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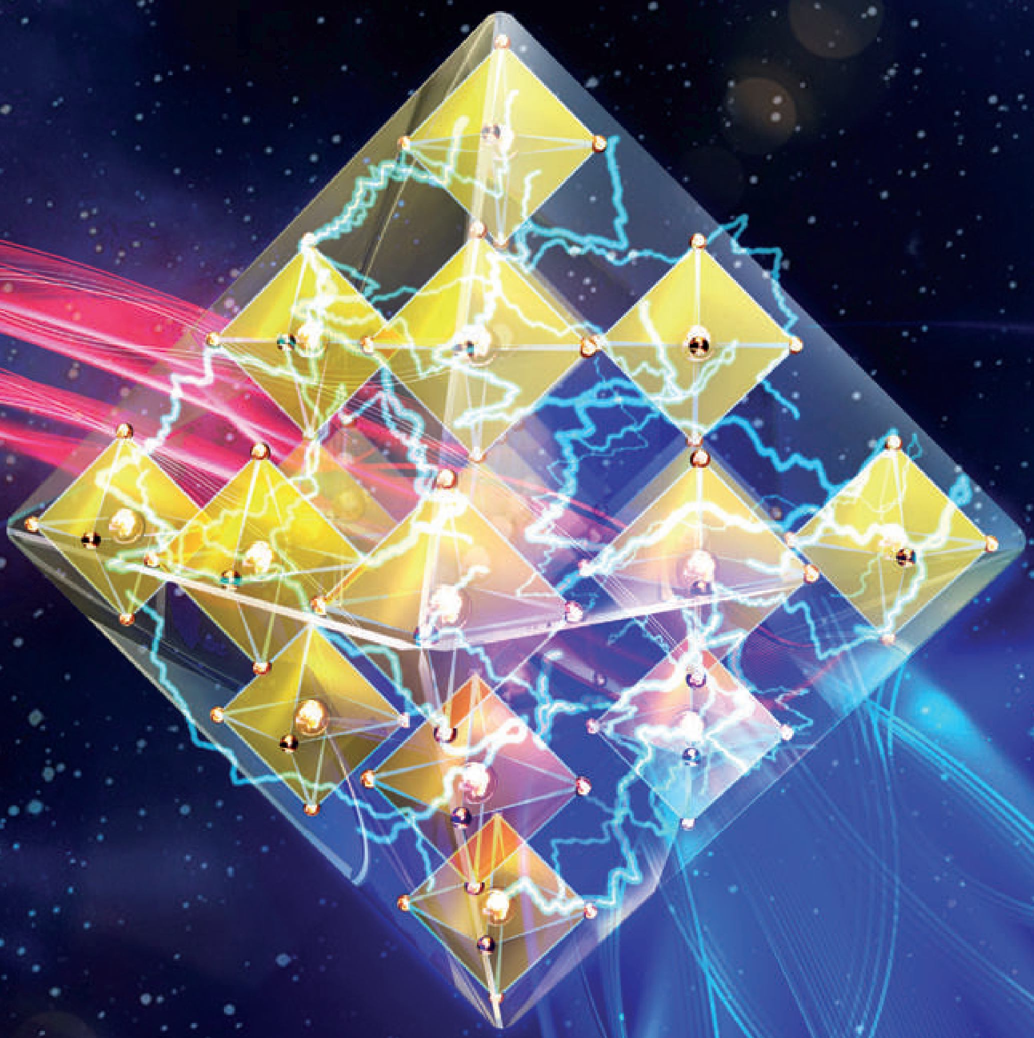
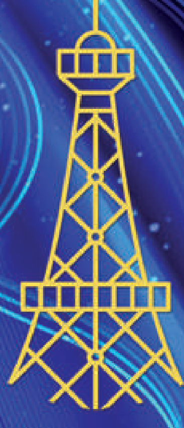


## IUPAC 2019 PARIS
## LET'S CREATE OUR FUTURE!



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## Let's create the future of Chemistry

2019 is a very unique year for chemistry and chemists because a large number of events and concerted actions related to chemistry are occuring. Indeed, this month in Paris, the IUPAC 2019 Congress and the joint 50$^{th}$ General Assembly will present a unique event as both will celebrate the Centenary of the International Union of Pure and Applied Chemistry (IUPAC). It was conceived in Paris, elaborated in London and signed in Brussels in 1919. Moreover, 2019 is an exceptional year for chemistry because the United Nations General Assembly proclaimed it as the International Year of the Periodic Table of the Elements established by Dmitri Mendeleev in 1869.

Chemistry is an exceptional discipline, a science that is playful for anyone who appreciates it! To be a little provocative, we will say that everything is chemistry: ourselves and our environment! Chemistry is a central discipline that nourishes, functionally intellectually and economically, both humanity and the academic and industrial worlds. Research in chemistry is at the frontiers with all disciplines (biology, mathematics, physics, engineering, environmental sciences, etc.) and covers both fundamental research, essential for the understanding of phenomena, and also research oriented towards industrial innovation. Our aim as chemists is to make chemistry better known as a science and also as an industry, and to show the unwavering links that they maintain and try to arouse vocations among the youngest.

Chemistry is indeed a source of inspiration, integration and evolution. There are "real challenges" behind the understanding of chemical processes and the production of new molecules, materials and systems. One of the major challenges in which chemists are involved concerns the reasoned development of bio-sourced or bio-inspired new molecules, materials and systems, with multi-functional structures able to respond to the societal and environmental demands needed for our well-being. These strategies, integrating inorganic and organic chemistries, supramolecular chemistry, physical chemistry in a broad sense with all their components, modeling and process engineering, are at the base of a strong current of research and new school of thought that are giving birth to a so-called "integrative" chemistry. In this context, today chemistry is a real cornucopia fueled by the creativity of chemists. Health (drugs, implants and prostheses, medical imaging, therapeutic vectors), cosmetics, textiles, packaging, construction, insulation, automotive, functional coatings, high technologies (micro-optics, and microelectronics), energy (solar, wind, hydraulic, nuclear, batteries, fuel cells…) are great examples. In addition, environmental sciences are already benefiting from the development of new materials in areas such as sensors, catalysis, purification, separation...

Even if technological and economic impact of chemistry are very important for our society, blue sky research should also be strongly supported because risky long-term research will allow to make non expected real progress. Risk taking is an essential part of research activity. "*The unpredictable is in the very nature of the scientific enterprise. If what we are going to find is really new, then it is by definition something unknown in advance*" (François Jacob, French biologist, 1920-2013).
Because of its centrality, chemistry is at the heart of major societal and environmental concerns, to which academic, industrial and public decision makers respond jointly. The stakes in terms of health, energy, depletion of the resource and the impact of anthropic activities on the ecosystem pose legitimate questions for the citizen. The teaching of chemistry, as of all other fields of experimental sciences, contributes to the development of the knowledge and the critical spirit of the citizens. Both will improve the science-society dialogue because it makes sense if our opinions are built, not exclusively on emotional reactions, but on established knowledge.

The programme of the 2019 IUPAC Centenary Congress, with the theme "*Frontiers in chemistry: Let's create our future!*", was built to merge the different fields of chemistry and to address today's most challenging issues.

2019 IUPAC meeting is composed of thirty symposia. Three main themes are forming the backbone of the Congress: Chemistry and Life, Chemistry and Energy, Chemistry and Environment.
Last but not least, the WCLM (World Chemistry Leadership Meeting) symposium is for the first time devoted to a special session during which the Presidents or CEOs of the largest chemical companies or users of chemistry will exchange their visions, perspectives, and approaches of the UN sustainability goals challenges.

The Centenary conjunction represents a unique opportunity to project the universality values of IUPAC, and it is worth remembering that the Union welcomes as well the scientists from pure academic research as those involved in applied and industrial aspects.

This special issue of *L'Actualité Chimique* illustrates through selected articles written by highly recognized scientists the main challenges of a very beautiful and useful science: CHEMISTRY.

**Clément Sanchez**, President of IUPAC 2019, Collège de France (Paris)

**Jean-Marie Lehn**, Honorary President of IUPAC 2019, Nobel Chemistry 1987, Institut de Science et d'Ingénierie Supramoléculaires (ISIS, Strasbourg)

**Jean-Pierre Vairon**, Coordinator of IUPAC 2019, Sorbonne Université (Paris)

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The cover image was originally published on the back cover of *Advanced Functional Materials*, 2018, vol. 28, issue 18. It features work by Tzu-Chiao Wei, Sudha Mokkapati, Ting-You Li, Chun-Ho Lin, Gong-Ru Lin, Chennupati Jagadish, and Jr-Hau He. Copyright Wiley-VCH Verlag GmbH & Co. KGaA. Reproduced with permission.

## Chemistry enabling "magic bullet"

Since Paul Ehrlich, the Nobel laureate in physiology or medicine, advocates the concept of "magic bullet" in the early 20th century, the selective delivery of drugs to target sites in the body has long been recognized as one of the most difficult challenges in scientific community. Indeed, many drug formulations composed from a combination of various materials have been developed to solve this issue of drug targeting; however, they were encountered many serious difficulties, such as a lack of longevity in blood circulation, limitations in versatility of loadable drugs, uncontrolled drug release at target sites, and concerns of accumulation toxicity. In the early 1980s, when this situation still continued, I started the challenge to solve these difficulties accompanying with drug targeting with a new approach that leveraged my background as synthetic chemist. As a result, based on the ordered formation of core-shell structured assemblies, named polymeric micelles, from molecularly-engineered amphiphilic block copolymers, novel drug nanocarrier with uniform size (~tens of nm) comparable to viruses was successfully developed (*figure 1*) [1-3]. Nowadays, this polymeric micellar nanocarrier (PMN) has come into clinical use as delivery systems for various anticancer agents [4].

As shown in *figure 1*, the polymeric micellar nanocarrier (PMN) we developed has dense outer shell structure composed of tens to hundreds of tethered polymer chains with hydrophilic and flexible nature, thereby revealing to effectively suppress non-specific interactions with blood components when administered intravenously (stealth function). Meanwhile, the inner core composed of polymer chains with high cohesive forces contributes to the stabilization of micellar structures, and functions as nano-reservoir to stably encapsulate delivering drugs. Furthermore, stimuli-responsive characteristics, including concentration changes in physiologically relevant substances (e.g., pH, glutathione, glucose, and ATP), can be introduced into the core-forming polymer chains. In this way, one can expect the smart functionalities to release or activate encapsulated drugs with desired timing of action in response to subtle microenvironmental changes at the target site [5].
The PMN is also characterized by its superior safety aspects, such as prevention of chronic accumulation toxicity, because after the release of encapsulated drugs the PMN loses the stability and dissociates into constituent block copolymers, which are smoothly excreted outside the body. Further appeal is that the PMN is feasible for directing particular cells and tissues with selectively delivering various agents (active targeting), by attaching target-directed molecules (peptides, antibodies, sugars, etc.) onto the periphery of the outer shell. Worth noting is that I focused from the beginning of my research on the PMN availability for the future clinical application. Thus, I chose hydrophilic and highly biocompatible poly(ethylene glycol) (PEG) as the shell forming component and biodegradable poly(amino acid), prepared by NCA polymerization, as the core forming component [1]. Actually, my career in synthetic polymer chemistry (anionic ring-opening polymerization) contributes greatly to pursue the molecular design of various PEG-poly(amino acid) block copolymers suitable for the PMNs with different biomedical applications.

A series of our developed PMNs loaded with hydrophobic anticancer drugs (paclitaxel, epirubicin) and platinum-complex-based anticancer drugs (cisplatin, dahaplatin) has already been derived to companies, and phase I-III clinical trials for the treatment of various cancers are ongoing in Japan, Asia, Europe, and USA [6]. In parallel with these clinical

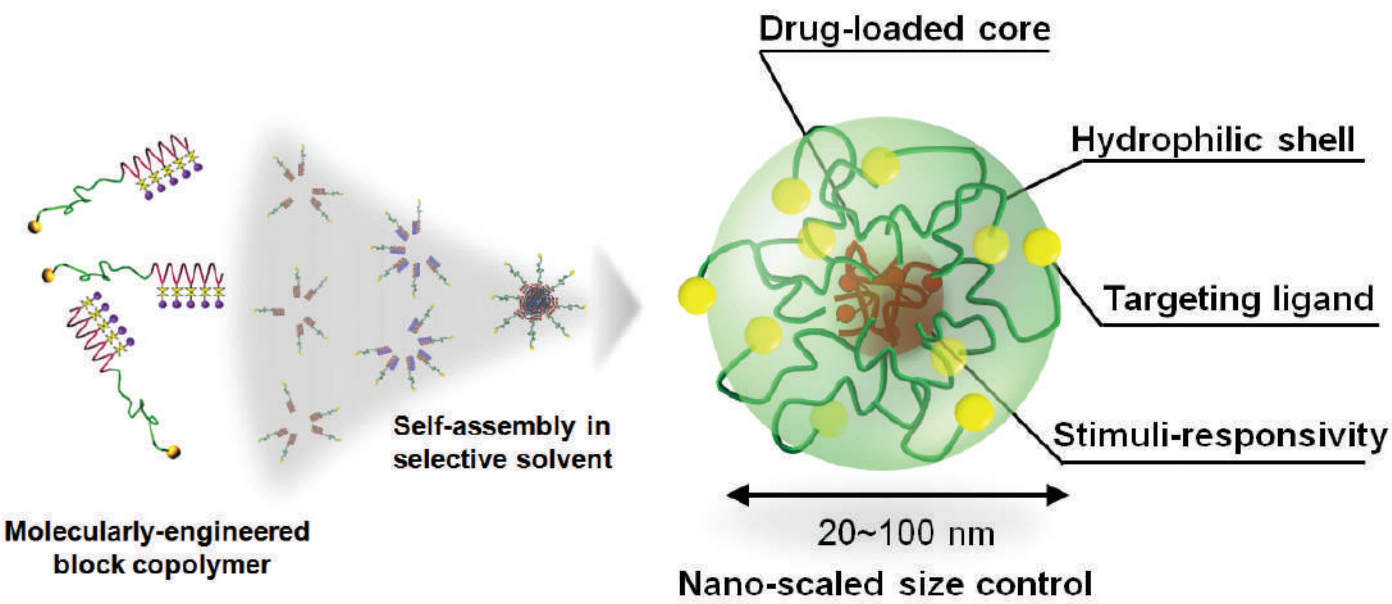


Figure 1 - Polymeric micellar nanocarrier (PMN) self-assembled from molecularly-engineered block copolymers.

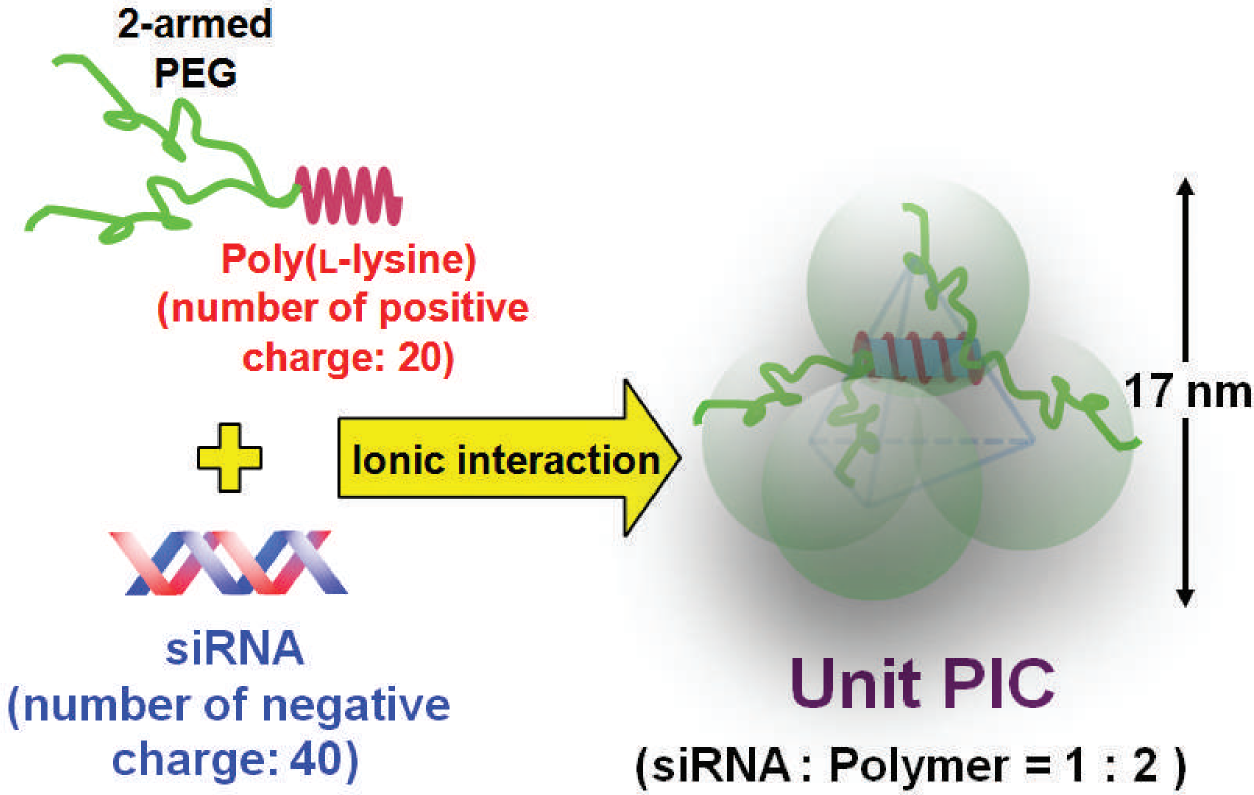


Figure 2 - Formation of unit PIC through charge-matched interaction of siRNA and 2-armed PEG-polycation block copolymer.

developments, I noted that in real clinical cases, the stroma is abundant in many cancers, which constitutes a barrier to the intratumoral penetration of drug-loaded nanocarriers. This fact led me to the idea that the drug could be efficiently penetrated into stromal rich tumors, such as pancreatic cancer, by the strict size control of PMNs. Then, we established the chemical procedure to control the size of PMNs loaded with anticancer drugs in the range of 30-50 nm to circumvent penetration barrier of stroma-rich intractable cancers [7-8]. As this finding is leveraged in the clinical trials of our developed PMNs, as well as being the study to clearly quantify the penetrability of drug-loaded nanocarriers (nanomedicines) in the intratumoral microenvironment, it has received a substantial acknowledgment in the field of cancer nanomedicine. In addition, I have recognized the importance of polymeric micellar-type MRI-contrast agents that can detect local fine-pH changes to predict the tumor malignancy [9]. Worth noting is that these PMN-based MRI-contrast agents are useful to estimate the efficacy of nanomedicines in individual patients who may have variations in their tumor microenvironment, including vascular and stromal permeability. Combination system of drug delivery and imaging functionality is termed "theranostics", and has been recognized as an emerging field with high attention [10].

I also inspired that polymeric micelles could also be formed based on ionic interactions between a pair of oppositely charged polyelectrolytes, given that at least one of the pairs is a block copolymer composed of charged and non-charged hydrophilic segments. Because, in this way, polyion complexed core of the micelles is sealed from outer environment by non-charged hydrophilic shell, thereby avoiding further progressive aggregation of polyion complex to form precipitates. Based on this idea, in 1995, the first examples of monodispersive polymeric micelles were prepared by our group, and are named as polyion complex micelles (PIC micelles) [11]. Worth noting from the standpoint of molecular recognition in this self-assembly process is that a strict chain-length recognition occurs upon the formation of PIC micelles from block copolymer pairs with opposite charges, and when a mixture of block copolymers of different lengths is solubilized in aqueous solution, PIC micelles are selectively formed from pairs of oppositely charged block copolymers having the same length of charged segments [12]. This is the manifestation of a new molecular recognition mechanism based on the requirement of the homogeneous distribution of the charged segments in the micellar core and the distinct phase separation of the outer shell/inner core interface.
Importance of PIC micelles in nanomedicine to enable "magic bullet" is their application to PMNs delivering charged biopolymers such as proteins and nucleic acid pharmaceuticals. We actually revealed this possibility in a series of studies done in the late 1990s to the early 2000s [13-17], and PIC micelles are now widely appreciated as useful nanocarriers in the research field of nanomedicine. More recently, we have established an approach of rigorous particle size control for PIC micelles, and successfully aligned their sizes to the same levels as antibodies (unit PIC) (*figure 2*) [18]. Thanks to their antibody-comparable size, the unit PICs easily reached the deep part of the tumor while repeatedly binding and dissociating with oligonucleotide pharmaceuticals bioorthogonally in the bloodstream, realizing the molecularly targeted treatment of intractable cancers such as malignant glioblastoma and stroma-rich pancreatic cancers. Furthermore, because of the high safety and easy formulation process of unit PIC, it has already reached the production stage satisfying GMP (good manufacturing practice), and clinical trials are planned to be initiated during this fiscal year in Japan.

The research results described above is positioned as a new interdisciplinary field research of nanomedicine based on the fusion of medicine, chemistry, pharmacy and engineering. Drug development is becoming increasingly diverse, including biopharmaceuticals such as antibodies and gene and nucleic acid pharmaceuticals, in addition to traditional small molecule pharmaceuticals, and many of them are required to optimize biodistribution and improve selectivity for target cells and organs. We expect that our initiated PMNs can greatly contribute to the practical application of these new pharmaceuticals due to their versatility in molecular design.


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## Advanced macromolecular engineering

The 21st century opened new avenues for synthesis of macromolecules with precisely controlled architectures and functionality, aiming to mimic biological systems. These polymers have been prepared by various chain-growth reactions using either vinyl or cyclic monomers [1]. Such well-defined (co)polymers are prepared by controlled/living polymerization employing reversible deactivation polymerization (RDP) techniques with the concurrent growth of all polymer chains (fast initiation) and greatly diminished contribution of chain breaking reactions (transfer and termination). Originally, living polymerizations were developed for anionic polymerization of non-polar vinyl monomers such as dienes and styrene and were subsequently extended to ionic ring-opening polymerization, coordination polymerization of both olefins and cycloolefins (ROMP), and eventually to radical polymerization (reversible deactivation radical polymerization, RDRP). Recently various catalysts used at parts per million concentration have been developed to be used in the presence of less expensive reagents, such as alkyl halides in atom transfer radical polymerization (ATRP) [2]. This approach very significantly reduced the cost of commercial synthesis of various (co)polymers and enabled macromolecular engineering (ME). ME can be defined as a process comprising rational design of (co)polymers for specific targeted applications, followed by their precise synthesis and processing procedures.

RDP permits precise control of the primary structure of polymer chains. These chains consist of carbon-carbon backbones formed in polymerization of vinyl monomers. In ring-opening polymerization, one can incorporate various heteroatoms to the backbone. It is also possible to copolymerize vinyl and cyclic comonomers facilitating their subsequent degradation. It is also important to extend the range of monomers from those that are "petroleum-based" to those from renewable resources thereby facilitating better control of polymer degradation and recycling.

