International Organization
for
Chemical Sciences in Development

New challenges in the chemical sciences for development

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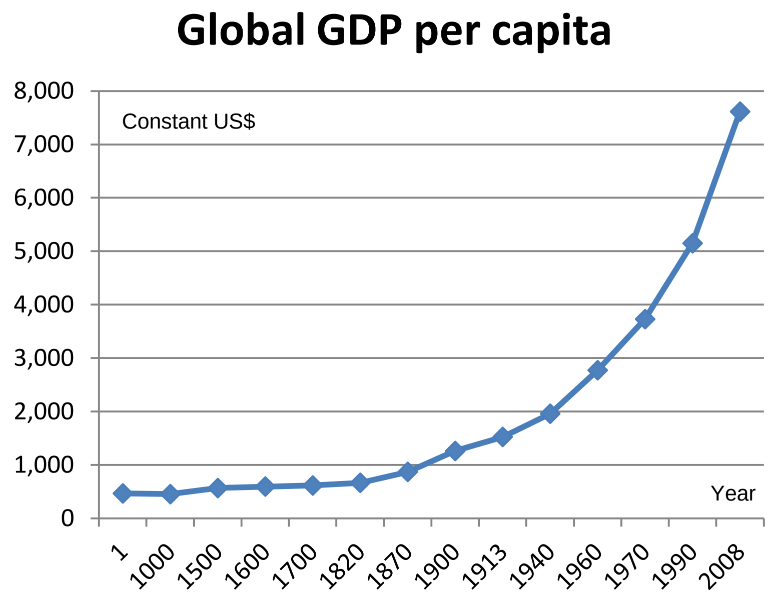
1. The chemical sciences have been good for wealth and health – up to a point, for some

The graph in Box 1 illustrates how human wealth has changed over time, plotting global Gross Domestic Product (GDP) per capita, expressed in constant dollars, over the last 2000 years.[1] Global GDP per capita remained relatively unchanged for more than the first three quarters of this whole period, but then began to rise increasingly steeply. An important precursor to this rise was the agricultural revolution, which took place in the 17-19th centuries in Europe. By greatly increasing agricultural output, it liberated large numbers of people from the business of growing food and they flocked to the towns and cities, where the industrial revolution was able to benefit from their labour.

Box 1



Data from Ref. 1

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The chemical sciences made a major contribution to this growing global wealth:[2]

- In 1800 Alessandro Volta established the beginnings of the field of electrochemistry, laying the foundations for the electrochemical industry, including the generation of electrical power, its storage in portable forms in batteries, and electrolysis processes that have provided many important industrial materials.
- Synthetic chemistry had its origins in the 1840s and 50s with work on the aniline dyes. The scale-up and commercialization of synthesis processes led to major growth in organic chemicals industries in several European countries.
- Work by Pasteur in the 1860s founded the field of biochemistry and paved the way for the development of the biotechnology industry.
- Over the course of a century from the 1830s to the 1930s, work by several scientists, including the Belgian Leo Baekeland, created a new set of industries manufacturing materials such as rubbers, fibres, polymers and plastics.
- Studies by Felix Hoffman on aspirin and by Paul Ehrlich on antibiotics in the period 1897-1909 provided the basis for medicinal chemistry and gave rise to the modern pharmaceutical industry, whose sales now approach a trillion dollars a year.
- William Herschel's work laid the foundations of spectroscopy in 1800, while the basis of chromatography was established a century later by Michael Tswett. The combination of powerful techniques for the separation and structure elucidation of chemical species provided the basis of a whole range of important analytical sciences with applications that include food, medicine and the environment.
- The second agricultural revolution had its origins in work in the early 20th century by Fritz Haber on nitrogen fixation and later by Paul Müller on the insecticidal properties of DDT. These were precursors to a wide range of agrochemical industry products.
- The demonstration by Michael Faraday of the first semiconductor effect in 1833 and work on transistors by William Shockley and a group of physicists and chemists at the Bell Laboratories in the late 1940s were important milestones in solid state chemistry. We are still seeing the expansion of information and communications technology industries based on this field today, with a host of applications of computer microchips that are transforming our lives.

