Modeling, Measurement and Management of U.S. Mortality Risk: Underlying Trends By Socioeconomic Group and Cause of Death

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Society of Actuaries Annual Meeting, Toronto, October 2019

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The 'Modelling, Measurement and Management of Longevity and Morbidity Risk' research programme is being funded by the ARC, the SoA and the CIA.

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Outline

- Background and motivation
- Source data
- All-cause mortality
- Cause-of-death mortality
- Cohort effects

Background and motivation

- Interested in mortality variation by socio-economic group
- Different levels of mortality
- Variable inequality gap through time
- Some differences due to controllable risk factors (e.g. smoking)

- We seek to understand the differences and dynamics

Data

- Exposures
- Deaths
- Leading to death rates, subdivided by
  - gender
  - education level
  - cause of death

Data: Deaths

- Source: Centers for Disease Control and Prevention (CDC)
- Individual death records 1989-2015
- Anonymised data from death certificates
- Calendar year
- Gender and age at death
- Educational attainment
- Cause of death
- .....

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Data: Deaths – issues

- Cause of death:
  - Classification: ICD-9 & ICD-10
  - Other changes in practice (e.g. UK 2011)
- Education:
  - Two classification systems
  - Missing data (years; states)

Data: Exposures

- Multiple sources
  - Human Mortality Database (HMD)
  - Current Population Survey (CPS)

- HMD
  - total US population, $E(t, x)$
  - adjusted for anomalies using Cairns et al. (2016)

Data: Exposures (cont.)

- CPS
  - sample data; $\sim$60,000 records per year
  - ages up to 79
  - includes educational attainment
- Small sample $\Rightarrow$ education proportions are noisy

Data: Exposures (cont.)

- Redondo Loures & Cairns (2019):
  - smoothing through time by cohort
  - smoothing for consistency within calendar years

$$E(e, t+s, x+s) = E(t+s, x+s).R(e, t+s, x+s)$$

  - e = education level
  - $R(e, t+s, x+s)$ = smoothed education proportions for cohort $t-x$.

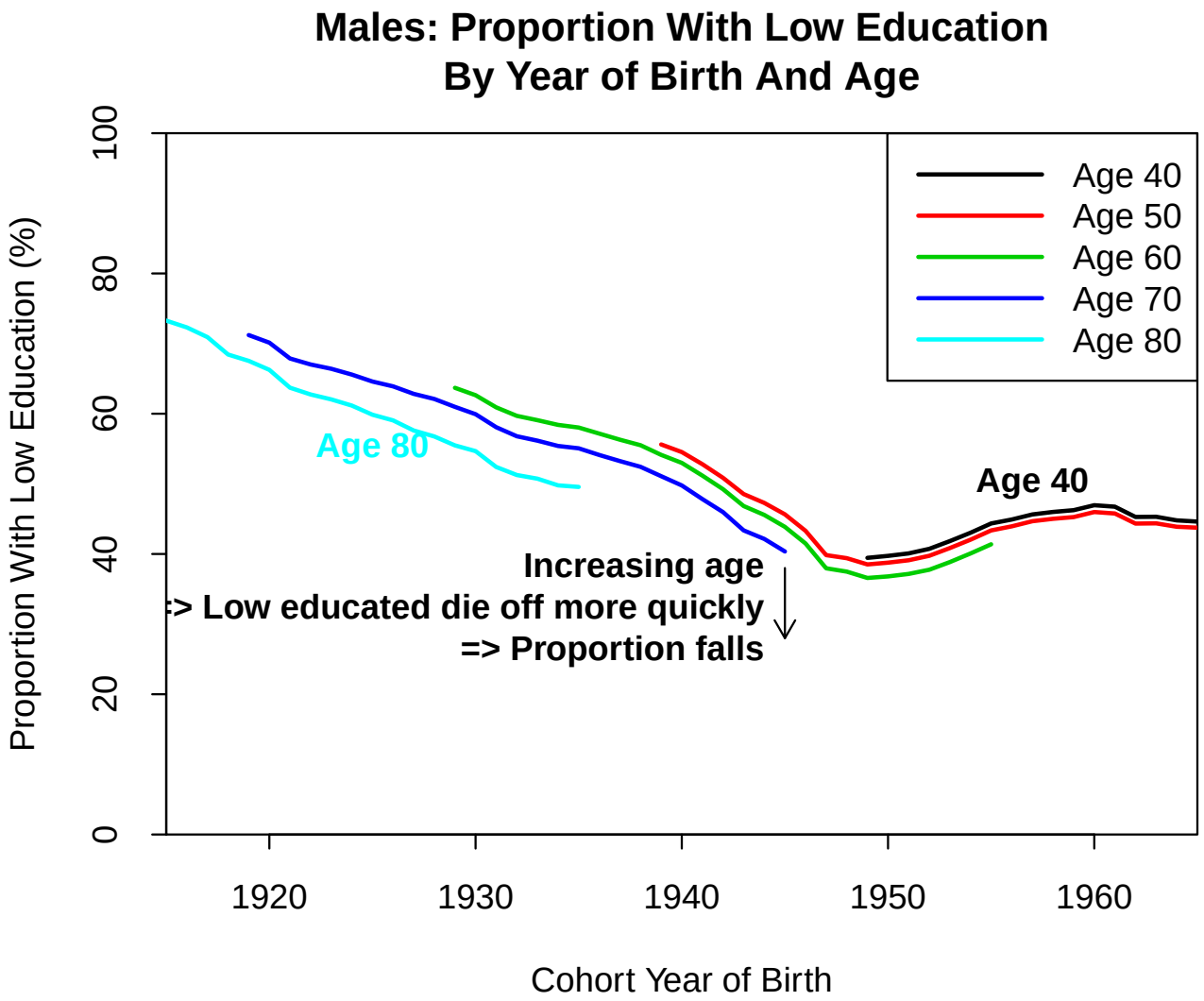
Education level: two coding systems

- Coding system 1 $\rightarrow$ system 2
  (years $\rightarrow$ level)
- Reasonable consistency for
  - Low: $\leq$ high school graduate
  - Medium: some college/university $<$ BSc
  - High: $\geq$ BSc

Education level: two coding systems (cont.)

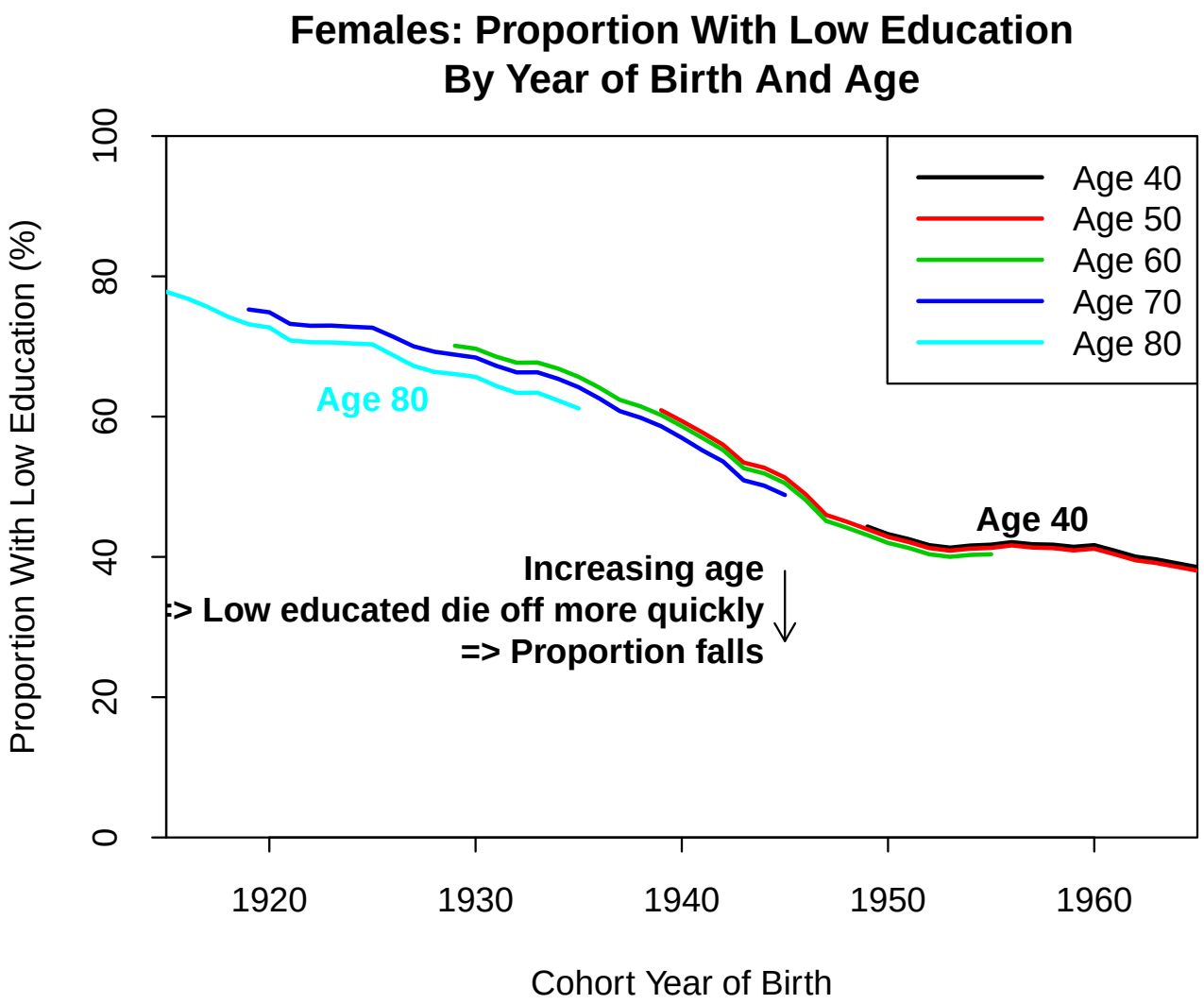
- Education level is self-reported
  (deaths and exposures)
  $\Rightarrow$ potential for unconscious bias
  E.g. true *medium* reported as *high* education on death certificate
  More obvious when we extrapolate above age 79 (CPS max)
- Final split:
  - Low: high school graduate or less
  - High: some college/university plus BSc and higher

Low education: males, proportions by cohort



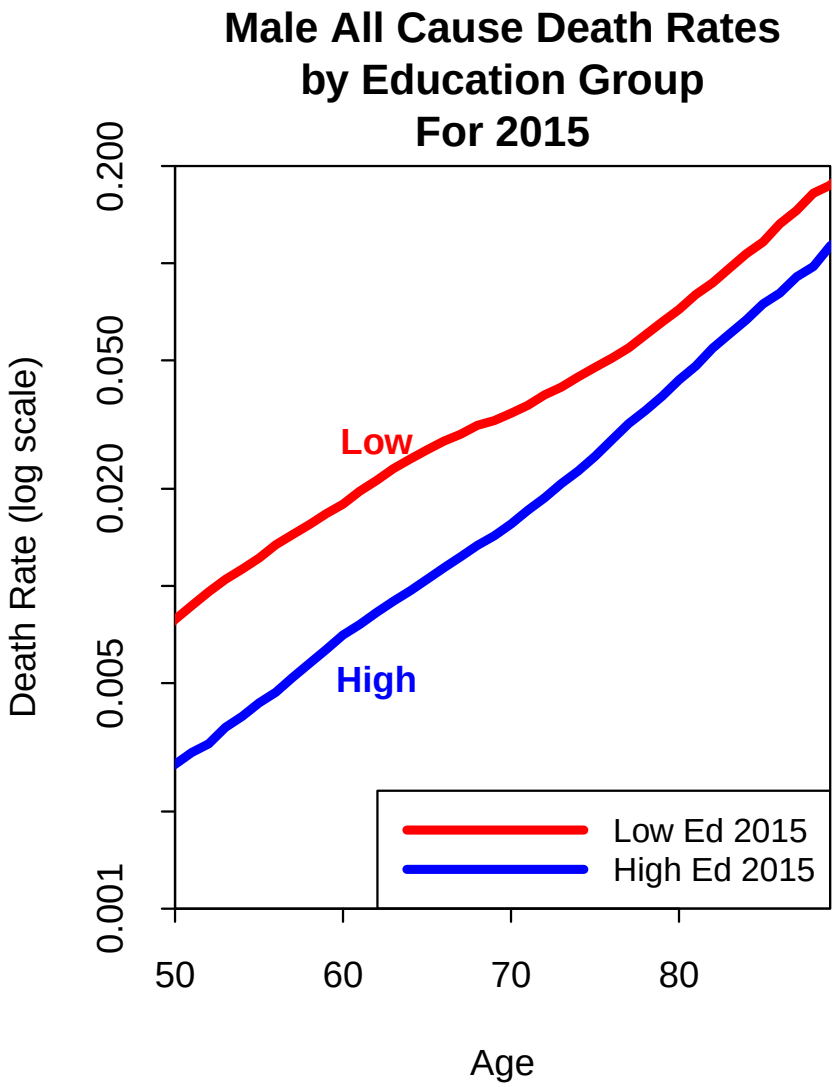
Potential cohort effects: general decline; "peak education": 1950 cohort

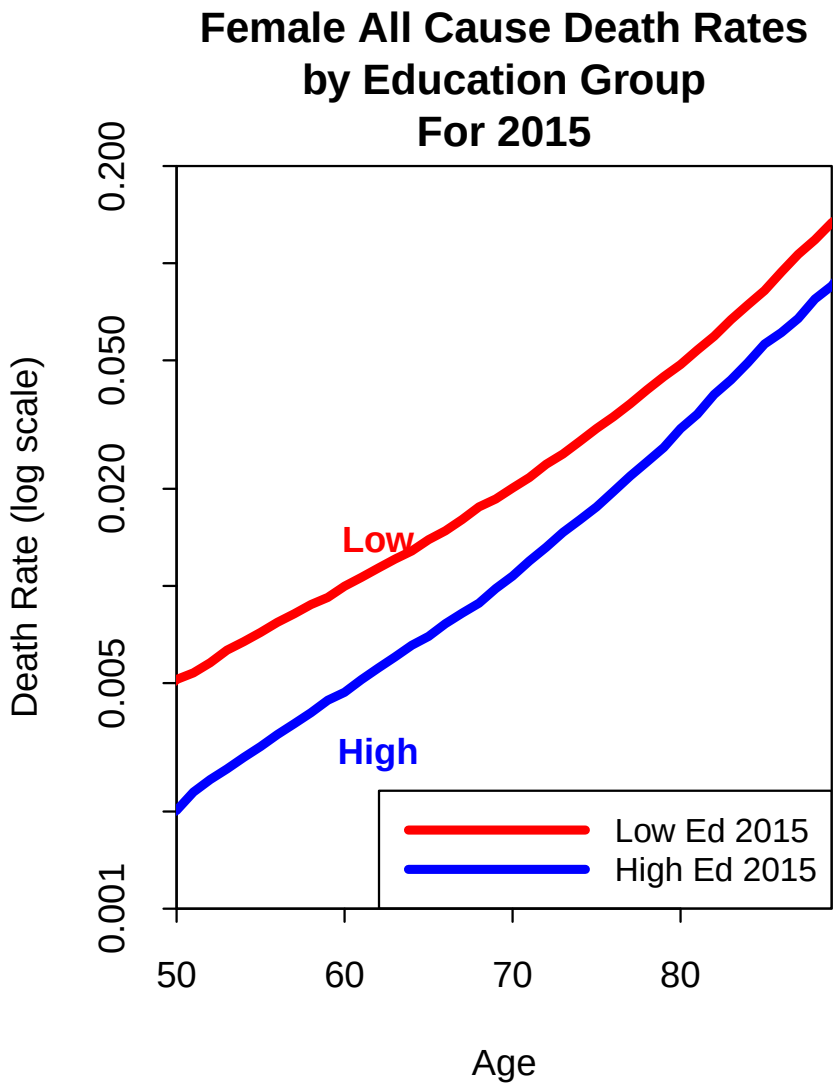
Low education: females, proportions by cohort



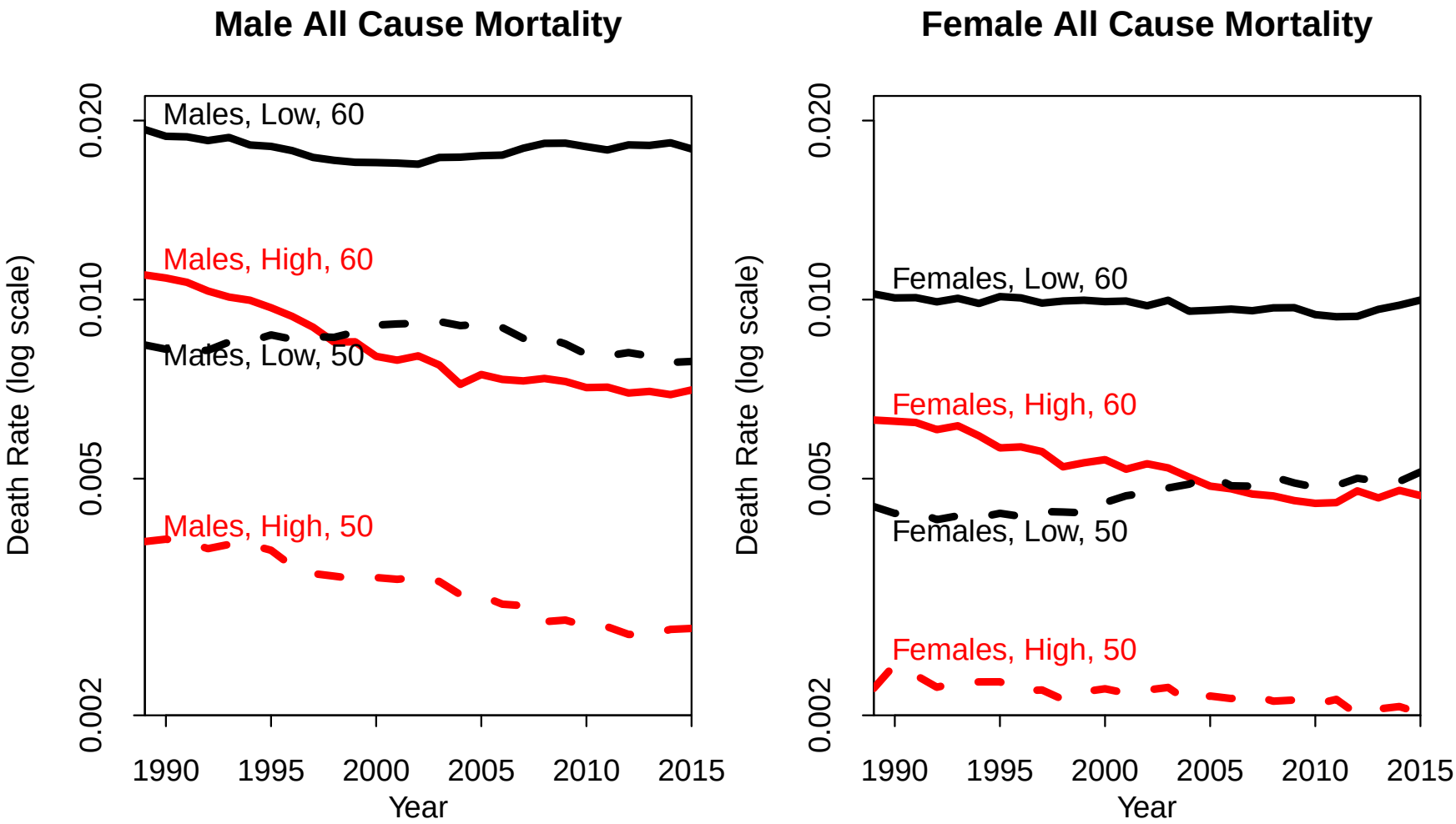
Similar pattern; higher levels of education than males since 1960 cohort

All cause mortality: males, females, 2015





All cause mortality: males, females aged 50, 60



Increasing inequality

Stagnation: low educated groups (Case and Deaton, 2015, 2017)

Deeper dive

- Significant mortality inequality by education group
- Greater inequality at younger ages
- Some evidence for cohort effects (year of birth)

- Cause of death data can give us some insight into trends and inequalities

Purpose of looking at cause of death data

- What are the key drivers of all-cause mortality?
- How are the key drivers changing over time?
- Which causes of death have high levels of inequality?
- Can we point to specific causes of death as responsible for *growing inequality*?

