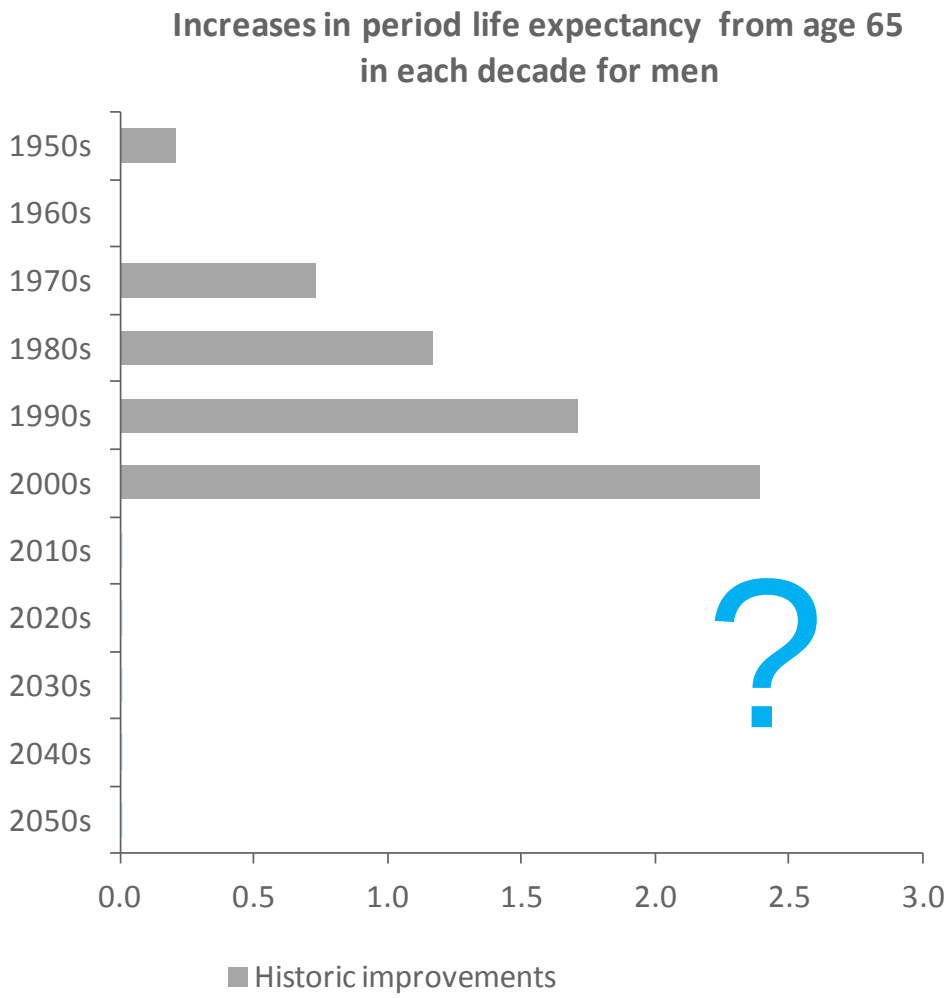
Where next?



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The modelling landscape for longevity trends

Approach	Projection Mechanism
Statistical (extrapolating the past)	Deterministic pathways
Expert Opinion	Stochastic
Explanatory	Scenarios (Qualitative)

Granularity spectrum

- Men and women separately
- Birth cohorts
- Socio-economic groups (using post codes)
- Cause of death/ disease groupings
- Individual

  eg personal genetic profiling
- Psycho-social profiling

Low

High

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Drivers for change

SUPPLY

- Improved availability of health data
- Emerging epidemiological insights
- Technology advances
- New conceptual frameworks

DEMAND

- Growing awareness that life-spans are not entirely random
- Uncertainty of future trends
- Free market competition
- Medically underwritten insurance products
- Regulatory pressure
- Human nature!

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Objectives

- To summarise past research:
  - Epidemiological / Medical
  - Actuarial
- What do we want from a model?
- Gauge interest in more structured research through the profession

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Epidemiological / Medical

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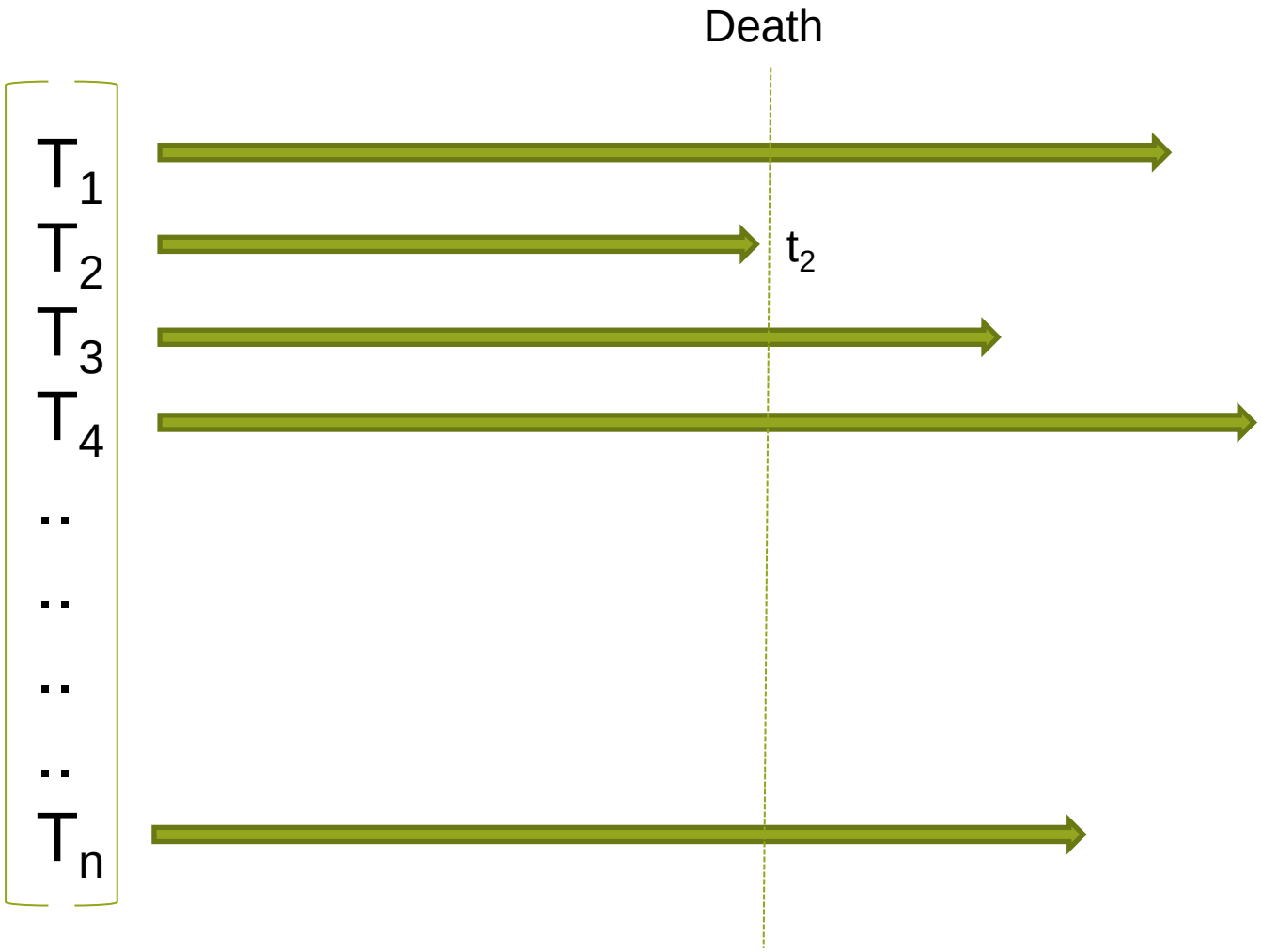
Theory of Independent Competing Risks



