IOCD
International Organization
for Chemical Sciences
in Development

Imperial College
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Institute of Global Health Innovation

One-World Chemistry for a Sustainable Future

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THE GRADUATE INSTITUTE GENEVA

GLOBAL HEALTH CENTRE

The RISE Institute
Institute for Reconstruction and
International Security through Education

One-World Chemistry for a Sustainable Future

- The chemical sciences have been central to global progress and will be essential to meeting oncoming global challenges – especially sustainable development

- To make its optimal contribution, chemistry must change
  - 'one-world' chemistry offers a framework

- As an example, 'the chemical sciences and health' needs systemic changes

Look at all the good things that chemistry has done for us!

The bad things are due to people, not chemistry!

systems

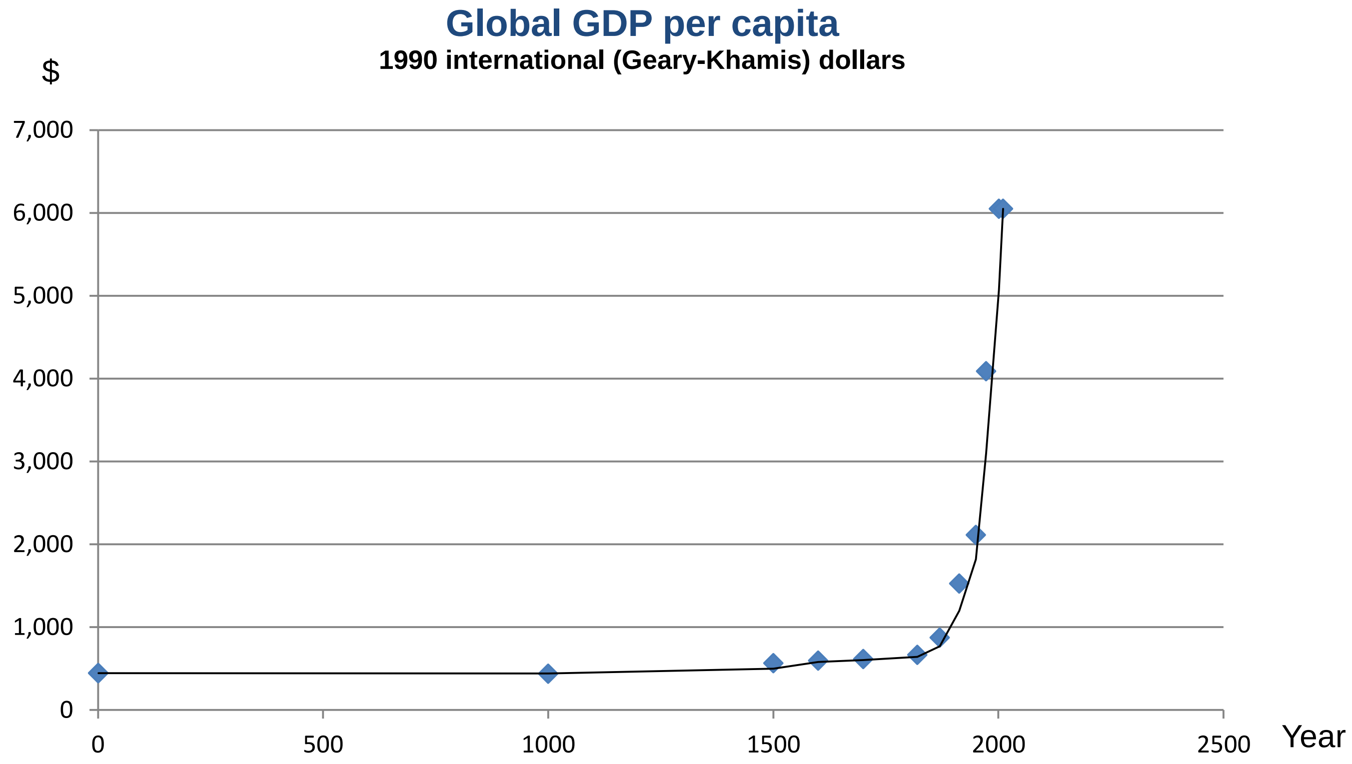
thinking

- <u>All</u> chemistry knowledge can be applied for good or bad:
  – it's people (scientists, policy-makers, public) who decide
- Chemistry literacy enables the capacity to make informed choices
- All choices have implications beyond the immediate setting: <u>systems thinking</u> is essential
  – chemistry literacy must be taught in the context of real-world applications

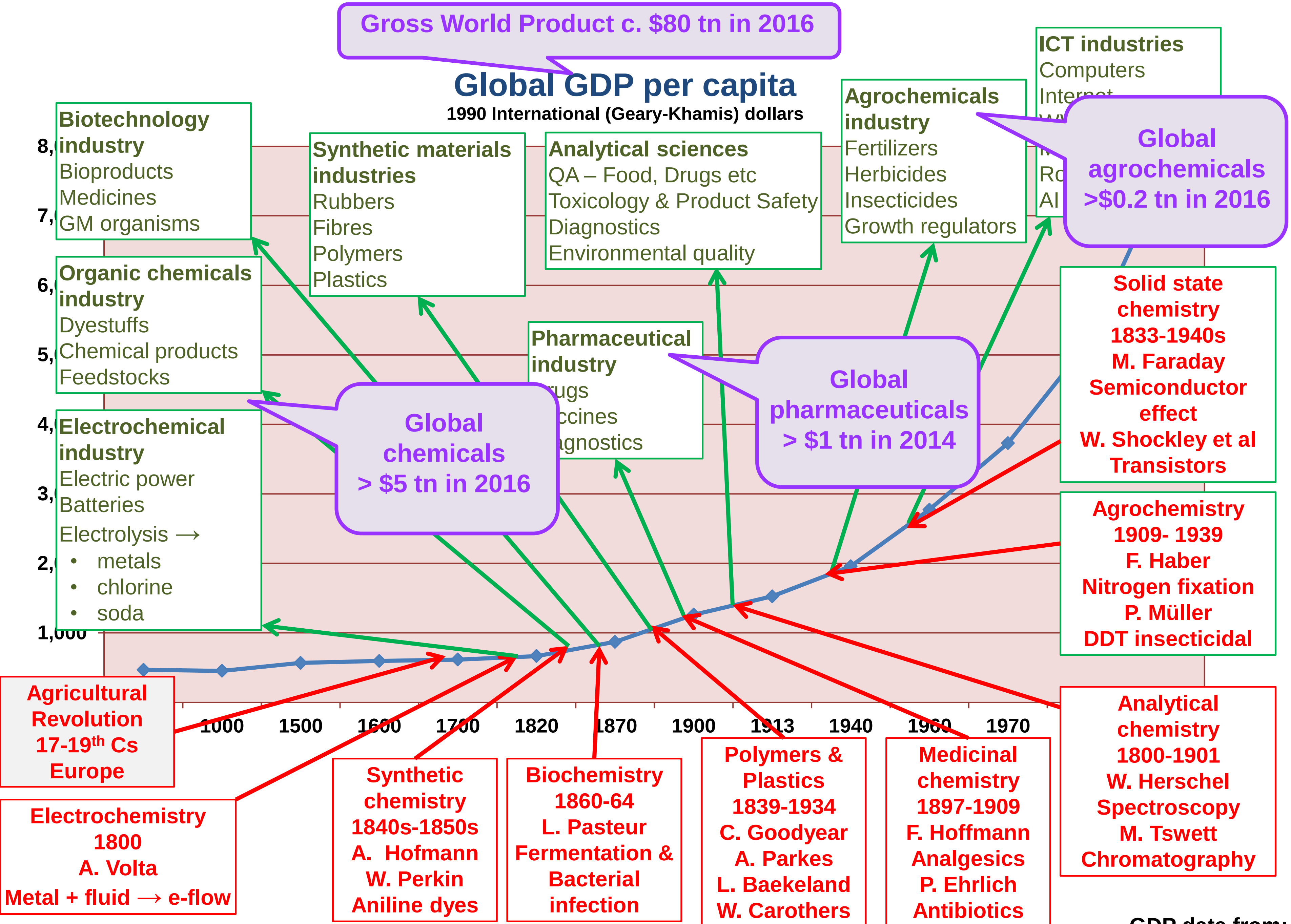
The chemical sciences have been central to global progress

- **Wealth**
- **Health**

Have the chemical sciences been good for wealth and health?



GDP data from:
A. Maddison, Statistics on World Population, GDP and Per Capita GDP, 1-2008 AD. www.ggdc.net/MADDISON/oriindex.htm



GDP data from:
A. Maddison, Statistics on World Population, GDP and Per Capita GDP, 1-2008 AD. www.ggdc.net/MADDISON/oriindex.htm

Country Income Groups GDP/capita (World Bank Classification 2016)

Belgium (2015 GDP/capita US$ 40,324)
19th century

- Ernest Solvay, Lieven Gevaert, Léo Baekeland, Albert Meurice

2015 chemical industry and life sciences

- Turnover >€ 64.3 billion: 24.2% of total manufacturing sector
- Direct employment 88,700 jobs: 18.9% of all manufacturing sector employment (+ sector creates c. 150,00 indirect jobs)
- Exports: 33% of total Belgian exports; positive trade balance >€ 20 bn
- Investment €1.93 billion: 30% of total manufacturing investment
- R&D expenditure in chemical & life sciences industry €3.6 billion: nearly 60% of all private-sector R&D in Belgium

www.essenscia.be/en/our_sector

No data

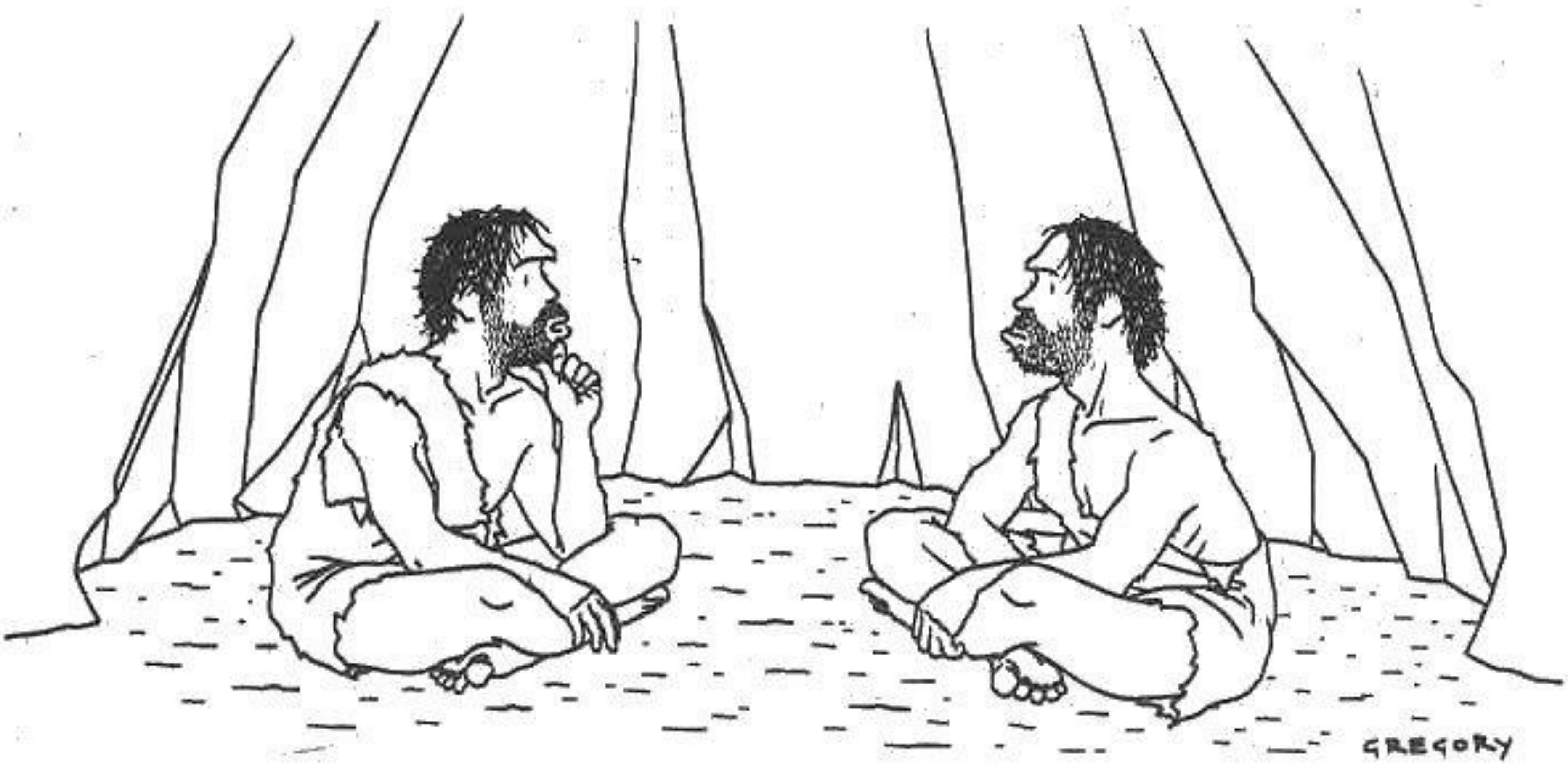
Taiwan (2015 GDP/capita US$ 22,469)
1950s: GDP/capita US$ 919
1990: GDP/capita US$ 7,358

- Chemical industry is largest industrial sector, contributing 24.2% of the total production value of US$165.3 billion (8.5% directly to export sales of US$95.6 billion).
- A leading producer of some plastics and synthetic fibres
  1. Established backwards-integrated chemical industry
  2. Developed 'debottle-necking' capacity
  3. Cooperation between up/mid/ downstream operators
  4. Strong support by the government