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Drivers of mortality improvements/differences

- Medical advances
- Health spending
- Public health initiatives
- Individual risk factors:
  - Controllable

    e.g. smoking, diet, exercise, alcohol, sun, drugs, ...

    leading to cohort effects and inequality
  - Not (easily) controllable

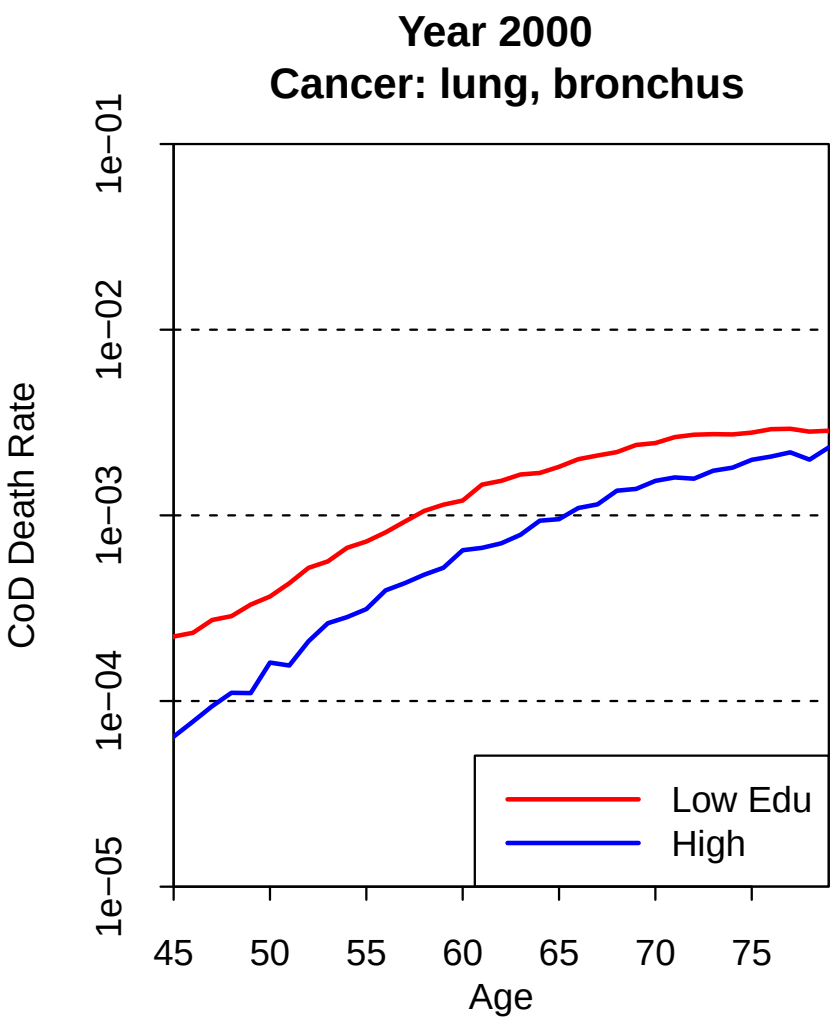
    e.g. genetic, affluence, education,

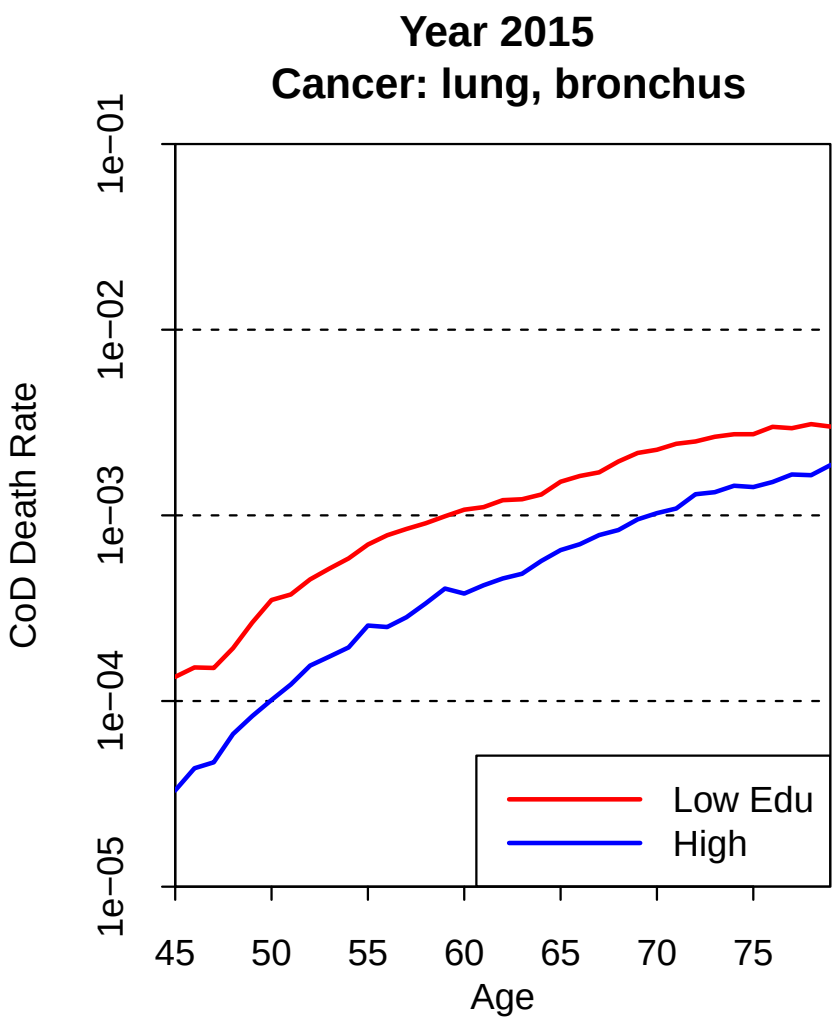
    character/personality traits, unemployment, ...

Cause of Death Groupings

1	Infectious diseases	2	Cancer: mouth, gullet
3	Cancer: stomach	4	Cancer: gut, rectum
5	Cancer: larynx	6	Cancer: trachea
7	Cancer: lung, bronchus	8	Cancer: breast
9	Cancer: uterus, cervix	10	Cancer: ovary
11	Cancer: other female genital	12	Cancer: prostate
13	Cancer: other male genital	14	Cancer: liver
15	Cancer: pancreas	16	Cancer: skin
17	Cancer: urinary organs	18	Cancer: bladder
19	Cancer: lymphatic	20	Benign tumours
21	Cancer: other locations		
22	Diseases: blood	23	Diabetes
24	Vascular dementia	25	Other mental illness
26	Diseases of nervous system excl. Alzh.	27	Alzheimers
28	Blood pressure + rheumatic fever	29	Ischaemic heart diseases
30	Other heart diseases	31	Diseases: cerebrovascular
32	Diseases: circulatory		
33	Chronic Obstructive Pulmonary Disease	34	Influenza, penumonia
35	Other respiratory diseases		
36	Diseases: digestive (excl. alcohol (# 40))	38	Diseases: urine, kidney,...
39	Diseases: skin, bone, tissue		
40	Road/other accidents	41	Other causes
37	Alcohol $\rightarrow$ liver disease	42	Suicide
43	Accidental Poisonings		

Females: lung cancer

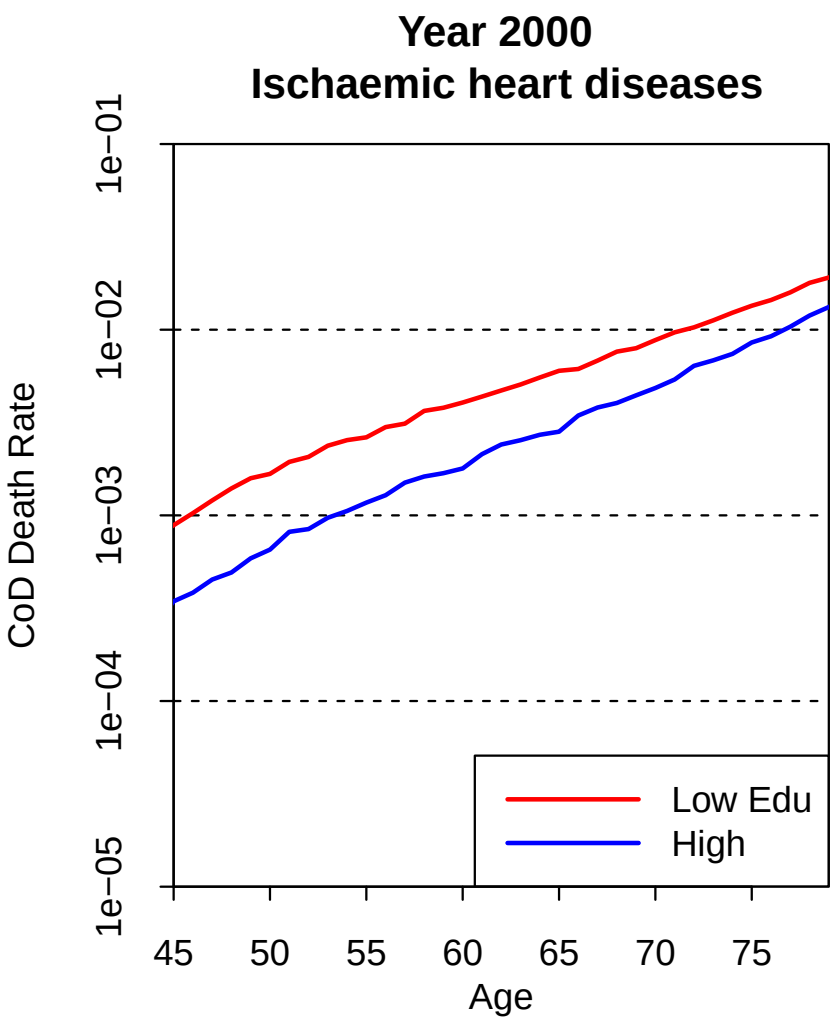


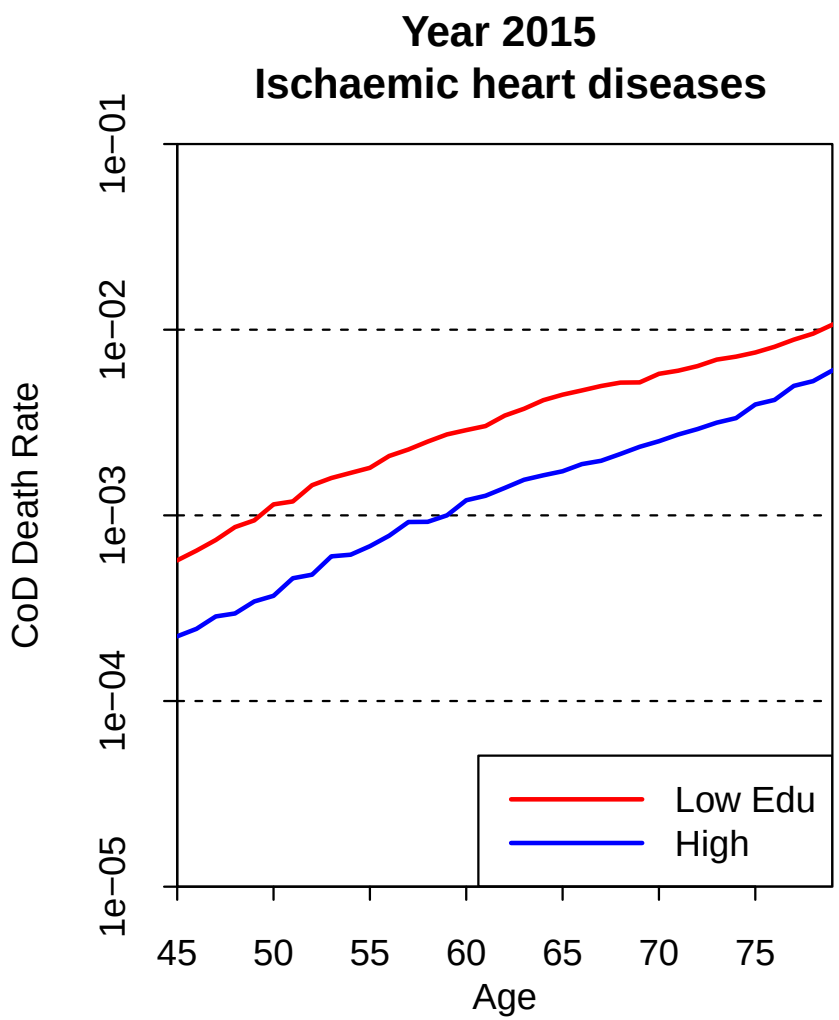


Wider gap; widening gap; stagnation

2017, age 45: $4\times \Rightarrow$ approx $4\times$ as many smokers

Males: ischaemic heart disease



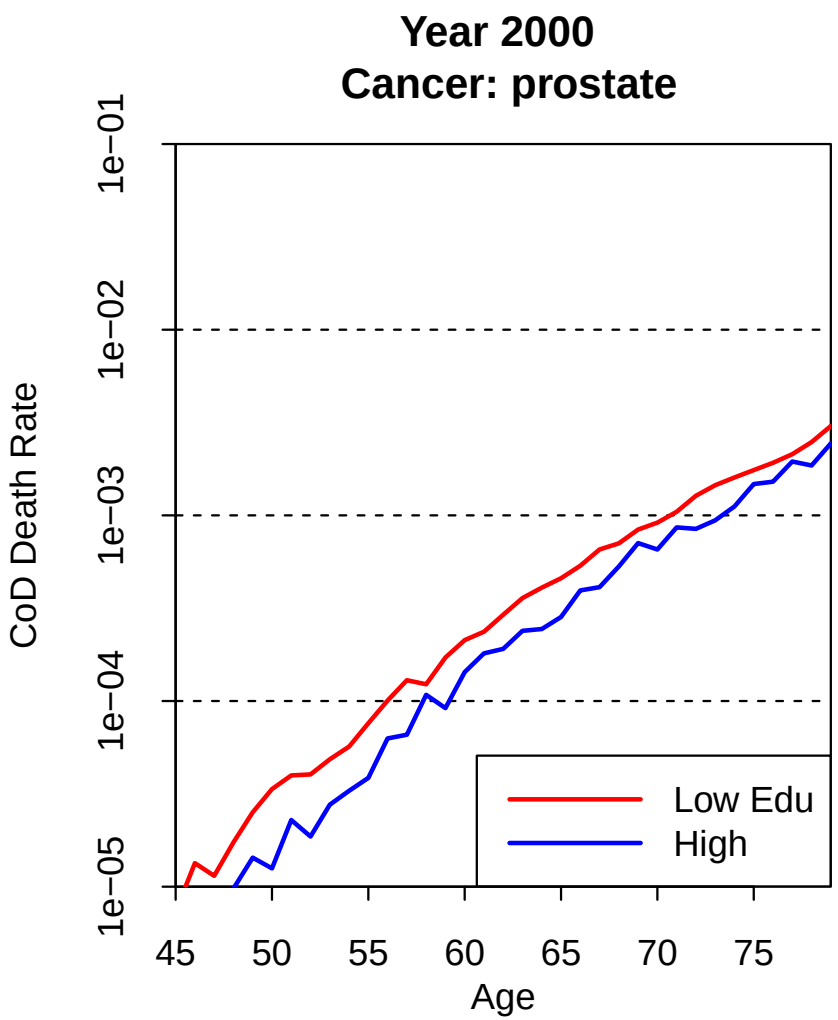


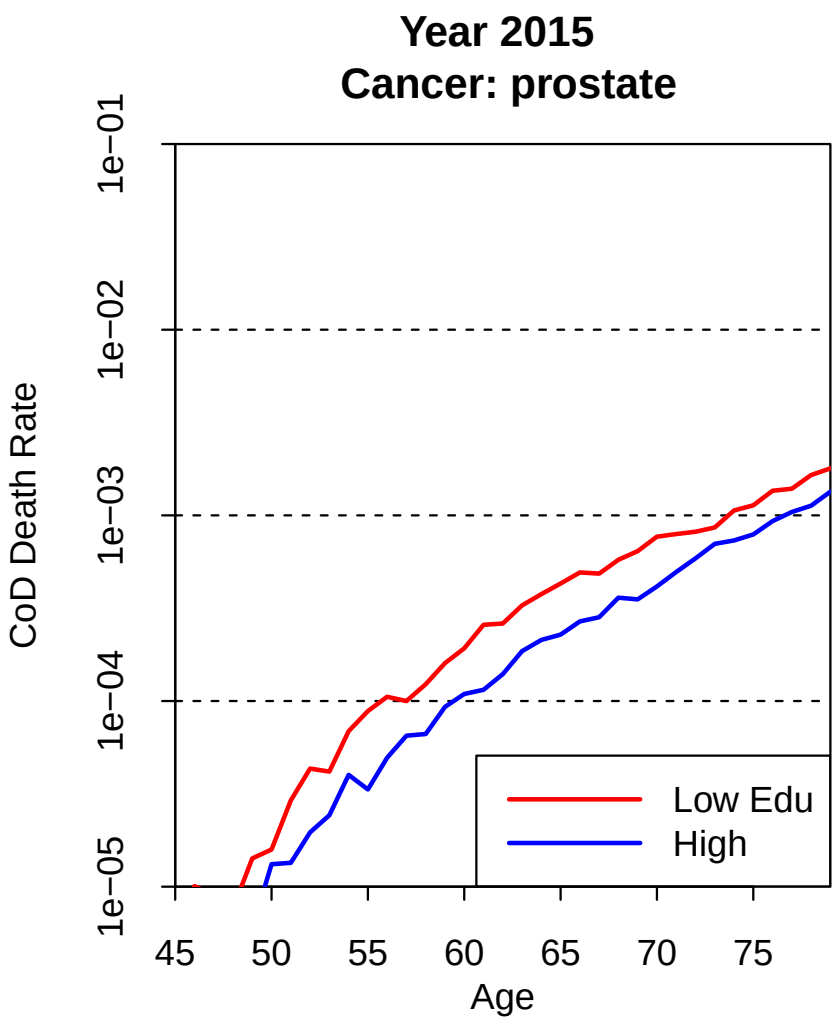
Wide gap; widening gap; improvements over time

Impact of Controllable Risk Factors

- Risk factors (controllable and not controllable)
  $\Rightarrow$
  Impact on cause of death rates
- Some risk factors $\Rightarrow$ big impact on some causes
  e.g. smoking $\longrightarrow$ lung cancer
  e.g. several risk factors $\longrightarrow$ ischaemic heart disease
  $\Rightarrow$ significant inequality gaps
- Some causes of death:
  no known (significant) controllable risk factors
  e.g. prostate cancer, breast cancer

