HealthPaths Dynamics: Using Functional Health Trajectories to Quantify the Relative Importance of Selected Health Determinants

- core concepts – life course trajectories, functional health
- estimating multiple co-evolving dynamic relationships
- using bootstrap weights
- drawing out the implications – using the HealthPaths microsimulation model

Michael Wolfson, uOttawa and Geoff Rowe, Stat Can

n.b. don't forget to look at (speaker's) notes view

General Plan of Analysis

- use one major longitudinal data set – Statistics Canada's National Population Health Survey
- characterize statistically multiple co-evolving individual health and health-related characteristics
- incorporate all estimated statistical relationships into a computerized microsimulation model
- generate baseline health-adjusted life expectancy (HALE)
- use "knock out gene" approach to attribute ΔHALE to selected health determinants

Statistics Canada's National Population Health Survey (NPHS)

- developed and fielded by Canada's national statistical bureau
- started in 1994; interviews every 2 years; includes institutionalized; includes mortality follow-up
- n = ~20,000 individuals initially; now ~14,000
- all responses self-report
- mostly conventional health survey content, e.g. socio-demographics, chronic disease check list, major risk factors, health care utilization
- some content more exploratory, e.g. Antonovsky's Sense of Coherence, McMaster Health Utilities Index (HUI)
- novel bootstrap weights

Focus of Analysis – Functional Health

- using NPHS Health Utility Index (HUI): a generic index of functional health status.

  1 ⇒ full health

  0 ⇒ as good as dead

  < 0 ⇒ worse than dead

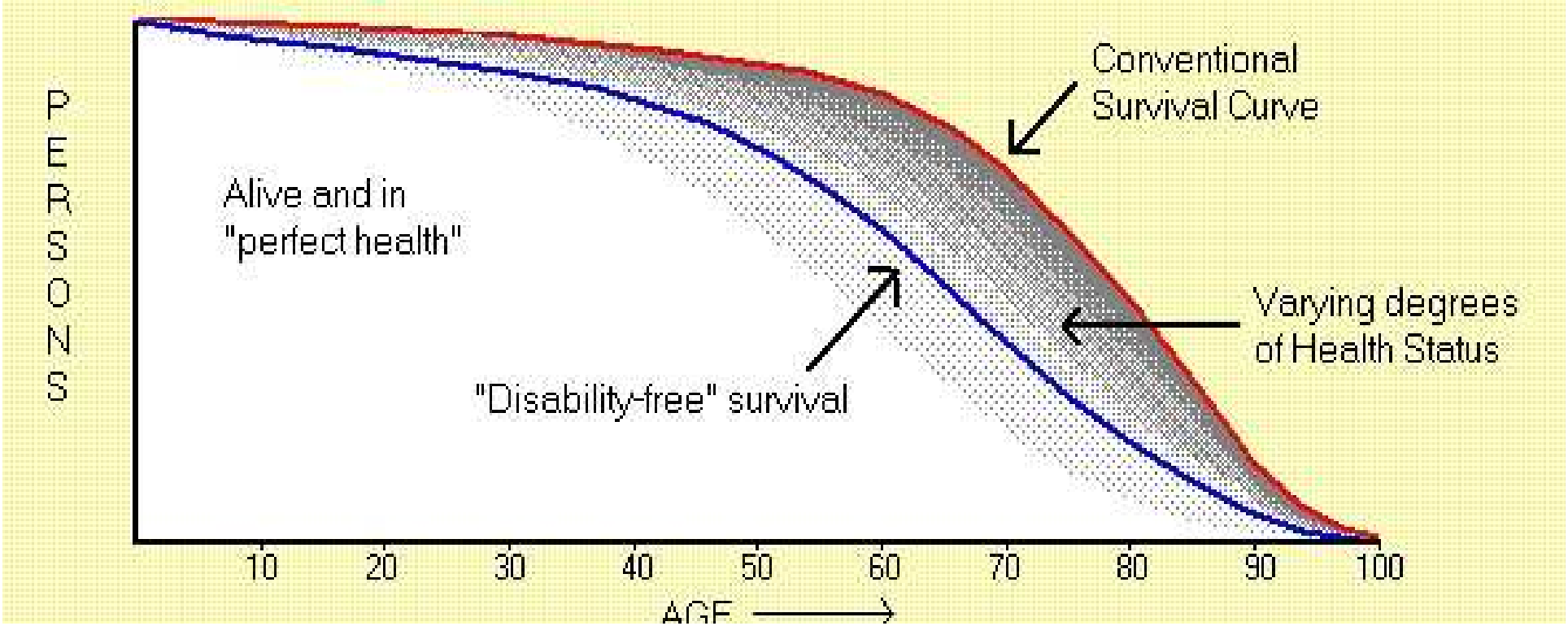
- based on eight separately assessed attributes: vision, hearing, speech, mobility, dexterity, cognition, emotion, and pain
- aggregated into a summary numerical index based on an empirical “weighting function”

Focus of Analysis – Health-Adjusted Life Expectancy

- extension of widely used concept of life expectancy (LE)
- combine length of life with “healthiness” of life, or vernacular “capacity to function” while alive, using HUI (eschew biomedical model)
- original approach – Sullivan method
- but here – complete lifecycle trajectories, using microsimulation

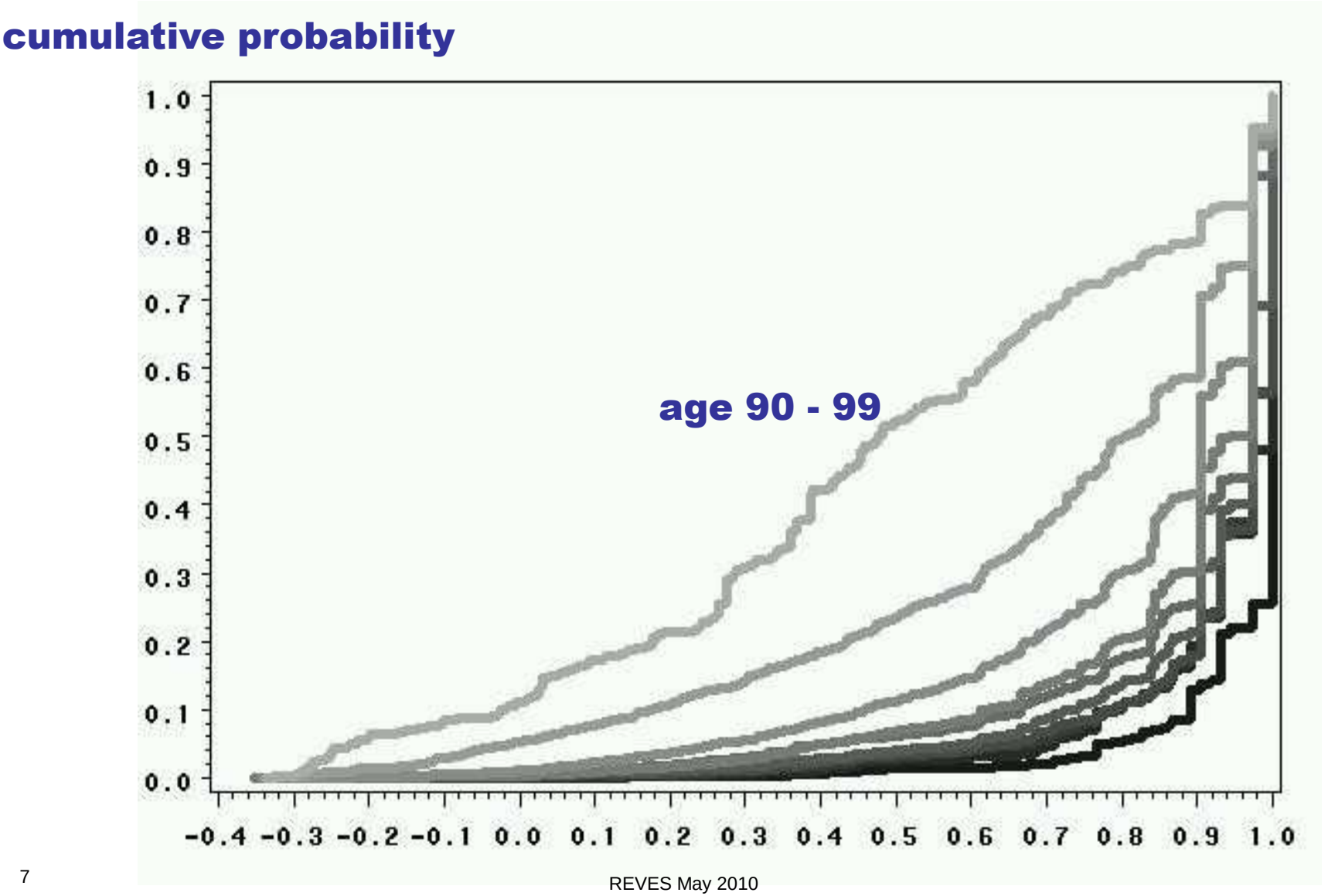
Basic Definitions

- LE = area under survival curve
- HALE = “weighted” area under survival curve
  - where “weights” are levels of individual health status, ranging between zero (dead) and one (fully healthy)