2010

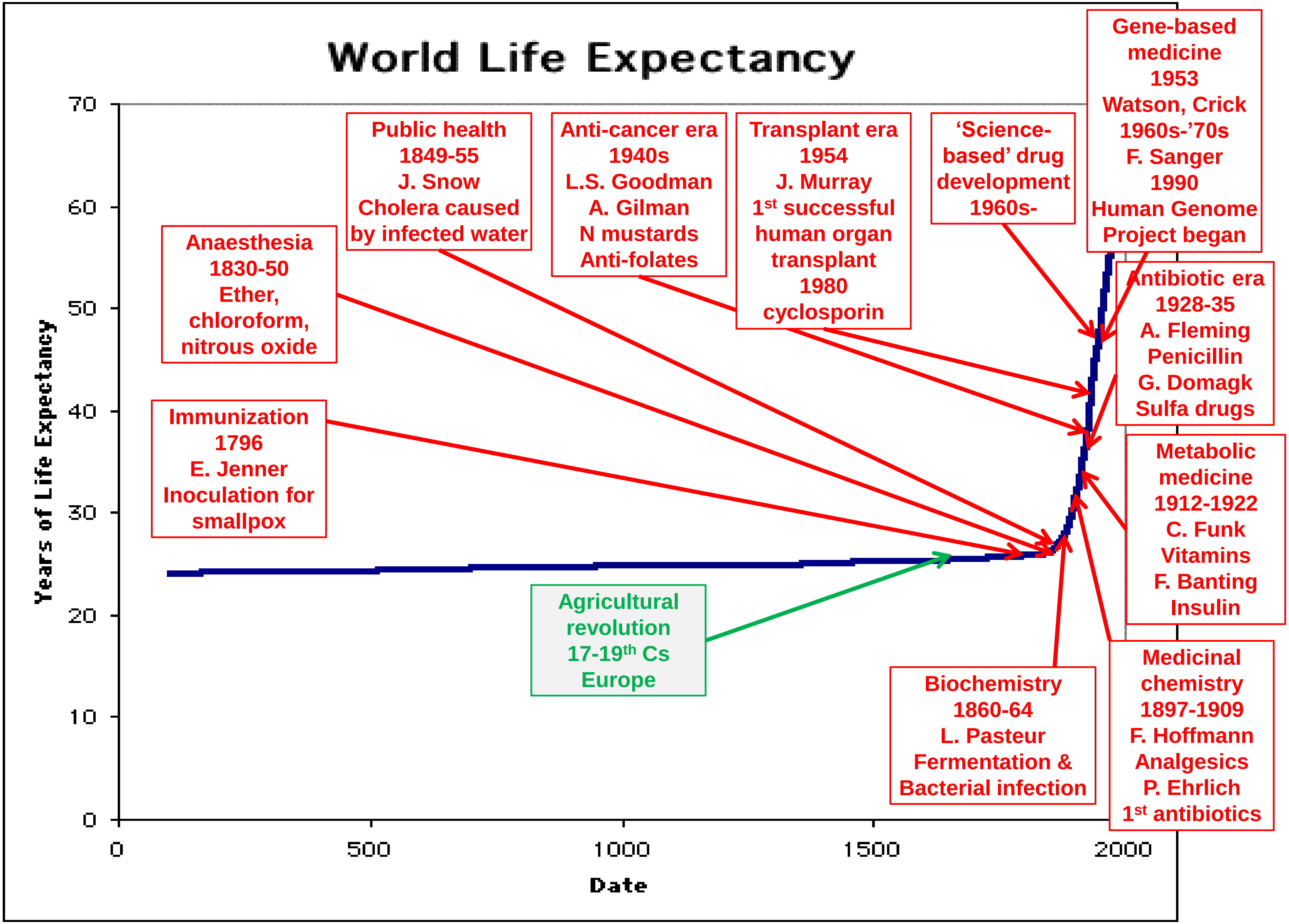
- Total revenue US$ 135 bn: 29.3% of GDP in manufacturing sector

www.aiche.org/sites/default/files/cep/20120441.pdf



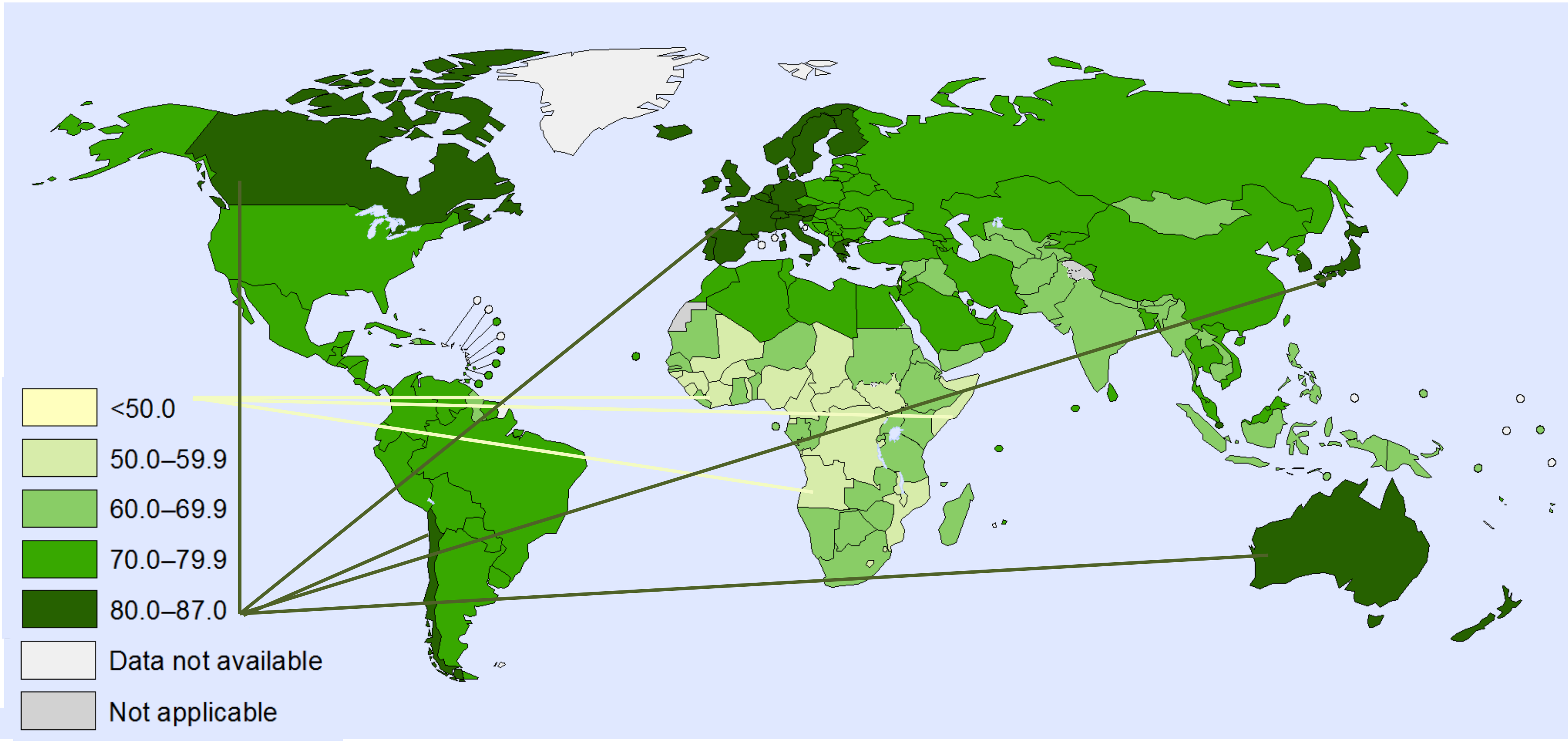
Our air is clean, our water is pure, we all get plenty of exercise, everything we eat is organic and free range, but something's just not right – nobody lives past thirty!

Alex Gregory. New Yorker, 22 May 2006. www.newyorker.com/cartoons/bob-mankoff/cave-cuisine

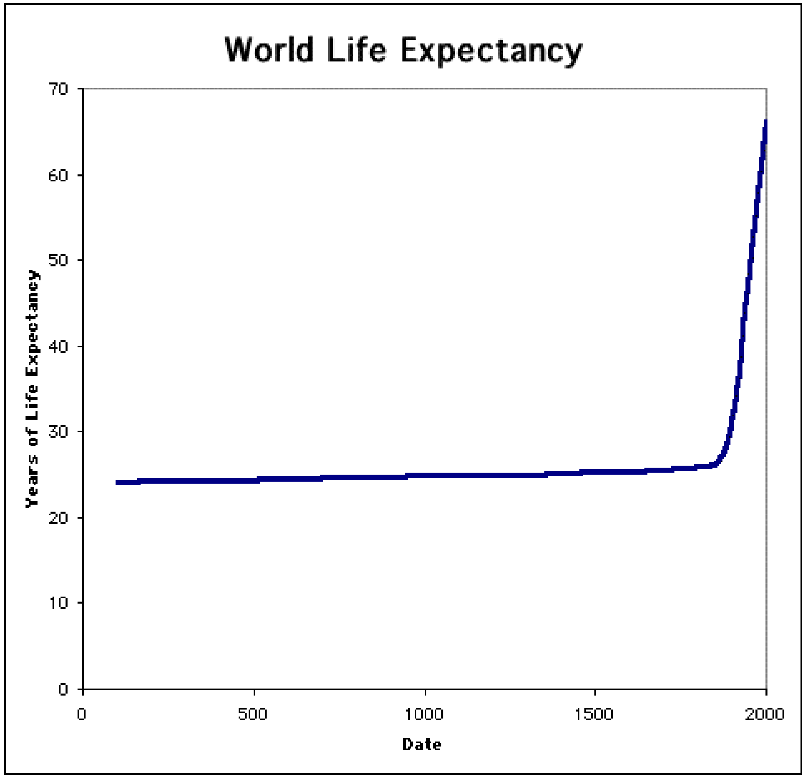


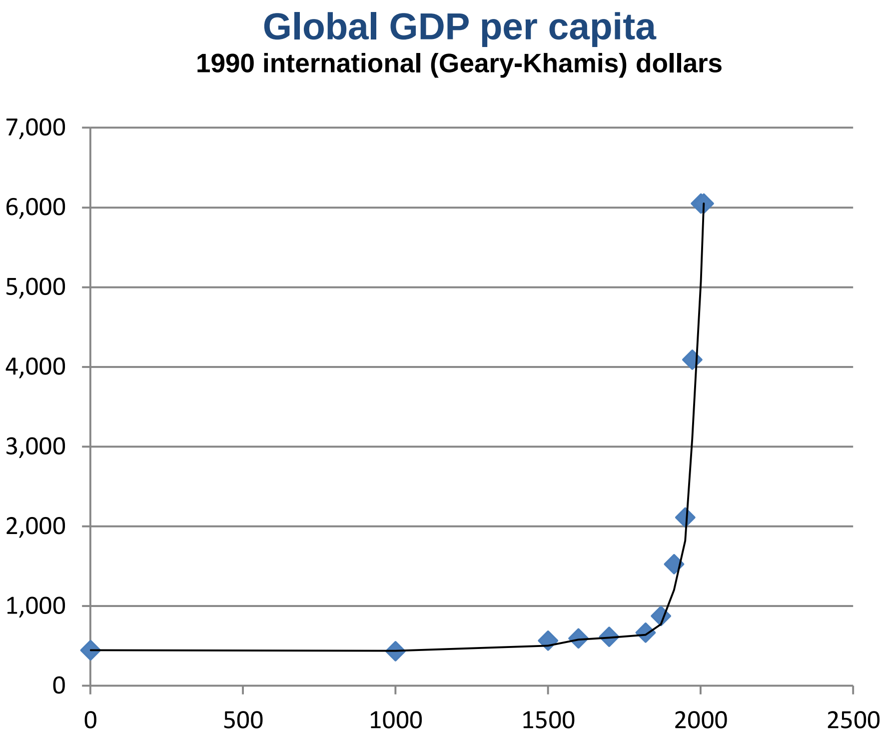
Life expectancy graph from:
www.j-bradford-delong.net/movable_type/images2/Life_Expect_Long.gif

World: Life expectancy at birth, both sexes, 2015



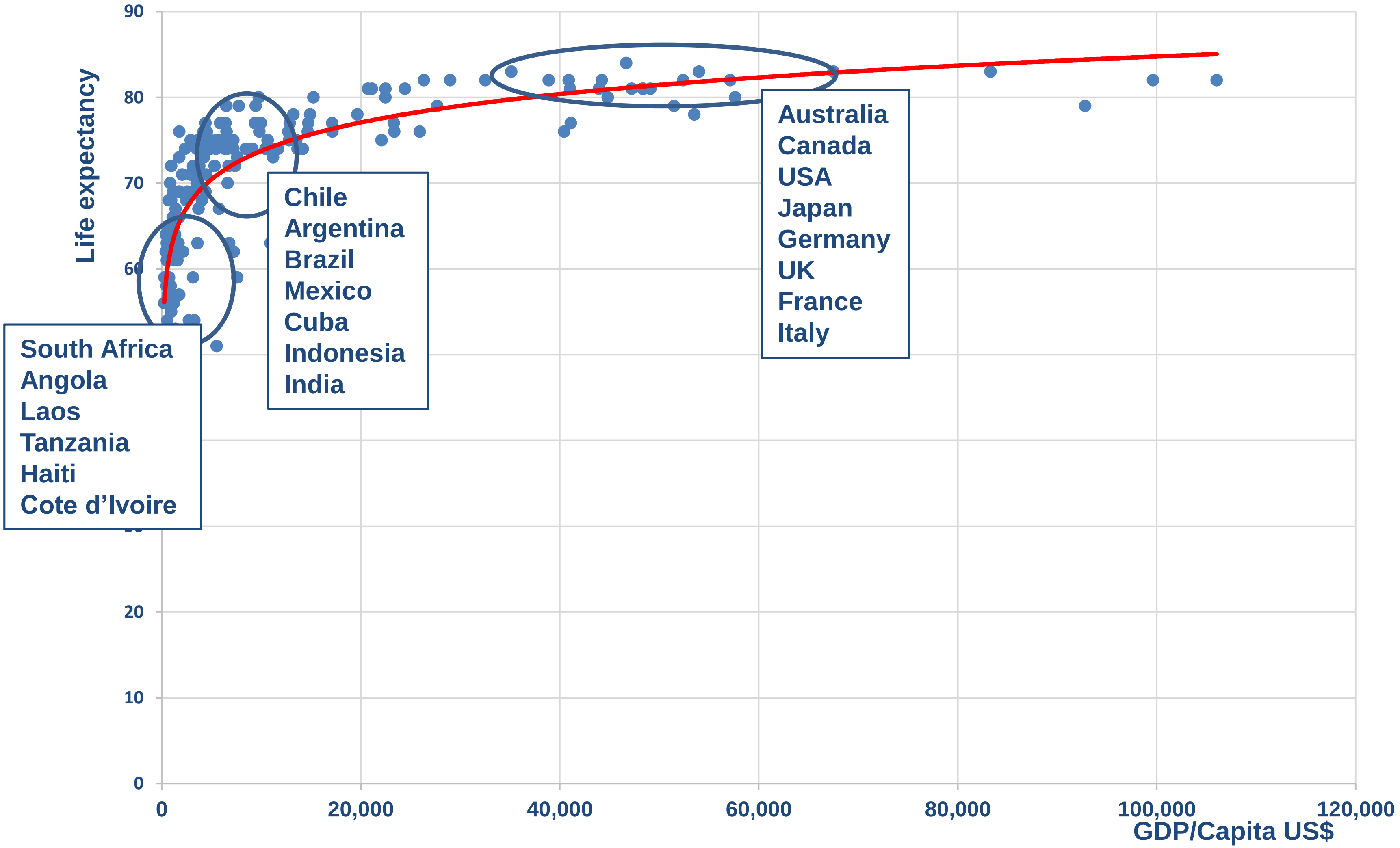
http://gamapserver.who.int/mapLibrary/Files/Maps/Global_LifeExpectancy_bothsexes_2015.png


World Life Expectancy
Years of Life Expectancy
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
Date


Global GDP per capita
1990 international (Geary-Khamis) dollars
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
500
1000
1500
2000
2500

How much health do you get for your wealth?