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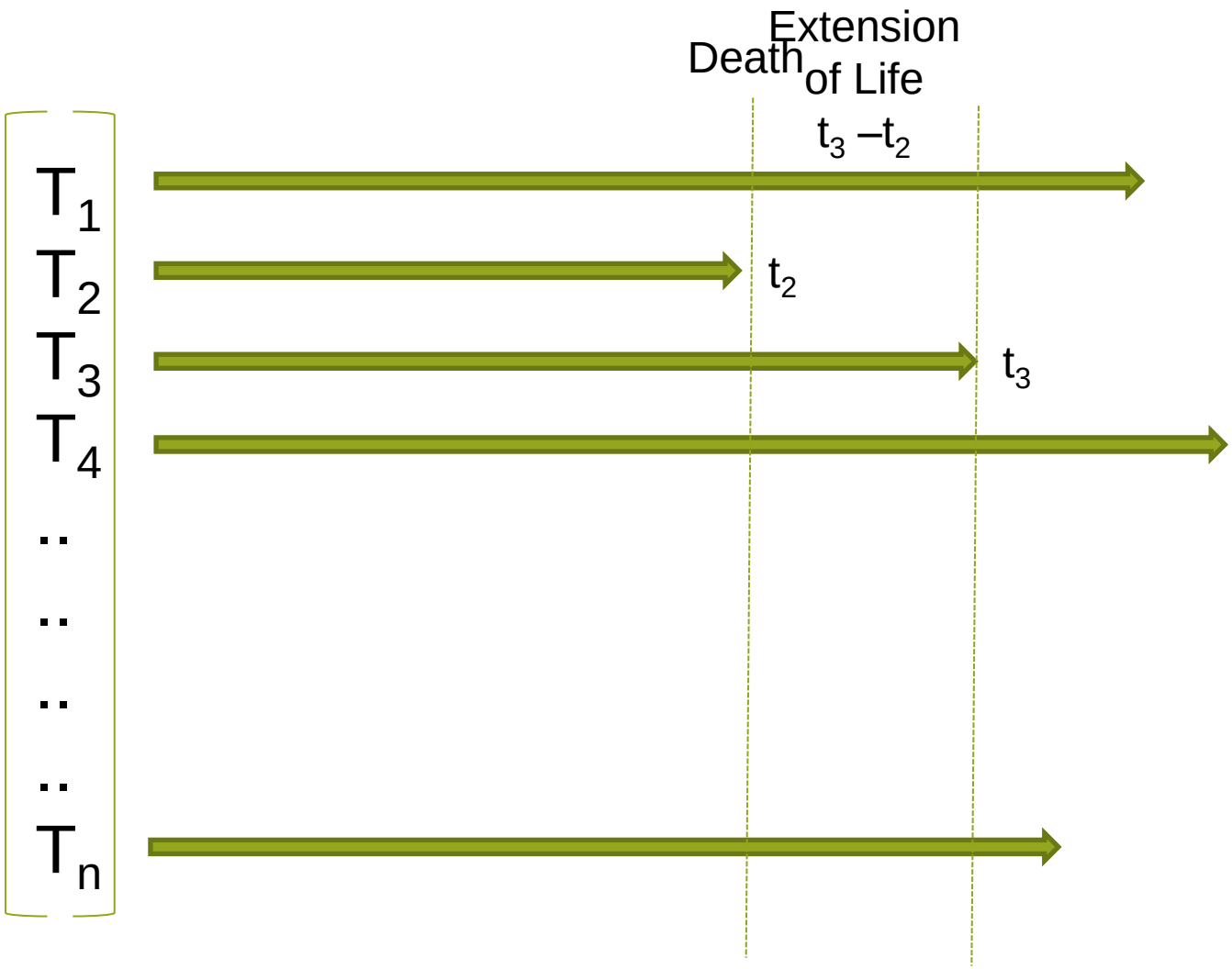
Theory of Independent Competing Risks



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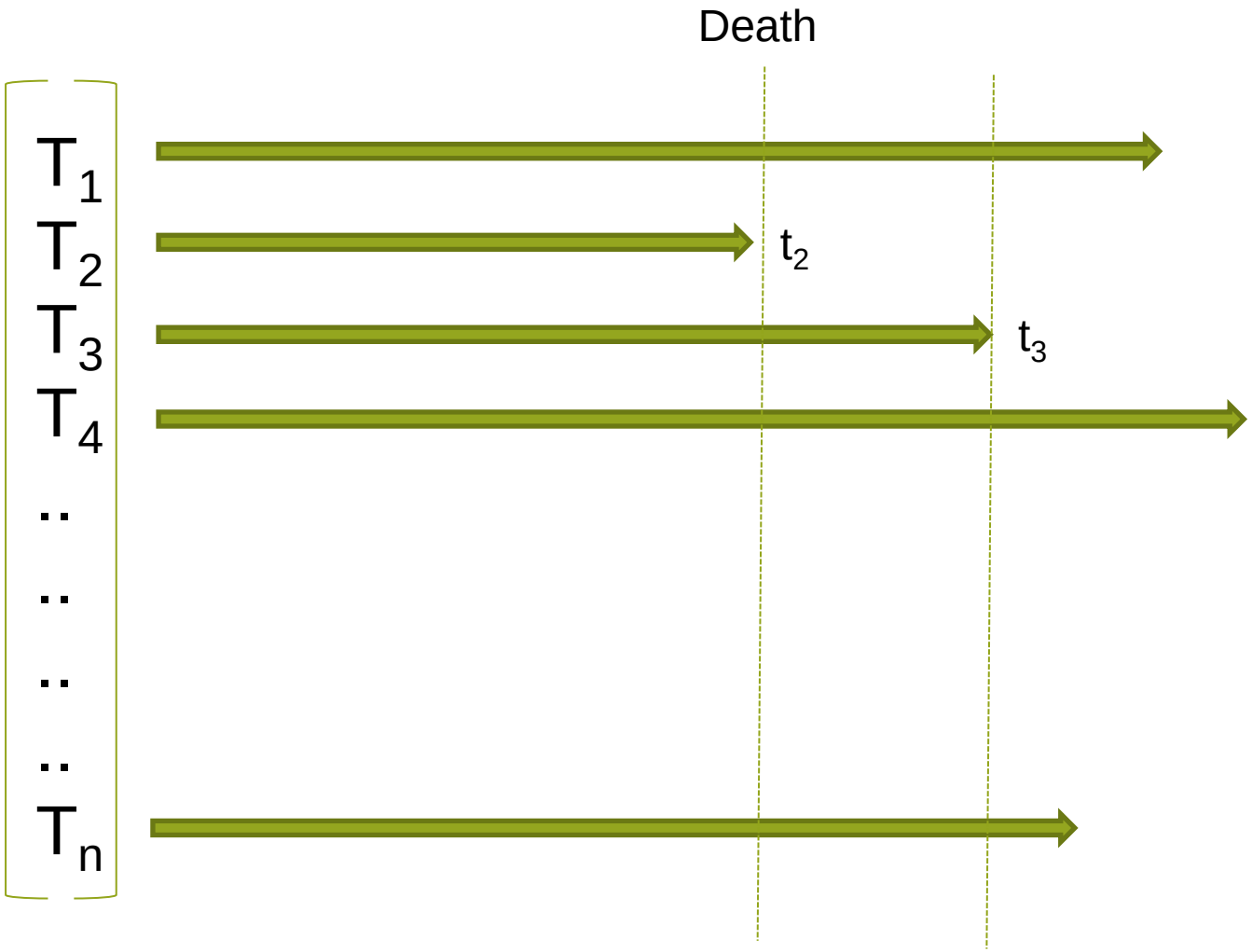

