Overview of Clinical Care

HST.956/6.S897
Machine Learning in Healthcare
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Outline

- Goals of Health Care
  - Mortality
  - Disability
  - Morbidity
- Tasks of Health Care
  - Diagnosis
  - Prognosis
  - Treatment
  - Prevention/Public Health
- Paying for Health Care

Goals of Medicine: (1) Cure the sick

Goals of Medicine: (1) Cure the sick

WHO Constitution defines “health”

“a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”

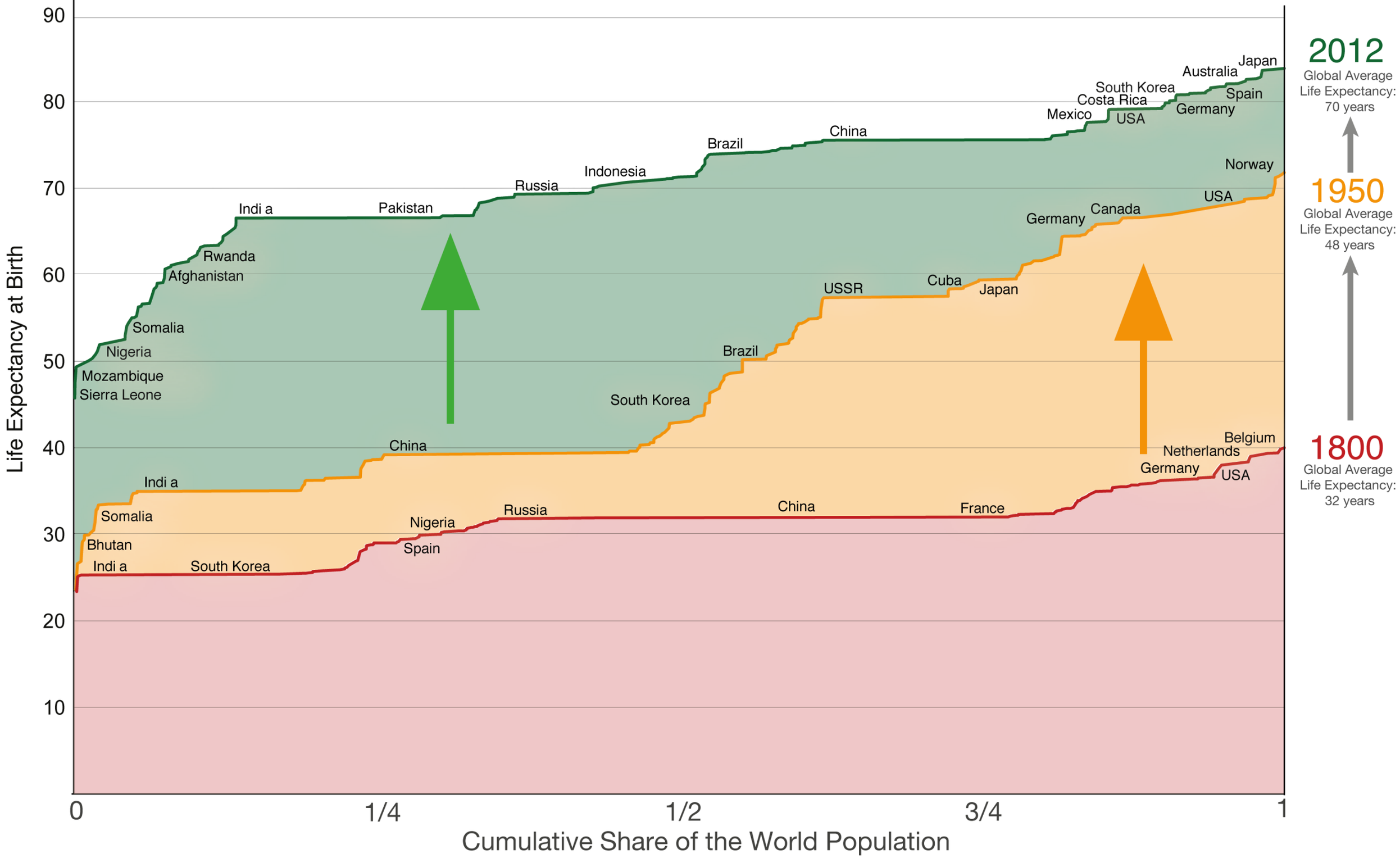
- Physical
- Mental
- Social

—very hard to measure

Our World in Data

Life Expectancy of the World Population in 1800, 1950 and 2012

Countries are ordered along the x-axis ascending by the life expectancy of the population. Data for almost all countries is shown in this chart, but not all data points are labelled with the country name.



Data source: The data on life expectancy by country and population by country are taken from Gapminder.org.

The interactive data visualisation is available at OurWorldinData.org. There you find the raw data and more visualisations on this topic.

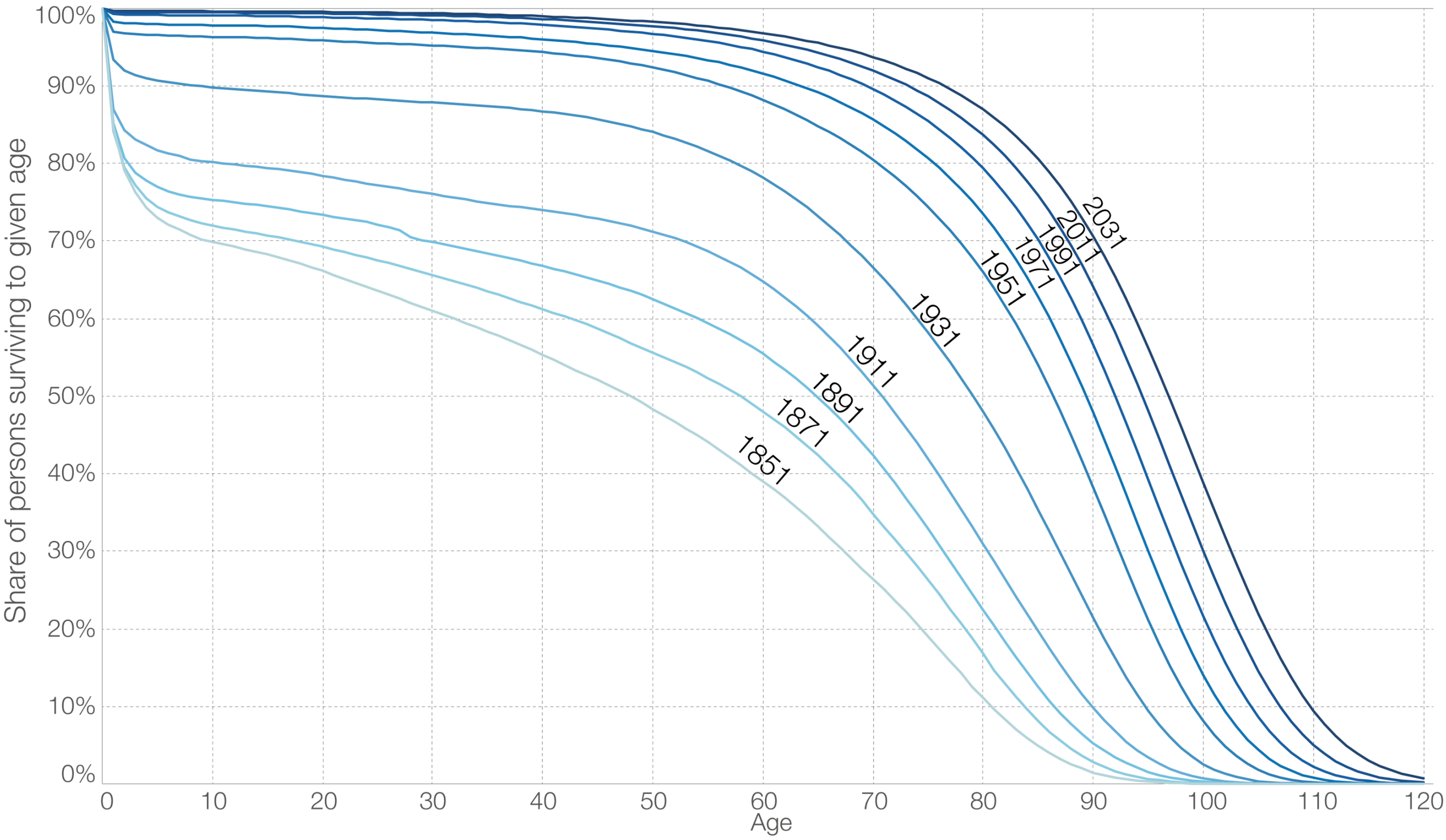
Longevity at birth
(CIA World Fact Book, 2001, 2018)

Country	*Male*		*Female*	
	2018	*2001*	*2018*	*2001*
Rwanda	62.6	38.35	66.5	39.65
South Africa	62.7	47.64	65.6	48.56
Kenya	63.1	46.57	66.1	48.44
Cambodia	62.7	54.62	67.9	59.12
Russia	65.6	62.12	77.3	72.83
Brazil	70.7	58.96	78.0	67.73
Turkey	72.9	68.89	77.7	73.71
Albania	76.0	69.01	81.6	74.87
Israel	80.8	76.69	84.7	80.84
USA	77.8	74.37	82.3	80.05
France	78.9	75.01	85.3	83.01
Japan	82.2	77.62	89.0	84.15

Share of persons surviving to successive ages for persons born 1851 to 2031, England and Wales

Our World in Data

according to mortality rates experienced or projected, (on a cohort basis)



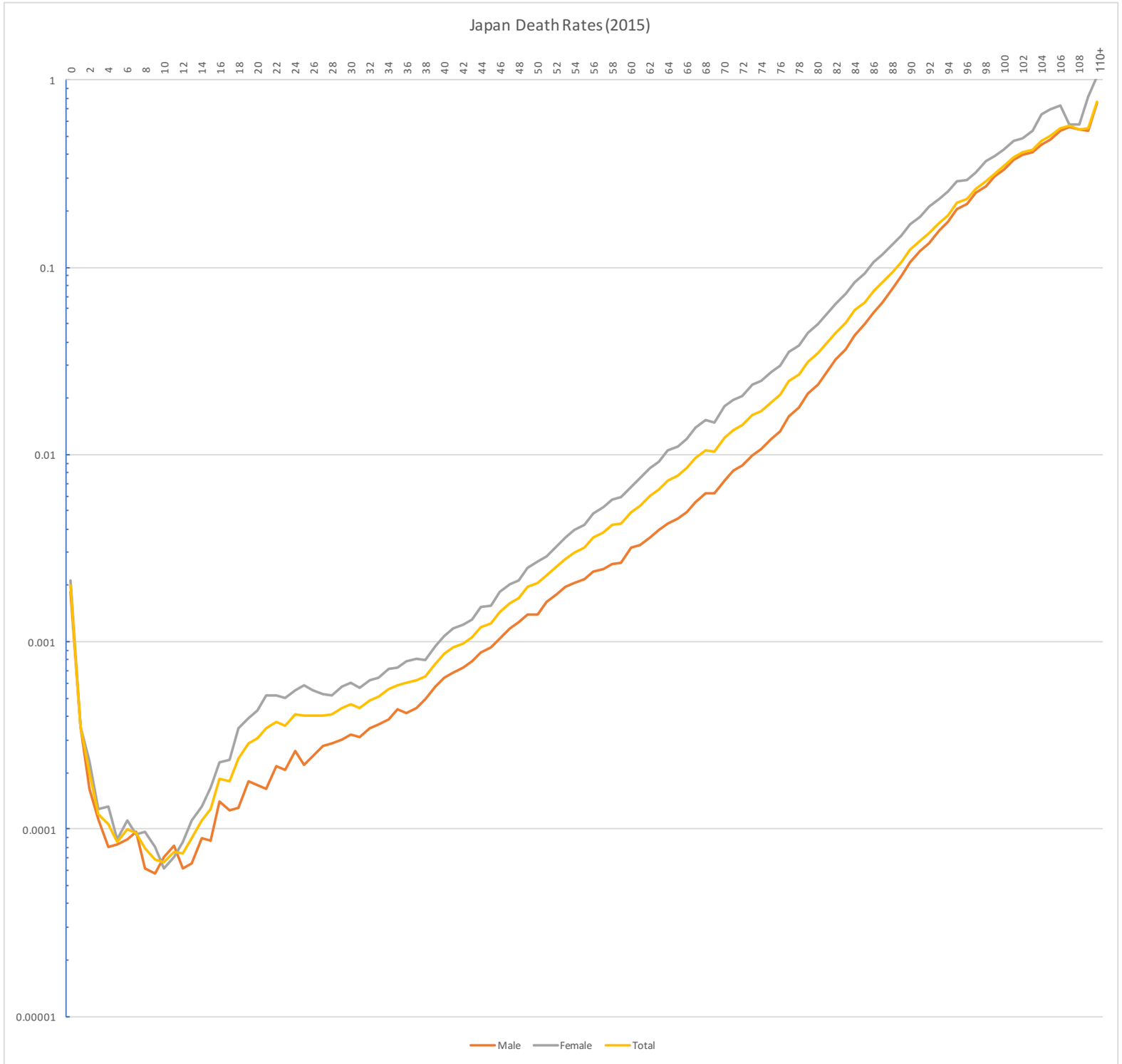
Data source: Office for National Statistics (ONS). Note: Life expectancy figures are not available for the UK before 1951; for long historic trends England and Wales data are used

The interactive data visualization is available at OurWorldinData.org. There you find the raw data and more visualizations on this topic.