Preston curve: Life expectancy vs GDP per capita 2012

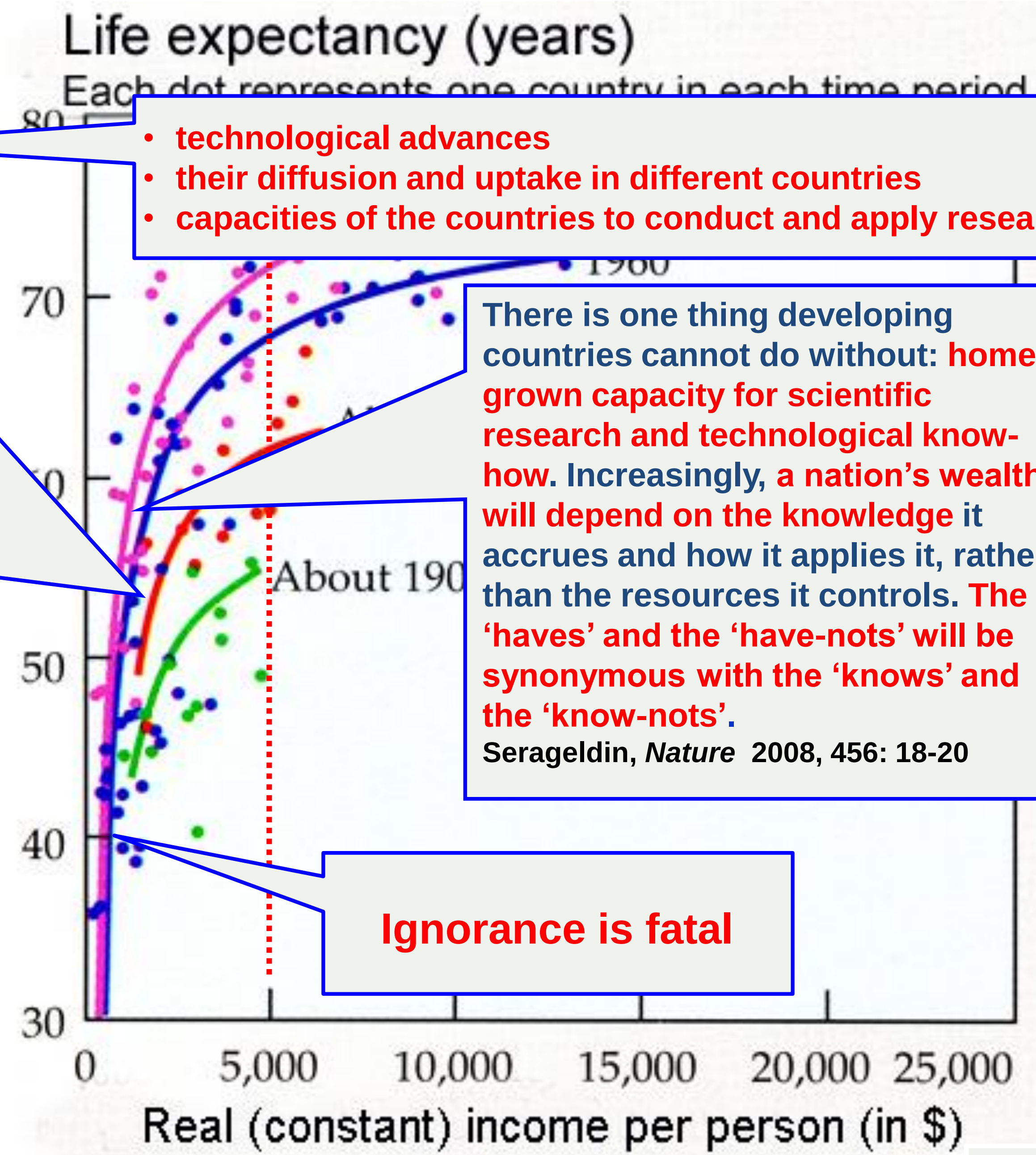


Matlin 2015: GDP data from World Bank 2015; Life expectancy data from WHO World Health Statistic 2014

Preston curves 1900-1990

- 20th century mortality decline had its origin in technical progress
  Easterlin, *European Review of Economic History 1999,* 3: 257–94

- Much of the variation in country outcomes results from very substantial cross-country variation in the rate of technical progress
  Jamison, *Disease Control Priorities in Developing Countries (DCP2), World Bank 2006*



- technological advances
- their diffusion and uptake in different countries
- capacities of the countries to conduct and apply research

There is one thing developing countries cannot do without: home-grown capacity for scientific research and technological know-how. Increasingly, a nation's wealth will depend on the knowledge it accrues and how it applies it, rather than the resources it controls. The 'haves' and the 'have-nots' will be synonymous with the 'knows' and the 'know-nots'.
Serageldin, *Nature* 2008, 456: 18-20

Ignorance is fatal

C. Dye; Preston curves from: www.gresham.ac.uk/lectures-and-events/is-wealth-good-for-your-health

The chemical sciences have been central to global progress and will be essential to meeting oncoming global challenges – especially sustainable development

2000 UN Millennium Development Goals for 2015

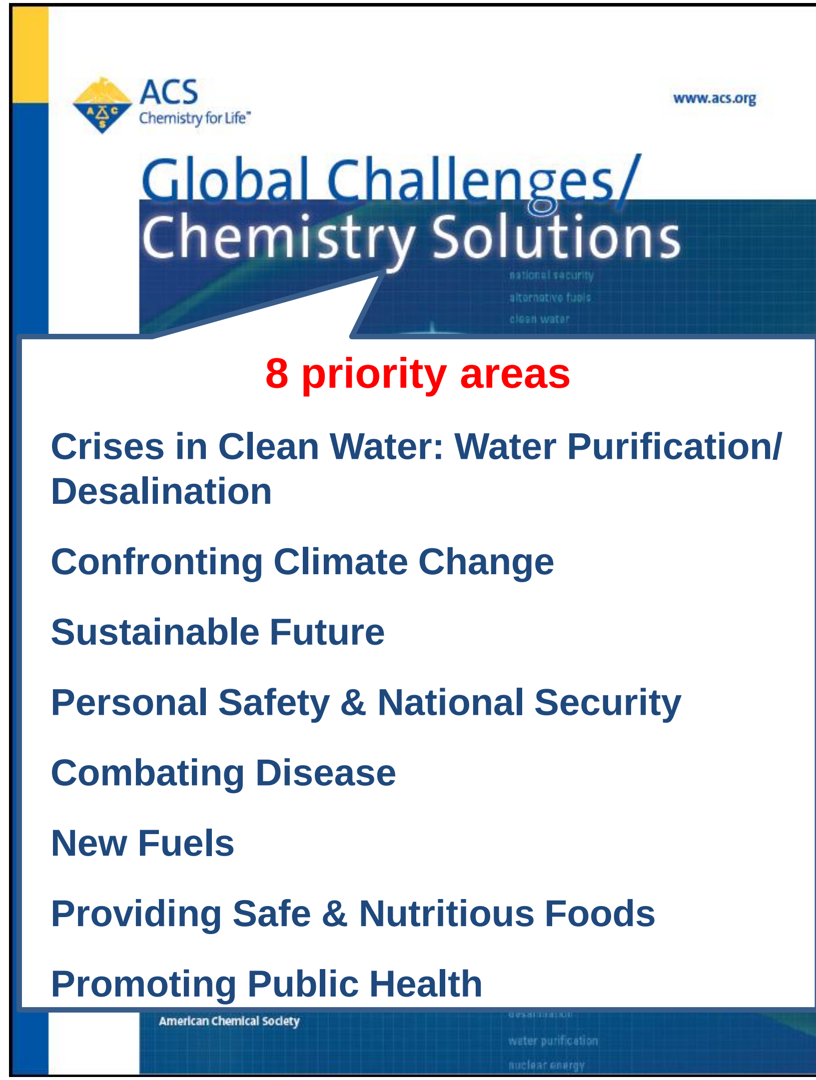
www.un.org/millenniumgoals/

The chemical sciences have been central to global progress and will be essential to meeting oncoming global challenges – especially sustainable development

Copenhagen Consensus III, 2012
10 of the world's biggest challenges

- armed conflict
- biodiversity
- chronic diseases
- climate change
- education
- hunger and malnutrition
- infectious diseases
- natural disasters
- population growth
- water and sanitation

www.copenhagenconsensus.com/copenhagen-consensus-iii/research
How to Spend $75 Billion to Make the World a Better Place



8 priority areas

Crises in Clean Water: Water Purification/ Desalination

Confronting Climate Change

Sustainable Future

Personal Safety & National Security

Combating Disease

New Fuels

Providing Safe & Nutritious Foods

Promoting Public Health

www.acs.org/content/acs/en/pressroom/podcasts/globalchallenges.html

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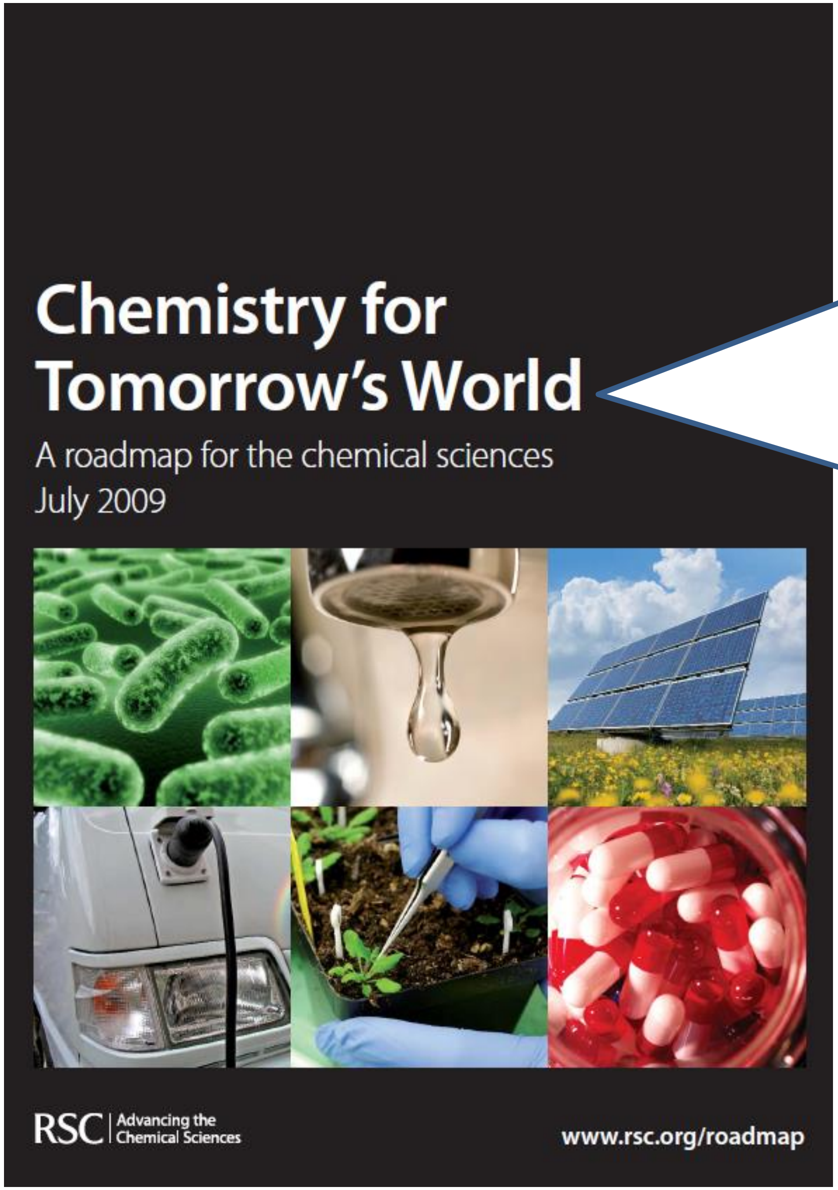

7 priority areas where chemistry can contribute

Energy: sustainability + efficiency

Food: safe, environmentally friendly, affordable

Future cities: meeting emerging needs of citizens

Human health: improving, maintaining; disease prevention

Lifestyle and recreation: sustainable route to richer, more varied lives

Raw materials and feedstocks: sustainability, preserving resources

Water and air: sustainable management of quality; availability of water resources

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1972 **The Limits to Growth (Club of Rome)**
Concept of a 'sustainable' world in which we would not see "overshoot and collapse" of the global system as the consequence of interactions between the Earth's and human systems

1987 **Brundtland Report: UN World Commission on Sustainable Development**
Development that meets the needs of the present without compromising the ability of future generations to meet their own needs

1992 **UN Conference on Environment and Development (Rio: 'Earth Summit')**
Earth Charter (Agenda 21): building of a just, sustainable, and peaceful global society in 21st C

- ***"socially inclusive and environmentally sustainable economic growth"***

2012 **United Nations Conference on Sustainable Development (Johannesburg: 'Rio+20')**
"The Future We Want": 192 governments renewed their political commitment to sustainable development

The chemical sciences have been central to global progress and will be essential to meeting oncoming global challenges – especially sustainable development

2015 UN Sustainable Development Goals for 2030

Ensure healthy lives and promote well-being for all at all ages

https://sustainabledevelopment.un.org

17 Sustainable Development Goals (SDGs)

1: No poverty
2: Zero hunger
3: Good health and well-being
4: Quality education
5: Gender equality
6: Clean water and sanitation
7: Affordable and clean energy
8: Decent work and economic growth
9: Industry, innovation and infrastructure
10: Reduced inequalities
11: Sustainable cities and communities
12: Responsible consumption and production
13: Climate action
14: Life below water
15: Life on land
16: Peace, justice and strong institutions
17: Partnerships for the Goals

"…leaving no-one behind"

Chemical sciences and global progress: Prospects and challenges

Crises facing the planet in the 21st century

- **Health**
  - Population, urbanization, ageing
  - Emerging and re-emerging diseases
  - Traditional model of drug development fails in some important areas
- **More people – but resource constraints**
  - Food
  - Water
  - Energy
  - Materials
  - Environment (air, land, sea)

- **It's a dirty world**
  - Pollution of land, sea, air harms the entire ecosphere
- **It's a fake world**
  - Counterfeiting and adulteration affect food, medicine, environment

The chemical sciences can contribute to solutions.
Challenges in:

- **Science content**
- **Capacity for science**
- **Governance of science**

The chemical sciences have been central to global progress and will be essential to meeting oncoming global challenges – especially sustainable development

commentary

The role of chemistry in inventing a sustainable future

Stephen A. Matlin, Goverdhan Mehta, Henning Hopf and Alain Krief

The Sustainable Development Goals adopted at a UN summit in September 2015 address many of the great challenges that our planet faces this century. Chemistry can make p… …tributions to help realize these ambitious goals, but first it must undergo major changes in its priori…

Chemistry can make pivotal contributions to help realize these ambitious goals, but first it must undergo major changes in its priorities, approaches and practices.

level — agreed on a collective global mission to transform the planet to achieve a sustainable future[1]. This mission is spelled out in 17 Sustainable Development Goals (SDGs) with a target date of 2030 (Box 1); progress towards them will be measured against 169 specific indicators[2]. These SDGs represent a profound shift in the world's approach to development over the past 15 years. Whereas the Millennium Development Goals agreed by governments at the UN in 2000 focused on specific problems of the world's poor and shaped the development aid policies of the richest countries[3], the new SDGs

past two centuries[5].