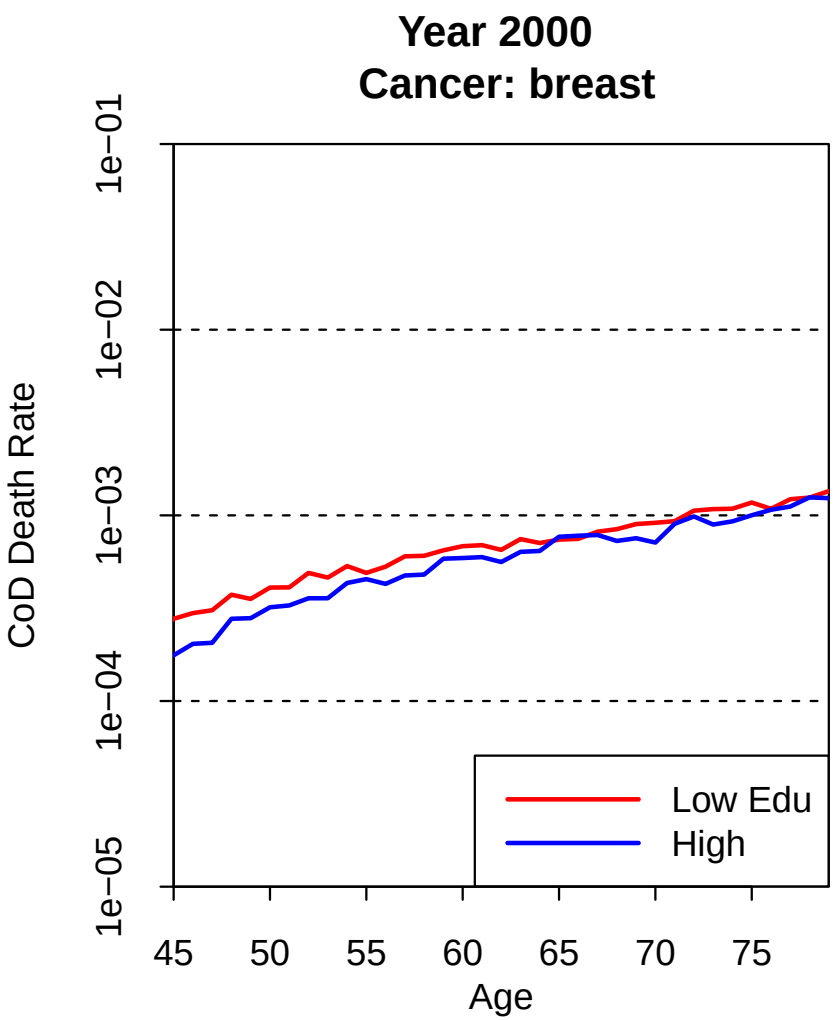
Males: prostate cancer

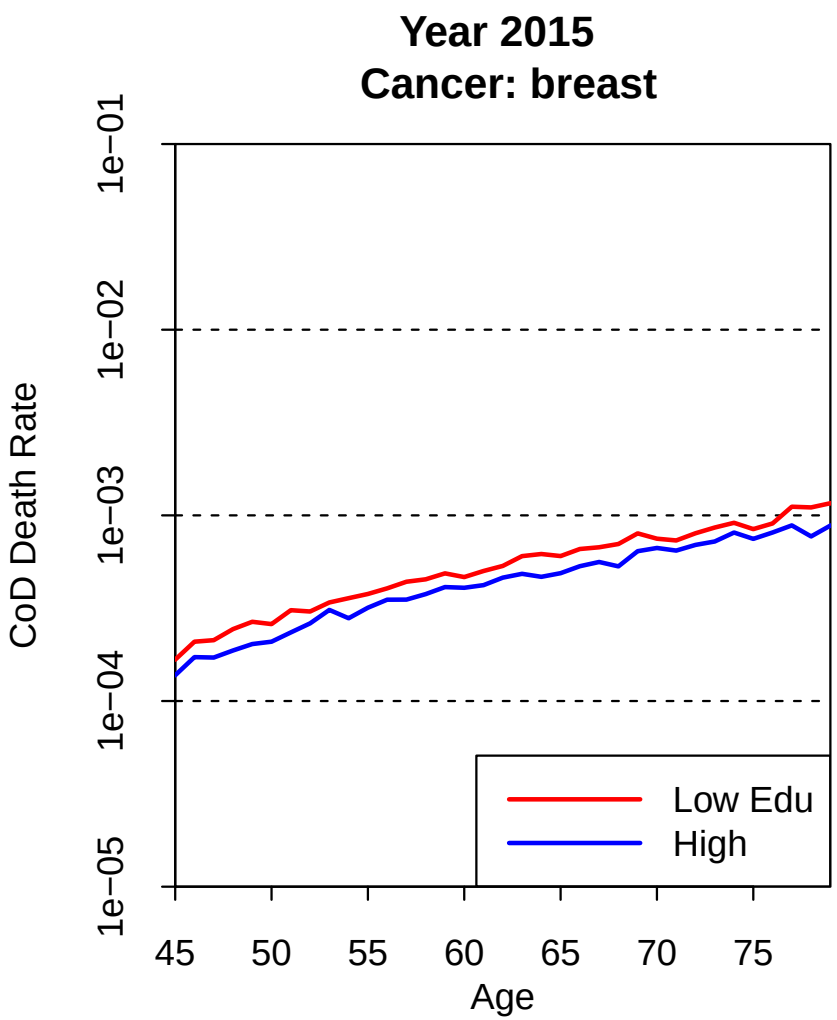




Small gap: healthcare; conscientiousness; genetic
(but wider gap than e.g. England and Denmark)

Females: breast cancer

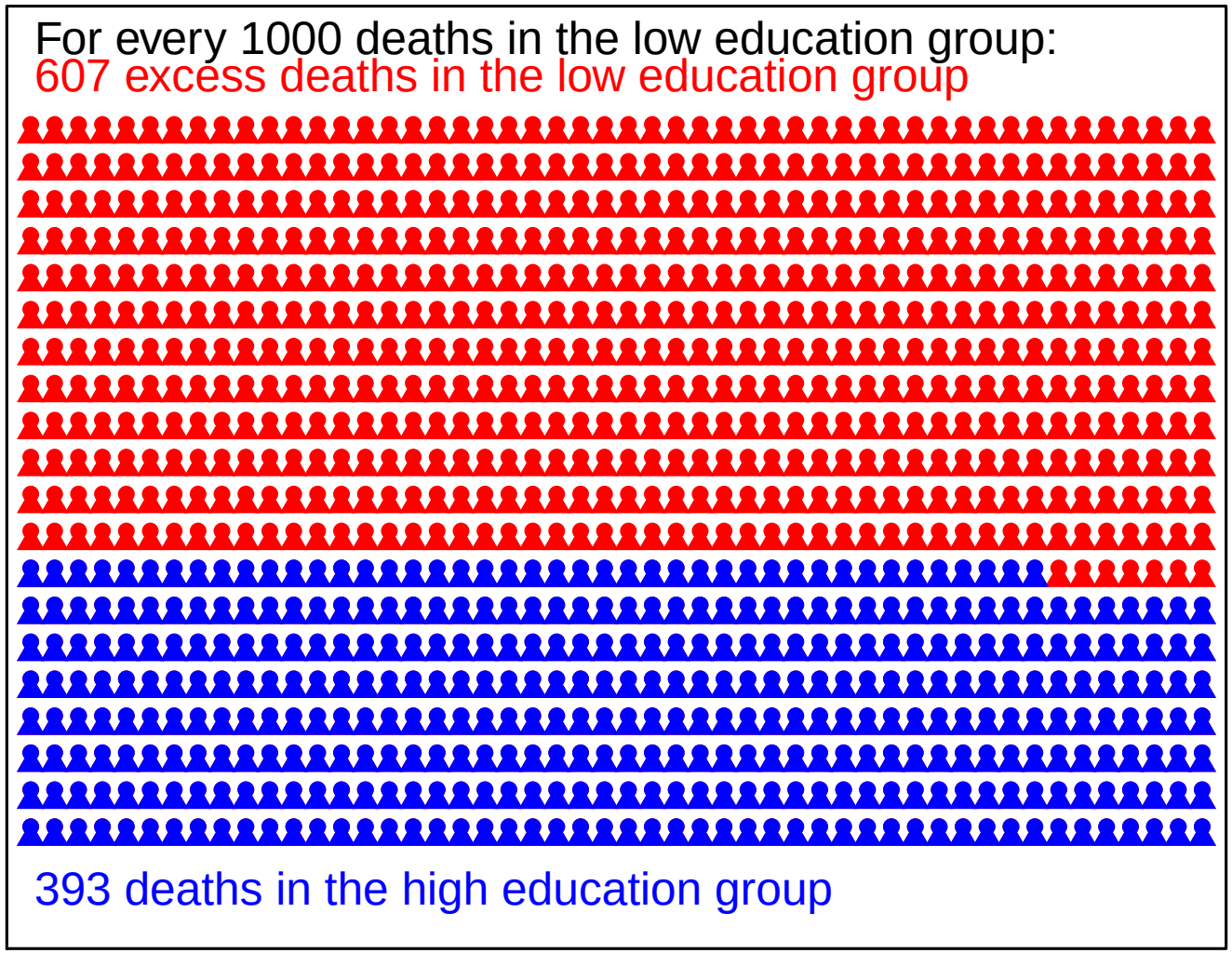




Small gap: healthcare; conscientiousness; genetic
(but wider gap than e.g. England and Denmark)

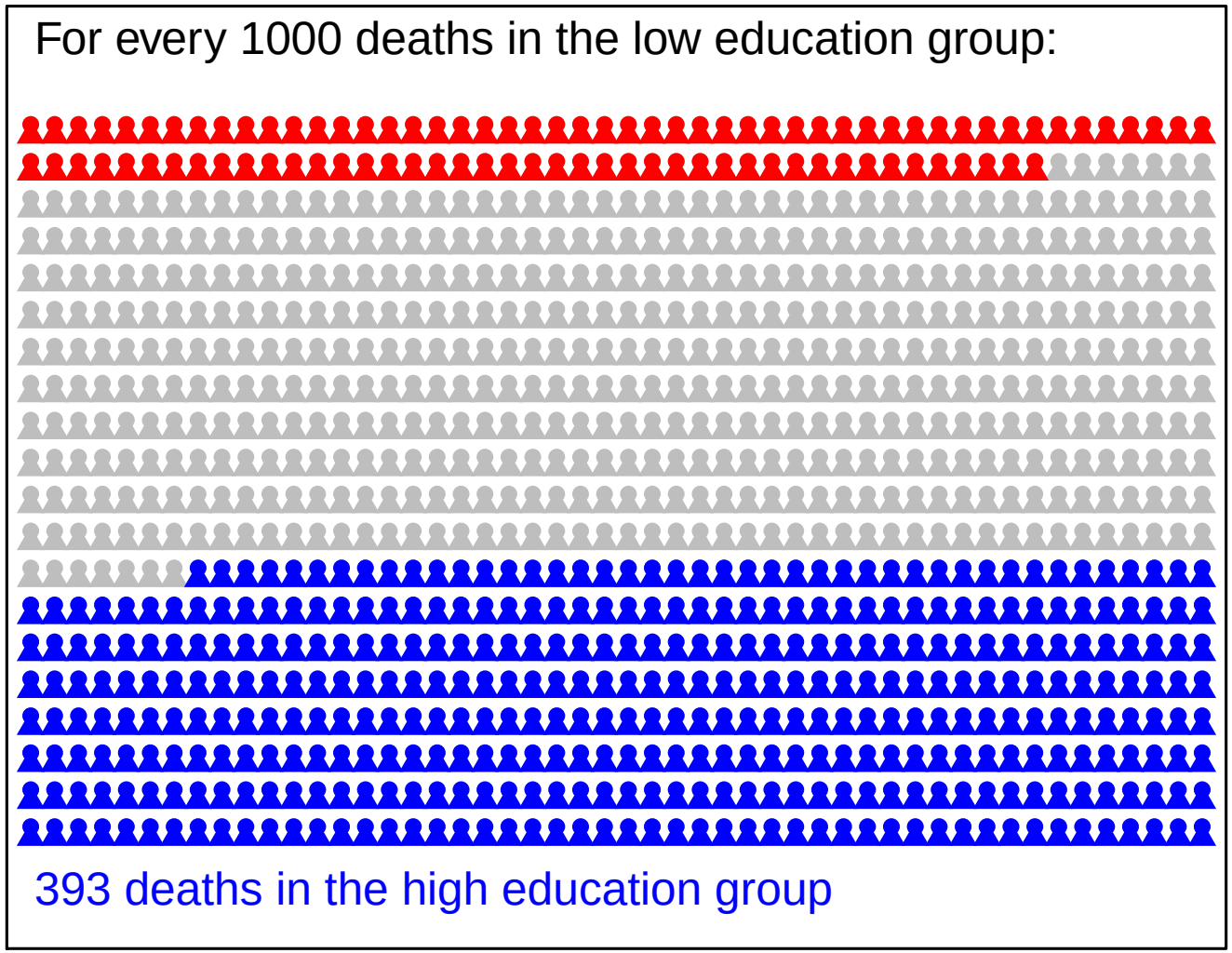
Differences between low and high education groups

Low v High Educated Males Aged 60



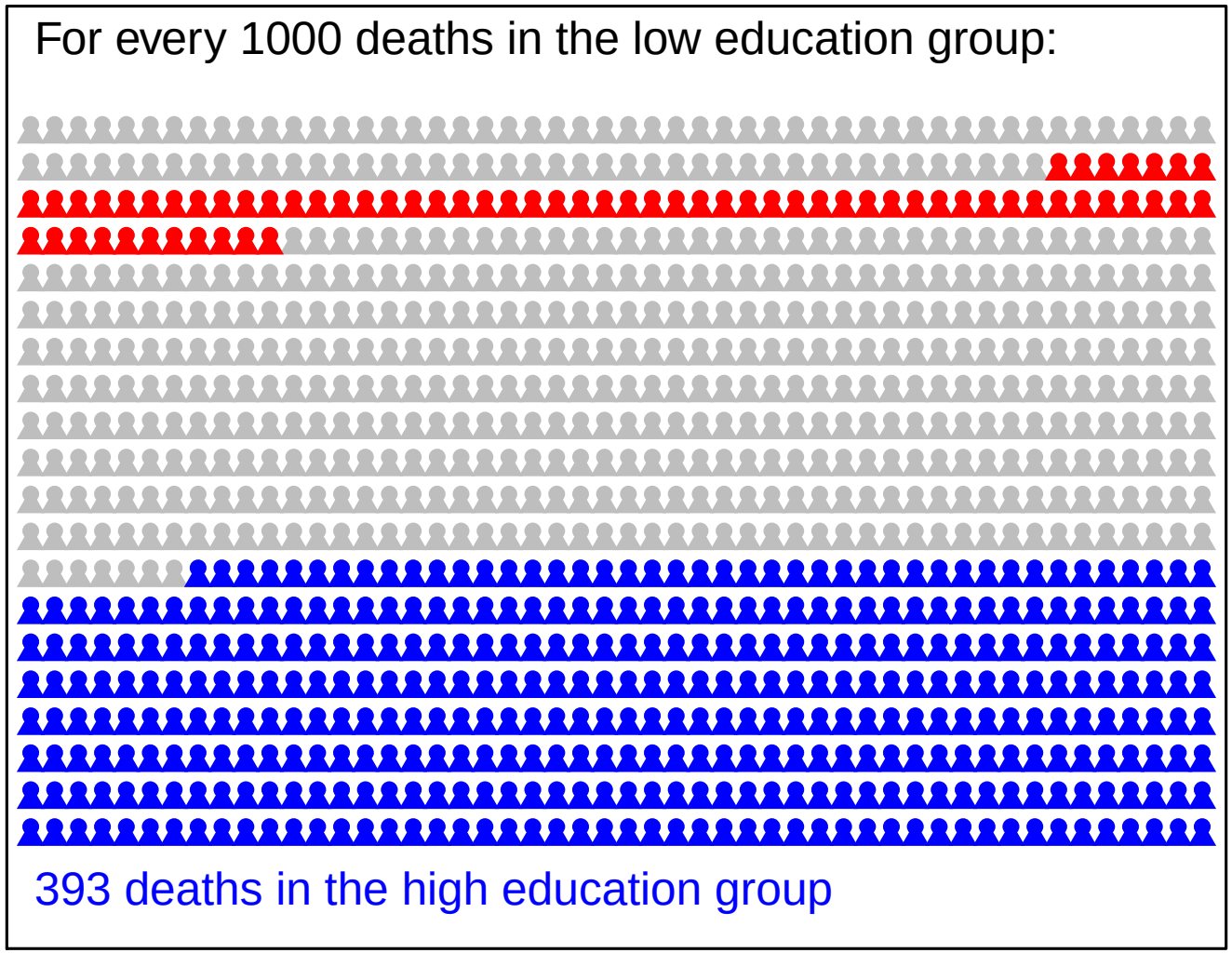
Differences between low and high education groups

Low v High Educated Males Aged 60
Ischaemic Heart Disease: 93 excess deaths



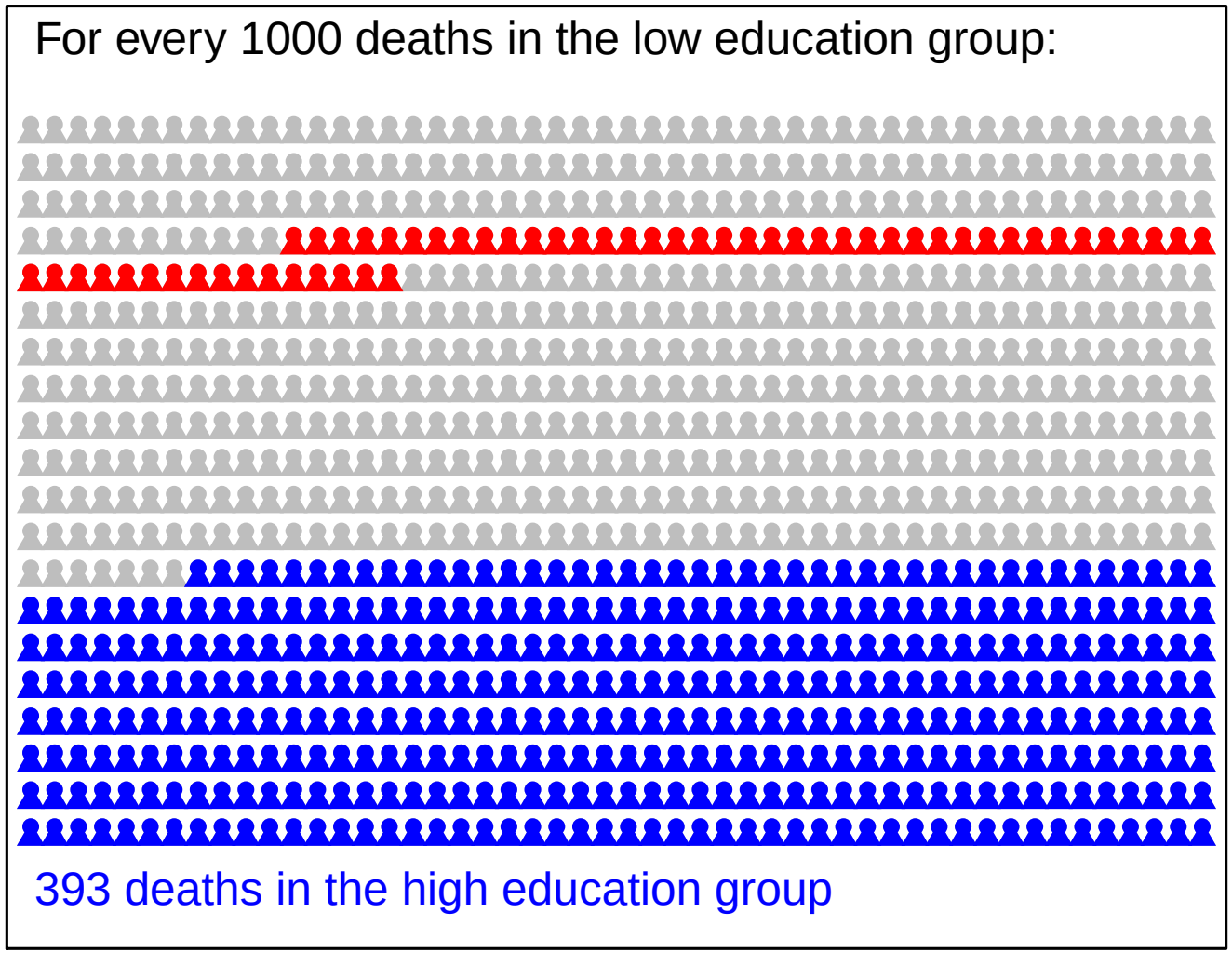
Differences between low and high education groups