Distribution of Death Rates by Age

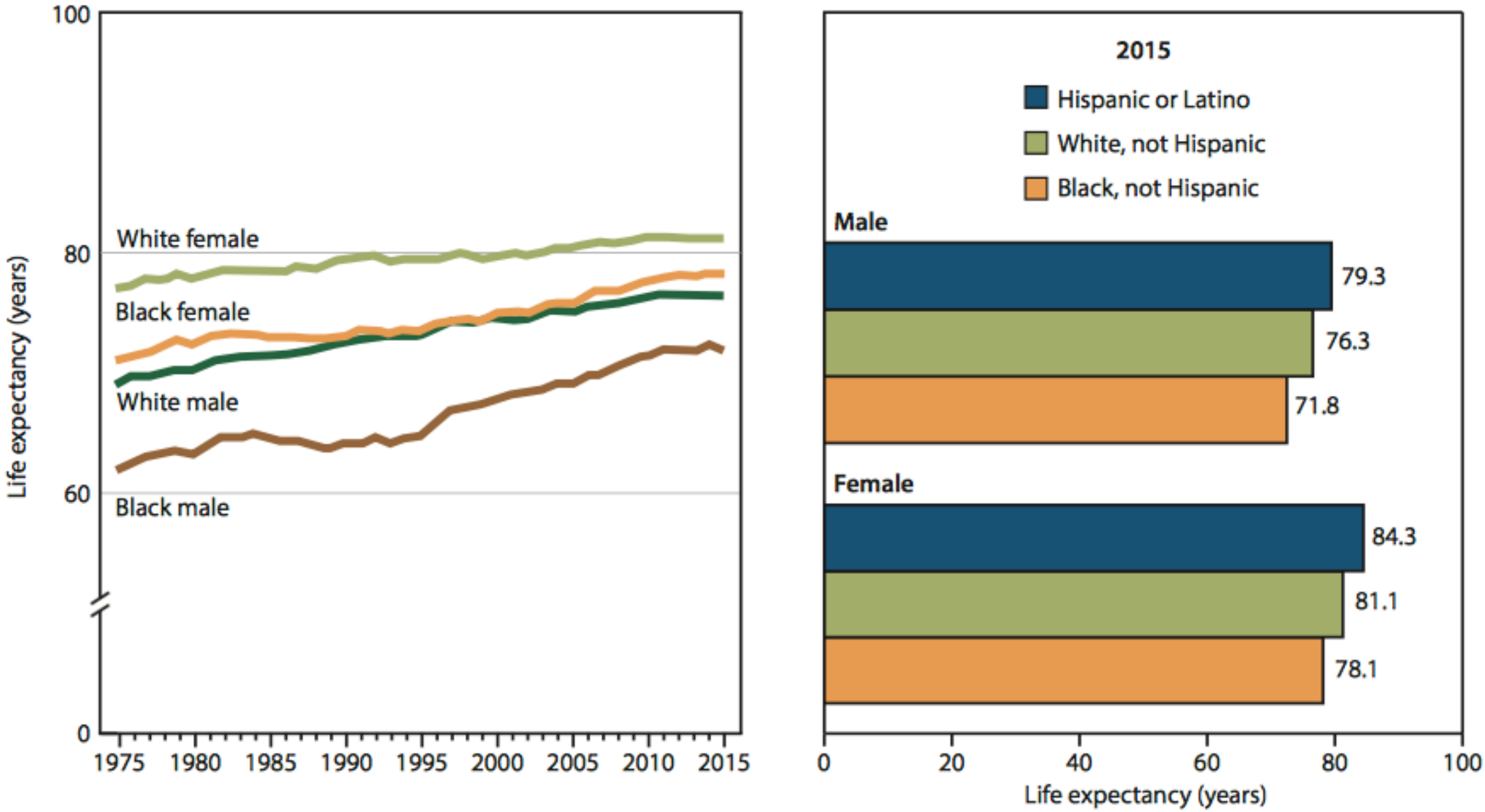
- Life table deaths by year (Japan, 2015)

http://www.ipss.go.jp/p-toukei/JMD/00/STATS/Mx_1x1.txt



Ethnic Differences

Figure 6. Life expectancy at birth, by sex, race and Hispanic origin: United States, 1975–2015



https://www.cdc.gov/nchs/data/hus/hus16.pdf#019

Causes of death
(USA, 2014)

Cause	Deaths/100K	%
Heart disease	192.7	23.4
Cancer	185.6	22.5
Chronic lower respiratory disease	46.1	5.6
Accidents	42.7	5.2
Stroke	41.7	5.1
Alzheimer's disease	29.3	3.6
Diabetes	24.0	2.9
Influenza and pneumonia	17.3	2.1
Kidney disease	15.1	1.8
Suicide	13.4	1.6
OTHER	*215.8*	*26.2*
TOTAL	823.7	100.0

https://www.medicalnewstoday.com/articles/282929.php

Morbidity: Top 10 Chronic Conditions
Persons aged ≥ 65

Condition	Both	Male	Female
Arthritis	49.6	40.7	55.7
Hypertension	39.0	33.0	43.2
Hearing impairment	30.0	35.2	26.3
Heart disease	25.7	26.9	24.9
Orthostatic impairment	16.8	15.7	17.8
Cataracts	15.5	11.3	18.4
Chronic sinusitis	15.2	13.7	16.2
Visual impairment	10.1	12.0	8.8
Genitourinary	9.9	11.3	8.9
Diabetes	8.9	7.8	9.7

U.S. Nat'l Ctr Health Stat, *Vital and Health Statistics*, 1985 (1982 data)

Next 10 Chronic Conditions
Persons aged ≥ 65

Condition	Both	Male	Female
Varicose veins	7.7	3.4	10.8
Hernia	7.6	9.1	6.5
Hemorrhoids	7.6	7.1	8.0
Psoriasis, dermatitis, dry skin	7.4	6.3	8.3
Hardening of arteries	7.4	7.3	7.4
Tinnitus	7.3	7.6	7.1
Corns, calluses & bunions	7.3	4.2	12.7
Constipation	6.5	4.4	8.0
Hay fever	6.4	6.4	6.5
Cerebrovascular	5.7	5.6	5.8

U.S. Nat'l Ctr Health Stat, *Vital and Health Statistics*, 1985 (1982 data)

Quality of life

Value of a total life depends on

- Length (assume now is N)
- Quality (q) over time
- Discounts (g) for future or past
  - depends very much on what the value is to be used for
  - what is an appropriate discount factor?

$$V_N = \int_{t=0}^{T} q(t)g(t-N)\mathrm{d}t$$

Activities of Daily Living

Basic

- Bathing and Showering
- Personal hygiene and grooming
  - brushing/combing/styling hair
- Dressing
- Toilet hygiene
- Functional mobility (“transferring”)
  - walk, get in and out of bed
  - get into and out of a chair
- Self-feeding (not including cooking or chewing and swallowing)

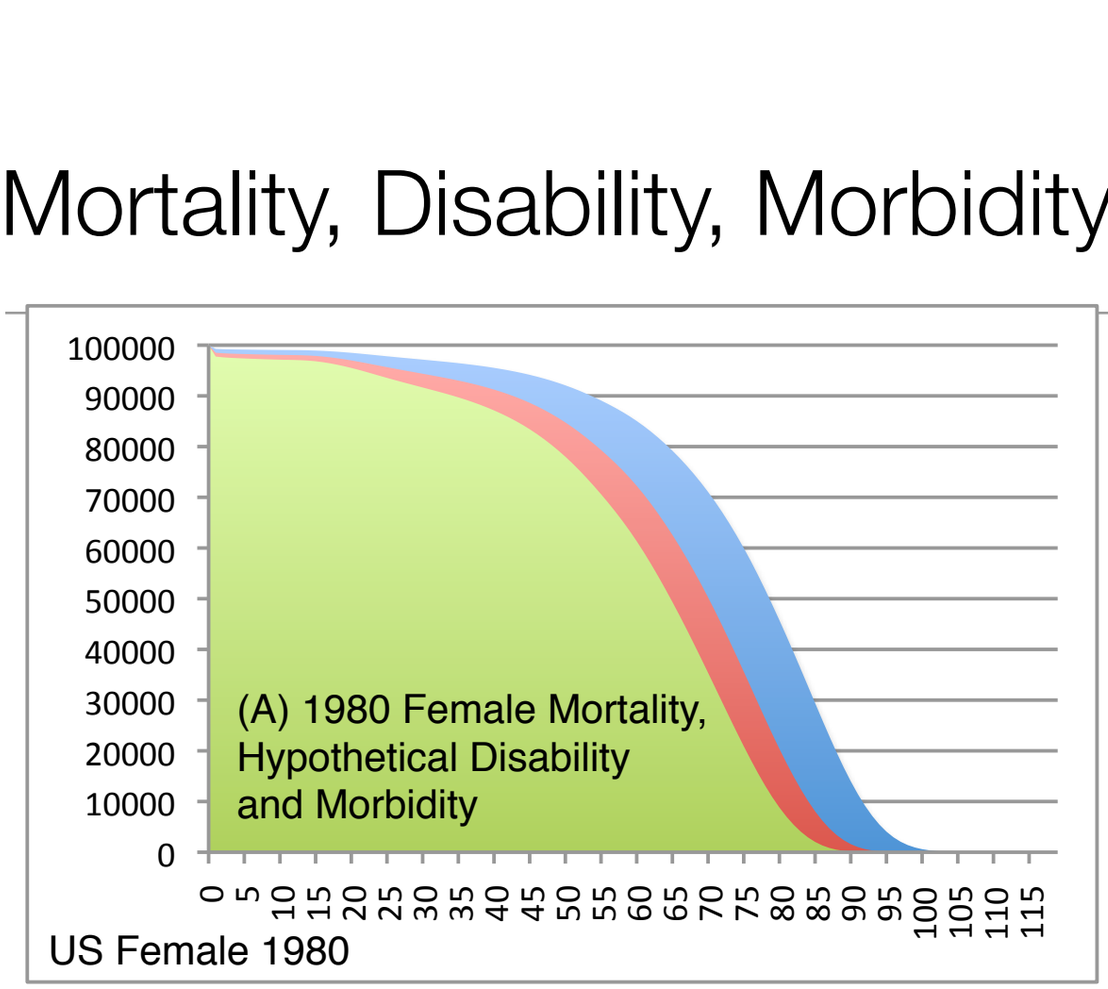
Instrumental

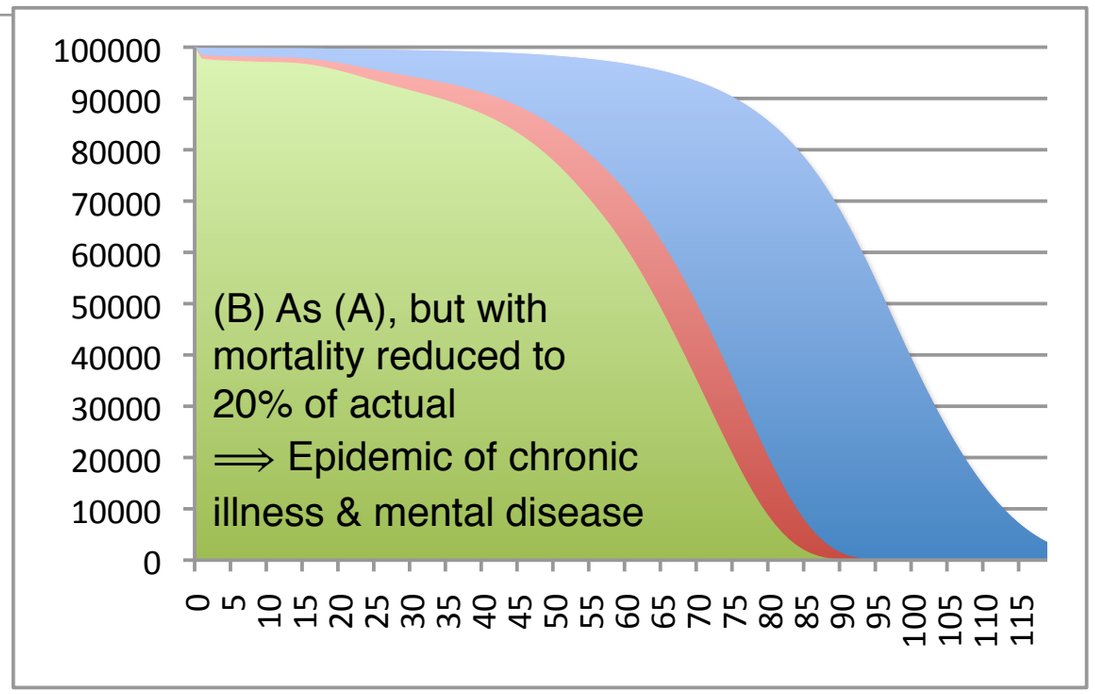
- Cleaning and maintaining the house
- Managing money
- Moving within the community
- Preparing meals
- Shopping for groceries and necessities
- Taking prescribed medications
- Using the telephone or other form of communication