Several elements of macromolecular architecture can be controlled in RDP. They include chain topology, chain composition, chain functionality, chain stereostructure and chain uniformity. They can be also combined as illustrated in the *figure 1*. These elements are based on chains with covalent bonds connecting monomeric units. In addition, dynamic non-covalent bonds can also form macromolecular chains with properties strongly affected by the dynamics of chain interactions (dynamers, vitrimers and self-healing materials) [3-6]. Eventually polymer chains can be assembled to secondary or even higher order structures through various weak supramolecular interactions in bulk or in solution as in polymerization-induced self-assembly.

Chain topology elements span from linear chains to cycles and various branching features. They can include long or short chain branching, lose or dense branching but also hyperbranched systems and dendrimers. Branches can be distributed with a tunable density along the chain, typically in graft copolymers, or very densely as in bottlebrush copolymers. Branches can be limited to one focal point as in star polymers which can be formed by an arm-first or core-first approach. The type and degree of branching can tremendously affect mechanical or rheological properties of resulting polymers. For example, bottlebrush copolymers can form photonic materials with regular and tunable periods of > 100 nm. Bottlebrush copolymers can become supersoft and superelastic with moduli lower than those of hydrogels. In contrast to hydrogels, which become hard after water evaporation, bottlebrushes can never dry out since their backbones are diluted by their short unentangled side chains rather than by water [8-9]. By variation of graft density, length of side chains and crosslinking density, it is now possible to prepare elastomeric materials with thermomechanical properties mimicking various biological tissues. It is important to design branching degree, uniformity, or location and correlate these elements with macroscopic properties and then precisely carry out synthesis of such materials.

Another essential parameter is chain composition. Block copolymers and segmented copolymers revolutionized polymer science sixty years ago and have been subject of very intense research both in academia and industry. In the chains of block copolymers, there are abrupt changes in composition on passing from one to another segment. This results in phase separation and formation of various regular nanostructured morphologies. Until recently, only diblock and triblock copolymers have been studied. In the latter case over thirty different morphologies were identified, greatly expanding upon the classical spherical, cylindrical, gyroidal and lamellar structures observed for binary systems. Recent progress in ATRP and RAFT (reversible addition-fragmentation transfer) radical polymerization has permitted synthesis of segmented copolymers with twenty or more blocks. There is a strong interest in controlling sequence in polymer chains, decreasing dimensions from long to short segments and to individual monomeric units. This approach has been expanded from classical periodic sequence such as $(AB)_n$ for alternating copolymers, to $(ABC)_n$, $(ABCD)_n$, and eventually to a programmed sequence that can be recorded and written back or even erased [10]. Such sequence control is inspired by biological systems, such as nucleic acids or proteins, and is indispensable for passing from primary to secondary and eventually to the tertiary structures. Another related objective is to design and prepare gradient copolymers with a smooth change of composition along the polymer chains. Such copolymers may have gradient with a linear, V-like, hyperbolic, exponential, or tapered shape. It is also possible to use gradient control not only in a binary system but also ternary, etc. systems. It is essential to make materials with a particular sequence, including multiblock copolymers and gradient copolymers but also to predict how these copolymers will

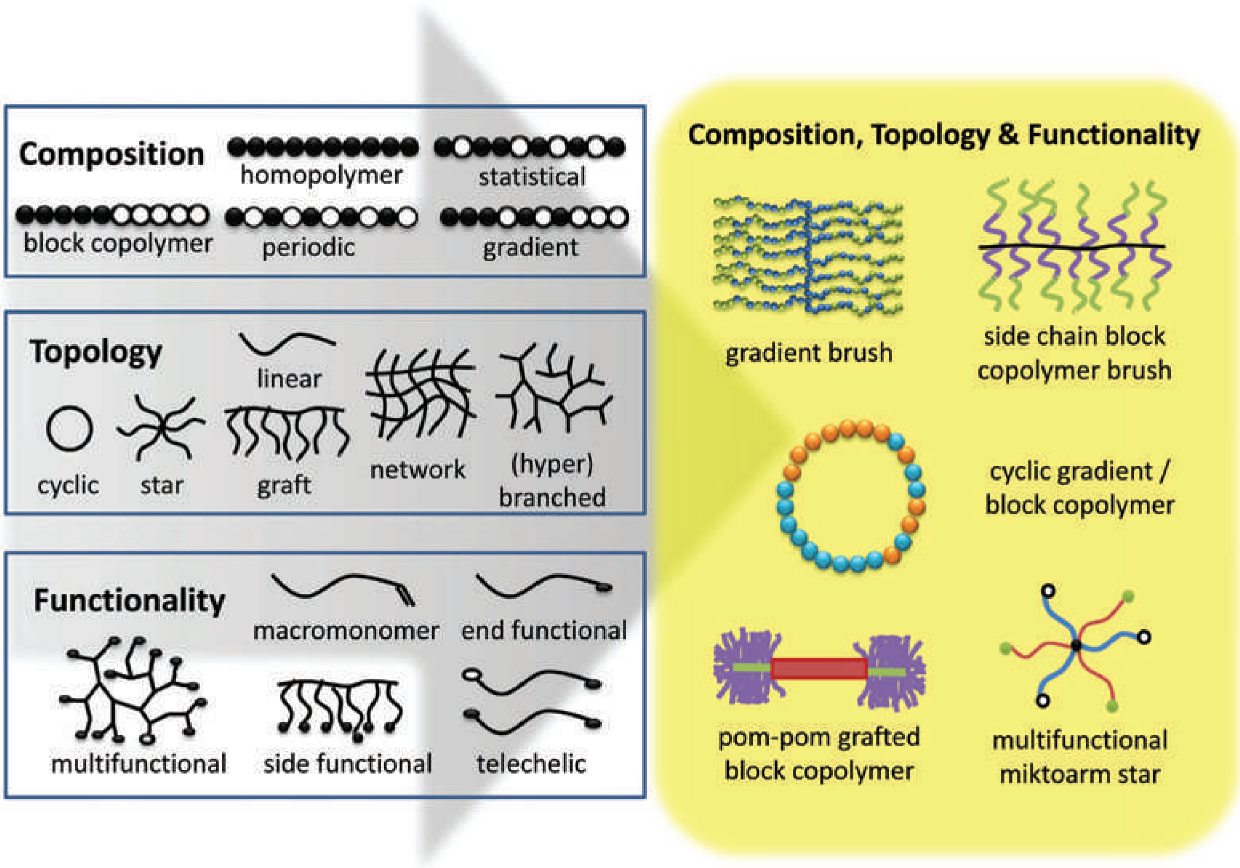


Figure 1 - Individual and combined basic elements of macromolecular architecture. From Matyjaszewski K., *Science*, **2011**, *333*, p. 1104 [7]. Reprinted with permission from AAAS.

assemble to secondary and higher order structures and what kind of properties they will have.

Functional groups can be placed in various parts of macromolecules. They can be located with a pre-determined density along the polymer backbones, at the extreme position of chains, including chain ends in telechelics, chain center, ends of arms in stars and bottlebrushes or in the cores of stars, or chain ends for hyperbranched or dendritic molecules. These groups should carry specific functions that can be used for further reactions, crosslinking or attachments of other moieties whether they are biomolecules, drugs, optoelectronic materials or other species. The site specific functionalities may be not only of one type but also based on several different functionalities. Some functional systems can form self-catalyzed structures that can provide additional control and even facilitate regeneration of formed products by concurrent or consecutive covalent and non-covalent polymerizations [11]. A challenge is to incorporate moieties in a specific position within macromolecules with reactive orthogonal functionalities for further reactions and synergistic effects.

New RDPs, especially proceeding by radical mechanisms, have opened avenues to prepare hybrid materials. They include organic/inorganic hybrids based on nanoparticles, nanotubes and flat surfaces but also bioconjugates formed by the covalent linking of natural products, proteins, nucleic acids, carbohydrates, with synthetic polymers [12]. Proteins with grafted polymer chains can circulate for a longer time in the human body, can survive at low pH, be dispersed in organic solvents and be used as catalysts at higher temperatures or as therapeutics [13-14]. Nucleic acids combined with polymers can self-assemble and pass efficiently through cell membranes and can form various polyplexes. They can be loaded with dyes forming very bright fluorescent probes which can target specific cells after linking with antibodies or aptamers. It is interesting to extend such bioconjugation to larger objects such as living cells or tissue. The challenge is how to design the most efficient materials and how to carry out their precise synthesis. The biohybrids or bioconjugates can be generated at a very basic level by linking proteins and nucleic acids with synthetic polymers in a nonspecific manner. Next step is to position these linkers at a specific location of biomolecule by using biotechnological approaches or by blocking/protection techniques. Eventually, by using macromolecular engineering, the bioconjugates evolve to the next generation of materials with precisely controlled complex architecture such as armored enzymes, exosomes or entirely modified cells [15].

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# Only fusion can meet the energy challenge mankind is facing

Imitating the processes at work within the core of the stars opens the way to a new, safe and sustainable energy source for the generation of electricity on a massive scale: this is what the international project ITER is about.

Whatever the projections or scenarios, and despite all the energy-saving measures we might implement, one thing is certain: we will need to produce more and more clean energy during this century to meet the needs of the planet's ever-growing population. By the end of this century, as the number of humans passes the ten billion mark, world energy demand will have increased by a factor of three. The share of electricity in global energy consumption, which is approximately 20 percent today, will have grown up to 50 percent. Meeting this huge increase in demand is one of the most daunting challenges mankind has ever had to face.

Our options are limited. The burning of fossil fuels, which drove the industrial revolution of the $19^{th}$ century and ensured the economic, technological and social development of our civilisation up to this day, is now recognized as threatening to the planet's environment and climate balance. Renewable energies, although attractive on many counts and necessary to invest in, have inherent limitations – notably as they are diffuse and intermittent.

## Fission…

What are we left with? Nuclear energy, or more accurately nuclear *fission* energy.
Today, nuclear fission accounts for approximately 10 percent of electricity production in the world – France is a major exception with 58 reactors producing more than 75 percent of the country's electricity.

As France's High Commissioner for Atomic Energy (2003-2009), and as Chairman and CEO of the French Alternative Energies and Atomic Energy Commission (2009-2015), I have devoted a good part of my professional life to nuclear fission. I know its merits, its limitations and its challenges.

The heart of the ITER installation: to the left, the Tokamak Complex with the circular structure of the "bioshield", a 3-meter-thick steel-and-concrete cylinder that will enclose the ITER Tokamak; to the right, the installation's industrial facilities (power conversion buildings, cryoplant, winding facility, etc.) (December 2018). © ITER Organization.

The 23,000-tonne ITER Tokamak will rest on a massive circular "crown" at the bottom of the bioshield. The openings in the cylindrical structure are for the different systems that need to reach into the machine: power feeders, vacuum pumping, heating, cryogenics, cooling water, diagnostics, etc. © ITER Organization.

The major attraction of nuclear fission is to provide a baseload source of massive power production without generating $CO_2$ or other greenhouse gases. However, the mineral resource it is based upon (uranium) is limited, with at best a horizon of two to three hundred years based on current thermal neutron technology. As for the challenges, they are many and I will only mention the two most important: continued improvement in safety, and long-term management of nuclear waste. And by "long-term" I mean several hundreds of thousands of years for the most active fission products.
My conviction is that nuclear fission energy is a valuable transitory solution for a limited number of countries; in no way can it be a long-term solution.

Operating the entire fission cycle, from uranium enrichment to fuel recycling and waste storage, not only requires scientific and technological expertise and a considerable industrial infrastructure; it also demands strong state institutions, independent control and long-term political stability.

Few countries possess these assets or can offer these guarantees today. And even fewer can pretend to sustain them for the dozens of millennia that long-life/high-activity nuclear waste management requires.
Fortunately, fission is not the only way to tap into the energy of the atom.

## …Fusion

While fission splits heavy atoms such as uranium, *fusion* does exactly the opposite: it fuses light atoms such as hydrogen into heavier ones. Both fission and fusion are mass-to-energy conversion reactions that generate considerable amounts of energy; both are spectacular illustrations of Einstein's famous equation $E = mc^2$.

More than 99 percent of the observable matter in the Universe is in a state of fusion. Fusion is the powerhouse at the core of the stars; it has caused our Sun to shine for the past five billion years, and is expected to continue to do so for an equivalent length of time.

It was not until the 1920s that physicists and astrophysicists (Jean Perrin in France, Arthur Eddington in the United Kingdom) began forming the notion that a fusion process was at work in the core of stellar bodies. In the decades that followed, the identification and clear understanding of the hydrogen fusion process (Hans Bethe) led to one ambition: if fusion reactions could be artificially created on Earth, a new, sustainable energy source would become available for the generation of electricity on a massive scale.

In the core of the Sun and stars, gravitational forces create the temperature and pressure conditions that make fusion possible. This process, which is efficient at the massive scale of the stars, cannot be replicated on Earth. But it can be imitated.

Physicists soon determined that an ultra-hot, ultra-low-density ionized gas (a plasma) – composed of equal parts of the hydrogen isotopes deuterium and tritium and confined by intense magnetic fields – would provide an environment in which fusion reactions could occur. "Low-density" is in fact a high vacuum – one million times less than the density of the Earth's atmosphere. "Ultra-hot" is a temperature in the range of 150 millions degrees Celsius, ten times that of the core of the Sun…

The advantages of fusion are many:
- The fusion reaction at the core of the process is intrinsically safe: the type of accidents that can occur in a fission plant – uncontrolled chain reactions, core meltdown, etc. – are physically impossible in a fusion installation;
- The fuel is virtually inexhaustible: deuterium is easily extracted from water and tritium will be produced inside the machine through the interaction of the fusion neutrons and lithium. A 1 GW fusion reactor (equivalent in power to an average fission reactor) will only require 100 kg of deuterium and three tonnes of natural lithium annually to generate 7 billion kilowatt hours;
- The impact on the environment is minimal: no $CO_2$ or greenhouse effect gases are generated;
- Fusion does not generate long-life/high-activity radioactive waste.

As early as the mid-1950s, "fusion machines" of various shapes, sizes and performance levels – such as pinch and mirror devices, stellarators, and tokamaks (a Russian acronym for "Toroidal Chamber, Magnetic Coils") – were operating in the Soviet Union, the US, the United Kingdom, Germany, France and Japan.

In that same decade, the veil of secrecy that had shrouded fusion research prior to World War II was lifted. Despite the Cold War tensions between East and West, Soviet fusion physicists, who were among the most advanced in the field, shared with their Western colleagues their data, hopes and frustrations. International collaboration became a staple of fusion research and has remained so to this day.

As they kept exploring the mind-boggling complexity of plasma physics and faced the technological challenges of building and operating fusion devices, physicists realized that in order to demonstrate the feasibility of fusion they would need a very large machine – one that no single nation, whatever its human, scientific and technological resources could design, build and operate alone.

The European JET (Join European Torus) was a first step in this direction. A very large tokamak, the machine achieved "First Plasma" in 1983 and was the first to implement the actual fusion fuels deuterium and tritium. Seven years later in 1991, JET produced a significant amount of power from fusion reactions. At about the same time, an American machine, the Tokamak Fusion Test Reactor (TFTR), was following the same route and obtaining similar results.
However, both JET and TFTR had required more energy to "light the fusion fire" than the "fire" had given back in return.

## ITER

As JET was bringing fusion to the threshold of feasibility with a record power production of 16 MW in 1997, another project, immensely more ambitious, was taking shape, this time at a truly international level.

### Chemistry will be central to ITER success

As a physical chemist by training, as President of the "Fondation de la Maison de la Chimie", and since 2015 a Director General of the largest and most ambitious energy project ever established, I am proud to say that chemistry will be central to ITER success. We will need to implement the most rigorous chemical processes to separate and recycle the isotopes we need, produce the purest materials, and the most efficient catalysts. The nature of ITER's demands, and the stringent requirements of our quality control processes will no doubt stimulate the field and offer large opportunities to both research and industry.

Initiated in the 1980s, ITER – the Latin word for "The Way" – received a decisive political and diplomatic push when President Reagan and Secretary General Gorbachev met for the first time in Geneva in November 1985 and agreed to launch "*the widest practicable development of international cooperation*" to develop fusion energy "*for the benefit of all mankind*."

Thirty-three years later, ITER progresses steadily towards its objective, demonstrating the technological feasibility of fusion as an energy source. The international collaboration brings together seven Members (China, the European Union, India, Japan, Korea, Russia and the United States) representing more than half the world's population and 85 percent of the planet's gross industrial product. Construction of the installation in Saint-Paul-lez-Durance, some 40 kilometers north of Aix-en-Provence (France), is now more than 70 percent complete.

ITER, whose construction began in earnest in 2010, is expected to produce its "First Plasma" in 2025 and commence full-power fusion operations in 2035. Over its fifteen to twenty years of operation, the project will explore the uncharted territories of "burning plasmas", validate the integrated operation of technologies for a fusion power plant, test materials, experiment tritium breeding technologies; and demonstrate the safety characteristics of a fusion device. ITER will be the first fusion machine to produce *net* energy, delivering 500 MW of fusion power from a heating power input of 50 MW ($Q \geq 10$).
The ITER machine will be the most complex ever built, which is both a huge challenge and a unique opportunity for the industries of the participating nations.

As Member contributions are provided essentially "in-kind" through the procurement of machine components and systems for the installation, industry has the opportunity to acquire competence and experience in areas as diverse as cryogenics, vacuum technologies, superconductors, cutting-edge robotics and remote handling, power electronics, ultra-high frequency signal transmission and more.

Building and operating ITER is an indispensable step towards fusion energy. The project marks both the culmination of six decades of research and development throughout the world, and the opening of a whole new chapter in the quest for unlimited energy – the beginning of a genuine industrial approach to fusion.

As the construction of the experimental ITER machine progresses, the ITER Members are already working on conceptual designs for a generic next-step machine, called DEMO. Whether the DEMO machine (or machines) will be built through international collaboration, through more restricted partnerships, or purely "nationally" remains an open question. By 2040, however, the DEMO concept – an industrial prototype founded on feedback from ITER operation – could enter the engineering design phase and open the way to large-scaled fusion development.

And just as DEMO will have succeeded ITER, industrial reactors will succeed DEMO. My conviction is that, depending on ITER's success, the first fusion plant will be connected to the grid early in the second half of this century. From then on, deployment will be rapid.

I hope to have a long life but, as mine began in the middle of the last century, I will most likely be gone when fusion-generated electricity becomes an everyday reality.

There has always been something of the cathedral builder in the fusion community: the generations that laid the foundations, built the first arcades, and raised the first buttresses knew that they would be long-gone when the highest towers were completed. Yet they had faith and determination.

Today, with ITER, fusion is nearing a historical breakthrough. Faith and determination are at last bearing their fruit.

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## $H_2$: energy vector or source?

The di-hydrogen presents obvious advantages: as a fuel it can burn without emitting greenhouse gases or particles and as a means of storing electricity, it enables large scale and long period storage. In comparison with other methods of storage, gas storage mainly underground, allows for months of autonomy in a country such as France when all our batteries will be empty in few minutes and our dams in few days. For many analysists, hydrogen produced from renewable electricity is the missing element which could facilitate the integration of high levels of variable renewable energy into the energy system.

At the moment, $H_2$ is mainly used in industry as a raw material and is only starting to be used as a fuel for cars, trains and buses. It is also essentially manufactured from methane by $CO_2$ emitting processes. Alternatives exist such as electrolysis that splits water into hydrogen and oxygen. When the electricity is decarbonized, this $H_2$ is called green $H_2$. If the objective is the storage of the intermittent renewable electricity, fuel cells then allow to go back to electricity. Today these processes are not yet very efficient. Power to gas to power results in a 70% loss of energy, but improvements are expected, especially with the reversible Solid Oxide high temperature Fuel Cell (SOFC). Bacteria activity, algae and oxidation processes of for instance iron rich material are also potential sources of $H_2$ [1]. All these methods are not at the same stage of development (technology readiness levels TRL vary from 1 to 8) and do not result in a homogeneous $H_2$ price. Trying to predict which process will be the cheapest in a few years and thus predict "the" winner is what a lot of consultant and strategy departments are working on but this may not be the best approach. The most important trend in the new energy world is decentralization. Depending on the local constraints, the optimum role of $H_2$ in a green energy mix will differ and therefore the best technology will depend on the use for and the users. In addition, the transport of $H_2$ over large distances by boat is not easy; economically it is close to being a killing factor – the opposite of methane which can easily be liquefied. Liquefaction of $H_2$ consumes up to half of its energy.

Today industry is mainly focusing its efforts concerning green $H_2$ on reducing the price of electrolysis and fuel cells. This means that many companies are considering $H_2$ as a vector. However, two game changers are emerging which could be very disruptive.

### First: native $H_2$

Natural $H_2$ produced by the water/rock interaction has been observed for long time but it was assumed that this production mainly occurred on a large scale along the mid oceanic ridges where hot oceanic newly created crust is in contact with sea water [2]. Roughly this reaction is an oxidation reaction of the $Fe^{2+}$ (or $Mg^{2+}$) and $H_2$ is released. The estimation of this production is between 4 000 and 10 000t/year/km of ridge.

New Caledonia: the hydrogen released from the subsurface reacts with the $CO_2$ in the atmosphere resulting in the carbonate precipitation. A natural carbon capture, utilization and storage (CCUS) process!

The conditions of deep water in the middle of nowhere with very hot fluids seem to exclude any economically viable production. However, for the past ten years, new data has shown that similar reactions happen at lower temperatures such as in Oman or New Caledonia [3] (*figure*) and that another oxidation reaction that takes place in old cratons where iron rich rocks are present also results in the continuous production of $H_2$ (in Russia [4], in the USA [5] and in Brazil [6]). At the same time, an accumulation of $H_2$ has been unexpectedly found in Mali at a shallow depth (110 m); the people who drilled the well were looking for water but the $H_2$ that they found instead has now been in production for five years [7]. It is burned to produce electricity for the town. The pressure hasn't decreased during all these years strongly suggesting a continuous generation of $H_2$. This discovery also proved that carrier bed and seal exist for $H_2$ as for any other fluids in the subsurface. In 2018, the permanent monitoring of $H_2$ emanations carried out in Brazil by Engie has confirmed the continuous emission of $H_2$ in the studied area although the rate is not constant and varies during the day. The possibility of producing large and cheap quantities of $H_2$ from the subsurface is now a realistic hypothesis and various groups are working to better define the geological conditions that will allow long term production.

## Second: $H_2$ produced using plasma torching

The second game changer comes simultaneously from the two main natural gas producers: the USA and Russia. $H_2$ could be produced using plasma torching of methane with black carbon as a by-product which, at least as a first step, could allow the process to be economically viable. The first large scale installation is currently managed in the States by monolith [8] and Gazprom announced by mid-2018 *via* a press release that they will massively invest in that technology in order to provide $H_2$ to western Europe in the coming decades with 100% $H_2$ in 2050... [9]. In Russia, as in the USA, because they will use up their huge reserves of cheap natural gas and their already in-place infrastructures, as soon as the plasma torch becomes cheaper, this $H_2$ is expected to rapidly reach a very competitive price. The current reserves of gas – 200 years of consumption worldwide – ensure the durability of such a green $H_2$ resource (from $CH_4$ but without producing $CO_2$). The technology used by Monolith is for a part tested in France, with Laurent Fulcheri's group at the Centre for Processes, Renewable Energies and Energy Systems at Mines ParisTech PSL Research University.