Low v High Educated Males Aged 60
Lung Cancer: 68 excess deaths



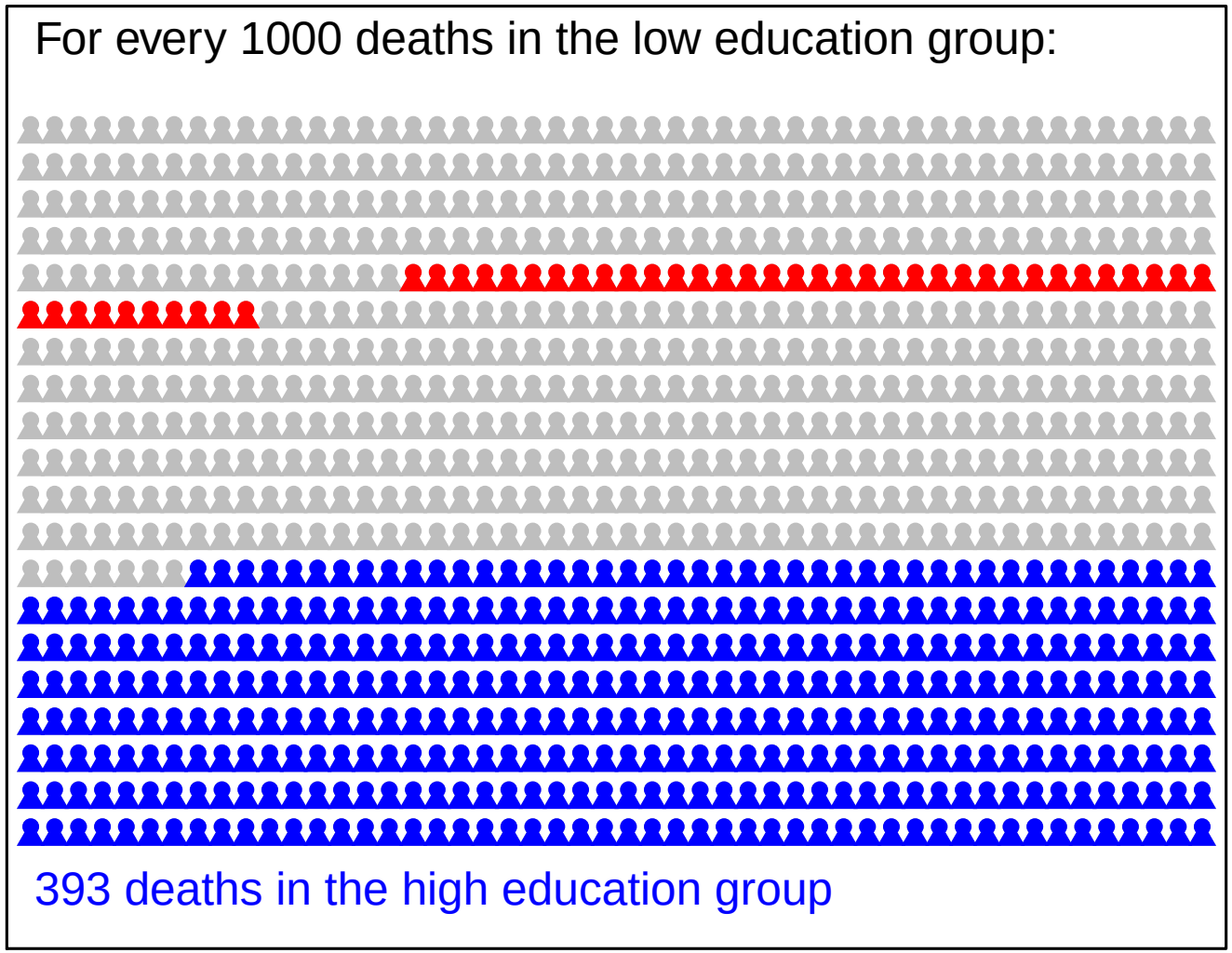
Differences between low and high education groups

Low v High Educated Males Aged 60
Deaths of Despair: 55 excess deaths



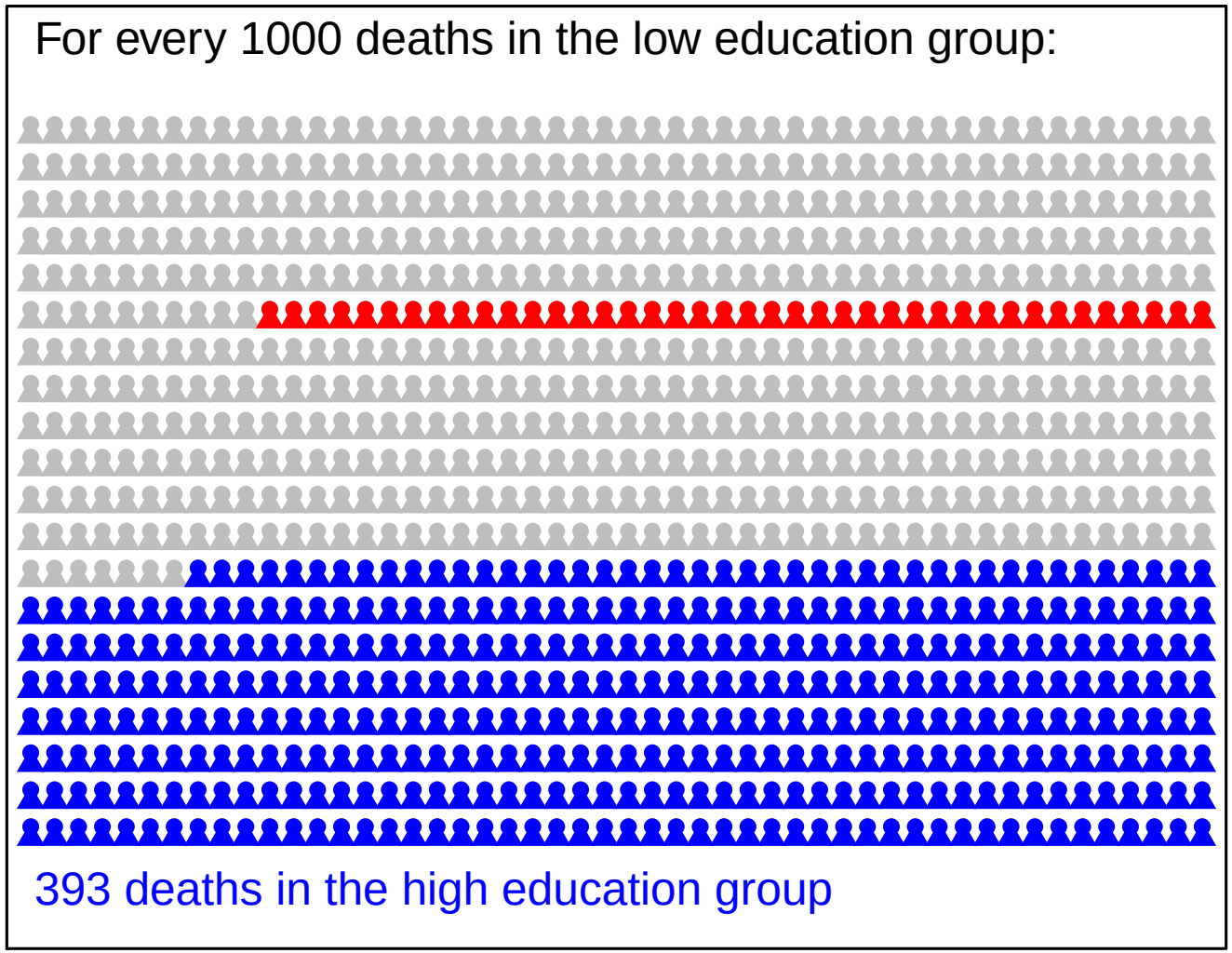
Differences between low and high education groups

Low v High Educated Males Aged 60
Chronic Obstructive Pulmonary Disease: 44 excess deaths



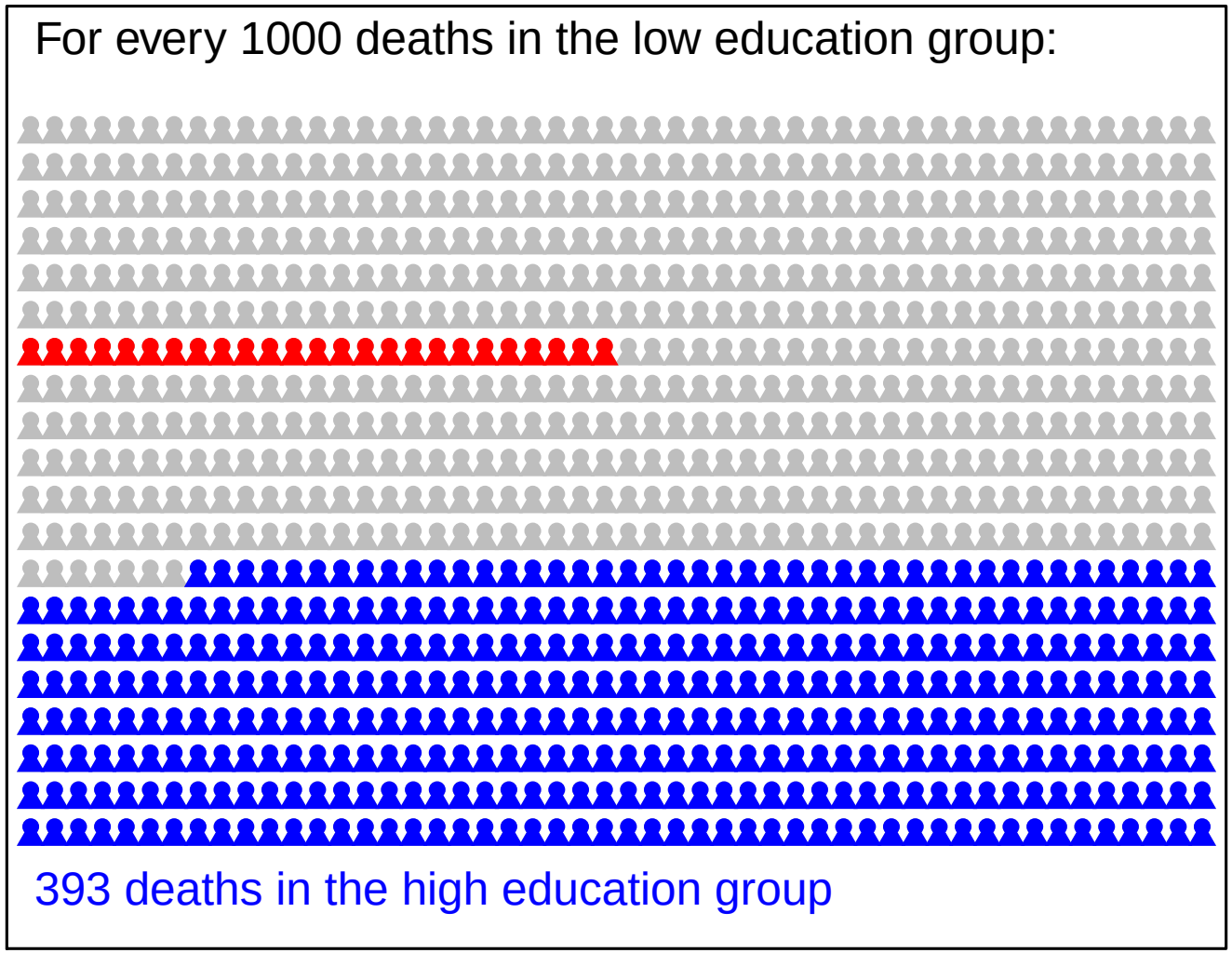
Differences between low and high education groups

Low v High Educated Males Aged 60
Other Heart Diseases: 40 excess deaths



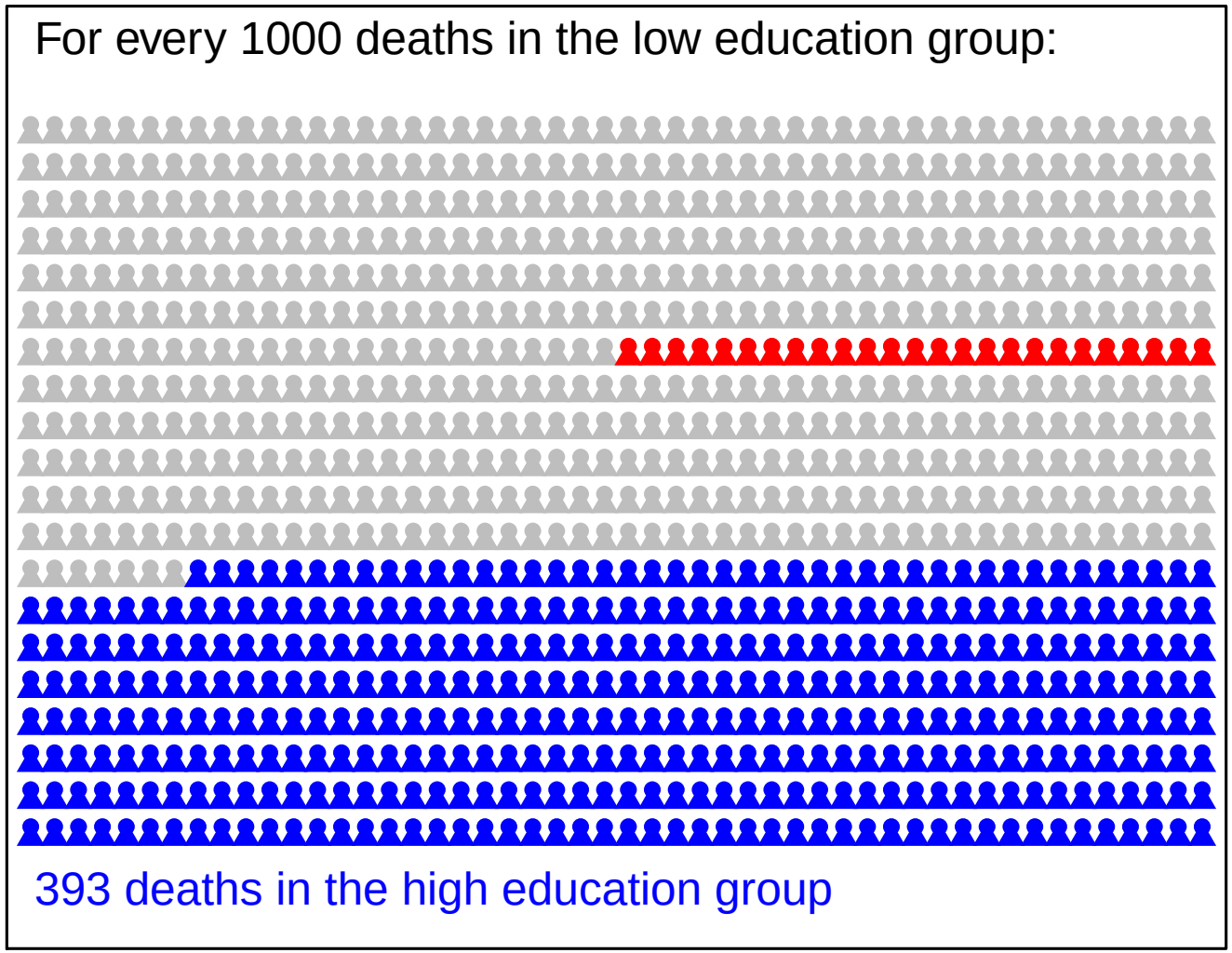
Differences between low and high education groups

Low v High Educated Males Aged 60
Infectious Diseases: 25 excess deaths



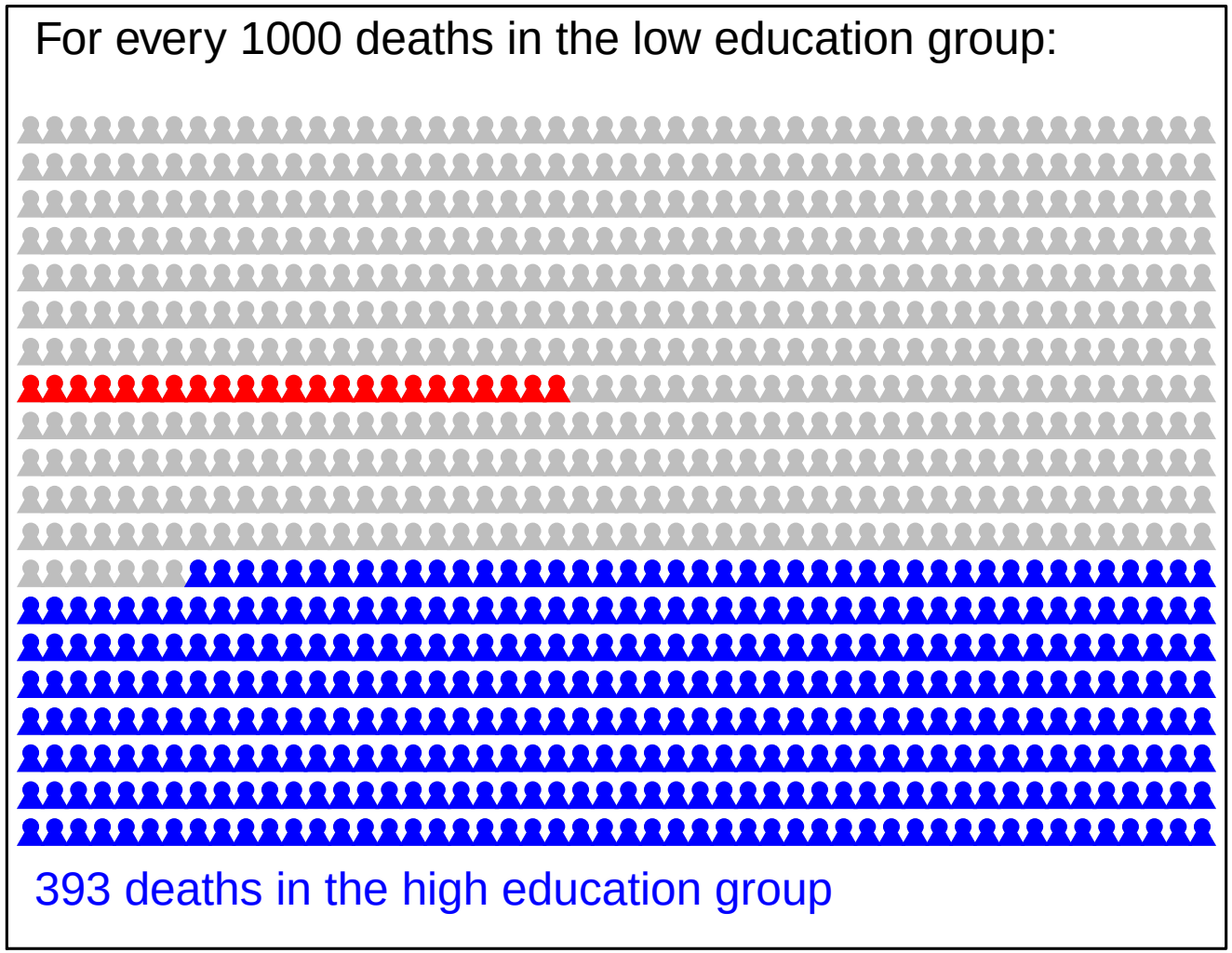
Differences between low and high education groups