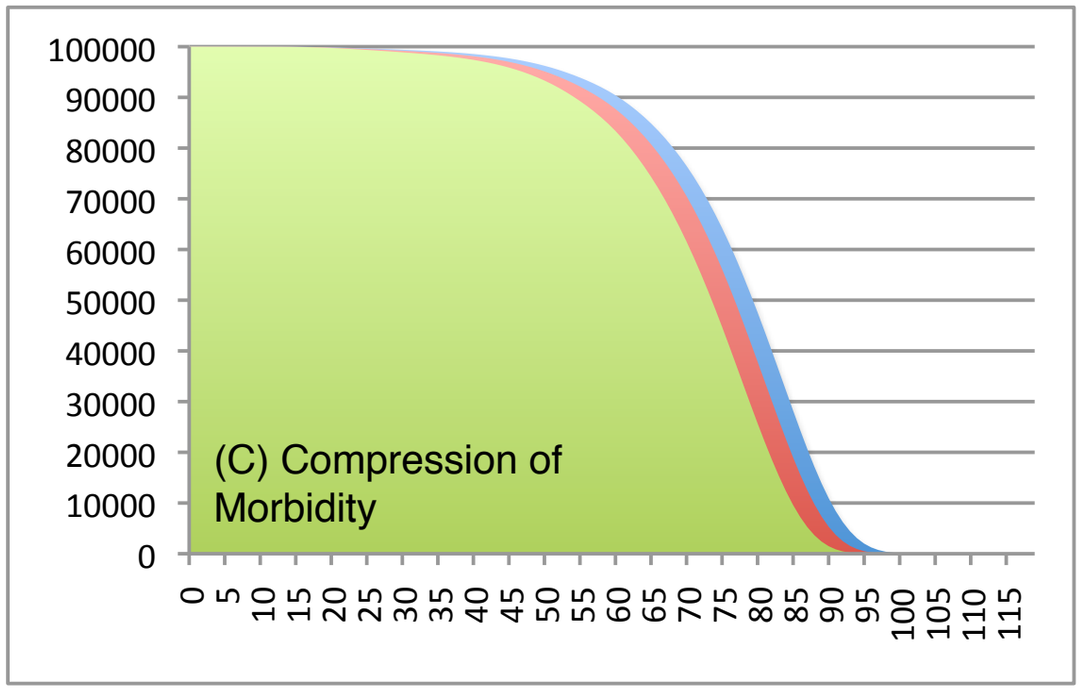
Goals of “Occupational Therapy”

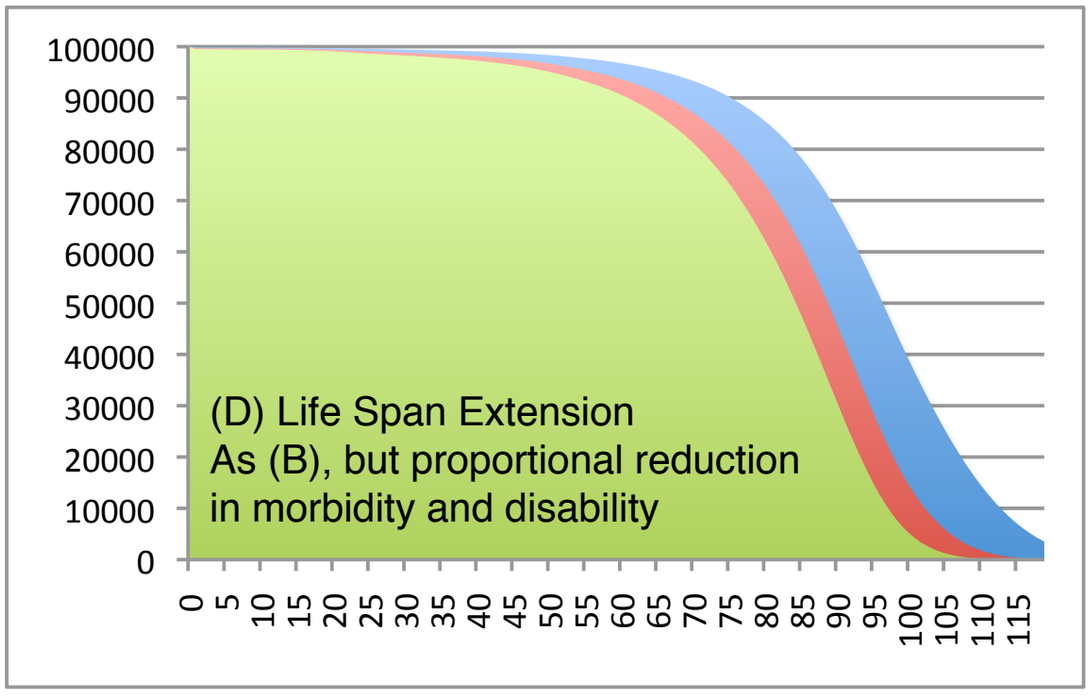
- Care of others (including selecting and supervising caregivers)
- Care of pets
- Child rearing
- Communication management
- Community mobility
- Financial management
- Health management and maintenance
- Home establishment and maintenance
- Meal preparation and cleanup
- Religious observances
- Safety procedures and emergency responses
- Shopping

Mortality, Disability, Morbidity









Societal quality of life

- Aggregation of individual qualities

+ Equity (distributions)

- Is more better? (Population control)
- Is less better?
- How much to spend?

Time scale in medicine

- Cure—usually acute illness
- Manage—long-term, chronic illness
- Prevent
- Predict

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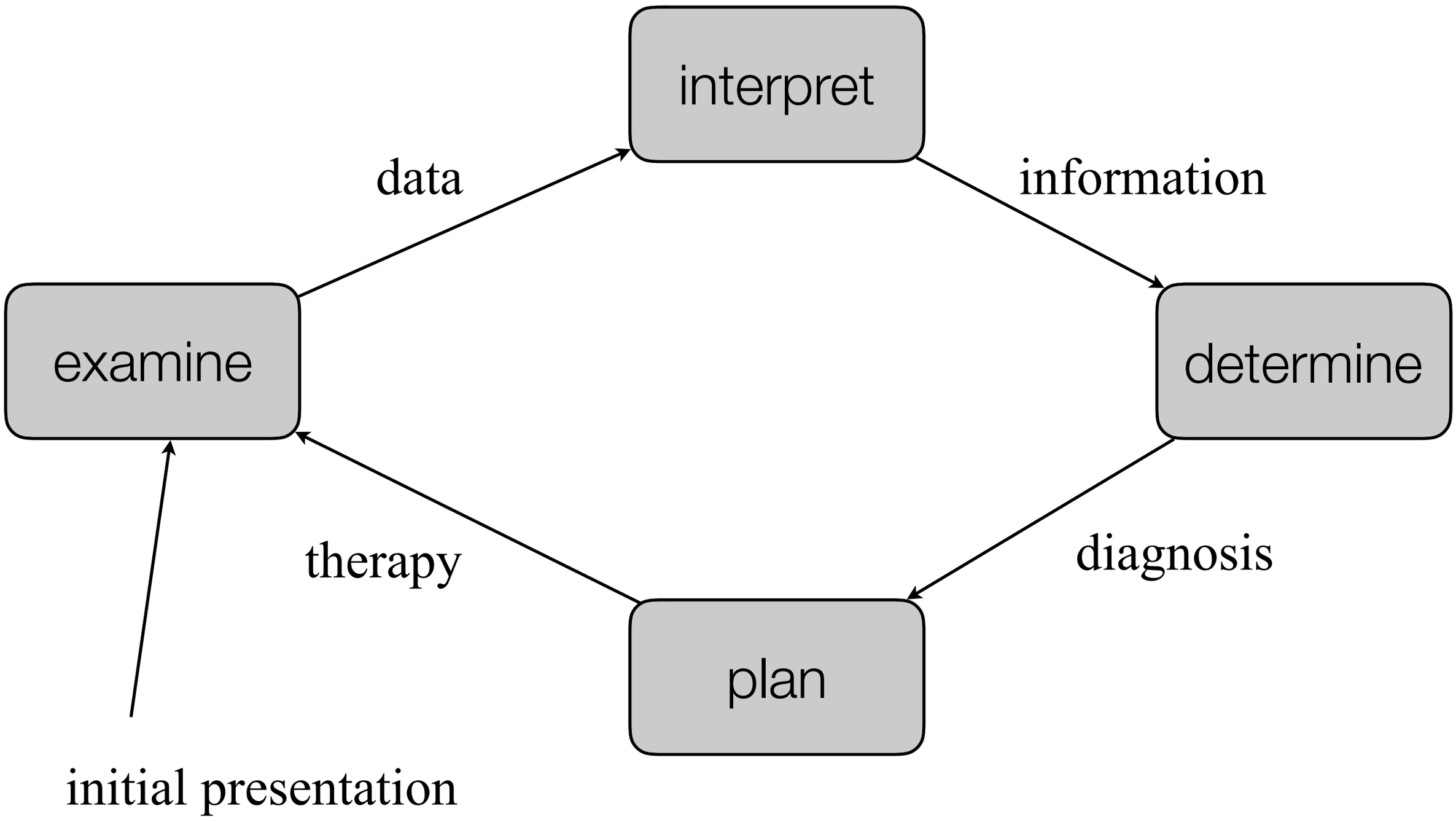
Traditional tasks of medicine

- Diagnosis
  - “the art or act of identifying a disease from its signs and symptoms”
- Prognosis
  - “the prospect of recovery as anticipated from the usual course of disease or peculiarities of the case”
- Therapy
  - “therapeutic medical treatment of impairment, injury, disease, or disorder”

Definitions from Meriiam-Webster

The Medical Cycle



Care Processes

- Data:
  - observation, instrumentation, monitoring, telemetry, lab tests
- Information:
  - interpretation, filtering, sampling, smoothing, clustering
- Diagnosis:
  - inference, model-based reasoning, classification
- Prognosis:
  - prediction, natural course, experience
- Therapy:
  - planning, predicting effects, anticipating

Cognitive Theory of Diagnosis

- From initial complaints, guess suitable hypothesis
- Use current active hypotheses to guide questioning
- Failure to satisfy expectations is the strongest clue to a better hypothesis; differential diagnosis
- Hypotheses are activated, de-activated, confirmed or rejected based on
  - (1) logical criteria
  - (2) probabilities based on:
    - findings local to hypothesis
    - causal relations to other hypotheses (coherence)

- ≈ Scientific Method

Pauker, S. G., Gorry, G. A., Kassirer, J. P., & Schwartz, W. B. (1976). Towards the simulation of clinical cognition. Taking a present illness by computer. The American Journal of Medicine, 60(7), 981–996.