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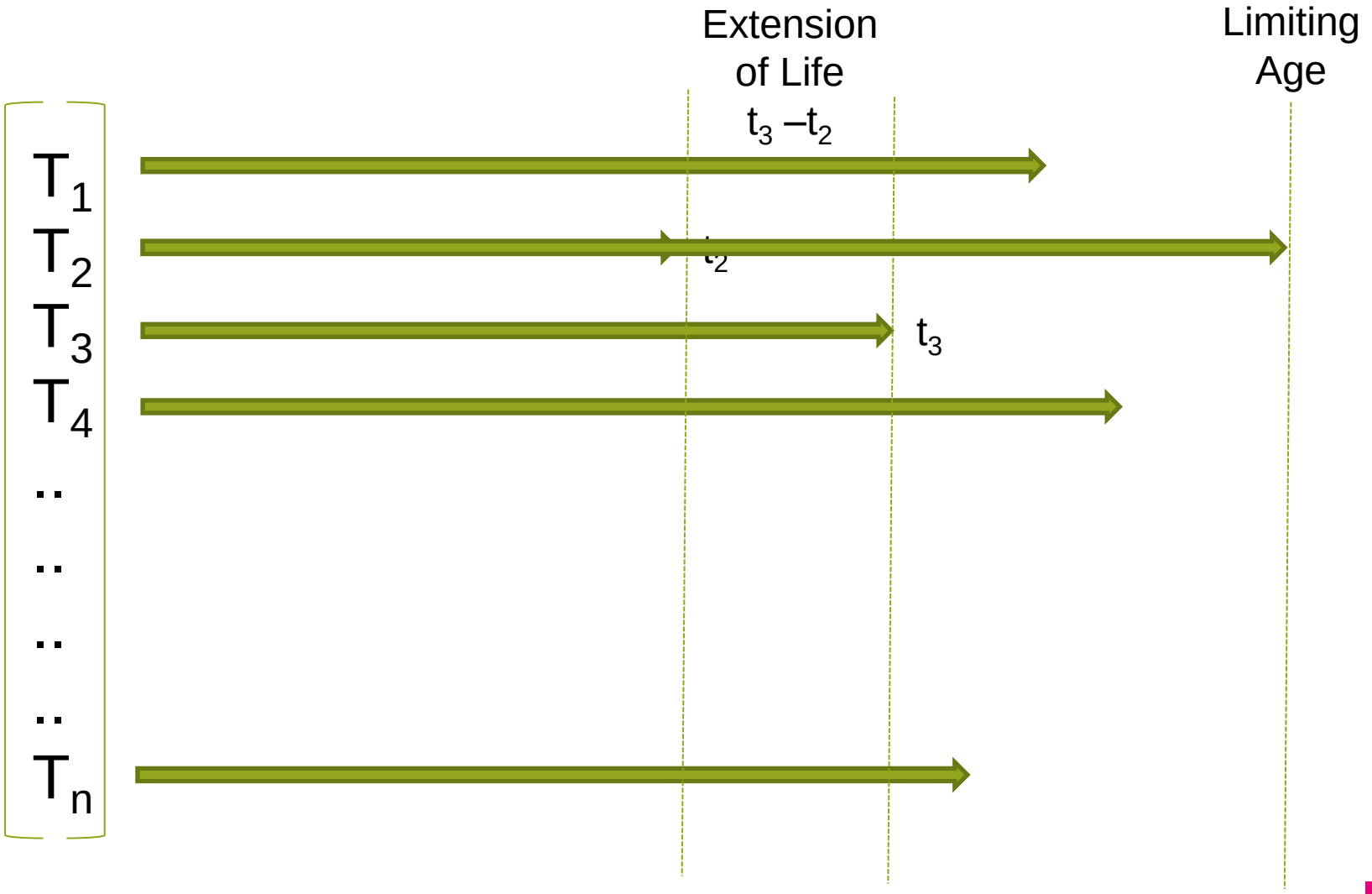

Concept from Dimitrova et al (2009)

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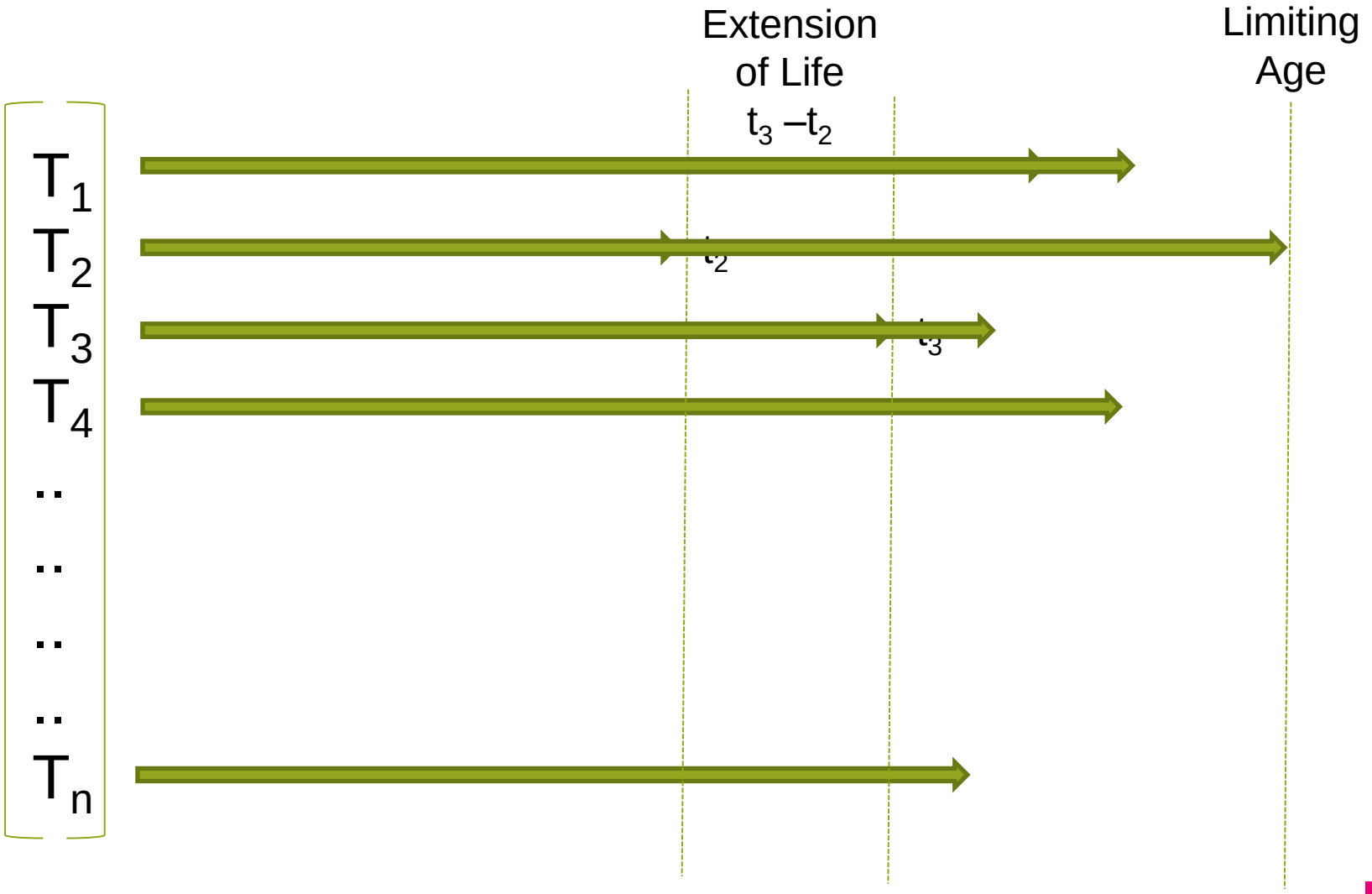
Dependent Competing Risks



Concept from Dimitrova et al (2009)

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Multiple Cause of Death Data

- UK death data records only the underlying cause of death
- Multiple causes of death (up to 20) are recorded in:
  - US
  - Netherlands
  - Australia (since 1997)

- International algorithm to determine underlying cause of death.
- Death certificates are not meant to record co-morbidities!

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Mackenbach et al (2005)

Table 2 Estimates of gains in life expectancy after elimination of four groups of underlying causes of death, with and without taking into account competing causes. The Netherlands, 1990

	Gain (in years)	
Underlying cause of death	*Conventional calculation*	*Revised calculation, taking into account: competing causes*
	Men	
Neoplasms*	3.83	3.83
Cardiovascular diseases	4.93	4.02
Respiratory diseases	0.82	0.41
Other diseases	2.51	1.91
	Women	
Neoplasms*	3.38	3.38
Cardiovascular diseases	4.52	3.37
Respiratory diseases	0.57	0.28
Other diseases	2.76	1.92

*Reference category.