Low v High Educated Males Aged 60
Road & Other Accidents: 25 excess deaths



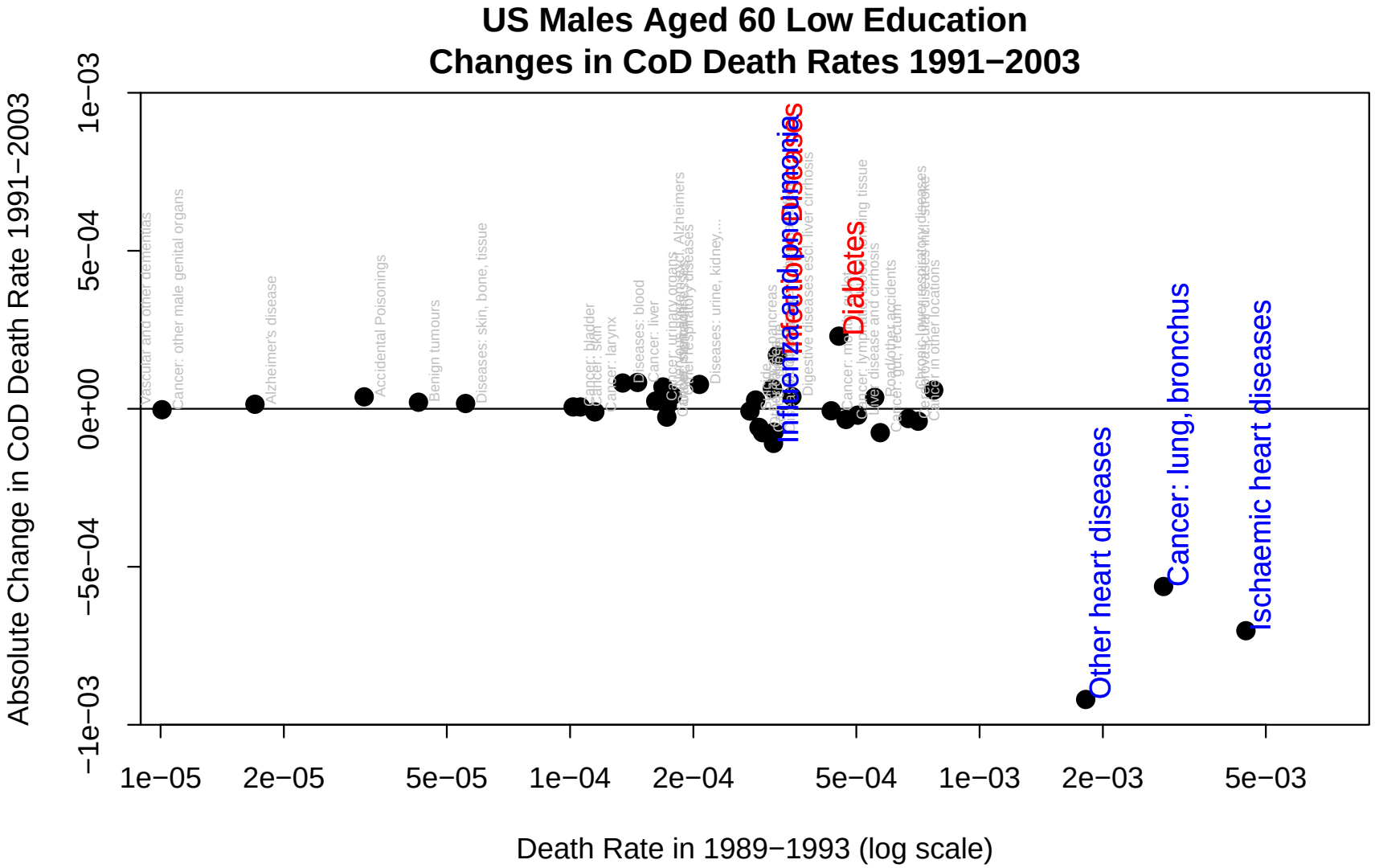
Differences between low and high education groups

Low v High Educated Males Aged 60
Diabetes: 23 excess deaths



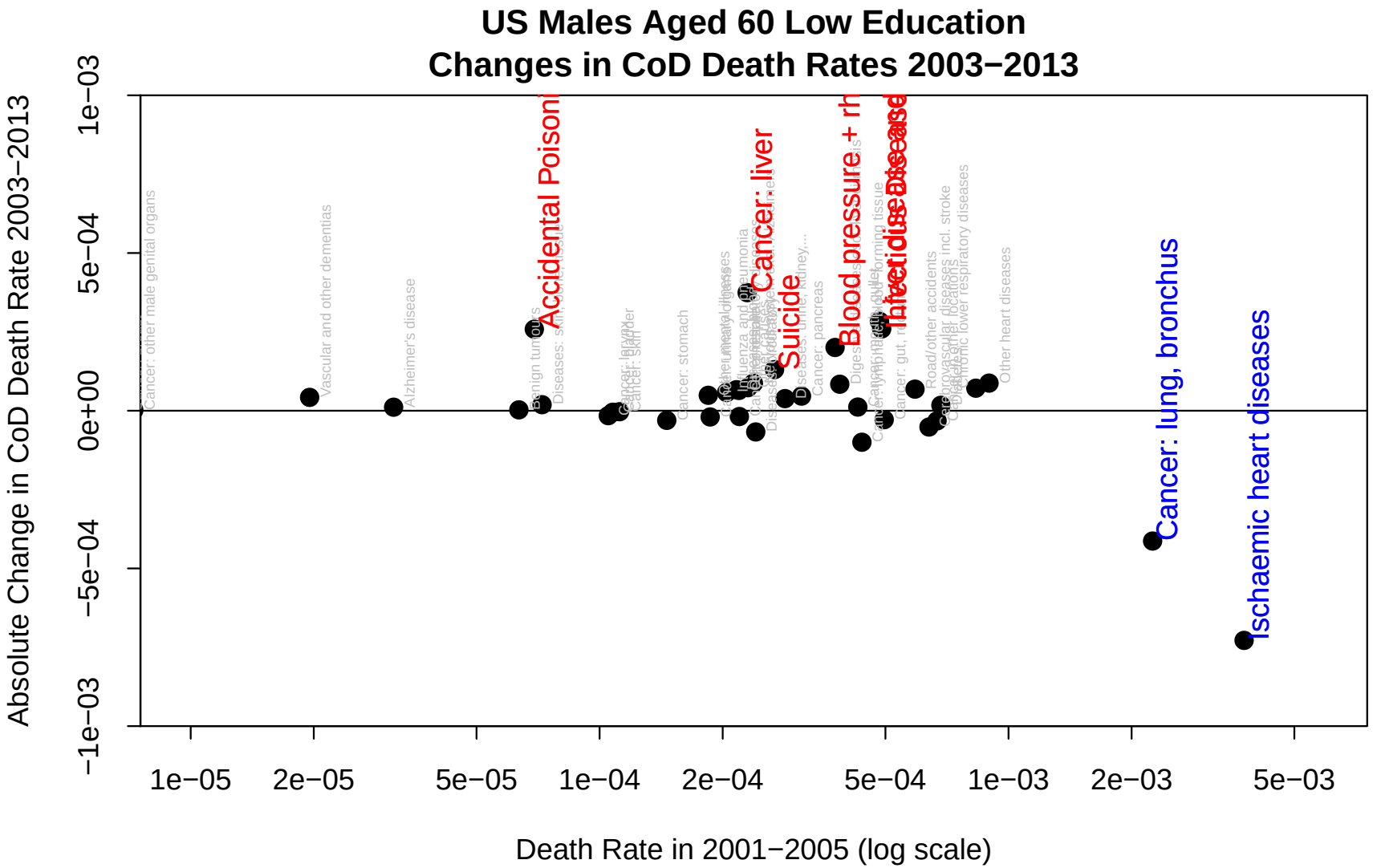
Drivers of Change 1991-2003, 2003-2013

- Which causes of death have contributed to
  - Improvements in mortality (gains)
  - Increases in mortality (losses)
- Low educated males
- 1993-2003
- 2003-2013
- Absolute change in mortality
  (not % change in cause of death rate)

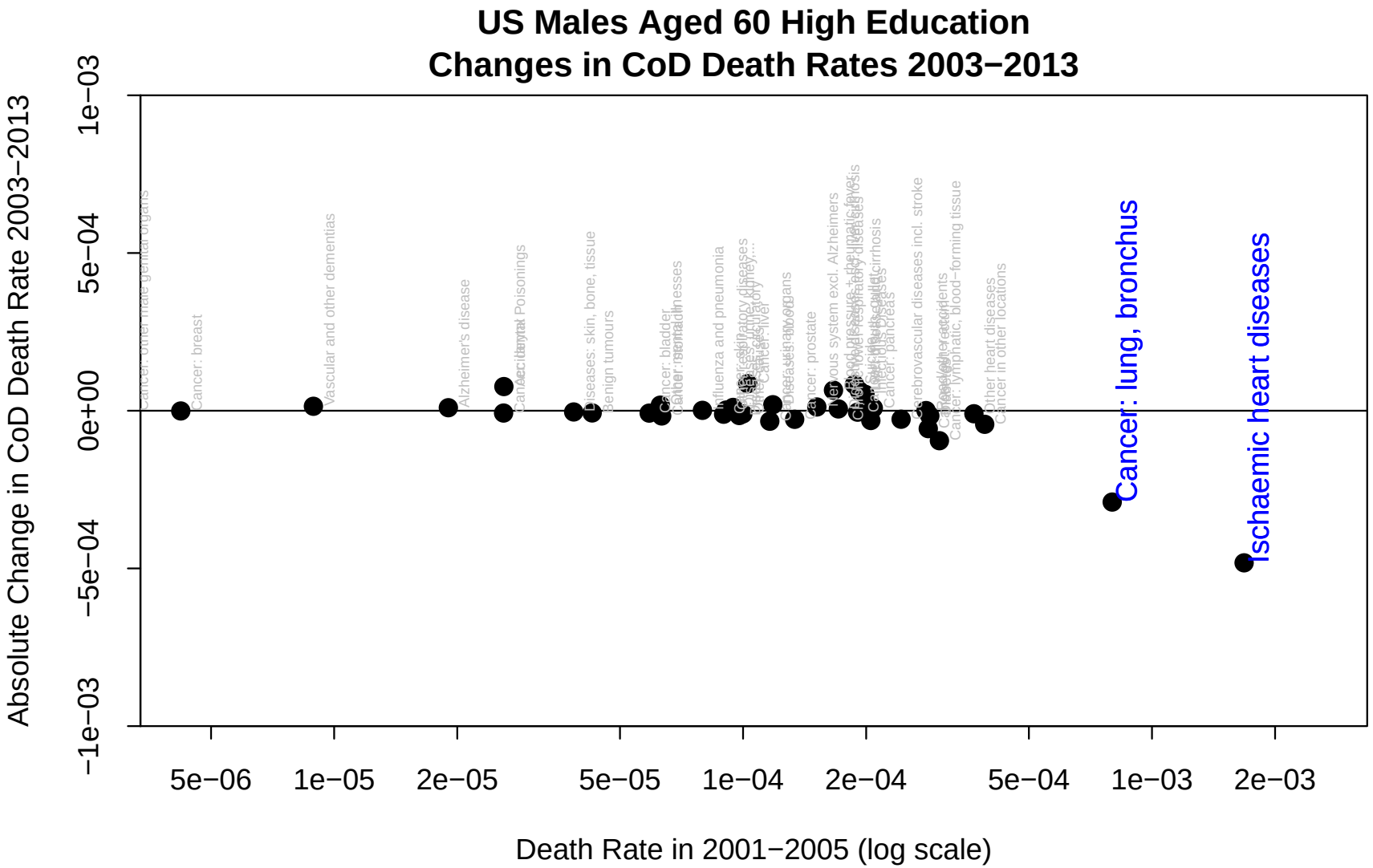


1991-2003: Three significant gains; others insignificant

"Other heart disease": gains mainly due to 1998 ICD change

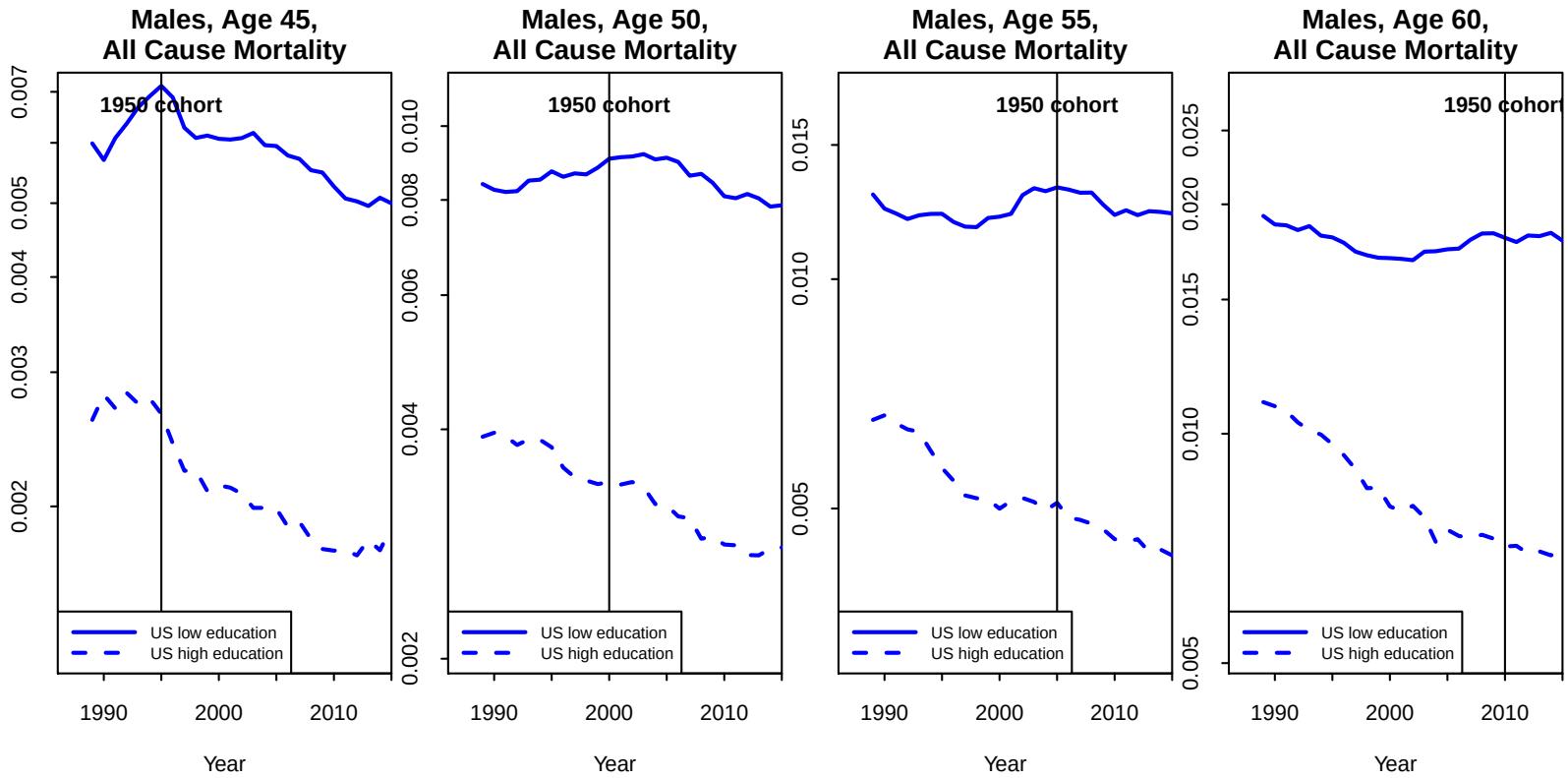


2003-2013: Some continued gains, but several more substantial losers: no single "bad" CoD; deaths of despair worsening



2003-2013: Same two "gainers", but no significant "losers"

US Males: A Possible Cohort Effect



Cohort effect: cohorts born around 1950 have poorer mortality than those born before or after.

Suggests: Weakens the hypothesis that the situation is generally bad for low educated males.

What is a cohort effect?

- Statistically:
  a component in a model that quantifies adjustments to mortality by year of birth
- How do they arise?
- One reason is:
  - populations might not be homogeneous
  - heterogeneities within a population are often linked to year of birth
  - examples of such heterogeneities are
    - smokers and non-smokers
    - healthy diet or exercise regime
    - manual and non-manual workers (e.g. pension plan)

Quantifying cohort effects

- Use stochastic mortality models.
- Here (suppress gender and education)

$$\log m(c,t,x) = \alpha(c,x) + \kappa_1(c,t) + \kappa_2(c,t)(x-\bar{x}) + \gamma(c,t-x)$$

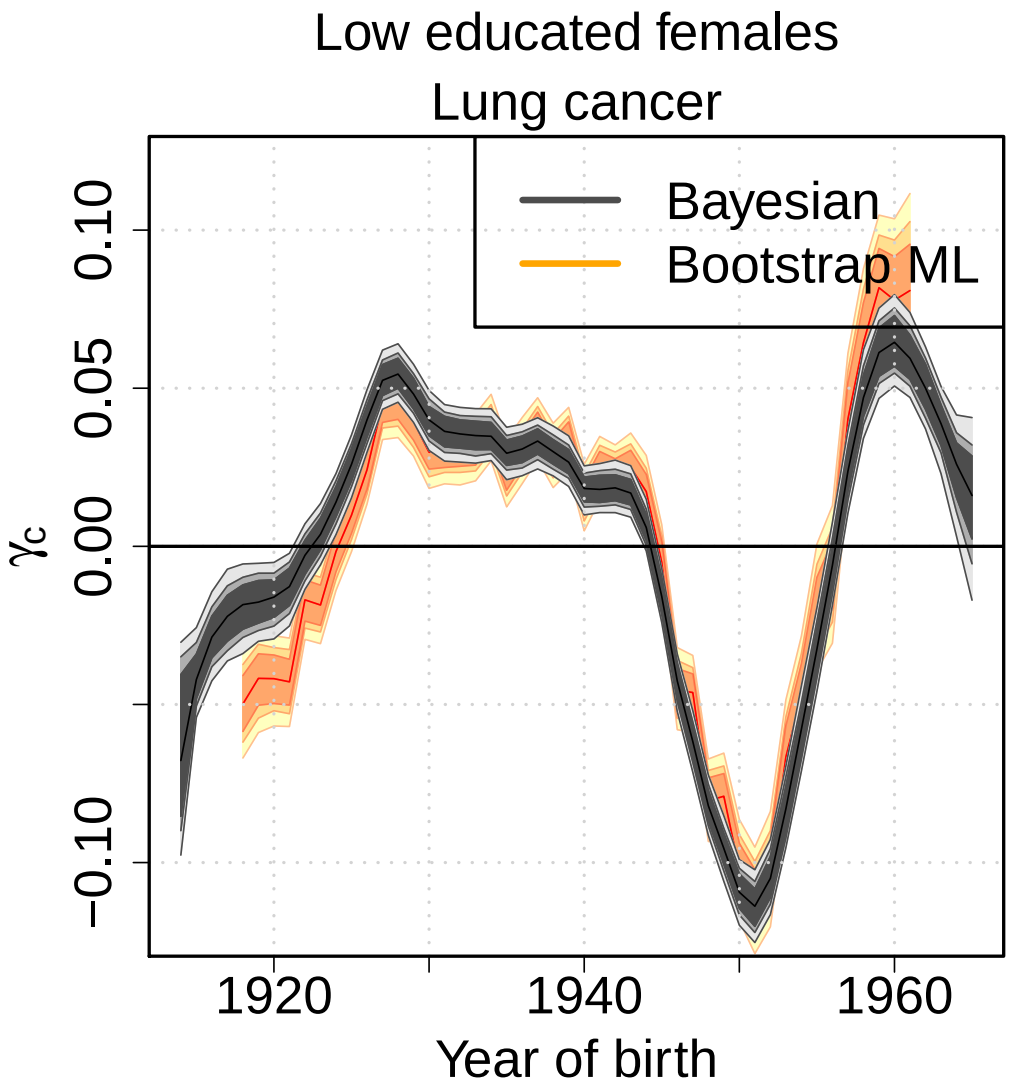
- c = cause of death (or all cause mortality)
- $t-x$ = year of birth
- $\alpha(c,x)$ = age effect; base table
- $\kappa_1(c,t)$, $\kappa_2(c,t)$ = period effects
- $\gamma(c,t-x)$ = cohort effect
- Model fitted to cause-specific deaths+exposures data
- Full Bayesian implementation
  - Bivariate random walk for κ
  - $AR(2)$ model for γ
- Outputs here: focus on $\gamma(c,t-x)$