Meta-level processes

- Acquisition and application of knowledge
- Education
- Quality control and process improvement
- Cost containment
- Reference (library)

Enterprise-level Clinical Process Automation…

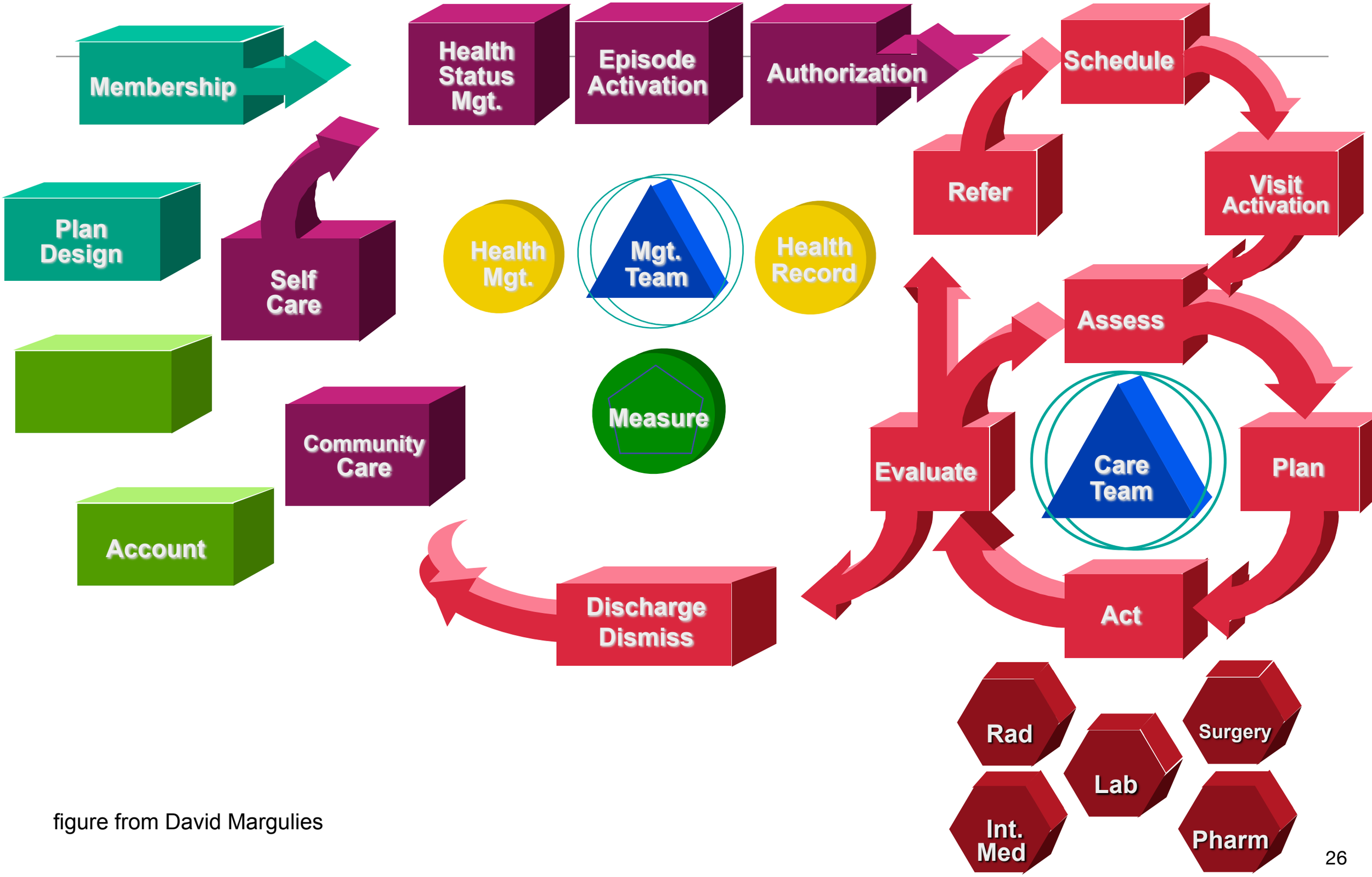
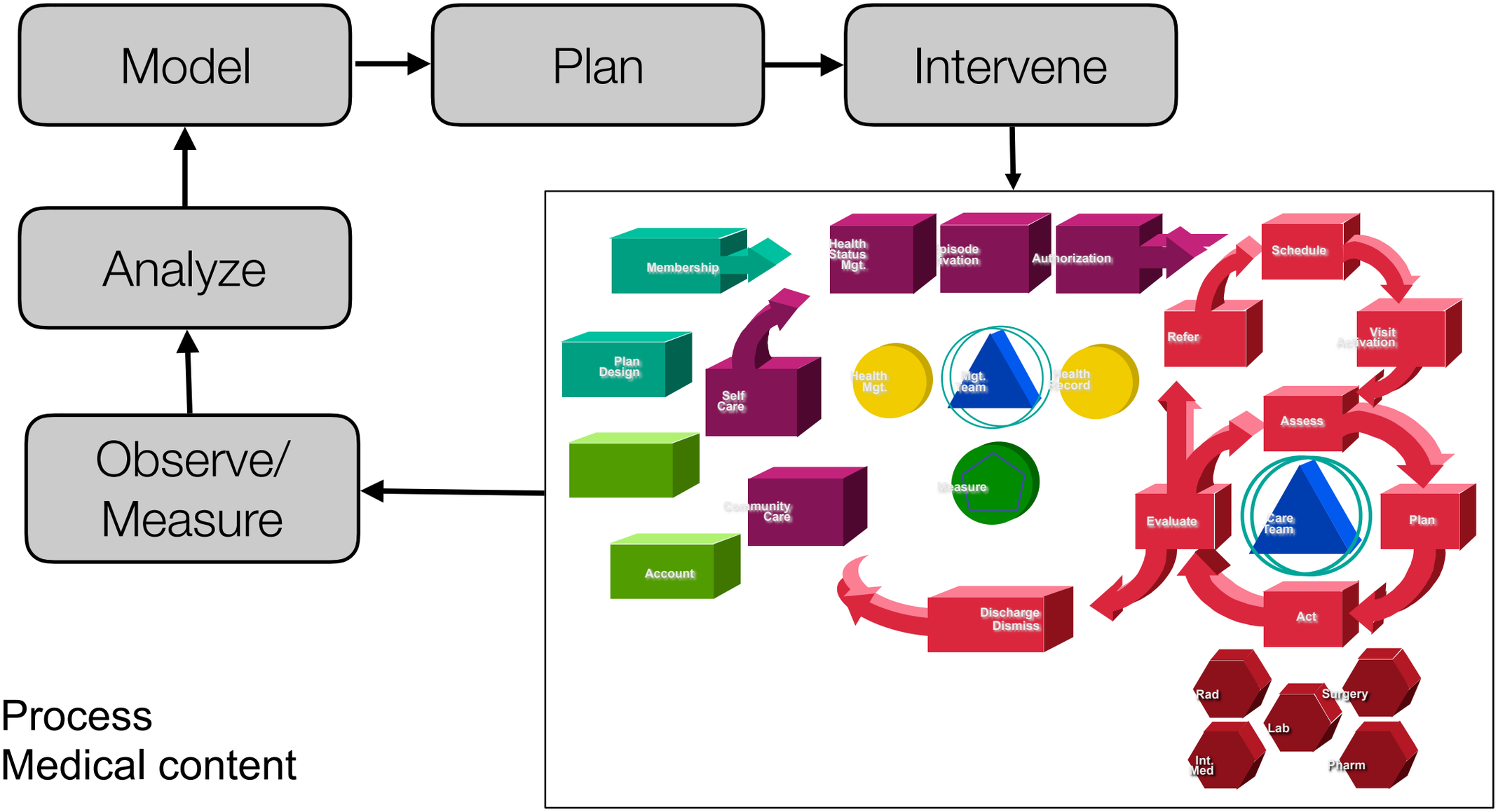


figure from David Margulies

The “Learning Health Care System”



- Process
- Medical content

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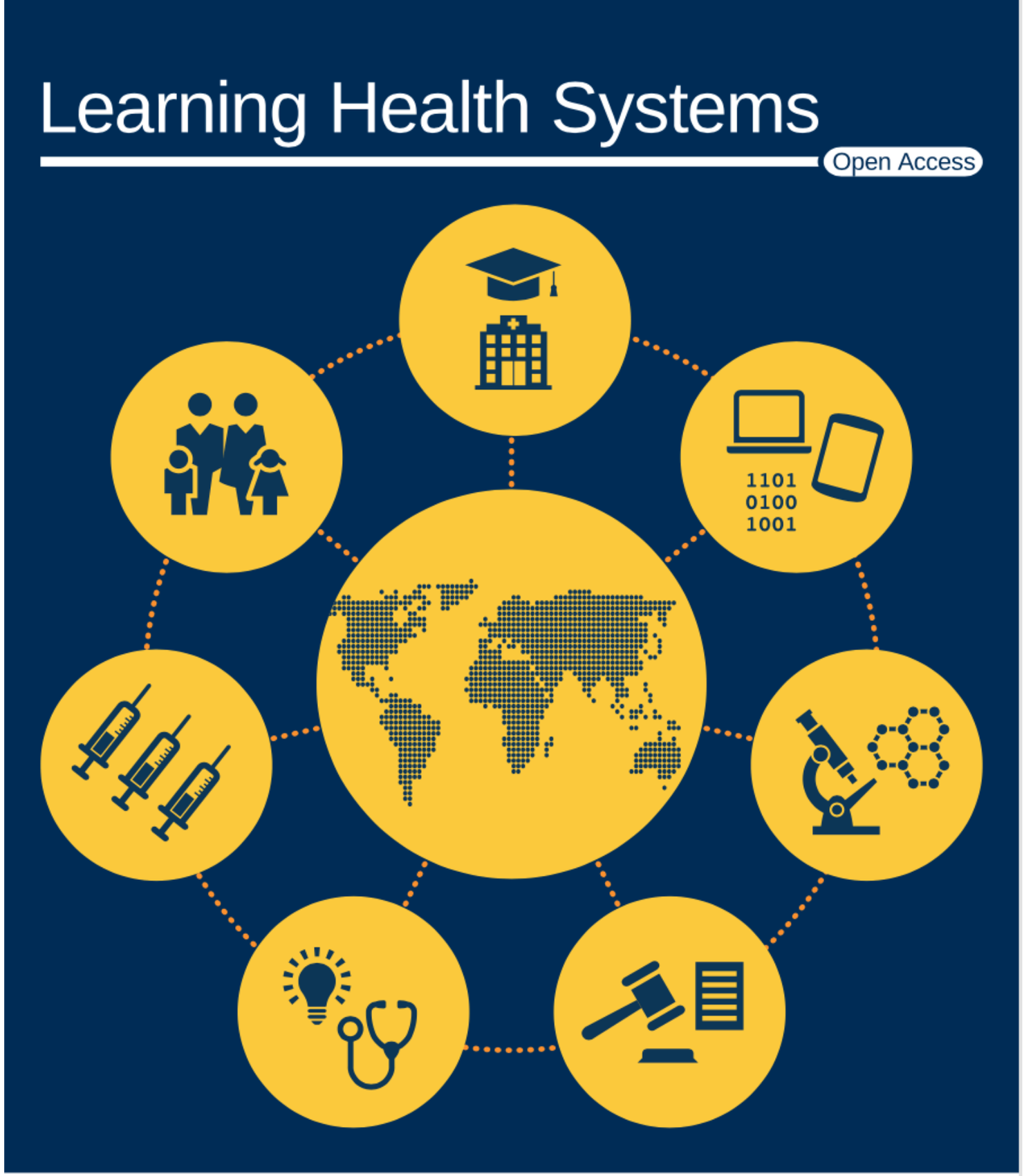

Volume 1, Issue 1

January 2017

COMMENTARY

The science of Learning Health Systems: Foundations for a new journal

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WILEY

How Does the Health System Learn?

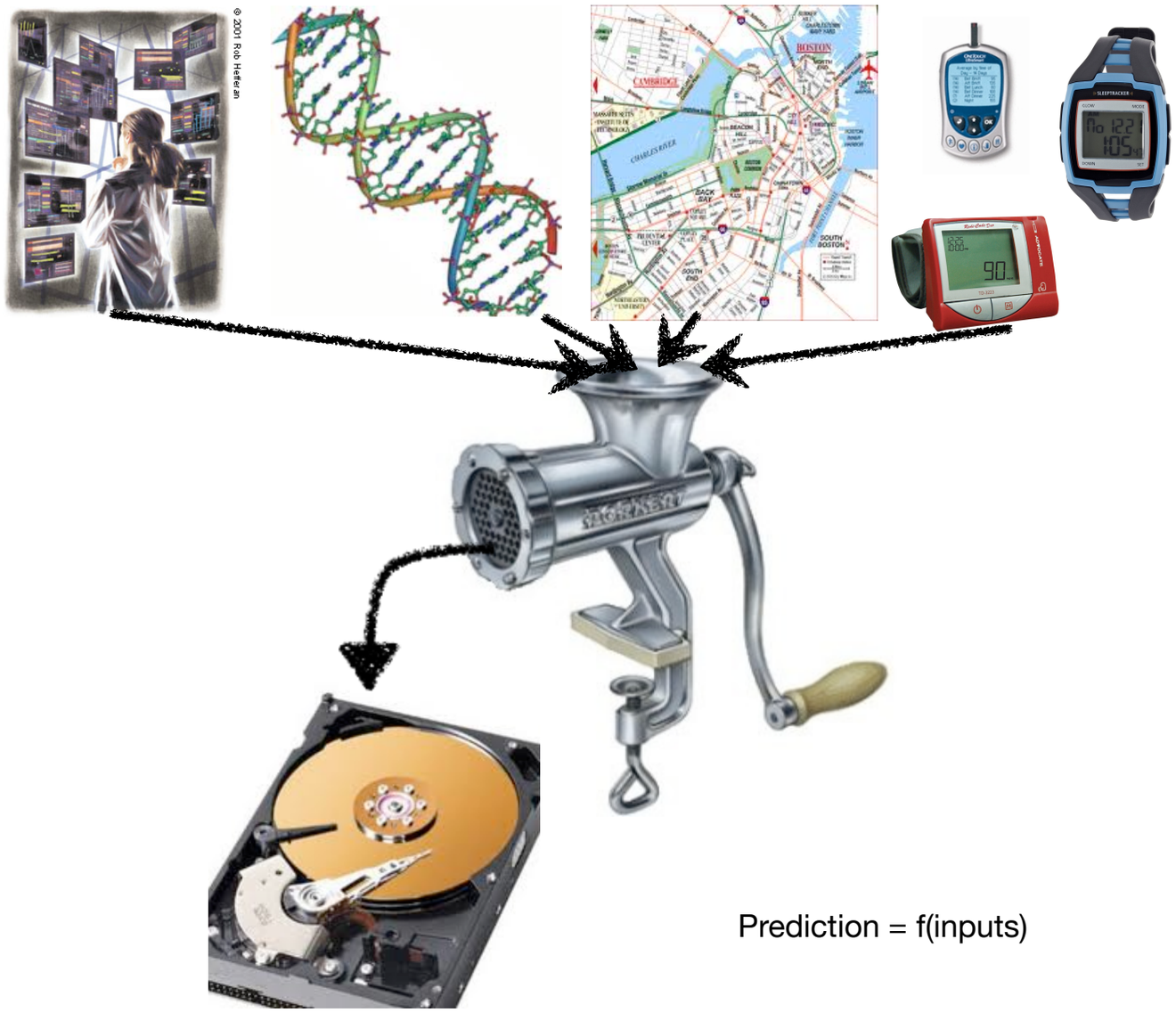
- "Evidence-Based Medicine"
  - Contrast with "Tradition-Based Medicine" — Apprenticeship
- Randomized Controlled Clinical Trial (RCT)
  - E.g., is drug A more effective than drug B for condition X?
  - Narrow selection of patient cases and controls
  - Careful collection of systematically organized data
  - Statistical analysis of outcomes