The UN's adoption of the SDGs has profound consequences for the world of chemistry and related molecular sciences. The chemical sciences can — and must — play a key role in developing the processes, products and monitoring mechanisms that the SDGs envisage. These emerging approaches must involve innovation that is frugal[6], disruptive[7] and widely applicable as well as sustainable. But to do so, all domains of chemistry — academia, industry, funding agencies, the professional bodies and associations at national and

development. On the positive side, the knowledge and products contributed by chemistry — providing sources of energy; a host of materials including polymers, plastics, semiconductors and solid-state display devices; agents for crop protection and plant growth; pharmaceuticals and much else — have been a major factor in the advances in human wealth, health and well-being over the past two centuries[8] and justify chemistry's claim[9] to be the 'quality-of-life' science *par excellence*. It promises to go on being the source of innovative new products and processes, including smart

Matlin et al, Nature Chemistry 2015, 7, 941-3

The chemical sciences have been central to global progress and will be essential to meeting oncoming global challenges – especially sustainable development

commentary

One-world chemistry and systems thinking

Stephen A. Matlin, Goverdhan Mehta, Henning Hopf and Alain Krief

The practice and overarching mission of chemistry need a major overhaul in order to be fit for purpose in the twenty-first century and beyond. The concept of 'one-world' chemistry takes a systems approach that brings together many factors, including ethics and sustainability, that are critical to the future role of chemistry.

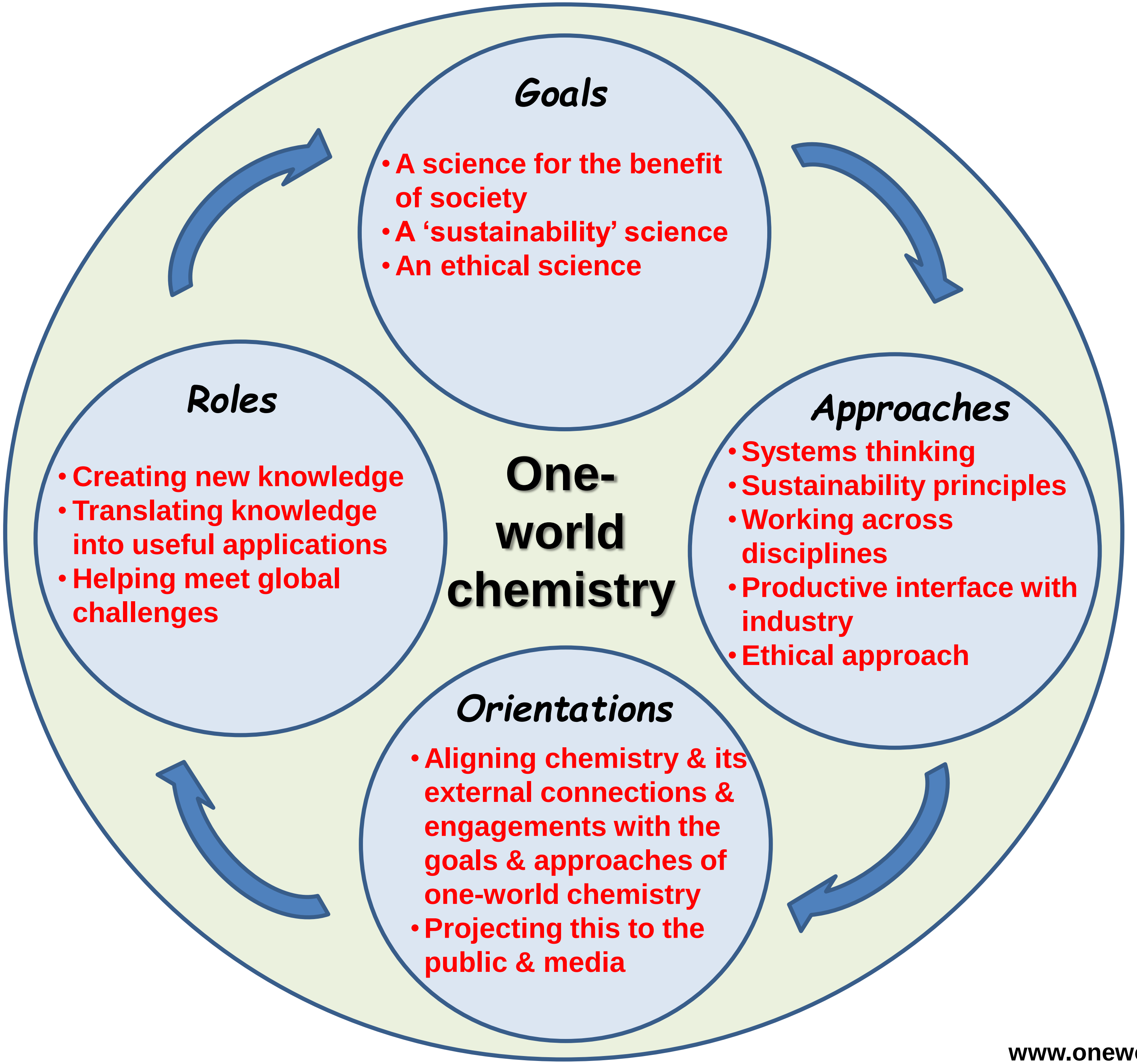
Chemistry has achieved outstanding success over the past two centuries in terms of advancing fundamental knowledge as well as its impact on applications relating to human health, wealth and well-being[1]. However, a number of observations suggest that chemistry is facing an existential crisis of sorts, including reflections from the fields of education[2], industry[3], the environment[4] and the public arena[5]. If this is the case, there are a number of likely contributory factors, including (1) the discipline has not been effective in reinventing itself or projecting its contemporary advances on prominent external platforms, (2) it is intrinsically

© FRAZER HUDSON / ALAMY STOCK PHOTO

as an exciting scientific pursuit generating groundbreaking new discoveries in its own right is giving way to its portrayal as a 'service science' for other fields.

Attitudes of the general public, media and policy-makers towards chemistry and its practitioners are complex. They sometimes recognize chemistry's pivotal utilitarian role that impinges on every facet of life[9] while at other times they focus on negative aspects, such as its ability to cause harm to people and the environment through deliberate (for example, chemical warfare) or accidental or unintended (chemical spillages, disasters in chemical plants, toxic side effects of drugs and food additives,

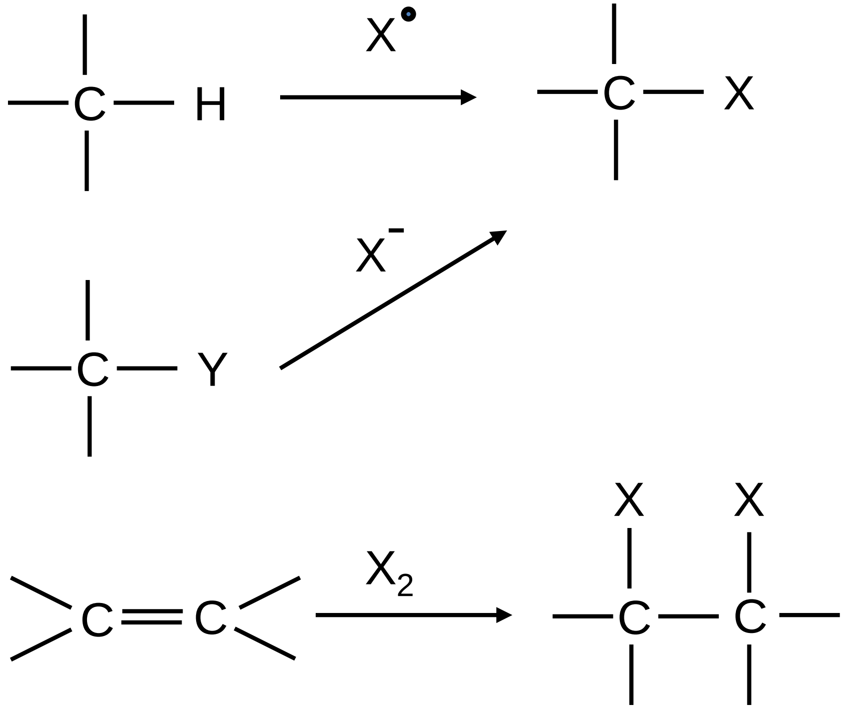
Matlin et al, Nature Chemistry 2016, 8, 393-8



www.oneworldchemistry.org

Synthesis of alkyl halides

X_2	m.pt.	b.pt.
F_2	-220	-188
Cl_2	-101	-35
Br_2	-7	59
I_2	114	184



CH_3-X	b.pt.
F	-78.4
Cl	-23.8
Br	3.5
I	42.4

<u>Examples of applications</u>

Polyvinyl chloride - PVC

Polychlorinated biphenyls – PCBs

Dichlorodiphenyltrichloroethane – DDT

Fluorocarbons

- **Anaesthetics – Fluothane**
- **Polytetrafluroethylene – PTFE**
- **Refrigerants**

Fluorocarbons

Refrigerants

A compressed gas gets colder when it expands; a liquid gets colder when it evaporates

- **Ideal materials have b.pt. < room temp: e.g. NH_3 (-27°C) – corrosive, toxic**

1928 **Thomas Midgley (General Motors) improved synthesis of chlorofluorocarbons (CFCs), e.g. CF_2Cl_2 (b.pt. -30°C).**

$$CCl_4 + HF \xrightarrow{SbF_3Cl_2} CFCl_3 + CF_2Cl_2 + HCl$$

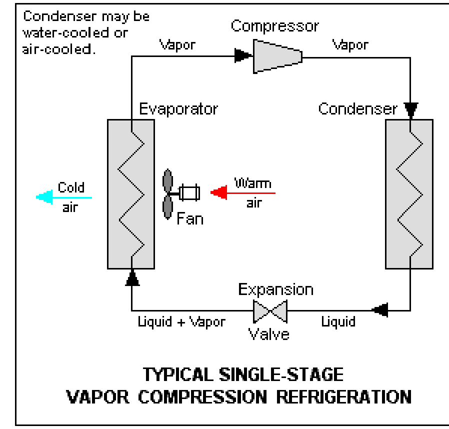
Patented and developed as Freon®; used in fridges from 1930; by 1960s 'halons' also widely used in aerosol cans and in fire-fighting

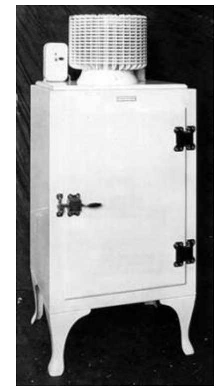
1957 **Electron capture detector invented by James Lovelock**

- **Extremely sensitive for detection of halogenated compounds in gas chromatography. Late 1960s, Lovelock first to detect the widespread presence of CFCs in the atmosphere**

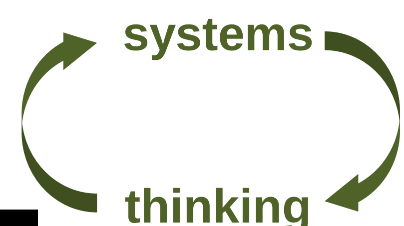
1974 **Mario Molina and Sherwood Rowland (Nobel 1995): photolysis of atmospheric CFCs releases chlorine atoms which break down ozone.**

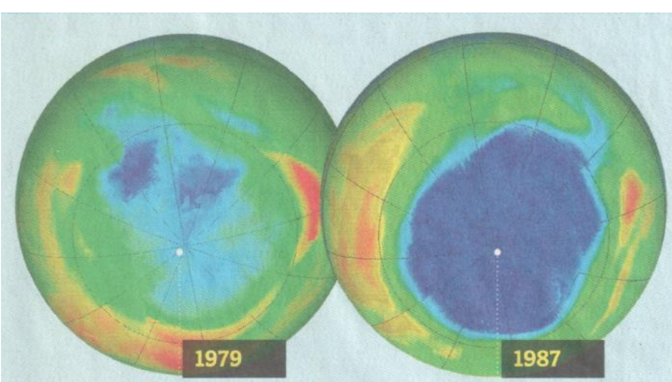
- **Since 1970s: 4 %/decade decline in atmospheric O_3 and much larger annual springtime decrease in stratospheric O_3 over S. polar region ('ozone hole' reported in *Nature*, 1985)**



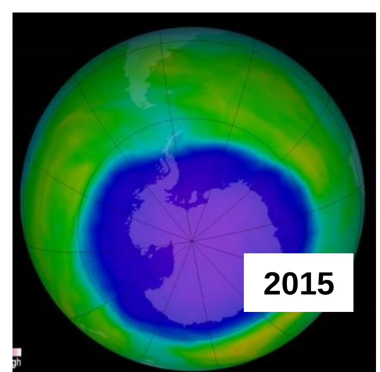


General Motors *Monitor Top* SO_2 fridge 1927



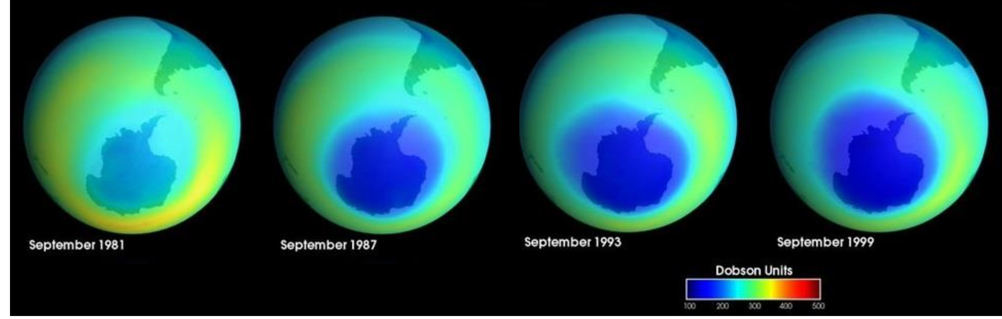


Two of the images that raised global alarm over the hole in the ozone layer (NASA-Corbis)



4th largest Antarctic ozone hole recorded 2 October 2015 over the Southern pole (NASA)

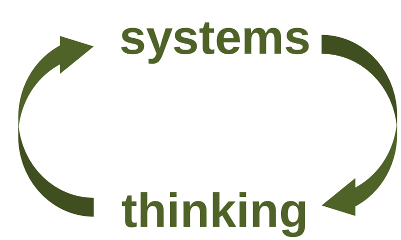
Antarctic ozone hole 1981-1999
Images from the Total Ozone Mapping Spectrometer (TOMS)



1977 **United Nations Environment Programme (UNEP): World Plan of Action on the Ozone Layer (research and monitoring of ozone layer)**
1981 work began to draft a global framework convention on stratospheric ozone protection.
1985 Vienna Convention: States agree to cooperate in relevant research and scientific assessments of the ozone problem, exchange information, and adopt "appropriate measures" to prevent activities that harm the ozone layer. Obligations are general: no specific limits on chemicals that deplete the ozone layer.