HUI Distributions by 10 Year Age Group

(ordered youngest (black) to oldest (gray)



Incremental Change in Single Steps

Two Health Change events (2x8=16 hazard equations):

Better Vision: ***Vision t+2 < Vision t***

Worse Vision: ***Vision t+2 > Vision t***

Instead of 30 types of transition (30x8=240 equations):

	Vision 1	Vision 2	Vision 3	Vision 4	Vision 5	Vision 6
Vision 1	X					
Vision 2		X				
Vision 3			X			
Vision 4				X		
Vision 5					X	
Vision 6						X

“Proxy” Determinants of HUI Change

- **n.b. “Proxy” since we are not sure whether there are important unobserved covariates ≡ modesty re “true” causal story**

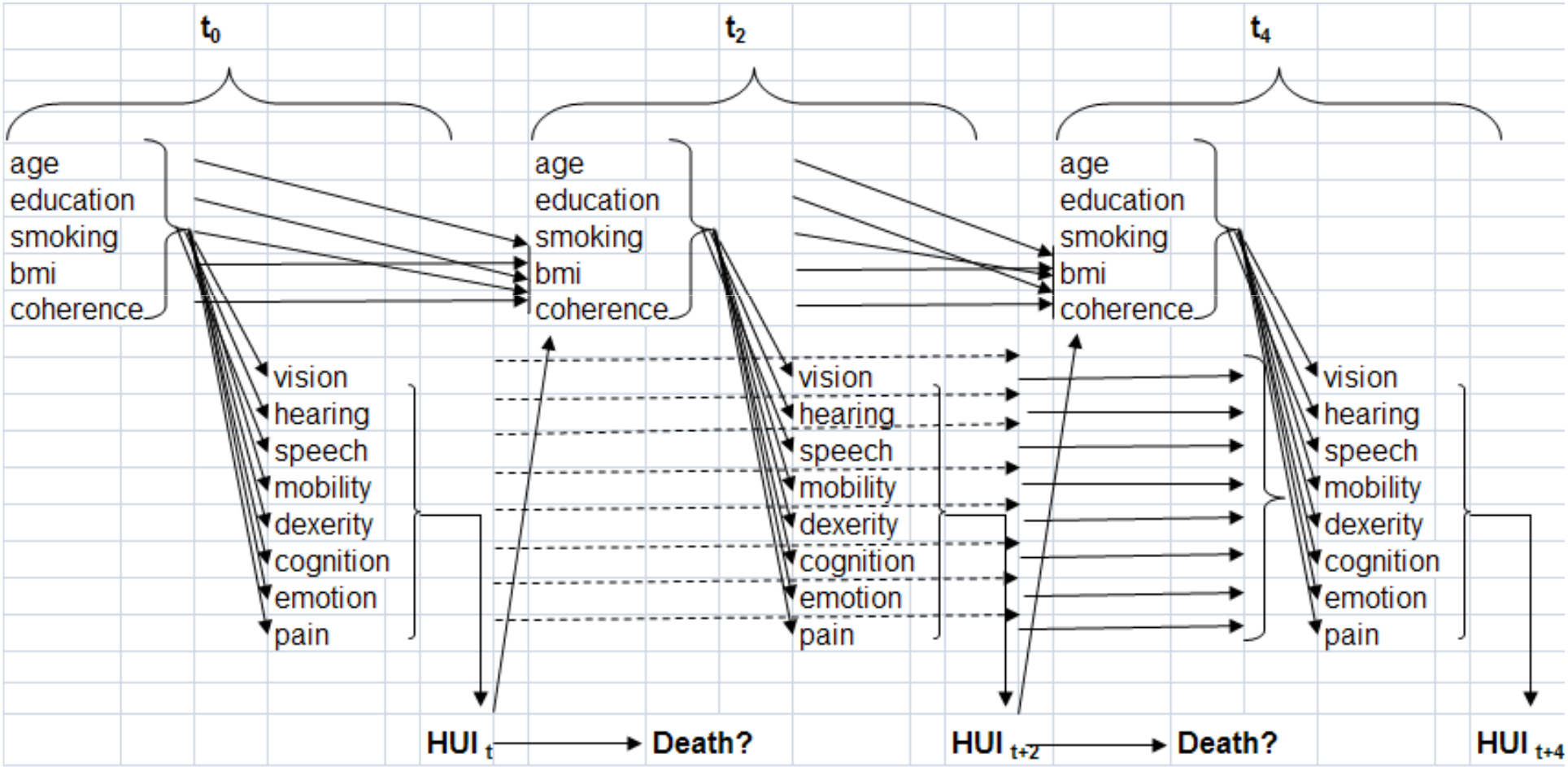
- **Socio-Economic Factors:** **Educational Attainment**
- **Behavioural Factors:** **Daily Smoking**
- **Lifestyle Factors:** **Body Mass Index (BMI)**
- **Psycho-Social Factors:** **Sense of Coherence (coping with stress)**

“The SOC scale seems to be a reliable, valid, and cross culturally applicable instrument measuring how people manage stressful situations and stay well.” Eriksson and Lindström, JECH 2005

Relationships Estimated from NPHS

n.b. designed for simulation, not publication

> 1,000 RHS variables for each of 16 HUI regressions



Stagewise Regression Algorithm

Start with $\beta_1, \ldots \beta_p = 0$, covariates *X* and likelihood L

- **Update β_0**
- **Find the index 'm' of the largest gradient $|\delta \ln(L)/\delta\beta_m|$**
- **Update $\beta_m = \beta_m + \varepsilon * \text{sign}(\delta \ln(L) / \delta \beta_m)$, [ε small]**
- **Repeat many times**

Hastie, et.al, 2007

NPHS and Bootstrap Weights

- NPHS has a complex sample design, so that simple random sample assumption-based variances are seriously understated
- one approach to enable straightforward and correct variance estimation is to provide bootstrap weights
  - 500 weights for each observation
  - weights derived from sub-sampling original sample clusters
  - so that for each bootstrap weight vector, ~40% of the weights are identically zero
- usual use: variances of statistics in cross-tabs, and of regression coefficients

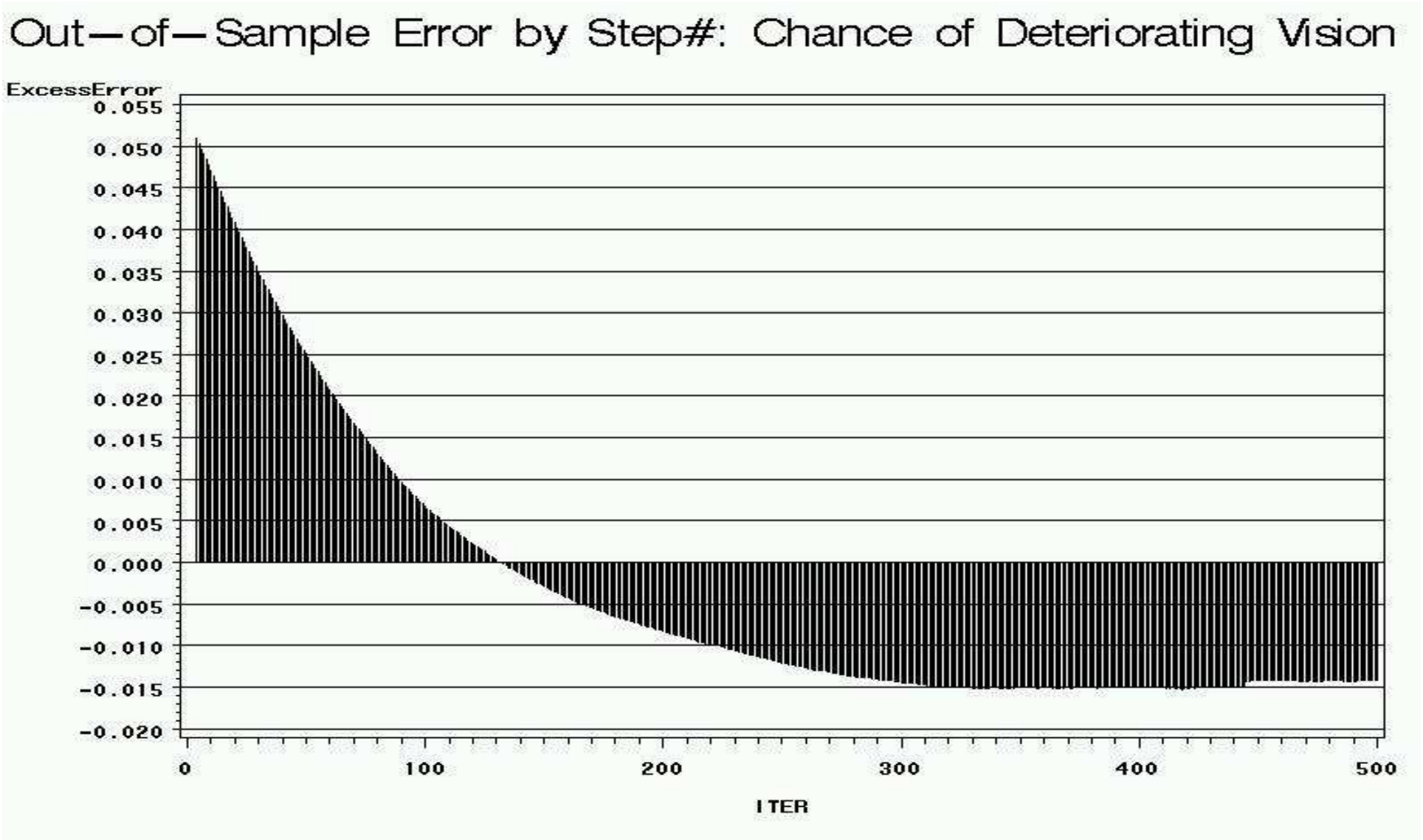
Three Roles for Bootstrapping Beyond Conventional Variances