    => Statistically significant conclusions
- But:
  - **Heterogeneity:** Most cases to which RCT results are applied do not fit trial criteria
  - **Short Follow-Up:** Trials run for limited times, but use is longer
  - **Small Samples:** Some effects are rare but devastating

“The Learning Health Care System”

- “one in which progress in science, informatics, and care culture align to generate new knowledge as an ongoing, natural by-product of the care experience, and seamlessly refine and deliver best practices for continuous improvement in health and health care” —IOM
- Needs not currently met:
  - Comprehensive collation of all clinical, social, demographic, behavioral, ... data that are now captured in the health care system
  - Routine capture of novel data sources:
    - genomes, gene expression, etc.
    - environmental factors (e.g., metagenomics)
    - physiological response to life situations
      - (related to fitness and wellness)
  - Technical infrastructure
    - Storage and analysis of truly “big data”
  - Incentives and demonstrations of utility

Use All Possible Data



Prediction = f(inputs)

Goals of Medicine: (2) Keep people healthy

- Public Health
  - Tracking disease prevalence
  - Tracing infections
  - Quarantine

Tracking disease prevalence by systematic classification

- 17th century: John Graunt on the London Bills of Mortality estimated mortality before age 6 at 36%
- 18th century: Sauvage, Linnaeus, Cullen made first attempts at systemic classification
- 1853—first International Statistical Congress led to Wm. Farr's system:
  - epidemic diseases
  - constitutional (general) diseases
  - local diseases arranged according to anatomical site
  - developmental diseases
  - diseases that are the direct result of violence

  (Note: pre-Pasteur)
- 1890s—Bertillon (Paris) classification: 161 titles, abstracted to 99, and 44
- 1920 International List of Causes of Death
- 1920s-40s—*Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death*
- 1975—ICD-9
- 2015—ICD-10
- ICD-*n* are under control of the World Health Organization (WHO)
- ICD-9CM, ICD-10CM are US "Clinical Modifications", mainly to support billing

https://www.who.int/classifications/icd/en/HistoryOfICD.pdf

Centers for Disease Control and Prevention (CDC)

- Today, we collect death certificates that record direct & indirect causes of death
- Insurance payments are based on classifications of disease, severity, tests, intervention, …

CAUSE OF DEATH (See instructions and examples)

32. PART I. Enter the chain of events--diseases, injuries, or complications--that directly caused the death. DO NOT enter terminal events such as cardiac arrest, respiratory arrest, or ventricular fibrillation without showing the etiology. DO NOT ABBREVIATE. Enter only one cause on a line. Add additional lines if necessary.

		Approximate interval: Onset to death
IMMEDIATE CAUSE (Final disease or condition ---------> resulting in death)	a. Cerebral hemorrhage	1 month
	Due to (or as a consequence of):	
Sequentially list conditions, if any, leading to the cause listed on line a. Enter the UNDERLYING CAUSE (disease or injury that initiated the events resulting in death) LAST	b. Nephritis	6 months
	Due to (or as a consequence of):	
	c. Cirrhosis of liver	2 years
	Due to (or as a consequence of):	
	d.	

PART II. Enter other significant conditions contributing to death but not resulting in the underlying cause given in PART I.

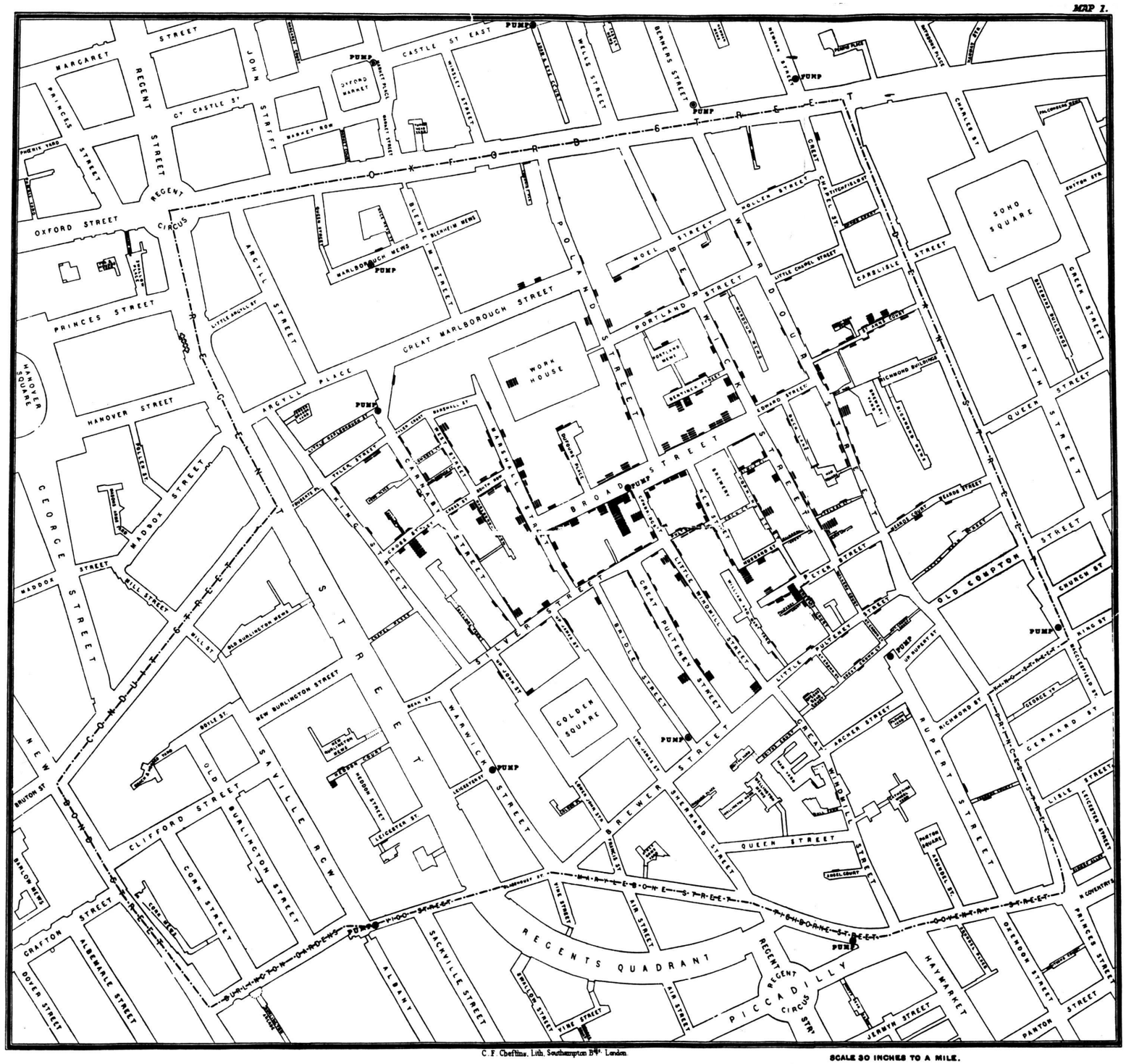
33. WAS AN AUTOPSY PERFORMED? • Yes • No

34. WERE AUTOPSY FINDINGS AVAILABLE TO COMPLETE THE CAUSE OF DEATH? • Yes • No

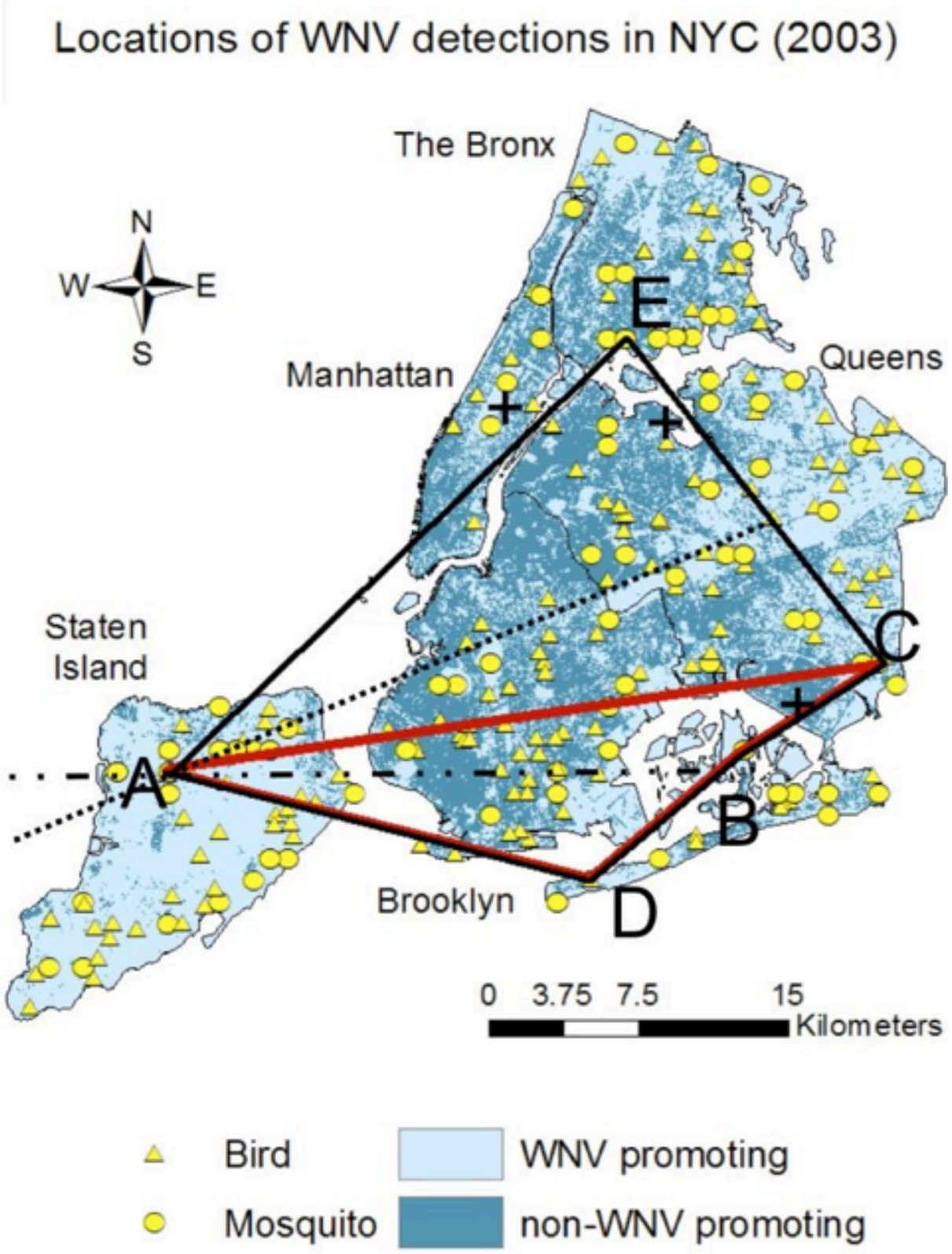
https://www.cdc.gov/nchs/ppt/nchs2012/li-14_minino.pdf

Cholera, John Snow, and the Broad Street Pump (1854)

- "germ-contaminated water was the source of cholera"
- Localization via mapping
- Led to sanitation improvements
- Snow also used:
  - Double-blind experimental technique
  - Voronoi diagrams to outline neighborhoods closest to each pump



https://upload.wikimedia.org/wikipedia/commons/2/27/Snow-cholera-map-1.jpg


Locations of WNV detections in NYC (2003)
The Bronx
N
W
E
S
E
Manhattan
Queens
Staten
Island
A
B
C
D
Brooklyn
0 3.75 7.5 15
Kilometers
Bird
Mosquito
WNV promoting
non-WNV promoting

Quarantine

- Isolation separates sick people with a contagious disease from people who are not sick.
- Quarantine separates and restricts the movement of people who were exposed to a contagious disease to see if they become sick.