1987 **Montreal Protocol on Substances that Deplete the Ozone Layer signed; came into force 1 January 1989**

- **Rapid phasing out CFCs**
- **Slower phasing out of hydrochlorofluorocarbons (HCFCs), 1996-2030**

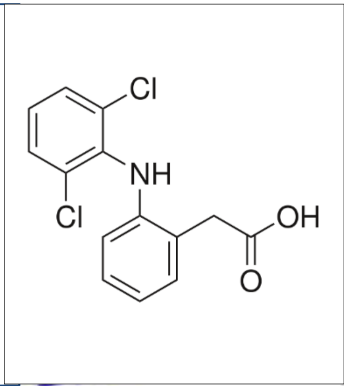


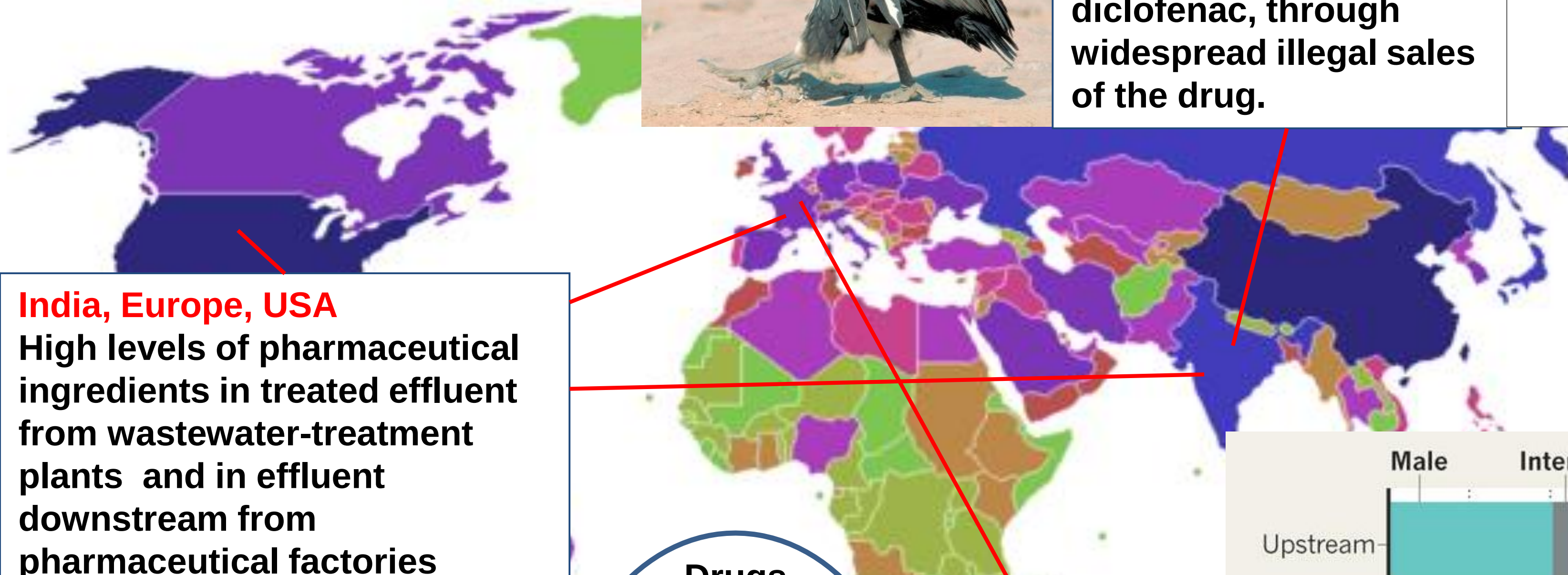
"To understand what was happening to the ozone layer, researchers… had to bridge traditional scientific disciplines and examine the earth as an interrelated system of physical, chemical, and biological processes occurring on land, in oceans, and in the atmosphere – processes that were themselves influenced by economic, political, and social forces."

RE Benedick (US State Department, Chief US Negotiator on the Montreal Protocol). www.eoearth.org/view/article/155895/

Contaminants in environment, food & pharmaceuticals

India
Critically endangered vultures in India are still at risk of exposure to the anti-inflammatory drug diclofenac, through widespread illegal sales of the drug.

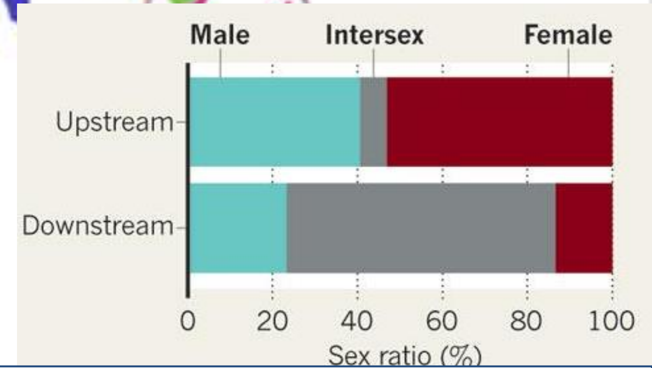




India, Europe, USA
High levels of pharmaceutical ingredients in treated effluent from wastewater-treatment plants and in effluent downstream from pharmaceutical factories

Gudgeon downstream of wastewater-processing plant had swollen abdomens and other abnormalities

Drugs excreted by patients can taint rivers, even after passing through wastewater-processing facilities



Fish downstream of a French pharmaceutical factory much more likely to show characteristics of both sexes (intersex) than those upstream

Nature.com August & September 2011

Contaminants in environment, food & pharmaceuticals

High levels of pharmaceutical ingredients found in treated effluent from wastewater-treatment plants and in effluent downstream from pharmaceutical factories.
Examples from India, USA and EU
USA and EU do <u>not</u> have regulations limiting the concentrations of pharmaceuticals released into the aquatic environment in either municipal wastewater or in effluent from manufacturing facilities.

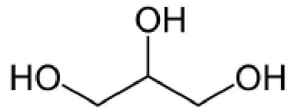
Nature, 15 August 2011.
www.nature.com/news/2011/110815/full/476265a.html

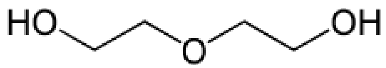
- **Need for better regulation and enforcement**
  – requires understanding and support from public and policy makers
- **Need for rapid, accurate, very sensitive, affordable analytical techniques**
  – preferably that can be applied at, or very close to, the site being inspected

systems

thinking

Contaminants in environment, food & pharmaceuticals

Glycerine


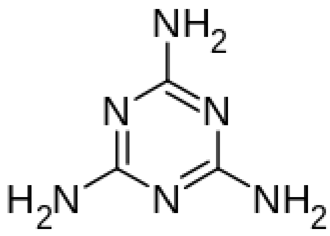
DEG


2011 UK
26 August
Class 1 Drug Alert
Nurofen Plus contaminated with Seroquel XL (antipsychotic) and Neurontin (epilepsy/ painkiller)

23 September
Man arrested in London and later convicted and jailed

- **Need for better regulation and enforcement**
- **Need for rapid, accurate, very sensitive, affordable analytical techniques**

2008 Nigeria
Dethylene glycol (DEG) in baby teething mixture
111 victims, 84 deaths reported
- **DEG traced to batch of glycerine from a local unlicensed pharmacy**
- **Last 20 years: hundreds of deaths of children and adults from DEG in medicines in Argentina, Bangladesh, Haiti, India, Nigeria, Panama**



Premier Wen visits victim at Beijing Children's Hospital

2008 China
Melamine in infant formula
300,000 affected, 53,000 hospitalised, 6 reported deaths
- **Samples from 22 out of 109 supplies of baby milk powder found to be contaminated with unsafe levels of melamine.**
- **People jailed; 2 executed**

Contaminants in environment, food & pharmaceuticals

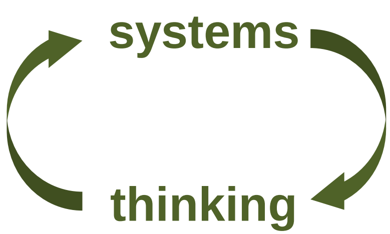
Impact of globalization on drug and food safety: important lessons

Extent of problem:

- **Toxicoses from contaminated food and drugs are often identified only when large numbers of people or animals are affected and numerous deaths result**
- **Deliberate contamination may be widespread but escape detection in poorly regulated markets.**
- **Contaminated raw material produced in a poorly regulated market may cross national boundaries and be used in manufacturing processes for numerous products, sometimes in more well-regulated markets.**

Capacity for solutions

- **It is not clear that regulatory organizations have the capacity to identify significant contaminations despite their best efforts.**
- **The [relevant scientific] communities, in cooperation with regulatory agencies, should develop cooperative programmes designed to detect and limit these global outbreaks.**
- **Although addressing regional or national outbreaks remains an important role for regulatory agencies, the [relevant scientific] communities must develop proactive <u>global</u> approaches to this global problem.**



Global problem needing global solutions

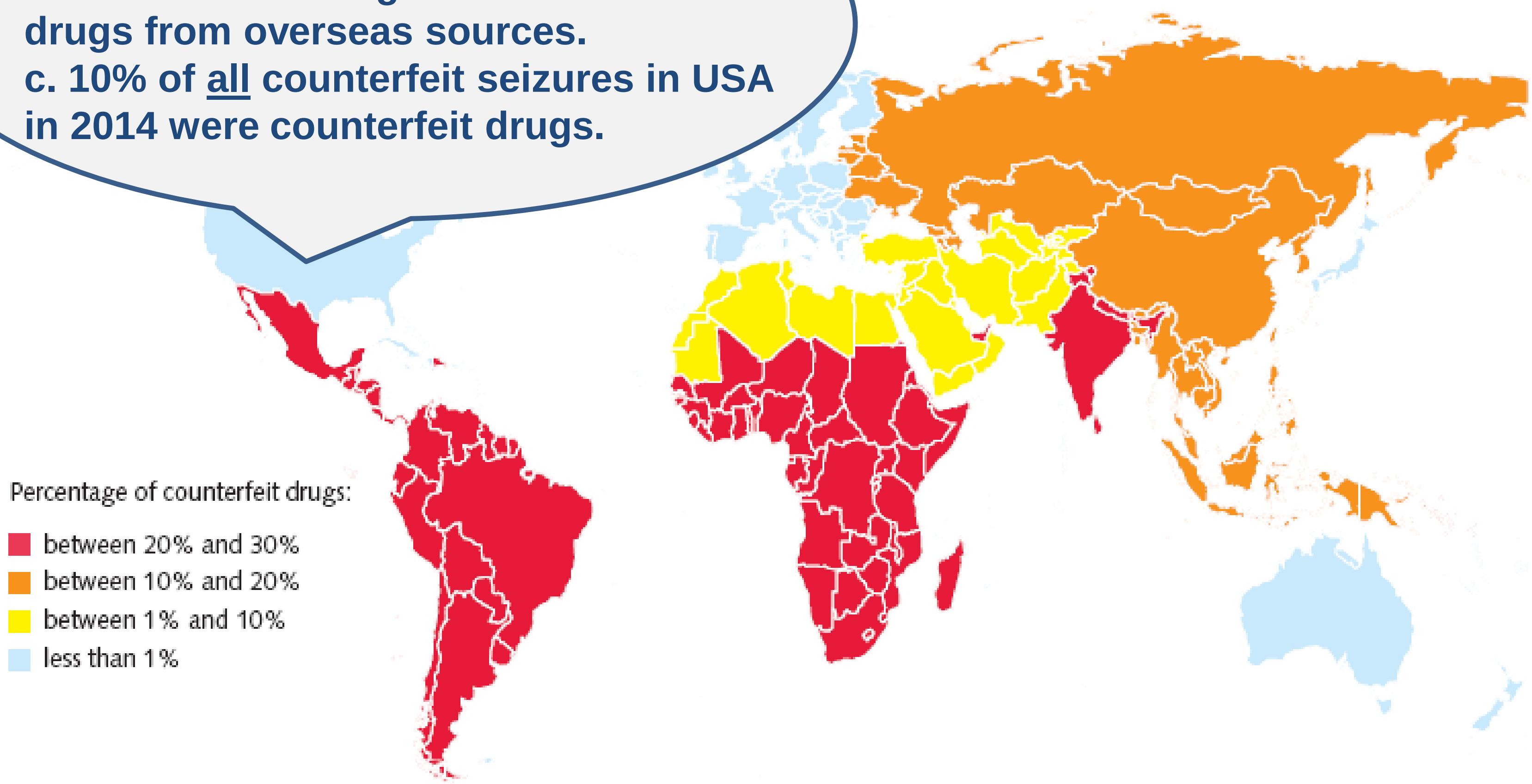
Brown & Brown *Vet Pathol* 2010, 47, 45-52

Counterfeit drugs

Its a fake world: Counterfeit drugs becoming increasingly available

- **Estimated counterfeit drug sales worth in the range US$ 75 - 200 billion/year globally Counterfeit medicines estimated to constitute >10% of global medicines market: c. 1% in HICs and 10-50% in LMICs**

c. 40 % of drugs in USA imported and c. 80 % of active ingredients in US drugs from overseas sources.
c. 10% of <u>all</u> counterfeit seizures in USA in 2014 were counterfeit drugs.