In another words, the probability of having access in the near future to a non-carbonated "natural" gas is not zero. In which case, the need to pass via electricity to decarbonize the energy mix will be questionable. It may even turn out to be the wrong solution, and consequently the need for huge batteries to store this electricity will also be questionable.

The future is not always predictable, even when we write it, and the race for cheap, green $H_2$ has started. Personally, I'm not sure that the electrolysers will be the (only?) winner.


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# Building to heal: chemistry for sustainable buildings

Most of the world's population is already living in urban areas [1] and it is known that the construction industry accounts for over 40% of all material extracted as well as 40% of total energy and 16% of annual water consumption. During the last century, overall global material consumption approximately multiplied tenfold, but consumption of construction minerals multiplied by a factor of 42 [2], showing a positive feedback-loop between socio-technical system evolution and its construction material requirement.

Furthermore, 50% of the building stock that will exist in 2050, mostly located in cities in emerging countries, is yet to be built. The weight of these future cities is tremendous. Quantitative analysis of the global resource requirements of future urbanization shows that without a new approach to urbanization, material consumption by the world's cities will grow from 40 billion tons in 2010 to about 90 billion tons by 2050 [3].

Following business-as-usual practices, buildings and infrastructure require resources and energy for their construction as well as during their use, but one can also turn the future challenges into opportunities. New buildings can be an opportunity for innovative solutions to mitigate environmental pressures and to generate economic growth while providing adequate, attractive and affordable housing for all. Future construction can be a way to reduce or even store carbon emissions when built with selected building materials. They can also be used as depositories of materials to be later mined. Building renovation can be a catalyst to re-activate social and economic networks in a neighborhood. Buildings rather than degrading the air quality can actually improve it as the humidity of the indoor air can be naturally controlled through earth plaster. Green façade reduces the heat island effect and provides a better air quality in the cities. Buildings can even help to reduce harmful effect of transportation through noise absorption and pollution absorption in self-cleaning façades. In a way what is the role of building materials in achieving a sustainable scenario? Can building technologies trigger virtuous mechanism to help improve not only housing conditions and environmental performances, but also the multiple aspects of the society tackled by the sustainable development goals?

To harness these opportunities and identify valuable resources, one needs to have an intimate understanding of urban dynamics [4]. Urban building stocks have been the focus of many fields of studies, from social sciences [5], geography [6], to mathematics [7], and cities have been analysed from many different angles. Cities are complex systems where natural and human processes interact to create a built environment, which in turn has its own dynamics [8].

Understanding these multiscale dynamics, tracking the appropriate materials and identify the leverage points to turn the existing system into a regenerative process is the core focus of this presentation:

- How can we transform our currently linear flow of materials through our cities towards a circular dynamic?
- How can this transformation towards circularity provide an improvement in social quality so that circular economy becomes regenerative?
- Can we measure and monitor these flows with appropriate accuracy to provide meaningful indicators in terms of policy perspective?
- Finally, can the intervention of the architects and engineers on one construction project have a wider impact and be used as a catalyst for change?

In the last decades, diverse solutions have been provided in order to align building technologies with current sustainability standards. However, despite these efforts, the objective of sustainability has proven not to be enough. A shift towards a regenerative approach, proposing to provide more positive benefits rather than trying to harm less, is then urgently needed. For instance, construction and demolition materials can be reintegrated in the flow of input materials through recycled concrete. Switzerland is ahead of others in this organization as nearly two third of demolition waste is already recycled [9]. However, excavation materials represent a much larger quantity than demolition waste. They actually represent as much as what Switzerland needs in primary material. Excavation materials can be carefully sorted and processed to produce fine and valuable gravels as well as earth material that can be promising development for earth construction. With small amount of additives, it is possible to turn this waste into a valuable construction material that would have appropriate mechanical performance as well as enhanced hygrothermal properties [10]. Another option is to increase the amount of bio-based materials in construction. This can transform the built environment in a carbon sink [11-12]. And finally, cement production even if it releases $CO_2$ emissions allows also to incorporate and valorize into a valuable product a large quantity of waste from other industries. In cement plants the primary materials do not represent more than 25% of the total amount of materials required (fuel included). We just need to use the right material at the right use for its right purpose. It is what we call grounded materials, a material that considering the local socio-economic context and availability of resources is offering the best opportunities.

## Monitoring material flows and their regenerative values

In a world where data is everywhere, it might seem easy to monitor material and energy flows through urban systems. However, to monitor a flow, one needs to be actually willing to address this issue, and feel the need to look at this problem. To quote the pioneering American environmental scientist Donella Meadows: "*We measure what we care about, and we care about what we measure*." Acknowledging resource, energy or water scarcity is not necessarily obvious among policy makers and the society as a whole, and a misleading indicator can be as detrimental as no measure at all: both can drive us in the wrong direction. One of the most pressing challenges regarding data monitoring is rather to create a demand. Data already considered valuable is typically already mined: what we are lacking is data about a city's hidden value.

## Trigger changes

One of the recurrent messages in sustainability conferences is that available technologies for a post carbon society are ready, but are not implemented because the current situation of our environment is not well explained to society and policy makers. This assumption – that through quantification and information, governments will engage in a transition – has not been proven right so far, as can be observed for instance from the slow progress of the IPCC (Intergovernmental Panel on Climate Change) [13]. Governments engage extremely slowly in a transition because they believe it necessarily involves a social transformation [14]. The construction sector is seen as conservative and risk adverse. Showcasing alternative materials and technological solutions while explaining current societal threats will thus not be enough to induce a change.

However, it might be important to use the power of a creative destruction when applied to construction [15]. Catastrophic events – floods, fire or earthquake – have the power to allow, during a short moment after the disaster, the local community to accept radical changes and rebuild differently. If at that moment, architects are ready to propose solutions that have been developed over a long period of time span by engineers, scientists and designers, there is a possibility to implement very fast radical changes and to design for hope. Loreta Castro (Mexico) and Stephen Lamb (South Africa) are developing engaging examples where rubbles after the earthquake were reassembled and filled a timber frame construction to provide a new community center in Oaxaca while South African invasive species causing fire and destruction were cut, chipped and used as aggregate in a new bio-concrete to provide dignified houses for people.

But when no dramatic event is happening, how to trigger changes? New attractive technologies can be used to nudge people and engage them towards sustainability without presenting these technologies as necessarily used for sustainability. The "Internet of Things" can first be attractive only to selected people (who may identify these technologies as being innovative or as providing a higher status). Yet, in fine, they may result in a significantly lower use of resources.

## Looking ahead

There is a fundamental interdependence between the natural and the built environments. Unfortunately, we have reached our planetary boundaries. We know that some of the biggest transitions have been done through crises and emergencies, whether driven by political will or natural disasters, but would it be possible to achieve a smooth transition? It might be important to recognise that traditional innovation cycles, from the idea, to multiple testing loops, to prototype, validation then market release, is simply too slow. We need to start thinking about how to support ecological restoration, and how to actually reconnect to the components of natural systems. As briefly explained, technologies and products exist, and to implement them, we just need to know which future we want to build: buildings that harm the environment or on the contrary, buildings that regenerate nature and improve living qualities in our cities. A native American once alarming about the disaster of uncontrolled nature degradation argued that before choosing our tools and our technologies, we need to choose our dreams and aspiration, because some technologies support their accomplishment while others drive us away from them.

The Light House in Hout Bay (Cape Town, South Africa) built by designers and builders Stephen Lamb and Andrew Lord (www.visi.co.za/this-is-the-house-that-xoma-wanted). Photo: Stephen Lamb.


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# Visualizing matter in transformation with ultrashort flashes of electromagnetic waves

A young unexperienced PhD student of Umeå University in Sweden enters the vast laboratories of Bell Labs in Murray Hill (NJ, USA). That is how my scientific life, and ultrafast science in Scandinavia, started in 1975 when Peter Rentzepis, one of the pioneers of the field, accepted me as a visiting student to his labs. For one and a half year I had the privilege to work with two more experienced scientists as my mentors, Danny Huppert and Ken Kaufmann. After learning the ins and outs of generating short, in these days, picosecond (1 ps = $10^{-12}$ s) pulses of light and to use them to measure very fast chemical events, I returned to Umeå, wrote my PhD thesis and started to build the first picosecond laboratory in Scandinavia. The very first experiments were performed in 1979 and fifteen years later, in 1994, the cradle of ultrafast science in Sweden was relocated to the south of Sweden and Lund University, where a brand new ultrafast lab was built.

Decades of research have shown that chemical transformations occur over a very broad time scale, from femtoseconds (1 fs = $10^{-15}$ s) to seconds, minutes... – fundamental processes like breaking and formation of chemical bonds, or redistribution of energy and charge within or between molecules, belong to the fastest processes, while compound chemical reactions can be very slow. Since long, scientists have therefore been developing experimental methods for the study of increasingly faster processes. A particularly powerful method is to initiate a reaction with a short flash of light and characterize the reaction progress with a series of increasingly delayed flashes. This development started in the early 1950s with the work of Lord George Porter and colleagues and was rewarded with the Nobel Prize in chemistry in 1967. In the early days of this development the accessible time scale was milliseconds, but the invention of the laser in 1960 and following rapid technological progress gave us the microsecond, nanosecond, picosecond and finally femtosecond time scales. The opening of the femtosecond time window and ability to study the fastest and most elementary reactions was coined femtochemistry and rewarded with the Nobel Prize in chemistry to Ahmed Zewail in 1999. In the early days of fast spectroscopy there was a very limited choice of wavelengths of short light pulses, severely limiting which molecules and processes that could be studied. The part of the 2018 Nobel Prize in physics awarded to Gérard Mourou and Donna Strickland for "chirped pulse amplification" makes it possible to generate very intense ultrashort laser pulses of almost any wavelength. *Figure 1* illustrates this "magic": an intense green femtosecond pulse is converted to white light when passing through a plate of calcium floride. This has opened up the possibility to study ultrafast dynamics in atoms, small molecules, large bio-molecules, materials of practical importance, etc.

In my own research I have been driven by a curiosity and interest to understand Nature's processes. Photosynthesis, the ultimate process supplying all of the organic compounds and most of the energy necessary for life on Earth, appeared to be

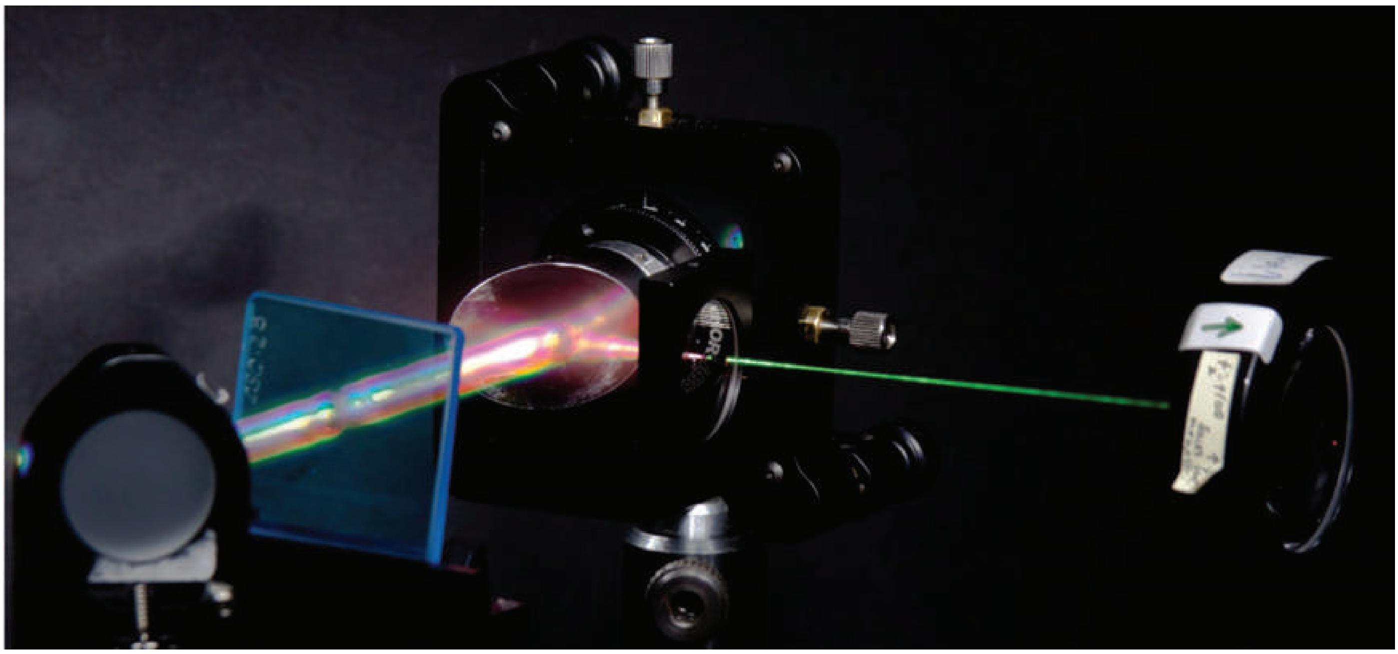

Figure 1 - White light generation by passing an intense femtosecond pulse through a plate of calcium floride. © Dr Jens Uhlig, Division of Chemical Physics, Lund University.

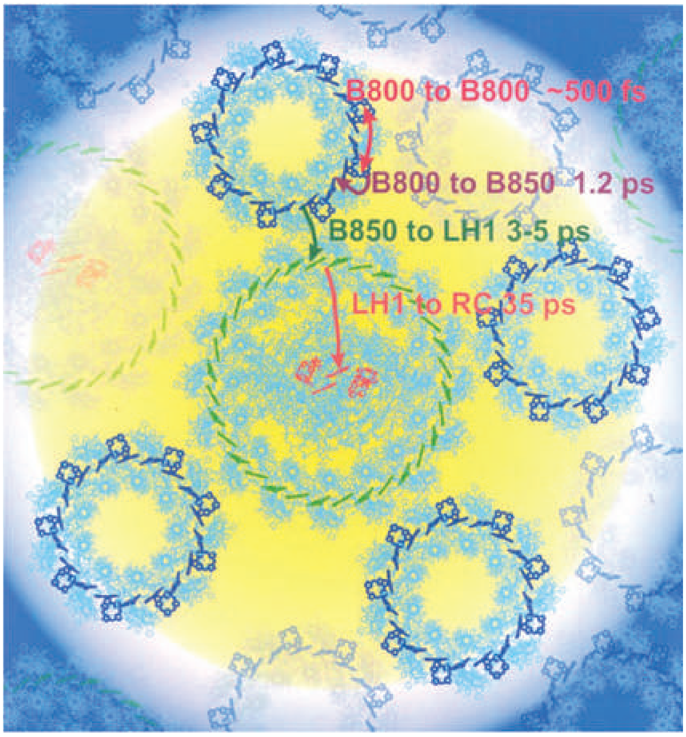


Figure 2 - Energy flow through the photosynthetic membrane of photosynthetic purple bacteria. The circles are antenna proteins – the smaller ones are the peripheral LH2 antenna, with dark blue bacteriochlorophylls (BChls), and the larger circle containing the reaction center in the middle (red pigment molecules) is the core antenna LH1 with green BChls. B800 and B850 denotes the wavelength of absorption, 800 and 850 nm, respectively, of the BChl molecules. © Prof. Tonu Pullerits, Division of Chemical Physics, Lund University.

a good choice and the light driven processes of photosynthesis was therefore an early target for my research. These processes include energy and electron transfer processes through pigment-protein complexes, so called antenna complexes, harvesting the light and reaction centers converting and storing the energy of light as electrochemical potential. Knowledge obtained from the study of photosynthetic systems could perhaps also be used in the development of solar cell materials or materials for artificial photosynthesis, i.e. production of fuels based on the photosynthetic principles.

Photosynthetic purple bacteria were chosen for these studies and a series of investigations, in collaboration with my colleague and friend Rienk van Grondelle of the Free University of Amsterdam, resulted in a detailed picture of the energy dynamics in these pigment systems. When the high resolution structure of the antenna proteins became available in 1995 through the work of Richard Cogdell and coworkers, dynamics and structure could be reconciled into a detailed picture of energy and charge flow through the whole photosynthetic unit [1]. This is illustrated in *figure 2* with superfast, 0.5-1 ps, energy transfer between neighboring chlorophylls within an antenna complex. On a somewhat slower time scale, 3-5 ps, the energy is transferred from the peripheral LH2 to the LH1 core antenna, and finally in about 35 ps to the reaction center. The ~50 ps it takes from absorption of a photon to storing it as an electrochemical potential in the reaction center is almost hundred times faster than all loss processes, implying that the process is almost 100% efficient. Thus, Nature shows us how energy of light can be converted to charge with close to 100% quantum efficiency, a goal to aim for in devices for solar energy conversion.

The unique ability of photosynthetic pigment-proteins to convert light to charge with very high quantum efficiency has inspired design of materials for new types of solar cells, dye sensitized solar cells (DSC) and plastic solar cells are two examples. In a DSC a thin film of titanium dioxide ($TiO_2$) nanoparticles is coated on an electrode and covered by a monolayer of dye molecules. The dye molecules play the role of the photosynthetic antenna and absorb the light, followed by injection of an electron from the excited state of the dye molecule into the $TiO_2$ nanoparticle. The injected electrons from many absorbed photons are transported through the network of nanoparticles of the thin film and collected at the electrode to perform work in an external circuit [2]. Until recently the best DSC used metal-organic complexes containing rare and expensive metals like ruthenium as dyes. For large scale implementation of DSCs, metal-free dyes or dyes containing cheap and abundant metals can only be used. Scientists have tried hard to replace ruthenium with iron, the fourth most common element in the Earth's crust, but with very limited success. Solar cells based on iron-containing dyes have a disappointingly low efficiency, because the excited states of these dyes have very short lifetimes and therefore very inefficient electron injection into the $TiO_2$ nanoparticles. In other words, very few of the absorbed photons are converted to electrons and electrical current in the solar cell.

In an effort to solve this problem, we started a collaboration at the Chemistry Department of our university where organic chemists lead by Prof. Kenneth Wärnmark designed and synthesized new iron-based complexes (Fe N-heterocyclic carbenes, Fe-NHC), spectroscopists from my own group studied the photochemistry and photophysics of the new molecules, and quantum chemists under the guidance of Prof. Petter Persson calculated and predicted energetics and dynamics to be compared with the experimental results. The work has been very successful: one of the first Fe-NHCs that we made had hundred times longer excited state lifetime than any other Fe-based dye, a second generation Fe-NHC could inject electrons into a $TiO_2$ nanoparticle film with 92% efficiency [3], and the most recent development has produced Fe-NHCs with hundreds of ps and even ns excited state lifetimes [4]. Luminescent iron-based dyes have also been produced for the first time ever [4]. This shows that complexes of Earth-abundant iron are becoming fully viable alternatives to noble metal complexes for a wide range of light-harvesting, light-emitting and photocatalytic applications.

A long nourished dream of chemists is to not only see static structures of molecules, but also see how these structures change in the course of a chemical reaction, like a molecular movie. The ultrafast spectroscopy methods used in the studies discussed above do not give direct information about how the structures change. Since static structures of molecules are obtained with X-ray radiation, it should be possible to catch changes in structure by taking snapshots of a chemical event with the help of short X-ray pulses. Synchrotrons provide ~100 ps X-ray pulses and X-ray Free Electron Lasers (XFELs) even shorter ones down to a few femtoseconds. There are two different types of time resolved (TR) X-ray experiments providing structural dynamics information – TR-X-ray diffraction provides information about global structural changes, while TR-X-ray spectroscopy gives more local structure information. Combining the two types of


Figure 3 - Part of the FXE beamline of the European XFEL in Hamburg. © Dr Frank Poppe, European XFEL Hamburg.

experiments makes the chemist's dream come true; we can now visualize how atoms move during a chemical reaction, passing through short-lived intermediates, to the final configuration of the products. *Figure 3* shows the part of the FXE-beamline of the European XFEL in Hamburg where such experiments can be performed.

In our own work, we have used these methods to explore the coupled ultrafast structural and electronic dynamics of supramolecular complexes for solar energy conversion. The X-ray experiments provided a uniquely detailed picture of the processes storing energy of light in chemical bond energy [5]. A handful of X-ray free electron lasers are presently in operation worldwide and several more are being built. This implies that powerful X-ray methods are becoming available to an increasing number of scientist and I believe that these machines have great potential to give us a wealth of new fundamental knowledge in chemistry, biology and physics, as well as help solving problems of more applied nature.

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# Does the public understanding of chemistry differ from that of science in general?

Chemistry seems to have a reputation problem. Once a source of glamour in Nylon and plastics, since the 1960s, it is associated with the hard path of progress and singled out as the "ugly duck" of dangerous and dirty science. This seems to suggest that the public image of chemistry is far apart from the image of other sciences. I would like to argue that the image of chemistry and that of science (and engineering) more general is rather unproblematic and similar. By gaging differences in perceptions, we tap into the increased competition for attention and profile among the sciences.

In 2015 the UK's Royal Society of Chemistry (RSC) conducted the project "Public understanding of chemistry"*. The project included two quantitative surveys, one among RSC members with 455 responses and another one of national opinions with 2,104 respondents. A key purpose of this project was to change how members of RSC thought of the public by confronting them with surprising facts and thus to disband with myths about the public's view of chemistry. It is difficult to gage whether this part of the project was successful, but the mere intention is noteworthy. One of the worries of RSC members was that in English "chemist" has two meanings easily confused: it means a drug store where you buy shampoo, lipsticks or get a prescription drug typically known as BOOTS as the leading chain, and it refers to a chemical scientist. RSC members see themselves as the latter and resent being associated with a high street convenience store.

Chemistry has had a pumper ride in public imagination. From the beginning of the ecological movement in the 1960s, it is associated with pollution of water, air and soil, as in Carsen's *Silent Spring*; with environmental disasters such as Seveso (Italy, 1976) which resulted in the highest known exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in a residential population; or in Bhopal (India, 1984), one of the world's largest industrial disaster, releasing methyl isocyanate (MIC) into the urban environment and causing many deaths and life-long injuries. These developments of the past fifty years left chemistry a legacy of being associated with the "hard path of development" like physics [1] and a disadvantage over other sciences.

In the light of this legacy, we ask how distinct is this public understanding of chemistry compared to other sciences? In survey research, one can vary the questions wording; for example by replacing "chemistry" with "engineering" or "science" in whatever question one might want to ask. The result then shows whether responses are the sensitive to different concepts. In UK, where we have public perception data, very similar questions were asked in one occasion about "chemistry" and in another about "science" and "engineering". In 2013 (May-July), the British Science Attitude (BSA) survey asked 1,747 British what they thought of some recent developments [2]. In 2015 (February-March), the RSC commissioned a national survey of 2,104 respondents asking similar questions about chemistry [3]. Both surveys were high quality: face-to-face interviews of stratified-random samples of the population. The BSA had an additional feature, it involved half the respondents in a conversation about "engineering", the other half about "science". For our purposes I will focus on those few items which are more or less identical in both studies, one with focus on "chemistry", the other with focus on "science".