Table 3 Estimates of gains in life expectancy after elimination of four groups of underlying causes of death, taking into account competing causes plus convergence or contributing causes

Gain (in years) Revised calculation taking into account competing causes plus:	
Convergence†	*Contributing causes*
Men	
3.83	3.90
4.34	4.55
0.49	0.43
2.15	2.16
Women	
3.38	3.42
3.71	3.85
0.33	0.29
2.16	2.26

J Epidemiol Community Health 1999;53:32–37

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Application to actuarial work

- Examined use of Copulas to define dependence;
- Different interpretations of removal of different causes of death;
- Didn’t address issues of how to parameterize the model with reference to real data.

Dependent competing risks: Cause elimination and its impact on survival

by

Dimitrina S. Dimitrova, Steven Haberman and Vladimir K. Kaishev

Faculty of Actuarial Science and Insurance,
Cass Business School, City University, London

3 November 2009

Abstract

The dependent competing risks model of human mortality is considered, assuming that the dependence between lifetimes is modelled by a multivariate copula function. The effect on overall survival of removing one or more causes of death is explored under two alternative definitions of removal, *ignoring* the causes and *eliminating* them. Under the ignoring definition deaths from the causes are removed by simply ignoring them and considering the marginal distribution of the remaining causes. Under the alternative eliminating definition, deaths are eliminated, by considering the limiting distribution of the competing risks' lifetimes, conditional on the corresponding eliminated lifetimes approaching infinity. Under the two definitions of removal, expressions for the overall survival functions in terms of the specified copula (density) and the net (marginal) survival functions, are given. The net survival functions are obtained as a solution to a system of non-linear differential equations, which relates them through the specified copula (derivatives) to the crude (sub-) survival functions, estimated from data. The overall survival functions in a model with four competing risks, cancer, cardiovascular diseases, respiratory diseases and all other causes grouped together have been implemented and evaluated, based on cause specific mortality data for England and Wales published by the Office for National Statistics, for year 2007. We show that the two alternative definitions of removal of a cause of death have different effect on the overall survival and in particular on the life expectancy at birth, at age 65 and on life annuities at age 65, when one, two or three of the competing causes are removed. An important conclusion, is that the eliminating definition is better suited for practical use in actuarial and other applications, since it is more intuitive, and allows for considering only positive dependence between the lifetimes which is not the case under the alternative ignoring definition.

Keywords: dependent competing risks model, lifetimes, failure times, overall survival function, copula functions, cause elimination, cause removal

Use of Large Population Based Studies

- Increasing worldwide establishment of population based studies;
- Many risk factors have moderate effect on a disease…
- …so larger and more careful studies are now required.

- Notable Historic studies
  - British Doctors Study – 1951 to 2001, 40k people
  - Framingham Heart Study – Ongoing from 1948, 5k people

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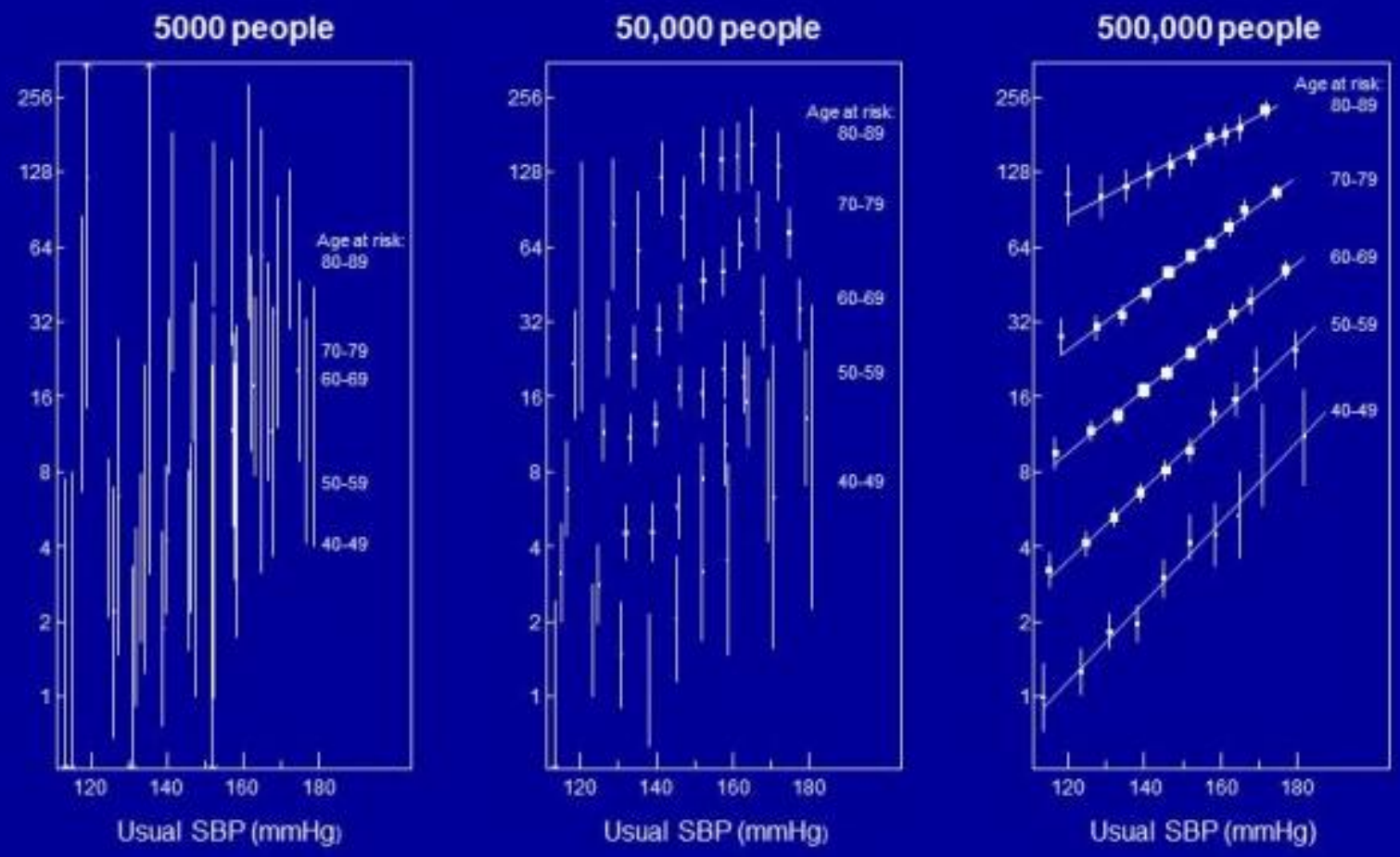
Summary of material from Prof Sir Collins, presentation to RSM (May 2012)

Need for prospective studies to be LARGE: CHD versus SBP for 5K *vs* 50K *vs* 500K people in the Prospective Studies Collaboration (PSC)



Source: Prof Sir Collins, presentation to RSM (May 2012)

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Examples of Current Large Prospective Studies

• Million Women Study	>1m
• Nurses' Health Study	121k
• EPIC (Europe)	520k
• Mexico City	160k
• Kadoorie (China)	500k
• UK Biobank	500k

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UK Biobank: Expected numbers of participants developing diseases during long-term follow-up

Condition	2012	2017	2022
Diabetes	10,000	25,000	40,000
MI/CHD death	7,000	17,000	28,000
Stroke	2,000	5,000	9,000
COPD	3,000	8,000	14,000
Breast cancer	2,500	6,000	10,000
Colorectal cancer	1,500	3,500	7,000
Prostate cancer	1,500	3,500	7,000
Lung cancer	800	2,000	4,000
Hip fracture	800	2,500	6,000
Rh. arthritis	800	2,000	3,000
Alzheimer's	800	3,000	9,000

Source: Prof Sir Collins, presentation to RSM (May 2012)

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The Clinical Practice Research Datalink (CPRD)

- English NHS observational data and interventional research service;
- Aim: to maximise the way anonymised NHS clinical data can be linked to enable many types of observational research and deliver research outputs that are beneficial to improving and safeguarding public health;
- CPRD administer the General Practioners Research Database (GPRD)