Data

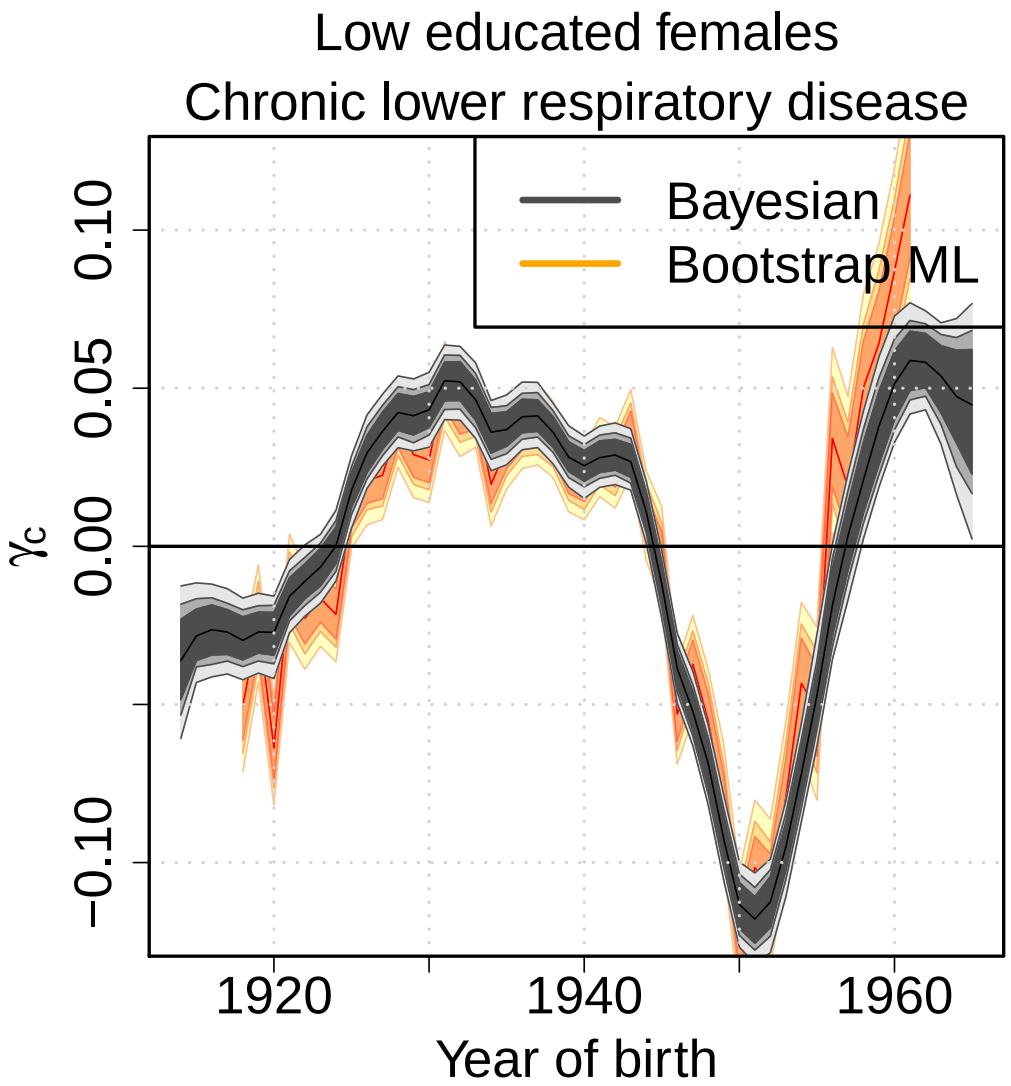
Model fitted to

- US males & females
- High & low education
- 1989-2015
- Ages 50-75

Females, low education: lung cancer

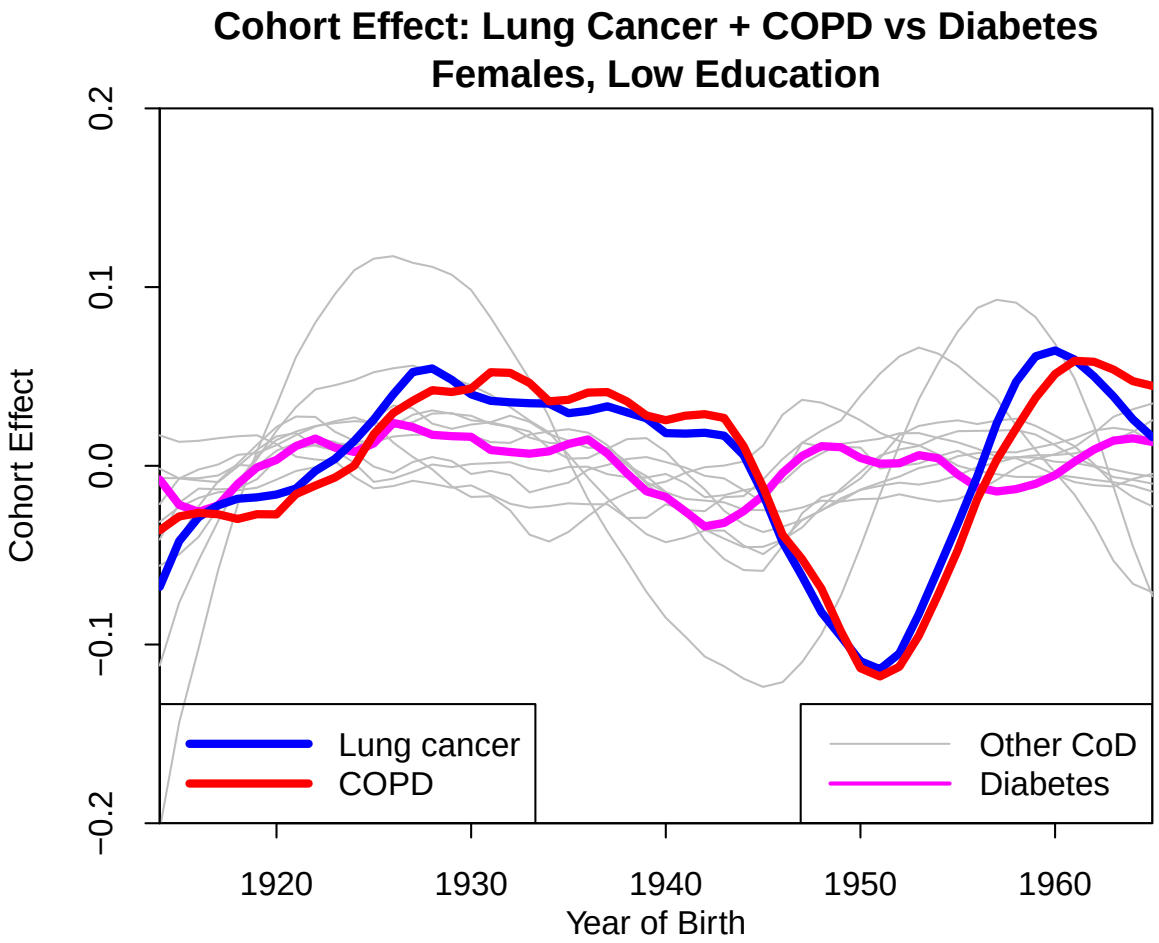


Females, low education: COPD



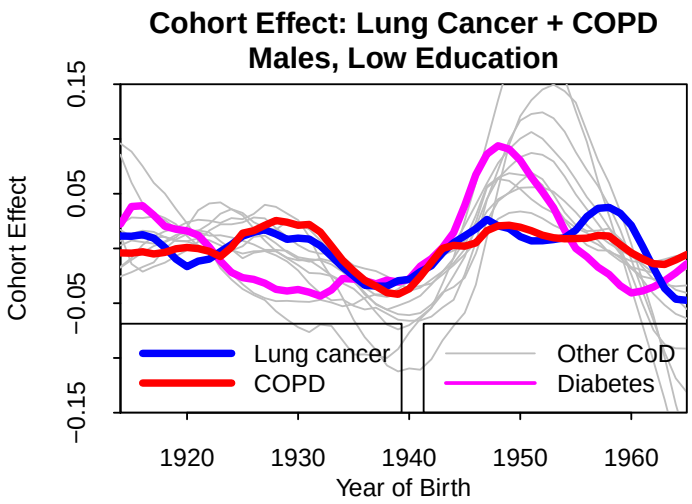
Very similar shape to lung cancer: single risk driver = smoking!

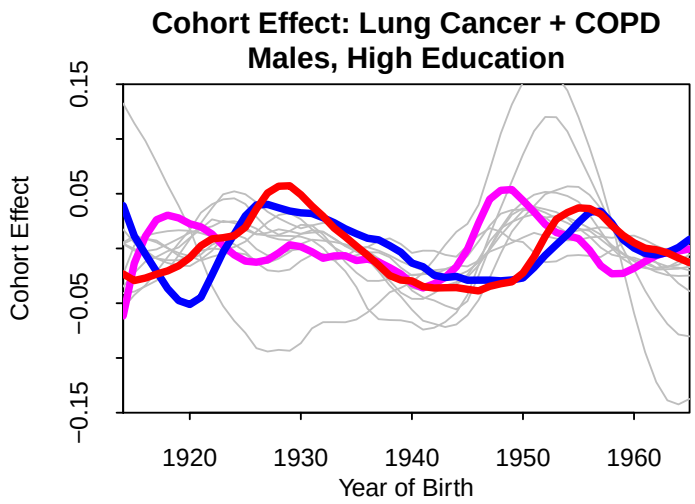
Smoking vs diet/exercise/alcohol

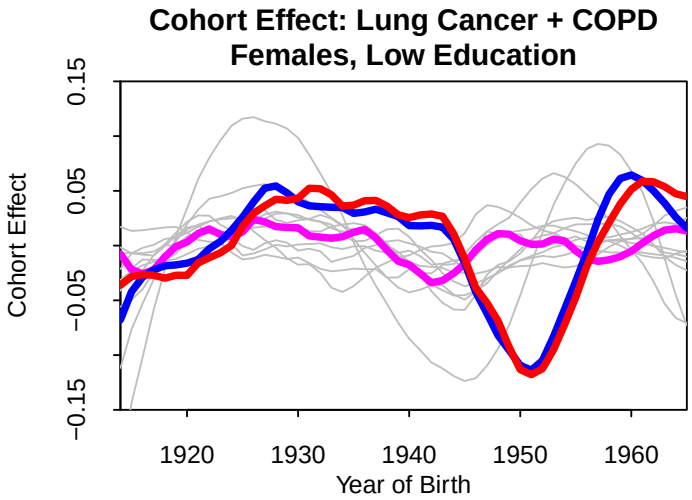


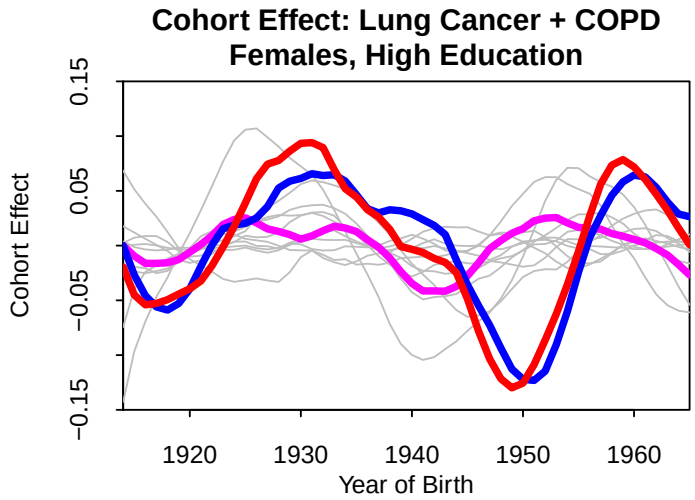
Cohort effect for diabetes is distinctly different

Smoking vs other cohort effects

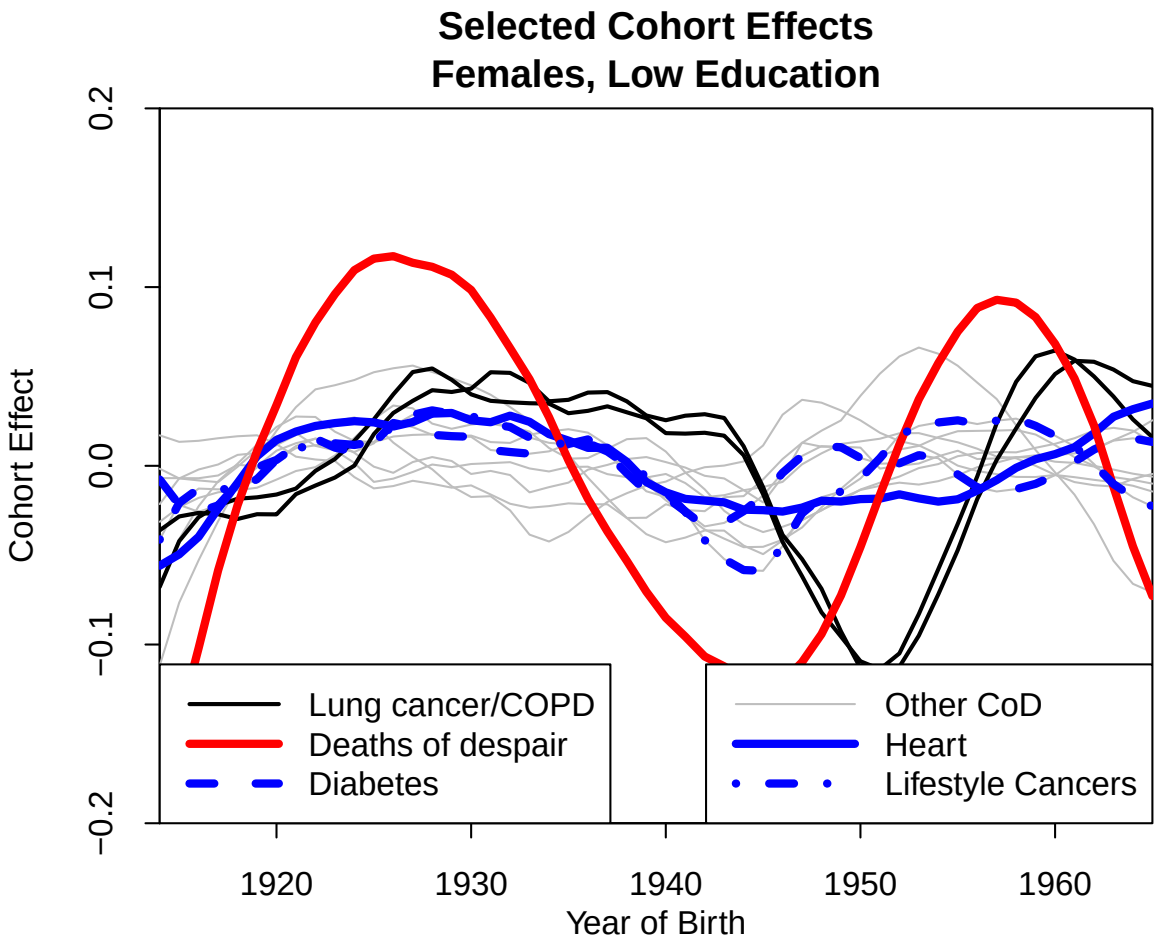






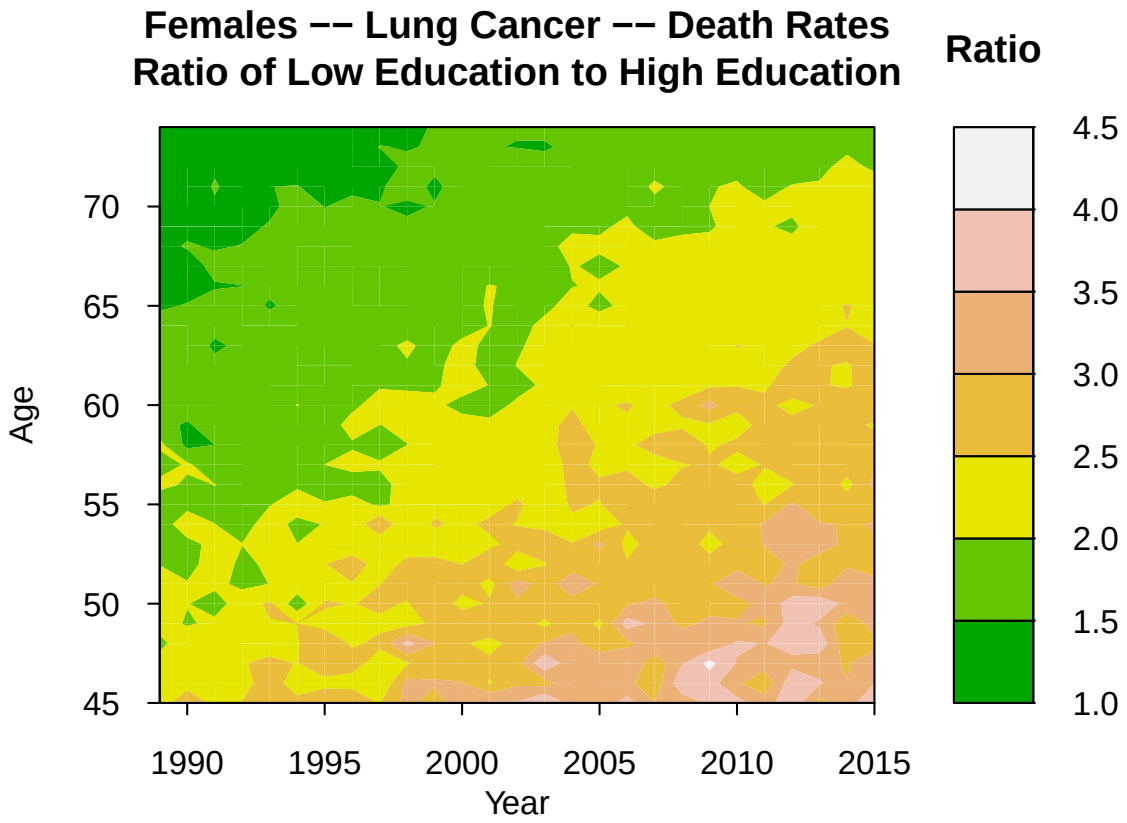


Smoking vs diet/exercise/alcohol



Possibly 3 distinct cohort effects: **smoking**; despair; other lifestyle factors