To determine similarities and differences requires criteria of comparison. We consider people's sense of being informed on the matter, being confident to talk about it, and their sources of information. We gage the image of chemists and the position of chemistry in the hierarchy of sciences. Finally, we evaluate chemistry as an industry and a daily convenience.

## Confidence to opine about chemistry

*Table I* shows that people feel better informed on "chemicals" than they are about "chemistry" or science R&D. Considering errors margin in these figures of 2-4%, there is very little difference how well people are informed; about 50% consider themselves well informed. This *table* also shows people confident to talk or understand matters: however, chemistry inspires less confidence than science and engineering. About 25% of British are comfortable to talk about "chemistry", while 50% are confident on science or engineering. Chemistry seems to be more remote from public mind.
There is very little difference on how people inform themselves. While more people get their chemistry news from TV news or programmes, family and friends or radio; science is more accessed in TV news, quality newsprint and maybe at work.

## Image of the chemist and chemistry

Both studies also asked about the virtues attributed to scientist. Respondents were asked: "*Looking at these pairs of words or phrases, which one of each of these pairs comes closest to your current view of scientists?*" The word pairs included interesting-boring and honest-dishonest. Not entirely surprising scientists have the very sober image of being interesting and honest people, the vast majority of British think so. However, chemists seem to be a bit less interesting (72% compared to 82% and 79%), but more honest (93% compared to 71% and 78%) in public eyes than scientists and engineers.

A way of revealing everyday understandings of a concept is by eliciting free associations, not only used by psychoanalysts on the couch. Associations reveal meaning that goes beyond the dictionary definition of a term. Thus we can contrast the "chemist" and "chemistry". And indeed, the "chemist" is most

Table I - Being informed, being confident about and sources of information (error margin ± 2.2% for n ~2000, ± 3.5% for n ~800).

| **How well informed do you feel about …… in your everyday life?** | Very well informed | Fairly well informed | Not very well informed | Not at all informed | Have never heard of it | DK | N |
|---|---|---|---|---|---|---|---|
| ***chemicals*** | 9 | 46 | 31 | 10 | 1 | 4 | 2104 |
| ***chemistry*** | 6 | 35 | 42 | 12 | 1 | 5 | 2104 |
| ***scientific R&D*** | 6 | 39 | 44 | 11 | | 1 | 1749 |
| | Strongly agree | Tend to agree | N/N | Tend to disagree | Strongly disagree | DK | N |
| ***I don't feel confident enough to talk about chemistry*** | 19 | 33 | 21 | 16 | 9 | 2 | 2104 |
| ***I don't think I'm clever enough to understand science and technology*** | 8 | 22 | 15 | 30 | 24 | 0 | 864 |
| ***I don't think I'm clever enough to understand engineering*** | 8 | 23 | 15 | 30 | 23 | 0 | 885 |
| **%** | TV news | TV programmes | Quality newspapers | Friends, family | Radio | Work | N |
| ***Chemistry/chemicals*** | 45 | 34 | 15 | 18 | 16 | 1 | 2104 |
| ***Science*** | 42 | 26 | 23 | 9 | 9 | 3 | 1749 |

often associated with the pharmacist (26%) dealing with prescriptions of doctors (22%), in drug stores (13%); there are residual notions of "men in white coat" (2.7%) and industrial employment (2.5%). "Chemistry" on the other hand elicits memories of school days (20%), of the science teacher (20%), of chemicals (13%) and medicine (7%), drugs (6%) and lab equipment (5%) and research (5%). There is a residual association with the periodic table of elements (3%). Chemistry has prominence as a metaphor for sexual attraction (3%) as strong relations between people.

Another feature of chemistry is its position among the sciences. Philosophy and public perceptions hold that not all sciences are equally "scientific", some are more prototypical; some are hard sciences as opposed to soft sciences. Our studies had people rate "how scientific is X", while X would vary from physics to sociology. We compare ratings from members of the RSC and from the general public as in *figure 1*. While for the general public medicine is the prototypical science, chemistry,

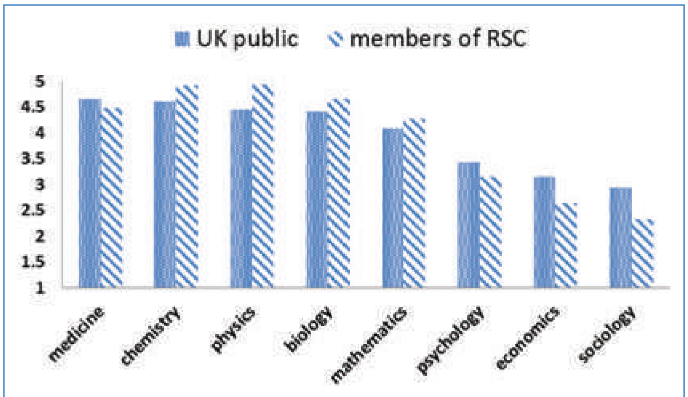


Figure 1 - The hierarchy of sciences according to members of RSC and the general public (rated on a scale of 1-5, where 1 = not at all scientific and 5 = very scientific).

physics, biology and mathematics follow closely. Medicine as the core of the social representation of science seems an enduring observation [4]. The public considers psychology, economics and sociology as "less scientific", whatever the specific meaning of "scientific" might be. By contrast, for members of the Royal Society, this hierarchy is slightly twisted: physics and chemistry are top, followed by the life sciences biology and medicine; further down the ladder are psychology, economics and sociology. It is remarkable that professional chemists as well as the general public reproduce a stereotype of "hard" and "soft" sciences.

## Evaluation of chemistry

Finally, we look at how the sciences are evaluated. Here researchers generally use items that point towards utility (promise) and items that express concerns (reserve; see [5]). Items of both kinds correlate among themselves. People who recognise one promise of science tend to recognise others; and people who express some reservation also tend to refer to others.

We consider a battery of eight questions as shown in *table II*. Considering error margin of 2-4% points, there is little different on this perception, with three exceptions. On things learnt at school, 52% agree that science was useful for life, while only 31% who concede the same to chemistry. When asked whether "it is important to know in my daily life", 72% think this of science, a mere 55% would say the same of chemistry. Consistent with the image of the chemist above, also less (62%) think of chemistry as interesting compared to science (73%). While most things are equal between science and chemistry, its use in everyday life is more doubtful.

Table II - Different facets of attitudes towards "chemistry" and "science" (error margin 2-4%).

| | Strongly agree | Tend to agree | N/N | Tend to disagree | Strongly disagree | DK | N | Agree rate |
|---|---|---|---|---|---|---|---|---|
| The benefits of chemistry are greater than any harmful effects | 19 | 40 | 27 | 7 | 2 | 6 | 2104 | 0.59 |
| The benefits of science are greater than any harmful effects | 14 | 41 | 26 | 13 | 3 | 4 | 1749 | 0.55 |
| On the whole, chemistry makes our life easier | 28 | 49 | 15 | 4 | 1 | 4 | 2104 | 0.77 |
| On the whole, science makes our life easier | 28 | 53 | 12 | 5 | 1 | 1 | 1749 | 0.81 |
| Chemistry R&D make a direct contribution to UK economic growth | 30 | 42 | 17 | 3 | 2 | 7 | 2104 | 0.72 |
| Scientific R&D make a direct contribution to UK economic growth | 28 | 48 | 14 | 3 | 1 | 6 | 1749 | 0.76 |
| Chemistry is a dying industry in the UK | 3 | 10 | 25 | 27 | 21 | 14 | 2104 | 0.13 |
| Science is a dying industry in the UK | 2 | 12 | 12 | 38 | 29 | 8 | 864 | 0.14 |
| The chemistry I learnt at school has been useful in my everyday life | 8 | 23 | 21 | 23 | 21 | 5 | 2104 | **0.31** |
| The science I learnt at school has been useful in my everyday life | 18 | 34 | 14 | 24 | 9 | 2 | 1749 | **0.52** |
| School put me off chemistry | 10 | 14 | 23 | 28 | 21 | 4 | 2104 | 0.25 |
| School put me off science | 8 | 16 | 13 | 29 | 34 | 1 | 1749 | 0.24 |
| Jobs in chemistry are interesting | 20 | 42 | 21 | 7 | 3 | 7 | 2104 | 0.62 |
| Jobs in science are interesting | 26 | 47 | 18 | 4 | 2 | 4 | 864 | 0.73 |
| It is important to know about chemistry in my daily life | 16 | 40 | 21 | 15 | 7 | 2 | 2104 | **0.55** |
| It is important to know about science in my daily life | 24 | 48 | 14 | 11 | 3 | 1 | 1749 | **0.72** |

## Sciences, a background of good will

In summary, we can say that while sourcing information very similarly, people feel less confidence to talk about chemistry than other sciences; chemists have a sober image of being less interesting, but more honest than scientists. Chemists are indeed associated with the pharmacy and men in white coats; chemistry elicits memories of lab equipment from school days, but also of sexual attraction by metaphor. Among the sciences, chemistry ranks top with physics, though for the public medicine is even more "scientific", and members of the professional body make sharper distinctions between hard and soft sciences. In terms of utility chemistry and science do not differ; what is doubtful is however the everyday relevance of chemistry. Overall, chemistry differs only marginally from the sciences when public appreciation is concerned. It seems that the public image of chemistry is not far apart from the general image of science; it seems protected from the halo of a solid reputation of science in British society.

Is Britain a special case? Probably not, the sciences are in relative good standing in most countries; what we can observe is a temporary fall from grace of some sciences in the eye of a public controversy. But in that fall, they profit from a general background of good will (see [6]).

* The project was led by Jon Edwards and managed by Chiara Ceci; Massimiano Bucchi (Trento University) and myself were part of their Scientific Advisory Board. I thank Jon Edwards for giving me access to the materials.

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# Are we all ready to get rid of gender inequality?

## A global approach to the gender gap in mathematical, computing, and natural sciences: how to measure it, how to reduce it?

Are you surprised to see few women's names on the list of Nobel Laureates? Are you surprised to see so few female scientists on the periodic table of chemical elements? Are you surprised to know there are still relatively low percentages female students in STEM (Science, Technology, Engineering and Mathematics) education programs? The answer to these questions might raise gender gap issues that have existed for a long time. The low representation of female scientists appears not only historically, but also currently in STEM education programs. While in most countries, women represent a majority of all graduates from tertiary education, fewer women than men complete STEM university degrees. Women account for less than 20% of entrants into tertiary level computer science programs in OECD countries and only around 18% of engineering entrants [1]. However, it seems that gender gap issues do not receive the attention they should. The United Nations proclaimed in its Sustainable Development Goals (SDGs): "*Providing women and girls with equal access to education, health care, decent work, and representation in political and economic decision-making processes will fuel sustainable economies and benefit societies and humanity at large*." However, much work remains to be done before such benefits can be reaped.

### The Gender Gap Project

This project, titled "A Global Approach to the Gender Gap in Mathematical, Computing, and Natural Sciences: How to Measure It, How to Reduce It?", aims to ensure women's full and effective participation and promote gender equality and the empowerment of all women and girls at all levels in mathematics and sciences. To achieve this aim, eleven international interdisciplinary unions have been collaborating on various tasks over three years (2017-2019): International Mathematical Union (IMU), International Union of Pure and Applied Chemistry (IUPAC), International Union of Pure and Applied Physics (IUPAP), International Astronomical Union (IAU), International Union of Biological Sciences (IUBS), International Council for Industrial and Applied Mathematics (ICIAM), International Union of History and Philosophy of Science and Technology (IUHPST), United Nations Educational, Scientific and Cultural Organization (UNESCO), Gender in Science, Innovation, Technology and Engineering (GenderInSITE), Organization of Women in Science for the Developing World (OWSD), and Association for Computing Machinery (ACM).

The tasks of the project include the following initiatives:

- To develop a robust and sustainable methodology to clarify the meaning of gender gap. Identify appropriate data and develop reliable instruments to collect this data so as to measure and analyze the gender gap in mathematics and natural science disciplines in various parts of the world. The instruments used include a survey of scientists and a study of gender differences in publication patterns.
- To create a database of good practices aimed at girls and young women, and disseminate them, particularly in developing countries.
- To formulate recommendations to reduce gender gap for unions, institutions, and individual women students and scientists, teachers, and parents. One of the unique features of this project is to collaborate with social scientists on formulating research questions and developing implementation strategies on gender in science.

#### Task 1: the survey

To facilitate dissemination of the survey, the project hosted three workshops in different regions across the world, including Asia, Latin America, and Africa. The three workshops were held in Taiwan (National Taiwan Normal University, 7-8 November 2017), Columbia (Universidad de los Andes, 22-24 November 2017), and South Africa (African Institute of Mathematical Sciences, 1-2 December 2017). The aim of the workshops was to inform the purposes of the major tasks of the project, to review the contents of the survey in order to reflect local needs, and to build up a network for disseminating the survey across different disciplines and countries.

The survey was developed in collaboration with social scientists and used a snowball sampling method. It collected answers from May 1 to December 31 2018. During these eight months, 32,000 responses were collected *via* the project website [2]. Both men and women were encouraged to respond. The survey was available in seven languages: Arabic, Chinese, English, French, Japanese, Russian, and Spanish. The numbers of respondents to the global survey of scientists per country are shown in *figure 1*. Nearly two thirds of the responses were in English, but it became clear at the workshops that the use of multiple languages encouraged inclusivity. We aim to analyze similarities and differences across regions and cultures, developing and highly developed countries, and across different disciplines.

The total number of respondents in chemistry field was 2,724 worldwide (8.9% of total). The data analysis will be carried out by American Institute of Physics (AIP) Statistical Research Center. Analyses will be conducted for countries in which there are enough respondents to maintain confidentiality.

#### Task 2: the publication patterns

The purpose of the second task was to design a methodology that allows analysis of publication patterns for different disciplines and extends the current research to longitudinal studies in the future. This work was based upon a comprehensive study carried out by Mihaljević-Brandt, Santamaria, and Tullney

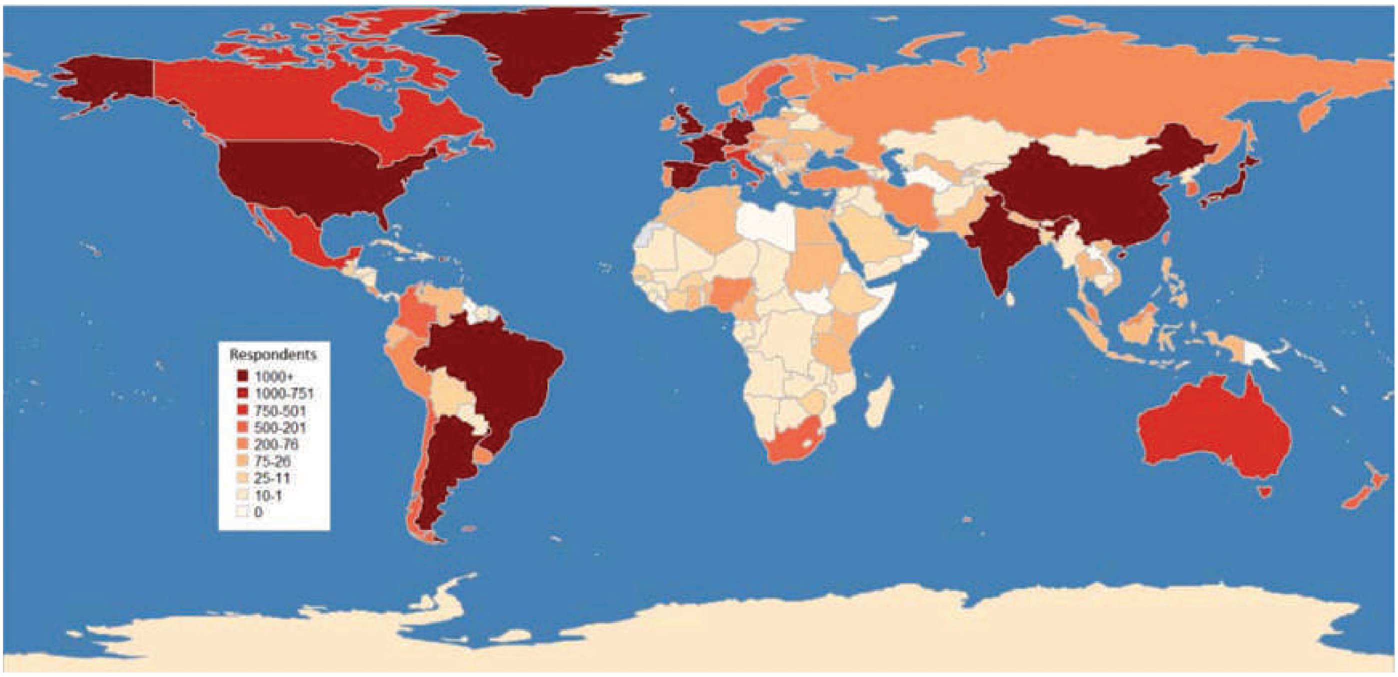


Figure 1 - Number of respondents to the global survey of scientists per country, 02/01/2019 (retrieved from [3]).

[4] on analyzing publication patterns of scholarly output of ~150,000 men and women mathematicians in the zbMATH database from the past four decades (1970-2013), in which significant differences between genders were found. The publication gap puts women at a disadvantage when they pursue careers in mathematics academia. The study revealed that the number of women mathematicians tripled since 1970, but that women published less than men at the beginning of their careers and leave academia at a higher rate. They also found that men publish far more single-authored papers than women, in particular, women regularly collaborate with the same researchers. Similar methodology will be used to study publication patterns in different disciplines (such as chemistry) and across countries and regions. In short, a key objective is to create a sustainable and dynamic methodology to provide a continuous data processing flow, and hence allow for easy updates and longitudinal data analyses.

### Task 3: the database of good practice

The third goal of this project is to establish a database of good practices that have been proved to be successful programs for promoting females and girls at different levels to work and study in science and mathematics fields. This collection of the practices will be made available to all countries who are interested in changing the situations of gender inequity and reforming the opportunities of working in educational and industrial sectors. Currently, fifty gender initiatives from thirty-nine countries were identified [5]. To extend the services and power of this database, we welcome more initiatives to be recommended across the global so more appropriate models could be researched for local needs and then adopted into local situations.

## How to reduce the gender gap?

This global gender gap project has four objectives, namely:
- to provide an evidence-based report and recommendations to stakeholders *via* a joint global survey and a study of publication patterns;
- to collaborate with social scientists working in gender and science, obtaining similarities and differences of outcomes across different geographical fields, age, degrees, genders, fields of science, and cultures, developing and highly developed countries, and across different disciplines;
- to provide easy access to materials to encourage young women to work in science and mathematics fields, including information and resources about careers and salaries directed at parents, schools, and others who can influence the careers of girls, in particular in the developing world;
- to identify and propose interventions to make improvements and to recommend good practices for girls and females in science, and further to recommend practical policies and actions that will reduce the gender gap across the globe.

So far, the project reinforced evidence that the global gender gap still exists. Preliminary results of the survey for chemistry and mathematics show that women report lower salaries, more career interruptions, and more instances of discrimination. A final project conference will be held at the International Centre for Theoretical Physics (ICTP) in Trieste (Italy) on 4-8 November 2019. Methodology, tools produced, survey results of the project, data analysis of publications, and compilation of good practices will be reported. Information about the use of resources and data from this project will also be shared.

### Acknowledgement

*It has been a great pleasure and honor to collaborate with our partners over the past two and half years: IMU, IUPAC, IUPAP, IAU, ICIAM, IUHPST, IUBS, ACM, UNESCO, GenderInSite, and OWSD. We are grateful for the grant from International Science Council (ISC) and the financial participation of all the partners.*

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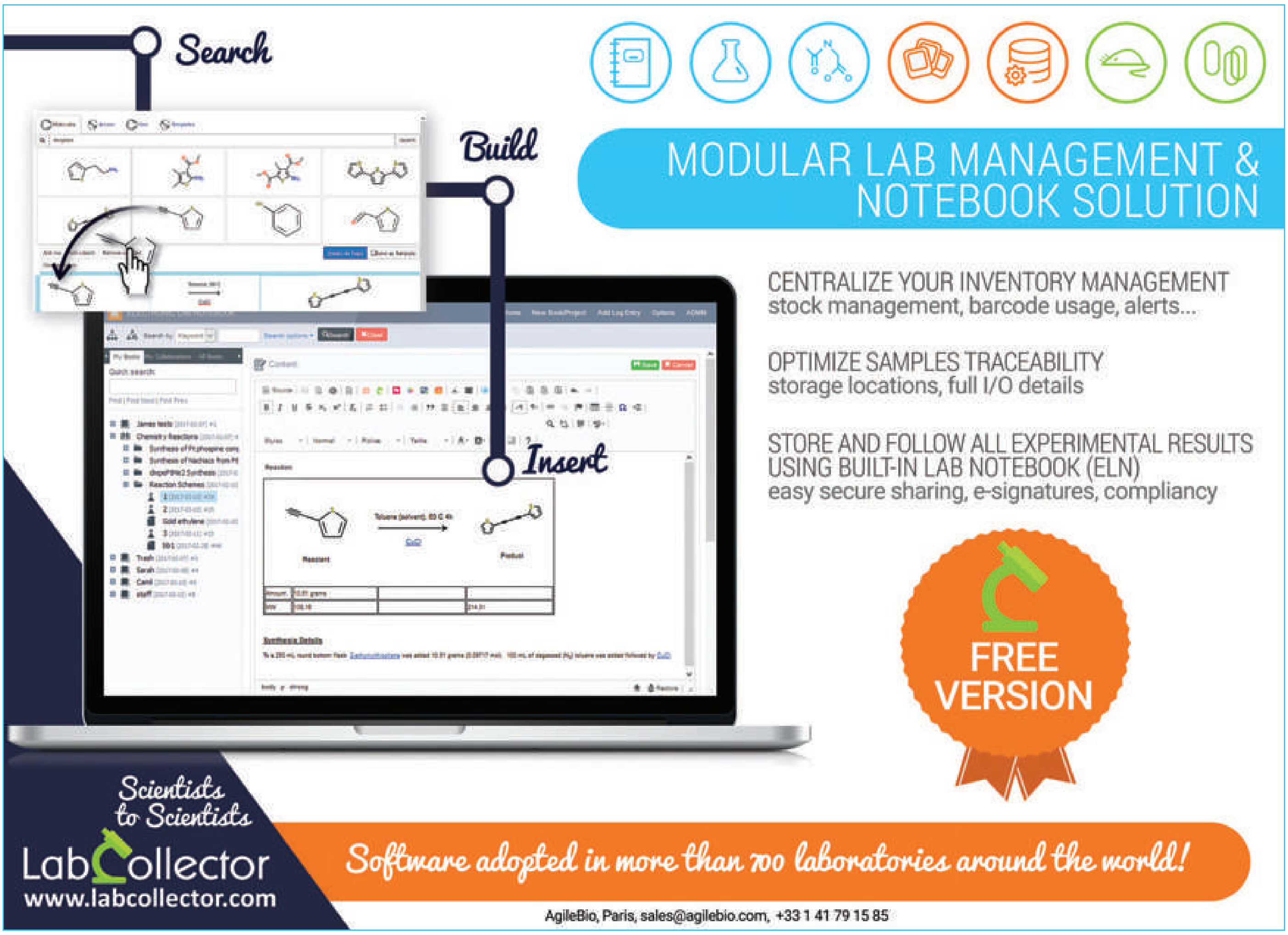

# Chemistry education now

The turning of the century showed the need for a change in science education. On the one hand the number of students in science dropped, while on the other hand the importance of future scientists became more and more obvious. Both the Lund Declaration [1], as well as the United Nations (UN) sustainable development goals [2] state the need for scientists in order to tackle the challenges the world society faces.