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Other recent papers

- Research into enhancing quality of extrapolative processes seem to have been successful;
- Linking to health indicators and economic correlations, sometimes through PCA;
  - Hanewald (2010) – included consideration of cause of death
  - Yang et al (2012)
  - French and O'Hare (2012)

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Cause of death projections

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Cause of death projections

- Much discussion and criticism levied against cause of death models:
  - GAD (2001)
  - CMI Working Paper 3 (2004)
  - Booth and Tickle (2008)
  - Stephen Richards (2010)
  - Risdale and Gallop (2010)

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Main Criticisms

- Independence / Dependence relationships
- Recording of data on death certificates
- Tendency to underestimate future mortality improvement rates
  - because causes of death that are slow to decline come to dominate in the long run (Wilmoth 1995)

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Further Criticisms

- Medical resources will shift between causes over time as their relative importance changes.
- There may be causes of mortality at extreme old ages that have not yet been identified as other, known, causes have resulted in deaths at earlier ages.
- Need to group illnesses results in lack of granularity;
- Links to Socio-economic groups;

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Mortality Projections by Cause Research Group

- Presented some initial findings March 2009:

Outline

- Introduction
- Scenarios – flat and steep improvement trends
- Heat Charts
- Scenario funnel against Lee-Carter Percentiles
- Caveats and Conclusions
- Where Next

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Mortality Projections by Cause Research Group

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CMI Working Paper 38

Despite these recognised limitations, those who favour the use of cause of death data argue that analysis by cause can help the user to understand the drivers of mortality change and form a view on whether the pace of change is likely to increase or decrease in the future as a result. It could be argued that this feature is of particular relevance at present because such a large proportion of improvements at higher ages in recent years have been driven by reduced deaths from circulatory disease.

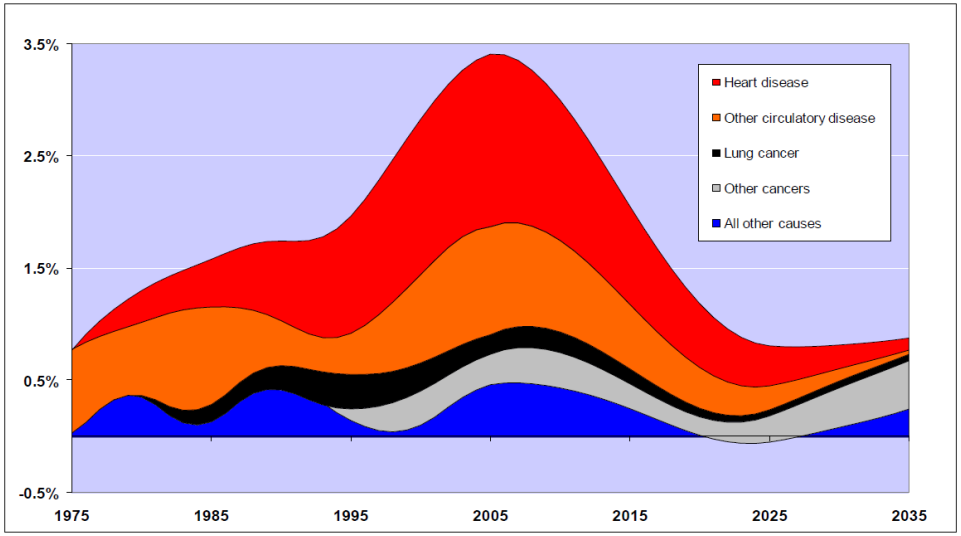

Figure A3: Average annual rate of improvement in age-standardised mortality rates for males in England & Wales aged 60-89, 1975-2035, by constituent cause, projected future rates consistent with CPMv*0.0* [1.0%]

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Life Tables for the United States Social Security Area 1900-2100 (2005)

- Sex and age specific rates by 7 illness groups;
- Example, for Ages 50-64

	Males		Females	
	1981 – 2001	Assumed Ultimate	1981 – 2001	Assumed Ultimate
Heart Disease	3.43	2.00	2.61	2.20
Cancer	1.43	0.40	1.03	0.40
Vascular Disease	2.19	1.50	1.96	1.60
Violence	1.62	0.80	1.27	0.80
Respiratory Disease	1.33	0.60	-1.08	0.70
Diabetes Mellitus	-3.15	0.30	-2.03	0.30
Other	0.33	0.90	0.06	0.80
Total	1.92	0.80	1.10	0.70

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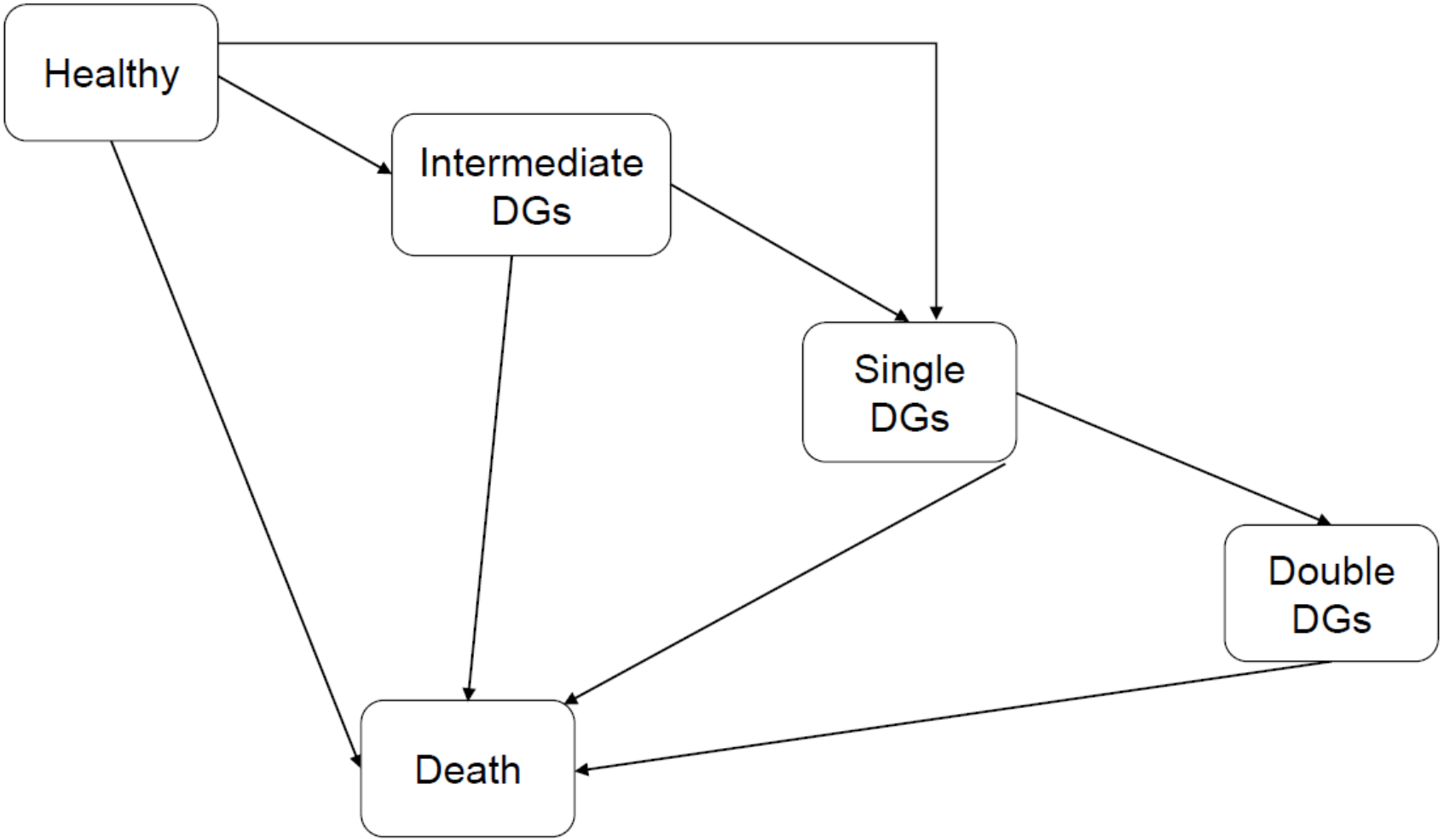
Disease Based Modelling



