Population over time

- Surprisingly stable population over long period of history
- As we will see in a moment – driven by stable mortality rates
- World population
  - Time of Christ, 300 million
  - Vikings, 1000 years later, about the same
  - 1700, 600 million
  - Today, 6 billion

- Pop(t) = population in year t
- Deaths(t), Births(t) similarly defined

- Dynamics for world
  - Pop(t+1) = Pop(t) + births(t) – deaths(t)

- Dynamics for country
  - Pop(t+1) = Pop(t) + births(t) – deaths(t) + netMig(t)
Demographic transition

• As industrialization takes hold, countries move from a high death/birth era to one of lower birth/death rates

• Birth rates/death rates move in unison

• Pop(t+1) = Pop(t) + births(t) – deaths(t)

• The rise in population must be driven by a reduction in mortality rates

• Historically, death rates did not decline much until the end of the late 19th century

• What drove the big decline in death rates?
McKeown

- Why the rapid increase in population (decline in mortality) in England/Wales?

- Key fact – most of the decline was due to a reduction in deaths from infectious diseases
  - 74% are attributable to microorganisms

Table 3.2 Reduction in Mortality
England/Wales 1850-1971

- Conditions attributable:  • Percent of reduction
  - Airborne diseases  • 40%
  - Water/food borne diseases  • 21%
  - Other micro organisms  • 13%
  - Conditions not attributable to micro-organisms  • 26%

- Why are people dying from infectious diseases at lower rates?
- McKeown suggests it is:
  - NOT medical care
  - NOT public health
- Question to consider: What evidence does McKeown to argue against public health as the driver??
McKeown’s argument

- What explains the decline in mortality?
- Decline in virulence of infection
- Why? Agricultural revolution
  - Limited food supply produced ‘small’ humans
  - People w/ small stature cannot ward off infection
  - The growth in agriculture productivity allows humans to grow and be healthier
- Evidence in McKeown?
Deaths due to infection

- Expected Deaths = P x E x I x D

- P = Population
- E = Number of times exposed to organism
- I = Probability of infection given exposure
- D = Probability of death given infection

Fogel

- Nobel prize winning economist from Chicago
- Wrote famous book on slavery w/ Engerman “Time on the Cross”
- Took McKeown’s idea to heart and provided critical data

At end of the 18th century, average height of adult in England/France was 5'4"
- Not much change throughout Europe until last half 19th century
- Height improved because of diet
- Height is an excellent predictor of disease incidence/mortality

<table>
<thead>
<tr>
<th>Row</th>
<th>Date of maturity</th>
<th>Great Britain</th>
<th>Norway</th>
<th>Sweden</th>
<th>France</th>
<th>Denmark</th>
<th>Hungary</th>
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<td>1</td>
<td>16-III</td>
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<td>165.9</td>
<td>168.1</td>
<td></td>
<td></td>
<td>168.7</td>
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<tr>
<td>2</td>
<td>16-IV</td>
<td>167.9</td>
<td>166.7</td>
<td>163.0</td>
<td>165.5</td>
<td>166.5</td>
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<td>3</td>
<td>18.1</td>
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<tr>
<td>4</td>
<td>19-III</td>
<td>171.6</td>
<td>169.0</td>
<td>165.2</td>
<td>166.8</td>
<td>166.3</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>19-IV</td>
<td>169.3</td>
<td>168.6</td>
<td>169.5</td>
<td>165.6</td>
<td>165.3</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>20-III</td>
<td>170.0</td>
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<td>177.4</td>
<td>172.0</td>
<td>176.6</td>
<td>176.9</td>
</tr>
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</table>

Sources: Fogel (1987 table 7) for all countries except France. For France, rows 3-5 were computed from M. A. von Meerum (1980) as amended by Wei (1983), with 0.5 cm added to allow for additional growth between age 20 and maturity (Benedict 1946, Werz 1974, and Frohman 1982). The entry in row 2 is derived from a time extrapolation of Meerum's data for 1653-1676 back to 1786, with 0.5 cm added to account for normal growth between age 20 and maturity. The entry in row 6 is from Fogel (1987 table 7).