Like physics and to a lesser extent biology, chemistry education has gone through a difficult period at the beginning of the century. In the ROSE ("Relevance of Science Education") report [3], students from about forty countries were interviewed about their attitudes towards science and science education. Students do seem to have a positive attitude towards science. They feel science makes their live easier and more comfortable, and will make work more interesting. There is some skepticism, especially among girls about the possible harmful effects of science and technology. Science education though is another matter. Students indicate that school science is less interesting than other subjects, most important school science has not shown the importance of science for society. Another important statement from the report was that science did not introduce new exciting job opportunities.

It was clear that the science curriculum, including chemistry, was not very up to date. The things students learned – equilibrium, acid-base theory, redox reactions, organic chemistry for example – had little or no relationship with current research at universities, or main problems in society. Other factors that had a negative influence were things like teacher domination, competitive assessment, traditional teaching methods, poor learning environment.

In order to let students appreciate science more, science-education had to change.

## A molecular science

Since 2000, chemistry education has undergone quite some changes. In chemistry education the focus changed from the study of chemical reactions towards the study of chemistry as a molecular science. Focusing not only on molecular processes, but also on the relation between (molecular) structure and properties. One of the main themes became the relationship between macroscopical phenomena and changes at the molecular level. With the emergence of nanotechnology, this intermediate size was studied as well.

The main challenge was how to make science education more relevant for students. Two aspects played a major role in the solutions that were ultimately found: the first was linking chemistry to the everyday world; the second showcasing chemistry research in education, to demonstrate how exciting research can be.

The use of contexts was one of the solutions that was tried out, and was successful in motivating students. Instead of just teaching certain concepts, a context is introduced and discussed before relating the concepts to the context. A context can be a lot of things. Normally it would be a societal situation, in which students are discussing, for example detergents, and learn about the molecular background of detergents. Cosmetics are another example that was often used as a context to introduce the difference between hydrophobic and hydrophilic substances.

In a recent example, students are confronted with the question: "Why does a baby not drink milk from a carton?" [4] (*figure 1*).


Figure 1 - This is milk as well, isn't it?

Since milk is basically built up as an emulsion of fats, proteins and carbohydrates, this leads to the introduction of the molecular properties of proteins, carbohydrates as well as fats. These substances can be studied in some detail, in which the chemistry of these compounds is introduced and learned by the students.

Going into more societal issues, it appears that after about one month the percentage of women still breastfeeding their babies drops to about 57%. The World Health Organization (WHO) advises complete breastfeeding until six months, bus as maternity leave ends after four weeks, quite a few women stop breastfeeding or mix it with formula milk.

The introduction of formula milk leads to questions about the composition and production of formula milk. How do you get from *figure 2a* to *figure 2b*?

Apart from discussing and learning about the production process of formula milk in a factory, students learn about chemical technology in general. This case leads to recent research done at the University of Groningen about the role of human oligosaccharides in breastmilk (HMOS). These HMOS

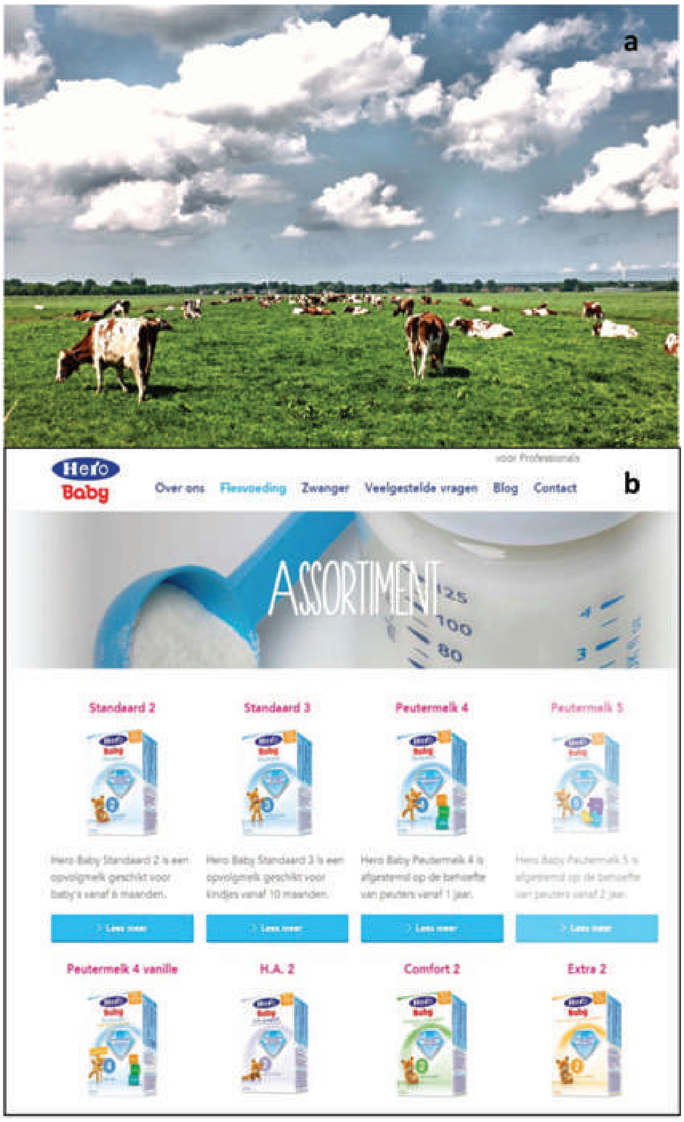


Figure 2 - From Dutch cows (a) to formula milk (b).

play a role in the development of gut bacteria in the baby (*figure 3*).

The research group in Groningen found that galacto-oligosaccharides (GOS) can have the same effect. Since then these GOS have been added to formula milk. This gave the opportunity to introduce both microbiology as well as the introduction of the intestinal system in humans. This includes the use of metagenomics for the identification of the gut bacteria.

It demonstrated to the students the role of recent research in a societal very relevant aspect of their lives. Most of the students have been breast fed, but have also had formula milk.

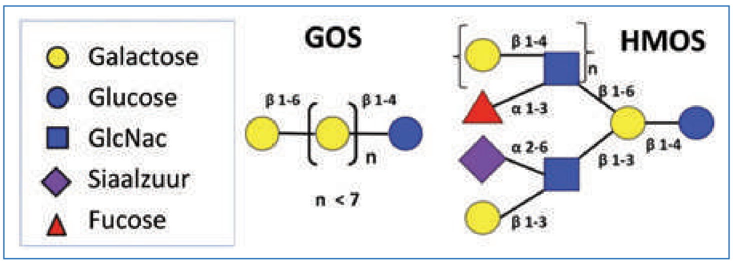


Figure 3 - Possible structures for human milk oligosaccharides (HMOS) and galacto-oligosaccharides (GOS).

This combination of the students own experiences and the underlying molecular explanations are a main feature of modern chemistry education. It motivates students, but also showcases relevant recent research taking place at the university (the educational material presented above can be found at [5]).

## Context and sustainable goals

Other research has been done to improve science education. Science education in early stages can become highly relevant for students, when it can be linked with sustainable development [6]. When students can see the role they themselves can play in sustainable development, now and in the future, they will be more motivated to understand the need for science.

Linking science education to the UN development goals for example is relatively easy. Goal 6 about clean water and sanitation for example can be used at the start of chemistry education. Separation methods like filtration, absorption as well as distillation are often introduced early on in chemistry education, in order to develop the concept of a pure substance. The preparation of drinking water is a perfect example and may lead to student work as illustrated in *figure 4*.

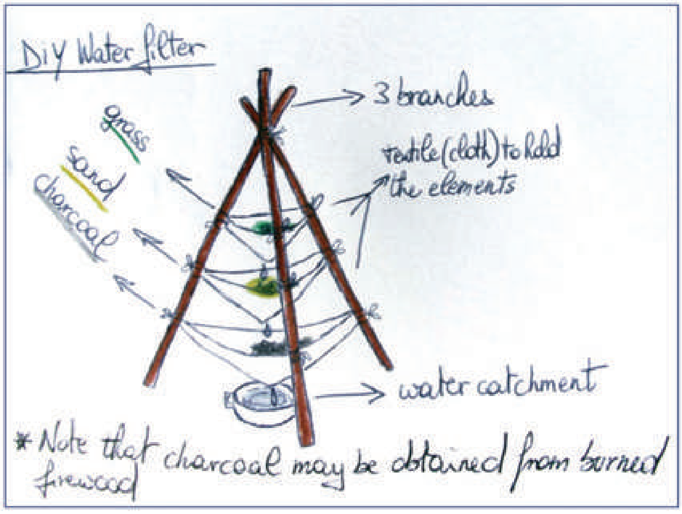


Figure 4 - Water purification (source Wikipedia).

Recently a discussion started about the central role of chemistry in relation with sustainability, as well as its relationship with other natural sciences. Chemistry is linking more and more with other natural sciences in research. The molecular aspects in astronomy, physics and biology lead to combined research groups, in which chemistry is a linking pin. This leads to all sorts of university masters in which different sciences are mixed.

Systems play a vital role in the study of environmental issues, and require a more holistic view of a problem, in which chemistry plays a role. As can be seen in the example of breast feeding discussed above, there are interfaces between chemistry and engineering, chemistry and biology, as well chemistry and sociology. While in biology systems are part of the normal curriculum, systems are not part of the normal chemistry curriculum.

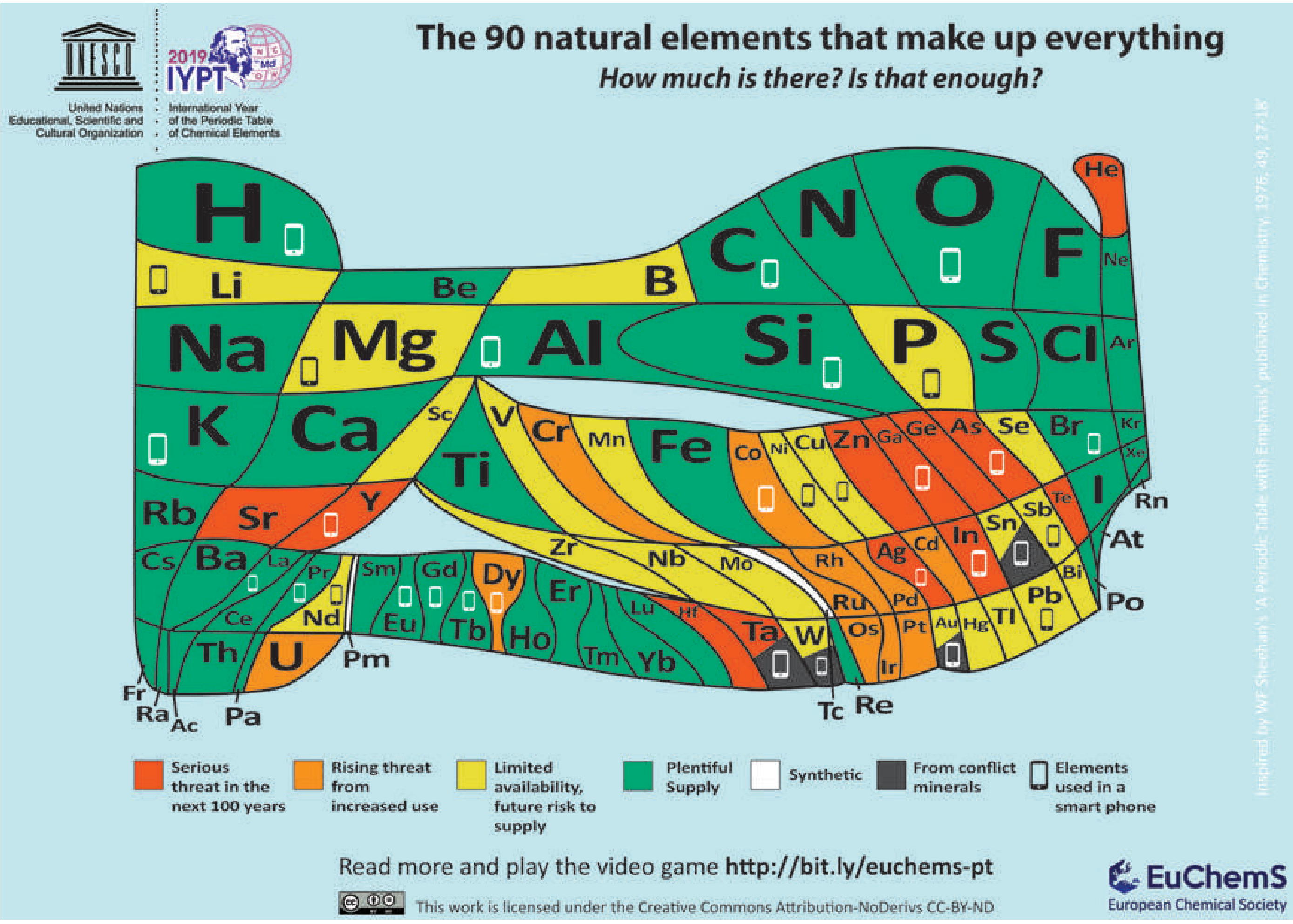


Figure 5 - Periodic table showing the availability of elements (credit: EuChemS/CC-BY-ND).

This has led to a discussion about the introduction of systems thinking in chemistry education.

The introduction of systems offers a way for studying concepts like life cycle analysis, cradle to cradle design, which are important if we want to discuss the future use of base materials. The publication of a periodic table by EuChemS to highlight 2019 as the International Year of the Periodic Table is a nice example of the problems associated with the availability of elements (*figure 5*).

Chemistry education continues to evolve around the world, and in the past twenty years has managed to change the negative trend in the appreciation of chemistry as a science [7].

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# International Union of Pure and Applied Chemistry (IUPAC): an adventure

The reflexions that follow are the fruit of a long engagement with the history of IUPAC, through its publications and archives. Many unanswered questions remain. Is it possible yet to present a coherent portrait of the Union? What image of the Union do I have as I write these lines? Do I see IUPAC as essentially an institutional structure that reveals little of the men and women behind it? And what underlying unity can we identify amid the striking diversity of its activities? These questions, about an organization of immense and shifting complexity, are ones that no single person can hope to answer. Hence what I offer here is necessarily impressionistic and incomplete.

## The Union as an international body

IUPAC is a hundred years old in 2019 [1]. On 28 July 1919, in Brussels, it was recognized as a constituent union of the International Research Council (IRC), along with other unions, for astronomy, geodesy and geophysics, and scientific radio-telecommunications. The mission of the IRC was to reorganize international science, through regulations and procedures adapted to the different disciplines. In this way, it was hoped to avoid the dispersion and duplication of effort at the international level.

IUPAC was at once a successor to the International Association of Chemical Societies (1911-1919) and a product of specifically post-war ideals, including an alliance between science and industry in which science would chart a future that industry would then bring to fruition. This alliance, reflecting the support that the nascent union received from the French and British societies of chemical industry, accounts for the decision that IUPAC should embrace all chemistry, both pure and applied.

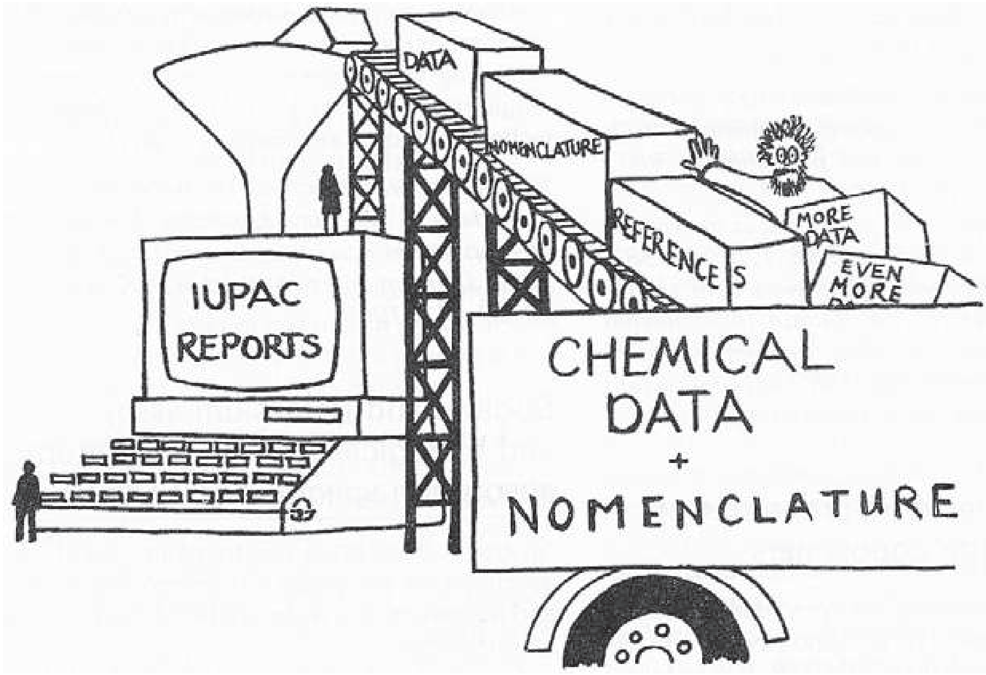
Created as an interallied union open exclusively to the nations that had fought on the Allied side in the war, IUPAC only became truly international in 1931, when its parent body, the IRC, was replaced by the International Council of Scientific Unions (ICSU). Along the way, however, there had been significant changes. In 1930, for example, the Union had already shortened its name to International Union of Chemistry. In doing so, it signalled a narrowing of its scope to pure chemistry and a severing of the explicit industrial links, which it considered to be adequately covered in the various congresses that took place under its auspices.

After the Second World War, the Union's very survival was in question. ICSU, recognized and supported by UNESCO as a force for world peace, faced approaches from a number of new specialized international committees, including some in chemistry that threatened the break-up of the Union. The result, in 1949, was a fundamental restructuring into six disciplinary sections, later named divisions: Physical Chemistry (I), Inorganic Chemistry (II), Organic Chemistry (III), Biological Chemistry (IV), Analytical Chemistry (V), and Applied Chemistry (VI). Each division was to enjoy a large measure of autonomy, with its president becoming one of the vice-presidents of the Union. The result was a body that once again embraced the whole of chemistry. It reverted, appropriately, to its original name of International Union of Pure and Applied Chemistry (IUPAC), and new specialities, such as macromolecular chemistry, were introduced. The restructuring of commissions continued through the 1960s and 1970s in response to revolutionary new analytical techniques, such as infrared spectroscopy and then NMR. And the development of biochemistry and clinical chemistry was the cause of frequent adjustments to divisions and standing committees throughout the last forty years of the 20$^{th}$ century.

Another challenge lay in advances in analytical and applied chemistry that made it necessary to plan a complete review of the two divisions in question. Since the late 1950s, gathering criticism among the general public had contributed to a feeling that science had been, for better or worse, a driver of rapid social change. The Union had no choice but to take account of such criticism and develop shared expertise with bodies primarily involved in such areas as education, health, nutrition, and the challenges of pollution. As the President Jacques Bénard (1971-1973) insisted in his report on the state of the Union: if IUPAC was being created in his day, it would surely have been very different; the original compartmentalization according to the traditional sub-disciplines of chemistry would no longer be appropriate [2]. Throughout its history, in his view, the Union had shown a capacity for adaptation, and if it did not adapt now, it would be condemned to sterility. In raising such questions, Bénard was expressing concerns that had been voiced for some time within the Union. And his successors heeded his warning.

## IUPAC confronts its history

The move to rethink IUPAC turned thoughts to the Union's past. The history of IUPAC became a matter for discussion as early as 1968. Five years later, Stig Veibel, a titular member of the commission on organic nomenclature (III-1), wrote a detailed account. But this remained unpublished, and it was left for Roger Fennell, editor of *Chemistry International* (1983-1985), to take up the challenge. His *History of IUPAC, 1919-1987* appeared in 1994, followed in 2001 by a substantial supplement for the years 1988-1999 by Stanley S. Brown (a past president of the Division of Clinical Chemistry, 1985-1987). This meant that work on the first eight decades of the Union's history coincided precisely with the comprehensive review of its structure. Through the 1990s, the continuing will for reform left its mark, not least in *Chemistry International*, which reported




By courtesy of *Chemistry International*, May 1989, *11(3)*, p. 112.

on the various proposals under discussion. Among the working documents put to members were the *Strategic Plan* and the *Projects System*, which together provided the foundation for the major reform that was finalized during Edwin Becker's term as Secretary general (1996-2003) and Joshua Jortner's as President (1998-1999) [3].

## Community and the individual in chemistry

This brings me to the chemists who have made up the Union and whose role is too easily obscured in the official record. Since it has never been the practice for IUPAC to give prominence to individual contributors, reports on the Union's work have had a rather anonymous character.

The fact is that IUPAC has been, above all else, a community of men and women who have brought to bear not only their scientific expertise but also their ideals and faith in chemistry. Some have served for long periods, occupying successive posts of responsibility. Among presidents whose names will be less known to members today are the multi-lingual physical chemist Ernst Cohen (Netherlands, 1925-1928), who did so much to promote IUPAC's transition from a still essentially interallied body to one that was truly international, and Marsten T. Bogert (USA, 1938-1947), who guided the Union through the difficult war years. We should also remember William A. Noyes Jr (USA, 1959-1963), who worked to ensure that the offices of the Union were open to members from any country; the first Russian President, Victor Kondratiev (1967-1969, decisive years for the Union); and the visionary Harold W. Thompson (UK, 1973-1975), the inspiration for a number of new departures between 1957 and 1975, including the establishment of the Triple Commission for Spectroscopy (a joint venture with the unions for physics and astronomy) and, in 1960, the journal *Pure and Applied Chemistry*.

The Secretary general too has had a crucial role, especially in the aftermath of the two world wars: first, after the Great War, when Jean Gérard (1919-1944) laid the foundations for what quickly emerged as a major inter-war union, and then after the Second World War, when Raymond Delaby (1945-1955) guided the relaunching of the Union in a context of reconciliation that served to maintain unity despite pressures that might well have led certain groups of chemists and specialities to withdraw. It would be impossible to mention all the other officers who have done so much to foster relations in an atmosphere invariably characterized by mutual respect. Over the years, many personal friendships have been struck in the context of debates on such potentially divisive matters as nomenclature, terminology, symbols, and analytical procedures. Far from being incidental, these have played their part in the resolution of differences that are largely glossed over in reports and publications, though plainly visible in the archives. At difficult moments, in fact, firmness and diplomacy have gone hand in hand with a degree of cordiality that has helped to achieve a solution acceptable to all concerned.