Source: Hande Love, presentation to Emerging Trends in Mortality and Longevity Symposium (September 2011)

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Disease Based Modelling

Disease groups	Diseases considered
Disease Group 1 (DG1)	stroke
Disease Group 2 (DG2)	cancers of breast, cervix, larynx, prostate and uterus plus malignant melanoma
Disease Group 3 (DG3)	aneurysms, ischaemic heart disease, heart failure
Disease Group 4 (DG4)	chronic obstructive pulmonary disease, pneumonia and tuberculosis
Disease Group 5 (DG5)	cancers of colon, ovary, rectum and urinary system, plus oral cancers, leukaemias and lymphomas
Disease Group 6 (DG6)	Crohn's disease, gastric and duodenal ulcers, clostridium difficile infection, ulcerative colitis, and kidney and liver disease
Disease Group 7 (DG7)	cancers of brain, lung, oesophagus, pancreas and stomach and multiple myeloma
Disease Group 8 (DG8)	Alzheimer's disease, dementia, Parkinson's disease
Intermediate Disease Group 1 (IG1)	atherosclerosis, cardiac arrhytmias, cardiomyopathy, diabetes, hypercholesterolaemia, hypertension, transient ischaemic attacks, valvular disease
Intermediate Disease Group 2 (IG2)	benign neoplasms, malignant skin cancers other than malignant melanoma
Intermediate Disease Group 3 (IG3)	epilepsy, motor neurone disease, MRSA, multiple sclerosis, osteoporosis, osteoarthritis, rheumatoid arthritis

Source: Hande Love, presentation to Emerging Trends in Mortality and Longevity Symposium (September 2011)

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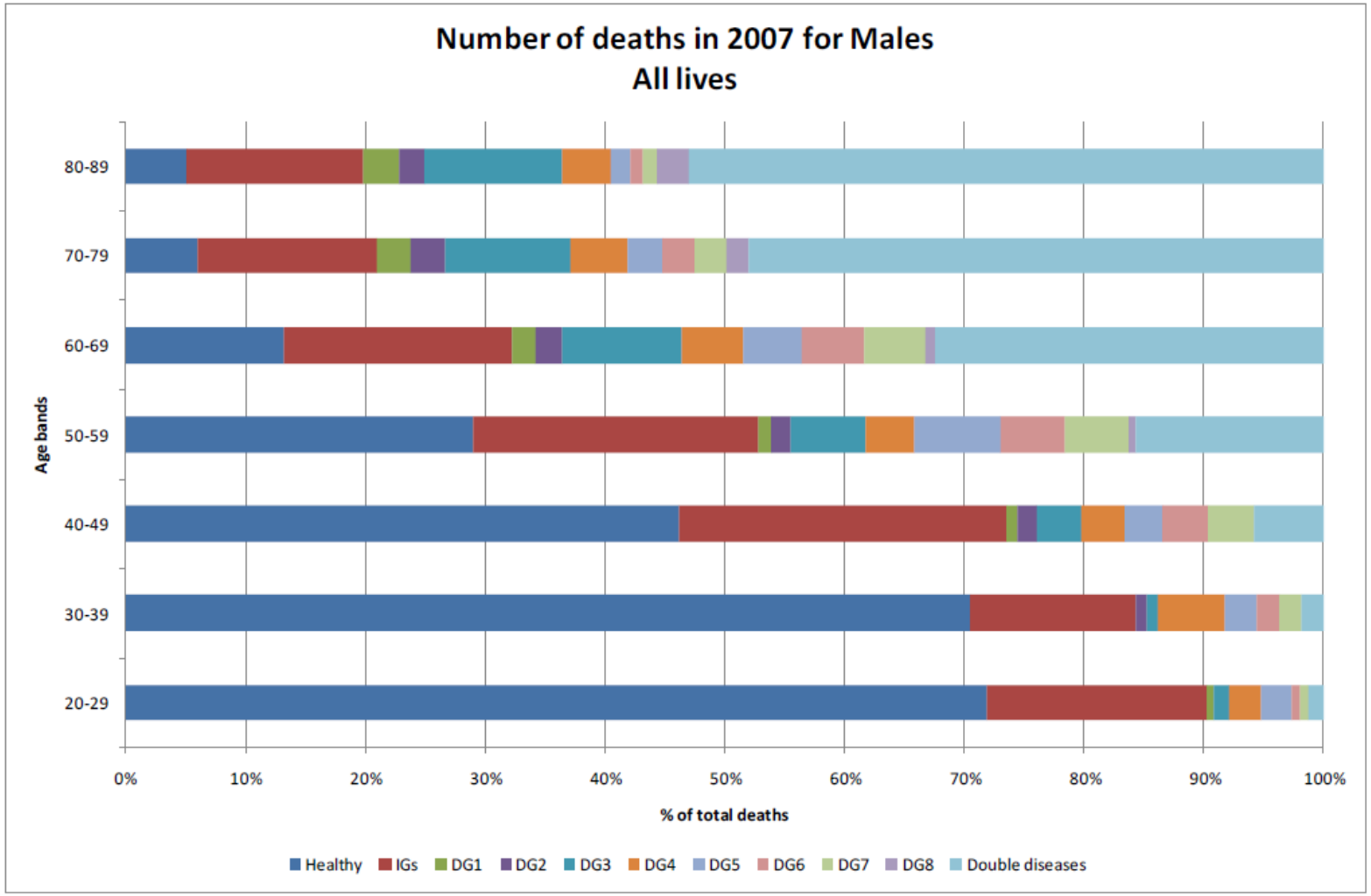
Disease Based Modelling



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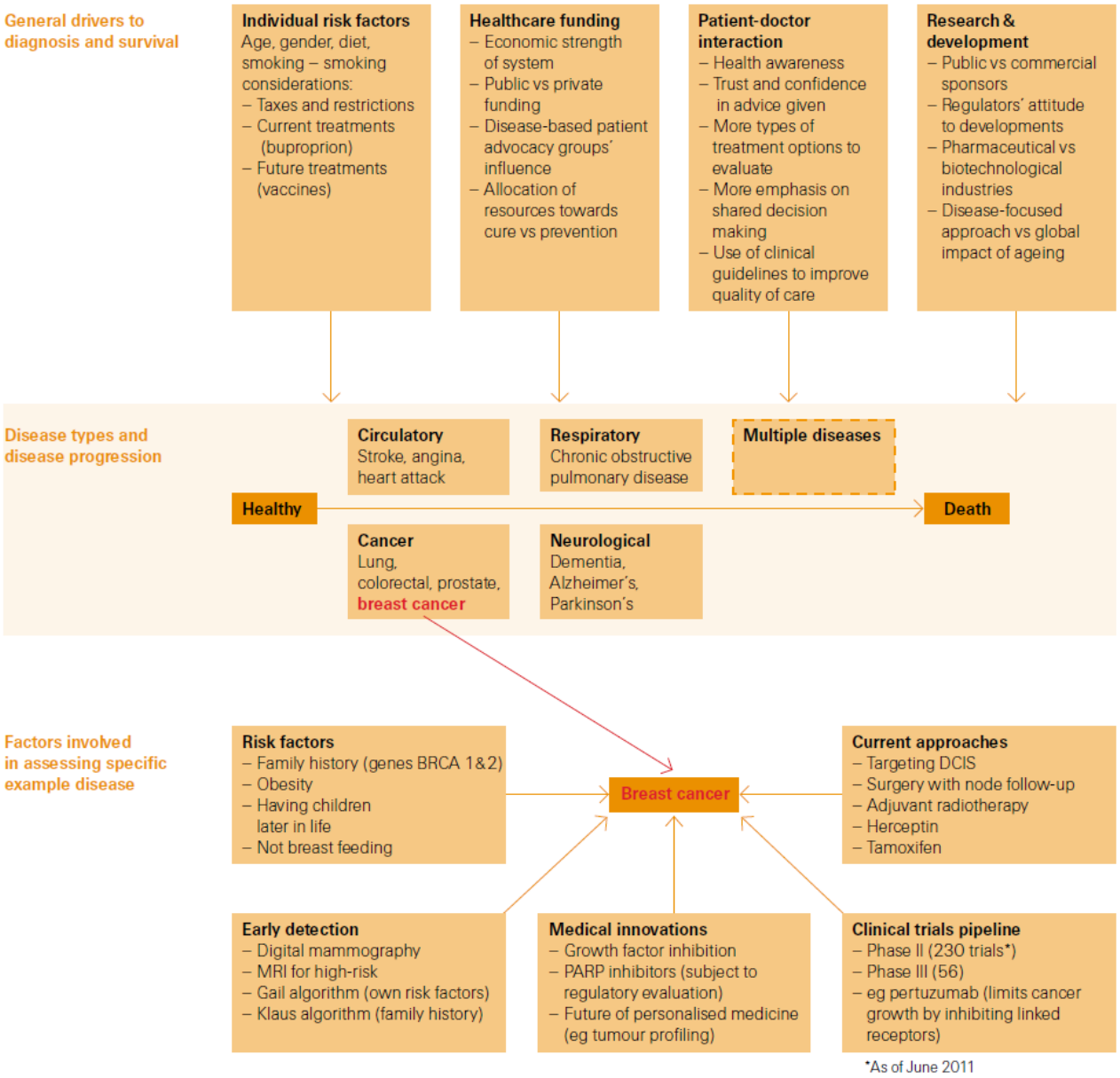