- Bootstrapping Stagewise Regression
  1. cross-validation to prevent over-fitting (Rowe & Binder, 2008)
  2. assess model selection uncertainty – i.e. specification error as well as coefficient variance

- Bootstrap Simulation
  3. Separate simulations based on equations estimated from separate bootstrap samples.

Cross-validation Prevents Over-Fitting

(evolution of forward stagewise prediction error over 500 iterations)



Bootstrapping Model Selection

- Typically, bootstrapping a model produces just estimates of coefficient standard errors.

- Bootstrapping the Stagewise Regression Algorithm produces sample estimates of coefficients and different models.

⟶ Variance of Estimates + Model Uncertainty

Bootstrap Simulation Protocol

Conventional Approach

1. Estimate the expected value of parameters (P) using all of the available data: $E(P)$
2. Simulate outputs of interest using the best estimates: $S[E(P)]$

Our Approach

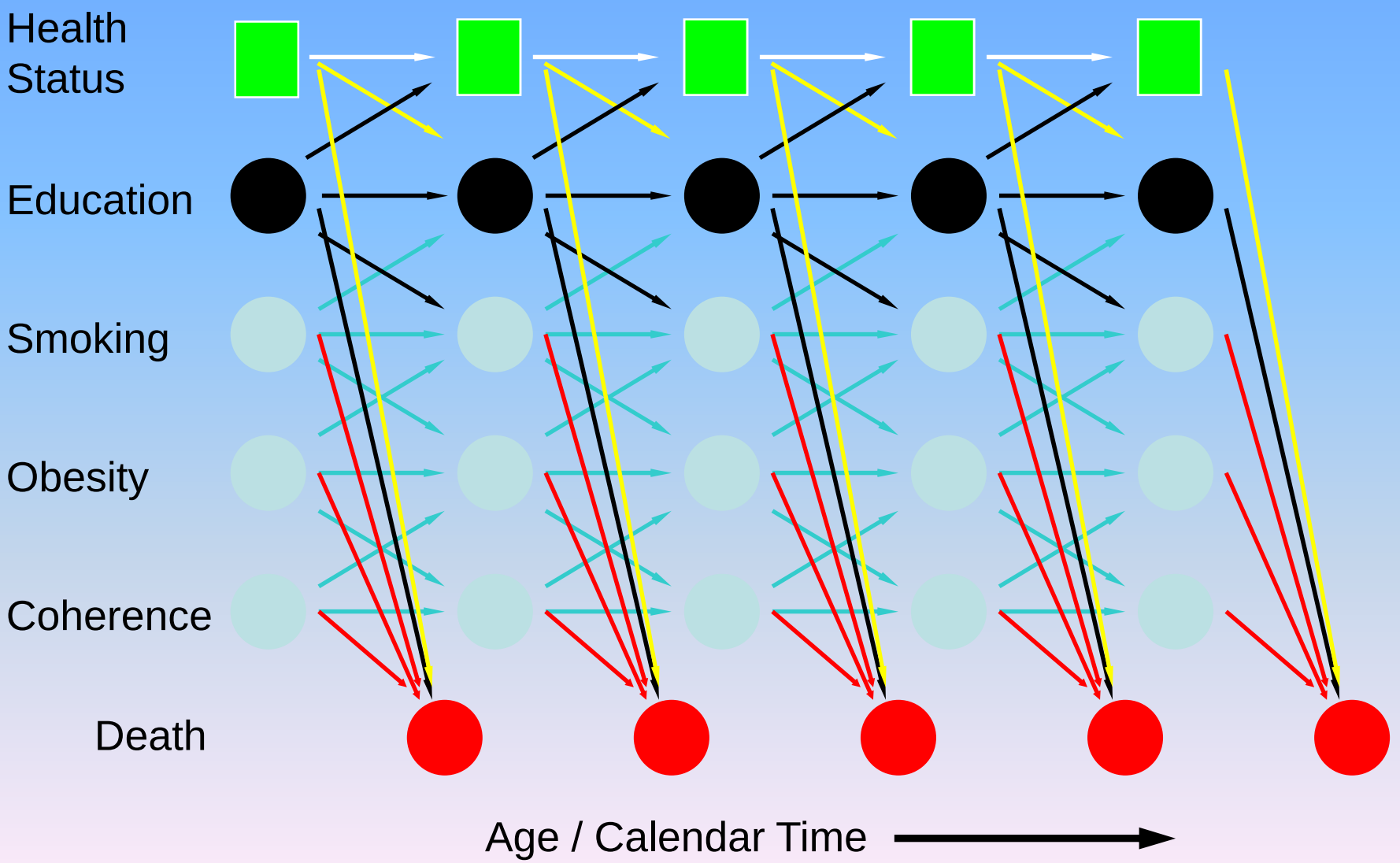
1. Estimate a sample value of parameters using each bootstrap subsample (B): P_B
2. Simulate derived outputs with the sample estimates: $S[P_B]$
3. Estimate the expected value of outputs: $E(S[P_B])$