Global Reporting of Counterfeit Medicines
http://ec.europa.eu/internal_market/indprop/docs/conf2008/wilfried_roge_en.pdf

Counterfeit drugs

Jan 1999 - Oct 2000 WHO: 46 reports from 20 countries (60% LMICs)

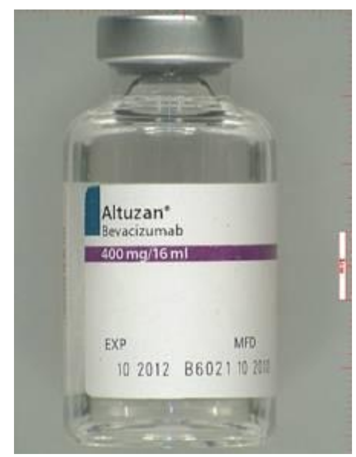
Counterfeit drugs included antibiotics, hormones, analgesics, steroids, antihistamines:

- **without active ingredients, 32.1%;**
- **with incorrect quantities of active ingredients, 20.2%;**
- **with wrong ingredients, 21.4%,**
- **with correct quantities of active ingredients but fake packaging, 15.6%;**
- **with high levels of impurities and contaminants, 8.5%**

➢ **In 2011, 64% of antimalarial drugs in Nigeria were found to be counterfeit**

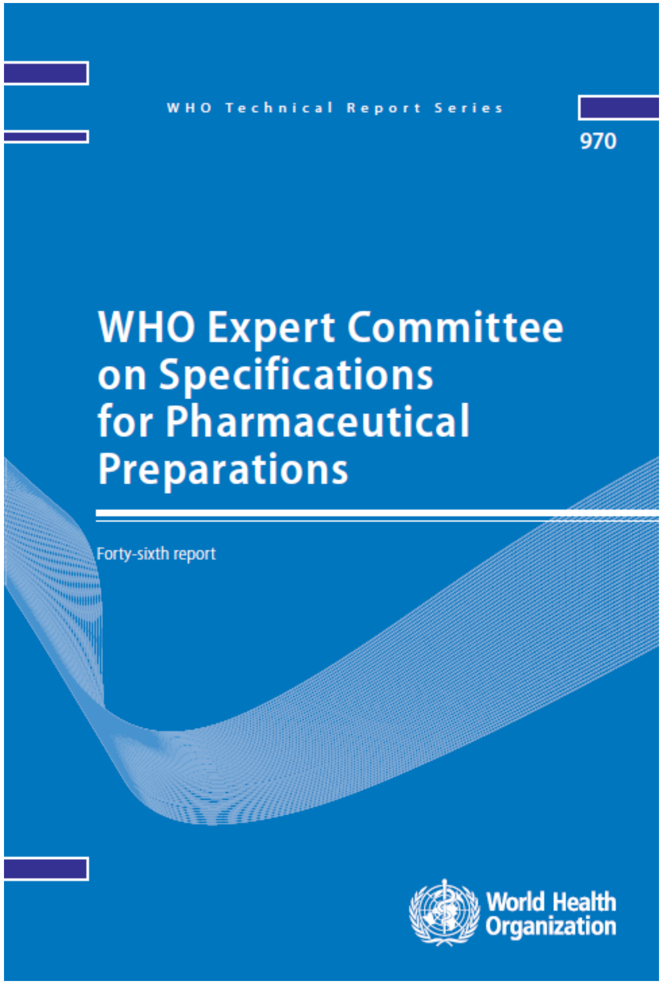
No simple solution

- **Problem has reached a global dimension and needs a global approach**
- **Absence of, or weak, drug regulation, testing, enforcement**



WHO 2011: www.who.int/medicines/services/counterfeit/overview
FDA 2012: www.fda.gov/Drugs/DrugSafety/DrugIntegrityandSupplyChainSecurity/ucm298047.htm

Counterfeit drugs



Every country, regardless of its stage of development, should consider investment in an independent national drug quality control laboratory

WHO Expert Committee on Specifications for Pharmaceutical Preparations 29th Report, 1984. http://whqlibdoc.who.int/trs/WHO_TRS_704.pdf

Absence of, or weak, drug regulation

- **In 2015, of 191 WHO member states c. 20% had well developed drug regulation. Of remainder, c. 50% implemented some drug regulation; another 30% either had no drug regulation in place or a very limited capacity that hardly functioned.**

General Information on Counterfeit Medicines, WHO 2015 www.who.int/medicines/services/counterfeit/overview/en/index1.html
Substandard, spurious, falsely labelled, falsified and counterfeit (SSFFC) medical products, WHO 2016. /www.who.int/mediacentre/factsheets/fs275/en/

Technologies to prevent/identify counterfeits

- **World market for pharmaceutical anti-counterfeiting technology c. US$ 3.4 billion in 2015**
- **Pharmaceutical + food anti-counterfeiting market may exceed US$ 160 billion by 2020**

www.visiongain.com/Report/1360/Pharmaceutical-Anti-counterfeiting-Technologies-Market-Analysis-and-Forecasts-2015-2025
www.hexaresearch.com/research-report/pharmaceuticals-and-food-anti-counterfeiting-technologies-industry/

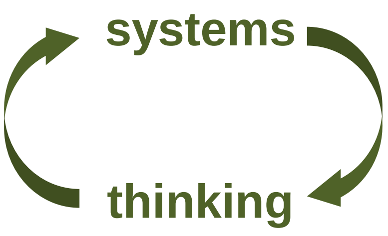
Contaminants in environment, food & pharmaceuticals

- **Challenges/opportunities for the chemical sciences**
  - **New chemistry products, processes and analytical methods:**
    *** Safe, effective, affordable, sustainable**

  - **Public and policy makers need to understand the dangers; and the policies and practices [systems] needed to counter them and to tackle highly ingenious criminals**
    **** Challenges for [chemical] science literacy***

- **Challenges for regulation**
  - **Better cooperation and harmonization among analysts in the fields of pharmaceuticals, food, environment**

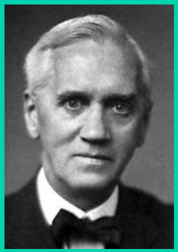
  - **Better cooperation and harmonization between analysts in all fields and policy makers**
    **** Challenges for capacities for [chemical] science literacy, communication, diplomacy***



Challenges in the chemical sciences for global progress

Antibiotic Resistant Bacteria (ARB)

Early 20th century
Pre-antibiotic era
Infections cause around 43% of deaths



1928
Fleming discovers penicillin;
First examples of resistant bacteria seen

1945
Fleming wins Nobel Prize

"note of warning … It is not difficult to make microbes resistant to penicillin in the laboratory by exposing them to concentrations not sufficient to kill them, and the same thing has occasionally happened in the body."

On average antibiotics and vaccines add 20 years to each person's life

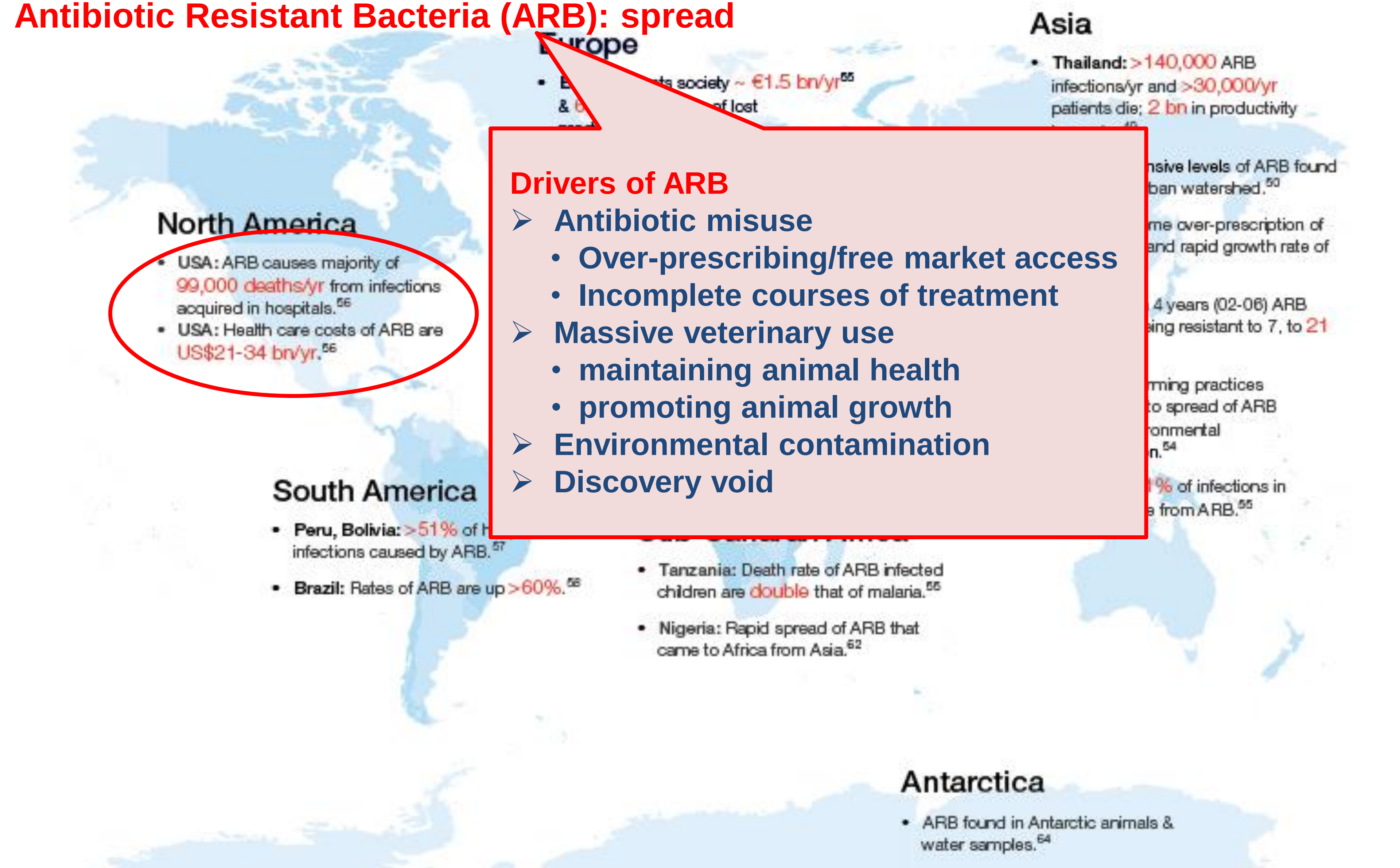
Late 20th century
'Golden age' of antibiotic discovery
By 2000, fewer than 7% of deaths caused by infections

1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010s

Professor Dame Sally C Davies, Chief Medical Officer, England

Challenges in the chemical sciences for global progress

Antibiotic Resistant Bacteria (ARB): spread



Drivers of ARB

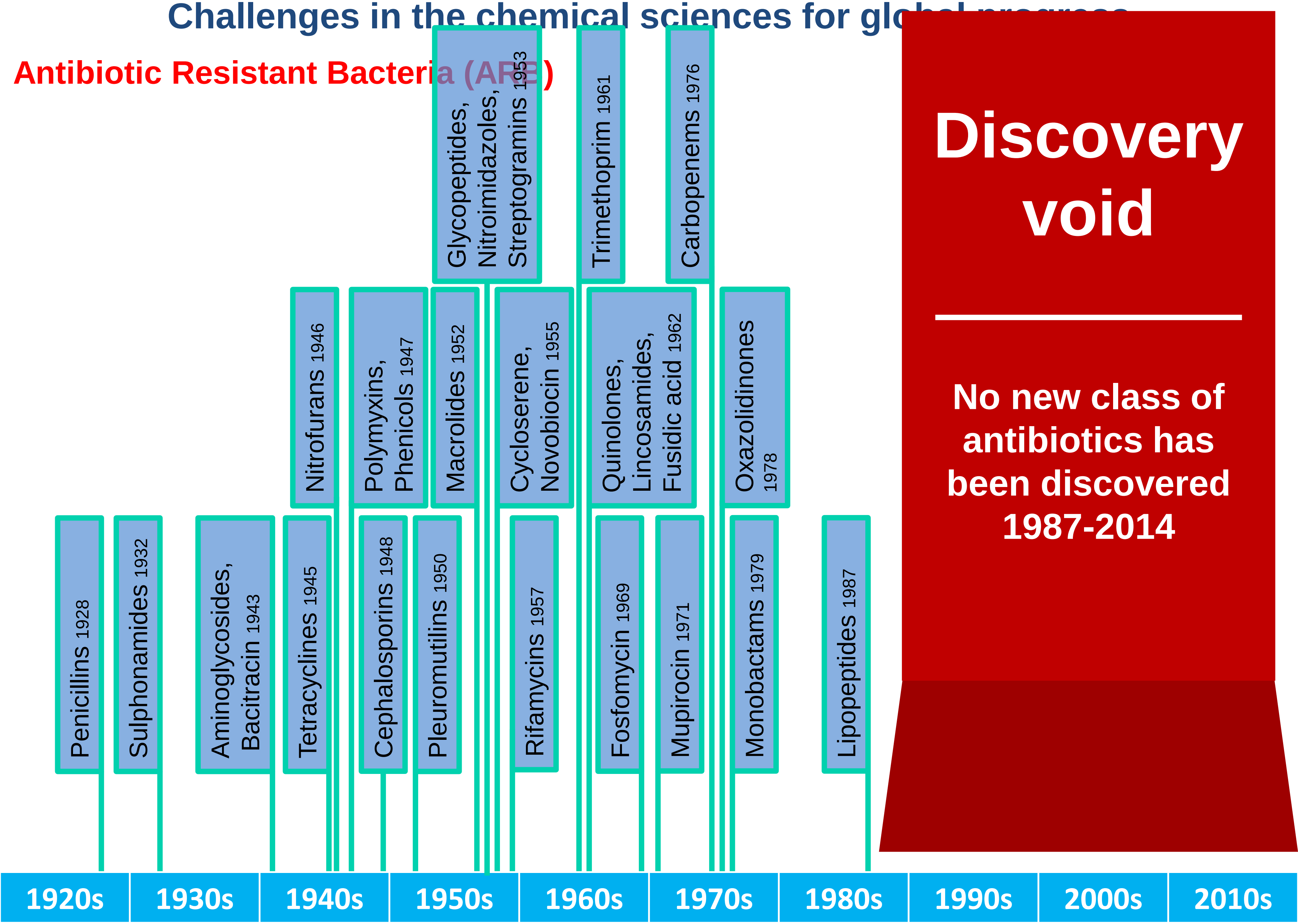
- Antibiotic misuse
  - Over-prescribing/free market access
  - Incomplete courses of treatment
- Massive veterinary use
  - maintaining animal health
  - promoting animal growth
- Environmental contamination
- Discovery void

1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010s

http://reports.weforum.org/global-risks-2013/view/risk-case-1/the-dangers-of-hubris-on-human-health/#read

Challenges in the chemical sciences for global progress

Antibiotic Resistant Bacteria (ARB)



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Challenges in the chemical sciences for global progress

Antibiotic Resistant Bacteria (ARB)