## Continuity and change

As we look back over the Union's last half century, two turning points stand out: first, the establishment of the permanent secretariat in Oxford in 1968, and secondly, in 1997, the move to Research Triangle Park in North Carolina and the subsequent deposit of IUPAC's archives at the Chemical Heritage Foundation, now the Science History Institute, in Philadelphia. The period between these two events was one of transition. It was marked by the growing importance of standing committees (CTC, CHEMRAWN, COCI…) and an associated recognition that chemistry could not be treated independently of its social and environmental implications. The first turning point also coincided with IUPAC's heightened presence in international organizations requiring its expertise, and its consequent involvement in defined, essentially administrative tasks of a less personal character. The second took place in the context of the restructuring of the Union that was completed at the beginning of the 21$^{th}$ century, after years of debate.

While the archives allow us to trace IUPAC's inner workings into the 1990s, the subsequent advent of electronic messaging has transformed both the Union's administrative procedures and its relations with members. Today, members store materials in their own computer systems, with consequences that present a challenge for the historian; at the very least, much risks being lost when a term of office comes to an end and offices move. This is something that those writing the history of IUPAC's next hundred years, with only published sources to work from, will necessarily regret, and we must hope that measures will be taken to preserve and manage the 21$^{th}$ century archives of the great lady that is IUPAC. Here the National Adhering Organizations (NAOs) could play a crucial role as vehicles for preserving archives on the national scale. And we should certainly seize the opportunity of recording oral accounts by the Union's many actors, especially those who have contributed to the changes of recent decades.

While the Union may appear remote from everyday life, two of its decisions speak to every one of us: the adoption, in 1961, of carbon 12 as the foundation for atomic weights and, ten years later, of the mole as the base unit of the International System.

Overcoming language barriers and laying aside political differences and considerations of race and religion, the men and women of IUPAC have given chemistry its vocabulary and rules. We should never forget, however, that today's present will become tomorrow's past. I leave members in this centenary year with that thought.

*The author thanks Robert Fox, Emeritus Professor of the History of Science, University of Oxford (UK) for kindly undertaking the translation of her original French text.*

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[3] Jortner J., Future mission, goals and functions of IUPAC, *Chem. Int.*, **1998**, *20(1)*, p. 1-2; IUPAC adopts strategic plan, *Chem. Int.*, **1998**, *20(2)*, p. 21-24; Strategy development and Implementation Committee, Report to the Executive Committee, *Chem. Int.*, **1998**, *20(3)*, p. 55-76; Becker E.D., Secretary General's Report, *Chem. Int.*, **1998**, *20(6)*, p. 165-167.



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## Preserving the memory of chemistry

Ever since I left Oxford University with a DPhil in physical chemistry under my belt, my career has, in some way or other, been involved in preserving the history of chemistry. In terms of printed books and archives in libraries, these have been reasonably well cared-for. For example, the IUPAC archive itself is carefully preserved in the institution of which I am now President, the Science History Institute in Philadelphia. But in terms of objects, the scene looks much thinner and patchy.

The material culture of chemistry is a difficult subject to deal with for two main reasons. Earlier objects themselves do not excite visually in the same way that instruments and apparatus from other disciplines do, and do not tend to be preserved to the same extent [1]. Microscopes, telescopes, orreries and astrolabes are innately photogenic: the brass shines and the carved ivory is intriguing. Test tubes, flasks and distillation apparatus are less visually attractive. It is likely that for this reason that the survival rate of chemical objects is much poorer than in the optical and mechanical categories which I have just mentioned. Glass test tubes are expendable because they are cheap and readily replaceable, and the historical evidence that can be extracted from them is usually much less. Secondly, there is the issue of understanding. Many members of the public are well aware of what a microscope or telescope does. Chemical objects are more arcane and difficult to fathom. It is true that the division between chemistry and other physical sciences converges as one approaches the present day when the black box syndrome hides the working parts of all types of instrument and makes them a challenge to display. As an example, one of the most important instrumental developments for chemistry of the post-Second World War years was the Beckman DU series of spectrophotometers, which made a major impact on the study of chemical and biological substances. Approximately 30,000 of these instruments were made between 1941 and 1976 and there is no denying their significance in research (*figure 1*). Yet the inner workings are surrounded by the archetypical metal black box which conceals how they function. Persuading the lay-public of their mode of operation and importance is extraordinarily difficult, and very few science museums even attempt it.

However, there can be no doubt of the importance of preserving the material culture of chemistry, which impinges on so many aspects of contemporary life. In their day-to-day work, chemists draw constantly on the findings of their predecessors, while museum specialists need to seek out collections in the major science museums to tell stories. Even if their displays are attenuated, the significance of chemical artefacts has been accepted by the Conservatoire National des Arts et Métiers in Paris (whose most-prized chemical objects must surely be the 18$^{th}$ century instruments of Antoine Laurent Lavoisier), the Deutsches Museum in Munich, and the Science Museum in London. These three are highlighted because they contain largely historical material, antiquities of the nature of which might be found in other types of history museums. There are plenty of science centres around the world which demonstrate scientific principles, but the devices which they contain are largely made to order and have not been used by practicing scientists in the normal sense of the word.

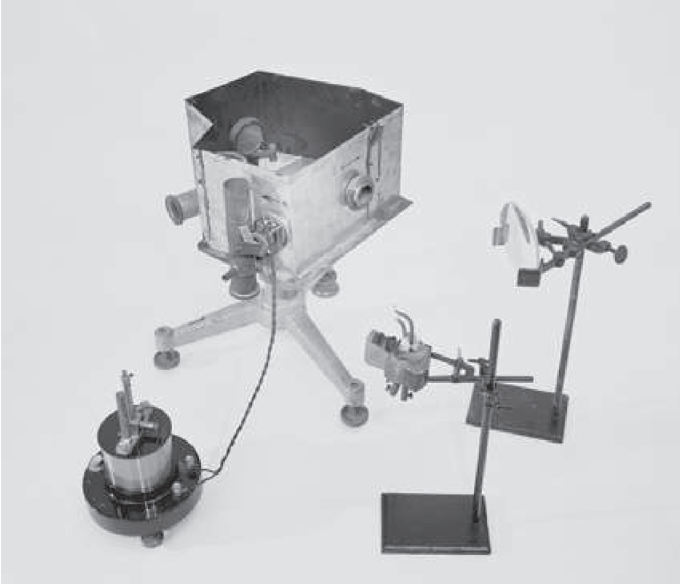

Figure 1 - Infra-red spectrometer created by Sir Harold Thompson in the 1930s at the University of Oxford. Collection of the Science Museum, London.

Apart from the large national science museums which have been mentioned and which contain chemical material, there are a number of what might be called “boutique” science museums which make no claims to be comprehensive but which contain associational instruments (including chemical ones) and apparatus. Examples which might be mentioned are the Teyler Museum and the Boerhaave Museum in Haarlem and Leiden in the Netherlands, the Royal Institution in London (with rich collections pertaining to Humphry Davy and Michael Faraday), the National Museum of Scotland (for Joseph Black’s teaching apparatus) and the Collection of Historical Instruments at Harvard University in the USA.

But these institutions contain few instruments dating from the latter part of the 20$^{th}$ century onwards, a period when instruments proliferate and can become very large and anonymous. That area has been best dealt with by the Science History Institute, which has made special efforts to preserve chemical instruments, either prototypes or examples which are widespread, and which have made a major impact on chemical practices. To fulfil this purpose, a committee was established of scientists who had personal experience of working in fields such mass spectroscopy, X-ray diffraction or chromatography. Fifty key objects (an arbitrary number) were identified and searched for. The collection now contains nearly all of these, and several are displayed at 315 Chestnut Street, Philadelphia.

When I was working at the Science Museum in the mid-1970s, I was anxious to acquire objects which I knew were in danger of being discarded. One of the desirable acquisitions

Figure 2 - Spectrophotometer in the DU range designed and manufactured by Beckman Instruments, 1940s. An early example of the "black box". Collection of the National Museum of American History, Smithsonian Institution, Washington DC.

I identified was the first infra-red spectrometer constructed pre-Second World War by the man who was my tutor at St John's College (Oxford), Sir Harold Warris Thompson (who, incidentally, became President of IUPAC). It was a very difficult task to wrest it from him: scientists can become quite sentimental about the instruments they work with. Eventually he called me on the telephone and agreed to part with it, but only if I came immediately to the headquarters of the Football Association (of which he was President) in Bayswater, and I walked across Kensington Gardens with the precious instrument in a cardboard box back to the Science Museum (*figure 2*).

Printed books on chemical subjects would seem to be safely preserved by many libraries, but there is no cause for complacency. Many libraries are freely disposing of printed monographs and journals, assuming that present and future generations will prefer to work with electronic images. If this is done without care, historical evidence might well be lost. Many chemistry books are annotated in some way or other. Early annotations may be prized by historians, and association copies, including those with bookplates can be of very great interest. Just because the notes or doodles of users of such books are of recent origin doesn't mean to say that in future years these may be recognized as forming vital evidence, especially when annotations are by the authors of the books themselves. An area which is often ignored is printed, non-book material. Such might include instrument manuals, commercial promotional leaflets and advertisements, conference programmes, lecture syllabuses, examination papers, scientific dealers' catalogues and so on, which when taken into account, provide a more rounded picture of the total chemical enterprise. These materials are not much-loved by librarians as they are difficult to catalogue and to store. In the case of dealers' catalogues, I did a survey of those surviving in major libraries [2]. They were not very common; about half of them were available only as a single copy. These kinds of publications are often difficult to collect, as they are considered ephemeral, and they are so easily disposed of as they are not often registered in the way books are because they lack ISBNs.

Another vitally important area for preservation are photographs. These can be individual portraits (useful for publications, though images of youthful chemists in their creative prime are difficult to find), group photographs (early 20$^{th}$ century ones of major conferences frequently seem to include the easily recognizable Albert Einstein) and laboratories (rarer than one might think). It is important when receiving photographs to annotate them quickly whilst the donor is still able to identify and date them. There are rather few paintings of chemical interest as few were commissioned and artists would be unlikely to be confident of future speculative sales. However, there is a significant genre of paintings which depict early chemists and alchemists in their places of operation, often by 17$^{th}$ and 18$^{th}$ century Netherlandish artists. The Science History Institute has a collection of about ninety of these. There are often very attractive woodcuts of chemical processes in textbooks of the 16$^{th}$ to 18$^{th}$ centuries but they have to be treated with caution as they may be symbolic rather than representative of real life.

Which brings us to archives and manuscripts. It is this category which is probably of greatest value to the historian, as the development of ideas can often be traced in handwritten or typed pages.in a way not possible in polished, final accounts in periodicals and books. The choice of what to collect is a fine art in itself. It must always be remembered that historical collections are not being compiled by libraries and museums simply for the present. One has to ask, what is going to be of interest in, say, twenty or fifty years? There has been a tendency to collect the works, unsurprisingly, of men and women currently recognized as being great. It must be remembered that reputations can change, and that the great scientist, as an individual, is only part of the process of conducting science. I have long argued for the papers of a few key laboratory technicians to be collected. One of the most significant of the laboratory support services is supplied by glassblowers, but where would one find evidence of how they think? Some nations have attempted to collect scientific archives systematically: The United Kingdom is one such place which developed a scheme of straightforward, simple indexing of papers for scientists who had just retired or died, these papers then being offered to appropriate libraries.

It must not be thought that the history of chemistry touches only historians: one does not have to be an historian to be an historian of science. I would claim that all scientists are necessarily historians in so far as they refer constantly to what has been written about in the past. It was Isaac Newton himself who captured that thought when he wrote in a letter of 1676 to Robert Hooke: "*If I have seen a little further it is by standing on the shoulders of Giants*" [3]. These words, I believe, are quite as pertinent today as they were in the 17$^{th}$ century.

*This paper was prepared for the centenary celebrations of IUPAC, held in Paris in July 2019.*

[1] Anderson R.G.W., Where has all the chemistry gone?, *Mitteilungen der Gesellschaft Deutscher Chemiker*, **2017**, *25*, p. 329.
[2] Anderson R.G.W., Burnett J., Gee B., *Handlist of Scientific Instrument Makers' Trade-Catalogues 1600-1914*, National Museums of Scotland, **1990**.
[3] Merton R.K., *On the Shoulders of Giants: A Shandian Postscript*, Free Press, New York, **1965**.

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is the President and CEO of the Science History Institute in Philadelphia (USA). His history of chemistry interests are in the Scottish enlightenment of the 18$^{th}$ century and in scientific instrumentation. He holds the Dexter Award of the ACS and the Bunge Prize of the Hans R. Jenemann Foundation. He is a former Director of the British Museum.

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# The creative chemist

As a 34-year old chemist, I belong to the ill-defined category of the "early-career scientists" or, more casually, the "young chemists": a generation that grew up under a dire lack of academic positions, was raised under the tyranny of the impact factor [1], and committed early on to a never-ending grant-seeking quest, in order to fulfill a passion for chemistry: its wonders, its wealth of possibilities, its collective endeavor, its ability to create a better world. Some of us are still studying, others are traveling the globe from a post-doctoral position to another, fewer are occupying teaching and faculty positions, the rest joined R&D in industrial groups or start-ups, or moved on to other career paths.

I am one of the lucky ones.
As a CNRS (French National Center for Scientific Research) researcher working with a secured job in a welcoming university, I was able to obtain research grants early on and initiate my own projects on topics close to my heart: nanoparticles design and their study for improving our utilization of small abundant molecules, such as $CO_2$. I build new compounds at the nanoscale and modify them with organic ligands to enhance their surface reactivity, hence contributing, if only by a jot, to the grand climate challenge.

I even get to spend time wondering about purely academic questions, like this one: "What are the meaningful descriptors of nano-scaled mater?" Indeed, chemists have improved their descriptions of molecules over centuries, from taste and smell, to molecular weight, then developed formulas and orbitals (see *figure*). Powerful concepts emerged, like the modern "aromaticity": today, one relevant descriptor of a molecule is its number of $\pi$ electrons. Technological byproducts of this concept range from new drug molecules to organic solar cells. Comparatively, nanochemistry is still in its infancy: we are barely at the description stage (composition, shape), except maybe for few systems like plasmonics nanoparticles or quantum dots… This is thrilling! An open horizon to stretch our legs, unleash our imagination and build the next set of solutions for the citizens and the planet: nanoparticles-based theranostic, smart energy harvesting technologies, quantum computers, etc.

Accomplishing any of these "young chemist's dreams" – whether in nanoscience or in any branch of chemistry – entails one thing: creativity, or more precisely, the factual set of conditions for creative thinking and creative work being carried out over a career.

In my views, current evolution of career paths and working conditions are strangling creativity of the young scientists. Short-term project funding [3], tenure evaluations based on productivity more than originality, conformism of some hiring processes that do not receive well the interdisciplinary profiles, mandatory duties on many fronts (administrative tasks, management, teaching, refereeing…), are as many obstacles preventing creative work. Despite a highly favorable work environment, my days are still filled with tasks that hijack my creative capabilities: organizing seminars and committees, ordering supplies and specifying equipment, filling forms (for administration, evaluation, traveling… you name it),

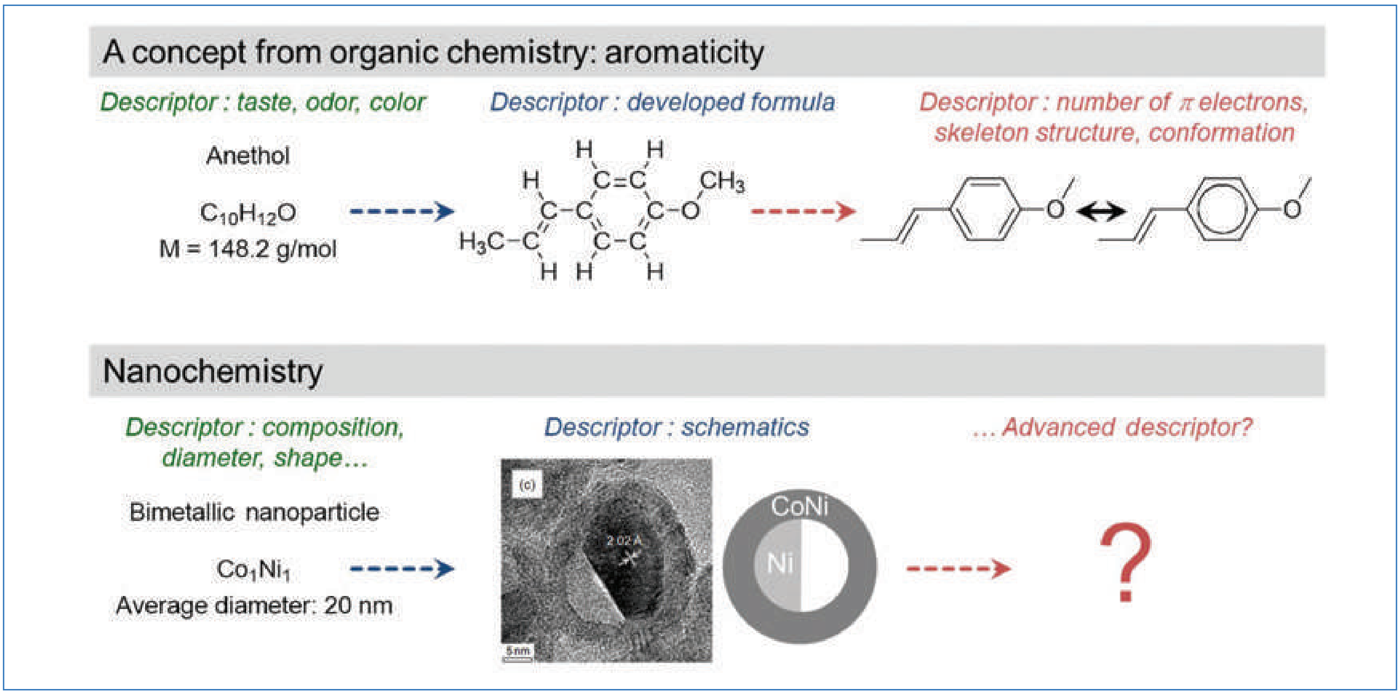


Figure - Top: descriptors in organic chemistry have matured over the centuries, from taste and odor to the modern concepts such as aromaticity. Bottom: descriptors in nanochemistry are the nanoparticles average diameter and composition, along with schematics to describe the morphology [2].

formatting documents for various purposes (e.g. satisfying journals and grant agencies requirements), helping with safety and training in the lab… most of them legit tasks, but, as a sum, unbearable. If I had to write my job description today, it would not be "to create knowledge" or "to tackle scientific questions", but something along "project manager, advisor, mentor, communicator, referee and technical document writer".

While I recognize the relevance of these missions, I strongly believe that, as a collective, we should find ways to establish a balance between these and the time for creative thinking [4]. Some of us excel in one or the other missions I mentioned above. However, peer pressure tends to push everyone in accomplishing the same mix. In my opinion, this endangers the "creative chemist" profile: the person who would rather spend long periods of uninterrupted time thoroughly reading old papers, listening to conferences outside her or his expertise, come up with unprecedented ideas (even if not fashionable), and build bridges between disciplines that ignore each other so far. Today, this is not a sustainable profile within the academic institution: such creative chemist will likely get no grant to implement her/his ideas, nobody to work with, and no recognition from the community.

Shutting down creative colleagues is a dangerous path: no more out-of-the-box thinking, no remodeling of the disciplines, no sparkles that may lead to truly disruptive results. On the broader picture, if chemistry stops questioning its basic concepts, like the descriptors I was mentioning above, it may become a technical set of tools for other fields to use rather than a living science. Societal consequences may follow. The public and the politics already have a negative vision of chemicals. Let's not make them disregard the chemists as well.

## What can be done?

First, we may consider improving the diversity (in age, culture, gender) within our hiring, evaluation and policy-making committees. For instance, it strikes me that long-term strategic decisions are often made within groups of persons that will not have to live with their consequences. I do not question their willfulness to make the right choice. However, it seems reasonable to systematically invite few colleagues in their 30's or 40's to participate to these discussions. Among young chemists, some should take the initiative or answer favorably to such requests, even if this means one more task on their plate. It also strikes me that our institutions actively promote inter-disciplinary work (through specific grants for instance) but that our evaluation processes do not reward it. Have you ever tried publishing beyond the typical journals of your field? That is usually painful… Few editors are tackling this question by creating inter-disciplinary journals, but as long as the impact factor is the metric of success, these will not suffice. I believe it is a responsibility of young chemists, as a collective, to grasp the new opportunities of a fast-changing publishing model and tackle the hegemony of a handful of journals [5].

Second, we have to draw in more financial means for research and education [6]. Young chemists can contribute by restoring the trust of the society in its scientists: science fairs are a good start but young chemists could also be more active in organizations that lobby in favor of science [7] (e.g. chemical societies [8], professional networks). Presence on the social networks, to explain what our job is, to participate in discussions and to break the fake news bubbles, also helps, as long as enough of us engage into this. Early-career chemists should empower the younger ones by actively mentoring the next generation, and helping them through the hurdles of the academic careers.

Last, all chemists should intervene at all opportunity when we can improve the values by which our work is prescribed and evaluated. Creativity will never be a productive activity [9]. By essence, it requires hesitation, internal struggling, construction then deconstruction. It also engages a diversity of personality types. Among all scientists, we, chemists, are of the few that fabricate matter, molecules, and materials with our hands, and then spend extensive time studying our own creations. This privilege we should also apply to ourselves: let's encourage atypical career paths, let's welcome people who crossed disciplinary boundaries, and let's improve our listening and collaboration skills to welcome the creative chemist.