Smoking: Low versus High Education; Lung Cancer



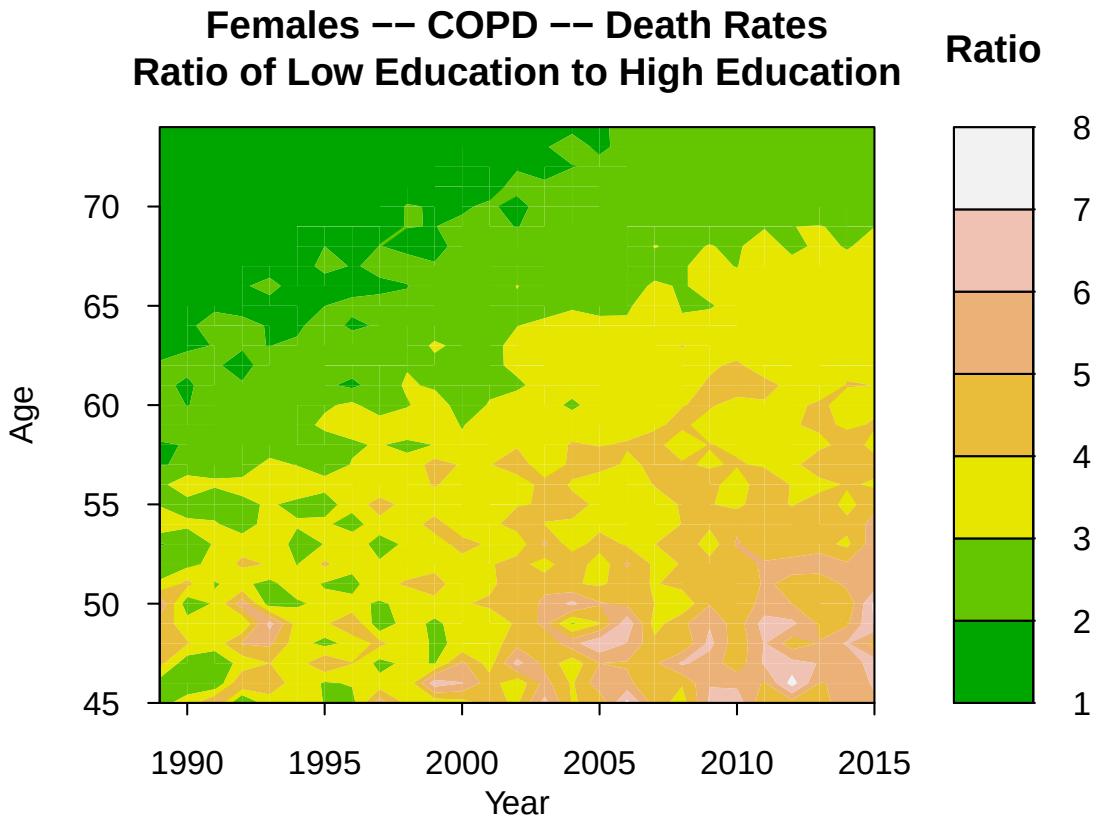
Ratio= $m(\text{low}, t, x)/m(\text{high}, t, x)$

Cohort effects: older $\rightarrow$ younger cohorts

Pattern $\Rightarrow$ high education smoking prevalence has fallen much faster

Widening smoking prevalence gap $\Rightarrow$ increased all-cause mort. inequality

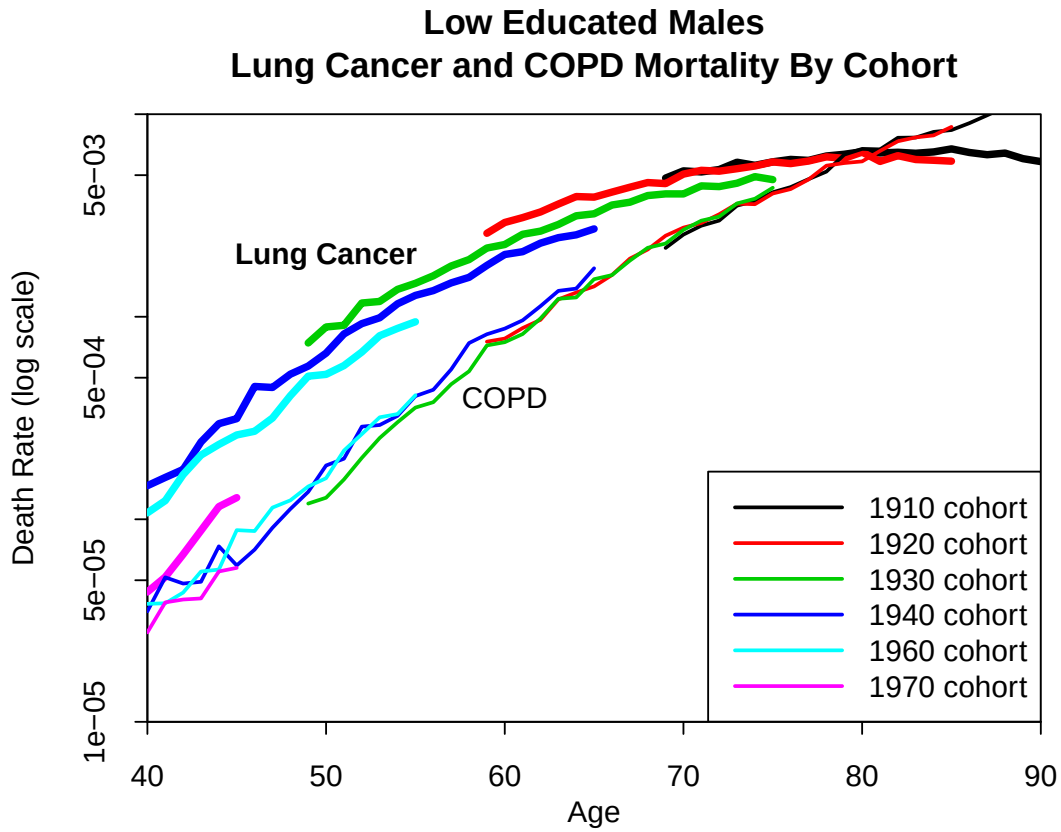
Smoking: Low versus High Education; COPD



Similar pattern to lung cancer but *stronger effect*:

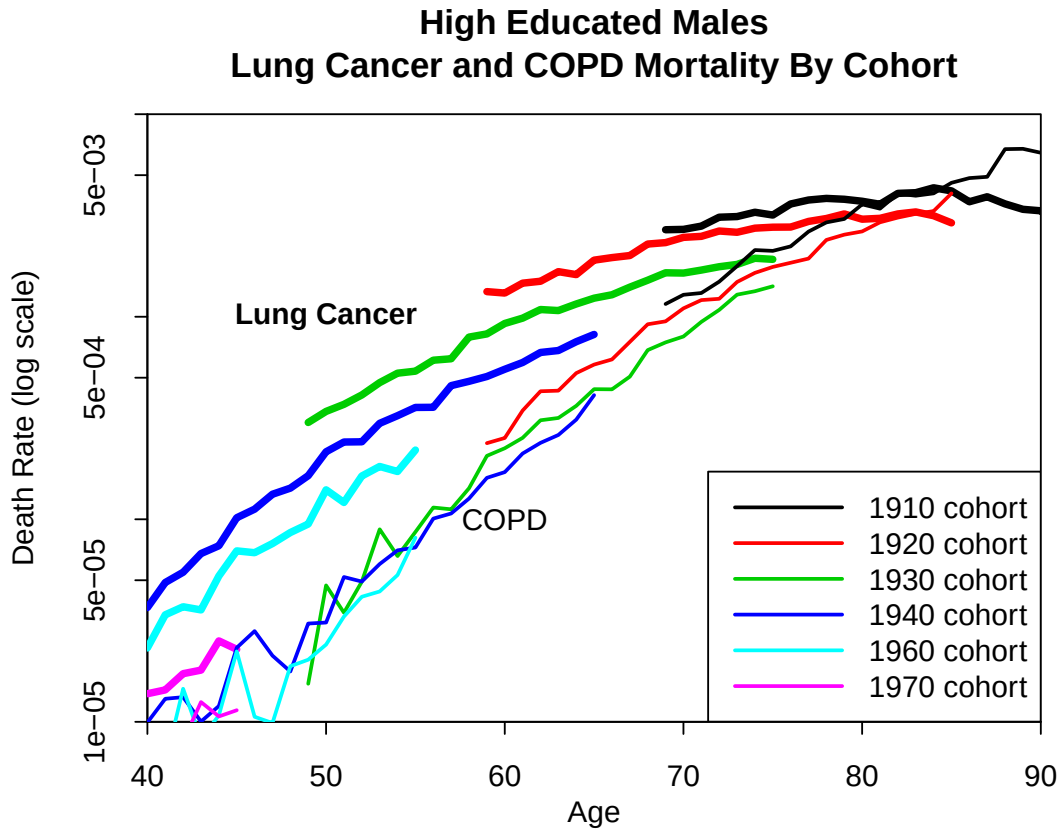
- baseline + excess smokers mortality
- ??? smoking relative risk higher for COPD
- ??? relative risk possibly changing over time
- ??? medical advances accrue more quickly to high educated

Smoking: Death Rates By Cohort



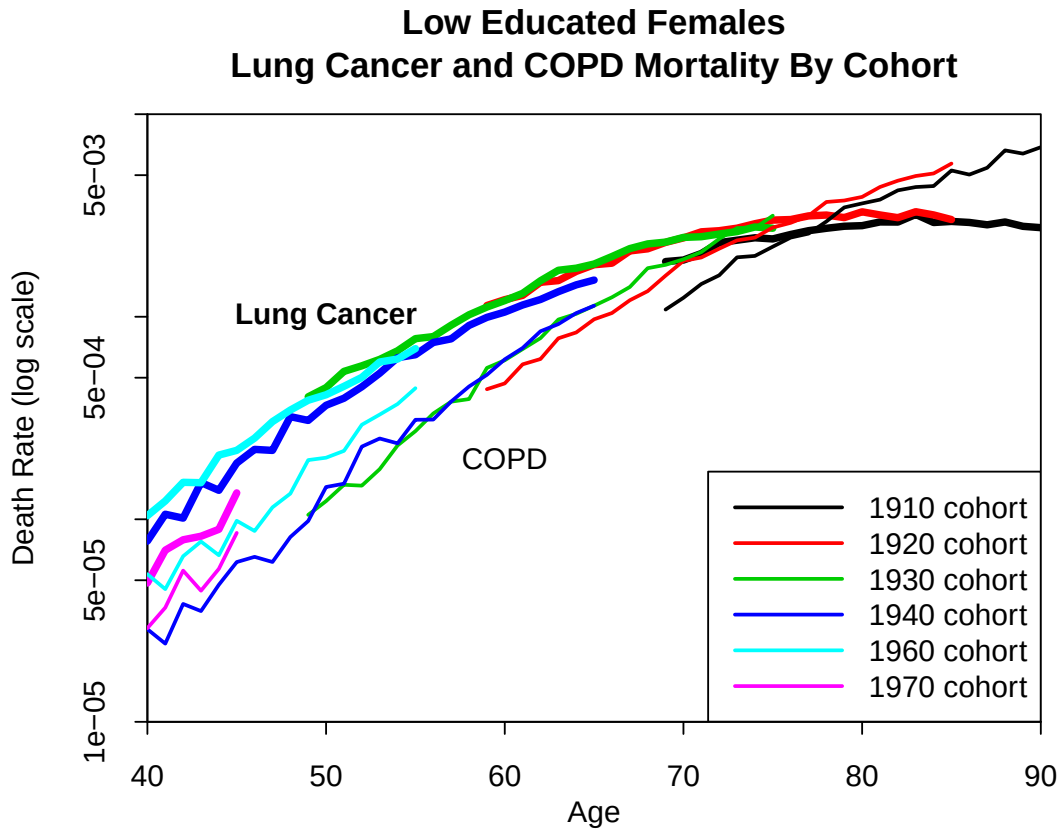
- Lung cancer and COPD: same group of smokers
- Cohort to cohort:
  - changes in smoking prevalence (lung cancer & COPD: the same)
  - improvements in treatment (different)

Smoking: Death Rates By Cohort



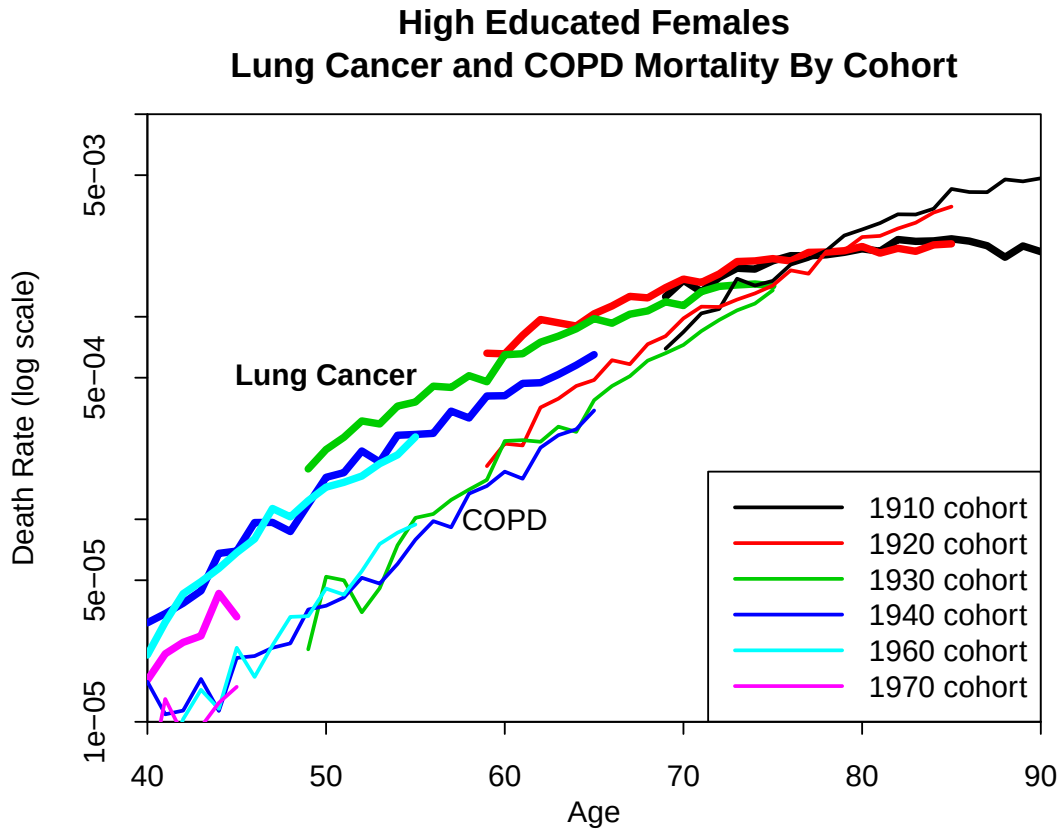
- Compared to low educated males:
  (infer) increasing gap in smoking prevalence

Smoking: Death Rates By Cohort



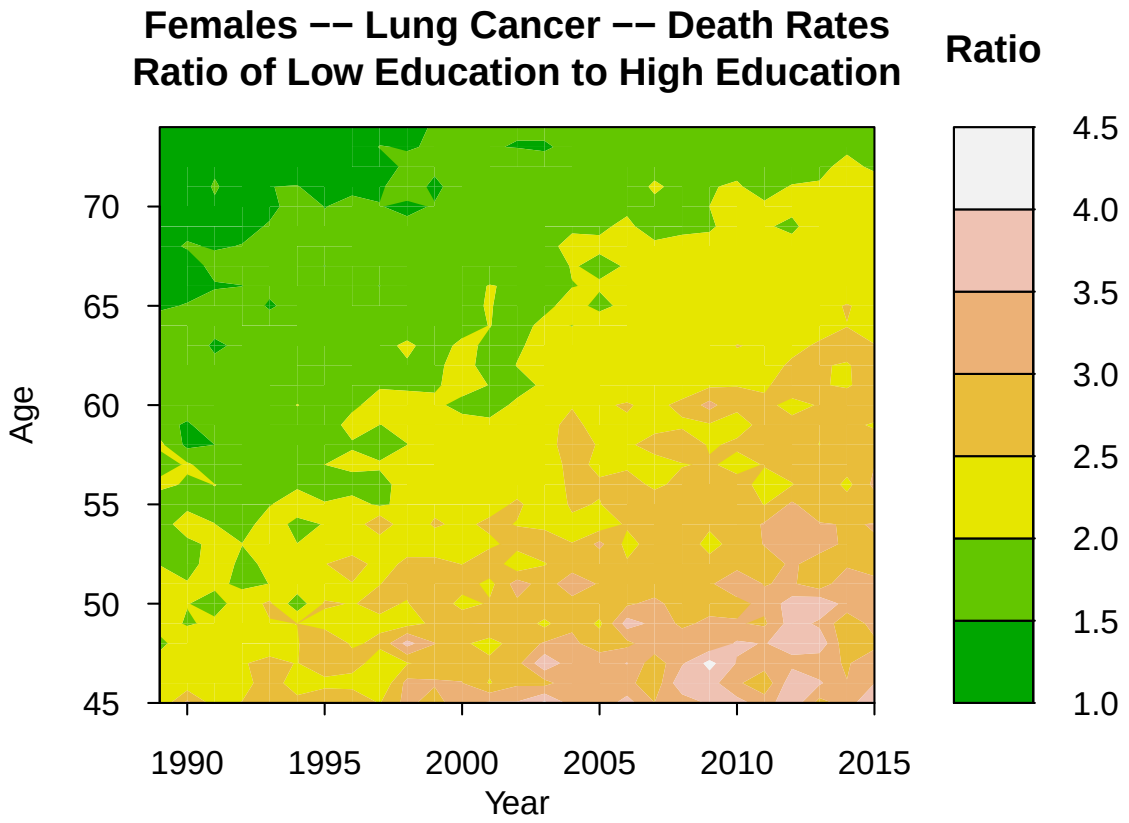
- COPD ⇒ increasing smoking prevalence
- Lung cancer ⇒ mitigated by advances in treatment

Smoking: Death Rates By Cohort



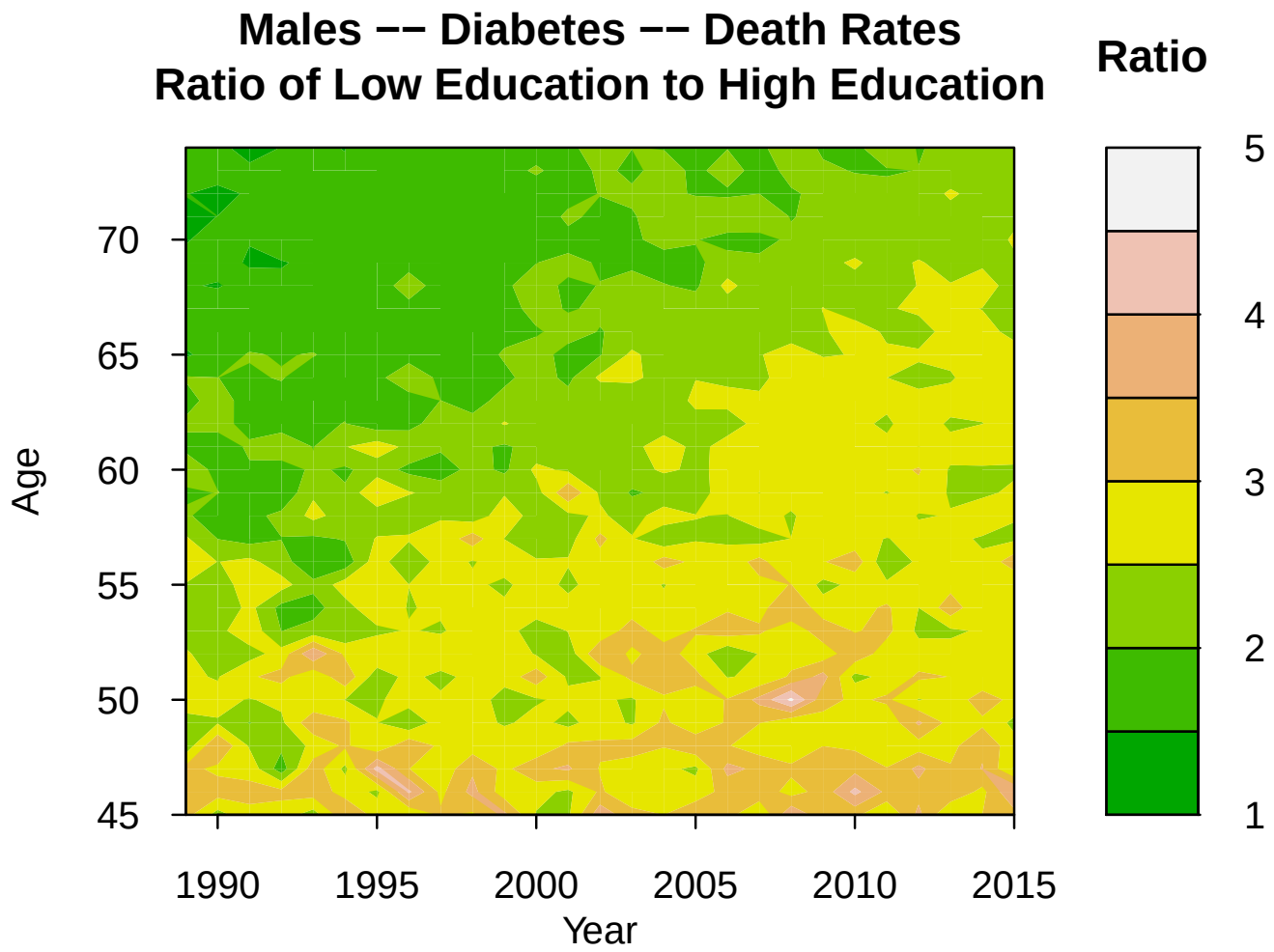
- Compared to low educated females: increasing gap in smoking prevalence