165 cm = 65 inches (5'5'')
175 cm = 69 inches (5'9'')
Calories available for work

- Basal metabolic rate
  - Calories necessary to keep vital organs working
  - 4/5ths of minimum calories
  - Function of body size
- Calories necessary to consume/digest food
  - 1/5th of minimum necessary
- Amount above these limits, calories available for work
- 1800-2600 calories available for work today in US
- In 1700 England, 1/3 to ¼ of the calories that are available today

Interesting facts

- Caloric intake in early 18th century France similar to 1965 Rwanda, the most malnourished country on the planet at that time
- During 18th century England, 50-75% of income went to food
- Caloric consumption in 1885 England similar to modern day India
What is BMI?

- Body mass index
- weight in kg/Height in meters squared
  - BMI < 20  underweight
  - BMI > 25  overweight
  - BMI > 30  obese
- To calculate BMI w/ inches/pounds
  - 703*pounds/inches squared
  - 5'9" and 165 pounds, BMI of 24.3

Relative risk defined on next page
Look at the next two graphs, and consider the following questions:

- What trends in the graphs are ‘good’ for Fogel's story
- What trends in the graphs are not so good for his hypothesis.

Slight problem for Fogel Theory

- Bones of exhumed remains can identify height
- Linear relationship between length of femur and height
- Need to know sex of skeleton

Whites: Height = 61.61 + 2.38 FL, N = 710, SEE = 3.27
Blacks: Height = 70.35 + 2.11 FL, N = 80, SEE = 3.94,
• Need to know that the person stopped growing, identified by the fusion of certain bones
• Femur makes up \( \frac{1}{4} \) of adult height – more in taller people
• U-shaped pattern over time, low point 1450-1750

Why health gains during middle ages?
• Favorable weather...increases crop yields
  – Temps 2° C warmer 900-1300
  – Extend growing season by 3-4 weeks/year
• Little exposure to infectious/communicable diseases
  – Smaller cities (London had <40K people)
  – Little trade between countries to spread
• These trends change after 1200
  – little ice age
  – Increase urbanization

<table>
<thead>
<tr>
<th>Era</th>
<th>Place</th>
<th>Average height (cm)</th>
<th>Sample size</th>
<th>Source</th>
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<tr>
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<td>172.3</td>
<td>22</td>
<td>Steffensen 1958</td>
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<tr>
<td>9–11th centuries</td>
<td>Iceland</td>
<td>172.2</td>
<td>71</td>
<td>Steffensen 1958</td>
</tr>
<tr>
<td>10–11th centuries</td>
<td>Sweden</td>
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<td>8</td>
<td>Gilberg 1976</td>
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<td>172.0</td>
<td>27</td>
<td>Steffensen 1958</td>
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<tr>
<td>11–12th centuries</td>
<td>Iceland</td>
<td>171.0</td>
<td>16</td>
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<tr>
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<tr>
<td>12th century</td>
<td>Britain</td>
<td>168.4</td>
<td>233</td>
<td>Muenter 1928</td>
</tr>
<tr>
<td>12–13th centuries</td>
<td>Norway</td>
<td>172.0</td>
<td>*</td>
<td>Huber 1968</td>
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<tr>
<td>12–13th centuries</td>
<td>Iceland</td>
<td>175.2</td>
<td>5</td>
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<td>13th century</td>
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<td>Boklen 1984</td>
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<tr>
<td>13th century</td>
<td>Sweden</td>
<td>174.3</td>
<td>66</td>
<td>Geypall 1960</td>
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<tr>
<td>13–14th centuries</td>
<td>England</td>
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<td>*</td>
<td>Huber 1968</td>
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<td>Middle Ages</td>
<td>Sweden</td>
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<td>180</td>
<td>Boklen 1985</td>
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<tr>
<td>Middle Ages</td>
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<td>Holck and Kvaal 2000</td>
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<td>Middle Ages</td>
<td>Sweden</td>
<td>170.8</td>
<td>457</td>
<td>Wedelius 1985</td>
</tr>
</tbody>
</table>
What about the role of public health?