- Mostly used at ports of entry, but sometimes to try to prevent epidemics
  - Ellis Island
  - “Typhoid Mary”
  - AIDS
  - Ebola

"TYPHOID MARY"

The Extraordinary Predicament of Mary Mallon, a Prisoner on New York's Quarantine Hospital

IT is probable that Mary Mallon is a prisoner for life—and yet she has committed no crime, has never been accused of an immoral or wicked act, and has never been a prisoner in any court, nor has she been sentenced to imprisonment by any judge.

Mary Mallon is a cook by profession. She has served in the kitchens of many New York millionaires with entire satisfaction for many years.

Mary Mallon for more than two years has been a prisoner on New York's quarantine island, along with the unfortunates who are from time to time removed to this isolated spot because they are suffering from smallpox, scarlet fever or other contagious diseases.

But while Mary sees these unfortunate victims of various diseases come on the hospital boat and, in due time, return to their homes and friends—Mary stays on forever.

There is probably in the whole wide world no prisoner that can furnish a parallel to the extreme misfortune which has brought Mary Mallon to North Brother Island. Through no fault of hers, Mary Mallon is a living, walking incubator of typhoid fever germs. Every day for two years the officials of the New York Board of Health have examined Mary, and they have been discouraged to find a bountiful supply of new typhoid fever bacilli freshly made each twenty-four hours by Mary.

Mary Mallon, in the five years before the authorities got their hands on her, was [illegible] of twenty-six cases of typhoid fever—[illegible] others. So far as is known, the woman [illegible] had the disease, and is not now sick with it. But somewhere in her anatomy, perhaps [illegible] of the gall duct, there is a never failing [illegible] typhoid fever germs. To the positive [illegible] Board of Health Mary has been generously [illegible] typhoid bacilli for seven years. This [illegible] they are able to trace her history [illegible]

MOST HARML

4 Londoners.

By Dr. Wm. H. Park, New York Board of Health.

MARY MALLON is the chief of fifty persons, fifteen of whom have been discovered within the past two years, in this country, whom we know in medical science as typhus bacilli carriers. Her case is the most remarkable with which we are acquainted, because of the number of persons to whom she has communicated the disease.

Our study of the case leads us to believe that the typhus germs lodge in the gall bladder, where they live indefinitely. From there they are carried through the body by the bile.

She is confined on North Brother Island, where she has been a prisoner for two years, and where, of course, she will remain indefinitely. She is a large, healthy looking woman, a typical cook, and there is nothing in her outward appearance to indicate that she is other than normal. She is, of course, segregated with the typhoid patients. When we consider that she has been spreading the contagion for many years, it is clear that she will be a prisoner on North Brother Island for a long time, perhaps for life; certainly until we are convinced that the typhus germs and typhus tendencies have been eliminated from her body.

Every effort has been made by the health authorities to cure the unfortunate woman, but so far without success. Examination is made each day, with the hope that some one of the various expedients we have tried may put an end to the discharge of bacilli. Nothing we have tried so far has proved effective. There is nothing at the present moment known to medical science which seems to reach a case like this. It is extremely unfortunate for the woman; but it is the plain duty of the health authorities to safeguard the public from such a menace.

The Extraordi[nary] and Dis[ease]

The Official [Report]

IN the Winter of 1906 I was called on to investigate a household epidemic of typhoid fever which had broken out in the latter part of August at Oyster Bay, N. Y. The epidemic had been studied carefully immediately after it took place, but its cause had not been ascertained with as much certainty as seemed desirable to the owner of the property.

The essential facts concerning the investigation follow:

At Oyster Bay, in the Summer of 1906, six persons in a household of eleven were attacked with typhoid fever. The house was large, surrounded with ample grounds, in a desirable part of the village, and had been rented for the Summer by a New York banker.

The first person was taken sick on August 27 and the last on September 3. The diagnosis of typhoid was positive. Two of the patients were sent to the Nassau Hospital at Mineola. The others were attended by capable physicians at Oyster Bay. None of the subsequent cases apparently resulted from the first, although the interval from the first to the last might permit of this assumption. But whether the disease was transmitted from one person to another after the first case occurred was not a matter of great consequence. The most important question was how the first case occurred.

Germ Source a Mystery.

Typhoid fever is an unusual disease in Oyster Bay, according to the three physicians who share the medical practice there. At the time of the outbreak no other case was known. None followed.

The milk supply of this house was the same as used by most of the other persons in the village, all of whom remained well. The cream also was from a source which supplied several other families in the vicinity.

To the first investigators it seemed that the water must have been contaminated. They were

HELMS CALLS FOR AIDS QUARANTINE ON POSITIVE TESTS

By **United Press International**
CHICAGO TRIBUNE

JUNE 16, 1987 | WASHINGTON

A quarantine of people who test positive for AIDS infection is the way to halt the spread of the deadly disease, Sen. Jesse Helms (R., N.C) said Sunday. Helms appeared on the CBS "Face The Nation" program after Education Secretary William Bennett, who suggested that prison inmates infected with the AIDS virus should be kept in custody after serving their sentences if they threaten to spread the disease to the general population to take "revenge on society."

Quarantine

- Quarantine is a controversial and debated issue. … significant risks related to human rights, creating fear and confusion…
- Quarantine should be used as a last resort
- Quarantines in urban areas are complicated by the size and density of their populations

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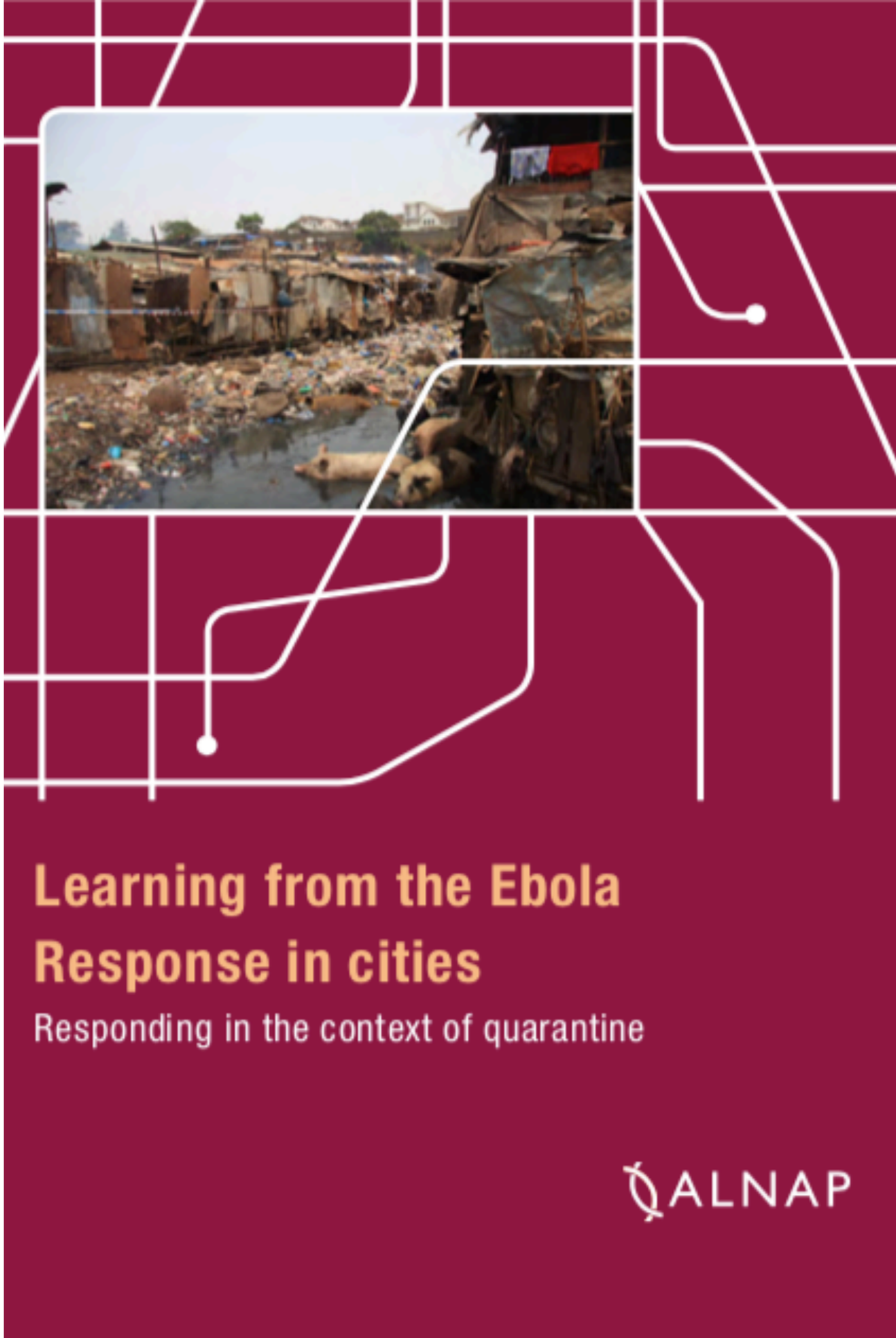
- Highly mobile populations make managing and enforcing quarantine more complex
- Large-scale quarantines result in equally large waste disposal needs and other water, sanitation and hygiene vulnerabilities



https://reliefweb.int/sites/reliefweb.int/files/resources/alnap-urban-2017-ebola-quarantine.pdf