Recap: Low versus High Education; Lung Cancer

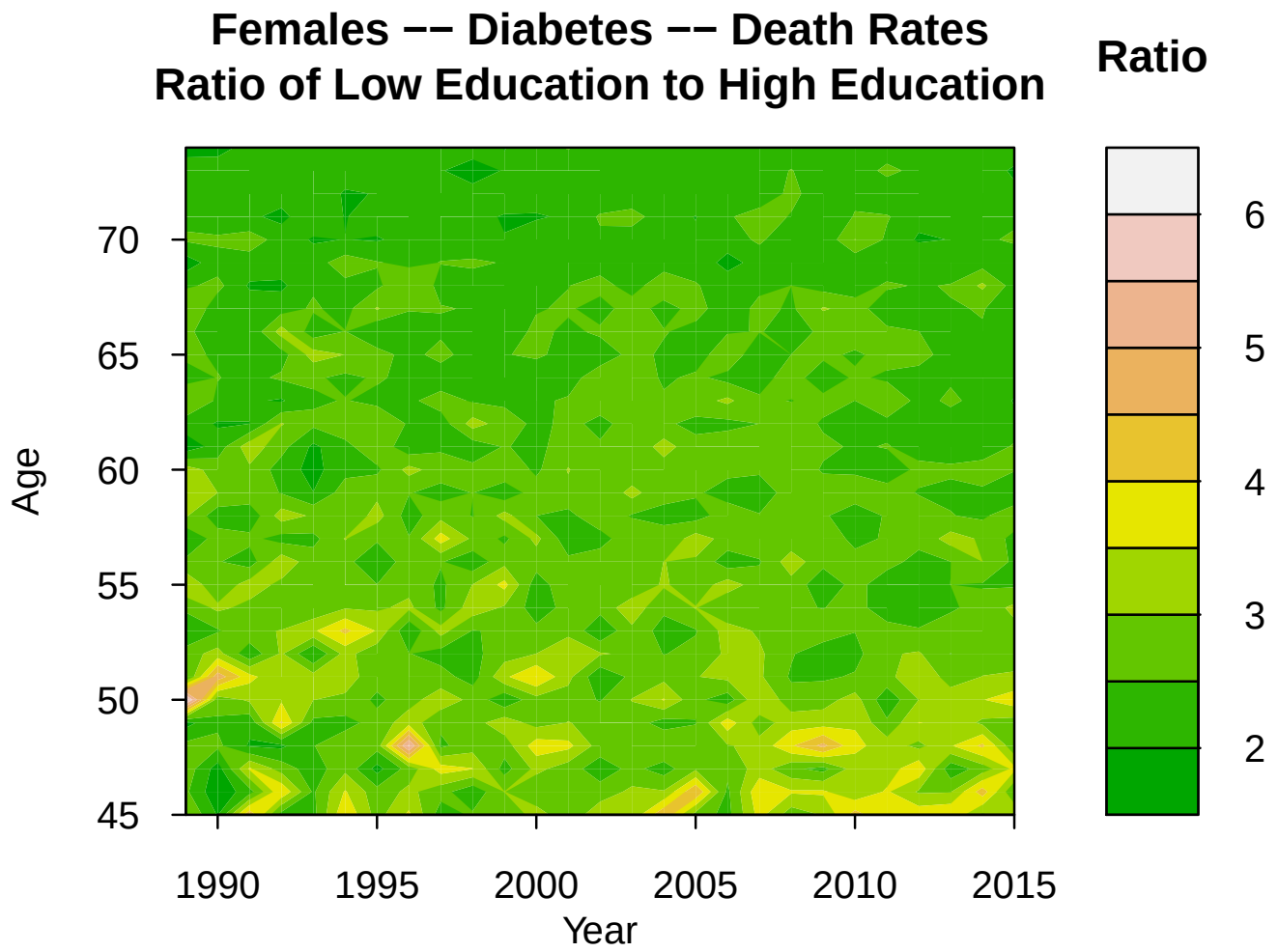


Ratio= $m(\text{low}, t, x)/m(\text{high}, t, x)$

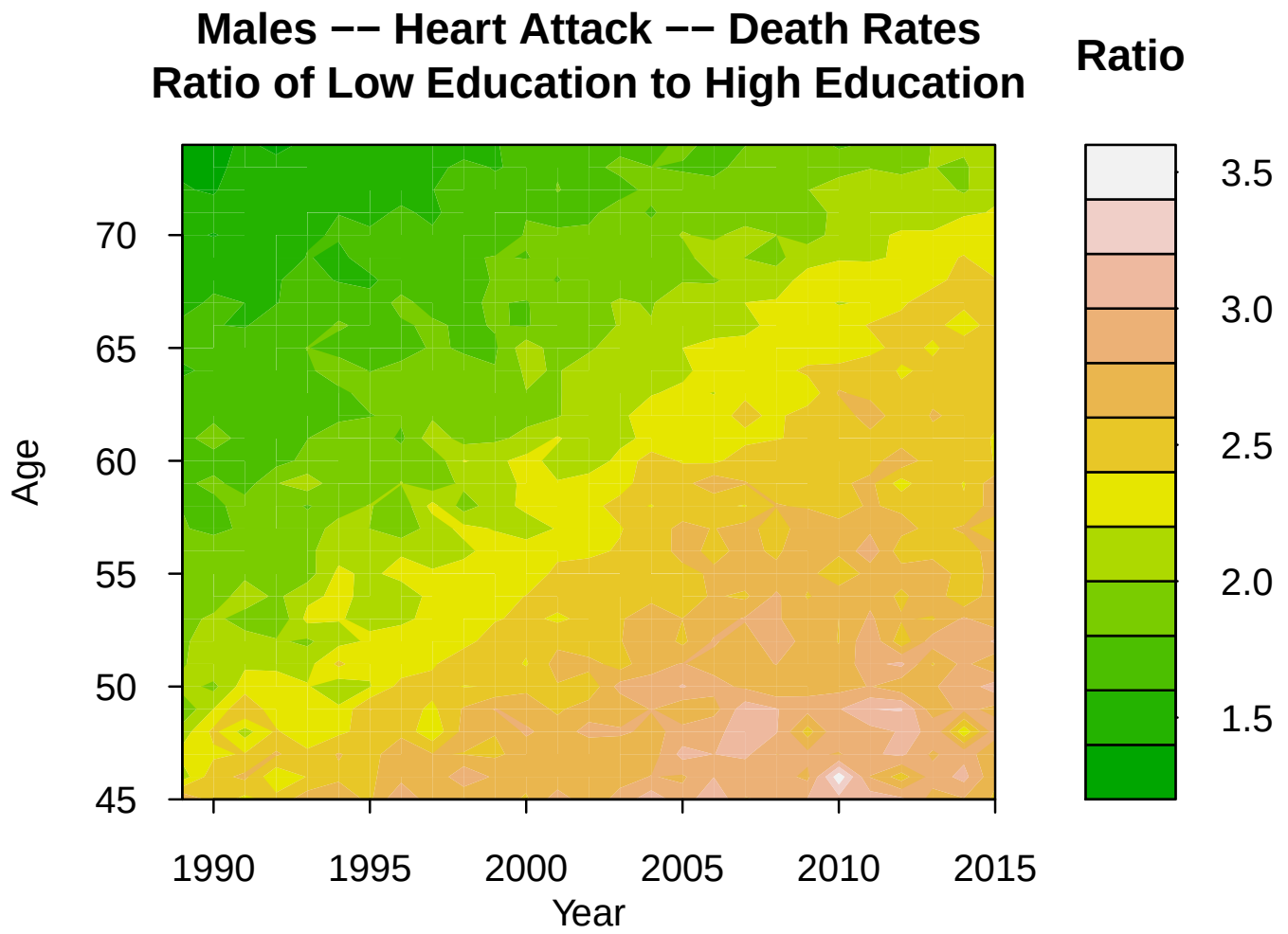
Low versus High: Other causes of death



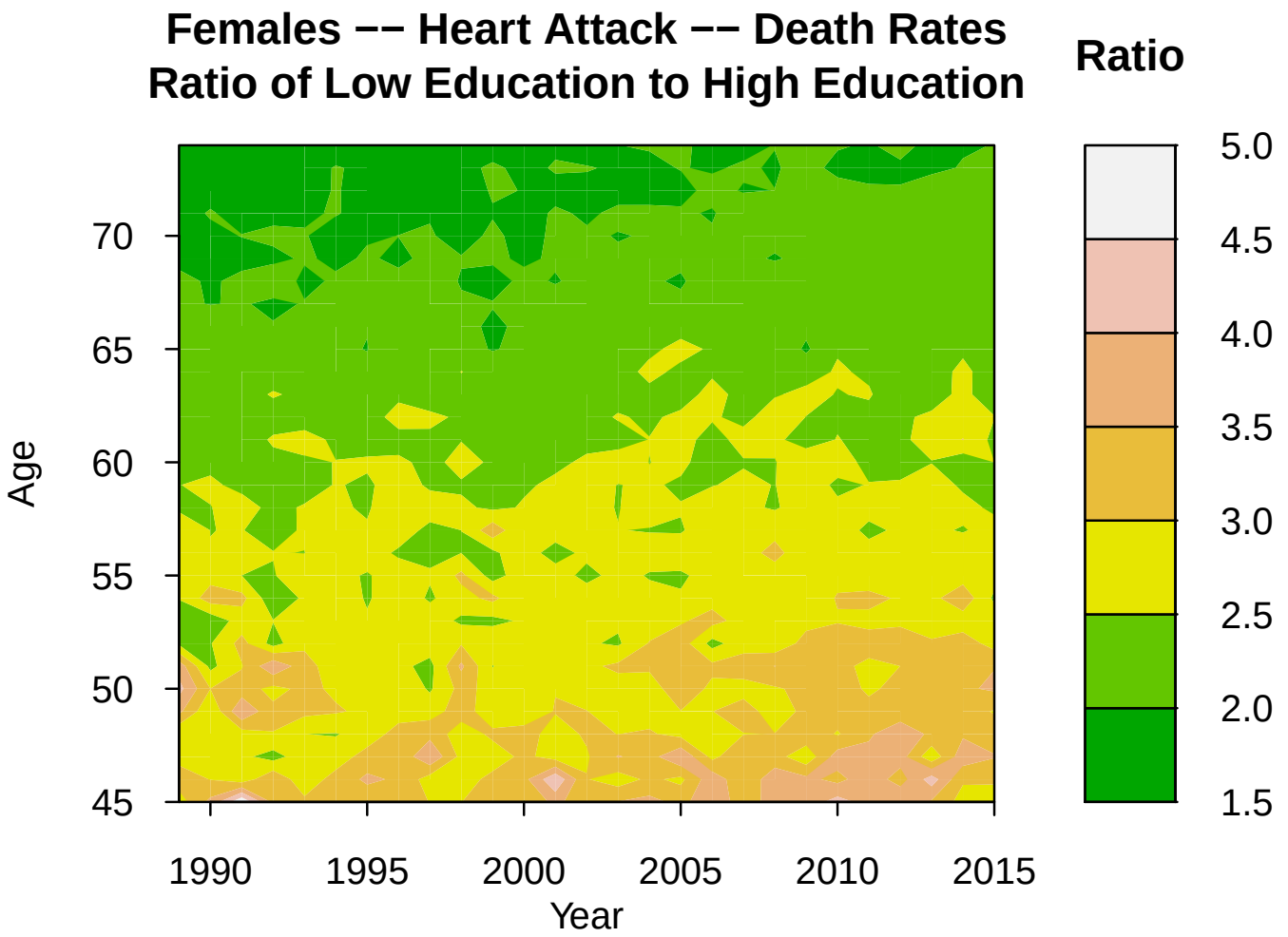
Low versus High: Other causes of death



Low versus High: Other causes of death



Low versus High: Other causes of death



Summary

- Work in progress!
- Data by education level requires multiple sources
- Cause of death data can provide insight into all cause mortality
  - time trends
  - inequality between groups
  - very significant inequality for some causes of death
  - (growing inequality)
- The US slow down is complex
  Partly due to a 1940-50's cohort effect
- Shape of cohort effect varies by cause of death
  linked to different underlying risk factors by cohort
- Broader understanding is also complex
  there is no simple story to tell

Thank You!

Questions?

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W: www.macs.hw.ac.uk/∼andrewc/ARCresources

Females smoking prevalence

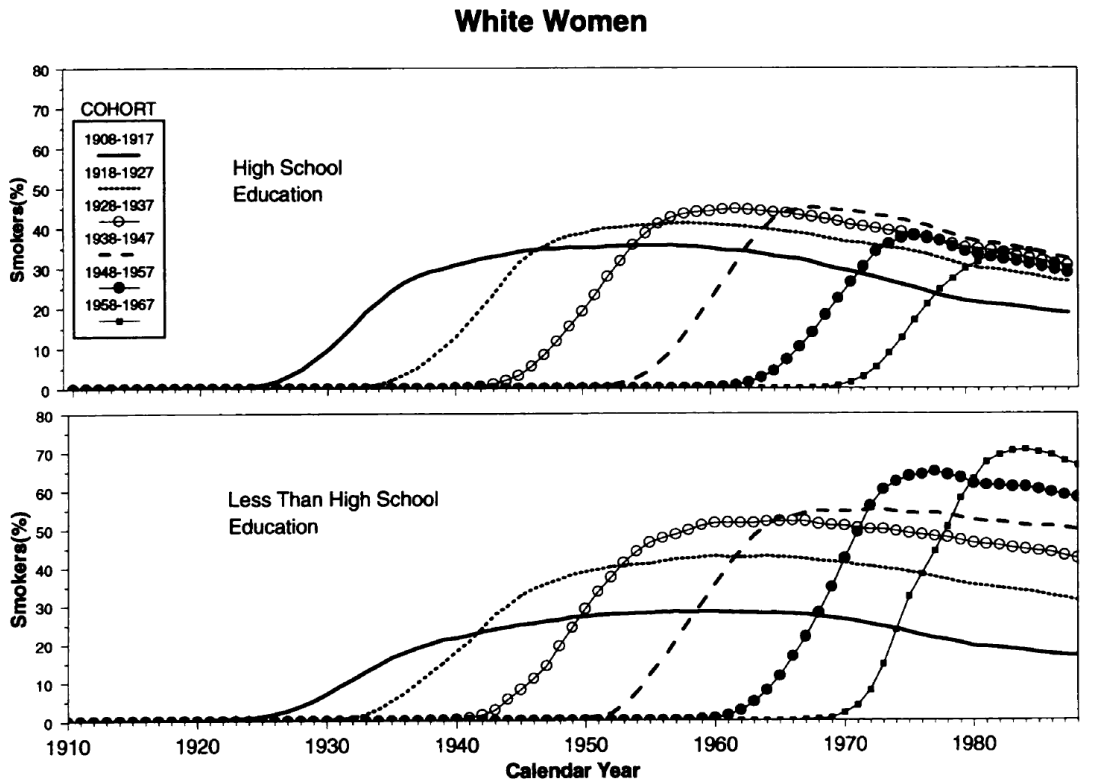
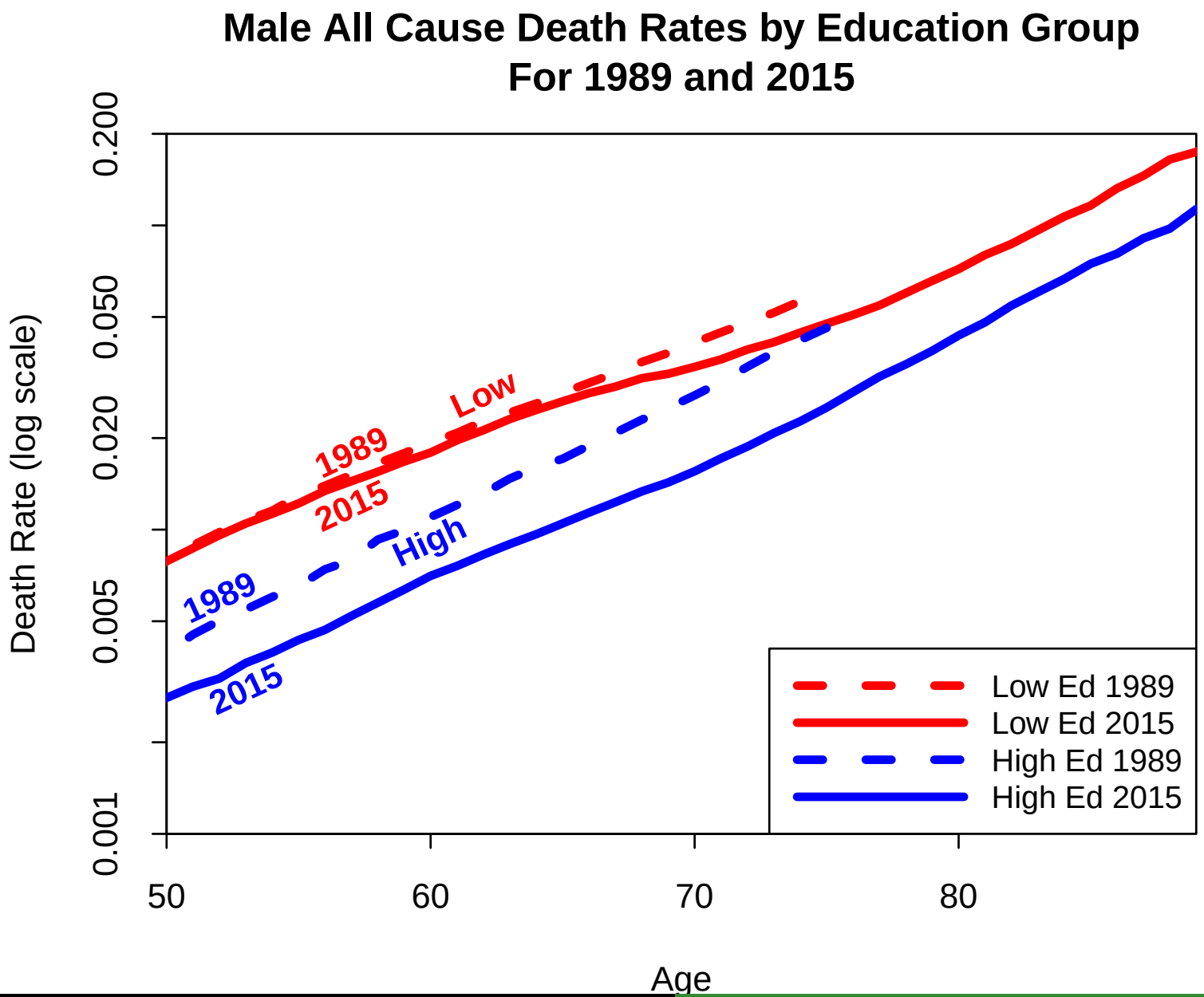


FIGURE 1—Smoking prevalence among birth cohorts of Whites, by sex and educational attainment, 1978–1980, 1987, and 1988 National Health Interview Surveys.

Source: Escobedo et al. (1996)

Note: Different definition of low/high education & ethnic group

All cause mortality: males 1989 $\rightarrow$ 2015



All cause mortality: females 1989 $\rightarrow$ 2015