- McKeown dismissed the importance of public health
  - Time period when there has been a big movement from more rural to urban population
  - Infections should have been more prevalent due to close proximity in people (TB etc)
- Most persistent criticism of McKeown, he understates value of public health
  - Sanitation
  - Water supply

Cutler and Miller

- Consider the role of public health via clean water and sanitation at turn of century
- Tell very different story – large role for public health campaigns
  - Effective at reducing infectious diseases
  - High rate of return

<table>
<thead>
<tr>
<th>Table 1. Percentage of Deaths, by Cause, in Major Cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cause of Death</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>Major Infectious Diseases</td>
</tr>
<tr>
<td>Tuberculosis</td>
</tr>
<tr>
<td>Pneumonia</td>
</tr>
<tr>
<td>Diarrhea and enteritis</td>
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<tr>
<td>Typhoid fever</td>
</tr>
<tr>
<td>Measles</td>
</tr>
<tr>
<td>Smallpox</td>
</tr>
<tr>
<td>Influenza</td>
</tr>
<tr>
<td>Childhood Infectious Diseases</td>
</tr>
<tr>
<td>Measles</td>
</tr>
<tr>
<td>Scarlet fever</td>
</tr>
<tr>
<td>Whooping cough</td>
</tr>
<tr>
<td>Diphtheria and diphtheria and whooping cough</td>
</tr>
</tbody>
</table>

Notes: All percentages are shares of total mortality.
Source: U.S. Census Bureau’s Mortality Statistics, 1900 and 1930.

Numbers for 2010

- Total deaths = 2,468,435 (100%)
- Tuberculosis (569) (0.02%)
- Pneumonia 49,597 (2%)
- Influenza 500 (.02%)
- AIDS 8,369 (0.3%)
- Malaria (10)
- Scarlet fever (3)
- Whooping cough (26)
Model

\[ \ln(m_{ct}) = \beta_0 + x_{ct} \beta_1 + \text{Filter}_{ct} \beta_2 + \text{Chlor}_{ct} \beta_3 + \mu_c + \nu_t + \epsilon_{ct} \]

\( m_{ct} \) = mortality rate (deaths / 100,000) city \( c \), year \( t \)
\( x_{ct} \) = other controls
\( \text{Filter}_{ct} = 1 \) if city \( c \) has filtration in year \( t \), 0 otherwise
\( \text{Chlor}_{ct} = 1 \) if city \( c \) has chlorination in year \( t \), 0 otherwise
\( \mu_c = \) city fixed effects
\( \nu_t = \) time fixed effects

Measure of financial effectiveness

- Benefits of a program: measured in lives
- Costs: measured in dollars
- How does one compare outcomes across projects?
- Cost/life saved
- Hold denominator constant, lower values mean larger bang per buck
Tengs et al. (1995)

- Review of 587 “cost per life year saved” estimates
- Median was about $80K
- Subgroup medians
  - Medical, $38K
  - Injury prevention $96K
  - Toxin control, $5.6 million

Example cost per life year saved

- Smoke detectors $60K
- Pneumonia vaccine $28K
- ARVs for HIV $50K
- CABG $250K
- Child restraints $1.5 Million
- State NOx rules $8.3 million
- Methylene chloride $12.7 million
- Benzene control $40 billion

Mortality rates in the 20th century

- Two halves
  - Decline in infant deaths (1/2 half)
  - Conquering cardiac disease
- Tremendous changes in aggregate statistics

Fig. 1.—Life expectancy at birth and age 50, United States, 1900–2000
Terms

- Mortality
  - Neonatal < 28 days
  - Infant < 1 year
- LBW < 2500 grams
- Very LBW < 1500 grams
- Preterm < 37 weeks

What causes big changes in life expectancy?