Failure
- Sc
  - ➢
  - ➢
- Ec
  - ➢
  - ➢

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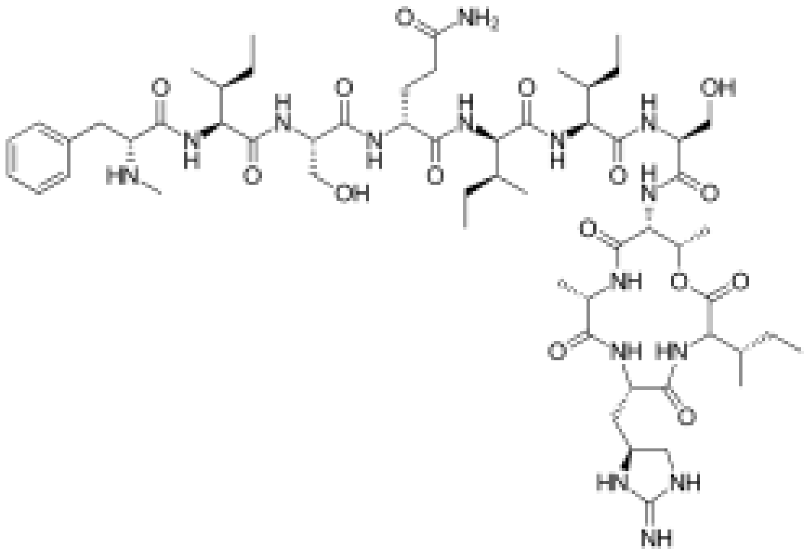
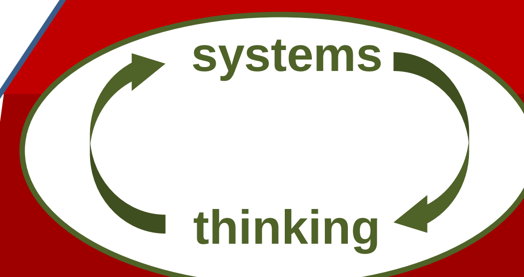


2015 Teixobactin discovered in soil sample (new screening technique for bacteria that cannot be culture in lab)

- ❑ First new class of antibiotics since 1987
- ❑ *“Without detectable resistance“* in G+ organisms
- ❑ Research was funded by US National Institutes of Health and German research agencies
- ❑ Patent owned by early-stage biotech company

Discovery void

No new class of antibiotics has been discovered 1987-2014



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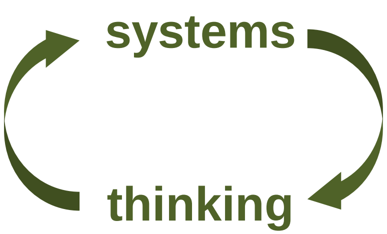
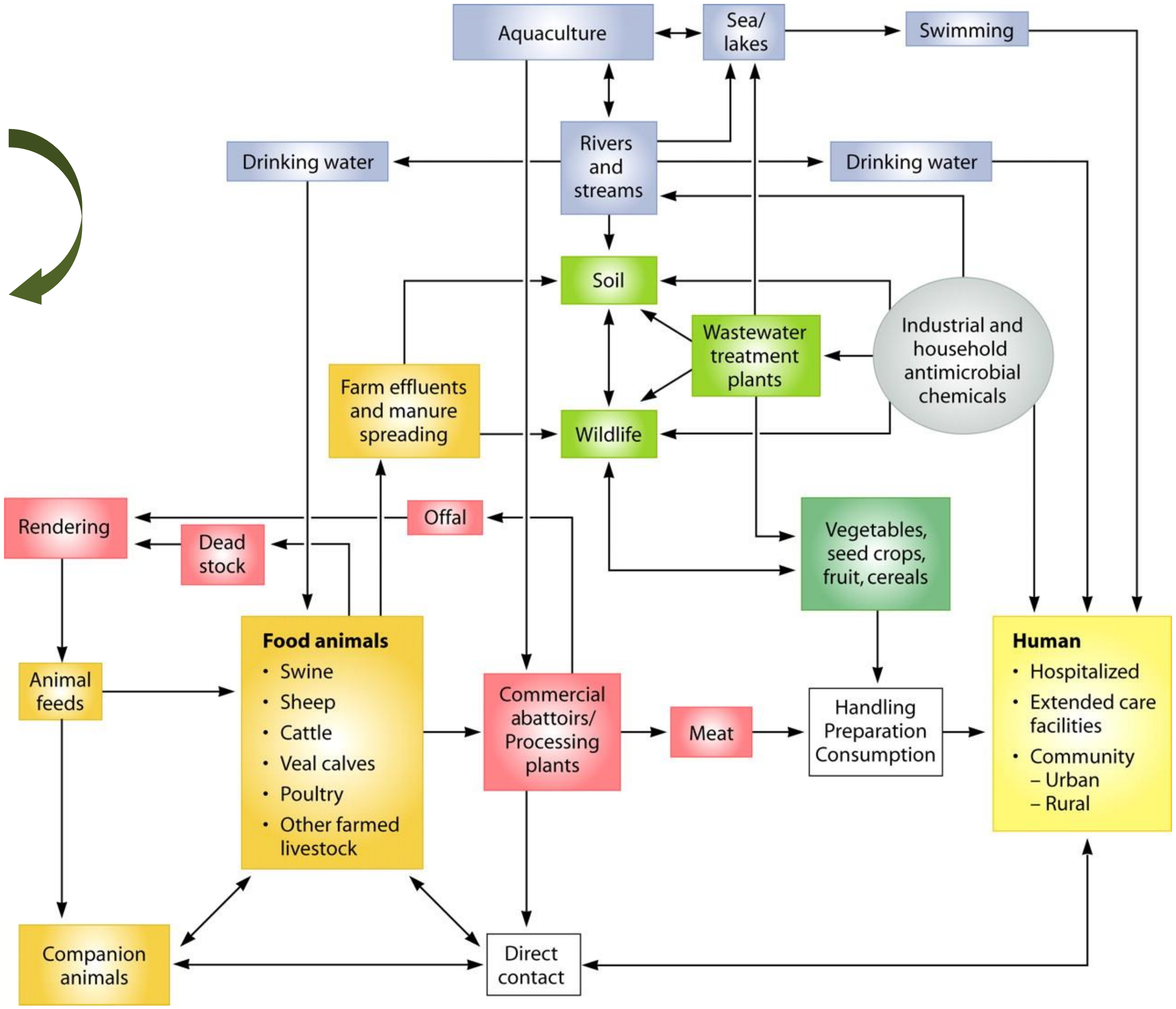
Determinants of AMR

Dissemination of antibiotics and antibiotic resistance within agriculture, community, hospital, wastewater treatment, and associated environments





Julian Davies, Dorothy Davies. Microbiol. Mol. Biol. Rev. 2010;74:417-433
http://mmbr.asm.org/content/74/3/417.full

Challenges in the chemical sciences for global progress

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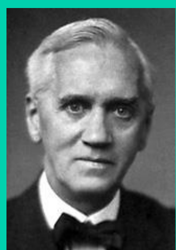

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Late 20th century
'Golden age' of antibiotic discovery
By 2000, fewer than 7% of deaths caused by infections

2013
Lancet
Infectious Diseases:
"We stand at the dawn of a post-antibiotic era … virtually all disease-causing bacteria are resistant to the antibiotics commonly used to treat them"

Mid 21st century
Without action, infection-related mortality may have returned to pre-antibiotic levels

1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010s

Professor Dame Sally C Davies, Chief Medical Officer, England

Challenges in the chemical sciences for global progress

Antibiotic Resistant Bacteria (ARB)

Need for better tools to recognize resistance

- Especially: cheap, accurate, rapid and easy-to-use **point-of-care test kits** for bacterial infections:
  - ✓ more targeted use of antibiotics
  - ✓ overall reduction in misdiagnosis and prescription
  - ✓ part of the toolkit for stewardship of antibiotics in the future

Need for greater investment in new antibiotics

- US: Obama administration nearly doubled the federal funding to combat antimicrobial resistance to more than $1.2 billion in 2016
- EU: Action Plan against Antimicrobial Resistance launched 2011
- IMI: EU/European pharmaceutical industry ‘Innovative Medicines Initiative’

Need for a coordinated global effort to counter antibiotic resistance

- May 2015 World Health Assembly: *Global action plan on antimicrobial resistance (AMR)*
  - ✓ governments all committed by May 2017 to put in place a **national action plan** on antimicrobial resistance, aligned with the global action plan
- USA+EU: Trans Atlantic Taskforce on Antimicrobial Resistance
- WHO, UN’s Food and Agriculture Organization and World Organisation for Animal Health collaborating closely

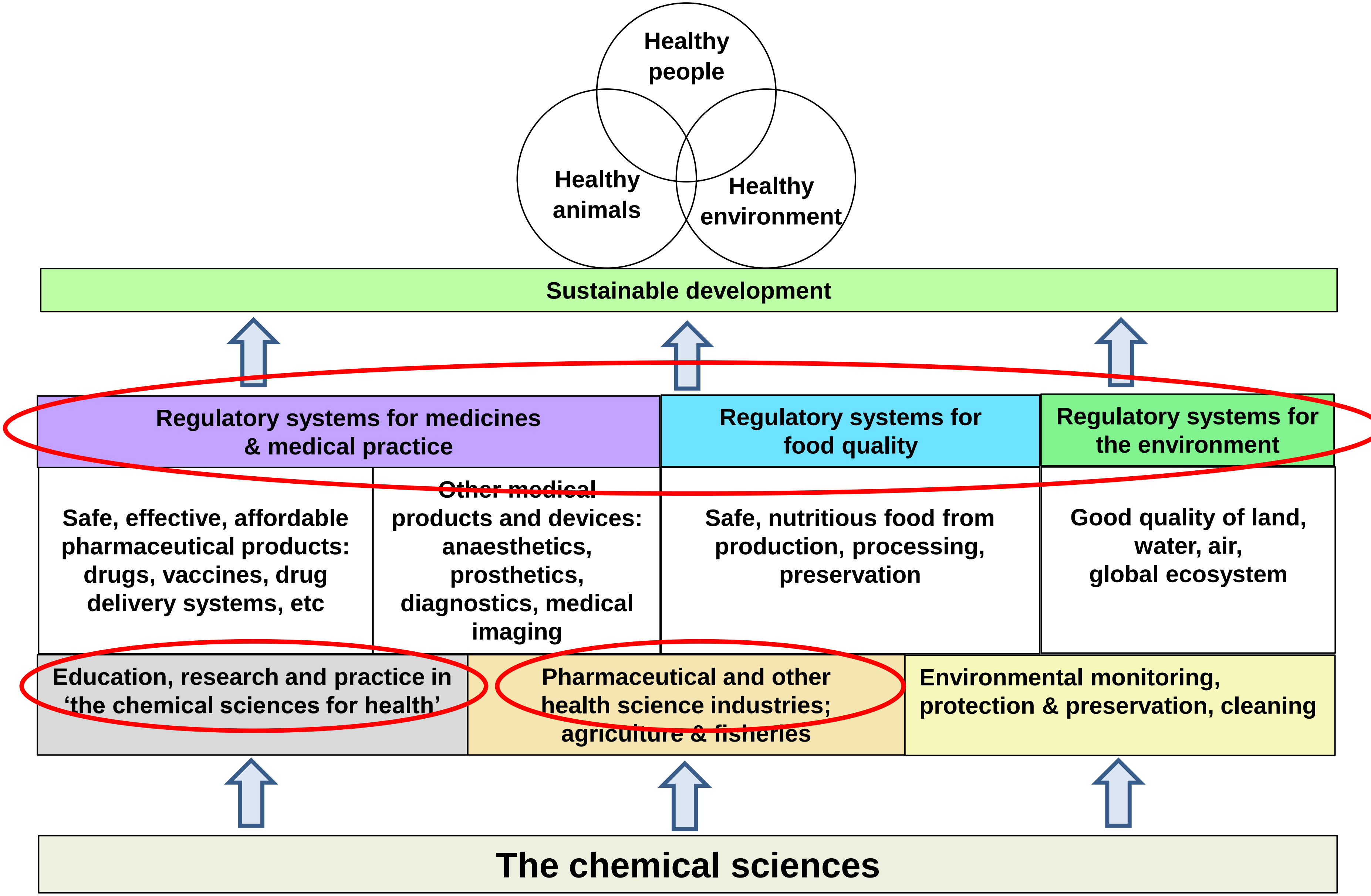
One-world chemistry, systems thinking and cross-disciplinarity applied to 'the chemical sciences and health'

- **The chemical sciences have been good for health**
- **Faced with the oncoming global challenges, even greater efforts are required**
- **The chemical sciences are not able to function optimally in helping to deliver SDG 3: *"Ensure healthy lives and promote well-being for all at all ages"* and *"leave no-one behind"***

Three systemic fragmentations:

1. **In the science discipline**
2. **In the functioning of the related industry**
3. **In the regulatory systems**