Source: A window into the future, Daniel Ryan, Swiss Re (2011)

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RMS Approach – A structural model of the drivers of mortality

Lifestyle Trends

Personal decisions like smoking habits, diet and exercise have strong influence on mortality levels.

Medical Intervention

New medical treatments, drugs, and advances in bio-technology bring about extensions in life expectancy.

Health Environment

The availability of healthcare and public health standards control the living conditions that determine mortality.

Regenerative Medicine

New technologies such as stem cell therapy and nanomedicine promise future mortality improvements .

Retardation of Aging

Research into radical new approaches of extending healthy life may impact mortality levels some time in the future.

Source: RMS website, accessed 1 November.

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Why do we want these models?

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What do we want from these models?

Provide qualitative scenarios to drive different short and long-term mortality improvement assumptions, both for the purposes of median/best-estimates assumptions and also stress scenarios.

Understand and justify extrapolative approaches e.g. how much past data should be used in extrapolative methods?

Better quantification of potential correlations in mortality improvements between different groups, e.g. males and females, underwritten lives and non-underwritten lives, different socio-economic groups, different products

In health related fields, different causes of death lead to different end of life costs.

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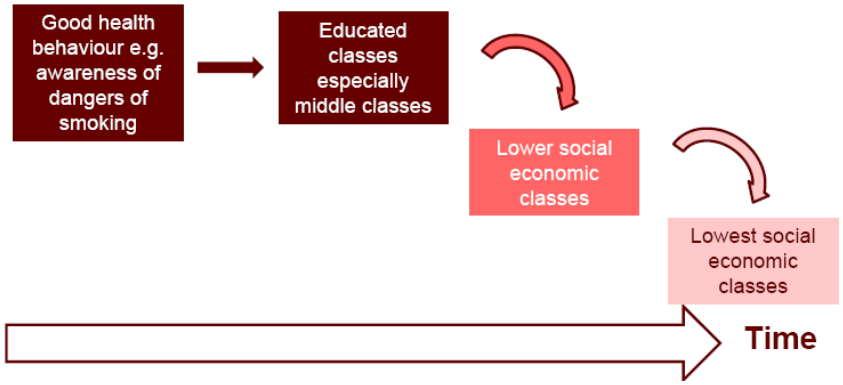
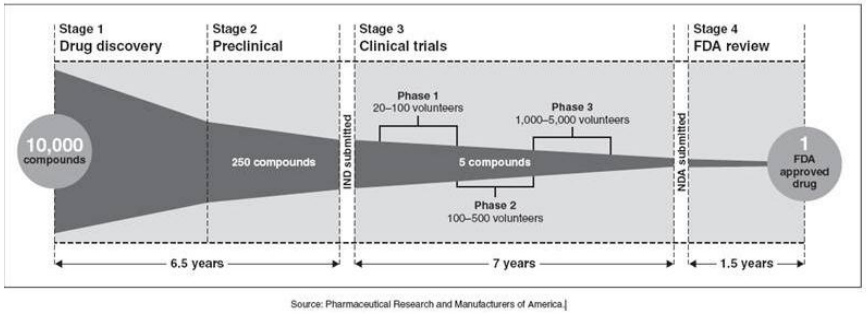
Social Cascade of Mortality Drivers

Short/Medium Term - Social Cascade



- Club Vita data consistent with the social cascade

Longer term

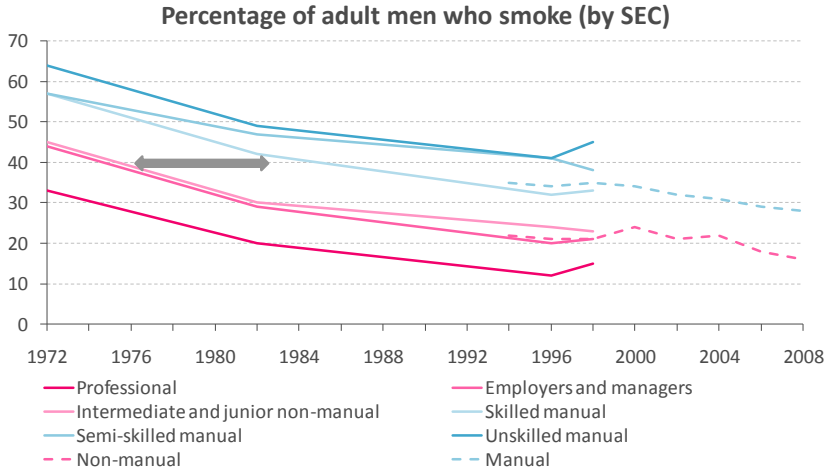


Source: Pharmaceutical Research and Manufacturers of America.

- Driven by new medical treatments becoming available
- Affordable to the higher socio-economic classes first
- Will this mean that **higher socio-economic groups** see bigger improvements?

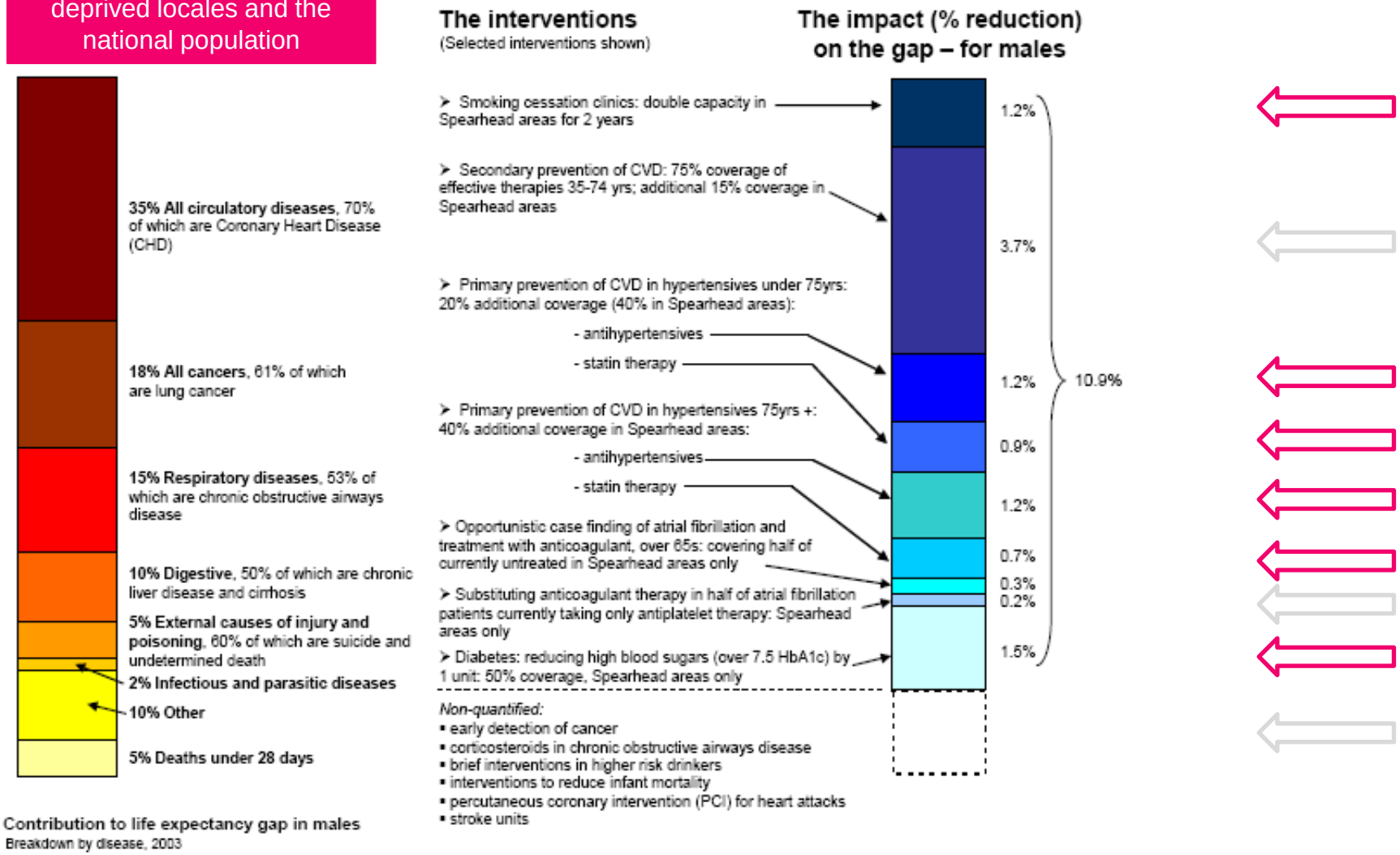
The social cascade in action: The **smoking transition**