In general: $E(S[P_B]) \neq S[E(P)]$

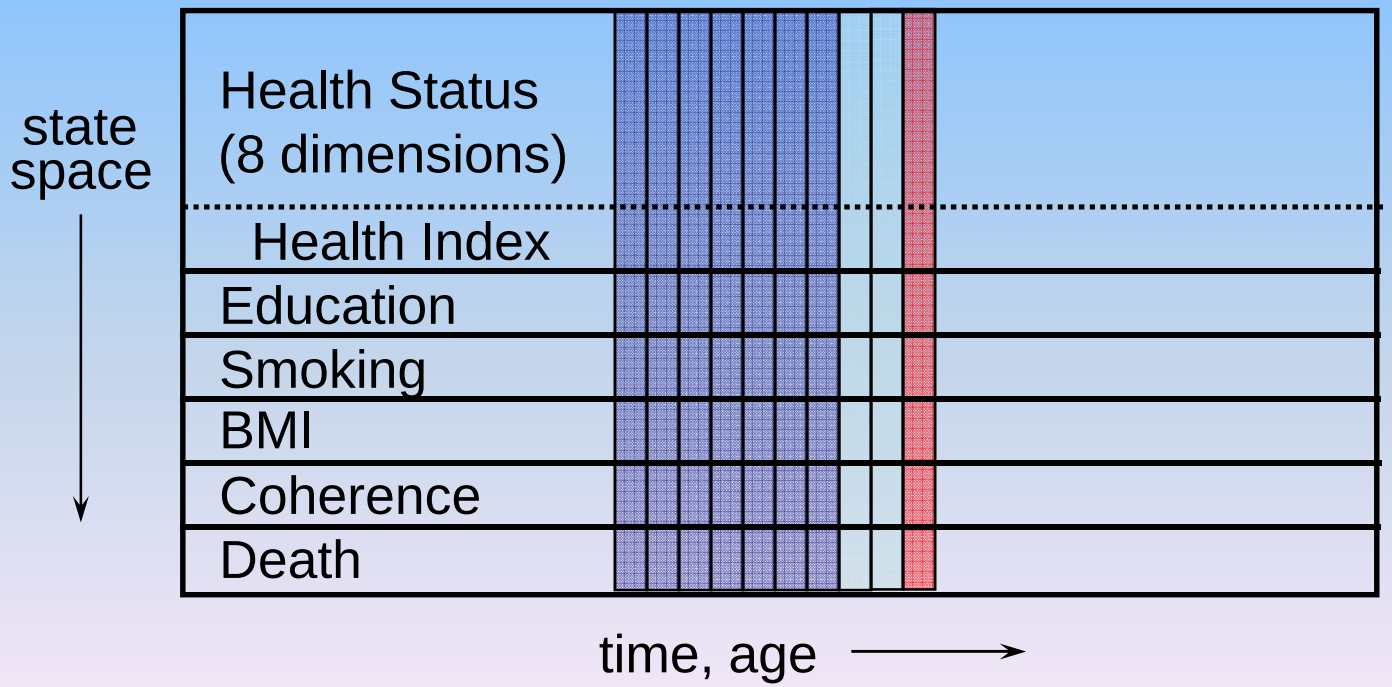
The HealthPaths Microsimulation Model

- variant of LifePaths - dynamic, longitudinal
- evolved from pension and PSE funding policy
- not co-evolving agents; i.e. not interacting
- written in ModGen, Statistics Canada's microsimulation "model generation" language
  - dialect of / pre-compiler into C++
  - discrete event, continuous time
  - one individual at a time, from birth to death
  - explicitly incorporates multi-factorial competing risks (via ModGen event queue)
- "industrial strength" vs "toy" model

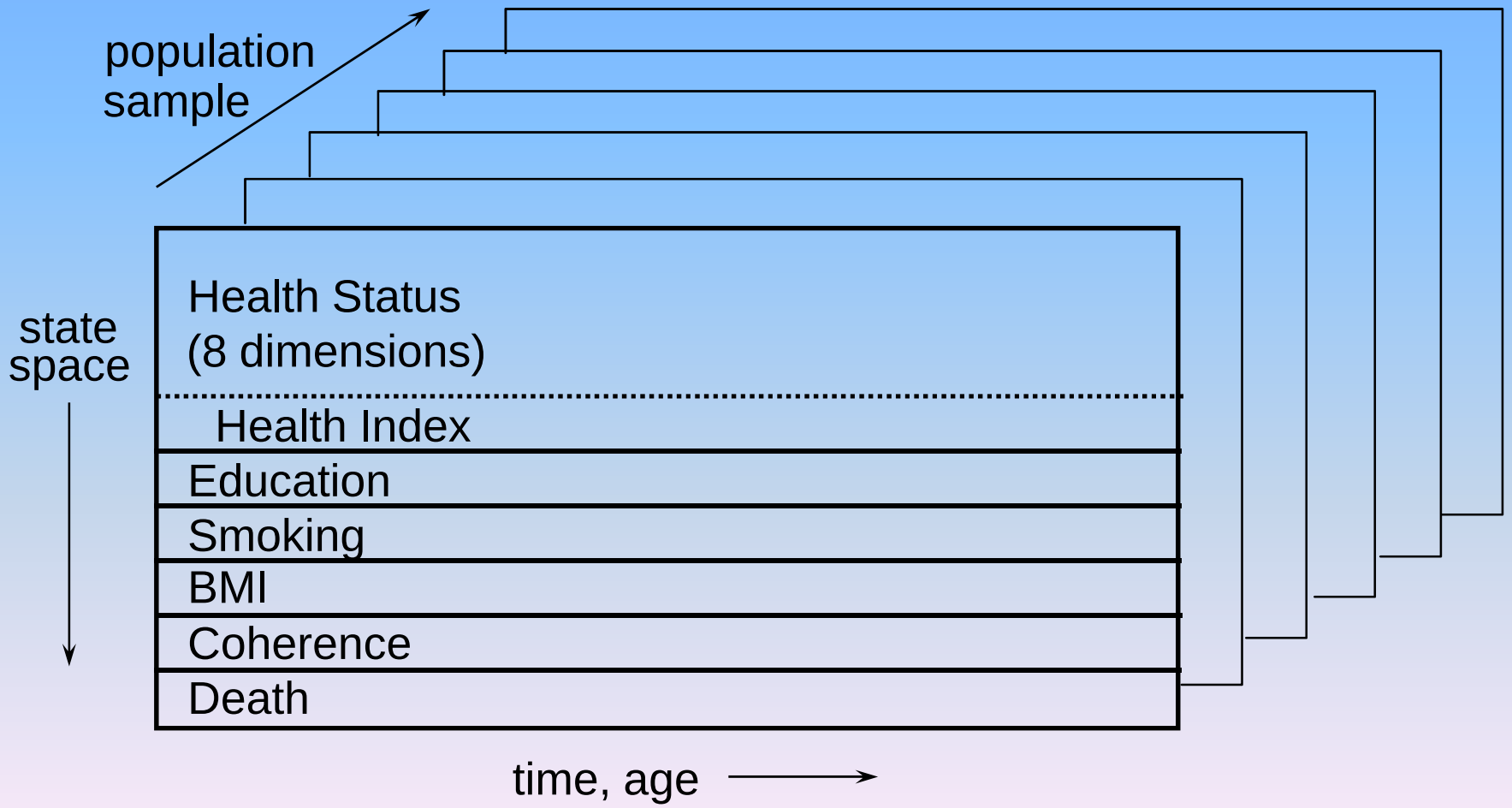
System of Recursive Equations



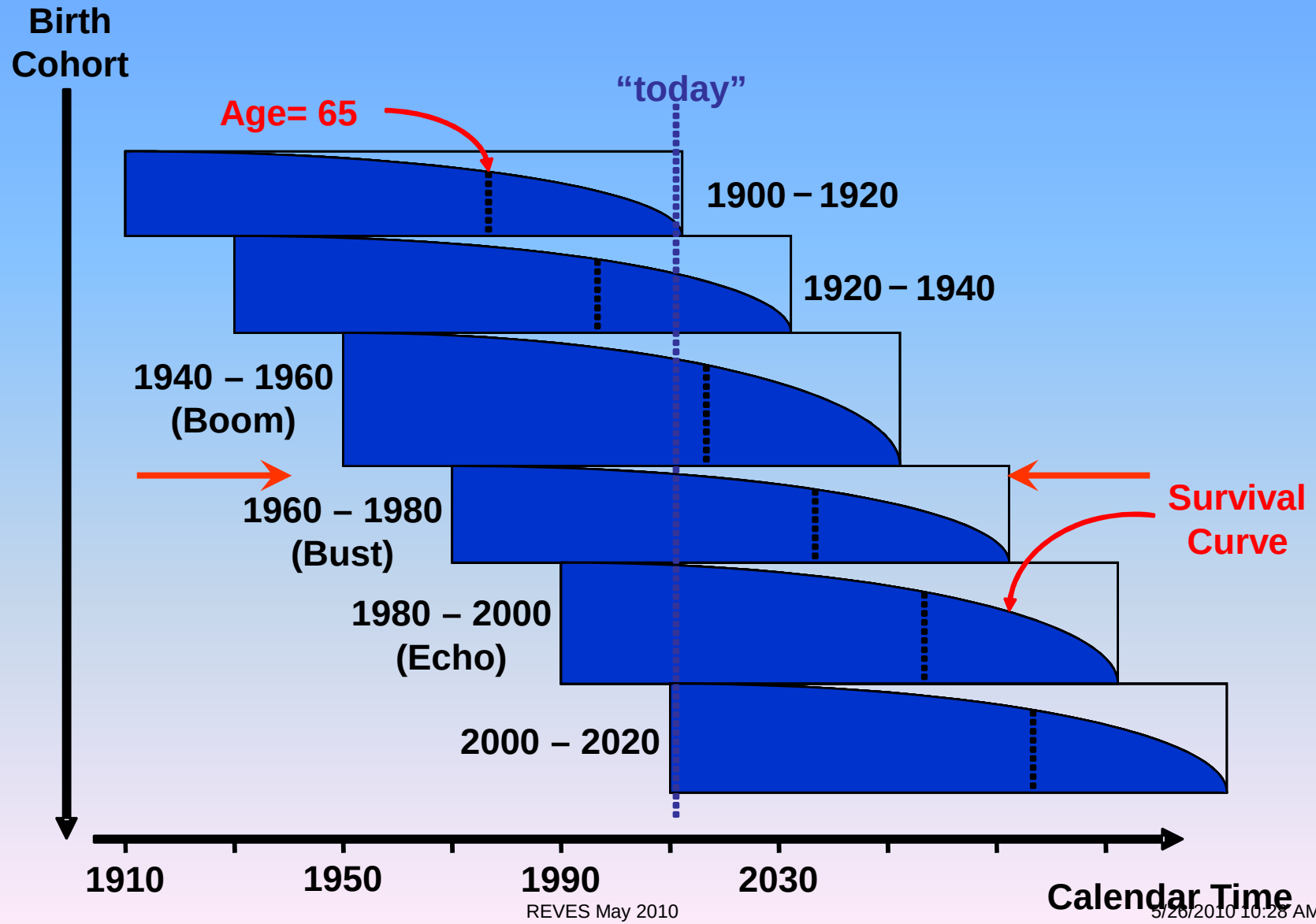
Individual Biography – Simulation in Progress