The chemical sciences support health through multiple channels

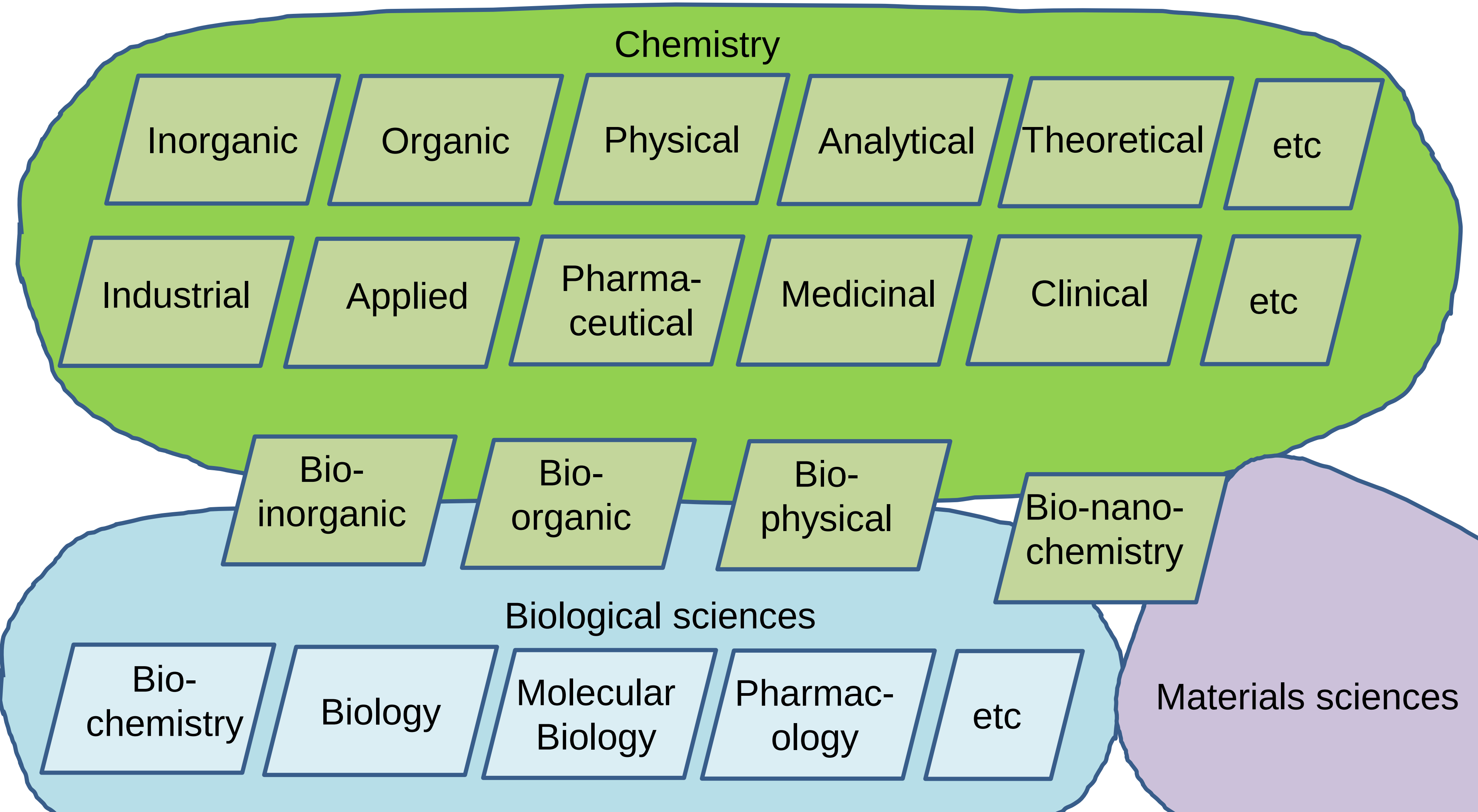


Matlin et al. *The chemical sciences and health: time for a more integrated approach*. 2017 in preparation

One-world chemistry, systems thinking and cross-disciplinarity applied to 'the chemical sciences and health'

Three systemic fragmentations:

1. **Compartmentalization in the science discipline**



One-world chemistry, systems thinking and cross-disciplinarity applied to ‘the chemical sciences and health’

Three systemic fragmentations:

1. **Compartmentalization in the science discipline**

The chemical sciences contribute greatly to better health

– **but ‘the chemical sciences and health’, or ‘chemistry and health’, does not exist as a recognised subject**

We propose that ‘the chemical sciences and health’ should be created as a recognised discipline, providing:

- **an overall vision of the roles and capacities of the chemical sciences in achieving better health, on which learning, research and practice can build**
- **a comprehensive platform of knowledge and skills on which graduates can build and on which they can engage in cross-disciplinary work applied to health, across the whole spectrum of education, research and practice.**
- **convergence of diverse knowledge streams in the chemical sciences – harnessing these convergences to enhance the innovative contributions of the chemical sciences and their synergy with the biological sciences.**

One-world chemistry, systems thinking and cross-disciplinarity applied to ‘the chemical sciences and health’

Three systemic fragmentations:

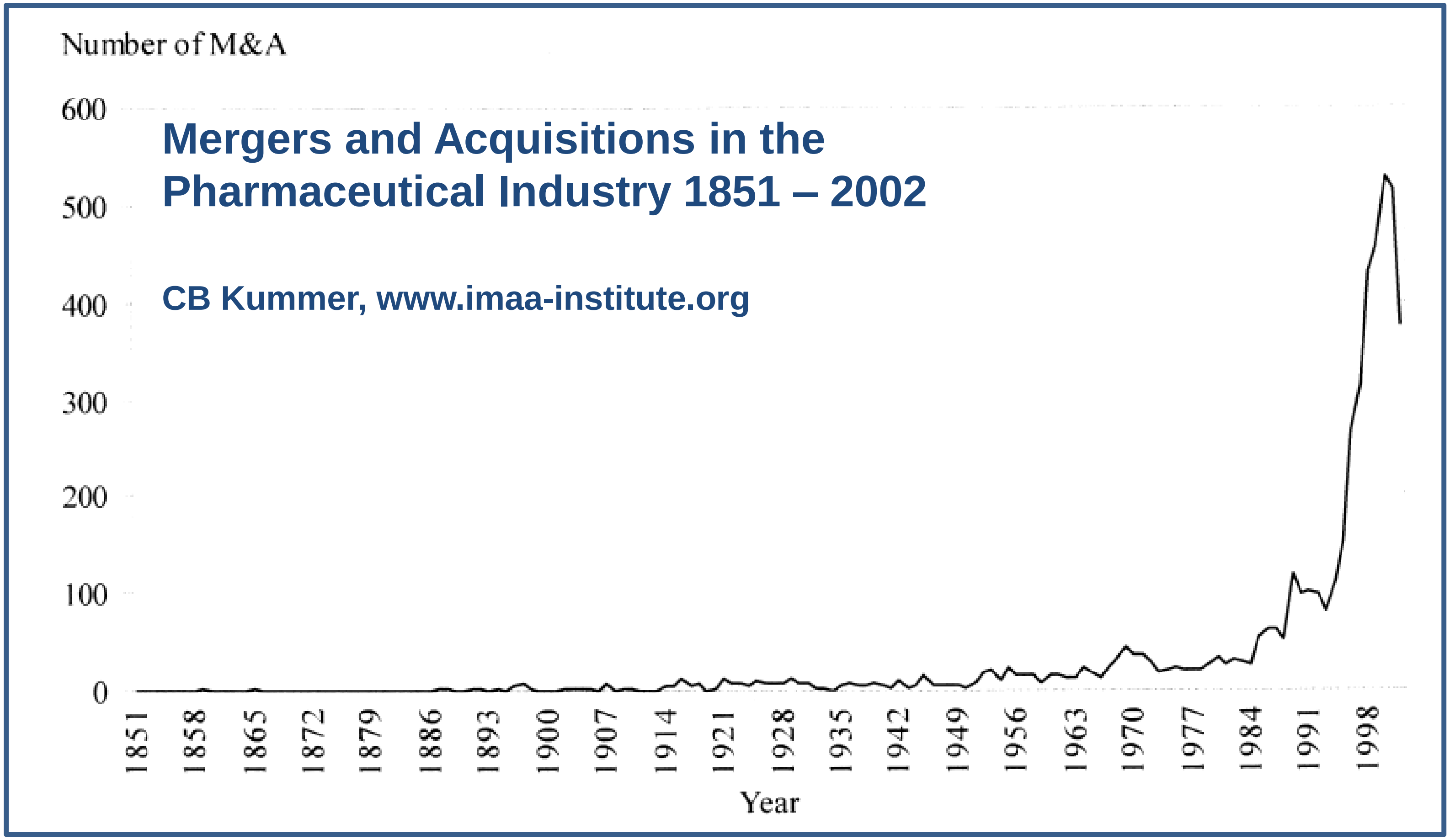
1. **Compartmentalization in the science discipline**
2. **Dis-integration in the pharmaceutical industry**

The pharmaceutical industry

- **Moving: production, consumption and R&D all increasingly taking place in the East and South – especially China & India**

Paradoxically:

- **Consolidation: Mergers and acquisitions**
- **Dis-integration – Shift from ‘vertical’ to ‘horizontal’ structures, including the separation of research from development**



The pharmaceutical industry

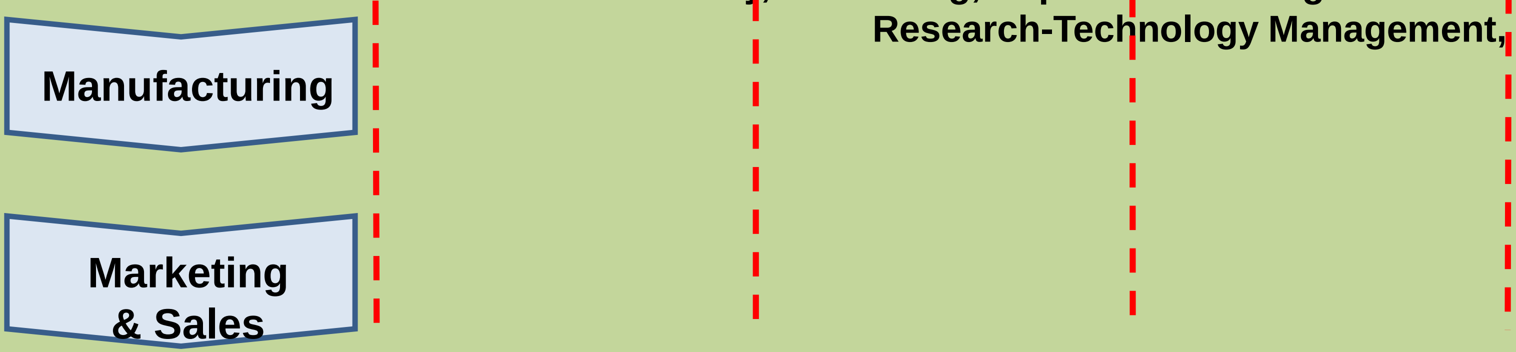
- **Moving: production, consumption and R&D all increasingly taking place in the East and South – especially China & India**

Paradoxically:

While mergers apparently have achieved cost reductions and addressed short-run pipeline problems, there is little evidence to date that they increased long-term R&D performance or outcomes. Many of the larger pharmaceutical firms… continue to deal with a persistent R&D productivity problem.

Grabowsky & Kyle 2008
Mergers and alliances in pharmaceuticals: effects on innovation and R&D productivity.
http://margaretkyle.net/G-K%20Merger%20chapter.pdf

Downey, Greenberg, Kapur. Reorienting R&D for a Horizontal Future
Research-Technology Management, 2003, 46(5): 22-28



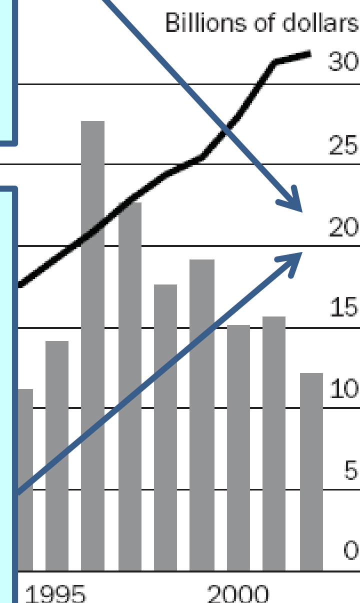
The pharmaceutical industry

- Moving: production, consumption and R&D all increasingly taking place in

Pa

ntal' structures, including the

USA, 1970–2002



Without a substantial increase in R&D productivity, the pharmaceutical industry's survival (let alone its continued growth prospects), at least in its current form, is in great jeopardy.

Paul et al (Lilly Research Laboratories, Eli Lilly and Co)
Nature Reviews 2010, 9, 203-214
www.nature.com/nrd/journal/v9/n3/pdf/nrd3078.pdf

Although mergers and acquisitions in the pharmaceutical industry might have had a reasonable short-term business rationale, their impact on the R&D of the organizations involved has been devastating.

LaMattina (former President of Pfizer Global R&D)
Nature Reviews 2011, 10, 2559-560
www.nature.com/nrd/journal/v10/n8/pdf/nrd3514.pdf

Lin... ng by PhRMA member companies, inflation-adjusted to constant 2002 dollars by the NIH Biomedical R&D price deflator.

IM Cockburn, The Changing Structure Of The Pharmaceutical Industry, *Health Affairs, 23, no.1 (2004):10-22.* http://content.healthaffairs.org/content/23/1/10.full.html

ABPI 2016

More organisations overall, particularly large firms, reported a greater increase in their global discovery investment than that in the UK. This could suggest that whilst areas of the landscape may be thriving, overall the UK may be proportionally losing out globally.

Thus the UK needs to consider how it can best maintain its position as a central player in a dynamic global discovery landscape.

www.abpi.org.uk/our-work/library/industry/Pages/The-changing-UK-drug-discovery-landscape.aspx

Does it matter where and how the science gets done, as long as new products are created to meet the growing health needs? Analysts differ:

- **Some: the metamorphosis has had ‘mixed results’**
- **Some: it has not been to the advantage of people’s health**
    - **decline in numbers of new drug entities coming into use annually**
    - **narrowing of focus on block-buster drugs while ‘diseases of the poor’ neglected**
    - **may be a shift in job opportunities in the relevant sciences accompanying the geographic relocation of pharmaceutical R&D to South and East Asia;**
    - **and this may decrease the popularity of these sciences in Europe and North America, weakening their traditionally strong capacities in research for health**

One-world chemistry, systems thinking and cross-disciplinarity applied to 'the chemical sciences and health'

Three systemic fragmentations:

1. **Compartmentalization in the science discipline**
2. **Dis-integration in the pharmaceutical industry**

The model needs revisiting since the world needs

- **more drugs and other health products at more affordable prices for more diseases and conditions**
- **a system that enables achievement of the SDG goals of health and health equity for all, based on the principle of 'leave no-one behind'.**

Solution(s) will not be straightforward:

- **driven by economic forces that do not originate in the pharmaceutical sector itself but in functioning of economic reward and innovation systems at national and global levels.**

If the high-income countries with traditionally strong pharmaceutical development capacities wish to retain their industries and their leadership roles in the field, they need to play close attention to systemic elements involved and bolster critical ones, including:

- **ensuring strong, robust and well-designed education programmes, including relating to the chemical sciences, that create a pool of talent with skills honed in conducting inter-disciplinary and trans-disciplinary research**
- **well-funded academic centres that can create new leads to health products**
- **innovation hubs that foster early-stage drug development**
- **national innovation systems and innovation financing that encourage the growth of independent middle-size companies that have options beyond buy-out when they create promising candidate products and high-value new licensed drugs**

One-world chemistry, systems thinking and cross-disciplinarity applied to ‘the chemical sciences and health’

Three systemic fragmentations:

1. Compartmentalization in the science discipline
2. Dis-integration in the pharmaceutical industry
3. Disconnections in the regulatory sector

It’s a dirty world and a fake world – affects pharmaceuticals, food and the environment

Need for more effective regulation

- Licencing
- Quality of products procured
- Quality of products in circulation
- Counterfeits
- Contamination of environment
- Contamination of foodstuffs

Regulation = Laws + policing + criminal justice system

- Analytical science feeds into all three
    - Sets position for what is possible
    - Sets practical framework for timescale and cost of what is detectable
    - Sets limits of what is ‘provable’ and therefore enforceable by courts

Dialogue essential: between scientists, policy makers, legal system, public, media

- ➢ Non-technical language
- ➢ Communication about ‘certainty’ and about ‘risk’

?

World Organization for Regulation of Food, Environment and Drugs

WORFED

Thank you

s.matlin@imperial.ac.uk