This phenomenal rise in global GDP per capita during the last few centuries is mirrored by another spectacular rise in the same period. Global average life expectancy remained below 30 years of age right up to the end of the 19th century, but in the last 100 years it has more than doubled and is still increasing.[3,4]

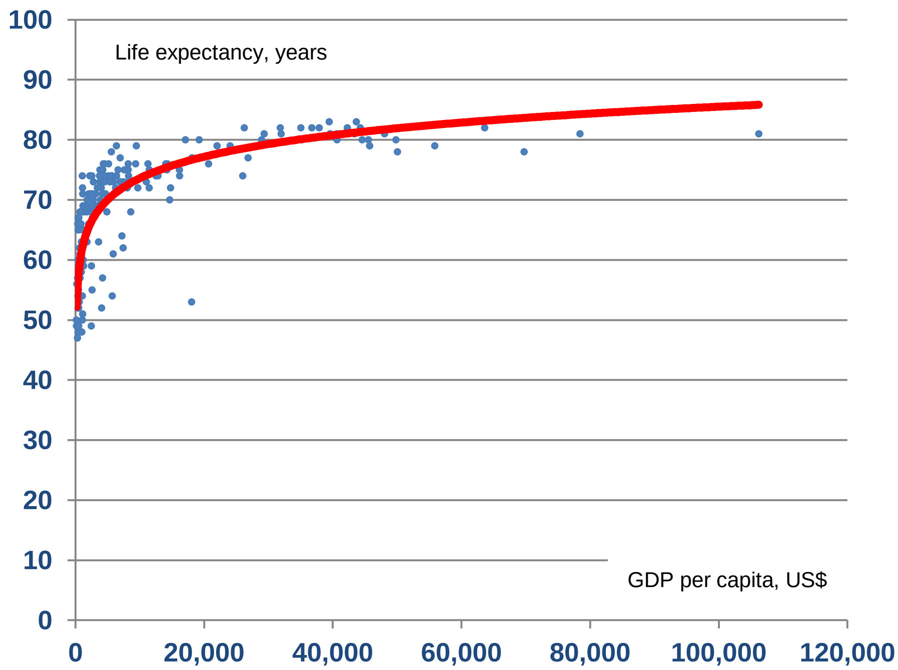
Like average wealth, average life expectancy is not evenly distributed around the world among different countries. National average life expectancies for some countries now exceed 80 years, while for others, national average life expectancies can be less than half that - including for some of the poorest countries such as those in parts of Africa and Central Asia.[5]

Increasing life expectancy is not simply a matter of economic development. If it were, the issue of these gross inequalities might soon resolve itself. The combined GDP of the 'developing and emerging' economies is rising rapidly and it has been predicted[6] that it will overtake the combined GDP of the 'advanced' economies by 2013. In 2010, China was the world's largest exporter and overtook Japan as world's 2nd biggest economy – East Asian countries are likely to emerge as the world's largest trading bloc by 2015;[7] in 2011, India overtook Japan[8] and Brazil overtook Britain in the world's economic rankings. One conclusion of this rapidly changing global economic scene is that we should stop talking about "developing countries" – a better terminology is that of high-income countries (HICs) and 'low- and middle-income countries' (LMICs), as classified by the World Bank.[9]

A plot of average national life expectancy against GDP per capita (known as a " Preston curve" after Samuel Preston[10]) shows that the relationship is not a straightforward linear one – beyond a certain national wealth, more money does not buy greater average life expectancy, but below this point it does seem that having more money makes a big difference (Box 2).[11]

Economics is clearly not the only factor involved in the dramatic increases we have seen in average life expectancies during the last hundred years. Plotting a set of Preston curves for the last century covering different time periods reveals that in any one time period there is a similar trend for the relationship between life expectancy and GDP per capita, but between each succeeding time period there is an overall increase in life expectancy.[12] So in constant dollars, the same amount of national wealth buys more life in a later period. Economists have concluded that the steep decline in mortality during the 20th century had its origin not directly in wealth but in technical progress – where 'technical progress' refers to a combination of technological advances and their diffusion and uptake in different countries and the capacities of the countries themselves to conduct and apply research.[13]

Box 2 Preston curve: Life expectancy vs GDP per capita 2009



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Ismail Serageldin, Director the Library of Alexandria in Egypt, has commented[14] that "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'." And clearly, for the poorer countries, not acquiring and using new knowledge is not only a matter of economics – it is also a question of life and death. To put it simply – "ignorance is fatal".[15]

Belgium is an example of a country whose prosperity has been greatly influenced by the chemical sciences. In the 19th century, work on the manufacture of soda, on photography, on plastics and on chemical analysis established a strong base of industrial chemistry in Belgium. Today the chemical industry and life sciences account for over a fifth of Belgium's total manufacturing sector turnover, nearly a fifth of all manufacturing sector jobs, a very significant export trade balance and large fractions of Belgium's manufacturing and research investment. In the chemical industry field, Belgium really does punch above its weight.[16]

Taiwan provides an example of an economic transformation during the second half of the 20th century, with planning and investment in chemistry capacity playing a key role. Between the 1950s and 1990s, Taiwan's per capita GDP rose eight-fold to over US$ 7,000 and in the 1990s the chemical industry was the largest industrial sector, contributing a quarter of the total production value. As well as technical and strategic factors, there was a crucial political component to Taiwan's success in the chemical industry sector – there was strong support by the government, including well planned industrial zones and tax, investment and export incentives.[17]

Of course, not all countries have made these kinds of investments in science, technology and innovation. Large variations exist between countries in R&D intensity (the percentage of GDP that is invested in R&D), with some of the countries in Africa, Central Asia and South America having among the lowest R&D intensities.[18] Not surprising, low rates of investment in R&D correlate with low levels of scientific capacity and output.[19]

2. New challenges in a changing world

The challenges that the chemical sciences for development face in a changing world are of three kinds: not just challenges for the ***specific science needed*** to solve particular problems, but also challenges in ***developing the capacity for science*** and in the ***governance of science***.