[1] "*The importance attributed to the Impact Factor today is quite absurd.* […] *To base the quality of a manuscript on the Impact Factor of the journal it is published in is nonsense!*," was already writing Peter Gölitz, editor of *Angewandte Chemie*, in 2012: Impact factors, open access, and 125 years of *Angewandte Chemie*, *Angew. Chem. Int. Ed.*, **2012**, *51*, p. 9704, doi:10.1002/anie.201206849.
[2] The example presented here is extracted from: Carenco S., Wu C.-H., Shavorskiy A., Alayoglu S., Somorjai G.A., Bluhm H., Salmeron M., Synthesis and structural evolution of nickel-cobalt nanoparticles under $H_2$ and $CO_2$, *Small*, **2015**, *11*, p. 3045.
[3] In France, the Institute of Chemistry of CNRS recently published a column signaling the dangers of stand-alone short term funding and pointing out the necessity to support blue-sky research: D'une vision scientifique à une vision sociétale, *L'Act. Chim.*, **2019**, *436*, p. 15.
[4] This concern is shared at all career stages and across disciplines, judging by the number of columns recently published by scientists. See for instance: Johnson A.C., Sumpter J., Six easy ways to manage your time better, *Nature*, **2019**, doi: 10.1038/d41586-019-00973-6; Woolston C., Workplace habits: full-time is full enough, *Nature*, **2017**, *546*, p. 175, doi:10.1038/nj7656-175a.
[5] The rules of scientific publishing are quickly transforming. "Plan S" is an example of political intervention in this matter (www.coalition-s.org). Young scientists networks such as the Global Young Academy are wondering about its consequences in the next few years: "Opportunities and challenges for implementing Plan S: the view of young Academies", 15 oct. **2018**, https://globalyoungacademy.net/wp-content/uploads/2018/10/YA-Statement-on-Plan-S-FINAL.pdf.
[6] This point is key, not only for chemistry but for all scientific disciplines. A recent survey report from the Global Young Academy points out the difficulties faced by young scientists worldwide: Friesenhahn I., Beaudry C., *The Global State of Young Scientists, Report and Recommendations*, **2014**, https://globalyoungacademy.net/wp-content/uploads/2015/06/GYA_GloSYS-report_webversion.pdf
[7] "*Young people are key drivers of sustainable development*", according to the United Nations (www.un.org/press/en/2015/ga11648.doc.htm). Young Academies are willing to contribute through policy advice, science communication and outreach, and capacity building: 3rd Worldwide Meeting of Young Academies Statement, The role of Young Academies in achieving the UN SDGs, Oct. **2017**, https://globalyoungacademy.net/wp-content/uploads/2017/10/Statement-RoleYoungAcademies-SDGs-Oct2017.pdf
[8] Few examples of younger chemists networks: the International Younger Chemists Network (IYCN) is independent and works in strong collaboration with IUPAC; the European Young Chemists Network (EYCN) is the young chemists Division of EuChemS; in France, the "Réseau des Jeunes chimistes" of the SCF (RJ-SCF, under the age of 35) constitutes about 40% of the members of the national society.
[9] For scientists like for artists, creative routines vary from one person to another, but creative work always requires resting and wandering time that are not productive. As an illustration, the following infographics nicely presents the daily routine of famous creative people: https://podio.com/site/creative-routines

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# The future of chemistry: a young chemist's perspective

As a young chemist and recent PhD graduate, I am constantly looking to the future to decide the next steps in my chosen profession. Fifty years from now, I will presumably be at the end of my career and it is hard to imagine what the world will be like. Technology advances much faster than it used to, and it has had a great impact on the chemical enterprise. However, we still have a long way to go to solve one of the most pressing issues; it is impossible to think of the next fifty years of our field without thinking of the impacts of climate change. Our generation, and the generations that follow, will have to adjust to an ever-changing world and, if the predictions of 2030 are accurate, we must act now. Climate change is a very large global with many facets to address; instead I will focus on two issues that I hope we in the chemistry community can address.

Firstly, a genuine concern of mine is the pollution of the oceans from plastic waste; banning plastic straws is one small step in a positive direction, but the problem is much larger than that. The discovery of a pregnant whale with 50 pounds of plastic in her stomach is evidence of how insidious the spread of plastic waste has been in our modern world. While traveling in Belize for a science course, I witnessed first-hand a small deserted island with the shorelines covered in plastic waste that had been washing up for decades. I am encouraged by the research that demonstrates microbes and mealworms can consume plastic, but we must strive for a more sustainable solution as this problem continues to grow.

Second, at a more human level, we must strive to improve the inclusion and diversity of the chemical field. Although women are more visible than in previous generations, men still hold many of the high-level leadership positions at universities and major companies. Moreover, the field is still predominantly white; people of color and people from different socio-economic backgrounds often are not afforded the same privileges when it comes to professional development. It is important that we use our resources to support not only the next-generation of scientists, but the current generation of scientists who are not given equal opportunities.

In order to combat these issues affecting our field and our world, it will require collaboration from all countries and cultures. As the next generation of scientists, representing over twenty-five countries, I believe the International Younger Chemists Network (IYCN) has a role to play. When we give presentations, we always say "*the future of chemistry is global*", and that is true now more than ever. For me, young scientist's groups like IYCN not only elevated my career but introduced me to a community of scientists who are paving the way forward. I believe every young chemist needs this kind of support and IYCN aims to be that support on a global scale. We are seeing ourselves in young scientists like 29-year-old Katie Bouman who championed the first ever image of a black hole as a shining example of what we can contribute. In spite of the dire situations facing our world, I have hope for the future.

In addition to my perspective, I asked the Chair of IYCN, the Chair of the European Younger Chemists' Network (EYCN), the Vice-President of the French Young Chemists Network (RJ-SCF) and others IYCN Board Members to share their views on the future of chemistry. The views expressed in the next page are entirely their own and not representative of their organization.

Join us all the week for a dedicated Young Symposia Programme* and for our **symposium "The International Younger Chemists Network (IYCN): Shaping the future worldwide"** on Tuesday July 9th from 08:30-12:30 (Young Scientists Programme, Symposium 7.6) during the 47$^{th}$ IUPAC World Chemistry Congress. IYCN membership is open to any chemist under the age of 35 or someone who is five years from their terminal degree or postdoctoral appointment.

For more information, you can reach us at IYCN@IUPAC.org. If you want to follow what we are doing, please visit iycnglobal.com, like us on Facebook (IYCN.global), and on Twitter (@IntlYoungerChem).

* www.iupac2019.org/young-scientists-programme

**Catherine M. RAWLINS,**
Conference Presence Committee Chair of the International Younger Chemists Committee (IYCN), Post-Doctoral Researcher, Université de Bordeaux (UMR CNRS 5248), France.

*conferencepresence.iycn@gmail.com

## Testimonials from international Young Chemists

*"Chemistry need to engage quickly in sustainable development to answer societal and environmental daily issues. One way will be to increase artificial intelligence, machine learning and robotization in each step of the process."*

**Alexandre HERVÉ**, PhD

Vice-President of the French Chemical Society (SCF)
Vice-President of the French Young Chemists Network (RJ-SCF)
Post-doctoral researcher at Sorbonne University, Paris (France)

**Evijola LLABANI**, PhD

Chair of the IYCN
PhD student at the University of Illinois, Urbana (USA)

*"Fifty years from now, I hope chemistry will have actionable solutions to today's global challenges despite the obstacles, and continue to be at the forefront of scientific progress in pursuit of improving our daily lives. Young chemists are leading such effort: give them the support they need, and their chemistry will deliver!"*

*"For many, energy or climate change would see the biggest advances, but I am more excited on many unanswered questions of the human body. In the next few years, I would wait new advances on the intersection between new materials (nano-materials… maybe) in the human body, such as the reconstruction of spinal medulla seen in the media at the end of last year."*

**Antonio M. RODRÍGUEZ GARCÍA**, PhD

Chair of the European Young Chemists' Network (EYCN)
Post-doctoral researcher at the Universidad de Castilla-La Mancha (Spain)

**Willis Collins AKEYO MUGANDA**, MSc

Finance Chair of the IYCN
PhD student at the University of Siegen, Siegen (Germany)

*"The future of this universe is in the hands of young chemists, whose brilliance and motivation will be needed to revitalise innovation with aim of fostering sustainability and digitalisation."*

*"It has been a wonderful experience to be a part of IYCN with global perspective of networking beyond our boundaries or labs especially among younger chemists. As Louis Pasteur once said:* "Science knows no country, because knowledge belongs to humanity, and is the torch which illuminates the world."

**Hmunshel JASHA**, PhD

IYCN Conference Presence Sub-Committee
Senior technical staff, Sophisticated Analytical Instrument Facility, North Eastern Hill University, Shillong (India)

**Gabriela Desiree TORMET-GONZÁLEZ**, MSc

Webmaster of the International Younger Chemists Network (IYCN)
PhD candidate, University of Campinas (Brazil)

*"For the future of chemistry, I am sure we will see a difference in the way chemistry is taught. We will have to teach to a new generation that has grown up with internet and social media, using technologies such as machine learning and virtual reality. It will be easier to understand abstract concepts like molecular orbitals or mechanisms."*

## European Chemistry Gold Medal

**Call for nominations**

Every two years, the exceptional achievements of one scientist working in the field of chemistry in Europe are rewarded. The winner is awarded the Gold Medal and the opportunity to give the opening lecture at the next EuChemS Chemistry Congress (ECC).
The first European Chemistry Gold Medal was awarded to Professor Bernard L. Feringa, Nobel Prize winner for chemistry in 2016. He was awarded the Gold Medal at the 7th EuChemS Chemistry Congress in Liverpool (UK) which took place in August 2018.

Ben Feringa (centre) was awarded the EuChemS chemistry Gold Medal from Herman Overkleeft (left, chair of the EuChemS chemistry Gold Medal committee) and Pilar Goya (right, President of EuChemS) during the 7th EuChemS Chemistry Congress in 2018. © Royal Society of Chemistry.

**The call for nominations is open until 30 September 2019**[(1)]. Note that the Portuguese Chemical Society (SPQ), with the support of the Portuguese Electrochemical Society (SPE), will organize the **8th EuChemS Chemistry Congress** (8ECC), to be held in Lisbon, Portugal, **from August 30 to September 3, 2020**[(2)].

(1) www.euchems.eu/wp-content/uploads/2019/03/P-010-European-Chemistry-Gold-medal-ver.2019.pdf
(2) www.euchems2020.org

## 2019 IUPAC-Zhejiang NHU International Award for Advancements in Green Chemistry

The first four recipients of the recently established IUPAC-Zhejiang NHU International Award for Advancements in Green Chemistry were announced on June 10. The awards will be presented during the closing ceremony of the IUPAC Congress in Paris on Friday, 12 July 2019.

This new collaborative award in Green Chemistry has been established to encourage young and experienced chemists, and to emphasize the importance of advancements in Green Chemistry and the value of sciences to human progress.
The first three prizes are awarded to early career chemists: **Mingxin Liu** from McGill University, Montreal (Canada), "*In recognition of his research in the field of clean redox reactions for aldehyde/alcohol and the application of photosensitizing semiconductors as catalyst for organic transformations*"; **Xiaofu Sun** from the Chinese Academy of Sciences, Beijing, "*In recognition of his research in the design and development of novel routes for $CO_2$ electroreduction into value-added chemicals and fuels*"; **Julian West** from Rice University, Houston (TX, USA), "*In recognition of his research in the design and development of new synthetic transformations using earth abundant element photocatalysts*".
The fourth prize is awarded to an experienced chemist: **Fabio Aricò** from the Università Ca' Foscari, Venezia (Italy), "*In recognition of his achievements employing dialkyl carbonates in biorefinery development and bio-based platform chemicals via chlorine-free chemistry*".

Managed by the International Committee on Green Chemistry for Sustainable Development (ICGCSD), the Award will be presented every two years and the next call will be announced in 2020, in advance of the **2021 IUPAC Congress** to be held **in Montreal, Canada, 13-20 August 2021**.

• https://iupac.org/awardees-of-the-2019-iupac-zhejiang-nhu-international-award-for-advancements-in-green-chemistry

## Horizon Europe, the next EU research framework programme, and chemistry

On June 7, the European Commission has adopted its proposal for Horizon Europe[(1)], an ambitious €100 billion research and innovation programme that will succeed Horizon 2020. This proposal, followed by the European Parliament's wish for a €120 billion budget, would make this the biggest research and innovation programme ever in the EU – even if it is still below the requests of most researchers for a €180 billion budget. The launch of Horizon Europe is scheduled for January 1, 2021.
For the European Chemical Society – EuChemS, representing over 150,000 scientists – this proposal sends a strong signal to the negotiators of the next EU budget of the importance of science, research and innovation in the future of Europe. And chemists have a central role to play in helping to provide solutions to the current challenges whether related to health, environment, energy, to feed the world and give access to drinking water…

How will European countries successfully compete with the research and innovation capacity of other countries as the United States or China? How can European science best be supported and encouraged? What role can chemistry play in shaping the EU's next research framework programme Horizon Europe? EuChemS' Science Communication and Policy Officer Alex Schiphorst delves into these questions in a recent article published in Open Access Government[(2)].

(1) https://ec.europa.eu/info/designing-next-research-and-innovation-framework-programme/what-shapes-next-framework-programme_en
(2) www.openaccessgovernment.org/future-of-europe/66524

## In July 2019, Paris lives at the pace of chemistry!

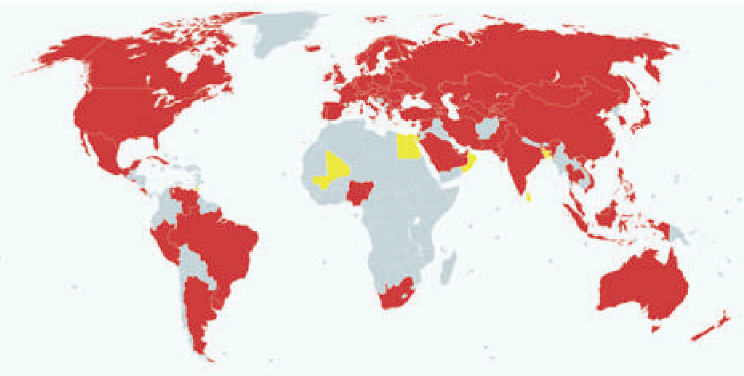

Do you know that IUPAC 2019 isn't the only international che-mistry event to take place in Paris in July 2019? France also hosts the 51st International Chemistry Olympiad (IChO) from July 21st to July 30th!

International Year of the Periodic Table (IYPT) 2019, IUPAC 2019, IChO 2019: three reasons, if needed, for the French ministry of education and youth to declare this school year "The year of chemistry, from primary school to university" which gathered hundreds of events, contests, exhibitions, shows, lectures, meetings… everywhere in France from September 2018 to September 2019.

The IChO is an annual contest for the world's most talented chemistry students at secondary school level, under twenty years old. Nations from all around the world send a team of four students who are tested on their chemistry knowledge and skills in an individual five-hour laboratory practical exam and an individual five-hour written theoretical exam.

The idea of the International Chemistry Olympiad was developed in the former Czechoslovakia in 1968 and the first edition took place in Prague in June 1968 with only three participants: the organizing country, Poland and Hungary. The event has been held every year since then, with the exception of 1971, and the number of countries involved has steadily increased.

The purpose of the competition is to promo-te friendship and coope-ration among the students, closer contacts among the young scientific workers, and exchange of pedagogical and scientific experience, as stated in the first regulations of the IChO.



Map of the participating countries (in red) and observating countries (in yellow).

Each participating country must organize a national selection process to determine four students who will attend the IChO. Countries who wish to participate in the IChO must send observers to two consecutive Olympiads before their students can attend the contest.

Paris hosted the 22nd IChO for the first time 29 years ago, in 1990. There were already 28 countries competing then… but it was nothing compared to the 51st edition, for which we expect 318 students and 280 mentors from 80 participating countries from all over the world and six observating countries: Bangladesh, Egypt, Mali, Oman, Sri Lanka, Trinidad, and Tobago!

This event is organized by the French ministry of Education and Youth, with the logistic part managed by the "Ligue de l'enseignement", and supported by many partners and sponsors like the French Society of Chemistry.

As it was the case in 1990, the practical and the theoretical exams will take place in ENCPB-lycée Pierre-Gilles de Gennes, huge scientific high school in the heart of Paris.

However, it also requires the very precious help of numerous volunteers: to accompany the students, to manage and mark their paper, to write the problems, to prepare the labs… In total, more than two hundred volunteers help us making the 51st IChO in Paris definitely unforgettable!

The participants will go home with lots of memo-ries and gifts, including objects created especially for the occasion. The work of Antoine Lavoisier, the French creator of modern chemistry, served indeed as a support for the creation of art objects inspired by the collection of the Museum of Arts and Crafts (MAM, Paris) gathering 500 objects that belonged to Lavoisier. Supported by the professional organization representing the chemical companies, France Chimie Ile-de-France, the **"Lavoisier challenge"** brought together students from four art and design schools who freely inspired pieces from this collection to create objects. The four projects selected by a jury of professionals (designers, chemists, education) were produced in series to be offered to participants of the 2019 IChO.

The next IChO will be held in Turkey (52nd IChO, 2020) and Japan (53rd IChO, 2021).

• https://icho2019.paris/en

Some of the projects of the "Lavoisier challenge" exhibited last May at the "Palais de la découverte", museum of science in Paris. © France Chimie Ile-de-France.

## Plastics in Europe: 2018 review and outlook

PlasticsEurope, the association of plastics manufacturers in Europe, held its annual press conference on June 4th 2019.

The numbers showed a global growth downturn for plastic materials in 2018, with an increase of +3.2% showing a slowdown compared to 2017. This trend is expected to continue in 2019.

Since 1990, the global plastic production went from 105 millions of tons to approximately 359 millions of tons in 2018. The average growth rate during those years has been +4.5%. 80% of the plastics produced are thermoplastics (i.e. polymers that can be melted and recast almost indefinitely), such as PE (polyethylene), PP (polypropylene) or PVC (polyvinylchloride).

Asia represents more than half of the world production, with China representing already one third on its own. Its production has grown from 37 Mt to 108 Mt between 2006 and 2018, and this trend is likely to continue, pulled by new units based on coal. In the US, shale gas development helped the return to investment in new polymer units. Its production went from 56 Mt to 65 Mt between 2006 and 2018. This increase is due to new production units based on ethane.

Since 1990, the average European growth rate has been +2.0%. With a decrease of 4.3% in comparison with 2017, the European production suffered from the global downturn, more than other regions. Between 2017 and 2018, production has decreased (-4.3%) but consumption has increased (+0.4%); imports has also increased (+5.2%) versus a decrease of exports (-3.0%). Packaging is the first sector using plastics, mostly for food application. Behind it are construction and automotive industry.

The French production decreased more than the European one (-5.1% for France versus -4.3% for Europe) but the sectors most using plastics are similar to the European ones.

### The challenges for the plastic industry

• *Industrial challenges*

In order to fight against litter and marine wastes, PlasticsEurope launched the *Operation Clean Sweep* (OCS) and the *Global Alliance To End Plastic Waste* with 1.5 billion dollars commitment on five years.

PlasticsEurope highlight the advantages of plastics through the life cycle analysis of plastics and alternative solutions. Plastic bottles vs gourds or plastic bags vs cotton bags are subjects of debate.

• *European challenges*

With the emerging of numerous national pacts, it becomes more important to contribute to the Circular Plastics Alliance of the European Commission, and to make sure that the national commitments stay coherent with the European Association commitment for 2030. It focuses on increasing re-use and recycling, preventing plastics leakage into the environment, and accelerating resource efficiency.

To reach the recycling and use of recycled plastic goals set by Europe, PlasticsEurope has shown a voluntary commitment through the development of platforms and the promotion of chemical recycling.

In France, the government's goal of 100% of recycled plastics by 2025 is very ambitious. Industries will try to reach it with the development of chemical recycling.

**N. Ben Hamouda**

## Get in your element: IUPAC Periodic Table Challenge

The year 2019 marks the 100th anniversary of IUPAC and also the 150th anniversary of the Periodic Table of the Elements. To celebrate these anniversaries, IUPAC is hosting an online challenge about the Periodic Table aimed at a global audience of young students. The goal is to reach players from every country from January until the end of 2019 (already 110 countries, 44,000 entries and 6,000 certificates in June and still counting!). To play, you will pick your avatar element and test your knowledge with 15 randomly chosen multiple-choice questions about the elements. Do well and advance to the Nobelium Contest for a chance to win a limited edition Periodic Table autographed by a Nobel Laureate in Chemistry! Entries in the Nobelium Contest will be posted on the website and will be eligible for a popular vote in Science, Art, and Education categories.

• https://iupac.org/100/pt-challenge

## How many chemical elements can you name?

The United Nations proclaimed 2019 the International Year of the Periodic Table of Chemical Elements, honoring the 150th anniversary of Dmitri Mendeleev's iconic creation. Yet many people struggle to recall more than a few of the 118 elements listed on the current table: despite many of these elements are familiar, a survey which comes courtesy of Philadelphia-based Science History Institute* reveals that one in five Americans can't name a single element, and 59% couldn't name more than ten elements. It also drives home a dearth of understanding of rare earth elements: 36% of the 1,263 adults surveyed in February had not heard this term, and 35% had heard it, but had no idea what it meant.

Time for a refresher course?

* Science History Institute is a multifaceted nonprofit organization whose mission is to preserve and celebrate our scientific and technological culture and to make it accessible for investigation and knowledge creation.

• www.sciencehistory.org/sites/default/files/rare-earth-elements-why-they-matter.pdf

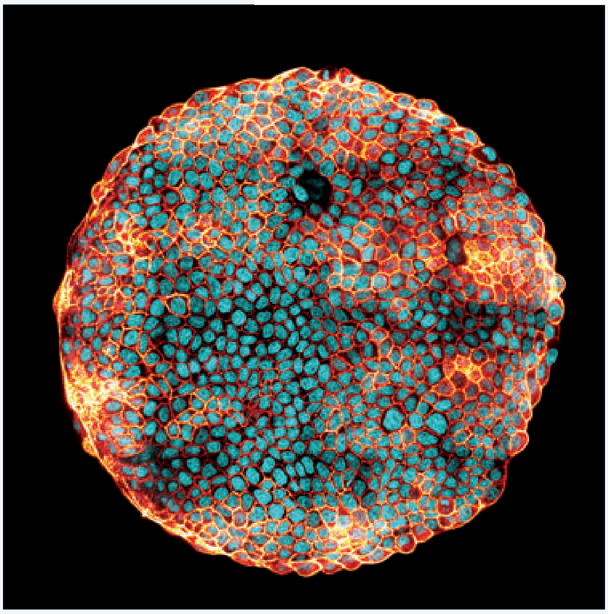
## On this day in chemistry and Molecule of the week…

Did you know that the Royal Society of Chemistry offers many useful resources on its website Learn Chemistry, including a calendar that gives the "chemical" information of the day(1)?

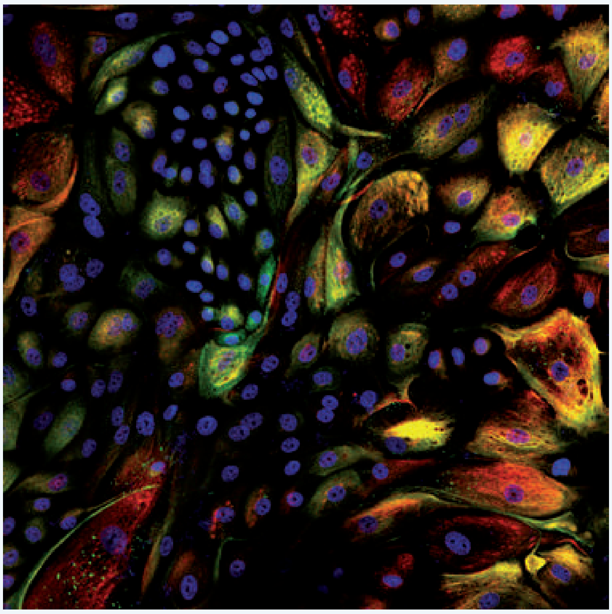
For its part, the American Chemical Society unveils a new molecule every week on its site since 2001. Many molecules are suggested by the website visitors. Every structure is reviewed by a scientist and displayed in 3-D and flat images with a brief description. Each week's molecule also links to a sample record from the CAS REGISTRY, which is searched using SciFinder®. Each record displays the registry number, index name and synonyms, bibliographic information, and more. All previous molecules are accessible via the archive.