- 54% of improvements in CHD mortality over 1981-2000 attributable to smoking *(Unal et al, 2005)*
- Takes 20+years for benefits of smoking cessation to feed through to mortality (initially benefits for heart disease, then COPD and cancers)
- Men used to be more likely to smoke, and have given up smoking in greater numbers => major factor in narrowing in gap of male and female longevity.
- Similarly, higher socio economic classes (SECs) tended to give up smoking sooner, and more fully
- Are short term prospects for high improvements better for **lower socio-economic groups**?



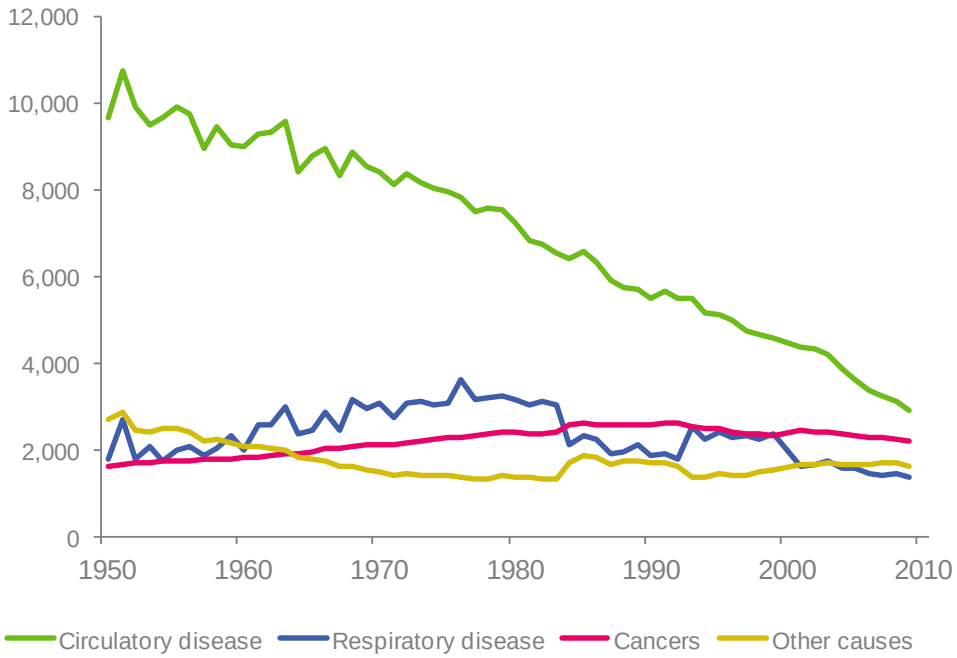
Incentivising behaviours

Comparing men in 20% most deprived locales and the national population



Is “Extreme Trend Reversal” possible?

Mortality rate per 100,000 men aged over 75 by cause of death



- For improvements to **rapidly** tail off....
- ....we would need to be seeing the following
  - **No** further smoking cessation
  - **No** further change in diets
  - **No** increase in exercise levels
  - **Reached** optimal uptake of statins / hypertensives

Source: Own calculations of age-standardised mortality rates based upon World Health Organisation data.

Source: RMS LifeRisks conference, July 2011

Drivers for change

SUPPLY

- Improved availability of health data
- Emerging epidemiological insights
- New technology
- New conceptual frameworks

DEMAND

- Growing awareness that life-spans are not entirely random
- Uncertainty of future trends
- Free market competition
- Medically underwritten insurance products
- Regulatory pressure
- Human nature!

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Your turn!

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This session will first present a summary of previous and current work in the field by actuaries, medics and epidemiologists. We will then host a debate to discuss:

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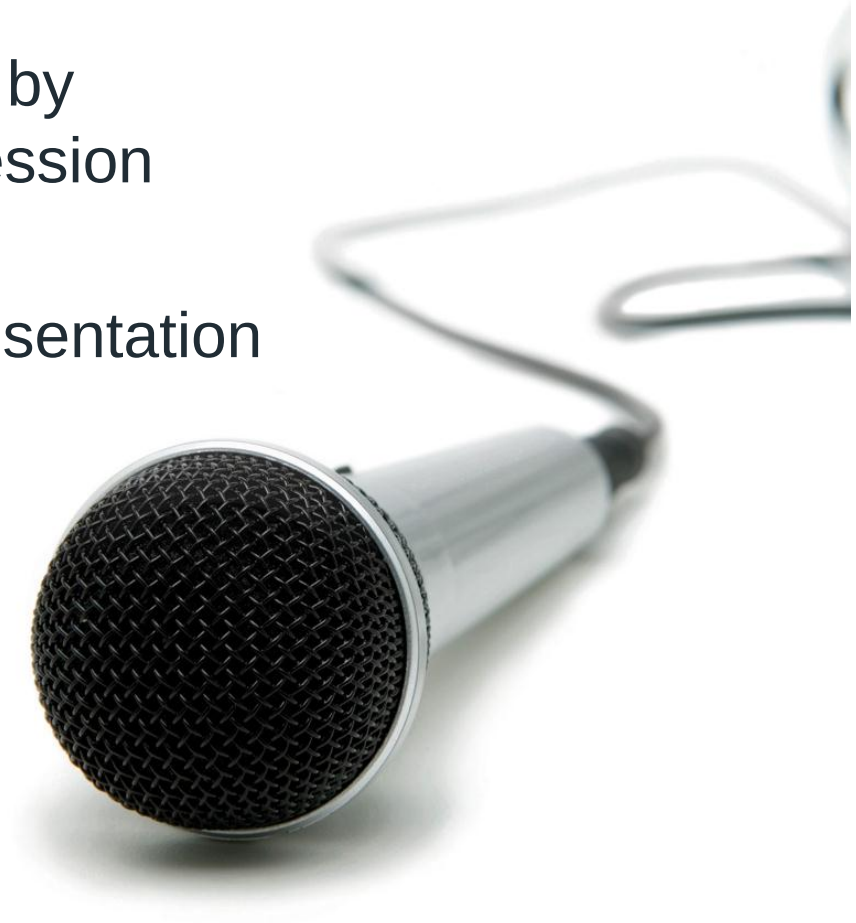
Questions or comments?

Expressions of individual views by members of The Actuarial Profession and its staff are encouraged.

The views expressed in this presentation are those of the presenter.



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