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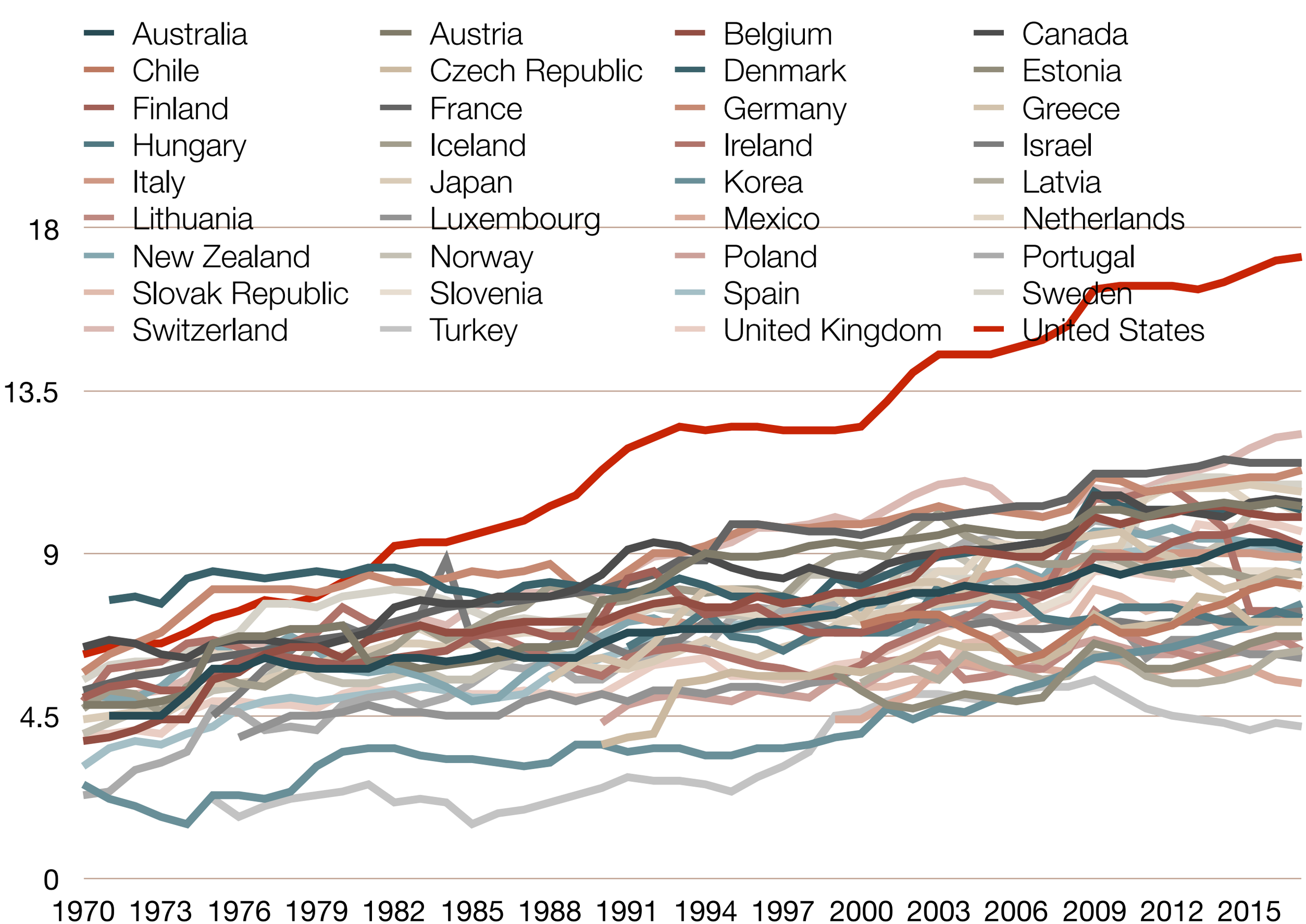
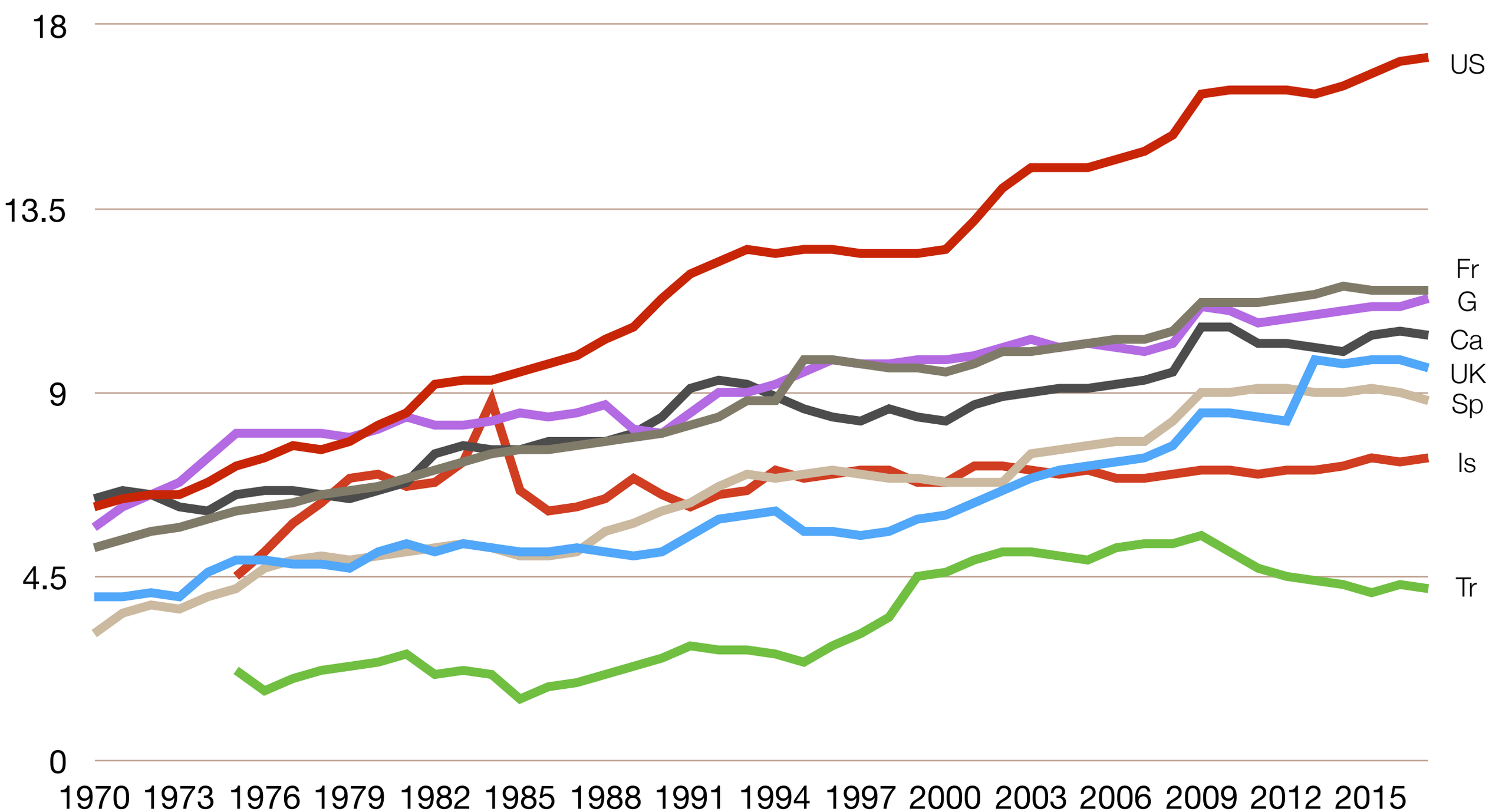
Paying for Health Care

- More healthcare than steel in GM cars
- Increased demand
  - Much more possible
  - Better tests, therapies
  - High human motivation
- No pushback
- Waste
  - Unnecessary procedures
    - ½ of health expenses in last year of life
  - Marginally useful procedures
    - Defensive medicine
  - Bad Medicine
    - IOM: 48-98K “unnecessary” deaths/year


Australia
Austria
Belgium
Canada
Chile
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Israel
Italy
Japan
Korea
Latvia
Lithuania
Luxembourg
Mexico
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Slovenia
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States
18
13.5
9
4.5
0
1970 1973 1976 1979 1982 1985 1988 1991 1994 1997 2000 2003 2006 2009 2012 2015

United States
United Kingdom
France
Spain
Germany
Israel
Canada
Turkey

1970–2017 % GDP spent on health care in various OECD countries

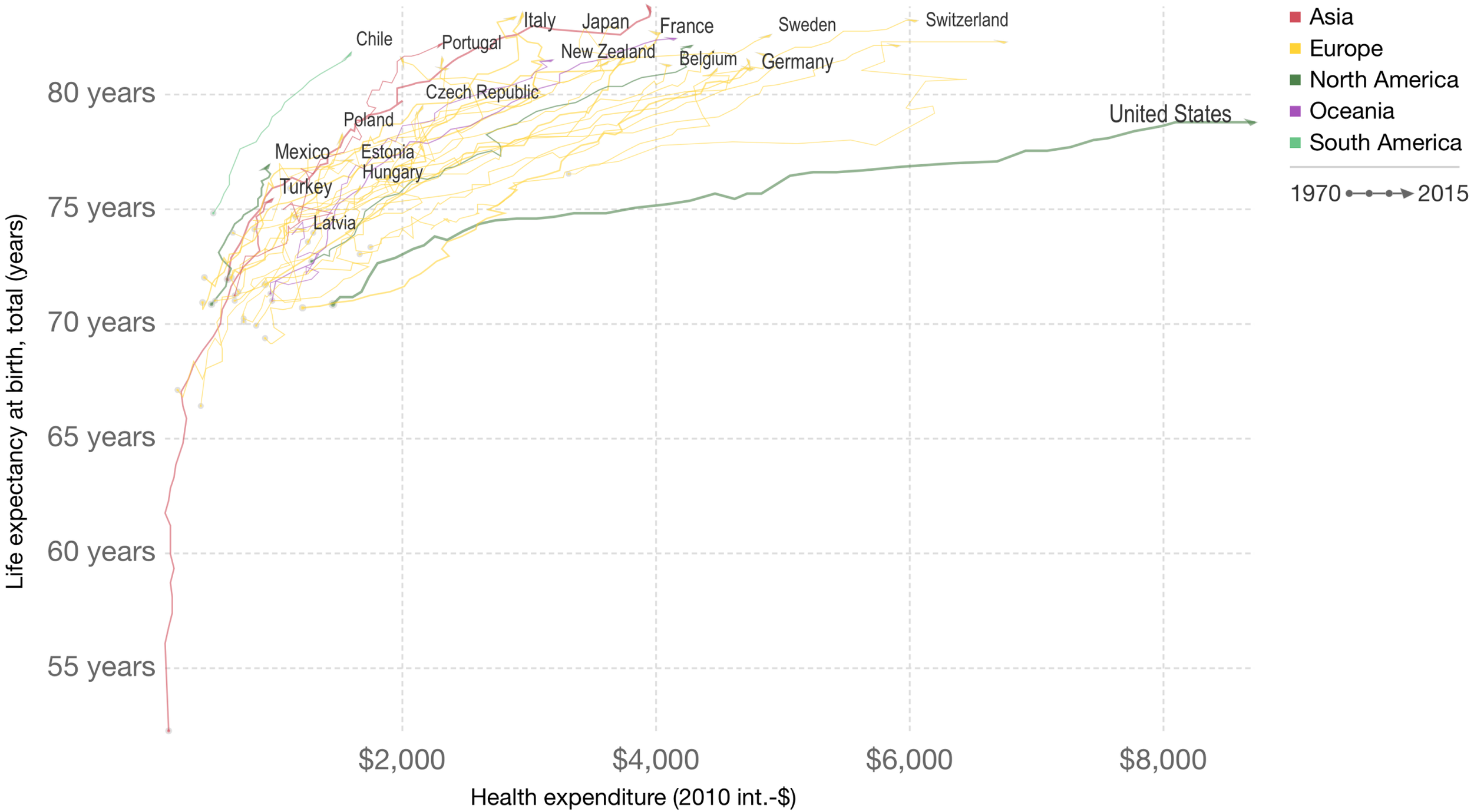


http://www.oecd.org/health/health-statistics.htm

Life expectancy vs. health expenditure, 1970 to 2015

Health financing is reported as the annual per capita health expenditure and is adjusted for inflation and price level differences between countries (measured in 2010 international dollars).

Our World in Data

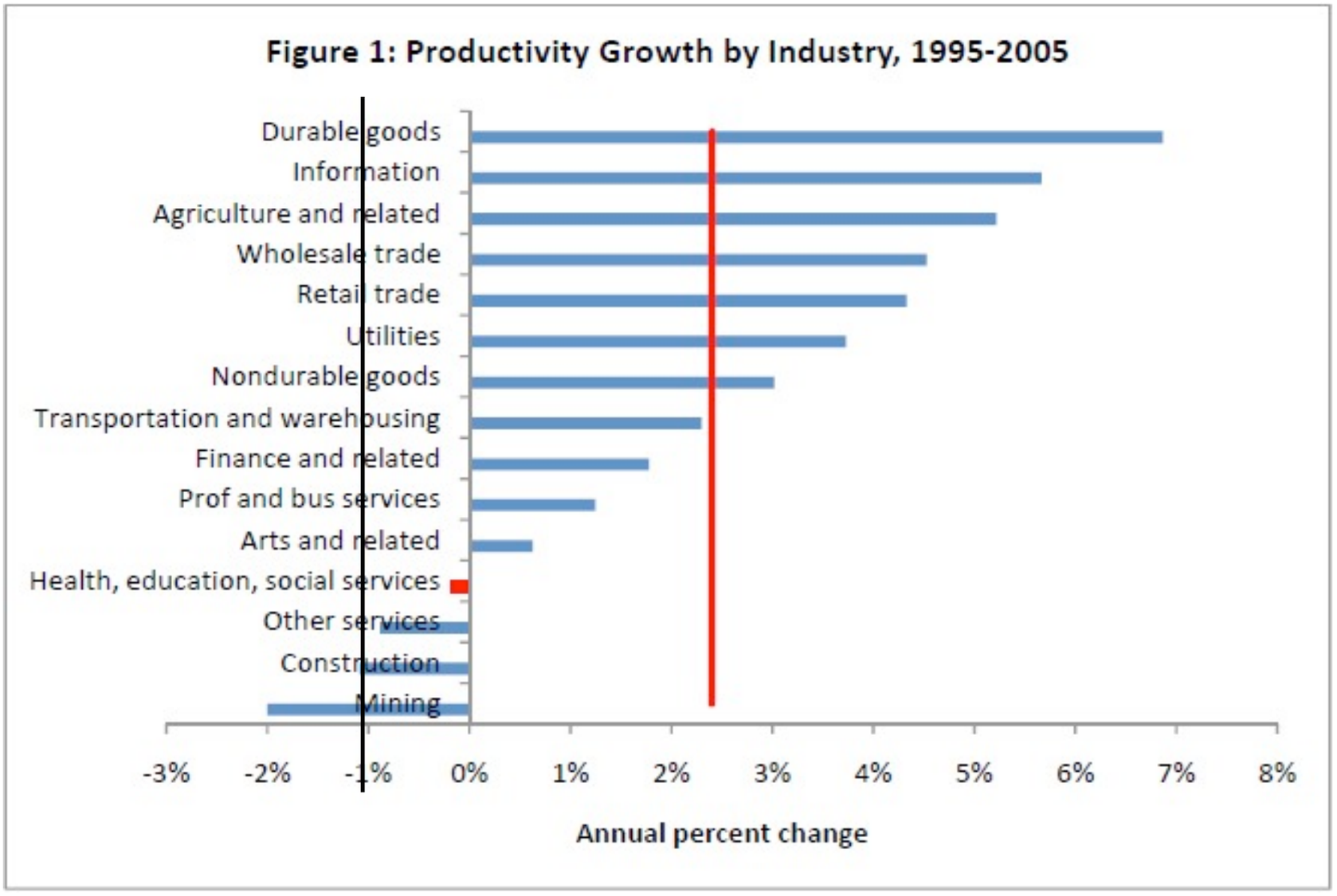


Source: World Bank – WDI, Health Expenditure and Financing - OECDstat (2017)
OurWorldInData.org/the-link-between-life-expectancy-and-health-spending-us-focus • CC BY-SA

https://ourworldindata.org/the-link-between-life-expectancy-and-health-spending-us-focus