- Most deaths are to the elderly
- But, when an infant dies, you add a small number to the numerator in a life expectancy calculation
- Big changes will be generated by
  - Changes in the infant mortality rate
  - Changes in mortality for the elderly which are a large fraction of deaths

Distribution of Deaths by Age

<table>
<thead>
<tr>
<th>Age</th>
<th>Fraction of deaths</th>
<th>Age</th>
<th>Fraction of deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>1.1%</td>
<td>55-64</td>
<td>10.4%</td>
</tr>
<tr>
<td>1-14</td>
<td>0.5%</td>
<td>65-74</td>
<td>17.3%</td>
</tr>
<tr>
<td>15-24</td>
<td>1.4%</td>
<td>75-84</td>
<td>28.9%</td>
</tr>
<tr>
<td>25-34</td>
<td>1.7%</td>
<td>85+</td>
<td>27.9%</td>
</tr>
<tr>
<td>35-44</td>
<td>3.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45-54</td>
<td>7.1%</td>
<td>74.1% of deaths are to people aged 65+</td>
<td></td>
</tr>
</tbody>
</table>

74.1% of deaths are to people aged 65+

Numeric Example

- Population with 100 people
- 10% die at age 1
  - ~ the 1900 infant mortality rate
- If they survive, they live to age 75
- Life expectancy = (0.1)(1) + (0.9)(75) = 67.6
- Suppose infant mortality rates drops to 1%
  - ~ the 1980 Infant mortality rate
- Life expectancy = (0.01)(1) + (0.99)(75) = 74.3
• What is the corresponding change in life expectancy necessary for the same type of change

\[(0.1)(1) + (.9)(81.4) = 74.3\]

<table>
<thead>
<tr>
<th>Table 1: Contributions to Life Expectancy at Birth</th>
</tr>
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<tbody>
<tr>
<td>Change in Life Expectancy at Birth</td>
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<tr>
<td>-----------------------------------------------</td>
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<tr>
<td>Total change</td>
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<tr>
<td>Change attributable to:</td>
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<tr>
<td>Infant mortality (0-1)</td>
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<tr>
<td>Child mortality (1-14)</td>
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<tr>
<td>Young adult mortality (15-44)</td>
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<tr>
<td>Old age mortality (45-64)</td>
</tr>
<tr>
<td>Elderly mortality (65+)</td>
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<tr>
<td>Covariance terms</td>
</tr>
</tbody>
</table>

Note: This text describes the decomposition:
- 57% of decline in 50 yrs
- 62% due to changes in older adults
- 62% due to child/infant health

Improvements in heart attack treatment

• In 1950s, standard treatment was bed rest
  – Medical textbook in the 1950s, “...bed rest for at least 6 weeks should be planned…”
  – Today we know bed rest is counter productive
• Now, right after heart attack
  – Patient is administered blood thinners (aspirin, heparin)
  – Beta blockers to make heart work more efficiently
  – Thrombolytics to dissolve clots

• Variety of surgical procedures to deal with blockages
  – Cardiac catheterization (detects extent of blockage)
  – CABG (coronary artery bypass surgery)
  – Angioplasty (balloon inserted into blocked artery and expanded to reduce clot)
  – Stents can be inserted to maintain bloodflow
<table>
<thead>
<tr>
<th>GDP/person</th>
<th>Infant mort.</th>
<th>Life exp.</th>
<th>% farming</th>
<th>Prim. Sch.</th>
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</thead>
<tbody>
<tr>
<td>US in 1850</td>
<td>$1,600</td>
<td>$2,700</td>
<td>$46,300</td>
<td>80%</td>
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<td></td>
<td>9.7%</td>
<td>23%</td>
<td>0.8%</td>
<td>40%</td>
</tr>
<tr>
<td></td>
<td>48 years</td>
<td>40 years</td>
<td>78 years</td>
<td>63%</td>
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<td>98%</td>
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