Some of the biggest science challenges we currently face can be summed up[20] by two very simple statements: (1) It's a **dirty** world and a **fake** world; and (2) There are **more people** and **limited resources**.

It's a dirty world...

... in which we are faced with increasing levels of contaminants in the environment, food and pharmaceuticals.

As an example of environmental contamination: A 2011 report[21] in *Nature* concerns high levels of pharmaceutical ingredients in treated effluent from wastewater-treatment plants and in effluent downstream from pharmaceutical factories, with examples coming from India, the USA, and the European Union. It is important to recognise that there has been a systematic failure, at both national and global levels, to deal with these problems: the USA and Europe do not have regulations limiting the concentrations of pharmaceuticals released into the aquatic environment in either municipal wastewater or in effluent from manufacturing facilities.

Another area of very serious concern is the contamination of pharmaceutical products themselves with harmful ingredients. For example:[20]

- Illegal use of diethylene glycol in various pharmacy products has caused hundreds of deaths across several countries in recent years.
- In China, widespread adulteration of infant feeding formulas with, melamine (a trimer of cyanamide) caused serious harm on a large scale.
- And in the UK, one of our most recent examples of deliberate contamination of a pharmaceutical product occurred in 2011, when a man was prosecuted and subsequently jailed for adulterating packages of the painkiller Nurofen Plus.

There are a number of important lessons to be drawn about drug and food safety in a globalized world:[22]

- The problem is often only identified when large numbers of people or animals are affected and there are numerous deaths.
- Deliberate contamination may be widespread but escape detection in poorly regulated markets.
- Contaminated raw material may cross national boundaries and be used in more well-regulated markets.
- It is not clear that regulatory organizations have the capacity to deal with the problem.
- There is a need to develop cooperative programmes to detect and limit these global outbreaks.
- The relevant scientific communities need to develop proactive global approaches to this global problem.

... and it's a fake world

Looking at the world of fake drugs, it's estimated that counterfeit drug sales were worth US$75 billion globally in 2011. Counterfeit medicines are estimated to constitute more than 10% of the global medicines market, with a range up to 50% in some low- and middle income countries. It remains a big challenge even in well-regulated pharmaceutical markets like that in the USA, because c. 40 % of drugs in USA are imported and c. 80 % of active ingredients in US drugs come from overseas sources.[23]

Of course, these types of fraud have been made very much easier by the use of the internet as a source of pharmaceutical products. A very recent case involving a Belgian man illustrates some of the typical global characteristics of these crimes – with production, marketing, supply and payment chains operating across several countries and making it very difficult for national enforcement agencies to catch and successfully prosecute the perpetrators.[24]

WHO assessments[25] have shown that a very wide range of drug types are involved, and a whole range of faults from little or no active ingredients to substitution with potentially harmful substances. It is clear that:

- The problem has reached a global dimension and needs a global approach.
- But in many places there is absence of, or weak, drug regulation

As the WHO stated in 1984: "every country, regardless of its stage of development, should consider investment in an independent national drug quality control laboratory".[26]

But: at present, of 191 WHO member states, only about a fifth have well developed drug regulation. Of remainder, about half implement some drug regulation while another 30% either have no drug regulation in place or a very limited capacity that hardly functions.[27]

There are more people and limited resources

A further set of challenges arise from the fact that the world we inhabit has an increasing population, but limited resources. The global population passed the 7 billion mark in 2011 and according to the most likely fertility projections will probably reach 8 billion by 2025 and 10 billion later this century. Most of this increase will take place in some of the poorest regions of the world.[28] We are already experiencing the fact that the world's physical and biological resources are limited and even at present levels there are shortages of energy, foodstuffs, water and raw materials. As the population grows, there will be increasing demand for a wide range of physical and biological products and for methods of production and waste management that do not harm the environment. These are areas where ingenuity and innovation in the chemical sciences can be harnessed globally for the benefit of the global population.