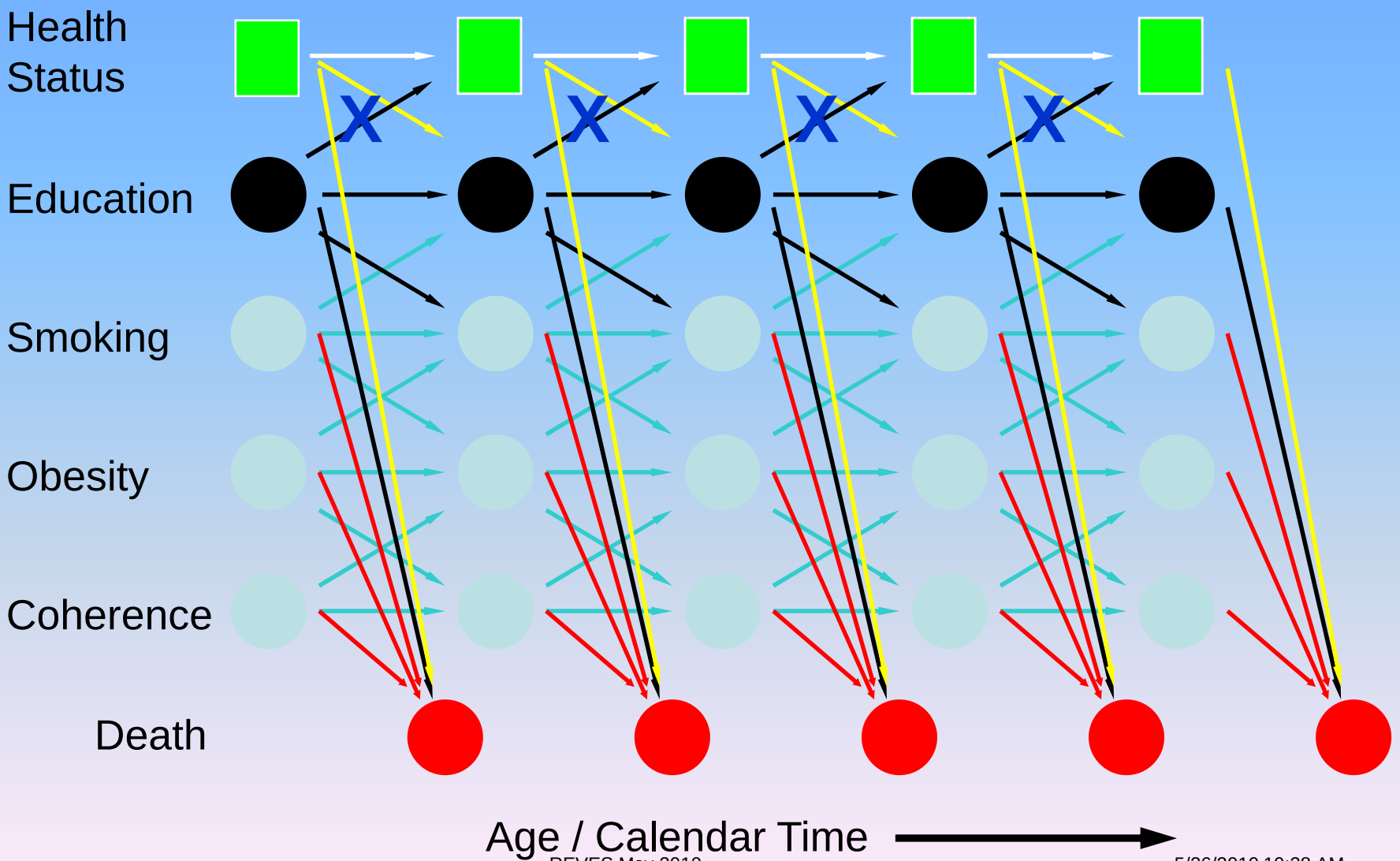
Population of Synthetic Biographies



Overlapping Birth Cohorts



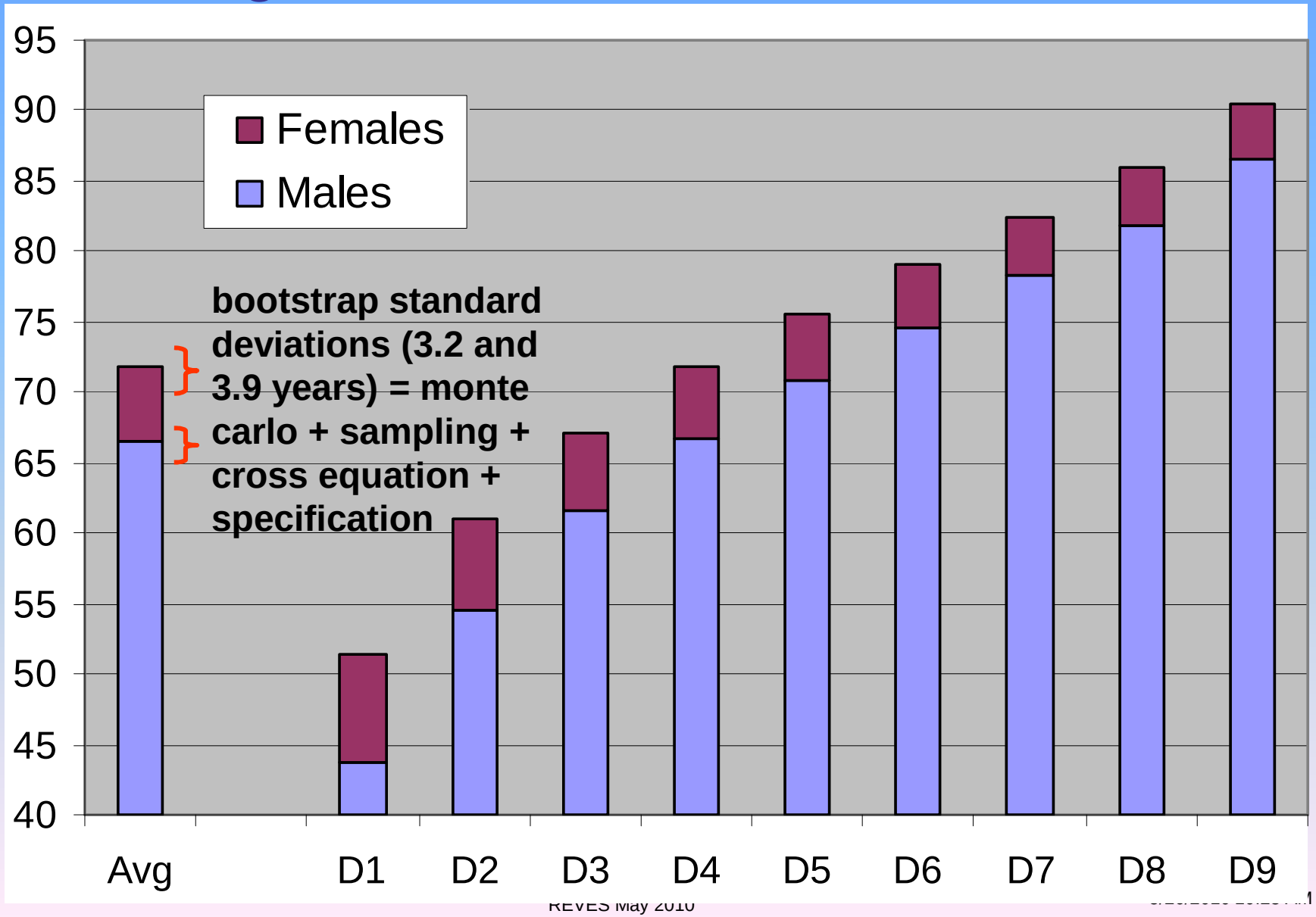
Knockout Gene Analogue



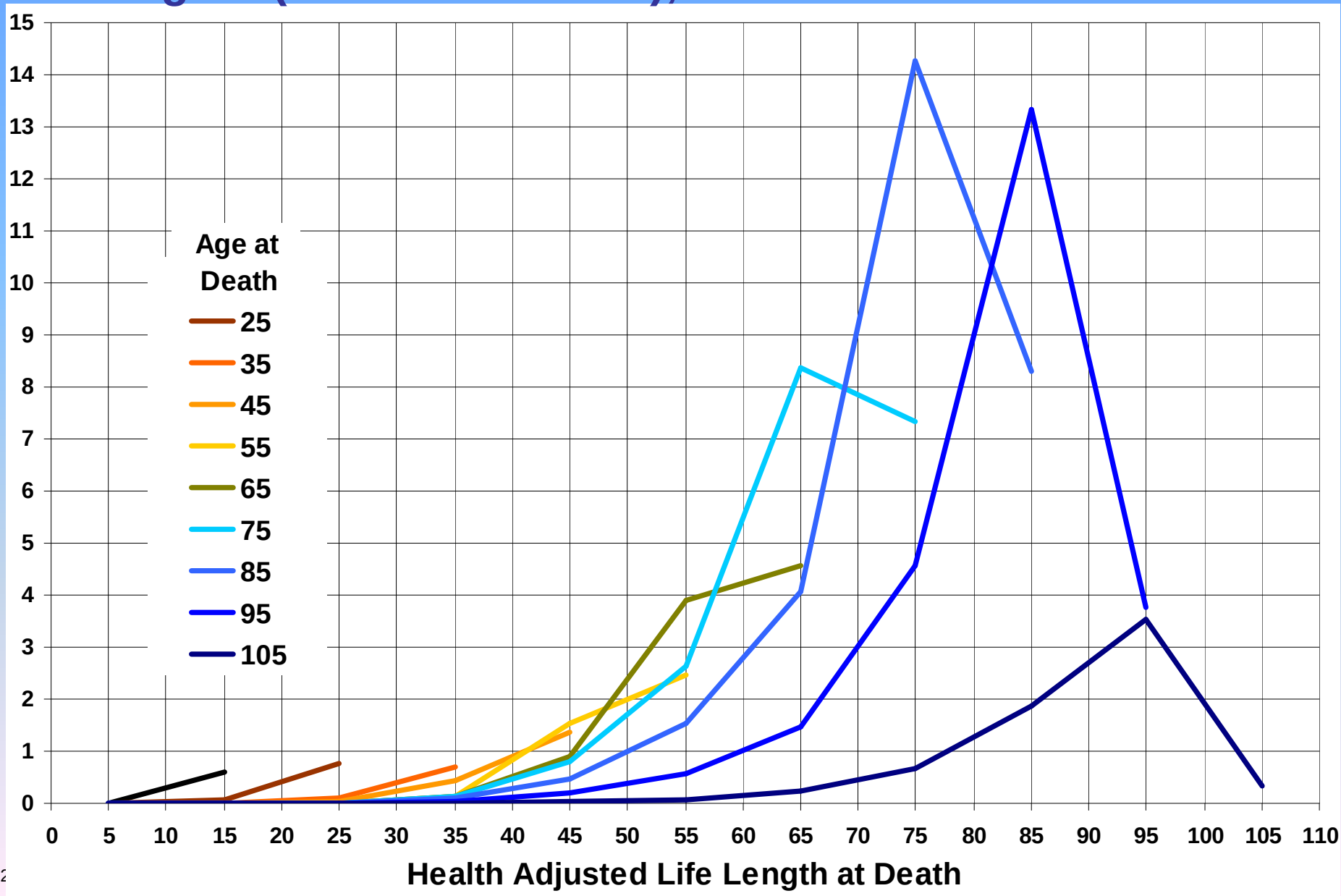
Antonovsky's Sense of Coherence

- in sum, life is comprehensible, manageable, and meaningful
- measured in the NPHS based on a 13 item scale
- "a global orientation that expresses the extent to which one has a pervasive, enduring though dynamic feeling of confidence that