(1) www.rsc.org/learn-chemistry/collections/chemistry-calendar
(2) www.acs.org/content/acs/en/molecule-of-the-week.html

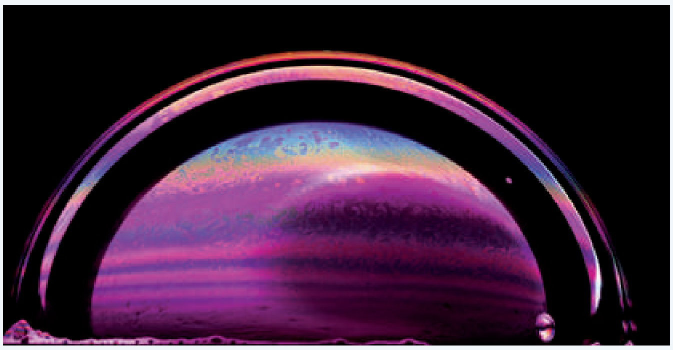
# BEAUTIFUL SCIENCE



"Island of cells": epithelial cells in culture. HARMAND Nicolas, doctoral student, PEREIRA David, postdoctoral student, and HENON Sylvie, professor in cellular microrheology (Paris).

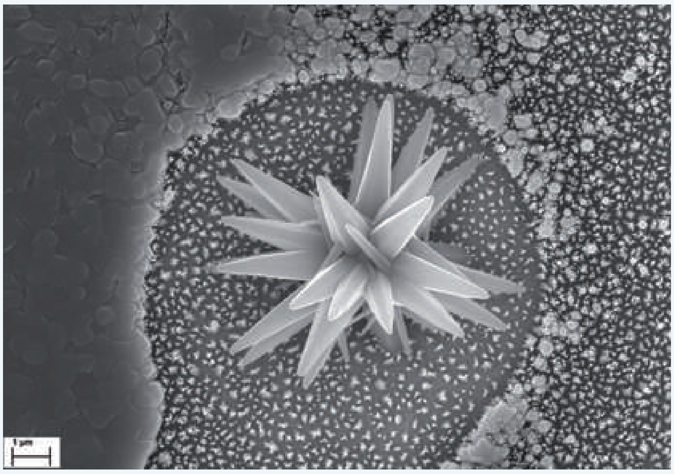


"Cellular hallucination": cells in culture, in green and red marking of two cytoskeletal proteins, in blue visualizing the nuclei of the cells by staining the DNA. BATAILLER Martine, Assistant Engineer in neuroendocrinology (Nouzilly).



"Planet under bell": turbulence on top of a soap bubble. KLEIN Hubert, associate professor (Marseille).

"In the privacy of a border crossing": air bubble that passes through an interface between water and oil. LAGARDE Antoine, doctoral student in fluid mechanism (Paris).



Winning work of the public vote, "Nano-needles in a tiny haystack": zinc oxide nanowires seen by scanning electron microscopy. GAFFURI Pierre, doctoral student (Grenoble).

Show science in its most beautiful and elegant form, from the infinitely small to the infinitely large! This was the theme of the first edition of the Beautiful Science contest organized by the French Physics Society. This images and sounds contest is about sciences in general. Anyone could participate, alone or in groups, and send one or multiple works. The best ones will be exposed in July at the Cité des Congrès of Nantes during the annual conference of the French Physics Society, and published in partners' reviews (as *L'Actualité Chimique*!). Their authors will receive some specials prices given by the sponsors: the Fondation Nanosciences (Nanoscience Foundation), the Association Française de Mécanique (Mechanic's French Association) and the Union des Professeurs de Physique et de Chimie (Physics and Chemistry Professors' Union).

The French Chemical Society is a partner in this event. Each partner could send one representative to vote for the best works. The works sent had to be aesthetic, original, arouse astonishment but mostly present a scientific interest. Four pieces were chosen by the jury, and one was chosen amongst ten by the public on social networks. The winners are five images and belong to the fields of biology, chemistry and physics.
This contest has given to these five people the opportunity to get their work exposed. But it also shared a beautiful image of science, often considerate inelegant or unattractive. Such contests are the perfect advertisement science need. Over 360 pieces were sent from people between 9 and 87 years old. A lot of scientists and artists/illustrators participated, but also a janitor or a security agent. It shows that it is accessible to everyone, that it is beautiful and full of surprises. Being opened to the public, it gives the chance to a non-scientist community to discover a side of science they never knew.

**N. Ben Hamouda**

• www.sfpnet.fr/oeuvres-laureates-du-concours-beautiful-science

## European Research & Innovation Days

### 24-26 September 2019

Brussels (Belgium)

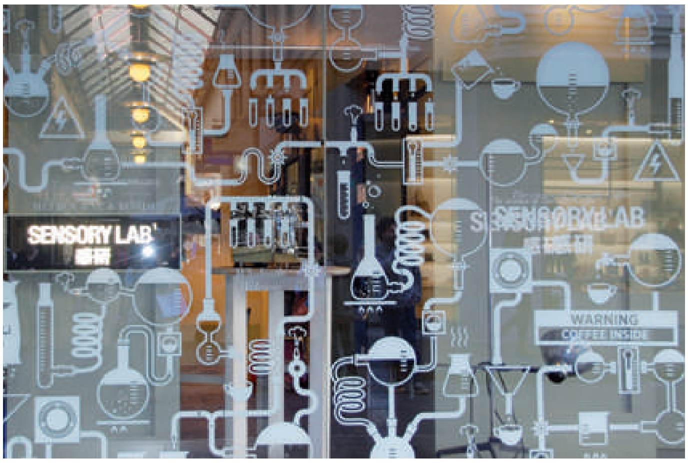
European Research and Innovation Days is the first annual policy event of the European Commission, bringing together stakeholders to debate and shape the future research and innovation landscape.
Speakers will include ministers, commissioners, members of European Parliament, researchers, as well as surprise guests each day.
A key challenge for Europe is delivering the next great transition of our economy, society and planet to secure a sustainable future that ensures the wellbeing of citizens. The event will be central to finding research and innovation solutions for this great transition by working across polices, setting the direction, spurring innovation and triggering investment. It will be the moment for all stakeholders to meet and co-create the strategic priorities for the European Commission's investment in research and innovation.
At the same time, the event aims to mobilise EU citizens and increase awareness of how important research and innovation are in addressing the challenges that faces society. It will include a free exhibition, **"Science is Wonderful!"**, to showcase and celebrate the very best EU research and innovation has to offer.

• https://ec.europa.eu/info/research-and-innovation/events/upcoming-events/european-research-and-innovation-days_en

## Spirit of chemistry all over the world

At the corner of a street, in a window, in a friend's bag… I still happen to be surprised by an unexpected arrival of a small dose of chemistry, where we did not expect it.
Photos: S. Bléneau-Serdel/SCF.

Barcelona in August 2007, jugs of water in a design store .




Melbourne in August 2016, decorating a shop window at a coffee shop (coffee is a real passion in Australia).

New York in June 2018, Marie Curie's hat in a metro station (thanks to Agathe Philip).

Copenhagen in May 2018, in the window of a famous decorating shop .


Paris in May 2019, street art by artist C215 representing Marie Curie on a wall in a historic district where she and Pierre Curie had their laboratory .

Villejuif (near Paris) in June 2012, artisan market of recycled objects.

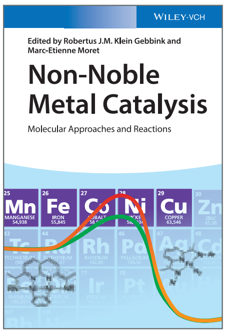
Paris in March 2013, jug of water of the city of Paris.

# From Carbon to Silver – we've got new books for you

Explore the elements and access free content

## As we continue to celebrate the International Year of the Periodic Table, check out our latest books spotlighting the chemical elements.

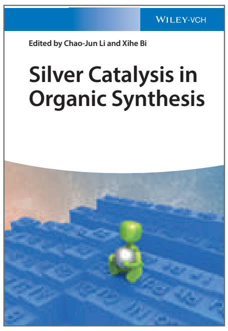
Visit **www.wiley.com/IYPT** to view more books and to order!




### Non-Noble Metal Catalysis: Molecular Approaches and Reactions

Robertus J. M. Klein Gebbink, Marc-Etienne Moret (Editors)

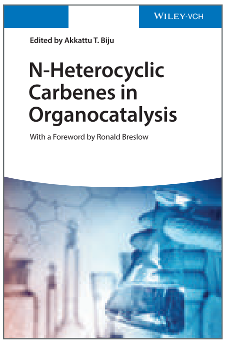
ISBN: 978-3-527-34061-3
February 2019




### Silver Catalysis in Organic Synthesis, 2 Volume Set

Chao-Jun Li, Xihe Bi (Editors)

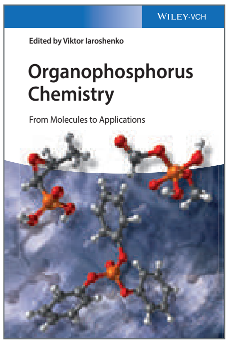
ISBN: 978-3-527-34281-5
February 2019




### N-Heterocyclic Carbenes in Organocatalysis

Akkattu T. Biju (Editor)

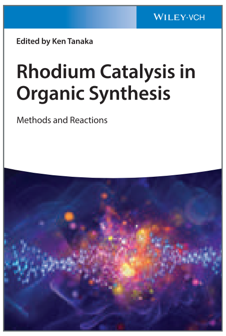
ISBN: 978-3-527-34310-2
March 2019




### Organophosphorus Chemistry: From Molecules to Applications

Viktor Iaroshenko (Editor)

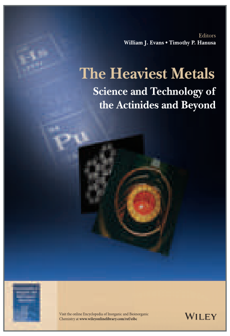
ISBN: 978-3-527-33572-5
March 2019




### Rhodium Catalysis in Organic Synthesis: Methods and Reactions

Ken Tanaka

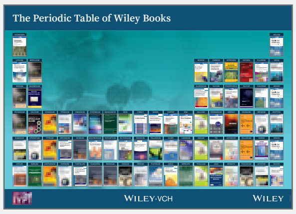
ISBN: 978-3-527-34364-5
March 2019




### The Heaviest Metals: Science and Technology of the Actinides and Beyond

William J. Evans, Timothy P. Hanusa (Editors)

ISBN: 978-1-119-30409-8
January 2019

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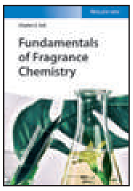
## New parutions


**Research and Practice in Chemistry Education**
**Advances from the 25th IUPAC International Conference on Chemistry Education 2018**
M. Schultz, S. Schmid, G.A. Lawrie, (eds)
274 p., 114.39 € (eBook 67.82 €)
Springer, May 2019

This book brings together fifteen contributions from presenters at the 25th IUPAC International Conference on Chemistry Education 2018, held in Sydney. Written by a highly diverse group of chemistry educators working within different national and institutional contexts with the common goal of improving student learning, it presents research in multiple facets of the cutting edge of chemistry education, offering insights into the application of learning theories in chemistry combined with practical experience in implementing teaching strategies. The chapters are arranged according to the themes novel pedagogies, dynamic teaching environments, new approaches in assessment and professional skills – each of which is of substantial current interest to the science education communities.
Providing an overview of contemporary practice, this book helps improve student learning outcomes. Many of the teaching strategies presented are transferable to other disciplines and are of great interest to the global community of tertiary chemistry educators as well as readers in the areas of secondary STEM education and other disciplines.




**Fundamentals of Fragrance Chemistry**
C.S. Sell
360 p., 79.10 € (eBook 67.80 €)
Wiley, Apr. 2019

Ernest Beaux, the perfumer who created Chanel No. 5, said, "*One has to rely on chemists to find new aroma chemicals creating new, original notes. In perfumery, the future lies primarily in the hands of chemists.*" This book provides chemists and chemists-to-be with everything they need to know in order to create welcome new fragrances for the world to enjoy. It offers a simplified introduction into organic chemistry, including separation techniques and analytical methodologies; discusses the structure of perfume creation with respect to the many reactive ingredients in consumer products; and shows how to formulate effective and long-lasting scents.


**Medicinal plants**
**Chemistry, Pharmacology, and Therapeutic Applications**
M.K. Swamy, J.K. Patra, G.R. Rudramurthy
238 p., 92.00 £
CRC Press, May 2019

This book details several important medicinal plants, their occurrence, plant compounds and their chemical structures, and pharmacological properties against various human diseases. It also gives information on isolation and structural elucidation of phytocompounds, bio-assays, metabolomic studies, and therapeutical applications of plant compounds.

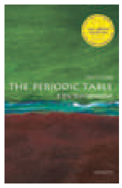

**The Promise of Science**
**Essays and Lectures from Modern Scientific Pioneers**
L. Karnath (ed.)
296 p., 75 £ (eBook 60 £)
World Scientific, May 2019

This thought-provoking publication covers a wide-range of innovative areas of research and technologies that are unlocking groundbreaking new potentials in science. It contains important scientific information gleaned from the lectures of some of the world's experts in their respective fields. The book offers exceptional scientific insights, oftentimes addressing challenges before they are even recognized as questions. Chronicling the revolutionary ideas of Nobel Laureates, winners of Wolf Prize, US National Medal of Science and other notable scientists.


**European Journal of Organic Chemistry**
**Special issue dedicated to 50 years of rotaxanes**

Fifty years ago, Gottfried Schill and Hubertus Zollenkopf reported the synthesis of a macrocyclic ring threaded onto a linear aromatic moiety capped by bulky end groups, which they named for the first time as rotaxanes. This **special issue guest-edited by Jean-Pierre Sauvage** honors this important milestone in supramolecular chemistry, which was published in *Liebigs Annalen*, one of the key founding journals of *EurJOC*. With contributions from Jean-François Nierengarten, Nicholas H. Evans, Maurizio Prato, Shinichi Saito, Nicolas Giuseppone and many more.

• https://onlinelibrary.wiley.com/toc/10990690/2019/2019/21




**The Periodic Table**
**A Very Short Introduction (2nd ed.)**
E.R. Scerri
184 p., 8.99 £
Oxford University Press, July 2019

This new edition, part of the *Very Short Introductions* series – over ten million copies sold worldwide –, considers the fundamental nature of the periodic table to the physical sciences. Published in the International Year of the Periodic Table, it celebrates the completion of the seventh period of the table, with the ratification and naming of elements 113, 115, 117 and 118 as nihonium, moscovium, tennessine and oganesson. It also incorporates new material on recent advances in our understanding of the origin of the elements, and explores the history of the discovery of trends among elements, the construction of various forms of the table, and the growth of understanding of its meaning.

# Calendar

**17-19 July 2019**
## Eurovariety in chemical education 2019
Prato (Italy)
https://shop.monash.edu/eurovariety-in-chemistry-education-2019.html

**21-25 July 2019**
## OMCOS 20
*20th IUPAC International symposium on organometallic chemistry directed towards organic synthesis*
Heidelberg (Germany)
www.omcos2019.de

**21-26 July 2019**
## ISNA-18
*18th International symposium on novel aromatic compounds*
Sapporo (Japan)
https://iupac.org/event/18th-international-symposium-novel-aromatic-compounds-isna-18

**26-28 July 2019**
## Mendeleev 150
*4th International conference on the periodic table*
Saint Petersburg (Russia)
http://mendeleev150.ifmo.ru

**29 July-2 August 2019**
## ICHC 2019
*12th International conference on the history of chemistry*
Maastricht (Netherlands)
www.ichc2019.org

**4-8 August 2019**
## ICSC 2019
*International conference on solution chemistry*
Xining (China)
http://icsc2019.csp.escience.cn/dct/page/1

**4-9 August 2019**
## 70th Annual meeting of the International Society of Electrochemistry
*Linking resources to sustainable development*
Durban (South Africa)
http://annual70.ise-online.org

**25-30 August 2019**
## TAN 19
*6th International conference on the chemistry and physics of the transactinide elements*
Wilhelmshaven (Germany)
www-win.gsi.de/tan19

**25-31 August 2019**
## Glyco 25
*International symposium on glycoconjugates*
Milan (Italy)
www.glyco25.org

**28-30 August 2019**
## CIS 2019
*Chemistry meets industry & society*
Salerno (Italy)
http://cis2019.com

**1-4 September 2019**
## 17e ECSSC
*European conference on solid state chemistry*
Lille (France)
https://ecssc17.com

**1-5 September 2019**
## Euroanalysis 2019
Istanbul (Turkey)
http://euroanalysis2019.com

**2-6 September 2019**
## ICNI 2019
*1st International conference on noncovalent interactions*
Lisboa (Portugal)
https://icni2019.eventos.chemistry.pt

**8-13 September 2019**
## Chemistry education and sustainable development
Lagos (Nigeria)
http://chemsociety.org.ng/acricecsnconference

**8-13 September 2019**
## IP'19
*International symposium on ionic polymerization*
Beijing (China)
https://iupac.org/event/international-symposium-on-ionic-polymerization-ip-19

**9-13 September 2019**
## Mendeleev 2019
*XI International conference on chemistry for young scientists*
Saint Petersburg (Russia)
Satellite event of the XXI Mendeleev congress supported by the European Young Chemists' Network (EYCN).
http://mendeleev.spbu.ru

**9-13 September 2019**
## XXI Mendeleev congress on general and applied chemistry
Saint Petersburg (Russia)
http://mendeleev2019.ru/index.php/en

**22-25 September 2019**
## EUGSC-4
*4th EuChemS conference on green and sustainable chemistry*
Tarragona (Spain)
http://eugsc4.iciq.es

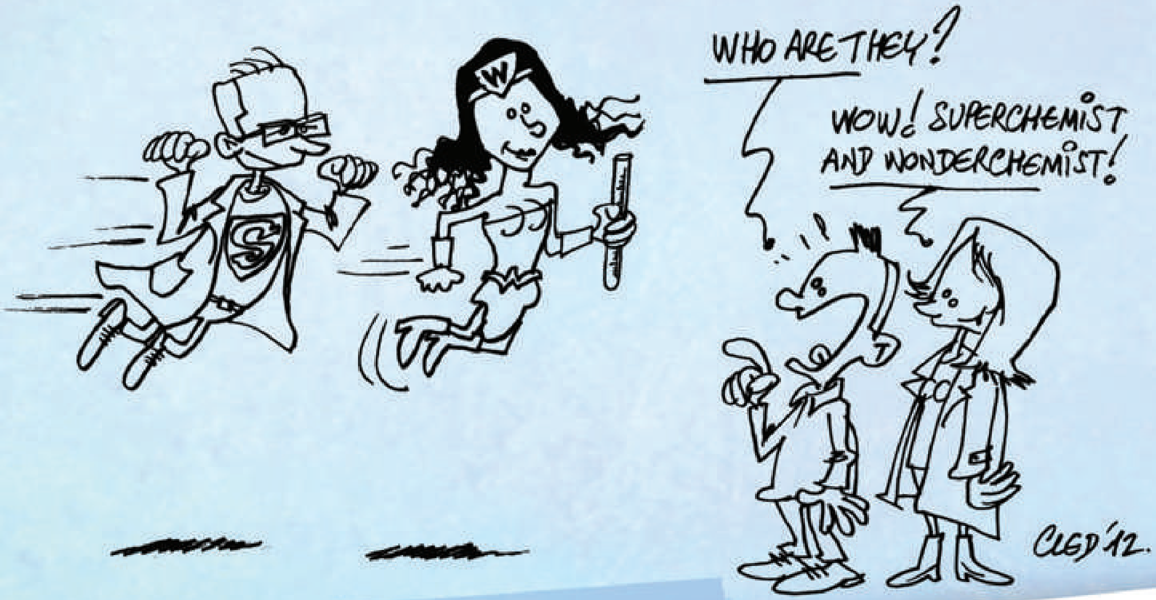
**22-26 September 2019**
## 6th International environmental best practices conference
Olsztyn (Poland)
https://ebp6.eu

**14-16 October 2019**
## International symposium on mycotoxins
Belfast (North Irlande)
www.iupac.org/event/wmfmeetsiupac2019

**4-8 November 2019**
## A global approach to the gender gap in mathematical, computing, and natural sciences
Trieste (Italy)
https//gender-gap-in-science.org

**5-10 January 2020**
## 2020 Electrochemistry GRC
Ventura (CA, United States)
https://iupac.org/event/grc2020-electrochemistry

**19-21 February 2020**
## ChemCYS 2020
*Chemistry conference for young scientists*
Floreal (Belgium)
https://chemcys.be/index.php


WHO ARE THEY?
WOW! SUPERCHEMIST AND WONDERCHEMIST!
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LET'S CREATE OUR FUTURE
G. THUNBERG
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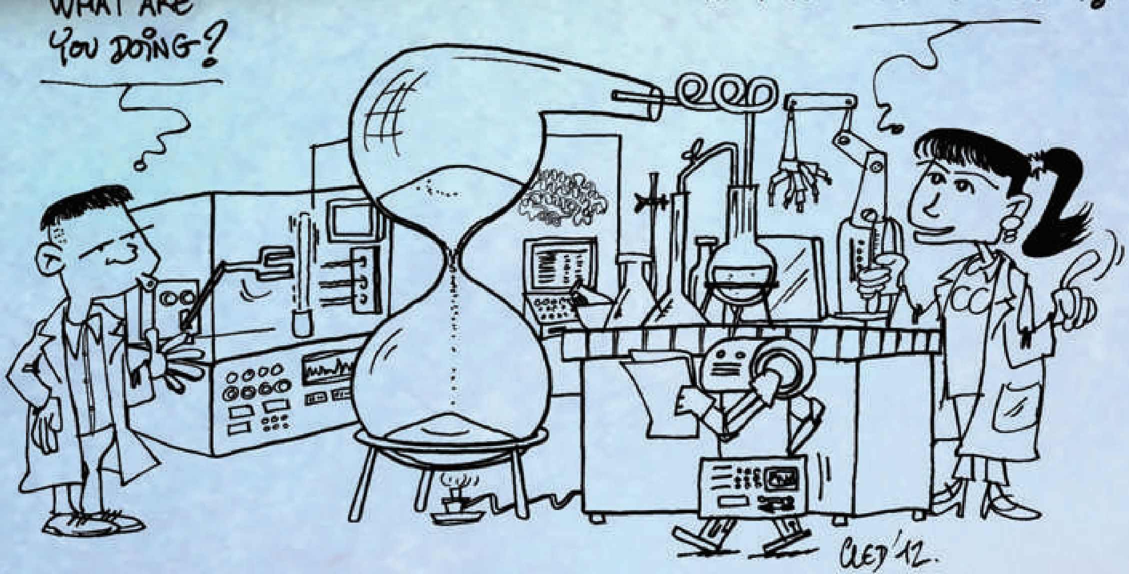
WHAT ARE YOU DOING?
WE'RE BUILDING THE FUTURE OF CHEMISTRY!
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# Uncover the Story Behind the Science

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ScienceHistory.org