3. IOCD: Meeting new challenges

IOCD was founded in 1981 by Pierre Crabbé, a Belgian chemist with wide experience in academia and industry and in development programmes. Crabbé was a humanitarian with a vision that sciences like chemistry could help to narrow the development gaps between richer and poorer countries. He was also very clear that development was not a matter of charity but of mutual assistance and mutual benefit. In his book[29] with Léon Cardyn he says: *"One does not go to a country to "assist" people, but to work with them. We should keep in mind that in cooperative programmes we learn more than we teach and receive more than we give."*

In the first phase of IOCD's work, through to the mid-1990's, IOCD moved away from UNESCO where it had been created in 1981, becoming registered in Belgium as a non-governmental organization in 1983 and establishing a Secretariat in Mexico with the support of the Mexican government in 1985. IOCD quickly established a series of working groups in aspects of medicinal chemistry and the utilization of natural products and created some analytical service centres at universities in HICs – to support chemists in LMICs by provided spectra free of charge. In the 1990s, this was followed on by assisting in the creation of the Network for Analytical and Bio-assay Services in Africa – developed under the leadership of Berhanu Abegaz.[30] IOCD's initial aims included scientific engagement in research projects, research facilitation and capacity building – which at the beginning was mainly at the level of the individual. IOCD has been fortunate to attract some very prominent and brilliant scientists to its cause – including the first President, the Nobel Laureate Glen Seaborg; the current President, the Nobel Laureate Jean-Marie Lehn; and members of the Senior Advisory Council including the Nobel Laureates Norman Borlaug (father of the 'green revolution'), Roald Hoffmann and Sune Bergstrom; as well as prominent scientists from LMICs like the eminent Indian chemist CNR Rao.[31]

Following Pierre Crabbé's tragic death in a traffic accident in 1987, IOCD appointed its second Executive Director, Robert Maybury, a chemist who had worked on science and development with UNESCO and the World Bank. The 1990s saw many changes in the development sphere, with on the one hand rising capacities for science in a number of countries but on the other hand a series of financial crisis and a severe 'donor fatigue' which meant that there was much less money available for development work. IOCD moved into the second phase of its existence, developing new Working Groups and programmes but shifting its approach from running research projects to meetings, seminars and workshops. The capacity building aspect also underwent substantial change, expanding its focus from the individual to institutional and working more with LMIC networks and on aspects of policy.[32]

By 2011, IOCD's portfolio encompassed 9 Working Groups and Programmes. Details of all the Working Groups can be found on IOCD's website, www.iocd.org. Taking one as an example: the Biotic Exploration Fund (BEF) was established in 1995 to facilitate and catalyse "ethical bioprospecting". The BEF has worked in Asia, Africa and Latin America. It has helped develop policies and bioprospecting systems e.g. in South Africa, Uganda and Kenya. In November 2011, IOCD's John Kilama participated in the launch of Kenya's new Bioprospecting Strategy which the BEF had helped to facilitate.[33]

IOCD has a significant record of achievements in its first 30 years. The overall impact of IOCD has been to help highlight the importance of chemical sciences as contributors to development; raise the profile of the field and its practitioners; initiate, promote or sustain a number of technical, managerial, policy and collaborative projects or networks advancing chemical sciences in LMICs; and contribute to vital resources for teaching, learning and research.

But the world has changed since 1981: economically, politically and socially. And the field of international development has changed. It has moved from 'international aid' (which some people describe as 'redistribution' or 'charity') to 'development cooperation', which involves:

- The need to have recipient countries in greater control of aid and for aid to be more focused on impact
- Shared responsibility
- Inclusion of all the stakeholders in the process
- Co-development and opportunities for "reverse innovation" in which HICs have much to learn from innovations created in and by LMICs
- "South-South" cooperation among LMICs themselves...
- ... and increasingly "triangular" cooperation, involving a traditional donor (HIC) an emerging (LMIC), and a beneficiary country (LMIC).

IOCD's third phase began with the appointment of Prof. Alain Krief as IOCD Executive Director in 2010 and recognition that, in a changing world, IOCD must renew its strategy, methods and membership. The new strategy[34] for this decade has three Strategic Priorities:

1. Chemistry for better health
2. Chemistry for a better environment
3. Capacity building in chemical education

IOCD's strategy is to *s*upport ownership, partnership and capacity building for the use of the chemical sciences in and for the benefit of LMICs. Our approach involves going beyond scientific aid for LMICs to fostering science applied to equitable global development. And our function is increasingly to serve as an umbrella and facilitator for programmes and funding for research, education and capacity building in the chemical sciences.

While the world is changing in many different ways, it's becoming clear that a much more effective and productive communication interface is needed between the different kinds of actors, including between scientists and policy makers. In particular, there is need for:

- Policy-makers to develop evidence-informed policy and an understanding of the significance of research results;
- Scientists to conduct policy-informed research and to develop their understanding of the significance of policy and practical constraints.
- The collective development of a shared non-technical language and a shared understanding about issues – especially those concerning questions of 'certainty' and 'risk'.

I believe that the future of IOCD is increasingly going to be found at this science-policy interface.

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