  - (1) the stimuli from one's internal and external environment in the course of living are structured, predictable, and explicable;
  - (2) the resources are available to one to meet the demands posed by these stimuli; and
  - (3) these demands are challenges, worthy of investment and engagement."

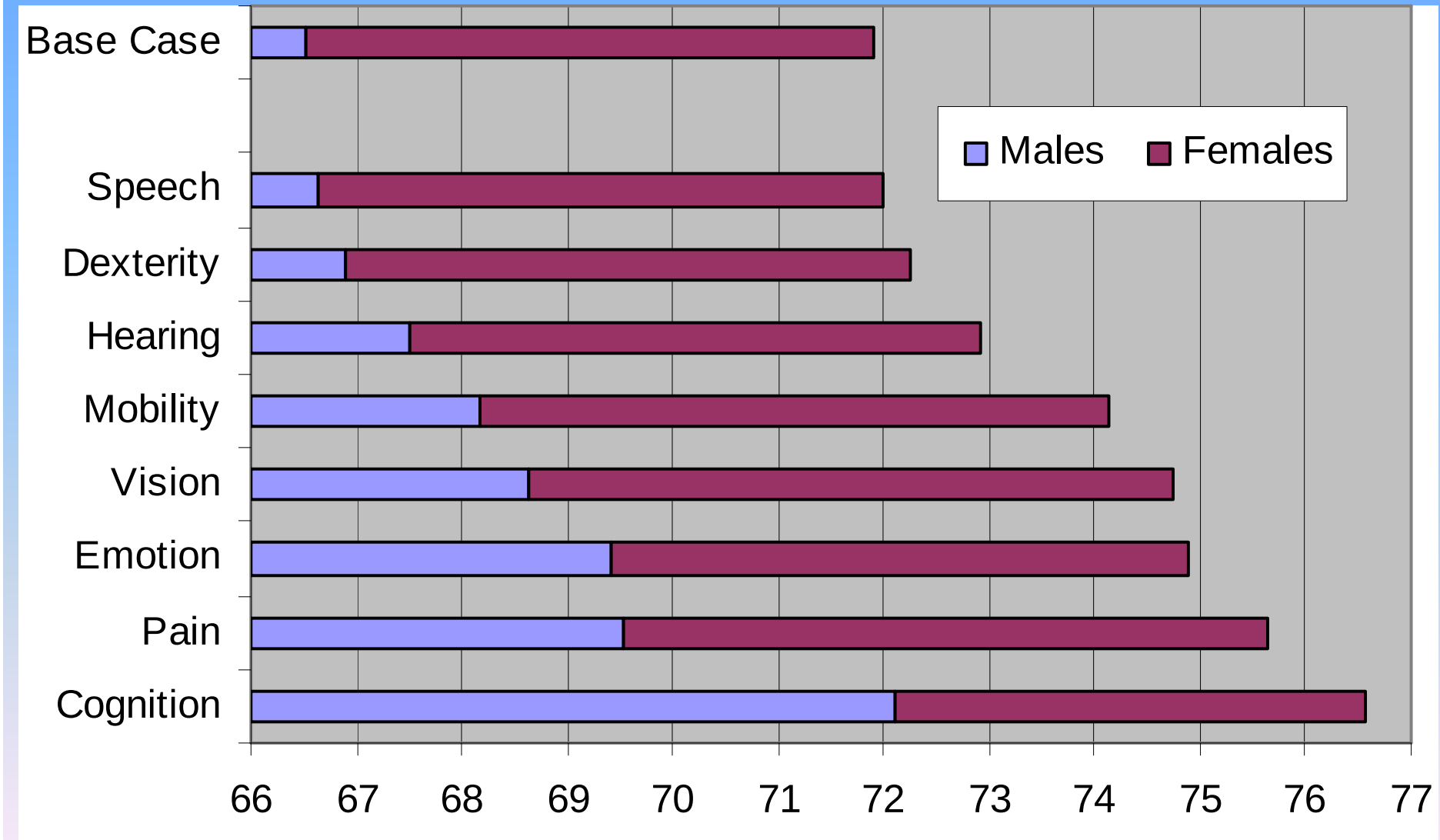
Simulated Distribution of Health-Adjusted Life Lengths, 1960 Birth Cohort