Standing Still is Not Good Enough

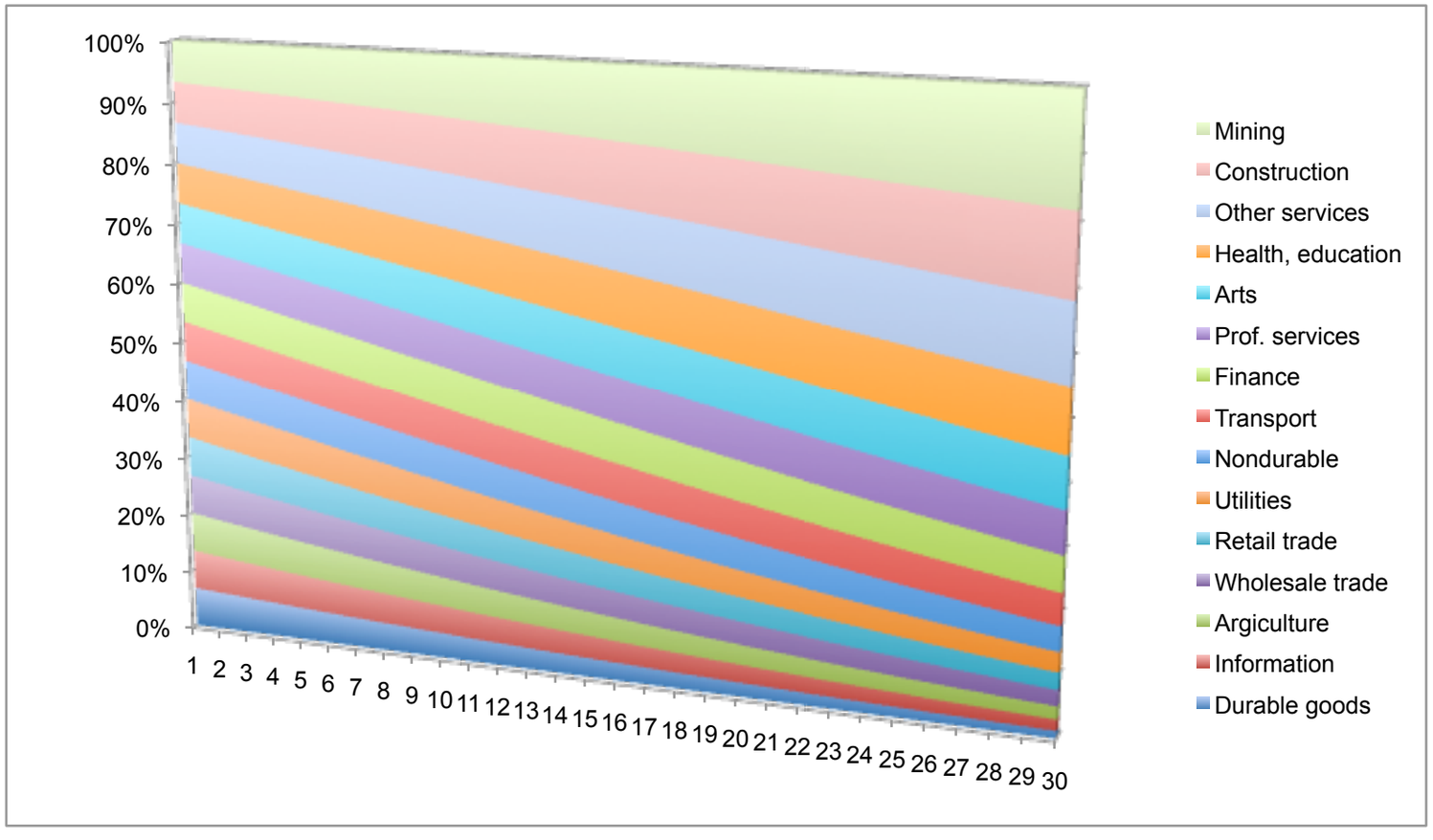
Chris Dede,
Harvard Ed



http://theincidentaleconomist.com/wordpress/the-health-care-productivity-problem/

Less Efficient Sectors Come to Dominate

- Hypothetical sector growth over 30 years, assuming constant demand for each sector



Hypothetical sector growth over 30 years, assuming constant demand for each sector. Productivity rates from OECD 2009.

How is care managed?

- Active case management:
  - Preadmission review
  - Continued-stay review
  - Second surgical opinion
- Selective case management—high-cost cohorts
  - Post-care management
- Institutional
  - Capitation
  - Institutional arrangements (referrals, hospitals, pharmacies, …)
  - Control “leakage”

Managed Care Scorecard

- “U.M. has helped to reduce inpatient hospital use and to limit inpatient costs…”
- “The impact of U.M. on net benefit costs is less clear. Savings on inpatient care have been partially offset by increased spending for outpatient care and program administration.”
- “U.M. … does not appear to have altered the long-term rate of increase in health care costs.”
- “Decisions that were once the exclusive province of the doctor and patient now may be examined in advance by an external reviewer—someone accountable to an employer, insurer, health maintenance organization (HMO), or other entity responsible for all or most of the cost of care. Depending upon the circumstances, this outside party may be involved in discussions about where care will occur, how treatment will be provided, and even whether some treatments are appropriate at all.”

—IOM, 1989

Managed Care Opposition

"In those days there was no bureaucratic regimentation, there were few forms to fill out, malpractice premiums were affordable, and the overhead costs of running a practice were reasonable. Our bills were simple, spelled out so anybody could understand them without the use of codes. Patients usually paid their own bills, promptly too, for which an ordinary receipt was given. Hospital charges were set by the day, not by the aspirin. Medical care was affordable to the average person with rates set by the laws of the marketplace, and care was made available to all who requested it regardless of ability to pay. Doctors were well respected; rarely were we denigrated by a hostile press for political reasons. Yes, in the days before government intervention into the practice of medicine, doctor's fees were low, but the rewards were rich; those were truly the 'golden years' for medicine."

Edward Annis, past President of AMA

Code Blue, 1993

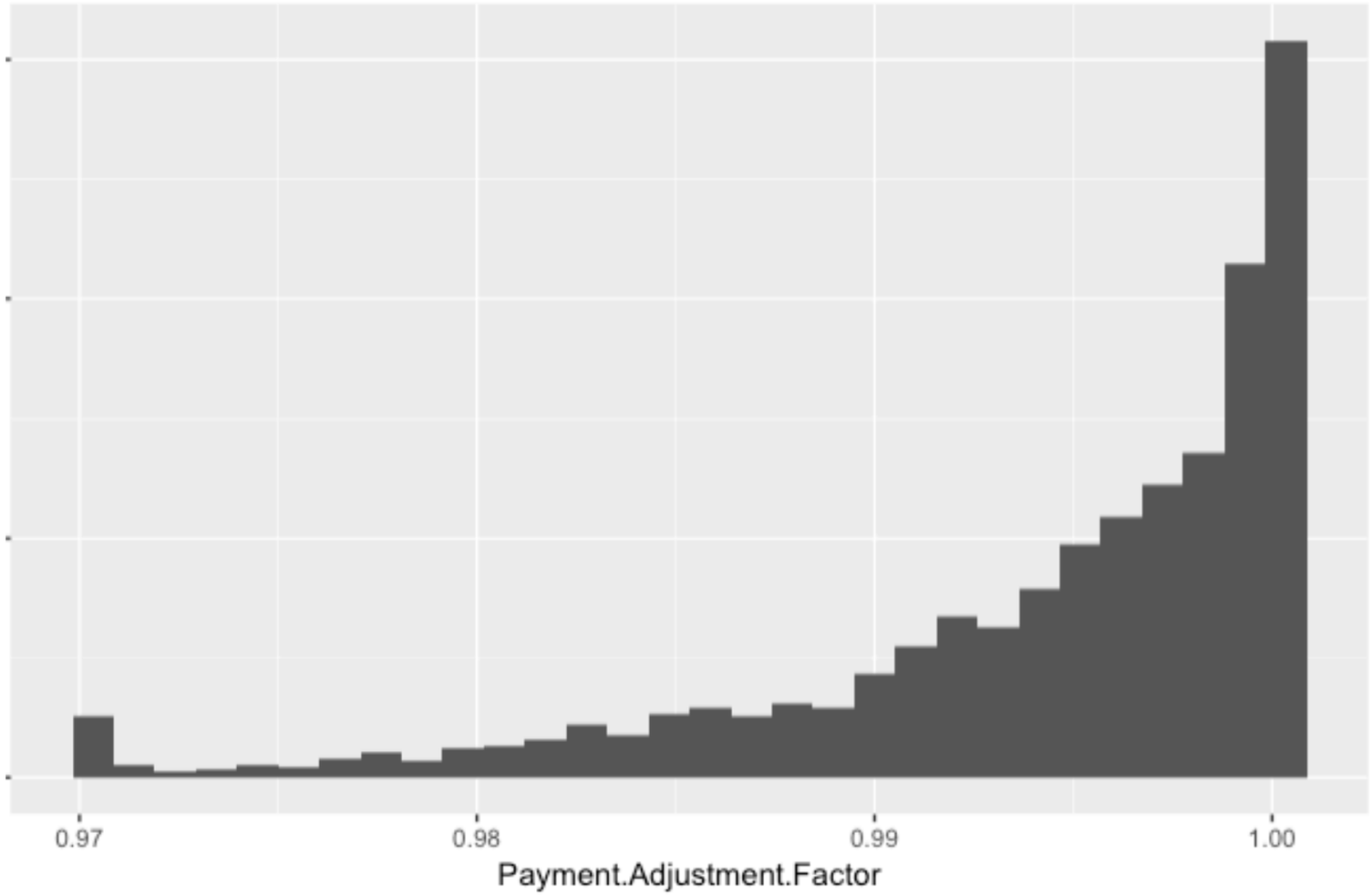
ObamaCare

- Universal coverage: everyone must get insurance
  - Employer
  - Insurance collaborative
  - Government (?) — rejected
- Insurance companies cannot deny insurance, cancel coverage, impose reimbursement limits based on illness, past or present
- Government assistance to poor people, small companies
- Health Information Technology (HIT) to smooth info flow
- Cost savings from avoiding billing disputes, ceasing to reimburse only procedures, evidence-based medicine
- *Accountable Care Organizations*

Hospital Readmissions Reduction Program

Excess readmission: within 30 days of discharge

- CMS uses excess readmission ratios (ERR) for:
  - Acute Myocardial Infarction (AMI)
  - Chronic Obstructive Pulmonary Disease (COPD)
  - Heart Failure (HF)
  - Pneumonia
  - Coronary Artery Bypass Graft (CABG) Surgery
  - Elective Primary Total Hip Arthroplasty and/or Total Knee Arthroplasty (THA/TKA)



Quality Improvement

- IOM Study: 96,000 US deaths/year from medical error (perhaps half preventable?)
- Information intervention *at the point of decision making* can improve decisions
- DPOE: Direct Physician Order Entry allows such intervention
- Leapfrog Group: Large employers ($$$) require DPOE from providers
- Patient Involvement: Indivo Health, Google Health, Microsoft Healthvault
  - *So far, all commercial failures*

Implications of Health Care Organization for Informatics

- Money determines much
  - Historically, medicine spends 1-2% on IT, vs. 6-7% for business overall, vs. 10-12% for banking
  - "Bottom line" rules, therefore emphasis on
    - Billing
    - Cost control
    - Quality control, especially if demonstrable cost savings
    - Retention and satisfaction (maybe)
  - Management by accountants
  - Slowly changing

Quo Vadis?

- Anticipated improvements in health care should give us better information
  - Genomic medicine
    - Genome, transcriptome, proteome, epigenome, metabolome, meta genome, …
  - Improved instrumentation, e.g.,
    - non-invasive examination of the body: ultrasound, MRI, CT, swallowable capsules, …
    - continuous recording: MEMS implantable devices, …
- Improved methods of data analysis, causal discovery, biology research, … should give us better understanding
- New interventions can improve therapy
  - Gene editing: CRISPR-CAS9, …
  - Targeted delivery of drugs to specific tissues

“Oh, the future’s so bright,
we’ll have to wear sunglasses!”

-- Barbara Kooyman, Timbuk 3
-- with thanks to Phil Greenspun

https://hst.mit.edu/admissions/gems-faq