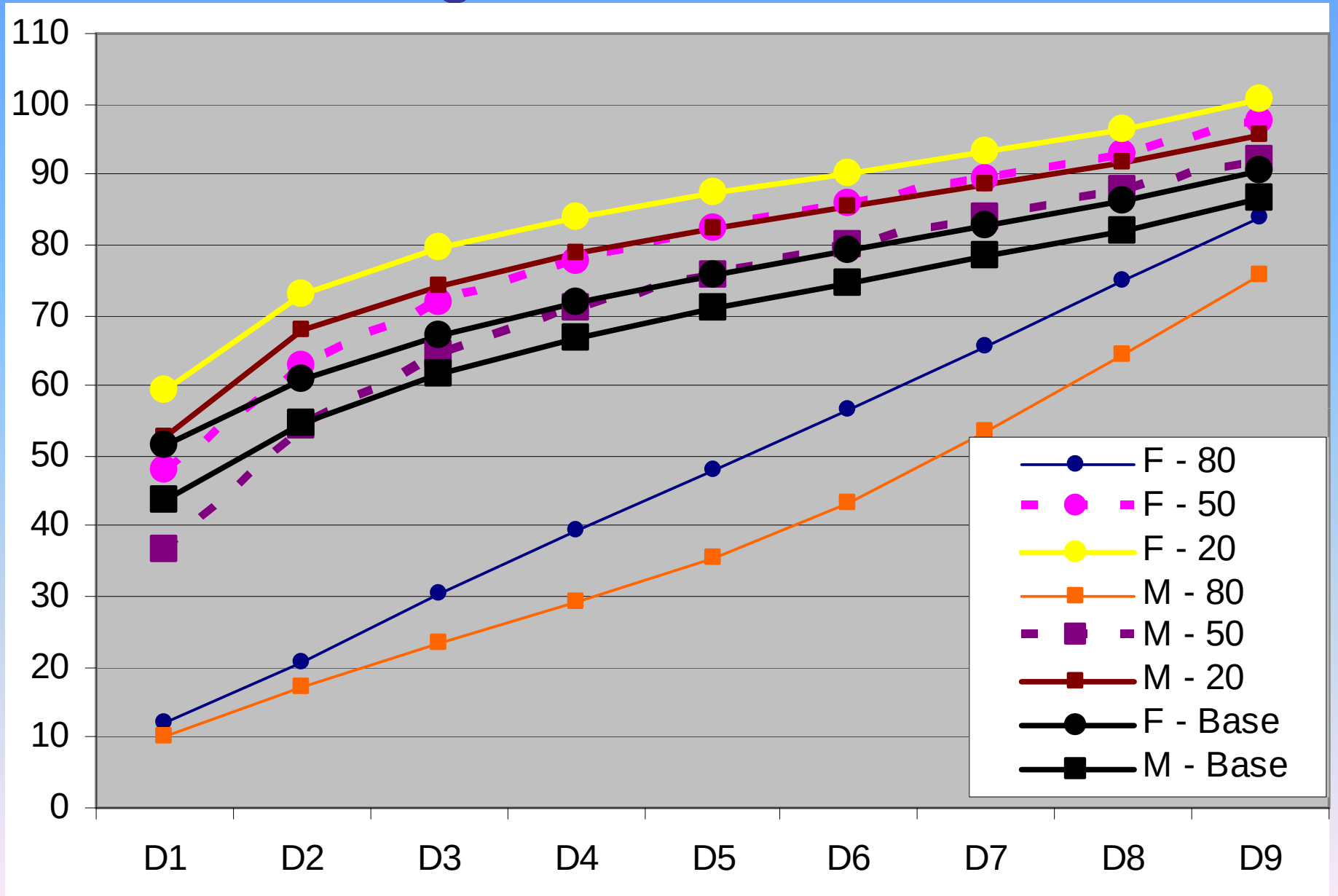
Distributions (%) of Health-Adjusted Life Lengths by Attained Life Lengths (nearest decades), 1960 Birth Cohort



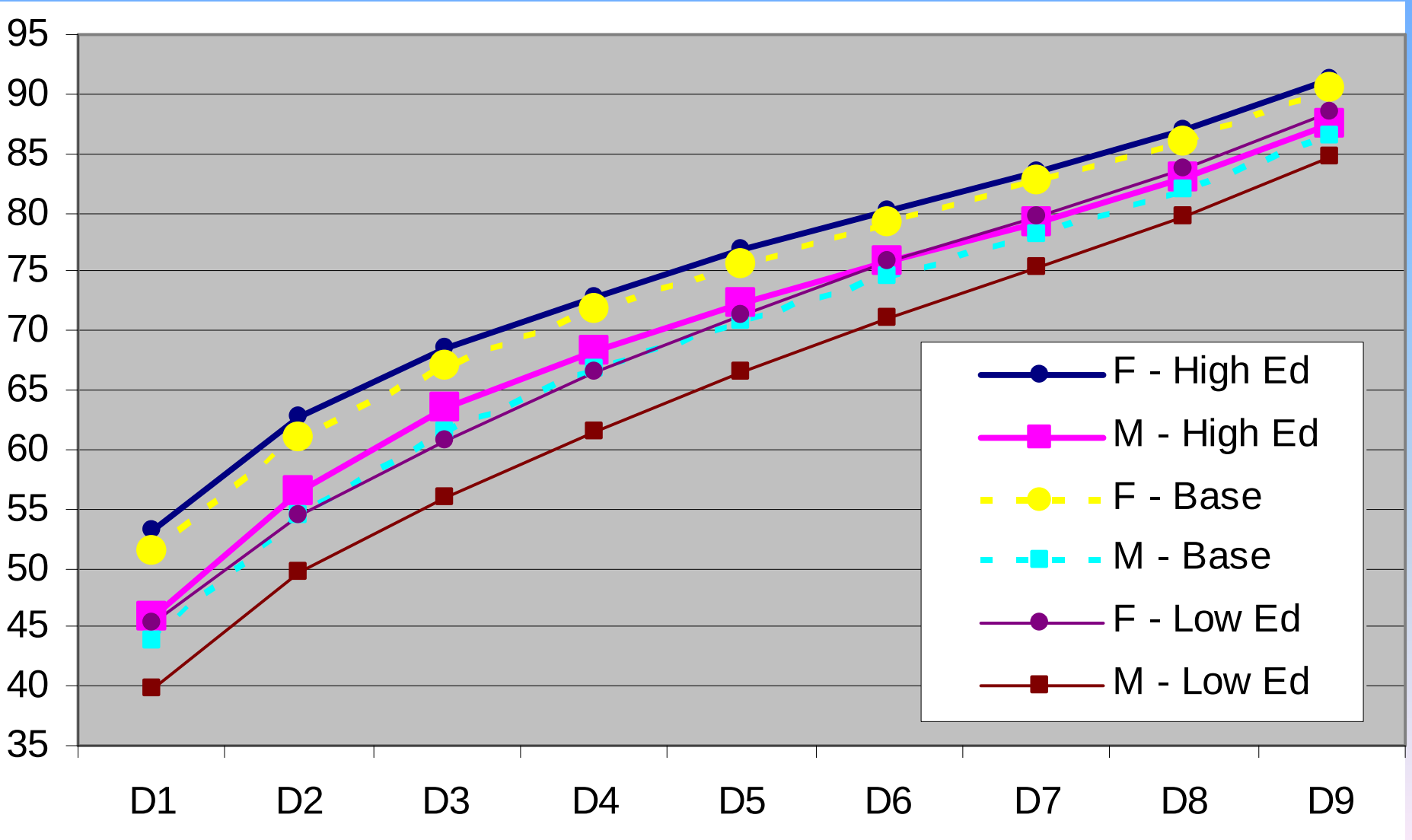
(HUI) Attribute-Deleted HALE



“What If” – Age Effects



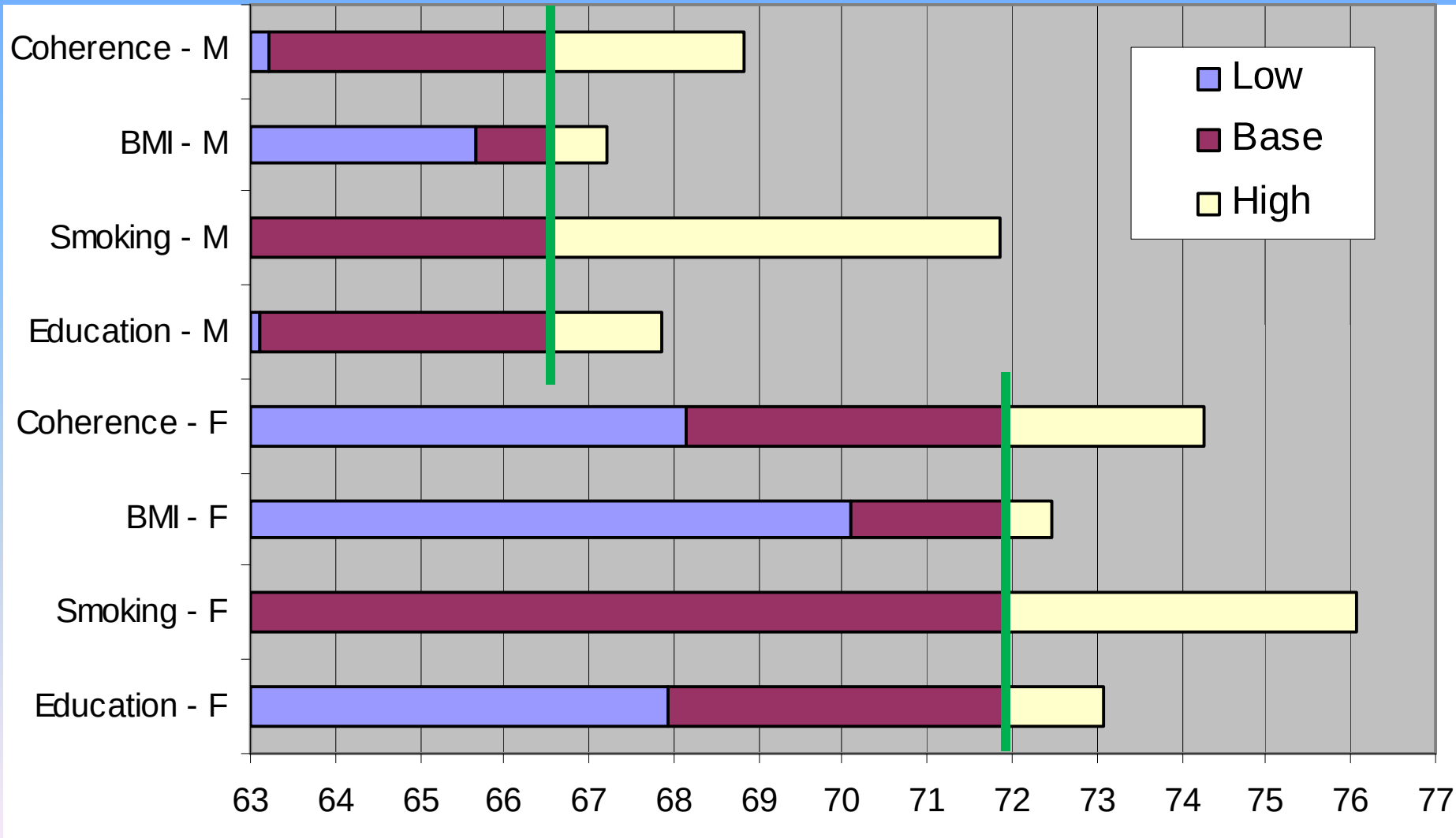
“What If” – Education Effects



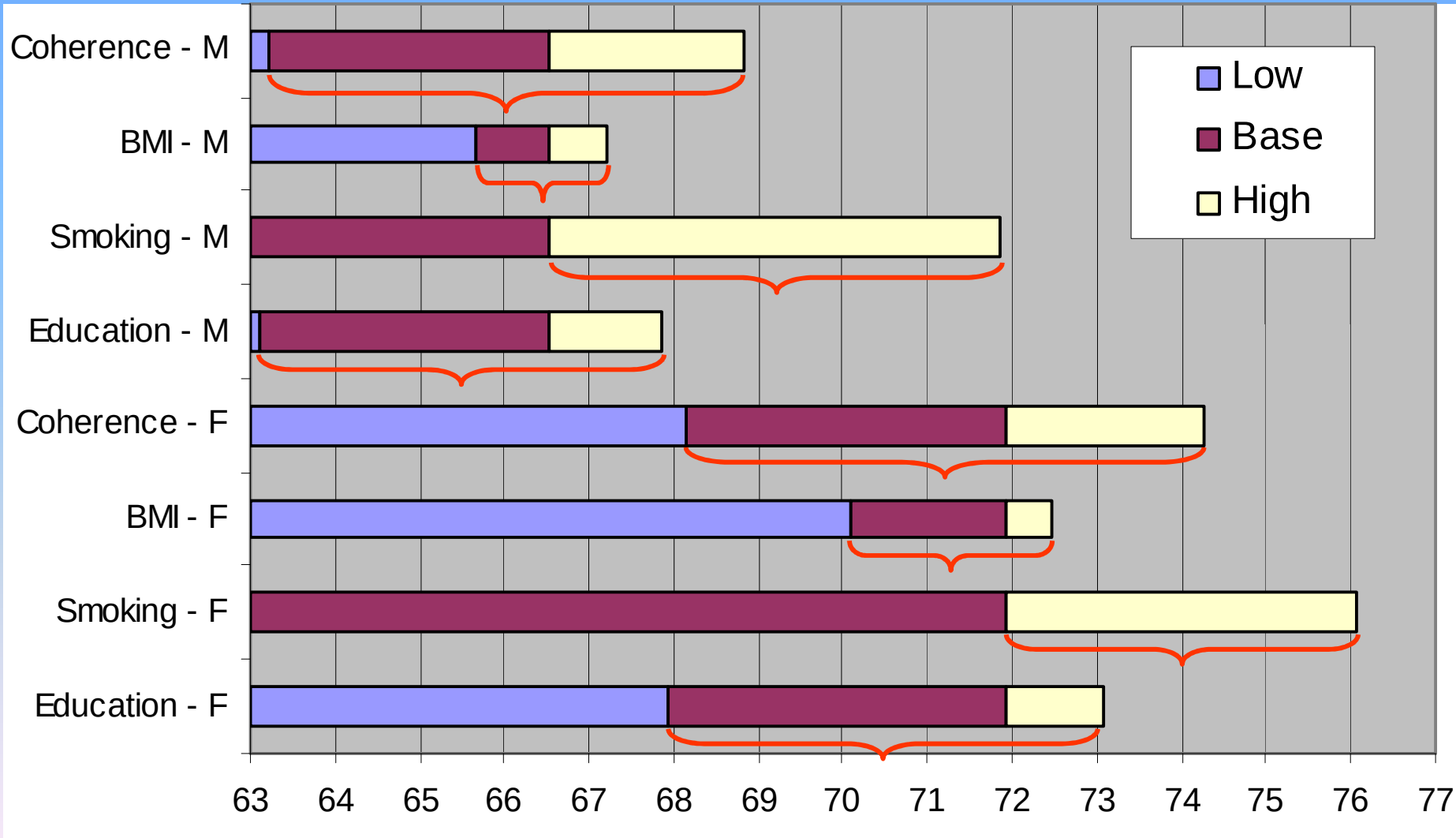
Four Sets of "What If?" Scenarios

- education – either all less than completed secondary, or all at least completed BA
- smoking – either status quo or none at all
- BMI – either all at 95th percentile, or all at 5th percentile
- coherence – either all at 95th percentile, or all at 5th percentile

“What If” – Comparative Knockout Effects of Four Health Determinants



“What If” – Comparative Knockout Effects of Four Health Determinants



Concluding Comments

- HealthPaths – still exploratory
- proof of concepts
  - novel use of bootstrap weights for estimation of a coherent network of dynamic relationships
  - by design, closely coupled with a dynamic microsimulation model
  - HealthPaths as analogue of knockout gene models
  - focus on full lifecycle HALE and health-adjusted life length as “bottom line” health indicator
- fascinating preliminary results: BMI << smoking / education << sense of coherence
  - caveat: sampling + specification + correlated cross equation errors are non-trivial

Antonovsky's Sense of Coherence
"How often do you have ...

- ... the feeling that you don't really care about what goes on around you?
- How often in the past were you surprised by the behaviour of people whom you thought you knew well?
- How often have people you counted on disappointed you?
- ... the feeling that you're being treated unfairly?
- ... the feeling you are in an unfamiliar situation and don't know what to do?
- How often do you have very mixed-up feelings and ideas?
- ... feelings inside that you would rather not feel?
- Many people -- even those with a strong character -- sometimes feel like sad sacks (losers) in certain situations. How often have you felt this way in the past?
- ... the feeling that there's little meaning in the things you do in your daily life?
- ... feelings that you're not sure you can keep under control?
- Until now has your life had no clear goals or purpose or has it had very clear goals and purpose?
- When something happens, do you generally find that you overestimate or underestimate its importance or you see things in the right proportion?
- Is doing the things you do every day a source of great pleasure and satisfaction or a source of pain and boredom?